KOEDOE - African Protected Area Conservation and Science
ISSN: (Online) 2071-0771, (Print) 0075-6458

Characterising the geomorphic dynamics of river systems: An example of the Sabie River, South Africa

Authors:
Jasper Knight[1]
Mary Evans[1]

Affiliations:
[1]School of Geography, Archaeology and Environmental Studies, University of the Witwatersrand, Johannesburg, South Africa

Corresponding author:
Jasper Knight,
jasper.knight@wits.ac.za

Dates:
Received: 03 Dec. 2021
Accepted: 17 Feb. 2022
Published: 29 Mar. 2022

How to cite this article:
Knight, J. & Evans, M., 2022, 'Characterising the geomorphic dynamics of river systems: An example of the Sabie River, South Africa', *Koedoe* 64(1), a1700. https://doi.org/10.4102/koedoe.v64i1.1700

Introduction

Semiarid climatic conditions prevail over much of southern Africa, with variations in rainfall over seasonal and interannual timescales (Saraiva Okello et al. 2015). This rainfall pattern provides rise to highly variable river discharge regimes from high-energy floods in the wet season to low perennial flow, or isolated remnant pools or dry river beds, in the dry season (Heritage et al. 2015; Rountree, Rogers & Heritage 2000). These discharge regimes have important implications for river properties as a whole, including water quality, maintenance of ecosystems and biodiversity, pollutant dispersal, and changes in river geomorphology (Seanego & Moyo 2013). The latter has been proposed as a means of mapping and classifying river systems in southern Africa, especially in areas with seasonally variable river regimes (e.g. Eze & Knight 2018; Knight in press; Rountree et al. 2000; Van Niekerk, Heritage & Moon 1995). The major river reach types identified through such mapping are mixed anastomosing, alluvial braided, mixed pool-rapid and alluvial single thread (Heritage, Van Niekerk & Moon 1997; Moon & Heritage 2001) that describe different combinations of bedrock *versus* loose sediment within and around the river channel(s) (Rosgen 1994). The substrate type and its properties and dynamics have implications for turnover of ecosystem biodiversity, persistence of endemic species, spread of invasive species and reducing flood risk (Entwistle et al. 2014; Pettit et al. 2005; Rountree et al. 2000). Despite such applications, many river systems in southern Africa have not been fully or accurately mapped at this scale, and individual reaches even along the same river can be highly variable in character. For example, along the Limpopo River system, the most common river reach category is low/moderate sinuosity with planform-controlled sand beds (37% of total river length), followed by meandering sand beds (26%) and bedrock-forced meanders (17%) (Knight in press). However, different tributaries of the Limpopo have different geomorphic characters, with bedrock-forced meanders being dominant (84%) on the Nzhelele River, meandering sand beds (69%) on the Elephantes River and low-sinuosity fine-grained beds (41%) on the Lotsane River (Knight in press).

Although river geomorphology can be mapped relatively easy, especially by remote sensing, the dynamics of many semiarid river systems are unknown. Here, 'dynamics' refers to how the geomorphology of the river system changes over time and space, especially in response to variations in rainfall and thus river discharge. Understanding the dynamics of river systems has implications for understanding floodwater and sediment flows and pathways, identifying which areas are likely to experience flood impacts, restoring eroded or polluted river reaches, and producing flood risk maps for human settlements and infrastructure (Gericke & Du Plessis 2012). Although this analysis has been undertaken for individual rivers (e.g. Heritage et al. 2015; Knight & Evans 2018; Milan et al. 2018) many rivers across southern Africa remain unmapped for these purposes. The aim of this study is to use geomorphology, sediments and dating evidence from the Sabie River in northeast South Africa in order to characterise its dynamics. This is located in a semiarid environment but subject to significant seasonal variations in river discharge, giving rise to repeated historical flood events. This article (1) describes the evidence for river system dynamics based on its (a) geomorphology, (b) sediment patterns and (c) dating evidence for its flood history; (2) proposes a model for the nature of flood events along different river reaches and (3) discusses how this information can be applied to river management.

The Sabie River

The Sabie River catchment (7096 km^2) has its source areas in the Eastern Escarpment of Mpumalanga province, South Africa, and drains eastwards into Mozambique and the Indian Ocean, traversing the Lowveld and Lebombo topographical zones (400 m and 200 m above see level (a.s.l.), respectively) (Figure 1a). Bedrock geology ranges from Precambrian igneous and metasedimentary rocks in headwater areas of the Eastern Escarpment to rhyolite, basalt and sandstones (Jurassic) found in middle and lower reaches of the Lowveld within Kruger National Park (KNP) (Schutte 1986). The variable topography results in a precipitation gradient from wetter conditions (~2000 mm yr^{-1}) in westward mountains to dryer conditions (~600 mm yr^{-1}) in eastward lowlands. Most rainfall takes place during the austral summer. Sabie River discharge is therefore highly seasonal with a winter average low flow of approximately 2 m^3 s^{-1}–3 m^3 s^{-1} and a summer average high flow of approximately 20 m^3 s^{-1}–50 m^3 s^{-1} (data for the period 1995–2014 from station X3H015, Figure 1a). Peak seasonal flood events commonly reach discharges of 300 m^3 s^{-1}–400 m^3 s^{-1} in its middle and lower reaches.

Sabie River geomorphology and sediment dynamics

Several lines of evidence exist for geomorphic change and sediment dynamics along the Sabie River and these are examined in turn. Integration of such evidence allows for the tempo or pacing of river geomorphology and sediment dynamics to be identified and this is a key step in developing a river-specific flood management model.

Mapping geomorphic patterns and geomorphic change

Several stretches of the Sabie have been mapped from aerial photographs or satellite images, and based on this, spatial patterns of bedrock versus sediment-dominated reaches have been described (e.g. Entwistle et al. 2014; Eze & Knight 2018; Heritage & Moon 2000) although in reality most reaches are of mixed type. Three geomorphological zones are identified (marked I–III in Figure 1a). Zone I: Headwater areas of the Eastern Escarpment sector are bedrock dominated, with pool and riffle systems present, limited loose sand available but often stacked fluvially transported boulders adjacent to the single channel and a restricted or narrow floodplain (Figure 1b). Zone II: A transitional zone exists in mid-catchment locations such as east of Hazyview where bedrock elements are separated by more sediment-dominant river stretches. Here, the single river channel is located within a narrow and incised bedrock-defined valley but valley side sediment accumulations are often present as either unpaired river terraces or as welded lateral bars with overbank deposits (Figure 1c). Zone III: In lowland reaches of the Sabie River,

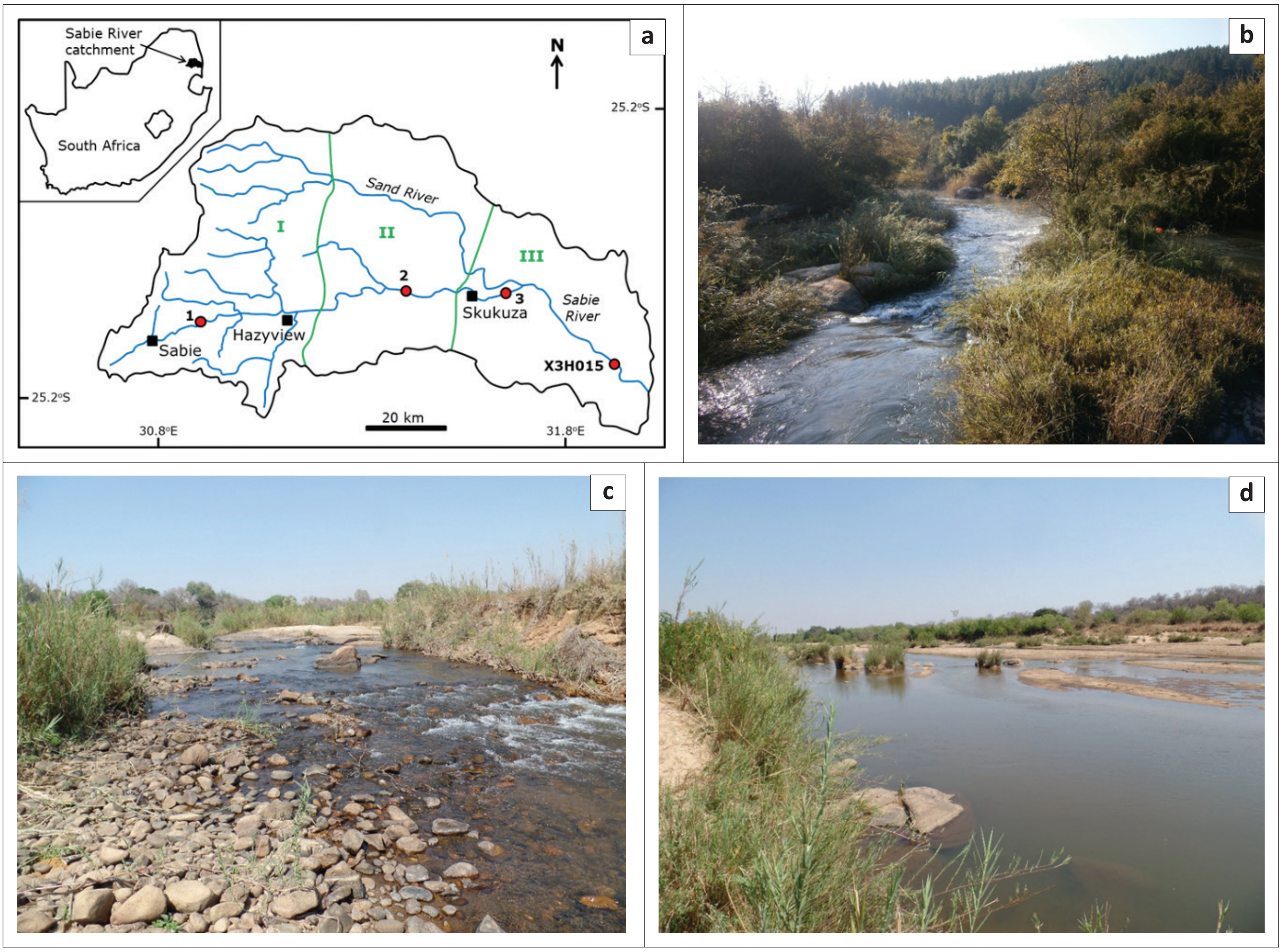

FIGURE 1: (a) Location of the Sabie River in northeast South Africa, showing the locations of sites named in the text (red dots), river gauging station X3H015 and the three river geomorphic zones (marked after Eze & Knight 2018) of (I) highland zone of gorges and bedrock-forced meanders; (II) low to moderately sinuous planform controlled mixed beds; (III) low sinuosity, fine grained beds and floodouts. Zones are separated by green lines on the map. (b) Photo of the Sabie River within Zone I at Bergvliet (site 1 on panel a); (c) photo within Zone II at Kruger Gate (site 2 on panel a); (d) photo within Zone III near the Sabie-Sand confluence (site 3 on panel a).

the main river basin is sediment dominated throughout and the main river channel, which may be braided or multichannel, extends across a wide floodplain (several 100 m) with shallow bedrock slopes on either side. For most of the year, the main channel is underfit but episodic floods cause reactivation of abandoned channels, enhanced mobility of in-channel bars and phases of overbank deposition that commonly extends across the width of the floodplain.

Rapid geomorphic change takes place in response to seasonal flood events. Such recent events coincide with Indian Ocean cyclones Dando (January 2012), Dineo (February 2017) and Idai (March 2019). High river velocity, basal shear stress and discharge during floods result in differential sediment erosion and deposition, leading to changes in the distributions of sand and exposed bedrock and changes in land surface elevation. Substrate types and elevation changes have been mapped in studies that compare pre- and post-flood river conditions. For example, using Light Detection and Ranging (LiDAR) data, Milan et al. (2018) calculated 66 880 m^3/km^{-1} of erosion and 24 380 m^3/km^{-1} of deposition during Cyclone Dando in the middle/lower Sabie. Broadhurst and Heritage (1998) showed that river channel responses to floods depend on antecedent sediment distributions, single or multichannels and floodplain width. This results in the development of distinctive landforms in different places along the river system (Heritage & Moon 2000). Bedrock and sediment substrates also show different responses to variations in river discharge. Sediment is easily able to erode and accrete, developing and destroying landforms and changing land surface elevation; bedrock only undergoes erosion and at much slower rates. A sediment cover can protect underlying bedrock from erosion but bedrock erosion rates may rapidly increase if the sediment cover is stripped away. These feedbacks highlight the variable rates and styles of geomorphic change in different reaches in response to floods (Heritage et al. 2015).

Sediment dynamics and mobility

Although changes in the areal sediment thickness can be evaluated using LiDAR data, this cannot discern changes in sediment type, properties or depositional structures. On the Sabie, field observations can inform on such patterns. Heritage and Moon (2000) showed some examples of different river landform types, including bars and boulder deposits. Knight and Evans (2017) described the characteristics of flood deposits in the lower reaches of the Sabie and a schematic 'flood stratigraphy' model comprising (from base to top):

- 2D and 3D sandy subaqueous dunes (migrating in-channel bedforms) overlying an erosional surface, overlain in turn by
- Climbing rippled sand (saltation transport at the base of the flow), transitional to
- Massive sand deposited by suspension under waning flow conditions, overlain by
- Laminated silts, deposited under stagnant water conditions, topped by
- Fragmented woody debris indicative of high-energy erosion during the flood and deposited when any remaining water in the floodplain or channel is lost.

Several studies have also shown that different parts of the river channel – and therefore different types of bars – became active at different flow stages and different seasons, depending on the flow regime (Heritage, Broadhurst & Birkhead 2001; Heritage et al. 2015). This means that higher elevation former channels will only become active under higher flow conditions and will be abandoned first when the water level falls. They will also act as sites for sediment deposition during waning flow stages (Cunningham, Evans & Knight 2015). Patterns of overbank and floodplain deposition by flood events on the Sabie have also been examined (Knight & Evans 2017, 2018; Milan et al. 2018), showing that there are different sedimentary expressions in different parts of the occupied floodplain depending on water depth, water velocity (thus shear stress) and local topography of the bedrock or sediment substrate. There is as yet no clear understanding of spatial patterns of sediment properties (grain size, sorting) along the Sabie or how in-channel bedforms change during flood stages, owing to a lack of field data.

Dating periods of sediment deposition

Organic-poor sandy sediments can be dated using luminescence methods, and this has been carried out extensively throughout southern African rivers, including on the Sabie (e.g. Colarossi et al. 2015; Cunningham et al. 2015; Heritage et al. 2015; Knight & Evans 2018). The basis behind this method is that the calculated luminescence age of a quartz sand grain is related to the time period as the grain was last exposed to sunlight (Murray & Wintle 2003). In a river system, sand grains are bleached (luminescence signal reset to zero) by exposure to sunlight during active erosion and transport, and grains become locked away from the surface when they are deposited and buried. Calculating the luminescence age of a sample can, therefore, inform on the timing of sediment erosion and deposition events, which, along the Sabie and similar rivers, take place during floods. On the Sabie, sediment samples around or in the present channel at 10 cm – 45 cm depth have yielded ages from 26 ± 7 to 131 ± 19 years (Knight & Evans 2018). Samples from 1.49 m–3.50 m depth have yielded ages from 188 ± 19 to 910 ± 278 years (Heritage et al. 2015). However, ages with a wide error margin may reflect incomplete bleaching of the luminescence signal within sediment grains during their transport (Colarossi et al. 2015; Cunningham et al. 2015). This means that individual grains can contain inherited luminescence signals from previous transport and deposition events. Several innovative studies have examined the nature of this inherited signal from the Sabie River. Cunningham et al. (2015) showed that of flood samples recovered from higher elevations along the Sabie, only 20% – 70% of grains are well bleached compared with > 80% of grains from low-flow positions. Based on luminescence signals of samples from different sites across the floodplain, Knight and Evans (2018) showed that sediments suspended in floodwaters at the centre of the channel are well mixed, and thus, when deposited, have a consistent luminescence signal throughout. By contrast, suspended sediment settling from slack water across the floodplain takes place more slowly, leading to increased bleaching and thus younger ages over time. This depositional model can explain relationships between the degree of sediment reworking (and luminescence signal bleaching) during floods and resulting river geomorphic and sedimentary signatures.

Discussion

Understanding the dynamics of river systems through considering their geomorphology, sediment patterns and dated periods of activity have implications for identifying the timescale of cyclic behaviour that typifies any river reach. With respect to the Sabie River, although significant cyclonic rainfall takes place in summer annually, this does not always give rise to a proportional flood response. This means that sediment transport and geomorphic change does not always take place outside of the main river channel, such that higher areas of the floodplain may not be affected by floods for (possibly) decades. Heritage et al. (2001, Figure 6) showed that ephemeral channels along the Sabie are only affected by floods that have a return period of > 10 years, and based on river gauge data they estimated the February 2000 flood to have a return period of > 60 years. Luminescence ages from river sand samples are older than the timing of significant recent flood events (e.g. from 2017, 2012, 2006, 2000), meaning that despite being very large events, these floods were possibly too rapid and carrying too much sand to allow the grains to become fully bleached, thus leading to inherited luminescence ages being present (Knight & Evans 2018). This also depends on the nature of the river reach itself. For example, in downstream reaches, floodwater can be accommodated across the width of the shallow floodplain. In upstream reaches where the river channel is constrained within a bedrock valley, accommodation space for floodwater is much less, leading to net erosion along constrained reaches and enhanced flooding and deposition immediately downstream at the transition into lowland areas (e.g. from geomorphic Zones I to II; Figure 1a). This variability in behaviour takes place according to the characteristics of the river reach in question: no river exhibits the same behaviour patterns of change throughout its length. This is manifested clearly in different combinations of bedrock and sediment substrates, different river channel types and different in-channel and floodplain landforms (Knight & Evans 2017, 2018).

Based on the foregoing evidence, we propose a model of river system behaviour in which bedrock- and sand-dominated reaches respond differently during flood events because of different initial sediment availability within and around the active channel (Figure 2). Under low-flow conditions, relict (inactive) sediment is found at higher elevations in bedrock hollows or across the floodplain (e.g. Figure 1d). Flood conditions result in excavation of sediment from these hollows, revealing a hard bedrock substrate. However, where a sediment floodplain exists, flooding leads to development of a scoured surface and active sediment deposition and erosion phases that extend across the floodplain (Figure 2). Higher sediment concentrations within the water column, over sandy substrates, lead to rapid development of migrating bedforms that are sustained by traction and saltation (Knight & Evans 2018). These sandy bedforms are generally absent in bedrock-dominated areas, even within active channels.

This model highlights that bedrock- and sand-dominated river reaches can exhibit different behaviours during and after flood events (Figure 2), and is consistent with previous work on Sabie River responses to floods (e.g. Heritage et al. 2015, their Figure 4). The luminescence dating does not show a clear difference between the sediment depositional histories of

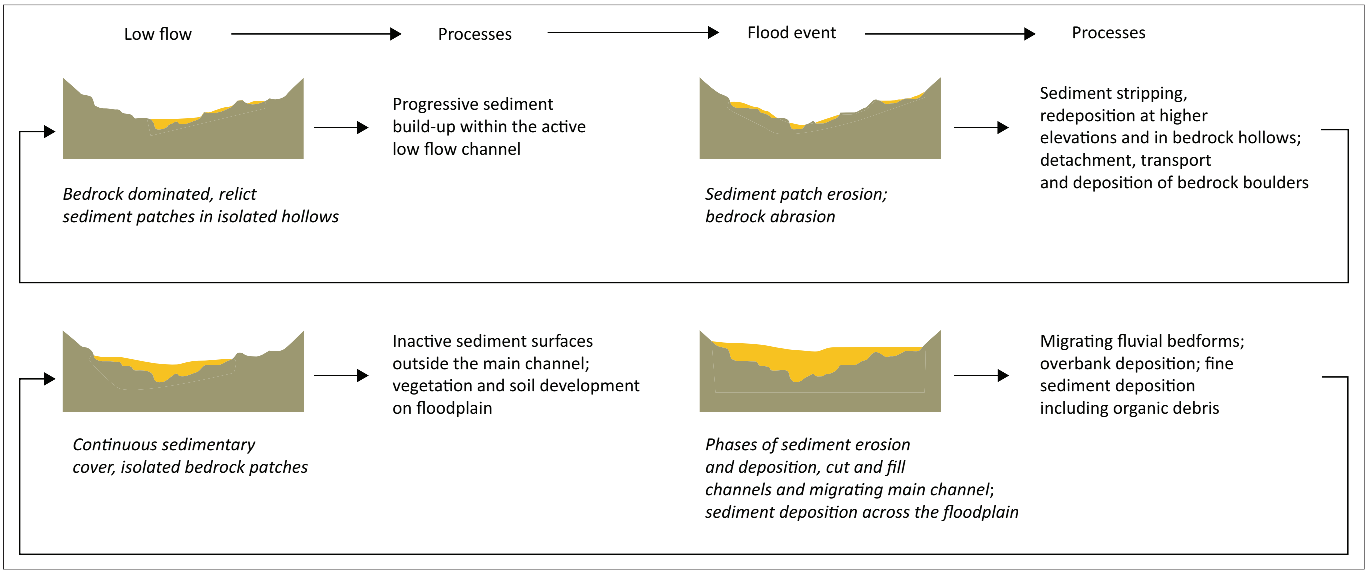

FIGURE 2: Conceptual process model of the evolution of bedrock-dominated (top) and sand-dominated river channels (bottom) in the Sabie River during low flow and then flood conditions. Note that this then returns to low flow conditions afterwards. A schematic cross-section of the river profile is presented, with bedrock (brown) and sediment areas (yellow) shown.

bedrock- and sand-dominated reaches (because luminescence samples are obtained from sediment, not bedrock); however, Cunningham et al. (2015) argued that sediments deposited in hollows in bedrock-dominated reaches have quite different luminescence signals because of the episodic nature of their deposition. Taken together, this shows that there is a decadal-scale tempo of river system responses to flood events along the Sabie and likely other rivers in the region (Colarossi et al. 2015; Milan et al. 2018). Bedrock-dominated substrates are less dynamic and show less interannual variation compared with sediment-dominated substrates, and this is simply controlled by sediment availability.

Understanding the nature of river system responses to flood events can inform on the most effective strategies for flood risk management. This is because different river reaches show different sensitivities to discharge variations, largely determined by their sediment availability and their landscape setting (Figure 1a). River management, especially in areas with significant human presence, tends to focus on managing every flood event, no matter how small or large, rather than just the most geomorphically effective floods that result in greatest impacts. The political imperative for management means that annual floods, which are most important for ecosystems and biogeochemical cycling within rivers, are 'over-managed' rather than allowing for natural river flooding to take place across the width of the floodplain. This study suggests that bedrock and sediment reaches respond differently to flood events, and that they are located in different landscape contexts. This means that a single river management strategy that ignores differences between individual reaches is not likely to be successful. River management strategies that allow 'space for water' let the river systems respond naturally to variations in discharge, including allowing riparian and floodplain elements to be flooded (e.g. Biron et al. 2014; Buffin-Bélanger et al. 2015). This more integrated approach to flood management works with, rather than against, the dynamics of the river system. It is the major (decadal-scale return period) floods that are most significant in geomorphic change along the Sabie River, whereas smaller annual floods require spatial planning action (land-use zoning, infrastructure design, and riparian vegetation planting) rather than flood management action. On the Sabie and other rivers in the Inkomati catchment, this may mean that different flood management strategies are needed inside (in KNP) and outside of formally protected areas (in headwaters) in response to both differences in river geomorphology and dynamics in these areas, and to differing community needs.

Conclusions

The semiarid Sabie River is affected by seasonal floods but their impacts vary between bedrock- and sediment-dominated reaches. Evidence for different river reach behaviour and their varied tempos of change can be evaluated based on river geomorphology, sediment patterns and informed by luminescence dating of phases of sediment deposition. The study results show that bedrock- and sediment-dominated reaches are quite different in terms of their properties and dynamics, and this has implications for strategies towards flood management.

Acknowledgements

Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

J.K. designed this study, J.K. and M.E. collected field data, J.K. and M.E. undertook lab analysis on samples, J.K. wrote the first draft of this article, and J.K. and M.E. contributed to the final draft of the submitted article.

Ethical considerations

This study followed all ethical standards for research without direct contact with human or animal subjects.

Funding information

This study is supported by National Research Foundation grant 91344 (to J.K.). The authors are very grateful to SANParks for permission to undertake research in Kruger National Park (permit KNIGJ1225) and for logistic support.

Data availability

The authors confirm that the data supporting the findings of this study are available within the article and in published articles cited in the text.

Disclaimer

The views expressed in the submitted article are of the authors and not an official position of the institution or funder.

References

Biron, P.M., Buffin-Bélanger, T., Larocque, M., Choné, G., Cloutier, C.-A., Ouellet, M.-A. et al., 2014, 'Freedom space for rivers: A sustainable management approach to enhance river resilience', *Environmental Management* 54(5), 1056–1073. https://doi.org/10.1007/s00267-014-0366-z

Broadhurst, L.J. & Heritage, G.L., 1998, 'Modelling stage-discharge relationships in anastomosing bedrock-influenced sections of the Sabie River system', *Earth Surface Processes and Landforms* 23(5), 455–465. https://doi.org/10.1002/(SICI)1096-9837(199805)23:5<455::AID-ESP860>3.0.CO;2-2

Buffin-Bélanger, T., Biron, P.M., Larocque, M., Demers, S., Olsen, T., Choné, G. et al., 2015, 'Freedom space for rivers: An economically viable river management concept in a changing climate', *Geomorphology* 251, 137–148. https://doi.org/10.1016/j.geomorph.2015.05.013

Colarossi, D., Duller, G.A.T., Roberts, H.M., Tooth, S. & Lyons, R., 2015, 'Comparison of paired quartz OSL and feldspar post-IR IRSL dose distributions in poorly bleached fluvial sediments from South Africa', *Quaternary Geochronology* 30(Part B), 233–238. https://doi.org/10.1016/j.quageo.2015.02.015

Cunningham, A.C., Evans, M. & Knight, J., 2015, 'Quantifying bleaching for zero-age fluvial sediment: A Bayesian approach', *Radiation Measurements* 81, 55–61. https://doi.org/10.1016/j.radmeas.2015.04.007

Entwistle, N., Heritage, G., Tooth, S. & Milan, D., 2014, 'Anastomosing reach control on hydraulics and sediment distribution on the Sabie River, South Africa', *IAHS Publication* 367, 215–219. https://doi.org/10.5194/piahs-367-215-2015

Eze, P.N. & Knight, J., 2018, 'A geomorphological characterisation of river systems in South Africa: A case study of the Sabie River', *Physics and Chemistry of the Earth* 105, 196–205. https://doi.org/10.1016/j.pce.2018.01.001

Gericke, O.J. & du Plessis, J.A., 2012, 'Evaluation of the standard design flood method in selected basins in South Africa', *Journal of the South African Institution of Civil Engineering* 54(2), 2–14.

Heritage, G., Tooth, S., Entwhistle, N. & Milan, D., 2015, 'Long-term flood controls on semi-arid river form: evidence from the Sabie and Olifants rivers, eastern South Africa', *IAHS Publication* 367, 141–146. https://doi.org/10.5194/piahs-367-141-2015

Heritage, G.L., Broadhurst, L.J. & Birkhead, A.L., 2001, 'The influence of contemporary flow regime on the geomorphology of the Sabie River, South Africa', *Geomorphology* 38(3–4), 197–211. https://doi.org/10.1016/S0169-555X(00)00090-8

Heritage, G.L. & Moon, B.P., 2000, 'The contemporary geomorphology of the Sabie River in the Kruger National Park', *Koedoe* 43(1), 39–55. https://doi.org/10.4102/koedoe.v43i1.207

Heritage, G.L., Van Niekerk, A.W. & Moon, B.P., 1997, 'A comprehensive hierarchical river classification system', *Geoöko Plus* 4, 75–84.

Knight, J., in press, 'Geomorphology and evolution of the Limpopo River', in F. Eckardt (ed.), *Landforms and landscapes of Botswana*, Springer.

Knight, J. & Evans, M., 2017, 'The sediment stratigraphy of a flood event: An example from the Sabie River, South Africa', *Catena* 151, 87–97. https://doi.org/10.1016/j.catena.2016.12.015

Knight, J. & Evans, M., 2018, 'Luminescence dating, sediment analyses, and flood dynamics on the Sabie River, South Africa', *Geomorphology* 319, 1–14. https://doi.org/10.1016/j.geomorph.2018.07.011

Milan, D., Heritage, G., Tooth, S. & Entwistle, N., 2018, 'Morphodynamics of bedrock-influenced dryland rivers during extreme floods: Insights from the Kruger National Park, South Africa', *GSA Bulletin* 130(11–12), 1825–1841. https://doi.org/10.1130/B31839.1

Moon, B.P. & Heritage, G.L., 2001, 'The contemporary geomorphology of the Letaba River in the Kruger National Park', *Koedoe* 44(1), 45–55. https://doi.org/10.4102/koedoe.v44i1.185

Murray, A.S. & Wintle, A.G., 2003, 'The single aliquot regenerative dose protocol: Potential for improvements in reliability', *Radiation Measurements* 37(4–5), 377–381. https://doi.org/10.1016/S1350-4487(03)00053-2

Pettit, N.E., Naiman, R.J., Rogers, K.H. & Little, J.E., 2005, 'Post-flooding distribution and characteristics of large woody debris piles along the semi-arid Sabie River, South Africa', *River Research and Applications* 21(1), 27–38. https://doi.org/10.1002/rra.812

Rosgen, D.L., 1994, 'A classification of natural rivers', *Catena* 22(3), 169–199. https://doi.org/10.1016/0341-8162(94)90001-9

Rountree, M.W., Rogers, K.H. & Heritage, G.L., 2000, 'Landscape state change in the semi-arid Sabie River, Kruger National Park, in response to flood and drought', *South African Geographical Journal* 82(3), 173–181. https://doi.org/10.1080/03736245.2000.9713711

Saraiva Okello, A.M.L., Masih, I., Uhlenbrook, S., Jewitt, G.P.W., Van der Zaag, P. & Riddell, E., 2015, 'Drivers of spatial and temporal variability of streamflow in the Incomati River basin', *Hydrology and Earth System Sciences* 19(2), 657–673. https://doi.org/10.5194/hess-19-657-2015

Schutte, I.C., 1986, 'The general geology of the Kruger National Park', *Koedoe* 29(1), 13–37. https://doi.org/10.4102/koedoe.v29i1.517

Seanego, K.G. & Moyo, N.A.G., 2013, 'The effect of sewage effluent on the physico-chemical and biological characteristics of the Sand River, Limpopo, South Africa', *Physics and Chemistry of the Earth* 66, 75–82. https://doi.org/10.1016/j.pce.2013.08.008

Van Niekerk, A.W., Heritage, G.L. & Moon, B.P., 1995, 'River classification for management: The geomorphology of the Sabie River in the eastern Transvaal', *South African Geographical Journal* 77(2), 68–76. https://doi.org/10.1080/03736245.1995.9713594