

Adapting to survive – Water management and aquatic science in the Kruger National Park

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Abstract

The availability of water has been a prime consideration for the management of the Kruger National Park (KNP) since its establishment in 1926. While the park is fed by five, historically perennial, river systems, its location at the downstream end of these systems has left the park vulnerable to external influences, which have compromised the integrity of its water resources. This article is based on a Masters of Arts study completed at North-West University in 2017, and provides a historical overview of water management in the KNP and its role in the development of aquatic science in South Africa. A specific focus is placed on the KNP Rivers Research Programme, a collaborative, multidisciplinary aquatic research programme, which was conducted in three phases between 1988 and 1999. The article explores the influence of this programme on changes in water management in the KNP as well as its role in the development of aquatic science in South Africa.

Keywords: Kruger National Park; Aquatic Science; Ecological Reserve National Water Act Integrated Water Resource Management Science-Policy Interface Strategic Adaptive Management.

Introduction

The Kruger National Park (KNP) was established by an Act of Parliament in 1926.¹ As South Africa's largest nature reserve, the park plays an important role in ecotourism and conservation, attracting over 1.4 million visitors a year.² The Kruger National Park is rich in fauna and flora, with an inventory of around 2 000 species of plants, 500 species of birds and 255 faunal species.³ In addition, at least 45 freshwater fish species have been identified in the park's rivers, many of them endemic to the area.⁴

1 J Stevenson-Hamilton, The Transvaal Game Reserve: An animal sanctuary for the Union, *Journal of the Royal African Society*, 25(9), April 1926, pp. 211-228.

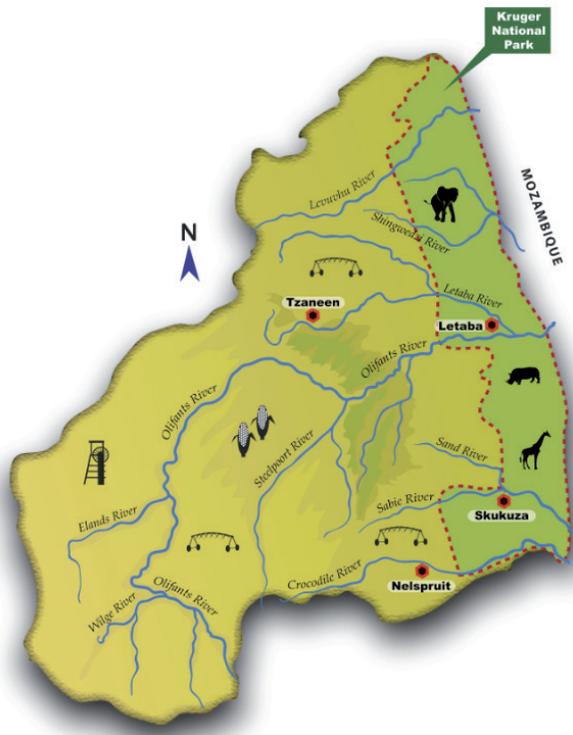
2 S Ferreira & A Harmse, Kruger National Park: Tourism development and issues around the management of large numbers of tourists, *Journal of Ecotourism*, 13(1), June 2014, pp. 16-34.

3 SCJ Joubert, The Kruger National Park – An introduction, *Koedoe*, 29(1), November 1986, pp. 1-11.

4 U de V Pienaar, Inaugural address, *Zoologica Africana*, 11(2), January 1976, pp. 227-231.

While initially only focused on the conservation of terrestrial species, water has always been central to the management of the KNP; a necessity borne out of the relatively water-poor character of its landscape.⁵ Two large river systems make up the bulk of the KNP's water resources, namely the Limpopo River system (including the Olifants-, Letaba- and Luvuvhu rivers) and the Incomati system (including the Sabie and Crocodile rivers). These five rivers are the only historically perennial rivers available to the KNP, with all remaining surface water resources inside the park's borders being intermittent in nature.⁶ The KNP also has usable groundwater resources, including a number of thermal springs.⁷

Image 1: The location of the Kruger National Park in relation to its main rivers and their catchments



Source: After HC Biggs, CM Breen & CG Palmer, Engaging a window of opportunity: Synchronicity between a regional river conservation initiative and broader water law reform in South Africa, *International Journal of Water Resources Development*, 24(3), September 2008, pp. 329-343.

5 SCJ Joubert, The Kruger National Park – An introduction, *Koedoe*, 29(1), November 1986, pp. 1-11.
6 U de V Pienaar, *The freshwater fishes of the Kruger National Park* (Pretoria, 1978), p. 3.
7 JR Vegter, Hydrogeology of Region 19: Lowveld, Water Research Commission (WRC) Report No. TT 208/03, (Pretoria, 2003), p. 3.

While the five main rivers feeding the park flow from west to east, the park has a north-south orientation, stretching across the provinces of Limpopo and Mpumalanga, and bordering Mozambique and Zimbabwe.⁸ This odd location on parcels of land originally deemed unsuitable for agriculture or any other “economic activity”, has left the KNP at the downstream end of the catchments feeding its main rivers.⁹ With the exception of the Olifants River, all of the main rivers have their sources in the Escarpment, where up to 80 per cent of their runoff is generated.¹⁰ In contrast, the area inside the borders of the KNP contributes less than ten per cent to the runoff of its main rivers.¹¹ The need for a stabilised water supply has been further exacerbated by the park’s climate, which oscillates between wet and dry cycles between seasons and across decades.¹²

Water management in the Kruger National Park

Unlike terrestrial ecosystems, river systems cannot be fenced or separated from outside influences. River ecosystems are indivisible from the landscapes that shape and feed them, and all activities in the catchment have an impact on the ways in which rivers behave.¹³ The catchments feeding the KNP’s rivers have been inhabited for thousands of years, but it has been the large-scale activities which commenced in the area in the late nineteenth century, such as mining, agriculture and forestry, that have had a marked impact on the quality and quantity of the KNP’s water resources.¹⁴ The KNP has adapted its management response in direct correlation with the intensification of upstream anthropological impacts, with management activities becoming more rigorous as flow disruption and pollution became more marked.

8 JT du Toit, KH Rogers & HC Biggs (eds), *The Kruger experience. Ecology and management of savanna heterogeneity* (Washington, 2003), p. 4.

9 Archive of South African National Parks (Sanparks), NK/18[1], Transvaal Native Department, Annual Report (Pretoria, 1906).

10 South African Water History Archival Repository (SAWHAR), Waterlit Collection, FJ Venter, Physical characteristics of the reaches of perennial rivers in the Kruger National Park.

11 A Pike & R Schulze, Development of a distributed hydrological modelling system to assist in managing the ecological reserve to the Sabie River system within the Kruger National Park, WRC Report No. 884/1/01 (Gezina, 2001), p. 2.

12 JV Redfern *et al.*, Surface water availability and the management of herbivore distributions in an African savannah ecosystem, *Journal of Arid Environments*, 63(1), October 2005, pp. 406-424.

13 J O’Keeffe, Sustaining river ecosystems: Balancing use and protection, *Progress in Physical Geography*, 33(3), June 2009, pp. 339-357.

14 Anon., State of the rivers report. Crocodile, Sabie-Sand and Olifants River systems WRC Report No. TT 147/01 (Gezina, 2001), p. 23.

Period of low intervention (1898-1945)

Following a period of intense exploitation, where large and small game were hunted by various groups, the predecessor to the KNP, the Sabi Game Reserve, was established in 1903 with the distinct purpose of conserving South African terrestrial species.¹⁵ The first warden of the Sabi Game Reserve (and later the KNP), Colonel James Stevenson-Hamilton, was intent on keeping the area inside the borders of the park as “natural” as possible, with little to no intervention by park management.¹⁶ The warden was initially against allowing visitors into the park, but eventually relented due to economic and political pressures.¹⁷ At this stage the rivers of the KNP were only valued as sources of water for the terrestrial animals the park was trying to conserve.¹⁸ Neither the Sabi Game Reserve nor the KNP were fenced when they were established, and animals were free to follow their traditional migration routes when water became scarce inside the conservation area.¹⁹

From the time he arrived in the area, Stevenson-Hamilton kept meticulous rainfall records, and the KNP’s water resource challenges were well known by the time the park was established.²⁰ Not well understood at the time was the link between upstream anthropogenic activities and impacts on the quantity of water reaching the KNP. A popular view of the time, shared by Stevenson-Hamilton, was that the area was becoming desiccated.²¹ Stevenson-Hamilton also noted the link between grazing and water resources, and that the veld surrounding water-rich areas were the first to be stripped bare during dry times, leaving those areas far from water relatively intact.²² These observations prompted the first in-depth investigations into artificially enhancing water supplies within the park, particularly focusing on food-rich areas located between the perennial rivers.²³ The same source indicates that Stevenson-

15 J Stevenson-Hamilton, The Transvaal Game Reserve..., *Journal of the Royal African Society*, 25(9), April 1926, pp. 211-228.

16 J Stevenson-Hamilton, *South African Eden. From Sabi Game Reserve to Kruger National Park, Revised Edition* (Rosebank, 2008), p. 263.

17 U de V Pienaar, *A cameo from the past. The prehistory and early history of the Kruger National Park* (Pretoria, 2012), p. 363.

18 J Stevenson-Hamilton, *Die Laeveld. Sy natuurlewe en sy mense* (Pretoria, 1949), pp. 146-149.

19 Sanparks, NK/18/1 [1], Letter: J Stevenson-Hamilton (Kruger National Park Warden)/National Parks Board of Trustees on increasing water supply in the park, 6 February 1930.

20 Sanparks, NK/18 [1], Transvaal Native Department, Annual Report (Pretoria, 1906).

21 Sanparks, NK/28 [1], Government Game Reserves, Sabi and Singwitsi Annual Report 1912, Report No. TP 4-(Pretoria, 1913).

22 Sanparks, B/5 [1], Report to the National Parks Board by J Dommissie, consulting engineer, on the supplies of the Kruger National Park with special emphasis on game requirements, 7 September 1957.

23 Sanparks, NK/18/1 [1], Letter: J Stevenson-Hamilton (Kruger National Park Warden)/National Parks Board of Trustees on increasing water supply in the park, 6 February 1930.

Hamilton also hoped, by providing more water resources within the park's borders, he would be able to prevent animals from straying into adjacent agricultural land where they were at risk of being hunted. Investigations into artificially enhancing water supplies in the KNP were further motivated by a decade of drought conditions, which persisted until 1934.²⁴

An ecological disaster befell the Sabie River even before the establishment of the KNP. In 1921 it was discovered that a number of gold mines upstream of the KNP were dumping their tailings directly into the Sabie River.²⁵ The same source indicated that the pollution wiped out all biological life in the river, and it was only when livestock losses were reported in 1944 that authorities forced the mines to cease their polluting activities. The gold mines had a negative effect on the quality of the Sabie River long after they closed as determined by aquatic scientists during surveys of the river in 1985.²⁶ And cyanide leaching from old mine dumps were sterilising the river reach up to 20 km below Sabie town.

Water resources in the KNP were initially enhanced through the drilling of boreholes and construction of dams. One of the first boreholes was aimed at providing water to the warden's headquarters at Skukuza in 1913.²⁷ Twenty years later a public outreach campaign was launched to raise funds for the drilling of more boreholes to provide water for game and, by 1935, fourteen such boreholes had been constructed. Further to this, the hydrology, general flat topography, high evaporation rates and the risk of siltation, made the construction of large dams unattractive, and early dams were generally small in size. Stevenson-Hamilton first experimented with an earth dam constructed at Satara in 1925.²⁸ This was followed by the Ntomeni Dam in the area of Pretoriuskop in 1931.²⁹ In 1933 and 1937 engineers from the (then) Department of Irrigation conducted investigations into the establishment

24 Sanparks, NK/28, Annual Report of the Warden of the Kruger National Park to the National Parks Board of Trustees (1933-1939).

25 Sanparks, B/8 [9-2], SCJ Joubert *et al*, Besoedeling – 'n Bedreiging vir lewens- en omgewingskwaliteite in die Laeveld, 1985.

26 Sanparks, B/5 [1], J O'Keeffe, Report to Sanparks on the conservation status of the Sabie and Groot Letaba rivers within the Kruger National Park, Special Report No. 85/2 (Grahamstown, 1985).

27 Sanparks, NK/28 [1], Government Game Reserves, Sabi and Singwitsi Annual Report, Report No. TP-2-1914 (Pretoria, 1913).

28 Sanparks, NK/28 [1], Annual Report of the Warden of the Kruger National Park to the National Parks Board of Trustees (1933 to 1939).

29 Sanparks, NK/28 [1], Annual Report of the Warden of the Kruger National Park to the National Parks Board of Trustees, 1932.

of dams in the KNP.³⁰ By the time the warden retired in 1945 eight small concrete and earth dams had been constructed in the KNP, including the Eileen Orpen Dam, which was completed in the Manzentondo River, in 1944, and named after a benefactor to the park.³¹

Image 2: The Eileen Orpen Dam, located near Tshokwane in the central section of the Kruger National Park, was completed in 1944



Source: Photo by Lani van Vuuren, 26 June 2016.

Water for game (1946-1960)

Colonel JAB Sandenbergh became the warden of the KNP in 1946. In 1949, the first of the perennial rivers, the Letaba River, ceased flowing for the first time as a result of increasing commercial agricultural activities upstream.³² Two years earlier the park reported its first fish kills, the cause of which was never established.³³ After a failed attempt to have the KNP declared a soil conservation area under the Soil Conservation Act (Act no. 45 of 1946) and so secure state funds to implement additional water development efforts,³⁴ the warden convinced the National Parks

30 Sanparks, NK/18/1 [1], Letter: T Hopwood/Secretary of the Kruger National Park on available dam sites, Pretoria, 1933-05-15; Sanparks NK/18/1 [1], Report by WA Lingnau, Department of Irrigation, to the National Parks Board of Trustees on possible dam sites in the Kruger National Park, 4 March 1937.

31 Sanparks, B/5 [1], Report to the National Parks Board by J Dommissie, consulting, engineer, on the supplies of the Kruger National Park with special emphasis on game requirements, 7 September 1957.

32 Sanparks, B/8 [9-1], Internal notes on the rainfall and streamflow data for the Kruger National Park, s.a.

33 National Parks Board of Trustees, Annual Report for the year 1947, p. 25.

34 National Archive Repository Pretoria (NAR), Central Archives Repository (SAB), Secretary of Native Affairs (1880-1975) 8075 [626/337], Report on soil and water conservation in the Kruger National Park by an inter-departmental committee for submission to the Soil Conservation Board, September 1947.

Board to launch the first phase of the water-for-game fund in 1949. To promote the fund, Sandenbergh travelled across the country, appealing to the general public to donate money towards the establishment of artificial water points in the KNP.³⁵ The campaign was considered successful and by 1961, 63 boreholes had been established, all fitted with windmills.³⁶

During the second phase of the water-for-game fund, which was launched in 1950, investigations into the construction of dams in the KNP were renewed. The focus remained the seasonal rivers. The first two dams constructed under this programme were the Mlondozi Dam (built in 1951), and the Ngwanetsi Dam (built in 1952).³⁷ By 1960 another 22 dams had been constructed of various sizes in the seasonal rivers of the KNP.³⁸ At this point the majority of the water infrastructure was constructed as per the preference of the warden and his rangers, without due consideration of their impact on the aquatic ecosystem; many of the sites were selected so that they could be easily viewed by tourists to the park.³⁹

Image 3: Elephants at a concrete reservoir fed by a borehole outside Letaba tourist camp



Source: Photo by Lani van Vuuren, 5 July 2011.

35 Sanparks, A/1 [1], Letter from the warden of the Kruger National Park to the National Parks Board on the development of water in the Kruger National Park, 1946-1950, Skukuza, 24 July 1950.

36 Sanparks, NK/28 [1], Jaarverslag van die natuurbewaringafdeling van die Nasionale Krugerwildtuin aan die Nasionale Parkeraad, 1964.

37 Sanparks, B/5 [1], Report to the National Parks Board by J Dommissie, consulting engineer, on the supplies of the Kruger National Park, with special emphasis on game requirements, 7 September 1957.

38 Sanparks, NK/18/1 [K39/1], AM Brynard, Interne memorandum oor water vir wild. 'n Geskiedkundige oorsig oor die waterverskaffingsprogram vir wild in the Nasionale Krugerwildtuin, s.a.

39 Sanparks, B/5 [1], U de V Pienaar, Internal report on the water resources of the Kruger National Park – past and present, s.a.

Management through intervention (1960 to 1980)

In 1951 the appointment of the first scientist at the KNP was followed by interventions in the park (including water) with new intensity.⁴⁰ Between 1960 and 1990, interventions were purposefully aimed at subduing the inherent variability of natural forces inside the park. This was achieved through such management programmes as controlled burning, culling of excess animals based on pre-determined population ceilings, and the acceleration of the water-supply.⁴¹ The wet cycle experienced between 1953 and 1961 concealed the increasing impact that upstream anthropogenic activity was having on the availability of water downstream. When the next dry climatic cycle started in 1962 it became evident that upstream activities such as agriculture, deforestation, industry and mining were causing water flow to the park to decrease significantly, especially during the winter months.⁴²

In response, the KNP accelerated its water-for-game programme. Between 1961 and 1969 the park spent more on the establishment of boreholes and dams than it had in the previous three decades.⁴³ The rolling out of infrastructure inside the park largely mimicked the construction of bulk water resource infrastructure elsewhere in the country, which peaked in the sixties, and also aimed to stabilise South Africa's erratic water resources.⁴⁴ Between 1961 and 1972 working boreholes inside the KNP increased from 63 to 230, and park management started investigations into a series of water-transfer schemes for piping water from perennial to seasonal rivers in order to serve tourist camps. These transfer schemes never materialised and, although the reasons were never recorded it is thought to be due to a lack of funding.⁴⁵ During this period, however, an additional 30 earthen and 24 concrete dams were constructed. These included the first structures in a perennial river, namely a set of four weirs built in the Letaba River (Engelhard, Shimuwini, Mingerhout and Black Heron).⁴⁶ Despite the significant investment in water infrastructure the success

40 J Carruthers, Conservation and wildlife management in South African National Parks 1930-1960s, *Journal of the History of Biology*, 41(2), Summer 2008, pp. 203-236.

41 U de V Pienaar, Research objectives in South African national parks, *Supplement to Koedoe*, 20(1), August 1977, pp. 38-48.

42 Sanparks, B/5 [1], U de V Pienaar, Interne verslag oor die waterbronne van die Krugerwildtion – 'n opsomming van die huidige toestand, asook die waterverskaffingsprogram – wat reeds vermag is en die pad vorentoe, 30 May 1969.

43 Sanparks, NK/18/1 [K39/A], AM Brynard, Interne memorandum oor water vir wild. 'n Geskiedkundige oorsig oor die waterverskaffingsprogram vir wild in die Nasionale Krugerwildtion, s.a.

44 L van Vuuren, *In the footsteps of giants – Exploring the history of South Africa's large dams* (Pretoria, 2012), p. 153.

45 Sanparks, NK/18/1 [K39/1], AE Kuschke & U de V Pienaar, Memorandum oor waterverbruik en toekomstige waterbehoefes van die Krugerwildtuin vir die Waterbeplanningskomitee vir Oos-Transvaal, 8 Desember 1972.

46 Sanparks, NK/18/1 [K39/1], AE Kuschke & U de V Pienaar, Memorandum oor waterverbruik en toekomstige waterbehoefes van die Krugerwildtuin vir die Waterbeplanningskomitee vir Oos-Transvaal, 8 Desember 1972.

of the water-for-game programme is questionable. The KNP remained largely dependent on its perennial rivers. The dams constructed in the seasonal rivers tended to silt up or dry up in winter, and during the drought years of the sixties, park management spent much time pumping water to these dams from boreholes. The lack of water – and concomitant lack of grazing – also led to large-scale animal mortalities during this period.⁴⁷ In 1965 the park began a culling programme to reduce pressure on available grazing, targeting large animals such as buffalo, elephant and hippopotami.

By the sixties the KNP management started to realise the importance of its rivers as more than just a water-supply for terrestrial animals. The park's first fish survey, which commenced in 1957, underlined the ecological richness of the park's main rivers, with 38 species of fish being recorded in the Sabie River alone (more than any other river in South Africa).⁴⁸ A potential solution came in 1966. The Commission of Enquiry into Water Matters was appointed under the chairmanship of Prof Stephanus Petrus du Toit Viljoen to investigate the availability of water in South Africa as compared to demand, and to make recommendations to secure the country's water future.⁴⁹ The KNP was one of two conservation areas whose water requirements were considered by the Commission, the other being Lake St Lucia, in KwaZulu-Natal. In its submission to the Commission, the KNP put forward a figure of 55 million gallons (250 034.95 m³) a day as its total water requirement as determined by the park engineer.⁵⁰ This estimate included the drinking requirements of game and the water needed to maintain river habitats, support riparian vegetation and supply water to tourists and employees.

Based on the above figure, as well as the figure put forward by St Lucia (354 595 m³ a day), the Commission determined that conservation water requirements made up around an estimated 1 per cent of the total water consumption in South Africa. The Commission recommended that provision be made in water resources planning for the “reasonable needs of nature conservation areas” to ensure the continued success of nature reserves such as the KNP.⁵¹ This was the first official document in South Africa in which

47 Sanparks, NK/18/1 [K39/1], AE Kuschke & U de V Pienaar, Memorandum oor waterverbruik en toekomstige waterbehoefes van die Krugerwildtuin vir die Waterbeplanningskomitee vir Oos-Transvaal, 8 December 1972.

48 S Joubert, *The Kruger National Park – A history 1* (Paarl, 2007), p 160.

49 NAR, SAB, Decisions of the Executive Council (URU), 5157 [1100], Appointment of the omission of Enquiry into Water Matters by CS Swart, 23 June 1966.

50 Sanparks, NK/18/1/ [K39/1], AE Kuschke, 'n Oorsig van bestaande en moontlik addisionele waterbronne in wildsuiiping in die Krugerwildtuin, 17 June 1969.

51 RSA, Report of the Commission of Enquiry into Water Matters, Report no. RP 34 (Pretoria, 1970).

the need to allocate water for the environment was expressed. Unfortunately, the Commission's recommendations did not immediately improve the KNP's water situation and further submissions were made to the water planning committee of the Eastern Transvaal in 1972 in an effort to secure water for the park.⁵² According to the same source the park management argued that the only way to improve the situation was to declare the Sabie-, Olifants-, Crocodile-, Luvuvhu- and Letaba rivers as state-controlled areas, and to guarantee minimum flows to the KNP. And the park called for a minimum flow of 1 m³/s from each of the five perennial rivers to sustain water resources inside its borders. No record has been found that these requests were acknowledged or adhered to.

Activities leading up to the Skukuza workshop (1983-1987)

In 1979, the KNP again entered a drought period, which lasted until 1987 – the most severe drought in the park's recorded history.⁵³ The natural situation was greatly exacerbated by increased upstream water abstraction, most notably for irrigation purposes. By 1982, the Sabie River reached its lowest flow on record (1.51 m³/s), resulting in the park having to construct emergency water-supply schemes for its tourist facilities at Sabie, Onder-Sabie and Pretoriuskop.⁵⁴ The water-for-game programme took on a renewed intensity during this time. By the time the KNP reviewed its water policy in 1997 the park had 365 boreholes and around 50 earth dams, leaving less than a fifth of the park more than 5 km away from a permanent water source.⁵⁵

The availability of water in previous waterless areas resulted in massive overgrazing. Artificial water points decreased the walking distance between water sources and allowed access to grazing that otherwise would be accessible only to stronger animals.⁵⁶ Water availability also increased the number of herding grazers such as zebra and impala, leaving lower density, rarer antelope species, such as sable antelope, more vulnerable to attack by carnivores.⁵⁷ The resulting over-supply of water and under-supply of grazing had a devastating

52 Sanparks, NK/18/1 [K39/1], AE Kuschke & U de V Pienaar, Memorandum oor waterverbruik en toekomstige waterbehoefes van die Krugerwildtuin vir die Waterbeplanningskomitee vir Oos-Transvaal, 8 December 1972.

53 Van Vuuren Private Archive (VVPA), Oral Archive (OA), F Venter, Sanparks Head: Conservation, 22 June 2016.

54 Sanparks, NK/28 [1], Jaarverslag van die Nasionale Krugerwildtuin aan die Nasionale Parkeraad, 1980/81.

55 IPJ Smit, Systems approach towards surface water distribution in Kruger National Park, South Africa, *Pachyderm*, 53(1), January-June 2013, pp. 91-98.

56 VVPA, OA, D Pienaar, Sanparks Head: Scientific Services, 23 June 2016.

57 IPJ Smit, Systems approach towards surface water distribution in Kruger National Park, South Africa, *Pachyderm*, 53(1), January-June 2013, pp. 91-98.

effect on the KNP's mammalian populations during the drought. When the drought peaked in 1982/83 an estimated 10 000 impala died from starvation along with huge numbers of buffalo, nyala, warthog, kudu and hippopotamus.⁵⁸

South Africa's water legislation at the time made no provision for water for the environment. In order to secure its water resources the KNP became increasingly dependent on its good relationship with the Department of Water Affairs (DWA), now the Department of Water and Sanitation,⁵⁹ This relationship intensified during the 1980s drought. In 1983 the park successfully negotiated with the Minister of Water Affairs to gain a portion of water from the Tzaneen Dam.⁶⁰ In order to achieve this, the park called on Section 9(1) of the Water Act, which regulated riparian water use and allowed for downstream water users to be compensated with water for "domestic use and livestock watering" when dams were built upstream.⁶¹ The KNP used formulas normally applied to determine irrigation water allocations, to claim eligibility for a share of 14.7 million m³ from the Tzaneen Dam.⁶² The KNP also received water released from the Phalaborwa Barrage on the Olifants River, constructed in 1968.⁶³ As a result, the Phalaborwa Water Board, the main user of the barrage, was granted a water permit on condition that it would ensure a minimum flow of 0.57 m³/s downstream of the barrage in the Olifants River for the sake of the KNP. This appears to be the earliest water set aside for ecological purposes in South Africa.

In 1985, when it launched a series of intensive catchment studies in the Lowveld, the DWA included the KNP as a key stakeholder alongside users such as irrigation and industry.⁶⁴ The studies were part of a first attempt by the department to move away from ad hoc water resource development towards a more integrated catchment management approach.⁶⁵ Although the environment was not yet reflected in policy, the DWA had started to recognise it as a legitimate

58 Sanparks, NK/298 [1], Jaarverslag van die Nasionale Krugerwildtuin aan die Nasionale Parkeraad, 1982/83.

59 For the sake of simplicity the abbreviation "DWA" will be used throughout.

60 Sanparks, B8/3 [2], Letter from Department of Environmental Affairs to Groot Letaba Main Irrigation Board, Gratis watertoekenning uit die Fanie Botha Dam aan die Nasionale Krugerwildtuin, 14 November 1983.

61 RSA, Water Act 54 of 1956.

62 Sanparks, B8/3 [2], Letter from Department of Environmental Affairs to Groot Letaba Main Irrigation Board, Gratis watertoekenning uit die Fanie Botha Dam aan die Nasionale Krugerwildtuin, 14 November 1983.

63 DC Midgley *et al.*, The Phalaborwa Barrage, *The Civil Engineer in South Africa*, 12(5), May 1970, pp. 111-116.

64 Sanparks, B8/3 [2], Background document for ad hoc study on water requirements for water conservation in the catchments of the Sabie, Letaba, Shingwidzi and Luvuvhu rivers, 1987.

65 FC van Zyl, Integrated catchment management: Is it wishful thinking or can it succeed? (in Water Institute of Southern Africa, River basin conference for sustainable development Volume 1, Kruger National Park, 15-17 May 1995, pp. 1-13.)

user of water, albeit in competition with other water users. As part of the study, the KNP had to provide information on its water requirements. Apart from simple calculations based on engineering formulae no attempt had been made to determine the quantitative and qualitative requirements of the KNP's river ecosystems. As a consequence, the park, together with DWA, called on South African aquatic scientists to attend a special workshop held at Skukuza on 14-19 March 1987, to undertake basic surveys of these rivers and provide a first estimate of the water needs of the KNP's aquatic ecosystems.

Ecological flow science had been developing steadily since the passing of the first environmental conservation policies in countries, such as the United States, in the sixties.⁶⁶ Initial flow methods were aimed at determining minimum flow requirements (i.e. the smallest volume of water by which aquatic life could survive), and modelled on temperate, Northern American rivers.⁶⁷ South African ecological flow methods did not exist at the time. More than sixty individuals from various disciplines were divided into teams to determine the minimum water requirements for each of the KNP's perennial rivers. While the Skukuza workshop succeeded in identifying the principles by which water requirements should be defined, the lack of knowledge of the relationships between water availability and ecosystem quality and functioning made the determination of exact water requirements nearly impossible.⁶⁸ The best response workshop delegates could come up with was a "guestimate" of what the minimum water requirements of each perennial river should be. Still, the Skukuza workshop is viewed as a defining moment in the South Africa's aquatic science history, because it introduced an era of vast state investment into building the country's knowledge regarding its aquatic ecosystems. In turn this knowledge was used to persuade public policy-makers to include the environmental reserve in the National Water Act (Act no. 36 of 1998).

Kruger National Park Rivers Research Programme (1988-1999)

The unsatisfactory answers emanating from the Skukuza workshop prompted new discussions over enhancing knowledge about the KNP's river systems and securing their sustainability. Discussions among the DWA, the National Parks Board (NPB), as well as research funding institutions, the

66 AC Benke, A perspective on America's vanishing streams, *Journal of the North American Benthological Society*, 9(1), March 1990, pp. 77-88.

67 S Postel & B Richter, *Rivers for life: Managing water for people and nature* (Island Press, Washington, 2010), pp. 45-48.

68 Sanparks, B/5 [1], KNP River ecosystems, framework document outlining the goals, objectives and funding requirements for research, monitoring and management, s.a.

Water Research Commission (WRC) and the National Research Foundation (NRF), resulted in the launch of a collaborative programme, the KNP Rivers Research Programme, in 1988, to fund and manage the necessary research in order to determine the ecological flow requirements of the KNP's main river systems.⁶⁹ The WRC, Foundation for Research Development (FRD) as well as the DWA and the Department of Environmental Affairs all contributed funds to the programme. In addition, the FRD provided secretarial services to the programme while the NPB (later renamed South African National Parks or SANPARKS) was responsible for research facilities and manpower.

The programme initially set the following objectives:⁷⁰

- To define, and evaluate scientific information pertinent to the allocation of water to the KNP.
- To develop the appropriate expertise for managing water allocation for ecological purposes.
- To develop and maintain the necessary inter-institutional cooperation and communication.
- To define and initiate research in priority areas.
- To secure and make recommendations for funding requirements.

The KNP was thus viewed as a living laboratory for (i) unravelling the complexity of South Africa's river systems and (ii) testing ecological flow determination methods and management scenarios that could ultimately be applied on a broader, national scale. A two-tier management system (comprising a public policy and a management committee), which included high-level representatives from both DWA and the NPB ensured that research output was more readily taken up in management policies, both those of the KNP and of the country as a whole.⁷¹

The first research project proposals were received in 1989 and, by 1991, the project was funding forty-one projects across various subjects.⁷² Three pertinent projects stand out during this period. The first focused on the historical origins of South African water law as a contribution towards

69 VVPA, OA, F Venter, Sanparks Head: Conservation, 22 June 2016.

70 SAWHAR, Waterlit Collection, Anon, Kruger National Park Rivers Research Programme. Programme Description phase 1, s.a. (ca 1991).

71 Sanparks, B/8 [8-1], Motivation for a cooperative multidisciplinary research programme on the Kruger National Park river systems, document drawn up by the Working Group on behalf of the National Parks Board, 19 July 1988.

72 Sanparks, B/8 [8-1], Minutes of the eleventh meeting of the coordinating committee for the KNP Rivers Research Programme, 1 November 1991.

amending the Water Act of 1956 to recognise the environment's right to water.⁷³ The study argued that such an amendment was necessary to:⁷⁴

... (e) establish a fair allocation system for water utilisation by all organisms [including the environment], and at preserving the resource.

The same study determined that water allocation to the environment could no longer be seen as a voluntary, but rather a, crucial function for safeguarding resource sustainability and its ongoing use by all water users. The study, therefore, recommended that environmental rights be accommodated in South African water law. Though publicly available, the results of the study were not widely shared until Lead researcher Maritza Uys and several project steering committee members contributed to the National Water Act, in which many of these early sentiments were eventually captured as the ecological reserve.⁷⁵

The second project, led by Jackie King (then of the University of Cape Town), was aimed at assessing the instream flow requirements of rivers in South Africa. The study led to the development of the first holistic ecological flow method in South Africa, namely the Building Block Methodology (BBM).⁷⁶ In the early 1990s BBM was applied during a series of instream flow requirement (IFR) workshops organised by DWA. The workshop's objective was to determine the water needs of the environment, particularly where further water resource developments were being planned.⁷⁷ Between 1992 and 1996 IFR workshops were held for the following river systems: Lephallale, Berg, Olifants (Western Cape), Lomati, Koededouw, Senqu (Lesotho), Mooi, Thukela, Mogalakwena, Mvoti rivers and the Olifants, Letaba, Luvuvhu, and Sabie-Sand rivers of the KNP.⁷⁸ The workshops demonstrated South African aquatic scientists' growing confidence in determining the ecological flow requirements of local river systems and persuaded lawmakers to include the ecological reserve in the National Water Act.⁷⁹

73 M Uys, A structural analysis of the water allocation mechanism of the Water Act 54 of 1956 Vol 1. WRC Report No. 406/1/96 (Gezina, 1996).

74 M Uys, Statutory protection for the water requirements of natural ecosystems, *Koedoe*, 35(1), September 1992, pp. 101-118.

75 VVPA, OA, M Uys, Advocate and water law expert, 4 June 2015.

76 JM King & RE Tharme, Assessment of the instream flow incremental methodology and initial development of alternative instream flow methodologies for South Africa WRC Report No. 295/1/94 (Gezina, 1993).

77 N van Wyk [vanwykn@dws.gov.za], IFR workshops, private email message to L van Vuuren [laniv@wrc.org.za], 2016-11-06.

78 JM King & RE Tharme, Assessment of the instream flow incremental methodology and initial development of alternative instream flow methodologies for South Africa WRC Report No. 295/1/94 (Gezina, 1993), p. 18.

79 VVPA, OA, J King, ecological flow scientist, 31 October 2016.

A third important project undertaken under the first phase of the KNP River Research Programme investigated the potential impacts of proposed new dams on the Sabie River on aquatic life in the river downstream of the KNP. At this stage DWA was considering seven dam sites, the largest being the 62m-high Madras Dam, to be located on the main stem of the Sabie River just outside the borders of the KNP.⁸⁰ Studies found that of all the dams under consideration, the Inyaka (also spelt Injaka) Dam would have the least impact on the flow of the Sabie River into the KNP, and in 1994 a decision was made to go ahead with the construction of this dam over the other proposed sites.⁸¹ The fact that environmental consideration impacted the location of a dam on the Sabie River is quite significant as, up to this time, there was no legislation compelling the South African government to consider the environment in any construction project. The operating rules of the dam included regular water releases to feed the KNP downstream. The KNP has come to rely on the water of the Inyaka Dam, and releases from the dam played a definite role in keeping the Sabie River flowing through the KNP during the El Niño-induced drought of 2015-16.⁸²

A review of the success of the KNP Rivers Research Programme led to a restructuring of the programme structure and goals prior to the launch of the second phase in 1994.⁸³ Participants were especially concerned about deteriorating relationship between engineers and scientists on the programme and a seemingly uncoordinated research effort.⁸⁴ Water managers felt that researchers were not committed to providing the information they required in a timely manner, while researchers were of the view that they were not being given enough autonomy to conduct research and were bound by a lack of formal processes by which information could be transferred between the two parties.⁸⁵

80 JH O’Keeffe & BR Davies, Conservation and management of the rivers of the Kruger National Park: Suggested methods for calculating instream flow needs, *Aquatic conservation: Marine and freshwater ecosystems*, 1(1), September 1991, pp. 55-72.

81 RSA, WP D-94, Report on the proposed Sabie River Government Water Scheme. First phase: Injaka Dam and Bosbokrand transfer pipeline. (Government Printer, Pretoria, 1994).

82 L van Vuuren, Drought – Nature’s lessons in overdrive in Kruger National Park, *The Water Wheel*, 15(5), September/October 2016, pp. 34-37.

83 A Görgens & J Lee, Kruger National Park Rivers Research Programme: Situation assessment and management assessment WRC Report No. 1977/5967 (Gezina, 1992).

84 Sanparks, B/8 [8-1], Minutes of the fourth meeting of the policy committee for the KNP rivers research programme, 3 June 1992.

85 SAWHAR, Waterlit Collection, F van Zyl, Making it happen – The Sabie experience, JJ Pigram & BP Hooper (eds), *Proceedings of Water allocation for the environment. An international seminar and workshop organised by Centre for Water Policy Research* (Armidale, 1991), pp 247-258; Sanparks, B/8 [8-1], KH Rogers *et al.*, An integrated programme for research on the Kruger National Park Rivers, p. 3.

Image 4: The lower Sabie River remained flowing during the height of the 2015/2016 drought thanks to environmental water releases from the Inyaka Dam upstream of the Kruger National Park



Source: Photo by Lani van Vuuren, 26 June 2016.

To refocus the programme and improve coordination and communication, research activities were divided into four sub-programmes, each with its own manager:⁸⁶

- Information systems development and management – aimed at the development and management of a central management system to capture all the output emanating from the research projects of the KNP Rivers Research Programme.
- Decision-support system and management – aimed at developing a decision-support system to more accurately link the information needs of managers and stakeholders with information emanating out of the research programme.
- Research, development and management – aimed at providing, through research, the information required to improve management of the rivers of the KNP.
- Training, information and technology transfer – aimed at ensuring that the information and methods developed through the research programme was transferred effectively to stakeholders and managers.

The Sabie River was selected as the focus area for phase 2, and most of the research projects in this phase centred on this river system. Charles Breen, who had earlier led research on the ecological flow requirements of

⁸⁶ SAWHAR, Waterlit Collection, C Breen *et al.*, *A description of the Kruger National Park Rivers Research Programme: Phase 2* (Pretoria, 1994).

the Pongolo floodplain, was appointed as the programme manager. The introduction of Breen – who brought with him the experience of dealing with diverse stakeholders at Pongolo – made a significant difference in the perceived success of the programme.⁸⁷ In addition to acting as a neutral go-between between the policy and management committees, Breen introduced a programme research committee, which included the managers of the sub-programmes. The research committee met a day before the management committee to discuss the status of research projects and to iron out any differences of opinion. In this way, a single message was passed on to the management committee.⁸⁸ Breen's action brought greater coherence to the management of the programme.

The second phase of the KNP Rivers Research Programme built on the strong scientific foundation of the first phase. A particular focus was to take the knowledge that had been gathered from the individual components of the aquatic ecosystems of the KNP and contribute towards a greater understanding of the health of the river systems, with the ultimate aim of predicting the outcome of upstream anthropogenic activities.⁸⁹ At this point the KNP had acquired intimate knowledge and inventories of all the major components of its river systems, from the fish and riparian vegetation to the invertebrates, hydrology and channel hydraulic characteristics of the rivers.⁹⁰ And by the end of phase two the KNP Rivers Research Programme was confirmed as having made “an important contribution to understanding the dynamics of [South Africa's] river systems”.

As an indirect consequence of the programme, the knowledge generated on the importance of the ecological functioning of the KNP rivers prompted Sanparks to start building working relationships with its upstream neighbours. Working groups were established in each catchment comprising various stakeholders, aimed at finding sustainable solutions to the water challenges experienced by the park.⁹¹ These relationships have persisted, and today the KNP is accepted as a major stakeholder in all decision-making processes around the water resource management in its river catchments.⁹²

87 VVPA, OA, K Rogers, Former researcher, 5 June 2015.

88 VVPA, OA, CM Breen, Former programme manager: KNP Rivers Research Programme, 7 July 2015.

89 J O'Keeffe & Y Coetzee, Status report of the Kruger National Park Rivers Research Programme: A synthesis of results and assessment of progress to January 1996 WRC Report No. 711/1/96 (Gezina, 1996), p. 27.

90 C Breen *et al.*, A description of the Kruger National Park Rivers Research Programme: Phase 3 (Pretoria, 1997), p. 20.

91 VVPA, OA, A Deacon, Former Sanparks senior scientist, 22 November 2016.

92 VVPA, OA, F Venter, Sanparks Head: Conservation, 22 June 2016.

Given the extensive knowledge of the functioning of the KNP's aquatic ecosystems, the vexing question remains as to how to manage these systems sustainably. The more the managers of the park learnt about how these systems functioned the more they realised how complex, variable and heterogeneous they are. In a changing social environment, the KNP could no longer shut out upstream stakeholders and attempt to solve its water challenges in isolation. Rather, it had to find ways of working with these stakeholders towards a common goal. It also became clear that the KNP's rivers could not be adequately managed under the traditional "command and control" management style which sought to stabilise the natural variability in the system.⁹³

Another important outcome of the KNP Rivers Research Programme was the development of a KNP management strategy that is still used. Known as "strategic adaptive management", this management style focuses on establishing a "balance in nature".⁹⁴ As a result, instead of establishing management rules that diminish natural variability and react to extreme events, strategic adaptive management recognises the "flux in nature", and rather aims at planning in advance how to manage extreme events. Sanparks introduced strategic adaptive management in the KNP in 1995.⁹⁵ Once successfully applied to the management of the rivers in the KNP, the management framework was expanded across the whole park, and to this day remains the framework around which all ecosystems are managed in the KNP.⁹⁶

In 1997, the KNP reviewed its water policy, and began to systematically close the artificial water points. Of the 325 boreholes that once existed in the KNP, 185 had been closed by 2016.⁹⁷ Dams and weirs that have become silted up or breached by floodwaters are targeted for removal.⁹⁸ During the 2015/16 drought the KNP's current water management policy was severely tested and found mostly successful. And artificial waterholes were closed to create pockets of good grazing away from water points. While the park did suffer some animal casualties, especially among the

93 VVPA, OA, H Biggs, former Sanparks senior scientist, 6 June 2015.

94 K Rogers & R Bestbier, Development of a protocol for the definition of the desired state of riverine systems in South Africa, Department of Environmental Affairs & Tourism (Pretoria, 1997).

95 DJ Roux & LC Foxcroft, The development and application of strategic adaptive management within South African National Parks, *Koedoe*, 53(2), May 2011, 1-5.

96 VVPA, OA, D Pienaar, Sanparks Head: Scientific Services, 23 June 2016.

97 A Watson, Kruger Park closes five man-made watering points to restore ecosystem, *The Citizen*, 2016-12-08 (available at <https://citizen.co.za/news/south-africa/1369297/kruger-park-closes-man-made-watering-points-to-restore-ecosystem/>, as accessed on 19 October 2017).

98 VVPA, OA, F Venter, Sanparks Head: Conservation, 22 June 2016.

hippopotami and buffalo populations, mostly old and diseased animals perished, whereas stronger animals were able to reach these grazing areas.⁹⁹

In 1997, when the KNP Rivers Research Programme entered its third phase, the milieu in which the programme was operating was vastly different to the one in which it had started in 1988. South Africa's water law review process was underway, and the needs of the environment were not only accepted but were being actively catered for in South Africa's new water legislation. The emphasis of the third phase, which ran until 1999, was therefore not so much on gathering further scientific information, but on consolidating existing information and processes and packaging it in such a way that it could be applied in public decision-making and monitoring in ways that contributed maximally to the new water resources management paradigm being established in South Africa.¹⁰⁰

Conclusion

The availability (and lack) of water resources has been a prime consideration for the management of the KNP since its establishment ninety years ago. While the park is fed by five perennial systems, its location at the downstream end of the river catchments, in addition to its semi-arid rainfall and non-perennial, localised water resources, has left the park vulnerable to upstream anthropogenic impacts, and has led much of its management actions. These vulnerabilities become abundantly clear during the drought cycles which the park experiences every decade or so.

Passing of the National Water Act in 1998 was the first legislation that made provision for environmental flows in South Africa. Up to that point, the KNP had devoted its water management efforts inwards towards enhancing its water resources through the additional of artificial water supplies. Water resource development began soon after the KNP's establishment, and intensified with each drought episode, leading to an advanced network of water points throughout the park. Despite these efforts, the KNP remained dependent on the exogenous water supply flowing downstream from its main rivers, and the success of the water-for-game programme was marred by the deleterious effects the enhanced water resources had on rare ungulates and the availability of grazing during droughts.

⁹⁹ VVPA, OA, D Pienaar, Sanparks Head: Scientific Services, 23 June 2016.

¹⁰⁰ VVPA, OA, CM Breen, Former programme manager: KNP Rivers Research Programme, 7 July 2015.

The developments in the KNP and the evolution of its water management policies cannot be viewed in isolation. Undoubtedly the questions the DWA began asking around the water use of the national park as part of its own efforts to ensure the environment received a “share” of water resources in the catchments, played a pivotal role in prompting the first real scientific studies into the KNP’s perennial rivers. In addition, the status of the KNP as an iconic conservation area prompted actions towards the conservation of its water resources. It is doubtful that so much effort would have been put into safeguarding the park against drought had the KNP not held the national status it had.

The KNP Rivers Research Programme came at an opportune time in South Africa’s water history. As the country entered a period of democratisation it offered the opportunity for various policies to be reviewed – including water. By building the necessary body of knowledge around the function and needs of South Africa’s aquatic environment, the KNP Rivers Research Programme left a marked legacy on the South African water landscape. Not only did this multi-decadal programme help to advance and develop the aquatic science discipline in South Africa, the knowledge and methodologies gained through the programme convinced lawmakers as to the necessity of including the environmental reserve in South Africa’s water legislation. By gaining knowledge on the behaviour and characteristics of its main river systems, the KNP was able to adopt a new management strategy that embraced the variability in the system and finally reach across the fence to its neighbours to take its place as an important stakeholder in the management of the Lowveld rivers.