STRATEGIC ENVIRONMENTAL ASSESSMENT FOR GAS PIPELINE DEVELOPMENT IN SOUTH AFRICA

Biodiversity and Ecological Impacts (Aquatic Ecosystems and Species) - Estuaries

STRATEGIC ENVIRONMENTAL ASSESSMENT FOR GAS PIPELINE DEVELOPMENT

Draft v3 Specialist Assessment Report for Stakeholder Review

ESTUARIES

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ABBREVIATIONS AND ACRONYMS

DWS	Department of Water and Sanitation
ECO	Environmental Control Officer
EFZ	Estuary Functional Zone
EIA	Environmental Impact Assessment
EMPr	Environmental Management Programme
HDD	Horizontal Directional Drilling
IAP	Invasive Alien Plant
ICM	Integrated Coastal Management Act
KZN	KwaZulu-Natal
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MPA	Marine Protected Area
NEMA	National Environmental Management Act (Act 107 of 1998)
NPAES	National Protected Areas Expansion Strategy
NWA	National Water Act (Act 36 of 1998)
PIGS	Pipeline Intelligence Gauge Station
ROW	Right-of-way
Sp.	Species
TDS	Total Dissolved Solids
ToPs	Threatened or Protected species
TSS	Total Suspended Solids

1 SUMMARY

This assessment aims, at a strategic level, to identify the potential impacts of constructing and maintaining gas pipeline infrastructure to estuaries along the South African coast.

Estuaries are highly productive, but also highly dynamic environments that require undisturbed "accommodation space" so that sedimentary processes can reset after floods into new channel configurations. Estuaries support highly sensitive habitat types, species of special concern, and play an important nursery function for estuarine and marine fish.

Key potential impacts of gas pipeline development to estuaries include:

- Estuarine habitat destruction caused by access roads and vegetation clearing;
- Altered estuarine physical and sediment dynamics caused by pipeline construction; e.g. infilling, altered channel migration, increased mouth closure;
- Deterioration of water quality associated with the disturbance of sediment;

Loss of connectivity and habitat fragmentation between system's upper catchments and/or marine environments with associated ecological impacts (e.g. loss of fish recruitment).

2 INTRODUCTION

Energy demands in South Africa are rising faster than electricity suppliers can meet them. An over-reliance on coal as an energy source poses a risk to future national development and has environmental consequences in generating large volumes of greenhouse gasses. South Africa is therefore investigating alternative means of power-generation. At present, South Africa does not have significant oil and gas reserves and produces oil and gas from imported crude oil and coal. The historic relative under-utilisation of gas as an energy source is as a result of the once abundant coal resources that allowed for the cheap production of petroleum and its by-products as well as electricity from coal. However, diminishing coal reserves and the relative cost of coal-produced electricity and petroleum, both financially and environmentally, has forced South Africa to diversify its energy mix, a process that is already under way. This involves the expansion of natural gas and oil production, and with it there is a need to plan and develop transmission pipelines between the points of origin, processing plants and the consumption districts.

As transportation systems involving fixed infrastructure that crosses large distances pipelines have inevitable environmental impacts. These include impacts to a variety of aquatic habitats, including estuaries (Chen and Gao, 2006; Yu et al., 2010). Indeed, pipeline crossings of aquatic ecosystems have been shown to have potential for substantial negative impacts (Reid and Anderson, 1998; Lévesque and Dubé, 2007; Castro et al., 2015). The construction of pipelines primarily affects physical and chemical characteristics of sensitive aquatic ecosystems, with detrimental knock-on effects on the associated biota such as invertebrates, fish and birds (Reid and Anderson, 1999; Chen and Gao, 2006; Lévesque and Dubé, 2007; Yu et al., 2010; Castro et al., 2015).

Estuaries are amongst the most productive ecosystems on earth, often far more so than their inflowing riverine and adjacent marine ecosystems (Costanza et al., 1997; Simenstad et al., 2000; Robins et al., 2005). These systems are critical migration links between marine spawning grounds and freshwater habitats for several species such as eels and prawns. They support diverse fauna and flora, but importantly also provide critical nursery habitat for estuarine and marine fish and invertebrates. Estuaries therefore provide ecological services that affect ecosystems at broader regional, national and global coastal scales.

The socio-economic importance of estuaries to humans is now widely recognised. In South Africa many people are directly or indirectly reliant on these resources. However, coastal development, water abstraction and catchment degradation has already resulted in marked impacts on the limited estuarine resources in South Africa. With a decline in the health and functionality of these systems due to various human interferences, increasing need and pressure is placed on relevant authorities to manage these resources wisely. Any proposed development that could affect estuarine resources must be adequately assessed for potential impacts.

This specialist study seeks to identify potential impacts, and assess risks of such impacts on estuaries that are associated with the construction and operation of gas pipelines within a selection of the Gas Pipeline corridors that are proposed along the coast of South Africa (i.e. Phases 5, 1, 2, 7 and 4 are selected for study). The remaining corridors, such as Phases 3, 6, 8 and inland, are not assessed as they fall in inland areas or are set back from the coastline.

3 SCOPE OF THIS STRATEGIC ISSUE

3.1 Understanding of development

3.1.1 Construction phase

Oil and gas pipeline crossings can be implemented using various techniques, including below- and above-ground methods (Lévesque and Dubé, 2007). Both methods incur a spatial “footprint” which includes a nominal Right of Way (ROW) of 30 to 50 m wide and temporary work space (which is the area needed during construction for work and travel lanes as well as a pile area where pipes, equipment and soil can be stockpiled during excavation) during the construction phase. The area used for temporary work space will be rehabilitated after construction.

The most common methods involved in pipeline construction spanning water bodies are below-ground methods and can be either trenched (wet open-cut and dry open-cut techniques) or trenchless techniques (information from Aquashare 2011, PennEast Pipeline 2016, NEB 2017):

1. **Wet open-cut techniques**, where construction does not involve diversion of stream flow and trenching and installation of the pipe is done within a waterbody (typically during the dry or low flow season). Once the pipe is installed the trenched area is backfilled with sediment.
2. **Dry open-cut techniques**, otherwise known as isolation techniques, separate the construction activities from stream flow of the waterbody by using high volume pumps, dams, culverts, or other methods to divert stream flow around the trench excavation and pipe installation. Pumped diversions are used to divert water around the (isolated) trench area to maintain natural downstream flows and prevent upstream ponding or damming effects. Before construction and installation, the area is de-watered.
3. **Trenchless techniques,** whereby a tunnel is drilled beneath the stream or water body. These techniques are typically used in areas that are environmentally sensitive, difficult to access or where surface activities cannot be disrupted. They require limited or no in-stream construction and so cause little to no disturbance to the watercourse bed and banks. However, they are not without potential environmental impacts. For installation they require excavation of pits intermittently along the pipeline route and the assistance of drilling fluids or bentonite based “muds”, and in the long term can affect groundwater flows. The most common type of trenchless crossing is **Horizontal Directional Drilling (HDD)**. HDD installation starts with a pilot hole being drilled along the predetermined drill path. The drill string is pulled back through the bore hole to enlarge the diameter of the drill hole. Pipe is welded into a string that is slightly longer than the length of the drill and is coated with abrasion resistant covering. Once the borehole has been widened to the appropriate diameter, the pipe string is pulled through. **Pipe jacking** is another trenchless technique. It relies on hydraulic jacks to push pipes through the ground behind an excavating shield. Trenchless techniques are typically longer and slower processes than traditional open-cut methods (time frames can be many months rather than days).

3.1.2 Operations phase

In addition to pipe infrastructure, Pipeline Intelligence Gauge Stations (PIGS), also referred to as "pigging stations", will be situated above ground at selected locations approximately every 130 km, but possibly as far apart as 250-500 km. The pigging stations will be approximately 30x80 m in size. There will also be block valves every 30 km, which will have a concrete slab (similar to a manhole cover) on the surface, leading to an inspection chamber. There will not be a permanent service road parallel to the pipeline, as usually required for power lines. The access roads to site camps used during construction and right of way will be rehabilitated.

A 10 m wide permanent servitude will be established and kept clear of all deep-rooted vegetation along the full length of the pipeline for access and maintenance. Shallow-rooted vegetation will be allowed to re-establish along this servitude.

During the operational phase, there is also the potential for accidents, leaks, and explosions**, which could result in impacts on estuaries**.

3.2 Key links with other topics

This specialist assessment exclusively focused on the direct impact of the gas pipeline development and infrastructure on estuarine abiotic processes and related biotic responses as encapsulated by the estuarine functional zone (EFZ[1]). However, given that estuaries are highly dependent on the condition of the rivers flowing into them and/or wetlands adjacent to estuaries, cross reference was also made to the Freshwater Specialist Assessment (De Winnaar & Ross-Gillespie, 2018) to ensure that downstream estuarine functionality is not impacted on by pipeline and associated infrastructure development. **In this report inflowing coastal rivers just above an estuary and/or coastal wetlands and seeps adjacent to estuaries are collectively referred to as supporting coastal freshwater ecosystems.**

This report does not focus on estuarine birds as these are being dealt elsewhere within the Avifauna specialist study (refer to Froneman & van Rooyen, 2018).

3.3 Data sources

For this specialist study information on relevant estuaries in the selected gas pipeline corridors was obtained from available data sources. No additional field studies were undertaken. The information and data sources included:

- Van Niekerk L and Turpie JK (eds). 2012. **National Biodiversity Assessment 2011: Technical Report. Volume 3: Estuary Component.** CSIR Report Number CSIR/NRE/ECOS/ER/2011/0045/B. Council for Scientific and Industrial Research, Stellenbosch. Available at: http://bgis.sanbi.org/nba/project.asp.
- Van Niekerk, L, Adams JB, Bate GC, Forbes N, Forbes A, Huizinga P, Lamberth SJ, MacKay F, Petersen C, Taljaard S, Weerts S, Whitfield AK and Wooldridge TH. 2013. **Country-wide assessment of estuary health: An approach for integrating pressures and ecosystem response in a data limited environment.** Estuarine, Coastal and Shelf Science 130: 239-251.
- Van Niekerk L, Taljaard S, Ramjukadh C-L Adams JB, Lamberth SJ, Weerts SP, Petersen C, Audouin M, Maherry A. 2017. **A multi-sector Resource Planning Platform for South Africa's estuaries.** Water Research Commission Report No K5/2464. South Africa.

[1] In South Africa the EFZ is generally defined by the +5 m topographical contour (as indicative of 5 m above mean sea level) and includes all the estuarine open water area; estuarine habitats (sand and mudflats, rock and plant communities) and adjacent floodplain area whether developed or undeveloped. It therefore encompasses not only the estuary water-body but also all the habitats that support physical and biological processes that characterise an estuarine system.

- Van Niekerk, L., Taljaard, S., Adams, J. B., Fundidi, D., Huizinga, P., Lamberth, S. J., Mallory, S., Snow, G. C., Turpie, J. K., Whitfield, A. K. and Wooldridge, T. H. 2015. **Desktop Provisional Ecoclassification of the Temperate Estuaries of South Africa.** WRC Report No K5/2187.
- Turpie, J.K., Wilson, G. and van Niekerk, L. 2012. **National Biodiversity Assessment 2011: National Estuary Biodiversity Plan for South Africa.** Anchor Environmental Consulting Cape Town. Report produced for the Council for Scientific and Industrial Research and the South African National Biodiversity Institute.
- The 2018 National Biodiversity Assessment is currently a work in progress, but where appropriate, interim findings from this study were considered here.

Key environmental attributes that were used in this study included the demarcated EFZs, ecological health condition, ecological importance and pressure status of estuaries (e.g. extent to which human disturbance already affected an estuary). Information on potential impacts and possible mitigation measures associated with the different construction methods and pipeline operations were sourced from international literature, as well as expert judgement.

3.4 Assumptions and limitations

The following assumptions and limitations apply to this estuarine assessment:

- This assessment assumes that only below-ground construction methods will be considered for estuary crossings by gas pipelines. Three below-ground methods will be investigated, namely wet open-cut construction, isolated (dry-open cut) construction and HDD.
- Given elevated water tables, corrosion associated with salt water and scouring potential associated with estuaries, above ground construction methods for the proposed gas pipeline (i.e. diverting over the river bed in the form of pipe-bridges or suspension below existing bridge infrastructure) were also assessed for completeness.
- At the broad, overview scale of this strategic assessment, operational phases involving pipeline maintenance is assumed largely to be similar for all options.
- Due to the strategic nature of the assessment and the expansive area under investigation, a generic approach was applied; selecting a suite of key estuarine attributes considered appropriate, to assess impact and associated risks for various construction methods, and during operation.
- This assessment provides a broad scale sensitivity rating for estuaries in the various corridors. As all estuaries are sensitive to altered sediment and hydrodynamic processes, more detailed spatially scaled sensitivity demarcation within the study areas will need to be refined during the detailed planning and construction phases.
- Consequence ratings applied in this assessment are associated with narrative qualitative statements, rather than detailed quantitative ratings (such as % loss of biota/habitat, or with regard to temporal or spatial extents). This was necessary given the scope and scale of this strategic environmental assessment.
- This assessment makes use of information available and in a useable format. No fieldwork was done and no additional raw data were collected and/or processed.
- All estuaries are important bird areas. Potential impacts to estuarine avifauna were assessed as part of the Avifauna specialist study (refer to Froneman & van Rooyen (2018) for further details).
- Marine-estuarine-freshwater connectivity, critical to some species of crustaceans and fish, is reliant on free flowing rivers and impacted by activities in rivers. Potential impacts to these fauna (e.g. *Anguillid* eels) in catchments above estuaries (i.e. rivers) were not dealt with in this assessment, but were assumed to have been addressed in the Freshwater specialist assessment (refer to De Winnaar & Ross-Gillespie (2018) for further details).

4 KEY ATTRIBUTES AND SENSITIVITIES OF STUDY AREAS

4.1 Overview of South African estuaries

An estuary is defined as ‘‘a partially enclosed permanent water body, either continuously or periodically open to the sea on decadal time scales, extending as far as the upper limit of tidal action, back-flooding or salinity penetration. During floods an estuary can become a river mouth with no seawater entering the formerly estuarine area, and when there is little or no fluvial input, an estuary can be isolated from the sea by a sandbar and become a lagoon or lake which may become fresh or hypersaline” (van Niekerk and Turpie, 2012:29).

South African estuaries differ considerably in terms of their physicochemical and biotic characteristics (Colloty et al., 2002; Vorwerk et al., 2008). Despite their differences, proactive planning and effective management of estuaries require an understanding of changing estuarine patterns, processes and responses to global change pressures (i.e. those that arise directly from anthropogenic activities as well as climate change). As human population pressures escalate, the need for strategic management becomes increasingly evident (Boehm et al., 2017; Borja et al., 2017). Reactive planning of resource allocation in these systems on an estuary-by-estuary basis is costly, time consuming and not feasible. Proactive planning requires a strategic assessment of change at a range of scales to ensure optimum resource use.

Estuaries and adjacent ecosystems form an interrelated network of life-support systems that includes neighbouring terrestrial and marine habitats. Many estuarine species are dependent on different habitats in order to complete their life cycles (Whitfield, 1998). Estuarine ecosystems are, therefore, not independent and isolated from other ecosystems. Rather, estuaries form part of regional, national and global ecosystems, directly through connections via water flows (e.g. the transport of nutrients and detritus) and indirectly via the movement of estuarine fauna (e.g. Gillanders, 2005; Ray, 2005). Linkages between individual estuaries and other ecosystems span scales ranging from a few hundred metres to thousands of kilometres. Therefore, impacts to a specific estuarine ecosystem may affect ecosystems seemingly remote from that estuary, and have ramifications for ecosystem goods and services that people rely on from areas distant over large spatial scales. The closure of Lake St Lucia for example, resulted in declines and eventual closure of a prawn fishery on the Thukela Banks over 100 km to the south.

South Africa has nearly 300 relatively small estuaries, the majority (>70%) of which are <50 ha in size. These estuaries fall into three biogeographical regions which characterise the South African coast; namely the Cool Temperate west coast, the Warm Temperate southern and south-east coast, and the Subtropical east coast (Emanuel et al., 1992; Harrison, 2002; Turpie et al., 2002) (Figure 1). In addition to obvious sea temperature differences, rainfall patterns in these regions vary significantly (Davies and Day, 1998; Lynch, 2004; Schulze and Lynch, 2007; Schulze and Maharaj, 2007). Annual runoff of South African rivers is highly variable and unpredictable in comparison with larger Northern Hemisphere systems, fluctuating between floods and extremely low (to zero) flows (Poff and Ward, 1989; Dettinger and Diaz, 2000; Jones et al., 2014) (Figure 2). Estuary catchment sizes range from very small (<1 km^2) to very large (>10 000 km^2), with those in the Cool Temperate region tending to be larger than those in the Warm Temperate and Subtropical regions (Jezewski et al., 1984; Reddering and Rust, 1990).

Strong wave action and high sediment availability results in more than 90% of South African estuaries having restricted inlets (or mouths). More than 75% of estuaries close for varying periods of time due to sand bar formation across the mouth (Whitfield, 1992; Cooper, 2001; Taljaard et al., 2009; Whitfield and Elliott, 2011). Most estuaries are highly dynamic with an average water depth of 1-5 m. The tidal range around the whole coast is microtidal (<2 m) but high wave energy, makes it a wave-dominated coast (Cooper, 2001).

Estuaries exhibit a high spatial heterogeneity, with each system characterised by its own unique geomorphology and physicochemical processes. Individual systems can be highly variable temporally and the full spatial extent (i.e. tidal limit or back-flooding mark) of many systems remains unknown. This makes it difficult to delineate the dynamic spatial area where estuarine processes occur within each system, the so-called EFZ. In South Africa the EFZ is generally defined by the +5 m topographical contour (as indicative of 5 m above mean sea level) and includes all the estuarine open water area; estuarine habitats (sand and mudflats, rock and plant communities) and adjacent floodplain area whether developed or undeveloped. It therefore encompasses not only the estuary water-body but also all the habitats that support physical and biological processes that characterise an estuarine system.

For the purposes of this study, and as is typical in estuarine assessment in a South African context, all permanent coastal water bodies (i.e. not ephemeral water bodies) sporadically or permanently linked to the sea were regarded as estuarine systems. Using existing estuarine vegetation and fish data sets, published and unpublished literature, as well as anecdotal information, all systems were evaluated by an expert panel and their health evaluated (Van Niekerk and Turpie, 2012).

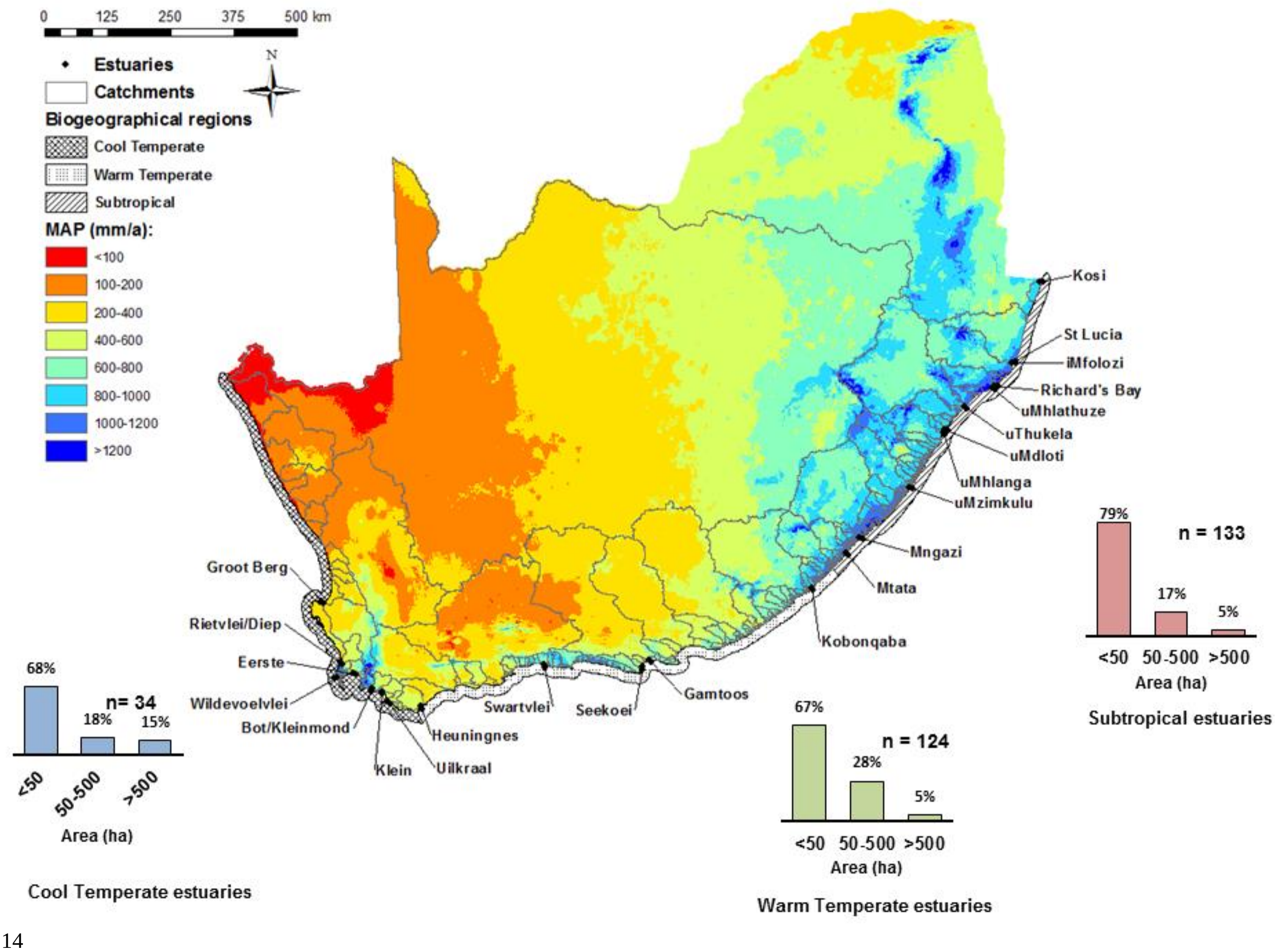


Figure 1: Map showing the three biogeographical regions, relative catchment size, mean annual precipitation (MAP) (in mm/a) and estuary size distribution (in ha) for South Africa (van Niekerk et al. 2013).

4.2 Estuarine sedimentary processes of importance

Estuaries are complex water bodies and differ considerably from fluvial systems. In estuaries the flow reverses due to tidal inflows being stronger than freshwater outflows. Water quality charges in an estuary are also complex due to both upstream and downstream sources.

Estuaries also have two sources of sediment; that from the river (delivered primarily during floods) and a supply of marine sediment from the ocean delivered by littoral drift and transported by tidal currents into the estuary. Within estuaries, tidal sediment transport is a result of the interaction of both currents and waves. This is especially dynamic in the mouth region of estuaries and further up the system wave action is rapidly reduced. Wave-current interaction considerably complicates sediment transport predictions. During neap tides, maximum water velocities in the estuary are low with little sediment transport, while both velocities and transport increase towards spring tides. Significantly, in some estuaries over this neap to spring period, there is a net upstream sediment transport, e.g. in the Goukou (Beck et al., 2004). If there is a long-term net ingress of marine sediment (which is often the case), then the only plausible way for a long-term equilibrium to be established is for occasional large river floods to flush out this accumulated sediment.

Floods therefore, are the most important natural processes which erode and transport sediments out of estuaries. Large volumes of sediments can be removed in a very short time during major floods with a return period of 1 in 50 years and more. Smaller floods with return periods of 1-2 years can sometimes also have a significant influence. Floods of various scales therefore play a major role in the equilibrium between sedimentation and erosion in estuaries (Beck et al., 2004).

This is an important consideration because sedimentation of South African estuaries has created several environmental and social problems. Sediment transport imbalances are caused by changes in the river inflow (especially floods), increased catchment sediment yields and hard structures in estuaries that change flow velocities. Reduced sediment transport capacities within estuaries and decreased flushing efficiencies cause increased sedimentation and in the long-term this may lead to the complete closure of estuaries.

Estuary channel formation is also highly dynamic on decadal time scales. During low flow periods shallow tidal flows can meander several sand banks in the EFZ. During floods rapid changes in estuarine morphology occur over very short time frames. The system can be completely reset and channels can be scoured by meters, only to be filled in over time again by catchment and marine sediment. These types of changes can be illustrated using the Thukela Estuary as an example (Figure 2). Scouring during flooding can be significant with numerical modelling studies indicating possible scour depths on larger river systems of between 20 and 30 m (Basson et al., 2017, as indicated in Figure 3 and Figure 4).

These dynamic processes are an integral part of the natural functioning of South African estuaries and need to be accounted for in proposals to develop within EFZs. In the context of the present work, proposed crossings of estuaries by pipelines need to be assessed with the knowledge that estuary channel formation can occur anywhere in the EFZ and that scouring during floods (with a return period of 1:10 years) is significantly deeper than the observed estuary bed levels under typical (non-flood) conditions.

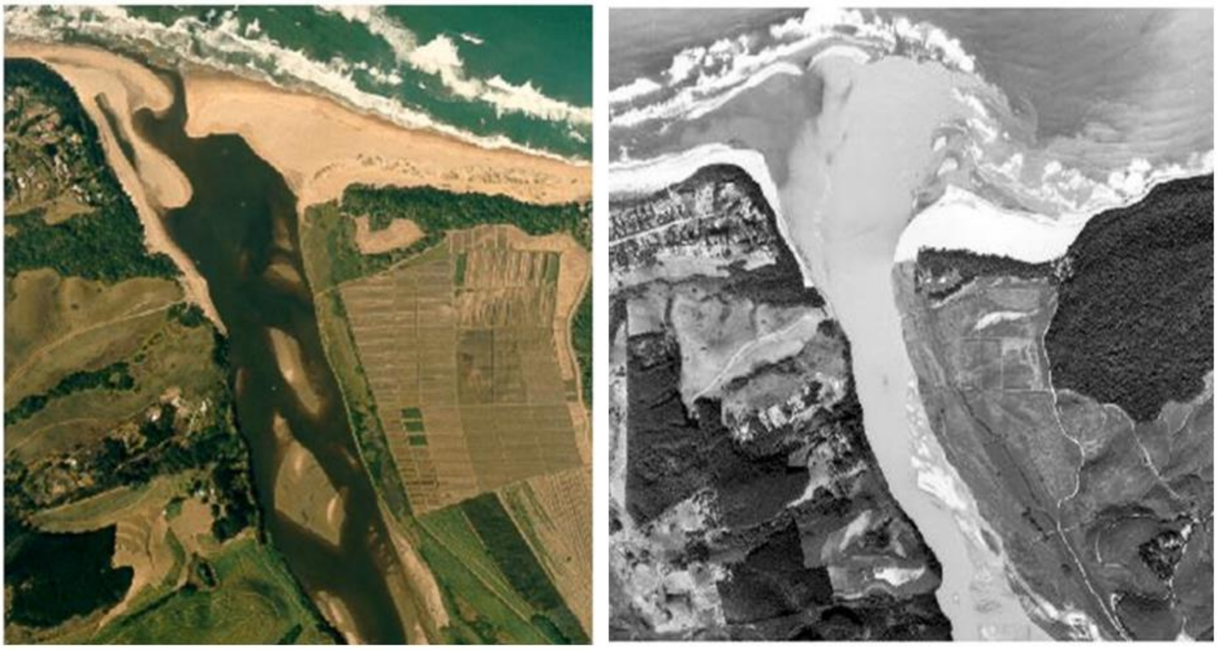


Figure 2: Thukela Estuary under low flow conditions with a stable channel meandering between sand banks (left) and the Thukela Estuary under resetting flood conditions with high volumes of sediment being eroded from the system (right).

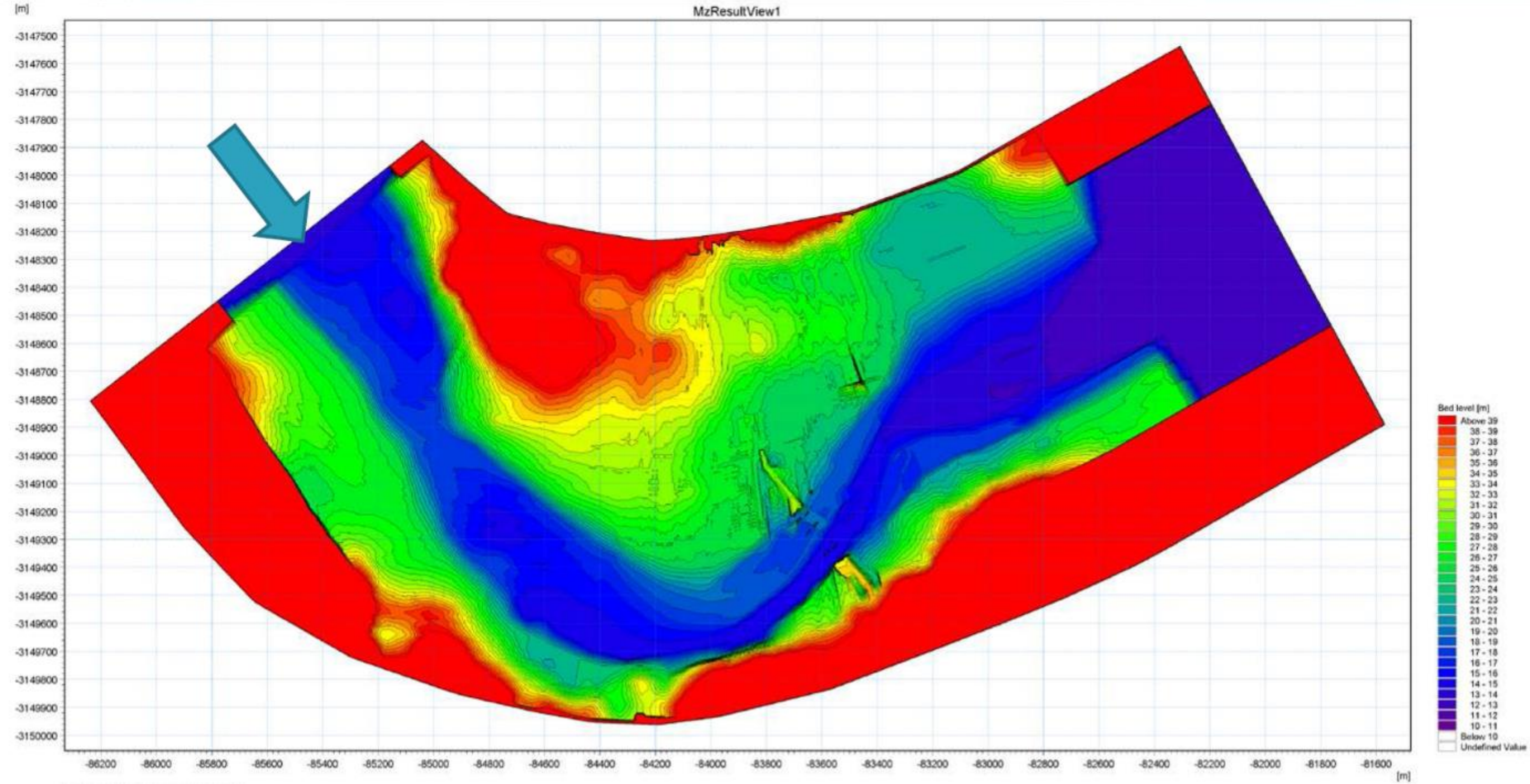


Figure 3: Predicted scouring in the uMfolozi River before floods (Basson et al., 2017). Arrow indicates flow direction.

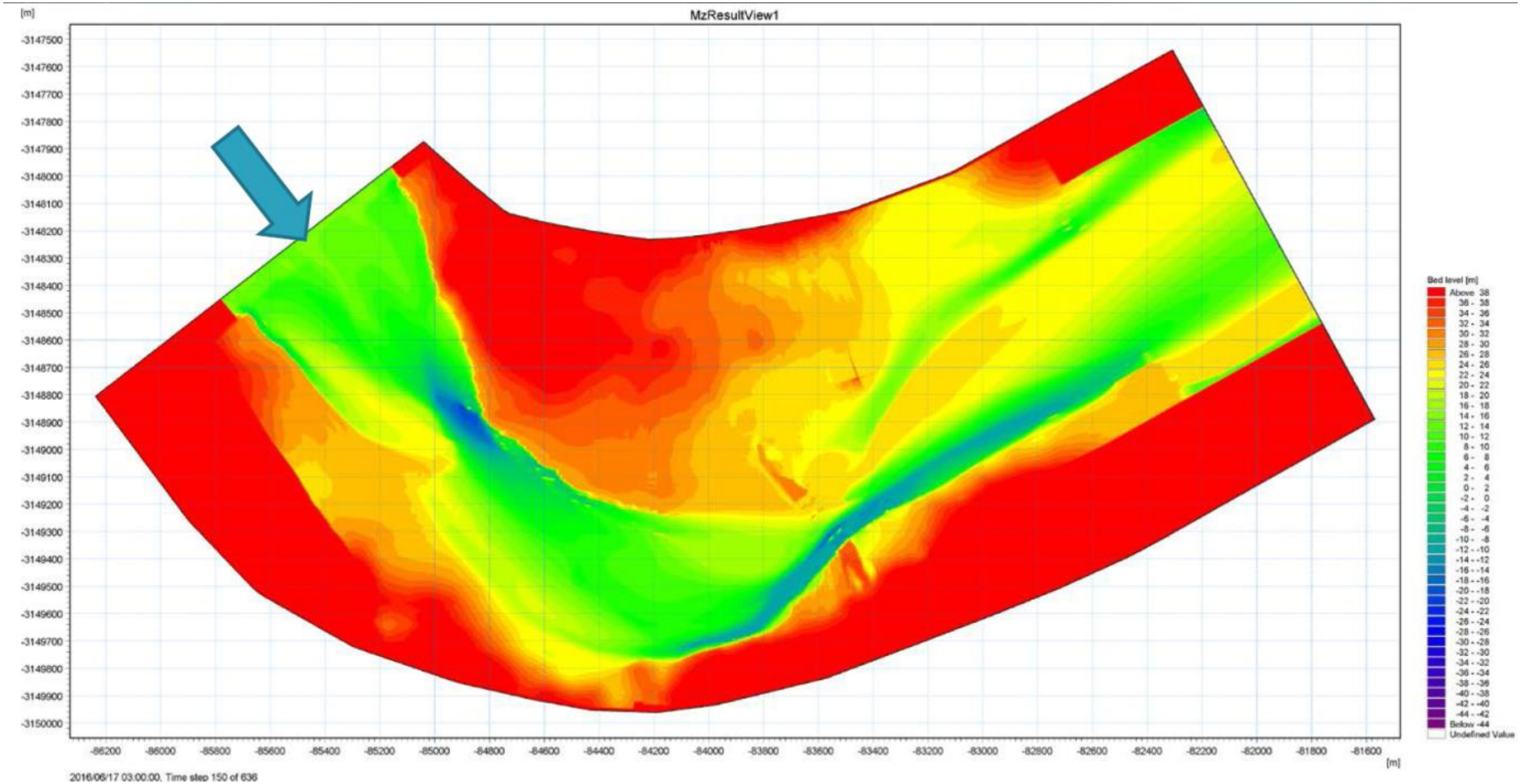


Figure 4: Predicted scouring in the uMfolozi River during floods (Basson et al., 2017). Arrow indicates flow direction.

4.3 Estuarine habitat of importance

Estuaries are generally made up of a high diversity of habitat types, which include open water areas, un-vegetated sand-, mudflats and rock areas, and vegetated areas (plant communities). Plant community types can be subdivided into submerged macrophytes, salt marsh, mangroves, reeds and sedges (Adams et al., 2018).

- **Open water area:** Un-vegetated basin and channel waters which are measured as the water surface area. The primary producers are the phytoplankton consisting of flagellates, dinoflagellates, diatoms and blue-green algae which occur in a wide range of salinity ranging from freshwater to marine conditions.
- **Sand / mudflats / rock:** Soft (mobile) substrates (sand and mud) and hard (non-mobile) substrates (rocks) and shorelines areas. Habitat mapping from aerial photographs cannot distinguish between sand and mud habitats and therefore in databases used for the purposes of this study are presented as a single area. The dominant primary producers of these habitats are the benthic microalgae.
- **Macroalgae:** Macroalgae may be intertidal (intermittently exposed) or subtidal (submerged at all times), and attached or free floating. Filamentous macroalgae often form algal mats and increase in response to nutrient enrichment or calm sheltered conditions when the mouth of an estuary is closed. Typical genera include *Enteromorpha* and *Cladophora*. Many marine species can get washed into an estuary and providing that the salinity is high enough, can proliferate. These include *Codium*, *Caulerpa*, *Gracilaria* and *Polysiphonia*.
- **Submerged macrophytes:** Submerged macrophytes are plants that are rooted in the substrate with their leaves and stems completely submersed (e.g. *Stukenia pectinata* and *Ruppia cirrhosa*) or exposed on each low tide (e.g. the seagrass *Zostera capensis*). *Zostera capensis* occupies the intertidal zone of most permanently open Cape estuaries whereas *Ruppia cirrhosa* is common in temporarily open/closed estuaries. *Stukenia pectinata* occurs in closed systems or in the upper reaches of open estuaries where the salinity is less than 10 ppt.
- **Salt marsh:** Salt marsh plants show distinct zonation patterns along tidal inundation and salinity gradients. Zonation is well developed in estuaries with a large tidal range e.g. Berg, Knysna and Swartkops estuaries. Common genera are *Sarcocornia*, *Salicornia*, *Triglochin*, *Limonium* and *Juncus*. Halophytic grasses such as *Sporobolus virginicus* and *Paspalum* spp. are also present. Intertidal salt marsh occurs below mean high water spring and supratidal salt marsh above this. *Sarcocornia pillansii* is common in the supratidal zone and large stands can occur in estuaries such as the Olifants.
- **Reeds and sedges:** Reeds, sedges and rushes are important in the freshwater and brackish zones of estuaries. Because they are often associated with freshwater input they can be used to identify freshwater seepage sites along estuaries. The dominant species are the common reed *Phragmites australis*, *Schoenoplectus scirpoides* and *Bolboschoenus maritimus* (sea club-rush).
- **Mangroves:** Mangroves are trees that establish in the intertidal zone in permanently open estuaries along the east coast of South Africa, north of East London where water temperature is usually above 20°C. The white mangrove *Avicennia marina* is the most widespread, followed by *Bruguiera gymnorrhiza* and then *Rhizophora mucronata*. *Lumnitzera racemosa*, *Ceriops tagal* and *Xylocarpus granatum* only occur in the Kosi Estuary.
- **Swamp forest:** Swamp forests, unlike mangroves are freshwater habitats associated with estuaries in KwaZulu-Natal. Common species include *Syzygium cordatum*, *Barringtonia racemosa* and *Ficus trichopoda*. It is often difficult to distinguish this habitat from coastal forest in aerial photographs.

4.4 Species of special concern

4.4.1 Plants

Plant species listed in the estuarine botanical database were cross referenced against the South African Red List (http://redlist.sanbi.org) to produce a list of estuarine plant species of conservation significance (Table 1). Categorisation was made on the basis of the IUCN Red List categories and Criteria version 3.1 (IUCN, 2012):

Some macrophyte species (mangroves and eelgrass) have only recently been reassessed in the Red Data List and freshwater mangrove *Barringtonia racemosa* was only added in 2016. If categorised as a species of special concern the data provided for each assessment was tabulated. Further research on these species was also captured. If categorised as 'Least Concern' details pertaining to the state of the population was not captured unless noted in a particular study. While the spatial location of all species of special concern is not known for South Africa's estuaries, what becomes clear from Table 1 is that all estuaries support estuarine habitat of concern and should be deemed as highly sensitive.

Interference (harvesting, clearing, removal) of mangrove and swamp forest is regulated under the National Forests Act No. 84 of 1998 (RSA 1998) and destruction or harvesting of indigenous trees requires a licence. All mangrove trees and swamp forests are protected under this act. The taxonomy of some salt marsh species is under currently under review; which makes it difficult to determine their population sizes, report on their threat status or set targets for protection. However according to the National Environmental Management: Integrated Coastal Management Act (Act 24 of 2008, as amended), all coastal wetlands, which include salt marshes and mangroves, form part of the coastal protection zone. The purpose of establishing this zone is to restrict and regulate activities in order to achieve the aims as set out in the Act. Other laws pertaining to species in these areas: National Environmental Management Act 1998, Marine and Living Resources Act 1998, The National Environmental Management: Biodiversity Act 2004, and National Forestry Act 1998.

4.4.2 Fish

The IUCN Red List of Threatened Species includes many fish that occur in estuaries in South Africa (ICUN, 2018). Table 2 lists those known to occur commonly in South African systems (i.e. excluding species that only occur sporadically in South African estuaries, species at the margins of their biogeographical ranges and which are more common in estuaries further north) (Whitfield, 1998, pers.obs). By far the majority of these fish are categorised as species of Least Concern. The IUCN Red List categories and criteria (IUCN 2012) are designed to be applied to the entire (global) range of a species and fish listed in the Least Concern category here range from those which are actually quite common and (still) abundant in South African systems (e.g. *Rhabdosargus sarba*) to species which are uncommon, rare and in a national sense could be considered as endangered (e.g. *Microphis brachyurus*). Included in Table 2 as a species of special concern, in the process of being IUCN red listed, is *Argyrosomus japonicus* (Dusky Kob), a species with South African populations at critically low levels (Griffiths, 1997, Mirimil et al., 2016). Predominant threats faced by the listed species include development (urban, commercial, recreational and industrial), agriculture, mining, resource use (fishing and harvesting of aquatic resources), modification of natural systems (flow modification and other), pollution, and climate change (ICUN 2018). **All estuaries in the corridors function as nurseries for Critically Endangered or Endangered fish species of high recreational or conservation importance.**

4.4.3 Mammals, Reptiles and Amphibians

Mammals, reptiles and amphibians are not traditionally assessed as part of estuarine studies. Given the overlap in sensitivity buffers between the study areas of the Estuary Specialist Assessment (i.e. this report) and the Freshwater Specialist Assessment (De Winnaar & Ross-Gillespie, 2018), the detailed features maps and four-tier sensitivity maps developed for Mammals, reptiles and amphibians in the later study can be regarded as applicable for estuaries.

1 Table 1: Macrophyte updates to the Red List of South Africa (Adams et al. 2018) (LC = Least Concern, EN = Endangered, NA = Not assessed, IUCN 2012).

Species	Common name	Category	Distribution	Habitat	Threats	Reference
Avicennia marina	White mangrove	LC	Widespread across the east coast from Chalumna to Kosi Bay and occurs in a large number of estuaries	Common and often dominant constituent of mangrove swamps (usually the inland fringes of mangrove associations) and is also a pioneer of new mud banks.	Continuous habitat loss due to urban, industrial development and infrastructure development	Adams et al., 2016a
Bruguiera gymnorrhiza	Black mangrove	LC	Widespread along the east coast of South Africa from the Nahoon to Kosi Bay.	Evergreen woodlands and thickets along the intertidal mud-flats of sheltered shores, estuaries and inlets, mainly towards the seaward side of mangrove formation.	Coastal development, over-harvesting	Adams et al., 2016b
Ceriops tagal	Indian mangrove	LC	Very limited distribution on the coast of South Africa	Evergreen woodlands and thickets along the intertidal mud-flats of sheltered shores, estuaries and inlets. The most inland of the rhizophoraceous mangroves.	No major threats	Adams et al., 2016c
Lumnitzera racemosa	Tonga mangrove	EN	Kosi Bay	Mangrove swamps, usually on the landward side.	Harvesting for firewood	Rajkaran et al., 2017
Rhizophora mucronata	Red mangrove	LC	Nahoon to Kosi Bay	Evergreen woodlands and thickets along the intertidal mud-flats of sheltered shores, estuaries and inlets, mainly in the seaward side of the mangrove formation.	Coastal development	Rajkaran et al., 2016
Xylocarpus granatum	Mangrove mahogany	NA	Single individual in Kosi Bay	Tidal mud of mangrove swamps, especially towards their upper limits.	Harvesting	SANBI, 2017
Barringtonia racemosa	Powder puff tree	LC	Coastal areas between the Eastern Cape and KwaZulu-Natal	Streamsides, freshwater swamps and less saline areas of coastal mangrove swamps.	Sensitive to salinity changes and tidal intrusion caused by infrastructure development and water abstraction as well as sea level rise associated to climate change. Fungal disease and chemical pollution is also problematic.	Von Staden, 2016
Zostera capensis	Eelgrass	LC	Olifants River Mouth on the Cape West Coast to Kosi Bay, northern KwaZulu-Natal.	Intertidal zone of permanently open estuaries. It occasionally persists in temporarily closed estuaries when conditions are saline.	Development, freshwater abstraction, catchment disturbance, eutrophication resulting in shading and outcompeting.	Adams & van der Colff, 2016

Table 2: Threatened South African estuarine fish species (CR = Critically Endangered, EN = Endangered, LC = Least Concern, DD = Data Deficient, IUCN 2012, * = Lower Risk/near threatened IUCN 1994 Categories & Criteria version 2.3, ** = Not IUCN listed, but critically low stocks in SA). The numbers indicated in the column entitled "Distribution within the relevant proposed Gas Pipeline Corridor" indicates the distribution of these estuarine fish species within the applicable corridors that are being studied as part of this assessment i.e. Phases 1, 2, 4, 5 and 7).

Scientific name	Common name	Red List status	Distribution within the relevant proposed Gas Pipeline corridor
Syngnathus watermeyeri	Estuarine Pipefish	CR	7
Clinus spatulatus	Bot River Klipfish	EN	1
Lithognathus lithognathus	White Steenbras	EN	1, 2, 5, 7
Hippocampus capensis	Knysna Seahorse	EN	2
Argyrosomus japonicus	Dusky Kob	EN**	1, 2, 4, 7
Anguilla bicolor	Shortfin Eel	NT	4, 7
Oreochromis mossambicus	Mozambique Tilapia	NT	1, 2, 4, 5, 7
Epinephelus malabaricus	Malabar Rockcod	NT	4, 7
Pomatomus saltatrix	Elf	VU	1, 2, 4, 5, 7
Acanthopagrus vagus	Estuarine Bream	VU	2, 4, 7
Rhabdosargus globiceps	White Stumpnose	VU	1, 2, 5, 7
Taenioides jacksoni	Bearded Goby	*LR/nt	4, 7
Albula oligolepis	Smallscale Bonefish	DD	4, 7
Hypseleotris cyprinoides	Golden Sleeper	DD	4, 7
Oligolepis acutipennis	Sharptail Goby	DD	4, 7
Megalops cyprinoides	Indo-Pacific Tarpon	DD	4, 7
Liza dumerili	Groovy Mullet	DD	1, 2, 4, 7
Microphis fluviatilis	Freshwater Pipefish	DD	4, 7
Ambassis natalensis	Slender Glassy	LC	4, 7
Anguilla marmorata	Marbled Eel	LC	1, 2, 4, 7
Anguilla mossambica	African Longfin Eel	LC	1, 2, 4, 7
Ablennes hians	Flat Needlefish	LC	4, 7
Caranx ignobilis	Giant Trevally	LC	4, 7
Caranx papuensis	Brassy Trevally	LC	4, 7
Lichia amia	Garrick	LC	1, 2 ,4, 5, 7
Scomberoides commersonnianus	Talang Queenfish	LC	2, 4, 7
Scomberoides lysan	Doublespotted Queenfish	LC	4, 7
Chanos chanos	Milkfish	LC	2, 4, 7
Eleotris fusca	Dusky Sleeper	LC	4, 7
Eleotris mauritiana	Widehead Sleeper	LC	4, 7
Eleotris melanosoma	Broadhead Sleeper	LC	4, 7
Elops machnata	Springer	LC	2, 4, 7
Stolephorus holodon	Natal Anchovy	LC	4, 7
Stolephorus indicus	Indian Anchovy	LC	4, 7
Thryssa setirostris	Longjaw Thryssa	LC	4, 7
Gerres filamentosus	Threadfin Pursemouth	LC	4, 7
Gerres longirostris	Smallscale Pursemouth	LC	4, 7
Gerres oyena	Longtail Pursemouth	LC	4, 7
Awaous aeneofuscus	Freshwater Goby	LC	4, 7
Croilia mossambica	Burrowing Goby	LC	4, 7
Favonigobius reichei	Tropical Sand Goby	LC	4, 7
Glossogobius callidus	River Goby	LC	2, 4, 7
Glossogobius giuris	Tank Goby	LC	4, 7
Oxyurichthys keiensis	Kei Goby	LC	4, 7
Paratrypauchen microcephalus	Blind Goby	LC	4, 7
Psammogobius biocellatus	Sleepy Goby	LC	4, 7
Redigobius bikolanus	Bigmouth Goby	LC	4, 7

Scientific name	Common name	Red List status	Distribution within the relevant proposed Gas Pipeline corridor
Redigobius dewaali	Checked Goby	LC	2, 4, 7
Stenogobius kenyae	Kenyan River Goby	LC	4, 7
Yongeichthys nebulosus	Shadow Goby	LC	4, 7
Lobotes surinamensis	Tripletail	LC	7
Lutjanus argentimaculatus	River Snapper	LC	4, 7
Monodactylus argenteus	Natal Moony	LC	1, 2, 4, 7
Monodactylus falciformis	Cape Moony	LC	1, 2, 4, 7
Chelon melinopterus	Giantscale Mullet	LC	4, 7
Crenimugil crenilabis	Fringerlip Mullet	LC	4, 7
Mugil cephalus	Flathead Mullet	LC	1, 2, 4, 7
Myxus capensis	Freshwater Mullet	LC	1, 2, 4, 7
Planiliza alata	Diamondscale Mullet	LC	4, 7
Planiliza macrolepis	Largescale Mullet	LC	2, 4, 7
Valamugil buchanani	Bluetail Mullet	LC	1, 2, 4, 7
Valamugil robustus	Robust Mullet	LC	4, 7
Ophisurus serpens	Sand Snake-eel	LC	4, 7
Sillago sihama	Silver Sillago	LC	4, 7
Acanthopagrus berda	Black Bream	LC	2, 4, 7
Crenidens crenidens	Karenteen Seabream	LC	4, 7
Diplodus capensis	Blacktail	LC	1, 2, 4, 5, 7
Rhabdosargus holubi	Cape Stumpnose	LC	1, 2, 4, 5, 7
Rhabdosargus sarba	Natal Stumpnose	LC	2, 4, 7
Rhabdosargus thorpei	Bigeye Stumpnose	LC	4, 7
Hippichthys cyanospilos	Bluespeckled Pipefish	LC	4, 7
Hippichthys heptagonus	Reticulated Pipefish	LC	4, 7
Hippichthys spicifer	Bellybarred Pipefish	LC	4, 7
Microphis brachyurus	Opossum Pipefish	LC	4, 7
Amblyrhynchotes honckenii	Evileye Pufferfish	LC	1, 2, 4, 7
Arothron immaculatus	Immaculate Pufferfish	LC	4, 7
Chelonodon laticeps	Bluespotted Pufferfish	LC	4, 7

4.5 Consideration of estuary condition and sensitivity to current and future impacts

Assessing the status and/or future impacts on estuarine ecosystems involves assessing anthropogenic pressures against a background of inherent variability and natural change (Gray and Elliott, 2009; Elliott, 2011). It requires an understanding of estuarine health, connectivity and coastal interaction on a regional scale, as well as consideration of resilience to natural and anthropogenic resetting events and recruitment processes. This requires an understanding of how pressures (including cumulative pressures) result in changes in the natural systems and the implications for resource use (Korpinen and Andersen, 2016).

Estuaries are by nature resilient systems, because their fauna and flora are adapted to living in ever changing conditions. However, development in and around estuaries can cause changes to the structural habitat of an estuary, resulting in local extinctions. Infrastructure development also prevents lateral movement of habitats such as salt marsh. Impacts caused by construction of hard structures in estuary floodplains are not easily reversible and can be mitigated at best. Even recovery from temporary disturbances can take decades to restore to natural conditions. For example, the crossing of the Nhlabane Estuary in KwaZulu-Natal by a mining dredger in 1993 involved construction of temporary sand berms across the estuary mid-way along the system (Jerling, 2005). Due to continuous freshwater inputs from groundwater seepage, the then closed estuary soon became fresh leading to change in the zooplankton community, including the appearance of freshwater taxa such as rotifers, Cyclopoids (*Mesocyclops* sp. *and Thermocyclops* sp.), freshwater *Cladocerans* and insect larvae. Estuarine species became less abundant or were lost from the system completely, including the copepod *Acartia natalensis*, the mysid *Mesopodopsis africana*, and larval stages of polychaetes, decapods and fish. Not all taxa recovered after the mouth reopened (Jerling, 2005). In addition, fine sediment intruded into the estuary from the berm wall area and caused a rapid decline in the density of benthic organisms and number of taxa. Recovery of the affected area was slow and characterized by initial proliferation of opportunistic colonizers (Vivier and Cyrus, 1999).

Coastal development along most of South Africa's coast has resulted in a continuous escalation of pressures on estuaries. While many of these estuaries are small, they act as a network, and incremental losses collectively add up to be significant and impact a large area of an estuarine system. Ribbon development along the coast is particularly problematic in this regard, well demonstrated by the KwaZulu-Natal south coast where urbanisation and development has led to significant habitat modification in all estuaries. Road and rail infrastructure negatively affects nearly every estuary along this coast. Bridge foundations and abutments, and road and rail berms have led to infilling of systems and consequential habitat destruction. They have resulted in changes to the natural flow and scouring dynamics in estuaries. Development across floodplains and channel stabilisation has affected natural flow patterns resulting in localised scour and deposition. Sugar cane farming along the banks of a large number of systems has led to infilling of floodplains, general constriction of tidal flows and large-scale loss of marginal vegetation and natural vegetation buffers around the estuaries. This has caused ever increasing "gaps" between functional estuaries along the coastline and large numbers of poor condition systems adjacent to each other is a concern. Little research has been done on the direct consequences of declining estuary condition and this type of loss of connectivity in an estuarine network, especially with respect to the ability of individual and collective systems to absorb and recover from events. It is nevertheless increasingly recognised that in the case of estuaries, the health of neighbouring systems matters as it ensures overall resilience of a regional network of estuaries. Future telemetry and genetic studies will assist in understanding this aspect of estuarine connectivity better, and inform the development of guidelines for regional resource allocation.

In particular it is important to preserve coastal connectivity to ensure recruitment from healthy neighbouring systems in the event of natural and anthropogenic disasters. In order to accommodate flood events, sea storms and climate change estuary floodplains and supporting habitats must be protected from infrastructure development to ensure resilience to extreme flooding (and allow for lateral channel movement), negate the need for premature artificial breaching of systems, and prevent coastal squeeze of estuarine habitats.

4.6 Description of estuaries in corridors/feature maps

Available information was used to describe important environmental attributes of estuaries within each of the applicable corridors. This includes a brief overview of present health conditions, biodiversity importance and important uses of estuaries in the selected study areas (corridors). Important ecological and socio-economic attributes of estuaries within each of the applicable corridors are summarised in Appendix A, Table A.1.

Figure 5 illustrates the proposed Gas Pipeline corridors. Note that Phases 3 and 8, as well as portions of the inland corridor (via the Karoo) are inland, and Phase 6 is set back from the coast. As such, estuaries are not directly affected by these corridors. As noted above, this assessment therefore focuses on Phases 5, 1, 2, 7, and 4 (from west to east) which are routed along the coast.

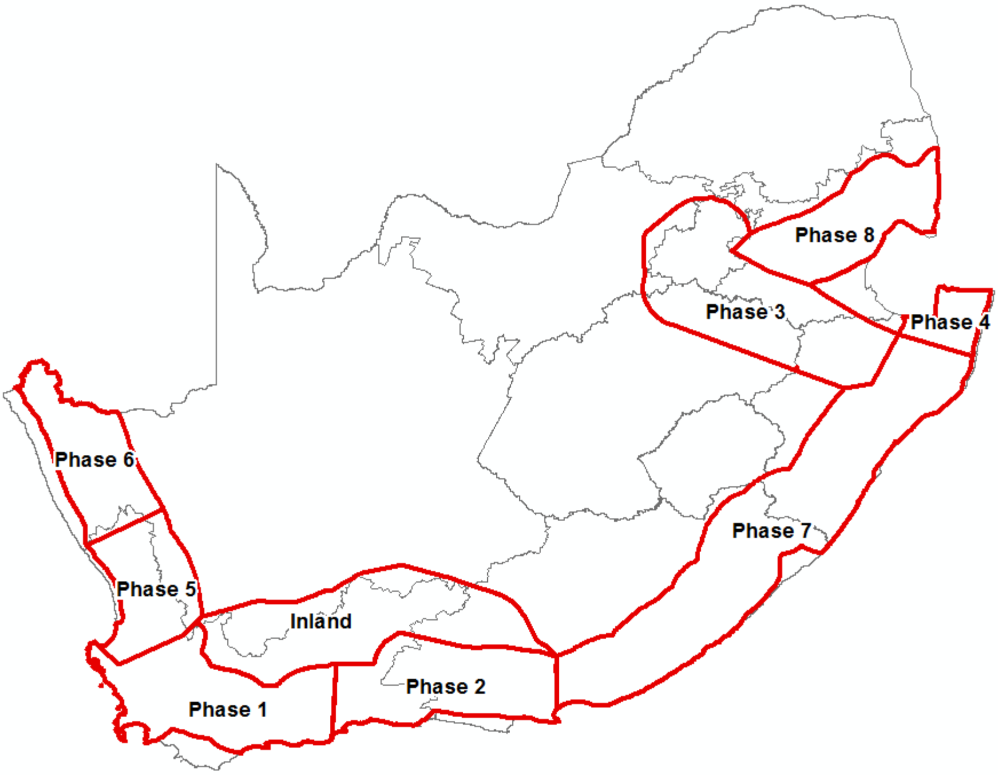


Figure 5: Image indicating the proposed Gas Pipeline corridors. Only the Phases 5, 1, 2, 7, and 4 corridors are considered in this study.

4.6.1 Phase 5 corridor

Three estuaries are situated within the Phase 5 corridor; the Olifants, Verlorenvlei and the Groot Berg. They have a combined estuarine habitat area of 8 600 ha (Figure 6) and are amongst the longest of South Africa's estuaries with the Groot Berg Estuary nearly 70 km and the Olifants Estuary about 40 km long. The Groot Berg roughly extends about 40 km into the Phase 5 corridor. Their health statuses vary between C and D Categories on the Department of Water and Sanitation (DWS) scale ("A" being near natural and "F" being extremely degraded) (Van Niekerk et al., 2018, in progress).

All three estuaries are national conservation priorities as identified in the national estuaries biodiversity plan (Turpie et al., 2012). The Olifants and Groot Berg are of very high biodiversity Importance, ranking in the top five estuaries in South Africa (Turpie et al., 2002; Turpie and Clark, 2009). These systems are also important fish nurseries that play a critical role in the maintenance and recovery of South Africa's recreational and commercial fish stock (Lamberth and Turpie, 2003; Van Niekerk et al., 2017). From a habitat diversity and abundance perspective the Olifants and Groot Berg are also considered highly important as they support large areas of sensitive estuarine habitats such as intertidal and supratidal saltmarsh.

4.6.2 Phase 1 corridor

In total 25 estuaries are situated within the Phase 1 corridor, with a combined estuarine habitat area of 3 100 ha (Figure 7). Most are not particularly long and extend less than 10 km into the proposed Gas Pipeline corridor. Exceptions are the Breede (<30 km), Gourits (<25 km), Duiwenhoks (<15 km), Goukou (<15 km), Sand (<10 km), Sout (Wes) (<10 km) and Rietvlei/Diep (<10 km).

The Langebaan, Wildevoëlvlei, Breë, Duiwenhoks and Goukou estuaries are of very high biodiversity importance, ranking in the top estuaries in South Africa (Turpie et al., 2002; Turpie and Clark, 2009). In addition the Rietvlei/Diep, Sand, Palmiet, Gourits estuaries are also rated as important from a biodiversity perspective.

Only eight estuaries in this corridor are in excellent or good conditions (Categories A to B); Langebaan, Schuster, Krom, Buffels Wes, Steenbras, Rooiels, Buffels (Oos), and Klipdrifsfontein. These systems have a high sensitivity to change as they will degrade from their near pristine state relatively easily.

Eleven estuaries in the corridor are identified as national conservation priorities in the National Estuaries Biodiversity Plan (Turpie et al., 2012). These include Langebaan, Rietvlei/Diep, Krom, Sand, Eerste, Lourens, Palmiet, Klipdrifsfontein, Breë, Goukou and Gourits estuaries. Seven estuaries are identified as important fish nurseries that play a critical role in the maintenance and recovery of South Africa’s recreational and commercial fish stock (Lamberth and Turpie, 2003; Van Niekerk et al., 2017). These include Langebaan, Rietvlei/Diep, Sand, Breë, Duiwenhoks, Goukou and Gourits estuaries. From a habitat diversity and abundance perspective the Langebaan, Rietvlei/Diep, Wildevoëlvlei, Sand, Palmiet, Breë, Duiwenhoks, Goukou and Gourits estuaries are also considered important as they support sensitive estuarine habitats such as intertidal and supratidal saltmarsh.

4.6.3 Phase 2 corridor

In total 26 estuaries (Figure 8) are situated within the Phase 2 corridor, with a combined estuarine habitat area of 7 000 ha (note that the Sundays Estuary overlaps with both the Phase 2 and Phase 7 corridor boundaries and is therefore included in both assessments). Most of the estuaries in the region are not particularly long and extend less than 10 km into the corridor, with the exception of the Sundays (<25 km), Swartkops (<15 km), Klein Brak (<10 km), Swartvlei (<10 km), Goukamma (<10 km), Knysna (<10 km), Keurbbooms (<10 km), Gamtoos (<10 km) and Coega (<10 km).

Only seven estuaries in this corridor are in an excellent or good condition (Categories A to B); Maalgate, Kaaimans, Goukamma, Noetsie, Keurbooms, Matjies and Van Stadens. These systems are highly sensitive to change as they will degrade from their near pristine state relatively easily.

The Wilderness/Touws, Swartvlei, Knysna, Keurbooms, Gamtoos, and Swartkops estuaries are of very high biodiversity importance, ranking among the top estuaries in South Africa (Turpie et al., 2002; Turpie and Clark, 2009). The Hartenbos, Groot Brak, Goukamma, Piesang, Kabeljous and Sundays estuaries are also rated as important from a biodiversity perspective.

Thirteen estuaries in the corridor are identified as national conservation priorities in the National Estuaries Biodiversity Plan (Turpie et al., 2012). These include Kaaimans, Wilderness, Swartvlei, Goukamma, Knysna, Noetsie, Piesang, Keurbooms, Gamtoos, Van Stadens, Maitland, Swartkops and Sundays estuaries. In addition, 13 estuaries are identified as important fish nurseries that play a critical role in the maintenance and recovery of South Africa’s recreational and commercial fish stock (Lamberth and Turpie, 2003; Van Niekerk et al., 2017). These include the Hartenbos, Klein Brak, Groot Brak, Wilderness, Swartvlei, Goukamma, Knysna, Piesang, Keurbooms, Kabeljous, Gamtoos, Swartkops and Sundays estuaries. From a habitat diversity and abundance perspective the Hartenbos, Klein Brak, Groot Brak, Wilderness, Swartvlei, Goukamma, Knysna, Piesang, Keurbooms, Kabeljous, Gamtoos, Swartkops, Coega and Sundays estuaries are also considered important as they support sensitive estuarine habitats such as intertidal and supratidal saltmarsh.

4.6.4 Phase 7 corridor

In total 155 estuaries are situated within the Phase 7 corridor, with a combined estuarine habitat area of about 55 100 ha (Figure 9 and Figure 10). Most of the estuaries in the region are not particularly long and extend less than 10 km into the corridor, with the exception of St Lucia (< 30km), Sundays (<25 km), Bushmans (<20 km), Keiskamma (<20 km), Kowie (<15 km), Great Fish (<15 km), Tyolomnqa (<15 km), Great Kei (<15 km), Thukela (<15 km), Mhlathuze (<15 km), Mfolozi (<15 km), Coega (<10 km), Kariega, (<10 km), Kleinemond Wes (<10 km), Mgwalana (<10 km), Bira (<10 km), Nahoon (<10 km), Mbashe (<10 km), Mtamvuna (<10 km), Mzimkulu (<10 km), Matigulu/Nyoni (<10 km), Mlalazi (<10 km), Richards Bay(<10 km) and Nhlabane (<10 km).

Seventy-nine estuaries in this corridor are in an excellent or good condition (Categories A to B). These systems vary from very small to large permanently open systems (refer to Appendix A for more detail). They are highly sensitive to change as they will degrade from their near pristine state relatively easily.

A total of 14 estuaries in this corridor are of very high biodiversity importance, ranking with the top estuaries in South Africa, namely Kariega, Kowie, Great Fish, Mpekweni, Mtati, Mgwalana, Keiskamma, Great Kei, Mbashe, Mngazana, Mlalazi, Mhlathuze, Mfolozi and St Lucia estuaries (Turpie et al., 2002; Turpie and Clark, 2009). In addition, 37 systems are also rated as important from a biodiversity perspective, namely Sundays, Bushmans, Kasuka, Riet, Kleinemond Wes, Kleinemond Oos, Bira, Gqutywa, Tyolomnqa, Nahoon, Qinira, Gqunube, Kwelera, Cefane, Qolora, Nxaxo/Ngqusi, Qora, Nqabara/Nqabarana, Xora, Mtata, Mzimvubu, Mzamba, Mtamvuna, Mzimkulu, Fafa, Mkomazi, Mgeni, Mhlanga, Mdloti, Tongati, Mhlali, Mdlotane, Zinkwasi, Thukela, Matigulu/Nyoni, Richards Bay, Nhlabane estuaries.

Sixty-one estuaries in the corridor are identified as national conservation priorities in the National Estuaries Biodiversity Plan (Turpie et al., 2012). These include Sundays, Bushmans, Kariega, Great Fish, Mgwalana, Bira, Gqutywa, Keiskamma, Ngqinisa, Ncera, Gqunube, Kwelera, Kwenxura, Quko, Great Kei, Ncizele, Nxaxo/Ngqusi, Ngqwara, Qora, Ngadla, Nqabara/Nqabarana, Mbashe, Xora, Mtata, Mngazana, Mzimvubu, Sikombe, Kwanyana, Mtolane, Mnyameni, Mpahlanyana, Mpahlane, Mzamba, Mtentwana, Mtamvuna, Mpenjati, Zotsha, Mzimkulu, Damba, Koshwana, Intshambili, Mhlabatshane, Mfazazana, Kwa-Makosi, Mkomazi, Umgababa, Msimbazi, Lovu, Mgeni, Mhlanga, Mhlali, Mvoti, Mdlotane, Zinkwasi, Thukela, Matigulu/Nyoni, Siyaya, Mlalazi, Mhlathuze, Richards Bay, Mfolozi/St Lucia estuaries. In addition, 53 estuaries are identified as important fish nurseries that play a critical role in the maintenance and recovery of South Africa's recreational and commercial fish stock (Lamberth and Turpie, 2003; Van Niekerk et al., 2017). These include the Sundays, Bushmans, Kariega, Kasuka,Kowie, Kleinemond Wes, Kleinemond Oos, Great Fish, Mpekweni, Mtati, Mgwalana, Bira, Gqutywa, Keiskamma, Kiwane, Tyolomnqa, Gxulu, Buffalo, Nahoon, Gunube, Kwelera, Cefane, Kwenxura, Quko, Morgan, Great Kei, Kobonqaba, Nxaxo/Ngqusi, Qora, Nqabara/Nqabarana, Mbashe, Xora, Mtata, Mngazana, Mzimvubu, Mzamba, Mtamvuna, Mzimkulu, Mhlabatshane, Mkomazi, Umgababa, Msimbazi, Lovu, Mgeni, Zinkwasi, Thukela, Matigulu/Nyoni, Mlalazi, Mhlathuze, Richards Bay, Nhlabane, Mfolozi and St Lucia estuaries.

From a habitat diversity and abundance perspective 96 estuaries are considered important as they support sensitive estuarine habitats such as mangroves, swamp forest or saltmarsh (intertidal and supratidal). These included Coega, Sundays, Boknes, Bushmans, Kariega, Kowie, Riet, Kleinemond Wes, Kleinemond Oos, Great Fish, Mpekweni, Mtati, Mgwalana, Bira, Gqutywa, Mtana, Keiskamma, Tyolomnqa, Ncera, Gxulu, Goda, Nahoon, Qinira, Gqunube, Kwelera, Bulura, Cintsa, Cefane, Kwenxura, Nyara, Quko, Morgan, Great Kei, Gxara, Kobonqaba, Nxaxo/Ngqusi, Ngqwara, Nqabara/Nqabarana, Mbashe, Xora, Mtata, Mngazana, Mzimvubu, Sikombe, Mnyameni, Mzamba, Mtamvuna, Sandlundlu, Tongazi, Kandandhlovu, Mpenjati, Umhlangankulu, Kaba, Mbizana, Bilanhlolo, Kongweni, Zotsha, Mbango, Mzimkulu, Mtentweni, Mhlangamkulu, Damba, Koshwana, Intshambili, Mhlabatshane, Mhlungwa, Mfazazana, Kwa-Makosi, Mnamfu, Fafa, Sezela, Mzinto, Mpambanyoni, Mkomazi, Umgababa, Lovu, Little Manzimtoti, Manzimtoti, Sipingo, Mgeni, Mhlanga, Mdloti, Tongati, Mhlali, Mdlotane, Nonoti, Zinkwasi, Thukela, Matigulu/Nyoni, Siyaya, Mlalazi, Mhlathuze, Richards Bay, Nhlabane, Mfolozi and St Lucia estuaries.

4.6.5 Phase 4 corridor

Three estuaries are situated within the Phase 4 corridor, with a combined estuarine habitat area of about 46 200 ha (Figure 11). Note there is overlap with St Lucia lakes system in Phase 7 corridor. Two of the systems in the corridor are very large, with St Lucia extending about 30 km and Kosi extending about 10 km in land. The Mgobezeleni extends less than 10 km inland.

The Mgobezeleni and Kosi estuaries are in an excellent to good condition (Categories A to B). These systems are highly sensitive to change as they will degrade from their near pristine state relatively easily. The St Lucia and Kosi estuarine lake systems are of very high biodiversity importance (Turpie et al., 2002; Turpie and Clark, 2009). All three estuaries in the corridor, St Lucia, Mgobezeleni and Kosi, are identified as national conservation priorities in the National Estuaries Biodiversity Plan (Turpie et al., 2012). St Lucia and Kosi are important fish nurseries that play a critical role in the maintenance and recovery of South Africa's recreational and commercial fish stock (Lamberth and Turpie, 2003; Van Niekerk et al., 2017). From a habitat diversity and abundance perspective the St Lucia, Mgobezeleni and Kosi estuaries are all considered important as they support sensitive estuarine habitats such as mangroves, swamp forest and saltmarsh.

4.7 Identification of feature sensitivity criteria

A generic suite of environmental and socio-economic sensitivity indicators, which could be mapped using existing knowledge and datasets, and which were suitable for assessing potential risks associated with the type of development assessed here (gas pipeline crossing) were selected (Table 3). Base maps were produced for each corridor demarcating the presence and locations of these sensitivity indicators. Based on expert opinion, each of these indicators was allocated a sensitivity rating (very high, high, medium, low, Table 3). This allowed for the translation of base maps into sensitivity maps for each of the study areas.

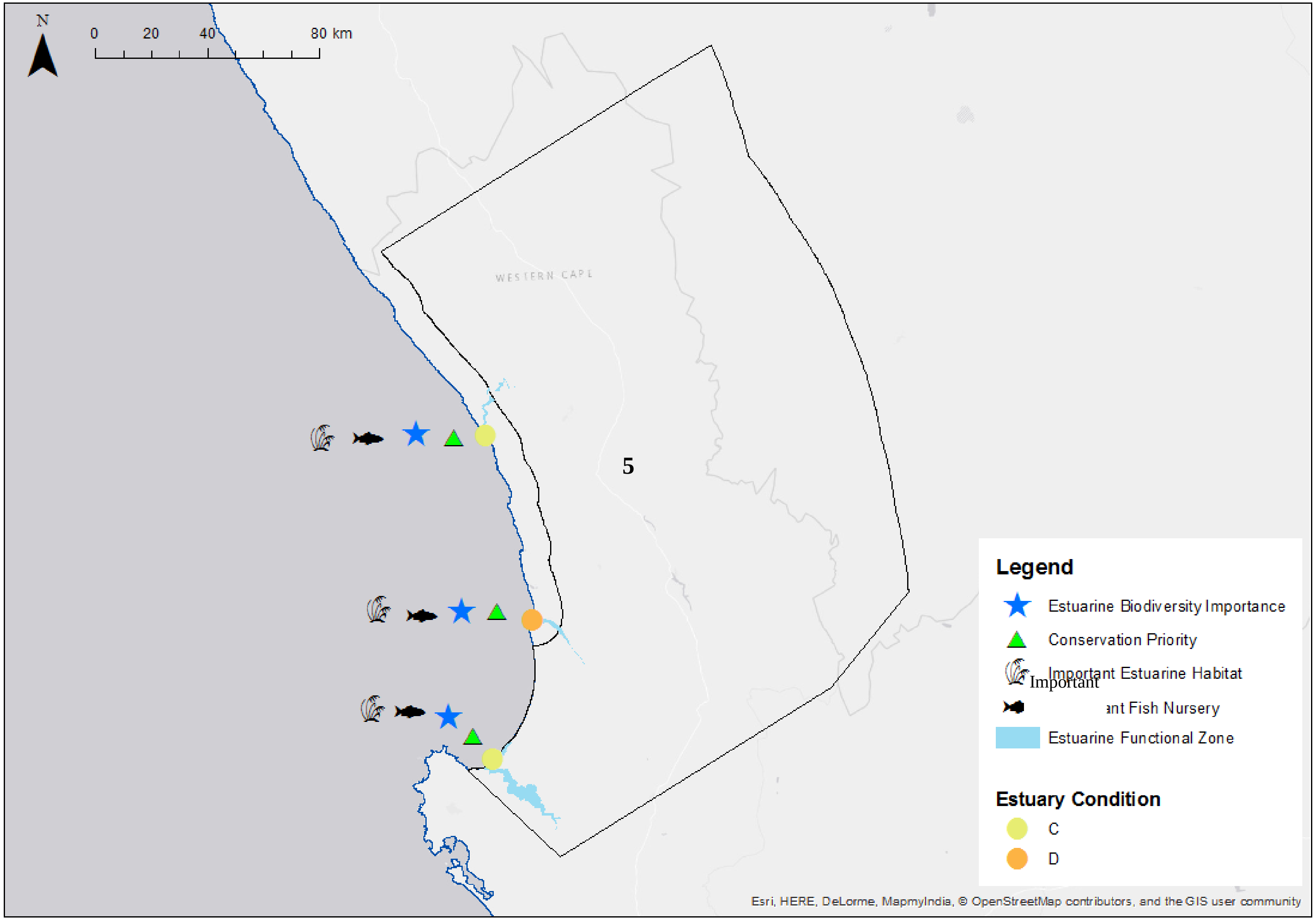


Figure 6: Estuarine feature map for the proposed Phase 5 Gas Pipeline corridor.

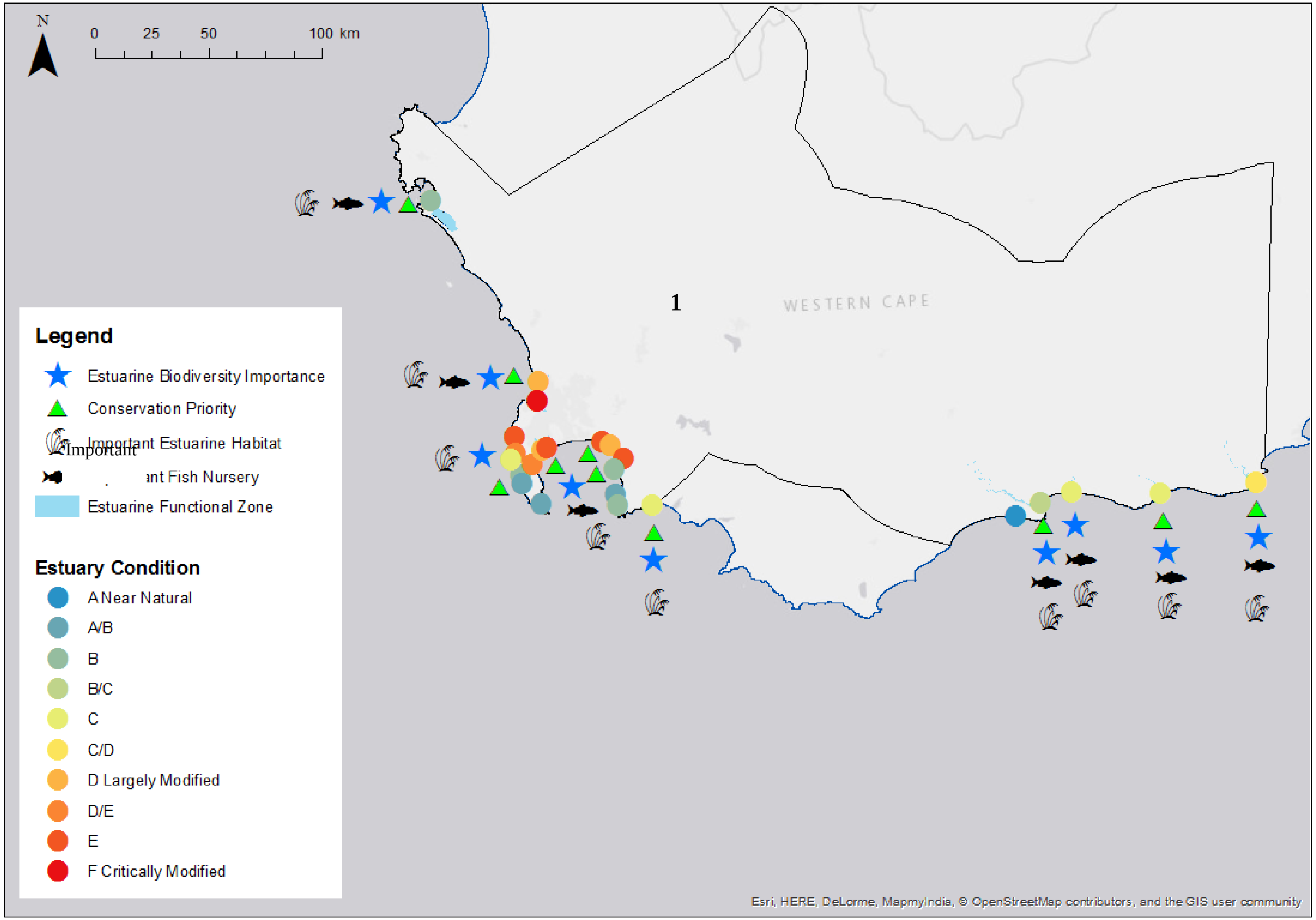


Figure 7: Estuarine feature map for the proposed Phase 1 Gas Pipeline corridor.

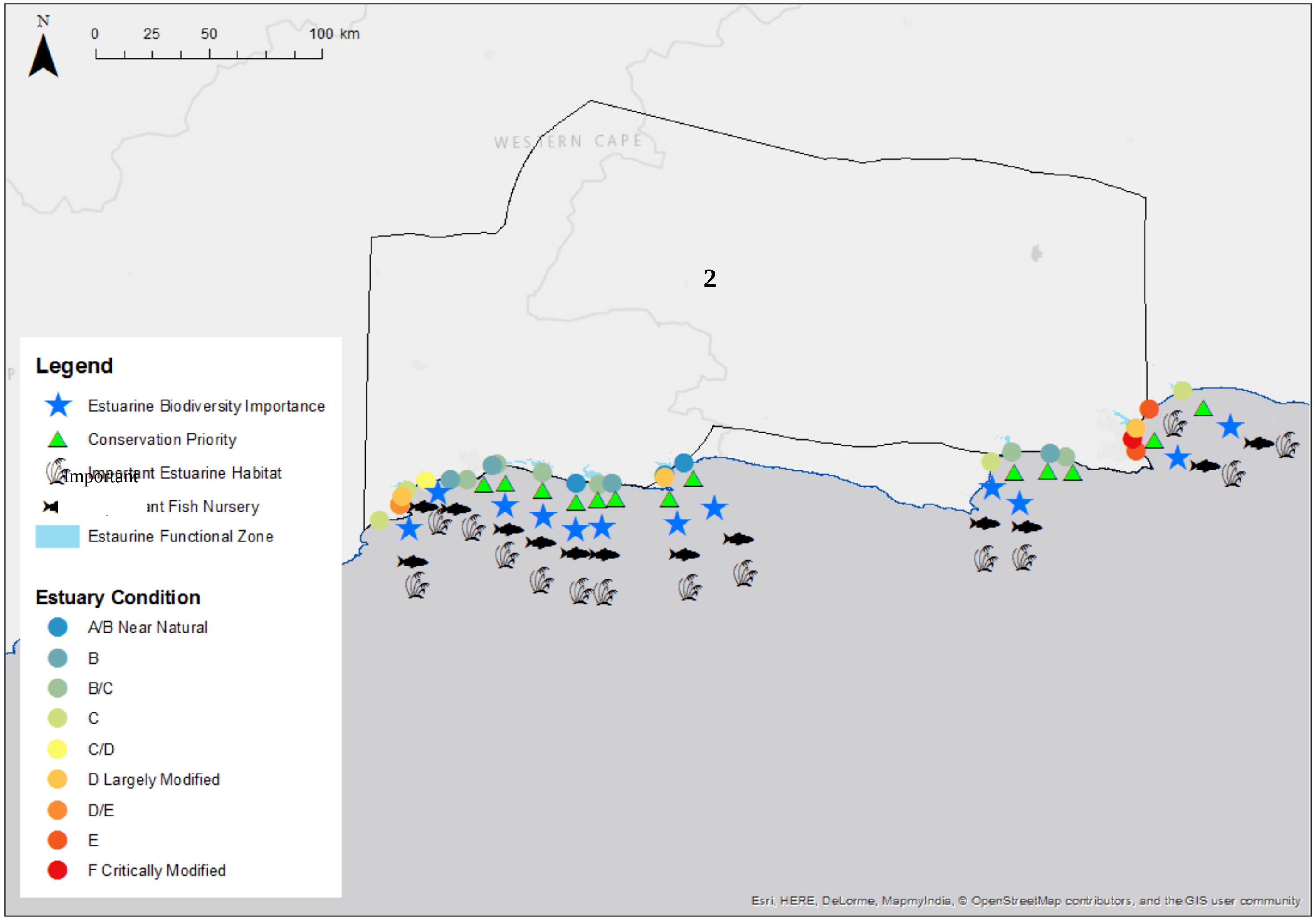
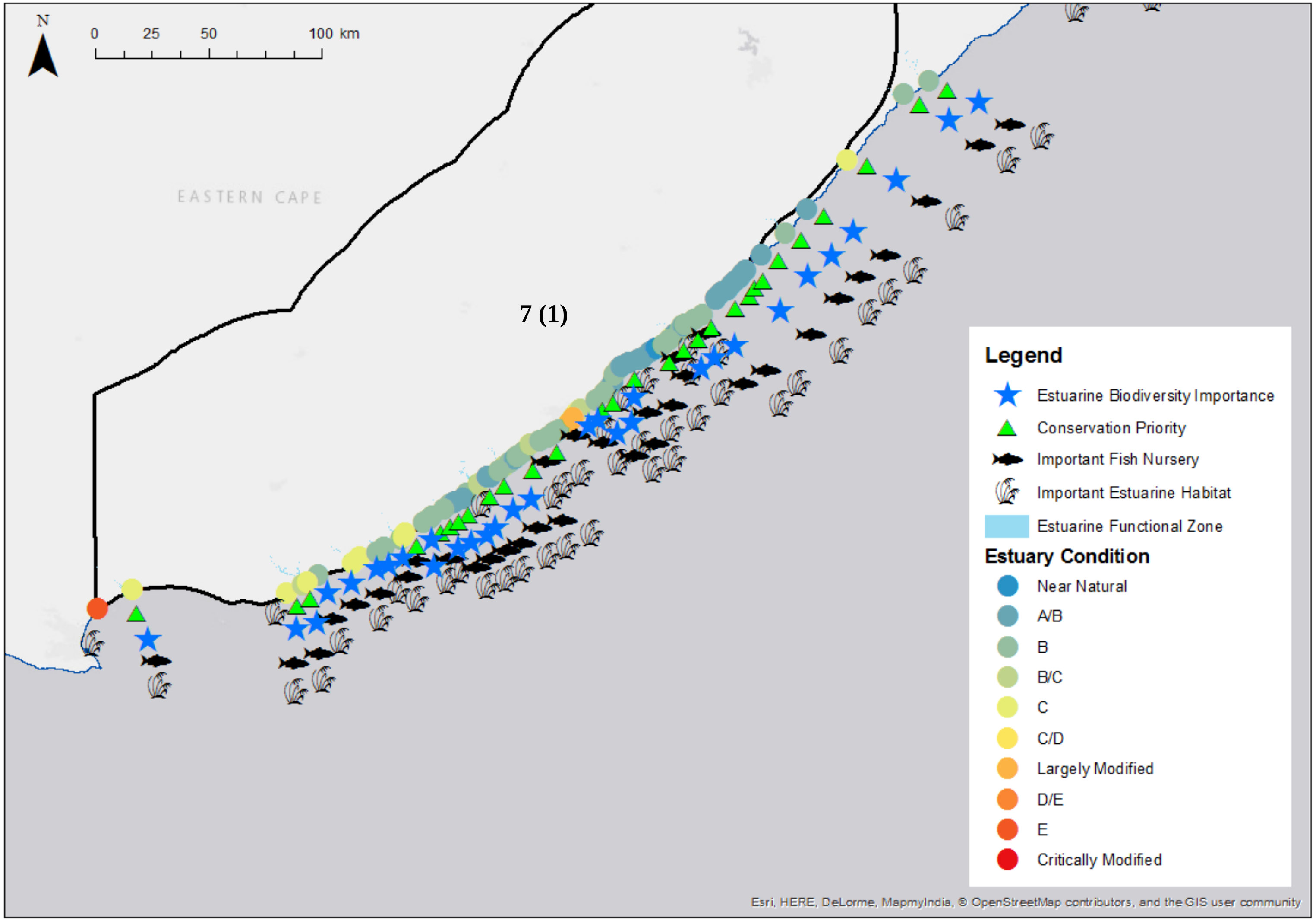


Figure 8: Estuarine feature map for the proposed Phase 2 Gas Pipeline corridor.



1
2 Figure 9: Estuarine feature map for the proposed Phase 7 Gas Pipeline corridor (Part 1).

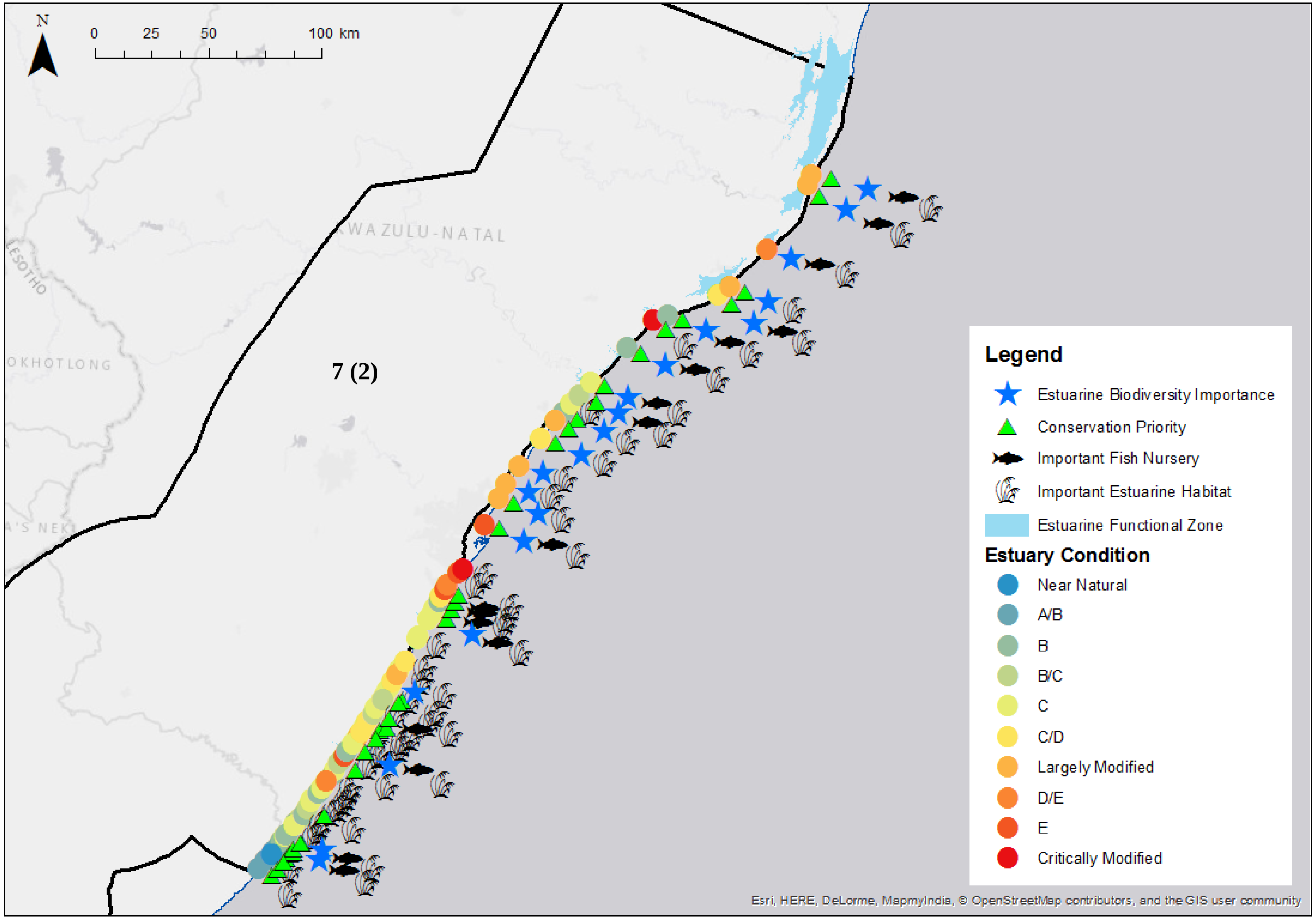


Figure 10: Estuarine feature map for the proposed Phase 7 Gas Pipeline corridor (Part 2).

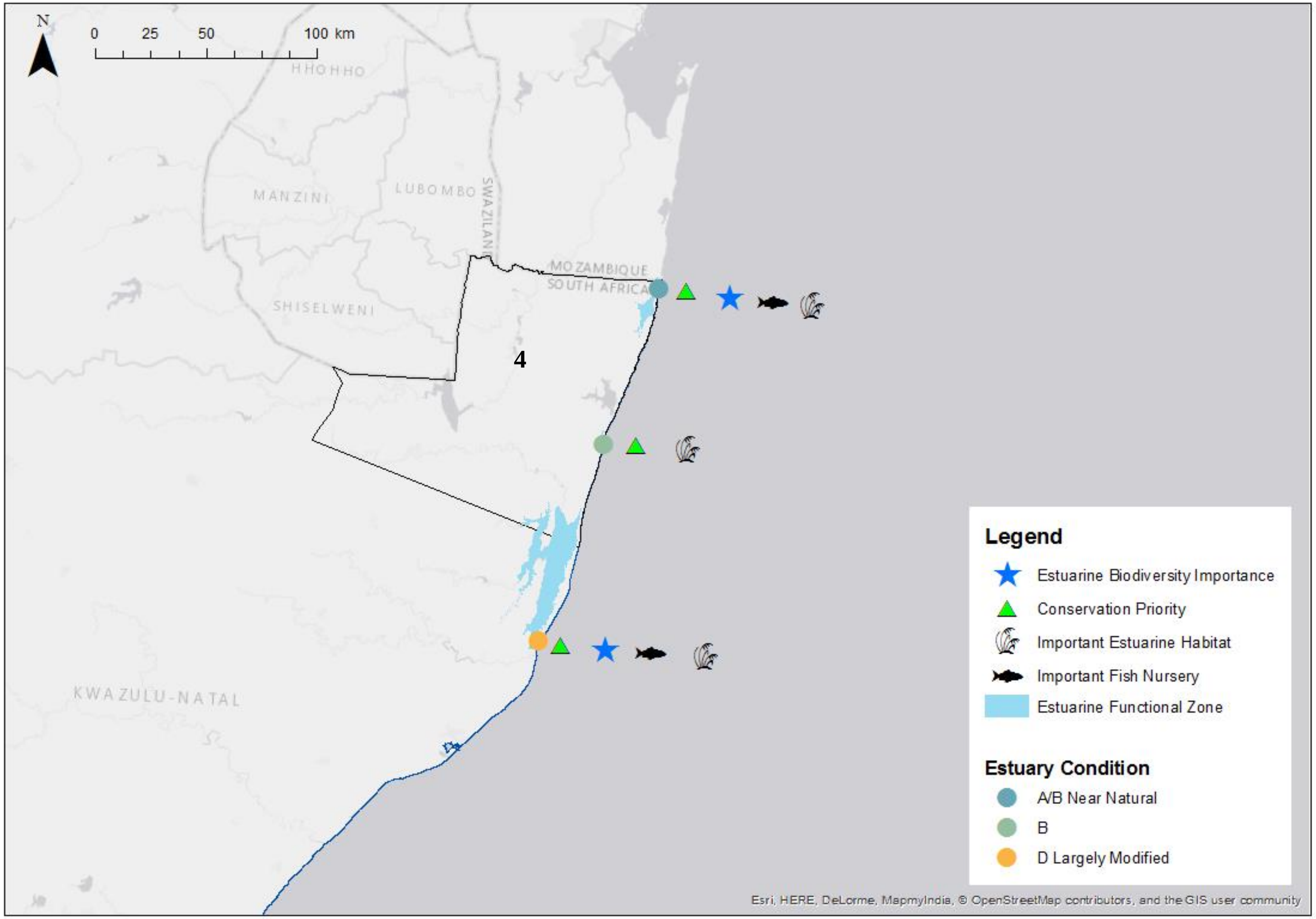


Figure 11: Estuarine feature map for the proposed Phase 4 Gas Pipeline corridor.

Table 3: Selected ecological sensitivity indicators and associated sensitivity ratings (applicable to all proposed Gas Pipeline corridors)

Sensitivity Indicator	Brief description/data source	Sensitivity Class	Zone of interest
Estuaries in Formally /desired protected areas	Marine, estuarine and terrestrial areas within the study area boundaries that are under formal protection or estuaries identified as desired protected areas in the National Estuaries Biodiversity Plan (Turpie et al., 2012)	Very High	EFZ
Estuaries of high biodiversity importance	In South Africa, estuary biodiversity importance is based on the importance of an estuary for plants, invertebrates, fish and birds, using rarity indices (Turpie et al., 2002). The Estuary Importance Rating takes size, the rarity of the estuary type within its biographical zone, habitat and the biodiversity importance of the estuary into account (Turpie et al., 2002, Appendix B).	Very High	EFZ
Important nurseries	Estuaries that are critically important nursery areas for fish and invertebrates and make an important contribution towards estuarine and coastal fisheries (Lamberth and Turpie, 2003; Van Niekerk et al., 2017)	Very High	EFZ
Important estuarine habitats	Estuaries that support important rare or sensitive habitats (saltmarsh, mangroves, swamp forest) that provide important ecosystem services (Van Niekerk et al., 2017)	Very High	EFZ
Natural or near natural condition estuaries	Estuaries in good condition (designated by a A or B health category are more sensitive to development (likely to degrade in overall condition) (Van Niekerk et al., 2017)	Very High	EFZ
Estuaries that support species of conservation importance	Estuaries that support species of conservation importance (IUCN Red listed fish species that are Endangered or Critically Endangered)	Very High	EFZ
Other estuaries	All estuarine habitats are highly sensitive to disturbance in the EFZ.	High	EFZ
Coastal rivers, wetlands and seeps above or adjacent to estuaries	The coastal rivers, wetlands and seeps adjacent or just upstream of estuaries that directly influence the quality and quantity of freshwater and sediments entering estuaries.	High	5 km buffer around EFZ
Coastal rivers, wetlands and seeps	The coastal rivers, wetlands and seeps adjacent or just upstream of estuaries that indirectly influence the quality and quantity of freshwater and sediments entering estuaries.	Medium	5 - 15 km buffer around EFZ
Terrestrial environment	Terrestrial environment that is not linked to aquatic processes that directly or indirectly influence estuaries.	Low	15 km or more from EFZ

4.8 Sensitivity Mapping

All estuaries under consideration here can be regarded as being systems of very high sensitivity based on one or more of the listed criteria in Table 3, e.g. priority estuary for conservation, an important nursery system, and/or as a system supporting endangered Red listed species such as White Steenbras.

Because of estuarine connectivity (and dependencies) on wider floodplain and riverine habitats, and because habitat impacts in estuaries accumulate over temporal and spatial scales, estuaries can thus not be assessed as discrete units as done in the case of terrestrial systems. For this assessment the EFZ of each estuary within the proposed gas pipeline corridor were buffered at 5 km intervals to reflect the sensitivity of estuaries and their associated inflowing rivers, wetlands and coastal seeps to potential infrastructure development. This approach also allows assessment of potential cumulative impacts of a linear structure crossing a number of estuaries within a region. Relative sensitivity of zones within each of the corridors are illustrated in Figure 12 to Figure 17.

4.8.1 Phase 5 corridor

While there are only three estuaries in this corridor they are very large systems of high biodiversity importance that stretch as far as 25 km into the corridor (see Figure 12). These areas are of Very High sensitivity to infrastructure development. The coastal rivers, wetlands and seeps adjacent or just upstream the estuaries, as demarcated by the 5 km buffer around the EFZ, are zones of high sensitivity as they directly influence the quality and quantity of freshwater and sediments delivered to these estuaries. The coastal rivers, wetlands and seeps adjacent or above the estuaries, as demarcated by the 5 to 15 km buffer around the EFZ, are zones of medium sensitivity as they indirectly influence the quality and quantity of freshwater and sediments entering estuaries.

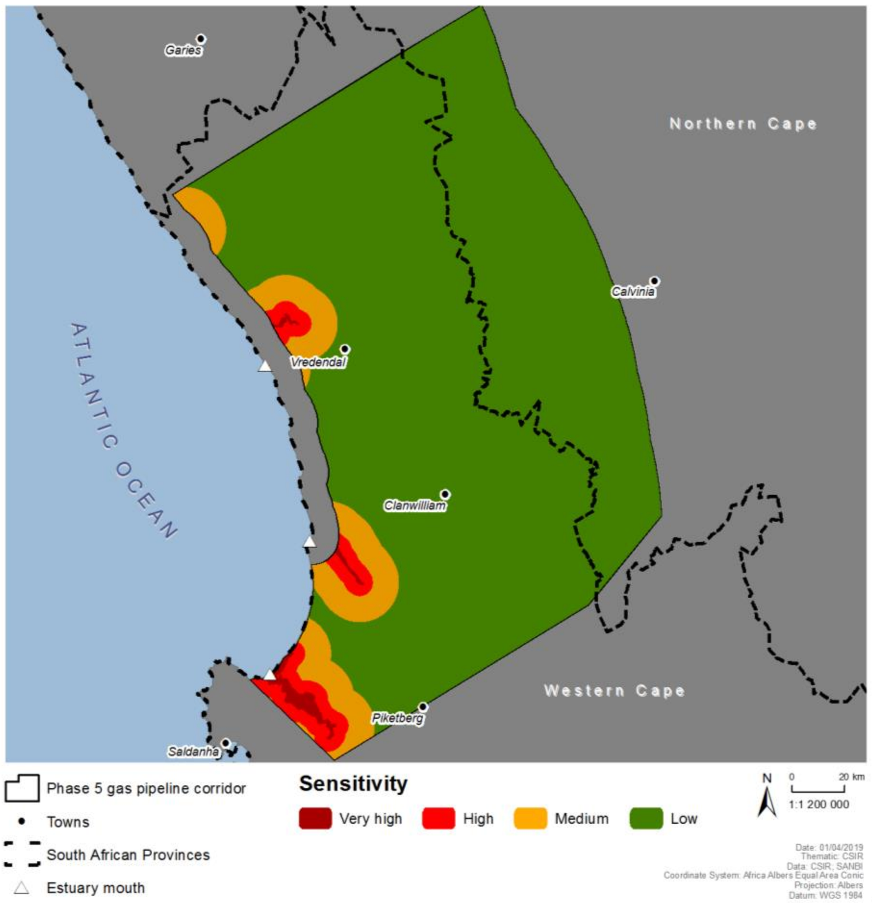


Figure 12: Sensitivity map for the estuaries, EFZ and associated features in the proposed Phase 5 Gas Pipeline corridor.

4.8.2 Phase 1 corridor

A total of 25 estuaries are located in the Phase 1 corridor, many of high biodiversity importance (Figure 13). The larger systems (the Breede and Gourits estuaries) stretch more than 25 km into the corridor. These areas are of Very High sensitivity to infrastructure development. Rivers, wetlands and coastal seeps adjacent or just above the estuaries, within a 5 km buffer around the EFZ, are zones of high sensitivity as they directly influence the quality and quantity of freshwater and sediments entering estuaries. These areas also provide important habitat for species, such as eels, that occur both in estuaries and freshwater aquatic ecosystems. The coastal rivers, wetlands and seeps adjacent or above the estuaries, as demarcated in a 5 to 15 km buffer around the EFZ, are zones of medium sensitivity as they indirectly influence the quality and quantity of freshwater and sediments entering estuaries.

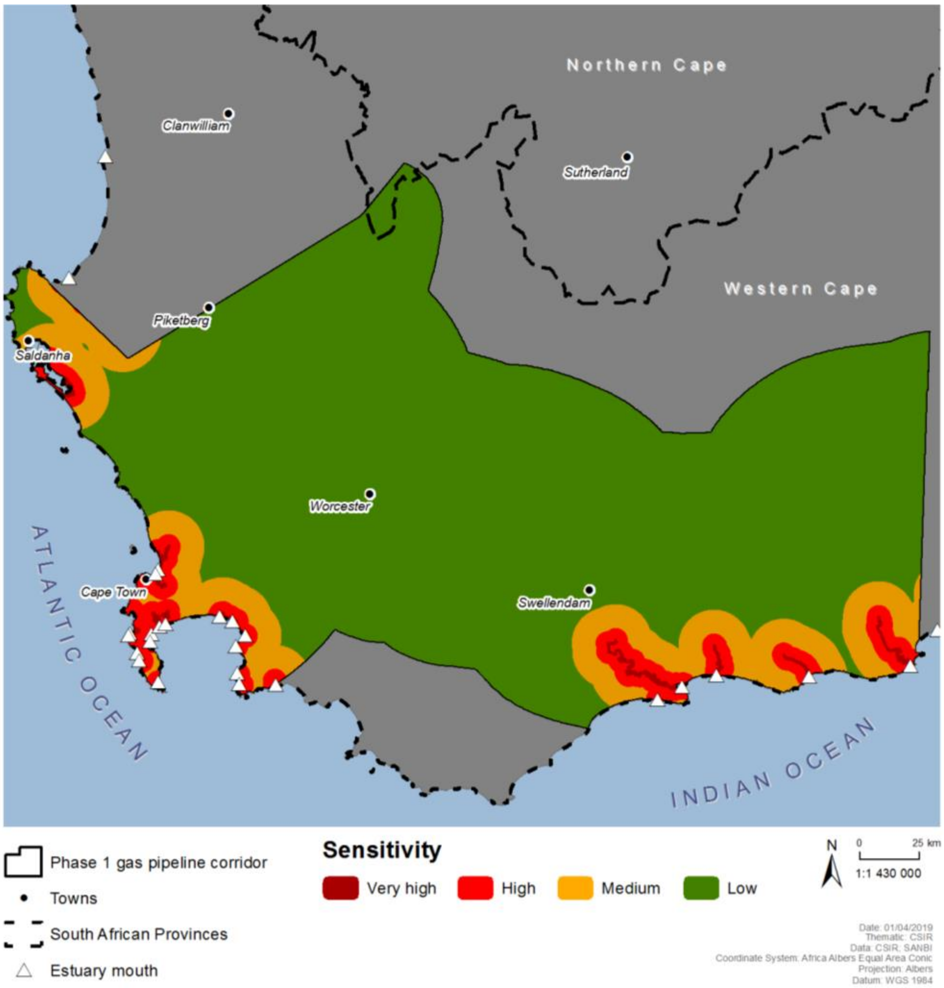


Figure 13: Sensitivity map for the estuaries, EFZ and associated features in the proposed Phase 1 Gas Pipeline corridor.

4.8.3 Phase 2 corridor

There are 26 estuaries in this corridor, a significant number of which are of High biodiversity importance and which stretch as much as 25 km into the corridor, i.e. Sundays Estuary (Figure 14). These areas are of Very High sensitivity to infrastructure development. Coastal seeps, wetlands and rivers adjacent or just above the estuaries, within a 5 km buffer around the EFZ, are deemed zones of high sensitivity as they directly influence the quality and quantity of freshwater and sediments entering estuaries. The coastal seeps, wetlands and rivers adjacent or above the estuaries, within the 5 to 15 km buffer around the EFZ, are zones of medium sensitivity as they indirectly influence the quality and quantity of freshwater and sediments entering estuaries.

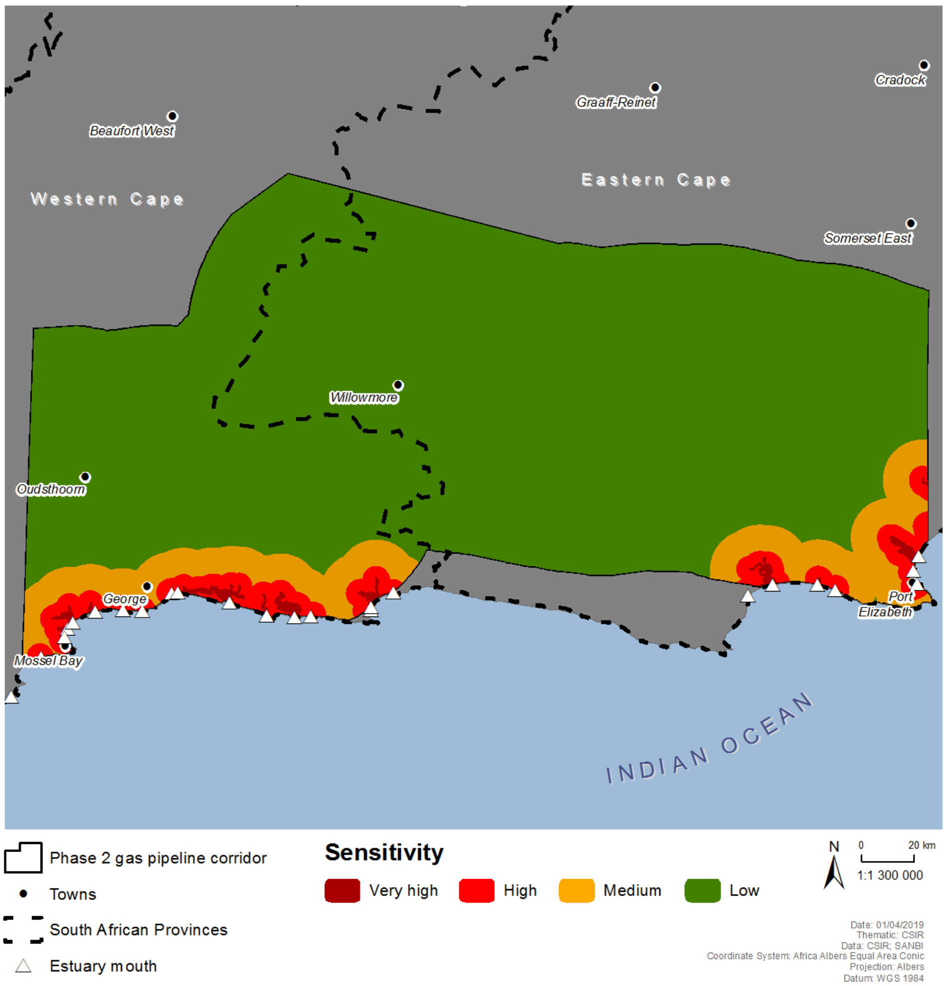


Figure 14: Sensitivity map for the estuaries, EFZ and associated features in the proposed Phase 2 Gas Pipeline corridor.

4.8.4 Phase 7 corridor

While there are a high number of estuaries in the Phase 7 corridor, most of them are relatively small and do not penetrate far inland. Exceptions are the Sundays and St Lucia estuaries (Figure 15 and Figure 16). These areas are demarcated as of very high sensitivity to infrastructure development. Rivers, wetlands and coastal seeps adjacent or just above the estuaries, within the 5 km buffer around the EFZ, are zones of high sensitivity as they directly influence the quality and quantity of freshwater and sediments entering estuaries. Disturbance of their physical processes will impact on the downstream estuary health. Due to the high number of estuaries in close proximity to each other the entire coastal zone in this area is of either very high- or high sensitivity. The inflowing rivers, wetlands and coastal seeps adjacent or above the estuaries, within the 5 to 15 km buffer around the EFZs, are of medium sensitivity as they indirectly influence the quality and quantity of freshwater and sediments entering estuaries.

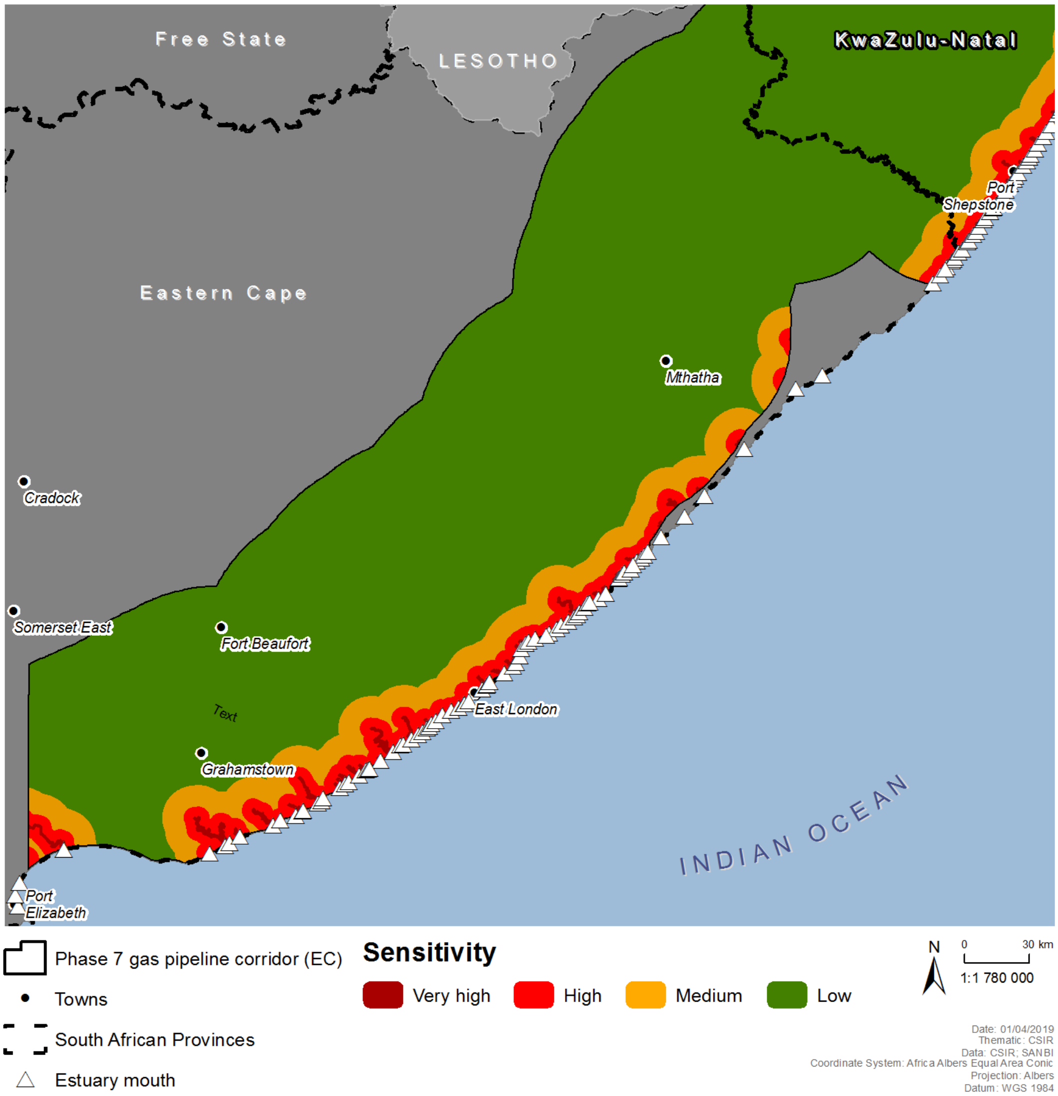


Figure 15: Sensitivity map for the estuaries, EFZ and associated features in the proposed Phase 7 Gas Pipeline corridor (Eastern Cape).

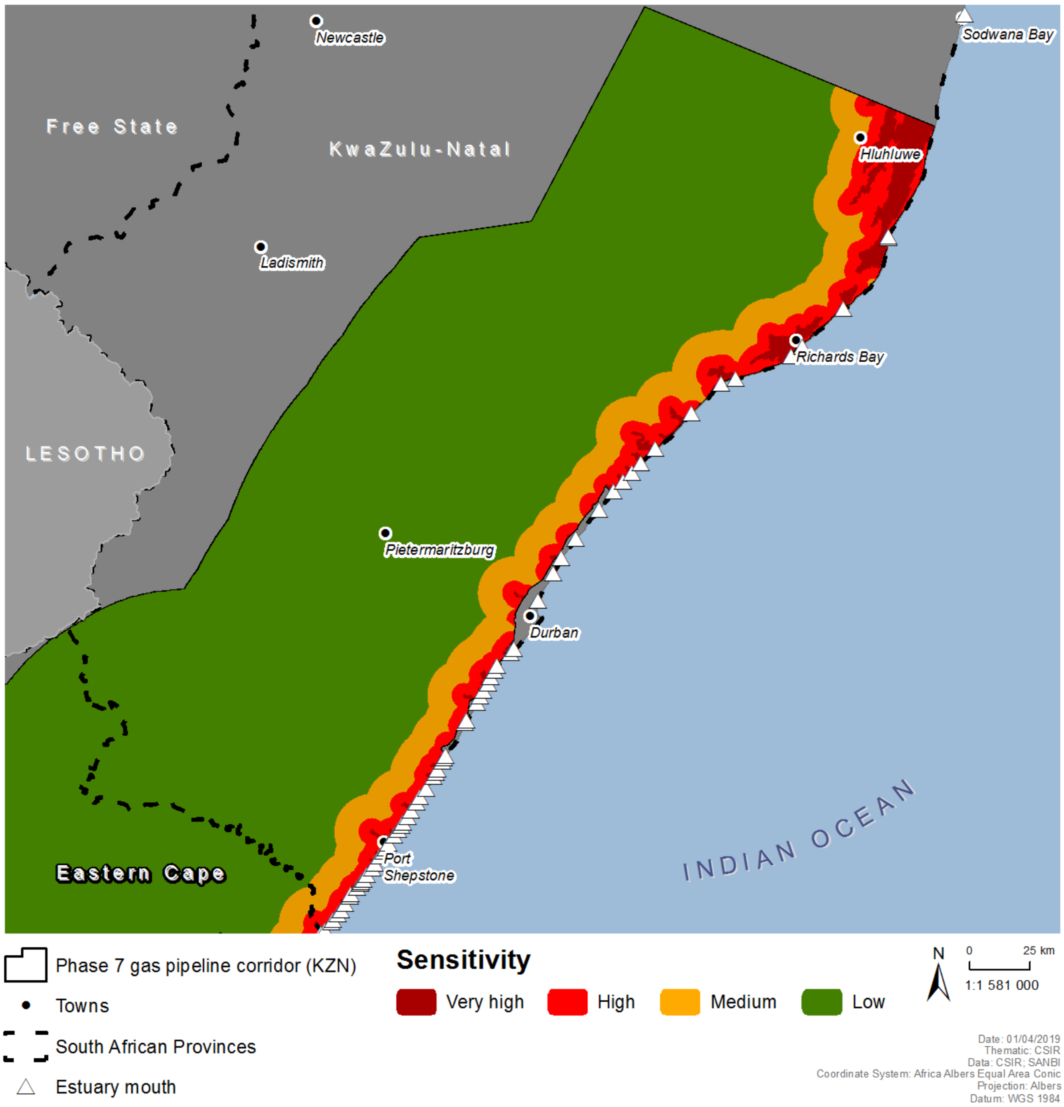


Figure 16: Sensitivity map for the estuaries, EFZ and associated features in the proposed Phase 7 Gas Pipeline corridor (KwaZulu-Natal).

4.8.5 Phase 4 corridor

While there are only three estuaries in this corridor, these include the St Lucia and Kosi estuarine lake systems, which are very large and of high biodiversity importance. These areas are of very high sensitivity to infrastructure development (Figure 17). Rivers, wetlands and coastal seeps adjacent or just above the estuaries, within the 5 km buffer around the EFZs, are zones of high sensitivity as they directly influence the quality and quantity of freshwater and sediments entering estuaries. Disturbance of their physical processes will impact the estuaries downstream. Rivers, wetlands and coastal seeps adjacent or above the estuaries, in the 5 to 15 km buffer around the EFZs, are of medium sensitivity as they indirectly influence the quality and quantity of freshwater and sediments entering estuaries.

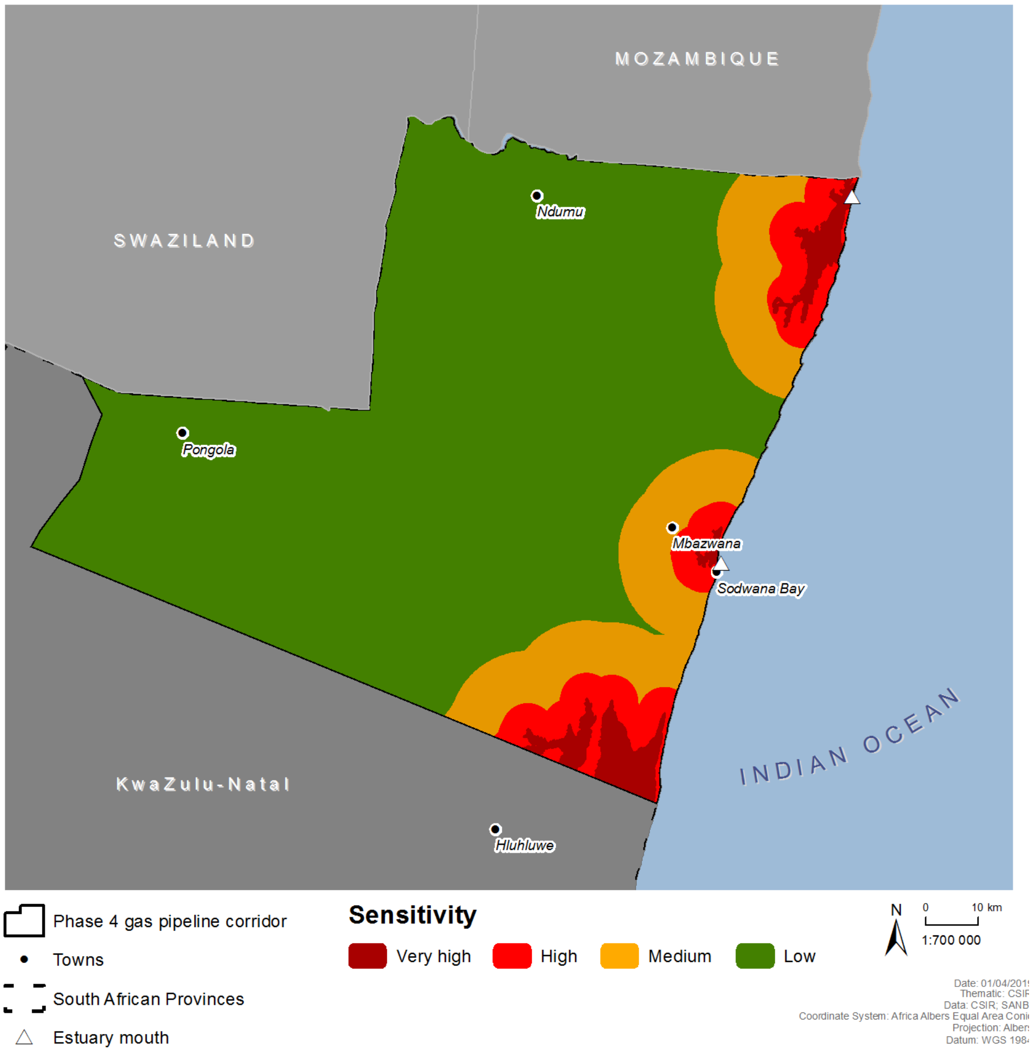


Figure 17: Sensitivity map for the estuaries, EFZ and associated features in the proposed Phase 4 Gas Pipeline corridor.

5 KEY POTENTIAL IMPACTS AND THEIR MITIGATION

Expanding production of natural gas and oil is driving demand for new or improved pipelines globally. The potential for these to negatively impact aquatic systems has been highlighted (Reid and Anderson, 1998; Lévesque and Dubé, 2007; Castro et al., 2015). These linear transportation systems cut across landscapes, intersecting a wide variety of sensitive aquatic habitats, including estuaries, with resultant environmental impacts (Chen and Gao, 2006; Yu et al., 2010). The construction of pipelines primarily affects physical and chemical characteristics of aquatic ecosystems, with knock-on detrimental effects on the associated biota such as invertebrates, fish and birds (Reid and Anderson, 1999; Chen and Gao, 2006; Lévesque and Dubé, 2007; Yu et al., 2010; Castro et al., 2015).

Impacts associated with gas pipeline development range from those that are obvious (e.g. excavation of trenches for pipelines and maintenance of vegetation within pipeline servitudes) to those that are more subtle and which occur over longer timeframes (e.g. disruption of estuarine channel dynamics, vegetation changes from continued servitude maintenance, and habitat fragmentation).

Major activities that may result in impacts on the estuarine environment include the **development of access roads to enable** construction, as well as permanent servitudes for ongoing maintenance during the operational phase. A variety of impacts ensue, including:

- Direct loss of estuarine vegetation (and associated riparian buffers), including potentially sensitive/important habitat supporting species of conservation concern.
- Fragmentation of estuarine hydrodynamic and sedimentary processes, resulting in an indirect loss of ecological processes such as species movement, dispersal and migrations, loss of habitat connectivity, increased edge effects and disturbance, and establishment of invasive alien plants (IAPs).
- Stormwater runoff causing increased flows in the receiving aquatic (estuarine and coastal river) environments, particularly in relation to runoff discharge points, which in turn can result in a number of impacts such as bank erosion and collapse, scouring and channel incision, headcut erosion, desiccation of wetland/riparian soils and vegetation, increased turbidity, sedimentation and smothering of benthos. The combined effects negatively affect the ecological integrity and ability of the aquatic ecosystems to function properly.
- Pollution and contamination of aquatic environments from foreign materials (e.g. fuels/hydrocarbons, cement, and building materials) being dumped and/or carried into aquatic environments.
- Compaction of soils and creation of preferential flow paths within and adjacent to wetland and river habitats.
- Direct loss of flora and fauna that inhabit wetland/river ecosystems and adjacent buffer/fringe habitats (including species of conservation concern or valuable as resources, harvested locally or further afield).

Stripping and removal of vegetation and topsoil to prepare the ROW for pipeline construction will result in similar impacts to the development of access roads, but will differ in terms of extent, duration and intensity. Typical ROWs are between 30 to 50 metres wide, translating to roughly one hectare for every 200 to 300 metres of pipeline constructed. Thus, the total area of vegetation that is removed will be based on the total length of pipeline and its servitude (which may be kept clear of deep rooted vegetation – shallow rooted plants such as short grasses are allowed to grow within the servitude) that passes through estuarine and associated coastal freshwater habitats.

Trenching and excavation to bury pipelines including the excavations for pigging stations, which will be positioned every 250 to 500 km. Trenching and excavations have the potential to cause mortality of fauna that inhabit aquatic habitats, in particular fossorial fauna (i.e. animals adapted to living in the sediment) but also less mobile fauna that are moving across the excavation path.

Construction of permanent and hard structures, such as gas pipelines (and possibly pigging stations) in the EFZ will markedly impact on long-term estuarine sediment dynamics. Estuary channels are highly dynamic and typically migrate across the wider EFZ on longer time scales. It is inevitable that pipe infrastructure across estuaries will disrupt estuarine physical processes (unless suspended or bridged above the entire EFZ, or drilled far below bed level). The likelihood is that pipe infrastructure, over time, will be exposed through lateral erosion and channel migration resulting in a high risk of failure.

Maintenance of the gas pipeline servitude (approximately 10 m wide) for accessing the pipeline and pigging stations will require ongoing vegetation management and clearing to maintain a strip of grass/herbaceous vegetation, with deep rooted trees/shrubs removed in most cases. This prevents rehabilitation of most estuarine vegetation, results in long term losses of valuable wetland flora, and associated fauna, and also impacts on physical processes. Such developments also provide access to estuaries and in doing so makes them susceptible to higher levels of exploitation than is already the case.

The development of both the pipeline and a servitude, as well as pigging stations and associated access roads, all potentially result in permanent loss of connectivity and habitat fragmentation. This presents a potential serious issue for many estuarine associated fauna, and contributes to populations becoming isolated, resulting in a reduction of inter-population connectivity and compromised genetic viability. For example, inappropriately designed and constructed pipelines could prevent fish from moving/migrating freely between an estuary and associated river system.

Drawing from available information, the key potential impacts that can lead to degradation/loss of estuarine biodiversity/ecosystem services were identified and assessed in this report:

<u>**Construction phase:**</u>

1. Estuarine habitat destruction and direct loss of estuarine vegetation caused by vegetation clearing;
2. Altered estuarine physical and sediment dynamics caused by pipeline construction; e.g. infilling, altered channel migration, increased mouth closure;
3. Deterioration of water quality associated with the disturbance of sediment;
4. Loss of connectivity and habitat fragmentation between system's upper catchments and/or marine environments with associated ecological impacts (e.g. loss of fish recruitment).

<u>**Operational phase:**</u>

5. Ongoing habitat destruction as a result of access roads and the clearing of the operational servitude;
6. Altered estuarine physical and sediment dynamics as a result of the instream pipeline crossing trapping sediment and increasing flood risk;
7. Deterioration of water quality through reduced tidal flows, spills and leakages;
8. Loss of connectivity and habitat fragmentation between upper catchment and/or marine environment and associated ecological impacts (e.g. fish recruitment).

Each of the key potential impacts listed above are discussed in greater detail below, together with possible mitigation measures. The nature and intensity of these impacts is likely to vary considerably depending on type of construction method.

5.1 Construction phase

5.1.1 Impact 1: Estuarine habitat destruction

Construction activities within and around the EFZ will result in habitat destruction, and loss of estuarine and riparian habitat (e.g. mangroves, saltmarshes, reeds, swamp forest). This in turn will directly degrade and reduce ecological function and productivity of affected estuaries. The removal of the natural vegetation in and around an estuary will also indirectly result in bank erosion by tidal action and river flow and floods causing destabilisation of the estuary channel, mud- and sand bank habitat (see Impact 2, Section 5.1.2). Habitat losses may occur from secondary impacts. Increased sedimentation during construction and backfilling of the trench in the estuary could cause drying out of the riparian habitat and loss of estuarine and associated floodplain vegetation.

The movement of heavy vehicles and machinery during construction within the ROW and the EFZ, riparian area and floodplain will affect the soil profile through soil compaction, which will result in the increased soil bulk density, reduced porosity, and reduced hydraulic conductivity. In addition soil chemistry (reflected in soil pH, organic matter and nitrogen content) in the trenched area will be altered.

Construction and the clearance of vegetation for the ROW will lead to the destruction of estuarine vegetation which will decrease overall estuarine habitat, reduce protection for biota and cause loss of nursery area. The destruction of estuarine habitat will affect estuarine invertebrates, fish and birds resulting in population and diversity reductions of these fauna. Unpredictable trophic network and knock-on impacts are likely. For example, decreased mangrove areas will decrease overall estuarine productivity and abundance of invertebrates, which will affect food availability for fish and birds. This in turn will impact on estuarine nursery function and the productivity for estuarine and coastal fisheries. In addition, the disturbance of estuarine habitat often results in a change in ecological functioning, and can allow for the introduction of IAPs; which in turn can further negatively impact estuarine functioning.

While disturbances from the construction of the pipeline may not be long-term, the restoration of altered habitat and recovery of invertebrate, fish and bird population can be prolonged (and is not assured). This depends on the overall complexity and health of the systems (Yu et al., 2010). There are no examples in South Africa of successful estuarine restoration following largescale degradation as has occurred in systems such as Nhlabane, Mhlanga, and St Lucia in KwaZulu-Natal. In most cases it has only been possible to restore a degree of functionality as reflected by the overall low health score in Appendix A.

Potential mitigation measures

- Preserve natural estuarine indigenous vegetation such as mangroves and saltmarsh.
- Avoid construction or ROW clearance in the EFZ.
- Adopt below ground pipe construction methods (HDD rather than trenching).
- Where possible, suspend pipelines over the EFZ, using existing infrastructure, e.g. existing road and rail bridges.

5.1.2 Impact 2: Altered estuarine physical and sediment dynamics caused by pipeline construction; e.g. infilling, altered channel migration, and increased mouth closure

Estuaries are high energy environments and their channel morphology is highly dynamic. Estuarine channels can develop and migrate anywhere within the EFZ under the influence of tidal flows, river inflow and floods. Stabilising sections of the estuary morphology or floodplain through pipeline construction can lead to changes in long-term physical dynamics, i.e. disrupting channel and bed formation, altering sediment structure, changing estuary hydrodynamics, mouth dynamics, and ultimately catchment and marine connectivity. This can lead to altered functioning of a system and ultimately affect biota. Loss of estuarine productivity and connectivity in turn will reduce nursery function and associated fisheries value derived along the South African coast.

Sediment eroding from a construction site and backfilling of the trench can cause sediment deposition and build-up in other parts of the estuary, causing drying out of the riparian zone, loss of water column habitat and premature mouth closure if the tidal flows become constricted (loss of marine habitat access). Changes in estuarine physical dynamics will lead to altered estuary productivity and biodiversity.

Potential mitigation measures

- No road infrastructure within the EFZ.
- No pipe infrastructure such as Pipeline Intelligence Gauge Stations (PIGS) within the EFZ.
- No trenching within the EFZ.
- No pipe jacking within the EFZ as the ground water table is shallow and variable in estuaries and required burial depths cannot be achieved with elevated water tables.
- No pipe infrastructure within the 1:100 year potential estuarine bed scouring levels.
- If pipeline infrastructure cannot be avoided within the EFZ, HDD with pipe buried at bed rock level or to depths of greater than 1:100 year potential bed scouring levels (estimated to be on average deeper than 20 m, (Personal communication, Prof G Basson, Stellenbosch University, 2018).
- Suspending pipelines over the EFZ, use existing infrastructure where possible, e.g. existing road and rail bridges.

5.1.3 Impact 3: Deterioration of water quality associated with sediment disturbance

During the construction phase, water quality may deteriorate as a result of sediment disturbance, the removal of estuarine vegetation, or pollution events, which could result in the following:

- decrease pH as a result of disturbance of the anoxic sediment profiles characteristic of estuaries,
- increase the Total Dissolved Solids (TDS),
- increase the Total Suspended Solids (TSS),
- increase the organic matter content, and
- increase the nutrient content.

This can have knock-on effects on the biota. Increased nutrient loading can cause algal blooms/eutrophication in an estuary, and, in turn, result in anoxia or hypoxia. Increased turbidity in clear water systems in turn can also lead to smothering of primary producers, disrupted predator-prey relationships and fish and invertebrate kills.

Disturbance of estuarine water quality results in a change in ecological functioning, and increases the risk of introduction and establishment of invasive alien species (vegetation, invertebrates and fish). Currently, deteriorating water quality in KZN estuaries is contributing to the establishment of floating invasive macrophytes in pest proportions as well as the spread of the invasive snail *Tarebia granifera* (Appleton et al., 2009, van Niekerk and Turpie, 2011). Once established invasive species out compete indigenous species and disrupt ecosystem processes.

Potential mitigation measures

- No road infrastructure within the EFZ.
- No pipe infrastructure such as PIGS within the EFZ.
- No trenching within the EFZ.
- No pipe jacking within the EFZ as the ground water table is shallow and variable in estuaries and required burial depths cannot be achieved at elevated ground water levels.
- No pipe infrastructure within the 1:100 year potential estuarine bed scouring levels.
- If pipeline infrastructure cannot be avoided within the EFZ, HDD with pipe buried at bed rock level or to depths of greater than 1:100 year potential bed scouring levels (estimated to be on average deeper than 20 m, (Personal communication, Prof G Basson, Stellenbosch University, 2018).
- Suspending pipelines over the EFZ, use existing infrastructure where possible, e.g. existing road and rail bridges.

5.1.4 Impact 4: Loss of connectivity and habitat fragmentation between upper catchment and/or marine environment

Estuaries are highly connected aquatic systems, with river inflow and tidal flows maintaining important circulatory processes and ensuring catchment and marine connectivity. Road infrastructure and construction activities can disrupt processes that support this connectivity, affecting the migration of invertebrates and fish across freshwater-estuarine-marine systems. As noted, estuaries serve as nursery habitats for both estuarine and marine fish. These systems also act as migratory destinations or stops for many birds as well.

Thus, road infrastructure and pipeline construction pose a direct (e.g. road through EFZ, pipeline construction cutting through an estuary) and indirect (e.g. prolonged mouth closure due to infilling of open water area) threat to estuarine connectivity and can increase habitat fragmentation.

A major concern is also the cumulative impact of pipeline construction on a multitude of estuaries along a stretch of coast and the collective risk it poses to estuarine connectivity and functioning. While the individual impacts may appear small, the cumulative resulting shifts in estuarine physical process, connectivity and production can be significant.

Potential mitigation measures

- No road infrastructure within the EFZ.
- No pipe infrastructure such as PIGS within the EFZ.
- No trenching within the EFZ.
- No pipe jacking within the EFZ as the ground water table is shallow and variable in estuaries and required burial depths cannot be achieved at elevated ground water levels.
- No pipe infrastructure within the 1:100 year potential estuarine bed scouring levels.
- If pipeline infrastructure cannot be avoided within the EFZ, HDD with pipe buried at bed rock level or to depths of greater than 1:100 year potential bed scouring levels (estimated to be on average deeper than 20 m, Personal communication, Prof G Basson, Stellenbosch University).
- Suspending pipelines over the EFZ, use existing infrastructure where possible, e.g. existing road and rail bridges.

5.2 Operational phase

5.2.1 Impact 5: Habitat destruction as a result of ongoing vegetation clearing of access roads and servitude for maintenance

Similar to Impact 1 (Section 5.1.1), access roads and the clearing of the operational servitude within and around the EFZ will result in estuarine and riparian habitat (e.g. mangroves, saltmarshes, reeds, swamp forest) destruction and fragmentation. This, in turn, will directly degrade and reduce estuarine function and productivity. The destruction of estuarine habitat will affect estuarine invertebrates, fish and birds resulting in a decrease in abundance and diversity. For example, decreased mangrove areas will decrease overall estuarine productivity and abundance of invertebrates, which will affect food availability for fish and birds. This in turn will impact on estuarine nursery function and the productivity for estuarine and coastal fisheries.

The ongoing removal of the natural vegetation in and around an estuary will also result in bank erosion by tidal action and river flow and floods causing destabilisation of the estuary channel, mud/sand bank habitats. In addition, the disturbance of estuarine habitat often results in a change in ecological functioning, and can allow for the introduction of IAPs; which in turn can further alter estuarine functioning.

Potential mitigation measures

- Preservation of natural indigenous vegetation such as mangroves and saltmarsh.
- Regular Control of I&APs

5.2.2 Impact 6: Altered estuarine physical and sediment dynamics as a result of the instream pipeline crossing trapping sediment and increasing flood risk

Stabilising sections of the estuary morphology or floodplain through pipeline infrastructure and the placements of pigging stations or block valves can lead to changes in long-term physical and sediment dynamics, i.e. disrupt channel and bed formation, alter sediment structure, mouth dynamics, and ultimately catchment and marine connectivity. This can cause altered functioning of impacted estuaries and ultimately affect the biota and value derived from these systems. Loss of estuarine productivity and connectivity in turn can reduce nursery function and estuarine contribution to coastal fisheries.

Over time migrating estuarine channels will expose pipeline infrastructure, changing flow velocities, and cause ongoing sediment erosion from such sites. This, in turn, can cause sediment deposition and accumulation in other parts of the estuary, causing drying out of the riparian zone, loss of water column habitat and can result in premature mouth closure if the tidal flows are constricted enough. Changes in estuarine physical dynamics will lead to altered estuary productivity and biodiversity.

Stabilizing or constricting natural channel migration will also ultimately increase flood risk to riparian properties as it will prevent estuarine channels from increasing in dimension under high flow and flood regimes. Natural flood attenuation processes in estuaries can therefore be detrimentally impacted. During large floods (1:10 to 1:100 year) most estuaries scour down to -20 to -30 m if not constrained by bed rock. This scour channel is filled in by post-flood sediment. Constructing a hard structure in the EFZ will disrupt this process.

It should also be noted that floods (in the case of estuaries the cumulative flow of the entire catchment) pose a significant risk to pipe failure and the destruction of associated pipe infrastructure. Failure in turn represents a risk of altered estuarine habitat (i.e. hard structures now exists where only soft bedforms should occur) and water quality risk (pollution).

Potential mitigation measures

- Monitor the condition of the infrastructure to ensure that there is no exposed section and ongoing erosion occurring.
- Should the pipe become exposed it would require the suspension of operations and the HDD of the pipe at greater depths below ground within 6 months, once sediment engineering studies have been done to confirm new burial depth.
- Operational staff should be made aware of the sensitivities of estuarine and freshwater environments.

5.2.3 Impact 7: Deterioration of water quality through reduced tidal flows, spills and leakages

During the operational phase water quality in estuaries that are crossed by gas pipelines can be impacted in the same way as during the construction phase. The likelihood of impacts arising might be reduced as operational impacts will largely be limited to periods when pipeline maintenance is taking place. Some long-term impacts (for example increased suspended solids) might occur as a result of the placement of the pipelines themselves. Similar knock-on effects to the estuarine biota might also be expected.

Potential mitigation measures

- Monitor the condition of the infrastructure to ensure that there is no exposed section, ongoing erosion or leakages.
- Should the pipe become exposed it would require the suspension of operations and the HDD of the pipe at greater depths below ground within 6 months, once sediment engineering studies have been done to confirm new burial depth.
- Operational staff should be made aware of the sensitivities of estuarine and freshwater environments.

5.2.4 Impact 8: Loss of connectivity and habitat fragmentation between upper catchment and/or marine environment and associated ecological impacts

Permanent roads (mainly associated with pigging stations), the operational servitude and pipeline infrastructure, and maintenance activities associated with long-term operation will disrupt processes that support estuarine connectivity, affecting the migration of invertebrates and fish across freshwater-estuarine-marine systems.

Potential mitigation measures

- Monitor the condition of the infrastructure to ensure that there is no exposed section and ongoing erosion occurring.
- Should the pipe become exposed it would require the suspension of operations and the HDD of the pipe at greater depths below ground within 6 months, once sediment engineering studies have been done to confirm new burial depth.
- Operational staff should be made aware of the sensitivities of estuarine and freshwater environments.

6 RISK ASSESSMENT

6.1 Likelihood and consequence levels

Quantitative assessment of impact likelihood was not possible but an indication of relative likelihood of different impacts (without and with mitigation, based on expert opinion and available knowledge) is provided below in Table 4.

Consequence is a function of the impact under consideration and sensitivity of the affected area. Consequences were rated qualitatively as modifications to estuaries following a similar approach as that applied in water reserve determination studies (Table 5). Cognisance was taken of the sensitivity of the receiving environment to a particular impact. Thus, a moderate degradation in a very sensitive estuary was regarded as having a greater consequence than a similar degradation in water quality in a lower sensitive system.

Consequences of impacts associated are not generic across different sensitivity zones (e.g. as represented by the sensitivity indicators), rather consequence is a function of the type of impact and the sensitivity rating (Table 3).

Table 4: Relative likelihood of relevant potential impacts occurring within the selected production systems (VU = very unlikely, NL = not likely, L= likely, VL = very likely).

Potential impact	Likelihood					
	Without mitigation	With mitigation				
		Isolated Trench	Shallow Pipe-jack/HDD	Deep HDD (>-20 m) No access roads	No development Avoid EFZ	Suspending pipelines
Construction phase:						
Estuarine habitat destruction	VL	VL	VL	NL	VU	VU
Altered estuarine physical and sediment dynamics	VL	VL	L	NL	VU	VU
Deterioration of water quality	VL	L	L	NL	VU	VU
Loss of connectivity and habitat fragmentation	VL	VL	L	NL	VU	VU
Operational phase:						
Estuarine habitat destruction	VL	VL	VL	NL	VU	VU
Altered estuarine physical and sediment dynamics	VL	VL	L	NL	VU	VU
Deterioration of water quality	VL	L	L	NL	VU	VU
Loss of connectivity and habitat fragmentation	VL	VL	L	NL	VU	VU

Table 5: Description of consequence levels to impacts to estuaries used in the risk assessment.

Consequence	General description
Slight	• Limited modification in all zones • Ecosystem attributes largely unmodified and little influence on other uses • Small changes in natural habitats and biota in the area may occur, but the ecosystem functions are essentially unchanged • Natural conditions and the resilience and adaptability of biota are not compromised • Characteristics of the resource are determined by unmodified natural disturbance regimes • Modification is of a temporary nature
Moderate	• Some modification in sensitive zones • Moderate modification in non-sensitive zones • A loss and change of natural habitat and biota occurs, but the basic ecosystem functions are still predominantly unchanged • Moderate modification of the abiotic template and exceedance of the resource base occurs of a permanent nature
Severe	• Moderate modification in sensitive zones • High modification in non-sensitive zones • Largely modified. A large loss of natural habitat, biota and basic ecosystem functions occurs, with risk of modifying the abiotic template and exceeding the resource base • Loss of well-being and survival of intolerant biota. Associated increase in the abundance of tolerant species does not assume pest proportions • Modification is of a permanent nature
Extreme	• High modification in sensitive zones • Extreme modification in non-sensitive zones • Seriously and critically modified with loss of natural habitat, biota and basic ecosystem functions • Modification is of a permanent nature

6.2 Risk assessment results

Risks were assessed based on the relationship between likelihood and consequence as illustrated in Table 6 .This was applied to all the process systems for the different sensitivity ratings (Table 7).

Table 6: Risk assessment look-up table showing relationship: Likelihood x Consequence = Risk.

		Consequence			
		Slight	Moderate	Severe	Extreme
Likelihood	Very likely (VL)	Low (L)	Moderate (M)	High (H)	Very high (VH)
	Likely (L)	Low (L)	Moderate (M)	High (H)	Very high (VH)
	Not likely (NL)	Low (L)	Low (L)	Moderate (M)	High (H)
	Very unlikely (VU)	Low (L)	Low (L)	Moderate (M)	Moderate (M)

Table 7: Risk Assessment for different locations in various corridors without and with mitigation

Impact	Location sensitivity rating	Without mitigation			Isolated Trench			Pipe-jack/ HDD Shallow depths			HDD >20 m depth / No access roads			No development or trenching in EFZ / Cross at existing infrastructure or pipe bridges		
		Cons-quence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk	Consequence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk
Construction Phase																
Estuarine habitat destruction	Very high	Extreme	VL	Very high	Extreme	VL	Very high	Severe	VL	High	Severe	NL	Moderate	Moderate	VU	Low
	High	Severe	VL	High	Severe	VL	High	Moderate	VL	Moderate	Severe	NL	Moderate	Moderate	VU	Low
	Medium	Moderate	VL	Moderate	Moderate	VL	Moderate	Slight	VL	Low	Moderate	NL	Low	Slight	VU	Low
	Low	Slight	VL	Low	Slight	VL	Low	Slight	VL	Low	Slight	NL	Low	Slight	VU	Low
Altered physical and sediment dynamics	Very high	Extreme	VL	Very high	Extreme	VL	Very high	Extreme	L	Very high	Severe	NL	Moderate	Moderate	VU	Low
	High	Severe	VL	High	Severe	VL	High	Severe	L	High	Moderate	NL	Low	Moderate	VU	Low
	Medium	Moderate	VL	Moderate	Moderate	VL	Moderate	Moderate	L	Moderate	Slight	NL	Low	Slight	VU	Low
	Low	Slight	VL	Low	Slight	VL	Low	Slight	L	Low	Slight	NL	Low	Slight	VU	Low
Deterioration of water quality	Very high	Severe	VL	High	Moderate	L	Moderate	Moderate	L	Moderate	Moderate	NL	Low	Moderate	VU	Low
	High	Moderate	VL	Moderate	Slight	L	Low	Slight	L	Low	Moderate	NL	Low	Moderate	VU	Low
	Medium	Slight	VL	Low	Slight	L	Low	Slight	L	Low	Slight	NL	Low	Slight	VU	Low
	Low	Slight	VL	Low	Slight	L	Low	Slight	L	Low	Slight	NL	Low	Slight	VU	Low

Impact	Location sensitivity rating	Without mitigation			Isolated Trench			Pipe-jack/ HDD Shallow depths			HDD >20 m depth / No access roads			No development or trenching in EFZ / Cross at existing infrastructure or pipe bridges		
		Cons-quence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk	Consequence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk
Loss of connectivity and habitat fragmentation	Very high	Severe	VL	High	Severe	VL	High	Moderate	L	Moderate	Moderate	NL	Low	Moderate	VU	Low
	High	Moderate	VL	Moderate	Moderate	VL	Moderate	Slight	L	Low	Slight	NL	Low	Slight	VU	Low
	Medium	Slight	VL	Low	Slight	VL	Low	Slight	L	Low	Slight	NL	Low	Slight	VU	Low
	Low	Slight	VL	Low	Slight	VL	Low	Slight	L	Low	Slight	NL	Low	Slight	VU	Low
Operational Phase																
Estuarine habitat destruction	Very high	Extreme	VL	Very high	Extreme	VL	Very high	Severe	VL	High	Severe	NL	Moderate	Moderate	VU	Low
	High	Severe	VL	High	Severe	VL	High	Severe	VL	High	Moderate	NL	Low	Moderate	VU	Low
	Medium	Moderate	VL	Moderate	Moderate	VL	Moderate	Moderate	VL	Moderate	Moderate	NL	Low	Slight	VU	Low
	Low	Slight	VL	Low	Slight	VL	Low	Slight	VL	Low	Slight	NL	Low	Slight	VU	Low
Altered physical and sediment dynamics	Very high	Extreme	VL	Very high	Extreme	VL	Very high	Severe	VL	High	Severe	NL	Moderate	Moderate	VU	Low
	High	Severe	VL	High	Severe	VL	High	Severe	VL	High	Moderate	NL	Low	Moderate	VU	Low
	Medium	Moderate	VL	Moderate	Moderate	VL	Moderate	Moderate	VL	Moderate	Moderate	NL	Low	Slight	VU	Low
	Low	Slight	VL	Low	Slight	VL	Low	Slight	L	Low	Slight	NL	Low	Slight	VU	Low

Impact	Location sensitivity rating	Without mitigation			Isolated Trench			Pipe-jack/ HDD Shallow depths			HDD >20 m depth / No access roads			No development or trenching in EFZ / Cross at existing infrastructure or pipe bridges		
		Cons-quence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk	Consequence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk
Deterioration of water quality	Very high	Severe	VL	High	Severe	L	High	Moderate	L	Moderate	Moderate	NL	Low	Moderate	VU	Low
	High	Moderate	VL	Moderate	Moderate	L	Moderate	Slight	L	Low	Slight	NL	Low	Slight	VU	Low
	Medium	Slight	VL	Low	Slight	L	Low	Slight	L	Low	Slight	NL	Low	Slight	VU	Low
	Low	Slight	VL	Low	Slight	L	Low	Slight	L	Low	Slight	NL	Low	Slight	VU	Low
Loss of connectivity and habitat fragmentation	Very high	Severe	VL	High	Severe	VL	High	Moderate	L	Moderate	Moderate	NL	Low	Moderate	VU	Low
	High	Moderate	VL	Moderate	Moderate	VL	Moderate	Slight	L	Low	Slight	NL	Low	Slight	VU	Low
	Medium	Slight	VL	Low	Slight	VL	Low	Slight	L	Low	Slight	NL	Low	Slight	VU	Low
	Low	Slight	VL	Low	Slight	VL	Low	Slight	L	Low	Slight	NL	Low	Slight	VU	Low

7 LIMITS OF ACCEPTABLE CHANGE

7.1 Relevant legislation, policies and guidelines

Legislation, policies and guidelines applicable to the protection of estuarine aquatic ecosystems are summarised in Table 8. Emerging as most critical in the context of the present assessment is the Recommended Ecological Category as defined by the National Water Act (Act 36 of 1998) (NWA) and set as desired state as part of the National Estuaries Biodiversity Plan (Turpie et al., 2011). In addition detailed Resource Quality Objectives for physical processes, water quality, habitat and higher biota are set under the NWA. These provide the benchmark conditions to maintain estuaries (or restore them).

Table 8: Relevant key legislation applicable to estuarine protection.

Legislation	Specifications
National Environmental Management Act (NEMA) (107 of 1998) and the associated Environmental Impact Assessment (EIA) Regulations of 2014 (as amended)	GNR 324 Listing Notice 3, NEMA EIA Regulations (2014, as amended in April 2017) identifies the EFZ as a sensitive area.
National Water Act (36 of 1998)	Preliminary Reserve Determination and Classification. Set desired state (“management class”) and measurable targets for water flow (“Reserve”), and water quality, habitat and biota in estuaries (“Resource Quality Objectives”) (these are set specifically for each estuary).
National Environmental Management: Biodiversity Act (10 of 2004)	Sets biodiversity targets for South Africa that need to be translated into site-specific targets for study area based on detailed quantitative assessments. These targets are articulated in the **National Protected Areas Expansion Strategy** (NPAES) (updated draft available from the Department of Environmental Affairs (DEA)). South Africa’s protected area network currently falls far short of sustaining biodiversity and ecological processes. The goal of the NPAES is to achieve cost-effective protected area expansion for ecological sustainability and increased resilience to climate change. It sets targets for protected area expansion, provides maps of the most important areas for protected area expansion, and makes recommendations on mechanisms for protected area expansion. The **National Estuarine Biodiversity Plan** (Turpie et al., 2012) determined the core set of estuaries in need of formal protection to achieve biodiversity targets.
Marine Living Resources Act (18 of 1998)	Marine Living Resources Act. The management and control of exploited living resources in estuaries fall primarily under the Marine Living Resources Act (MLRA) (No. 18 of 1998). The primary purpose of the act is to protect marine living resources (including those of estuaries) through establishing sustainable limits for the exploitation of resources; declaring fisheries management areas for the management of species; approving plans for their conservation, management and development; prohibit and control destructive fishing methods and the declaration of Marine Protected Areas (MPAs) (a function currently delegated to the DEA). The MLRA overrides all other conflicting legislation relating to marine living resources.
National Environmental Management: Integrated Coastal Management Act (ICM Act) (24 of 2008, as amended)	Recreational waters. Water quality guidelines for the coastal environment: Recreational use (DEA, 2012). Set water quality targets for recreational waters to protect bathers.
	Protection of aquatic ecosystems. Water quality guidelines for protection of natural coastal environment (DWAF 1995, in process of being reviewed by DEA). This will set targets for use of specific chemicals in marine waters and sediments to protect ecosystems.
National Estuarine Management Protocol	National Estuary Management Protocol sets the standards for Estuarine Management in South Africa (Regulation No. 341 of 2013 promulgated in support of section 33 of the ICM Act).
National Environmental Management: Protected Areas Act (57 of 2003)	Sets specific targets for protected areas (site specific as set in regulations/government notices) – relevant to estuaries in protected areas.
National Port Act (12 of 2005)	Legal requirements as stipulated in terms of the National Ports Act (No. 12 of 2005) must be complied with in commercial ports – relevant to estuaries which have ports in them.

7.2 Permit requirements

Where any construction or operation will occur within the Very Highly sensitive or Highly sensitive areas the following permits may be required:

- Where necessary, a water use licence (WUL) process will be required to authorise certain activities as per Section 21 of the NWA based on the DWS assessment requirements for all wetlands that occur within 500 metres of the gas pipeline development.
- Permits are likely to be required for any activities that require the discharge of an effluent into the EFZ under the ICM Act. This will set targets for use specific chemical in marine waters and sediments to protect ecosystems.
- Permits are likely to be required for any activities that may affect listed Endangered and/or Vulnerable species, Threatened or Protected species (ToPs), and/or regionally protected fauna and flora.

8 BEST PRACTICE GUIDELINES AND MONITORING REQUIREMENTS

8.1 Planning phase

Estuarine physical processes are highly dynamic. Any hard structures within the EFZ will impact on estuarine dynamics over long-time scales. In most cases the most effective mitigation is to avoid the estuaries and not construct pipeline infrastructure through or below them. This approach also poses less risk to the pipe infrastructure (e.g. floods and associated scouring may expose the pipelines set across estuaries and damage them).

Thus, the correct planning of the preferred gas pipeline alignment and associated ancillary infrastructure (e.g. access roads and pigging stations) has the potential to greatly reduce impacts on estuaries and associated coastal freshwater ecosystems that feed into them through simply avoiding areas of very high and high sensitivity. In order to further significantly reduce potential impacts on estuaries and associated supporting coastal freshwater biodiversity (inflowing rivers and/or wetlands/seeps with in a 10 km radius of the EFZ), sub-quaternary catchments classified with a very high or high sensitivity should also be avoided (as per the freshwater assessment by De Winnaar & Ross-Gillespie (2018)). Where these coastal freshwater ecosystems cannot be avoided, detailed desktop investigation should be conducted, followed by specialist in-field assessments and verification to determine whether the fine-scale, micro-sited gas pipeline alignment and development footprint can avoid the actual estuary, EFZ, associated coastal freshwater ecosystems, and associated buffers (as per the freshwater assessment by De Winnaar & Ross-Gillespie (2018)), as well as to determine appropriate management actions to be implemented as required. Where it is impossible to avoid estuarine ecosystems it will be necessary to undertake more detailed specialist sedimentary studies and impacts assessments to determine the depth to which HDD need to be undertaken in the EFZ. Where it is impossible to avoid coastal freshwater ecosystems (i.e. wetland and river habitats draining into estuaries) and their associated buffers altogether, it will be necessary to undertake more detailed specialist studies, impacts assessments, and if necessary investigate needs and opportunities for offsets. Note, that opportunities for off sets do not exist in estuaries. Preference should be given to the position of gas pipelines within already disturbed/degraded areas. Mitigation specific to impact significance should be considered that is cognisant of the mitigation hierarchy, where very high significance impacts are avoided, while high and medium significance impacts are mitigated as far as possible. Offsets should only be considered once alternatives and mitigation measures have been exhausted. Any coastal freshwater ecosystems that will be affected by gas pipeline development must be subject to a condition of authorisation. See De Winnaar & Ross-Gillespie (2018) for more detail.

8.2 Construction phase

Given the high sensitivity and ecological importance of estuaries it is recommended that no clearing of estuarine vegetation and no disturbance of estuarine processes, i.e. no pipeline development should occur within or below the EFZs. If development cannot be avoided, HDD should be done to levels below potential bed scouring (1:100 year return period). Given the dynamic nature of estuaries, this would involve HDD across the entire length of the EFZ at depth potentially exceeding 20m (personal communication, Prof G Basson, Stellenbosch University).

In addition, construction may involve the establishment of ROWs and construction of pipelines and pigging stations within or in proximity to coastal freshwater ecosystems (rivers, wetland and seeps) feeding into estuaries. Typical impacts that can be expected are disturbance to wildlife through noise/light pollution, creation of dust, erosion and degradation/disturbance of habitats and vegetation (including areas for access via roads and servitudes and movement of heavy machinery), and bulldozing and vegetation/habitat clearing. Specific measures and actions required during the construction phase are presented in De Winnaar & Ross-Gillespie (2018), but some key measures to include from the perspective of protecting downstream estuarine physical and ecological processes from knock-on effects are:

- Timing of construction activities to occur in the dry season as far as is practicable;
- Appointment and involvement of an Environmental Control Officer (ECO) to provide oversight and guidance to all construction activities, as well as ensure full consideration and implementation of the Environmental Management Programme (EMPr); and
- Environmental monitoring (or biomonitoring) required for pre-construction, during construction and post construction at strategically selected monitoring sites based on additional detail specified in Section 8.5 below.
- Avoid the EFZ and avoid and/or minimise road crossings through coastal wetlands and rivers within a 10 km radius of estuaries which may negatively impact estuaries downstream. Minimise the number of coastal river and wetland access roads crossings upstream of estuaries. Ensure adequate freshwater watercourse crossings (i.e. culverts of the correct specification) are designed and constructed where roads traverse these areas so that the concentration of flow (particularly during high flow conditions) is minimised as far as possible. In the case of river crossings, bank stabilisation measures (gabions, eco logs, geofabric, sediment fences) are required when wetland or watercourse banks steeper than 1:5 are denuded during construction. Appropriate rehabilitation procedures/measures should be planned to minimise the risk of increased sediment load in coastal rivers leading to downstream deposition in associated estuaries.
- Avoid clearing of estuarine vegetation within the EFZ in any manner to prevent estuarine erosion. Avoid clearing of riparian indigenous vegetation upstream of estuaries within 10 km of the EFZ as far as possible and implement rehabilitation of riparian vegetation as soon as possible to stabilise soil. In addition, there should be as little disturbance to surrounding vegetation as possible when construction activities are undertaken, as intact vegetation adjacent to construction areas will assist in the control of sediment dispersal from exposed areas. Furthermore dust suppression methods (e.g. spraying surfaces with water) should be used to minimise the transport of wind-blown dust.
- All estuaries and coastal rivers / wetlands within 10 km of an estuary should be avoided as far as possible. If avoidance is possible the areas must be appropriately demarcated as such. No vehicles, machinery, personnel, construction materials, cement, fuel, oil or waste should be allowed into these areas without the express permission of and supervision by an on-site ECO.
- All construction activities (including establishment of construction camps, temporary lay-down areas, construction of haul roads and operation of heavy machinery), should take place during the dry season to reduce potential impacts to estuaries and associated inflowing coastal freshwater ecosystems within 10 km of an estuary.
- No construction activities may occur within estuaries (i.e. EFZ). Construction activities associated with the establishment of access roads through inflowing associated coastal wetlands or rivers (if unavoidable) within 10 km of an estuary should be restricted to a working area of 10 m in width either side of the road, and these working areas should be clearly demarcated. No vehicles, machinery, personnel, construction material, cement, fuel, oil or waste should be allowed outside of the demarcated working areas.
- Construction camps, toilets, temporary laydown areas and borrow pits should be located outside of the EFZ and recommended buffer areas around inflowing coastal wetlands and rivers within 10 km of an estuary and should be rehabilitated following construction. Pits or excavations should be checked regularly by the on-site ECO and plans put in place for species rescue and relocation

- No fuel storage, refuelling, vehicle maintenance or vehicle depots should be allowed within 30 m of the edge of any estuary, coastal river or coastal wetlands.
- Refuelling and fuel storage areas, and areas used for the servicing or parking of vehicles and machinery, should be located on impervious bases and should have bunds around them. Bunds should be sufficiently high to ensure that all the fuel kept in the area will be captured in the event of a major spillage.
- Vehicles and machinery should not be washed within 30 m of the edge of any estuary, wetland or watercourse.
- No effluents or polluted water should be discharged directly into any estuary, river or wetland areas.
- No spoil material, including stripped topsoil, should be temporarily stockpiled within 30 m of the edge of any estuary, wetland or river. Aquatic ecosystems located in close proximity to construction areas (i.e. within ~30 m) should be inspected on a regular basis by the ECO for signs of disturbance from construction activities, and for signs of sedimentation or pollution. If signs of disturbance, sedimentation or pollution are noted, immediate action should be taken to remedy the situation and, if necessary, an estuarine and/or freshwater ecologist should be consulted for advice on the most suitable remediation measures depending on the site and potential downstream impact.
- Workers should be made aware of the importance of not destroying or damaging the vegetation along estuaries, coastal rivers and coastal wetland areas, of not undertaking activities that could result in the pollution of drainage lines or wetlands, and of not killing or harming any animals that they encounter. This awareness should be promoted throughout the construction phase and can be assisted through erecting appropriate signage.
- Fixed point photography to monitor vegetation changes and potential site impacts occurring during construction phase.
- In the case of construction of a coastal river upstream of an estuary, fish should be rescued from within the isolated area and returned live to the associated river / wetland immediately downstream of the worksite. The construction area should then be excavated; the pipe is laid in place and backfilled. Once the bed and banks of the river/wetland are re-established the diversion should be removed and water returned to the channel. Reclamation is done to stabilize the disturbed area and restore vegetation along the banks. At all-time care should be taken not to increase the sediment load down-stream to the estuary.

8.3 Operations phase

- Assuming that no pipeline development would occur in the EFZ as a result of very high sensitivity and ecological importance of estuaries, this phase will predominantly include activities typical of routine maintenance, such as clearing/trimming of riparian or wetland vegetation upstream of the estuaries (to maintain pipeline servitudes), as well as IAP control and application of herbicides. Specific measures and actions required during the operational phase are presented in De Winnaar & Ross-Gillespie (2018), but some key measures to include from the perspective of protecting estuarine processes are:
- Fixed point photography could be used to monitor long-term vegetation changes and potential site impacts.
- Avoid the use of herbicides in close proximity (close than 50 m) to wetlands or rivers and do not disturb riparian/or wetland buffer areas.
- At all-time care should be taken not to destabilise riparian areas and increase the sediment load down-stream to the estuary.

8.4 Rehabilitation and post closure

Assuming that no pipeline development would occur in any EFZs as a result of very high sensitivity and ecological importance of estuaries, rehabilitation and post-closure measures would mostly be required for ROWs across or in proximity to associated supporting coastal freshwater ecosystems, as well as for areas degraded by access routes, operation of vehicles/heavy machinery, and infestation of servitudes by IAPs in the freshwater reaches upstream of estuaries. In general, the following processes/procedures are recommended (James and King, 2010; De Winnaar & Ross-Gillespie, 2018):

- Initiation – to assemble the rehabilitation project team/specialists, identify problem/target areas, establish reference condition and desired states, and define rehabilitation targets and objectives;
- Planning- to account for constraints, budgeting and timeframes;
- Analysis – evaluation of alternatives and strategies to achieve the objectives, and to develop preliminary designs and inform feasibility;
- Implementation – a including detailed engineering designs, construction and inspections; and
- Monitoring – to establish need for maintenance and repair of interventions, as well as provide feedback regard success and failure.

Additional points to be considered regarding rehabilitation of degraded areas within and adjacent to supporting coastal freshwater ecosystems (i.e. coastal rivers, wetland and seeps flowing into estuaries) include (De Winnaar & Ross-Gillespie, 2018):

- IAP clearing and control – an IAP control programme should be developed and implemented based on site-specific details, including, but not limited to, types of IAPs, growth forms, densities and levels of infestation, potential dispersal mechanisms, knock-on impacts to freshwater ecosystems caused during implementation (e.g. herbicide drift and contamination);
- Erosion control and re-vegetation – the objective should be to establish indigenous vegetation cover as soon as possible, as well as to control and limit secondary impacts caused by rainfall-runoff. Where necessary geotextile fabrics, brush mattresses/bundles, geocells, and hydroseeding with a suitable grass seed mix should be considered, while more severe cases of erosion/bank collapse will require more advanced stabilisation methods (e.g. reshaping, planting, concrete blocks, riprap, and gabions/reno mattresses).

8.5 Monitoring requirements

Given the high sensitivity and ecological importance of estuaries it is recommended that, where possible, no pipeline development should occur within the EFZs. However, pipeline construction may involve the establishment of ROWs and construction of pipelines and pigging stations within or in proximity to coastal freshwater ecosystems such as rivers, wetland and seeps feeding into estuaries. Where impacts to estuaries (i.e. HDD) and/or coastal freshwater ecosystems within 10 km of estuaries cannot be avoided, monitoring measures should be implemented at a minimum, with additional supporting input from in-depth specialist studies where required.

For all construction activities within the 10 km above an estuary as delineated by the EFZ, monitoring of a potential impact is recommended at suitable sites to be determined in-field by estuarine and/or freshwater ecosystems specialists as required. Sampling is required prior to construction taking place to allow for the establishment of the systems baseline condition (i.e., its state prior to development activities). Monthly monitoring is recommended for the duration of construction to evaluate trends, with summer and winter monitoring at three year intervals recommended thereafter during the operation phase.

Depending on the impact site, monitoring/sampling is to be conducted by estuarine/freshwater specialists with relevant qualifications pertaining to estuarine sediment dynamics, physical processes, water quality and ecology (or freshwater aquatic ecology if in coastal freshwater ecosystem). Resource Quality Objectives as set under the NWA provide the benchmark conditions to maintain in estuaries or rivers. **Table 10 details the monitoring requirements for estuaries, with critical features highlighted in blue. These requirements are specifically important in the event of HDD through an estuary and its EFZ is impossible to avoid.** Monitoring of other aspects (e.g. water quality, microalgae, invertebrates, fish and birds) are required even if the estuary or EFZ is not directly impacted, but where upstream activities may cause indirect impacts to an estuary (Table 10).

Note: There are no prescriptive estuarine methods for the monitoring of reptiles, amphibians and mammals. The monitoring programme should be implemented as prescribed by the Freshwater Ecosystems Specialist Assessment Report (De Winnaar & Ross-Gillespie, 2018).

Table 9: Requirements for monitoring ecological components of estuaries following direct and indirect impacts from gas pipeline development.

	Ecological Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
In the event of direct impacts (e.g. through trenching)	**Hydrodynamics**	Record water levels	Continuous	Near mouth
		Aerial photographs of estuary	During spring low tide Before construction, during operation, and every 3 years afterwards	Entire estuary
	Sediment dynamics	Bathymetric surveys: Series of cross-section profiles and a longitudinal profile collected at fixed 500 m intervals, but in more detail in the mouth (every 100 m). The vertical accuracy should be about 5 cm.	Before construction, during operation, and every 3 years afterwards	Entire estuary
		Set sediment grab samples (at cross section profiles) for analysis of particle size distribution (PSD) and origin (i.e. using microscopic observations)	Before construction, during operation, and every 3 years afterwards (with invert sampling)	Entire estuary
	Water Quality	Record longitudinal salinity and temperature (pH, dissolved oxygen, and suspended solids/turbidity profiles)	Summer and winter survey before construction, during operation, then every summer and winter survey every 3 years afterwards	Entire estuary (3-10 stations)
	Macrophytes	Ground-truthed maps; Record number of plant community types, identification and total number of macrophyte species, number of rare or endangered species or those with limited populations documented during a field visit; Record percentage plant cover, salinity, water level, sediment moisture content and turbidity on a series of permanent transects along an elevation gradient; Take measurements of depth to water table and ground water salinity in supratidal marsh areas	Summer survey before construction, during operation, then Summer survey every 3 years afterwards	Entire estuary
	Microalgae	Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms and blue-green algae. Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. HPLC, fluoroprobe. Intertidal and subtidal benthic chlorophyll-a measurements.	Summer and winter survey before construction, during operation, then every summer and winter survey every 3 years afterwards	Entire estuary (5 – 10 stations)
	Invertebrates	Record species and abundance of zooplankton, based on samples collected across the estuary at each of a series of stations along the estuary; Record benthic invertebrate species and abundance, based on subtidal and intertidal core samples at a series of stations up the estuary, and counts of hole densities; Measures of sediment characteristics at each station	Summer and winter survey before construction, during operation, then every Summer and winter survey every 3 years afterwards	Entire estuary (5 – 10 stations)

	Ecological Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
	Fish	Record species and abundance of fish, based on seine net and gill net sampling.	Summer and winter survey before construction, during operation, then every Summer and winter survey every 3 years afterwards	Entire estuary (5 – 20 stations)
	Birds	Undertake counts of all water associated birds, identified to species level.	Summer and winter surveys before construction, once off during operation, then Summer and winter survey every year	Entire estuary (3 – 5 sections)
In the event of indirect impacts (e.g. through relevant upstream impact within 10 km of an estuary)	**Water Quality**	Record longitudinal salinity and temperature (pH, dissolved oxygen, and suspended solids/turbidity profiles)	Summer and winter survey before construction, during operation, then every summer and winter survey every 3 years afterwards	Entire estuary (3-10 stations)
	Microalgae	Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms and blue-green algae. Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. HPLC, fluoroprobe. Intertidal and subtidal benthic chlorophyll-a measurements.	Summer and winter survey before construction, during operation, then every summer and winter survey every 3 years afterwards	Entire estuary (5 – 10 stations)
	Invertebrates	Record species and abundance of zooplankton, based on samples collected across the estuary at each of a series of stations along the estuary; Record benthic invertebrate species and abundance, based on subtidal and intertidal core samples at a series of stations up the estuary, and counts of hole densities; Measures of sediment characteristics at each station	Summer and winter survey before construction, during operation, then every Summer and winter survey every 3 years afterwards	Entire estuary (5 – 10 stations)

	Ecological Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
	Fish	Record species and abundance of fish, based on seine net and gill net sampling.	Summer and winter survey before construction, during operation, then every Summer and winter survey every 3 years afterwards	Entire estuary (5 – 20 stations)

In cases where freshwater ecosystems upstream of estuaries are likely to be affected by gas pipeline development appropriate measures of monitoring should be considered, including (De Winnaar & Ross-Gillespie, 2018):

- Upstream and downstream biomonitoring to include appropriate indicators/measures of assessing rivers (e.g. diatoms, water quality/clarity, macro-invertebrates using the SASS5 method, instream and riparian habitat using the IHI method) and wetland habitats (e.g. WET-Health and WET-EcoServices) of a potential impact is recommended at suitable sites to be determined in-field by a specialist.
- Monitoring/sampling is to be conducted by suitably qualified specialists (e.g. DWS accredited SASS 5 practitioners) with sufficient experience in assessing aquatic ecology and water quality;
- A single sampling event is recommended prior to construction taking place to serve as a reference condition;
- Monthly monitoring is recommended for the duration of construction to evaluate trends;
- Biannual monitoring is recommended thereafter during the operation phase, up to the point in time when the monitoring can establish that the systems are stable;
- Fixed point photography to monitor changes and long term impacts.

9 GAPS IN KNOWLEDGE

The most critical information gap for the purposes of confident assessment of estuarine impacts relates to the site specific sedimentary processes occurring within each potentially affected estuary. Without this detailed estuary-specific sediment process understanding it is difficult to assess likelihood and consequences of impacts arising from planned structures across and under estuaries. Most important in this regard are issues relating to planned pipelines obstruction to flows during floods and causing long-term estuary bed transformation and infilling. Estuarine physical processes are highly dynamic requiring detailed information over long planning horizons, e.g. understanding the impacts of a 1:100 year flood.

Once a specific project has been determined (based on market demand and the securing of a source of gas), the following detailed information is required at each system in the event an estuary is crossed. This information would be required prior to the construction of the gas pipeline, to inform the depth of HDD, e.g. 20m below bed level and for the actual site specific assessments.

- Estuary bathymetry of the entire system corrected to mean sea level (not just at the crossing site);
- Information on the sediment structure (i.e. sediment core samples taken to bed rock or at a minimum 20 m depth at small to medium sized systems and at a depth of > 20 m at estuaries with a high Mean Annual Runoff (MAR));
- Estimates of daily sediment loads from the catchment;
- Hourly flood hydrographs of the 1:5, 1:10, 1:20, 1:50 and 1:100 year flood to determine the scouring potential at each system;
- Detailed flood and sediment modelling to determine the degree to which the estuary may scour below its current bed during a flood (before infilling occurs again).

10 REFERENCES

Adams, J, Fernandes, M, and Riddin, T, 2018. Chapter 6: Estuarine Habitat extent and trend. South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Environment. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol4/A (Draft Report)

Adams, J., Rajkaran, A. & van der Colff, D. 2016a. *Avicennia marina* (Forssk.) Vierh. National Assessment: Red List of South African Plants version 2017.1. Accessed on 2018/05/30

Adams, J., Rajkaran, A. & van der Colff, D. 2016b. *Bruguiera gymnorrhiza* (L.) Lam. National Assessment: Red List of South African Plants version 2017.1. Accessed on 2018/05/30

Adams, J., Rajkaran, A. & van der Colff, D. 2016c. *Ceriops tagal* (Perr.) C.B.Rob. National Assessment: Red List of South African Plants version 2017.1. Accessed on 2018/05/30.

Adams, J., van der Colff, D. 2016. *Zostera capensis* Setch. National Assessment: Red List of South African Plants version 2017.1. Accessed on 2018/05/30

Appleton CC, Forbes AT and Demetriades NT (2009). The occurrence, bionomics and potential impacts of the invasive freshwater snail *Tarebia granifera* (Lamarck, 1822) (Gastropoda: *Thiaridae*) in South Africa. *Zoologische Medelingen Leiden* 83(4):525-536.

Aquashare 2011. Victoria desalination project Fact Sheet. Pipe jacking. https://www.aquasure.com.au/uploads/files/PipeJacking.pdf (Date accessed: 29/05/2018)

Basson, GR. 2018. Short discussion on scouring levels of South African estuaries. Personal communication. Stellenbosch University.

Basson, GR, Bosman, DE & Vonkeman JK. 2017. Proposed new uMfolozi River N2 Road Bridge. Hydrodynamic modelling of scour and hydrodynamic forces. *Stormwater Hydraulics*, STIAS, 10 Marais Road, Stellenbosch University.

Beck JS, A Kemp, AK Theron, P Huizinga and GR Basson (2004). Hydraulics of Estuarine Sediment Dynamics in South Africa: Implications for Estuarine Reserve Determination and the Development of Management Guidelines. WRC Report No. 1257/1/04. Pretoria, South Africa.

Boehm, A.B., Ismail, N.S., Sassoubre, L.M., Andruszkiewicz, E.A. 2017. Oceans in Peril: Grand Challenges in Applied Water Quality Research for the 21st Century. *Environmental Engineering Science* 34: 3-15.

Borja, A., Elliott, M., Snelgrove, P.V.R., Austen, M.C., Berg, T., Cochrane, S., Carstensen, J., Danovaro, R., Greenstreet, S., Heiskanen, A., Lynam, C.P., Mea, M., Newton, A., Patricio, J., Uusitalo, L., Uyarra, M.C., Wilson, C. 2017. Bridging the Gap Between Policy and Science in Assessing the Health Status of Marine Ecosystems. *Frontiers in Marine Science* 4:32.

Castro, J.M., Macdonald, A., Lynch, E. and Thorne, C.R. 2015. Risked-based approach to designing and reviewing pipeline stream crossings to minimize impacts to aquatic habitats and species. *River Res. Applic*. 31: 767-783.

Chen, L. and Gao, Q. 2006. Chance and challenge for China on Ecosystem management: Lessons from the West-to-East pipeline project construction. *Ambio*. 35(2): 91-93.

Colloty, B.M., Adams, J.B., Bate, G.C. 2002. Classification of estuaries in the Ciskei and Transkei regions based on physical and botanical characteristics. *South African Journal of Botany* 68: 312-321.

Cooper, J.A.G. 2001. Geomorphological variability among microtidal estuaries from the wave-dominated South African coast. *Geomorphology* 40: 99-122.

Costanza, R., D'arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'niell, R.V., Paruelo, J., Raskin, R.G., Sutton, P., Van Der Belt, M. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387: 253-259.

Davies, B., Day, J. 1998. *Vanishing Waters*. University of Cape Town Press, Cape Town, South Africa.

De Winnaar, G. & Ross-Gillespie, V. 2018. Freshwater Ecosystems. *In* CSIR Strategic Environmental Assessment for Gas Pipeline Development. Snyman-van der Walt, L., Walsdorff, A. & Abed, R. (*Eds*.). CSIR: Stellenbosch.

DEA (Department of Environmental Affairs) 2012. South African Water Quality Guidelines for coastal waters. Volume 2: Guidelines for recreational use.

Dettinger, M.D., Diaz, H.F. 2000. Global Characteristics of Stream Flow Seasonality and Variability. *Journal of Hydrometeorology* 1: 289-310.

DWA (Department of Water Affairs). 2013. Water Resource Protection and Assessment Policy Implementation Process. Resource Directed Measures for protection of water resources: Methodology for the Determination of the Ecological Water Requirements for Estuaries. Version 3. Pretoria.

DWAF (Department of Water Affairs and Forestry) 1995. South African water quality guidelines for coastal waters. Volume 1. Natural Environment. Volume 3: Mariculture, Volume 4: Industrial Use. Pretoria: Department of Water Affairs.

DWAF (Department of Water Affairs and Forestry) 2008. Water Resource Protection and Assessment Policy Implementation Process. Resource Directed Measures for protection of water resources: Methodology for the Determination of the Ecological Water Requirements for Estuaries. Version 2. Pretoria.

Elliott, M. 2011. Marine science and management means tackling exogenic unmanaged pressures and endogenic managed pressures – A numbered guide. *Marine Pollution Bulletin* 62: 651-655.

Emanuel, B.P., Bustamante, R.H., Branch, G.M., Eekhout, S., Odendal, F.J. 1992. A zoogeographic and functional approach to the selection of marine reserves on the west coast of South Africa. *South African Journal of Marine Science* 12: 341-354.

Froneman, A. & Van Rooyen, C. 2018. Avifauna. *In* CSIR. Strategic Environmental Assessment for Gas Pipeline Development. Snyman-van der Walt, L., Walsdorff, A. & Abed, R. (*Eds*.) CSIR: Stellenbosch.

Gillanders BM 2005. Using elemental chemistry of fish otoliths to determine connectivity between estuarine and coastal habitats. *Estuarine, Coastal and Shelf Science* 64: 47-57.

Gillanders, B.M., Kingsford, M.J. 2002. Impact of changes in flow of freshwater on estuarine and open coastal habitats and the associated organisms. *Oceanography and Marine Biology: An Annual Review* 40: 233-309.

Gray, J.S., Elliott, M. 2009. *Ecology of Marine Sediments. From Science to Management*, 2nd Edn. Oxford University Press, New York. 256 pp.

Griffiths, M.H., 1997. Management of South African dusky kob *Argyrosomus japonicus* (Sciaenidae) based on per-recruit models. *South African Journal of Marine Science*, 18: 213-228.

Harrison, T. D. 2002. Preliminary assessment of the biogeography of fishes in South African estuaries. *Marine and Freshwater Research* 53: 479-490.

IUCN 2012. 2001 IUCN Red List Categories and Criteria version 3.1. Second edition. *International Union for Conservation of Nature*, Gland, Switzerland. 32 pp.

IUCN 2018. The IUCN Red List of Threatened Species. Version 2018-1. <http://www.iucnredlist.org>. Downloaded on 05 July 2018.

Jerling, HR (2005) Zooplankton community changes in Nhlabane estuary, South Africa, induced by man-made structures and drought, *African Journal of Aquatic Science*, 30:1, 29-35, DOI: 10.2989/16085910509503831

Jezewski, W.A., Pyke, P.D., Roberts, C.P.R. 1984. Estuarine and Lake Freshwater Requirements. Department of Water Affairs and Forestry, Pretoria, South Africa. Technical Report No TR123.

James, C.S. and King, J.K. 2010. Ecohydraulics for South African Rivers: A review and guide. Pretoria: Water Research Commission, WRC Report No. TT 453/10.

Jones, N.E., Schmidt, B.J., Melles, S.J. 2014. Characteristics and distribution of natural flow regimes in Canada: a habitat template approach. *Canadian Journal of Fisheries and Aquatic Science* 71: 1616-1624.

Korpinen, S., Andersen, J. 2016. A global review of cumulative pressure and impact assessments in marine environments. *Frontier Marine Science* 3:153.

Lamberth, S.J., Turpie, J.K. 2003. The role of estuaries in South African fisheries: economic importance and management implications. *African Journal of Marine Science* 25: 131-157.

Lévesque, L. and Dubé, M. 2007. Review of the effects of in-stream pipeline crossing construction on aquatic ecosystems and examination of Canadian methodologies for impact assessment. *Environ Monit Assess* 132: 395-409.

Lynch, S.D. 2004. Development of a raster database of annual, monthly and daily rainfall for Southern Africa. WRC Report 1156/1/04, Water Research Commission, Pretoria, South Africa, pp 78.

Mirimin, L., Macey, B., Kerwath, S., Lamberth, S., Bester-van der Merwe, A., Cowley, P., Bloomer, P. and Roodt-Wilding, R., 2016. Genetic analyses reveal declining trends and low effective population size in an overfished South African sciaenid species, the dusky kob (*Argyrosomus japonicus*). *Marine and Freshwater Research*, 67: 266-276.

NEB 2017. How do pipelines cross rivers and streams? Government of Canada National Energy Board. Regulatory Snapshot. http://www.neb-one.gc.ca/bts/nws/rgltrsnpshts/2016/10rgltrsnpsht-eng.html. Accessed 02/08/2018.

PennEast Pipeline 2016. How we cross rivers and streams. URL: https://penneastpipeline.com/wp-content/uploads/2016/03/Rivers_Streams_3-10-16-6pm.pdf (Date accessed: 29/05/2018)

Poff, N.L., Ward, J.V. 1989. Implications of Streamflow Variability and Predictability for Lotic Community Structure: A Regional Analysis of Streamflow Patterns. *Canadian Journal of Fisheries and Aquatic Sciences* 46: 1805-1818.

Rajkaran, A., Adams, J. & van der Colff, D. 2016. *Rhizophora mucronata* Lam. National Assessment: Red List of South African Plants version 2017.1. Accessed on 2018/05/30

Rajkaran, A., Adams, J. & van der Colff, D. 2017. *Lumnitzera racemosa* Willd. var. *racemosa*. National Assessment: Red List of South African Plants version 2017.1. Accessed on 2018/05/30

Ray, G.C. 2005. Connectivities of estuarine fishes to the coastal realm. *Estuarine, Coastal and Shelf Science* 64: 18-32.

Reddering, J.S.V., Rust, I.C. 1990. Historical changes and sedimentary characteristics of southern African estuaries. *South African Journal of Science* 86: 425-428.

Reid, S.M. and Anderson, P.G. 1998. Suspended sediment and turbidity restrictions associated with instream construction activities in the United States: An assessment of biological relevance. International Pipeline Conference. Volume 2. Downloaded from: http://proceedings.asmedigitalcollection.asme.org/ on 16/01/2018.

Reid, S.M. and Anderson, P.G 1999. Effects of sediment released during open-cut pipeline water crossings. *Canadian Water Resources Journal*. 24:3 235-251. DOI:10.4296/cwrj2403235.

Robins, J.B., Halliday, I.A., Staunton-Smith, J., Mayer, D.G., Sellin, M.J. 2005. Freshwater-flow requirements of estuarine fisheries in tropical Australia: a review of the state of knowledge and the application of a suggested approach. *Marine and Freshwater Research* 56: 343-360.

SANBI. 2017. *Xylocarpus granatum* J.König. National Assessment: Red List of South African Plants version 2017.1. Accessed on 2018/05/30

Schulze, R.E., Lynch, S.D. 2007. Annual Precipitation. In: Schulze, R.E. (Ed). 2007. South African Atlas of Climatology and Agrohydrology. WRC Report 1489/1/06, Section 6.2. Water Research Commission, Pretoria, RSA.

Schulze, R.E., Maharaj, M. 2007. Rainfall Seasonality. In: Schulze, R.E. (Ed). 2007. South African Atlas of Climatology and Agrohydrology. WRC Report 1489/1/06, Section 6.5. Water Research Commission, Pretoria, RSA.

Simenstad, C.A, Brandt, S.B., Chalmers, A., Dame, R., Deegan, L.A., Hodson, R., Houde, E.D., 2000. Habitat-biotic interactions. In: Hobbie, J.E. (Ed.), Estuarine Science: A Synthetic Approach to Research and Practice. Island Press, Washington, DC, pp. 427 -455.

Taljaard, S., Snow, G., Gama, P., Van Niekerk, L. 2009. Verification of a conceptual model of water quality for small temporarily open/closed estuaries: East Kleinemonde Estuary, South Africa. *Marine and Freshwater Research* 60: 234-245.

Turpie, J.K and Clark B 2009. Development of a Conservation Plan for temperate South African estuaries on the basis of biodiversity importance, ecosystem health and economic costs and benefits. CAPE programme.

Turpie, J.K., Adams, J.B., Joubert, A., Harrison, T.D., Colloty, B.M., Maree, R.C., Whitfield, A.K., Wooldridge, T.H., Lamberth, S.J., Taljaard, S., Van Niekerk, L. 2002. Assessment of the conservation priority status of South African estuaries for use in management and water allocation. *Water SA* 28: 191-206.

Turpie, J.K., Wilson, G. and van Niekerk, L. 2012. National Biodiversity Assessment 2011: National Estuary Biodiversity Plan for South Africa. Anchor Environmental Consulting Cape Town. Report produced for the Council for Scientific and Industrial Research and the South African National Biodiversity Institute.

Turpie, JK, Taljaard, S, Van Niekerk, L, Adams, J, Wooldridge, T, Cyrus, D, Clark, B & Forbes, N 2013. The Estuary Health Index: a standardised metric for use in estuary management and the determination of ecological water requirements. WRC Report No. 1930/1/12. 90pp.

Van Niekerk L and Turpie JK (eds). 2012. National Biodiversity Assessment 2011: Technical Report. Volume 3: Estuary Component. CSIR Report Number CSIR/NRE/ECOS/ER/2011/0045/B. Council for Scientific and Industrial Research, Stellenbosch. Available at: http://bgis.sanbi.org/nba/project.asp.

Van Niekerk L, Taljaard S, Ramjukadh C-L Adams JB, Lamberth SJ, Weerts SP, Petersen C, Audouin M, Maherry A. 2017. A multi-sector Resource Planning Platform for South Africa's estuaries. Water Research Commission Report No K5/2464. South Africa.

Van Niekerk, L, Adams, JB Lamberth, SJ, MacKay, F, Taljaard, S, Turpie, JK, Ramhukad, C-L, South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Environment. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol4/A. Draft Report.

Van Niekerk, L, Adams JB, Bate GC, Forbes N, Forbes A, Huizinga P, Lamberth SJ, MacKay F, Petersen C, Taljaard S, Weerts S, Whitfield AK and Wooldridge TH. 2013. Country-wide assessment of estuary health: An approach for integrating pressures and ecosystem response in a data limited environment. *Estuarine, Coastal and Shelf Science* 130: 239-251.

Van Niekerk, L., Taljaard, S., Adams, J. B., Fundidi, D., Huizinga, P., Lamberth, S. J., Mallory, S., Snow, G. C., Turpie, J. K., Whitfield, A. K. and Wooldridge, T. H. 2015. Desktop Provisional Ecoclassification of the Temperate Estuaries of South Africa. WRC Report No K5/2187.

Vivier, L, Cyrus D.P. 1999. Dune Mining and the Nhlabane Estuary, South Africa: the Effect of a Dredger Crossing on the Zoobenthic Community, *Marine Pollution Bulletin*, Volume 39, Issues 1–12.

Von Staden, L. 2016. *Barringtonia racemosa* (L.) Roxb. National Assessment: Red List of South African Plants version 2017.1. Accessed on 2018/05/30

Vorwerk, P.D., Froneman, P.W., Paterson, A.W., Strydom, N.A., Whitfield, A.K., 2008. Biological responses to a resumption in river flow in a fresh water deprived, permanently open southern African estuary. *Water SA* 34: 597-604.

Whitfield, A., Elliott, M. 2011. Ecosystem and Biotic Classifications of Estuaries and Coasts. In: Wolanski E and McLusky DS (eds.) *Treatise on Estuarine and Coastal Science*, Vol 1. Academic Press, Waltham, pp. 99-124.

Whitfield, A.K. 1998. Biology and ecology of fishes in Southern African estuaries. *Icthyological Monograph of the J.L.B. Smith Institute of Ichthyology* 2: 1-223.

Whitfield, A.K., 1992. A characterization of southern African estuarine systems. *Southern African Journal of Aquatic Sciences* 18: 89-103.

Yu, X., Wang, G., Zou, Y., Wang, Q., Zhao, H. and Lu, X. 2010. Effects of pipeline construction on wetland ecosystems: Russia-China oil pipeline project (Mohe-Daqing section) *Ambio*. 39: 447-450.

Appendix A : List of estuaries and their key features for each corridor

Table A.1: Summary of important environmental and socio-economic attributes of estuaries in each of the proposed Gas Pipeline corridors

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							Reference Mean Annual runoff (m³x106)	Flood risk	Biodiversity Importance rating	Conservation Priority set (NBA 2012 Biodiversity Plan)	Estuary health (A=Natural, F=Severely degraded)	Important Fish Nursery (5=High, 1+Low)	Important Estuarine habitat (ha)					Total habitat area (ha)	IUCN Critically/ Endangered Fish species
	0-5	5-10	10-15	15-20	20-25	25-30	30-35							Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Mangroves	Swamp forest		
Phase 5																				
Olifants	x	x						1070.10	x	Very Important	SA/CAPE	C	5	91.9	849.1	47.74	0.0	0	1353.68	x
Verlorenvlei	x	x	x					52.21		Important	SA	D	3	16.2	7.6	3.68	0.0	0	34.74	x
Groot Berg	x	x	x	x	x	x	x	916.00	x	Very Important	SA/CAPE	C	5	1667.0	2545.0	206	0.0	0	6799	x
Phase 1																				
Langebaan	x							-		Very Important	SA	B	5							x
Rietvlei/Diep	x	x						63.29	x	Important	SA/CAPE	D	5	0.0	0.0	0	0.0	0	0	x
Sout (Wes)	x	x						31.11		Ave Importance		F	1	0.0	0.0	0	0.0	0	99.7	x
Houtbaai	x							15.18		Ave Importance		E	1	0.0	0.0	0	0.0	0	21.05	x
Wildevoëlvlei	x							2.14		Very Important		D/E	1	12.7	0.0	0	0.0	0	230.87	x
Bokramspruit	x							2.01		Ave Importance		C	1	0.0	0.0	0	0.0	0	1.2	x
Schuster	x							2.57		Ave Importance		B	1	0.0	0.0	0	0.0	0	0.6	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							Reference Mean Annual runoff (m^3x106)	Flood risk	Biodiversity Importance rating	Conservation Priority set (NBA 2012 Biodiversity Plan)	Estuary health (A=Natural, F=Severely degraded)	Important Fish Nursery (5=High, 1+Low)	Important Estuarine habitat (ha)					Total habitat area (ha)	IUCN Critically/ Endangered Fish species
	0-5	5-10	10-15	15-20	20-25	25-30	30-35							Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Mangroves	Swamp forest		
Krom	x							6.99		Ave Importance	SA/CAPE	A/B	1	0.0	0.0	0	0.0	0	8.7	x
Buffels Wes	x							0.45		Ave Importance		A/B	1	0.0	0.0	0	0.0	0	3.75	x
Elsies	x							0.59		Ave Importance		D/E	1	0.0	0.0	0	0.0	0	18.45	x
Silvermine	x							3.75		Ave Importance		E	1	0.0	0.2	2.02	0.0	0	6.52	x
Sand	x	x						21.73		Important	SA/CAPE	D	5	11.6	0.0	0	0.0	0	155.48	x
Zeekoei	x							22.33		Ave Importance		E	1	0.0	0.0	0.2	0.0	0	3.17	x
Eerste	x							104.60	x	Ave Importance	SA/CAPE	E	2	0.3	0.0	0	0.0	0	10.2	x
Lourens	x							66.27	x	Ave Importance	SA/CAPE	D	1	0.0	0.0	0	0.0	0	7.09	x
Sir Lowry's Pass	x							0.14		Ave Importance		E	1	0.0	0.0	0	0.0	0	2.95	x
Steenbras	x							33.70		Ave Importance		B	1	0.0	0.0	0	0.0	0	1.88	x
Rooiels	x							8.64		Ave Importance		A/B	1	0.0	0.0	0.03	0.0	0	4.13	x
Buffels (Oos)	x							9.70		Ave Importance		B	1	0.0	0.0	0	0.0	0	2.9	x
Palmiet	x							256.30	x	Important	SA/CAPE	C	1	0.1	0.0	0	0.0	0	33	x
Klipdrifsfontein	x							0.24		Ave Importance	SA/CAPE	A	1	0.0	0.0	0	0.0	0	0.6	x
Breë	x	x	x	x	x	x		1785.00	x	Very Important	SA	B/C	5	20.5	29.6	6	0.0	0	1564.6	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							Reference Mean Annual runoff (m^3x106)	Flood risk	Biodiversity Importance rating	Conservation Priority set (NBA 2012 Biodiversity Plan)	Estuary health (A=Natural, F=Severely degraded)	Important Fish Nursery (5=High, 1+Low)	Important Estuarine habitat (ha)					Total habitat area (ha)	IUCN Critically/ Endangered Fish species
	0-5	5-10	10-15	15-20	20-25	25-30	30-35							Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Mangroves	Swamp forest		
Duiwenhoks	x	x	x					94.19	x	Very Important		C	4	26.0	0.0	0	0.0	0	98	x
Goukou (Kaffirkui	x	x	x					102.78	x	Very Important	SA/CAPE	C	4	57.0	0.0	5	0.0	0	324	x
Gourits	x	x	x	x				628.78	x	Important	SA/CAPE	C/D	5	137.8	0.0	0	0.0	0	525.5	x
Phase 2																				
Blinde	x							1.25		Ave Importance		C	1	0.0	0.0	0	0.0	0	5.4	x
Gericke	x							35.60		Ave Importance		D/E	1	0.0	0.0	0	0.0	0	0	x
Tweekuilen	x							0.30		Ave Importance		D/E	1	0.0	0.0	0	0.0	0	0	x
Hartenbos	x							4.63		Important		D	3	47.0	0.0	0	0.0	0	99	x
Klein Brak	x	x						53.37		Ave Importance		C	4	494.0	0.0	3	0.0	0	664	x
Groot Brak	x							36.79		Important		C/D	3	13.0	26.6	0	0.0	0	105.1	x
Maalgate	x							26.64		Ave Importance		B	1	0.0	0.0	0	0.0	0	28	x
Gwaing	x							43.53		Ave Importance		B/C	1	0.0	0.0	0	0.0	0	9	x
Kaaimans	x							35.73		Ave Importance	SA	B	1	0.0	0.0	0	0.0	0	9.2	x
Wilderness	x							29.66		Very Important	SA/CAPE	B/C	5	42.3	0.0	4	0.0	0	295.3	x
Swartvlei	x	x						83.15	x	Very Important	SA/CAPE	B/C	5	135.6	0.0	219.39	0.0	0	1286.29	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							Reference Mean Annual runoff (m^3x106)	Flood risk	Biodiversity Importance rating	Conservation Priority set (NBA 2012 Biodiversity Plan)	Estuary health (A=Natural, F=Severely degraded)	Important Fish Nursery (5=High, 1+Low)	Important Estuarine habitat (ha)					Total habitat area (ha)	IUCN Critically/ Endangered Fish species
	0-5	5-10	10-15	15-20	20-25	25-30	30-35							Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Mangroves	Swamp forest		
Goukamma	x	x						57.50		Important	SA/CAPE	A/B	3	1.5	5.2	0	0.0	0	18.21	x
Knysna	x	x						83.20	x	Very Important	SA/CAPE	B/C	5	551.9	0.0	238	0.0	0	2038.72	x
Noetsie	x							4.36		Ave Importance	CAPE	B	1	0.0	0.0	0	0.0	0	13.4	x
Piesang	x							5.20		Important	SA	D	3	1.5	0.0	0	0.0	0	20	x
Keurbooms	x	x						232.00	x	Very Important	SA/CAPE	A/B	5	72.2	41.8	88.73	0.0	0	674.74	x
Matjies	x							5.10		Ave Importance		A/B	1	0.0	0.0	0	0.0	0	2.8	x
Kabeljous	x							11.52		Important		C	3	0.0	10.5	21.51	0.0	0	117.94	x
Gamtoos	x	x						388.84	x	Very Important	SA/CAPE	B/C	5	92.9	80.8	5.14	0.0	0	501.25	x
Van Stadens	x							17.19		Ave Importance	SA/CAPE	B	1	0.0	0.0	0	0.0	0	24.2	x
Maitland	x							12.86		Ave Importance	SA/CAPE	B/C	1	0.0	0.0	0	0.0	0	18.65	x
Baakens	x							4.11		Ave Importance		E	1	0.0	0.0	0	0.0	0	0	x
Papenkuils	x							2.92		Ave Importance		F	1	0.0	0.0	0	0.0	0	0	x
Swartkops	x	x	x					97.62	x	Very Important	SA/CAPE	D	5	165.0	5.0	44.7	0.0	0	531.2	x
Coega (Ngcura)	x	x						10.13		Ave Importance		E	1	0.0	2.3	1.2	0.0	0	10.14	x
Sundays	x	x	x	x	x			273.00	x	Important	SA/CAPE	C	5	21.8	0.0	0	0.0	0	485.7	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							Reference Mean Annual runoff (m³x106)	Flood risk	Biodiversity Importance rating	Conservation Priority set (NBA 2012 Biodiversity Plan)	Estuary health (A=Natural, F=Severely degraded)	Important Fish Nursery (5=High, 1+Low)	Important Estuarine habitat (ha)					Total habitat area (ha)	IUCN Critically/ Endangered Fish species
	0-5	5-10	10-15	15-20	20-25	25-30	30-35							Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Mangroves	Swamp forest		
Phase 7																				
Coega	x	x						10.13		Ave Importance		E	1	0.0	2.3	1.2	0.0	0	10.14	x
Sundays	x	x	x	x	x			273.00	x	Important	SA/CAPE	C	5	21.8	0.0	0	0.0	0	485.7	x
Boknes	x							14.44		Ave Importance		C	1	1.5	5.0	0.5	0.0	0	20	x
Bushmans	x	x	x	x				42.86		Important	SA/CAPE	B/C	5	118.3	0.0	39.8	0.0	0	340.9	x
Kariega	x	x						21.69		Very Important	SA/CAPE	C	5	36.1	364.4	3.26	0.0	0	565.35	x
Kasuka	x							4.30		Important		B	3	0.0	0.0	0	0.0	0	20.7	x
Kowie	x	x	x					31.82		Very Important		C	5	35.2	0.0	8.2	0.0	0	126.83	x
Rufane	x							1.20		Ave Importance		C	1	0.0	0.0	0	0.0	0	0.81	x
Riet	x							2.42		Important		B	1	0.0	17.4	2.64	0.0	0	73.06	x
Kleinemond Wes	x	x						6.00		Important		B	3	0.0	7.1	8.2	0.0	0	47.8	x
Kleinemond Oos	x							2.86		Important		B	3	2.5	2.8	14.5	0.0	0	46.94	x
Klein Palmiet	x							0.82		Ave Importance		B	1	0.0	0.0	0.02	0.0	0	0.531	x
Great Fish	x	x	x					513.29	x	Very Important	SA/CAPE	C	5	133.0	65.0	0	0.0	0	368	x
Old Womans	x							1.11		Ave Importance		C	1	0.0	0.0	0	0.0	0	25.12	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							Reference Mean Annual runoff (m^3x106)	Flood risk	Biodiversity Importance rating	Conservation Priority set (NBA 2012 Biodiversity Plan)	Estuary health (A=Natural, F=Severely degraded)	Important Fish Nursery (5=High, 1+Low)	Important Estuarine habitat (ha)					Total habitat area (ha)	IUCN Critically/ Endangered Fish species
	0-5	5-10	10-15	15-20	20-25	25-30	30-35							Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Mangroves	Swamp forest		
Mpekweni	x							2.44		Very Important		B	3	0.0	27.2	1.59	0.0	0	141.41	x
Mtati	x							6.03		Very Important	CAPE	B	3	0.0	54.3	3.2	0.0	0	286.35	x
Mgwalana	x	x						9.71		Very Important	SA	B	3	0.0	7.6	1.12	0.0	0	226.72	x
Bira	x	x						12.01		Important	SA	B	3	0.0	2.6	5.3	0.0	0	163.54	x
Gqutywa	x							3.52		Important	SA/CAPE	B	3	0.0	1.2	2.5	0.0	0	51.64	x
Ngculura	x							0.65		Ave Importance		B	1	0.0	0.0	0	0.0	0	2.35	x
Mtana	x							1.06		Ave Importance		B	1	0.0	2.5	2.54	0.0	0	15.69	x
Keiskamma	x	x	x	x				138.94	x	Very Important	SA/CAPE	B/C	5	210.4	91.3	12	0.0	0	744.53	x
Ngqinisa	x							1.18		Ave Importance	SA	A/B	1	0.0	0.0	0	0.0	0	12.67	x
Kiwane	x							5.32		Ave Importance		A/B	3	0.0	0.0	3.56	0.0	0	18.8	x
Tyolomnqa	x	x	x					35.56		Important		B	3	3.7	15.7	0	0.0	0	107.44	x
Shelbertsstroom	x							0.63		Ave Importance		B/C	1	0.0	0.0	0	0.0	0	0.46	x
Lilyvale	x							1.11		Ave Importance		B	1	0.0	0.0	0	0.0	0	2.3	x
Ross' Creek	x							0.55		Ave Importance		A/B	1	0.0	0.0	0.2	0.0	0	1.3	x
Ncera	x							10.99		Ave Importance	SA	B	1	0.0	2.9	1	0.0	0	28.4	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							Reference Mean Annual runoff (m^3x106)	Flood risk	Biodiversity Importance rating	Conservation Priority set (NBA 2012 Biodiversity Plan)	Estuary health (A=Natural, F=Severely degraded)	Important Fish Nursery (5=High, 1+Low)	Important Estuarine habitat (ha)					Total habitat area (ha)	IUCN Critically/ Endangered Fish species
	0-5	5-10	10-15	15-20	20-25	25-30	30-35							Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Mangroves	Swamp forest		
Mlele	x							2.00		Ave Importance		B	1	0.0	0.4	0	0.0	0	3.6	x
Mcantsi	x							2.84		Ave Importance		B	1	0.0	0.5	0	0.0	0	9	x
Gxulu	x							15.56		Ave Importance		B/C	3	1.0	11.9	0	0.0	0	48.5	x
Goda	x							6.19		Ave Importance	CAPE	B	1	0.0	1.9	0	0.0	0	17.2	x
Hlozi	x							1.75		Ave Importance		B	1	0.0	0.0	0	0.0	0	0.7	x
Hickman's	x							1.42		Ave Importance		B	1	0.0	0.8	0	0.0	0	4.3	x
Mvubukazi	x							0.00		Ave Importance		B	1	0.0	0.0	0	0.0	0	0.1	x
Ngqenga	x							0.43		Ave Importance		B	1	0.0	0.0	0	0.0	0	0.1	x
Buffalo	x							96.03		Ave Importance		D	3	0.0	0.1	0	0.0	0	98	x
Blind	x							0.65		Ave Importance		D	1	0.0	0.1	0	0.0	0	0.5	x
Hlaze	x							0.32		Ave Importance		C/D	1	0.0	0.1	0	0.0	0	1.5	x
Nahoon	x	x						38.20		Important		C	3	2.8	0.0	2.3	1.6	0	58.72	x
Qinira	x							8.44		Important		B/C	1	16.8	5.7	0	0.0	0	72.13	x
Gqunube	x							34.07		Important	SA	B	3	3.7	2.2	0.8	0.0	0	53.4	x
Kwelera	x							34.83		Important	SA	B	3	9.3	7.2	2.3	0.0	0	50.1	x

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	0-5	5-10	10-15	15-20	20-25	25-30	30-35							Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Mangroves	Swamp forest		
Bulura	x							3.73		Ave Importance		B	1	2.8	5.6	0.4	0.0	0	35.5	x
Cunge	x							0.32		Ave Importance		A/B	1	0.0	0.0	0	0.0	0	0.35	x
Cintsa	x							3.99		Ave Importance		B	1	7.0	7.1	0	0.0	0	29.3	x
Cefane	x							3.95		Important		B	3	28.1	21.4	0	0.0	0	82.7	x
Kwenxura	x							16.89		Ave Importance	SA/CAPE	A/B	3	0.0	3.3	0	0.0	0	29.1	x
Nyara	x							4.34		Ave Importance		A/B	1	1.1	6.3	0	0.0	0	17.1	x
Mtwendwe	x							1.07		Ave Importance		A/B	1	0.0	0.0	0	0.0	0	0	x
Haga-haga	x							2.15		Ave Importance		A/B	1	0.0	0.3	0	0.0	0	3.4	x
Mtendwe	x							1.41		Ave Importance		A/B	1	0.0	0.0	0	0.0	0	0	x
Quko	x							17.18		Ave Importance	SA/CAPE	A	3	3.9	0.0	0	0.0	0	36.18	x
Morgan	x							2.74		Ave Importance		B	3	0.0	2.0	0	0.0	0	24	x
Cwili	x							1.18		Ave Importance		B	1	0.0	0.0	0	0.0	0	1.2	x
Great Kei	x	x	x					954.93	x	Very Important	SA/CAPE	C	5	5.8	6.2	0	0.0	0	222.4	x
Gxara	x							3.44		Ave Importance		A/B	1	0.0	1.9	0	0.0	0	23.9	x
Ngogwane	x							0.79		Ave Importance		B	1	0.0	0.0	0	0.0	0	9.12	x

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	0-5	5-10	10-15	15-20	20-25	25-30	30-35							Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Mangroves	Swamp forest		
Qolora	x							8.90		Important		B	1	0.0	0.0	0	0.0	0	22.9	x
Ncizele	x							1.00		Ave Importance	SA	A/B	1	0.0	0.0	0	0.0	0	6.635	x
Timba	x							0.35		Ave Importance		B	1	0.0	0.0	0	0.0	0	0	x
Kobonqaba	x							36.22		Ave Importance		B	3	2.3	4.5	1	0.5	0	26.4	x
Nxaxo/Ngqusi	x							23.27		Important	SA/CAPE	B	3	2.4	8.6	0.04	9.5	0	153.98	x
Cebe	x							5.69		Ave Importance		A/B	1	0.0	0.0	0	0.0	0	16.53	x
Gqunqe	x							6.96		Ave Importance		A/B	1	0.0	0.0	0	0.0	0	17.94	x
Zalu	x							1.69		Ave Importance		A/B	1	0.0	0.0	0	0.0	0	12.36	x
Ngqwara	x							5.24		Ave Importance	SA	A/B	1	0.0	2.3	0	0.0	0	19.36	x
Sihlontlweni/Gcin	x							2.21		Ave Importance		A/B	1	0.0	0.0	0	0.0	0	11.01	x
Nebelele	x							1.05		Ave Importance		A/B	1	0.0	0.0	0	0.0	0	0	x
Qora	x							78.52	x	Important	SA/CAPE	A/B	3	0.0	0.0	8.5	0.0	0	89.63	x
Jujura	x							11.27		Ave Importance		A/B	1	0.0	0.0	0.05	0.0	0	4.77	x
Ngadla	x							1.56		Ave Importance	SA	A/B	1	0.0	0.0	0	0.0	0	13.884	x
Shixini	x							42.28		Ave Importance	CAPE	A/B	1	0.0	0.0	0	0.0	0	22.1	x

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	0-5	5-10	10-15	15-20	20-25	25-30	30-35							Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Mangroves	Swamp forest		
Nqabara/Nqabarana	x							76.44	x	Important	SA	A/B	3	0.0	0.0	1.2	11.8	1.23	112.96	x
Mbashe	x	x						801.82	x	Very Important	SA/CAPE	B	5	2.3	0.0	1.5	9.2	4.8	127.15	x
Xora	x							53.00	x	Important	SA	A/B	3	0.0	13.0	2.6	25.5	0	159.76	x
Mtata	x							392.20	x	Important	SA	C	3	0.0	21.0	0	31.5	0	166.79	x
Mngazana	x							49.34	x	Very Important	SA	B	5	1.3	7.4	2	118.0	7.8	199.05	x
Mzimvubu	x							2665.58	x	Important	SA	B	5	0.0	0.0	0	0.0	5	392.03	x
Sikombe	x							6.79		Ave Importance	SA	A/B	1	0.0	0.0	0	0.0	1.18	11.48	x
Kwanyana	x							3.99		Ave Importance	SA	A/B	1	0.0	0.0	0	0.0	0	7.13	x
Mtolane	x							1.78		Ave Importance	SA	A	1	0.0	0.0	0	0.0	0	1.29	x
Mnyameni	x							45.87		Ave Importance	SA	A/B	1	0.0	0.0	0	5.0	0.01	32.92	x
Mpahlanyana	x							1.11		Ave Importance	SA	A/B	1	0.0	0.0	0	0.0	0	3.85	x
Mpahlane	x							2.73		Ave Importance	SA	A/B	1	0.0	0.0	0	0.0	0	3.92	x
Mzamba	x							67.43	x	Important	SA	B	3	0.0	0.0	0	0.3	4.74	70.99	x
Mtentwana	x							1.26		Ave Importance	SA	C	1	0.0	0.0	0	0.0	0	11.43	x
Mtamvuna	x	x						275.19	x	Important	SA	B	5	0.0	0.0	0	1.0	0.1	96.7	x

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	0-5	5-10	10-15	15-20	20-25	25-30	30-35							Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Mangroves	Swamp forest		
Zolwane	x							2.19		Ave Importance		B	1	0.0	0.0	0	0.0	0	2.3	x
Sandlundlu	x							5.07		Ave Importance		C	1	0.0	0.0	0	0.0	0.25	10.5	x
Ku-Boboyi	x							1.00		Ave Importance		B	1	0.0	0.0	0	0.0	0	5.1	x
Tongazi	x							7.00		Ave Importance		B/C	1	0.0	0.0	0	0.0	3	6.78	x
Kandandhlovu	x							1.53		Ave Importance		B	1	0.0	0.0	0	0.0	5.2	11.2	x
Mpenjati	x							23.61		Ave Importance	SA	B/C	1	0.0	0.0	0	0.0	6	28.6	x
Umhlangankulu	x							2.87		Ave Importance		C	1	0.0	0.0	0	0.5	4	15.8	x
Kaba	x							3.15		Ave Importance		C	1	0.0	0.0	0	0.0	1.1	5.1	x
Mbizana	x							36.30		Ave Importance		B	1	0.0	0.0	0	0.0	3	28.4	x
Mvutshini	x							1.66		Ave Importance		B/C	1	0.0	0.0	0	0.0	0	3.88	x
Bilanhlolo	x							5.02		Ave Importance		C	1	0.0	0.0	0	0.0	1.1	4.6	x
Uvuzana	x							1.05		Ave Importance		C	1	0.0	0.0	0	0.0	0	6.1	x
Kongweni	x							1.95		Ave Importance		D/E	1	0.0	0.0	0	0.5	0.25	7.17	x
Vungu	x							27.79		Ave Importance		B	1	0.0	0.0	0	0.0	0	7.13	x
Mhlangeni	x							9.29		Ave Importance		C	1	0.0	0.0	0	0.0	0	15.6	x

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	0-5	5-10	10-15	15-20	20-25	25-30	30-35							Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Mangroves	Swamp forest		
Zotsha	x							15.74		Ave Importance	SA	B/C	1	0.0	0.0	0	0.0	5	29.3	x
Boboyi	x							8.25		Ave Importance		B/C	1	0.0	0.0	0	0.0	0	14.3	x
Mbango	x							3.00		Ave Importance		E	1	0.0	0.0	0	0.0	2	12.9	x
Mzimkulu	x	x						1452.49	x	Important	SA	B	5	0.0	0.0	0	0.0	15	117.9	x
Mtentweni	x							12.07		Ave Importance		C	1	0.0	0.0	0	0.0	4.5	18.48	x
Mhlangamkulu	x							2.06		Ave Importance		C	1	0.0	0.0	0	0.0	0.2	100.1	x
Damba	x							4.56		Ave Importance	SA	D	1	0.0	0.0	0	0.0	9	19.65	x
Koshwana	x							2.06		Ave Importance	SA	C/D	1	0.0	0.0	0	0.0	6	18.18	x
Intshambili	x							6.48		Ave Importance	SA	C	1	0.0	0.0	0	0.0	6.25	10.45	x
Mzumbe	x							58.53	x	Ave Importance		C/D	1	0.0	0.0	0	0.0	0	35.8	x
Mhlabatshane	x							6.46		Ave Importance	SA	B/C	3	0.0	0.0	0	0.0	11.5	19.27	x
Mhlungwa	x							5.78		Ave Importance		C	1	0.0	0.0	1.5	0.0	1	16.5	x
Mfazazana	x							2.77		Ave Importance	SA	C	1	0.0	0.0	0	0.0	5	15.6	x
Kwa-Makosi	x							3.23		Ave Importance	SA	B/C	1	0.0	0.0	0	0.0	7	14.95	x
Mnamfu	x							3.08		Ave Importance		C	1	0.0	0.0	0	0.0	4	14.28	x

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	0-5	5-10	10-15	15-20	20-25	25-30	30-35							Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Mangroves	Swamp forest		
Mtwalume	x							57.60		Ave Importance		C	1	0.0	0.0	0	0.0	0	38.8	x
Mvuzi	x							1.65		Ave Importance		C	1	0.0	0.0	0	0.0	0	17.8	x
Fafa	x							46.45		Important		C/D	1	0.0	0.0	0	0.0	6.6	32.9	x
Mdesingane	x							2.02		Ave Importance		D	1	0.0	0.0	0.5	0.0	0	7.14	x
Sezela	x							3.92		Ave Importance		C	1	0.0	0.0	0	0.0	0	28	x
Mkumbane	x							3.79		Ave Importance		C	1	0.0	0.0	0	0.0	0	12.25	x
Mzinto	x							23.17		Ave Importance		C/D	1	0.0	0.0	0	0.0	4.5	29.5	x
Mpambanyoni	x							60.06	x	Ave Importance		C	1	0.0	0.0	0	0.0	0.25	12.57	x
Mahlongwa	x							13.76		Ave Importance		C	1	0.0	0.0	0	0.0	0	13.9	x
Mkomazi	x							1077.74	x	Important	SA	C	5	0.0	0.0	0	1.0	10	88	x
Ngane	x							3.83		Ave Importance		C	1	0.0	0.0	0	0.0	0	8.36	x
Umgababa	x							10.56		Ave Importance	SA	C	3	0.0	0.0	0	0.0	2.6	61.7	x
Msimbazi	x							10.04		Ave Importance	SA	B	3	0.0	0.0	0	0.0	0	28.2	x
Lovu	x							119.10	x	Ave Importance	SA	C/D	3	0.0	0.0	0	0.0	5	39.5	x
Little Manzimtoti	x							2.84		Ave Importance		E	1	0.0	0.0	0	0.0	6.5	9.6	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							Reference Mean Annual runoff (m^3x106)	Flood risk	Biodiversity Importance rating	Conservation Priority set (NBA 2012 Biodiversity Plan)	Estuary health (A=Natural, F=Severely degraded)	Important Fish Nursery (5=High, 1+Low)	Important Estuarine habitat (ha)					Total habitat area (ha)	IUCN Critically/ Endangered Fish species
	0-5	5-10	10-15	15-20	20-25	25-30	30-35							Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Mangroves	Swamp forest		
Manzimtoti	x							5.30		Ave Importance		D/E	1	0.0	0.0	0	0.0	2.5	21.17	x
Mbokodweni	x							31.52	x	Ave Importance		E	1	0.0	0.0	0	0.0	0	17.74	x
Sipingo	x							109.40		Ave Importance		F	1	0.0	3.0	0	3.8	16	26.6	x
Mgeni	x							671.30	x	Important	SA	E	3	8.4	0.0	1	31.7	0.5	107.79	x
Mhlanga	x							13.34		Important	SA	D	1	0.0	0.0	0	0.0	0.2	82.78	x
Mdloti	x							100.19	x	Important		D	1	0.0	0.0	0	0.0	7.8	58.1	x
Tongati	x							70.79	x	Important		D	1	0.0	0.0	0	0.0	3.4	37.3	x
Mhlali	x							56.26	x	Important	SA	C/D	1	0.0	0.0	0	0.0	7	42	x
Mvoti	x							374.66	x	Ave Importance	SA	D	1	0.0	0.0	0	0.0	2	111	x
Mdlotane	x							6.04		Important	SA	B	1	0.0	0.0	0.71	0.0	12.33	25.42	x
Nonoti	x							36.24		Ave Importance		C	1	0.0	0.0	2.5	0.0	1	27	x
Zinkwasi	x							14.49		Important	SA	B/C	5	0.0	0.0	0	0.0	11.28	71.16	x
Thukela	x	x	x					3753.60	x	Important	KZn priority	C	3	0.0	0.0	0	0.0	0.27	133.32	x
Matigulu/ Nyoni	x	x						192.27	x	Important	SA	B	5	0.0	0.0	0.5	0.0	2	127	x
Siyaya	x							6.50		Ave Importance	SA	F	1	0.6	0.0	0.08	0.0	3.72	9.52	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							Reference Mean Annual runoff (m^3x106)	Flood risk	Biodiversity Importance rating	Conservation Priority set (NBA 2012 Biodiversity Plan)	Estuary health (A=Natural, F=Severely degraded)	Important Fish Nursery (5=High, 1+Low)	Important Estuarine habitat (ha)					Total habitat area (ha)	IUCN Critically/ Endangered Fish species
	0-5	5-10	10-15	15-20	20-25	25-30	30-35							Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Mangroves	Swamp forest		
Mlalazi	x	x						164.31	x	Very Important	SA	B	5	0.0	39.3	0.001	60.7	3.46	238.771	x
Mhlathuze	x	x	x					645.00	x	Very Important	SA	C/D	5	60.0	0.0	28.5	652.1	0	1714.6	x
Richards Bay	x	x						0.00		Important	SA	D	5	52.0	0.0	0	267.0	16	2044	x
Nhlabane	x	x						29.00		Important		D/E	3	0.0	0.0	1.1	0.0	0.3	14.4	x
Mfolozi	x	x	x					885.00	x	Very Important	SA	D	5	0.0	0.0	0	78.2	1683.1	3458.5	x
St Lucia	x	x	x	x	x	x		417.89	x	Very Important	SA	D	5	414.7	0.0	431.5	209.5	17.4	40832.8	x
Phase 4																				
St Lucia	x	x	x	x	x	x		417.89	x	Very Important	SA	D	5	414.7	0.0	431.5	209.5	17.4	40832.8	x
Mgobezeleni	x							0.00		Ave Importance	SA	B	1	0.0	0.0	0	4.5	4	15.3	x
Kosi	x	x						0.00		Very Important	SA	A/B	5	58.0	229.0	652	71.0	869	5396	x