

Supplementary material

I. **Table S1.** An overview of existing data used with resolution, date, source and the subsequent data derived.

Representation type	Scale/resolution	Year	Reference	Data derived and use
Artificial wetlands layer	South Africa, 1:50 000	2018	Van Deventer et al. (2018)	This layer was reassessed and refined to reflect all instream dams in the updated layer used for NBA 2018. The updated artificial wetlands layer was intersected with the river lines in ArcGIS 10.6 (ESRI, 1999-2016) to determine if any medium (12-30 m) to large (≥ 30 m) dams intersected a FFR. If such dams intersected the FFR the date of when the dam construction or completion was obtained from the dams register and verified on Google Earth Pro (Google, 2017) using imagery of the relevant year. Certain rules were applied when a dam intersected a FFR.
Dams layer (polygons)	South Africa, 1:500 000 1:50 000		DLA:CDSM (2005-2007) and DWS (2016) integrated and updated by Van Deventer et al. (2019)	Dams layer integrated and updated from DLA-CDSM (2005-2007) and DWS (2016) by Van Deventer et al. (2019) with and artificial wetlands to produce a new version of the dams layer.
Dam register	South Africa, 1:500 000 1:50 000	2016	DWS (2016)	The DWS dam register (DWS, 2016) is a spreadsheet that listing the location (coordinates) and sizes of dams. The coordinates of dams were mapped and the point shapefile used to validate the presence of dams in FFRs. This included newly built dams in the updated artificial wetlands layer of the NBA 2018 project (Van Deventer et al., 2018).

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Digital Elevation Model (DEM) (raster)	South Africa, 50 m	2009	Council for Scientific & Industrial Research (CSIR) (unpublished)	The 50m DEM was created in (ArcGIS 10.3) (ESRI, 2014) using the Topo-to-Raster tool in Spatial Analyst using spot height points from the 1:50 000 topographical maps and 20m interval contour line shapefiles (DRDLR).
Ecoregions Level 1 (polygons)	South Africa, 1:500 000	2004	Kleynhans, Thirion, & Moolman (2005)	River ecosystem types. Ecoregion typing is a hierarchical procedure that involves the delineation of ecoregions with a progressive increase in detail at each higher level of the hierarchy. Thirty-one Level 1 (coarsest scale) ecoregions were identified for South Africa to classify the landscape based on topography, altitude, slope, rainfall, temperature, geology and potential natural vegetation (Kleynhans, Thirion, & Moolman, 2005). The landscape through which a river flows is broadly characterised by ecoregions, such that rivers in the same ecoregion share similar broad ecological characteristics compared to those in different ecoregions.
Flow variability, (attribute field in the river network lines layer)	South Africa, 1:50 000	2005	DLA-CDSM (2005-2007)	River flow types Flow variability categories were based on the flow variability categories of the DWS (date) river categories that were assigned one of three categories: 'perennial', 'non-perennial' or 'dry'. Owing to the uncertainty in the perennial and non-perennial classes being assigned accurately from historical aerial or orthophotos that were only sporadically available across the hydrological cycles, the first two were aggregated into a permanent/seasonal category, and the dry to the not permanent category, which refers to ephemeral rivers (Nel et al., 2007).

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Mainstem Rivers	South Africa, 1:500 000	2006	DWAF (2006b)	Mainstems were defined as the river lines that drained quaternary catchments whereas tributaries drained sub-quaternary catchments (SQ4s) and formed confluences with the mainstem rivers in the quaternary catchment
National Protected Area Expansion Strategy (NPAES) for 2024 (polygons)	South Africa, 1:500 000	2016	DEA (2016)	The extent of protected areas envisaged for expansion in South Africa if the priority areas identified are included in the revised NPAES for 2024 that will include freshwater ecosystems.
Present Ecological State (attribute field)	South Africa, state assigned at the at 4 th level quaternary catchment-scale (mean size 650 km ²)	2011-2018 (last updated incorporated 2018)	Kleynhans (2000)	Ecological condition of mainstem rivers. First determined during 2011 and updated with reassessment of river reach data.
Protected areas (polygons) of 2008	South Africa, deeds register (surveyed)	2008	RSA (2010)	Extent of protected areas dating to 2008. Types include national parks, provincial and local nature reserves, forest nature reserves, wilderness areas, contract nature reserves, protected environments, mountain catchment areas, private nature reserves and world heritage sites.
Protected areas (polygons) of 2018, Protected Areas and	South Africa, 1:500 000	2013	(DEA, 2017-2018)	Extent of protected areas dating to 2018. Types include national parks, provincial and local nature reserves, forest nature reserves, wilderness areas, contract nature reserves, protected environments, mountain catchment areas, private nature reserves and world heritage sites.

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Conservation Areas' (PACA)				<p>The 'Protected Areas and Conservation Areas' (PACA) dataset and the publicly available South African Protected Areas Database (SAPAD) version 2017 and more recent updates of 2018 of the Department of Environmental Affairs (DEA), were integrated for use in the NBA 2018 (DEA, 2017-2018). These datasets included primarily gazetted reserves, de facto reserves, where these areas do not occur in the SAPAD or are gazetted, but are in most cases already formally protected and can include areas owned and managed by the relevant agencies as nature reserves without any legal status.</p> <p>The FFRs were intersected with the protected are polygons using the Albers Equal Area Coordinate system of South Africa (central meridian = 25°E with standard parallels at 24°S and 33°S). This coordinate system was used since it least distorts the distance of the rivers. A frequency table was calculated using the FFR and flagship river identification field, the aggregated ecological condition, the NPA attribute field and the extent of the rivers, after which the table was exported to Excel as the output.</p>
Quaternary catchment boundaries (polygons)	South Africa, varying extent (mean size 650 km ²)	1994	Midgley, Pitman, & Middleton (1994)	Hydrological catchment boundaries at the 4 th division level of South Africa.
River longitudinal geomorphological zones (attribute field in the river)	South Africa, 1:500 000	2007	Moolman, Kleynhans & Thirion (2002)	Longitudinal geomorphic zones of river lines used for river ecosystem typing in South Africa. Ten longitudinal zones were based on thresholds of slope defined by Rowntree & Wadeson (1999) and Rowntree, Wadeson, & O'Keefe (2000) including source, mountain stream, transitional, upper foothills, lower foothills, lowland river, rejuvenated bedrock fall, rejuvenated foothills and upland plain zones. Rowntree et

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network lines layer)				al. (2000), characterises ten zones in which the river has the ability to store and transport sediment while providing a different physical template in each zone to riverine biota. These ten longitudinal geomorphic zones were aggregated into four categories for the ecosystem types, including mountain streams, upper foothills, lower foothills and lowland rivers.
River network (line layer)	South Africa, 1:500 000	2006	DWAF (2006b) updated by (Nel et al., 2011a); Nel et al. (2011b)	<p>River ecosystem types, river condition, free-flowing and flagship rivers.</p> <p>River ecosystem types are comprised distinct combinations of Level 1 ecoregions, flow descriptions and river longitudinal geomorphological zones. River ecosystem types represented the diversity of rivers across the country and served as coarse-filter surrogates of biodiversity (Roux et al., 2006). The free-flowing rivers represented long reaches of rivers on the 1:500 000-river network GIS layer that have no instream dams and therefore flow undisturbed from their source to the confluence with a larger river or to the sea. Flagship free-flowing rivers were identified based on their representativeness of free-flowing rivers across the country, as well as their importance to ecosystem processes and biodiversity value, which were prioritised for conservation (Nel et al., 2011b).</p> <p>During the NFEPA project an additional 97 coastal rivers were included in this base layer from the 1:50 000 rivers network (DLA:CDSM, 2005-2007) in order to associate each estuary identified in the NFEPA project to a river line (Nel et al., 2011b; Van Deventer et al., 2018).</p>
South African Protected Areas	South Africa, 1:50 000	2017	https://egis.environment.gov.za	The SAPAD, maintained by the Department of Forestry, Fisheries and the Environment (DFFE) and released publicly each quarter, formed the core of the protected area dataset used in the NBA 2018. The strength of this

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Database (SAPAD)				<p>dataset is that it includes designation dates and allows for time-series protection analysis. A limitation of the dataset is that the date of declaration of protected areas audited against the government gazette and establishment date do not always coincide. The database does not yet represent all existing protected areas and was supplemented with spatial data from provincial conservation agencies and the South African National Parks (SANParks) (Skowno et al., 2019b).</p> <p>Gazetted reserves included were either state-or privately-owned (Nel et al., 2017). The SAPAD 2018 second quarter dataset employed in the NBA 2018 required various restructuring steps for use in the protection level analysis. Overlaps were resolved and inconsistencies between the protected area spatial data sourced and SAPAD were investigated and resolved. The steps involved in this process are described in detail by Skowno et al. (2019b). The terrestrial protected area estate of South Africa increased by 11% between 2010 and 2018, covering almost 9% of the mainland (Skowno et al., 2019b). Biodiversity stewardship programmes underpinned much of this increase and continue to be the most cost-effective mechanism for protected area expansion. Results from the national protected area extent account project showed that protected areas in 2020 was 11 280 684 ha or 9.2% of the mainland surface area (Skowno et al., 2019b; Stats SA, 2021).</p>
Sub-quaternary boundaries	South Africa, 1:50 000 (varying extent mean size 135 km ²)	2011	(Nel et al., 2011a; Nel et al. 2011b)	5 th level catchment boundaries nested within quaternary catchment boundaries and delineated as hydrological planning units for the South African conservation plan. The sub-quaternary catchments were modelled from a 50 m DEM (CSIR, unpublished) using ArchHydro Geoprocessing Tools 2.0 (ArcGIS 10.2) (ESRI, 2013) to delineate planning units (Nel et al., 2011b).

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Tributaries				Tributaries nest within a single quaternary catchment while mainstems pass through a quaternary catchment into a neighbouring quaternary catchment.

II. **Table S2.** Free-flowing rivers in South Africa with IDs. The bold italics are flagship free-flowing rivers

FFR NAME	FFR ID	FFR NAME	FFR ID
EASTERN CAPE		KWAZULU-NATAL	
Riet	10	<i>Mzimkhulu*</i>	36
Kap	11	Mzumbe	37
Mpekweni	12	Mkomazi & tributaries*	41
<i>Kobonqaba</i>	14	<i>Mkuze & tributaries*</i>	68
iNxaxo	15	<i>Nsuze* tributary of Thukela</i>	42
Qhorha & tributaries*	16	<i>Black Mfolozi & tributaries*</i>	44
Shixini	17	Mfule	52
<i>Nqabarha*</i>	18		
Xora*	20	LIMPOPO	
Mncwasa	21	<i>Mutale-Luvuvhu*</i>	64
<i>Mtakatye*</i>	23	<i>Mohlapitse</i>	65
Mnenu	24	MPUMULANGA	
Sinangwana	25	<i>Ntombe tributary of Phongolo</i>	58
Mngazana	26	Hlelo*	59
Mntafufu	27	Upper Vaal*	60
Mkozi	29	Elands*	61
Msikaba*	30	Mbyamiti	62
<i>Mtentu*</i>	31	Nwanedzi-Sweni*	63
Sikombe	32		
Mpahlane	33	NORTHERN CAPE	
<i>Mtamvuna & tributaries*</i>	35	Upper Sak, Klein- Sak & tributaries*	45
<i>Kraai & tributaries*</i>	46		
WESTERN CAPE		NORTHWEST	

FFR NAME	FFR ID	FFR NAME	FFR ID
<i>Doring & tributaries*</i>	1	<i>Upper Groot-Marico</i>	66
Klaas Jaegers	2		
<i>Rooiels</i>	3		
Touws	4		
Karatara-Hoogekraal	69		
Knysna	6		
Bietou-Palmiet	7		
<i>Groot (Garden Route)</i>	8		
Bloukrans	9		

*Free-flowing rivers longer than 100km

III. Changes in FFRs in provinces and ecoregions

The majority of FFRs with a change in status occurred in the KwaZulu-Natal Province (Table 3). The extent of FFRs tributary length amounted to 30% of the total FFRs extent. The change in ecological condition of a FFR due to the influence of a deteriorating PES score only occurred in 1% of the FFRs identified. Most of these changes in KwaZulu-Natal were due to disruptions in flow as a result of dam presence on the mainstem river. The aMahlongwa River, a short coastal FFR of only 33.6 km has a 3 000 m² dam in the upper reaches, the Nsonge has a 55 000 m² (Tigerhoek) dam in the upper reaches, and a 54 000 m² (Hlatikulu) and a 80 000 m² dam in the lower reaches while the Ngogo River has a smaller 8 000 m² dam in its upper reaches. In addition, deterioration was also a result of land transformation due to factors such as agriculture, rural and semi-urban communities, road construction and sedimentation within the catchments.

Most protection levels of FFR extent have primarily increased within the Eastern Coastal Belt & Uplands and Highveld & Escarpment aggregated ecoregions, which had no FFRs in a natural/largely natural ecological condition within the NPAs in 2008. The extent of FFRs in the same ecological condition and NPAs also increased in the Southwestern Coastal Belt & Uplands aggregated ecoregions.

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