3 An indication of the scope of, and the purpose for which, the report was prepared;

West Coast Resources (Pty) Ltd (WCR) is a private company owned by Trans Hex Operations (Pty) Ltd (Trans Hex), RE:CM and Calible Limited (RAC), the Government of South Africa, Dinoka Investment Holdings (Pty) Ltd and the Namaqualand Diamond Trust Fund. Trans Hex has entered into an agreement with the other shareholders of WCR to oversee and manage the operations WCR. WCR is re-establishing diamond mining operations in the Koingnaas area on the Namaqualand coast, which was previously mined by De Beers and under the existing mining environmental authorisation (EA) that was issued in terms of the National Environmental Management Act (Act No. 107 of 1998) in July 2012. As part of their operations, WCR intend to mine deposits that are located on land as well as specific deposits that extend seaward from the land potentially for several hundred metres. While some of the intended activities remain authorised in terms of the existing EA, other activities require a new EA. Myezo Environmental Management Services were appointed by WCR to undertake the Scoping and Environmental Impact Assessment (EIA). The scoping phase was been completed recently and revealed that various specialists would be required to complete the EIA. Henceforth, Anchor Environmental Consultants (Pty) Ltd. were appointed by Myezo Environmental Management Services in June 2016 to conduct a specialist study for the Swartlintjies Estuary. Both, data collected during a site visit in June 2016 as well as existing literature were used to describe the current biophysical state of the estuary. This specialist report assesses future prospecting and mining impacts on estuarine ecology and functioning based on available biophysical data and elaborates on future rehabilitation requirements.

4 The date and season of the site investigation and the relevance of the season to the outcome of the assessment;

The site visit was conducted in Winter on the 22 June 2016 during sunny weather conditions. The Namaqualand receives most of its rainfall between April and September resulting in episodic peak flows during this time (Heydorn & Tinnley, 1980). The Swartlintjies catchment had received some rain prior to the site visit, which was favourable in assessing biophysical characteristics of the estuary. Firstly, vegetation within the Estuarine Functional Zone had come to life after the rain, which allowed us to identify most plant species. Furthermore, although closed to the sea, the estuary contained some water, attracting a number of water associated bird species, who were feeding primarily on brine shrimp. We were also able to record water quality (water temperature, dissolved oxygen, salinity, conductivity and pH) and to sample benthic macrofauna, which represents the first invertebrate record for the estuary. Finally, wet soils preserved animal foot prints and therefore facilitated the identification of various mammals that visit the estuary and its flood plain.

5 A description of the methodology adopted in preparing the report or carrying out the specialised process;

A site visit was undertaken on 22 June 2016 to collect biophysical data on water quality, sediment characteristics, benthic macrofauna, fish, bird and vegetation. Data and observations from the site visit along with existing literature (Heinecken, 1980) and data (e.g. historic aerial photographs) were used to describe the current biophysical state of the Swartlintjies Estuary and to identify potential impacts of future prospecting and mining activities on the estuary. The impact assessment was completed according the template provided by Myezo Environmental Management

Services. The following sections elaborate on the methods used to collect and analyse biophysical data obtained on 22 June 2016.

5.1 Water quality

Water quality measurements for temperature, salinity, conductivity, dissolved oxygen and pH were taken at three sites in the estuary using a handheld Hach water quality meter (Figure 1). Depth profiles were not produced due to the fact that the water was very shallow (< 50 cm deep).

5.2 Sediments

Sediment samples were collected at three sites distributed along the length of the estuary (Figure 1). Samples were placed in sterile sampling jars on ice immediately after collection and submitted to an SANAS accredited analytical laboratory for determination of grain size distribution, as well as organic and trace metal (Al, As, Cd, Cu, Mn, Ni, Pb, Zn, Hg) content.

Data on sediment grain size distribution for both intertidal and subtidal sediments were analysed using GRADISTAT (Blott & Pye 2001). GRADISTAT software automates the process of classifying and characterising sediments both quantitatively and qualitatively.

Sediments were also analysed for concentrations of aluminium (Al), arsenic (As), cadmium (Cd), Copper (Cu), manganese (Mn), nickel (Ni), lead (Pb), zinc (Zn) and mercury (Hg). Trace metals concentrations in the sediments were determined using a Nitric Acid (HNO3) / Perchloric Acid (HClO3)/ Hydrogen Peroxide (H2O2)/ Microwave digestion and JY Ultima Inductively Coupled Plasma Optical Emission

Spectrometer. The concentrations of metals in the sediments of the Swartlintjies Estuary on 22 June 2016 are shown in (Section 10.3.2.1).

Trace metals were normalised against aluminium by dividing the concentration of each metal by the concentration of aluminium, a procedure commonly conducted for metal analysis (Summers, Wade, Engle, & Malaeb, 1996). As concentrations of metals in sediments are affected by total organic content, sediment grain size, and mineralogy, correct interpretation requires normalising their concentrations rather than using their raw concentrations (Summers et al., 1996). Metal concentrations are commonly normalised against the concentration of aluminium, as aluminium ubiquitously coats all sediments and thus occurs in proportion to the surface area of the sediment (Gibbs, 1994).

5.3 Benthic macrofauna

Benthic macrofauna samples were collected at Site 1 and 2 (Figure 1). The estuary was not connected to the sea at the time of the survey and sampling was therefore not dependent on tidal cycles. Samples were collected by inserting a 14.5 cm diameter corer into the sediment to a depth of 30 cm, plugging the open end, extracting the core and transferring the contents to a 0.5 mm mesh bag. Two cores with a surface area of 0.02 m^2 were taken and pooled at each sampling station (A-E) of Site 1. Due to shallower water and associated difficulties in processing the sample, only one core was sampled at each sampling station (A-E) of Site 2. The mesh bag was submerged and agitated until all the fine sediment was removed and the remaining contents placed in a sample jar. 5% formalin was added as a preservative. No benthic macrofauna was present in the samples and negated further analysis.

5.4 Fish

Experimental seine netting was conducted using a beach-seine net, 30 m long, 2m deep, with a stretched mesh size of 12 mm at Site 1. No fish were caught due to hypersaline conditions in the estuary, which negated any further sampling and analysis.

5.5 Birds

Water-associated birds (i.e. wading birds, waders, gulls and terns) were identified and counted prior to sediment, benthic macrofauna and fish sampling activities to avoid disturbance. Bird species in the surrounding shrub and flood plain were identified by call and/or sight and counted during a 30 minute walk through the flood plain (Figure 1).

5.6 Mammals

Recent rain had resulted in a muddy terrain, which preserved animal footprints well. Photos of these footprints were taken and identified using The Field Guide to the Animal Tracks of Southern Africa by Liebenberg (2008).

5.7 Vegetation

Vegetation was delineated prior to the field visit using Google Earth imagery and a high resolution aerial photograph dated 2011 and provided by WRC. The preliminary vegetation map was ground truthed by delineating/confirming vegetation groups (i.e. salt marsh, shrub, dune vegetation) and identifying the species that make up these groups. Identification was facilitated by taking photos and vegetation samples. Photos were also taken from higher ground (haul road and edge of flood plain) to confirm vegetation groups from a birds eye perspective. Lists of important species for specific vegetation types were obtained from the BGIS website (National Vegetation Map 2012 beta2: Map Viewers).

5.7.1 Delineation of the Swartlintjies Estuary

An estuary is defined in terms of the National Environmental Management: Integrated Coastal Management Act (ICMA) (Act No. 24 of 2008) and the NEMA 2014 EIA Regulations as "a body of surface water—

a. that is permanently or periodically open to the sea;
b. in which a rise and fall of the water level as a result of the tides is measurable at spring tides when the body of surface water is open to the sea; or
c. in respect of which the salinity is higher than fresh water as a result of the influence of the sea, and where there is a salinity gradient between the tidal reach and the mouth of the body of surface water."

While this definition is in line with those used internationally in respect of estuary water bodies it is considered somewhat limited inasmuch as it encapsulates only the estuary water body and not the adjacent physical and biological processes and habitats required to support estuarine function and health. Thus, as part of the Estuary Component of the National Biodiversity Assessment (NBA) (Van Niekerk & Turpie, 2012) a definition for the estuarine functional zone (EFZ) was formulated which extended the lateral boundaries of an estuary up to the 5 m contour, with the downstream boundary taken as the estuary mouth and the upstream boundary taken as the limits of tidal variation or salinity penetration, whichever penetrates furthest.

Protection/rehabilitation of the estuarine functional zone is considered essential for protection of estuarine biodiversity and associated ecological processes (Van Niekerk & Turpie, 2012).

The Swartlintjies Estuary has been classified as a small ephemeral river outlet and is not considered one of the 289 functional estuaries in South Africa (Van Niekerk & Turpie, 2012). Using the NBA definition for delineating the extent of the Swartlintjies Estuary would result in a very small and meaningless management unit, which is not practically implementable. Consequently, the extent of the estuary, i.e. the EFZ, was determined according to the 5 m contour above mean sea level (MSL) (Figure 1).

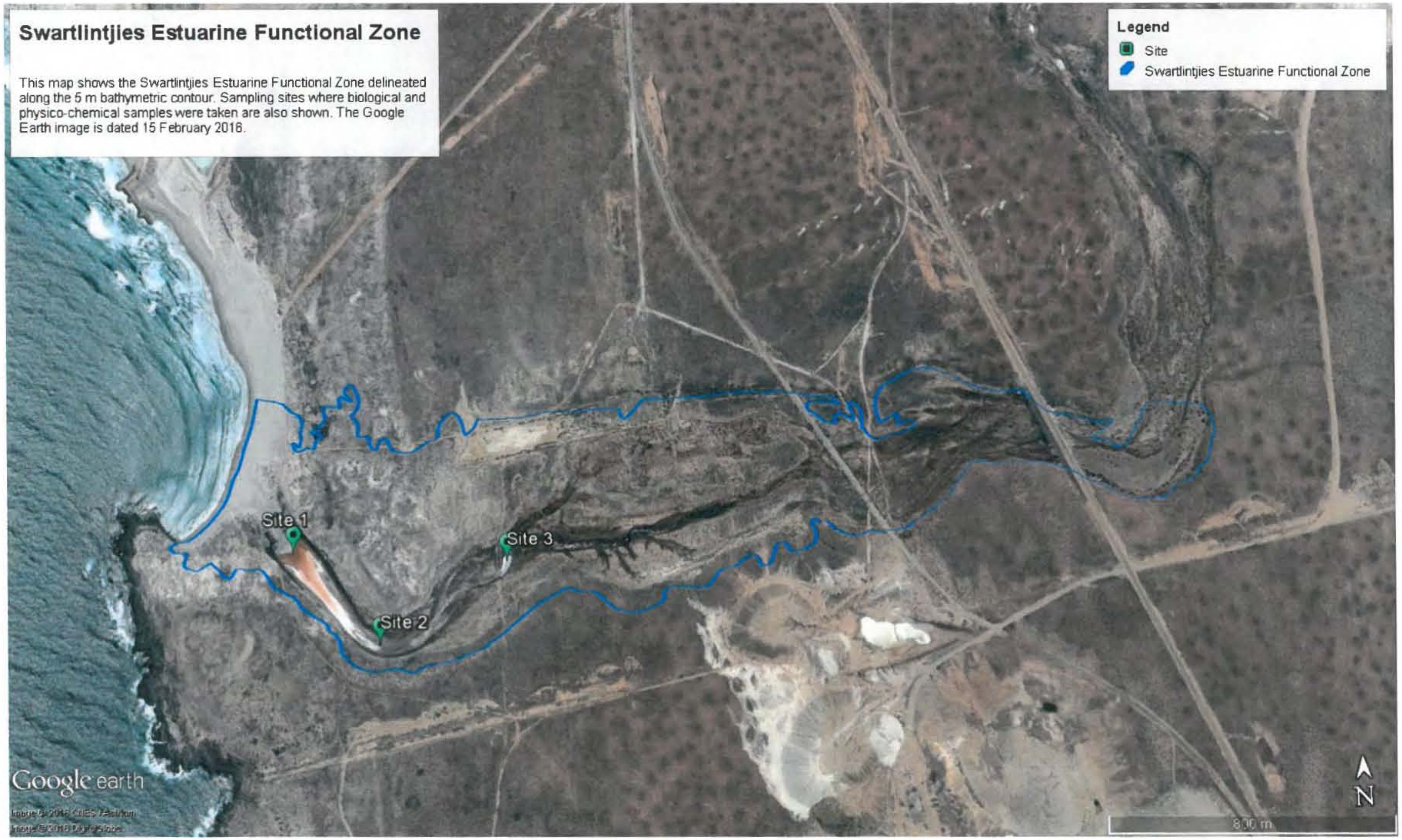

Figure 1 The Swartlintjies Estuarine Functional Zone showing biological and physico-chemical sampling sites (Source: Contour lines provided by WCR).

6 The specific identified sensitivity of the site related to the activity and its associated structures and infrastructure;

None of the proposed land based, surf zone, beach- and offshore channel mining activities are planned to be carried out within the Swartlintjies EFZ. However, mining activities occurring outside the boundaries of the EFZ could have an impact on the estuary and were assessed in Section 10.4.

While the preferred sites for future slimes dams (Sites C and G) are not going to impact on the Swartlintjies Estuary, the alternative (Site 2) to sites A, C and G is situated 9 km upstream of the Swartlintjies Estuary and may be problematic. This alternative site is an existing slimes dam and is located within the Swartlintjies River catchment (Figure 2). Although the prevailing wind carries most of the dried saline sediment to the northeast, it is likely that the surface runoff during episodic rainfall events washes salt from the dam into the Swartlintjies River. This salt will eventually reach the EFZ, impacting on biodiversity through accelerated salinisation. This problem is compounded by the 10-15 m high haul road situated 3 km upstream of the mouth, which runs through the Swartlintjies EFZ and prevents much of the runoff from the catchment reaching the estuary. Pipes in the haul road provide a conduit for water to flow past this barrier, but the inlets for the pipes are elevated at least 1 m above the river bed, which means that very little (if any) water is actually able to pass through this barrier (Figure 3). Prior to the commencement of mining activities in the area, the Swartlintjies River would have come down in flood unhindered during episodic rainfalls, creating a braided flood plain with channels of varying depths (Section 10.3.1). These channels were then colonised by plants during dry periods, creating a biodiverse habitat that reflects the topographic mosaic of the floodplain (Section 10.3.3.1). This suggests that the episodic flooding of the Swartlintjies River is an important ecological process for maintaining biodiversity of the Swartlintjies EFZ.

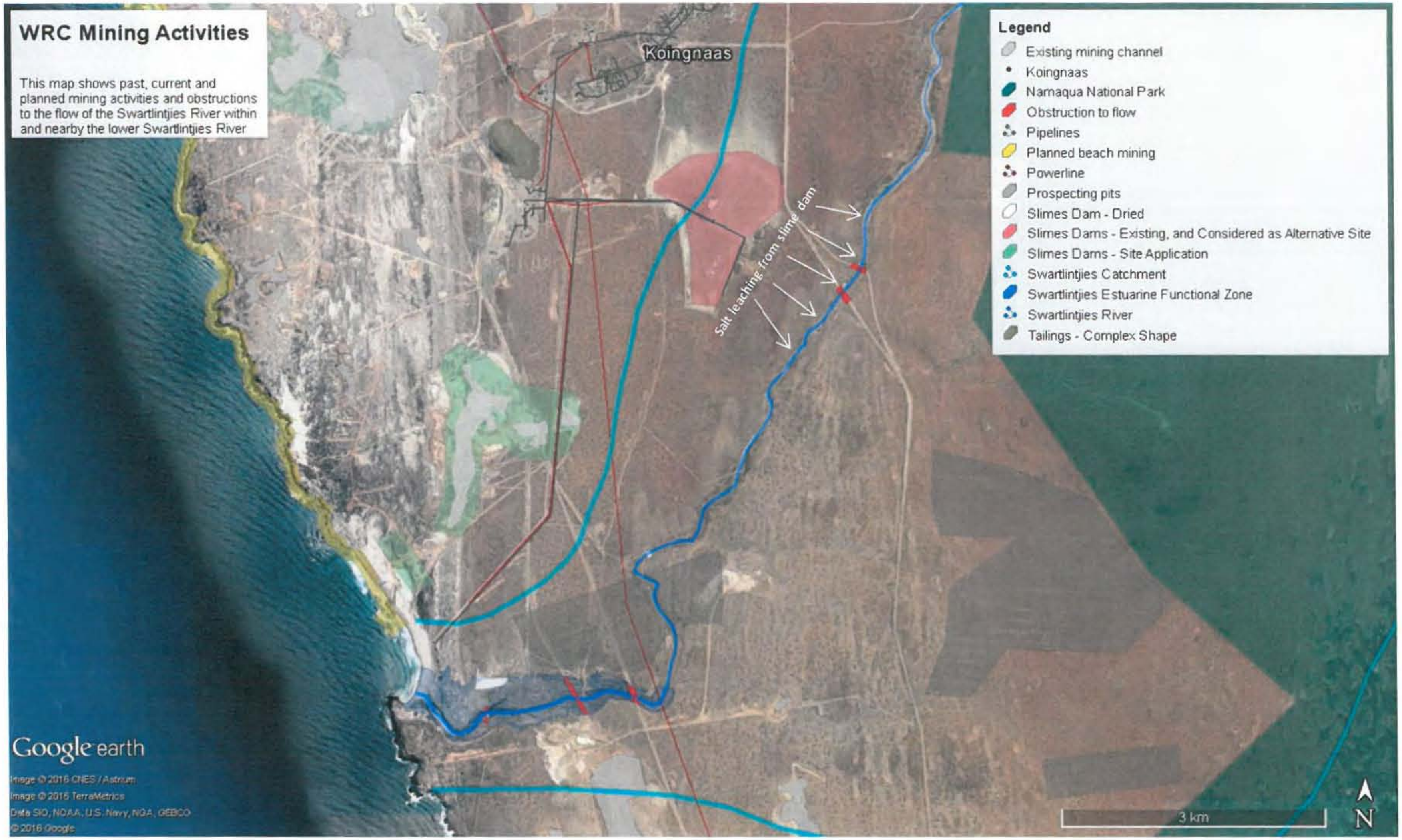

Figure 2 **Past, current and proposed mining activities that impact on the Swartlintjies Estuary.**

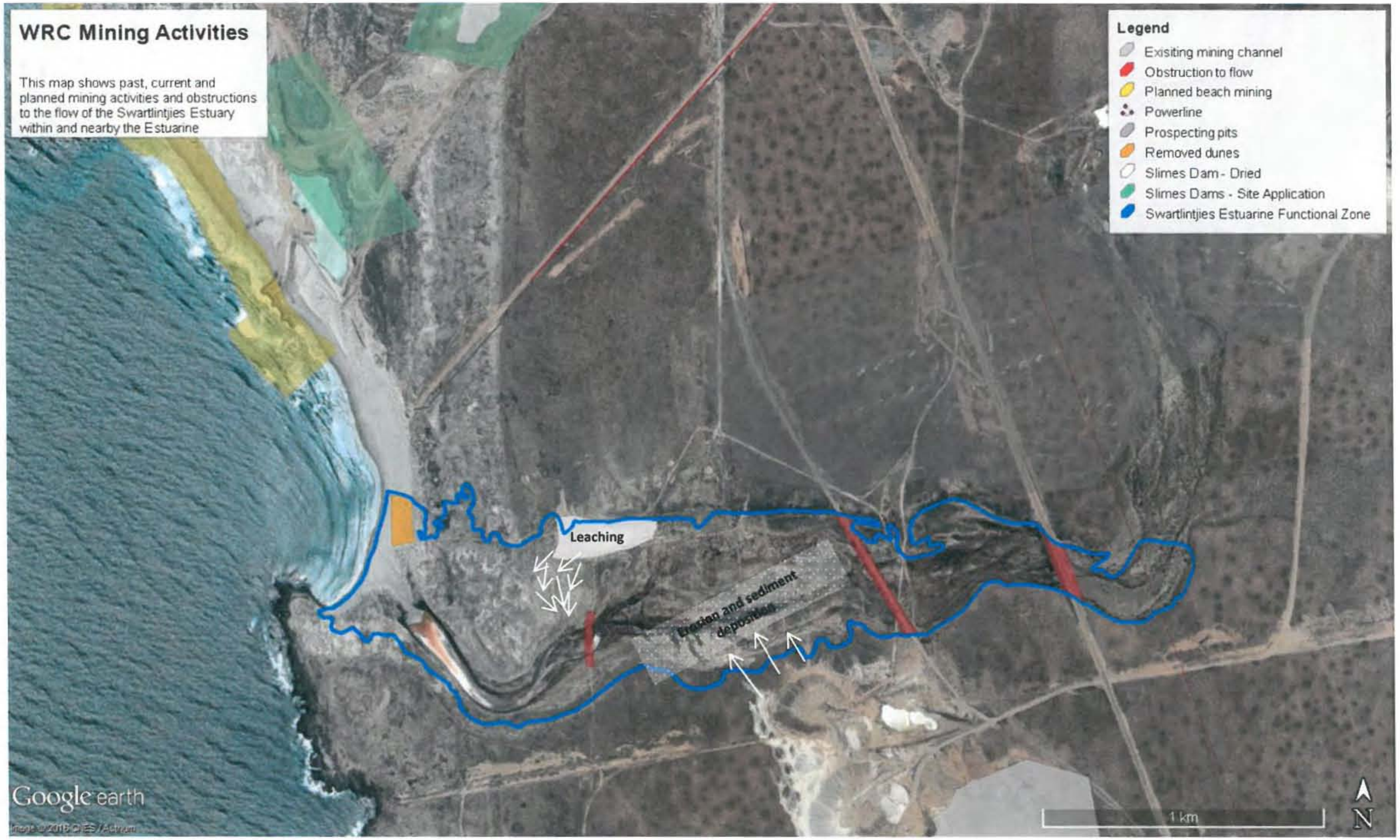

Figure 3 **Past, current and planned mining activities and impacts on the Swartlintjies Estuarine Functional Zone.**

7 An identification of any areas to be avoided, including buffers;

No new and continued use of slimes dams within the Estuarine Functional Zone and the Swartlintjies River catchment should take place (Figure 2 and Figure 3). Further fragmentation of the vegetation by roads and pathways within the EFZ must be prevented.

8 A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;

Refer to Figure 2 and Figure 3.

9 A description of any assumptions made and any uncertainties or gaps in knowledge;

It is unknown whether slimes dams indeed cause significant acceleration of salinisation of the system. It is, however, clear that the obstructions in the catchment and the EFZ have removed any possibility that excess salts can be flushed from the system flush out during episodic flood events. A precautionary approach is therefore highly recommended. This is especially important considering that it remains unknown whether the system will flush sufficiently (magnitude and frequency) under natural conditions (i.e. restored flows).

10 A description of the findings and potential implications of such finding on the impact of the proposed activity, including identified alternatives on the environment;

10.1 Abbreviations

EA	Environmental Authorisation
WCR	West Coast Resources (Pty) Ltd
RAC	RE:CM and Calible Limited
EIA	Environmental Impact Assessment
ECRU	Estuarine and Coastal Research Unit
MAR	Mean Annual Runoff
Mm^3	Million Meters Cubed
SANBI	South African National Biodiversity Institute
GIS	Geographical Information System

10.2 Glossary of terms used in this report

Barchanoid dune	Crescent-shaped and moving forward continually, the horns of the crescent pointing downwind
Benthic	Bottom-living
Berm	A natural or artificially constructed narrow terrace, shelf or ledge of sediment
Endemic	Confined to and evolved under the unique conditions of a particular region or site and found nowhere else in the world.
Episodic	Sporadic and tending to be extreme
Eutrophication	The process by which a body of water is greatly enriched by the natural or artificial addition of nutrients. This may result in both beneficial (increased productivity) and adverse effects (smothering by dominant plant types.
Habitat	Area or natural environment in which the requirement of a specific animal or plant are met
Hummock dune	A low rounded hillock or mound of sand
Hydrology	The study of water, including its physical characteristics, distribution and movement
Salinity	The proportion of salts in pure water, in parts per thousand by mass. The mean figure for the sea is 34.5 parts per thousand

10.3 Description of the Estuary

10.3.1 Catchment and hydrology

The Swartlintjies Estuary is situated on the West Coast of South Africa, approximately 6.5 km south of Hondeklip Bay within a strict security area of the Koignaas mining concession, which was previously mined by De Beers and where WCR is currently re-establishing diamond mining operations. The estuary is situated within the cool temperate biogeographic region of South Africa (Harrison, Cooper, & Ramm, 2000) and spans the Kamiesberg and Nama Khoi Local Municipalities (part of the Namaqua District Municipality) in the Northern Cape Province. The estuary is fed by the Swartlintjies River, which is approximately 65 km long with a catchment size of 1748.48 km^2 (RSA DWA, 2009) (Figure 4).

The ephemeral Swartlintjies River only flows for short periods of time after rainfall events which occurring mostly between April and August. The Swartlintjies river and its tributaries have zero flow for more than 75% of the time and hence the catchment receives a low Mean Annual Runoff (MAR) of 1.45 Mm^3 (RSA DWA, 2009). The riverbed in the upper catchment is deeply incised and the presence of braided channels indicates that the river should, if unhindered, come down in flood during episodic rainfall events (Heinecken, 1980). As is the case with other west coast rivers, the Swartlintjies is young in geological terms and is fast flowing when in flood. Such floods cause considerable erosion and the river is expected to deposit its silt load in the coastal flood plain (Heinecken, 1980; RSA Department of Agricultural Technical Services, 1975).

Flow in the lower catchment and into the estuary has been severely reduced as a result of the construction of roads through the riverbed. The road connecting Hondeklip Bay with the Koingnaas mining entrance crosses the river 9 km from the mouth connecting the river on either side by a pipe with a diameter of approximately 50 cm. The pipe is not visible on the upstream side of the gravel road and it is suspected that the inlet is buried, causing the road to act as a flood attenuating, and minimally permeable barrier (
Figure 5). The haul road situated 3 km upstream of the mouth within the restricted mining concession area of the WCR represents another barrier to the flow of the Swartlintjies River, preventing runoff from much of the catchment from reaching the estuary and the river from reaching the floodplain. In an attempt to connect the river to the estuary, a number of pipes have been buried in the gravel of the haul road. These pipes are, however, ineffectual as the inlets for the pipes are elevated approximately 1 m above the river bed (

Figure 6). Two smaller roads situated 1 km and 2.2 km from the mouth are no longer in use but are still in place and are further impeding the very limited flow that would otherwise reach the estuary.

Two small excavated trenches on the estuary banks just north of the estuary mouth contained stagnant and eutrophic water at the time of the field survey for this study. At the time of the ECRU survey in 1980, these trenches contained water to a depth of 20 cm. The water level in these hollows was approximately 1.25 m below the level of the dry riverbed, indicating a relatively high water table.

Rainfall had been followed by spring tide conditions (high tide approximately 1.75 m on 22 June) on the day of the field visit (South African Navy, 2016). The estuary was filled with hypersaline seawater of up to 50 cm depth and a continuous water body extended approximately 450 m inlands from the berm (Figure 7). Stagnant pools and water in narrow channels extended up to approximately 980 m upstream above this point. The presence of recent and bleached dried kelp 500 m upstream coincides with observations made during the Estuarine and Coastal Research Unit (ECRU) survey on 16 October 1980, and indicates that seawater regularly penetrates the river outlet at spring tide. Hypersaline conditions and stagnant water with signs of eutrophication 980 m from the mouth (Figure 7) indicates that seawater possibly penetrates 1 km inland during spring tide and evaporates slowly, thereby forming a salt crust (Figure 7) until the next spring tide occurs. It is, however, possible that rainfall prior to the field visit also contributed to the amount of water that was present in the upper reaches of the estuary. The impact of the rain was evident in very muddy conditions in depressions on the floodplain and on the banks of the narrow channels (

Figure 8).

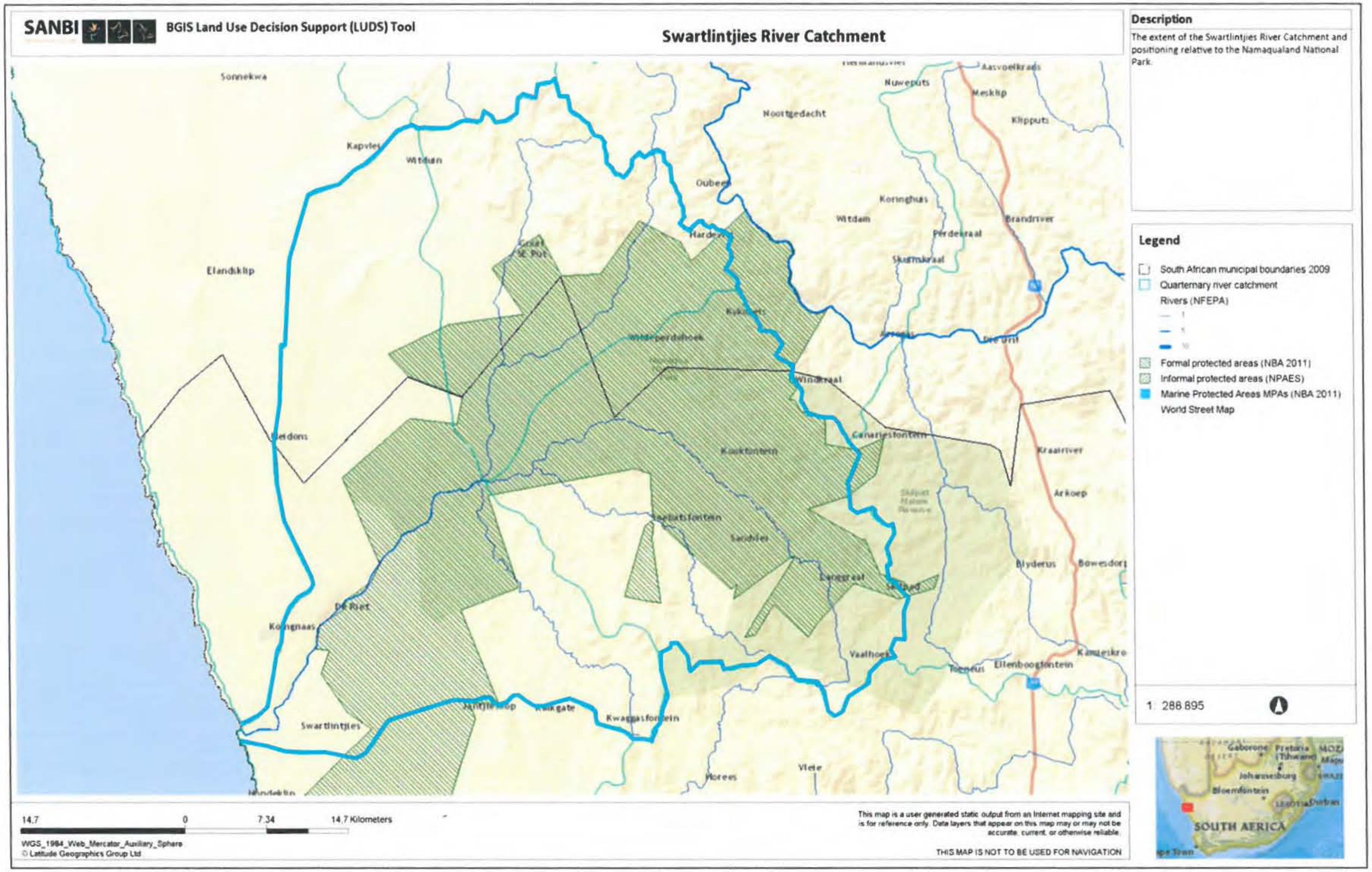

Figure 4 **The catchment area (in light blue with dotted boundary) of the Swartlintjies River and its tributaries in relation to the Namaqua National Park (Source: Biodiversity GIS Online Map viewer 2016).**

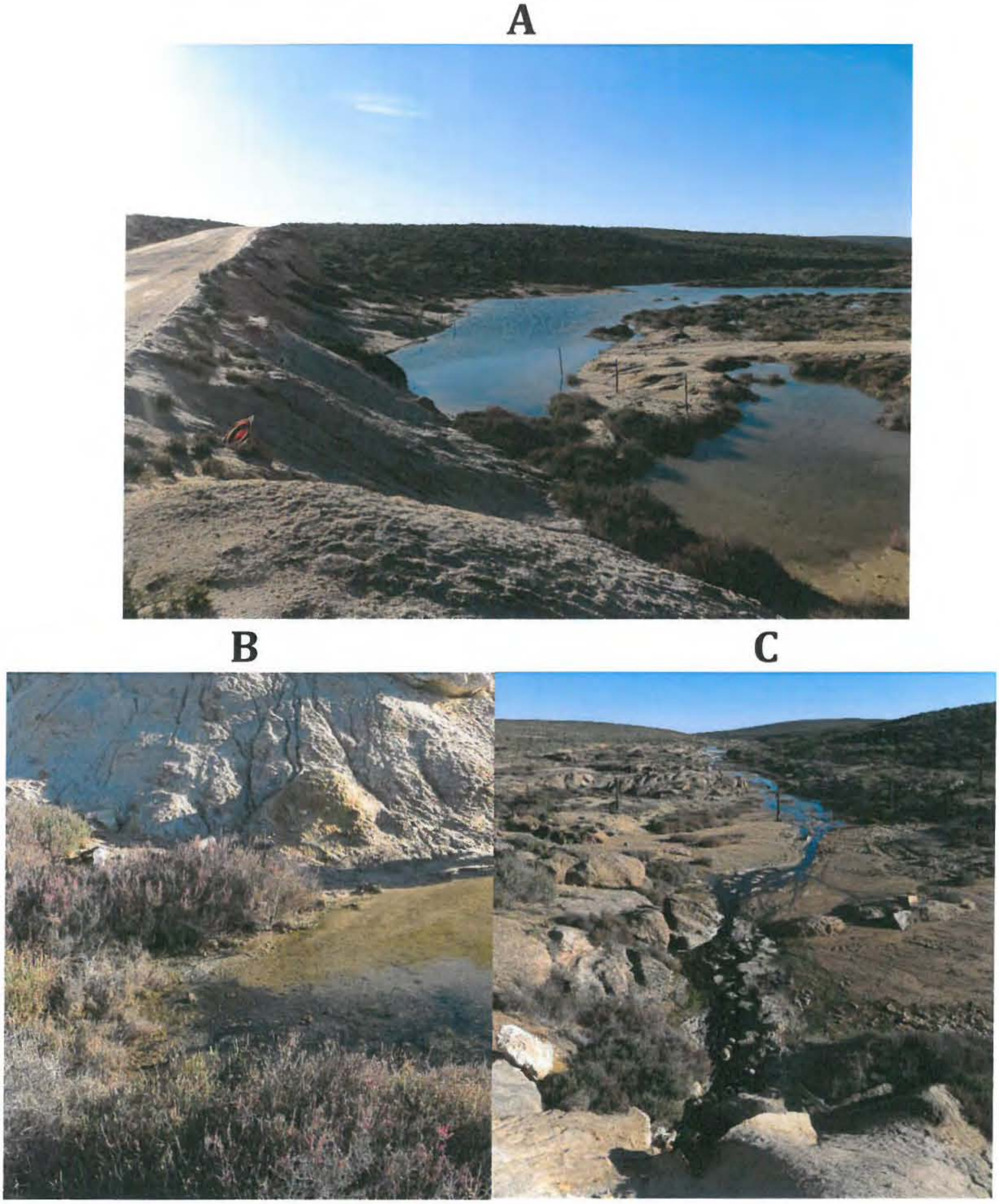

Figure 5 Photos of the road that connects Koignaas mine entrance with Hondeklip Bay. The road crosses the river approximately 9 km from the Swartlintjies Estuary mouth and acts as a minimally permeable flood attenuating barrier (C). Stagnation and signs of eutrophication are evident in the upstream water body (B). Photos were taken on 22 June 2016.

A

B

Figure 6 Photos of the main haul road situated 3 km upstream of the mouth within the restricted mining concession area of the WCR. This road prevents the river from reaching the floodplain. Photo A faces upstream and photo B shows how the intake pipe is elevated at least 1 m above the riverbed. Photos were taken on 22 June 2016.

A

B

C

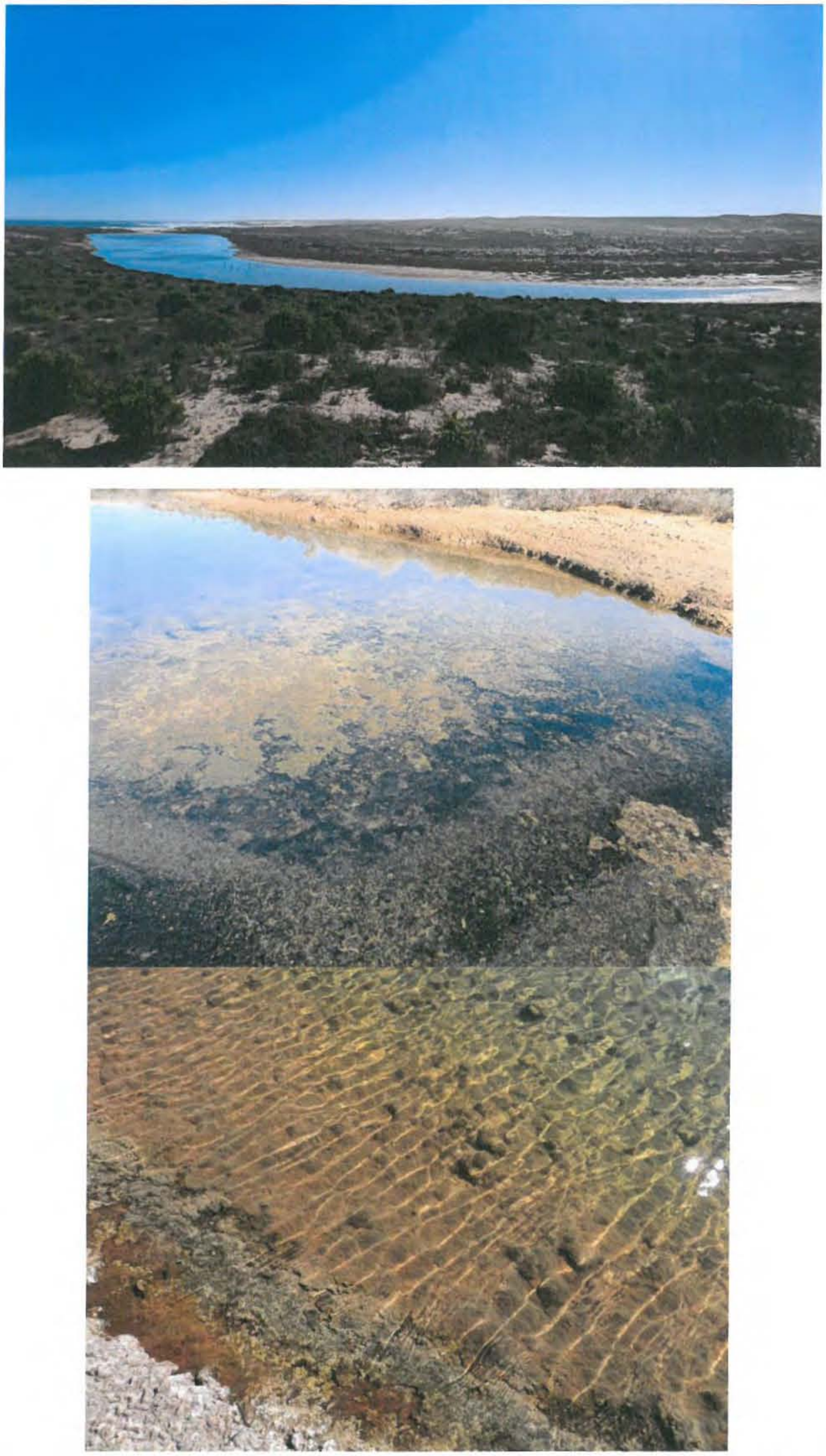

Figure 7 Photos of the upper reaches of the Swartlintjies Estuary, approximately 1 km upstream from the estuary mouth. Photo A shows the continuous water body extending from the mouth 480 m inland. Photo B shows signs of eutrophication in the water body that were found approximately 1 km from the mouth. Photo C shows the salt crust and salt crystals that overlaid the sediment in all water bodies. Photos were taken on 22 June 2016.

A

B

C

Figure 8 Photos of the upper reaches of the Swartlintjies Estuary and its floodplain. Photo A shows muddy banks of the upper estuary channel, demonstrating that rainfalls could have contributed to relatively high water levels in the estuary. Photo B shows muddy sediment on the otherwise dry floodplain (Photo C). Photos were taken on 22 June 2016.

10.3.2 Physical and chemical characteristics of the estuary

The Swartlintjies EFZ covers 1.37 km^2. The lower reaches of the Swartlintjies riverbed is characterised by two extended meanders that widen out into the floodplain that was created by an extensive network of braided flood channels. The floodplain is approximately 400 m wide and 1.8 km long. The riverbed then narrows into a channel that is flanked by low-lying vegetated dunes but widens again slightly towards the mouth, which opens northwards into a small bay (Heinecken, 1980). Low hummock dunes can be found south of the flat sandbar (approximately 0.5 m above Mean High Water Spring tide level) (Heinecken, 1980) that separates the river outlet from the sea. Parts of the barchanoid dunes to the north of the mouth were removed permanently during trench excavation in the past (Section 10.3.3.1).

10.3.2.1 Geology and sediments

The basement rock of the area falls within the Namaqualand –Natal belt of metamorphism and granitisation and is overlain by a number of sedimentary sequences. The sediments of the Swartlintjies Estuary and surroundings are derived from these sequences and are locally known as the Koignaas Complex (Heinecken, 1980). The soil type has been categorised as "Red and yellow, well drained sandy soils with high base status" (SANBI, 2016a). More detailed information was provided by Heinecken (1980), who described three distinct bands of surface soil formations. The triangle of barchanoid dunes north of the estuary were not vegetated in 1980 but have since then been colonised by Namaqualand Seashore Vegetation (SANBI, 2016b) (Section 10.3.3.1). However, these dunes have been largely destroyed by mining activities along the coast. Inland of the barchanoid dunes, a band of vegetated white dunes approximately 400 m wide were followed by vegetated red sands with darker termitaria "heuweltjies" extending inland.

A 1 cm salt crust covered grey riverbed sand mixed with black organic sludge. Particle size analysis of the sediment showed that sand was coarse and poorly sorted at the mouth, suggesting the presence of marine sediments that were transported into the lower estuary by spring tides. At Sites 2 and 3, the sand was medium-grained and sorted moderately and poorly respectively (classification according to Forbes and Demetriades (2003)). The organic content (measured as Total Organic Carbon) of the riverbed sand underlying the water bodies was high at all sites with an average of 11.1±1 %. It is generally accepted that organic content > 4% is indicative of a eutrophic system (Forbes & Demetriades, 2003). Heinecken (1980) also described a black organic sludge near the surface of the dry river bed, although this was covered by a thin layer of light grey fine sand instead of a salt crust. A sediment core taken in the dry riverbed during the ECRU survey showed that black organic sludge was separated by a thin layer of rust coloured fine sand and medium to coarse grained sand at 6 cm and 44 cm depths, respectively. This black organic sludge overlaid fine grey sand (Forbes & Demetriades, 2003).

Trace metal levels in the estuary sediments were compared with guideline screening levels published by The National Oceanic and Atmospheric Administration (NOAA), which cover a broad spectrum of concentrations from toxic to non-toxic levels as shown in Table 1. The Effects Range Low (ERL) represents the concentration at which toxicity may begin to be observed in sensitive species. The ERL is calculated as the lower 10th percentile of sediment concentrations reported in literature that co-occur with any biological effect.

The metal concentrations in the sediment collected at the Swartlintjies Estuary were all below the ERL threshold, except for Cadmium at Site 2, which exceeded the threshold by 0.1 µg/g. It was not only Cadmium that was elevated at this site. All of the trace metals that were assayed at this site were elevated, indicating that this location acts as a trace metal sink.

It is unlikely that the high metal levels occur as a result of point source pollution, but rather as a result of accumulation over time. Due to the obstructions to freshwater flow within the lower catchment and EFZ (Section 10.3.1), the estuary has not, for a while, experienced floods with the capacity to flush sediments, salts and trace metals to sea.

Manganese levels in the estuary are high, however, it has been shown that substrate along the west coast of South Africa is naturally high in Manganese (. Overall, the diamond mining industry does not use chemicals for the processing of diamonds and is therefore not considered to pollute the environment (with the exception of salinisation as a result of the seawater used for diamond washing).

Table 1 Metal concentrations in sediment collected at Site 1-3 compared to the National Oceanic and Atmospheric Administration (NOAA) sediment quality guidelines (where applicable). Concentrations are parts per million dry weight, ERL = Effects Range Low.

Metal	*Effect Range-Low (µg/g)*	*Site 1*	*Site 2*	*Site 3*
Arsenic	8.2	0.2	3.6	1.3
Cadmium	1.2	0.3	1.5	0.4
Copper	34	3.7	11.4	3.6
Lead	46.7	2.6	15.1	4
Mercury	0.15	34.6	138.5	34.6
Nickel	20.9	9.1	17.3	10.3
Zinc	150	12.5	67.6	14
Aluminium	-	0.79	3.58	1.48
Manganese	-	299	634.8	268.1

10.3.2.2 Water quality

The Swartlintjies estuary was dry during the ECRU Survey that was carried out in October 1980 and therefore water quality data collected during the field visit on 22 June 2016 represents the first record for the Swartlintjies Estuary.

Hypersaline conditions prevailed at all three sites within the EFZ (Figure 1), with conductivity ranging from 147-172 mS/cm (> 100 ppt salinity) (Table 2). The primary reason for hypersalinity is the regular intrusion of seawater during spring tides. Seawater enters the riverbed and remains trapped behind the berm, evaporating slowly and leaving salts behind. This is combined with the fact that episodic floods no longer reach the estuary due to obstructions to flow in the lower catchment and the EFZ. The little surface water runoff that occurs within the EFZ during rainfall events between April and September are not enough to temporarily dilute the water. Rainfall also carries salts from sediments outside the EFZ into the riverbed, which is responsible for the saline conditions within the dry flood plain (saltmarsh vegetation dominates in the main river channel). Generally, the Namaqualand area experiences higher evaporation rates than precipitation, which naturally leads to the formation of salt pans (Heinecken, 1980; RSA DWA, 2009). Lastly, it is possible that the abandoned slimes dam north of the estuary leaches additional salt into the riverbed. A saltpan is present in the river bed below the abandoned slime dam (Figure 3).

Water temperature gradually increased from the mouth upstream, although it must be noted that the first reading was taken at the mouth in the late morning and the last reading in the upstream river (9 km from the mouth) was taken in the late afternoon.

Dissolved oxygen was relatively high and did not indicate eutrophic conditions, although the sediments underneath the salt crust were classified as eutrophic based on the organic content (Section 10.3.2.1).

The water was slightly basic near the mouth (pH >7.3) and neutral in the upper estuary and in the river (pH 6.6-7.3). The spatial variability can be attributed to the inverse relationship between temperature and pH.

Table 2 Water quality data collected at three sites in the Swartlintjies Estuary on 22 June 2016.

Site	Temperature (°C)	Conductivity (mS/cm)	Dissolved oxygen (mg/l)	Dissolved oxygen (% saturation)	pH
Site 1	11.8	147	10.72	102	7.54
Site 2	18.1	172	14.81	155.5	7.42
Site 3	17.6	166	10.64	106	7.33
River (9 km from the mouth)	18.0	67.9	11.88	125	7.25

10.3.3 Fauna and Flora

Only specialised organisms can exist and thrive in the extreme hypersaline conditions of this estuary (>100 ppt). Artemia is a genus of aquatic crustaceans known as brine shrimp, which are adapted to such conditions and were found in the water column during the field visit. A variety of wading birds and waders were feeding on the brine shrimp throughout the day. No fish or benthic invertebrates were found in the estuary and these groups have therefore been omitted from the sections below.

10.3.3.1 Flora

A total of 36 semi-aquatic and terrestrial plant species from 15 families have been identified within the Swartlintjies EFZ to date (Table 3). *Leipoldtia sp.* could not be identified to species level with confidence. The growth form shows that it could be *Leipoldtia frutescens,* which is listed as vulnerable on the Red List of South African

Plants (SANBI, 2016c). Although all other species that were identified have not been listed as threatened on the Red List of South Africa (i.e. least concern), three species are endemic to South Africa, namely *Limonium equisetinum*, *Chaetobromus involucratus subsp. Dregeanus* and *Eragrostis sabulosa*. The latter two species are important and unique to the Namaqualand Strandveld and Namaqualand Coastal Duneveld respectively (Table 3).

The National Vegetation Map published by the South African National Biodiversity Institute (SANBI) provides a rough guide to the vegetation types and associated species that can be expected to occur in the Swartlintjies EFZ and surroundings. This rough guide was then ground truthed during the field visit on 22 June 2016, from which a more detailed vegetation map was produced in Google Earth Pro (

Figure 9). The vegetation in the EFZ had come to life after the rainfall event prior to the field trip with some species being in flower (Figure 10).

The only species found at the Swartlintjies Estuary which could be considered as semi-aquatic when water is present in the system are the saltmarsh plants such as *Sarcocornia natalense*, *Sarocornia pillansii* and *Eragrostis sabulosa*, which is also present along the coast just above High Spring tide level (Heinecken, 1980).

Seashore vegetation can be found in near the mouth on the dunes and extends as a thin band north and south of the estuary encompassing the beach and dune fields (note that this excludes Namaqualand Coastal Duneveld Vegetation type (
Figure 9)). Seven species unique to this vegetation type have been identified to date (Table 3). At the estuary mouth, patches of *Sarcocornia perennis* on slightly elevated beach sand were present avoiding inundation by regular penetration of the sea during spring tide (
Figure 11). Filamentous algae were growing on the edge of the water body near the mouth and further upstream (

Figure 11).

The riverbed and core of the floodplain provides suitable conditions for Arid Estuary Salt Marsh. Perennial *Sacrocornia natalensis* and *Sarcocornia pillansii* were found to dominate the main river channel on the floodplain, where salt has accumulated over time (
Figure 12). Away from the main river channels, less pronounced channels could be found which were characterised by transitional vegetation with a mix of salt marsh species and various shrubs types (

Figure 9 and Table 3). A variety of succulent shrubs was found on ground slightly elevated relative to the old channels (as little as 0.5 m) and included species such as *Othonna cylindrica, Drosanthemum luderitzii* and *Amphibolia rupis-arcuatae* (Figure

13). Prior to mining activities in the area, the Swartlintjies River came down in flood unhindered during episodic rainfalls, creating a braided flood plain with channels of varying depths (Section 10.3.1). These channels were then colonised during dry periods, creating a biodiverse habitat that reflects the topographic mosaic of the floodplain. This shows that the episodic flooding of the Swartlintjies River is an important ecological process for maintaining biodiversity of the Swartlintjies EFZ. The elevated edges of the floodplain transitioned to the surrounding vegetation type, namely Namaqualand Coastal Duneveld to the northwest and south of the EFZ and Namaqualand Strandveld to the north of the EFZ.

Although the vegetation in the Swartlintjies EFZ is still largely intact, several areas, amounting to 17.8 ha have been impacted by previous mining activities (

Figure 9). A large strip of barchanoid dunes was removed north of the estuary mouth, while the northern portion of the EFZ has been fragmented by an old slimes dam and roads leading to and away from this area. The slimes dam also seems to have leached on the western side towards the river channel, leaving only sparse vegetation behind. The old and current haul roads through the EFZ have also fragmented the vegetation in places. The mining area south of the EFZ is a source of sediment that erodes towards the EFZ during episodic rainfall events and has resulted in sparser vegetation on the edges of the EFZ.

Table 3 Family and growth form of 36 species that have been identified in the Swartlintjies Estuarine Functional Zone (EFZ) to date. The applicable vegetation types for each species are marked with X. Some species were not listed in the vegetation types and were allocated to likely vegetation types (marked with a red X) (Source: Heinecken 1980 and Anchor Environmental Consultants (Pty) Ltd., Vegetation types and associated species lists sourced from SANBI). The table also shows the approximate size of the intact extent of each vegetation type (in ha) (obtained from Google Earth Pro). Note that approximately 17.8 ha of the EFZ have been impacted by mining activities.

Family	*Growth form*	*Scientific name*	*Namaqualand Seashore Vegetation*	*Namaqualand Coastal Duneveld*	*Namaqualand Stranveld*	*Arid Estuarine Saltmarsh*	*Namaqualand Saltpans*
Total area within the EFZ			10.6 ha	17.7 ha	3.4 ha	36.3 ha	N/A
Aizoaceae	Low Shrubs	*Galenia fruticosa*		X	X		
Aizoaceae	Succulent Shrubs	*Tetragonia fruticosa*	X	X	X		
Aizoaceae		*Amphibolia laevis*	X	X	X		
Aizoaceae		*Leipoldtia sp (possibly Leipoldtia frutescens)*		X	X		
Amaranthaceae		*Sarcocornia pillansii*				X	
Amaranthaceae		*Sarcocornia perennis*	X				
Asparagaceae	Low Shrubs	*Asparagus capensis var littoralis*	X	X			
Asteraceae	Succulent Shrubs	*Othonna floribunda (Synonym Crassothonna floribunda)*	X				
Asteraceae	Succulent Shrubs	*Othonna cylindrica (Synonym Crassothonna cylindrica)*		X	X		
Asteraceae	Succulent Shrubs	*Arctotis decurrens(Synonym Arctotis scullyi)*	X				
Asteraceae	Succulent Shrubs	*Didelta carnosa (L.f.) Aiton var. tomentosa (Less.) Roessler*	X	X			
Asteraceae	Succulent Herbs	*Arctotheca populifolia*	X				
Asteraceae	Succulent Shrubs	*Othonna sedifolia*		X	X		
Asteraceae	Herb	*Gazania sp. Cf. rigida*	X	X			
Asteraceae	Herb	*Oncosiphon suffruticosum*		X	X		
Chenopodiaceae	Succulent Shrubs	*Salsola aphylla*					X
Chenopodiaceae	Succulent Shrubs	*Sarcocornia littorea*	X				
Chenopodiaceae	Succulent Shrubs	*Sarcocornia natalensis*				X	
Ebenaceae	Tall Shrubs	*Euclea racemosa*		X	X		
Fabaceae	Low Shrubs	*Lebeckia cinerea*	X	X			

Family	*Growth form*	*Scientific name*	*Namaqualand Seashore Vegetation*	*Namaqualand Coastal Duneveld*	*Namaqualand Stranveld*	*Arid Estuarine Saltmarsh*	*Namaqualand Saltpans*
Total area within the EFZ			10.6 ha	17.7 ha	3.4 ha	36.3 ha	N/A
Frankeniaceae	Low Shrub	*Frankenia repens*	X				
Malvaceae	Low Shrubs	*Hermannia pfeilii*			X (?)		
Mesembryanthemaceae	Succulent Shrubs	*Lampranthus sp.*			X (?)		
Mesembryanthemaceae	Succulent Shrubs	*Drosanthemum luderitzii*	X				
Mesembryanthemaceae	Succulent Shrubs	*Amphibolia rupis-arcuatae*	X	X			
Mesembryanthemaceae	Succulent Shrubs	*Stoeberia utilitis*	X	X	X		
Mesembryanthemaceae	Succulent Herbs	*Mesembryanthemum crystallinum (synonym: guerichianum)*	X				X
Molluginaceae	Succulent Shrubs	*Hypertelis (Kewa) angrae-pequenae*	X				
Molluginaceae		*Pharnaceum microphyllum*			X (?)		
Plumbaginaceae	Herb	*Limonium equisetinum*	X				X
Poaceae	Graminoids	*Chaetobromus involucratus subsp. Dregeanus*			X		
Poaceae	Graminoids	*Cladoraphis cyperoides (synonyms Eragrostis cyperoides)*	X	X	X		
Poaceae	Graminoid	*Eragrostis sabulosa*		X			
Poaceae	Graminoids	*Sporobolus virginicus*	X			X	X
Solanaceae	Succulent Shrubs	*Lycium sp.*	X (?)				
Zygophyllaceae	Succulent Shrubs	*Zygophyllum morgsana*	X	X	X		

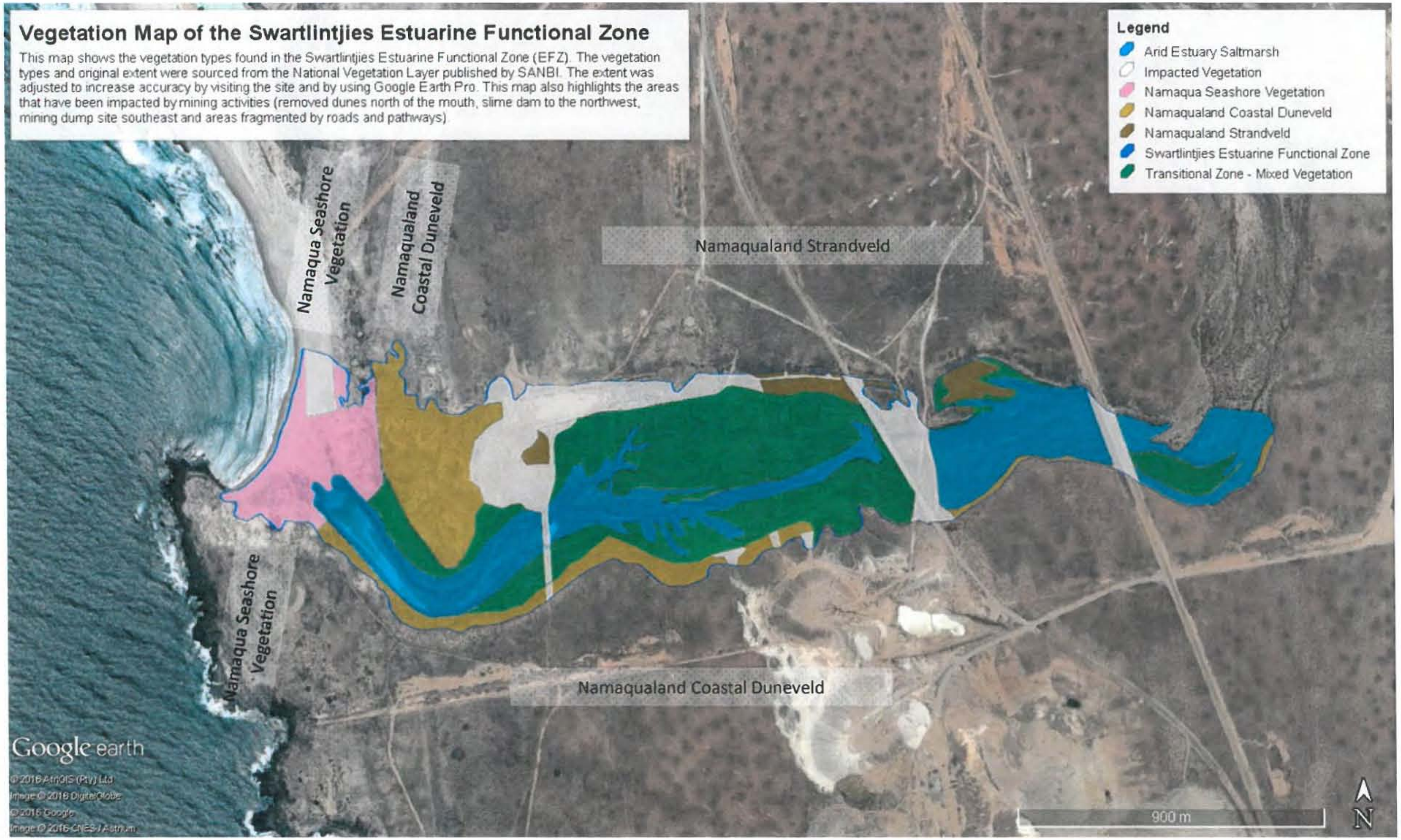

Figure 9 **Vegetation communities present in the Swartlintjies Estuarine Functional Zone.**

Amphibolia laevis

Othonna cylindrica

Oncosiphon suffruticosum

Unidentified succulent

Unidentified succulent

Figure 10 Photos of flowering terrestrial plants in the Swartlintjies Estuarine Functional Zone. The Photos were taken on 22 June 2016.

A

B

Figure 11 Patches of *Sarcocornia perennis* (A) and filamentous algae on the water's edge (B). The Photos were taken on 22 June 2016.

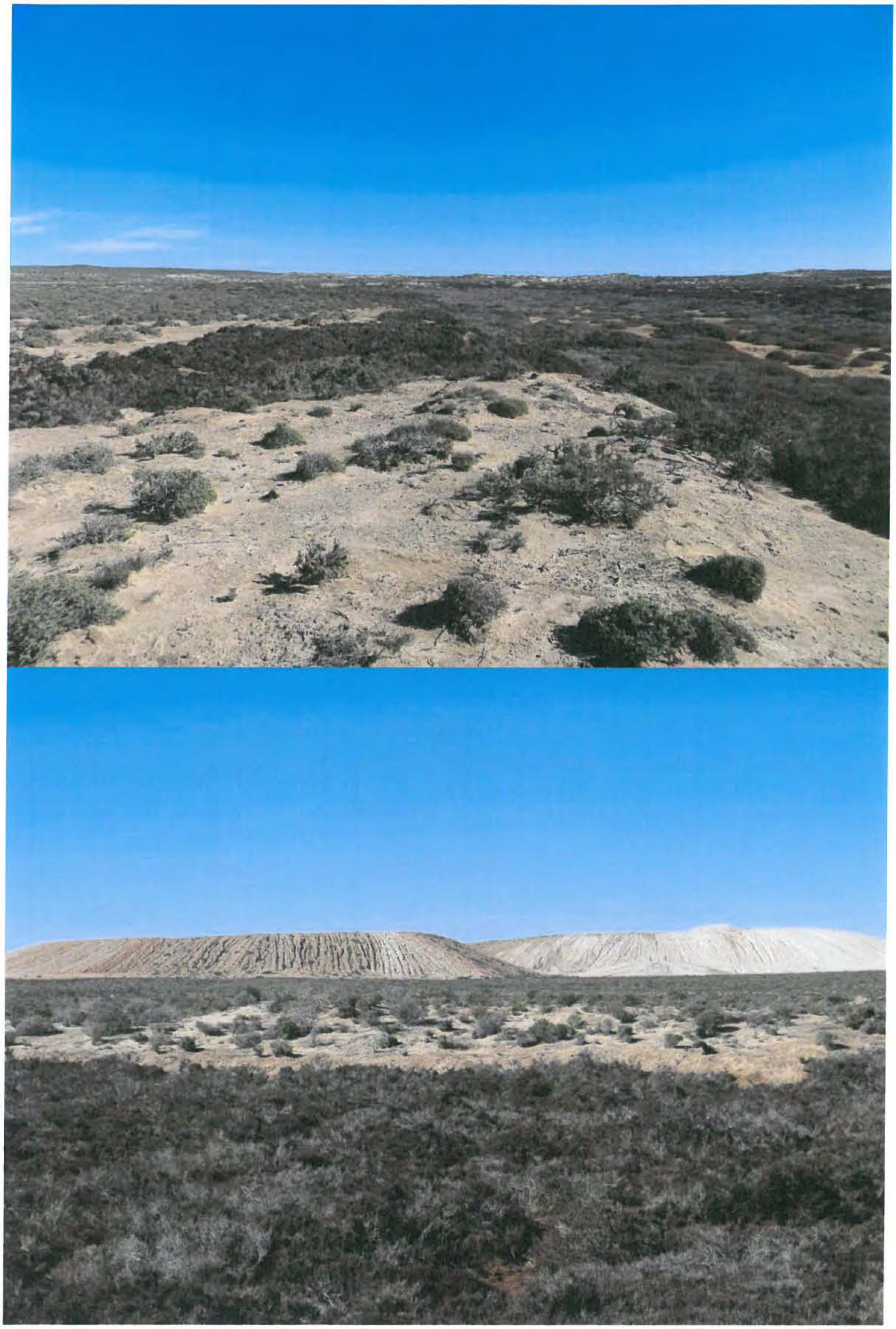

Figure 12 The river channel is shown by the red saltmarsh vegetation (*Sarcocornia natalense and Sarcocornia pillansii*). Transitional vegetation with a mix of saltmarsh and shrub can be seen on elevated ground.

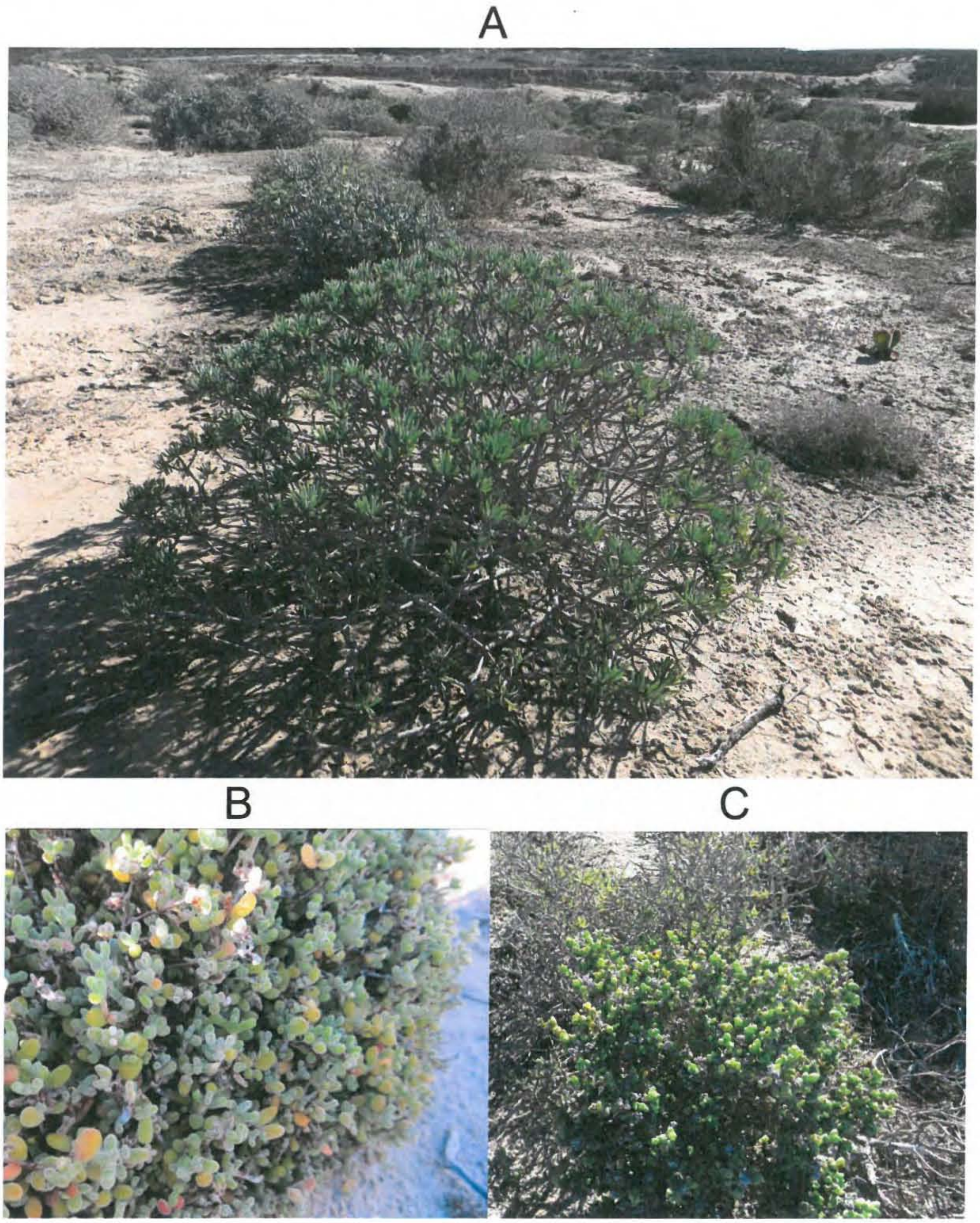

Figure 13 Photos showing (A) *Othonna cylindrical* (B) *Drosanthemum luderitzii* and (C) *Amphibolia rupis-arcuatae.*

10.3.3.2 Insects and other invertebrates

During the ECRU survey in 1980, Heinecken (1980) found a hydrophilid beetle (*Berosus spretus*) at the saline pools in the estuary. The bladder grasshopper (*Pneumoridae*) and a tenebrionid beetle were collected in the vicinity of the estuary. Casts of the marine crabs *Guinusia chabrus* and *Ovalipes punctatus* were found at the edges of the dry estuary, which were likely washed into the estuary by the springtide or when the mouth had been opened artificially at the beginning of the year. Dead millipedes were found in the dry floodplain and in on the edges of the hypersaline water Figure 14.

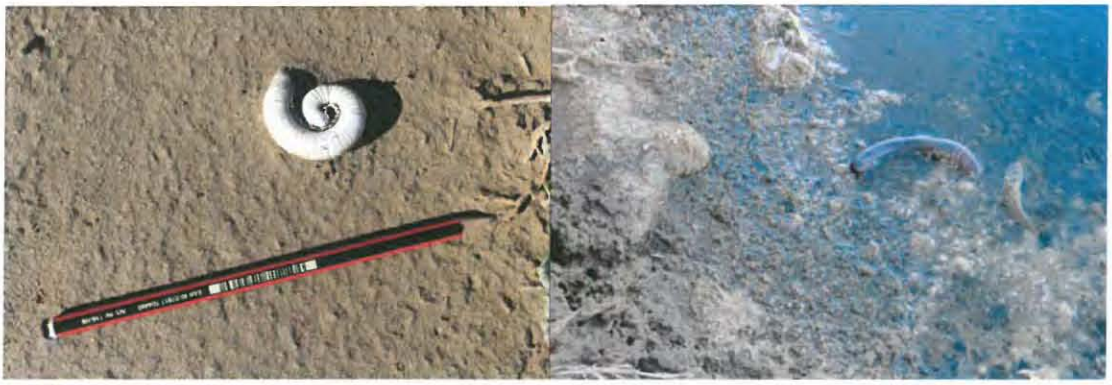

Figure 14 Photos of dead millipedes in the dry flood plain (bleached) and drowned in shallow hypersaline water. Photos were taken on 22 June 2016.

10.3.3.3 Birds

A total of 26 bird species have been recorded at the Swartlintjies Estuary and on the floodplain to date (Table 4). The waterbirds of the Swartlintjies Estuary can be divided into five taxonomic orders, the most species-rich being the Charadriiformes, which include the waders, gulls and terns (Table 5).

At the time of this survey, a family of greater flamingos, avocets, black-winged stilts and possibly also the Cape teals (omnivorous) were feeding on brine shrimp near the mouth (