AQUATIC ECOSYSTEMS ASSESSMENT OF THE SKA PHASE 1 IN SOUTH AFRICA

Prepared by:

Kate Snaddon, SACNASP Professional Natural Scientist (Reg. No. 400225/06), Director at the Freshwater Research Centre, and Senior Consultant and Partner at the Freshwater Consulting Group;
Dean Ollis, SACNASP Professional Natural Scientist (Reg. No. 400102/06), Director at the Freshwater Research Centre, and Senior Consultant and Partner at the Freshwater Consulting Group;
Tumisho Ngobela, SACNASP Candidate Natural Scientist (Reg. No. 100010/15), Freshwater Research Centre, and Freshwater Consulting Group; and
Donovan Kirkwood, SACNASP Professional Natural Scientist (Reg. No. 400351/14).

Reviewed and edited by:

Dr Wietsche Roets, SACNASP Professional Natural Scientist (Reg. No. 400191/10), Specialist Scientist: In-stream Water Use at the Department of Water and Sanitation;
Dr Betsie Milne, DST-NRF Professional Development Programme, South African Environmental Observation Network Arid Lands Node; and
Patrick Morant, SACNASP Professional Natural Scientist (Reg. No. 401514/83).

FCG

water & sanitation
Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

NRF
National Research Foundation
SAEON
South African Environmental Observation Network

I. Introduction

The Karoo Central Astronomy Advantage Area 1 (KCAAA1), located in the Northern Cape Province, is approximately 12 000 000 hectares in area, within which lies the study area for the first phase of the Square Kilometre Array covering an area of approximately 628 000 hectares.

The SKA Phase 1 SEA study area comprises the core area (covering an area of approximately 131 000 hectares and dish-antennae including the original KAT-7 and MeerKAT projects) and three spiral arms (covering a total area of approximately 497 000 hectares). The SKA infrastructure includes dish-type antennae, access roads, power and fibre optic cables and associated buildings.

The Strategic Environmental Assessment (SEA) of the Square Kilometre Array (SKA) Phase 1 Project is conducted in support of Strategic Infrastructure Project (SIP) 16, and takes a similar approach to a series of SIP SEAs, where the possible impacts of key infrastructure projects are assessed from a regional perspective, to identify sensitivities and cumulative effects. The aim of this SEA is to go beyond the assessment of impacts, and to develop a decision-making tool for current and future development of infrastructure, relating, in this instance, to the SKA project.

The surface aquatic ecosystem assessment of the SEA had the following objectives:

- Identify, map and describe the aquatic features – wetlands (including pans) and watercourses – within the broad KCAAA1 and, in more detail, within the SKA Phase 1 SEA study area;
- Develop a sensitivity map for the SKA Phase 1 SEA study area with regard to the condition and ecological importance of the aquatic features of the region, and their sensitivity to the impacts associated with this project;
- Identify, describe and assess the significance of the impacts associated with the design, construction and operation of the SKA Phase project;
- Recommend mitigation measures and management actions which would avoid or minimise the impacts, and where there is unavoidable or residual impacts, to rehabilitate or propose biodiversity and/or functional offsets, and
- Make recommendations with regard to the regulatory framework governing activities that may have an impact on wetlands and watercourses in the affected region.

In this report, the term "wetlands" refers to depressions (including pans), valley-bottom wetlands, floodplain wetlands and seeps, and "watercourses" refers to rivers. The term "aquatic features" is used as a collective term for both wetlands and watercourses.

II. Definitions

- Aquatic features: in this report, this term is used collectively for wetlands, pans and watercourses
- Borehole: includes a well, excavation or any artificially constructed or improved underground cavity which can be used for the purpose of -
    - Intercepting, collecting or storing water in or removing water from an aquifer;
    - Observing and collecting data and information on water in an aquifer; or
    - Recharging an aquifer.
- Catchment: in relation to a watercourse or watercourses or part of a watercourse, means the area from which any rainfall will drain into the watercourse or watercourses or part of a watercourse, through surface flow to a common point or common points.

- Core area: this refers to the central portion (approximately 131 000 hectares) of the SKA Phase 1 project, where the highest density of SKA Phase 1 dish-type antennae will be located. The original KAT-7 (7 dish-antennae) and MeerKAT (64 dish-antennae) projects lie in the SKA core area.
- Extent of a watercourse:
    - The outer edge of the 1 in 100 year flood line and/or delineated riparian habitat, whichever is the greatest distance, measured from the middle of the watercourse of a river, spring, natural channel, lake or dam; and
    - Wetlands and pans: the delineated boundary (outer temporary zone) of any wetland or pan.
- Pan: any depression collecting water or that is inward draining (i.e. endorheic) or a flow-through system with flow contributions from surface water, groundwater or interflow or combinations thereof. NOTE: pans are wetlands (see below).
- Regulated area of a watercourse for NWA Section 21 (c) and/or (i) water uses means:
    - The outer edge of the 1 in 100 year flood line and/or delineated riparian habitat, whichever is the greatest distance, measured from the middle of the watercourse of a river, spring, natural channel, lake or dam; and
    - In the absence of a determined 1 in 100 year flood line or riparian area the area within 100m from the edge of a watercourse where the edge of the watercourse is the first identifiable annual bank fill flood bench (subject to compliance to section 144 of the Act);
    - A 500 m radius from the delineated boundary (extent) of any wetland or pan;
- Rehabilitation: the process of reinstating natural ecological driving forces within part or the whole of a degraded watercourse to recover former or desired ecosystem structure, function, biotic composition and associated ecosystem services.
- Riparian habitat (or zone): includes the physical structure and associated vegetation of the areas associated with a watercourse which are commonly characterised by alluvial soils, and which are inundated or flooded to an extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent land areas.
- River management plan: any river management plan developed for the purposes of river or storm water management in any municipal/metropolitan area or described river section, river reach, entire river or sub quaternary catchment that considers the river in a catchment context and as approved by the Department.
- Spiral arms: there are three spiral arms of the SKA Phase 1 array accommodating a total of seven dish-antennae each.
- Watercourse:
    - A river or spring;
    - A natural channel in which water flows regularly or intermittently;
    - A wetland, lake or dam into which, or from which, water flows; and
    - Any collection of water which the Minister may, by notice in the Gazette, declare to be a watercourse, and a reference to a watercourse includes, where relevant, its bed and banks
- Water resource: includes a watercourse, surface water, estuary, or aquifer.
- Wetland: means land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil. NOTE: in this report, pans (depressions) are considered to fall within this definition.

III. Data Sources

Data title	Source and date of publication	Data Description
NFEPA wetlands	Nel J.L., Driver A., Strydom W., Maherry A., Petersen C., Roux D.J., Nienaber S., van Deventer H, Smith-Adao LB and Hill L. (2011). Atlas of Freshwater Ecosystem Priority Areas in South Africa: Maps to support sustainable development of water resources. WRC Report No. TT 500/11, Water Research Commission, Pretoria	This layer codes Wetland Freshwater Priority Areas (FEPAs), wetland ecosystem types and current condition on a national scale. The delineations were based largely on remotely-sensed imagery and therefore did not include historic wetlands lost through drainage, ploughing and concreting.
NFEPA rivers	Nel J.L., Driver A., Strydom W., Maherry A., Petersen C., Roux D.J., Nienaber S., van Deventer H, Smith-Adao LB and Hill L. (2011). Atlas of Freshwater Ecosystem Priority Areas in South Africa: Maps to support sustainable development of water resources. WRC Report No. TT 500/11, Water Research Commission, Pretoria	The layer provides river condition, river ecosystem types and free-flowing river information that were used in deriving Freshwater Ecosystem Priority Areas (FEPAs) for river ecosystems. It used the 1:500 000 river GIS layer available from DWS.
NFEPA sub-catchments	Nel J.L., Driver A., Strydom W., Maherry A., Petersen C., Roux D.J., Nienaber S., van Deventer H, Smith-Adao LB and Hill L. (2011). Atlas of Freshwater Ecosystem Priority Areas in South Africa: Maps to support sustainable development of water resources. WRC Report No. TT 500/11, Water Research Commission, Pretoria	Sub-quaternary catchments classified according to the FEPA rivers they contain.
NFEPA groundwater recharge	Nel J.L., Driver A., Strydom W., Maherry A., Petersen C., Roux D.J., Nienaber S., van Deventer H, Smith-Adao LB and Hill L. (2011). Atlas of Freshwater Ecosystem Priority Areas in South Africa: Maps to support sustainable development of water resources. WRC Report No. TT 500/11, Water Research Commission, Pretoria	High groundwater recharge areas are sub-quaternary catchments where groundwater recharge is three times higher than the average for the related primary catchment. Data consulted
Strategic Water Source Areas	Jeanne Nel, Christine Colvin, David Le Maitre, Janis Smith and Imelda Haines (2013). South Africa's Strategic Water Source Areas. CSIR Report no. CSIR/NRE/ECOS/ER/2013/0031/A	Strategic Water Source Areas are those quaternary catchments that supply a disproportionate amount of runoff to geographical areas of interest. The data are expressed as the % contribution of runoff to the country's water supply. Those catchments contributing more than 50% of supply are considered to be strategic water source areas. This dataset was used for corridor descriptions.
Level 1 river ecoregions	Kleynhans *et al.* (2005) A level 1 river ecoregional classification system for South Africa, Lesotho and Swaziland. Department of Water Affairs and Forestry.	The country is divided into 31 Level 1 ecoregions, based on physiography, climate, rainfall, geology, natural vegetation. This dataset was used for corridor descriptions.

Data title	Source and date of publication	Data Description
NFEPA wetveg groups	Nel, J.L., Murray, K.M., Maherry, A.M., Petersen, C.P., Roux, D.J., Driver, A., Hill, L., Van Deventer, H., Funke, N., Swartz, E.R., Smith-Adao, L.B., Mbona, N., Downsborough, L. and Nienaber, S. (2011). Technical Report for the National Freshwater Ecosystem Priority Areas project. WRC Report No. K5/1801.	A GIS layer of wetland vegetation groups used to classify wetlands according to Level 2 of the national wetland classification system (SANBI 2010), which characterises the regional context within which wetlands occur. This dataset was used for corridor descriptions, and for determination of wetland types.
Threat status	Driver A., Sink, K.J., Nel, J.N., Holness, S., Van Niekerk, L., Daniels, F., Jonas, Z., Majiedt, P.A., Harris, L. & Maze, K. 2012. National Biodiversity Assessment 2011: An assessment of South Africa's biodiversity and ecosystems. Synthesis Report. South African National Biodiversity Institute and Department of Environmental Affairs, Pretoria.	Ecosystem threat status of wetland and river types.
Veg map	Mucina and Rutherford, 2006	Maps and descriptions of vegetation types for South Africa and Lesotho
PESEIS assessment	Department of Water and Sanitation. 2014. A Desktop Assessment of the Present Ecological State, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa. Compiled by RQIS-RDM: https://www.dwa.gov.za/iwqs/rhp/eco/peseismodel.aspx	A mostly desktop assessment of the Present Ecological State and Ecological Importance and Sensitivity of sub-quaternary river reaches across South Africa, in order to replace the PESEIS 1999 classes. Expert review and local expert knowledge was sourced for some catchments, and some areas were ground-truthed.

IV. Assumptions and Limitations

Limitation	Included in the scope of this study	Excluded from the scope of this study	Assumption
In-field delineation of wetland and riparian area boundaries	Visual delineations of aquatic features, either desktop or in-field	Delineation according to national protocol	Assumption is that the rough delineations provided in the feature maps are sufficient for decision-making and for guiding the design and management of the SKA project area.

V.Study methodology

1) Karoo Central Astronomy Advantage Area 1

The Karoo Central Astronomy Advantage Area 1 (KCAAA1) was mapped using and editing existing spatial datasets (see Section III for more detail on data sources). The underlying images were SPOT5 images, Google Earth imagery, and NGI aerial photographs captured circa 2011. The data were edited as follows:

1. National Freshwater Ecosystem Priority Area (NFEPA) wetlands. The NFEPA wetlands layer was edited within the KCAAA1 as follows:
   - "Valleyhead seeps" were replaced by "Seeps" (valleyhead seeps are no longer a wetland type, as determined by the National Classification System for Wetlands (Ollis *et al.*, 2013));
   - Confirmed that no self-overlapping polygons were present using topology rules.
   - Unioned wetlands map with Level 1 Aquatic Ecoregions (Kleynhans *et al.* 2005) to provide additional contextual information for specialists and data summary (ecoregions do not directly influence sensitivity rating or buffer sizes);
   - The original classification of wetland types in the NFEPA dataset was done using DEM-derived slope/type classes, which were not cleaned and so included individual grid cell pixels and associated slivers. These spurious small wetland subdivisions were removed by using the Eliminate tool, which was run several times for all features less than 5000m2, to dissolve spurious wetland polygons into larger adjoining polygons (with longest shared boundary).
   - Artificial wetlands associated with dams were consistently classified as separate natural features in the original data set. These wetlands adjacent to dams were selected and dissolved into the adjoining dam polygon (selection rule: "WETCON" = 'Z2' AND "MAJWETCON" = 'Z3') using several iterations of Eliminate Tool until no further reduction in the selected polygon number occurred. A few remaining Z2+Z3 features were not contiguous with dams and were not obviously artificial and were left.
   - Updated with latest Ramsar polygons – however, there are no Ramsar wetlands in the study area.
   - Spatial join with ecosystem threat status (from NBA 2011 project).

2. Azonal vegetation types from Mucina and Rutherford's vegetation map, using the 2012 version from BGIS website. The Azonal vegetation types relevant for KCAAA1 are:
   - Bushmanland Vloere: these are the salt pans and broad riverbeds of intermittent river systems in the Northern Cape (Mucina *et al.*, 2006). A large proportion of the Sak River system has been classified as Bushmanland Vloere. The pans themselves and the active channels are generally devoid of vegetation, while the banks and surrounds tend to be dominated by *Rhigozum trichotomum*, with *Lycium* spp., and *Salsola* spp. also occurring here. A mixture of non-succulent dwarf shrubs is also generally associated with this vegetation type. Silty and clayey alluvial deposits characterise these systems, with a high content of concentrated salts. This vegetation type is Least Threatened, and is not conserved in any statutory conservation areas.
   - Highveld Salt Pans: a few of these pans are located in the far eastern portion of KCAAA1. They are endorheic depressions in the landscape containing temporary to permanent waterbodies. The pans are also generally not vegetated towards the centre, with the surrounding vegetation being characterised by sparse grassy dwarf shrubland. The base of the pans is clayey, derived from Ecca shales. These pans are differentiated from other pan vegetation types, such as Bushmanland Vloere, by the predominance of sedges (cyperoids). This vegetation type is also Least Threatened, with only a small proportion protected in conservation areas.

3. NFEPA rivers (scale of 1:500 000) dataset – no editing of river lines was done, however, the attributes were reduced, and a join was done to link the up to date Present Ecological State (PES) data from the DWS 2014 PESEIS (DWS, 2014) study.

4. Hydrological features National Geo-spatial Information (NGI) dataset from the Department of Rural Development and Land Reform. These include the following features (NGI terminology):
   - Dry pans;
   - Dry Watercourses;
   - Flood Bank Areas;
   - Lakes, Marshes and Vleis, and
   - Non-perennial and Perennial Rivers and Pans

5. Springs NGI dataset.

The various datasets that were edited for the KCAAA1 were not consolidated, but kept separate, as there are overlaps that would take considerable time to resolve.

2) SKA Phase 1 SEA study area

Mapping in the SKA Phase 1 SEA study area took the KCAAA1 maps as base layers, and edited and improved these layers (wetlands and rivers) through digitising off aerial photographs (circa 2011), Google Earth images, and SPOT imagery (SPOT5), generally at a scale of 1:10 000 to 1:20 000. Instead of keeping the NGI datasets as separate layers, these were combined with the wetlands layer, to provide a single, detailed wetlands map for the study area (see Figure V.1). The detailed mapping was supported through ground-truthing of the general study area during the field visits. Both the NFEPA rivers layer (generally at a scale of 1:500 000) and 1:50 000 NGI river lines database were edited and refined for the SKA Phase 1 SEA study area, and were also used to locate and map the wetlands.

The river types assigned to the NFEPA rivers layer were used, however typing of the 1:50 000 NGI rivers database was not attempted, as this would take a significant amount of time. Each of the wetland polygons (i.e. all edited NFEPA wetlands, NGI hydrological features and all newly digitised wetlands) were typed to Level 4a of the National Classification System for Wetlands (Ollis *et al.*, 2013), i.e. hydrogeomorphic (HGM) unit, based on its location in the landscape and its characteristics. The HGM units were combined with the NFEPA wetveg group (NFEPA database – see Data Sources) using a spatial join, in order to determine the NFEPA-aligned wetland type.

A present ecological state (PES) class was assigned to each wetland and river reach in the study area. The ecological condition of river reaches was updated in 2014 during the PESEIS project[1] run by DWS (DWS, 2014), and these data were used for the 1:500 000 river condition, while the condition of the 1:50 000 river reaches was assigned during the detailed mapping of the SKA Phase 1 SEA study area. The presence of alien vegetation – in this case, *Prosopis glandulosa* (mesquite) – dams, roads, agriculture and buildings were used to derive a PES for each river reach. The same rules for assessing ecological condition were applied to each wetland polygon. The condition classes were:
- AB – good to natural;
- C – moderately modified; and
- DEF – largely modified.

Each polygon in the wetlands database was assigned a confidence level, both for mapping of the wetland as well as for the wetland typing. Field verification of river reaches and wetlands improved the confidence and accuracy of the map in places. A hand-held GPS (accurate to approximately 2 – 3 m) was used to roughly delineate channels and wetland boundaries. No detailed delineation of aquatic ecosystems was done using the accepted DWS protocol for determining the boundaries of wetlands and riparian areas (DWA, 2005).

[1] This was largely a desktop assessment, but expert review of the PES categories was sourced for many of the catchments.

All of the wetlands and all river reaches were classified as being either no-go areas or areas of high sensitivity, and varying sensitivity to potential SKA impacts was also taken into account by means of a variable buffer size. Thus, buffers around each wetland and river reach were determined based on a set of buffering rules. Buffers represent zones in which construction or habitat degradation would risk direct or indirect impacts on aquatic features and local hydrology. The rules were based on wetland type (HGM type) or river type, FEPA status (from the NFEPA project (Nel *et al.,* 2011)) and threat status (from the list of nationally threatened ecosystems (Nel and Driver, 2012)), where this information was available. The rules were different for wetlands and rivers, due to the confidence level attached to each dataset. For instance, the wetlands map used for NFEPA varies in accuracy, but is especially inaccurate in the drier parts of the country, and so FEPA status assigned to wetlands is also inaccurate. FEPA status was thus not used for wetlands. However, the rivers map used for NFEPA is more accurate, and FEPA status assigned to the sub-catchments and river reaches is considered to be more reliable as a result, and so these data were used as a buffering rule. Similarly, the threat status data are considered to be more accurate for rivers than for wetlands. For both the wetlands and the rivers mapped in the SKA Phase 1 area, the PES data were of most use, as this was verified at least at a desktop level during the detailed mapping.

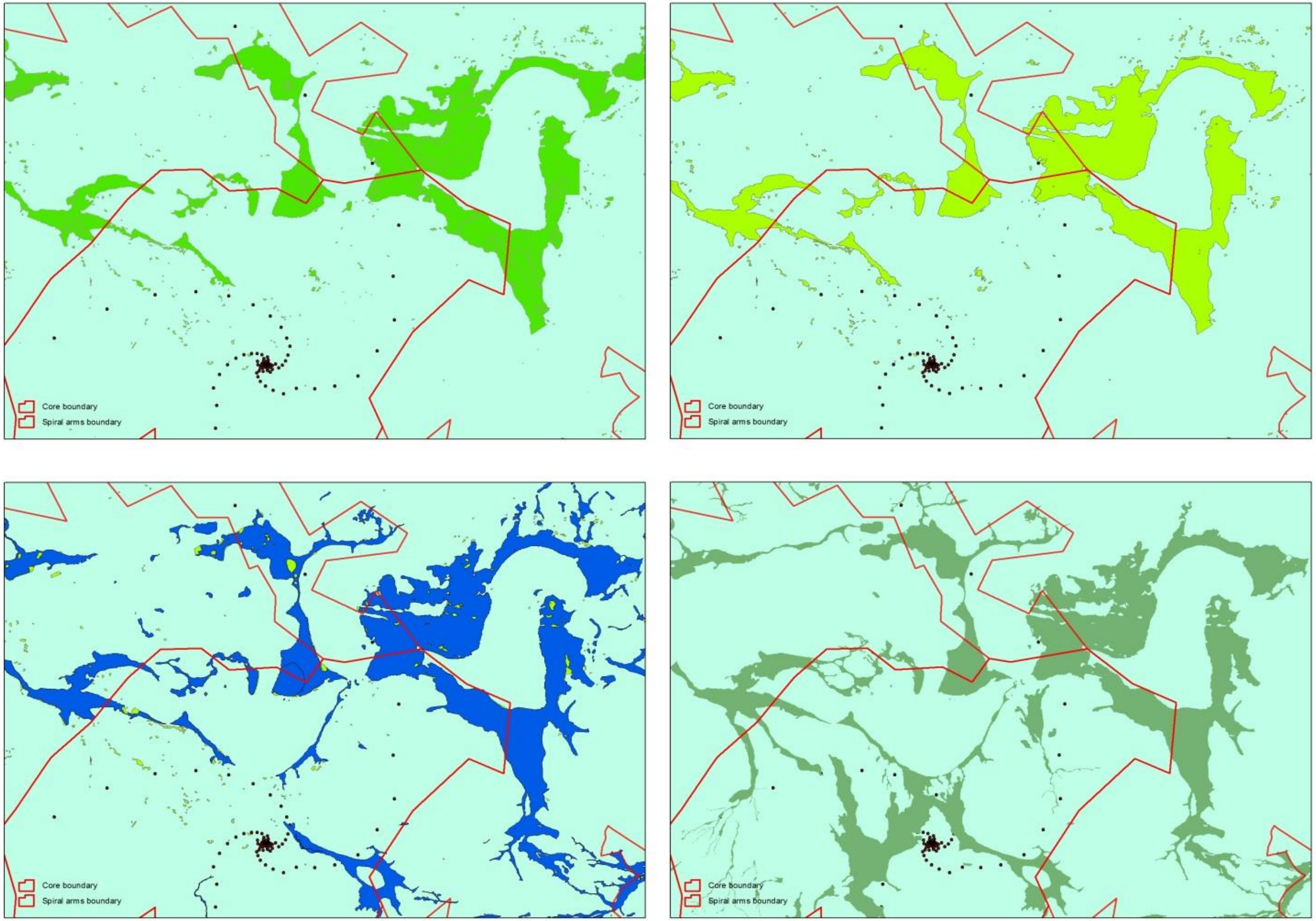


Figure V.1 Progression of the wetland mapping in the SKA Phase 1 site – top left: unedited NFEPA map; top right: edited NFEPA map; bottom left: NGI's hydrological features; bottom right: merged edited NFEPA, NGI hydrological features, and FCG's newly digitised wetlands.

The criteria used for the buffering rules are assumed to be relevant surrogates for the overall sensitivity of aquatic features to the specific impacts associated with the SKA project. The national Preliminary Guideline for the Determination of Buffer Zones for River, Wetlands and Estuaries (MacFarlane *et al.,* 2014a) was used to determine a desktop-level buffer width, which was based on the types of impacts associated with above- and below-ground construction and operation of communication and power (electrical) infrastructure[2]. The generic buffer for this type of activity is 55 m for all aquatic ecosystems located in an area with low rainfall. The buffer guideline allows for the refinement of the desktop level buffer width, through the entering of specific on-site information. However, it is felt that a desktop determination of buffer width is sufficient for an SEA-level study. The buffer recommended in the Namakwa District Environmental Management Framework is 32m, and this was used as the minimum buffer width for this assessment (Chidley *et al.,* 2011).

Table V.1 Criteria used for buffering rules for rivers (buffers are provided in metres). CR = Critically Endangered, EN = Endangered, LT = Least Threatened. A Present Ecological State (PES) of ABC = good condition to moderately modified; DEF = largely modified to poor condition.

1:500 000 river lines					
	Threat status (NBA 2012):	**EN[3]**	**LT**		
	FEPA status:	**FEPA or Upstream**	**FEPA**	**Upstream**	
	Ecological condition (PES):	**Any condition**	**Any condition**	**ABC**	**DEF**
River type	Free-flowing rivers	200	200	200	200
	Mountain stream OR Upper foothill	n/a	80	55	35
	Lower foothill OR Lowland river	100	100	80	55
1:50 000 river lines					
	Ecological condition (PES):	**ABC**		**DEF**	
All river types (Upper & Lower River Zones)		55		32	

Table V.2. Wetland buffer size rules. CR = Critically Endangered, EN = Endangered, LT = Least Threatened. A Present Ecological State (PES) of ABC = good condition to moderately modified; DEF = largely modified to poor condition.

Wetlands			
Threat status (NBA 2012):	**CR, EN, VU**	**LT**	
Ecological condition (PES):	***Any condition***	***ABC***	***DEF***
All wetland types	65	55	35

There was insufficient time during this study to undertake an assessment of the ecological and functional importance and sensitivity of all of the wetlands and watercourses that may be affected by SKA Phase 1. Hence, it was necessary to choose a suitable surrogate for mapping sensitivity and in this case, HGM types and their vulnerability to the impacts of the SKA project were used as surrogates. The highest sensitivity level – **no go** - was

[2] The buffer tool allows the user to select the category of activity that is being assessed. In this case, the option for "Service infrastructure – above/below ground communication/power (electricity) infrastructure" was chosen, as this comes closest to the kinds of impacts expected to be associated with the SKA project.

[3] There are no Critically Endangered (CR), or Vulnerable (VU) river types in the area

assigned to the depressional and seep wetlands and the wetland flats. These wetlands tend to be discrete wetland features, with fairly clear boundaries (in the Northern Cape), and it is possible for infrastructure to avoid these features. The remaining wetland types, all of which are riverine – i.e. floodplain and valley-bottom wetlands – occupy a large proportion of the SKA Phase 1 SEA study area, and are more difficult to delineate, both on a map and in the field. The wetland characteristics of these features are difficult to determine, and it is impossible to build linear infrastructure in the area that would avoid these features. These features were assigned a **high** sensitivity category.

All ecological buffers were categorised as being of high sensitivity. Ecological buffers are essentially setbacks, within which there are limits to developments that could impact on the biodiversity and ecological functioning of aquatic ecosystems (see Macfarlane *et al.,* 2014). Buffers are essential for the protection of the aquatic feature, for instance a well vegetated buffer serves to remove excess nutrients and possibly other pollutants from surface and subsurface runoff, through uptake by plants and soils. In some instances, buffers are important for sustaining the feature itself - for instance, the slopes surrounding a wetland provide surface runoff into the wetland. In all cases, buffers are important for maintaining connectivity between the wetland or watercourse and the terrestrial environment (e.g. Kotze *et al.*, 2009; Macfarlane *et al.,* 2014). Thus, ecological buffers are seen to be almost as sensitive to impacts as the features themselves, and developments should preferably not encroach into them.

This fairly broad-brush categorisation into No Go and High sensitivity classes is in line with the approach used for other SEAs related to the SIPs (Skowno *et al.* (2014); Snaddon *et al.* (2015); Holness *et al.* (in prep)), but does mean that some resolution is lost. For instance, some of the extensive washes and alluvial floodplains are probably less sensitive to development encroachment than others. However, the large spatial extent of the mapping done for the SKA Phase 1 SEA and the overall low to medium level of confidence assigned to the typing of the wetlands requires a broad-brush approach. Site level ground-truthing of the map of aquatic features and their buffers and more detailed assessments of the relative sensitivity and importance of aquatic ecosystems in the SKA Phase 1 SEA study area will lead to greater confidence in assigning sensitivity classes, improved knowledge of the significance of site level impacts, and the appropriateness of mitigation measures.

In summary, all freshwater ecosystems and their buffers should preferably be avoided. Where high sensitivity features and buffers cannot be avoided at the design stage, key mitigation measures are impact minimisation, ecosystem rehabilitation and biodiversity and/or functional offsets.

3) Field work

Field work in the SKA Phase 1 SEA study area focused on the spiral arms, and was undertaken from 14th to 18th March 2016, in late summer. Access to some sites was denied by the landowners, nonetheless, based on the preliminary configuration for the SKA Phase 1 project, eleven of the 21 dish-antenna sites within the spiral arms of the SEA study area were visited, in addition to a drive-around of the MeerKAT site (in the "core area") and immediate surrounds. It is recommended that further field work in the core area is commissioned at a later date, once permission to enter the properties has been gained.

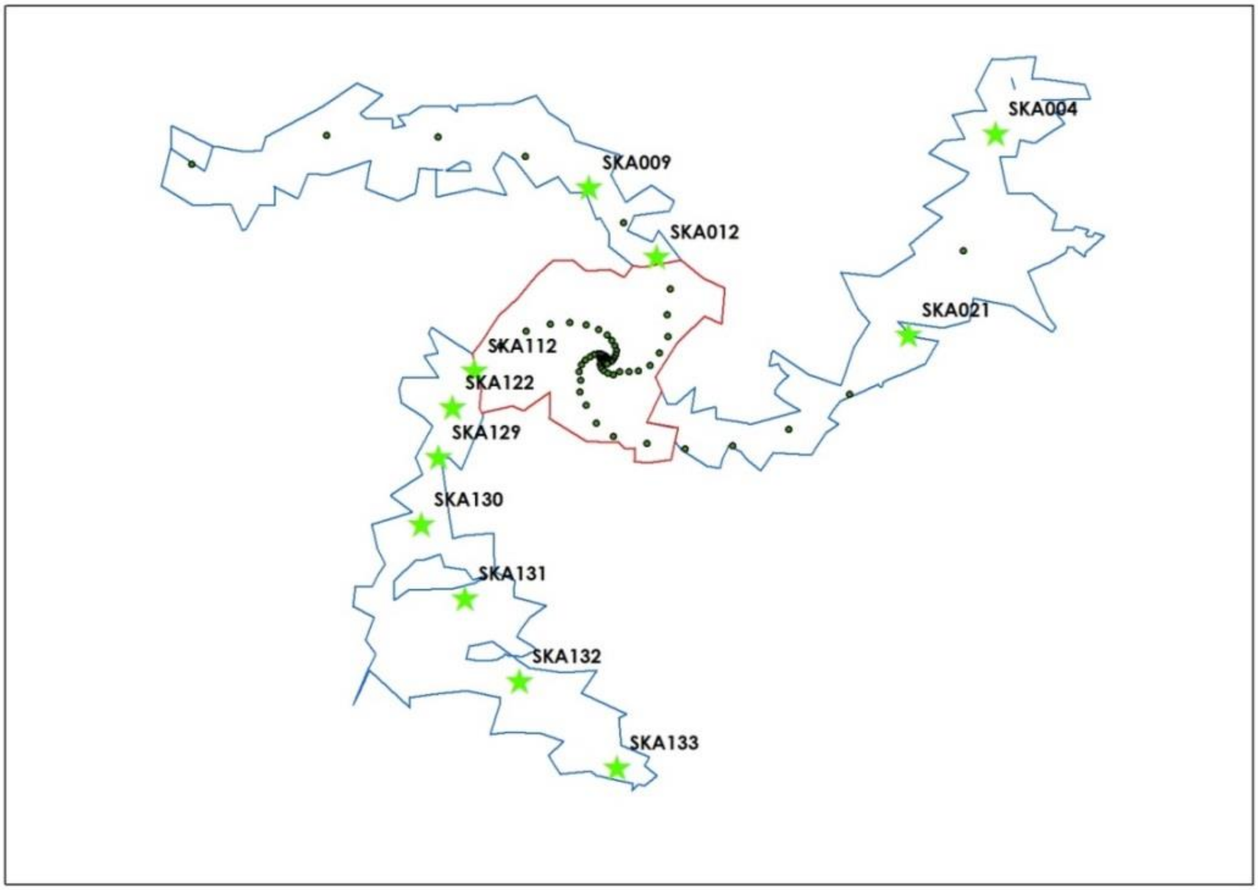


Figure V.2 Preliminary configuration of the SKA Phase 1 dish-antennae (black dots) dated May 2015, and the 11 sites visited during the field trip in March 2016 (green stars). The three SKA Phase 1 SEA study area spiral arms are outlined in blue and the core area in red.

The list of SKA Phase 1 dish-antennae sites which were visited, based on the preliminary configuration of the SKA Phase 1 (dated May 2015), is as follows:

- Brandvlei: SKA 009, SKA 012
- Carnarvon: SKA 004; SKA 021
- Williston: SKA 133, SKA 132, SKA 131, SKA 130, SKA 129, SKA 122, SKA 112

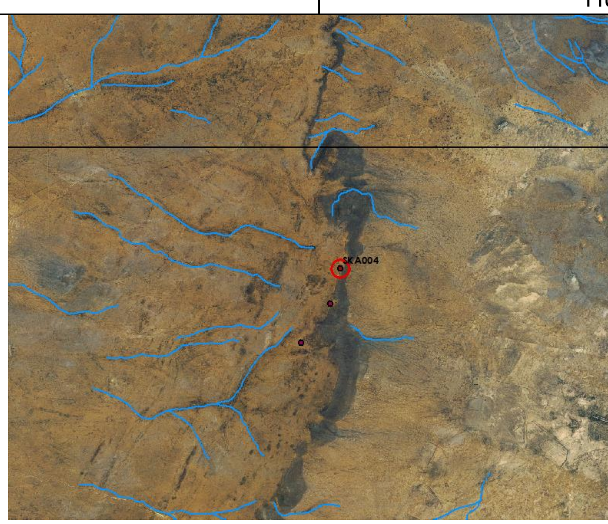
VI. Sites visited in March 2016 and fieldwork notes

1) SKA 004 – Farm 40 Klein Markt

Although the site was some 400 m distant from the closest point of access, it was clear that there are no aquatic features on the site. It is situated on a dolerite escarpment/crest, and is stony with moderately disturbed red apedal, sandy soils of Hutton soil form (Soil Classification Working Group, 1991). Moderate scale disturbance permits colonization of annual plants/weeds, such as *Citrullus lanatus* and creeping *Tribulus terrestris.* Other species recorded in the area include *Rhigozum trichotomum, R. obovatum, Schmidtia kalihariensis, Tragus racemosus, Stipagrostis obtusa, Eragrostis lehmanniana, E. obtusa, Digitaria eriantha* and *Cenchrus ciliaris.*

Vegetation typical of the area around the site.

Dolerite boulder field close to the site. Note the red Hutton soils.



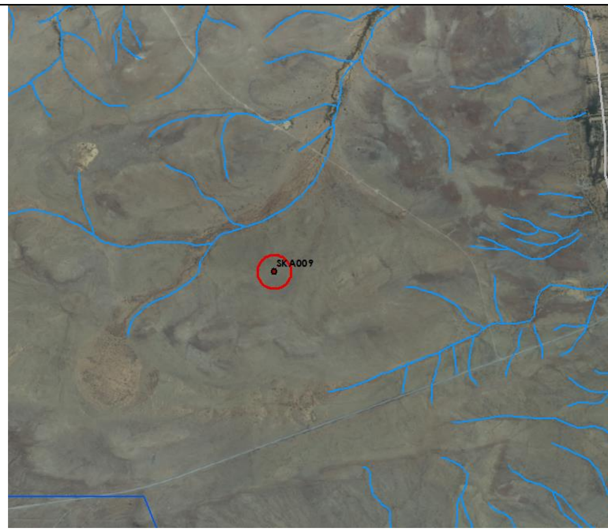
The site is located on the edge of a dolerite escarpment (dark areas).

2) SKA 009 – Farm RE58 Moffys Dam

No aquatic features are located within and adjacent to the proposed antenna location. The general habitat feature on the area is an open flat plain with denuded veld due to excessive grazing. The vegetation cover is very low, it is patchy and dominated mostly by *Rhigozum trichotomum* and overgrazed *Stipagrostis* sp., to root level. The surface is composed of dolerite sills and weathered shale particles and the soil is characteristic of lime and Glenrosa soil form. An ephemeral stream is located south of the antenna. The ephemeral stream has a defined confined channel and defined riparian vegetation and coarse to stone alluvium bedform.

The watercourse is infested with *Prosopis glandulosa*.

	The site is stony, with very sparse vegetation cover.
	Watercourse to the north of the site. This ephemeral stream leads into a fairly major tributary of the Sak River.



Location of the site.

3) SKA 012 – Farm 62/1 Jagt Pan and Farm 63/1 Dubbelde Vlei

The proposed antenna is located adjacent to a pan, and nearby a wind-pump and water storage tanks. There are several drainage channels running through the site. The salt pan is extensive, with a dry, flat bottom covered in places by dolerite stones and silt washed down from surrounding dolerite outcrops. The soils of the pan are yellow to white, derived from weathered material of calcrete with a loamy to clayey soil texture. Patches of low scrub species adapted to saline systems are found here, such as *Salsola aphylla, S. tuberculata, Rhigozum trichotomum, Lycium pumilum* and *Stipagrostis namaquensis*.

Impacts noted here were grazing, trampling, and a small, breached dam on the main drainage line feeding into the pan.

Pan adjacent to the site.

Dry watercourse running through the site of SKA 012, showing many faunal tracks in the soft sand.

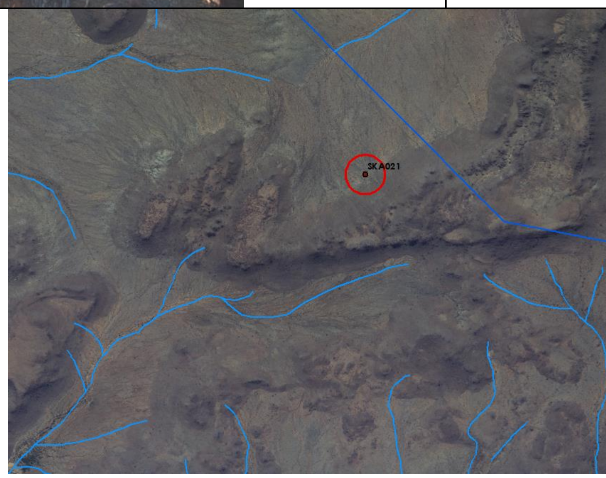
Location of the site, adjacent to the pan.

4) SKA 021 – Farm RE74 Garst Kolk

The proposed antenna site is located on a confined dry alluvial fan sloping in a northerly direction. The feature has fine silt particle sediment derived from the shale bedrock and downstream wash from the mountain, and some segments of the feature have dolerite sill/stone on the bed. This particular feature splits downstream into many drainage networks that later diminish. Shale underlies the terrestrial bottomlands and uplands.

The vegetation shows low grazing impacts, thus providing good cover for fauna. The vegetation is mostly dwarf shrubland dominated by *Rhigozum obovatum, Aristida adscensionis and Stipagrostis ciliata*.

Vegetation typical of the site proposed for SKA 021.



Site location, some distance away from any major drainage lines, but with a fine network of drainage lines fanning across the site.

5) SKA 112 – Farm RE69 Waterkloof

The proposed antenna site is at the foot of dolerite hills. The apedal soils are generally red to yellow in colour, with calcrete and lime nodules. The terrestrial vegetation is homogenous and dominated primarily by *Rhigozum trichotomum*. Plant species recorded within the watercourse include *Stipagrostis* sp.

The site has been heavily overgrazed, and there is evidence of a loss of topsoil. The landscape and the watercourse have also been impacted by roads and erosion.

The site of SKA 122 has been heavily overgrazed. The dominant plant species is *Rhigozum trichotomum*.

Location of the site, showing the dolerite hills to the west, and the drainage lines washing off these hills in an easterly direction, onto the core site.

6) SKA 122 – Farm RE77 Zand Puts

The proposed antenna site is located adjacent to a dry watercourse, which has a poorly defined channel and banks. The bed comprises fine grained sand, and has been impacted by a road track. There is an absence of in-stream vegetation, but the sand has allowed the establishment of a few plants such as *Salsola* sp. and some large *Eucalyptus* trees.

The surrounding landscape is dominated by overgrazed grassy vegetation. The site is close to a stock watering point.

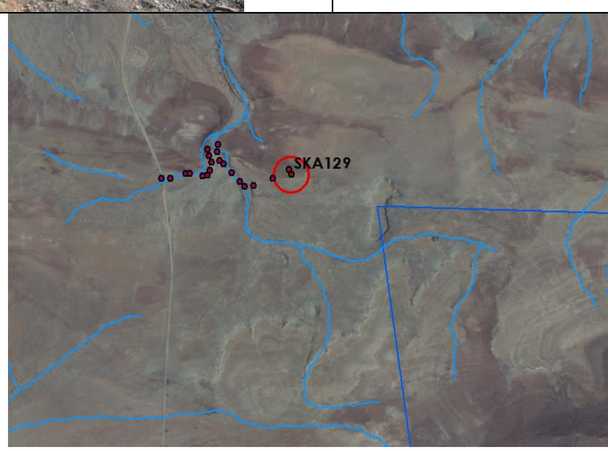
Dry riverbed, with an ill-defined channel, adjacent to the site of SKA 122. The vegetation is heavily overgrazed.

Close up of site location.

7) SKA 129 – Farm 91 Biesies en Anteel Kolk

The proposed antenna site is located on a gentle slope adjacent to a dolerite rocky outcrop. The sandy loam soils are red-yellow apedal soils, weathered from shale and sandstone. The veld is dominated by low sparse scrubby patches of *Rhigozum trichotomum, Stipagrostis ciliata* and *Salsola tuberculata*. A number of ephemeral watercourses are located on the valley bottom, east of the location of the antenna. The ephemeral streams braid and then meet to form a clearly defined wide channel with low vertical banks. The bed is comprised of silt and coarser gravel, with some shale bedrock. The plants recorded both in the stream and in the riparian zone include *Stipagrostis namaquensis, Melinis repens, Scirpus nodosus, Fingerhuthia africana, Eragrostis lehmanniana, Felicia muricata, Cadaba aphylla, Asparagus mucronatus, Sporobolus fimbriatus* and *Cenchrus ciliaris.*

	View of the site, showing the gentle slope and dryland vegetation.
	View looking downstream, of the rocky banks of the ephemeral stream to the north of the site, showing a clear riparian zone of *Stipagrostis namaquensis* on the right-hand bank.



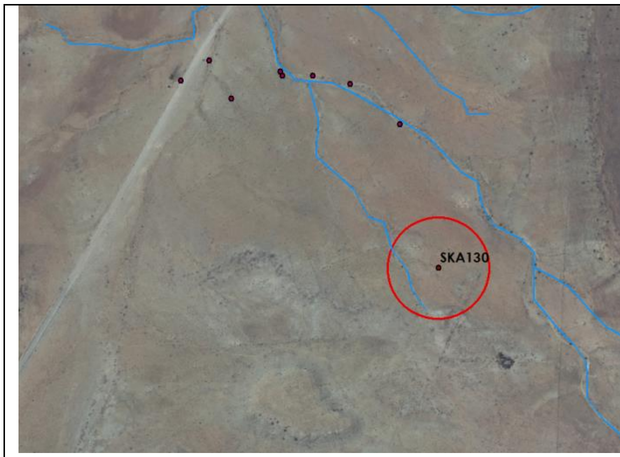
Aerial view of the site, showing location of ephemeral streams, and field waypoints.

8) SKA 130 – Farm RE108/3 Koega

The proposed antenna site is located between ephemeral streams. The ephemeral streams are defined by a confined channel with an average width of 5 m and defined vertical banks of shale (slate) depositing silt into the channel bed. The ephemeral streams have shale bedrock and some segments of the stream have fine silt sediment and coarse gravel. The in-stream vegetation is dominated by *Stipagrostis namaquensis, Melinis repens* and on the banks, *Lycium cinereum, Salsola* sp., *Cadaba aphylla.* The dryland vegetation is dominated by *Rhigozum trichotomum*. Faunal activity is high within the streams (vertebrates and invertebrates).

Impacts include the nearby road, erosion and grazing.

	Dryland vegetation typical of the site, dominated by *Rhigozum trichotomum*.
	Corrugations on a streambed at the site – Ecca mudstones. Streambeds are typically gravel/sand/shale sediments on the base, and some bedrock, with gravel/cobble/bedrock banks.
	*Stipagrostis namaquensis* – grass typically growing in the drainage lines across the whole study area. The species usually occurs with a number of other grasses including *Melinis repens* and *Eragrostis truncata*.



Close up of site, showing location of ephemeral streams, and field waypoints. The road to the west is clearly visible.

9) SKA 131 – Farm RE133 Banksfontein

The proposed antenna site is located close to dense networks of alluvial fans that are in a dendritic pattern. The alluvial fans emerge from a confined stream flowing from the upland dolerite outcrops. The narrow channels have shallow dry soils and shale-derived silt on the bed. The area is located on a slope that is relatively rocky with dolerite sills. The vegetation cover is high, providing necessary cover for fauna; the dominant plants are *Rhigozum trichotomum* and *Stipagrostis ciliata*.

Impacts include over-grazing and some erosion.

Dryland vegetation at SKA 131, dominated by *Rhigozum trichotomum*. The site is located slightly upslope of an ephemeral stream

	Larger stream downslope of the site, showing animal (including human) prints in the soft sand.
 Close up of the site, showing surrounding drainage lines.	

10) SKA 132 – Farm RE152 Vloks Werven

The aquatic features located adjacent to the proposed antenna site are alluvial fans and drainage lines, running off the surrounding slopes, and down into the Sout River, a tributary of the Sak River. The drainage channels are composed of fine sand with Ecca shale and calcrete material. The general habitat comprises gentle sloping topography from dolerite outcrop and semi open low dwarf shrub vegetation, consisting of *Lycium cinereum*, *Eriocephalus ericoides* subsp. *ericoides, Aristida adscensionis* and *Stipagrostis ciliata*.

The site has been impacted by grazing.

	View of the antenna site.
	The Sak River, to the west of the site. The river flows in a north-westerly direction from this crossing, from right to left on this photo.

Close up of the site, showing surrounding minor drainage lines, and the Sak River to the south.

11) SKA 133 – Farm RE204 Korfsplaats

The proposed antenna site is approximately 70 m from the edge of a watercourse (Palmietfontein se Loop River, a tributary of the Sak River). The site is located in overgrazed veld of low dwarf shrubland (approximately 40% cover), on a stony flat plain of dolerite and weathered soil derived from shale and mudstone. The soils on the site are characteristic of the Mispah soil form, derived from weathered rocks. The dominant shrub species recorded is *Salsola tuberculata*. Faunal activity appeared to be low at this site.

	Site of antenna SKA 133, showing fairly sparse vegetation cover, from over-grazing. The cliffs above the watercourse to the north of the site () can be seen in the distance.
	Sedges (*Ficinia nodosa*) and rushes growing in the bed of Palmietfontein se Loop to the north of the site.
 Close up of the site, and its proximity to Palmietfontein se Loop.	

VII. Broad description of KCAAA1

1) Climate and runoff

The KCAAA1 encroaches very slightly into the winter rainfall zone, but generally shows a gradual shift from winter rainfall in the south-west through to summer rainfall in the north-east (Figure VII.1). Rainfall is very low – ranging from 100 – 520 mm per year across the study area (Figure VII.2) – which translates into low annual runoff (Figure VII.3). In these semi-arid western and central regions of South Africa C3 grasses and shrubs predominate (Palmer and Ainslie, FAO website, www.fao.org).

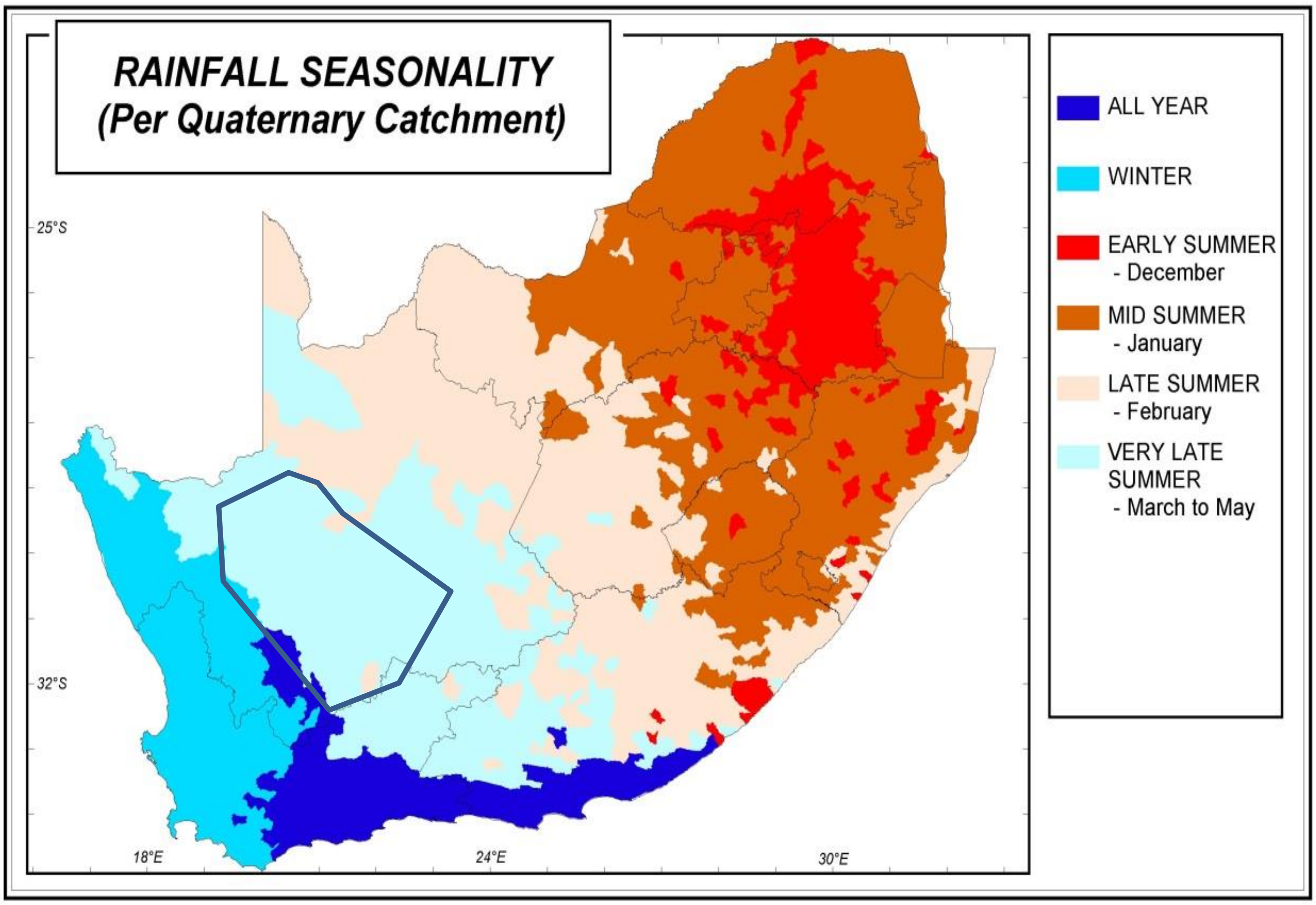


Figure VII.1 Rainfall regions of South Africa (from Schulze *et al.*, 2007). The KCAAA1KCAAA1is shown as a blue outline.

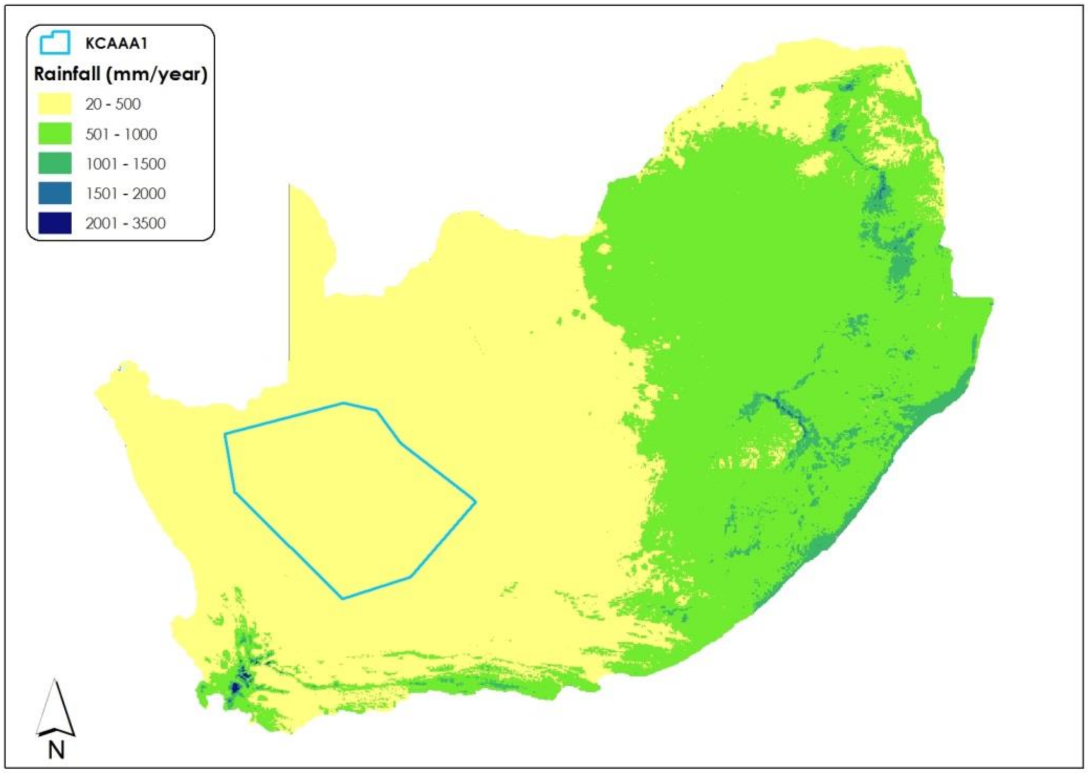


Figure VII.2 Rainfall totals per annum in mm/year.

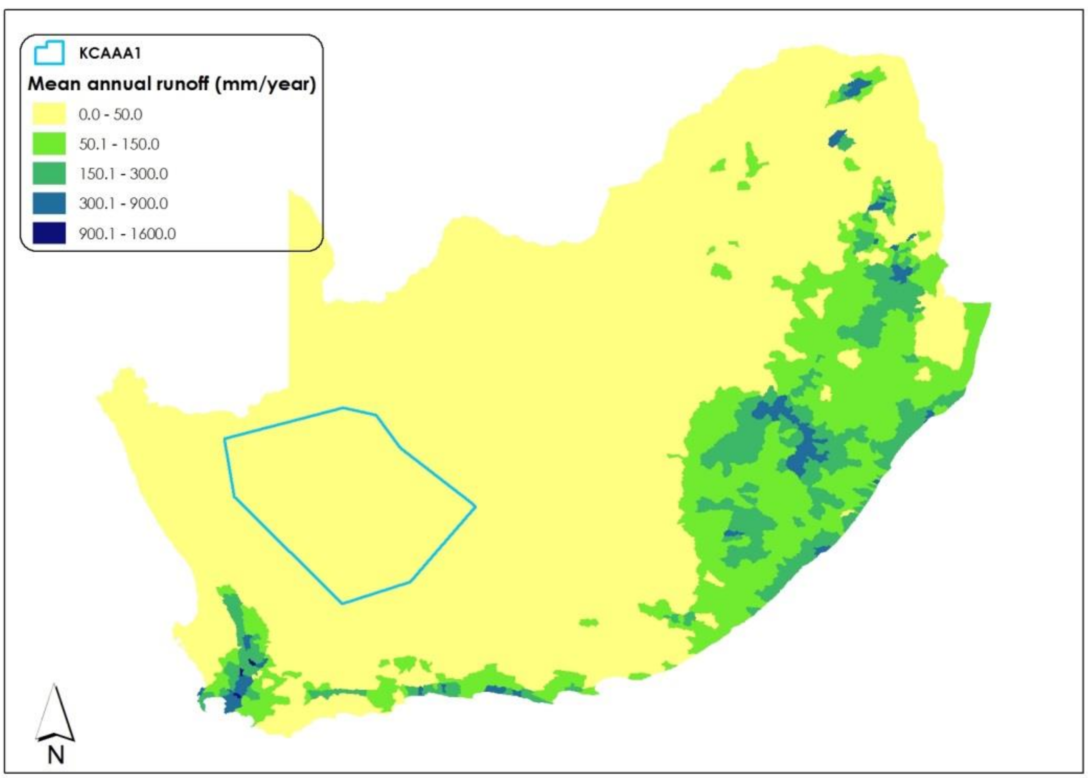


Figure VII.3 Mean annual runoff totals in mm/year.

2) Catchments, Ecoregions and Biomes

The study area lies completely within the Lower Orange Water Management Area (WMA14) and almost entirely within the Nama Karoo Level 1 ecoregion (Kleynhans *et al.*, 2005) (Figure VII.4). The characteristics of this ecoregion are:

- Topography is diverse, dominated by plains with a moderate to high relief and lowlands, hills and mountains with moderate to high relief;
- Most of the rivers in the region are seasonal to ephemeral, such as the Hartbees and Sak rivers. Perennial rivers that traverse this region include the Riet (tributary of the Vaal River located in the eastern part of the ecoregion) and Orange rivers;
- Rainfall is moderate to low (around 500 mm/year) in the east, decreasing to arid in the west (around 70 mm/year). Coefficient of variation of annual precipitation is moderate to high in the east to very high (30 to 40%) in the west, and
- Drainage density is generally low, but medium to high in some parts.

The Nama Karoo ecoregion includes the northward flowing rivers in the study area, with the main system into which these rivers flow being the Orange River. The KCAAA1 also includes very small areas of Great Karoo (in the west of the study area) and Orange River Gorge (in the north) ecoregions. Other primary catchments (in addition to the Orange River, or D catchment) in the KCAAA1 include the Olifants-Doring in the west of the area, and the Gouritz in the south. The full list of quaternary catchments within and intersected by the KCAAA1 is provided in Table VII.1.

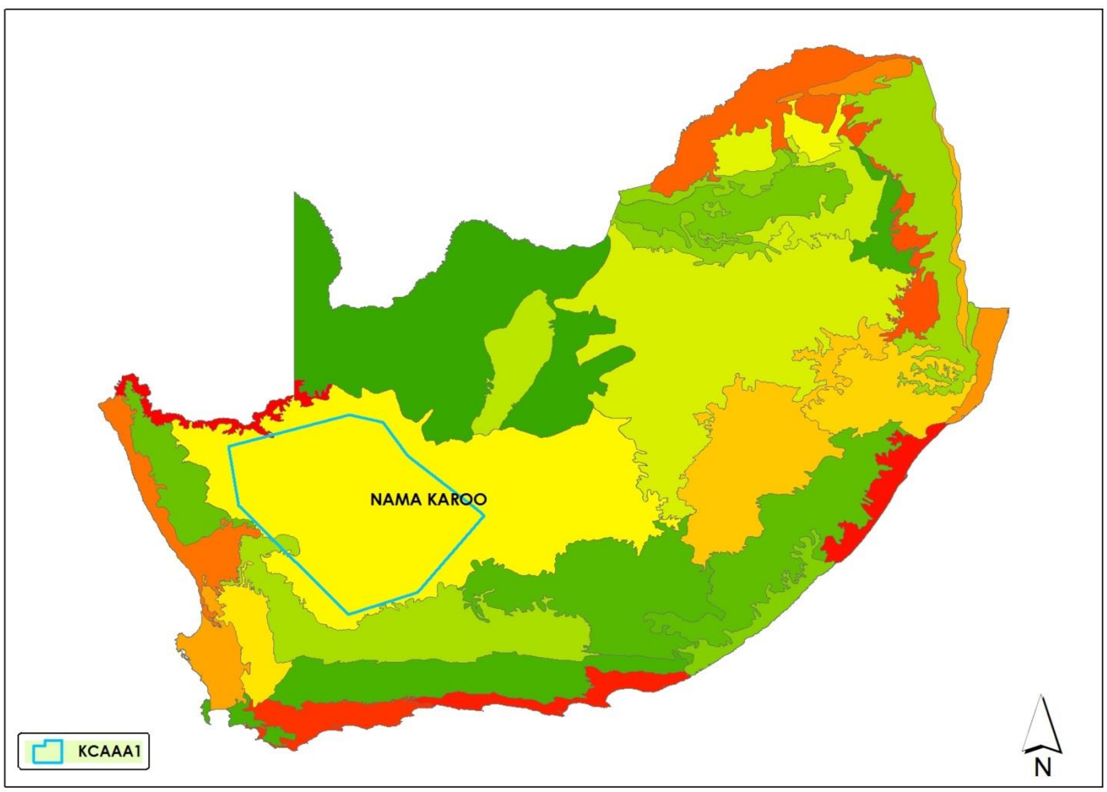


Figure VII.4 Level 1 ecoregions of South Africa. The KCAAA1 lies almost exclusively within the Nama Karoo ecoregion. The ecoregions are too numerous to include in the legend.

Table VII.1 Quaternary catchments within and intersecting with the KCAAA1. Data from Water Resources of South Africa 2012 Study (WR2012; Bailey and Pitman, 2015).

Quaternary catchment	Area (hectares)	Rivers (R = River)
D51B	873	Renoster River: Onderplaas to Sterkfontein
D51C	522	Renoster River
D52C	465	Vis
D52E	609	Vis
D52F	1146	Vis
D53A	1939	Hartbees
D53B	1713	Hartbees
D53C	1899	Hartbees: Kenhardt to Tuins R confluence.
D53D	1842	Tuins
D53E	826	Hartbees: Tuins to Sout R confluence
D53F	8040	Endorheic
D53G	4747	Upper Sout
D53H	1589	Middle Sout to Hartbees confluence
D53J	455	Hartbees from Sout R to Orange
D54A	1518	Carnarvonsleegte source to Dwaalberg
D54B	4053	Boesak R: Carnarvonsleegte to just N of Vanwyksvlei
D54C	1342	Vanwyksvlei
D54D	5071	Endorheic
D54E	3326	Endorheic
D54F	3809	Endorheic
D54G	4503	Nameless tributary Carnarvonsleegte to Sak R confluence
D55A	1872	Sak R Headwaters to Jakkalsfontein
D55B	1260	RENOSTER RIVER
D55C	761	Brak R source to Loxton, incl Damfontein se rivier
D55D	1889	Brak R: Loxton to Sak R, incl Slangfontein se Riviers
D55E	2240	Sak R. Brak R confluence to Sout R confluence.
D55F	2632	Brak R to Gansvlei R confluence
D55G	1293	Gansvlei R to Brak R confluence
D55H	1151	Sak R: Brak confluence to Middle of Bundu
D55J	1998	Sak R: Md Bundu to Klein Sak R confluence
D55K	1247	Klein Sak to Sak R. confluence
D55L	1242	Sak R from K. Sak confluence to Blouheuwel
D55M	1813	Sak: Blouheuwel to Vis R confluence
D56A	510	Portugals R
D56B	519	Riet R to Portugals R

Quaternary catchment	Area (hectares)	Rivers (R = River)
D56C	920	Nameless R & Riet from Portugal confluence to Onder Riet R
D56D	621	Riet R: Onder Riet R to Klein R confluence
D56E	666	Klein Riet R source
D56F	1038	Klein Riet and Kabee R – Middle
D56G	651	K Riet R
D56H	447	REElands R to Riet confluence
D56J	931	Riet R: Elands confluence to Renoster confluence + Leenderts R
D57A	853	Sak R: Vis confluence to Enkeldoorn
D57B	2274	Endorheic
D57C	637	Sak R. Enkeldoorn to Brandvlei
D57D	4444	Sak R: Brandvlei to Grootvloer inflow
D57E	1957	
D58A	763	Renoster: Riet confluence to Vis R confluence
D58B	1131	Vis R. Renoster confluence to Klein Vis confluence
D58C	2521	Vis R: Vis confluence to Sak R confluence
D61F	873	Brak source to minor road
D61G	744	Brak R: Minor Rd to Vosburg Rd
D61H	1086	Brak R from Vosbburg Rd + Visgat R to Ongers R
D61J	1558	Groen R – upper
D61K	1608	Upper Smartt Syndicate - Groen R
D61L	1016	perdepoortsleegte to Smartt Synd (Mostly Endoreic)
D61M	943	Ongers R: Brak confluence to Smartt Synd Dam
D62A	2243	Ongers: Smart Syndicate to Minnieskloof Sta
D62B	3117	Ongers R: (Mostly Endoreic)
D62H	2062	(Endoreic)
D72B	2569	Orange R: Prieska to Westerberg
D72C	2776	Orange R: Westerberg to Boegoeberg
D73C	6221	Orange R: Buchuberg mountains to Kheis
D73D	4291	Orange R: Kheis to Grootdrink
D73F	4630	Orange R: Upington to Kakamas
D81A	2311	Orange River: Kakamas to Blouputs
D81D	1826	Orange R: Daberas to Skuitdrift
D81F	1841	Orange R: Onseepkans to Pella
D81G	2007	Orange R: Pella to Klein Pella
D82B	4877	Endorheic
D82C	3996	Endorheic
E31A	2865	Endorheic
E31B	1476	Kromme

Quaternary catchment	Area (hectares)	Rivers (R = River)
E31C	1572	Kromme
E31D	839	Sout, Handhaaf (Knersvlakte area)
E31E	478	Sout, Handhaaf (Knersvlakte area)
E31G	1238	Sout, Handhaaf (Knersvlakte area)
E32A	1118	Kromme R
E32B	828	Sout, Handhaaf (Knersvlakte area)
E32D	616	Sout, Handhaaf (Knersvlakte area)
J22B	322	Gamka, Dwyka, Traka
J22G	567	Gamka, Dwyka, Traka

In terms of terrestrial vegetation, the area lies within the Nama Karoo biome (Figure VII.5). The main characteristics of this biome are as follows (adapted from Todd *et al.*, in prep.):

- The biome has a total area of 335 040 km2 (Mucina and Rutherford, 2006);
- Cowling & Hilton-Taylor (1999) reported 2147 species within the 'core' of the Nama Karoo Biome with 377 endemic species;
- Landscapes that are more rugged and at higher elevations in the Nama Karoo biome generally have a higher species diversity and greater abundance of species of conservation concern than other landscapes, making them more sensitive to anthropogenic impacts. These landscapes, especially those that are in good condition, are important for providing for resilience to climate change (Thuiller *et al.* 2006, cited in Todd *et al.*, in prep.);
- In general, taller and denser vegetation types are considered to be more vulnerable to fragmentation, as there is a greater contrast in vegetation characteristics between cleared and intact areas, and
- The extensive endorheic pans in Bushmanland are not well studied, but there are indications that the biodiversity of plankton in these depressions is rich (Hamer & Rayner, 1996; Anderson, 2000).

The KCAAA1 extends across the Bushmanland and Upper Karoo bioregions (Figure VII.6).

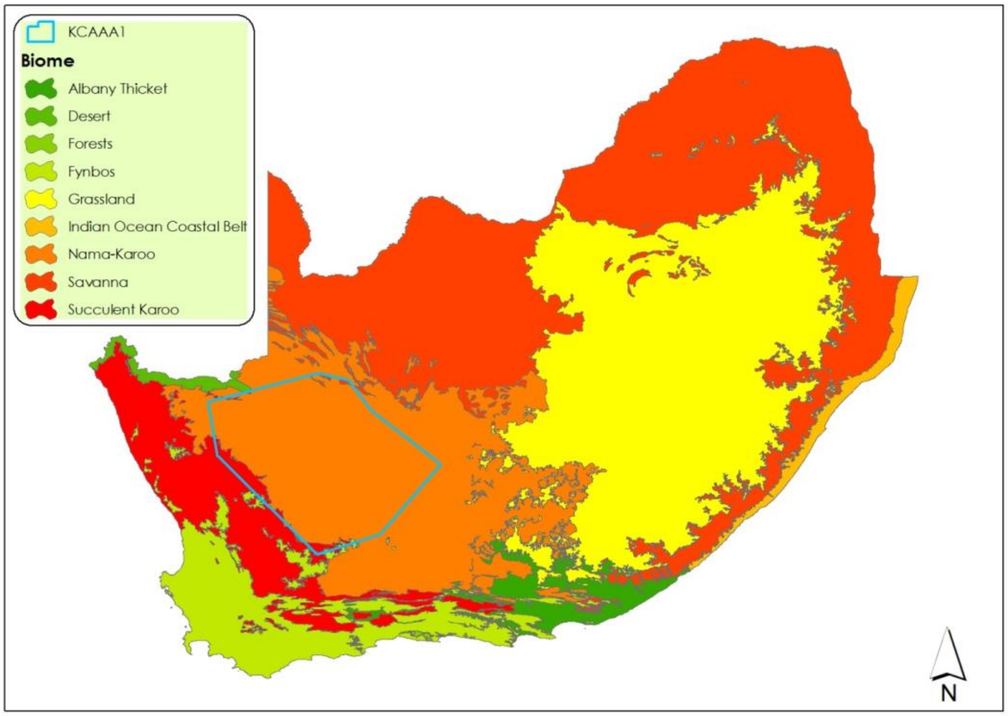


Figure VII.5 The terrestrial biomes of South Africa (Mucina and Rutherford, 2006). The KCAAA1 lies within the Nama Karoo biome, with some Succulent Karoo encroaching across the western boundary.

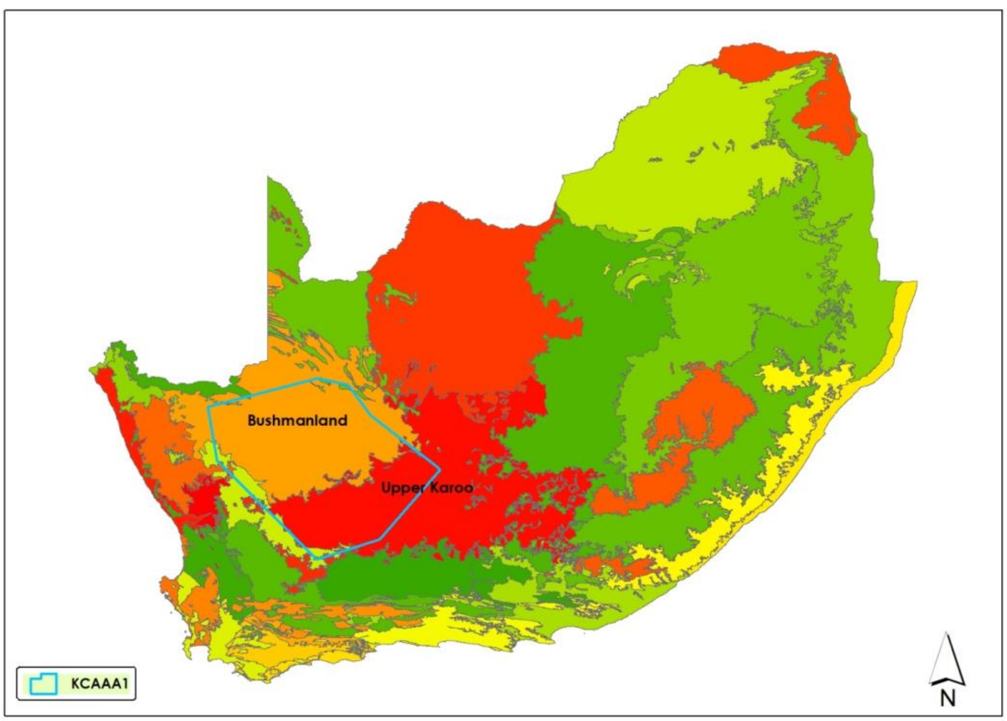


Figure VII.6 The bioregions of South Africa (from Mucina and Rutherford, 2006). The KCAAA1 primarily spans the Bushmanland (orange) and Upper Karoo (red) bioregions. The bioregions are too numerous to include in the legend.

3) Geology and topography

The Nama Karoo is underlain by a 3000 m-thick succession of sedimentary rocks. At depth is the Cape Supergroup, which is of marine origin, and above this lie the Dwyka tillites, deposited 400 – 300 million years ago (mya), and then the Karoo Supergroup, which includes the Ecca and Beaufort Groups, deposited in an inland sea 300 – 180 mya (Mucina *et al.*, 2006). Igneous activity approximately 180 mya led to the intrusion of dolerite sills and dykes into Karoo sediments. The strata of the Nama Karoo remained relatively horizontal, in comparison with the intense folding that occurred further south and that led to the Cape Fold Mountains of the Fynbos and Succulent Karoo biomes. As a result, the Karoo is flat to gently undulating, with boulder outcrops and flat-topped mesas. There are numerous drainage lines across this flat landscape, draining water off slopes, and more slowly across plains or basins. Due to the low gradient of most of the terrain, these drainage lines proliferate, sometimes with a number of lines running more or less in parallel across the plains, creating a wash effect (e.g. MacDonald, 2008). Drainage patterns are also fairly dynamic due to the lack of gradient, as a small obstruction to flow (plant roots, rocks, burrows etc.) can change the way water moves across the flat surface. In many instances, water flows into flat endorheic pans. Soils tend to be silty clay-loams, with high lime content.

4) Water supply and recharge

The KCAAA1 is located in an area of low runoff and recharge (see Figure VII.7 and Figure VII.8). Furthermore, there are no strategic water source areas (SWSAs) in the KCAAA1. These are defined as areas that "…supply a disproportionate amount of mean annual runoff to a geographical region of interest." (Nel *et al.*, 2013). National SWSAs were derived for the NFEPA project by grouping mean annual runoff into categories representing 10, 30, 50, 75, 90 and 100% of South Africa's water supply. Those areas supplying ≥ 50% of supply are considered to be SWSAs.

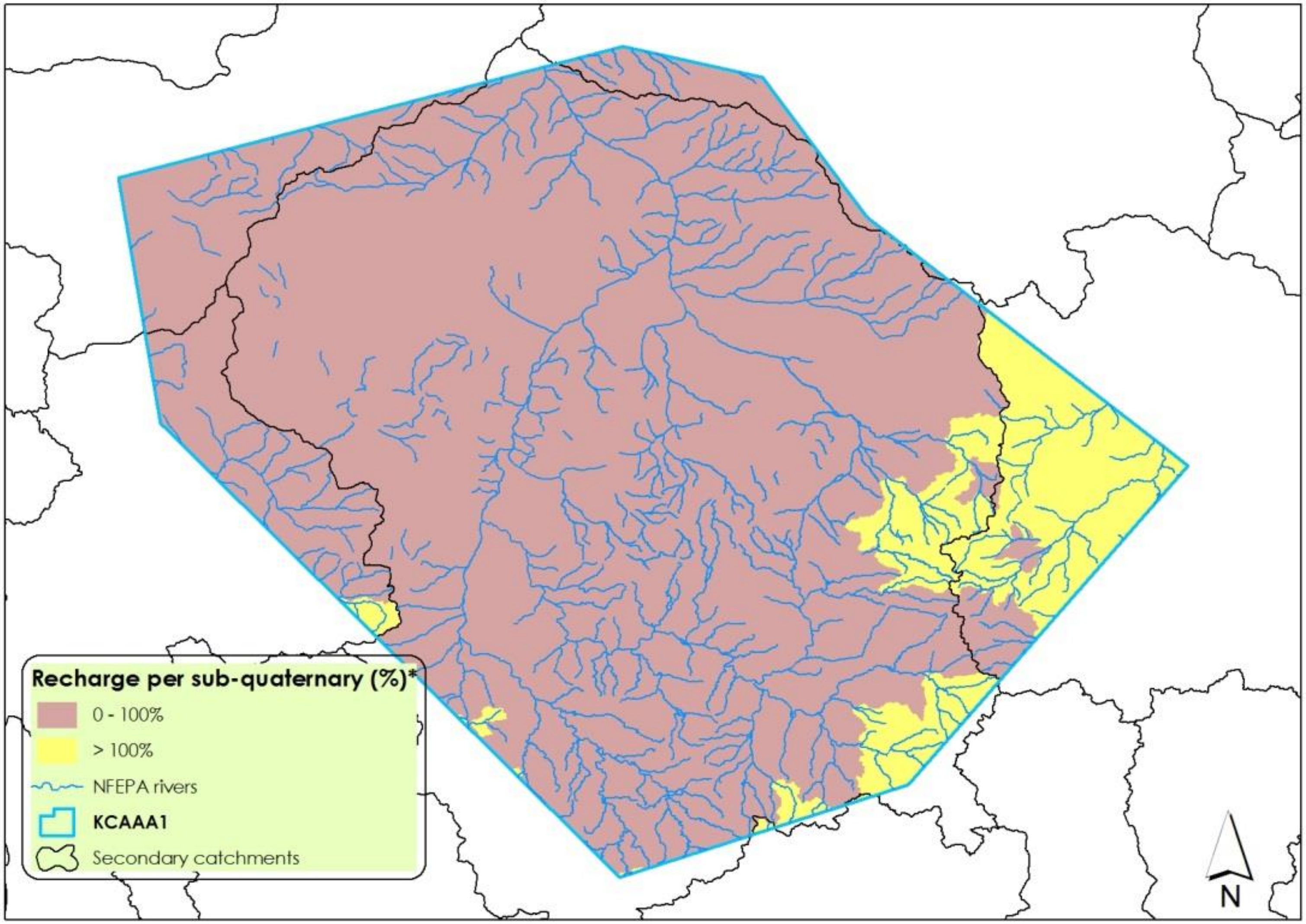


Figure VII.7 Groundwater recharge per sub-quaternary catchment, calculated for the NFEPA project as a ratio of the recharge per sub-quaternary to the recharge for the relevant primary catchment[4]. In the KCAAA1 there are a few catchments that exceed the primary catchment average, primarily in the east of the area, but the percentage does not exceed 200%.

[4] The data are expressed as a percentage, and where this exceeds 100%, the sub-quaternary contributes more than the average recharge for the primary.

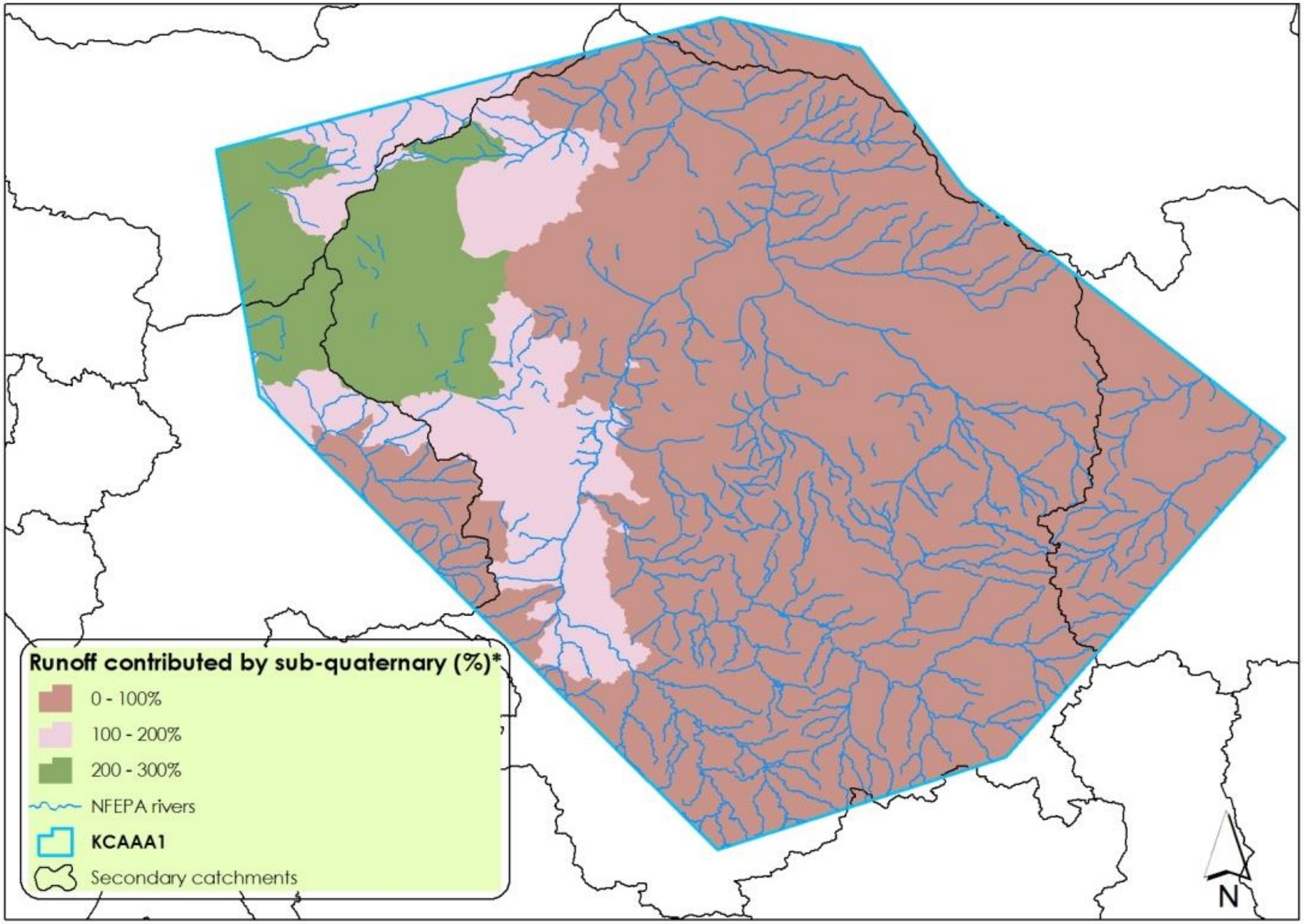


Figure VII.8 Runoff contributed by the NFEPA sub-quaternary catchments[5]. Sub-quaternary catchments contributing more than 300 times the primary average are considered "high water yield areas". There are none in the KCAAA1 .

[5] The data were calculated as the ratio of mean annual runoff for the sub-quaternary, against the runoff for the relevant primary, expressed as a percentage. Where this exceeds 100%, the sub-quaternary contributes more than the average runoff for the primary.

5) Rivers and wetlands

The Karoo landscape is heavily influenced by the occurrence of dolerite dykes, sills and rings, which control drainage patterns and the occurrence of wetlands (Woodford and Chevalier, 2002; Gibson, 2003). Surface–groundwater interactions are thought to be important in dry environments such as the Karoo, for sustaining surface water ecosystems, while evaporation is the dominant component of the water balance (Allan *et al.*, 1995; Seaman *et al.*, 2016). Most of the surface water ecosystems are intermittent or ephemeral, being inundated only for brief periods each year, with periods of drought that are unpredictable in duration. Inundation and flow in surface water ecosystems becomes more ephemeral towards the north of the study area (see Figure VII.9).

The ephemeral rivers of the Karoo are highly dependent on groundwater discharge, which will occur at springs and when groundwater recharge (through precipitation at higher elevations) allows the water table to intersect with the river channel. Groundwater discharge in this manner will deplete groundwater storage and discharge will cease at some point. The most significant river systems in the study area are the Sak, Carnarvonleegte, and Riet-Vis rivers. The Sak River rises in the Nuweveldberge, north of Beaufort West, and is joined by the Riet-Vis River system between Williston and Brandvlei. The Sak River flows into vast panlands around Brandvlei, and then into the Grootvloer pan just to the north, which only flows out northwards during periods of high flow, flowing into the Hartbees River and then the Orange River. This river provides an important migration route for fauna between the Sak and Orange rivers (Lloyd and Le Roux, 1985). Carnarvonleegte flows into the endorheic Verneukpan to the east of Grootvloer, which may sometimes also connect with the Hartbees River during the wet season.

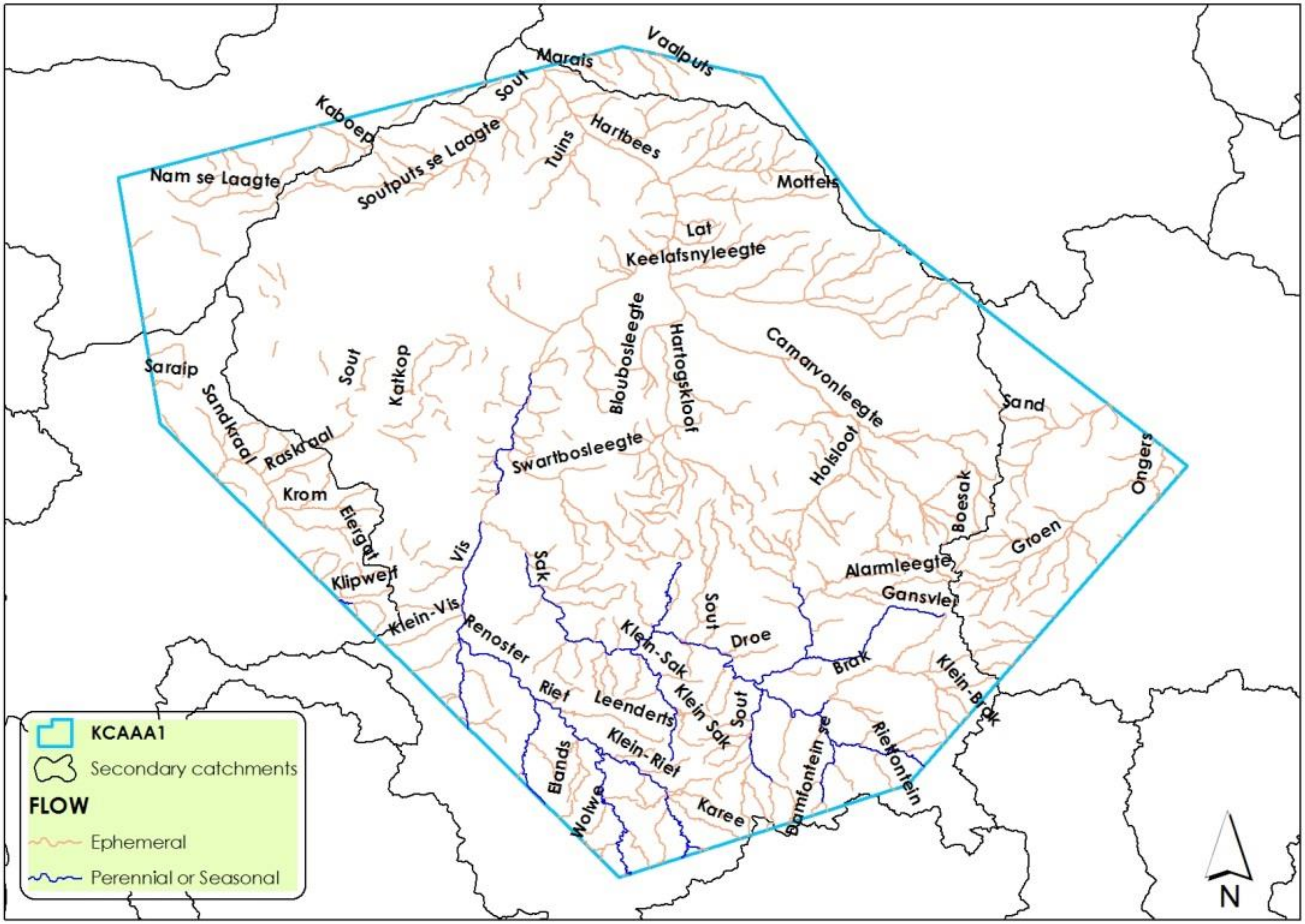


Figure VII.9 **The main rivers (at a scale of 1:500 000) of the study area, showing flow characteristics – perennial/seasonal *versus* ephemeral.**

Ephemeral or seasonal wetlands make up the majority of the lentic (non-flowing) systems located in the study area. Many of these wetlands – predominantly depressions or pans – are endorheic, i.e. isolated from other surface water ecosystems, usually with inflowing surface water but no outflow. There is generally little or no direct connection with groundwater, and these pans tend to be fed by rainfall. Endorheic pans are the most common wetland type in arid and semi-arid environments (Allan *et al.*, 1995), and are generally thought to form as a result of the synergy of a number of factors and processes, including low rainfall, sparse vegetation, flat to gently sloping topography, disrupted drainage, geology (e.g. dolerite sills and dykes) grazing and deflation[6]. The Bushmanland endorheic pans, or "vloere" as they are called locally, are one of the most extensive salt pan systems in South Africa (Mucina *et al.*, 2006). They appear to be concentrated around the relict channels of the ancient Tertiary Orange River catchment (Mucina *et al.*, 2006). These pans vary in size with the largest being the Verneukpan-Grootvloer system to the north of Brandvlei.
Inundation periods can last from a few days to months to a year. Similarly, the frequency is highly variable, from once a year or less (some pans in the Northern Cape are inundated once every few decades) to several inundations per year. The flat, central portion of these pans tends to be devoid of vegetation, with a typical zonation of plants occurring around the margins. They tend to filled with clayey, fine sediments, with a high salt content, due to salt-bearing substrates and mineral-rich groundwater.

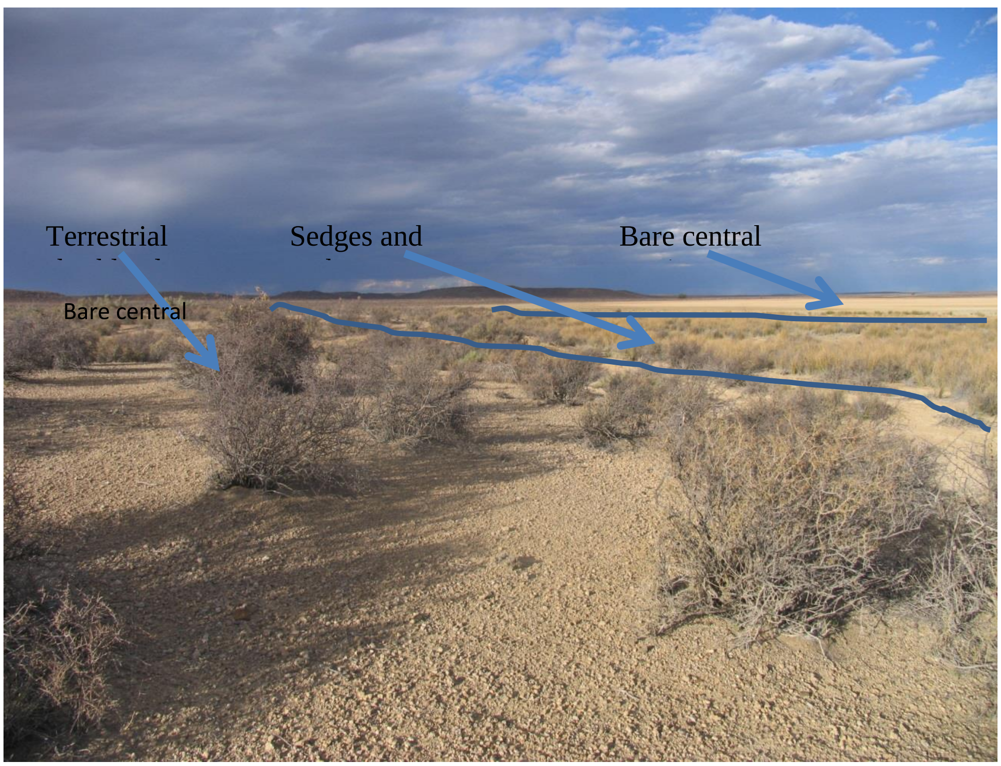


Figure VII.10 Typical zonation of vegetation around salt pan margins in the study area. The central flat portion is bare, followed by a zone of sedges and rushes (genera such as *Juncus*, *Scirpoides*, and *Ficinia*) around the margins, meeting the more terrestrial shrubland on the outer edge.

The less common, perennial springs and seeps associated with Karoo dolerite dykes and sills occur on peaty soils typically at the base of dolerite cliffs or on dolerite slopes, in depressions along fractures or topographical breaks, and are fed by groundwater seeping from deep, fractured aquifers, or even from unconfined alluvial aquifers (Nhleko, 2003). These comprise one of five types of aquifer-dependent ecosystems (ADEs) recognised in South Africa (Chevalier *et al.*, 2004; Colvin *et al.*, 2009). Little is known of the fauna and flora inhabiting these springs and seeps.

[6] The lifting and removal of fine, dry particles of silt, soil, and sand by the wind.

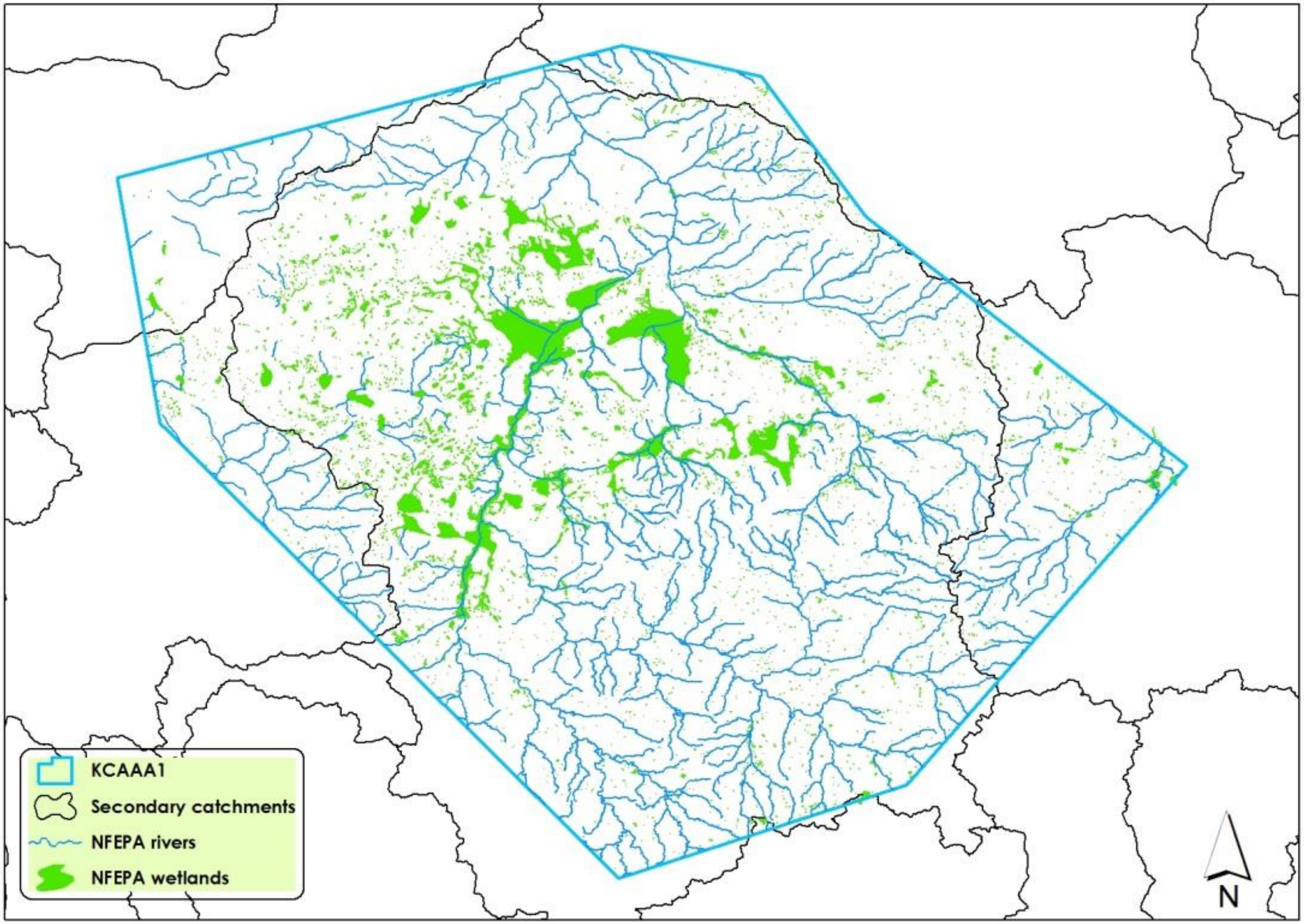


Figure VII.11 Wetlands and rivers in the KCAAA1 area, mapped for the NFEPA project (Nel *et al.*, 2011).

A dominant feature of the Karoo landscape is the alluvial floodplains or washes. These systems are difficult to classify, as their hydrological and geomorphological characteristics (the way water and sediment flows into, through and out of these features) are difficult to determine, and the ecological functioning and importance of these alluvial features are little known. They are characterised by numerous channels that traverse a floodplain, valley floor or alluvial fan. Surface water may flow along a particular channel in one year, but due to their being little topographic definition or gradient across the landscape, a parallel channel may be eroded the following year, leading to a network of channels. Some ecologists call these features "dendritic drainage systems", while others refer to them as washes or floodplains. They tend to be classified as watercourses rather than as wetlands as they show very few wetland characteristics in the strictest sense. MacDonald (2008), in his botanical assessment of the MeerKAT site, referred to three different types of washes – silt, gravel and sand washes. According to his descriptions, the silt washes occur on fine silty soils that is not as freely drained as the gravelly soils of the gravel washes, and which supports a shrubland dominated by *Salsola aphylla*, a species that is an obligate wetland plant growing in seasonal watercourses, on floodplains and on the edges of pans. Gravel washes have more sandy, well drained soils, and MacDonald's sand washes are the seasonal watercourses that traverse the other types of washes. Here the soils have been washed clean of silt, with sand of medium to fine grain remaining. These watercourses tend to have mostly bare beds, with vegetation occurring in clumps along the bed and more densely along the banks. Species typical of the river banks include *Stipagrostis namaquensis*, *Cenchrus ciliaris, Lycium cinereum* and *Melinis repens*.

Alluvian fans are also tricky to classify as they do not sit neatly in any of the hydrogeomorphic units used by the National Classification System for Wetlands and other Inland Aquatic Ecosystems (Ollis *et al.*, 2013). Alluvial fans are typically created when valleys widen suddenly or a stream flows from a narrow, relatively steep valley onto a wider, gradually sloping valley floor or flatter plain. These circumstances result in the rapid deposition of much of the sediment load carried by surface water, giving rise to an alluvial fan. Some alluvial fans (or portions of alluvial fans) have distinct channels, while others may lose this distinction as water and sediment disperse and settle relatively evenly across the fan.

According to the WET-Health document (MacFarlane *et al.*, 2008), alluvial fans possessing wetland characteristics are often classified as valley-bottom wetlands, with the distinction between channelled and unchannelled valley-bottom wetland depending on the degree of channel development. Where portions of an alluvial fan occur on a slope, the feature may rather be classified as a seep, especially where diffuse surface and sub-surface flows dominate.

The rivers and wetlands in the study area are mostly in good condition, with a Present Ecological Status (PES) of A or B (see Figure VII.12 for river condition), due to the low level of impact from the extensive rather than intensive human activities in the area. Impacts are associated with roads, encroachment of farmed areas into watercourses and wetlands, the construction of berms in river channels, floodplains and in pans to trap surface water for stock and crops, and the spread of invasive alien plants, primarily *Prosopis* sp. Ephemeral rivers and wetlands are particularly vulnerable to changes in hydrology and water quality (e.g. Seaman *et al.*, 2016), as they are specifically adapted to brief periods of inundation and flow, and pollutants and sediments entering these watercourses are not regularly diluted or flushed out of the catchment, thus leading to a lack of resilience against pollution, erosion and sedimentation.

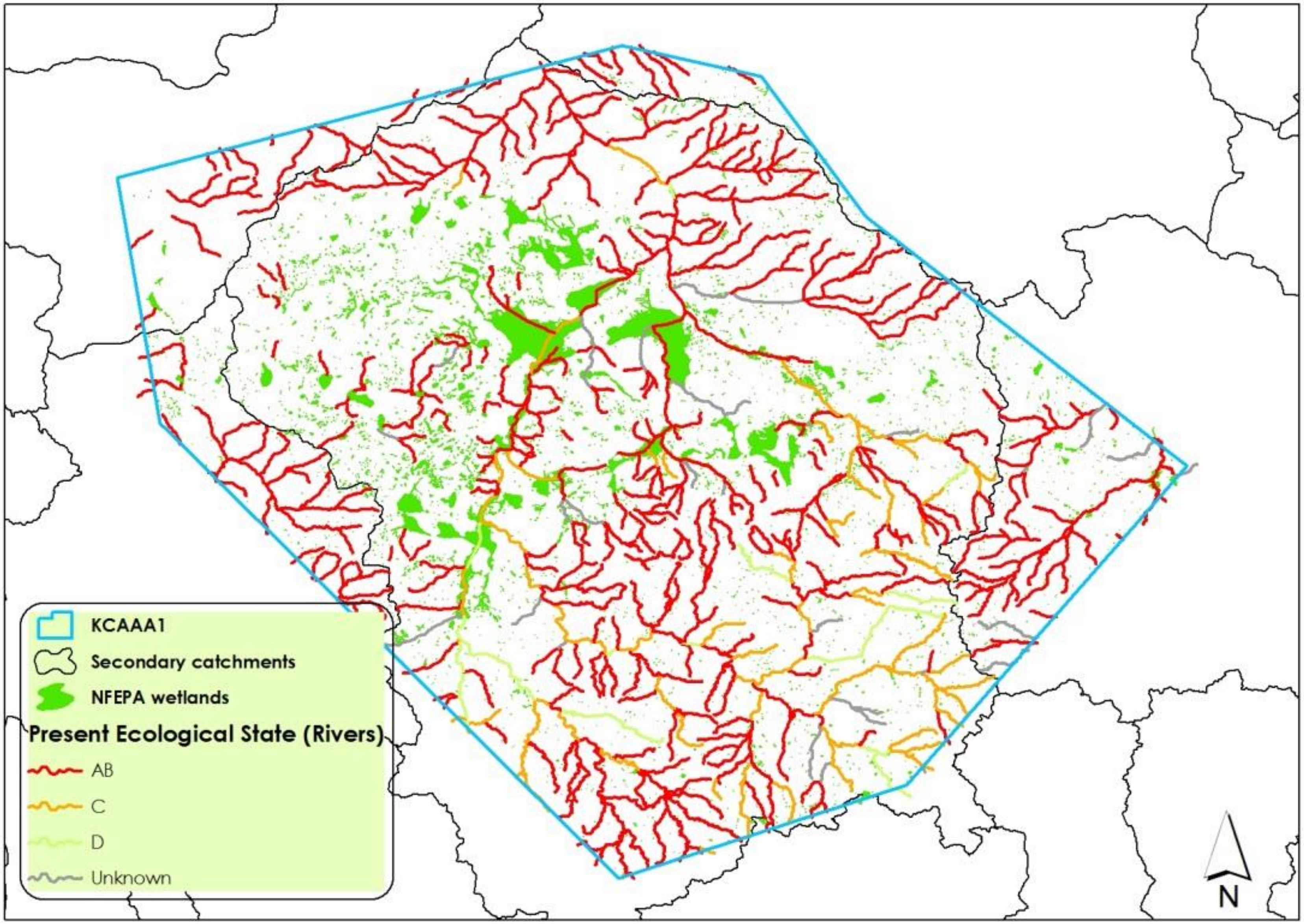


Figure VII.12 NFEPA mapped wetlands and rivers in the KCAAA1, showing the Present Ecological Status (PES) of each river reach, where this has been determined (Nel *et al.*, 2011; DWS, 2014). AB = natural to largely natural; C = moderately modified; D = largely modified.

6) Species information

The Nama Karoo biome or ecoregion is characterised by a depauperate aquatic fauna, and a southern temperate ichthyofauna (L. Day, Ecoregions of the World, www.feow.org). Most of the species are hardy opportunistic species, that migrate to water as and when it becomes available, breed rapidly and then disperse more widely when condition are favourable. Perennial and seasonal pools, rivers and wetlands provide refugia for many of these species (e.g. Seaman *et al.*, 2016).

The fauna of these ephemeral systems is not well-known, but the pans have been found to provide aquatic habitat for a diverse array of species that depend on brief periods of inundation for hatching, mating, feeding and refuge (e.g. Hamer and Rayner, 1996; Anderson, 2000; Minter *et al.*, 2004). Ephemeral watercourses and wetlands also provide habitat for fauna seeking refuge during dormant or drought-resistant stages. A great number of other organisms are not confined to these temporary systems, but derive crucial benefits from them, like migratory birds and many invertebrates that move opportunistically from permanent to temporary habitats on a regular basis.

- **Invertebrates**

Very little is known of the invertebrate fauna of the watercourses and wetlands of the Karoo region. Given the constant shift from aquatic to dry phases, ephemeral wetlands support unique, well-adapted biotic communities with species that show rapid hatching, fast development, high fecundity, and short life spans. For example, the tadpole shrimp, *Triops granarius*, is reportedly common where the mean duration of inundation is less than one month; this invertebrate reaches sexual maturity within days. Many taxa will reproduce asexually several times during the wet season.

Organisms that inhabit temporary wetlands rely on the production of desiccation-resistant or dormant propagules (such as eggs, cysts, seeds, spores) to survive this kind of environment. Propagules allow for the organisms to lie-in-wait during the dry period, and then come back to life when the wetland is inundated. There are several taxa that are completely dependent on ephemeral wetlands to complete their life-cycles. Phyllopod crustaceans are well-known inhabitants of ephemeral wetlands; these include the Anostraca (fairy shrimp, e.g. *Streptocephalus* sp.), Notostraca (tadpole shrimp, e.g. *Triops namaquensis*), Spinicaudata (clam shrimps, e.g. *Eocyzicus gigas*), Laevicaudata (clam shrimps), Cladocera (water fleas, e.g. *Daphnia gibba*), and Ostracoda (seed shrimps) (Lloyd and Le Roux, 1985; and Musa Mlambo, Albany Museum, pers. comm., January 2016).

- **Fish**

Most of the fish records received from SAIAB are in the southern portion of KCAAA1 where perennial rivers are more common. One exception is *Pseudocrenilabrus philander* (Southern mouthbrooder), which occurs up on the northern boundary of the study area, in Boegoeberg Dam on the Orange River. This species is associated with the Orange River system (Skelton, 1993). Four fish species are known from the Sak River – *Barbus anoplus, Labeobarbus aeneus, Labeo umbratus* and *L. capensis* (Hocutt and Skelton, 1985). Pools that persist for long periods in the river channel provide refugia for these species during dry periods.

Ephemeral wetlands generally do not support fish species, but fish are likely to occur in seasonal systems, surviving dry periods in permanent pools. The greatest threats to the fish fauna of the Karoo are the direct loss of aquatic habitat, lowered water table due to abstraction, loss of connectivity in watercourses affecting movement, and the introduction of alien fish species.

Table VII.2 Fish species recorded in the KCAAA1 (data from SAIAB).

Genus	Species	Common name	Threat status	Notes
Barbus	*anoplus*	Chubbyhead barb	Least Concern	Widely distributed in the interior, including the Karoo, and coastal rivers of the Southern and Western Cape. Prefers cooler waters, from small streams to large rivers and lakes. Prefers shelter in the form of logs and marginal vegetation. Lays adhesive eggs in vegetation, and breeds throughout summer when watercourses are flowing after rain. Feeds on insects, zooplankton, seeds, algae and diatoms.
Cyprinus	*carpio*	Carp	n/a	Introduced species, now widespread throughout South Africa, but absent from mountainous areas. Hardy , tolerant species favouring large waterbodies and slow-flowing large rivers with soft sediments. The species thrives in farm dams and feeds on plant and animal matter found in sediments.
Labeo	*capensis*	Orange River mudfish	Least Concern	Occurs in the Sak, and Orange-Vaal River systems. Occurs in flowing large rivers, but also in impoundments. Grazes on rock and plant surfaces and breeds in summer, laying eggs in shallow riffles and rapids.
Labeo	*umbratus*	Moggel	Least Concern	Fairly widely distributed in larger river systems in the interior (including the Sak River), and some coastal rivers. Prefers standing or gently flowing water, and thrives in farm dams and larger impoundments. Feeds on soft sediments and detritus. Breeds after rains have fallen, migrating upstream to find suitable spawning sites on flooded grassy floodplains or in shallow rocky runs.
Labeobarbus	*aeneus*	Smallmouth yellowfish	Least Concern	Occurs in the Sak, Orange and Vaal rivers, but has also been translocated to the Eastern Cape. Prefers clear, flowing large rivers, with sandy or rocky substrates. Breeds in spring through to midsummer after rains have fallen, migrating upstream to spawn and lay eggs over suitable gravel beds. Feeds on molluscs, vegetation, algae and detritus.
Pseudobarbus	*burchelli*	Burchell's redfin	Critically Endangered	Occurs in the Breede River system and other rivers in the south Western Cape. Record in KCAAA1 is from the Hek River, a tributary of the Groen River. The species inhabits pools and deeper, flowing runs of larger watercourses. Feeds on detritus and small benthic organisms. Breeds in summer.

Genus	Species	Common name	Threat status	Notes
Pseudocrenilabrus	*philander*	Southern mouthbrooder	Not assessed	Occurs in a wide range of biotopes, from flowing water to lakes and isolated sinkholes. Usually prefers vegetated areas. Male constructs a nest, and female takes brood into her mouth for protection. Preys on insects, shrimps and small fish.
Salmo	*trutta*	Brown trout	n/a	Widespread exotic species, preferring clear, well-oxygenated cool water, in mountain and upland watercourses. May also occur in lakes and impoundments. Generally feeds on insects, crabs, frogs and small fish. Breeds in autumn or early winter, with adult males moving upstream to find gravel beds.

- **Amphibians**

A number of frog species have been recorded during the national frog atlas survey in the quarter degree squares (QDS) incorporated in the KCAAA1 (Minter *et al.,* 2004). These data do not provide exact locations, and distributions are of a very low resolution. Finer resolution data received from SAIAB included only one species record, that of *Heleophryne purcelli* (Cape ghost frog), recorded in the Sandfontein River in the Cedarberg, i.e. in the far western extent of KCAAA1.

There are no threatened species that are known to occur in the study area. One species considered a near endemic to the arid Karoo is the Karoo Dainty Frog (also known as the Karoo Caco), *Cacosternum karooicum*. This species is considered to be threatened by a general loss of habitat in the Karoo. All the other species likely to occur in KCAAA1 are widespread, occurring in a range of habitats. Most species survive the dry periods as eggs or through aestivation, in cracks, crevices and under rocks. When the rains fall, breeding occurs rapidly to take advantage of the favourable conditions. The Karoo Toad, *Vandijkophrynus gariepensis,* and Karoo Dainty Frog breed in temporary pools associated with watercourses and wetlands.

The greatest threat to amphibians in the study area is fragmentation of the landscape as a result of urban encroachment, roads, and loss of wetland and riverine habitat, and also the direct threat of loss of life on roads, especially after rains have fallen.

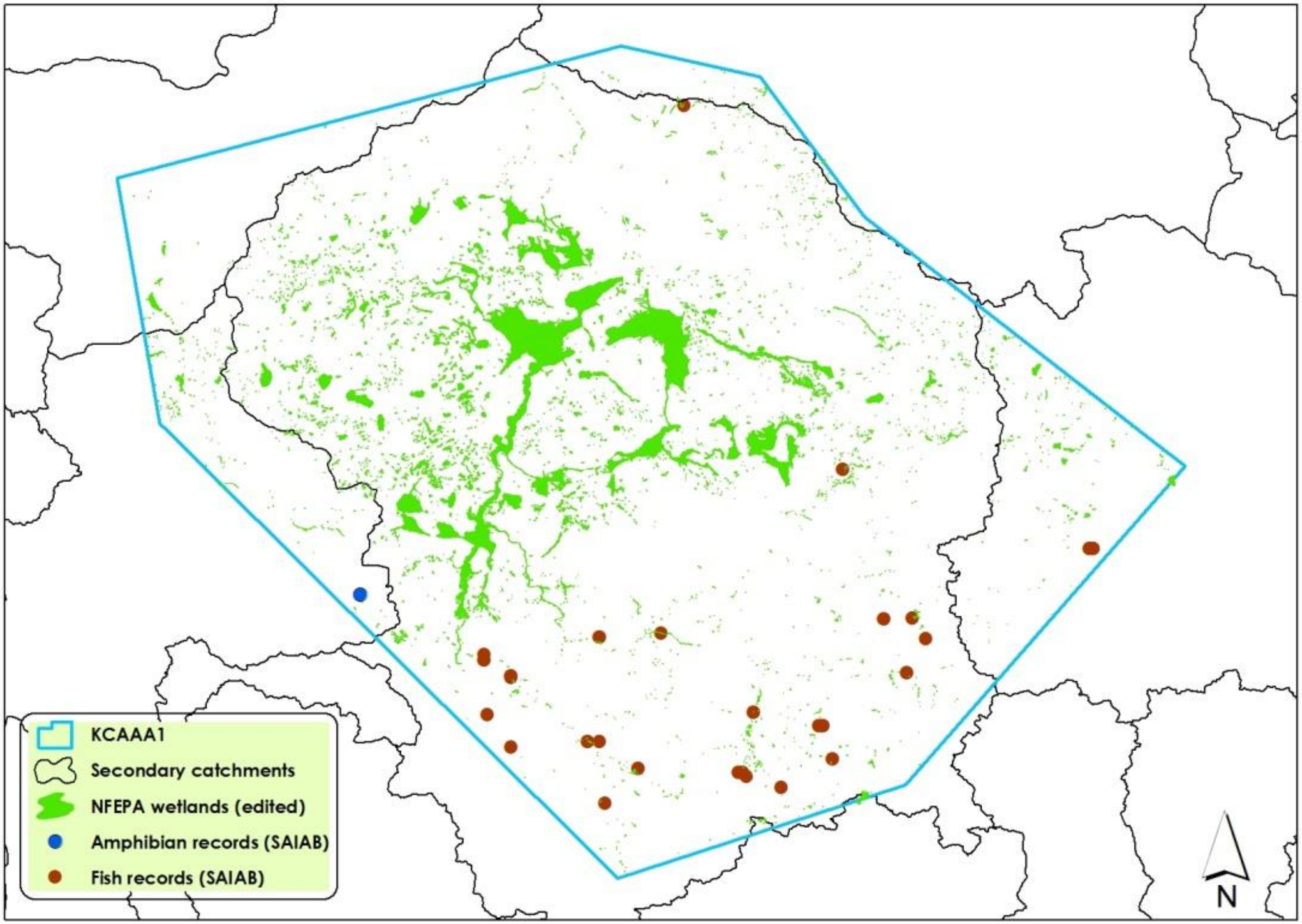


Figure VII.13 Amphibian and fish records received from SAIAB for the KCAAA1 area.

Table VII.3 Amphibian species listed in the national frog atlas as likely to occur in the study area, and one actual species record from SAIAB for *Heleophryne purcelli*.

Genus	Species	Common name	Threat status	Notes
Afrana	*angolensis*	Common river frog	Least concern	Frequently associated with human habitation, it lives in ditches and ponds, often where there are reeds and water lilies. Breeds in shallow water at the margins of pools and streams, in standing and flowing water.
Afrana	*fuscigula*	Cape river frog	Least concern	Widespread throughout the Karoo. Associated with permanent springs, ponds and farm dams, and also occurs along well vegetated, rocky watercourses. Breeds throughout the year.
Amietophrynus	*gutturalis*	Guttural toad	Least concern	Occurs along the wooded banks of the Orange River and its major tributaries. Occurs around open ponds, dams, vleis, and other waterbodies, common in suburban gardens and farmland. Spends the dry season in termite mounds, lizard burrows, etc.
Amietophrynus	*poweri*	Western olive toad	Least concern	Very similar to A. garmani (Garman's Toad). Shelters under logs, grass tussocks, termite mounds or rock cracks, emerging after rain.
Amietophrynus	*rangeri*	Raucous toad	Least concern	Restricted to the Gariep/Orange River corridor. Breeds in farm dams, ponds and pools in slow-flowing rivers, and are found in abundance in grassy agricultural areas.
Amietophrynus	*robinsoni*	Paradise toad	Least concern	Restricted to inselbergs in the Nama Karoo. Usually found in or near rocky, mountainous areas where it finds refuge in rock cracks and holes. Breeds in permanent or temporary seeps, springs, vleis, streams and rivers, and also in man-made depressions and dams. Not found in the large perennial rivers of the area.
Amietophrynus	*vertebralis*	Southern pygmy toad	Least concern	Occurs primarily in the Nama Karoo. Occurs in gravels sand, grassy areas, and in Karoo scrub, finding refuge under rocks and logs, and in mud cracks, leaf litter and termite mounds. Breeds in temporary shallow pans, pools or depressions, and occasionally in culverts and in rocky pools in seasonal watercourses.
Cacosternum	*boettgeri*	Common caco	Least concern	Favours open areas with short vegetation, breeds in any temporary waterbody, and is found in pans and along watercourses. Spends the dry season in mud-banks, burrows of other animals or termite mounds, and under stones.
Cacosternum	*karooicum*	Karoo dainty frog or Karoo caco	Least concern	Endemic to arid Karoo. Breeds in shallow pools on rocky beds of small, temporary streams, and in small impoundments. Spends dry period in rock cracks and crevices in shale.
Cacosternum	*namaquense*	Namaqua caco	Least concern	Breeds in temporary pools formed in granitic bedrock, in rocky streambeds, permanent pools and seeps or springs in granite inselbergs.

Genus	Species	Common name	Threat status	Notes
Heleophryne	*purcelli*	Cape ghost frog	Least concern	Occurs in clear, permanent mountain streams in wooded ravines and gorges. Occurs only in the south-western part of the study area, in the Sandfontein River, Cedarberg.
Phrynomantis	*annectens*	Marbled rubber frog	Least concern	Breeds in pools of rainwater trapped in rocky outcrops and inselbergs. Spends the dry season in rock cracks.
Pyxicephalus	*adspersus*	Giant (African) bullfrog	Least concern	Breeds in shallow, seasonal grassy pans in flat, open areas but also occurs in non-permanent vleis, and margins of waterholes and dams. Prefers sandy substrates, but sometimes inhabits clay soils. Spends dry season in burrows.
Strongylopus	*grayii*	Clicking stream frog	Least concern	Not threatened and can tolerate range of water quality; rarely found far from permanent water, and even breeds in brackish water
Strongylopus	*springbokensis*	Namaqua stream frog	Least concern	Restricted to springs, seeps, small permanent and non-permanent streams, and dams.
Tomopterna	*cryptotis*	Tremelo sand frog	Least concern	Breeds in shallow standing water at the edges of dams, pans and even puddles. Burrows into sandy soils or dry river beds during dry season.
Tomopterna	*delalandii*	Cape sand frog	Least concern	Inhabits lowlands, and valleys through the fynbos and succulent karoo biomes; breeds in pans, vleis and dams
Tomopterna	*tandyi*	Tandy's sand frog	Least concern	Occurs in loose, sandy soils, along small streams, pans and temporary rain pools. Commonly associated with farm dams.
Xenopus	*laevis*	Common platanna	Least concern	Tolerates poor water quality, can breed in any water
Vandijkophrynus	*gariepensis*	Karoo toad	Least concern	Occurs in a number of habitats from open sandy areas to grasslands, and rocky areas. Breeds in a variety of permanent and non-permanent waterbodies.

- **Waterbirds**

The avifauna survey conducted during the SEA deals specifically with the bird species known to occur or visit the area (Dean, 2016), however, for completion, some comments are made here regarding this important faunal group. As stated in the avifauna report, all of the bird species that are known to be associated with wetlands and watercourses in the arid Karoo are considered to be nomads (Dean, 2016). These species become resident once the wetlands and watercourses are inundated, with some remaining there until the water dries out. Birds how a remarkable ability to find recently inundated aquatic ecosystems, sometimes arriving within hours of inundation (Simmons *et al.*, 1999). Some of the more frequently observed species found in association with wetlands and watercourses in the Northern Cape are listed in Table VII.4 (Simmons *et al.*, 1998; Herrmann *et al.*, 2005; Dean, 2016).

Table VII.4 Some of the more common bird species known to be found in association with wetlands and watercourses in the Northern Cape (e.g. Simmons *et al.*, 1998; Herrmann *et al.*, 2005; Dean, 2016).

Species	Common name	Threat status
Phoenicopterus roseus	Greater Flamingo	Least Concern
Phoeniconaiais minor	Lesser Flamingo	Least Concern
Recurvirostra avosetta	Pied Avocet	Least Concern
Himantopus himantopus	Black-winged Stilt	Least Concern
Charadrius pallidus	Chestnut-banded Plover	Near threatened
Chlidonias hybrida	Whiskered Tern	Least Concern
Phragmacia substriata	Namaqua Warbler	Least Concern
Tadorna cana	South African Shelduck	Least Concern
Spatula smithii	Cape Shoveler	Least Concern
Fulica cristata	Red-knobbed Coot	Least Concern

The rapid arrival and proliferation of aquatic (e.g. zooplankton, dragonflies) and terrestrial invertebrates (e.g. termites), amphibians and ultimately fish once sufficient rain has fallen to inundate wetlands and rivers means that these systems are important for foraging and breeding, and many bird species move through the region, moving from pan to pan (Simmons *et al.*, 1998; Herrmann *et al.*, 2005). Some species, such as the South African Shelduck and the Cape Shoveler, require open waterbodies or densely vegetated vleis for refuge during the moulting season (Hockey *et al.*, 2005). The network of wetlands and watercourses crossing the arid landscape provides corridors for movement. In the summer of 1977/1978, Greater flamingos bred on an island in Van Wyksvlei and the chicks were moved to a dam near Carnarvon when the vlei dried up (Anderson, 2000). Interestingly, flamingoes also bred at this dam on a few other occasions before 1978, always preferring to breed on relatively inaccessible islands in the dam. These islands have since been invaded by *Prosopis*, and are no longer suitable for breeding.

The vegetation is frequently denser in riparian zones around rivers and on the margins of wetlands, with a greater occurrence of taller shrubs and trees, and this provides a diversity of nesting and breeding sites for many species. Many of the birds that are associated with wetlands and watercourses in arid regions tend to build their nests a short distance away from the water's edge, and so the vegetation in these buffer zones provides protection for the nests. In the case of the Shelduck, this species is known to build its nest at the mouth of disused aardvark holes (Milton and Dean, 2016).

7) FEPA sub-catchments

The NFEPA project of Nel *et al.* (2011) identified a number of sub-catchments as Freshwater Ecosystem Priority Areas (FEPAs), based either on the location of watercourses in good condition, or of known populations of threatened fish species in rivers within the sub-catchment[7]. A cluster of Fish FEPA sub-catchments incorporate the upper tributaries of the Sak River in the south-eastern section of the KCAAA1 (Figure VII.14). These tributaries support known populations of the Moggel, *Labeo umbratus*, providing important sanctuaries for this species.

Fish FEPAs are sub-catchments in which there are known populations of threatened fish species, in rivers that are in good (Class A or B) condition. Where these rivers are in a poor condition (Class C and below), the sub-

[7] Note: FEPA sub-catchments do not consider wetland presence, status or condition.

catchment is categorised as a Fish Support Area – there is one such sub-catchment in the southern part of the KCAAA1, and one to the north-east (see Figure VII.14). There are no Fish Corridors in the study area.
The remaining FEPA sub-catchments are categorised as such based on the fact that there are rivers in good condition within them that are important for achieving biodiversity targets. Their FEPA status indicates that they should remain in a good condition in order to contribute to national biodiversity goals and support sustainable use of water resources.

Most of the sub-catchments in the area are not categorised by NFEPA, or are categorised as Upstream Management Areas. Upstream Management Areas are sub-catchments in which human activities need to be managed to prevent degradation of downstream FEPAs and Fish Support Areas (Nel *et al.*, 2011).

8) Desktop mapping

As discussed above, the desktop mapping for the broader KCAAA1 brought together a number of available datasets, which were edited and amended according to the methods presented in Section V. These maps are presented in Figure VII.15 to Figure VII.19

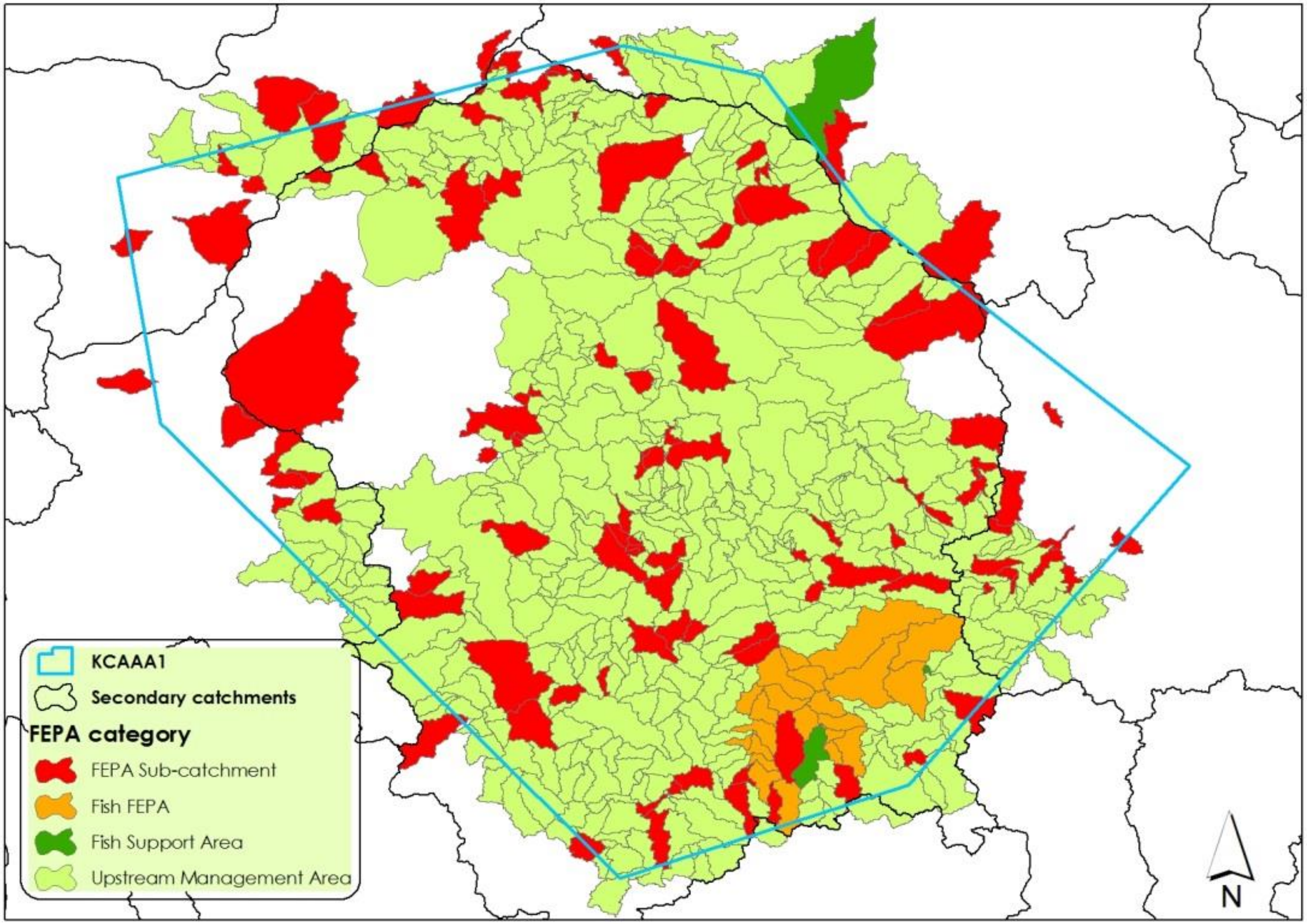


Figure VII.14 FEPA sub-catchments in KCAAA1. (Data from Nel *et al.*, 2011)

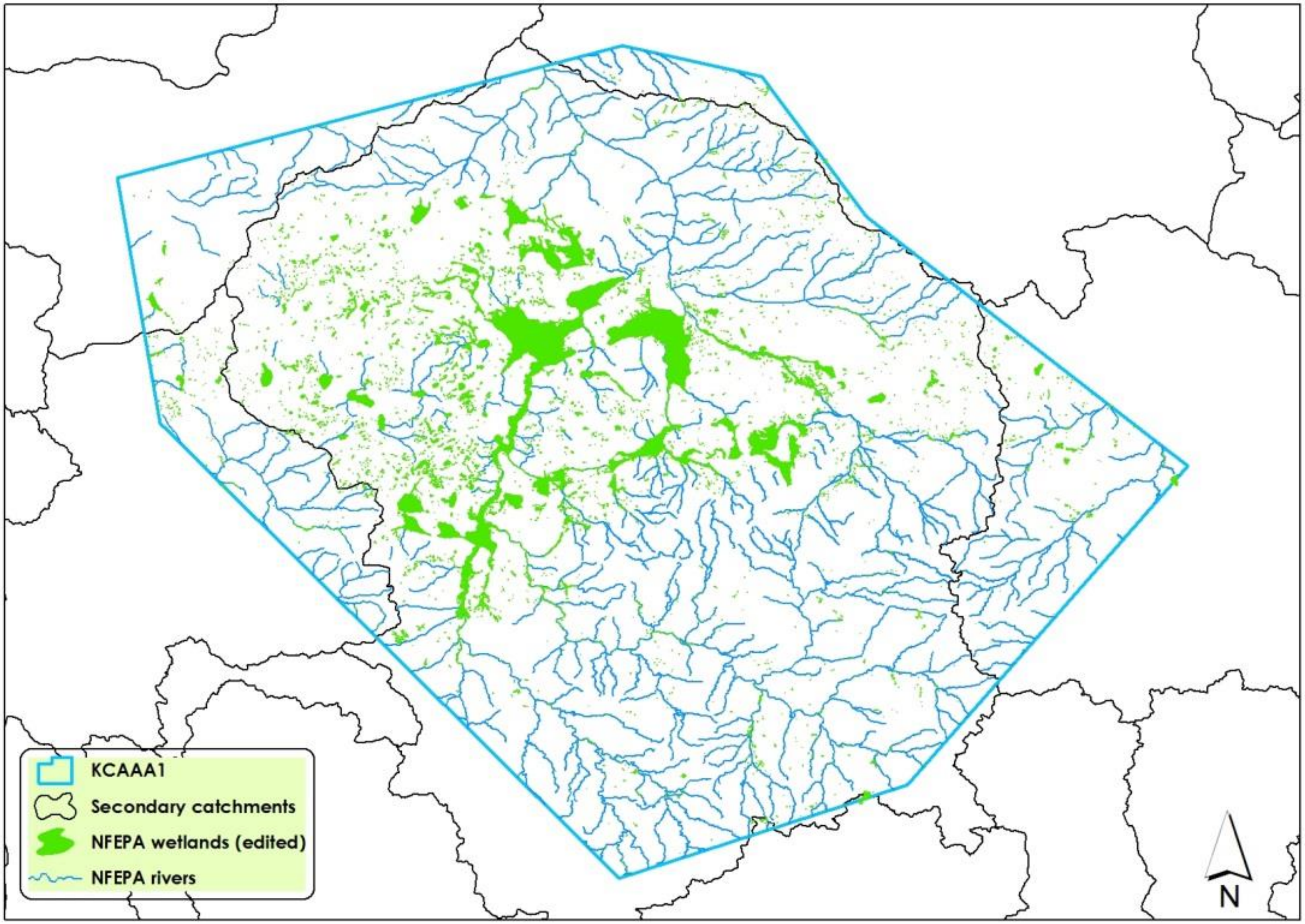


Figure VII.15 The edited map of NFEPA wetlands and rivers in KCAAA1.

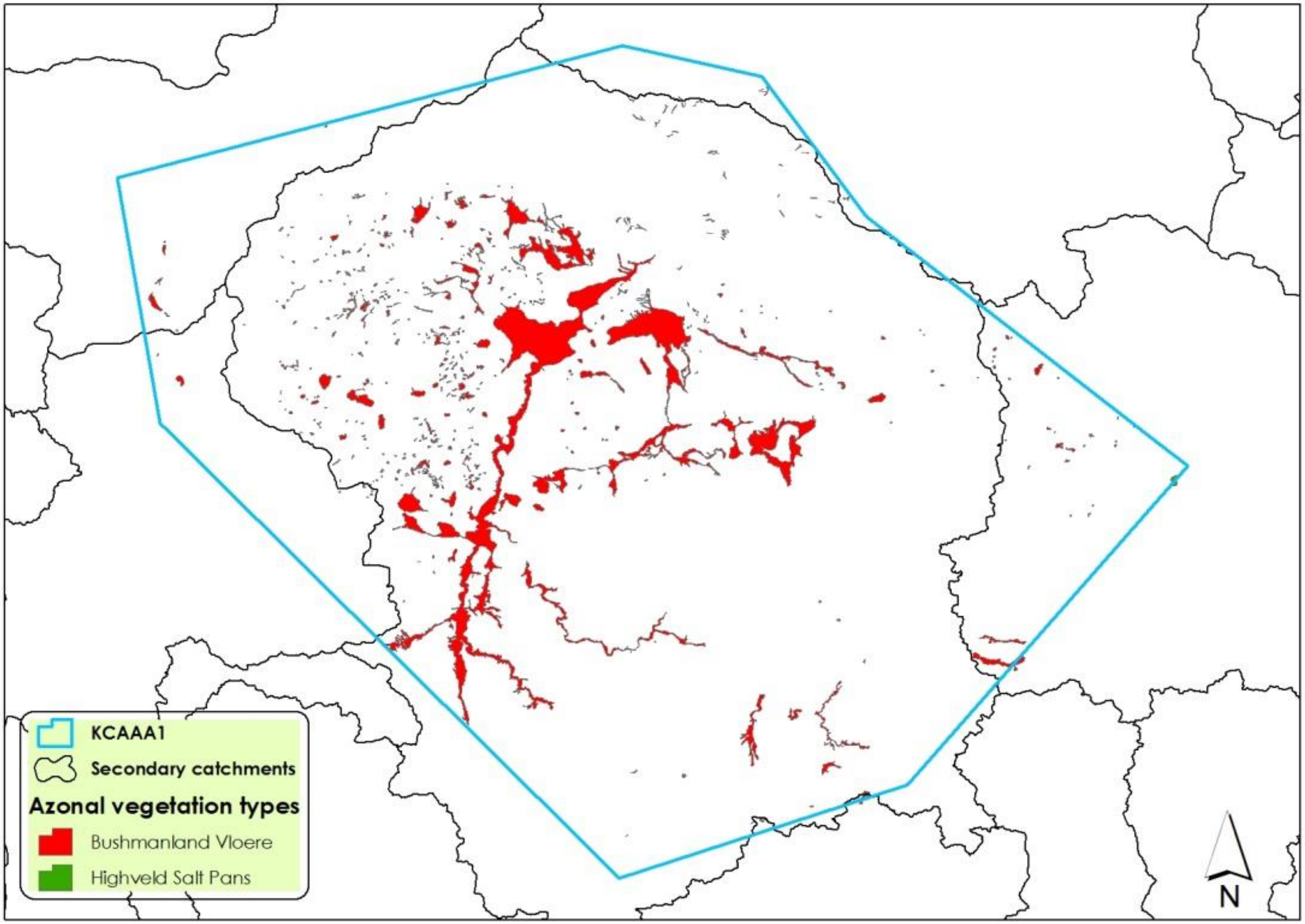


Figure VII.16 Azonal vegetation types in the KCAAA1. The Highveld Salt Pans are limited to a few small pans in the eastern part of the KCAAA1.

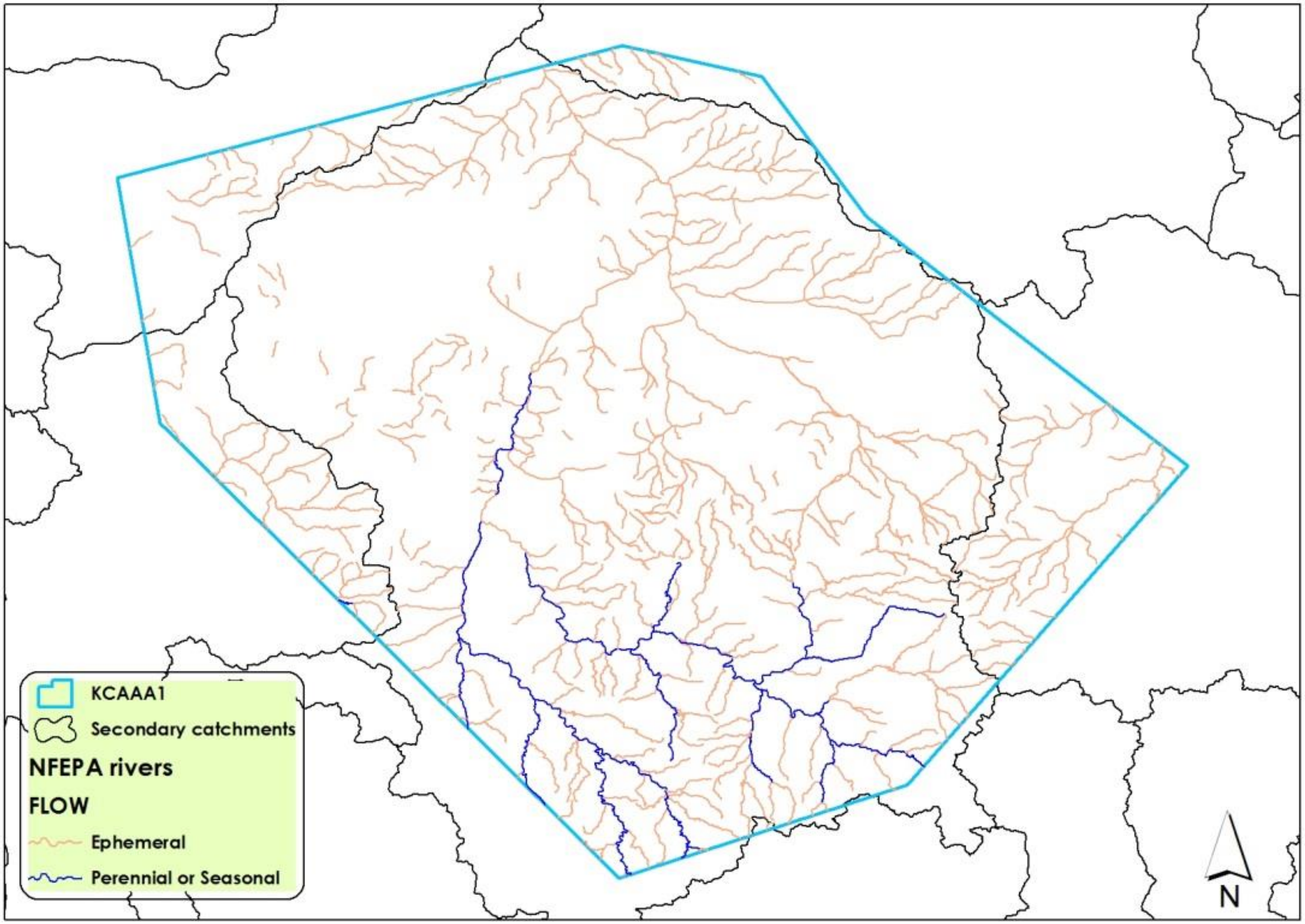


Figure VII.17 NFEPA rivers located within the KCAAA1, indicating ephemeral versus perennial/seasonal systems.

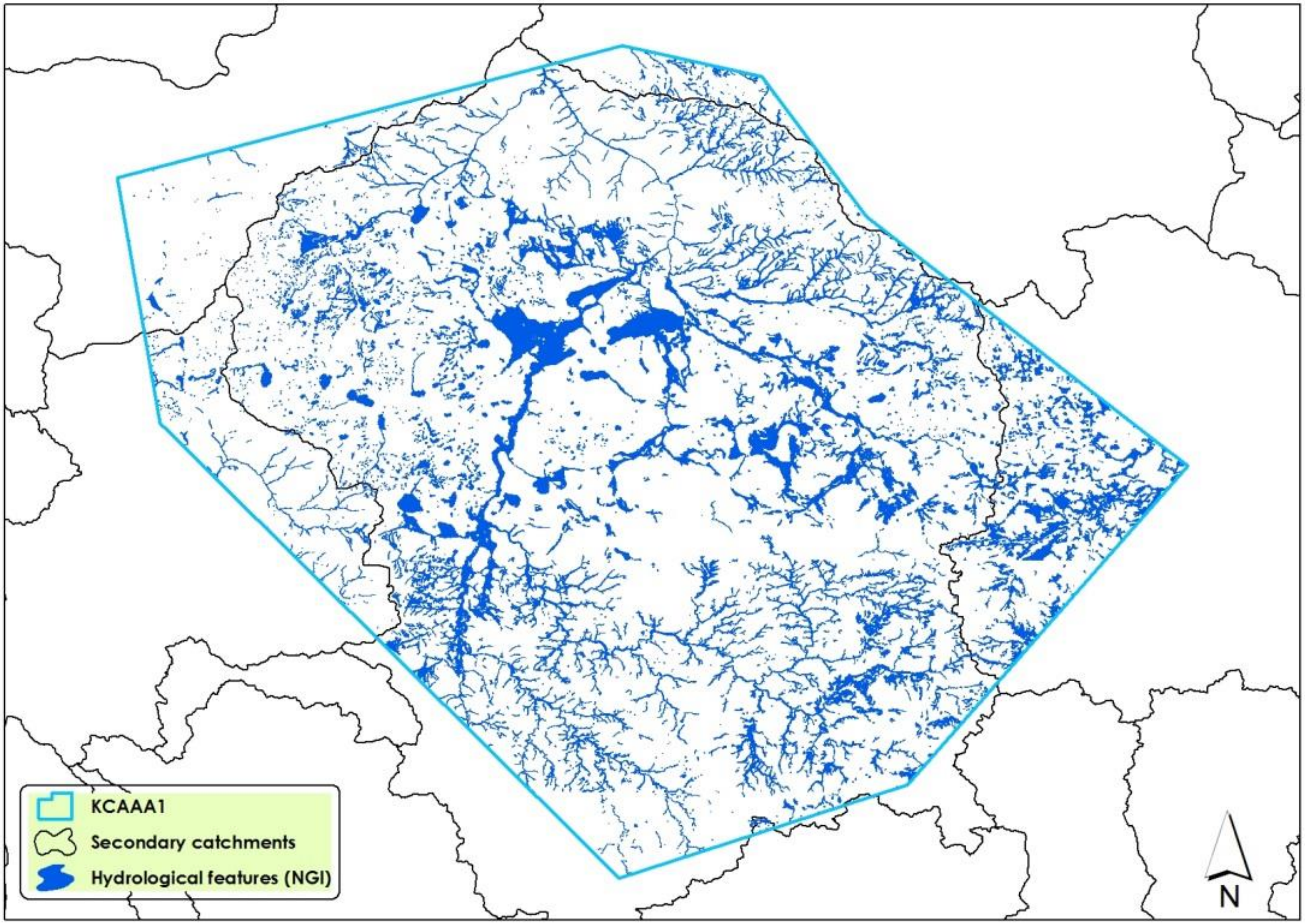


Figure VII.18 Hydrological features from the NGI dataset located in KCAAA1.

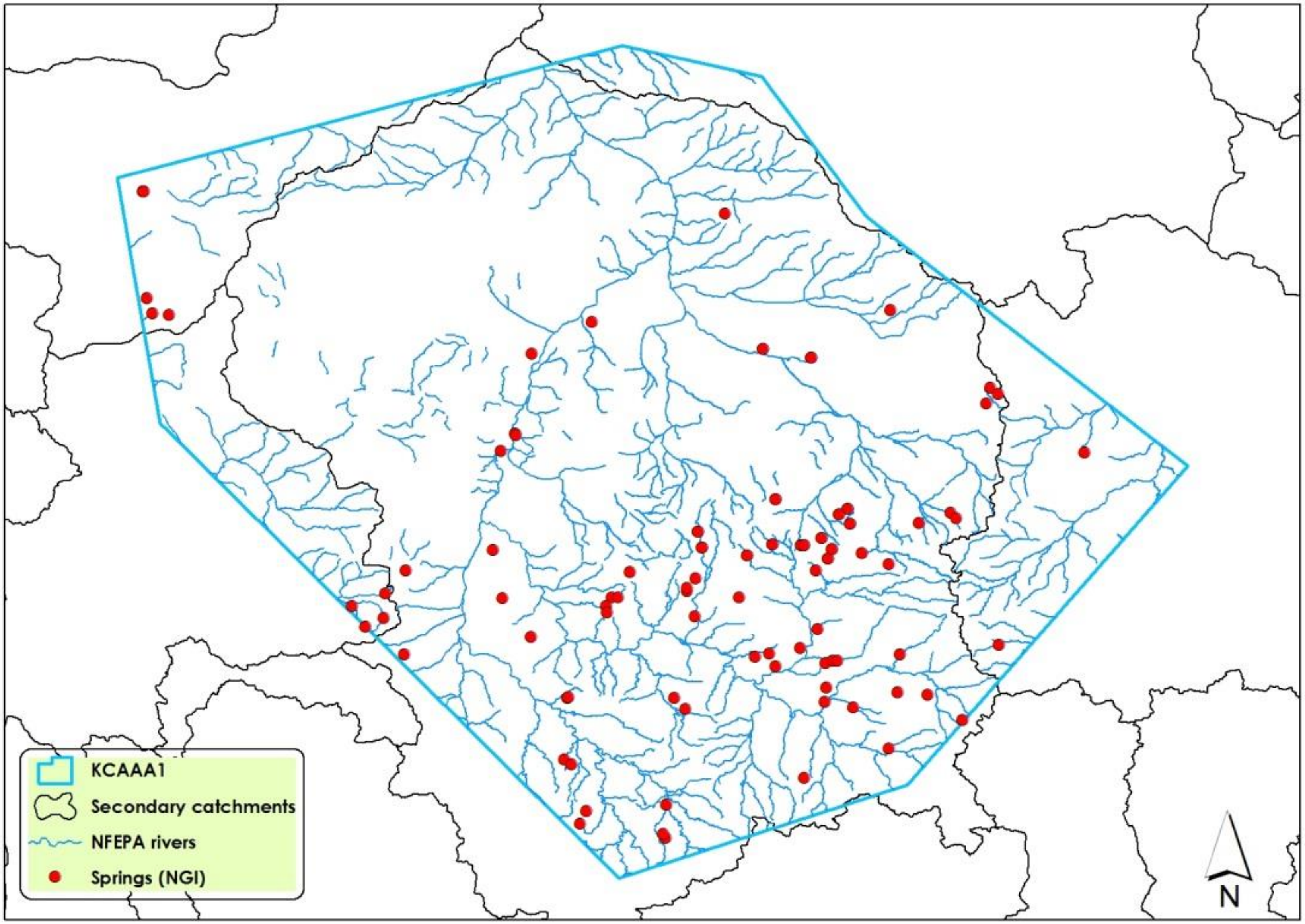


Figure VII.19 Point locations for springs in KCAAA1, from the NGI dataset.

VIII. Detailed description of SKA Phase 1 SEA study area

The more detailed mapping of wetlands and watercourses in and immediately adjacent to the SKA Phase 1 SEA study area led to the delineation of 11 wetland types and seven river types.

By far the largest area of wetland is made up of Nama Karoo depressions and floodplain wetlands (Table VIII.1), while the river types are dominated by ephemeral lower foothill rivers (Table VIII.2). With only a few exceptions, the wetland types are least threatened – the exceptions all lie within the Upper Nama Karoo ecoregion, but comprise a small area. Two seeps of less than 2 hectares in total area are listed as Critically Endangered by NBA (2011), while 11 channelled valley bottom wetlands are endangered wetland types. A total length of approximately 35 km of the Sak River is considered to be an Endangered river type, and the remaining rivers are least threatened. The low ecosystem status of many of these Northern Cape wetland and river types probably has a lot to do with the lack of knowledge of these systems, and also the wide, relatively homogeneous extent of the ecoregions and wetveg groups, i.e. a perceived lack of diversity and a concomitant lack of uniqueness. This may change with an increase in data collected from these ecosystems.

Table VIII.1 Wetland types in and around the SKA Phase 1 SEA study area.

Wetland type (Wetveg group and hydrogeomorphic unit)	% of total wetland area	Area (hectares)
Nama Karoo Bushmanland Channelled valley-bottom wetland	**21**	29 114.6
Nama Karoo Bushmanland Depression	**38**	52 177.3
Nama Karoo Bushmanland Floodplain wetland	**27**	37 253.2
Nama Karoo Bushmanland Seep	**1**	2 040.9
Nama Karoo Bushmanland Unchannelled valley-bottom wetland	**4**	5 284.8
Nama Karoo Bushmanland_ Wetland flat	**1**	1 462.0
Upper Nama Karoo Channelled valley-bottom wetland	**1**	1 668.0
Upper Nama Karoo Depression	**<1**	650.2
Upper Nama Karoo Floodplain wetland	**7**	9 171.7
Upper Nama Karoo Seep	**<1**	1.4
Upper Nama Karoo Unchannelled valley-bottom wetland	**<1**	3.7
Total wetland area (hectares)		**138 828**

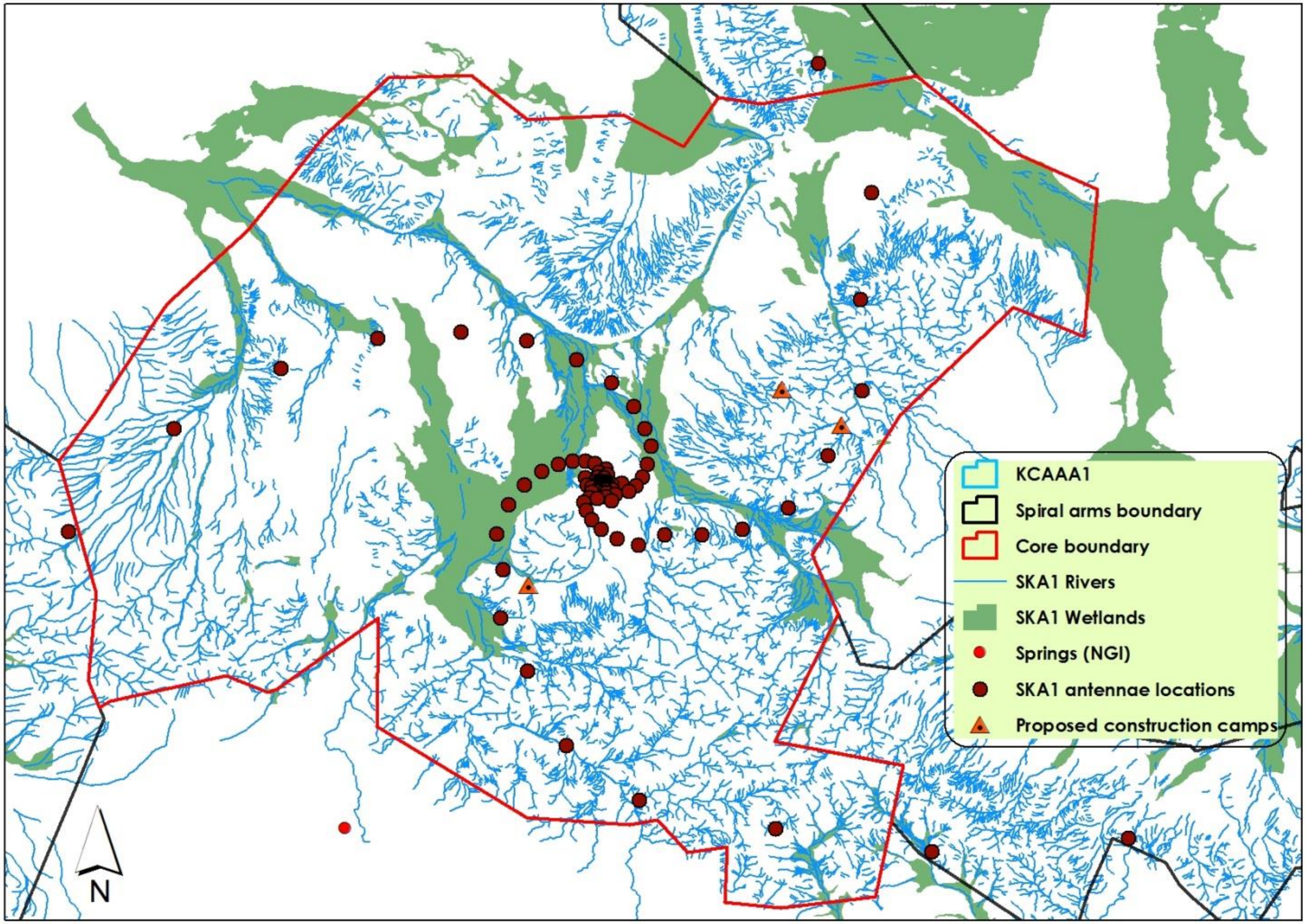


Figure VIII.1 Wetlands and watercourses in and around the core area.

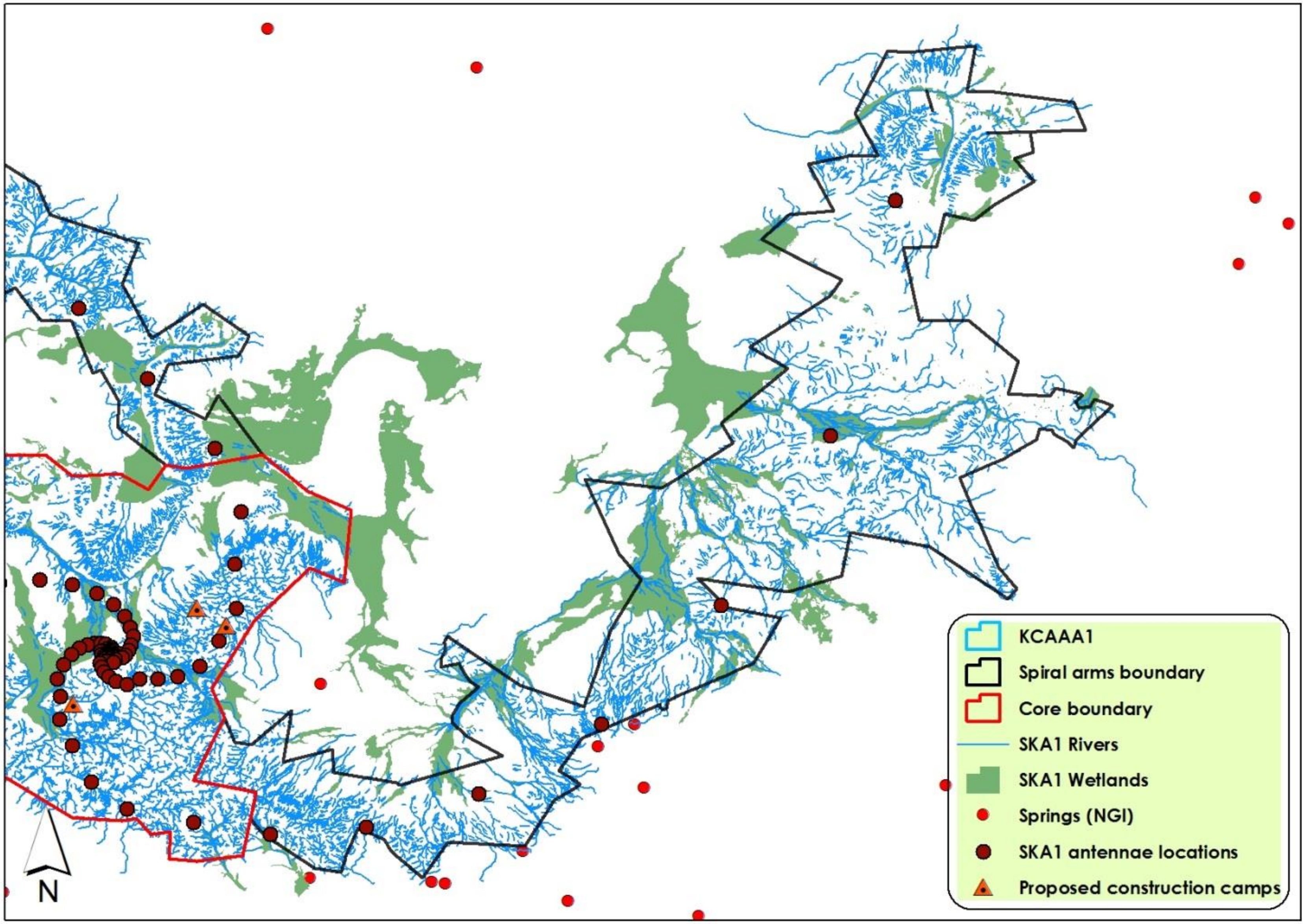


Figure VIII.2 Wetlands and watercourses in and around the Carnarvon spiral arm.

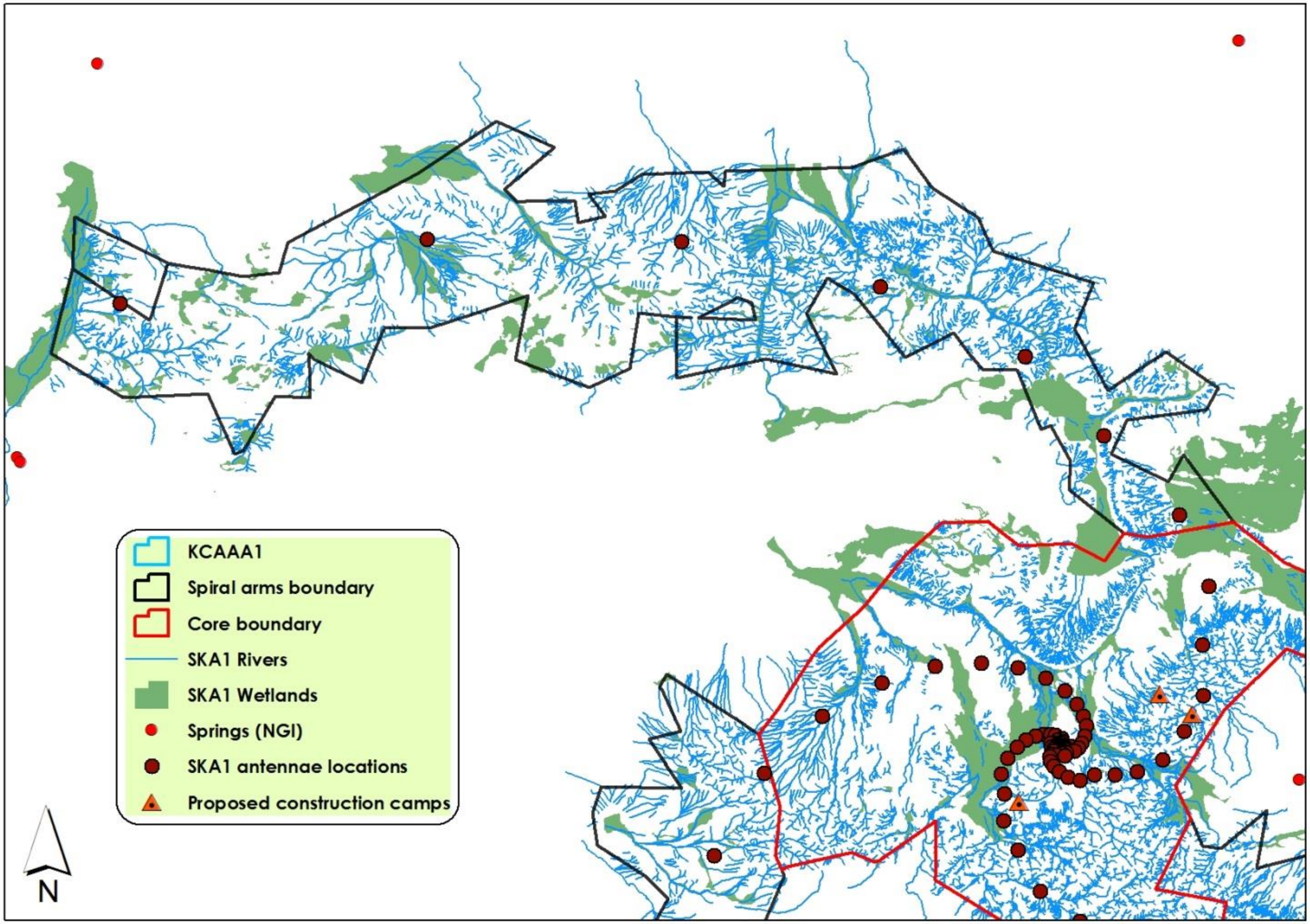


Figure VIII.3 **Wetlands and watercourses in and around the Brandvlei spiral arm.**

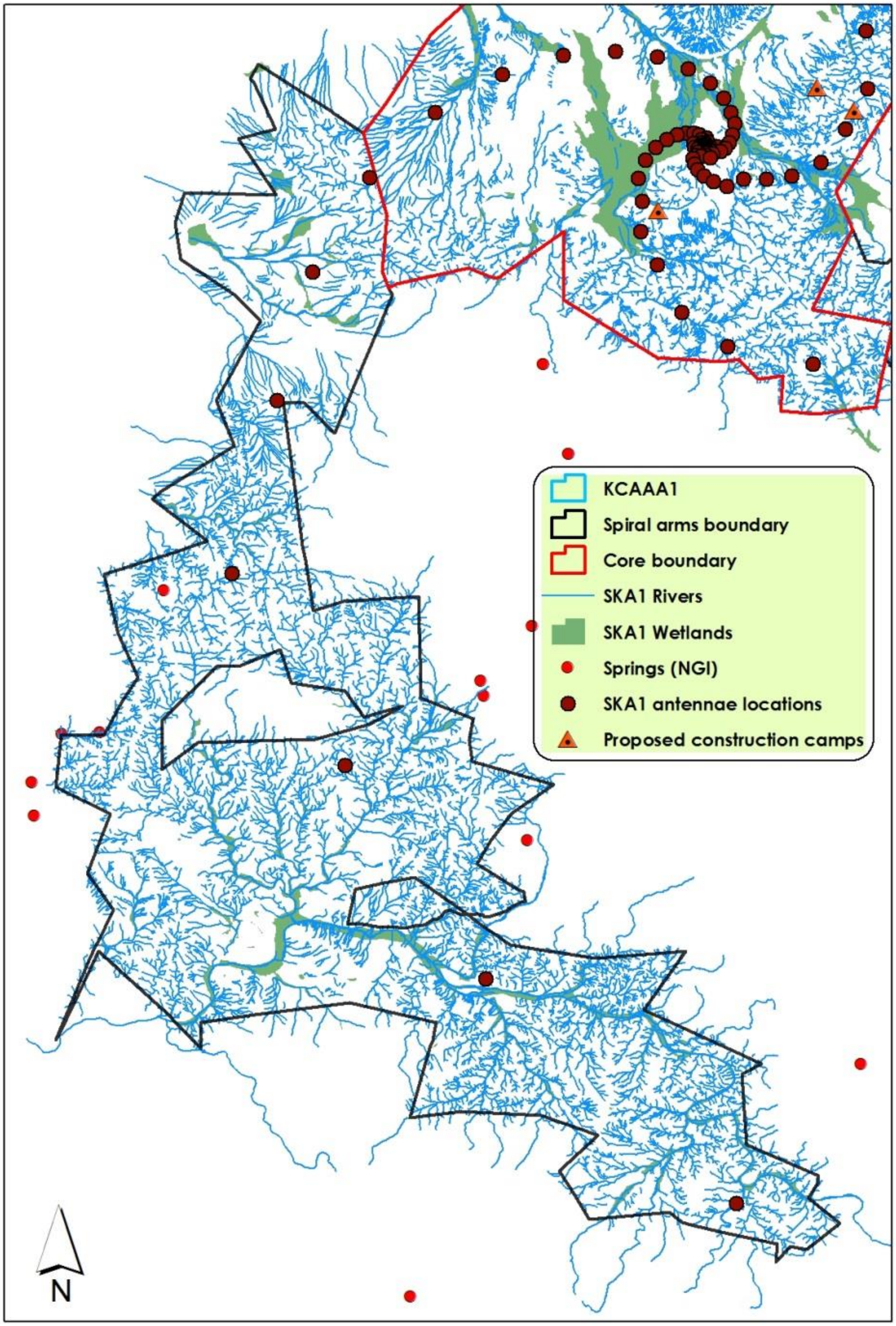


Figure VIII.4 Wetlands and watercourses in and around the Williston spiral arm.

Table VIII.2 River types in and around the SKA Phase 1 SEA study area. River length is calculated for the main rivers only (at a resolution of 1:500 000).

River type (flow and geomorphological zone)	River length (km)
Ephemeral	
Mountain stream	11
Upper foothill river	252
Lower foothill river	454
Lowland river	< 1
Perennial/Seasonal	
Upper foothill river	20
Lower foothill river	77
Lowland river	34
Total river length (km)	**850**

The condition of the aquatic ecosystems is largely good throughout the study area. Impacts on the wetlands and watercourses include:

- Overgrazing of the surrounding vegetation, leading to loss of topsoil, erosion and increased sediment input into wetlands and watercourses;
- Poor drainage around road crossings, leading to channelization of surface flow and gully and head-cut erosion;
- Farm dams, and berms for trapping surface flow, and
- Alien vegetation in the riparian zone and in dry watercourses

The aquatic ecosystems of the Northern Cape are poorly protected or, in the case of all of the wetland types identified in this study, not protected at all. There is only one small protected area in the KCAAA1, the Dr Appie van Heerden Nature Reserve near Carnarvon, and a few areas have been identified as being part of the National Protected Areas Expansion Strategy (June 2010). None of these lies within the SKA Phase 1 SEA study area.

IX. Four-tiered sensitivity maps

The highest sensitivity level – no go - was assigned to the depressional and seep wetlands and the wetland flats. These wetlands tend to be discrete wetland features with fairly clear boundaries, and it is possible for infrastructure to avoid these features. The remaining wetland types, all of which are riverine – i.e. floodplain and valley-bottom wetlands – occupy a large proportion of the SKA Phase 1 SEA study area, and are more difficult to delineate, both on a map and in the field. The wetland characteristics of these features are difficult to determine, and it is impossible to build linear infrastructure in the area that would completely avoid these features. These features were assigned a high sensitivity category.

All ecological buffers were also assigned to the high sensitivity category.

- No go features/areas in black, and
- High sensitivity features/areas in red.

Only the no go and high sensitivity areas have been mapped (see Figure IX.1 to Figure IX.5), as the remainder of the landscape is of medium to low sensitivity, in terms of the aquatic features.

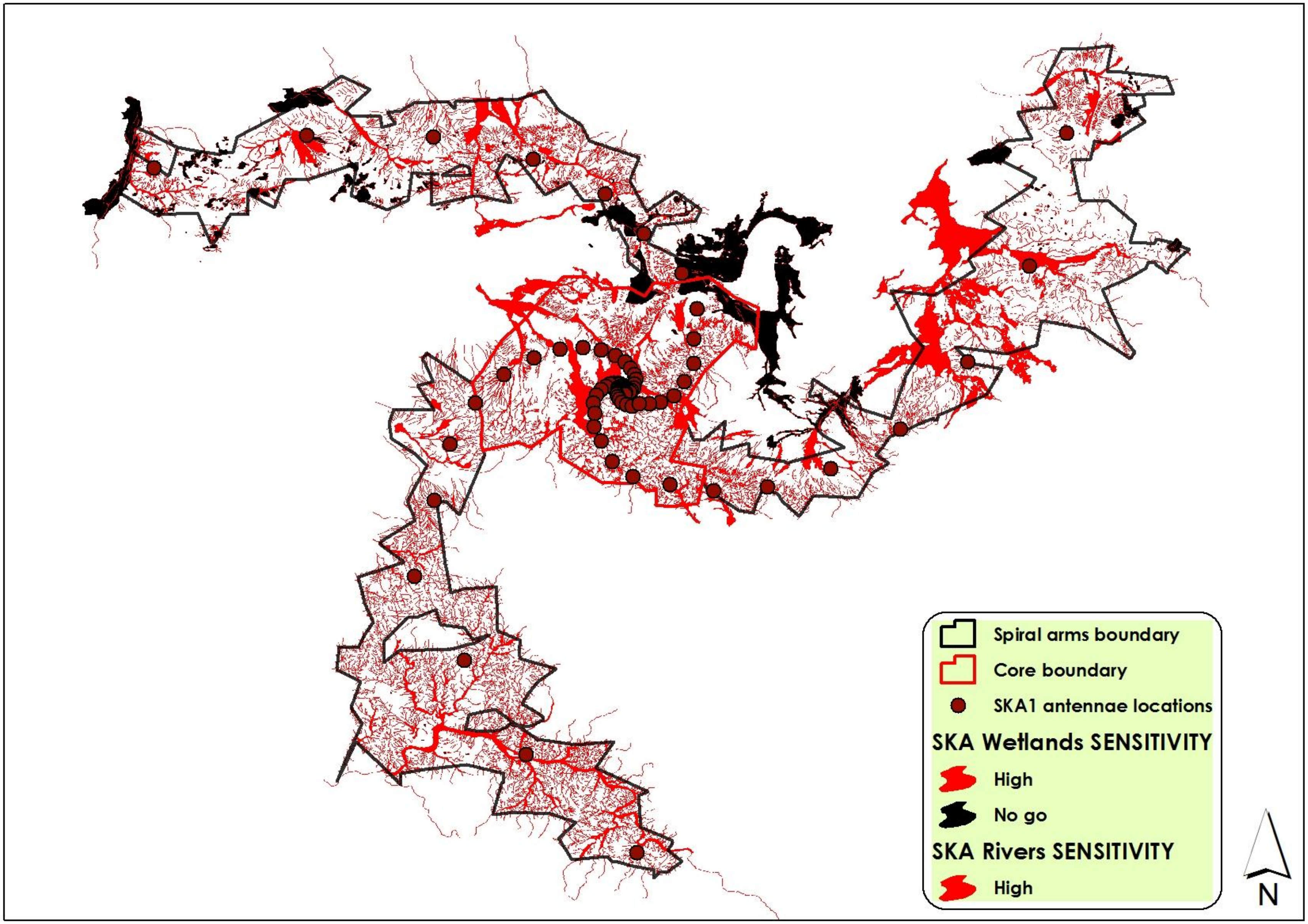


Figure IX.1 Overview of the sensitivity map for the SKA Phase 1 SEA study area.

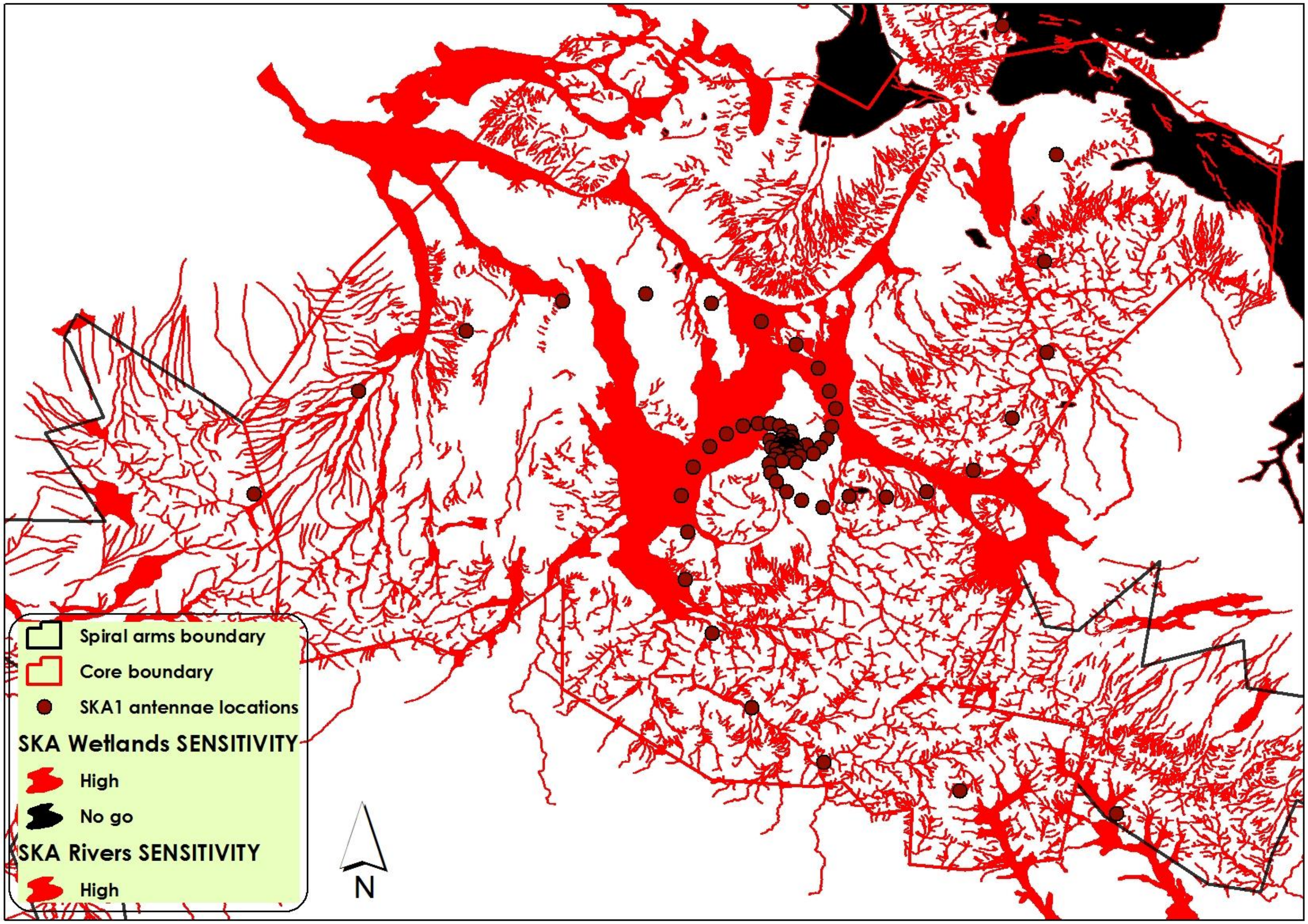


Figure IX.2 Sensitivity map of the core area.

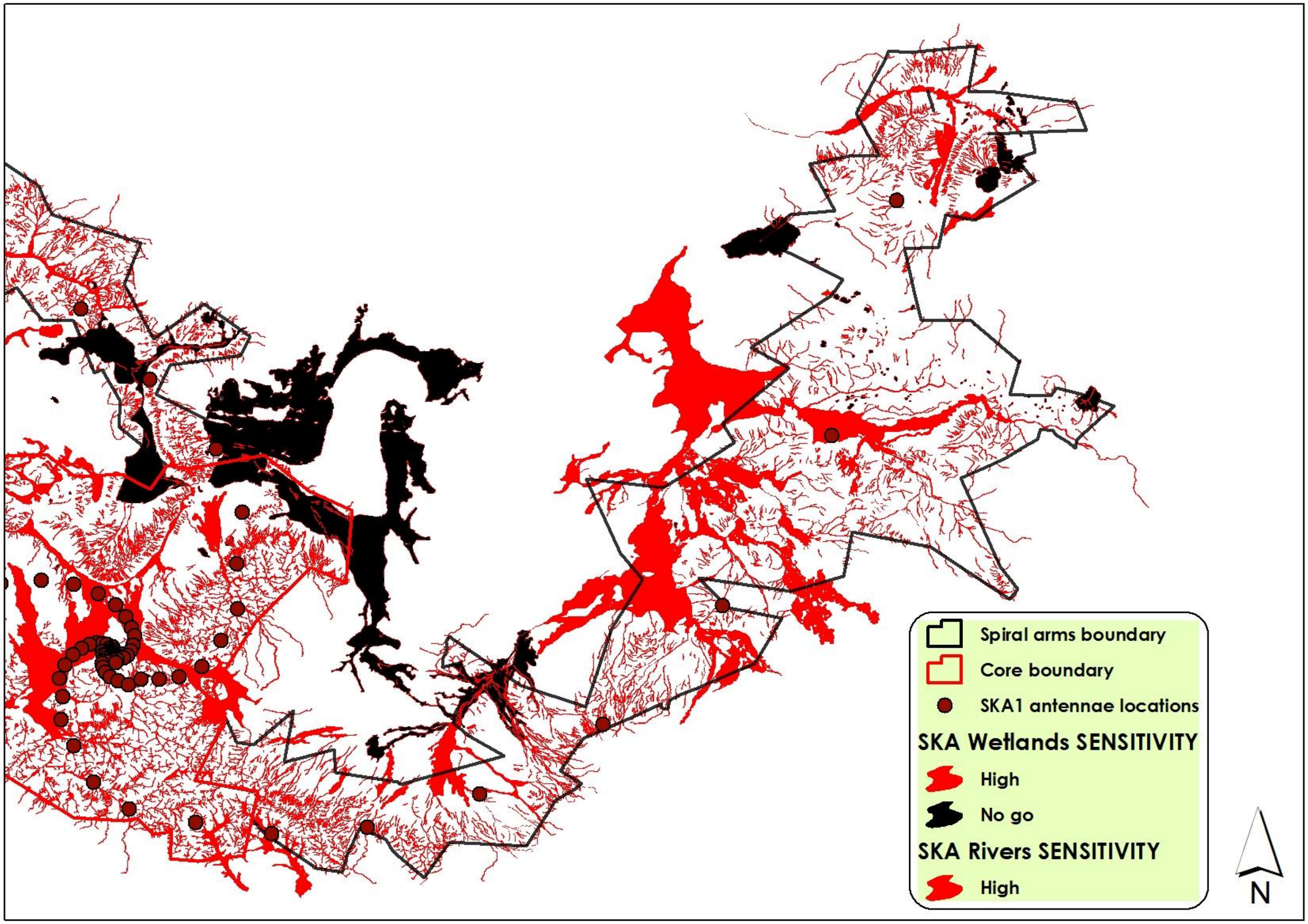


Figure IX.3 **Sensitivity map of Carnarvon spiral arm.**

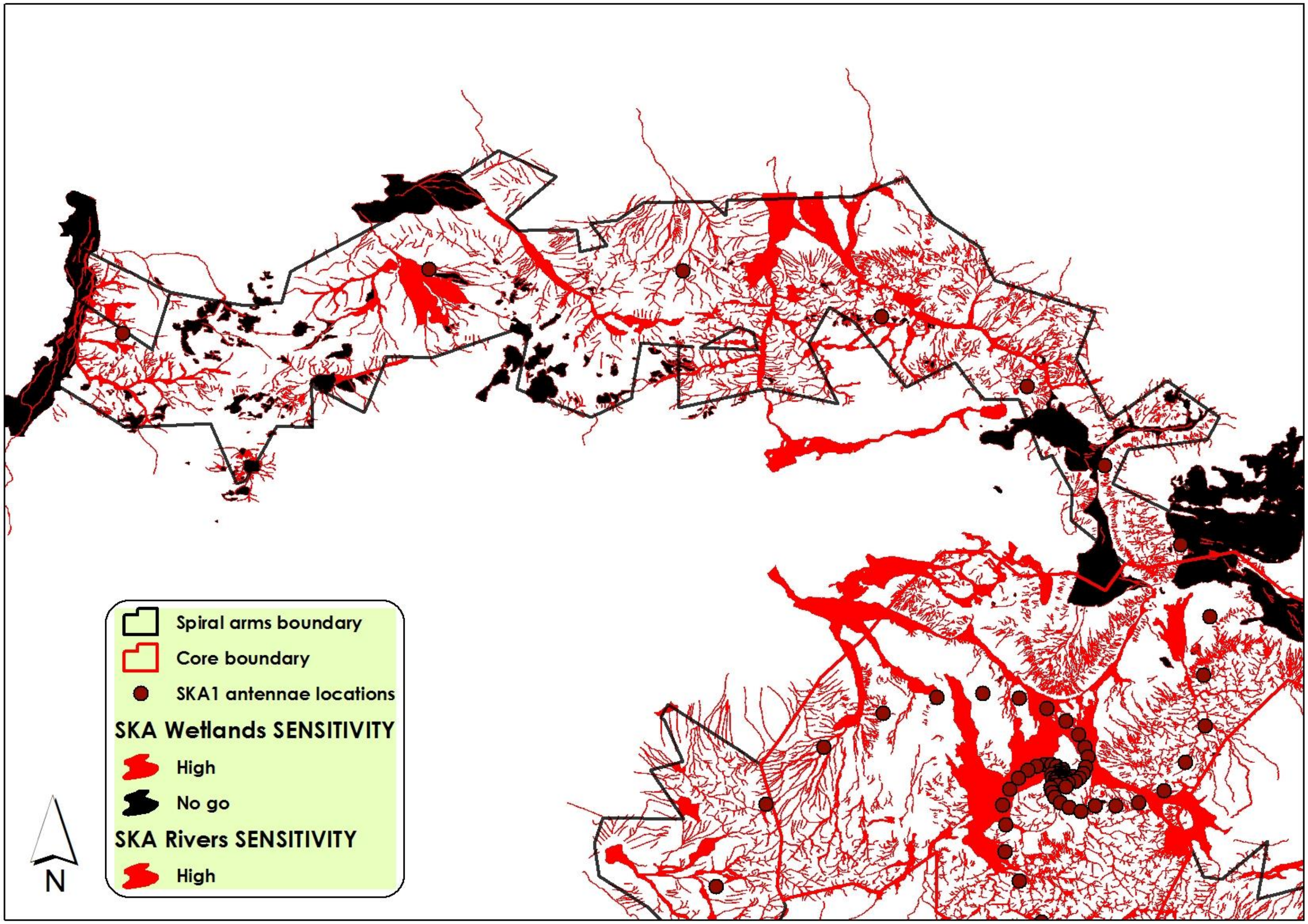


Figure IX.4 **Sensitivity map of Brandvlei spiral arm.**

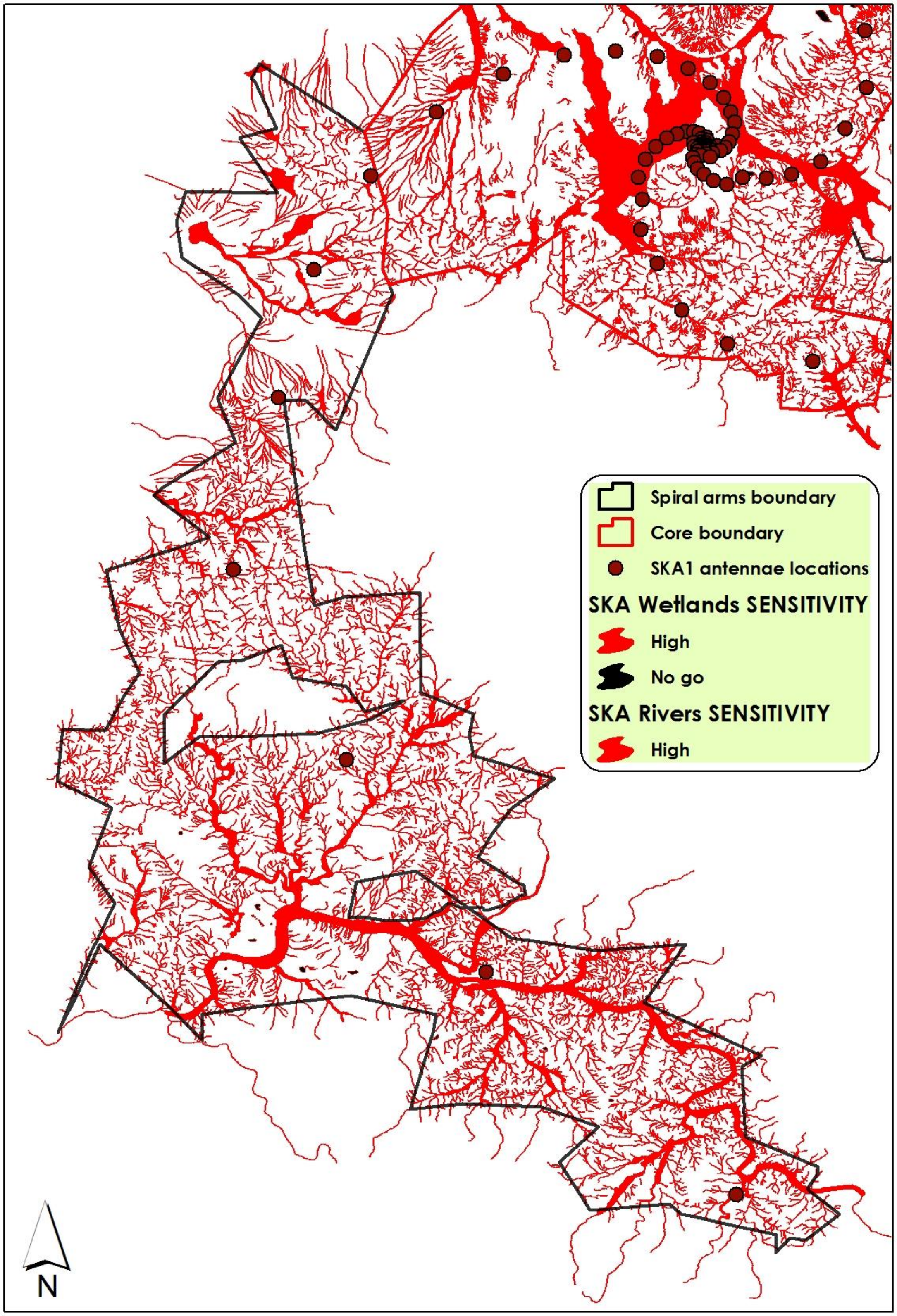


Figure IX.5 Sensitivity map of Williston spiral arm.

X. Assessment of the potential impacts of SKA activities on the aquatic features

1) Description of activities

The SKA activities that are most likely to impact on freshwater ecosystems include:

- Location of antenna sites, and associated infrastructure in or close to surface freshwater ecosystems;
- Construction activities, especially those that require the removal of earth (e.g. borrow pit sites), re-shaping of beds and banks of watercourses or wetlands (e.g. for road construction), or in-filling (e.g. for levelling of antenna sites);
- Trenching and soil compaction, for the burial of cables close to dish-antennae;
- Stormwater generation by roads and hardened surfaces, and stormwater management, and
- Roads and services crossing over wetlands and watercourses.

Construction of the Phase 1 infrastructure is expected to commence in late 2018, and will take approximately 36 months to complete. Construction will be deployed from central construction camps located in the core, as most of the work will occur there. A maximum of 740 people is expected at any time during the construction of SKA Phase 1 dish-antennae and associated infrastructure.

2) Roads

Approximately 560 km of road works is required for SKA Phase 1 - 150 km will be new roads in the spiral arms; 12 km will be new roads in the core and the remaining 398 km will be existing farm and district roads in the spiral arms. Existing roads will be upgraded to improve access. For roads occurring in areas that are subject to flooding, the aim is to build roads above the base level, thus allowing water to flow under the road in culverts and/or pipes. These roads will be built to a higher specification than other roads to reduce the risk of being washed away. Earth berms will be used to divert water towards preferred flowpaths, both around roads and the antenna platforms.

Basic farm roads will consist of an in-situ rip and compacted roadbed, with a 150 mm-thick gravel wearing course, sourced from the local borrow pits. Earth-lined cut-off drains and channels will divert runoff towards concrete drifts at certain points.

The standard gravel roads will comprise an approximately 150 mm-thick in-situ layer, a 150 mm-thick sub-base layer, 150 mm-thick base and a gravel wearing course, sourced from the local borrow pits. Stormwater runoff will be conveyed through a system of earth-lined channels, concrete channels, culverts, berms and concrete drifts.
SKA SA will maintain all roads leading to dish-antennae and in the core area.

The following new roads, as they are currently located, will have an impact on aquatic features and their buffers:

- Brandvlei Arm:
  - The roads accessing SKA008 (Farm RE5);
  - Roads along the mid-fibre (Farms RE10, RE14, 26/1, 57/4, 62/1, 63/1);
  - Road along the mid-fibre close to SKA006 (Farms RE13, 14/2, 24/2 (36));
- Williston Arm:
  - Road accessing the woodpole powerline between SKA133 and SKA132 (Farm RE493; RE133);
  - Road accessing infrastructure around SKA130 (Farm 108/3);
  - Road accessing infrastructure around SKA129 and SKA122 (Farms RE91; RE69; RE77);

- Carnarvon Arm:
    - Roads accessing infrastructure around SKA128 and SKA127 (Farms RE498; RE499);
    - Road between SKA124 and SKA120 (Farm RE489);
    - Roads accessing SKA120 and SKA021 (Farm 74/3; RE74);
    - Road accessing mid-fibre close to SKA011 (Farm 38/1);
    - Road accessing SKA004 (Farm 40).
- There are a number of proposed watercourse crossings in the core area.

3) Antenna platforms

The siting of the dish-antennae was done by the SKA project using remote sensing. The dish-antenna foundation to be used for SKA Phase 1 is a solid (pre-cast concrete) 7 m-diameter ring beam, placed on piles to a depth of 1.5 m in a gravel wearing course that extends to a radius of 15 m from the edge of the dish foundations, (see Chapter 1-1 of this IEMP). An additional outer portion, also gravel, will extend a further 15 m from the edge of the inner portion, demarcated from the inner portion by a row of stones. The whole platform will be built with a 0.5% fall for drainage, and will be raised 150 mm above the ground surface.

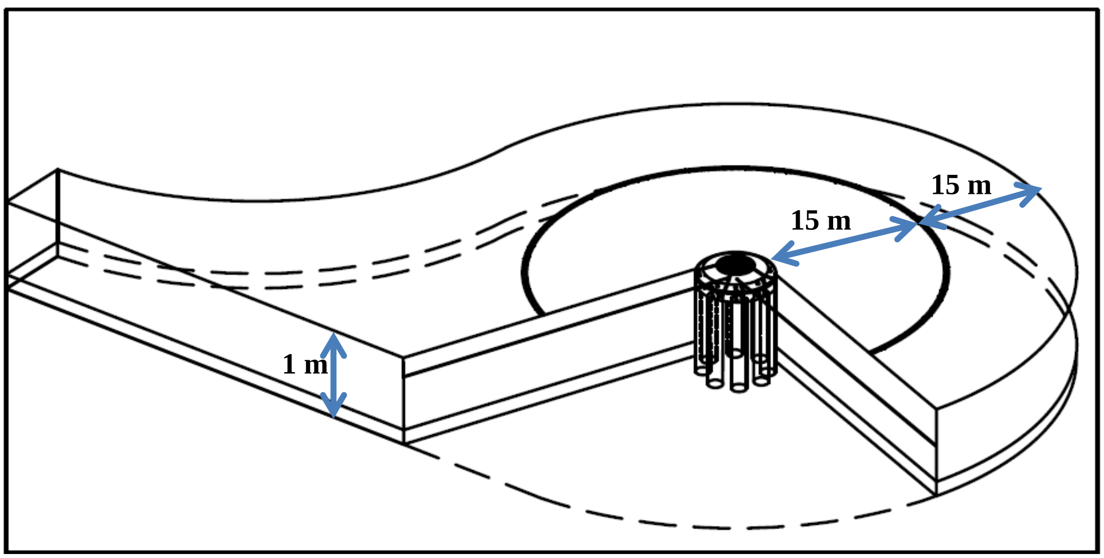


Figure X.1 Diagrammatic representation of an antenna platform, showing the inner and outer portions (gravel), and the depth of the foundations.

Taking into account the preliminary SKA Phase 1 layout (provided for this SEA and dated May 2015) of the dish-antennae locations, those that are located within aquatic features or their buffers are listed in Table X.1.

Table X.1 Dish-antennae sites located in aquatic features or their buffers.

Location	Dish-antennae sites affected	Action required
Within no-go wetland (depressions, seeps, wetland flats) boundaries	None	n/a
Within high sensitivity wetland (floodplain and valley-bottom wetlands) boundaries	15 dish-antennae sites: SKA011; SKA016; SKA018; SKA023; SKA024; SKA025; SKA026; SKA028; SKA031; SKA032; SKA034; SKA060; SKA107; SKA113; SKA119	Preferably moved out of the wetland and its buffer, but could remain with mitigation. Biodiversity and/or functional offset to be determined if there are residual negative impacts.
Within 500m of a no-go wetland	4 dish-antennae sites: SKA008; SKA012; SKA117; SKA129	DWS risk assessment matrix needs to be applied to determine water use authorisation required
Within 500m of any wetland (all wetland types)	34 dish-antennae sites: SKA007; SKA008; SKA009; SKA011; SKA012; SKA016; SKA018; SKA020; SKA022; SKA023; SKA024; SKA025; SKA026; SKA028; SKA029; SKA031; SKA032; SKA034; SKA040; SKA060; SKA063; SKA105; SKA107; SKA112; SKA113; SKA117; SKA118; SKA119; SKA123; SKA124; SKA125; SKA128; SKA129; SKA133	DWS risk assessment matrix needs to be applied to determine water use authorisation required
Within the buffer of a no-go wetland	None	n/a
Within any wetland buffer	SKA128	Preferably moved out of the wetland and its buffer, but could remain with mitigation. Biodiversity and/or functional offset to be determined if there are residual negative impacts.
Within a watercourse (including the 32m buffer)	16 dish-antennae sites SKA008; SKA010; SKA012; SKA016; SKA019; SKA027; SKA028; SKA105; SKA108; SKA110; SKA115; SKA119; SKA120; SKA125; SKA126; SKA132	To be moved out of the watercourse
Within a watercourse buffer (in addition to the 16 listed above)	9 dish-antennae sites: SKA009; SKA011; SKA021; SKA024; SKA026; SKA128; SKA129; SKA130; SKA131	Preferably moved out of the buffer, but could remain with mitigation. Biodiversity and/or functional offset to be determined if there are residual negative impacts.

4) Power supply and fibre optic cables

The power infrastructure required for the SKA Phase 1 will be a combination of medium voltage and low voltage underground cabling and 22kV overhead power lines. Approximately 22 km of additional low voltage cabling will be required for the provision of power to the additional dishes in the core area. Approximately 8 km of new medium voltage underground cabling will be required in the core area, in order to facilitate supply to the spiral arms.

The overhead powerlines supplying the spiral arms will commence a distance of 5 km from the centre of the core area (i.e. outside of Zone 2) and run on steel poles to the outer edge of Zone 3 30 km from the centre of the core, and then on wooden poles to the end of the spiral arms. Cables will be laid underground from a distance of 2 km from each of the dish-antennae in the spiral arms, at a depth of at least 800 mm.

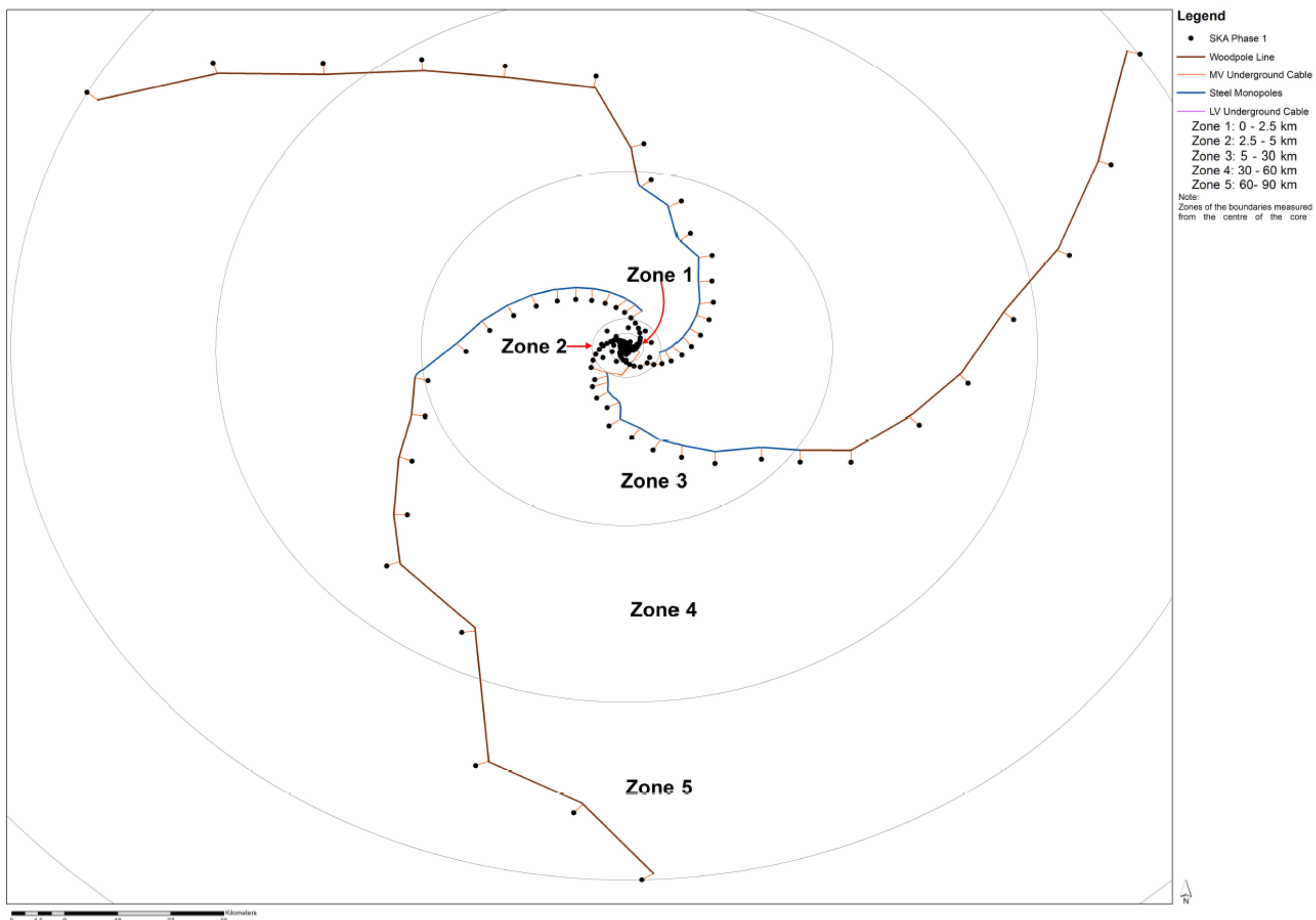


Figure X.2 SKA zones. Zone 1 = 0 – 2.5 km from the centre of the core; Zone 2 = 2.5 – 5 km; Zone 3: 5 – 30 km; Zone 4: 30 – 60 km; Zone 5: 60 – 90 km.

The preliminary SKA Phase 1 powerlines layout (provided for this SEA and dated May 2015)will impact on aquatic features and buffers in a number of places, too numerous to list here.

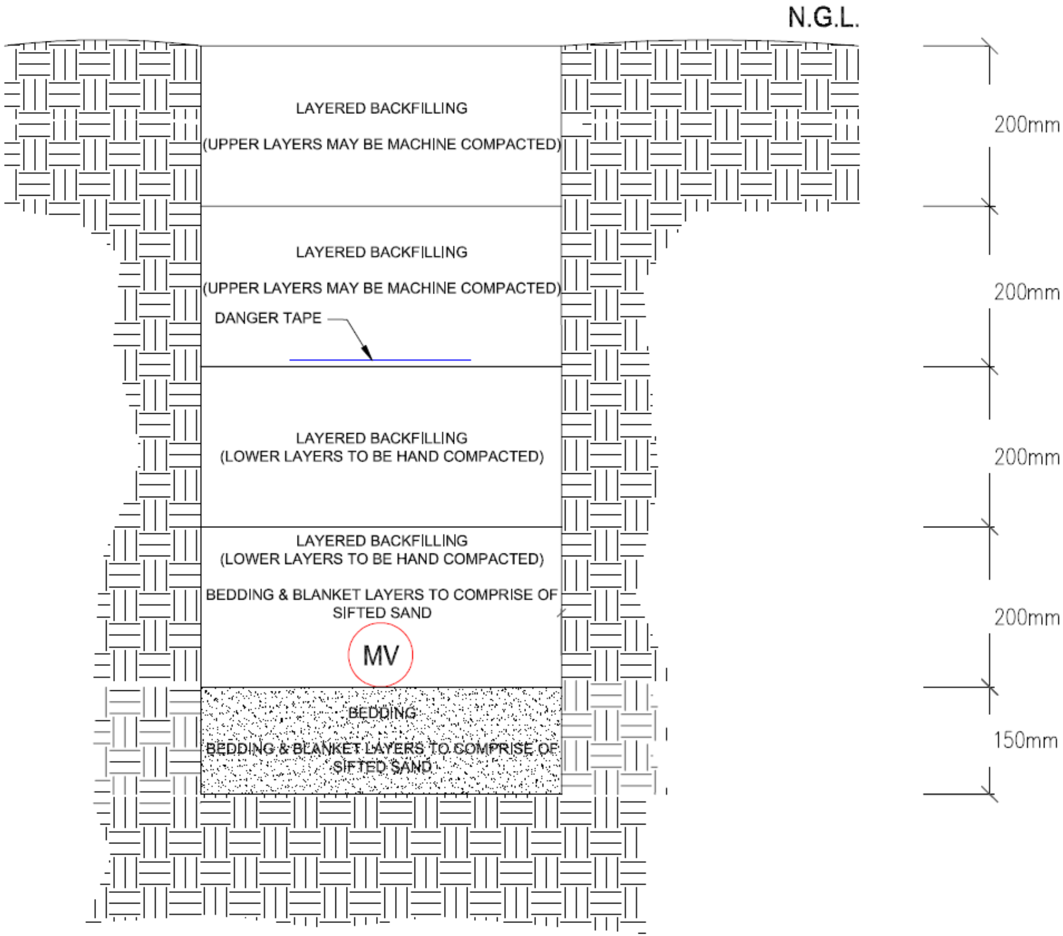


Figure X.3: Typical section through medium voltage cable trench.

There are 21 existing 315 kVA substations currently being used for MeerKAT, and 16 of these will be used as is for supply to the Phase 1 sites. The remaining five substations will be upgraded to 500kVA units. An additional fourteen new substations will be built.

Ideally, the fibre optic cable will run with the power cables, and not require any additional reticulation. There will be 12 fibres supplied to each antenna.

5) Water and sanitation

The existing water and sanitation infrastructure will be expanded for SKA Phase 1. This will include:

- Expansion of water treatment works and reticulation at Losberg and the two new construction camps (Bergsig and Swartfontein);
- Provision of water for construction works, using mobile facilities in the spiral arms;
- Expansion of sewage treatment works and reticulation at Losberg and the two new construction camps, and
- Mobile sanitation facilities (toilets and washing areas) in the spiral arms.

Sewer lines are to be installed with pumps, package treatment plants and evaporation dams. Indicative volumes of wastewater have been provided, reaching a maximum of 18 000 litres per day at the largest camps. Further information on water and sanitation for SKA Phase 1 is provided in Chapter 1-1 of this IEMP.

6) Construction camps and borrow pits

Three construction camps have been proposed: Bergsig, Meys Dam and Swartfontein. Bergsig is located between two watercourses (1:50 000 river lines) and could impact on these watercourses. There is sufficient space between the channels to avoid the watercourses and their ecological buffers. The other two are not within an aquatic feature or buffer.

A geotechnical study is being done in order to determine the location of the borrow pits. These must be located outside of aquatic features and their buffers.

7) Impacts and effects on freshwater ecosystems

The following table describes how the activities described above are likely to impact on the local aquatic ecosystems, their fauna and flora.

Table X.2 **Description of impacts and the effects on freshwater ecological habitat, fauna and flora associated with the SKA Phase 1 activities.**

Project phase	Activity	Impact	Effect
Design	Placement of dish-antennae, buildings, services and access roads within or close to wetlands or watercourses	Loss of habitat through infilling of wetlands, watercourses and riparian areas	• Loss of both faunal and floral biodiversity, and loss or impairment of ecological processes (such as dispersal, migration, breeding etc).
		Fragmentation of aquatic habitat (mostly as a result of road or fence construction and services) within wetlands and watercourses	• Loss of ecological integrity through the disruption of ecological processes, and loss of resilience of ecosystems to degradation, and
		Hydrological alteration which includes largely the interruption of natural surface and/or subsurface passage of flow and the concentration of flows due to roads or services across wetlands or watercourses.	• Flow changes result in degradation of the ecological functioning of these ecosystems that rely on a specific hydrological regime to maintain their integrity. • Geomorphological and hydrological changes lead to loss of habitat quality and a consequent degradation of ecological integrity
		Erosion caused by loss of vegetation cover through site clearing, and consequent sedimentation of aquatic ecosystems. Erosion is particularly a high risk in steep systems, and in drainage lines that lack channel features and are naturally adapted to lower energy runoff with dispersed surface flows (such as unchannelled valley-bottom wetlands).	• Alterations in moisture availability and soil structure can promote the invasion of weedy and/or alien species at the expense of more natural vegetation and thus a loss of habitat integrity and/or biodiversity.

Project phase	Activity	Impact	Effect
Construction	Establishment of construction camps or temporary laydown areas within or in close proximity to wetlands or watercourses	Physical destruction or damage of surface freshwater ecosystems by workers and machinery operating within or in close proximity to wetlands or watercourses	• Loss of both faunal and floral biodiversity and the ecosystem services provided by these habitats.
	Abstraction of groundwater for use during construction	Drawdown of groundwater causing a cone of depression in the vicinity of boreholes	• Reduced availability of groundwater for species and ecosystems
	Stockpiling of materials within or in close proximity to wetlands or watercourses	Soil compaction and shading caused by stockpiles	• Habitat degradation, and loss of sensitive species
	Storage of fuels on site (due to remote location of construction sites)	Pollution (water quality deterioration) of freshwater ecosystems and groundwater through spillage and/or runoff of contaminants such as fuel, oil, concrete, wash-water, sediment, and hazardous chemicals	• Deterioration in surface and groundwater quality • Sedimentation
	Washing of equipment in close proximity to wetlands and watercourses		
	Generation of waste water		
	Construction of access roads for movement of machinery, materials and people	Erosion and sedimentation of wetlands and rivers, especially where roads are raised above the surrounding base level.	• Reduction in habitat quality • Increased turbidity • Smothering of gills, eyes, sensitive fauna and flora
	Trenching for the laying of underground electrical reticulation (within 2 km of each antenna)	Interception of subsurface flow by compaction of soil above cables, and creation of preferential flowpaths around pipes/cables	• Changes in subsurface and surface flow patterns, leading to concentration of flow and consequently head-cut and gully erosion • Sedimentation in wetlands and watercourses

Project phase	Activity	Impact	Effect
Construction	Excavation of borrow pits for road construction	Loss of habitat	• Loss of both faunal and floral biodiversity, and loss or impairment of ecological processes (such as dispersal, migration, breeding etc).
		Alterations to surface and subsurface hydrology	• Changes in subsurface and surface flow patterns, leading to concentration of flow and consequently head-cut and gully erosion • Sedimentation in wetlands and watercourses
	Operation of heavy machinery within or in close proximity to wetlands or watercourses	Disturbance of aquatic and semi-aquatic fauna, as a result of the noise and light pollution from construction teams and their machinery working within or in close proximity to wetlands and rivers.	• Noise and light pollution can have a disruptive influence on some species, causing them to avoid areas where this occurs. • Disruption to mating/feeding/movement may result in a reduction in numbers.
	Introduction and spread of alien and invasive species	Reduced ecological functioning, habitat condition and water availability due to encroachment of alien and invasive species into aquatic features and buffers	• The dense infestations of mesquite grow in the watercourses, riparian zones and wetlands, leading to reduced availability of water, and deterioration in habitat condition, as very little appears to grow or thrive under these trees.
Operation	Abstraction of groundwater for domestic use at accommodation and facilities	Drawdown of groundwater resources	• Reduced availability of groundwater for species and ecosystems
	Storage and disposal of treated water from wastewater treatment plants	Pollution (nutrient enrichment) of surface and groundwater resources	• Deterioration in surface and groundwater quality
	Use of gravel roads	Erosion of road verges, and sedimentation on land surrounding roads	• Erosion of sensitive surface freshwater ecosystems and loss of soil • Smothering of sensitive ecosystems, smothering of gills, eyes, and sensitive fauna and flora as a result of sedimentation. • Alteration of watercourse characteristics.

Project phase	Activity	Impact	Effect
Operational	Clearing or trimming of natural wetland or riparian vegetation around facilities – e.g. around antenna sites	Loss of vegetation cover through site clearing	• Loss of vegetation cover leads to hardening of the upper soil layers as a result of rain falling on bare soil. • Bare soil is more likely to erode. • Potential disturbance of species of conservation concern.
	Stormwater runoff on and off access roads, and from hardened and compacted surfaces at each antenna site	Channelling of flow (concentration of flow, and speeding up velocity) in the vicinity of roads, hardened antenna sites, and facilities, and erosion on downhill slopes	• Changes in flow patterns from diffuse to channellised • Concentration of flow leads to increased flow velocities • Increased flow velocities lead to head-cut and gully erosion • Erosion leads to sedimentation in wetlands and watercourses
			• Changes in flow patterns from diffuse to channellised • Concentration of flow leads to increased flow velocities • Increased flow velocities lead to head-cut and gully erosion • Erosion leads to sedimentation in wetlands and watercourses
	Alien clearing and control of invasive species (primarily *Prosopis*)	Improved ecological functioning, habitat condition and water availability	• The dense infestations of mesquite grow in the watercourses, riparian zones and wetlands, leading to reduced availability of water, and a deterioration in habitat condition, as very little appears to grow or thrive under these trees.

XI. Impact assessment methodology

1) Criteria

The impacts identified in Section X were assessed according to the criteria provided in the EIA regulations (2014) and listed in Table XI.1.

Table XI.1 Criteria used for the assessment of impacts associated with the SKA project.

Criterion	Description
Nature of Impact	Define or describe the type of effect that a proposed activity would have on the environment. This description includes what is to be affected and how. • Direct impacts are caused directly by the activity and generally occur at the same time and at the place of the activity. These impacts are usually associated with the construction, operation or maintenance of an activity and are generally obvious and quantifiable. • Indirect impacts are indirect or induced changes that may occur as a result of the activity. These types of impacts include all the potential impacts that do not manifest immediately when the activity is undertaken or which occur at a different place as a result of the activity. • Cumulative impacts are impacts that result from the incremental impact of the proposed activity on a common resource when added to the impacts of other past, present or reasonably foreseeable future activities. The cumulative impacts will be assessed by identifying other land use/human activity/projects in the local area.
Status of impact	A description as to whether the impact will be **positive** (environment overall benefits from impact), **negative** (environment overall adversely affected), or **neutral** (environment overall not affected).
Spatial Extent	Describe whether the impact occurs on a scale limited to the **site** area itself, **local** area (i.e. limited to within 2 km of the activity), **regional** (within 30 km of the site), **national** (e.g. affecting a national FEPA) or **global** (e.g. from the extinction of a species).
Duration	Predict whether the lifespan of the impact will be: • **Temporary** (less than 2 years, and probably associated with construction), • **Short term** (2 to 5 years); • **Medium term** (5 to 15 years); • **Long term** (longer than 15 years), or • **Permanent** (i.e. mitigation through natural processes or human intervention will not occur in such a way or in such time span that the impact can be considered transient).
Reversibility	The degree to which an impact can be reversed, from **fully reversible**, to **partly reversible** to **irreversible**.
Irreplaceable loss of	The degree to which resources will be irreplaceably lost as a result of the activity, as

Criterion	Description
resources	follows: • **High** irreplaceability of resources (project will destroy unique resources that cannot be replaced); • **Moderate** irreplaceability of resources; • **Low** irreplaceability of resources; or • **Replaceable** (the affected resource is easy to replace/rehabilitate).
Intensity	Describe whether the intensity (magnitude) of the impact is: • **Very high** (loss of species), • **High** (severe alteration of natural systems, patterns or processes such that they temporarily or permanently cease, sever impact on livelihood and/or quality of life); • **Medium** (notable alteration of natural systems, patterns or processes; where the environment continues to function but in a modified manner); or • **Low** (negligible or no alteration of environmental functions, natural systems, patterns or processes).
Probability	Describe the probability of the impact actually occurring as: • **Improbable** (little or no chance of occurring <10%) • **Low** Probability (10 - 25% chance of occurring) • **Probable** (25 - 50% chance of occurring) • **Highly probable** (50 – 90% chance of occurring) • **Definite** (>90% chance of occurring)
Significance	The significance of impacts shall be assessed with and without mitigation. The significance of identified impacts on components of the affected environment shall be described as: • **High**: where the impact could have a no-go implication for the development or a component of the development, regardless of any possible mitigation. • **Medium**: where the impact could have an influence on the environment which will require modification of the development design or alternative mitigation/s. • **Low**: where the impact will have a slight influence on the environment, but this can be accommodated without modification to the development design. • **Negligible**: where the impact will not have an influence on the environment.
Degree to which an impact can be mitigated	The impact can be **fully** mitigated, **partly** mitigated or **not mitigated**.
Confidence of assessment	The degree of confidence in the predictions, based on the availability of information and specialist knowledge. This should be assessed as **high**, **medium** or **low**.

2) Scoring

The criteria described above were integrated to a certain extent through assigning scores to each category.

Extent was scored as follows:

Extent description	Score
Site specific	1
Local (<2 km from site)	2
Regional (within 30 km of site)	3
National	4
International/Global	5

Duration was scored as follows:

Duration description	Score
Temporary (less than 2 years) or duration of the construction period	1
Short term (2 to 5 years)	2
Medium term (5 to 15 years)	3
Long term (> 15 years but where the impact will cease after the operational life of the activity)	4
Permanent (mitigation will not occur in such a way or in such a time span that the impact can be considered transient)	5

Intensity and **irreplaceability** were scored as follows:

Potential Intensity description (negative)	Rating	Score
Potential to severely impact Human Health (morbidity/mortality); or to lead to Loss of species[8] (fauna and/or flora)	**Very High/Fatal Flaw**	16
Potential to reduce faunal/flora population or to lead to severe reduction/alteration of natural process, loss of livelihoods or sever impact on quality of life[9], individual economic loss	**High**	8
Potential to reduce environmental quality – air, soil, water. Potential loss of habitat, loss of heritage, reduced amenity	**Medium**	4
Nuisance	**Medium-Low**	2
Negative change – with no other consequence	**Low**	1
Potential Intensity description (positive)	**Rating**	**Score**
Potential Net improvement in human welfare	**High**	8
Potential to improve environmental quality – air, soil, water. Improved individual livelihoods	**Medium**	4

[8] *Note that a loss of species is a global issue and is differentiated from a loss of a population.*
[9] *Note that a visual impact or air emissions for example could be considered as severely impacting on quality of life should it constitute more than a nuisance but not being life threatening.*

Potential Intensity description (negative)	Rating	Score
Potential to lead to Economic Development	**Medium-Low**	2
Potential positive change – with no other consequence	**Low**	1

Probability was scored as follows:

Probability description	Score
Improbable (little or no chance of occurring <10%)	0.1
Low probability (10 - 25% chance of occurring)	0.25
Probable (25 - 50% chance of occurring)	0.5
Highly probable (50 – 90% chance of occurring)	0.75
Definite (>90% chance of occurring).	1

The magnitude of the impact was calculated as the sum of the intensity, duration and extent:

Impact magnitude = intensity + duration + extent

Finally, the significance of the impact was calculated as the product of the magnitude and the probability and scored according to

Impact significance = magnitude x probability

Table XI.2 Scoring of impact significance, calculated as the product of impact magnitude and probability of occurrence.

Scoring	Significance rating	Description
18-26	**Fatally flawed**	The project cannot be authorised unless major changes to the engineering design are carried out to reduce the significance rating.
10-17	**High**	The impacts will result in major alteration to the environment even with the implementation on the appropriate mitigation measures and will have an influence on decision-making.
5-9	**Medium**	The impact will result in moderate alteration of the environment and can be reduced or avoided by implementing the appropriate mitigation measures, and will only have an influence on the decision-making if not mitigated.
<5	**Low**	The impact may result in minor alterations of the environment and can be easily avoided by implementing appropriate mitigation measures, and will not have an influence on decision-making.

All impacts were assessed before and after all the key proposed mitigation measures have been implemented.

XII. Mitigation Measures and Environmental Management Actions

Mitigation measures and management actions fall into two broad categories:

- **Key management actions and mitigation measures** – these are measures that must be written into, and enforced through the draft Environmental management Programme (EMPr) included in Part 3 of this IEMP– these key measures and actions are **not negotiable** and must be implemented as specified in the draft EMPr; and

- **Additional management actions** – these are additional measures/actions that would further reduce the negative impacts of the activities associated with SKA, and increase the positive impacts, and should be implemented as specified in the draft EMPr.

The mitigation hierarchy of "avoid, minimise, rehabilitate, offset" is taken into consideration here, where the first step should always be to avoid aquatic features and their buffers, wherever possible. If features cannot be avoided, then the impacts must be minimised and where impact affects an ecosystem, then to rehabilitate. Biodiversity and/or functional offsets are then only considered an option where there will be significant unavoidable residual loss of aquatic biodiversity or ecological processes (MacFarlane *et al.*, 2014b).

For all SKA infrastructure, care should be taken at the design stage to avoid all no-go aquatic features, and preferably also features of high sensitivity. Where infrastructure (probably linear) cannot avoid high sensitivity areas, these areas must be assessed and verified on the ground (ground-truthed), in order to:

- Verify the location and extent of the aquatic features;
- Assess the current condition, and ecological importance and sensitivity of the features;
- Determine the most appropriate ecological buffer, according to the condition and sensitivity of the feature and the condition of the buffer;
- Fine-tune the mitigation measures recommended in this SEA report, in order to minimise impacts where these cannot be avoided;
- Make specific recommendations for rehabilitation, where necessary and appropriate, and
- Determine whether there will be residual negative impacts associated with SKA infrastructure and activities that would warrant an offset.

Table XII.1 **Impacts, mitigation objectives and mitigation measures.**

Phase	Impact	Mitigation Objectives	Mitigation measures and management actions
Design	Direct loss of habitat through infilling of wetlands, watercourses and riparian areas	Avoid sensitive habitats	• SKA infrastructure such as dish-antennae, camps, services (pylons, cables, pipes, electrical substations) and access roads must avoid no-go areas and their buffer zones. **KEY MITIGATION MEASURE** • Where placement of infrastructure cannot avoid high sensitive features, then off-site biodiversity and ecosystem functioning offsets are required. **KEY MITIGATION MEASURE**
	Fragmentation of aquatic habitat (mostly as a result of road or fence construction and services)	Avoid or minimise new crossings over wetlands and watercourses	• Avoid placing infrastructure in wetlands and watercourses and their buffers. **KEY MITIGATION MEASURE** • Minimise new crossings over wetlands and watercourses. • If wetlands or watercourses cannot be avoided, the preferred crossing for smaller watercourses is a drift crossing with no hardened surfaces. **KEY MITIGATION MEASURE** • If hardening of the ground surface is unavoidable (e.g. to avoid erosion), riprap, gabion mattresses, and/or other permeable material must be used, to minimise the alteration of surface and sub-surface flow, together with pipe crossings or culverts to ensure connectivity and avoid fragmentation of ecosystems, especially if these are linked to watercourses. **KEY MITIGATION MEASURE** • Fences should not be permitted to cross over watercourses, or through wetlands. **KEY MITIGATION MEASURE**
	Hydrological alteration which includes largely the interruption of natural surface and/or subsurface passage of flow and the concentration of flows due to	Avoid or minimise encroachment of infrastructure into wetlands and watercourses, and minimise concentration of	• Minimise the number of new watercourse crossings for access roads where this is unavoidable. • If wetlands or watercourses cannot be avoided, the preferred crossing is a drift crossing with no hardened surfaces.

Phase	Impact	Mitigation Objectives	Mitigation measures and management actions
	roads or services across wetlands or watercourses.	surface runoff	• Ensure adequate watercourse crossings (i.e. pipes or culverts) are designed and constructed where roads traverse these areas so that the concentration of flow (particularly during high flow conditions) is minimised as far as possible. **KEY MITIGATION MEASURE**
	Erosion caused by loss of vegetation cover through site clearing, and consequent sedimentation of aquatic ecosystems	Avoid or minimise removal of indigenous vegetation cover	• Avoid clearing of indigenous vegetation. **KEY MITIGATION MEASURE** • Bank stabilisation measures (gabions, eco logs, geofabric, sediment fences) are required when wetland or watercourse banks steeper than 1:5 are denuded during construction. **KEY MITIGATION MEASURE** • Areas cleared for construction must be adequately rehabilitated, with input from an ecologist. **KEY MITIGATION MEASURE**
Construction	Physical destruction or damage of surface freshwater ecosystems by workers and machinery operating within or in close proximity to wetlands or watercourses	Avoid sensitive habitats	• All wetlands and watercourses and their recommended buffers should generally be treated as "no-go" areas and appropriately demarcated as such. **KEY MITIGATION MEASURE** • Areas cleared for construction must be adequately rehabilitated, with input from an ecologist. **KEY MITIGATION MEASURE** • Watercourses and wetlands affected by road construction or by construction of dish-antennae platforms and the associated services must be rehabilitated, such that erosion does not occur. A rehabilitation plan must be prepared for such areas, with input from an ecologist. **KEY MITIGATION MEASURE** • No vehicles, machinery, personnel, construction materials, cement, fuel, oil or waste should be allowed into these areas without the express permission of and supervision by the ECO. • There should be as little disturbance to surrounding vegetation as possible when construction activities are undertaken, as intact vegetation adjacent to construction areas will assist in the control of

Phase	Impact	Mitigation Objectives	Mitigation measures and management actions
			sediment dispersal from exposed areas. • Construction activities associated with the establishment of access roads through wetlands or watercourses (if unavoidable) should be restricted to a working area of 5 m in width either side of the road, and these working areas should be clearly demarcated. **KEY MITIGATION MEASURE**
	Pollution (water quality deterioration) of freshwater ecosystems and groundwater through spillage and/or runoff of contaminants such as fuel, oil, concrete, wash-water, sediment, and hazardous chemicals	Divert pollutants away from sensitive habitats	• Waste water should be dealt with through the commissioning of package treatment plants that have an adequate capacity to deal with the waste water at each of the three construction camps. **KEY MITIGATION MEASURE** • New septic tanks should not be established closer than 50 m to aquatic ecosystems. **KEY MITIGATION MEASURE** • Areas where machinery is operated, stored and washed must be adequately bunded, to ensure that spilled substances do not reach any natural ecosystems. **KEY MITIGATION MEASURE** • All machinery must be supplied with drip trays to avoid leakage of oil and fuel. Equipment found to be leaking must be repaired immediately. **KEY MITIGATION MEASURE** • Spills must be cleaned up immediately, and contaminated soil, plants, etc placed in a marked container. The container must be collected by a registered waste removal company and disposed of in the appropriate manner. **KEY MITIGATION MEASURE** • Areas affected by spills or contamination must be adequately rehabilitated, with input from an ecologist. **KEY MITIGATION MEASURE**
	Drawdown of groundwater causing a cone of depression in	Minimise water use	• Water should not be used wastefully, and only sufficient water for

Phase	Impact	Mitigation Objectives	Mitigation measures and management actions
	the vicinity of boreholes		construction and domestic use may be abstracted. **KEY MITIGATION MEASURE**
	Soil compaction and shading caused by stockpiles	Avoid sensitive habitats	• Areas used for stockpiling must be rehabilitated, with input from an ecologist. **KEY MITIGATION MEASURE**
	Interception of subsurface flow by compaction of soil above cables, and creation of preferential flow-paths around pipes/cables	Minimise disturbance and compaction of soils	• Compaction of soil must be minimised, and restricted to the area immediately above the cable trench. • Layered backfilling and limited compacting must be done by hand, not machine, where trenches cannot avoid sensitive areas.
	Disturbance of aquatic and semi-aquatic fauna, as a result of the light and noise from construction teams and their machinery working within or in close proximity to wetlands and rivers	Avoid sensitive habitats and minimise disturbance	• Construction work should preferably not be done at night, to avoid unnecessary use of light. If lights must be used, they must be directed away from wetlands and watercourses. **KEY MITIGATION MEASURE**
	Introduction and spread of alien and invasive species	Control invasion of alien and invasive species	• Active control, follow-up and monitoring of relevant species. **KEY MITIGATION MEASURE**
Operation	Drawdown of groundwater resources causing a cone of depression in the vicinity of boreholes	Minimise water use	• Minimise water use, and so reduce the necessity of drilling additional boreholes. • Boreholes should not be located near to (less than 50 m) wetlands and watercourses. **KEY MITIGATION MEASURE**
	Pollution (nutrient enrichment) of surface and groundwater resources from waste water	Avoid deterioration in water quality	• Treated waste water must not be discharged into any natural areas, but can be used for irrigation of gardens and landscaped areas. **KEY MITIGATION MEASURE**
	Loss of vegetation cover through site clearing	Avoid or minimise vegetation clearing	• Natural vegetation cover must be kept intact wherever possible. **KEY MITIGATION MEASURE**
	Channelling of flow	Minimise alteration of surface	• Surface runoff from any hardened surface at all antenna sites (not just

Phase	Impact	Mitigation Objectives	Mitigation measures and management actions
	(concentration of flow, and speeding up velocity) in the vicinity of roads, hardened antenna sites, and facilities, and erosion on downhill slopes	hydrology and avoid wetlands and watercourses	those located in or close to wetlands and watercourses) must be encouraged to flow as diffuse or sheet flow. **KEY MITIGATION MEASURE** • Sufficient drainage must be provided under roads to prevent channeling of flow – culverts should preferably span the width of the watercourse. **KEY MITIGATION MEASURE** • Drainage under roads must cater for 1:100 year flood events. • This could be achieved through designing runoff trenches, swales and spreaders, with input from a freshwater ecologist.
	Alien clearing	This is a **positive** impact so there are no mitigation measures.	

XIII. Results of impact assessment

The significance of impacts takes into account ecosystem sensitivity. For instance, the placement of dish-antennae in a No-Go feature or an area of High sensitivity will have moderate to high negative significance, whereas if the antenna is located outside of these features, then the significance is lower.

For this SEA, the preliminary layout of the SKA Phase 1 dish-antennae sites and infrastructure dated May 2015 was used, and significance of the impacts is at the overall Phase 1 project level, not at each dish-antennae sites level.

Most impacts are closely tied to the location and layout of dish-antennae sites and the associated infrastructure. The sensitivity maps prepared during this assessment were used to inform the siting of infrastructure and activities for the revised configuration of the SKA Phase 1 development. In many cases, careful planning of the siting and layout of activities away from No-Go areas and areas of high sensitivity can substantially mitigate their impact. There are also impacts in the following table that are linked to the carrying out of ongoing activities as part of SKA operations.

A summary table of the impacts and their associated ratings is included in Section XI of this report.

1) Design phase

Activity: Placement of dish-antennae, buildings, services and access roads within or close to wetlands or watercourses.

Criterion	Description
Nature of Impact	Loss of habitat through infilling of wetlands and riparian areas
Status of impact	**Negative**
Spatial Extent	The extent of the direct impact of habitat loss may be limited to the footprint in the aquatic feature or buffer itself, but there will be cascade effects that extend beyond the development footprint, due to the inter-connectedness between ecosystems, species and the landscape. For instance, loss of wetland habitat may drive wetland-dependent species away from a particular area, which would have a knock-on impact on the success or occurrence of predators on these species. Another example would be the landscape-wide effects of a local loss of water storage capacity within a wetland, i.e. infilling a wetland or drainage channel will divert water towards areas that were previously protected from flooding by that aquatic feature. Cumulatively, this can lead to flooding, erosion and sedimentation, river capture, etc. Spatial extent is thus **regional**.
Duration	The loss of habitat must be assumed to be **permanent**, if this is resulting from the location of permanent infrastructure within aquatic features or their buffers.
Reversibility	If the activity ceased, and all infrastructure removed, the ecosystems would recover, but very slowly, and unlikely to return to the same state. So the impact is only **moderately reversible.**
Irreplaceable loss of resources	Although the wetland and river types in the SKA Phase1 study area are not Critically Endangered or Endangered, they are still important and sensitive ecosystems. The conservation targets for freshwater ecosystem types are not rigorous and their uniqueness is relatively unknown. The loss may very well be **irreplaceable**.
Intensity	Given the above, the intensity of this impact is considered to be **high**.

Criterion	Description
Probability	Taking the whole of the SKA Phase 1 site as a whole, the likelihood of sites being placed unavoidably in or near to an aquatic feature or its buffer is **highly probable.**
Significance before mitigation	**High negative**
Degree to which an impact can be mitigated	**Partly mitigated**
Significance after mitigation	**Low** (this could even be as low as negligible or even positive, if effective offsets are implemented)
Confidence of assessment	**Medium**

Criterion	Description
Nature of Impact	Fragmentation of aquatic habitat within wetlands and watercourses
Status of impact	**Negative**
Spatial Extent	The encroachment of dish-antennae and infrastructure into wetlands, watercourses and their buffers can lead to disturbance of a physical footprint that may lead to a loss of connectivity between or within aquatic features. A road is the most obvious example of this, where the physical presence of the road does not allow the movement of fauna and flora across the landscape, thus limiting migration/feeding/breeding patterns. Although habitat may appear undisturbed by the actual road, the impacts are felt on either side of it, extending into the surrounding landscape. The spatial extent is thus **regional**.
Duration	The loss of connectivity and consequent fragmentation of the landscape must be assumed to be **permanent**, if this is resulting from the location of permanent infrastructure within or across aquatic features or their buffers.
Reversibility	If the activity ceased, and all infrastructure removed, the ecosystems, fauna and flora would recover, but very slowly, and unlikely to return to the same state. So the impact is only **moderately reversible**
Irreplaceable loss of resources	Although the wetland and river types in the SKA Phase1 study area are not Critically Endangered or Endangered, they are still important and sensitive ecosystems. The conservation targets for freshwater ecosystem types are not rigorous and their uniqueness is relatively unknown. The loss may very well be **irreplaceable**.
Intensity	Given the above, the intensity of this impact is considered to be **high**.
Probability	Taking the whole of the SKA Phase 1 site as a whole, the likelihood of infrastructure being placed unavoidably in, across or near to an aquatic feature or its buffer, in particular the likelihood of roads crossing over watercourses and wetlands, is **highly probable.**
Significance before mitigation	**High negative**
Degree to which an impact can be mitigated	**Partly mitigated**
Significance after	**Low**

Criterion	Description
mitigation	
Confidence of assessment	**Low to medium**

Criterion	Description
Nature of Impact	Hydrological alteration which includes largely the interruption of natural surface and/or subsurface passage of flow and the concentration of flows due to roads or services across wetlands or watercourses.
Status of impact	**Negative**
Spatial Extent	The hydrological connectedness of aquatic features (through surface and subsurface flow) means that an impact in one location can have a downstream or even upstream impact. For instance, a road or berm across a wetland can result in the drying out of the downstream portion of that wetland, and any watercourse that leaves it. Such desiccation could result in permanent aquatic habitat loss. The spatial extent is **regional**.
Duration	Disruptions to hydrology must be assumed to be **permanent**, if this is resulting from the location of permanent infrastructure within aquatic features or their buffers.
Reversibility	If the activity ceased, and all infrastructure removed, the ecosystems would recover, but very slowly, and unlikely to return to the same state. Over time, flowpaths may shift, and not return to where they originally were located. So the impact is only **moderately reversible.**
Irreplaceable loss of resources	Although the wetland and river types in the SKA Phase1 study area are not Critically Endangered or Endangered, they are still important and sensitive ecosystems. The conservation targets for freshwater ecosystem types are not rigorous and their uniqueness is relatively unknown. The loss may very well be **irreplaceable**.
Intensity	Given the above, but taking into consideration the fact that surface water flow in this area is very intermittent, the intensity of this impact is considered to be **medium**.
Probability	Taking the whole of the SKA Phase 1 site as a whole, the likelihood of sites being placed unavoidably in or near to an aquatic feature or its buffer is **highly probable.**
Significance before mitigation	**Medium negative**
Degree to which an impact can be mitigated	This impact could be **partly mitigated**, as there are likely to be significant residual impacts even if all key mitigation measures are implemented.
Significance after mitigation	**Medium negative**
Confidence of assessment	**Medium**

Criterion	Description
Nature of Impact	Erosion caused by loss of vegetation cover through site clearing, and consequent sedimentation of aquatic ecosystems.

Criterion	Description
Status of impact	**Negative**
Spatial Extent	Erosion could extend some distance up- and downstream of the nickpoint, with sedimentation occurring also some distance away. Given the general gradient of the study area, it is unlikely that this will extend further than 2 km. The spatial extent is **local**.
Duration	The effects of erosion and sedimentation are likely to be evident in the **short-to medium-term**, depending on the extent of the impact. On shallow gradients, erosion gullies may stabilise and vegetation cover may return, further stabilising the erosion and preventing downstream sedimentation. This is less likely on steeper gradients, where gullies may continue eroding for some time.
Reversibility	If the activity ceased, erosion will stabilise in the short- to medium-term, as described above. However, recovery is unlikely to return the ecosystem to its original state. So the impact is only **moderately reversible.**
Irreplaceable loss of resources	Although the wetland and river types in the SKA Phase1 study area are not Critically Endangered or Endangered, they are still important and sensitive ecosystems. The conservation targets for freshwater ecosystem types are not rigorous and their uniqueness is relatively unknown. The loss may very well be **irreplaceable**.
Intensity	Given the above, the intensity of this impact is considered to be **medium**.
Probability	Taking the whole of the SKA Phase 1 site as a whole, the likelihood of project activities causing erosion, especially around roads, is **highly probable.**
Significance before mitigation	**Medium negative**
Degree to which an impact can be mitigated	**Partly mitigated**
Significance after mitigation	**Low negative**
Confidence of assessment	**Medium**

Figure XIII.1 Erosion upstream of a road crossing a minor watercourse in the core area, showing small erosion gullies advancing uphill away from the channel. On a steeper gradient, these would continue advancing upslope each time sufficient rain falls to generate surface runoff.

2) Construction phase

Activity: Establishment of construction camps or temporary laydown areas within or in close proximity to wetlands or watercourses

Criterion	Description
Nature of Impact	Physical destruction or damage of surface freshwater ecosystems by workers and machinery operating within or in close proximity to wetlands or watercourses
Status of impact	**Negative**
Spatial Extent	The direct impact of habitat destruction and damage may be limited to the development footprint, but the effects may extend off site, as the loss of vegetation will impact on herbivores, the loss of small faunal species will impact on predators, etc. Spatial extent is thus **local**.
Duration	Construction impacts will mostly cease upon completion of the built footprint and services. However, the landscape and ecological processes will take some time to recover or resume if damaged, with some damage possible being permanent. Overall, duration of the impact is likely to be **short- to medium-term.**
Reversibility	Once construction has ceased, and all construction equipment and infrastructure removed, the ecosystems, fauna and flora are likely to recover, but very slowly, and in places possibly not to the original state. So the impact is **moderately reversible**
Irreplaceable loss of resources	Although the wetland and river types in the SKA Phase1 study area are not Critically Endangered or Endangered, they are still important and sensitive ecosystems. The conservation targets for freshwater ecosystem types are not rigorous and their uniqueness is relatively unknown. The loss may very well be **irreplaceable**.
Intensity	Given the above, the intensity of this impact is considered to be **low to medium**.
Probability	The proximity of some of the dish-antennae sites and infrastructure to aquatic features and their buffers means that destruction of or damage to these ecosystems is **highly probable.**
Significance before mitigation	**Medium negative**
Degree to which an impact can be mitigated	**Partly mitigated**
Significance after mitigation	**Low negative**
Confidence of assessment	**Medium to high**

Activity: Abstraction of groundwater for use during construction

Criterion	Description
Nature of Impact	Drawdown of groundwater causing a cone of depression in the vicinity of boreholes

Criterion	Description
Status of impact	**Negative**
Spatial Extent	Drawdown of groundwater can cause a cone of depression of the water table, that can extend some distance from the actual borehole. Spatial extent is thus **local**.
Duration	Duration of the impact is likely to be **short-term.** Once abstraction for the purposes of construction has ceased, the local water table will take some time to return to the same level as before, while species and ecosystems dependent on groundwater will take longer. The volumes required for construction are not substantial however**.**
Reversibility	The impact is **fully reversible**
Irreplaceable loss of resources	The extent of the impact is such that there is unlikely to be a loss of any resources. However, if there were to be some permanent impact on the water resource, the loss would be **irreplaceable** in such a water-stressed area.
Intensity	Given the above, the intensity of this impact is considered to be **low**.
Probability	The probability of this impact occurring is **low**, as the volumes are not great, but any abstraction of groundwater in this water-stressed area will have an impact on the groundwater, even if it is short-lived.
Significance before mitigation	**Low negative**
Degree to which an impact can be mitigated	This impact **cannot be mitigated**.
Significance after mitigation	**Low negative**
Confidence of assessment	**Medium**

Activity: Stockpiling of materials within or in close proximity to wetlands or watercourses

Criterion	Description
Nature of Impact	Soil compaction and shading caused by stockpiles
Status of impact	**Negative**
Spatial Extent	Spatial extent is limited to the **site**.
Duration	Duration of the impact is likely to be **short-term.** Once stockpiles are removed, compacted soils will take some time to recover, unless these areas are rehabilitated (see mitigation measures).
Reversibility	The impact is **fully reversible**
Irreplaceable loss of resources	The spatial extent of the impact (limited to stockpiles) is unlikely to lead to an irreplaceable loss of resources, so is considered to be **replaceable**.
Intensity	Given the above, the intensity of this impact is considered to be **low**.
Probability	The probability of this impact occurring is **low**, as it should be relatively easy to avoid sensitive areas for stockpiles, and use previously disturbed areas close to the construction camps.
Significance before mitigation	**Low negative**
Degree to which an	This impact can be avoided by making sure that stockpiles are kept in

Criterion	Description
impact can be mitigated	disturbed areas, away from sensitive habitats. Thus it can be **fully mitigated**.
Significance after mitigation	**Negligible**
Confidence of assessment	**Medium**

Activity: Storage of fuels on site (due to remote location of construction sites), washing of equipment in close proximity to wetlands and watercourses, and generation of waste water.

Criterion	Description
Nature of Impact	Pollution (water quality deterioration) of freshwater ecosystems through spillage and/or runoff of contaminants such as fuel, oil, concrete, wash-water, waste water, sediment, and hazardous chemicals
Status of impact	**Negative**
Spatial Extent	If pollutants do enter any watercourses or wetlands, it is likely that these will impact on an area broader than the construction site itself. The intermittent rainfall and lack of frequent flushing flows in the area mean that there may be a build-up of pollutants or sediment during construction that then is washed further downstream, or into a wider wetland area, during wetter months. Spatial extent is thus **local**.
Duration	The generation of pollutants during the construction phase will effectively cease on completion of the project. However, the flushing of accumulated contaminants is likely to take some time if these remain on site. The construction activities are not likely to generate large volumes of pollutants due to the small size of each construction footprint, however, it is likely that road construction will lead to the washing of sediment onto the landscape and into watercourses and wetlands, and this will take some time to dissipate. Duration of the impact is likely to be **short-term.**
Reversibility	Once construction has ceased, and all construction equipment and infrastructure removed, the ecosystems, fauna and flora are likely to recover, but very slowly, and in places possibly not to the original state. So the impact is **moderately reversible**
Irreplaceable loss of resources	Although the wetland and river types in the SKA Phase1 study area are not Critically Endangered or Endangered, they are still important and sensitive ecosystems. The conservation targets for freshwater ecosystem types are not rigorous and their uniqueness is relatively unknown. The loss may very well be **irreplaceable**.
Intensity	Given the above, the intensity of this impact is considered to be **low to medium**.
Probability	The proximity of some of the dish-antennae sites and infrastructure to aquatic features and their buffers means that destruction of or damage to these ecosystems is **highly probable.**
Significance before mitigation	**Medium negative**
Degree to which an impact can be mitigated	**Partly mitigated**

Criterion	Description
Significance after mitigation	**Low negative**
Confidence of assessment	**Medium to high**

Activity: Construction of access roads for movement of machinery, materials and people

Criterion	Description
Nature of Impact	Erosion and sedimentation of wetlands and watercourses
Status of impact	**Negative**
Spatial Extent	Erosion could extend some distance up- and downstream of the nickpoint, with sedimentation occurring also some distance away. Given the general gradient of the study area, it is unlikely that this will extend further than 2 km. The spatial extent is **local**.
Duration	The effects of erosion and sedimentation are likely to be evident in the **short-to medium-term**, depending on the extent of the impact. On shallow gradients, erosion gullies may stabilise and vegetation cover may return, further stabilising the erosion and preventing downstream sedimentation. This is less likely on steeper gradients, where gullies may continue eroding for some time.
Reversibility	Once construction has ceased, erosion may stabilise in the short- to medium-term, as described above. However, recovery is unlikely to return the ecosystem to its original state. So the impact is only **moderately reversible.**
Irreplaceable loss of resources	Although the wetland and river types in the SKA Phase1 study area are not Critically Endangered or Endangered, they are still important and sensitive ecosystems. The conservation targets for freshwater ecosystem types are not rigorous and their uniqueness is relatively unknown. The loss may very well be **irreplaceable**.
Intensity	Given the above, the intensity of this impact is considered to be **medium**.
Probability	Taking the whole of the SKA Phase 1 site as a whole, the likelihood of road construction causing erosion is **highly probable.**
Significance before mitigation	**Medium negative**
Degree to which an impact can be mitigated	**Partly mitigated**
Significance after mitigation	**Low to medium negative**
Confidence of assessment	**Medium**

Activity: Trenching for the laying of underground electrical reticulation (within 2 km of each antenna)

Criterion	Description
Nature of Impact	Interception of subsurface flow by compaction of soil above cables, and creation of preferential surface flowpaths around pipes/cables
Status of impact	**Negative**
Spatial Extent	The site-level impacts of trenching are likely to have some up- and downstream impacts, especially if the channelling of surface flow leads to the formation of

Criterion	Description
	erosion gullies and/or head-cut erosion, that may move beyond the site. Diversion of water away from areas that would have naturally received runoff will lead to desiccation of these areas, which is particularly significant if there are wetlands or watercourses down the slope. The spatial extent is thus **regional**.
Duration	Once the trenching is complete, and the underground cabling buried, compaction of soils above the cables may still have an effect on subsurface and surface hydrology. Disruptions to hydrology may thus be **long-term**.
Reversibility	The ecosystems would recover, but very slowly, and unlikely to return to the same state. Over time, flowpaths may shift, and not return to where they originally were located. So the impact is only **moderately reversible.**
Irreplaceable loss of resources	Although the wetland and river types in the SKA Phase1 study area are not Critically Endangered or Endangered, they are still important and sensitive ecosystems. The conservation targets for freshwater ecosystem types are not rigorous and their uniqueness is relatively unknown. The loss may very well be **irreplaceable**.
Intensity	Given the above, but taking into consideration the fact that surface water flow in this area is very intermittent, the intensity of this impact is considered to be **medium**.
Probability	Taking the whole of the SKA Phase 1 site as a whole, the likelihood of sites being placed unavoidably in or near to an aquatic feature or its buffer is **highly probable.**
Significance before mitigation	**Medium negative**
Degree to which an impact can be mitigated	This impact could be **partly mitigated**, as there are likely to be significant residual impacts even if all key mitigation measures are implemented.
Significance after mitigation	**Low to medium negative**
Confidence of assessment	**Medium**

Activity: Excavation of borrow pits for road construction

Criterion	Description
Nature of Impact	Loss of habitat
Status of impact	**Negative**
Spatial Extent	The extent of the direct impact of habitat loss may be limited to the footprint in the aquatic feature or buffer itself, but there will be cascade effects that extend beyond the footprint of the borrow pit, due to the inter-connectedness between ecosystems, species and the landscape. For instance, loss of wetland habitat may drive wetland-dependent species away from a particular area, which would have a knock-on impact on the success or occurrence of predators on these species. Another example would be the landscape-wide effects of a local loss of water storage capacity within a wetland through the removal of soil and vegetation. Spatial extent is thus **local**.
Duration	The loss of habitat is likely to be **long-term**, as these areas are unlikely to recover quickly from such an activity.

Criterion	Description
Reversibility	After borrow pit closure, the ecosystems would recover, but very slowly, and unlikely to return to the same state. So the impact is only **moderately reversible**
Irreplaceable loss of resources	Although the wetland and river types in the SKA Phase1 study area are not Critically Endangered or Endangered, they are still important and sensitive ecosystems. The conservation targets for freshwater ecosystem types are not rigorous and their uniqueness is relatively unknown. The loss may very well be **irreplaceable**.
Intensity	Given the above, the intensity of this impact is considered to be **high**.
Probability	Taking the whole of the SKA Phase 1 site as a whole, the likelihood of a borrow pit being placed in or near to an aquatic feature or its buffer is **low.**
Significance before mitigation	**Low negative**
Degree to which an impact can be mitigated	**Partly mitigated**
Significance after mitigation	**Low negative to negligible**
Confidence of assessment	**Low to medium**

Criterion	Description
Nature of Impact	Alterations to surface and subsurface hydrology
Status of impact	**Negative**
Spatial Extent	The site-level impacts of trenching are likely to have some up- and downstream impacts, especially if the channelling of surface flow leads to the formation of erosion gullies and/or head-cut erosion, that may move beyond the site. Diversion of water away from areas that would have naturally received runoff will lead to desiccation of these areas, which is particularly significant if there are wetlands or watercourses down the slope. The spatial extent is thus **regional**.
Duration	Once the trenching is complete, and the underground cabling buried, compaction of soils above the cables may still have an effect on subsurface and surface hydrology. Disruptions to hydrology may thus be **long-term**.
Reversibility	The ecosystems would recover, but very slowly, and unlikely to return to the same state. Over time, flowpaths may shift, and not return to where they originally were located. So the impact is only **moderately reversible.**
Irreplaceable loss of resources	Although the wetland and river types in the SKA Phase1 study area are not Critically Endangered or Endangered, they are still important and sensitive ecosystems. The conservation targets for freshwater ecosystem types are not rigorous and their uniqueness is relatively unknown. The loss may very well be **irreplaceable**.
Intensity	Given the above, but taking into consideration the fact that surface water flow in this area is very intermittent, the intensity of this impact is considered to be **medium**.
Probability	Taking the whole of the SKA Phase 1 site as a whole, the likelihood of sites being placed unavoidably in or near to an aquatic feature or its buffer is **highly**

Criterion	Description
	probable.
Significance before mitigation	**Medium negative**
Degree to which an impact can be mitigated	This impact could be **partly mitigated**, as there are likely to be significant residual impacts even if all key mitigation measures are implemented.
Significance after mitigation	**Low to medium negative**
Confidence of assessment	**Medium**

Activity: Operation of heavy machinery within or in close proximity to wetlands or watercourses

Criterion	Description
Nature of Impact	Disturbance of aquatic and semi-aquatic fauna, as a result of the noise and light pollution from construction teams and their machinery working within or in close proximity to wetlands and rivers.
Status of impact	**Negative**
Spatial Extent	The site-level disturbance may have impacts off site, that may extend up to 2 km, and possibly further if faunal species move some distance away. The spatial extent is thus **local**.
Duration	Once construction is complete, animals may return to the area. The impact is likely to be **temporary**.
Reversibility	The impact is likely to be **fully reversible.**
Irreplaceable loss of resources	The affected area is likely to be **replaceable**.
Intensity	The intensity of this impact is considered to be **low**.
Probability	The impact is **highly probable,** as there will inevitably be noise and light associated with the construction. In the more remote parts of the study area, this will be more noticeable.
Significance before mitigation	**Low negative**
Degree to which an impact can be mitigated	This impact could be **partly mitigated**, but cannot be fully mitigated as although there are ways to reduce noise and light associated with construction teams, it is impossible to avoid it altogether.
Significance after mitigation	**Low negative**
Confidence of assessment	**Medium**

Activity: Introduction and spread of alien and invasive species

Criterion	Description
Nature of Impact	Reduced ecological functioning, habitat condition and water availability due to encroachment of alien and invasive species into aquatic features and buffers
Status of impact	**Negative**
Spatial Extent	The spatial extent is **regional**. The trees use more water than the indigenous

Criterion	Description
	vegetation, thus reducing regional water availability.
Duration	The duration of the impact is **long-term**, as it will take some time for the impact to be reversed in the event that all alien and invasive species were to be removed.
Reversibility	The impact is likely to be **partly reversible**, as there will be some permanent effects associated with the impact, for instance as the result of the local extinction of species impacted by alien and invasive species.
Irreplaceable loss of resources	There may be an **irreplaceable** loss of some species, such as those outcompeted by exotic species leading to their local extinction.
Intensity	The intensity of this impact is considered to be **high**.
Probability	The impact is **highly probable,** as disturbance of soils during construction leaves areas vulnerable to invasion by alien and invasive plant species. The introduction and/or spread of alien or invasive animal species is less probable.
Significance before mitigation	**High negative**
Degree to which an impact can be mitigated	This impact could be **partly mitigated**, but cannot be fully mitigated as although there are ways to control the spread of alien and invasive plant species, it is virtually impossible to avoid the introduction of such species. The introduction and spread of alien animal species can be avoided through mitigation.
Significance after mitigation	**Low to medium negative**
Confidence of assessment	**Medium**

3) Operational phase

Activity: Abstraction of groundwater for domestic use at accommodation and facilities

Criterion	Description
Nature of Impact	Drawdown of groundwater causing a cone of depression in the vicinity of boreholes
Status of impact	**Negative**
Spatial Extent	Drawdown of groundwater can cause a cone of depression of the water table, that can extend some distance from the actual borehole. Spatial extent is thus **local**.
Duration	Duration of the impact is likely to be **permanent**, if it occurs, as the amount of water required will remain the same over time. The volumes required are not substantial however.
Reversibility	The impact is **fully reversible**
Irreplaceable loss of resources	The extent of the impact is such that there is unlikely to be a loss of any resources. However, if there were to be some permanent impact on the water resource, the loss would be **irreplaceable** in such a water-stressed area.
Intensity	Given the above, the intensity of this impact is considered to be **low**.
Probability	The probability of this impact occurring is **low**, as the volumes are not great, but any abstraction of groundwater in this water-stressed area will have an impact

Criterion	Description
	on the groundwater, even if it is short-lived.
Significance before mitigation	**Low negative**
Degree to which an impact can be mitigated	This impact **cannot be mitigated**.
Significance after mitigation	**Low negative**
Confidence of assessment	**Low to medium**

Activity: Storage and disposal of treated water from wastewater treatment plants at permanent sites.

Criterion	Description
Nature of Impact	Pollution (nutrient enrichment) of surface and groundwater resources
Status of impact	**Negative**
Spatial Extent	If pollutants do enter any watercourses or wetlands, it is likely that these will impact on an area broader than the discharge site. The intermittent rainfall and lack of frequent flushing flows in the area mean that there may be a build-up of nutrients over time that then are washed further downstream, or into a wider wetland area, during wetter months. Spatial extent is thus **local**.
Duration	If the impact does occur it is likely to be **permanent**, as the facilities will be permanent.
Reversibility	If the discharge of pollutants were to cease, the ecosystems, fauna and flora are likely to recover, but very slowly, and possibly not to the original state. So the impact is **moderately reversible**
Irreplaceable loss of resources	Although the wetland and river types in the SKA Phase1 study area are not Critically Endangered or Endangered, they are still important and sensitive ecosystems. The conservation targets for freshwater ecosystem types are not rigorous and their uniqueness is relatively unknown. The loss may very well be **irreplaceable**.
Intensity	The volumes of treated water that may be discharged are likely to be very low, so the intensity of this impact is considered to be **low**.
Probability	The package treatment plants that will be used are likely to be effective with discharged water probably being used for irrigation of gardens. So there is a **low probability** of this impact occurring.
Significance before mitigation	**Low negative**
Degree to which an impact can be mitigated	The impact can be **fully mitigated**.
Significance after mitigation	**Negligible**
Confidence of assessment	**Medium**

Activity: Use of gravel roads

Criterion	Description
Nature of Impact	Erosion of road verges, and sedimentation on land surrounding roads
Status of impact	**Negative**
Spatial Extent	Spatial extent is **local**, as erosion can extend away from the road, both up- and downslope. Sediment can also be carried some distance across the landscape or downstream in natural channels.
Duration	Duration of the impact is likely to be **permanent**, if it occurs, as gravel roads will continue to erode over time, even if regularly maintained.
Reversibility	The impact is **moderately reversible**
Irreplaceable loss of resources	The extent of the impact is such that there is unlikely to be a loss of any resources. However, if there were to be some permanent impact on the water resource, the loss would be **irreplaceable** in such a water-stressed area.
Intensity	Given the above, the intensity of this impact is considered to be **low**.
Probability	The probability of this impact occurring is **low**, as the volumes are not great, but any abstraction of groundwater in this water-stressed area will have an impact on the groundwater, even if it is short-lived.
Significance before mitigation	**Low negative**
Degree to which an impact can be mitigated	This impact can be **partly mitigated**. While some measures can be taken to avoid erosion on either side of gravel roads, there will always be some residual impact, due to the erodibility of the soils in the area.
Significance after mitigation	**Low negative to negligible**
Confidence of assessment	**Low to medium**

Activity: Clearing or trimming of natural wetland or riparian vegetation around facilities – e.g. around antenna sites

Criterion	Description
Nature of Impact	Loss of vegetation cover through site clearing
Status of impact	**Negative**
Spatial Extent	Spatial extent is **local.** While the clearing may be limited to a particular site (e.g. the periphery of an antenna site), the hardening of the soil can lead to altered surface flow.
Duration	Duration of the impact is likely to be **permanent**, as clearing of vegetation, if it occurs, will be done regularly, and these areas that must be cleared will be maintained as such.
Reversibility	The impact has **low reversibility,** and will take affected areas some time to recover, unless some rehabilitation is done.
Irreplaceable loss of resources	The extent of the impact is such that there is unlikely to be a loss of any resources. However, if there were to be some permanent impact on the water resource, the loss would be **irreplaceable** in such a water-stressed area.
Intensity	The intensity of this impact is considered to be **medium**. It is assumed that many of the areas to be cleared will already have been transformed.
Probability	The probability of this impact occurring is **high**, as there will be areas around dish-antennae and other facilities that must be kept cleared for practical

Criterion	Description
	purposes.
Significance before mitigation	**Medium negative**
Degree to which an impact can be mitigated	This impact can be **partly mitigated**. Clearing can be kept to a minimum, but it is probably not possible to avoid this altogether.
Significance after mitigation	**Low negative**
Confidence of assessment	**Medium**

Activity: Stormwater runoff on and off access roads, and from hardened and compacted surfaces at each antenna site

Criterion	Description
Nature of Impact	Channelling of flow (concentration of flow, and speeding up velocity) in the vicinity of roads, hardened antenna sites, and facilities, and erosion on downhill slopes
Status of impact	**Negative**
Spatial Extent	The hydrological connectedness of aquatic features (through surface and subsurface flow) means that an impact in one location can have a downstream or even upstream impact. For instance, a road or berm across a wetland can result in the drying out of the downstream portion of that wetland, and any watercourse that leaves it. Such desiccation could result in permanent aquatic habitat loss. The spatial extent is **regional**.
Duration	Disruptions to hydrology must be assumed to be **permanent**, if this is resulting from the location of permanent infrastructure within aquatic features or their buffers.
Reversibility	If the activity ceased, and all infrastructure removed, the ecosystems would recover, but very slowly, and unlikely to return to the same state. Over time, flowpaths may shift, and not return to where they originally were located. So the impact is only **moderately reversible.**
Irreplaceable loss of resources	Although the wetland and river types in the SKA Phase1 study area are not Critically Endangered or Endangered, they are still important and sensitive ecosystems. The conservation targets for freshwater ecosystem types are not rigorous and their uniqueness is relatively unknown. The loss may very well be **irreplaceable**.
Intensity	Given the above, but taking into consideration the fact that surface water flow in this area is very intermittent, the intensity of this impact is considered to be **medium**.
Probability	Taking the whole of the SKA Phase 1 site as a whole, the likelihood of sites being placed unavoidably in or near to an aquatic feature or its buffer is **highly probable.**
Significance before mitigation	**Medium negative**
Degree to which an impact can be mitigated	This impact could be **partly mitigated**, as there are likely to be significant residual impacts even if all key mitigation measures are implemented.

Criterion	Description
Significance after mitigation	**Low negative**
Confidence of assessment	**Medium**

Activity: Alien clearing (primarily *Prosopis*) and control of invasive species.

Criterion	Description
Nature of Impact	Clearing of mesquite from watercourses, riparian zones and wetlands
Status of impact	**Positive**
Spatial Extent	The spatial extent is **regional**. The trees use more water than the indigenous vegetation, thus reducing regional water availability.
Duration	If alien clearing operations continue throughout the operational phase of the SKA project, the impact should be permanent.
Reversibility	The positive impact is **reversible** – if clearing operations cease, the trees will return.
Irreplaceable loss of resources	n/a
Intensity	A successful alien clearing programme will have major ecological benefits, thus the impact is considered to be of **high** intensity.
Probability	Successful alien clearing operations across the SKA Phase 1 SEA study area are **probable.**
Significance before mitigation	**Medium positive**
Degree to which an impact can be mitigated	n/a
Significance after mitigation	**Medium positive**
Confidence of assessment	**Medium**

XIV. Water use authorisation

1) Regulatory environment

The main regulatory requirements with regards to aquatic features relates to the National Water Act No. 36 of 1998 (NWA). The NWA regulates 11 water uses that require authorisation, some of which are likely to be applicable to the SKA project. Section 21 of the NWA defines water use as:

a) Taking water from a water resource;
b) Storing water;
c) Impeding or diverting the flow of water in a watercourse;
d) Engaging in a stream flow reduction activity;
e) Engaging in a controlled activity identified and declared as such in terms of the Act;

f) Discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduit;
g) Disposing of waste in a manner which may detrimentally impact on a water resource;
h) Disposing in any manner of water which contains waste from, or which has been heated in, any industrial or power generation process;
i) Altering the bed, banks, course or characteristics of a watercourse;
j) Removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people; and
k) Using water for recreational purposes.

Section 21 (a) and (b) thus apply to consumptive use of ground- or surface water (which includes both rivers and wetlands), while the remaining sub-sections refer to non-consumptive water uses. Construction and operation of the SKA project and its infrastructure are likely to result only in non-consumptive water uses, specifically Section 21 (c) and (i). These non-consumptive water uses may impact on the integrity and function of water resources and the overall quality of the resource and therefore must be authorised as a water use by the Department of Water and Sanitation (DWS) or competent authority (such as a Catchment Management Agency).
Entitlement or authorisation of water use is governed by:

- Schedule 1 of the Water Act (this covers reasonable domestic use and storage, gardening, watering of animals, and recreational use);
- Existing lawful use;
- Section 22 (3) of the Water Act, where DWS can dispense with authorisation requirements if satisfied that the purpose of the National Water Act will be met by other legislation, or another competent authority;
- General Authorisation (GA); or
- Licensing.

The process to be followed to obtain authorisation for these categories of water use are different, and relate to the risk associated with the water use. Lower risk water uses fall under a number of GAs, and authorisation is a simpler, faster process than for licensing. For instance, the full WULA process requires the determination of the "Reserve" for the relevant catchment, sub-catchment or resource unit. WULAs for groundwater abstraction can only be processed in catchments or resource units where the groundwater reserve determination has already been undertaken.

The risk associated with the water use (risk class) is determined through a risk matrix, supplied by DWS, that scores the severity, spatial scale (extent) and duration of an impact, as well as the likelihood of the impact occurring, in order to assess the significance of the impact, and consequently, the risk rating of each impact. The risk is assessed before and after mitigation. This approach is very similar to the impact assessment methodology, so one can generally assume that when an activity has a medium to high negative significance impact associated with it after mitigation, this equates to a moderate to high risk. This risk matrix must be completed by a suitably qualified SACNASP-registered professional.

A GA permits the use of water in a specific area, or according to a set of conditions or limits. DWS or a Catchment Management Agency can also generally authorise specific groups of users in a catchment, so that they can make productive use of certain water resources, without having to apply for a licence. Individuals, groups or organisations who are using water under a GA must still register this water use. Currently, there are two GAs, one for consumptive and one for non-consumptive use, with each specifying areas of applicability and exclusion. The non-consumptive water use GA is summarised below.

GA 509 of 26th August 2016 provides guidance and the conditions of authorisation regarding impeding and diverting the flow in a watercourse (Section 21 (c)), or altering the bed, banks, course

and characteristics of a watercourse (Section 21 (i)), and is thus applicable to encroachment of a built footprint into an aquatic feature or its buffer, and the construction or widening of river or wetland crossings, which are likely to be required for the SKA roads and services.
According to the amended GA:

1. A person who owns, or has legal access to or occupation of land may:

    - Undertake the Section 21 (c) and (i) water uses set out below, **subject to the conditions of the GA**:

Person	**Activity**
Farmers and any other land owners	Emergency river crossings for vehicles to gain access to livestock, crops or residences etc.
Any landowner	Maintenance to private roads and river crossings provided that footprint remains the same and the road is less than 4 m wide.
Any landowner	Erection of fences provided that the fence will not in any way impede or divert flow, or affect resource quality detrimentally in the short, medium or long term.

    - Undertake a Section 21 (c) and (i) water use if it is assessed as having a low risk (see below for more details of the risk assessment matrix);
    - Undertake maintenance work associated with a Section 21 (c) and (i) existing lawful water use that has a low risk;
    - Conduct river and storm water management activities as contained in a river management plan (the details of which are specified in the box below);
    - Conduct rehabilitation of wetlands (read together with GA 1198 (18th December 2009)) or rivers where such rehabilitation activities have a low risk;
    - Conduct emergency work arising from an emergency situation or incident associated with an existing water use entitlement, provided that all work is executed and reported in the manner prescribed in the Emergency Protocol (specified in the GA).

2. In addition, all State Owned Companies (SOCs), and other institutions specified in the GA, having lawful access to that property or land, may undertake Section 21(c) and (i) water uses on that property use water as specified below:

SOCs, Institution or Individuals	**Activities**
ESKOM and other institutions	Construction of new transmission and distribution infrastructure, and minor maintenance of roads, river crossings, towers and substations where footprint will remain the same.
SANPARKS and provincial conservation agencies	All bridges, low water bridge crossings and pipelines below 500 mm in diameter.
SANRAL and other provincial Departments of Transport or municipalities.	All maintenance of bridges over rivers, streams and wetlands and new construction of bridges done according to SANRAL Drainage Manual or similar norms and standards.
TRANSNET and other institutions	All 1.5 metre diameter and smaller pipelines (*except sewage pipelines*) and maintenance of

	railway line crossings of rivers and wetlands outside the boundary of a wetland.
Gautrain Management Agency	Maintenance of existing infrastructure and expansion to crossings of rivers within the existing servitude.
TELKOM and other communication companies	All cables crossing rivers and wetlands outside delineated wetland boundary.
RAND WATER and other water boards	All raw water 1.5 metre diameter and smaller pipelines crossing rivers and wetlands outside delineated wetland boundary.
Municipalities and other institutions.	Mini-scale hydropower developments with a maximum capacity of 10kW – 300kW. These hydropower plants will provide basic, non-grid electricity to rural communities and agricultural land and must in no way affect the flow regime, flow volume and/or water quality including temperature.

It is unclear as to whether SKA SA is considered to fall within any of these categories, but if SKA activities are covered in the activities column they may undertake a Section 21 (c) and (i) water use **subject to the conditions of the GA**.

3. Lastly, all those exercising an existing Section 21 (c) and (i) water use, subject to previous GAs may continue with such water use, subject to the conditions of the amended GA.

River Management Plans (RMPs) for storm water and river management activities must contain information on all the river and storm water management activities in terms of Section 21(c) and (i) water uses of the Act, with a section addressing all relevant supporting technical information used to ensure that a **low risk** will be posed to the resource quality of the watercourses and that this management plan has been submitted to the relevant regional operations or Catchment Management Agency (CMA) office for **approval**.

When developing a River Management Plan, the following procedure must be followed:

1. Identify the River Management Plan domain, preferably from a whole-catchment perspective;
2. Identify an accountable, representative body that should take unbiased custodianship of the RMP and drive its implementation;
3. Identify key stakeholders;
4. Divide the river into useful management units;
5. Identify major drivers of river disturbance and instability - human and natural, and their primary and secondary effects;
6. Complete Risk assessment as per the DWS-approved Risk Matrix for identified mitigation activities;
7. Solicit input from stakeholders on their priorities and objectives;
8. Define best practice measures for rehabilitation and maintenance;
9. Design a plan for ecological monitoring, which is specifically linked to stated objectives; and
10. Develop an implementation programme and review mechanism for the RMP.

The report must include, but may not be limited to:

a) Impact assessment and mitigation report completed by an independent consultant as required by NEMA and NWA;

b) All the relevant specialist reports supporting the proposed mitigation measures. Specialist reports must address the level of modification/risk posed to resource quality, i.e. flow regime, water quality, geomorphological processes, habitat and biota of the watercourses and contain Present Ecological state (PES) and Ecological Importance and Sensitivity (EIS) data for relevant watercourses;
c) Environmental management plan giving effect to all actions required to mitigate impacts (What, When, Who, Where and How);
d) Best practices applicable to these activities, where applicable;
e) Generic designs and method statements, where applicable;
f) Norms and standards, where available;
g) Monitoring programme that must include "present day" conditions to be used as baseline values;
h) Monitoring, auditing and reporting programme (reports must be sent on request to the region or CMA); and;
i) Internalized controls and auditing, where applicable.

This GA does **not** apply under the following circumstances:

- Section 21 (c) and (i) water uses that occur within the regulated area around watercourses (see box for definition of the regulated area), where the risk class of the water use (see below for the risk assessment matrix) is Medium or High;
- If the water user must make an application for a license for any other water use in terms of Section 21;
- When storage of water results from the impeding or diverting flow, or from altering the bed, banks, course or characteristics of a watercourse
- Section 21 (c) and (i) water uses associated with the construction or installation or maintenance of any sewerage pipelines, pipelines carrying hazardous materials, and water and wastewater treatment works.

<u>The regulated area</u>

The new GA is very specific about the regulated area (i.e. the area applicable to the GA) regarding aquatic features, as follows:

a) The outer edge of the 1 in 100 year **flood line and/or delineated riparian habitat**, whichever is the greatest distance, measured from the middle of the watercourse of a river, spring, natural channel, lake or dam; and
b) In the absence of a determined 1 in 100 year **flood line or riparian area** the area within 100m from the edge of a watercourse where the edge of the watercourse is the first identifiable annual bank fill flood bench;
c) A 500 m radius from the delineated boundary (extent) of any **wetland** or **pan**;

It is important to note that the regulatory area is not the same as an ecological buffer, which is established to protect species and processes. The regulatory area is that area within which certain actions are legally required, such as permitting of water use.

The amended GA replaces the need for the full WULA process if all the specified conditions are met. All Section 21 (c) and (i) water uses that fall within the ambit of the amended GA, require registration. On completion of the registration, a certificate of registration is provided within 30 days of submission, after which the user may commence with the water use.

2) Assessment of risk class for SKA activities and impacts

A water use licence has already been granted to SKA SA for the MeerKAT project, covering operations at Meys Dam (Licence No: 14/D54E/ACGI/1012, File No: 27/2/2/D54E/F/68/1/3/4/9) and Losberg (Licence No: 14/D54E/A/1911, File No: 27/2/2/D54E/F73/1/9), specifically Section 21 (a), (c), (g) and (i). The SKA Phase 1 project, however, will require additional water to be abstracted, additional waste water to be stored and discharged, and additional activities that could impede or divert flow, and alter the bed, banks, course or characteristics of a number of watercourses (e.g. road crossings). It is not possible to complete the risk assessment matrix without the exact details of the activities that will impact on the watercourses, as these will determine the actual risks to the quality of the resource. For instance, design details for bridge crossings are required, and stormwater management plans for all infrastructure. The main impacts of concern are those that affect the surface hydrology of the landscape.

However, it is possible at the generic level to determine that, given the current layout of the project (dish-antennae sites, roads, cabling, construction camps, etc), the risks associated with the overall project are moderate, after mitigation. It must be noted that if one road crossing triggers a moderate to high risk, then the whole project is assumed to have that level of risk[10].

It is recommended that SKA SA pursue a full WULA, providing design details and sufficient site-specific information (exact locations of all dish-antennae and road crossings) to complete the risk assessment matrix, and the accompanying river management and monitoring plans.

XV. Management, Rehabilitation and Monitoring

1) Management

The management plans of relevance to the monitoring and management of aquatic ecosystems within the SKA Phase 1 area are:

- A stormwater management plan to be implemented during the construction and operation of the SKA Phase 1 project; and
- Measures to protect hydrological features such as streams, rivers, pans, wetlands, dams and their catchments, and other environmental sensitive areas from construction impacts including the direct or indirect spillage of pollutants.

Essentially, the mitigation measures and management actions described in Section XII form the basis of these management plans. In summary, the stormwater management plan should address the following:

1. Management of runoff from any hardened areas at the dish-antennae sites, including where soils have been compacted: It is recommended that all surface runoff be allowed to flow as sheet flow wherever possible. This will require the sloping of the antenna platforms, but also the addition of a gravel-filled swale around the edge of the platform, which will allow water to filter into the ground during periods of low

[10] This has been confirmed with DWS (Dr Roets, pers. comm., 23rd June 2016)

rainfall and runoff, and which will discharge water through spreaders, during periods of high rainfall and runoff. This "managed" runoff will then be allowed to flow overland towards natural drainage channels, rather than being channelled in that direction. This will vastly reduce the likelihood of erosion around the platforms.

2. Management of runoff from road surfaces: Similarly, it is recommended that runoff be spread as sheet flow as much as possible, preventing the channelization of water flowing away from roads. This can be achieved through multiple drainage channels allowing water to flow off the road surface and spread onto the landscape. These areas will always need maintenance.

In addition, the WULA recommended in Section XIV requires the preparation of River Management Plans (RMPs) where stormwater management will impact on watercourses, as well as rehabilitation and monitoring plans. An RMP can only be prepared once the exact details of the project activities are known, and must include the following:

a) Impact assessment and mitigation report completed by an independent consultant as required by NEMA and NWA;

b) All the relevant specialist reports supporting the proposed mitigation measures; Specialist Reports must address the level of modification/risk posed to resource quality, i.e. flow regime, water quality, geomorphological processes, habitat and biota of the watercourses and contain Present Ecological state (PES) and Ecological Importance and Sensitivity (EIS) data for relevant watercourses;

c) Environmental management plan giving effect to all actions required to mitigate impacts (What, When, Who, Where and How);

d) Best practices applicable to these activities;

e) Generic designs and method statements, where applicable;

f) Norms and standards, where available;

g) Monitoring programme that must include "present day" conditions to be used as baseline values;

h) Monitoring, auditing and reporting programme (reports must be sent on request to the region or CMA); and;

i) Internalized controls and auditing, where applicable (institutional arrangements related to this).

2) Rehabilitation

The principles governing the design and implementation of a rehabilitation plan are as follows:

- Rehabilitation is the reinstatement or improvement in the effectiveness of the driving forces that created and continue to shape and sustain the ecosystem (Kotze *et al.*, 2009; Russell, 2009);
- The goal of rehabilitation should not be to return an ecosystem to and maintain it in a static state at some time in the past, but rather to aim to achieve a dynamic and resilient system that can respond to change and that is largely self-maintaining, requiring little human intervention over time;

- Rehabilitation should be integrated with the surrounding landscape in order to address the upstream and downstream causes of degradation;
- If a rehabilitation programme is to be effective and sustainable, there must be ownership of the project by SKA SA, and their commitment to sustaining the integrity of the system must be demonstrated, and
- Rehabilitation should be well-planned with clearly stated and measurable objectives, effectively implemented, and must be continually monitored and evaluated.

Areas of the SKA Phase 1 site that will require rehabilitation include all aquatic features and their buffers that have been negatively impacted by construction activities. Most of the rehabilitation revolves around the re-shaping and stabilisation of the bed and banks of watercourses and wetlands, in order to ensure that surface hydrology returns to pre-construction patterns and flow levels.

- **Re-shaping of river banks**

The ideal longitudinal gradient to prevent erosion in a river channel is 1:7, while re-shaped bank slopes should, in general, not be steeper than 1:3 (Russell, 2009).

It is recommended that the shape of the rehabilitated river or wetland bank be fairly heterogeneous – with steeper sections and gentler sections, in order to mimic the natural shape of a river bank.

Work in watercourses and wetlands shall be undertaken in such a manner so as to minimise the extent of impacts caused by such activities. Surface flow should be diverted while work is underway, in such a way that does not cause erosion of the surrounding landscape, and in order to avoid mobilisation of sediments downstream.

All river diversion materials must be completely removed from the river after completion of the rehabilitation works.

- **Stabilisation of banks**

It is important to consider using various stabilisation measures after the banks have been shaped, in order to prevent erosion. Stabilisation materials include:

- Ecologs (dry woody material or sand contained in a hessian and chicken wire roll – see Figure XV.1) – these are particularly effective in areas of low gradient, such as over much of the SKA site;
- Biodegradable netting/matting;
- Geofabric (a non-woven geotextile matting of thick filaments designed to be secured over a vulnerable slope to prevent surface erosion, see Figure XV.2 for an example); or
- Mulch stabilization

Figure XV.1 Ecologs installed for stabilisation.

Figure XV.2 Geofabric – MacMat® in this example.

- **Alien clearing**

The main problem alien in the area is *Prosopis glandulosa*, and a more detailed alien management programme has been prepared by Dr Milton. This tree prefers to grow where there is moisture, and so tend to invade riparian areas, river channels, floodplains, and wetlands. Rehabilitation of areas cleared of alien trees may be necessary.

3) Monitoring

The overall aim of monitoring would be to track the success of the mitigation measures recommended in this report in controlling or minimising the impacts associated with SKA project activities. The success of a monitoring programme is highly dependent on the existence of good baseline data. This means that monitoring activities should preferably commence before the impacting activities begin. Once the final layout of the project has been determined, suitable monitoring sites could be chosen. These sites should preferably be located up- and downstream of areas of impact. For instance, monitoring sites should be located up- and downstream of a major road crossing.

Aquatic parameters that could be monitored:

Aspect	Parameters
Water quantity	Discharge (rivers), water depth (wetlands), depth to water table, rainfall
Water quality	pH, conductivity, turbidity and Total Dissolved Solids
Habitat condition / Present Ecological State	Gully profiles for monitoring erosion/sedimentation; Rapid Habitat Assessment Method or Index of Habitat Integrity (rivers), EcoStatus indicators (rivers – riparian vegetation, invertebrates, fish), WET-Health (wetlands – geomorphology, hydrology, vegetation), 2m x 2m plots for tracking changes in plant community composition and cover
Species composition, abundance/biomass	Plant species presence/absence, South African Scoring System (only for rivers that are regularly inundated), invertebrate species presence/absence for ephemeral watercourses and wetlands

Due to the spatial extent of the SKA Phase 1 project, with a large area to monitor, the location of monitoring sites needs to be done in conjunction with the monitoring programme being implemented in the core area by SAEON.

XVI. Conclusions & Recommendations

1 The SEA study led to the delineation of 11 wetland types and seven river types in and immediately adjacent to the SKA Phase 1 SEA study area. The landscape is heavily influenced by the occurrence of dolerite dykes, sills and rings, which control drainage patterns and the occurrence of streams and wetlands. Most of the surface water ecosystems are intermittent or ephemeral, being inundated only for brief periods each year, with periods of drought that are unpredictable in duration. Many of the wetlands and rivers are endorheic. The more perennially inundated Sak and Riet-Vis rivers lie to the south and west of the SKA Phase 1 SEA study area. A dominant feature of the Karoo landscape is the alluvial floodplains or washes. These systems are difficult to classify, as their hydrological and geomorphological characteristics (the way water and sediment flows into, through and out of these features) are difficult to determine, and the ecological functioning and importance of these alluvial features are little known. They are characterised by numerous channels that traverse a floodplain, valley floor or alluvial fan. Surface water may flow along a particular channel in one year, but due to there being little topographic definition or gradient across the landscape, a parallel channel may be eroded the following year, leading to a network of channels.

2 The rivers and wetlands in the study area are mostly in good condition, with a Present Ecological Status (PES) of A or B, due to the low level of impact from the extensive rather than intensive human activities in the area. Impacts are associated with roads, encroachment of farmed areas into watercourses and wetlands, the construction of berms in river channels, floodplains and in pans to trap surface water for stock and crops, and the spread of invasive alien plants, especially of *Prosopis* sp. Ephemeral rivers and wetlands are particularly vulnerable to changes in hydrology and water quality, as they are specifically adapted to brief periods of inundation and flow, and pollutants and sediments entering these watercourses are not regularly diluted or flushed out of the catchment, thus leading to a lack of resilience against pollution, erosion and sedimentation.

3 The aquatic ecosystems of the Northern Cape are poorly protected or, in the case of all of the wetland types identified in this study, not protected at all.

4 The highest sensitivity level – no go - was assigned to the depressional and seep wetlands and the wetland flats. These wetlands tend to be discrete wetland features with fairly clear boundaries, and it is possible for infrastructure to avoid these features. The remaining wetland types, all of which are riverine – i.e. floodplain and valley-bottom wetlands – occupy a large proportion of the SKA Phase 1 SEA study area, and are more difficult to delineate, both on a map and in the field. The wetland characteristics of these features are difficult to determine, and it is impossible to build linear infrastructure in the area that would completely avoid these features. These features were assigned a high sensitivity category. All ecological buffers were assigned to the high sensitivity category.

5 The SKA activities that are most likely to impact on freshwater ecosystems include:

- Siting of antenna sites, and associated infrastructure in or close to surface freshwater ecosystems;
- Construction activities, especially those that require the removal of earth (e.g. borrow pit sites), re-shaping of beds and banks of watercourses or wetlands (e.g. for road construction), or in-filling (e.g. for levelling of antenna sites);
- Trenching and soil compaction, for the burial of cables close to dish-antennae;
- Stormwater generation from roads and hardened surfaces, and stormwater management, and

- Crossing of roads and services over wetlands and watercourses.

6 The assessment of the impacts associated with the project was hampered by the lack of detail regarding the exact placement of SKA infrastructure. For this SEA, however, the significance of impacts was assessed according to the current layout provided to all specialists.

7 Implementation of the mitigation measures recommended in this report could reduce the significance of the impacts down to, at most, a medium negative significance.

8 The mitigation hierarchy of avoid, minimise, rehabilitate, offset was taken into consideration here, where the first step should always be to avoid aquatic features and their buffers, wherever possible. If features cannot be avoided, then the impacts must be minimised and where impact affects an ecosystem, then to rehabilitate. Biodiversity and functional offsets are then only considered an option where there will be significant unavoidable residual loss of aquatic biodiversity or ecological processes.

9 For all SKA infrastructures, care should be taken at the design stage to avoid all no-go aquatic features, and preferably also features of high sensitivity. Where infrastructure (probably linear) cannot avoid high sensitivity areas, these areas must be assessed and verified on the ground (ground-truthed), in order to:

- Verify the location and extent of the aquatic features;
- Assess the current condition, and ecological importance and sensitivity of the features;
- Determine the most appropriate ecological buffer, according to the condition and sensitivity of the feature and the condition of the buffer;
- Fine-tune the mitigation measures recommended in this SEA report, in order to minimise impacts where these cannot be avoided;
- Make specific recommendations for rehabilitation, where necessary and appropriate, and
- Determine whether there will be residual negative impacts associated with SKA infrastructure and activities that would warrant a biodiversity offset.

10 The clearing of mesquite trees from the study area is considered to be a significant positive impact of the project.

11 The management plans of relevance to the aquatic environment of the SKA Phase 1 area are:

- A stormwater management plan to be implemented during the construction and operation of the project; and
- Measures to protect hydrological features such as streams, rivers, pans, wetlands, dams and their catchments, and other environmental sensitive areas from construction impacts including the direct or indirect spillage of pollutants.

12 Essentially, the mitigation measures and management actions described in this report form the basis of these management plans.

The stormwater management plan should address the following:

- Management of runoff from any hardened areas at the dish-antennae sites, including where soils have been compacted: It is recommended that all surface runoff be allowed to flow as sheet flow wherever possible. This will require the sloping of the antenna platforms, but also the addition of a gravel-filled swale around the edge of the platform, which will allow water to filter into the ground during periods of low rainfall and runoff, and which will discharge water through spreaders, during periods of high rainfall and runoff. This "managed" runoff will then be allowed to flow overland towards natural drainage channels, rather than being channelled in that direction. This will vastly reduce the likelihood of erosion around the platforms.

- Management of runoff from road surfaces: Similarly, it is recommended that runoff be spread as sheet flow as much as possible, preventing the channelisation of water flowing away from roads. This can be achieved through multiple drainage channels allowing water to flow off the road surface and spread onto the landscape. These areas will always need maintenance.

13 It is recommended that SKA SA pursue a full WULA, providing design details and sufficient site-specific information (exact locations of all dish-antennae and road crossings) to complete the risk assessment matrix, and the accompanying river management and monitoring plans.

14 It is highly probable that there will be a significant, unavoidable residual loss of aquatic biodiversity or ecological processes as a result of the construction and operation of the SKA Phase 1 project. A biodiversity and/or ecosystem functioning offset should therefore be considered as mitigation for this loss. In the light of the lack of protection status accorded the wetlands and watercourses of the KCAAA1 as a whole, it is recommended that the core area of the SKA Phase 1 SEA study area be given protection status as intended by SKA SA, but that the extent of this protected area must follow sub-catchment boundaries in such a way that entire wetlands can be incorporated. Additional land purchases would be necessary to achieve this.

15 Input from a freshwater ecologist would be required to determine the acceptable area of offset, and where this could be achieved.

XVII. Summary impact table

Table XVII.1 Impact assessment summary table.

Phase	Impact description	Status	Extent	Extent Score	Duration	Duration score	Reversibility	Potential Intensity	Potential Intensity Score	Probability	Probability Score	Significance (without mitigation) Score	Significance (without mitigation)	Significance (with mitigation)	Confidence level
Design	Loss of habitat through infilling of wetlands and riparian areas	Negative	Regional (3)	3	Permanent (5)	5	Moderate reversibility	High (8)	8	Highly probable (0.75)	0.75	12	High	Low	Medium
	Fragmentation of aquatic habitat within wetlands and watercourses	Negative	Regional (3)	3	Permanent (5)	5	Moderate reversibility	High (8)	8	Highly probable (0.75)	0.75	12	High	Low	Medium
	Hydrological alteration due to roads or services across wetlands or watercourses.	Negative	Regional (3)	3	Permanent (5)	5	Moderate reversibility	Medium (4)	4	Highly probable (0.75)	0.75	9	Medium	Medium	Medium
	Erosion caused by loss of vegetation cover through site clearing	Negative	Local (2)	2	Medium Term (3)	3	Moderate reversibility	Medium (4)	4	Highly probable (0.75)	0.75	6.75	Medium	Low	Medium

Phase	Impact description	Status	Extent	Extent Score	Duration	Duration score	Reversibility	Potential Intensity	Potential Intensity Score	Probability	Probability Score	Significance (without mitigation) Score	Significance (without mitigation)	Significance (with mitigation)	Confidence level
Construction	Physical destruction or damage of surface freshwater ecosystems by workers and machinery	Negative	Local (2)	2	Medium Term (3)	3	Moderate reversibility	Medium -Low (2)	2	Highly probable (0.75)	0.75	5.25	Medium	Low	High
	Drawdown of groundwater causing a cone of depression in the vicinity of boreholes	Negative	Local (2)	2	Short Term (2)	2	Highly reversible	Low (1)	1	Low Probability (0.25)	0.25	1.25	Low	Low	Medium
	Soil compaction and shading caused by stockpiles	Negative	Site specific (1)	1	Short Term (2)	2	Highly reversible	Low (1)	1	Low Probability (0.25)	0.25	1	Low	Negligibl e	Medium
	Pollution (water quality deterioration) of freshwater ecosystems	Negative	Local (2)	2	Short Term (2)	2	Moderate reversibility	Medium -Low (2)	2	Highly probable (0.75)	0.75	4.5	Medium	Low	High
	Erosion and sedimentation of wetlands and watercourses from construction of access roads	Negative	Local (2)	2	Medium Term (3)	3	Moderate reversibility	Medium (4)	4	Highly probable (0.75)	0.75	6.75	Medium	Low to medium	Medium

Phase	Impact description	Status	Extent	Extent Score	Duration	Duration score	Reversibility	Potential Intensity	Potential Intensity Score	Probability	Probability Score	Significance (without mitigation) Score	Significance (without mitigation)	Significance (with mitigation)	Confidence level
Construction	Interception of subsurface flow by compaction of soil above cables	Negative	Regional (3)	3	Long Term (4)	4	Moderate reversibility	Medium (4)	4	Highly probable (0.75)	0.75	8.25	Medium	Low to medium	Medium
	Loss of habitat through borrow pit excavation	Negative	Local (2)	2	Long Term (4)	4	Moderate reversibility	High (8)	8	Low Probability (0.25)	0.25	3.5	Low	Low to negligibl e	Low
	Alterations to surface and subsurface hydrology in and around borrow pits	Negative	Regional (3)	3	Long Term (4)	4	Moderate reversibility	Medium (4)	4	Highly probable (0.75)	0.75	8.25	Medium	Low to medium	Medium
	Disturbance of aquatic and semi-aquatic fauna, as a result of the noise and light pollution from construction teams and their machinery	Negative	Local (2)	2	Temporary (1)	1	Highly reversible	Low (1)	1	Highly probable (0.75)	0.75	3	Low	Low	Medium
	Introduction and spread of alien and invasive species	Negative	Regional (3)	3	Long Term (4)	4	Moderate reversibility	High (8)	8	Highly probable (0.75)	0.75	11.25	High	Low to medium	Medium

Phase	Impact description	Status	Extent	Extent Score	Duration	Duration score	Reversibility	Potential Intensity	Potential Intensity Score	Probability	Probability Score	Significance (without mitigation) Score	Significance (without mitigation)	Significance (with mitigation)	Confidence level
Operation	Drawdown of groundwater causing a cone of depression in the vicinity of boreholes	Negative	Local (2)	2	Permanent (5)	5	Highly reversible	Low (1)	1	Low Probability (0.25)	0.25	2	Low	Low	Low
	Pollution (nutrient enrichment) of surface and groundwater resources from storage and discharge of waste water	Negative	Local (2)	2	Permanent (5)	5	Moderate reversibility	Low (1)	1	Low Probability (0.25)	0.25	2	Low	Negligibl e	Medium
	Erosion of road verges, and sedimentation on land surrounding roads	Negative	Local (2)	2	Permanent (5)	5	Moderate reversibility	Low (1)	1	Low Probability (0.25)	0.25	2	Low	Low to negligibl e	Low
	Loss of vegetation cover through site clearing	Negative	Local (2)	2	Permanent (5)	5	Low reversibility	Medium (4)	4	Highly probable (0.75)	0.75	8.25	Medium	Low	Medium

Phase	Impact description	Status	Extent	Extent Score	Duration	Duration score	Reversibility	Potential Intensity	Potential Intensity Score	Probability	Probability Score	Significance (without mitigation) Score	Significance (without mitigation)	Significance (with mitigation)	Confidence level
Operation	Channelling of flow (concentration of flow, and speeding up velocity) in the vicinity of roads, hardened antenna sites, and facilities, and erosion on downhill slopes	Negative	Regional (3)	3	Permanent (5)	5	Moderate reversibility	Medium (4)	4	Highly probable (0.75)	0.75	9	Medium	Low	Medium
	Alien clearing	Positive	Regional (3)	3	Permanent (5)	5	Moderate reversibility	Medium (4)	4	Probable (0.5)	0.5	6	Medium	Medium	Medium

XVIII. References

1 Allan DG, Seaman MT, Kaletja B. (1995). The endorheic pans of South Africa. In: Cowan, GI. (Eds), *Wetlands of South Africa.* Department of Environmental Affairs and Tourism, Pretoria, South Africa. 75-101.

2 Anderson, M. D. 2000. The status of flamingos in the Northern Cape Province, South Africa. *Ostrich*, 71, 425-437.

3 Bailey, A.K and Pitman, W.V. 2015. *Water Resources of South Africa 2012 Study (WR2012).* WRC Report K5/2143/1, November 2015 draft.

4 Chevallier, L., Gibson, L.A., Nhleko, L.O., Woodford, A.C., Nomquphu, W., and Kippie, I., 2004. Hydrogeology of fractured-rock aquifers and related ecosystems within the Qoqodala dolerite ring and sill complex, Great Kei Catchment, Eastern Cape. WRC Report No. 1238/1/05, Pretoria, 126pp

5 Chidley, C., Le Roux, R. and Holton, E. 2011. Environmental Management Framework and Strategic Environmental Management Plan: Namakwa District Municipality. Report prepared by Nemai Consulting, for the Namakwa District Municipality, March 2011.

6 Colvin, C., Riemann, K., Brown, C., Le Maitre, D., Mlisa, A., Blake, D., Aston, T., Maherry, M., Engelbrecht, J., Pemberton, C., Magoba, R., Soltau, L. and Prinsloo, P. 2014. Ecological and Environmental Impacts of Large-scale Groundwater Development in the Table Mountain Group (TMG) Aquifer System. Water Research Commission Report, 1327/1/08.

7 Dean, W.R.J. 2016. Avifauna desktop study of the SKA1_MID SEA study area. Report prepared for the CSIR by RENU-KAROO Veld Restoration cc and Research Associate, DST/NRF Centre of Excellence at the Percy FitzPatrick Institute of African Ornithology, University of Cape Town, 2016.

8 Department of Water and Sanitation (DWS). 2014. A Desktop Assessment of the Present Ecological State, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa. Compiled by RQIS-RDM: https://www.dwa.gov.za/iwqs/rhp/eco/ peseismodel.aspx

9 DWAF. 2005. A practical field procedure for identification and delineation of wetlands and riparian areas. Report prepared by Department of Water Affairs and Forestry, Pretoria.

10 Esterhuyse, S., Avenant, M., Watson, M., Redelinghuys, N., Kijko, A., Glazewski, J., Plit, L.A., Kemp, M., Smit, A., Sokolic, F., Vos, A.T., Reynolds, D., Von Maltitz, M., Van Tol, J., Bragg, C., Van Soelen, B. and Ouzman, S. 2014. Development of an interactive vulnerability map and monitoring framework to assess the potential environmental impact of unconventional oil and gas extraction by means of hydraulic fracturing. Report TT2149/1/14. Water Research Commission. Pretoria. 272 pp + Appendices.

11 Gibson, L.A. 2003. The detection of wetlands using remote sensing in Qoqodala, Eastern Cape. Masters thesis. Cape Town: University of Cape Town, School of Architecture, Planning and Geomatics.

12 Hamer, M., and Rayner, N. A. 1996. A note on the unusual crustacean community of a temporary pool in the Northern Cape. *Southern African Journal of Aquatic Sciences*, 22, 100-104.

13 Herrmann, E., Anderson, M.A. and Seaman, M. 2005. Occurrence and abundance of waterbirds at an ephemeral pan in the Northern Cape Province, South Africa. *Ostrich* 75 (4): 275 – 284.

14 Hockey, P. A. R.; Dean, W. R. J.; Ryan, P. G. 2005. *Roberts birds of southern Africa*. Trustees of the John Voelcker Bird Book Fund, Cape Town, South Africa.

15 Hocutt, C. H. and Skelton, P. H. 1983 Fishes of the Sak River, South Africa with comments on the nomenclature and a description of the smallmouth yellowfish *Barbus aeneus* (Burchell, 1822). Special Publication No. 32. Grahamstown, South Africa. JLB Smith Institute of Ichthyology.

16 Holness, S., Driver, A., Todd, S., Snaddon, K., Hamer, M., Raimondo, D., Dean R. and Daniels, F. In prep. Chapter 7: Biodiversity and ecological impacts: landscape processes, ecosystems and species. Contribution to the Strategic Environmental Assessment of the Shale Gas Exploration and Mining Project, June 2016.

17 Kleynhans, CJ, Thirion, C and Moolman, J (2005). A Level I River Ecoregion classification System for South Africa, Lesotho and Swaziland. Report No. N/0000/00/REQ0104. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria, South Africa.

18 Lloyd, J. W. and Le Roux, A. 1985 A conservation assessment of the Verneukpan-Copperton area. Cape Town, South Africa. Department of Nature and Environmental conservation.

19 MacDonald, D. 2009. Botanical Assessment of proposed site for the MeerKAT radio astronomy facilities on the farms Losberg and Mey's Dam near Carnarvon, Northern Cape. Report submitted to SKA, July 2008, 30 pp.

20 MacFarlane, D.M., Bredin, I.P., Adams, J.B., Zungu, M.M., Bate, G.C. and Dickens, C.W.S. 2014a. Preliminary Guideline for the Determination of Buffer Zones for Rivers, Wetlands and Estuaries. Water Research Commission Report, TT 610/14, 169 pp.

21 Macfarlane, D., Holness, S.D., von Hase, A., Brownlie, S. & Dini, J., 2014b. Wetland offsets: a best-practice guideline for South Africa. South African National Biodiversity Institute and the Department of Water Affairs. Pretoria. 69 pages.

22 Milton, S.J and Dean, R.J. 2016. Nama Karoo Ecosystems, incorporating bedrock, sandy & stony plains, pans and dry river systems. In: Cadman, M. (Ed). *Fynbos Forum Ecosystem Guidelines for Environmental Assessment in the Western Cape.* Edition 2, 2016.201 pp.

23 Minter, L.R., Burger, M., Harrison, J.A., Braack, H.H., Bishop, P.J. and Kloepfer, D. 2004. *Atlas and Red Data Book of the Frogs of South Africa, Lesotho and Swaziland.* SA/MAB series 9, 360 pp.

24 Mucina, L., and Rutherford, M. C. (Eds.). 2006. *The vegetation of South Africa, Lesotho, and Swaziland.* SANBI, Strelitzia 19 (2006).

25 Mucina, L., Rutherford, M.C., Palmer, A.R., Milton, S.J., Scott, L., Lloyd, J.W., van der Merwe, B., Vlok, J.H.J., Euston-Brown, D.I.W., Powrie, L.W. and Dold, A.P. 2006. Nama Karoo Biome. In: Mucina, L., and Rutherford, M. C. (Eds.). 2006. *The vegetation of South Africa, Lesotho, and Swaziland.* SANBI, Strelitzia 19 (2006).

26 Nel J.L. and Driver A. 2012. South African National Biodiversity Assessment 2011: Technical Report. Volume 2: Freshwater Component. CSIR Report Number CSIR/NRE/ECO/IR/2012/0022/A, Council for Scientific and Industrial Research, Stellenbosch.

27 Nel J.L., Driver A., Strydom W., Maherry A., Petersen C., Roux D.J., Nienaber S., van Deventer H, Smith-Adao LB and Hill L. 2011. Atlas of Freshwater Ecosystem Priority Areas in South Africa: Maps to support sustainable development of water resources. WRC Report No. TT 500/11, Water Research Commission, Pretoria

28 Nhleko, O.L. 2003 Implications of The Geological Structure of The Qoqodala Dolerite Ring Complex For Groundwater Dynamics Masters thesis. Cape Town: University of the Western Cape, Department of Earth Sciences, Faculty of Natural Sciences.

29 Ollis, D.J., Snaddon, C.D., Job, N.M. and Mbona, N. 2013. *Classification System for wetlands and other aquatic ecosystems in South Africa. User Manual: Inland Systems.* SANBI Biodiversity Series 22. South African National Biodiversity Institute, Pretoria.

30 Schulze, R. E., Maharaj, M., Warburton, M. L., Gers, C. J., Horan, M. J. C., Kunz, R. P., and Clark, D. J. 2007. South African atlas of climatology and agrohydrology. Water Research Commission, Pretoria, RSA, WRC Report,1489(1), 06.

31 Seaman, M., Watson, M., Avenant, M., King, J., Joubert, A., Barker, C., Esterhuyse, S., Graham, D., Kemp, M., le Roux, P., Prucha, B., Redelinghuys, N., Rossouw, L., Rowntree, K., Sokolic, F., van Rensburg, L., van der Waal, B., van Tol, J. and Vos, T. 2016. DRIFT-ARID: A method for assessing environmental water requirements (EWRs) for non-perennial rivers. *Water SA* Vol 42(3): 356 – 367.

32 Simmons, R.E., Barnard, P.E. and Jamieson, I.G. 1998. What precipitates influxes of wetland birds to ephemeral pans in arid landscapes? Observations from Namibia. *Ostrich* 70 (2): 145 – 148.

33 Skowno, A., Todd, S., Snaddon, K. and Ewart-Smith, J. 2014. National Wind and Solar PV SEA Specialist Report - Terrestrial and Aquatic Biodiversity. Report submitted to the CSIR, July 2014.

34 Snaddon, K., Todd, S., Kirkwood, D. and Ewart-Smith, J. 2015. National Electricity Grid Infrastructure SEA Specialist Report: Terrestrial and Aquatic Biodiversity. Report submitted to CSIR, July 2015.
35 Soil Classification Working Group, 1991. *Soil Classification: A Taxonomic System for South Africa.* Memoirs on the Agricultural Natural Resources of South Africa No. 15, Soil and Irrigation Research Institute, Pretoria, 1991, 257 pp.
36 Todd, S., Hoffman, M.T., Henschel, J.R., Cardoso, A.W., Brooks, M. and Underhill, L.G. In prep. The potential impacts of fracking on Karoo biodiversity.
37 Woodford, A.C and Chevallier, L., 2002. Hydrogeology of the main Karoo Basin: Current Knowledge and Future research needs. Water Research Commission Report No TT 179/02, 466pp