FINAL PRE-CONSTRUCTION AVIAN IMPACT ASSESSMENT OF THE CSP 5, NEAR UPINGTON, NORTHERN CAPE

Prepared for: Savannah Environmental (PTY) LTD

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1 SUMMARY

This study reports on avian monitoring for the proposed Karoshoek Solar Valley Development, proposed by Emvelo Eco Projects (Pty) Ltd on various farms near "Karoshoek" east of Upington, Northern Cape. Our specific objective is to determine the numbers of collision-prone birds attracted to the proposed solar development before and after rains in November 2015 and March 2016 to understand and mitigate possible impacts to sensitive and threatened species.

A brief review of recent literature on Concentrating Solar Power (CSP) and their effects on avifauna reveals that CSP trough technology, which utilizes parabolic mirrors may attract birds to its reflective surfaces, and median levels of mortality and displacement may occur relative to other PV and CSP (tower) technology. Here we identify potential impacts associated with these facilities in the proposed Karoshoek Solar Development.

The possible impacts are:

- Displacement of nationally important species from their habitats by the presence of the parabolic mirrors;
- Loss of habitats for such species due to direct habitat destruction;
- Disturbance during construction of the array; and
- Collision with the parabolic troughs by birds that mistake them for water bodies (the so-called "lake effect").

Indirect and cumulative impacts include water abstraction from the Orange River which may reduce flow rate in low-flow seasons and force avifauna to seek alternative habitats.

The impact zone of the CSP trough CSP 5 lies on the interface of Nama Karoo and Kalahari Shrubland. Bird atlas data combined with our records data indicate that habitat in the Karoshoek Solar Valley development footprint supports up to 114 bird species, including 14 species ranked in the top 100 collision-prone species. Six of these species are also red-listed: Black Harrier *Circus maurus*, Lanner Falcon *Falco biarmicus,* Kori Bustard *Ardeotis kori,* Ludwig's Bustard *Neotis ludwigi*, Verreaux's Eagle *Aquila verreauxi* and Secretarybird *Saggitarius serpentarius.* Given that harriers, eagles and bustards are highly collision-prone species, they may interact negatively with the CSP 5 infrastructure. Similarly, the proximity to the Orange River may attract wetland species seeking other wetland areas, and cause mortality as birds attempt to land on the CSP mirrors. In addition, resident birds will lose habitat totaling ~610 ha.

Since the degree and significance of bird impacts will be related to the abundance and movements of key species, we calculated bird densities in the site footprint and the passage rate of the collision-prone birds through the site. Our 1 km surveys revealed a higher species richness of smaller birds in the wet season (18.0 v 10.0 species km^{-1}). The **Passage rate** of larger collision-prone birds were at medium high levels of 0.92 birds per hour with more birds in the dry season. Wetland birds, that may be attracted to the mirrored surfaces, were not recorded in either season. Low levels of sandgrouse and Sociable Weavers were recorded.

The volume of water required for the generation of steam at one CSP is about 80 000 m^3 per year. Thus, the 8 CSPs planned for the solar park development will require amounts exceeding 600 000 m^3 of water from the Orange River. The cumulative impacts of four other CSP solar farms in the immediate vicinity along the Orange River may reduce flow at low flow, forcing wetland species to seek other water sources.

We quantified the impacts and found medium high levels of significance for the collision-prone threatened bustard species on CSP 5 that requires some mitigation.

To mitigate the possible problems of impacts with the CSP troughs, we recommend that:

- Bird scaring techniques are used, including rotating prisms and experimental use of Torri lines (ribbons used on trawlers to deter albatrosses from taking baited hooks and drowning) if birds are found to impact the CSP mirrors;
- Developments are kept away from the high avian sensitivity sites identified.

Systematic monitoring during construction and post-construction of the CSP facility is recommended by trained ornithologists given the high probability of avian impacts to South Africa's red data birds.

1.1 CONSULTANT'S DECLARATION OF INDEPENDENCE

Birds & Bats Unlimited are independent consultants to Savannah Environmental. They have no business, financial, personal or other interest in the activity, application or appeal in respect of which they were appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of this specialist performing such work.

1.2 QUALIFICATIONS OF SPECIALIST CONSULTANT

Birds & Bats Unlimited Environmental Consultants (http://www.birds-and-bats-unlimited.com/), were approached to undertake the specialist avifaunal assessment for the pre-construction phase of the CSP solar parks proposed by Emvelo (Pty) Ltd, east of Upington, Northern Cape. Dr Rob Simmons is an experienced ornithologist, with 30 years' experience in avian research and impact assessment work. He has published over 100 peer-reviewed papers and 2 books, (see www.fitzpatrick.uct.ac.za/docs/robert.html for details). More than forty avian impact assessments have been undertaken throughout Namibia and South Africa. He also undertakes long-term research on threatened species (raptors, flamingos and terns) and their predators (cats) at the FitzPatrick Institute, UCT.

Marlei Martins, co-director of Birds & Bats Unlimited, has over 5 years' consultancy experience in avian wind farm impacts as well as environmental issues, and has been employed by several other consultancy companies all over South Africa because of her expertise in this field. She has published papers on her observations including a new species of raptor to South Africa (http://www.birds-and-bats-unlimited.com/).

2 TERMS OF REFERENCE

- To provide a desktop and field assessment of all potential impacts to avifauna by the CSP Parabolic trough technology at CSP 5 within Karoshoek Solar Park development, near Upington;
- The final avian impact assessment should include assessments of all revised areas proposed after the initial site visit in November 2015;
- To provide a summary of expected impacts for all threatened or collision-prone species found in the area;

- To quantify the expected impacts with and without mitigation measures;
- To determine the cumulative impacts to the avifauna in the area;
- To provide possible mitigation measures to reduce impacts wherever they occur;
- Provide recommendations for an environmental management plan to monitor the site, during and post-construction to determine impacts to the avifauna, and provide mitigation solutions were necessary.

We start with a review of the solar technology to be employed to contextualize it, relative to possible and known avian impacts elsewhere in the world.

3 BACKGROUND

3.1 CSP SOLAR POWER

Renewable energy is generally provided either by water, wind or solar power and has the potential to supply the human population with unlimited non-polluting power. As a major greenhouse gas emitter South Africa is a signatory to the Kyoto Protocol and is committed to turning to green energy sources that emit no greenhouse gases or other pollution. Southern Africa's Kalahari region is one of the Earth's hot spots for solar radiation because deserts provide some of the longest periods of continuous sunlight in the world http://www.iir-sa.gr/files/news/CSP.pdf. This makes it the ideal hub for solar projects that capture the sun's energy to provide an energy-hungry South Africa with the power it requires.

Three options are generally employed to capture solar energy:

(i) Concentrated Solar Power (CSPs) using heliostats that focus the sun's energy onto a central tower that heats a salt or oil liquid that drives a turbine (CSP tower);

(ii) a CSP using trough technology with smaller parabolic mirrors that capture and focus the sun's energy onto a central pipe that also employs a heat-transfer liquid to heat steam to drive a turbine. This is the preferred option by the developer Emvelo (Pty) Ltd, in the Ilanga Solar development CSP 5; or

(iii) Photo-voltaic panels that capture and convert sunlight directly into electrical power using conventional or Fresnel PV technology.

There are fewer direct risks associated with the PV and CSP trough technology than CSP towers from an avian perspective (see below). However, all forms of solar technology appear to draw in birds because research suggests birds perceive the shiny mirrored-surfaces as open water (the so-called "Lake Effect" – Kagan et al. 2014). This CSP trough technology is the only one assessed in this report for the Emvelo solar development at CSP 5.

3.2 Potential avian impacts with CSP facilities

The main avian impacts according to a position paper on the subject by Birdlife SA (http://www.birdlife.org.za/images/stories/conservation/birds_and_wind_energy/solar_power.pdf) are:

- displacement of nationally important species from their habitats;
- loss of habitats for such species;
- disturbance during construction, and operation of the facility;
- collision with the CSP mirrors (mistaking them for water bodies); or
- collision with associated infra-structure.

The nature and magnitude of impacts to birds from solar facilities is related to three factors: (a) location, (b) size of the facility, and (c) the technology involved (i.e. Photo-voltaic *vs* CSP trough *vs* CSP tower). Thus, the location in relation to avian flyways, wetlands, nest sites, roost sites and the habitat removed in the footprint may have an important effect on the impact to birds at the solar site. The size of the footprint will be directly related to the negative impact on smaller birds, thus, habitat of range-restricted or collision-prone species around the site must be determined with accuracy.

An area up to 700 ha is required in the operation of the CSP 5 facility, and this will reduce habitat availability for birds where construction takes place. It is a simple exercise to calculate the numbers potentially lost from our estimates of birds per unit area. These are likely to be minimal considerations given that smaller birds generally occur at higher densities than larger birds, breed faster, and are less likely to suffer high population reduction. However, avoidance of some habitats will reduce the impact.

Avian fatalities at CSP sites have been summarised from those investigated in the USA by two recent reports (Kagan et al. 2014, Walston et al. 2015). Of the three types of solar energy capture (PV, CSP trough and CSP tower) the CSP trough sites recorded median levels of avian fatalities relative to the PV and CSP tower sites in one review (Kagan et al. 2014).

Given that impact trauma was the most common cause of mortality at two of the three solar sites investigated, minimising the reasons for the cause of that trauma are paramount. Biologists believe that birds mistake the troughs in the solar arrays for a body of water (the Lake effect – Kagan et al. 2014) and suffer physical trauma when they attempt to land on it. Birds, particularly wetland species, are the main victims of this sort of impact.

In a review of all bird fatalities at large scale operational solar plants across the world (mainly the USA but one in Israel) Walston et al. (2015) found that few solar plants had undertaken systematic monitoring of bird fatalities (Table 1).

Table 1. Summary of all avian fatality data from large-scale solar facilities from the USA (after Walston et al. 2015). The results for CSP trough technology are given in **bold**.

Project Name	Avian Fatality Data – systematic or incidental?	Survey Period	Incidental Fatalities	Systematic Fatalities (Unadjusted)**
Mohave Solar (CSP trough)	Incidental	Aug. 2013–March 2014	14	None collected
Genesis (CSP trough)	Incidental	Jan. 2012–May 2014	183	None collected
California Valley Solar Ranch (PV)	Systematic	Aug. 2012–Aug. 2013	Not Available	368
Desert Sunlight (PV)	Incidental	Sept. 2011–March 2014	154	None collected
Topaz Solar Farm (PV)	Incidental and Systematic	Jan. 2013 –Jan. 2014	19	41
California Solar One (CSP tower)	Systematic	May 1982–May 1983 (40visits)	Not Available	70 (114 birds)
Crescent Dunes (CSP tower)	Systematic	Under construction	Not available	Not available
Ivanpah (CSP Tower)	Systematic	Oct. 2013–March 2014	159	376 (includes 7 injured birds)

*Causes of death include: solar flux, impact trauma, predation, electrocution and emaciation

** Unadjusted refers to the fact that numbers are not adjusted for biases resulting from predator removal or human observer bias

In summarising the avian species found, Walston et al. (2015) noted that:

- most birds were small passerines (40%-63% at 7 solar farms);
- Kagan et al. (2014) also found 20 of the 30 birds identified at the Genesis CSP trough site in California were smaller passerine birds or swallows;
- they also recovered waterbirds such as grebes, herons and gulls suggesting these species may be attracted by the *perceived* availability of water or the lake effect (Kagan et al. 2014);
- overall, waterbirds were found to average 11% of the fatalities at solar farms, but reached 46% of all fatalities at one solar PV facility (Desert Sunlight) in California;
- there were too few fatalities at different types of facilities to test the lake effect of Kagan et al. (2014);

- there was a clear trend at all solar facilities for resident species to dominate the fatalities. At the Genesis CSP trough facility 64% of the fatalities were resident species, meaning that 36% were migrants (Walston et al. 2015), the highest among those reviewed.

Tabulating fatalities of birds at solar sites is insufficient to determine the impact to birds of conservation significance. They must be collected systematically and account for human error in (not) finding carcasses, and the rate of carcass removal by scavengers.

In an arid environment where sensitive species may not occur at all if rains do not fall (Dean 2004, Dean et al. 2009) even a full year's monitoring is unlikely to be sufficient. Thus, visits must be timed to coincide with the most productive time of year – the rain season. Therefore, the present CSP trough CSP 5 was closely and *systematically* monitored by Birds & Bats Unlimited, over a dry and wet season, to determine movements and rates of passage of all collision-prone species (as defined by BARESG 2014). We followed the draft Birdlife/EWT guidelines (Jenkins et al. 2015) for such monitoring to minimise the possibility of inappropriate or under-sampling obvious in some other EIA reports.

As a relatively new field, and with the burgeoning solar farm industry in South Africa focussed on the Kalahari Desert, we need to be pro-active in our research and innovative designs to reduce mortality.

3.2.1 Habitat loss – Destruction, Disturbance and Displacement

The construction and maintenance of CSP technology causes mainly permanent habitat destruction under the parabolic mirrors. Maintenance activities are likely to cause some disturbance to birds in the general surrounds, and especially the shy or ground-nesting species resident in the area. Mitigation of such effects requires that best-practice principles be rigorously applied – i.e. sites are selected to avoid the destruction of key habitats for red data species, and the disturbance and construction and the final footprint size, for key species, should all be kept to a minimum. Construction time for each facility is expected to take 2-3 years.

From the habitat removal point of view, it is a simple exercise to calculate the numbers of birds potentially lost from our density estimates of important species/birds per unit area of habitat. These are likely to be minimal considerations, given that smaller birds are generally more common than larger birds, breed faster, and are less likely to suffer high population reduction.

However, where range-restricted species occur on sites ear-marked for development, this can have a larger impact.

Because CSP facilities are not yet operational in South Africa, and there are relatively few published studies of avian mortalities at such sites in other parts of the world (Table 1), this section is necessarily brief and is in need of further study, transparency and data sharing in southern Africa.

3.2.2 Collision – with reticulation lines and CSP troughs

Several South African bird species are well known to collide with overhead power lines, fences, towers and other aerial objects (Jenkins et al. 2010). These have been tabulated and the reasons for their propensity for collision investigated (Martin and Shaw 2010). The extenuating factors were then extrapolated to all South African species based on wing loading, aerial flights, nocturnal activity, red-data status (Taylor et al. 2015) and several other contributing factors (BARESG 2014).

We have used Birdlife South Africa's list and taken the top 100 species as the most likely to collide with power lines. The most collision-prone species are generally the larger species such as bustards and cranes, but also raptors. It is somewhat surprising that birds also collide with ground-based structures and, as shown above (Table 1), these include passerines, and wetland birds in collision with CSP troughs in the USA. While we do not know which species will be similarly prone in South Africa, they are likely to be a similar suite of wetland and aerial species, as well as those known to collide with aerial structures (bustards and raptors). It is these we focused on during our surveys.

4 STUDY METHODS

4.1 Aims and methods

The primary aims of the avian pre-construction monitoring at the CSP 5 proposed by Emvelo (Pty) Ltd at the Karoshoek Solar Valley development are to:

- Determine the densities of birds regularly present, or resident, within the impact area of the CSPs before the construction phase;
- Document the patterns and movements of birds in the vicinity of the proposed CSPs before their construction;
- Monitor the patterns and rates of movements of birds in the CSP areas in relation to time of day, and over one dry and one wet season when bird numbers and

species richness may change;

- Establish a pre-construction baseline for all Red data and collision-prone bird species including all breeding birds within the study area;
- Quantify the impacts before and after mitigation;
- Quantify, if possible, the cumulative impacts around the solar park
- Inform final design, construction and management strategy of development with a view to mitigating potential impacts.

We consulted several published sources of bird data including:

- Information on the ecology (Hockey et al 2005), distribution (Harrison et al. 1997) and conservation status (Taylor et al. 2015) of all South African birds;
- The Important Bird Areas Programme (IBA) of Birdlife South Africa (Barnes 1998)
- Contemporary South-Africa-wide atlas data were extracted from the Southern African Bird Atlas Project (SABAP), which were obtained from the Animal Demography Unit website (http://sabap2.adu.org.za/index.php) for the relevant "pentads" of 5′ x 5′ (of 9 km x 8km) surrounding the planned development areas. From these data we compiled a list of the avifauna likely to occur within the impact zone of the proposed power lines. Because of the remoteness of the area there were limited SABAP2 data available at http://sabap2.adu.org.za/index.php for this region.
- These data were combined with data from two visits to the area in November 2015 and March 2016 to record bird densities and passage rates.

This report combines the data gleaned from all sources to give an assessment of the birds present in the site and, the potential impacts they face arising from the solar developments.

4.2 Study Area

The Karoshoek Solar Valley Development is located approximately 30 km east of Upington within the Khara Hais Local Municipality, which falls under the Siyanda District Municipality in the Northern Cape. The facility is proposed on the farm Karos sett 944 and the CSP 5 is geographically centred on S28°30' 38.0 E 21°30' 35.0"

4.2.1 Vegetation of the study area

The study area occurs on the interface between the Nama Karoo biome to the south and Kalahari Savannah biome to the north (Mucina and Rutherford 2006, p44). A large swathe of Bushmanland Arid Grassland runs north-south through the park (Mucina and Rutherford p335), and elements of five other vegetation types are found and described by Todd (2012). The area experiences summer rainfall up to 510 mm near Upington. High day-time temperatures occur in summer (mean 37°C) and relatively cool temperatures occur in winter (4-23°C). The site was dry and all but the larger trees were dormant in November 2015, our first site visit. Substantial rains (~250 mm in February and March 2016), had fallen by our second site visit in March 2016 and new grass cover was evident and the *Rhigozum* bushes and *Acacia* and *Boscia* trees were in full leaf.

4.2.2 Avian microhabitats

Bird habitat in the region consists of two basic vegetation types: Nama Karoo scrub and Kalahari Savannah with a very sparse cover of *Boscia* and *Acacia* trees along the dry water courses. The main avian micro-habitats were provided by the grasses, (exploited by bustards, korhaans, larks and finches) and the trees (exploited by flycatchers, sociable weavers and perching raptors). Artificial habitats are provided by the farmers - windmills, water points and power poles. Some water points occurred on the southern boundary of CSP 5 attracting sandgrouse, and other smaller species.

Photo 1: Spotted Eagle Owls were only seen twice in areas surveyed in the Karoshoek Solar Valley, once at CSP 5 and once at CSP 4. Both birds were roosting on active Sociable Weaver nests

Photo 2: Typical dry-season habitat (top) on CSP 5 in the eastern half of the Karoshoek solar development showing sparse dry grass cover, some *Rhigozum* shrubs (middle distance), and mature *Boscia albitrunca* trees. The wet-season transformation (above) saw the grasses and *Rhigozum* bushes (foreground), and trees in full leaf, but with bare sand still visible.

5 ON SITE METHODS

Two site visits were undertaken to the CSP 5 to coincide with different environmental conditions:

- a dry season visit from 31 October - 7 November 2015;
- a wet-season visit following on-going rains from 29 February – 9 March 2016;
- in each visit we surveyed birds in 1-km transects in areas proposed for the CSP solar arrays. These transects covered all main habitat types present;
- we also undertook Vantage Point observations covering 12 h in each season as prescribed by the draft BARESG guidelines (Jenkins et al. 2015).

All **1-km bird transects** took place in the morning (bird-active) hours.

- Each transect was walked slowly over 35 to 60 minute duration, depending on terrain and number of birds present;
- All species were identified where possible using Swarovski 8.5 x 42 binoculars, and the number of individual birds and the perpendicular distance to them, recorded;
- In denser habitat, or with some cryptic birds (e.g. larks), species were identified by call and the distance to them estimated. This allows an estimate of the density (birds per unit area and per km, expressed as bird km^{-1}) and the species richness in each area;
- We simultaneously recorded all large birds (mainly bustards and raptors) and noted and recorded the position of any nests found;
- Over 900 (dry season) and 1300 (wet season) individual birds were recorded in the CSP areas in these transects alone.

The most important aspect of this monitoring is **Vantage Point (VP) surveys:**

- This determines the number of flights **of collision-prone species** per hour through the possible area of impact, which in turn gives an indication of the collision-risk to larger species that may impact the infrastructure in the solar park;
- 12 hours per VP is the minimum recommended observation time for each VP (draft BARESG guidelines: Jenkins et al. 2015);
- Each VP should have a view-shed (area of observation) not exceeding 2 km;
- Because of the large size and flat nature of the terrain we walked some areas not well covered by the VP points at each site.

6 RESULTS

6.1 PRESENCE AND MOVEMENTS OF SENSITIVE SPECIES

Large sensitive species, observed from our walking transects or VPs, are defined as those species that are known, or expected, to be at risk from the CSP infrastructure, or attracted by the reflective surfaces of the CSP troughs. These species are typically large and threatened red data species that occur in the study areas (e.g. bustards and raptors), but could include wetland species attracted by the mirrored surfaces.

No recent (SABAP2) data were available from the Southern African Bird Atlas Projects website (http://sabap2.adu.org.za/index.php) for the Karoshoek solar footprint itself. Therefore, we took information from a slightly wider net that included the Ilanga power line (Birds Unlimited 2014). To these we added our own dry- (November 2015) and wet-season (March 2016) data for those species found directly on site.

6.2 AVIAN SPECIES RICHNESS AND RED DATA SPECIES

The CSP 5 is shown in Figure 1. A total of 114 bird species were recorded on the 17 bird atlas cards from the Ilanga solar development and similar areas to the west (following the proposed Ilanga power line) submitted to the Animal Demography Unit from 2007 to 2014 (Appendix 1). Of these, 8 were collision-prone as ranked by BARESG (2014), and only 2 were red-listed (Kori Bustard *Ardeotis kori* and Lanner Falcon *Falco biarmicus*).

However, we noted four additional red data species in our two site visits: a Black Harrier *Circus maurus*, breeding Verreaux's Eagle *Aquila verreauxii*, a Secretarybird *Sagittarius serpentarius*, and numerous Ludwig's Bustards *Neotis ludwigi*. Thus, 6 red-data species occur in the development area (Table 2)**.** A further 8 collision-prone species (Table 2) were recorded, giving 14 collision prone/red data species in total for the greater Karoshoek Solar Valley development area.

This may over-estimate the numbers on site because the SABAP data includes some Orange River pentads. Therefore, we tallied only those species recorded in our transects, VPs and incidental observations to determine overall species richness in the dry and wet seasons in the development area itself. A total of 72 species were recorded which will be added to the SABAP2 data base.

In summary, a total of **14 collision-prone species** occur in the greater Karoshoek solar development areas, **of which six are red-listed.**

Table 2. Threatened (**in red**) and collision-prone bird species (**in bold**) likely to occur over the proposed CSP 5 trough development drawn from SABAP2 atlas cards for 4 pentads. These are based on 17 cards, submitted

to the SABAP2 project from 2007 to 2015. Those shaded were seen in our site visits in November 2015 and March 2016, but not previously recorded.

					Susceptible to:
Common name	**Scientific name**	**Threat status**	**Reportin g Rate***	**Collision Rank****	**Disturbance**
Verreaux's Eagle	*Aquila verreauxii*	**Vulnerable**		**2**	Moderate
Black Harrier	*Circus maurus*	**Endangered**		**6**	High
Ludwig's Bustard	*Neotis ludwigii*	**Endangered**		**10**	Moderate
Secretarybird	*Saggitarius serpentarius*	**Vulnerable**		**12**	Moderate
Lanner Falcon	*Falco biarmicus*	**Near-threatened**	6%	**22**	
African Fish Eagle	*Haliaetus vocifer*	-	35%	**27**	
Kori Bustard	*Ardeotis kori*	**Vulnerable**	6%	**37**	Moderate
Karoo Korhaan	*Eupodotis vigorii*		6%	**49**	
Booted Eagle	*Aquila pennatus*	-		**55**	
Black-chested Snake Eagle	*Circaetus pectoralis*			**56**	
Pale Chanting Goshawk	*Melierax canorus*	-	6%	**73**	Moderate
N Black Korhaan	*Afrotis afroides*		12%	**91**	
Black-shouldered Kite	*Elanus caeruleus*	-	24%	**96**	
Spotted Eagle Owl	*Bubo africanus*	-	6%	**100**	

*Reporting rate is a measure of the likelihood of occurrence, as recorded in the atlas period.

** Collision rank derived from the BAWESG 2014 guidelines. Smaller numbers denote more collision-prone.

Seasonal differences in the composition of the bird community are expected to be large in an arid environment (Dean 2004). This arises for several reasons for different groups of birds:

- wetland species (e.g. geese, stilts and crakes) are attracted by the sudden appearance of wetlands that were not available prior to pans flooding. They follow rain fronts to find such ephemeral wetlands (Simmons et al. 1999, Henry et al. 2016);
- other birds, including sandgrouse, will use pans that fill with water (Lloyd 2005);
- nomadic species (e.g. bustards, larks) are attracted to high rainfall areas because of the flush of insects that follow rains (Allan and Osborne 2005).

Thus, an arid area such as the Kalahari Desert is very much a "boom or bust" landscape and one dry season visit can give a biased impression relative to the explosion in biodiversity that can follow high rainfall events (Lloyd 1999).

These differences were apparent after good rains that fell in February 2016 and continued into March at the time of our second visit. Thus, the avian species richness values will be close to their maximum.

6.2.1 Density of birds recorded within the proposed CSP sites

In our 1-km surveys we recorded an average of 10.0 species km^{-1} in the dry season and 18.0 species km^{-1} in the wet season (Table 3). The higher species richness in the wet season was also reflected in the density of birds per kilometre that was almost three-fold higher (Table 3). These species comprised typical Kalahari birds such as korhaans, scrub-robins, larks, chats, prinias, finches, weavers and sandgrouse (Appendix 1).

Table 3: Comparison of Dry vs Wet season bird species richness recorded over 1 km at CSP 5 in November 2015 and March 2016.

Summary	Species km^{-1}	Birds km^{-1}	Collision-prone species
CSP 5 dry season	10.0	35.0	Ludwig's Bustard; Spotted Eagle-Owl; Northern Black Korhaan
CSP 5 wet season	18.0	52.0	N Black Korhaan, Karoo Korhaan,
Means	**13.0 sp km^{-1}**	**30.5 birds km^{-1}**	**4 species**

6.2.2 Passage rates of collision-prone species within CSP 5

Six collision-prone species in the top 100 (BARESG 2014) were present in the CSP 5 (Table 4) of which Ludwig's Bustard was the only red data species. The rate at which they flew through the site was much higher in the dry season than in the wet season (Table 4) and averaged 0.92 birds h^{-1}.

Other aerial species that may be influenced by the mirrored surfaces included Namaqua Sandgrouse that were rare in the dry season but were present in the wet season (averaging 2.1 birds h^{-1} : Appendix 1).

Table 4: Comparison of Passage Rates of Collision-prone species from VP observation at Ilanga CSP 5, November 2015 and March 2016

Summary	Birds	Hours	Passage Rate	Collision-prone species
Passage Rate (dry season)	18	12	1.5 birds h^{-1}	Ludwig's Bustard, Northern Black Korhaan, Karoo Korhaan, Pale chanting Goshawk, Rock Kestrel, Spotted Eagle Owl
Passage Rate (wet season)	4	12	0.30 birds h^{-1}	Ludwig's Bustard, Northern Black Korhaan, Karoo Korhaan
Means			**0.92 birds h^{-1}**	**6 species**

Only one wetland bird species was recorded on site – a pair of Egyptian Geese *Alopochen aegyptiaca*.

Of the 6 species of collision-prone birds recorded on site, two species were korhaans

(Northern Black *Afrotis afroides* and Karoo Korhaan *Eupodotis vigorii*), one was a threatened bustard, and three were raptors (Table 4).

6.2.3 Flights paths of collision-prone species within CSP 5

The flight paths of the collision-prone species through the proposed CSP 5 are shown in Figure 2. The most important species were 3 Ludwig's Bustards that were concentrated in the north-east and the south-west. Also in the south-west we recorded a Spotted Eagle Owl (collision-prone) a pair of Pygmy Falcons (not highly collision-prone) both associated with a Sociable Weaver nest (Figure 2). Further south-west, but outside the site we recorded a Pale chanting Goshawk (with a Cape Cobra).

Other non-collision-prone species recorded on site included Namaqua Sandgrouse (25 birds in 12 hours). Their interaction with mirrored surfaces is unknown.

In summary:

- 72 species, 14 collision-prone species and 6 threatened red-data species have been recorded over the greater Karoshoek Solar Valley Development;
- Species richness was lower on CSP 5 with the density of smaller species being higher in the wet (18.0 km^{-1}) than in the dry season (10.0 km^{-1});
- Namaqua Sandgrouse were present on site in the wet season recorded at 2.1 birds h^{-1};
- Six collision-prone species were recorded in CSP 5 of which one is a red-data species (Ludwig's Bustard).
- The Passage Rate of these birds was medium-high at 0.92 birds h^{-1}.

6.3 SENSITIVITY MAP OF COLLISION-PRONE RED DATA SPECIES

By combining all records of the collision-prone red data species we can map the most sensitive areas for birds within CSP 5. The presence of 7 threatened Ludwig's Bustard and 1 Kori Bustard recorded in the eastern portion of CSP 5 indicates high use of this area and a highly sensitive area (Figure 4). The medium high sensitivity area (left) encompasses 3 Ludwig's Bustards, a Spotted Eagle Owl, a pair of Pygmy Falcons all associated with a Sociable Weaver nest (Figure 4).

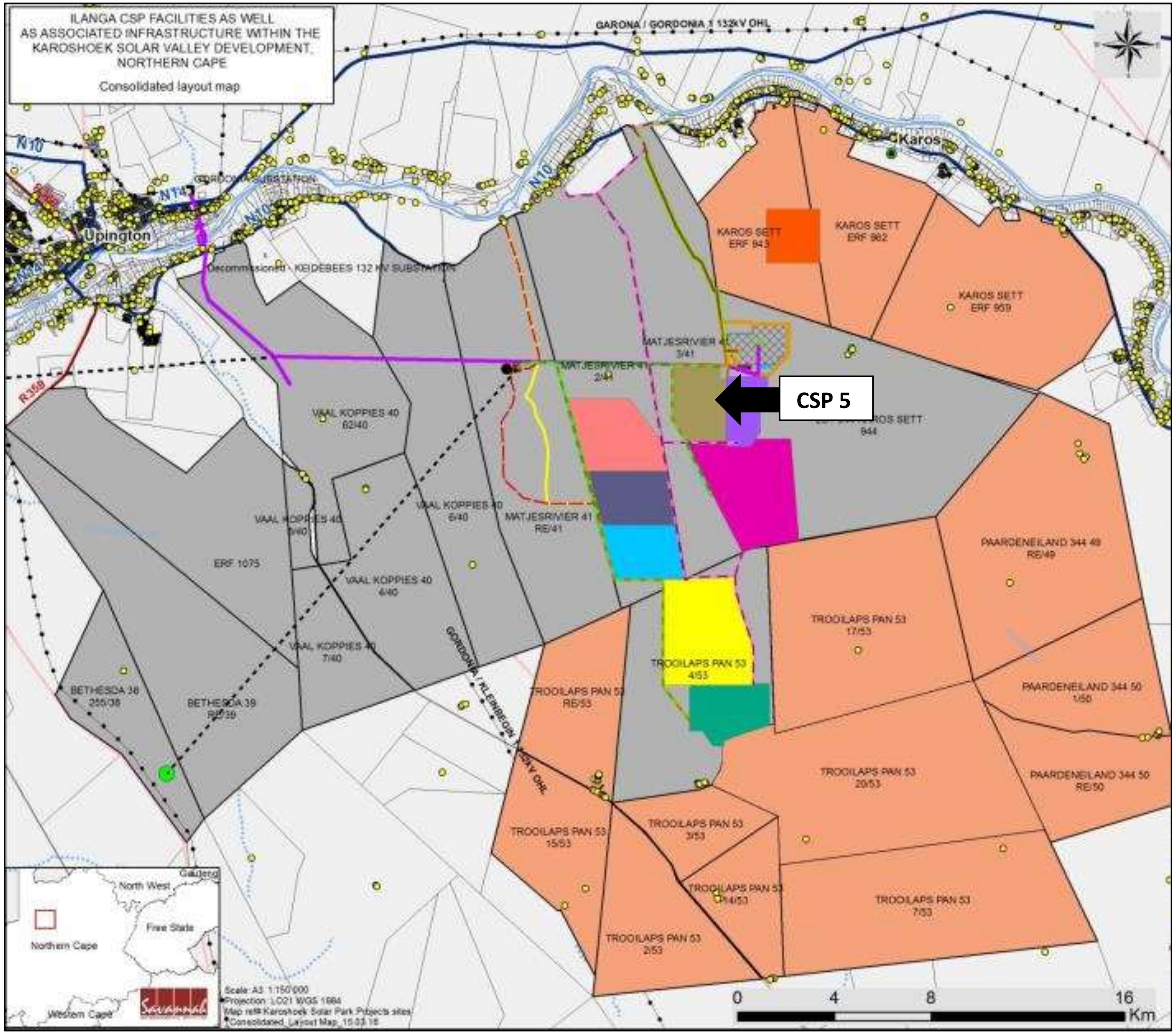

Figure 1: Layout of the **Ilanga Karoshoek** solar park showing the location of CSP trough site 5.

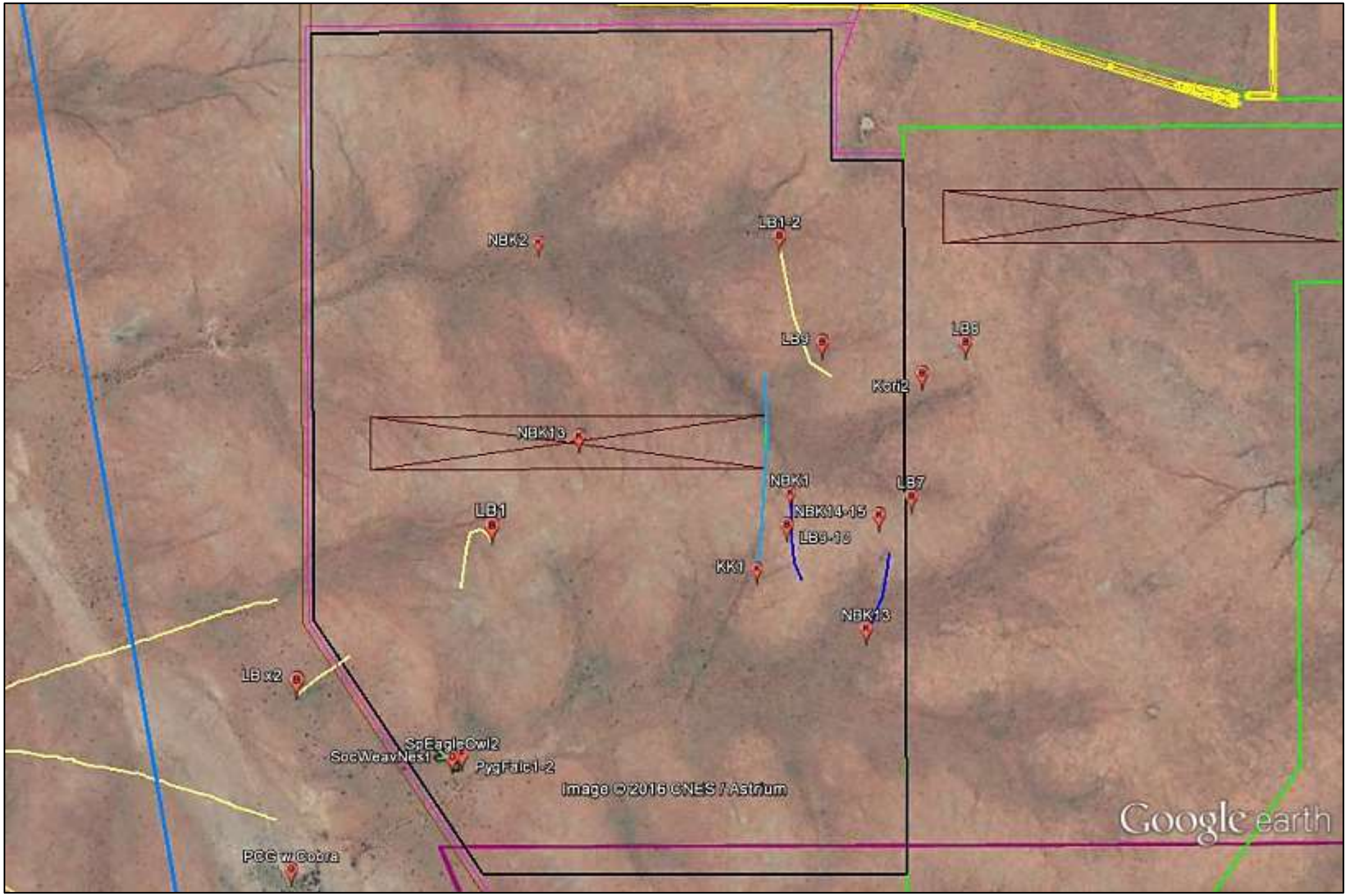

Figure 2: Collision-prone bird movements and perch sites in the CSP 5 solar plant on the farm Karos nett Lot 944 near Upington, from November 2015 and March 2016. Six species of collision-prone birds were recorded in flight in the site, LB = Ludwig's Bustard (pale yellow), NBK = Northern Black Korhaan (blue), KK = Karoo korhaan. Two raptors occurred on site (Spotted Eagle Owl and Pygmy Falcons, bottom left) and a Pale chanting goshawk. The scale is given by the central polygon which is 1.3 km in length.

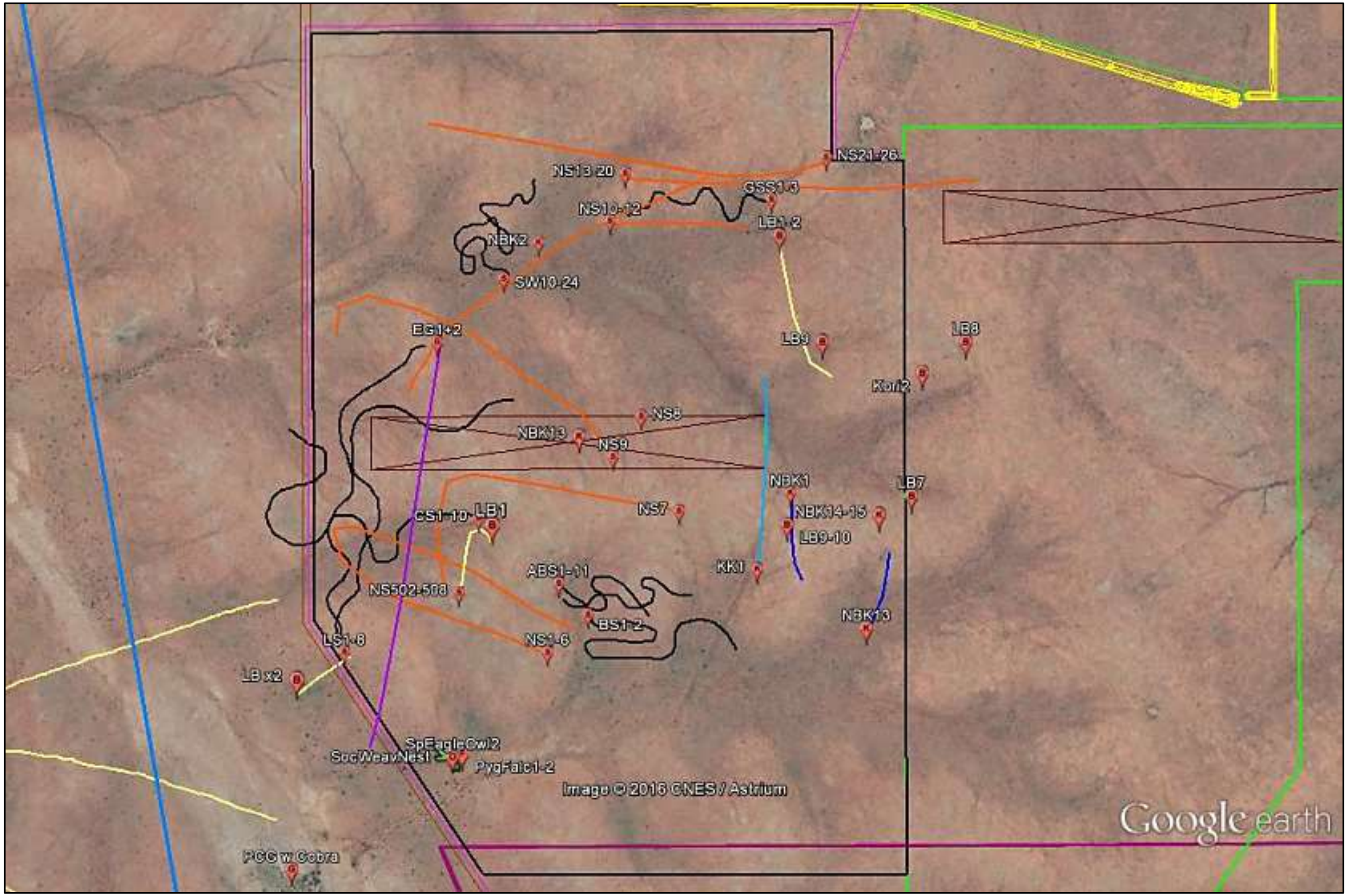

Figure 3: All aerial bird movements and perch sites in the CSP 5 solar plant on the farm Karos Nett 944 near Upington, November 2015 and March 2016. The main non-collision-prone species recorded in flight in the site were the Ludwig's Bustard (pale yellow lines). Flights of 25 sandgrouse were recorded in 12 h of observation in the wet season (March 2016) through the site in an east-west direction.

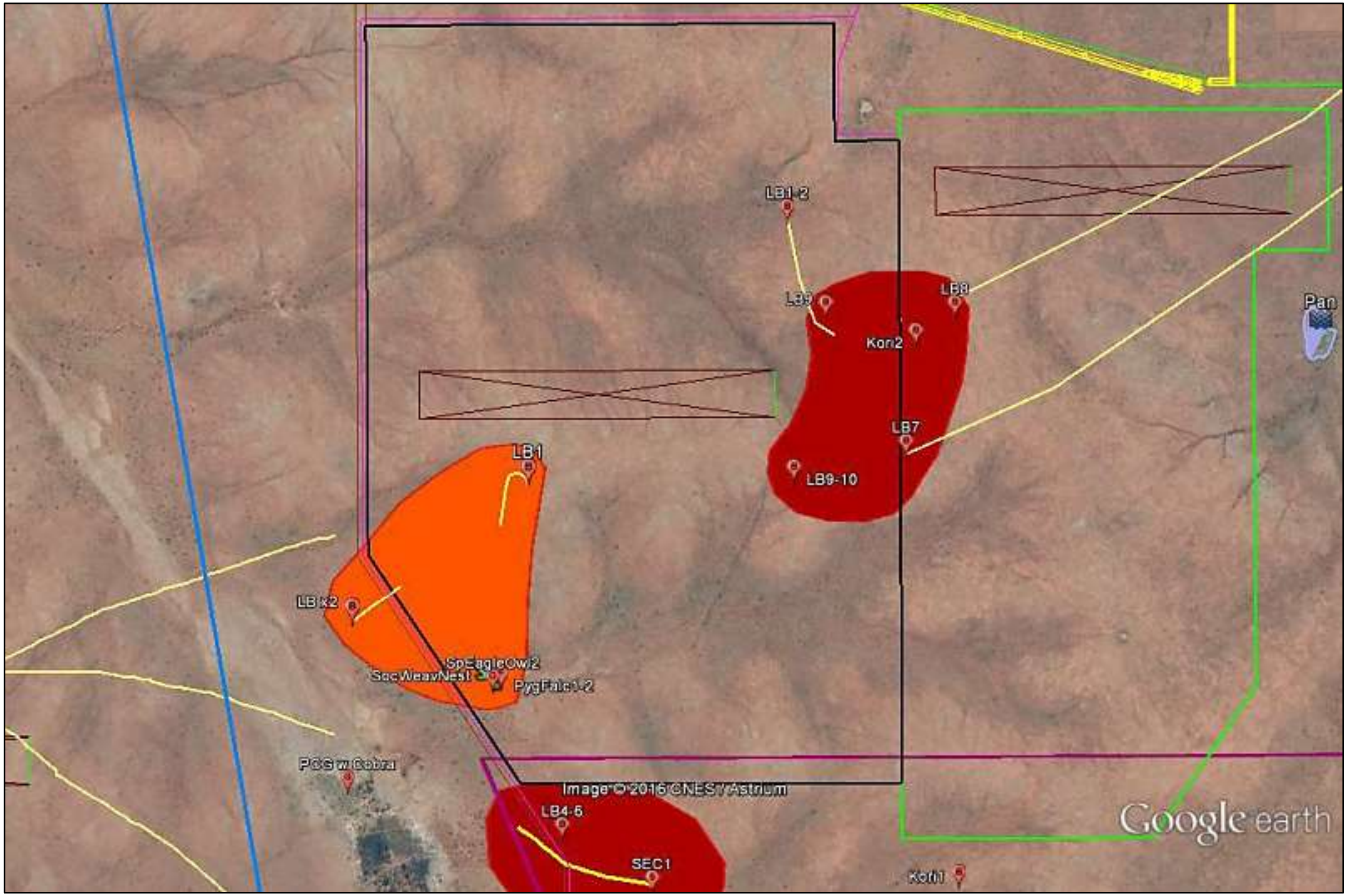

Figure 4: Sensitivity map of the collision-prone red data species on Karoshoek solar development CSP 5. On site, two areas of medium-high (orange) and high sensitivity (red) occurred. Off site, a high sensitivity area with 2 Ludwig's Bustards and a Secretarybird (=Sec1) was apparent on the southern border. The high sensitivity area on site (right) indicates where 7 threatened Ludwig's Bustard and 1 Kori Bustard were recorded in November 2015 (LB=Ludwig's Bustard, Kori = Kori Bustard). The medium high sensitivity area (orange polygon, left) encompasses 3 Ludwig's Bustards a Spotted Eagle Owl, a pair of Pygmy Falcons, each associated with a Sociable Weaver nest.

7 QUANTIFYING THE IMPACTS

The Significance (**S**) of the impacts can be semi-quantified by independently assessing the extent (**E**) of the impact in length or area, the duration (**D**) in months or years, the expected Magnitude (**M**) in terms of its impact (minor to major) on the species likely to be affected, and the probability (**P**) that the impact will occur. The significance can then be calculated as **S = (E+D+M)P**], as follows (Table 4).

Nature: The impact of the proposed CSP trough areas will generally be negative given the certainty that: (i) ~700 ha will be transformed and the associated bird habitat destroyed; (ii) birds may collide with the CSP mirrors if they mistakenly perceive them as open water; and (iii) collision-prone species living around the periphery may collide with any overhead power lines linking the solar development to the substation. This will be assessed in a separate Basic Assessment.

The Extent (**E,** from 1-5) of the impact will occur within the chosen CSP area (of 700 ha) = **(1)**

The Duration (**D**, from 1-5) will be long-term **(4)** for the lifetime of the CSP area.

The Magnitude (**M,** from 0-10) of the impact of habitat destruction on the CSP areas is expected to have a high impact **(8)** for the Ludwig's Bustard, given that up to 7 Ludwig's Bustards and a Kori Bustard will be displaced on the 700 ha site. Some raptors and korhaans will be displaced (**3:** none are threatened species) and few wetland birds will be displaced **(1).**

For bustards, and any wetland birds, some **(4)** may be killed by collision with the parabolic mirrors (Kagen et al. 2014). For the raptors and korhaans the magnitude will be lower **(2)**

The Probability of occurrence (**P,** from 1-5) of the bustards occurring and having a negative interaction with the CSP troughs is ranked high **(5)** because two red data species will be displaced by habitat destruction during construction. For the non-threatened korhaans and raptors the probability of occurrence is medium **(3)**, and for wetland birds **(1).**

The Significance S, [calculated as **S = (E+D+M)P**], is as follows (Table 4) for the species identified as at risk in the (i) CSP site due to displacement or avoidance and (ii) collision after construction.

The scale varies from 0 (no significance) to 100 (highly significant and unacceptable). A score above 50 is considered high and mitigation is required.

Table 4. A summary of the quantified impacts to the collision-prone bustards, raptors and wetland bird species likely to be impacted by **(i) displacement and avoidance** and **(ii) collision** with the CSP mirrors or associated infra-structure.

(i) Within the CSP site itself (DISPLACEMENT AND AVOIDANCE) **Nature:** Mostly negative due to direct impact mortality (or displacement /avoidance of area) around the **CSP 5** for the Red-listed bird groups identified as at risk above. (**Bust** = Bustards, **Rapt** = Raptors, **Korh** = Korhaans, **WetB** = Wetland birds):		
	Without mitigation	**With mitigation**
Extent	**1**	**1**
Duration	**4**	**4**
Magnitude	**8 (Bust)** high **3 (Rapt)** medium-low **1 (WetB)** medium-low **1 (Korh)** low	**5 (Bust)** medium **2 (Rapt)** low **1 (WetB)** low **1 (Korh)** low
Probability	**5 (Bust)** high **3 (Rapt)** medium **1 (WetB)** medium **3 (Korh)** low	**4 (Bust)** medium-high **2 (Rapt)** low **1 (WetB)** low **2 (Korh)** low
Significance (E+D+M)P	**65 (Bust)** high **21 (Rapt)** medium-low **6 (WetB),** low **21 (Korh)** medium-low	**40 (Bust)** medium **16 (Rapt)** low **6 (WetB)** low **12 (Korh)** low
Status (+ve or –ve)	Negative	Negative-
Reversibility	Medium	medium
Irreplaceable loss of species?	Yes, two red data species of bustard will lose foraging habitat without mitigation.	

Can impacts be mitigated?	Probably yes: but these red data birds on site may not return if disturbance is too great

Mitigation for impacts through collision at the CSP troughs

There are only two mitigations for displacement or avoidance of the CSP troughs by red data birds: (i) move them away from highly sensitive bird area (especially feeding/nesting areas or roosts), or (ii) reduce disturbance post-construction to allow birds to re-settle.

Cumulative impacts:

For the CSP itself the mortality and displacement impact on birds is poorly known, but many solar farms are now being constructed in the Kalahari/Karoo region and more will occur in the future: thus more research and monitoring of the combined impacts is required. This will require data sharing to a central authority to allow a meta –analysis of multiple data sets. See section 7.1 below for details.

Residual impacts:

After mitigation, displacement or avoidance by the species identified above may still occur. An environmental management programme will assess the efficacy of the mitigations to reduce avoidance sandgrouse, or the aerial swallows/swifts impacting panels. Further research and mitigation can then be suggested and tested as the need arises.

(ii) Within the CSP site itself – COLLISIONS (post construction)

Nature: Mostly negative due to direct impact mortality from impacting the mirrored surfaces in the **CSP 5** for the Red-listed bird groups identified as at risk above. We don't expect any collisions to occur pre-construction.
(**Bust** = Bustards, **Rapt** = Raptors, **Korh** = Korhaans, **WetB** = Wetland birds):

	Without mitigation	**With mitigation**
Extent	**1**	**1**
Duration	**4**	**4**
Magnitude	**3 (Bust)** low **3 (Rapt)** low **5 (WetB)** medium **2 (Korh)** low	**2 (Bust)** low **2 (Rapt)** low **3 (WetB)** low **1 (Korh)** low
Probability	**2 (Bust)** low **2 (Rapt)** low	**1 (Bust)** **1 (Rapt)**

	5 (WetB) medium **2 (Korh)** low	**3 (WetB)** **1 (Korh)**
Significance (E+D+M)P	**16 (Bust)** low **16 (Rapt)** low **50 (WetB),** medium **14 (Korh)** low	**7 (Bust)** low **7 (Rapt)** low **24 (WetB)** low **6 (Korh)** low
Status (+ve or –ve)	Negative	Neutral
Reversibility	Medium	(mitigations untested)
Irreplaceable loss of species?	No, few red data species expected to collide with mirrors. It depends entirely whether wetland species (or other African species) are attracted to and collide with the mirrors.	
Can impacts be mitigated?	Probably yes: the use of bird scaring strategies on the site will probably deter species from interacting negatively.	
Mitigation for impacts for the CSP troughs There are two classes of mitigation for the CSP troughs: (i) move them away from highly sensitive bird area (especially pans or other nests or roosts), or (ii) employ bird-diverters to deter birds mistaking the troughs for open water. We recommend that Emvelo install video cameras above some troughs for post-construction monitoring of any mortality of birds in the vicinity, through direct observation and carcass searches in a systematic and regular fashion.		
Cumulative impacts: For the CSP itself the collision-mortality of birds is poorly known, but many solar farms are now being constructed in the Kalahari/Karoo region and more will occur in the future: thus more research and monitoring of the combined impacts is required. See 7.1 below.		
Residual impacts: After mitigation, direct mortality through collision by the species identified above may still occur. An environmental management programme will assess the efficacy of the mitigations to reduce direct impacts or any problems with sandgrouse, or the aerial swallows/swifts impacting panels. Further research and mitigation can then be suggested and tested as the need arises.		

7.1 CUMULATIVE IMPACTS

Cumulative impacts are defined as "Impacts that result from incremental changes caused by either past, present or reasonably foreseeable actions together with the project" (Hyder, 1999, in Masden et al. 2010).

Thus, in this context, cumulative impacts are those that will impact the general avian communities in and around the Karoshoek solar development, mainly by other solar farms and associated infrastructure. This will happen via the same factors identified here viz: collision, avoidance and displacement. Therefore, we need to know as a starting point the number of solar farms around the region within 50 km, and secondly, to know their impact on avifauna.

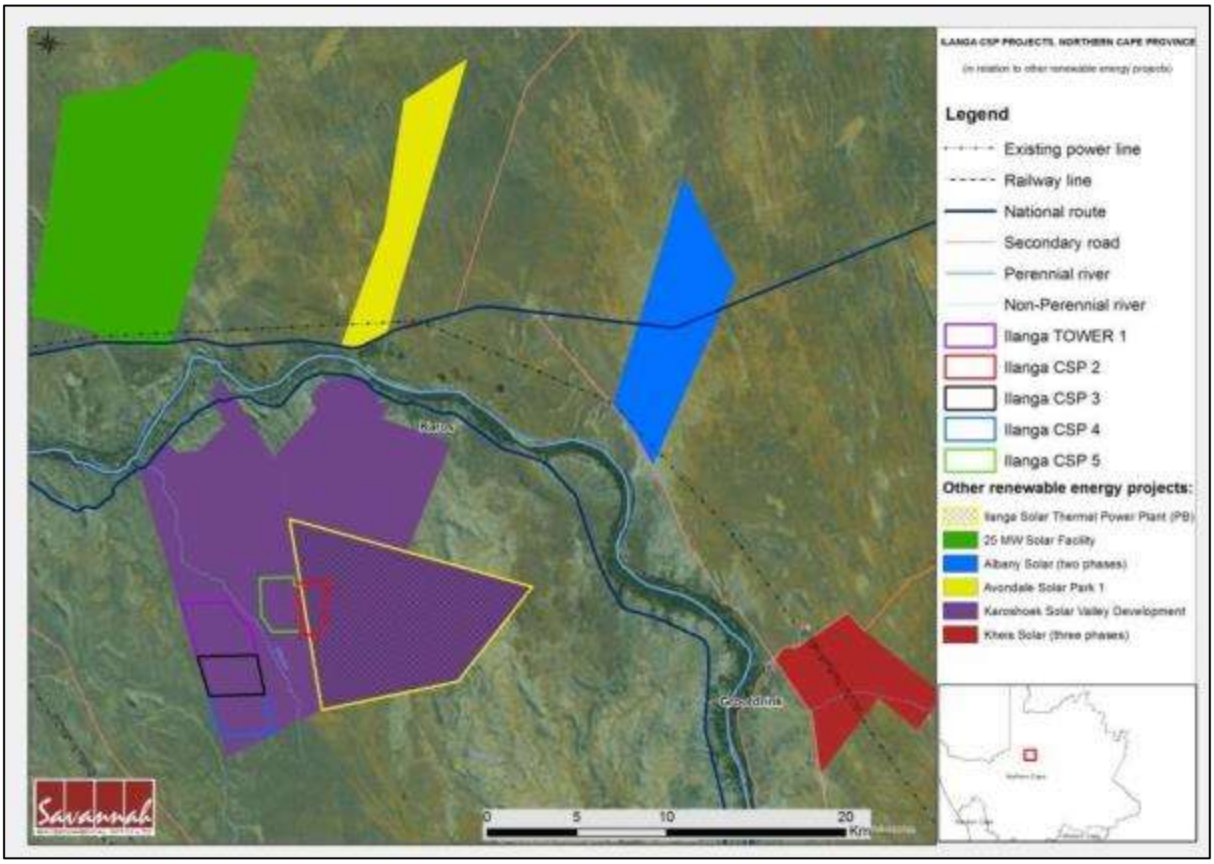

Figure 5: The location and extent of all other solar farm developments in the Karos/Upington area (as supplied by Savannah Environmental) in 2016.

There are four proposed or approved solar farms of various sizes within 50 km of Karoshoek (Figure 5).

Given the general assumption that footprint size and bird impacts are linearly related for CSP solar farms, a starting point in determining cumulative impacts is to determine:

- the number of bird displaced per unit area, by habitat destruction, or disturbed or displaced by human activity;
- the number of birds killed by collision with the structures on site;
- the number of birds killed by collision with infrastructure leading away from the site;
- the number of birds killed by flying through the solar flux of CSP tower sites.

Because there are no post-construction mortality data or displacement data for any of these aspects in South Africa, it is a futile exercise to attempt to put any figures to the Cumulative Impacts for birds in and around the Orange River's solar farms. Once the data is collected and published (or released to other specialists) we can quantify this aspect.

Orange River water off–take rates are considerations already under investigation by hydrologists. However, the influence on the Orange River's wetland birds, which use the river as a linear oasis (Simmons & Allan 2002), needs to be assessed. This arises because the Orange River flow is reduced at certain times of year to very low rates. But at all times no less than 20% of the flow is required as an ecological reserve to maintain ecological functioning of the river (http://orangesenqurak.com/challenge/water+demand/environmental+flows.aspx). Further off-take amounting to a possible 640 000 m^3, (8 CSP sites x 80 000 m^2) particularly at low flow (November-December) may force some wetland species to seek other water sources. This may become an issue for the CSPs and the bank of mirrored surfaces that will be in the environment surrounding the river environs. If the Lake Effect of Kagen et al. (2014) attracts such water-seeking wetland birds then the large off-take of water from the Orange River may exacerbate this effect. We would predict:

- a seasonal influx of wetland birds attracted to the CSPs in the dry season and an increase in mortality;
- greater mortality with time, as more and more solar developments take more and more water away at low-flow periods.

A simple calculation of the Cumulative Impact of this would be related to:

- the *rate* of avian mortality per surface area of the mirrored surfaces of the CSPs per year;

- the total surface area of the mirrored surfaces of each CSP in the area;
- the reduction in flow of the Orange River causing more birds to seek other water sources; and
- the number of solar farms within 50 km of the Karoshoek site.
-

In 2016 we cannot yet quantify all of these variables, so a prediction of Cumulative Impact is not possible. Data gathering and sharing over even just one 12-month period, of one or more solar farms, will allow us to determine impacts on Orange River avifauna.

8 ENVIRONMENTAL MANAGEMENT PLAN

Given the size and number of the CSP plants proposed for the total Karoshoek Solar Valley Development, the overall impact on the avifauna species requires systematic monitoring at both the construction and post-construction phases. This is a recommendation of the draft BARESG guidelines (Jenkins et al. 2015).

The guidelines suggest an adaptive and systematic monitoring of bird displacement (comparing avian densities before and after construction, particularly for collision-prone and red data species) and all fatalities. The latter must take account of biases introduced by scavengers removing carcasses and observers not detecting bird remains.

The monitoring should include the following (after Jenkins et al. 2015):

- Post-construction monitoring should be started as the facility becomes operational, bearing in mind that the effects of the CSP facility may change over time;

- Post-construction monitoring can be divided into two categories: a) quantifying bird numbers and movements (replicating baseline data collection), and b) estimating bird mortalities;

- Estimating bird fatality rates includes: a) estimation of searcher efficiency and scavenger removal rates, b) carcass searches, and c) data analysis incorporating systematically collected data from *a* and *b*;

- A minimum of 20-30% of the CSP solar footprint should be methodically searched for fatalities, with a search interval informed by scavenger removal trials and objective monitoring. Any evidence of mortalities or injuries within the remaining area should be recorded and included in reports as incidental finds;

- The search area should be defined and consistently applied throughout monitoring;
- Observed mortality rates must be adjusted to account for searcher efficiency (which could change seasonally depending on vegetative condition of the site), scavenger removal and the proportion of the facility covered by the monitoring effort. Some of these factors may change seasonally due to the breeding season of scavengers and whether visibility of the survey area changes through the year;
- The duration and scope of post-construction monitoring should be informed by the outcomes of the previous year's monitoring, and reviewed annually;
- Post-construction monitoring of bird abundance and movements and fatality surveys should span 2-3 years to take inter-annual variation into account;
- If significant problems are found or suspected, the post-construction monitoring should continue as needed in conjunction with adaptive management and mitigations, taking into account the risks related to the particular site and species involved.

A comprehensive assessment guided by the principles above is required not only to enact and experiment with different mitigation measures where significant mortality is found, but to allow data to be collected that will benefit the welfare of avifauna at other solar farms. This will also be important for a study of cumulative avian impacts for the large number of solar farms planned for the Northern Cape of South Africa.

Management interventions: Where avian fatalities are found to occur (i) to red-data species, or (ii) at unacceptably high levels, to these or other species, then mitigation measures should be brought into play. Thus, experiments with bird deterrent techniques such as Torri Lines, successfully used to prevent albatrosses and petrels descending onto baited hooks behind trawlers at sea, can be tried and tested (http://www.birdlife.org.za/conservation/seabird-conservation/albatross-task-force). Bird-scaring prisms are also an option that can be tested. Where natural or artificial pans occur and attract wetland species that are then killed by the CSP mirrors, action to close down the pan or dam will then be required. (Avoiding construction around natural pans beforehand will pre-mitigate such action).

9 CONCLUSIONS AND RECOMMENDATIONS

The proposed CSP 5 plant in the Karoshoek Solar Valley Development, near Upington, is one of many such renewable energy initiatives being proposed for this high-flux solar radiation region of South Africa.

The avifauna of the area may be affected by the infrastructure of the Solar Power (CSP) plant and our analysis of the number of collision-prone birds on CSP 5 suggests that:

- A threatened bustard and some wetland birds may be impacted. The significance for displacement and avoidance will be medium–low this red data species;
- mitigation measures include avoiding the medium sensitivity areas identified;
- for the wetland birds, korhaans and raptors the significance is lower because they are less collision-prone and less threatened;
- sandgrouse, which were very numerous on site, are unlikely to react to mirrored surfaces as they do not land on water;
- a structured and systematic construction and post-construction assessment, as laid out in the Environmental Management Programme (above) by trained ornithologists will determine the impacts and provide appropriate mitigations.

Precious little research in South Africa is presently available to determine the impact of CSP trough and tower technology on the South African avian community, so a minimum of 12 months' post-construction monitoring at this site by trained ornithologists is strongly recommended.

We also recommend that all available precautions are taken to avoid threatened species and wetland birds being attracted to the troughs. If species are attracted and collide with the CSP troughs by mistaking them for open water then we recommend that innovative bird deterrent techniques are used, such as the Torri lines mentioned above and in the avian Scoping Report (Simmons and Martins 2015).

If these recommendations can be followed and prove effective, we believe that the CSP 5 development can be allowed to proceed with the least impact to the avifauna of the area.

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19 April 2016

11 APPENDICES

Appendix 1: All bird species recorded around the Karoshoek Solar development

All bird species and their likelihood of occurrence in the greater Karoshoek solar development area, from the bird atlas pentads that run along the Ilanga power line to the CSP site. These pentads are: 2825_2115, 2825_2120, 2825_2125, 2825_2130 from the period 2007 to 2013. Extracted from the Animal Demography Unit, University of Cape Town website http://sabap2.adu.org.za and based on 17 cards. **Red data species are given in red, collision-prone species in bold.** Blue shading indicates wetland species that may be attracted to the parabolic mirrors.

Note: this list includes pentads that overlap the Orange River inflating the number of species that will occur in the drier footprint of the Karoshoek solar development. We have added our species records in the last column, which includes no Orange River areas.

Species	Pentads/4	Records	Total cards	Reporting Rate %	Recorded in our site visits in Karos solar park
Ostrich, Common	1	1	17	5.9	√
Grebe, Little	1	2	17	11.8	
Cormorant, White-breasted	2	6	17	35.3	
Cormorant, Reed	3	6	17	35.3	
Darter, African	2	7	17	41.2	
Heron, Grey	1	4	17	23.5	
Heron, Black-headed	1	1	17	5.9	
Heron, Goliath	1	1	17	5.9	√
Egret, Little	1	4	17	23.5	
Egret, Cattle	3	10	17	58.8	
Bittern, Little	1	1	17	5.9	
Hamerkop	2	8	17	47.1	
Stork, Abdim's	1	1	17	5.9	
Ibis, African Sacred	3	5	17	29.4	√
Ibis, Hadeda	3	16	17	94.1	
Goose, Egyptian	2	11	17	64.7	√
Shelduck, South African	2	2	17	11.8	
Duck, African Black	1	1	17	5.9	
Duck, Yellow-billed	1	1	17	5.9	
Teal, Cape	1	1	17	5.9	
Red-billed Teal					√
Harrier, Black					√
Eagle, Verreaux's					√
Eagle, Booted					√
Falcon, Lanner	**1**	**1**	**17**	**5.9**	√
Kestrel, Rock					√
Falcon, Pygmy	1	1	17	5.9	√
Kite, Black-shouldered	2	4	17	23.5	

Fish-Eagle, African	**2**	**6**	**17**	**35.3**	
Pale-chanting Goshawk	**1**	**1**	**17**	**5.9**	√
Guineafowl, Helmeted	2	8	17	47.1	
Common Quail					√
Crake, Black	1	1	17	5.9	
Moorhen, Common	1	1	17	5.9	
Bustard, Kori	**1**	**1**	**17**	**5.9**	√
Bustard, Ludwig's					√
Korhaan, Karoo	**1**	**1**	**17**	**5.9**	√
Northern Black Korhaan	**1**	**2**	**17**	**11.8**	√
Plover, Three-banded	2	4	17	23.5	
Lapwing, Crowned	1	5	17	29.4	
Lapwing, Blacksmith	3	9	17	52.9	√
Sandgrouse, Namaqua	2	2	17	11.8	√
Double-banded Courser					√
Pigeon, Speckled	3	16	17	94.1	
Dove, Red-eyed	3	13	17	76.5	
Turtle-Dove, Cape	3	14	17	82.4	√
Dove, Laughing	3	15	17	88.2	√
Dove, Namaqua	1	3	17	17.6	√
Cuckoo, Diderick	1	3	17	17.6	
Owl, Barn	1	3	17	17.6	
Owlet, Pearl-spotted	1	1	17	5.9	
Eagle-Owl, Spotted	1	1	17	5.9	√
Common Swift					√
Swift, White-rumped	2	3	17	17.6	
Swift, Little	3	12	17	70.6	√
Palm-Swift, African	2	12	17	70.6	
Mousebird, White-backed	3	14	17	82.4	√
Mousebird, Red-faced	1	8	17	47.1	√
Kingfisher, Pied	2	5	17	29.4	
Kingfisher, Giant	2	4	17	23.5	
Kingfisher, Malachite	2	3	17	17.6	
Kingfisher, Striped	1	1	17	5.9	
Bee-eater, European	1	2	17	11.8	
Bee-eater, Swallow-tailed	3	4	17	23.5	
Hoopoe, African	2	10	17	58.8	
Barbet, Black-collared	1	1	17	5.9	
Barbet, Acacia Pied	3	4	17	23.5	√
Barbet, Crested	3	9	17	52.9	
Honeyguide, Lesser	1	2	17	11.8	
Shrike, Lesser Grey					√
Woodpecker, Golden-tailed	1	3	17	17.6	
Lark, Fawn-coloured	1	2	17	11.8	√

Lark, Sabota	3	4	17	23.5	√
Lark, Spike-heeled	2	2	17	11.8	√
Stark's Lark					√
Swallow, Barn	2	4	17	23.5	√
Swallow, White-throated	1	6	17	35.3	
Swallow, Greater Striped	2	10	17	58.8	√
Martin, Rock	3	6	17	35.3	√
Martin, Brown-throated	3	8	17	47.1	
Tit, Ashy	1	1	17	5.9	
Crow, Pied	1	4	17	23.5	√
Bulbul, African Red-eyed	3	16	17	94.1	
Rock-Thrush, Short-toed	1	1	17	5.9	
Wheatear, Capped	1	1	17	5.9	√
Chat, Ant-eating					√
Chat, Karoo					√
Chat, Familiar	3	3	17	17.6	
Robin-Chat, Cape	3	12	17	70.6	
Scrub-Robin, Karoo	3	5	17	29.4	√
Kalahari Scrub Robin					√
Swamp-Warbler, Lesser	2	5	17	29.4	
Reed-Warbler, African	2	3	17	17.6	
Eremomela, Yellow-bellied					√
Warbler, Rufous-eared	1	4	17	23.5	√
Cisticola, Zitting	3	6	17	35.3	
Cisticola, Levaillant's	3	4	17	23.5	
Cisticola, Desert					√
Prinia, Black-chested	3	8	17	47.1	√
Warbler, Namaqua	1	1	17	5.9	√
Tit-Babbler, Chestnut-vented	2	2	17	11.8	√
Tit-babbler, Layard's					√
Flycatcher, Chat					√
Flycatcher, Fiscal	3	3	17	17.6	
Batis, Pririt	3	4	17	23.5	
Wagtail, African Pied	1	1	17	5.9	
Wagtail, Cape	2	13	17	76.5	√
Pipit, African	2	3	17	17.6	
Fiscal, Common	2	11	17	64.7	√
Bokmakierie,	2	4	17	23.5	√
Brubru	1	3	17	17.6	
Starling, Wattled	2	9	17	52.9	
Starling, Cape Glossy	3	4	17	23.5	
Sunbird, Dusky	3	5	17	29.4	√
Sparrow-Lark, Grey-backed					√
Sparrow-Lark, Black-eared					√

Sparrow-Weaver, White-browed	2	9	17	52.9	√
Weaver, Sociable	3	5	17	29.4	√
Sparrow, House	3	13	17	76.5	
Sparrow, Cape	3	13	17	76.5	√
Masked-Weaver, Southern	3	15	17	88.2	√
Quelea, Red-billed	3	6	17	35.3	√
Bishop, Southern Red	2	9	17	52.9	
Firefinch, Red-billed	2	4	17	23.5	
Finch, Scaly-feathered					√
Waxbill, Common	2	2	17	11.8	
Whydah, Pin-tailed	1	4	17	23.5	
Canary, Black-headed					√
Canary, Black-throated	2	6	17	35.3	
Canary, Yellow	2	3	17	17.6	√
White-throated Canary					√
Dove, Rock	3	8	17	47.1	
Thrush, Karoo	1	13	17	76.5	
White-eye, Orange River	3	15	17	88.2	
Lark, Eastern Clapper	1	1	17	5.9	√
Coucal, Burchell's	1	3	17	17.6	
Sparrow, Southern Grey-headed	2	3	17	17.6	
Bunting, Lark-like					√

APPENDIX 2: BIRD DENSITIES BY HABITAT

Species recorded on site in 1-km transects on the Karoshoek Solar Valley Development CSP 5 in November 2015 and March 2016.

NOVEMBER 2015 (Dry season)	Number	PerpDist	Date	Transect	Habitat
Black-chested prinia	1	10	31/10/2015	KT1.4-1	Low scrub, some grass
Northern black korhaan	1	15	31/10/2015	KT1.4-1	Low scrub, some grass
Karoo prinia	2	20	31/10/2015	KT1.4-1	Low scrub, some grass
Northern black korhaan	2	35(3)	31/10/2015	KT1.4-1	Low scrub, some grass
Stark's lark	1	15	31/10/2015	KT1.4-1	Low scrub, some grass
Barn swallow	2	5(3)	31/10/2015	KT1.4-1	Low scrub, some grass
Clapper lark	1	10(4)	31/10/2015	KT1.4-1	Low scrub, some grass
Karoo prinia	1	5	31/10/2015	KT1.4-1	Low scrub, some grass
Northern black korhaan	1	10(5)	31/10/2015	KT1.4-1	Low scrub, some grass
Namaqua sandgrouse	1	40	31/10/2015	KT1.4-1	Low scrub, some grass
Barn swallow	1	5(2)	31/10/2015	KT1.4-1	Low scrub, some grass
Scaly-feathered finch	9	5	31/10/2015	KT1.4-1	Low scrub, some grass
Scaly-feathered finch	3	2	31/10/2015	KT1.4-1	Low scrub, some grass
Namaqua sandgrouse	2	60	31/10/2015	KT1.4-1	Low scrub, some grass
Black-chested prinia	1	20	31/10/2015	KT1.4-1	Low scrub, some grass
Black-chested prinia	1	6	31/10/2015	KT1.4-1	Low scrub, some grass
Karoo prinia	1	5	31/10/2015	KT1.4-1	Low scrub, some grass
Cape turtle dove	1	50	31/10/2015	KT1.4-1	Low scrub, some grass
White-throated canary	1	15	31/10/2015	KT1.4-1	Low scrub, some grass
Barn swallow	1	20(3)	31/10/2015	KT1.4-1	Low scrub, some grass
Spike-heeled lark	1	30	31/10/2015	KT1.4-1	Low scrub, some grass
Rufous-eared warbler	1	20	31/10/2015	KT1.4-1	Low scrub, some grass
Namaqua sandgrouse	1	20	31/10/2015	KT1.4-1	Low scrub, some grass
Karoo eremomela	2	10	31/10/2015	KT1.4-1	Low scrub, some grass
Karoo prinia	1	40	31/10/2015	KT1.4-1	Low scrub, some grass
Common fiscal	1	30	31/10/2015	KT1.4-1	Low scrub, some grass
Bokmakierie	1	55	31/10/2015	KT1.4-1	Low scrub, some grass
15 species	**42**	**birds**	**In this trans: Red Data species = 0**		**Collision-prone species = 1**
Pygmy falcon	2	0	01/11/2015	KT1.4-2	Dry river bed, short scrubby bushes
Spotted eagle-owl	1	0	01/11/2015	KT1.4-2	Dry river bed, short scrubby bushes
Sociable weaver	20	1(1)	01/11/2015	KT1.4-2	Dry river bed, short scrubby bushes
Little swift	1	1(8)	01/11/2015	KT1.4-2	Dry river bed, short scrubby bushes
Cape turtle dove	1	30	01/11/2015	KT1.4-2	Dry river bed, short scrubby bushes
Little swift	1	50	01/11/2015	KT1.4-2	Dry river bed, short scrubby bushes
Ludwig's bustard	2	100(7)	01/11/2015	KT1.4-2	Dry river bed, short scrubby bushes
5 species	**28**	**birds**	**In this trans: Red Data species = 1**		**Collision-prone species = 3**
Total Birds	**70**				
Total Species	**20**				
Total Collision-prone sp	**3**	Ludwig's Bustard; Spotted Eagle-Owl; Northern Black Korhaan			
Total Red-data Species	**1**	**Ludwig's Bustard**			
Summary (DRY)	**Species**	**Birds**	**Habitat**		
KT1.4-1	15	42	Low scrub, some grass		
KT1.4-2	5	28	Dry river bed, short scrubby bushes		
Means	**10.00**	**35.00**			

MARCH 2016 (Wet season)	Number	PerpDist	Date	Transect	Habitat
Cape clapper lark	2	5	29/02/2016	KT1.4-1	Low scrub, some grass
Northern black korhaan	1	50	29/02/2016	KT1.4-1	Low scrub, some grass
Grey-backed sparrowlark	6	10	29/02/2016	KT1.4-1	Low scrub, some grass
Common swift	12	5(8)	29/02/2016	KT1.4-1	Low scrub, some grass
Northern black korhaan	1	40	29/02/2016	KT1.4-1	Low scrub, some grass
Ostrich	1	100	29/02/2016	KT1.4-1	Low scrub, some grass
Karoo prinia	1	40	29/02/2016	KT1.4-1	Low scrub, some grass
Northern black korhaan	1	55	29/02/2016	KT1.4-1	Low scrub, some grass
Rufous-eared warbler	1	70	29/02/2016	KT1.4-1	Low scrub, some grass
Cape clapper lark	1	20	29/02/2016	KT1.4-1	Low scrub, some grass
Namaqua dove	1	30	29/02/2016	KT1.4-1	Low scrub, some grass
Fawn-coloured lark	1	10	29/02/2016	KT1.4-1	Low scrub, some grass
Rufous-eared warbler	1	20	29/02/2016	KT1.4-1	Low scrub, some grass
Grey-backed sparrowlark	1	10	29/02/2016	KT1.4-1	Low scrub, some grass
Alpine swift	1	10(3)	29/02/2016	KT1.4-1	Low scrub, some grass
African black swift	3	50(10)	29/02/2016	KT1.4-1	Low scrub, some grass
Grey-backed sparrowlark	1	15	29/02/2016	KT1.4-1	Low scrub, some grass
Bokmakierie	1	50	29/02/2016	KT1.4-1	Low scrub, some grass
Grey-backed sparrowlark	1	15	29/02/2016	KT1.4-1	Low scrub, some grass
Greater striped swallow	1	60	29/02/2016	KT1.4-1	Low scrub, some grass
Spike-heeled lark	5	2	29/02/2016	KT1.4-1	Low scrub, some grass
Lesser grey shrike	1	70	29/02/2016	KT1.4-1	Low scrub, some grass
Cape turtle dove	1	50	29/02/2016	KT1.4-1	Low scrub, some grass
Namaqua dove	2	35	29/02/2016	KT1.4-1	Low scrub, some grass
Karoo korhaan	2	120	29/02/2016	KT1.4-1	Low scrub, some grass
Sabota lark	2	20	29/02/2016	KT1.4-1	Low scrub, some grass
18 species	**52**	**birds**	**In this trans: Red Data species = 0**		**Collision-prone species = 2**
Total Birds	**52**				
Total Species	**18**				
Total Collision-prone sp	**2**	Karoo Korhaan; Northern Black Korhaan			
Total Red-data Species	**0**				
Summary (WET)	**Species**	**Birds**	**Habitat**		
KT1.4-1	18	52	Low scrub, some grass		
Means	**18.00**	**52.00**			
Overall means	9.5	30.5			

Appendix 3: Passage rates of Collision-prone species

Date	Time	Obsv period	Hrs	Vantage Point	No.	Species	GPS pos on map	Height
31/10/2015	6h45	07h30-11h30	4	**VP1.4-1**	**2**	**Ludwig's bustard**	LB1-2	0m
	8h28				**2**	**Ludwig's bustard**	LB3-4	0m
	8h53				2	Namaqua sandgrouse	NS77-78	20m
	9h01				**1**	**Pale-chanting goshawk**	PCG2	0m
	9h49				**2**	**Karoo korhaan**	KK4-5	0m
01/11/2015	07h30	07h00-13h00	6	**VP1.4-2**	**2**	**Karoo korhaan**	KK6-7	15m
	08h15				3	Namaqua sandgrouse	NS79-81	0m
	10h00				2	Pygmy falcon	PF1-2	0m
	10h16				**1**	**Spotted eagle-owl**	SEO1	0m
	11h09				**2**	**Ludwig's bustard**	LB5-6	15m
	12h01				**1**	**Rock kestrel**	RK1	10m-15m
	12h23				**2**	**Karoo korhaan**	KK8-9	0m
06/11/2015	14h15	14h00-16h00	2	**VP1.4-3**	**1**	**Northern black korhaan**	NBK13	0m
	15h55				**2**	**Karoo korhaan**	KK2-3	0m
			12	**TOTALS**	25	**Birds**	**8**	**Species**
				Total	**18**	**Collision-prone birds**		
Passage rate:		25	birds in	12	hr	2.08	birds/hr	All birds
Passage rate:		**18**				**1.50**	**birds/hr**	**Collision-prone birds**

Date	Time	Obsv period	Hrs	Vantage Point	No.	Species	GPS pos on map	Height
29/02/2016	07h21	06h30-12h30	6	**VP1.4-1**	2	Egyptian goose	EG1+2	10-10-12m
	08h01				**1**	**Ludwig's Bustard**	LB1	2-2m
					6	Namaqua sandgrouse	NS1-6	5-5-5-7-3m
	09h02				1	Namaqua sandgrouse	NS7	15m
	09h06				1	Namaqua sandgrouse	NS8	0m
	09h35				1	Namaqua sandgrouse	NS9	15-15-15-15m
	12h14				**1**	**Karoo korhaan**	KK1	10-10-15-15m
	12h20				**1**	**Northern black korhaan**	NBK1	10-12-15-20m
02/03/2016	07h15	07h00-13h00	6	**VP1.4-2**	3	Namaqua sandgrouse	NS10-12	Heard only
	08h03				7	Namaqua sandgrouse	NS13-20	15-15m
	08h25				6	Namaqua sandgrouse	NS21-26	15-15-20m
	11h57				**1**	**Northern black korhaan**	NBK2	Heard only
			12	TOTALS	**31**	**Birds**	**4**	**Species**
				Totals	**4**	**Collision-prone birds**		
Passage rate:		31 birds in		12	hr	2.58	birds/hr	
Passage rate: (wet)		**4**		**12**		**0.33 birds/h**	**Collision-prone birds**	
Overall Passage rate (wet+dry) 22				24				**0.92 Collision-prone birds**
Passage Rate (sandgrouse)			25	12		**2.1 birds/h**	Sandgrouse alone	