Environmental Impact Assessment for the proposed Concentrated Solar Thermal Power Plant on the farm Sanddraai 391, Northern Cape – Surface Water Study

Solafrica Thermal Energy (Pty) Ltd

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Royal HaskoningDHV
Enhancing Society Together

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Signature

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Glossary of Terms

Aeolian	Wind-borne – i.e. referring to wind-borne and deposited materials, and erosion caused by wind
Alluvial Fan	An alluvial deposit that is typically fan-shaped that is formed by a stream or watercourse where its velocity is abruptly decreased, as at the mouth of a ravine or at the foot of a slope
Alluvial Material / Deposits	Sedimentary deposits resulting from the action of rivers, including those deposited within river channels, floodplains, etc.
Azonal	A type or class of vegetation with physical and vegetative characteristics that are a response to localised edaphic (soil related) factors such as volumes and duration of activation of water and salts, rather than to macroclimatic and geological patterns on a landscape level, that would normally be the determining factors for vegetation community development. In such cases the stresses and problems that plants would encounter in a wetland or saltmarsh environment, for example, are sufficiently unique and in some cases so extreme that only highly adapted species that are sufficiently enabled to deal with those stresses and problems are encountered in these environments, thus forming their own typical vegetation composition.
Baseflow	The component of river flow that is sustained from groundwater sources rather than from surface water runoff
Calcrete	A type of rock cemented together by calcareous material, formed in soils in semi-arid conditions
Cumulative impact	The impact of an activity that in itself may not be significant but may become significant when added to the existing and potential impacts eventuating from similar or diverse activities or undertakings in the area.
Environmental Impact Assessment (EIA)	In relation to an application to which scoping must be applied, means the process of collecting, organising, analysing, interpreting and communicating information that is relevant to the consideration of that application as defined in NEMA.
Ephemeral	A river or watercourse that only flows at the surface periodically, especially those drainage systems that are only fed by overland flow (runoff).
Episodic	Relating to rivers and watercourses typically located within arid or semi-arid environments that only carry flow in response to isolated rainfall events
Fluvial	Pertaining to rivers and river flow and associated erosive activity
Herbaceous	A plant having little or no woody tissue and persisting usually for a single growing season
Hydric Soils	(= Hydromorphic soils) Soils formed under conditions of saturation, flooding or ponding for sufficient periods of time for the development of anaerobic conditions and thus favouring the growth of hydrophytic vegetation.
Hydrology	The science encompassing the behaviour of water as it occurs in the atmosphere, on the surface of the ground, and underground.
Interfluve	A watershed.
Opslag	An informal term used in the context of the Karoo to denote non perennial plants that appear seasonally or intermittently, in response to rainfall – e.g. annuals, ephemerals, herbs, weeds, etc.
Phreatophyte	A plant with a deep root system that draws its water supply from near the water table.
Reach	A portion of a river
Rip rap	Broken rock or stone loosely deposited on an exposed surface to provide a foundation and protect the underlying substrate from scour or erosion – this is typically used for

	revetments, embankments, breakwaters, etc.
Riparian Area / Corridor	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
Run	The part of a river channel defined by a moderate current and a smooth surface
Semi-arid	A description of a climatic zone that is not sufficiently dry to be termed arid (arid climates are typically defined as having annual rainfall less than 250mm/year), but which is characterised by very low annual rainfall. Under the Köppen climate classification semi-arid climates are termed at steppe climates – being intermediate between desert climates and humid climates in ecological characteristics and agricultural potential.
Semi-desert	The transition zone between true desert and more mesic (moist) climatic areas, generally receiving annual rainfall in a range between 250 - 500mm/year. In terms of the Köppen climate classification, semi-desert climatic zones are intermediate between the desert climates and humid climates in ecological characteristics and agricultural potential.
Slip-off slope	The gentle slope on the inside bend of a river meander, on the opposite side to a river-cut cliff
Stream Order	A morphometric classification of a drainage system according to a hierarchy or orders of the channel segments. Within a drainage network the un-branched channel segments which terminate at the stream head are termed as “first order streams”
Understorey	The part of the forest / woodland which grows at the lowest height level below the canopy
Wrack (Flood Wrack)	Material (primarily vegetative) that is transported along watercourses and rivers during floods, and which is typically deposited behind structures or large vegetation by the flood waters, especially at levels higher than the typical flow levels.

Glossary of Terms

BSP – Biodiversity Sector Plan

CBA – Critical Biodiversity Area

CSP – Concentrated Solar Power

DWS – Department of Water and Sanitation

EIA – Environmental Impact Assessment

EIS – Ecological Importance and Sensitivity

FEPA – Freshwater Ecosystem Priority Area

FSA – Fish Support Area

HTF – Heat Transfer Fluid

NFEPA – National Freshwater Ecosystem Priority Areas

NWA – National Water Act 36 of 1998

PES – Present Ecological State

PV – Photovoltaic

RHDHV – Royal HaskoningDHV

RoW – Right of Way

VEGRAI – Riparian Vegetation Response Assessment Index

WUL – Water Use Licence

Specialist Declaration

I, **Paul da Cruz**, declare that I –

- act as a specialist consultant in the field of Surface Water assessment
- do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed in terms of the Environmental Impact Assessment Regulations, 2010;
- have and will not have any vested interest in the proposed activity proceeding;
- have no, and will not engage in, conflicting interests in the undertaking of the activity;
- undertake to disclose, to the competent authority, any material information that have or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document required in terms of the Environmental Impact Assessment Regulations, 2010; and
- will provide the competent authority with access to all information at my disposal regarding the application, whether such information is favourable to the applicant or not.

PAUL DA CRUZ

EXECUTIVE SUMMARY

1 INTRODUCTION

Solafrica Thermal Energy (Pty) Ltd has appointed Royal HaskoningDHV to undertake an environmental impact assessment (EIA) study for a proposed Concentrated Solar Thermal Power Plant on the farm Sanddraai 391, near Groblershoop in the Northern Cape Province. As part of the undertaking of the environmental studies for the proposed development, a surface water study has been identified as one of the studies that are required to be undertaken. A surface water scoping study was undertaken in late 2014, and this report investigates the affected surface water environment and the potential impacts associated with the proposed development in greater detail.

The project is located in the Northern Cape, an arid to semi-arid part of South Africa. In this context drainage systems and their associated riparian zones are highly sensitive and environmentally important, in particular the Orange (Gariep) River that flows through the study area. Although the majority of the smaller watercourses are not typically characterised by active flow of water or the presence of hydric (wetland) soils, riparian corridors of watercourses in this area are a critical component of the surface water drainage environment, as they are often distinct from the surrounding terrestrial environments in terms of their species composition and physical vegetative structure. In the context of a semi-arid environment, the sensitivity of these surface water features is largely related to different biodiversity assemblage that characterises them. These features are critical for the sustaining of ecological processes as well as human livelihoods through the provision of water for drinking and other human uses. As such surface water resources and wetlands are specifically protected under the National Water Act, 1998 (Act No. 36 of 1998) and generally under the National Environmental Management Act, 1998 (Act No. 107 of 1998). In the context of the development of a solar power plant and associated infrastructure, the physical disturbance of these drainage systems and their riparian zones constitutes an important potential surface water-related impact. This report thus focuses on the identification of surface water features on the development site and surface water-related issues and potential impacts arising from the proposed development.

1.1 Aims of the Study (Project Terms of Reference)

The aims of the study are to:

- Assess the affected surface water features within the footprint of the solar power plant components and within the alignment of linear infrastructure in the field, to determine their physical characteristics and associated sensitivity.
- Delineate all riparian zones that are within the footprint of the proposed infrastructure.
- Determine the nature and degree of risk posed to surface water features by solar power plant and associated infrastructure
- Recommend suitable mitigation measures to ameliorate identified impacts.
- Comparatively assess alternatives and recommend preferred alternatives from a surface water perspective.

1.2 Assumptions and Limitations

This report has not assessed the potential impact of abstraction on the Orange River, as it is understood that this is being assessed under the auspices of a separate study.

This report has been prepared to support the EIA application, but has does not fully meet the requirements for the Water Use Licence (WUL) for the solar power plant development. Undertaking the water use licence for the proposed development does not form part of the scope of works of RHDHV and although this report will be able to form the basis of the WUL surface water technical report, it does not fully meet the requirements of such a report in that all surface water crossings have not been individually assessed. This would need to form part of separate scope of works.

It has been assumed that the PV (Photovoltaic) components of the proposed development have been removed from the scope, and thus do not need to be assessed.

The field assessment was undertaken in December 2015 at a time when the study area had received very little rainfall. There was accordingly very little to no annual vegetation ("opslag") present and much of the non-woody vegetation (such as grasses) displayed no active growing parts such as inflorescences. This has not allowed a number of non-woody species in the riparian corridors assessed to be identified, thus lowering the confidence of the riparian vegetation response assessment (VEGRAI) to a degree.

1.3 Definition of Surface Water Features, Wetlands and Hydric Soils

1.3.1 Surface Water Features

In order to set out a framework in which to assess surface water features, it is useful to set out what this report defines as surface water resources. In this context National Water Act 36 of 1998 (NWA) is used as a guideline. The Act includes a number of features under the definition of water resources, i.e. watercourses, surface waters, estuaries and aquifers. The latter two do not apply as estuaries are marine features and this report does not consider groundwater, thus surface waters and water courses are applicable in this context. The Act defines a watercourse as (inter alia):

- 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

The definition of a water course as used in the Act is taken to describe surface water features in this report. It is important to note that the Act makes it clear that **reference to a watercourse includes, where relevant, its bed and banks**. This is important in this report, as the riparian habitat associated with most linear drainage features in the study area have been included as an important part of surface water features and are thus given consideration in this report.

It is equally important to note that the Act does not discriminate on the basis of perenniality, and any natural channel, however ephemeral, is included within the ambit of water resources. This definition is applied in this report.

It should be noted that no wetlands were encountered in the study area due to the arid nature of the climate.

1.3.2 Riparian Habitat and Riparian Zones

The National Water Act defines riparian habitat as:

"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"

As detailed in the Department of Water and Sanitation (DWS – formerly DWA and DWAF) 2005 guidelines for the delineation of wetlands and riparian areas, riparian areas typically perform important ecological and hydrological functions, some of which are the same as those performed by wetlands (DWAF, 2005).

Riparian areas include plant communities adjacent to and affected by surface and underground water features such as rivers, streams, lakes, or watercourses. It is important to note that these areas may be a few metres wide along smaller systems or more than a kilometre in floodplains. Both perennial and non-perennial streams support riparian vegetation (DWAF, 2005).

Because riparian areas represent the interface between aquatic and upland ecosystems, the vegetation in the riparian area may have characteristics of both aquatic and upland habitats. Many of the plants in the riparian area require large volumes of water (moisture) and are adapted to shallow water table conditions. Due to water availability and rich alluvial soils, riparian areas are usually very productive. Tree growth rate is high. This is certainly the case in riparian zones in the arid western interior of South Africa, as they typically contain trees and shrubs of a height, density and species diversity that is not present in the surrounding terrestrial habitats.

Riparian areas are important as they perform the following functions (DWAF, 2005):

- Storing water and thus assisting to reduce floods
- Stabilising stream banks
- Improving water quality by trapping sediment and nutrients;
- Maintaining natural water temperature for aquatic species;
- Providing shelter and food for birds and other animals;
- Providing corridors for movement and migration of different species;
- Acting as a buffer between aquatic ecosystems and adjacent land uses;
- Can be used as recreational sites; and
- Providing material for building, muti, crafts and curios.

These ecosystems may be considered 'critical transition zones' as they process substantial fluxes of materials from closely connected adjacent ecosystems (Ewel *et al*, 2001).

As discussed below riparian habitat is important from a legislative perspective – in terms of the National Water Act. Section 3.2 of this document should also be referred to for a synopsis of the VEGRAI (Riparian Area Characterisation and Assessment) Template.

1.4 Legislative Context

The following section briefly examines the legislation that is relevant to the scope of the surface water assessment. The stipulations / contents of the legislation and policy that is relevant to the study are explored.

1.4.1 The National Water Act

It is important to note that water resources are protected under the National Water Act 36 of 1998. 'Protection' of a water resource, as defined in the Act entails:

- Maintenance of the quality of the quality of the water resource to the extent that the water resource may be used in a sustainable way;
- Prevention of degradation of the water resource
- The rehabilitation of the water resource

In the context of the current study and part of the remit of the study to assess the impact of the proposed development on surface water features, the definition of pollution and pollution prevention contained within the Act is relevant. 'Pollution', as described by the Act is the direct or indirect alteration of the physical, chemical or biological properties of a water resource, so as to make it (inter alia)-

- Less fit for any beneficial purpose for which it may reasonably be expected to be used; or
- Harmful or potentially harmful to the welfare or human beings, to any aquatic or non-aquatic organisms, or to the resource quality.

The inclusion of physical properties of a water resource within the definition of pollution entails that any physical alterations to a water body, for example the excavation of a wetland or changes to the morphology of a water body can be considered to be pollution. Activities which cause alteration of the biological properties of a watercourse, i.e. the fauna and flora contained within that watercourse are also considered pollution.

In terms of section 19 of the Act owners / managers / people occupying land on which any activity or process undertaken which causes, or is likely to cause pollution of a water resource must take all reasonable measures to prevent any such pollution from occurring, continuing or recurring. These measures may include measures to (inter alia):

- Cease, modify, or control any act or process causing the pollution
- Comply with any prescribed waste standard or management practice
- Contain or prevent the movement of pollutants
- Remedy the effects of the pollution; and
- Remedy the effects of any disturbance to the bed and banks of a watercourse

Accordingly the identification of mitigation measures for all identified impacts is important.

One of the key principles on which the National Water Act, as promulgated to replace the Water Act of 1956, was formulated was that that surface- and groundwater systems are indivisible from each other (le Maitre et al, 1999). This is important in the context of this report, as the larger drainage systems (especially the Orange River) and their associated vegetation communities are understood to be sustained by the presence of not only surface water, but shallow groundwater which is very closely linked to surface water.

1.4.1.1 The National Water Act and Riparian Areas

Riparian habitat is afforded protection under the National Water Act in a number of ways. Firstly reference in the National Water Act to a watercourse includes its banks, on which riparian habitat is encountered. Riparian areas are thus afforded the same degree of protection as the rivers and channels alongside which they occur.

Riparian habitat is also important in the context of resource quality objectives that are a critical part of the Act. In terms of section 13(1) of the Act resource quality objectives must be determined for every significant water resource, and are central part of data type specifications relating to national monitoring systems and national information systems as determined in section 137(2) and section 139(2) of the Act respectively. Under Section 27 of the Act resource quality objectives must be taken into account in the issuing of any licence or general authorisation, and form a critical part of the duties of catchment management agencies. The purpose of resource quality objectives in the Act is to establish clear goals relating to the quality of the water resources. Resource quality is important in the context of riparian habitat as resource quality as defined in the Act means the quality of all aspects of a water resource and **includes the character and condition of the riparian habitat**. In terms of Section 26(4) of the Act, the need for the conservation and protection of riparian habitat must be taken into account in the determination and promulgation of regulations under the Act.

1.5 Bioregional and National Conservation Planning Context

1.5.1 National Freshwater Ecosystem Database

The National Freshwater Ecosystem Priority Areas (NFEPA) Database has been analysed in order to determine whether any of the potentially-affected surface water resources on the development site have been classified as being nationally or regionally important.

The NFEPA database is a result of a process to develop cross-sector policy objectives for conserving South Africa's inland water biodiversity, which led to the definition of a national goal for freshwater conservation policy in South Africa: "to conserve a sample of the full diversity of species and the inland water ecosystems in which they occur, as well as the processes which generate and maintain diversity" (Driver *et al,* 2011). The project provided strategic spatial priorities for conserving South Africa's freshwater ecosystems and supporting sustainable use of water resources. These strategic spatial priorities are known as Freshwater Ecosystem Priority Areas, or **FEPAs**.

The NFEPA database has designated sub-quaternary catchments of importance, or priority catchments. This catchment approach is derived from a focus on sustainable development, given the current and future pressures on water resources. Protection and utilisation of natural resources need to work hand-in-hand to achieve sustainable development. In the context of water resources management, this means that catchments can be designed to support multiple levels of use, with natural rivers and wetlands that are minimally-used supporting the sustainability of hard-working rivers that often form the economic hub of the catchment. This concept is firmly embedded in the National Water Act, and forms the foundation of the water resources classification system (Dollar et al. 2010). Keeping some rivers and wetlands in the catchment in a natural or good condition serves a dual purpose of conserving South Africa's freshwater biodiversity and promoting the sustainable use of water resources in the catchment.

A number of different FEPA types are relevant to the current study:

- **River FEPAs** - River FEPAs achieve biodiversity targets for river ecosystems and threatened/near-threatened fish species, and were identified in rivers that are currently in a good condition (A or B ecological category - refer to section 3.2 below and Figure 10 for the EcoStatus classes). 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.
- **Wetland FEPAs** - Wetland FEPAs were identified using ranks that were based on a combination of special features and modelled wetland condition.
- **Wetland Clusters** - Wetland clusters are groups of wetlands embedded in a relatively natural landscape. This allows for important ecological processes such as migration of aquatic biota between wetlands.

It is important to note that for River FEPAS, management of the catchment is also important; although FEPA status applies to the actual river reach within such a sub-quaternary catchment, surrounding land and smaller stream networks need to be managed in a way that maintains the good condition (A or B ecological category) of the river reach. These are known as **Phase 1 FEPA catchments**.

Phase 2 River FEPAs and associated catchments have also been designated. Phase 2 FEPAs were identified in moderately modified rivers (C ecological category), only in cases where it was not possible to meet biodiversity targets for river ecosystems in rivers that were still in good condition (A or B ecological category). River condition of these Phase 2 FEPAs should not be degraded further, as they may in future be considered for rehabilitation once FEPAs in good condition (A or B ecological category) are considered fully rehabilitated and well managed.

FEPAs related to fish sanctuaries and fish support areas have also been created. These are rivers that are essential for protecting threatened and near-threatened freshwater fish species that are indigenous to South Africa, and are mapped at the level of the quaternary catchment. Quaternary catchments are designated as Fish Sanctuaries or Fish Support Areas (FSAs).

1.5.1.1 Site Analysis

The reach of the Orange River that flows adjacent to the development site has not been designated as a wetland FEPA, as it does not meet the PES status criteria for wetland condition (it has been assigned a wetland condition of C – moderately modified - refer to section 3.2 below and Figure 10 for the EcoStatus classes). No wetland clusters occur in the study area. Similarly the Orange River also does not meet the river condition criteria for designation as a River FEPA, as it has been assigned a status of C – moderately modified. However it has been designated as a Fish Support Area and Fish Sanctuary based on the presence of the fish species *Barbus* *anoplus.* The river would not ordinarily be designated as a fish sanctuary due to its moderately modified condition, but it qualifies as a FSA as it has been identified as a translocation area identified for the threatened fish species. In the light of this categorisation the impacts of any development on this river should be considered of national importance, and should be avoided or adequately mitigated.

1.5.2 Provincial / Bioregional Context

The Northern Cape does not have a provincial-level bioregional plan that designates CBAs. Accordingly the Namakwa District Municipality (NDM) Biodiversity Sector Plan (BSP) must be used to investigate whether any parts of the study area have been designated as CBAs; although the study area does not fall within the Namakwa District Municipality, the NDMBSP can be used to investigate whether the study area falls within any CBA, as the rea of designation extends up the Orange River corridor from the west. Under the NDMBSP the Orange River riparian corridor qualifies as a CBA due to the presence of the Lower Gariep Alluvial Vegetation type which is classified as a threatened ecosystem (refer to Section 4.1.3 below).

2 PROJECT DESCRIPTION

2.1 Project Technical Description

Solafrica Energy (Pty) Ltd (Solafrica) is currently assessing the feasibility of constructing a Concentrated Solar Plant with a maximum generation capacity of 150 MW based on Central Receiver technology including all associated infrastructure with a maximum generation capacity of 150 MW on the farm Sanddraai 391. The proposed plant is required to be sited on a technically and environmentally feasible site and to this end, Solafrica has considered land availability, land use capability, fuel availability and costs, grid connection proximity, capacity and strengthening, and other aspects related to the feasibility of solar power sites.

The CSP plant using central receiver technology will consist of the following components:

- A solar collection field of heliostats;
- A heat transfer fluid system with thermal storage option; and
- A power block (incl. steam cycle, steam generator, cooling system).

The footprint of the proposed plant is approximately 1000ha in total. The facility will also include ancillary infrastructure in support of the power plants including water abstraction systems, waste management systems, power lines, roads, storage facilities, administration and operation buildings, construction laydown areas and temporary housing facilities.

The fundamental principle of CSP technologies is to collect the energy carried by sunrays, allowing a heat transfer fluid (HTF) to absorb the collected energy and thereby converting the thermal energy into further useful forms such as electricity (refer to Figure 1).

The process of energy conversion in a CSP plant is illustrated in Figure 2. Since a thermal intermediary is always involved, a conventional steam power turbine generator can be coupled for power generation. Energy storage is possible either in thermal form (e.g.: steam, molten salt) or as electrical energy (e.g. batteries). Losses occur throughout the energy conversion process.

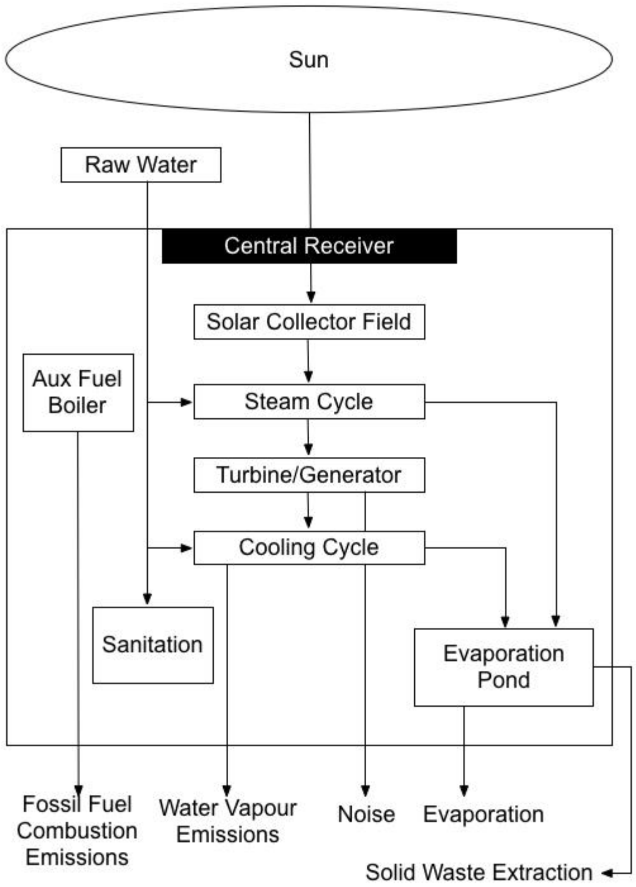

Figure 1 - Overview of the central receiver technology

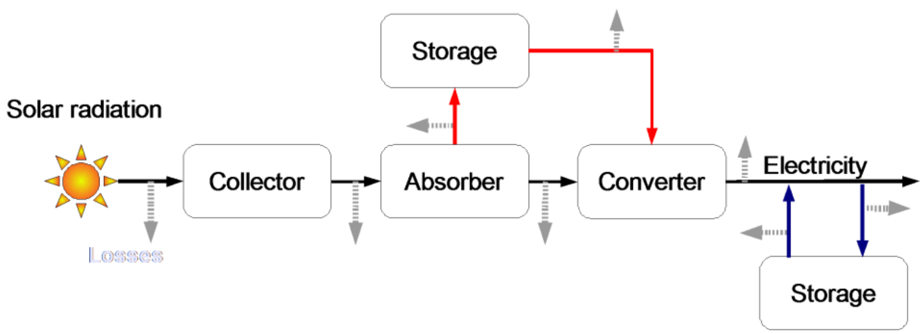

Figure 2 - Schematic of the energy conversion in a CSP plant. Storage is optional (Red – thermal energy; Blue – electrical energy; Grey - losses)

CSP technologies can be categorised by two concentrating methods according to the receiver types where sunrays are reflected to a point as in central receiver (Figure 3), a line receiver as in parabolic trough (Figure 4) or linear fresnel (Figure 5) technology.

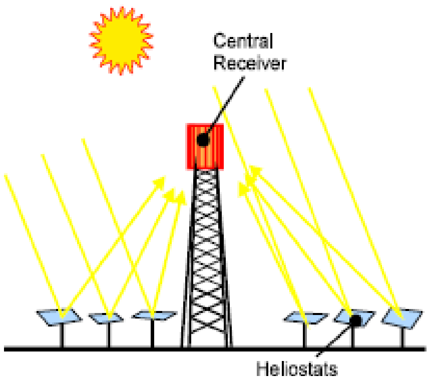

Figure 3 - Central Receiver

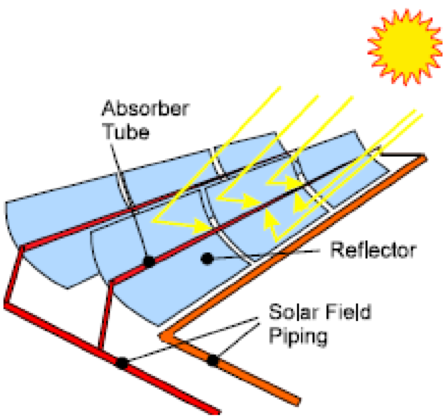

Figure 4 - Parabolic trough system

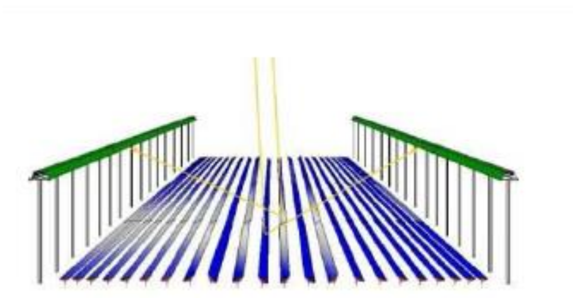

Figure 5 - Linear Fresnel

The HTF may be thermal oil (parabolic trough), molten salt (parabolic trough/central receiver/linear fresnel) or direct steam (parabolic trough/central receiver/linear fresnel) for the transportation of thermal energy. A thermal oil application is more commonly found in existing parabolic trough plants, molten salt and direct steam solutions are used in existing central receiver plants, and direct steam is used in existing linear fresnel plants although molten salt examples are emerging. The receivers, reflectors, HTF and the associated supporting structures make up the solar field. The design of the solar field is the core to the CSP technology. It is also the differentiator amongst the vendor designs.

Figure 6 – An example of a central receiver CSP Plant as viewed from the N10 Highway near the Upington Airport

2.2 Site Location and Description

The Study Site is located within the central part of the Northern Cape Province, being located to the north-west of the town of Groblershoop and to the south-east of Upington in the !Kheis Local Municipality. The development site is rural in nature, with intensive cultivation occurring in a narrow strip alongside the Orange River. The remainder of the development site and surrounding area comprises of rangeland (used for rearing of livestock (sheep and cattle) and game that consists of sparse natural semi-desert vegetation.

The development site is uninhabited, with the only permanent human habitation being located along the Orange River corridor and its immediate surrounds, concentrated around the Sanddraai Farmstead. The Bokpoort Solar Power Plant is located to the east of the site (refer to Figure 8 below), and represents a very large-scale power generation development that is resulting in development of large-scale industrial infrastructure over a large footprint and the concomitant transformation of the affected area from a natural state.

A number of linear infrastructure features are located in the vicinity of the development site; a district road – the Gariep Road – that runs from the N8 highway (located to the south of the development site), running east of the Orange River to the N14 highway bisects the south-western part of the development site. This road provides local access to properties on the eastern bank of the Orange River as it flows northwards towards Upington. The Sishen-Saldanha Iron Railway runs through part of the development site, crossing the Orange River close to the Sanddraai Farmstead. Lastly a 132kV power line bisects the southern part of the development site, running in an east-west orientation. The Study area is indicated in Figure 7 below

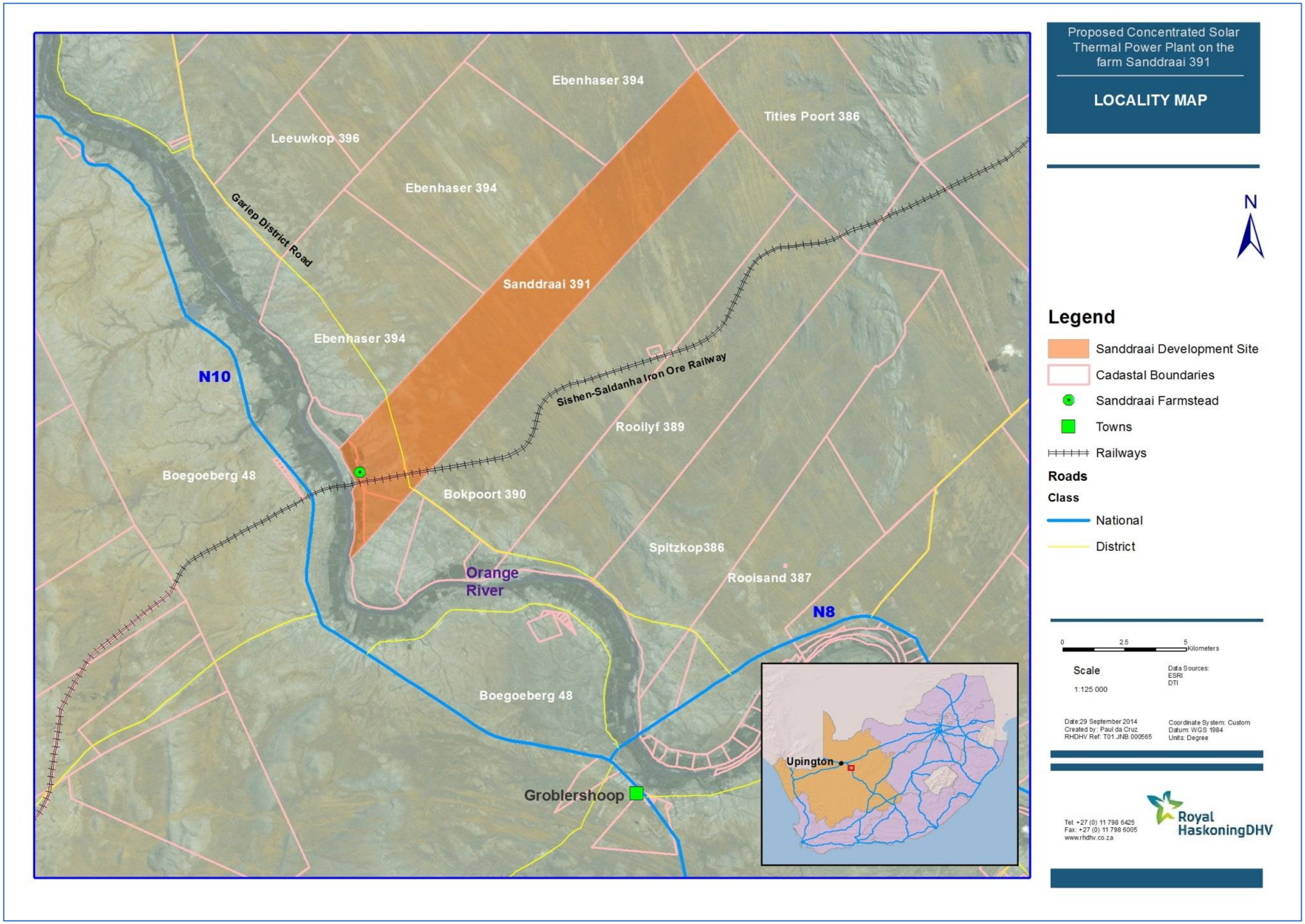

Figure 7 – Study Area

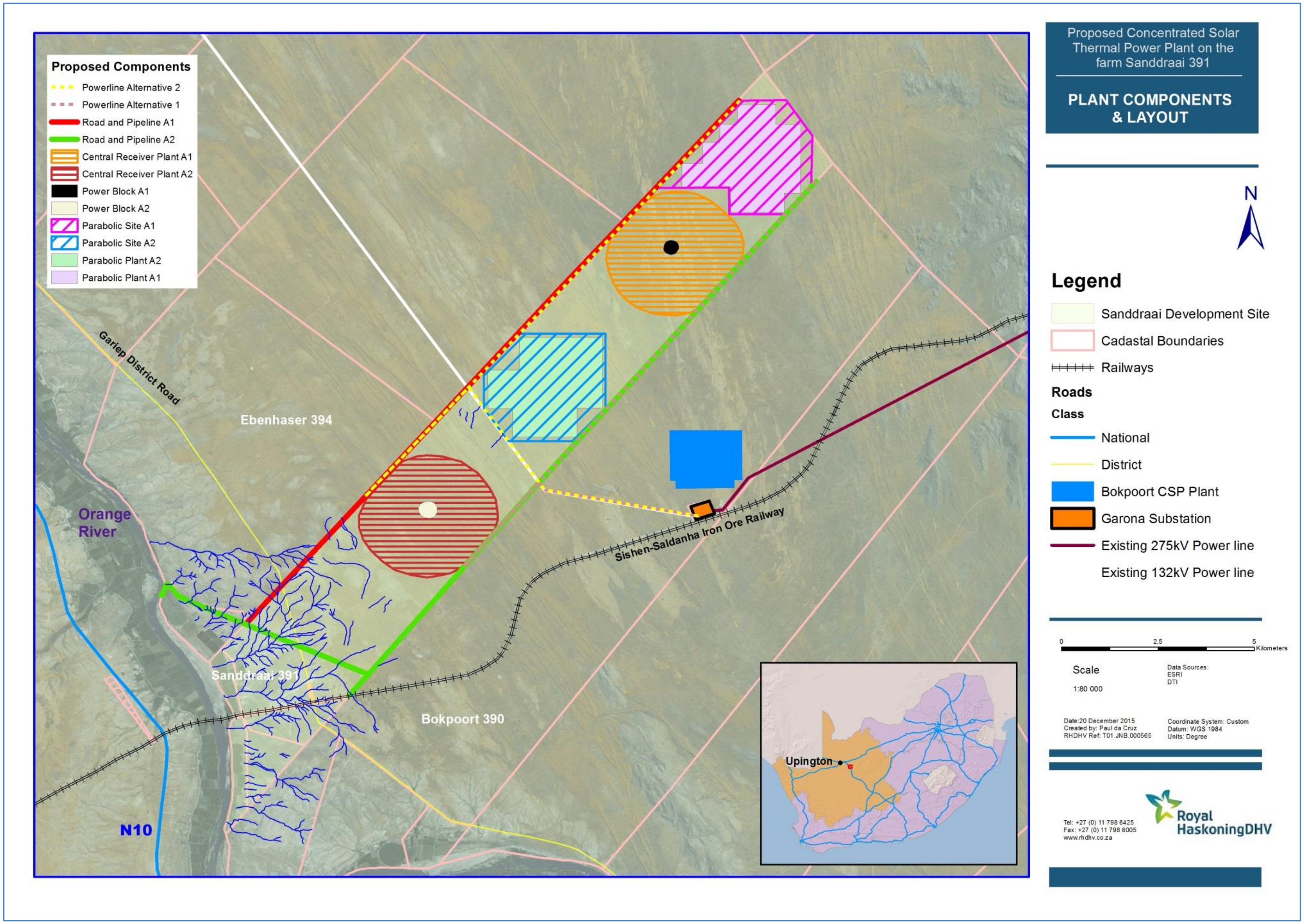

Figure 8 – Proposed Development Component Alternatives

3 METHODOLOGY FOR ASSESSMENT

3.1 Field Assessment and Riparian Zone Delineation

Surface water features crossed by the proposed pipeline and road alternative alignments were visited in the field and a VEGRAI EcoStatus Tool assessment was undertaken for the larger watercourses, as described below. Use was made of a GPS to identify important points (e.g. boundaries of zones within the riparian corridors). These GPS points were converted into a GIS shapefile to allow these points to be mapped and to enable the creation of the GIS shapefile of riparian boundaries.

3.2 Riparian Area characterisation and assessment template

The VEGRAI (Riparian Vegetation Response Assessment Index) assessment methodology (Kleynhans *et al*, 2007) was utilised as the primary tool to assess the riparian corridors of the ephemeral watercourses, as well as the Orange River. With the exception of the Orange River, all surface water features potentially affected by the proposed pipeline are ephemeral watercourses. The most important vegetative and structural feature of these watercourses is their riparian corridor, and as such the VEGRAI tool was used to assess these features.

This section briefly introduces riparian zones in terms of the hydromorphological and vegetation classification as per the VEGRAI (Riparian Vegetation Response Assessment Index) assessment methodology (Kleynhans *et al*, 2007), which has been used to classify riparian zones in this report.

In terms of the VEGRAI structure, riparian areas / corridors are divided into three (3) vegetation zones:

- Marginal Zone
- Lower Zone
- Upper Zone

This vegetation zone classification has been based upon:

- Periodicity of hydrological influence
- Marked changes in lateral elevation or moisture gradients
- Changes in geomorphic structure
- Changes in plant species distribution or community composition along lateral gradients

In spite of these zones being vegetative, they are also distinguished based on a combination of other factors including geomorphic structure and elevation along with vegetation. Elevation within the riparian zone is used as a surrogate for hydrological activation, which is taken to be moistening or inundation of the substrate by water in the channel. The figure below (from Kleynhans *et al*, 2007) indicates a typical riparian zone:

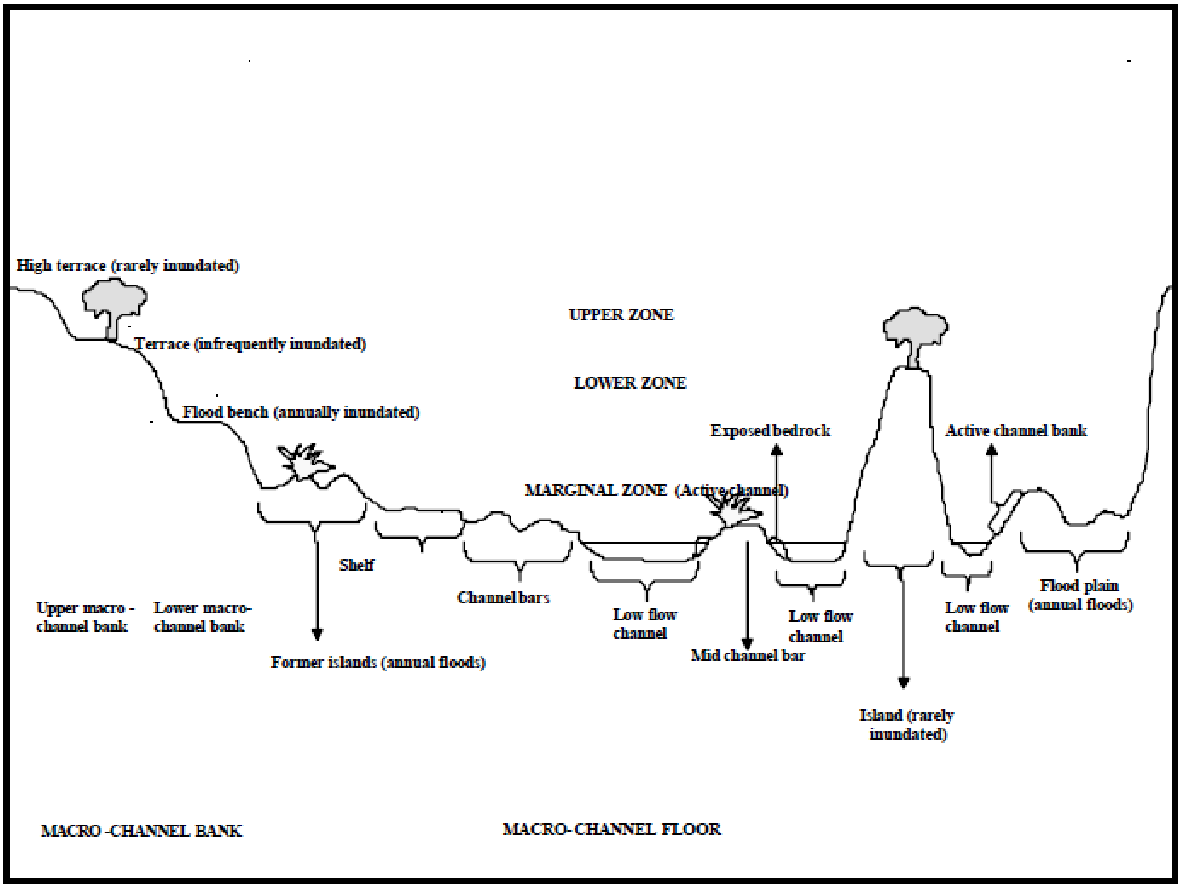

Figure 9 – Schematic diagram indicating the three zones within a riparian area relative to geomorphic diversity (Kleynhans et al, 2007)

3.2.1 Marginal Zone

The marginal zone incorporates the area from the water level at low flow (where present – if flow is not present areas that would be subject to baseflows would be included) to those features that are more or less permanently inundated. Vegetatively the marginal zone is typically characterised by the presence of hydrophytes that are vigorous in terms of abundance due to the near-permanent availability of moisture. In the context of the ephemeral watercourses on the site the marginal zone is typically restricted to the narrow active channel.

3.2.2 Lower Zone

The lower zone is the area of seasonal inundation (hydrological activation in this context is yearly inundation during high flows, or every 2-3 years), extending from the edge of the marginal zone to the point at which there is a marked increase in lateral elevation. This change in elevation may or may not be characterised by an associated change in species distribution patterns.

It is important to note that for the ephemeral watercourses on the development site the lower and upper zones have not been delineated due to the nature of the hydrology and associated infrequency of inundation of parts of the riparian corridor beyond the active channel. In essence the lower zone as defined in the VEGRAI template is not present and the riparian corridor not located within the active channel can be considered to comprise the upper zone.

3.2.3 Upper Zone

The upper zone is characterised by hydrological activation on an ephemeral basis (less than every 3 years) and extends from the end of the lower zone to the end of the riparian corridor. The upper zone is usually characterised by steeper slopes and the presence of both riparian and terrestrial species, the latter typically having an enlarged structure as compared to the areas outside of the riparian area.

The note above regarding the zonation of the riparian corridors of the ephemeral watercourses has reference.

VEGRAI uses a number of metrics (measurement or ratings) for different riparian characteristics to define and rate riparian state:

- Abundance (how much indigenous vegetation there is under present condition)
- Cover (a measure of the extent to which the ground is covered by vegetation, and is measured as canopy cover)
- Recruitment (the arrival and establishment of new individuals into riparian populations / communities)
- Population structure (the relative abundance of life stages within respective populations of selected indicator species)
- Species composition (the arrangement of species in the riparian community that comprise the riparian assemblage in the study area)

All of these characteristics of riparian areas can be measured in terms of the level of divergence from what would be considered a reference state. Reference conditions for riparian zones are usually natural, i.e. conditions prior to significant human interaction with riparian structure and function. It is important that reference state be defined in terms of an understanding of the nature of impacts on a riparian corridor.

The VEGRAI methodology has defined six (6) different types of riparian vegetation to guide assessments of reference state:

- Tree-dominated state,
- Shrub-dominated state,
- Grass-dominated state,
- Herbaceous-dominated state,
- Reed-dominated state,
- Open-dominated state (substrate such as sand/rock).

There are degrees of flux between these different states that may be influenced by impacts on the riparian zone – e.g. the removal of woody vegetation from the riparian zone.

The key impacts that act on riparian zones include:

- **Vegetation Removal** – resulting in increases in water temperature, effecting aquatic primary production, and adversely affecting the ability of riparian areas to retain water
- **Exotic Invasion** – resulting in displacement of indigenous species and subsequently to a change in ecosystem properties, bank instability due to the exclusion of natural riparian vegetation due to vigorous growth, decrease of organic input, or a reduction in riparian habitat diversity
- **Water quantity change** (change in volume and seasonality of flows) – resulting in increased stream widths or down cutting of the streambed that can lead to the loss of riparian vegetation
- **Water quality change** – resulting in impacts on indigenous riparian plants and possible excessive growth of exotic riparian vegetation in the case of eutrophication.

Riparian zones can be divided up into a number of generic ecological categories based on their state of degradation (EcoStatus), as indicated in the figure below. The VEGRAI EcoStatus Tool ascribes riparian reaches assessed into one of the following EcoStatus classes.

ECOLOGICAL CATEGORY	DESCRIPTION	SCORE (% OF TOTAL)
A	Unmodified, natural.	90-100
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.	80-89
C	Moderately modified. Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.	60-79
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	40-59
E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.	20-39
F	Critically modified. Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible	0-19

Figure 10 – EcoStatus Classes (Ecological categories)

3.3 Identification of Surface Water and Riparian Zone Impacts and Mitigation Measures

All potential impacts that could be caused by the proposed linear infrastructure and that would affect surface water features along the alternative alignments route have been identified. Mitigation measures to either ensure that the identified impact does not materialise, or to ameliorate / limit the impact to acceptable levels have been stipulated.

4 PHYSICAL ENVIRONMENT OF THE STUDY AREA

4.1 Study Area Biophysical Characteristics and how these relate to / affect surface water features

4.1.1 Climate

The study area is located in a semi-arid climatic zone (semi-desert), being located on the boundary between the Great Karoo and the Kalahari semi-desert and receives a mean annual rainfall figure of approximately 215mm (Source: SA Rainfall Atlas Database). There is a relatively strong seasonality in the rainfall figures, indicating that the area falls within the summer rainfall areas within the subcontinent; most of the rainfall occurs in the late summer / autumn between the months of January and April. The scarcity of rainfall and nature of precipitation also entails that rainfall events are episodic in nature, i.e. single rainfall events will contribute a relatively significant portion of rainfall.

4.1.2 Geology, Macro-geomorphology and Topography

The eastern bank of the Orange River in the vicinity of the study area is characterised by the presence of rocky terrain that rises from an alluvial terrace within the Orange River valley bottom that abuts the channel of the river (this terrace has been subject to intense cultivation). The Orange River corridor is underlain by alluvial sediments of recent geological origin. These sediments are only located in a narrow band along the river. Located immediately adjacent to the Orange River corridor and occupying the most south-westerly part of the development site is a wider band of basement rocks (Quart-muscouite schists, quartzites, quart-amphibole schists and greenstones) of the Brulpan Group of the Groblershoop Formation. Areas underlain by the relatively more resistant quartzites form the low ridges (interfluves) in this area. The terrain in this part of the site is rugged, with widespread outcropping of bedrock rising away from the river, forming a number of low ridges and accompanying shallow small valleyheads. In the southern part of the site the terrain rises to form a local highpoint, with this high ground extending right down to the Orange River on the farm Ebenhaeser 394 to the north where an outer bend of the Orange River has cut into these strata to form low cliffs on the river's eastern bank. The presence of the rocky strata in the south-western part of the site has an important bearing on surface water drainage, as discussed below.

Figure 11 – Low cliffs along the eastern bank of the Orange River formed by outcropping strata of the Brulpan Group on the Ebenhaeser Property

To the east of the Gariep District Road the underlying substrate changes from the Brulpan Group rocks, with a concomitant change in terrain. Most of the site as it extends north-eastwards from the Orange River valley is underlain by siliciclastic rocks of the Kalahari Group, with notable surface outcropping of calcrete. The terrain changes from the incised and more steeply-sloping terrain closer to the river valley to much flatter terrain that is characterised by two prominent landforms – flat calcrete plains and sandy duneveld. The duneveld occupies large parts of the central and north-eastern parts of the site, and is comprised of sand of wind-blown (aeolian) origin. A number of parallel-running longitudinal dunes that are aligned in a north-south orientation are encountered as one moves onto the site, moving away from the Orange River. It should be noted that an inlier of more resistant strata of the Brulpan Group extends across the centre of the development site. This inlier is expressed topographically by a rocky ridge that rises above the surrounding flatter topography, close to where the existing 132kV power lines are aligned across the site.

As described above linear sand dunes are an important topographical feature of the site. These dunes are comprised of aeolian material, having formed from material eroded from sedimentary deposits that was reworked into dunes during drier periods of the geological past. The dunes that occur widely over the Kalahari region that occupies much of the western interior of the sub-continent are comprised of the unconsolidated sands of the Kalahari Group that cover an area of over 2.5 million km^2 (Haddon, 2005). The thickness of these unconsolidated sands varies across the basin, from a few centimetres to over 200m. The dominant landform associated with the sands is the dune fields. Sand dunes throughout the Kalahari Basin are largely stable and are generally classified as relict- or palaeo-forms as dune construction itself is not currently taking place (Haddon, 2005).

The dunes in the South African part of the Kalahari Basin are characterised by partly vegetated linear dunes of 2-15 m in height, dune widths of 150-250 m (Lancaster, 1988, 2000) and are characterised by broad, inter-dune areas which are commonly grassed (Haddon, 2005). These characteristics are present within the study area with a series of dunes aligned in parallel in a broadly northern-southern orientation located on the development site. The dunes on the site were typically observed to be relatively low in height, varying between 2-10m. The dunes are typically well-vegetated, with shrubs and grasses located on the dunes themselves and the flat intervening areas between dunes being well grassed. This dunefield topography has important implications for the occurrence of surface water drainage on the development site as discussed in section 4.2.2 below.

4.1.3 Vegetation Types

A number of vegetation types are encountered on and in the vicinity of the development site. Most important in a surface water (riparian) context is the azonal Lower Gariep Alluvial Vegetation type. This vegetation type in essence comprises the riparian corridor of the Orange River along its lower reaches. The vegetation type is described as comprising of flat alluvial terraces and riverine islands supporting a complex of riparian thickets and reedbeds with flooded grasslands and herblands along sandbanks and terraces (Mucina and Rutherford, 2006). It is important to note that this vegetation type is classified as an ***endangered terrestrial ecosystem*** under the National Environmental Management: Biodiversity Act (Act 10 of 2004). Up to 50% of it has been transformed through agricultural activities and it is also threatened by diamond mining and prospecting and by proliferation of alien invasive vegetation (Mucina and Rutherford, 2006).

Away from the river, the sloping rugged terrain falls into the Bushmanland Arid Grassveld Vegetation Type, described as extensive to irregular plains sparely vegetated by grassland that is dominated by *Stipagrostis* grass species. The central part of the site is comprised of the Gordonia Duneveld Vegetation type (as consistent with the topographical description of the site in section 4.1.2 above). This vegetation type is characterised by parallel dunes rising approximately 3-8m above the plains, with open shrubland and ridges of grassland. The northern-most third of the site is comprised of Kalahari Karooid Shrubland, comprising of low Karooid shrubland on flat, gravel plains.

It should be noted that the ephemeral watercourses located away from the Orange River corridor that are crossed by the proposed pipeline and road alternatives are predominantly located within the Bushmanland Arid Grassveld vegetation type; these are not part of a separate vegetation type to the surrounding terrestrial habitats. The associated riparian corridors of these watercourses accordingly share many characteristics of the surrounding terrestrial habitats, but are divergent in a number of respects such as their species composition, species richness and structure.

4.2 Study Area Surface Water Drainage and characteristics

Rivers and wetlands are very important features of the natural landscape both in a hydrological and an ecological context. The freshwater ecosystems that occur within rivers and wetlands, as well as the associated riparian habitats, are very important in the context of biodiversity, as unique plant and animal communities occur within them. This is particularly important in the context of the semi-arid Great Karoo and Kalahari, where the availability of moisture in the vicinity of watercourses has led to the development of vegetation communities distinct from the surrounding terrestrial habitats.

In a macro drainage context, the study site is located adjacent to the Orange River, and thus occurs in the Lower Orange Water Management Area. The study site is located in the D73D quaternary catchment, a large quaternary catchment that encompasses a long reach of the Orange River from Kheis to the east of Groblershoop at the upstream end, to Lambrechtsdrift to the south-east of Upington at its downstream end, as well as a number of non-perennial tributaries of the Orange River along this reach of the river.

4.2.1 Surface Water Typology

Wetlands and surface water features can be found all across a landscape. The landscape can be divided up into a number of units, each of which can contain wetlands. Wetlands occurring on these different terrain units typically differ in terms of their formative processes and hydrological inputs, and thus differ in terms of their functionality.

The classification of surface water type has been based upon the most updated aquatic ecosystem classification system for South Africa – the Classification System for Wetlands and other Aquatic Ecosystems in South Africa (Ollis *et al*, 2013). The system uses a six-tiered approach for classifying inland aquatic systems, including wetlands. Levels 4 and 5 (hydrogeomorphic (HGM) unit and hydrological regime respectively) are the focal points of the classification system – i.e. these describe the functional unit (Ollis *et al,* 2013). Table 1 below indicates the tiered classification for the different types of surface water features along the proposed alignment.

Table 1- Tiered classification for the different types of surface water features along the proposed alignments

<table>
<tr><th></th><th>Level 1 – System</th><th>Level 3 – Landscape Unit</th><th>Level 4 – HGM Unit</th><th>Level 4B – River longitudinal zonation</th><th>Level 5A – Hydrological Regime</th><th>Level 6 – Other descriptors</th></tr>
<tr><td>Orange River</td><td rowspan="2">Inland</td><td rowspan="2">Valley Floor</td><td rowspan="2">River</td><td>Lowland River</td><td>Perennial</td><td rowspan="2">-Natural
-Salinity – Freshwater
-Substratum Type – Mix of bedrock and alluvial material</td></tr>
<tr><td>Ephemeral Water-courses</td><td>Transitional</td><td>Ephemeral / Episodic</td></tr>
</table>

A number of surface water features can be classified as rivers rather than wetlands, due to the nature of their hydrology which is characterised by flow within a defined channel with limited or no diffuse flow and limited lateral water inputs, with overtopping of the channel occurring during large spate / flow events.

Rivers are classified in terms of the classification system by a number of sub-level descriptors, of which the most important are the level 4 river longitudinal zonation and the hydrological regime. Under the hydrological regime only the Orange River is perennial whilst all other watercourses on the study site are non-perennial in character.

The affected reach of the Orange River falls into the Lowland River longitudinal class, as defined by the NFEPA Rivers database. Such rivers are typically characterised by a gradient of 0.0001–0.0010 and typically have a low-gradient, alluvial sand-bed channel. These drainage systems are often confined, but fully developed meandering pattern within a distinct floodplain develops in unconfined reaches where there is an increase in silt content in bed or banks (Ollis et al, 2013).

The ephemeral watercourses are too small to appear on the DWS rivers base, but are best described as fitting into the transitional longitudinal class as they display a channel (with a mix of bedrock-dominated substrate and alluvial material) and occur within confined valley heads, although in terms of their stream order would theoretically be classified as mountain headwater streams.

4.2.2 The Orange River

The primary surface water feature on the site is the Orange (Gariep) River, which runs in a north-south orientation adjacent to the development site. This river is the largest river in South Africa and one of the larger rivers on the southern African subcontinent. The river drains a very large catchment comprising of much of the interior plateau of South Africa, rising in the highlands of Lesotho just west of the continental divide. The river is thus a mature river as it passes the site.

The present-day course of the Orange River was formed over a geological timespan through the capturing of the upper reaches of the palaeo-Karoo River by the palaeo-Kalahari River in the Cretaceous Period (Partridge *et al,* 2010). Towards the end of the Cretaceous period the palaeo-Kalahari River drained the western interior of southern Africa. A second major system, the palaeo-Karoo River drained the eastern highlands and flowed southwest, draining into the sea near the present day Olifants River mouth on the Atlantic coast. Uplift along the Griqualand–Transvaal axis, together with the westward tilting of the interior, resulted in the capture of the upper reaches of the palaeo-Karoo River by the palaeo-Kalahari River, forming the present-day Orange River course. The section of the Orange in the study area is part of the course of the palaeo-Kalahari River.

A classification for characterisation of rivers based on the geomorphic features has been developed, and South Africa has been divided into a number of geomorphic provinces (Partridge *et al*, 2010). Geomorphic provinces have been defined as similar areas containing a limited range of recurring landforms that reflect comparable erosional, climatic and tectonic histories and they impose broad constraints on lower levels of organisation (Partridge *et al,* 2010). The section of the Orange River in the study area falls into the Lower Vaal and Orange River Valleys Geomorphic Province. The Augrabies Falls, located downstream of the site (to the northwest) constitutes a major knickpoint in the Orange River, separating the two phases of down cutting (Miocene and Plio-Pleistocene). Upstream of Augrabies hard rock barriers create steps within a fairly flat, concave longitudinal profile (Partridge *et al*, 2010). This is true of the study area as the river flowing northwards in the study area consists of a series of rocky outcroppings that create shallow rapids, interspersed with runs. The average valley cross-sectional width of the Orange River is considerably narrower than its tributaries, but it is also significantly flatter, so that the sediment storage surrogate descriptor is medium (Partridge *et al*, 2010).

Although the Orange River in the study area forms part of a longer reach that is not meandering, two meanders occur just north of the Sanddraai Farm. These two meanders have resulted in the creation of a westward-eroding outer bank between the Saalskop (on the western bank) and Sanddraai farmsteads and associated depositional area (slip-off slope) on the opposite (eastern bank). This has resulted in the development of extensive sand flats partly colonised by *Phragmites australis* reedbeds on the eastern bank of the river from the railway bridge north onto the neighbouring Ebenhaeser property. The river then turns back eastward, incising into the resistant outcropping strata as described in section 4.1.2 above.

The riparian zone of the river is located beyond the active channel. The cross-sectional profile of the riparian zone of the river varies, depending on whether the point along the reach is located on an inner out outer bed. In the part of the reach near the Sanddraai Farmstead, the riparian zone is characterised by a wide, flat flood bench (sand flats referred to above) located just beyond the active channel. This flood bench consists of alluvially-deposited silt, with little mature riparian thicket vegetation, rather open areas and silt banks or areas of dense *Phragmites australis* reedbeds. Where the river bends back in an eastward direction to the north of the Sanddraai Farmstead, the riparian zone becomes much narrower and more steeply sloping from the edge of the active channel, rising up from a much narrower flood bench characterised by reedbeds (that is even absent in certain places) through a series of steeper slopes and terraces to the top (outer edge) of the macro-channel bank. Beyond this macro-channel bank a wide alluvial terrace is located on which cultivation and orchards have been established. The current edge of the riparian zone ends at the start of this terrace (where the orchards and fields start), but under natural conditions the riparian zone is likely to have extended onto the floodplain terrace, which has now been completely transformed.

Figure 12 – Typical structure of the upper part of the riparian zone close to the current Ebenhaeser abstraction point where the riparian zone is narrow and more sloping, characterised by riparian thickets on alluvially-deposited material

A section of the riparian corridor of the Orange River is proposed to be traversed by the pipeline and road alignment from the proposed abstraction point. The impact of this proposed pipeline on the riparian corridor of the affected reach is discussed and assessed in section 7.3.2 below.

4.2.3 Ephemeral Watercourses

Away from the Orange River, no surface water drainage features characterised by perennial flow are encountered in the study area. Thus all surface water drainage features (watercourses) are episodic or ephemeral in nature, being characterised by highly intermittent flows of short duration that are directly related to precipitation events of sufficient volume and intensity to result in surface flows. Such precipitation events do not commonly occur in the study area due to the arid climate.

Very importantly the presence of surface water drainage on the development site is strongly dependent on slope and substrate. Surface water drainage was observed to be most pronounced in the south-western-most quarter of the site characterised by rocky terrain that rises from the alluvial terrace within the Orange River valley bottom. A number of first order watercourses of short length with very small catchments rise in this incised terrain located behind (to the east and north of the Sanddraai Farmstead) and flow down to the Orange River valley bottom. These watercourses are narrow features that are typically characterised by a very shallow channel that has eroded into the underlying rocky substrate, with a poorly to moderately developed riparian zone depending on the size of the catchment of the watercourse; along the smaller first order watercourses the channels are flanked by *Senegalia (Acacia) mellifera* shrubs with no larger trees that characterise the larger watercourses with larger catchment areas in flatter terrain (such as are found on the Sanddraai Farm to the south of the rail bridge). Along the slightly larger lower order watercourses more developed riparian vegetation is encountered with a dense but narrow zone of *Senegalia (Acacia) mellifera* shrubs and scattered *Ziziphus mucronata* trees along the bank. The channels of these larger watercourses are characterised by a sandier, more defined channel.

These downstream ends of these watercourses have been significantly physically modified as they enter the zone of intense cultivation within the Orange River valley bottom. The larger watercourses have been channelised as they drain through the cultivated fields and vineyards, with extensive to near-complete removal of the naturally-occurring riparian vegetation, and reworking of the banks of the watercourses. A number of the smaller watercourses have been modified even further, with the natural structure of the drainage line on the valley bottom terrace (whether a channel or alluvial fan-type depositional feature) having been completely modified / removed. These watercourses now ‘terminate’ at the outer edge of the cultivated alluvial terrace, being physically blocked at this point, and no drainage structure remains in the cultivated zone between the edge of the footslopes and the current edge of the Orange River riparian zone. One such watercourse of more natural morphological structure within the Orange River valley bottom terrace was encountered (crossing Alt1-2_2). As it enters the terrace in the outer part of the valley bottom, it became increasingly incised as it neared the Orange River riparian corridor, with evidence of deposition of fluvially-transported material in the exposed bank profiles.

A number of these watercourses in this rugged south-western part of the development site are crossed by the proposed pipeline and road alternative alignments, as these alternatives are aligned parallel to the Orange River valley. The potential impact of the pipeline and road on these watercourses is discussed in section 7.3.1 below.

A major change in drainage density and occurrence was noted on the majority of the site located at a further distance from the Orange River. As described above most of the site to the north-east of the Gariep District Road is comprised of flatter topography than the area closer to the river, comprising of duneveld and certain areas of flat calcrete plains. As described above the duneveld is comprised of low, parallel-aligned dunes, with intervening flat areas of sandy substrate covered in a grassy vegetation cover. No surface water drainage was observed in this duneveld, except in the vicinity of the ridge in the central part of the site as described below. The combination of a highly permeable substrate (sandy material), flatter topography and the presence of parallel-aligned dunes prevents the development of surface drainage features that would under normal circumstances be aligned westwards / south-westwards towards the Orange River valley bottom. The dunes are aligned perpendicularly to the natural direction of drainage and thus block surface water drainage towards the valley bottom. Where flat calcrete plains are located (in the northern third of the development) no visible surface water features were encountered. No pans or depressions were noted on the site either.

Only in the vicinity of the ridge along which the existing power line servitude is aligned is surface water drainage present in the central part of the development site. A small drainage line of similar characteristics to the smaller drainage lines encountered in the rugged terrain closer to the Orange River as described above was noted. The presence of this drainage line is due to the sloping terrain of the ridge hillslope which naturally promotes surface flows and accompanying incision. It is important to note that this course of this watercourse is short, as it drains into a flat area lying behind a dune, and dissipates as it reaches the dune. It should be noted that no components of the CSP layout are located in this central part of the site and thus these short watercourses are unlikely to be physically affected. However the alignment of the proposed power line crosses these watercourses but these will be able to be spanned.

4.2.3.1 Hydrology and Morphology of Ephemeral Watercourses in the study area

All watercourses on the study site with the exception of the Orange River are ephemeral / episodic. Flow regimes of rivers within the wider Succulent Karoo (a biome to the south-west of the study site, but with a similarly arid climate) are highly erratic with prominent temporal and spatial variability in flows even in the larger rivers (Le Maitre, *et al*, 2009). The nature of the soils in the catchments of watercourses and riparian areas, especially with respect to clay soils, entail that soil or mineral crusting (dispersed clay particles can form a 'cap' that significantly blocks infiltration into the soil – Esler *et al*, 2010) tends to be prevalent in overgrazed, bare areas. This has the result that when rainfall events occur there is a high degree of surface water runoff into the drainage systems, due to the reduced infiltration capacity in the soil. As a result the riverine habitats are naturally unstable and are subject to unpredictable flooding events, with consequent high levels of disturbance and soil movement (Palmer and Hoffamn, 1997). This is likely to be the case in the study area, as described above, as much of the study area is underlain by a rocky substrate and structured soils, on which a soil cap may have developed.

No evidence of active surface water flow was noted along any of the watercourses assessed in the field away from the Orange River, and all are likely to be strictly episodic, flowing only in response to rainfall events of sufficient duration and intensity. Evidence of periodic flow along these watercourses is provided primarily by the presence of wrack that is deposited on the upstream side of obstacles in the path of the watercourse, in particular the fence lines along which most of both pipeline alternative route run. In this context wrack is the (primarily vegetative) material washed down river courses during flood / spate flow events, and which is trapped behind branches and other obstacles, remaining in situ after the flood has passed. The evidence of wrack beyond the active channel indicates that these areas were inundated by flood waters and gives a good indication of the extent of higher / spate flows along the rivers in the study area. Although the presence of wrack does not provide an indication of the frequency of flooding, it does give an indication that a spate flow did occur along the water course, and the position of the wrack horizontally away from the channel, and vertically above the channel bed indicates the extent of the flooding and the volume of water that passed along the system, and is a reliable indicator of the extent of maximum hydrological activation and as such is a good indicator of the lateral extent of the riparian zone.

Figure 13 – Example of a watercourse along Alternative 1 (Crossing Alt1_15) with a very poorly defined channel and riparian vegetation

Rainfall events of sufficient intensity are associated with significant runoff, and results in flows along the river systems for short periods of time. Once overland flow from the catchment area drops off, surface flows typically respond by decreasing and ceasing. Surface water is typically transpired into alluvial sediments, or is lost to evaporation. This hydrological regime of no surface baseflow punctuated by short-lined flow events in response to rainfall is typical of ephemeral watercourses, as found across the study area.

There is likely to be an interrelationship between groundwater and surface water in the watercourses of this semi-arid area. Although no extensive alluvial deposits were observed along any of the ephemeral watercourses in the study area, there is likely to be some form of hydrological connection between the watercourses and groundwater, albeit on a small scale.

In a hydromorphological context most of the watercourses assessed in the field contained a main (active) channel, a feature of most fluvial systems. The high stream order of certain of the watercourses crossed by the pipeline alternatives is indicated by the relatively lack of incision and lateral extent of most of the channels of the watercourses crossed. The largest watercourse crossed (Crossing Alt2_22) was characterised by a relatively un-incised central channel. Fluvial channels were not noted to be subject to significant degrees of channel bank erosion. Active channels were characterised by a sandy, alluvial substrate with little vegetative cover, or alternatively areas of bedrock outcropping. This alluvial substrate is likely to shorten the period of flow within the system following a rainfall event, as it would enhance the ability of overland flow entering and flowing down the system to permeate into the substrate.

Figure 14 – The largest of the ephemeral watercourses (Crossing Alt2_22), displaying a more defined channel and more developed riparian vegetation

The reaches of ephemeral watercourses along the pipeline / road route were not noted to be morphologically impacted by any anthropogenic factors except for certain that are crossed by farm access roads or by the Gariep District Road, contrary to the high state of modification closer to the Orange River valley (see section 4.2.2 below). A short section of the affected reach of these watercourses has been transformed by the track / road.

4.3 The Orange River Riparian Zone

The Orange River riparian zone is assessed in this report as a section of the proposed water pipeline is proposed to run within the riparian zone of the river from the proposed abstraction point, and thus riparian vegetation is likely to be removed and cleared.

Morphologically, the riparian corridor of the river is heavily fluvially influenced by flooding along the riverine corridor that results in the deposition of alluvial silt in the bed and banks of the river. The cross-sectional profile of reach of the river close to the proposed abstraction point is characterised by a steep bank that slopes up from the water level to the top of the macro channel bank with no intervening terraces. Behind the top of the macro channel bank lies a wide terrace that has been extensively transformed by agricultural cultivation (orchards) as described in section 4.2.1 above. The access to the water's edge at the abstraction point has cut into the macro channel bank to allow a less steep access to the water level, however the macro-channel bank remains on either side of the concreted access. A number of vegetated gulleys / channels were noted in parts of the reach extending from the edge of the terrace down to the main channel of the river.

The morphological template of the riparian zone is not homogenous, and varies according to factors such as bedrock outcropping and the curvature of the river, with the inner and outer banks differing in terms of degree of deposition versus erosion. Downstream of the abstraction point on the same (eastern) side of the river the riparian corridor narrows and then effectively disappears for a stretch due to the presence of cliffs that rise up from the edge of the active channel. Upstream of the reach assessed the eastern bank of the river is characterised by a wide sandy flood terrace partially occupied by Phragmites reedbeds that extends for a distance from the edge of the active channel.

The vegetation in the riparian zone adjacent to the abstraction point consists of dense thickets of trees and shrubs with a dense understorey. The primary tree and shrub species noted were *Vachellia (Acacia) karroo, Ziziphus mucronata, Rhus lancea, Diospyros ramulosa* and *Lycium cinereum* in the substratum. A dense but narrow stand of the reed *Phragmites australis* is encountered along the water's edge. It was apparent that the riparian vegetation along the reach had been invaded by *Prosopis spp.*, with an estimated 30% coverage of the riparian corridor by alien vegetation, primarily of this species.

5 STATE AND ECOLOGICAL & SENSITIVITY ASSESSMENT

5.1 Riparian Vegetative State

The state of surface water features affected by the proposed road and pipeline has been assessed. The VEGRAI EcoStatus Tool has been used to calculate an ecological category for the eastern bank of the riparian corridor of the affected reach of the Orange River, as well as collectively for the ephemeral watercourses. The ephemeral watercourses crossed by the road and pipeline have been collectively assessed due to their physical and vegetative homogeneity, which is due mainly to their location at the head of small catchments (thus being small first order drainage lines). VEGRAI has been used as the tool to assess state as, due to the nature of these watercourses as ephemeral features, the riparian vegetation is the most ecologically and physically important characteristic, and will be the feature of these watercourses (as that of the Orange River) that is most impacted on by the proposed pipeline and road.

The following riparian zone characteristics (as relevant to the VEGRAI assessment) were noted as part of the assessment:

Orange River Riparian Zone

- Agricultural cultivation is the prominent land use within the Orange River valley bottom that has historically, and continues to exert a significant impact on the riparian zone of the river. Along the outer part of the riparian zone of the affected reach cultivation (orchards) has resulted in an ***extreme degree of modification*** of this part of the riparian corridor that would naturally be expected to extend slightly beyond the edge of the macro channel bank onto the wide flood terrace. In this area all natural vegetation has been removed and this part of the riparian corridor has been totally transformed.
- The vegetative and physical structure of the remainder of the riparian zone appears to be largely intact, except for parts invaded by alien invasive plants and the existing farm abstraction point (where the proposed abstraction point is located) where the riparian vegetation has been cleared and the slope graded and concreted (to form a ramp) down to the river.
- Alien invasive vegetation was present in the riparian zone; coverage of alien species was estimated to be approximately 30% along the reach assessed.
- The marginal zone is comprised of the active channel of the river. A narrow lower zone is comprised of *Phragmites australis* reedbeds. Most of the lateral extent of the riparian zone of the eastern bank of the river is comprised of the upper zone which is characterised by dense riparian thickets. A high degree of coverage of woody vegetation characterises the upper zone of the riparian corridor.

Ephemeral Watercourses

- Stock farming is the prominent land use that would potentially affect the riparian zones of ephemeral watercourses along the proposed alignments. It is difficult to fully assess the degree of impact of stock farming on riparian zones without having a more comprehensive understanding of current levels of rainfall; however this landuse appeared to have a relatively low impact footprint in the context of altering the vegetative composition and morphological structural integrity of riparian zones, with current drought conditions being the main driver of vegetative state.
- An almost complete absence of alien invasive vegetation was noted along the alignment (in terms of the ephemeral watercourses), which is a very important factor in the overall state of these watercourses.
- The marginal zone was limited to the central active channel of the respective watercourses, as the channel is the part of the riparian corridor most likely to be hydrologically activated when surface flow

occurs along these systems. The other parts of the riparian zone would only be hydrologically activated in significant flood events, thus being delineated as the non-marginal zone (i.e. a combination of the upper and lower zones).

- The channels were found to be largely devoid of vegetation, with no woody vegetation present
- Lastly, an assessment of the reference state needed to be made, in relation to the above factors. Overall, the findings of the assessment was that the reaches of the watercourses assessed were relatively undisturbed and thus not greatly altered from a reference state, although the very dry conditions prevalent at the time of the site visit had limited the coverage of non-woody (annual) vegetation..

Table 2 below present the outcomes of the VEGRAI assessment in terms of the ecological category assigned to each of the watercourses assessed.

Table 2 – VEGRAI Ecological Category Scores

Surface Water Features	Level 3 VEGRAI % score	VEGRAI Ecological Category
Orange River Riparian Zone (Eastern Bank)	**74.5**	**C**
All Ephemeral Watercourses	**82.3**	**B**

5.2 Ecological Importance & Sensitivity and Hydrological Importance

The following scores (out of 4) for ecological importance & Sensitivity and Hydrological / Functional Importance have been assigned to the reach of the Orange River riparian zone (eastern bank) and the ephemeral watercourses on the site (collectively):

Surface Water Features	Ecological Importance & Sensitivity	Hydrological / Functional Importance
Orange River Riparian Zone (Eastern Bank)	**2.7**	**2.1**
All Ephemeral Watercourses	**2**	**1.1**

The ecological importance and sensitivity score of 2.7 (out of 4) assigned to the reach of the Orange River riparian zone reflects a riparian zone of moderately high ecological importance and sensitivity. All riparian corridors are ecologically important, due to the ecological linkage provided and due to the ecological processes related to the interface of aquatic and terrestrial habitats that occur within these habitats. The reach assessed displays a relatively higher ecological importance and sensitivity rating for a number of reasons:

- The location of the riparian zone of the river in a highly arid location; the presence of a large perennial river has allowed the development of mature riparian thicket as the predominant habitat type, as well as other habitat types that provide sustained moisture, foraging, breeding and shelter opportunities for fauna. This has allowed a faunal assemblage to be present that would not otherwise be present in this location.
- Relatively intact riparian habitat with a relatively low disturbance factor and high PES score.
- The location of the riparian zone within the Lower Gariep Alluvial Vegetation Ecosystem, which is listed as being nationally endangered.

These factors underlie the ecological importance of the riparian corridor. The riparian corridor is nonetheless sensitive to changes in hydrology as the non-marginal zones of the corridor are highly dependent on flooding that occurs periodically and which deposits fertile sediment within the upper parts of the riparian zone, as well as being dependent on a high water table which sustains the larger trees.

The ephemeral watercourses have been assigned a lower EIS score as the hydrology of these drainage systems is highly episodic and as a result they mostly display a poorly-defined riparian zone in terms of vegetative structure. Nonetheless these systems are still important as movement corridors and do provide foraging, breeding and shelter opportunities for fauna, albeit to a lesser degree than that of the Orange River riparian corridor. The low degree of disturbance to which the assessed reaches of these watercourses have been subjected is another factor that raises the ecological importance of these drainage systems.

6 SURFACE WATER CROSSINGS IN THE STUDY AREA

Twenty-five (25) surface water crossings (including the riparian corridor of the Orange River) along the proposed pipeline and road alignment alternatives have been identified. The surface water crossings associated with the proposed development are indicated in the maps below.

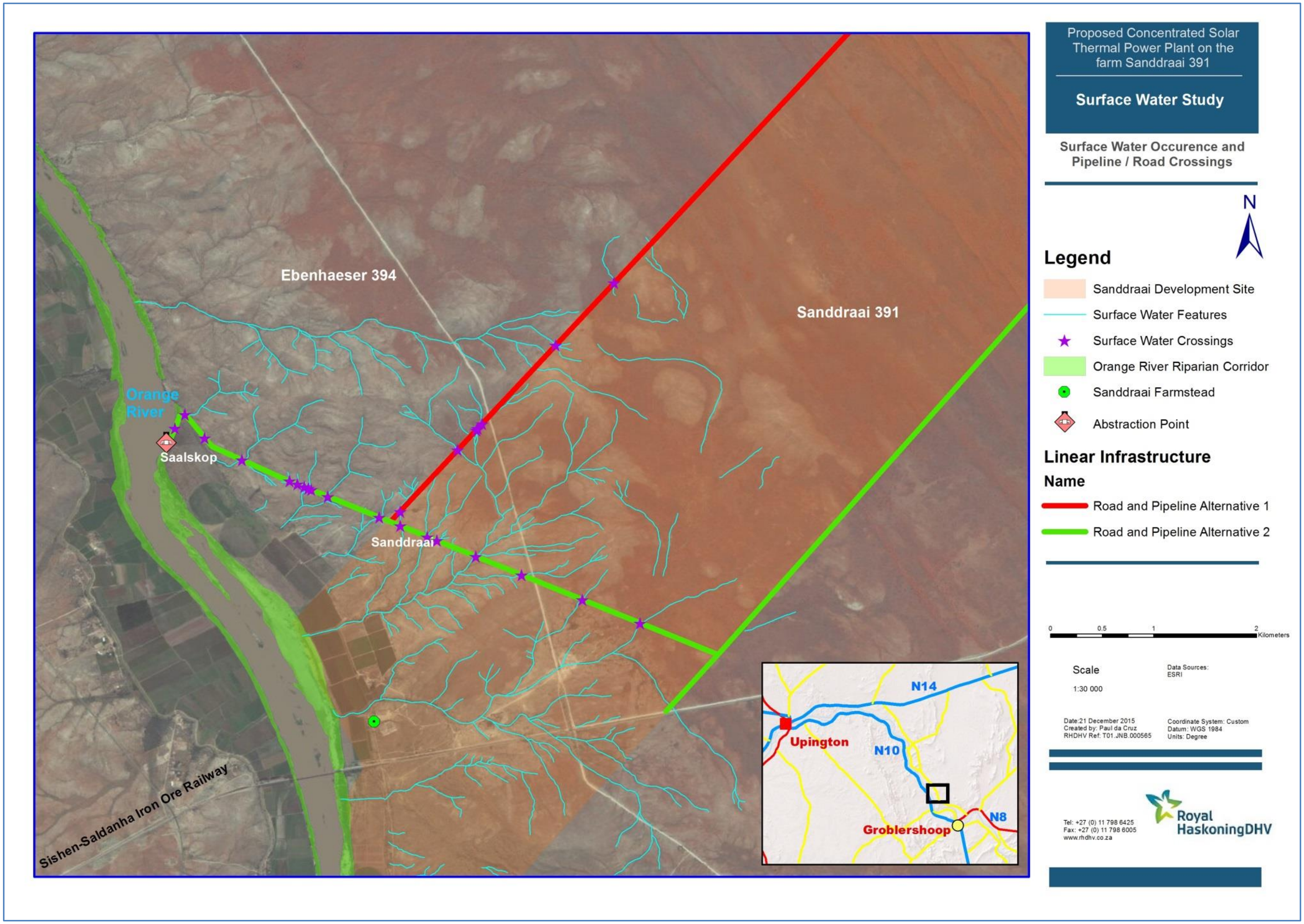

Figure 15 – Surface Water Crossings along the road and pipeline alignments

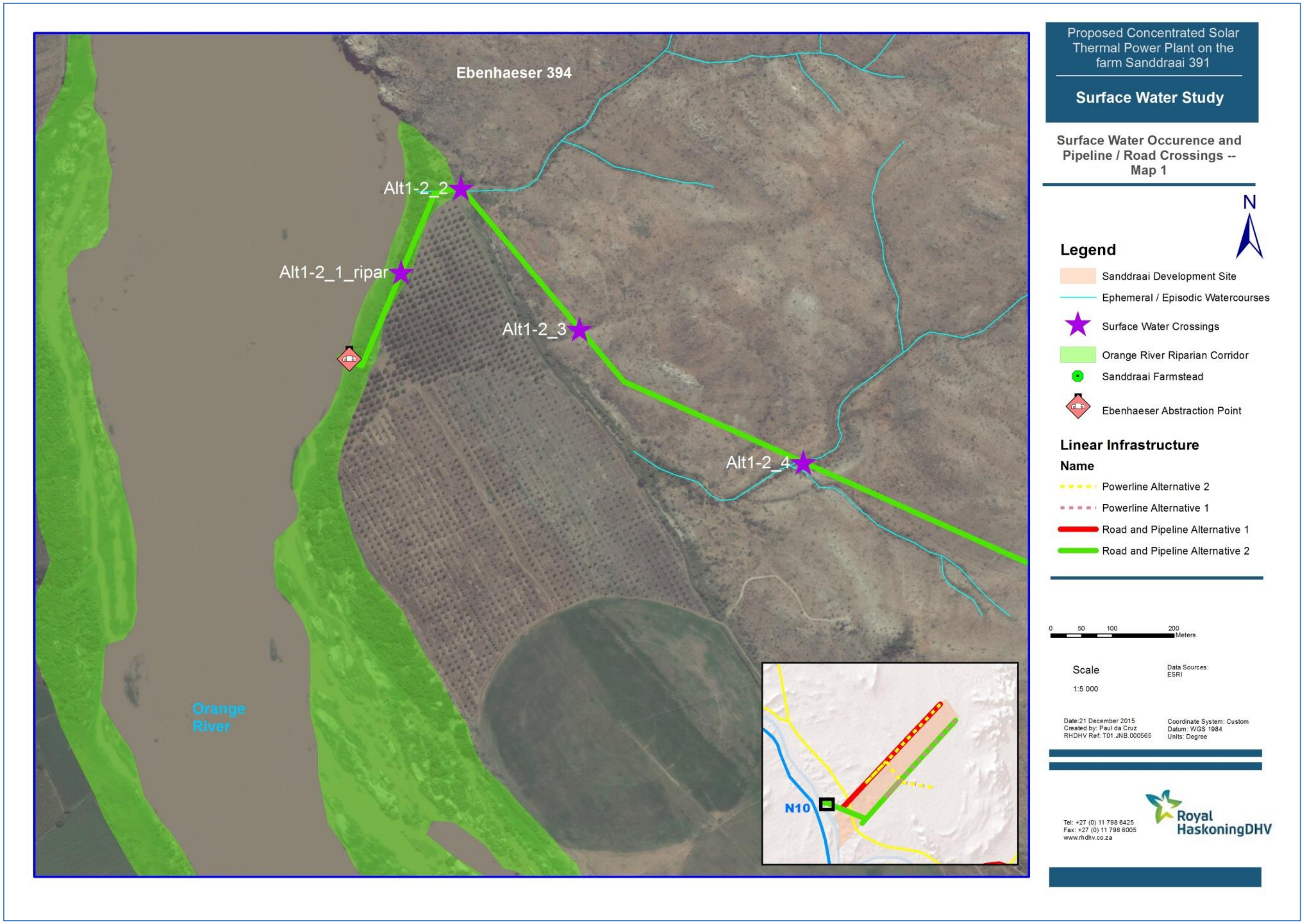

Figure 16 – Surface Water Crossings 1-4

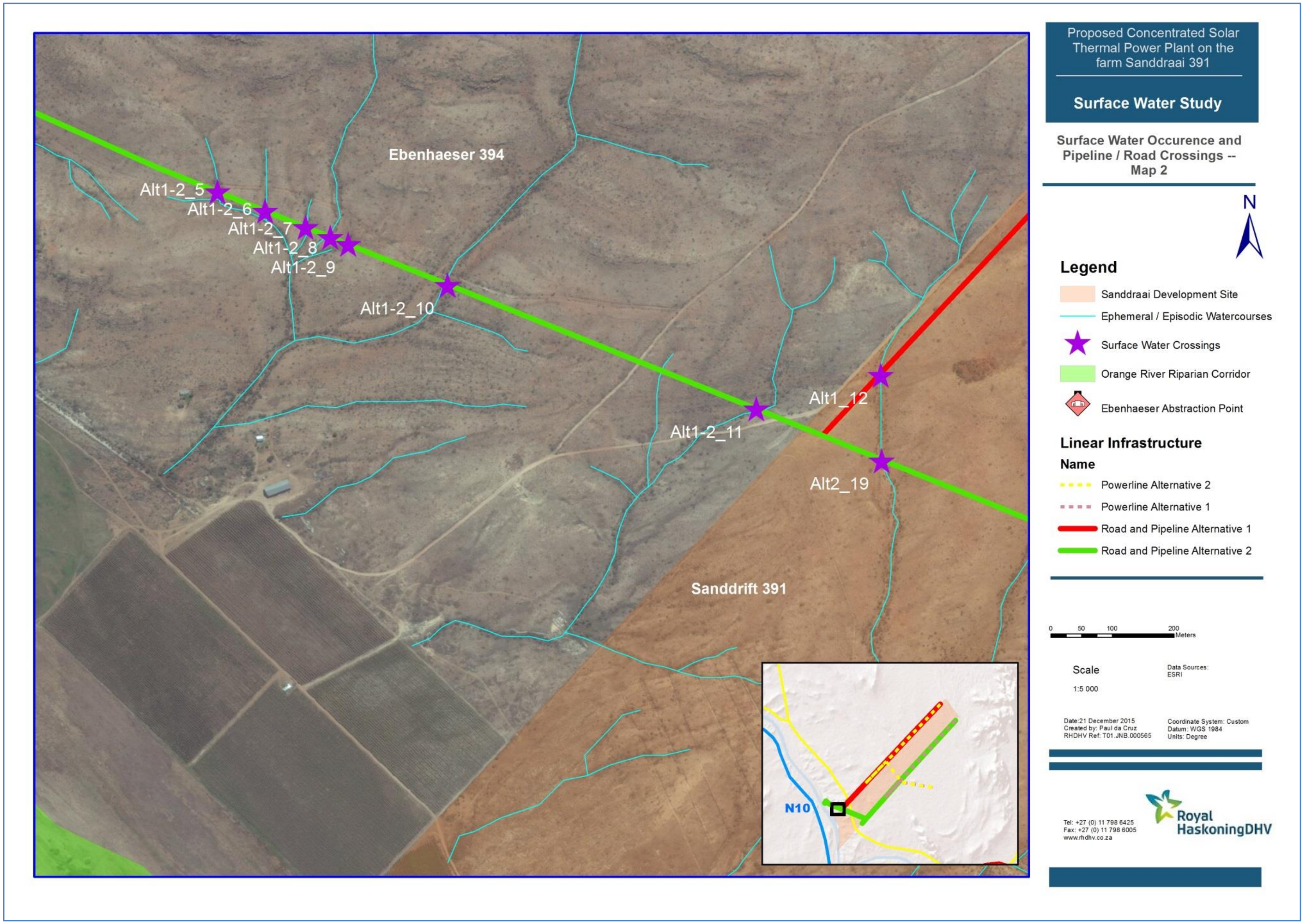

Figure 17 – Surface Water Crossings 5-12

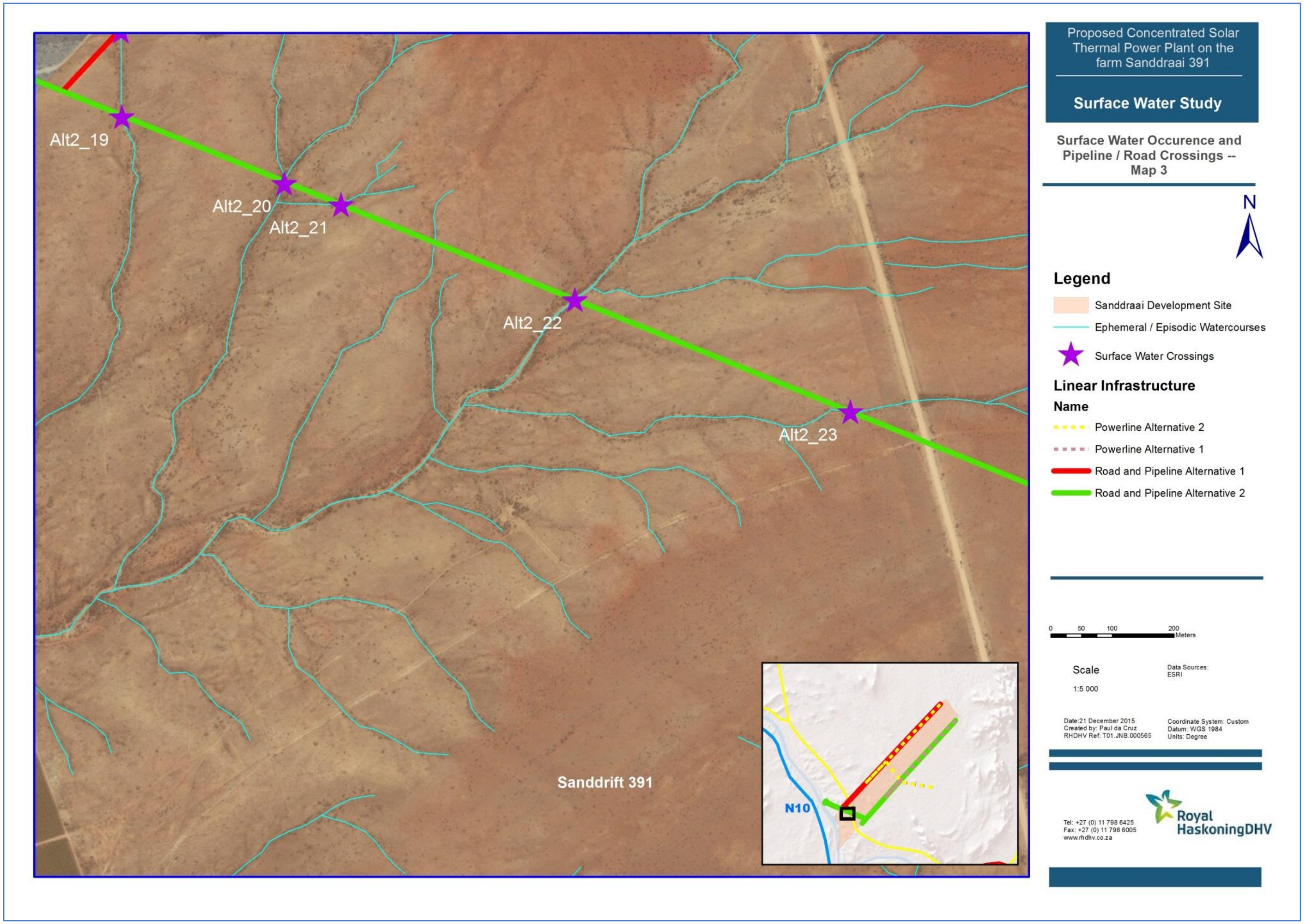

Figure 18 – Surface Water Crossings 19-23

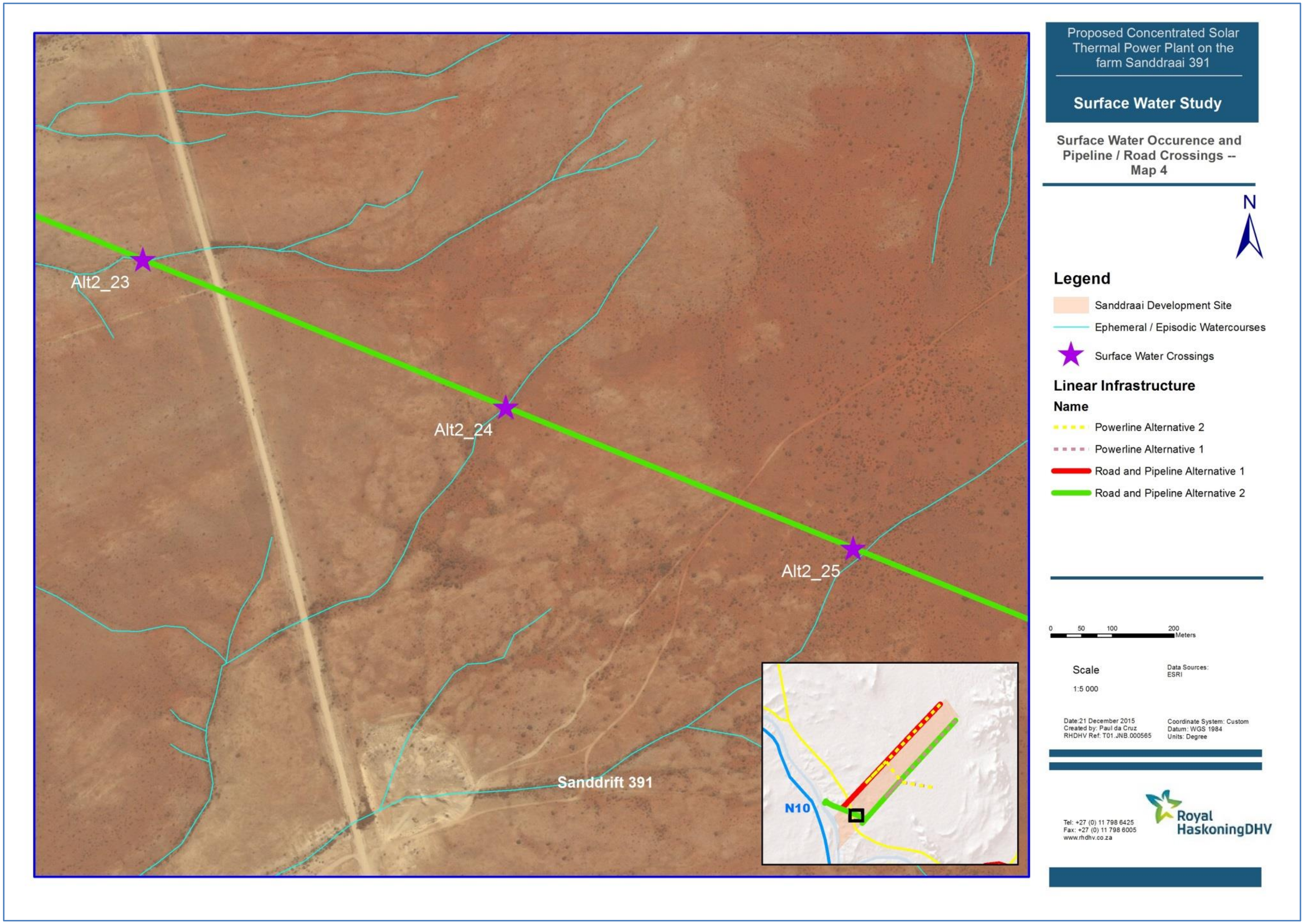

Figure 19 – Surface Water Crossings 23-25

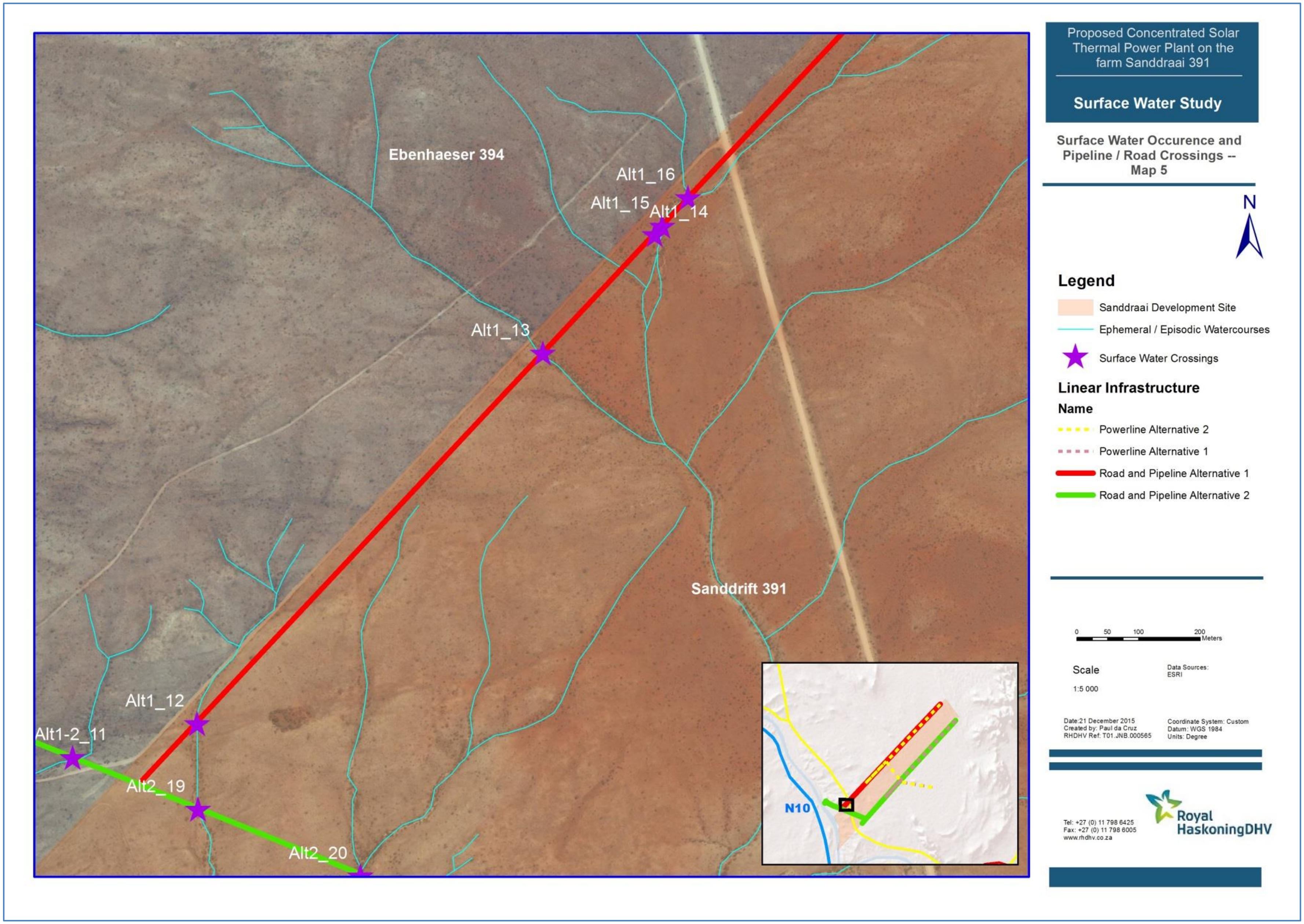

Figure 20 – Surface Water Crossings 13-16

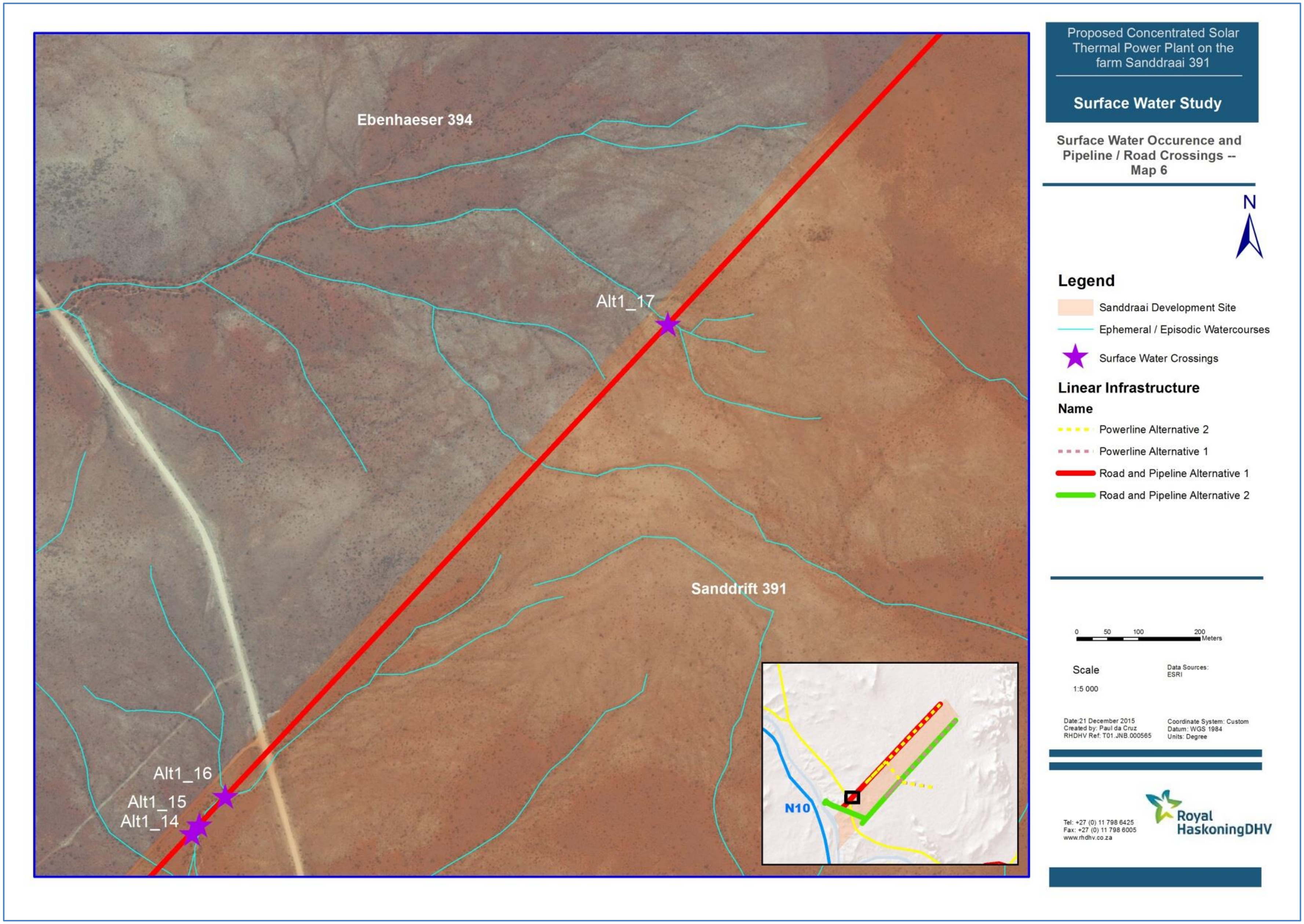

Figure 21 - Surface Water Crossings 14-17

7 IMPACTS AND MITIGATION ASSOCIATED WITH THE PROPOSED DEVELOPMENT

7.1 Impacts associated with the proposed solar power generation (Central Receiver) infrastructure

As discussed in section 4.2.2 above, surface water features are limited to a certain part of the development site – the south-western part of the site located east of the Orange River (including the Orange River itself) and towards the Gariep District Road. The nature of topography (characterised by linear sand dunes and flat calcrete plains) has not been conducive to the development of surface water features in other parts of the site.

The central receiver plant site alternatives of the solar power plant are both located in such a part of the site in which no surface water features are located. The development of either of the central receiver alternatives will accordingly have no physical (footprint) impact on any surface water features.

The associated linear infrastructure, i.e. the road and water pipeline will however exert an physical impact on surface water features located closer to the Orange River valley bottom and on the riparian corridor of the Orange River itself, as discussed in section 7.3 below.

7.2 Impacts associated with the proposed solar power generation (Parabolic) Infrastructure

As discussed in section 4.2.2 above, surface water features are limited to a certain part of the development site – the south-western part of the site located east of the Orange River (including the Orange River itself) and towards the Gariep District Road. The nature of topography (characterised by linear sand dunes and flat calcrete plains) has not been conducive to the development of surface water features.

The parabolic trough component site alternatives of the solar power plant are both located in such a part of the site in which no surface water features are located. The development of either of the parabolic plant alternatives will accordingly have no physical (footprint) impact on any surface water features.

The associated linear infrastructure, i.e. the road and water pipeline will however exert an physical impact on surface water features located closer to the Orange River valley bottom and on the riparian corridor of the Orange River itself, as discussed in section 7.3 below.

7.3 Impacts associated with the proposed pipeline and service road

The linear infrastructure associated with the solar power plant (i.e. the proposed water pipeline and service road which are proposed to run in parallel) will impact a number of ephemeral watercourses and will traverse a section of the Orange River riparian corridor and will thus be the aspect of the proposed development that will have an impact on surface water features. As these two linear developments will run in parallel, they are treated under one section below.

7.3.1 Ephemeral Watercourses

The primary impact associated with the proposed road and pipeline is the disturbance of watercourses and associated riparian zones through excavation of the pipeline and through the laying of the road. The pipeline will be buried, and thus a pipeline trench will need to be excavated across the affected watercourses. This will result in the disturbance of substrate within and immediately adjacent to the watercourses. A trench line and adjacent working right of way will need to be established, thus vegetation in the riparian zone within the footprint of the works will need to be cleared. The creation of a working right of way for machinery and the excavation of a trench would result in the felling and removal of all vegetation, in particular woody vegetation. It is not certain whether the working right of way for the pipeline will be used as the road alignment; if not the development of the road running in parallel would effectively widen the footprint of the affected (cleared) area. This clearing of vegetation would leave the servitude devoid of vegetation after construction, which is important for a number of reasons.

The felling of all vegetation impacts negatively on the structural integrity of the riparian zone. The removal of (woody) vegetation from the servitude is one of the most important impacts on riparian zones that can occur, as it alters the vegetative composition in the affected reach of the watercourse, and exposes the underlying substrate to the risk of erosion – both by water and wind. There would be a low risk of water-borne erosion due to the semi-arid nature of the climate and the highly irregular occurrence of rainfall events. Although the watercourses along the pipeline rarely flow, when flow does occur along these watercourses it is possible that flows of high volume and velocity, although brief in duration, would occur along the watercourses. Such flows would be associated with a relatively high degree of erosive force and this would be greatly exacerbated if vegetation in the servitude was removed, leaving the sandy substrate highly vulnerable to erosion. The occurrence of a flow event through such an un-vegetated area could initiate a ‘knickpoint’ which may lead to development of gulley (donga) erosion into the upstream part of the watercourse or into the adjacent riparian corridor.

Wind-borne erosion would be associated with a higher risk of removal of unconsolidated (unprotected) substrate, especially if the substrate in the riparian zone was of sandy or silty consistency. In arid environments wind can be a significant cause of erosion of unconsolidated substrate. For this reason securing the servitude through measures such a re-vegetation is an important mitigation measure as discussed below.

Importantly the clearing of vegetation introduces another potential impact– that of the invasion of the riparian zone by alien invasive vegetation. This introduces the edge effect which can have an important effect on biota within the riparian zone, and create a very convenient ‘entry point’ into the riparian zone and wider riverine corridor for alien invasive vegetation – such human-related disturbances further exacerbate the natural susceptibility of riparian ecosystems to invasion by alien plants, as the transformed habitat is highly suitable for colonisation by alien invasives, and is less suitable for the less aggressive indigenous riparian species (Holmes et al, 2005). Riparian corridors are particularly vulnerable to invasion by alien plants due to their dynamic hydrology and opportunities for recruitment following floods (Holmes et al, 2005). Servitude clearing is similar in that the cleared area is similar in nature to an area of the riparian corridor where flooding has washed away much of the vegetation. Many alien invaders of riparian habitats in South Africa are tall trees with higher water consumption than the indigenous vegetation (Holmes et al, 2005), and this could affect the vegetation-groundwater balance. Although the actual spatial area of the cleared servitude is likely to be relatively small in the context of the wider riparian corridor, this could create a convenient foothold for the invasion of wider areas of the riparian corridor, and initiate an impact over a much wider area than simply the cleared servitude. No alien invasive vegetation was noted along any of the ephemeral watercourses traversed by the proposed pipeline (with the exception of crossing Alt1-2_2 that is located just outside the edge of the Orange River riparian corridor in which alien vegetation was encountered) and the risk of this impact is deemed to be low, nonetheless this is an impact that could materialise, especially with respect to alien species such as *Prosopis spp.*

The ephemeral nature of these watercourses and the relatively shallow depth of the pipeline trench or road foundations is unlikely to result in the presence of any shallow water tables that would result in seepage in the trench or works area, as it often is in the case of construction through water features. It is unlikely that seepage water will be encountered within the trench or roads work area, as such shallow groundwater is unlikely to be present unless construction occurs immediately following a large flow event.

Apart from the transformative impact of the pipeline and road's footprint as discussed above, the road component could exert a hydrological impact on the watercourses crossed if no culverts or culverts of insufficient diameter are installed in the crossing structure. Due to the ephemeral / episodic nature of the watercourses crossed and due to their physical characteristics as small, high order drainage features, it would seem likely that the road crossing structure would be a drift-type structure, as opposed to a spanning feature. It would be important that such structures allow flow to bypass or underpass them through culverts that are included in the design. Should culverts not be included flows occurring in the watercourse could be impounded behind the structure, not allowing flows into the downstream part of the watercourse. In spite of the high infrequency of surface flows, this could have a significant adverse localised impact as these ephemeral watercourses are likely to depend on flow inputs that drain into the substrate, thus sustaining riparian vegetation. Too few culverts within a crossing structure may have a scouring impact on the downstream channel, although the highly infrequent flows along these systems are likely to obviate the likelihood of such an impact from materialising.

The other potential impact associated with the proposed road, especially if the road is tarred, is the risk of pollutants spilled on the road surface draining into the watercourses crossed. As the road would be used by vehicles, such pollutants are most likely to be hydrocarbons such as oil or petroleum. If such pollutants entered the watercourse and the underlying permeable sandy substrate, this would adversely affect habitat integrity and may pollute shallow groundwater.

A number of factors will determine the intensity of the impact of the pipeline and road construction on each watercourse; the length of the works through each riparian zone affected, the width of the works area, and the physical (especially vegetative) characteristics of the affected riparian zone, and possibly most importantly the current state of modification of the respective watercourses. As discussed in section 4.2.2 above, most of the ephemeral watercourses crossed are narrow, high order drainage systems that do not display a prominent riparian vegetative structure. The largely absent surface water flow and the absence of a distinctive and broad riparian corridor would lessen the intensity of the impact of the road and pipeline on these watercourses. However overall the potentially affected reaches of these watercourses were assessed to be in a largely undisturbed state and thus any impacts (even localised impacts) could adversely affect the state of these drainage systems.

The re-instatement of vegetation within the riparian corridor of the watercourse after the pipeline trench has been reinstated and the road becomes operational is a critical factor in the prevention of impacts during the operational phase on the affected surface water feature. If vegetation is not re-instated after construction, soils would remain exposed. This is exacerbated by the likely operational practice of keeping the pipeline servitude free of large *deep-rooted* woody shrubs and trees that may damage the pipeline through their roots. This is likely to preclude the reestablishment of the larger trees and shrubs over the pipeline trench, i.e. *Senegalia (Acacia) mellifera* and *Ziziphus mucronata.* The inability to re-establish a woody vegetation layer could hinder efforts to re-establish an understorey of grass and other shrubs, although coverage of woody vegetation is not high and the non-woody species that occur in the riparian zones are tolerant of exposure to full sun. Reinstatement of non-woody vegetation within the footprint of the works area and in the road servitude is a very important priority once the pipeline trench has been reinstated. The use of spoil rock in the road reserve, rather than vegetation in the context of the aridity of the climate could be considered as these measures could be more affective to stabilise embankments and other slopes.

Lastly, the incorrect reinstatement of the channel bed and banks within the pipeline servitude could have an impact on the integrity of the riparian zone, and could result in an important hydrological impact. If the channel and banks of the drainage features, as well as features such as flood terraces were not restored to a pre-construction state, this could lead to a permanent alteration of the hydromorphological state of the watercourse and associated vegetation composition. It is important that the cross-sectional channel structure be restored to a pre-construction state as far as possible.

7.3.2 Impacts on the Orange River Riparian Zone

As described above there is an existing abstraction point at the locality at which the abstraction for the plant from the Orange River is proposed, being used for abstraction to supply the local farming (cultivation) activities. As such the riparian zone has been physically modified, with a concreted access to the river having being cut through the macro-channel bank. The placement of an extra pump and associated piping within this modified area is unlikely to further impact the Orange River riparian corridor. However a section of the proposed road and pipeline has been aligned from this point through the Orange River riparian corridor (running northwards), presumably so as to avoid having an impact on the orchards located adjacent to the riparian zone. The road and pipeline would thus exert a physical footprint over the section of the riparian corridor. This would result in loss of riparian habitat (i.e. the loss / transformation of a certain area of largely indigenous vegetation) and the likely re-profiling of certain parts of the affected section of the riparian corridor where the topography within the riparian corridor is not flat. The presence of a road with vehicles accessing the abstraction point would increase noise levels and thus the disturbance factor for fauna sensitive to disturbance, and would constitute a hard barrier separating the riparian corridor from the area behind it. The impacts of the proposed pipeline on the riparian vegetation would be very similar to that on the riparian corridors of the ephemeral watercourses, as discussed above. The practice of keeping the servitude clear of woody vegetation would be very significant in the context of the Orange River riparian corridor, as this would retain the servitude in a state of permanent vegetative transformation and would be highly conducive for the proliferation of alien invasive vegetation in this part of the riparian corridor.

Although this impact would be localised and restricted to the length of the section of the pipeline and road through the riparian corridor, it would in reality be of greater significance for two reasons. Firstly this would constitute part of a cumulative impact on this reach of the river's riparian corridor, considering the likely loss (transformation) of a component of the outer part of the upper zone due to the historical creation of orchards on the flood terrace of the river. An increased area of riparian habitat along the reach would thus be physically and irreversibly transformed. Secondly this impact would take on a great significance as it would affect an *endangered* ecosystem - the Lower Gariep Alluvial Vegetation Type (AZa 3) is listed as an *Endangered* Ecosystem. In this context it is critical that consideration be given to moving the alignment of both the pipeline and the road away from the current boundary of the riparian zone into the adjacent orchard, as discussed further in section 7.5 below.

7.4 Other Potential Construction-related Impacts

The process of constructing the pipeline and road through watercourses could potentially impact these features in other ways through a series of construction-related impacts. The following impacts on surface water features can result from construction activities along the pipeline servitude:

- The uncontrolled interaction of construction workers with watercourses that could lead to the pollution of these watercourses, e.g. dumping of construction material into the drainage system, washing of equipment (in the case of the Orange River) etc.
- The lack of provision of adequate sanitary facilities and ablutions on the servitude may lead to direct or indirect faecal pollution of surface water resources.
- Leakage of hazardous materials, including chemicals and hydrocarbons such as fuel, and oil, which could potentially enter nearby surface water resources through stormwater flows, or directly into the sandy soils within watercourses. This may arise from their incorrect use or incorrect storage. This is not only associated with a risk of pollution of surface water, but with a risk of the pollution of shallow groundwater within the riparian zone due to the presence of typically highly permeable alluvial substratum.
- The incorrect mixing (batching) of cement could lead to siltation and contamination of watercourses, as described above.
- Inadequate stormwater management and soil stabilisation measures in cleared areas could lead to erosion that could cause the loss of riparian vegetation and which would lead to siltation of nearby watercourses.

7.5 Mitigation Measures

7.5.1 Selection of Preferred Alternative and Recommended realignments

- As discussed in section 7.6.1 below it is recommended that Alternative 1 alignment of the road and pipeline be developed as this will lessen the impact of this aspect of the proposed development on surface water features.
- The impact assessment section (7.3.2 above) has detailed the significance of the Orange River riparian habitat transformation that would occur if the road and pipeline under the current alignment were to be developed. It is thus strongly recommended that the road and pipeline be realigned to run *outside of the riparian corridor* within the orchards flanking the riparian corridor to prevent unnecessary habitat transformation of this endangered ecosystem.
- Related to the above recommendation, in the same part of the route it is recommended that a further realignment of the pipeline and road be undertaken to avoid the crossing of the ephemeral watercourse Alt1-2_2 close to the boundary of the Orange River riparian zone. The pipeline and road alignment intersects this watercourse before turning to the east, and by keeping the alignment within the orchards, this will avoid the need for this watercourse to be affected and impacted.

7.5.2 Pipeline and Road Construction

A number of mitigation measures can be specified to minimise impact on the ephemeral watercourses and their associated riparian zones. As an overarching principle, it is very important that these surface water features, although mostly devoid of flow must be recognised as sensitive features, with care being taken to avoid unnecessary impacts on them.

- The footprint of the works area through these watercourses must be kept a narrow as possible, and be restricted to a width that allows construction vehicles and equipment to access the trench line and road construction footprint, with provision made on the opposite side of the trench for stockpiling of excavated substrate.
- The pipeline must be strung outside of the riparian area, and extra space for stringing the pipeline must not be created within the works area within the riparian zone of watercourses.
- Both the trench line and working right of way must be clearly demarcated prior to any construction occurring through the affected watercourse.
- No stockpiles or lay down areas must be established in the riparian zone of any watercourse along the pipeline.
- No storage areas for hazardous materials must be located within 100m of the outer edge of a riparian corridor.
- Once vegetation has been removed from the works areas, the adjacent riparian zone that does not fall within the footprint of the works must be demarcated as a no-go area that must not be physically affected by the proposed works.
- Construction should ideally occur during the drier winter months, when the possibility of rainfall and thus flow within these drainage systems is reduced.
- Once the pipe has been laid, the original substrate must be reinstated as far as possible (it is recognised that padding material may need to be laid adjacent to the pipeline to protect it). Any excess material that is not required for reinstatement must be removed from the riparian zone and placed elsewhere.
- The channel and banks of all watercourses crossed by the pipeline must be restored to a pre-construction state as far as possible. It is very important that the channel be reinstated to a level that is similar to the upstream and downstream level, and no structures that could impound water behind them must be constructed across the channel.
- It is very important as described above that the pipeline and road be realigned out of the Orange River riparian corridor, but it is equally important that the construction footprint not encroach in any way into the riparian corridor of the Orange River.

7.5.3 Other road-related mitigation measures

- Watercourse crossing structures along the road must allow flow to bypass or underpass the structure through culverts that must be included in the design of the crossing structure.
- All embankments and other sloping ground associated with the road must be properly rehabilitated with vegetation or waste rock / rip rap in order to stabilise these areas and prevent sedimentation into adjacent watercourses.
- Stormwater management measures must be included in the design of the road, in order to prevent erosion, and to discharge stormwater off the road into the surrounding environment, especially surface water features, in a manner that does not result in erosion and scouring. In sections of the road located adjacent to or which cross watercourses, it is recommended that stormwater not be discharged directly into the channel of the surface water feature, but be passed through a detention area or infiltration area first.

7.5.4 Servitude Rehabilitation and Re-vegetation

It is important that re-vegetation be undertaken to ensure that the works footprint does not remain devoid of vegetation and thus vulnerable to erosion by aeolian and water-borne processes. A number of mitigation measures are pertinent in this case:

- The topsoil within the works area of the pipeline must be retained once excavation for the pipeline has been completed and must be reinstated over the pipeline as this will contain a natural seed bank that will assist with natural re-vegetation.
- Once reinstatement of the pipeline has been completed and the rehabilitation of the servitude through riparian areas is underway, the riparian area must be reseeded with a grass species mix consisting of grasses found in the local area such as *Cenchrus ciliaris* and *Stipagrostis spp*.
- It is important that a shrub layer be re-established over the pipeline servitude, with non-deep rooted species being re-established, as detailed below
- Bare areas, such as reinstated banks and terraces, and especially those areas vulnerable to erosion by water during flow events must be protected from erosion while re-vegetation is occurring. It is recommended that geotextile be used to cover such areas, staked into the ground to protect seedlings. Waste rock / rip rap could also be considered for this purpose in sloping areas.
- Where possible (e.g. in the footprint of the construction right of way for the pipeline), the growth of shrubs and bushes, as well as grasses must be encouraged, as this will assist in the protection of the understorey. It is recommended that shrubs of species indigenous to the area with shallow root systems be sourced from local nurseries and established in such areas.
- Monitoring of re-vegetated areas must be undertaken, and follow up re-vegetated measures undertaken if necessary.
- It is critical that operational procedures for the rehabilitation and subsequent management of the pipeline servitude and road include measures to remediate any developing erosion and to remove and prevent proliferation of alien invasive vegetation. This should be undertaken at an interval of at least 6 months. Thus for a period after construction the servitude through riparian areas must be monitored for the development of erosion, as well as the growth of alien invasive plant species.
- If erosion is noted to be developing, immediate measures must be taken to remediate the erosion. It is very important that the integrity of the riparian zone post-construction be checked
- In the case of alien invasive vegetation, all such species must be fully removed and measures taken to prevent further proliferation. In this context it is also very important that parts of the servitude adjacent to the watercourses (outside of riparian zones) also be subject to similar measures as without this the servitudes outside of the riparian zones would become 'springboards' for proliferation into the riparian area.

7.6 Comparative Assessment of Alignments

7.6.1 Alignment Alternatives

Two pipeline / road alignment alternatives have been presented for comparative assessment. Both alignments share the section of the pipeline and road that are proposed to traverse the Orange River riparian corridor, and accordingly this significant impact cannot be used as a factor to differentiate the two alternatives. The respective alternative alignments cross a similar number of crossings, thus other factors need to be taken into account.

The sections of the respective alternatives that are not shared both cross a number of first order drainage lines. The largest of these ephemeral watercourses (crossing Alt2_22) is crossed by Alternative 2. This watercourse is characterised by the (vegetatively) most developed riparian corridor of all of the ephemeral watercourses, and would be characterised by the largest volumes of flows during flow events. The potential impacts of the road and pipeline would thus be of greater intensity and overall magnitude compared to the higher order watercourse crossings along Alternative 1.

The other factor to consider in comparatively assessing the two alternative alignments is the location of the alignments; the section of Alternative 1 that would cross surface water features is aligned along a cadastral (property boundary) to the north of the Gariep District Road along which a farm track is aligned. In addition the alignment runs close to an existing farm track on the Sanddraai property to the south-west of the Gariep District road. Due to the presence of these farm access tracks, the watercourses crossed along this section of Alternative 1 have been already modified, albeit to a low degree, by a linear development. In contrast the reaches of most of the watercourses along Alternative 2 have not been altered by any anthropogenic developments.

For this reason Alternative 1 is marginally preferred to Alternative 2. However the development of Alternative 2 is acceptable from a surface water perspective, provided that the mitigation measures stipulated in section 7.5 above are implemented.

7.7 Impact Rating Matrix

The Impact rating matrices for the road alternatives appear below. No Impact rating matrix has been provided for the solar power components as these will not impact any surface water resources.

Table 3 – Pipeline-Road Alternative 1 Impact Rating Matrix

Phase	Potential Aspect and or Impact	Significance rating of impacts before mitigation	Mitigation	Significance rating of impacts after mitigation
Construction	• Irresponsible construction practices could lead to the pollution of watercourses and rivers (e.g. faecal contamination, or pollution of surface water through hydrocarbons) • Poor stormwater management could lead to the siltation (pollution) of surface waters • Temporary accesses across watercourses could cause hydrological and morphological impacts and degrade the resource quality • Excessive removal of / damage to vegetation would degrade the resource quality of the riparian zone	**Extent:** Site (-1) **Duration:** Medium-term (-3) **Frequency:** Very Frequent (-4) **Intensity:** Medium (-3) **Probability:** Very Likely (-4) **Significance: Medium to High (-15)**	• Construction to be monitored by an ECO according to the stipulations of the EMPr • No batching or chemical / fuel storage areas to be located within any surface water feature or **within 100m of a surface water feature** • Clearing of vegetation to be limited to the construction footprint • No temporary construction accesses (other than the construction right of way) to be constructed through any surface water feature and no machinery to enter any surface water feature unless authorised under the EMPr by the ECO as part of a construction activity • Watercourse channels and other parts of the surface water feature must be restored to as close a pre-construction state as possible. • The pipeline-road route must be aligned out of the Orange River riparian corridor, and the construction footprint must in no way encroach into this riparian corridor.	**Extent:** Site (-2) **Duration:** Medium-term (-3) **Frequency:** Very Frequent (-4) **Intensity:** Medium (-3) **Probability:** Probable (-2) **Significance: Medium to High (-13)**
Operations	• The pipeline servitude as it crosses riparian areas will be kept cleared of most woody trees and shrubs due to the limitations relating to deep root systems, thus constituting an impact on the affected part of the riparian corridor for the entire operational length of the pipeline. • Improper rehabilitation of the construction works area through riparian areas would leave such parts of the riparian zones vulnerable to erosion by water and wind.	**Extent:** Site (-1) **Duration:** Long-term (-4) **Frequency:** Frequent (-3) **Intensity:** Medium (-3) **Probability:** Likely (-3) **Significance: Medium to High (-14)**	• All construction footprint areas through riparian areas must be fully rehabilitated with the re-establishment of a vegetative cover that matches pre-construction vegetative cover. • Any development of erosion must be carefully monitored and managed. • It is critical that all alien invasive vegetation management in the servitude be undertaken at regular intervals (at least every 6 months) for the operational life of the pipeline servitude. This must not just be undertaken for riparian areas but for servitudes in	**Extent:** Site (-1) **Duration:** Long-term (-4) **Frequency:** Unusual (-2) **Intensity:** Low (-2) **Probability:** Probable (-2) **Significance: Medium to High (-11)**

Phase	Potential Aspect and or Impact	Significance rating of impacts before mitigation	Mitigation	Significance rating of impacts after mitigation
	• In addition, the cleared servitude through the riparian corridor will pose a risk of encroachment of alien invasive vegetation into the riparian zone due to the servitude creating favourable conditions for the establishment of alien pioneers. The risk will be even greater should operational management of the servitude not be properly undertaken. • Pollutants from the road (e.g. hydrocarbons) could enter riparian corridors, causing pollution of the surface water feature.		adjacent areas. As part of this management all alien invasive vegetation within the servitude must be removed. • Formal stormwater measures must be incorporated into the design of the road and no stormwater must be directly discharged into the channel of any watercourse.	
Decom-missioning	• The termination of servitude management through riparian corridors post-decommissioning could increase the risk of alien invasive plant encroachment into the servitude area, and thus into adjoining riparian habitat.	**Extent:** Site (-1) **Duration:** Medium-term (-3) **Frequency:** Very Frequent (-4) **Intensity:** Medium (-3) **Probability:** Very Likely (-4) **Significance: Medium to High (-15)**	• Decommissioning to be monitored by an ECO according to the stipulations of the EMPr • No temporary accesses to be constructed through any surface water feature and no machinery to enter any wetland unless authorised under the EMPr by the ECO as part of a decommissioning activity • After decommissioning of the pipeline, management of alien invasive vegetation should continue for a period.	**Extent:** Site (-2) **Duration:** Medium-term (-3) **Frequency:** Very Frequent (-4) **Intensity:** Medium (-3) **Probability:** Probable (-2) **Significance: Medium to High (-13)**
Cumulative	• If the road-pipeline were to be developed through the Orange River riparian corridor a further (cumulative) loss of riparian habitat would occur. This would constitute a cumulative impact due to the existing loss of riparian vegetation and habitat within the Orange River due to clearing for orchards and due to other impacts. • Impacts on individual surface water features across the site could result in a cumulative impact on respective catchments, although other land use-related practices are more likely to cause degradation of watercourses and	**N/A**	• Refer to activity / phase specific mitigation measures above	**N/A**

Phase	Potential Aspect and or Impact	Significance rating of impacts before mitigation	Mitigation	Significance rating of impacts after mitigation
	their associated riparian zones. • Pollutants released into more than one surface water feature through construction activities could result in downstream impacts, although this is thought to be unlikely.			

Table 4 - Pipeline-Road Alternative 2 Impact Rating Matrix

Phase	Potential Aspect and or Impact	Significance rating of impacts before mitigation	Mitigation	Significance rating of impacts after mitigation
Construction	• Irresponsible construction practices could lead to the pollution of watercourses and rivers (e.g. faecal contamination, or pollution of surface water through hydrocarbons) • Poor stormwater management could lead to the siltation (pollution) of surface waters • Temporary accesses across watercourses could cause hydrological and morphological impacts and degrade the resource quality • Excessive removal of / damage to vegetation would degrade the resource quality of the riparian zone	**Extent:** Site (-1) **Duration:** Medium-term (-3) **Frequency:** Very Frequent (-4) **Intensity:** Medium-High (-4) **Probability:** Very Likely (-4) **Significance: High (-16)**	• Construction to be monitored by an ECO according to the stipulations of the EMPr • No batching or chemical / fuel storage areas to be located within any surface water feature or **within 100m of a surface water feature** • Clearing of vegetation to be limited to the construction footprint • No temporary construction accesses (other than the construction right of way) to be constructed through any surface water feature and no machinery to enter any surface water feature unless authorised under the EMPr by the ECO as part of a construction activity • Watercourse channels and other parts of the surface water feature must be restored to as close a pre-construction state as possible. • The pipeline-road route must be aligned out of the Orange River riparian corridor, and the construction footprint must in no way encroach into this riparian corridor.	**Extent:** Site (-2) **Duration:** Medium-term (-3) **Frequency:** Very Frequent (-4) **Intensity:** Medium (-3) **Probability:** Probable (-2) **Significance: Medium to High (-13)**
Operations	• The pipeline servitude as it crosses riparian areas will be kept cleared of most woody trees and shrubs due to the limitations relating to deep root systems, thus constituting an impact on the affected part of the riparian corridor for	**Extent:** Site (-1) **Duration:** Long-term (-4) **Frequency:** Frequent (-3)	• All construction footprint areas through riparian areas must be fully rehabilitated with the re-establishment of a vegetative cover that matches pre-construction vegetative cover. • Any development of erosion must be carefully	**Extent:** Site (-1) **Duration:** Long-term (-4) **Frequency:** Unusual (-2)

Phase	Potential Aspect and or Impact	Significance rating of impacts before mitigation	Mitigation	Significance rating of impacts after mitigation
	the entire operational length of the pipeline. • Improper rehabilitation of the construction works area through riparian areas would leave such parts of the riparian zones vulnerable to erosion by water and wind. • In addition, the cleared servitude through the riparian corridor will pose a risk of encroachment of alien invasive vegetation into the riparian zone due to the servitude creating favourable conditions for the establishment of alien pioneers. The risk will be even greater should operational management of the servitude not be properly undertaken. • Pollutants from the road (e.g. hydrocarbons) could enter riparian corridors, causing pollution of the surface water feature.	**Intensity:** Medium (-3) **Probability:** Likely (-3) **Significance: Medium to High (-14)**	monitored and managed. • It is critical that all alien invasive vegetation management in the servitude be undertaken at regular intervals (at least every 6 months) for the operational life of the pipeline servitude. This must not just be undertaken for riparian areas but for servitudes in adjacent areas. As part of this management all alien invasive vegetation within the servitude must be removed. • Formal stormwater measures must be incorporated into the design of the road and no stormwater must be directly discharged into the channel of any watercourse.	**Intensity:** Low (-2) **Probability:** Probable (-2) **Significance: Medium to High (-11)**
Decom-missioning	• The termination of servitude management through riparian corridors post-decommissioning could increase the risk of alien invasive plant encroachment into the servitude area, and thus into adjoining riparian habitat.	**Extent:** Site (-1) **Duration:** Medium-term (-3) **Frequency:** Very Frequent (-4) **Intensity:** Medium (-3) **Probability:** Very Likely (-4) **Significance: Medium to High (-15)**	• Decommissioning to be monitored by an ECO according to the stipulations of the EMPr • No temporary accesses to be constructed through any surface water feature and no machinery to enter any wetland unless authorised under the EMPr by the ECO as part of a decommissioning activity • After decommissioning of the pipeline, management of alien invasive vegetation should continue for a period.	**Extent:** Site (-2) **Duration:** Medium-term (-3) **Frequency:** Very Frequent (-4) **Intensity:** Medium (-3) **Probability:** Probable (-2) **Significance: Medium to High (-13)**
Cumulative	• If the road-pipeline were to be developed through the Orange River riparian corridor a further (cumulative) loss of riparian habitat would occur. This would constitute a cumulative impact due to the existing loss of riparian vegetation and habitat within the Orange River due to clearing for orchards and		• Refer to activity / phase specific mitigation measures above	**N/A**

Phase	Potential Aspect and or Impact	Significance rating of impacts before mitigation	Mitigation	Significance rating of impacts after mitigation
	due to other impacts. • Impacts on individual surface water features across the site could result in a cumulative impact on respective catchments, although other land use-related practices are more likely to cause degradation of watercourses and their associated riparian zones. • Pollutants released into more than one surface water feature through construction activities could result in downstream impacts, although this is thought to be unlikely.			

8 CONCLUSIONS AND RECOMMENDATIONS

The physical characteristics of the Sanddraai development site entail that surface water features are restricted to the south-western part of the site. This has implications for the potential impact of the solar power plant on surface water as none of the power generation components will be located in parts of the site in which surface water is located. The associated linear infrastructure is located within the south-western part of the site in which surface water features are located and a number of surface water crossings would thus materialise.

The most important potential impact would be the loss of riparian habitat (vegetation) within a reach of the Orange River riparian corridor due a section of the pipeline-road being aligned within it. This impact would be of high significance as the riparian corridor forms part of the Endangered Lower Gariep Alluvial Vegetation Ecosystem, and this reach of the riparian corridor has already been impacted by clearing of riparian vegetation for the establishment of orchards. One of the key recommendations of this study is that the pipeline-road be realigned to run outside of the riparian corridor, thus avoiding the physical disturbance of the Orange River riparian corridor.

A number of smaller ephemeral / episodic watercourses are crossed by the two pipeline-road alternatives. These crossings could exert a localised impact on the affected reaches of the watercourses, especially as the affected reaches are largely in a natural state. A number of design, construction and operational mitigation measures have been stipulated to mitigate the potential impacts to acceptable levels or to avoid the creation of such impacts altogether.

In the context of the comparative assessment of the two road-pipeline alignment alternatives, Alignment 1 is marginally preferred, as it would run for a portion of its length in parallel to a farm track, thus the surface water crossings are already subject to a slightly greater impact than Alternative 2. In addition the largest of the smaller watercourses with a more developed riparian corridor is located along Alternative 2, and by avoiding the crossing of this watercourse the intensity and overall impact of the road and pipeline-related impact would be lessened.

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