APPENDIX D6: Estuarine Specialist Report

ESTUARINE SPECIALIST STUDY AND IMPACT ASSESSMENT FOR THE PROPOSED LOWER UMKHOMAZI BULK WATER SUPPLY SYSTEM, KWAZULU-NATAL PROVINCE

Anchor Environmental Consulting Report No, 1778/1

ESTUARINE SPECIALIST STUDY AND IMPACT ASSESSMENT FOR THE PROPOSED LOWER UMKHOMAZI BULK WATER SUPPLY SYSTEM, KWAZULU-NATAL PROVINCE

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EXECUTIVE SUMMARY

Description of the affected environment

The uMkhomazi Estuary is situated 50 km south-west of Durban and is one of only two estuarine systems within the eThekwini Municipal boundary classified as permanently open and one of only five such systems between uThukela and Mtamvuna. This classification is not totally rigid however, as a number of mouth closure events have been recorded for this system in the last few decades. With a catchment area of ca. 4 300 km^2 it is one of KwaZulu-Natal's largest estuaries. At present, the Sappi weir above the old metal bridge about 6 km from the mouth, sets an artificial and absolute limit on tidal and to some extent saline penetration into the system.

The uMkhomazi Estuary in its present state is estimated to be 69% similar to the natural condition, which translates into a Present Ecological State (PES) of a "C" Category which is attributed to the following factors:

- The weir in the upper reaches reducing the connectivity between the river and estuary and contributing to loss of estuarine habitat;
- Sand mining that has taken away the sandbanks in the upper reaches, resulting in loss of intertidal areas and backwater refuge areas;
- Recreational activities (e.g. boat launching) in the lower reaches affecting bird abundance;
- Over exploitation of living resources (e.g. cast netting and line fishing); and
- Agricultural activities and disturbance in the Estuary Functional Zone (EFZ) causing loss of estuarine habitat.

Both flow and non-flow related impacts have played a role in the degradation of the estuary. Of significant importance is the quality of influent water. Non-flow-related impacts to the system include habitat loss (within the 5 m contour and above the Sappi weir) along with water quality problems because of the high nutrient load associated with Waste Water Treatment Works (WWTWs) (e.g. Craigieburn sewerage treatment plant), are considered to be the most important factors influencing the ecological health of the system. Excess nutrients in the inflowing water are likely to become increasingly important in future especially with increased abstraction of freshwater from the system. Retention of these high concentrations of nutrients could lead to nuisance algal growth, low dissolved oxygen in the water and reduced habitat quality.

The Estuary Importance Score (EIS) takes size, the rarity of the estuary type within its biographical zone, habitat, biodiversity and functional importance of the estuary into account. Biodiversity importance, in turn is based on the assessment of the importance of the estuary for plants, invertebrates, fish and birds, using rarity indices. EIS was estimated at 85, i.e. the estuary is rated as "Highly Important". The functional importance of the uMkhomazi Estuary is very high. It serves as an important nursery for exploited fish stock. In addition, it is also an important movement corridor for eel species found in this system, at least one of which (*Anguilla bicolor*) is CITES listed. The contribution of the uMkhomazi Estuary to ecological functioning of the nearshore marine environment is also considered to be very high. It is one of five key systems (Mfolozi, Mvoti, uMngeni, uMkhomazi, and Umzimkulu) that supply sediment, nutrients and detritus to the coast. The sediment load from the uMkhomazi is especially important as it is habitat forming, and plays an important role in maintaining the beaches and near shore habitats along this coast. The uMkhomazi also forms part of the core set of priority estuaries identified in the National Estuary Biodiversity Plan in need of protections to meet biodiversity targets under the Biodiversity Act and National Estuarine Management Protocol promulgated under the Integrated Coastal Management Act.

Given the high conservation importance of this estuary, and in spite of the fact that the ehalth of the system is rated as C at present, the recommended category for the system as gazetted in terms of the classification study that was undertaken for the system (DWS 2014), is a B category (i.e. one level higher than present).

Project description

Current water resources supplying the South Coast of KZN are considered insufficient to meet the projected water demands. The upper and middle South Coast are currently supplied by water from local rivers and dams, augmented by the Mgeni System. The Mgeni System is the main water source that supplies about six million people and industries in the eThekwini Municipality, uMgungundlovu District Municipality (DM), Msunduzi Local Municipality (LM), and a small portion of Ugu DM. The Lower uMkhomazi Bulk Water Supply System (LUBWSS) is the recommended augmentation option to be implemented to supplement potable water supply to the existing Upper and Middle South Coast supply area. Most of the requirements for water in the Mvoti sub-area are used for irrigation, although significant quantities are also required for urban and industrial purposes, as well as for rural use and to allow for the impacts of afforestation. Water use in the Mkomazi sub-area is characterised by the large requirements for bulk industrial use at the Sappi Saiccor pulp and paper mill near the coast. The proposed development falls within the Mvoti to Umzimkulu Water Management Area (WMA) (Figure 1.1) and is mostly located in quaternary catchment U10M, with a small portion falling within U80L in the uMkhomazi River Catchment.

The proposed LUBWSS development will have a potentially negative effect on the uMkhomazi estuary. In total two potential impacts on the estuarine environment were identified for the construction phase and the operational phase of the project:

- Decreased flow of water due to abstraction of water from the river
- Impact to sediment balance

Impacts during the proposed construction phase of the development were all deemed to be of **low** significance and with recommended mitigation would decrease to **very low** according to the scoring system used to evaluate impacts (Appendix A).

Impacts during the proposed operational phase of the development on the other hand were both scored as a **high** significance and could be reduced to a **medium** significance with appropriate mitigation.

With regard to mitigation, it is suggested that projected water requirements for the LUBWSS should be achieved through one of the flow scenarios identified in the Mvoti to Umzimkulu Classification study (DWA 2014) that enabled the uMkhomazi estuary to achieve the Recommended Ecological Category (REC) for the system of a "B" (viz. MK21, MK22, MK23, and MK42). A summary of the monthly flow requirements for these scenarios (in m^3/s) is presented in the table below. In terms of these flow requirements, the minimum flow at the head of the estuary should not drop below 1.2

m^3/s even under extreme drought conditions (flows should exceed this level 99.9% of the time). This translates to a minimum monthly flow rate of 3.2 Mm^3. This is designed to ensure that the mouth of the estuary remains open as was the case historically.

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	198.0	129.1	174.9	200.2	240.4	247.5	132.3	126.9	82.9	32.4	32.3	226.7
99	78.4	126.7	131.5	197.8	215.7	221.7	110.9	98.2	39.5	22.3	27.0	79.9
90	12.3	32.9	77.8	112.8	133.2	106.1	60.6	18.0	7.2	7.8	4.5	4.1
80	9.5	21.0	55.6	80.7	105.1	76.8	42.1	11.6	6.2	4.7	3.9	3.8
70	8.0	17.8	39.2	68.0	81.9	58.3	28.7	10.6	5.6	4.0	3.4	3.5
60	6.8	14.3	27.1	52.3	69.3	52.0	25.7	9.5	5.1	3.6	3.0	3.1
50	5.7	12.5	20.2	39.9	60.0	44.0	24.1	8.5	4.7	3.0	2.3	2.5
40	4.6	10.5	16.3	29.6	46.7	40.3	19.0	7.1	3.8	2.5	1.7	2.0
30	3.8	8.2	12.0	22.0	41.6	36.4	12.7	5.8	3.1	1.9	1.5	1.7
20	2.8	5.6	8.2	13.9	32.9	28.8	10.0	4.5	2.2	1.5	1.4	1.5
10	1.6	3.1	3.8	8.1	19.6	21.3	6.6	3.5	1.8	1.3	1.3	1.3
1	1.3	1.6	1.9	3.3	4.5	7.9	5.2	2.0	1.4	1.2	1.2	1.2
0.1	1.3	1.6	1.9	2.9	2.1	6.5	4.7	1.6	1.3	1.2	1.2	1.2

The Mvoti to Umzimkulu Classification study (DWS 2014) also included a number of additional non-flow related environmental offset interventions that should be implemented in conjunction with the recommended flow scenario. While it is recognised that most of these interventions are not within the power of Umgeni Water to implement these are nonetheless included here for completeness:

- Remove sand mining from the upper reaches below the Sappi Weir to increase natural function, i.e. restore intertidal area.
- Restoration of vegetation upper reaches and along the northern bank, e.g. remove aliens and allow disturbed land to revert to natural land cover (is already on upwards trajectory).
- Curb recreational activities in the lower reaches through zonation and improve compliance.
- Reduce/remove cast netting in the mouth area through estuary zonation or increase compliance; and
- Relocate upstream, or remove, the Sappi Weir to restore upper 15% of the estuary.

Recommendations and a monitoring regime are also tabled in the final section of this report.

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GLOSSARY

Alien	An organism occurring outside its natural past or present range and dispersal potential including any parts of the organism that might survive and subsequently reproduce (organisms whose dispersal is caused by human action).
Anaerobic conditions	The absence of molecular oxygen or air
Autotroph	An organism capable of synthesizing its own food from inorganic substances using light or chemical energy. E..g. green plants, algae, and certain bacteria.
Bathymetry	The measured depth of water in oceans, seas, or lakes
Catadromous	Migratory behavior of organisms that spend most of their lives in freshwater but travel to the sea to breed
Chlorophyll	The green pigment found in the chloroplasts of higher plants and in cells of photosynthetic microorganisms (e.g. photosynthetic bacteria), which is primarily involved in absorbing light energy for photosynthesis.
Clariflocculators	Is a combination of flocculation and clarification in a single tank.
Detritivores	An organism that feeds on and breaks down dead plant or animal matter, returning essential nutrients to the ecosystem
Ephemeral	A stream that flows only briefly during and following a period of rainfall in the immediate locality.
Epiphyte	A plant that grows on another plant upon which it depends for mechanical support but not for nutrients.
Exotic	See definition of 'Alien'
Fauna	General term for all of the animals found in a particular location.
Flagellum	Plural flagella or flagellums. In protists, a long, whiplike membrane-enclosed organelle used for locomotion or feeding. In bacteria, a long, whip-like proteinaceous appendage, used for locomotion.
Flora	General term for all of the plant life found in a particular location.
Frustules	the siliceous cell wall of a diatom
Invasive	Alien organisms that have naturalised in a anew area and expanding their range.
Invertebrate	An animal that has no backbone or spinal column and therefore does not belong to the subphylum Vertebrata of the phylum Chordata
Macrobenthos	Benthic organisms that are big enough to be seen with the naked eye.
Macrophyte	A macroscopic plant, commonly used to describe aquatic plant, that is large enough to be visible to the naked eye.
Oligotrophic	A waterbody characterised by low accumulation of dissolved

	nutrients, supporting only a sparse growth of algae and other organisms, with a high oxygen content owing to the low organic content.
Plankton	Small organisms that float or drift in great numbers in bodies of salt or fresh water. Plankton is a primary food source for many animals, and consists of bacteria, protozoans, certain algae, cnidarians, tiny crustaceans such as copepods, and many other organisms.
Taxa	A group of one or more populations of an organism or organisms seen by taxonomists to form a unit.
Turbidity	The cloudiness or haziness of a fluid caused by large numbers of individual organic and/or inorganic particles that are generally invisible to the naked eye, similar to smoke in air. The measurement of turbidity is a key test of water quality.
Upwelling	A process that is induced by offshore winds transporting coastal surface water offshore, which is replaced by rising deep, cold and nutrient-rich water.
Zooplankton	Plankton that is of animal origin.

LIST OF ABBREVIATIONS

AADD	Average Annual Daily Demand
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
OCS	Cwabeni Off-channel storage
CUMEC	Cubic Metres per Second
DM	District Municipality
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EFZ	Estuarine Functional Zone
EIA	Environmental Impact Assessment
KZN	KwaZulu Natal Province
LM	Local Municipality
LUBWSS	Lower uMkhomazi Bulk Water Supply System
MAR	Mean Annual Runoff
MPB	Microphytobenthos
MSL	Mean Sea Level
PES	Present Ecological Status
RMZ	Recommended Mixing Zone
TSS	Total Suspended Solids
WC/WDM	Water Conservation and Water Demand Management
WMA	Water Management Area
WQG	Water Quality Guidelines
WTP	Water Treatment Plant
WWTW	Waste Water Treatment Works

1 INTRODUCTION

1.1 Background

Relevant details regarding the proposed develop under consideration in this report are summarised from the Technical Feasibility Study report (AECOM, 2016a). The current water resources supplying the South Coast of KZN are insufficient to meet the projected water demands for the region. The Upper and Middle South Coast are currently supplied by water from local rivers and dams, augmented by the Mgeni System. The Mgeni System is the main water source that supplies about six million people and industries in the eThekwini Municipality, uMgungundlovu District Municipality (DM), Msunduzi Local Municipality (LM), and a small portion of Ugu DM. These municipal areas comprise the economic powerhouse of the KZN.

Currently, Umgeni Water is pursuing this project as a scheme for domestic water supply to the South Coast. Augmentation of the water resources supplying the South Coast is urgently needed to relieve the load on the Umgeni Water supply system, and to meet growing water demands along the South Coast of KZN.

Recently, Ugu DM and the Department of Water and Sanitation (DWS) agreed on the Cwabeni Off-channel Storage (OCS) Dam as a solution for the Lower South Coast Area. As such, a dedicated augmentation for the Upper and Middle South Coast supply area (Hibberdene to Amanzimtoti) is required. Two main options are being investigated at a feasibility level: (1) desalination of seawater, and (2) the Lower uMkhomazi Bulk Water Supply System (LUBWSS).

The LUBWSS is the recommended augmentation option to be implemented to supplement the potable water supply to the existing Upper and Middle South Coast areas. To determine the size of the proposed LUBWSS, the supply area and current and future water requirements had to be defined. The supply area extends from Amanzimtoti in the north to Hibberdene in the south, and covers both eThekwini and Ugu Municipalities.

A pre-feasibility scheme concept was provided by Umgeni Water which investigated scheme configuration options for the LUBWSS based on the supply area and current and future water requirements. The details of the scheme chosen are as follows:

- Releasing water from the Ngwadini Dam into the river in the dry months and abstracting the water again at two alternative points lower down the uMkhomazi River (previously Mkhomazi River); one point 13 km downstream at the existing Goodenough weir, and one point 17 km downstream at the existing Sappi Saiccor abstraction weir.
- The return of stored water to the river from Ngwadini Dam in the low flow periods and abstraction at the existing Goodenough weir and delivery to the WTP through a shorter 7km pipeline.

The proposed scheme will supply water to the Middle and Upper South Coast areas (Hibberdene to Amanzimtoti) within KZN. The project area is situated in the eThekwini Metropolitan Municipality in KZN. The proposed developments are located approximately 10 km north of Scottburgh.

The Goodenough Weir and Abstraction Works, and Goodenough High Lift Pump Station are located on the uMkhomazi River. From the abstraction works and pump station, the rising main to hydrocyclones runs towards the High Lift Pump Station. A rising main then runs from the High Lift Pump Station to the Raw Water Goodenough Reservoir. The gravity main runs from the Goodenough Reservoir to the two alternative WTP sites. The two WTP alternatives, the gravity mains and the Quarry Reservoir, are located within the town of Craigieburn. The towns Roseneath, Naidooville and Magabeni are located near the proposed developments.

The LUBWSS pipeline routes traverse both Ingonyama Trust land and private land. Affected landowners and land users have been consulted during the Pre-feasibility and Feasibility Studies. It was essential that the first interactions provided a solid base from which Umgeni Water can continue engagement and negotiations (AECOM, 2016).

The proposed development falls within the Mvoti to Umzimkulu Water Management Area (WMA) (Figure 1.1) and is mostly located in quaternary catchment U10M, with a small portion falling within U80L in the uMkhomazi River Catchment.

The WMA is drained by several parallel rivers including the Mvoti, Mgeni, Mkomazi, Umzimkulu and Mtamvuna Rivers which all flow in a south-easterly direction to discharge into the Indian Ocean (DWAF, 2003). Rainfall is relatively high and uniformly spread compared to other parts of South Africa, and ranges from 800 mm per year to nearly 1 500 mm along the coast and at the escarpment. Most of the rain occurs in summer, with occasional dustings of snow in some high lying areas.

Most of the requirements for water in the Mvoti sub-area is for irrigation, although significant quantities are also required for urban and industrial purposes as well as for rural use and to allow for the impacts of afforestation. Water use in the Mkomazi sub-area is characterised by the large requirements for bulk industrial use at the Sappi Saiccor pulp and paper mill near the coast.

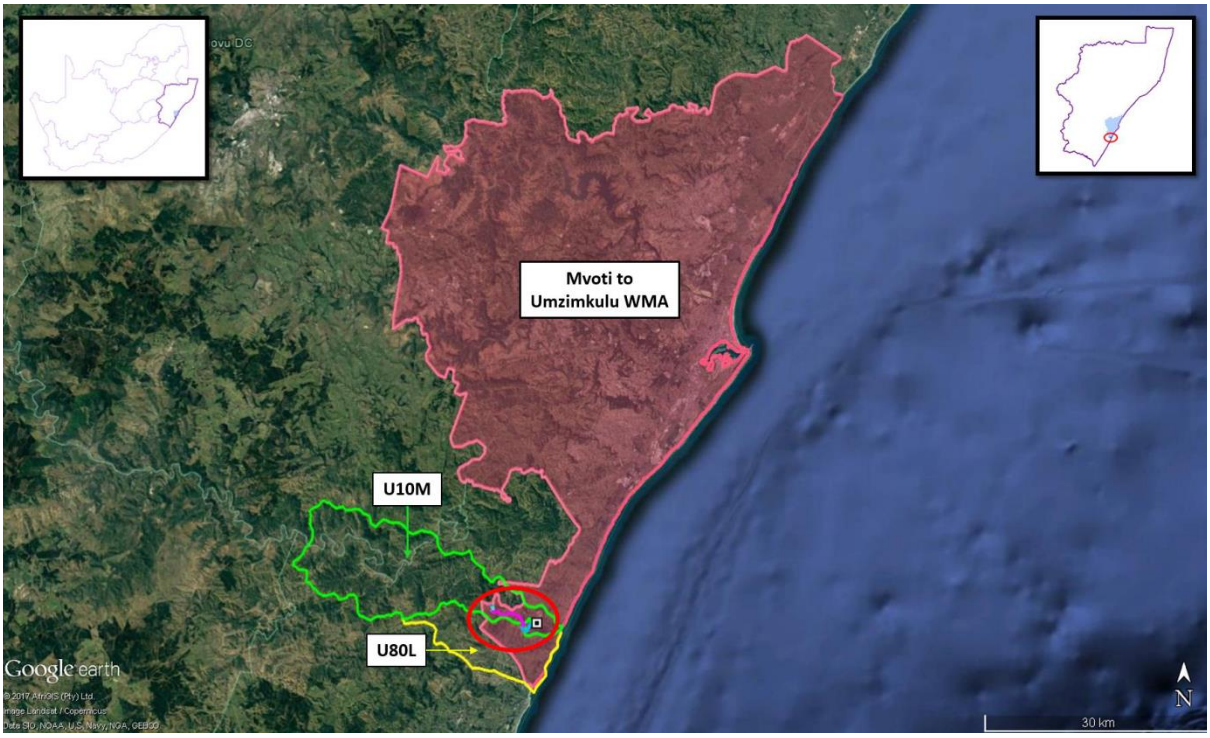

Figure 1.1 Mvoti to Umzimkulu Water Management Area (WMA).

1.2 Terms of Reference

This specialist report and impact assessment focuses on the uMkhomazi estuary, but also considers the wider uMkhomazi River catchment area's biogeographical context. Information and data collected from previous studies conducted within the river system were used with available scientific literature to describe the estuarine, microalgae, macrophyte, invertebrate, fish and bird ecology in the uMkhomazi estuary (Figure 1.2). For the purposes of the assessment, the study area was considered to include the functional zone of the estuary (Figure 3.1). This is the portion of the estuarine environment that is likely to be most impacted by the proposed development.

Impacts of returning sediment from hydroclones at the abstraction works and operational reservoirs back to the uMkhomazi River were assessed in the general context of the estuarine habitats found in the area and impacts and mitigation measures are provided with particular reference to the flow alterations and sediment loads.

All information contained in this report is based on a review of the technical reports for the LUBWSS project, environmental impact assessments conducted for estuaries elsewhere in South Africa, relevant scientific literature, World Wide Web sources and the consultant's own experience and knowledge of estuarine ecology.

ToR for this estuarine specialist study included in the Scoping Report for this study included the following elements:

- Undertake desktop study (literature review, topographical maps and aerial photographs) and baseline survey and describe the uMkhomazi Estuary.
- Determine ecological status of the receiving estuarine environment, including the identification of endangered or protected species.
- Assess impacts related to the proposed LUBWSS and associated release of sediments on the uMkhomazi Estuary, with particular reference to the flow alterations and sediment loads.
- Provide suitable mitigation measures to safeguard the estuary during project life-cycle.
- Recommend monitoring programme and indicators for project life-cycle, where findings from survey would serve as baseline data.
- Compile a report that reflects the above and includes appropriate mapping. Ensure that the report complies with Appendix 6 of GN No. R982 (2017), as part of the EIA Report.

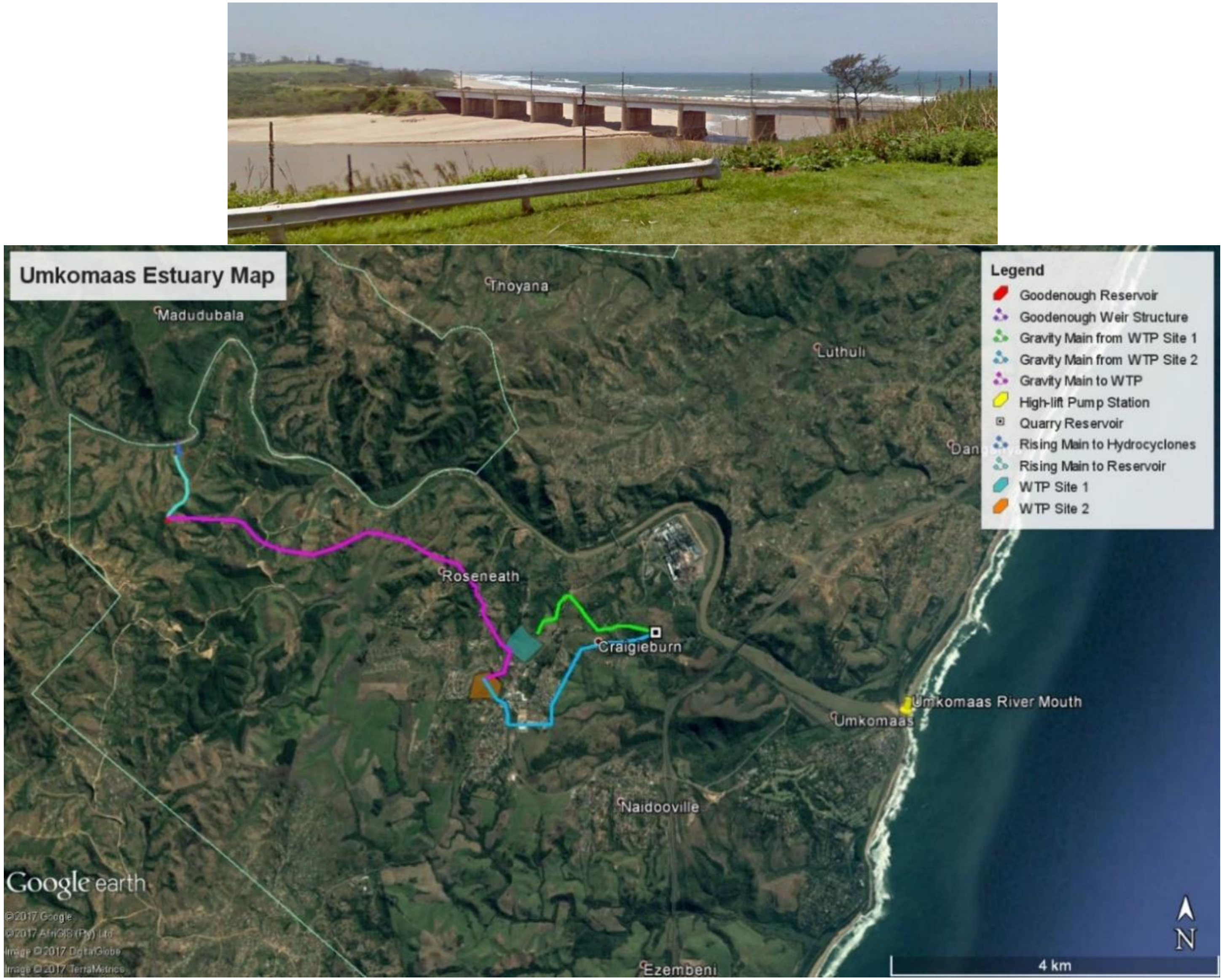

Figure 1.2 **Locality and current project layout of the proposed LUBWSS along the uMkhomazi River and Estuary.**

2 DESCRIPTION OF THE PROPOSED DEVELOPMENT

Water demand projections for the lower South Coast indicate that demand will rise from the current 85 Mℓ/d average annual daily demand (AADD), and 110 Mℓ/d peak demand, to somewhere between 155 and 205 Mℓ/d over the next 30 years, depending on the scenario chosen (low, medium or high water demand) AECOM (2016a). Very little of this additional demand can reliably be supplied by existing water sources, as the current water demands are very close to exceeding the available water in the system. The Lower uMkhomazi BWSS has been identified as a potential solution to this problem and comprises of the following (Figure 2.1):

1. The Ngwadini Weir and abstraction works with rated capacity of capacity of 1.0 m^3/s designed to fill the Ngwadini off-channel storage (OCS) Dam during summer periods of excess flow;
2. The Ngwadini OCS Dam, with a capacity of 10 million m^3, and outlet infrastructure to release water back into the river and augment low flow periods;
3. A second abstraction downstream at the Goodenough Weir site to abstract the raw water for delivery to the water treatment plant (WTP);
4. A pump station to pump water from the Goodenough abstraction to the WTP via a short rising main and 7km gravity main with a break pressure tank that also serves as a raw water storage reservoir;
5. Hydrocyclones before the pump station and WTP to remove sediments during periods of higher turbidity river flows and reduce the WTP residual "sludge", and the unnecessary pumping of additional sediments;
6. A 100 Mℓ/d WTP in the town of Craigieburn; and
7. A potable gravity water pipeline from the WTP to Quarry Reservoir, the potable water delivery and tie-in point on the South Coast Pipeline.

It is not clear exactly how much water will be extracted from the uMkhomazi River as part of this scheme but it is assumed to correspond to what is described in the Classification Study for the Mvoti to Umzimkulu Water Management Area (DWS 2014) as "Scenario MK2: Ultimate Development, uMkhomazi Water project (uMWP-1) and Ngwadini OCD (No uMWP-1 Support)".

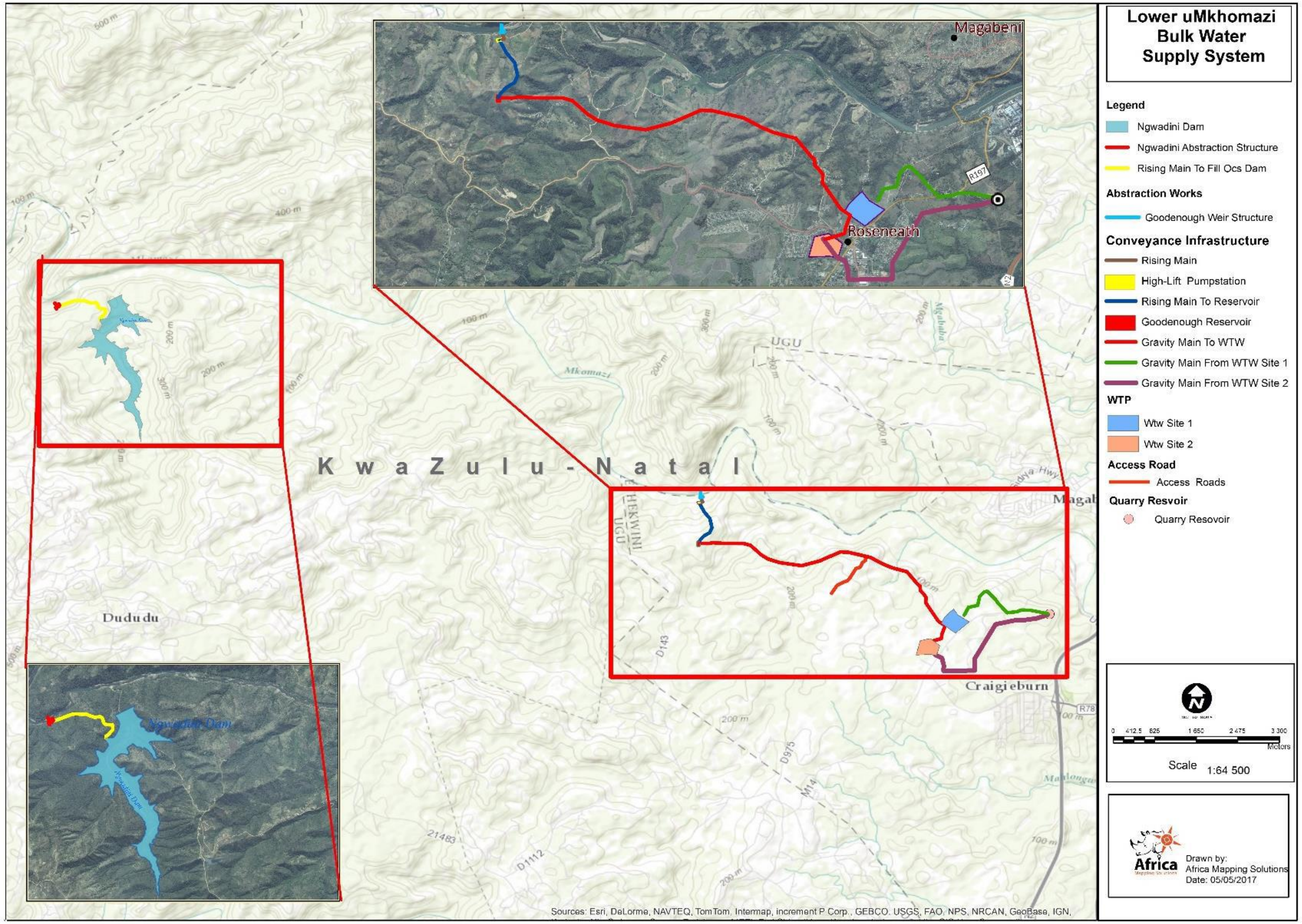

Figure 2.1 Proposed location of the LUBWSS along the uMkhomazi River, KwaZulu-Natal Province.

3 DESCRIPTION OF THE UMKHOMAZI ESTUARY

3.1 Geographic Setting

By definition, an estuary constitutes a partly enclosed coastal body of water with one or more rivers or streams flowing into it, and with a free connection to the open sea. These systems form a transition zone between river and ocean environments and are subject to both marine influences (e.g. tides, waves, and the influx of saline water) and riverine influences (e.g. flows of fresh water and sediment). The high productivity in estuaries stems from the inflow of both seawater and freshwater, which provide high levels of nutrients in both the water column and sediment.

The Umkhomazi Estuary is located approximately 42km south of Durban, at the river mouth of the uMkhomazi River 30°12’S, 30°49’E (Figure 3.1). The existing Goodenough weir is located 14 km from the river mouth of the Umkhomazi (Figure 2.1). The uMkhomazi Estuary is classified as a “permanently open” estuary, but the marine influence upstream of the inlet is limited for a large part of the year (Whitfield, 1992). The uMkhomazi estuary is relatively straight for much of its length only undulating around the headland on which the Sappi Saiccor factory is located. It is a wide shallow system with a mouth that very seldom closes. The suburb of Umkomaas lies on the south bank of the estuary. While the system was classified as a permanently open estuary by Whitfield (2000), it is the authors’ contention that this system is better classified as a river mouth. This is confirmed by almost 10 years of data on this system which includes both low flow and high flow periods (Forbes *et al.* 2008). This would make it the only one of this type within the municipality. There are two existing bridges, viz. the combined road and rail bridge at the mouth and the newer N2 freeway bridge further upstream. The old steel bridge is above the present limit of estuarine penetration.

For the purposes of this study, the geographical boundaries of the estuary are defined as follows (Figure 3.1):

- Downstream boundary - Estuary mouth: 30°12'4.45"S 30°48'8.65"E
- Upstream boundary - 30°10'25.64"S 30°44'51.42"E
- Lateral boundaries - 5 m contour above Mean Sea Level (MSL) along each bank

Figure 3.1. Geographical boundaries of the uMkhomazi Estuary based on the Estuary Functional Zone. *Goodenough Weir is not visible on this map, Sappi Weir is located at the dark and light blue boundary.

The true extent of the upper boundary (marked in dark blue in Figure 3.1) of the uMkhomazi Estuary is not known as the full extent of tidal penetration is currently constrained by a weir (Sappi Weir). However, for the purpose of this study the upper reaches were taken as about 1.7 km upstream of the weir, based on channel and vegetation features. The original boundary may well be significantly further upstream. The positioning of the uMkhomazi Estuary's upper boundary is further confounded by back flooding above the weir, which decreases flow velocities that in turn leads to localised sedimentation in this zone under normal flow conditions. Topographical survey information is needed to accurately determine the upper boundary of this system.

The uMkhomazi Estuary has been divided into four distinct zones for ease of reference and were delineated according to bathymetry (DWS 2014). Table 3.1 below lists some of the key features of the uMkhomazi Estuary zonation that were used by DWS to determine the weighting of scores.

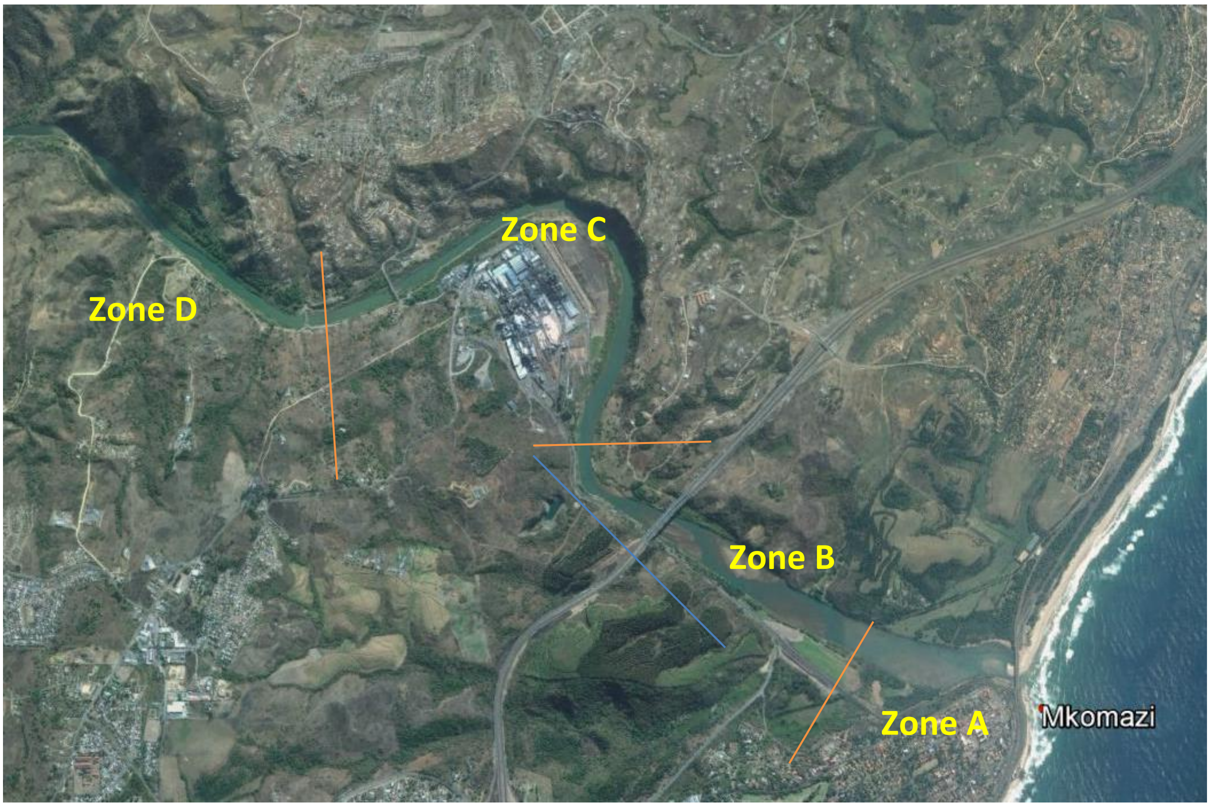

Figure 3.2 **Zonation of the uMkhomazi Estuary (DWS 2014).**

Table 3.1 **Key features of the uMkhomazi Estuary zonation (DWS 2014).**

	Zone A: Lower	Zone B: Middle	Zone C: Upper	Zone D: Historical upper
Area (ha)	26.5	20.1	16.1	9.4
Maximum depth (to MSL)	-0.5 to -1.0	-1.5 to - 2.0	-2.0 to -3.0	1.0 – 2.0 deep (at about -1. m MSL)

3.2 River Catchment and Hydrological Characteristics

3.2.1 Physico-chemical Properties

3.2.1.1 Physical

According to historic documentation the normal flow and flood events in the uMkhomazi, generally lead to high sediment loads within the estuary. While there have been times in the past that when the river was navigable for 24km and there was a natural harbour for 60 ton vessels, the general trend has been the gradual infilling of the estuary over time (Forbes et al. 2008). In 1967 160mm of rain in the catchment produced 608,000 tons of sediment and on another occasion 190mm of rain produced 494,000 tons of sediment. This can have a negative impact on an estuary if sediment load inundates benthic life or alters the terrain and habitat to such an extent that the environment becomes dysfunctional. Alternatively, events like that in 1987, described by Perry (1989) as a "wet flood", where a flood event was preceded by periods of sustained heavy rainfall which amounted to less sediment being available for removal by the river, consequently allowing for deeper scouring of the river bed (Forbes et al. 2008). It is evident that over geological time, and assuming stable sea and land levels, there will be a net sediment accumulation in an estuary, with periodic pulses of scouring or accumulation depending on the nature and frequency of flood events.

The uMkhomazi estuary has experienced a gradual shallowing over time due to the somewhat regular flood events and seasonal transport of sediment to the system. Begg (1978) cited estimated annual loads of 900,000 tons per year between 1965 and 1967. Other estimates are of 752 000 tons in summer and 15 000 tons in winter. By the early 1980s the deepest point of the estuary was on the south side and approximated as 2.3 m (Forbes et al. 2008). Regular sedimentation resulted in the estuary becoming a shallow system where much of the bottom becomes exposed as emergent banks at low tide (Forbes et al. 2008). During this time bottom sediments were primarily sandy, but both the types of sediments and their distribution varied longitudinally and across the estuary from soft mud to relatively coarse sediment depending on the meanderings of the channel and the input of marine sands (Forbes et al. 2008).

Sediment analyses provided by Forbes et al. (2008) indicated very uniform, well sorted sediments in the mouth area consisting of medium (0.25 mm) to fine (0.125 mm) sands. Sediments in the mid reaches below the N2 bridge were not as well sorted as the mouth sediments and relatively much coarser consisting of a mix of granules (2 mm), very coarse (1 mm) and coarse (0.5 mm) sands. The area below the weir was continually affected by the Sappi weir and the activities of the local sand miner resulting in highly variable sediments ranging from pebbles and small rocks to very fine silty sediments with sub-sieve components ranging from less than five to 40%.

Records of the mouth condition from 1979 to 2008 indicated that the system was essentially permanently open, although it did close for a few days in July 1980 and September 1982 as well as during winter periods of low flow between 1992 and 1996 (Forbes et al. 2008). The rare occasions of closure meant that artificial breaching was generally not seen as necessary but apparently skiboat owners were known to "encourage" the mouth to switch from a northerly to a more southerly position to facilitate launches (Airey pers.comm., Forbes et al. 2008). One official artificial breach occurred in 2003 shortly after a mouth closure. It has remained open since this time. The open condition was maintained by river discharge, wave and tidal scour but there was some alteration of the mouth position.

In short, historical sedimentation from intense flooding periods ultimately led to shallowing of the estuary from an upstream to downstream gradient over time which ultimately led to intermittent closures of the estuary. The infrequency of the closures still lend to the classification of an open estuary as long as natural river discharge events are allowed.

3.2.1.2 Chemical

Unpublished data (MER, DWS 2014) show that salinities in the uMkhomazi estuary are frequently stratified, even in depths as shallow as 40 cm, but this will vary widely depending on the state of the tide and the river flow. Low river flows result in marine intrusions and layering but strong river flows result in freshwater conditions virtually to the surf zone. Temperatures follow the salinity distribution patterns with river water often being markedly cooler (Winter: Surface 16-21.5 °C, Bottom 15.8-21.2°C; Summer: Surface 27.5-29.8° C, Bottom 27.5-29.5 °C) than any intruding sea water (Forbes *et al.* 2008).

According to the estuarine specialist study by Forbes et al. (2008), the estuary is generally well oxygenated due to the strong river or tidal flows (DO 5.6 8.4 mg/L, DO % sat 80-88) with the only reductions occurring in the vicinity of the Mpisini inlet which is surrounded by an industrial waste dump, municipal refuse dump and sewage works. Oxygen levels in this area occasionally drop to less than 1 ppm (Forbes *et al*. 2008). Turbidity is increased by strong freshwater inflows during summer months and reduced during low flow periods or by intruding seawater, more likely in winter (Forbes *et al*. 2008). Apart from the potential pollutants referred to above, the SAICCOR factory which began operating in June 1955 (Burton 1960) and particularly the discharge of its effluent material into the sea immediately south of the estuary mouth, have been major factors in the past. The most notable development from the discharge of calcium lignosulphate, which had a detergent effect, and in combination with strong wave action, resulted in a “stable white foam that frequently covered the shore to a considerable depth” (Burton 1960, Forbes *et al.* 2008). Investigations into possible effects on the estuarine fauna using the benthic fauna of sandy sediments as indicators, were eventually abandoned because of the “sparseness of the fauna” which was possibly due to non-pollutant influences (Forbes et al. 2008). Begg (1984a), however, recorded investigations of the high level of toxicity of the effluent and the concern over seepage and periodic spillages from the concrete effluent canal into the estuary. The effluent liquid was also lighter than seawater and consequently tended to float on the seawater and could then be blown back or tidally transported into the estuary where the high oxygen demand resulted in fish kills. A very small number of water analyses between 1964 and 1982 aimed at identifying other sources of pollution indicated raised levels of phosphates in summer 1964, of suspended solids in July 1981 and August 1982 and E.coli and presumptive coliforms in November 1979, July 1981 and August 1982. The broad interpretation at the time was that the uMkhomazi was slightly, and possibly only locally polluted (Forbes *et a*l 2008). Harrison *et al.* (2000) rated the water quality as good. While nutrient levels were relatively low during the two sampling events (NH_3 0.03-0.056 mg l^{-1}, NO_2 0.001-0.003 mg l^{-1}, NO_3 0.1-3.14 mg l^{-1}, PO_4 0.05-5.58 mg l^{-1}) both previous work (MER, unpublished data) and the 2007/2008 MER programme (Forbes et al. 2008) showed that the Mpisini stream is a constant source of nitrates and phosphates with values up to an order of magnitude and two orders of magnitude higher respectively than anywhere else (Demetriades and Forbes 2007). This is attributable to the Umkomaas Waste Water Treatment works which is not able to cope with increasing demands. The MER survey found relatively low bacterial levels in the uMkhomazi estuary in August 2007 (*E. Coli* and F. coliform 0-130 counts/100 ml) although there were raised levels at the Mpisini stream and the factory site. Much higher levels (*E. Coli* and F. coliform 420-1000 counts/100 ml) were found in February 2008 despite this being a period of generally higher river flows which would be expected to reduce the numbers. The low chlorophyll values (0.2-0.4 mg m^{-3}) are in keeping with the lower retention times that would occur in summer.

3.2.2 Land use and vegetation

Begg (1978), Day (1981) and Forbes et al. (2008) paint a picture of a largely impacted estuarine environment by development over time. A 1937 aerial survey showed an estuary already highly impacted by human habitation on the southern bank at the mouth and by extensive agriculture on both banks (Forbes et al. 2008). The riparian zone was heavily impacted, especially on the southern bank. The earliest recordings on the vegetation are those by Day (1981) who referred to conditions in 1950 when coastal bridge construction associated with embankments on the north bank protected a “muddy cove overgrown with reeds and coarse grasses and a small stand of mangroves including Avicennia, Brugueira and the freshwater mangrove (sic.) *Hibiscus tiliaceus* (Forbes et al. 2008). (This cove) subsequently silted up and mangroves now occur on the south bank about 700 m from the sea”. Begg (1984) described the peripheral vegetation as being better preserved downstream because of the absence of sugarcane. The most significant area was in the lower reaches along the south bank where there was a “dense fringe of lagoon hibiscus (*Hibiscus tiliaceus*) beyond which was a relict mangrove community” ”in poor condition because of impeded drainage and inadequate tidal exchange.” “On the opposite bank (was) a mixed community of reeds, sedges and bullrushes”. According to Day (1981), based on observations in 1950, there was no submerged vegetation of any description at that time. The Marine and Estaurine Research (MER) survey of 2007 shows little change. Sugar cane farming occurs to the water’s edge, clearing of riparian vegetation for the Sappi railroad and pipeline and removal of dune scrub at the mouth for an access road and car park are all features of the southern bank (Forbes et al. 2008). Excessive clearing of vegetation at the ski-boat base and along the south bank to gain access to the estuary for fishing were reported. A rocky cliff on the north bank, too steep for cultivation, has remnant coastal forest with a well-developed under-storey. Sand mining activities are destroying floodplain and riparian vegetation and creating roads and stockpiles within the estuary. The northern bank at the mouth is impacted by Casuarina trees, an invasive species, and removal of riparian vegetation in favour of an extensive, lawned area. These marks of current development documented by Forbes et al. (2008) indicate a greatly altered estuarine environment.

3.3 Ecology

The uMkhomazi estuary is an ecologically important environment that has been degraded over time by human influence through development and use. The Estuary Importance Score (EIS) takes size, the rarity of the estuary type within its biographical zone, habitat, biodiversity and functional importance of the estuary into account. Biodiversity importance, in turn is based on the assessment of the importance of the estuary for plants, invertebrates, fish and birds, using rarity indices. Estuary importance was estimated at 85, i.e. the estuary is rated as “Highly Important”. The functional Importance of the uMkhomazi Estuary is very high. It serves as an important nursery for exploited fish stock and plays a very important role from a fish egg production perspective. In addition, it is also an important movement corridor for eels (CITES listed species). The functional importance of uMkhomazi Estuary is also very high for the nearshore marine environment. It is one of five key systems (Mfolozi, Mvoti, uMngeni, uMkhomazi, and Umzimkulu) that supply sediment, nutrients and detritus to the coasts. The sediment load from the uMkhomazi is especially important as it is habitat forming and plays an important role in maintaining the beaches and near shore habitat along this coast (DWS 2014).

3.3.1 Microalgae

The microalgae component comprises the autotrophic microorganisms, i.e. those that contain chlorophyll and, as a result, are able to convert sunlight into living material. In this capacity they are at the base of the food chain and responsible for most of the food consumed by the primary consumers. This is especially important in that they provide the food resources for the juvenile fish and benthic microorganisms, including those that, in the adult form, are found in the sea and play an important role in the South African economy (DWS 2014).

They are grouped into two main types, the planktonic and the benthic. The planktonic group are the phytoplankton (plants in the water column) while the benthic group comprise the microphytobenthos (small plants found mostly attached to sediment particles (mud, sand, gravel, rocks). The true phytoplankton usually have flagellae which enable them to maintain a position in the water column, while the microphytobenthos are not flagellated and are therefore unable to maintain a position in the water column (DWS 2013).

These organisms are greatly influenced by the amount of water flowing through the estuary as well as the way it passes through the estuary, i.e. they are sensitive to the hydrology and the hydrodynamic flows. The amount of water in the system and the continuity of flow determine the volume available and thus the absolute maximum amount of material available, while the hydrodynamic factor influences the stability of the system and especially the microphytobenthos (MPB). Estuaries with a large Mean Annual Runoff (MAR) are open more often, are usually larger and therefore are in the open mouth state for longer than those with a smaller MAR. Estuaries with a large MAR tend to be less sensitive to flow variation than do those with a small MAR. The importance of the hydrodynamic flow is that the flooding regime influences the state of the mouth, (open or closed- faunal recruitment or not) (DWS 2014).

The MPB are very important both when they are attached to sediment particles but also when they are attached to submerged or emergent plants (epiphytes), thus the status of the macrophyte community also impacts on the state of the microalgal community and whether or not the juvenile fish have an available food source in a protected environment, i.e. they have a measure of protection plus a source of food in amongst the living plant material (DWS 2014).

Microalgae respond to the nutrient status of the water column. Under reference conditions, the nitrogen and phosphorus contents are usually low, but might occasionally be raised by an abundance of large terrestrial animal excreta. Thus, the reference condition is considered to be one of low nutrient status to which the microalgae respond by having a high diversity of species. Where pollution raises the nutrient levels, the biomass rises but the species diversity is lowered, but only under extreme conditions (DWS 2014).

The flagellate components of the microalgal community are able to maintain themselves in the water column using their flagellae and they are usually numerically dominant when counts are made. They are made up of both autotrophic and heterotrophic organisms, the latter being consumers rather than photosynthetically productive. Despite this, they are still components that are ingested and are therefore part of the food available to larger consumers and especially fish.

The cyanophytes (blue-green microalgae) are a group of non-flagellated photosynthetic bacteria that can make up a large component of both the planktonic and benthic microalgal community. They can be important in that under certain conditions (including anaerobic) they can utilise gasses such as hydrogen sulphide in order to grow. Some species are able to fix nitrogen and can become important under conditions where the water column is oligotrophic. Certain species of cyanophytes can produce toxins which can be harmful if present in high concentration.

The green microalgae are a very diverse group that can be present in estuary waters in fairly high proportions. They are included mostly in the flagellated group and because of the flagellum they are able to maintain their presence within the water column rather than sink to the sediment surface as do the diatoms because of their silica based frustules. The phytoplankton are more sensitive to extreme floods than are the MPB which are only lost from the system under very strong flooding conditions. All records appear to show that the microalgae are a very resilient group of organisms (DWS 2014).

Under reference conditions, the flagellate community would be relatively small while under polluted conditions the heterotrophic component of the flagellate community would be expected to be high because of a high organic component in the water (DWS 2014).

3.3.2 Macrophytes

The uMkhomazi Estuary has historically supported limited estuarine vegetation according to documented reports (Day 1981, Forbes *et al.* 2008, DWS 2014). However, these macrophytes are important as they add to the aesthetic appearance of the lower reaches, filter sediments and nutrients and stabilize the banks. Swamp forest with coastal or lagoon Hibiscus (*Hibiscus tiliaceus*) was the most abundant habitat. Reeds and sedges, covered the second largest area and fringed both banks of the estuary. A stand of black mangroves, *Bruguiera gymnorrhiza*, and a few large white mangrove*, Avicennia marina*, trees were located on the south bank along the Impisini stream inlet close to the mouth of the estuary. A few tall *B. gymnorrhiza* trees were also located amongst a stand of invaded coastal forest on the north bank near the mouth. Common reed (*Phragmites australis*), bush tick berry (*Chrysanthemoides monilifera*), morning glory creeper (*Ipomoea pes-capre*) and inkberry (*Scaevola plumieri*) were visible amongst this invaded stand (DWS 2014).

A small patch of coastal forest occurred on the sloping north bank in the middle reaches. A steep rock face, vegetated with *Acacia natalensis*, was present in the middle reaches, opposite the Sappi Saiccor Factory. Hygrophilous grasses interspersed the reeds and sedges in the middle reaches of the estuary. Grasses present were antelope grass (*Echinocloa pyramidalis*), *Panicum maximum*, broad-leaved bristle grass (*Setaria megaphylla*), buffalo grass (*Stenotaphrum secundatum*) and the exotic *Paspalum dilatum* and *Paspalum urvillei*. A number of invasives were present in the estuary including Spanish/giant reed (*Arundo donax*), black wattle (*Acacia mearnsii*), beefwood (*Casuarina cunninghamiana*), Brazilian pepper tree (*Schinus terebinthifolius*) peanut butter bush (*Senna didymobotrya*) and syringa (*Melia azedarach*) (DWS 2014).

Some areas previously cultivated have been colonised by opportunistic grasses, weeds and exotic species. Species present in these disturbed areas were pennywort (*Centella asiatica*), climbing/spreading dayflower (*Commelina diffusa*), *Conyza scabrida*, prickly lettuce (*Lactuca serriola*), River nettle (*Laportea penduncularis*), *Persicaria decipiens* and bulrush (*Typha capensis*). Sediment in the reed areas was soft and muddy and no macroalgae were visible. No submerged macrophytes were found. There was no evidence to suggest the historical occurrence of any Red Data List species (DWS 2014). Species composition of uMkhomazi Estuary, including exotics are provided in a specialist report (Part of Report 8.3; Report Number: RDM/WMA11/00/CON/CLA/0714).

3.3.3 Invertebrates

The invertebrate community of the uMkhomazi estuary has a naturally low diversity and abundance at any one time. DWS (2014) sampled for invertebrates, at six sites from the mouth to the upper estuary, during the low flow winter and high flow summer periods. There was a strong contrast between the diversity and abundance of the macrobenthos in August - September 2013, when 27 taxa were recorded, and February 2014 when this number dropped to 12. The numbers of taxa at each site in August 13-September 14 were lowest at the two upper sites (6), increasing to 12 - 13 at the N2 bridge, skiboat and mouth with a maximum of 16 in the Mpisini stream. The fauna at the three upper sites was totally dominated by amphipod crustaceans. This changed to a dominance of the polychaete *Desdemona ornata* at the skiboat site. The tanaid crustacean *Apseudes digitalis* was numerically dominant in the muddy Mpisini stream but the small crab *Paratylodiplax blephariskios*, a typical inhabitant of this area, made the major biomass contribution. As indicated above, the diversity and particularly the abundance, crashed in February after the high summer flows with a maximum of five species recorded at the N2 bridge site. The only species that retained any of their winter abundance were the tanaid *A.digitalis* and the crab *P.blephariskios*, both in the relatively physically stable Mpisini stream. This is in keeping with current understanding of benthic invertebrate communities which will be disturbed and depressed by repeated strong river flows and depositional events.

All the physico-chemical parameters measured during this particular study period, and when seen in conjunction with data accumulated during the past decade (MER, 2002 - 2013) as well as the historical records (Day, 1981; Begg, 1978, 1984) characterise the uMkhomazi estuary as a naturally highly variable environment which has arguably been further modified by the actions of extensive sand mining between the N2 bridge and the weir. The variability is derived from seasonal flow fluctuations coupled with periodic major flood events such as last occurred in 1987.

Table 3.2 Physical description and average percentage cover or count of biota at six surveyed sites (DWS 2014). Values given are the average of 18 quadrats at each site (per 0.25 m²).

Substratum/Taxa		Control 1	Control 2	Control 3	Impact 1	Impact 2	Impact3	Overall
Substratum	Depth	2.4	1.7	1.9	3.0	2.7	1.6	2.23
	%Rock	80.3	81.4	73.8	88.9	73.1	76.4	79.86
	%Boulder	5.6	10.7	25.3	2.8	13.9	0.0	9.21
	%Gravel	10.8	10.3	13.9	4.4	0.0	13.1	8.56
	%Sand	1.2	2.1	3.3	3.9	8.1	10.6	5.10
Mobile Taxa (Counts)	Kelps stipes	4.9	3.1	3.8	3.5	4.3	5.8	4.25
	Urchins	23.2	0.0	0.0	0.1	0.0	0.0	3.87
	Whelks	3.8	0.2	0.2	0.9	0.7	0.1	0.97
	Limpets	0.3	2.1	0.8	0.7	0.1	0.1	0.67
	Lobsters	0.3	0.4	0.6	0.4	0.8	0.1	0.42
	Periwinkles	0.0	0.0	0.4	0.0	0.0	0.2	0.11
	Abalone	0.0	0.0	0.0	0.4	0.1	0.0	0.10
	Reticulated Starfish	0.0	0.1	0.1	0.2	0.2	0.0	0.10
	Sea Cucumber	0.6	0.0	0.0	0.0	0.0	0.0	0.09
	Cape Rock Crab	0.0	0.0	0.1	0.1	0.1	0.0	0.05
	Chitons	0.1	0.1	0.1	0.0	0.0	0.0	0.04
	Crab Sp.	0.0	0.1	0.0	0.0	0.0	0.0	0.01
	Hermit Crab	0.0	0.1	0.0	0.0	0.0	0.0	0.01
Sessile Taxa (% Cover)	Red Algae	5.0	27.0	29.6	29.7	31.9	24.2	24.57
	Encrusting coralline	15.2	28.8	22.4	27.3	4.1	23.9	20.30
	Sponge	16.3	3.5	14.6	6.4	4.1	12.1	9.49
	Cape reef worm	0.0	13.4	7.2	0.0	19.1	5.6	7.55
	Mussels	35.0	0.0	0.2	1.1	0.1	0.3	6.09
	Anemones	5.2	0.7	0.8	1.2	0.3	0.7	1.47
	Spiral fanworm	0.0	0.6	1.1	0.4	0.0	0.2	0.37
	Green algae	0.1	0.3	0.5	0.1	0.1	1.2	0.36
	Upright coralline	0.0	0.7	0.7	0.0	0.6	0.0	0.33
	Black boring worm	0.0	0.0	0.1	1.2	0.3	0.1	0.28

3.3.4 Fish

A wide variety of fishes have been sampled in the uMkhomazi system (60 distinct species) and this is reflective of reference conditions (DWS 2014). Comparative few dominate the assemblage numerically, however. This is typical of estuarine fish assemblages. Estuarine dependent marine species, followed by estuarine resident fishes, dominate the fish fauna by both numbers of species and abundance of individuals. The relative abundance of estuarine dependent marine species across indicates the nature of the uMkhomazi to be strongly estuarine and that the system is an important nursery area for these fishes. Marine taxa are more abundant than freshwater species, a fact suggestive of regular saltwater penetration under present day conditions. Under reference condition marine taxa would have occurred with less frequency and in lower abundances. Catadromous fishes (Anguillid eels) transit through the estuary, rather than spending significant time in it.

Trophically, the fish assemblage has typically been dominated by zoobenthivores and detritivores. On average zooplanktivores and piscivores contribute very little to the abundance of fishes in the system. The paucity of zooplanktivores is likely the result of poorly developed zooplankton biomass. The relative abundance of benthivores is atypical of KZN estuaries, which are usually dominated by detritivores (mullet in particular contributing high abundances). Zoobenthic feeders form a significant component of the fish assemblage. This is likely to be reflective of reference conditions (DWS 2014).

According to the DWS Estuarine Determination Report (2014), estuarine dependent marine fishes dominate the uMkhomazi fish assemblage in terms of frequency of occurrence, number of species and relative abundance. This is brought about by an abundance of juveniles of euryhaline marine fishes that are strongly dependent on estuaries (Whitfield's category IIa fish). While mullet play an important role in this, several other perciform fishes contribute significantly. These fishes occur in highest abundances the lower sections of Zone C of the estuary. This area of the estuary is where fine sediments are deposited naturally under the influence of flow and flocculation. Muddy sandbanks with stratified overlying waters (5 - 20 PSU) are strongly favoured habitat for several key estuarine as well as estuarine dependent marine fish species.

The estuarine plume in coastal waters off the uMkhomazi is an important feature of the system, playing a role in the recruitment of marine spawned fishes as well as acting as estuarine habitat during periods of high flow. In the uMkhomazi where salinity can fluctuate widely over the tidal cycle, even during normal flows, some fishes are likely to use estuarine plume waters on a tidal basis, occurring in the brackish turbid coastal waters at low tide and following them into the estuary as they are pushed back with incoming high tides. Under reference conditions tidal freshwaters would have occurred upstream of the Sappi Saiccor weir. This section of the estuary would have been favoured habitat for a number of estuarine and estuarine dependent marine fishes.

3.3.5 Birds

The avifaunal investigation done as part of the DWS (2014) study (see Avifaunal Specialist Report - (Part of Report 8.3; Report Number: RDM/WMA11/00/CON/CLA/0714) confirmed that the uMkhomazi Estuary does not support a particularly rich diversity, or large numbers, of waterbird species. The estuary also does not appear to support significant habitat for any Red Data waterbird species and the only two such species to have been recorded during counts are the Pink-backed Pelican and Woolly-necked Stork, both recorded only on single occasions. The configuration of the mouth, the bridges present there and, especially, the high level of human disturbance precludes the use of the area by large numbers of roosting terns and gulls. The reason for this relatively depauperate waterbird community is likely the absence under normal circumstance of particularly attractive waterbird habitats, e.g. there are no extensive, natural floodplain habitats associated with the estuary.

A spring field survey (DWS 2014) coincided with a period of peak back-flooding of the estuary, with the mouth closed and high inflow from the river. Relatively high numbers of a wide diversity of waterbirds were noted exploiting the ephemerally flooded areas on both the north and south banks of the estuary. This opportunistic observation demonstrates the particular value of the estuary to waterbird populations during these temporarily ideal conditions.

3.4 Current Health of the Estuary

The uMkhomazi Estuary in its present state is estimated to be 69% similar to its natural condition, which translates into a PES C Category defined as moderately modified and a marker of fair health (DWA 2013). This is mostly attributed to the following factors:

- The weirs in the upper reaches severing connectivity with the catchments.
- Sandmining that have taken away the sandbanks in the upper reaches (Zone C), resulting loss of intertidal areas and backwater refuge areas. It has also impacted on access to grazing areas as the river cannot be crossed in this section anymore.
- Recreational activities (e.g. boat launching) in the lower reaches affecting birds abundance.
- Over exploitation of living resources (e.g. cast netting and line fishing); and
- Agricultural activities in the EFZ causing loss of estuarine habitat.

Based on available literature, a number of characteristic 'states' can be identified for the uMkhomazi Estuary, related to mouth condition, tidal exchange, salinity distribution and water quality. These are primarily determined by river inflow patterns, water level and duration since last breaching. The different states are listed in Table 3.3. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions and processes are still predominantly unchanged (Table 3.4) (DWS 2013).

The water quality in a large number of estuaries in the Mvoti to Umzimkulu WMA has been modified significantly. This is largely attributed to diffuse agricultural runoff in rural areas (e.g. fertilizers, herbicides and pesticides) and contaminated stormwater runoff from urban development (e.g. nutrients and toxic substances). In some estuaries, water quality has been compromised by point source wastewater treatment works (WWTWs') effluent being discharged into estuaries or into rivers near the head of estuaries. Within the uMkhomazi estuary, the aspects that need targeting for restoration/rehabilitation were identified as significant flow reduction, poor water quality, and habitat destruction.

In addition, the system also forms part of the core set of priority estuaries in need of protection to achieve biodiversity targets in the National Estuaries Biodiversity Plan and the National Biodiversity Assessment (NBA) 2011 (Turpie et al. 2013, Van Niekerk and Turpie 2012). The NBA 2011 recommends that the minimum Category for the uMkhomazi should be a B, it be granted full no-take protection, and that 25 % of the estuary margin be undeveloped.

Table 3.3 Summary of abiotic states that can occur in the uMkhomazi Estuary.

State	Flow range (m^3/s)	Description	State	Flow range (m^3/s)
State 1: Closed, brackish	< 1.0	The estuary mouth is closed for weeks to months. Zones A, B, and C are well mixed and salinity is brackish throughout. Zones A, B and C have salinity of about 20, 20 and 10 respectively, Zone D is fresh.	State 1: Closed, brackish	< 1.0
State 2: Open, full salinity gradient	1.0 – 2.0	The system shows a marine influence due to reduced freshwater inflow and regular breaching. Zones A, B and C have salinity of about 25, 15 and 10 respectively, Zone D is fresh.	State 2: Open, full salinity gradient	1.0 – 2.0
State 3: Open, limited salinity gradient	2.0 – 5.0	Zones C and D are fresh, with limited saline intrusion into Zone B (salinity ~10). Zones A have salinity of about 20, with strong tidal flucuations been tween 30 on the high tide and 10 on the low tide.	State 3: Open, limited salinity gradient	2.0 – 5.0
State 4: Open fresh	> 5	All zones are fresh.	State 4: Open fresh	> 5

Table 3.4 PES of the estuaries of Mvoti to Umzimkulu WMA (extracted from DWS 2014).

Name	Hydrology	Hydrodynamics	Water Quality	Physical Habitat	Habitat Score	Microalgae	Macrophytes	Invertebrates	Fish	Birds	Biological Score	PES
uMkhomazi	C	A	C	D	C	C	D	C	D	D	C	**C**

4 IMPACT ASSESSMENT

The proposed LUBWSS development will have a potentially negative effect on the uMkhomazi estuary. In total two potential impacts on the estuarine environment during the construction phase were identified and two during the operational phase of the project:

Construction phase:

- Decreased flow of water due to abstraction of water from the river
- Impact to sediment balance

Operation phase:

- Decreased flow of water due to abstraction of water from the river
- Impact to sediment balance

Decommissioning phase

It is anticipated that impacts during the decommissioning phase are unlikely due to no decommissioning plans in the future.

Each identified impact is likely to affect the associated physical, chemical and biotic characteristics in different ways and at varying intensities depending on the nature of the affected habitat and the sensitivity of the environment and biota. The degree of each impact depends on the construction method used. The 'construction footprint' is defined as the total area of new infrastructure as determined by design engineers and includes any increase in weir height.

In the estuarine environment a disturbance can be relatively short-lived (e.g. temporary reduction of flow rate) or the effect may have a much longer lifetime (e.g. abstraction of water at large, unsustainable volumes that may alter the estuarine environment). The assessment and rating procedure described in Appendix 1 addresses the effects and consequences (i.e. the impact) on the environment rather than the cause or initial disturbance alone. To reduce negative impacts, precautions referred to as 'mitigation measures' are set and attainable mitigation actions are recommended. Results of each impact assessment are presented in Table 4.1 to Table 4.2 and are summarised in Table 4.27 and Table 4.28.

4.1 Construction phase

4.1.1 Alteration of Water Flow

The Goodenough Weir will be raised by 2.8 m during the construction phase which will require the temporary reduction or complete diversion and reintroduction of water flow downstream. Reduction of flow will alter flow dynamics in the estuary which can potentially lead to shallowing of the channel or destabilise estuary banks. Because the estuary is a wide shallow system any further reduction in water depth could be detrimental. However, because the duration of the impact is short term, the significance of this impact is rated as **low** (Table 4.1).

Table 4.1 Impact 1: Alteration of water flow during weir upgrade.

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	Local **1**	Low **3**	Short-term **1**	**Low 5**	Definite	**LOW**	**- ve**	Low
Essential mitigation measures: • Limit time taken to complete construction activities in the uMkhomazi River; • Constrain spatial extent of impacts to the minimum required; • Redirect water flow downstream of weir;								
With mitigation	Local **1**	Low **1**	Short-term **1**	**Very low 3**	Definite	**VERY LOW**	**- ve**	Low

4.1.2 Decrease in sediment load

The increase in height of the Goodenough weir may temporarily decrease the sediment load downstream of the construction area. Dams in rivers lead to changes in sediment load in estuaries in KwaZulu-Natal that reduce sediment supply to beaches in the region, resulting in coastal erosion. It is well documented that De Lange *et al*. (2009), for example, estimate that dams and mining remove 60-80% of natural sediment supply to the coastal zone in KZN. However, because the duration of the impact is short term, the significance of this impact is rated as **low** (Table 4.2). Additionally, more detail in sediment transport volumes and management of this system will be addressed in the Sediment Specialist Report.

Table 4.2 Impact 2: Decrease in sediment load.

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	Local **1**	Medium **1**	Short-term **1**	**Low 3**	Definite	**LOW**	**- ve**	Low
Essential mitigation measures: • Return sediment to system guided by an appropriate management scenario								
With mitigation	Local **1**	Low **1**	Short-term **1**	**Very Low 3**	Definite	**VERY LOW**	**- ve**	Low

4.2 Operational phase

4.2.1 Abstraction of water during periods of high flow

Three water demand scenarios for the LUBWSS were considered in the Lower Umkhomazi Bulk Water Supply Scheme Detailed Feasibility Study (AECOM 2016) to account for the inherent uncertainty in 30-year water demand projections – a low, medium and high demand projection. The medium demand scenario was selected as the preferred scenarios as this would increase water supply to the lower south coast region to 180 mL/d which is in line with expected increases in demand over the next 30 years. It is not clear from the feasibility study report exactly how much water will be extracted from the uMkhomazi River as part of this scheme but it was assumed to correspond to what is described in the Classification Study for the Mvoti to Umzimkulu Water Management Area (DWS 2014) as "Scenario MK2: Ultimate Development, uMkhomazi Water project (uMWP-1) and Ngwadini OCD (No uMWP-1 Support)". In terms of this scenario flows in the uMlhomazi River will be reduced from the present 943.39 x 10^6 m^3/a to 719.12 x 10^6 m^3/a – i.e. from 88% of natural MAR to 67%. Changes in the seasonal distribution of flow under this scenario relative to Present and Natural are shown in Table 4.3-Table 4.5.

Changes in low flows and floods reaching the uMkhomazi estuary that occur under Scenario MK2: Ultimate Development, uMkhomazi Water project (uMWP-1) and Ngwadini OCD (No uMWP-1 Support) are summarised in Table 4.6 and Table 4.7.

Table 4.3 Summary of the monthly flow (in m3/s) distribution at the uMkhomazi estuary under Scenario MK2: Ultimate Development, uMkhomazi Water project (uMWP-1) and Ngwadini OCD (No uMWP-1 Support). Source: DWS (2014).

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	196.6	127.3	179.6	198.7	239.0	245.8	130.5	125.1	81.5	36.2	32.3	228.3
99	76.7	124.8	131.1	196.3	214.5	219.9	109.2	96.3	41.8	21.8	25.5	80.1
90	8.4	34.8	82.6	112.8	131.4	104.5	59.1	16.3	5.1	6.3	1.6	1.9
80	2.8	17.9	60.9	86.2	105.6	75.3	40.4	8.3	1.8	1.2	1.2	1.2
70	1.3	11.0	43.4	67.7	80.4	56.5	27.0	7.0	1.3	1.2	1.2	1.2
60	1.2	5.8	32.3	54.1	67.4	50.4	24.0	3.8	1.2	1.1	1.0	1.2
50	1.2	2.5	21.0	42.8	58.6	42.8	22.1	2.5	1.2	1.0	0.8	1.0
40	1.2	1.5	9.8	32.7	51.0	39.2	17.2	1.5	1.2	0.8	0.7	0.8
30	1.2	1.3	4.6	21.4	40.1	34.6	10.8	1.3	1.1	0.7	0.6	0.7
20	1.0	1.3	2.6	13.4	32.1	27.5	7.9	1.2	0.9	0.6	0.6	0.6
10	0.8	1.2	1.3	3.3	17.7	19.4	3.6	1.0	0.6	0.5	0.5	0.5
1	0.6	0.6	0.9	0.8	1.2	1.3	1.1	0.6	0.5	0.5	0.4	0.4
0.1	0.5	0.6	0.6	0.5	0.6	1.2	0.9	0.6	0.5	0.4	0.4	0.4

Table 4.4 A summary of the monthly flow (in m3/s) distribution at the uMkhomazi estuary under the Present State. Source: DWS (2014).

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	203.4	133.8	186.6	205.1	245.6	251.5	136.6	130.8	89.2	44.9	40.9	248.4
99	83.5	131.6	146.0	203.1	221.2	226.4	115.9	103.2	48.2	29.5	32.8	92.0
90	23.6	55.2	95.9	119.6	138.4	111.1	66.7	23.6	12.2	14.2	8.2	12.1
80	15.9	34.5	70.1	92.7	112.3	81.9	47.4	15.3	8.7	5.7	4.7	7.6
70	12.2	28.8	55.9	74.8	87.3	63.7	34.5	14.3	6.2	4.1	3.7	5.1
60	8.1	22.8	47.0	64.7	76.8	58.6	31.5	10.9	5.2	3.3	2.9	3.6
50	5.9	19.1	41.2	52.5	65.9	49.7	29.2	9.7	4.8	2.7	2.3	2.5
40	4.3	14.3	32.2	44.4	58.0	45.7	24.5	8.6	4.1	2.2	1.6	2.0
30	3.4	10.3	26.0	37.5	46.7	41.0	18.4	7.4	3.3	1.6	1.3	1.6
20	2.8	8.8	16.1	29.2	39.8	37.6	15.4	5.3	2.3	1.3	1.1	1.3
10	1.6	6.6	8.7	22.8	26.5	28.6	10.9	3.7	1.6	1.1	1.0	1.1
1	1.1	1.3	3.0	5.5	9.1	12.0	4.9	1.7	1.1	1.0	1.0	1.0
0.1	1.0	1.2	2.6	5.0	4.7	10.0	4.5	1.3	1.0	1.0	1.0	1.0

Table 4.5 A summary of the monthly flow (in m3/s) distribution at the uMkhomazi estuary under the Reference State. Source: DWS (2014).

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	209.5	145.4	204.5	217.6	255.8	260.3	148.6	142.2	94.6	51.7	48.7	269.7
99	91.6	133.7	160.6	216.8	233.4	236.9	122.2	109.0	55.2	36.0	38.1	101.3
90	27.8	61.9	104.8	126.3	149.3	119.9	73.4	25.6	16.0	16.5	12.2	15.8
80	19.6	39.4	78.1	100.9	122.3	85.3	52.5	19.2	12.2	9.0	8.5	11.5
70	15.6	33.3	61.8	82.8	94.7	68.0	38.6	17.0	9.6	7.3	6.9	8.8
60	11.7	26.9	51.6	70.7	82.1	62.7	35.0	14.4	8.6	6.4	6.1	7.2
50	9.1	23.7	45.2	57.8	71.2	54.9	32.2	13.4	8.0	5.9	5.4	6.0
40	7.7	18.5	36.3	48.7	63.1	49.2	28.5	12.5	7.3	5.3	4.5	5.2
30	6.5	14.1	29.7	41.6	50.3	46.2	23.6	10.9	6.3	4.5	3.8	4.8
20	5.7	12.3	19.2	33.9	44.5	40.7	19.1	8.9	5.3	3.6	3.2	4.1
10	4.3	10.1	11.0	25.6	29.3	32.3	14.5	6.8	4.4	2.8	2.5	2.9
1	2.8	3.8	5.5	8.3	11.9	14.9	8.4	4.8	3.0	2.1	1.8	1.6
0.1	2.6	3.7	5.4	7.8	7.1	12.4	7.8	4.0	2.8	2.0	1.8	1.6

Table 4.6 Summary of the change in low flow conditions to the uMkhomazi Estuary under Scenario MK2 relative to Present and Reference conditions. Source: DWS (2014).

Percentile	Monthly flow (m^3/s)		
	Reference	Present	Scenario MK2
30%ile	8.5	5.0	1.2
20%ile	6.3	3.1	1.0
10%ile	4.4	1.6	0.7
% Similarity in low flows		**47.7**	**15.1**

Table 4.7 Summary of the ten highest simulated monthly volumes to the uMkhomazi Estuary under Scenario MK2 relative to Present and Reference conditions. Source: DWS (2014).

Date	Monthly volume (x10^6 m^3/month)		
	Reference	Present	A
Sep 1987	747.67	688.8	634.5
Mar 1925	704.19	681.1	666.0
Mar 1976	630.39	606.1	590.0
Oct 1987	620.40	591.0	573.3
Feb 1985	596.34	580.5	562.3
Feb 1932	582.99	550.0	532.8
Mar 1988	580.22	542.8	524.5
Apr 1925	560.76	511.8	495.6
Apr 1943	557.29	526.4	509.9
Mar 1927	468.49	436.0	420.1
% Similarity in floods		**94.4**	**91.1**

Likely impacts of changes in flow on the uMkhomazi estuary under Scenario MK2 were assessed by DWS (2014) using standardised methods for the determination of environmental flow requirements of estuaries (DWA 2012). A summary of how this methodology is applied is included in Box 1 below.

Impacts on hydrology were considered to be significant with hydrology health score dropping from 66.8% to 45.4%, mostly due to a severe reduction in low flows (Table 4.8).

Table 4.8 EHI scores for hydrology under Scenario MK2 relative to Present and Reference conditions. Source: DWS (2014).

Variable	Scenario Group	
	Present	A
a. Similarity in low flows	48	15
b. Similarity floods	95	91
Hydrology score	**66.8**	**45.4**

Impacts on hydrodynamic functioning and mouth condition were also severe, and are described as changing from a situation at present where mouth closure occurs for about 1% of the time for relatively short periods to a situation where mouth closures of weeks to months in duration become a significant feature, owing to the fact that flow less than 1.0 m^3/s is likely to occur for about 20% of the time. Hydrodynamic health score was thus estimated to drop from 95% at present to 75%.

Box 1: Methods for the determination of environmental flow requirements of estuaries (DWA 2012).

Step 1: Initiate study defining the study area, project team and level of study (confirmed in the **inception report** of this study).

Step 2: Delineate the geographical boundaries of the resource units (confirmed in the **delineation report** of this study).

Step 3a: Determine the **Present Ecological State** (PES) of resource health (water quantity, water quality, habitat and biota) assessed in terms of the degree of similarity to the reference condition (referring to natural, unimpacted characteristics of a water resource, and must represent a stable baseline based on expert judgement in conjunction with local knowledge and historical data). An Estuarine Health Index (EHI) is used to evaluate the current condition of the estuary (Table 1.1).

Table 4.9 Estuarine Health Index (EHI) scoring system

Variable	Score	Weight	Weighted score
Hydrology	...	25	...
Hydrodynamics and mouth condition	...	25	...
Water quality	...	25	...
Physical habitat alteration	...	25	...
Habitat health score			**...**
Microalgae	...	20	...
Macrophytes	...	20	...
Invertebrates	...	20	...
Fish	...	20	...
Birds	...	20	...
Biotic health score			**...**
Estuary Health Score Mean (Habitat health, Biological health)			**...**

In the case of this assessment the EHI scoring of the various variables is based on a review of historical data, as well as data collected during a field monitoring programme in 2013 (refer to Appendices for specialist reports).

The estuarine health score is translated into one of six Ecological Categories provided below in Table 1.2.

Box 1. Continued.

Table 4.10 Translation of EHI scores into Ecological Categories

EHI score	PES	General Description
91 – 100	A	Unmodified, or approximates natural condition; the natural abiotic template should not be modified. The characteristics of the resource should be determined by unmodified natural disturbance regimes. There should be no human induced risks to the abiotic and biotic maintenance of the resource. The supply capacity of the resource will not be used
76 – 90	B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place, but the ecosystem functions are essentially unchanged. Only a small risk of modifying the natural abiotic template and exceeding the resource base should not be allowed. Although the risk to the well-being and survival of especially intolerant biota (depending on the nature of the disturbance) at a very limited number of localities may be slightly higher than expected under natural conditions, the resilience and adaptability of biota must not be compromised. The impact of acute disturbances must be totally mitigated by the presence of sufficient refuge areas.
61 – 75	C	Moderately modified. A loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged. A moderate risk of modifying the abiotic template and exceeding the resource base may be allowed. Risks to the wellbeing and survival of intolerant biota (depending on the nature of the disturbance) may generally be increased with some reduction of resilience and adaptability at a small number of localities. However, the impact of local and acute disturbances must at least partly be mitigated by the presence of sufficient refuge areas.
41 – 60	D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred. Large risk of modifying the abiotic template and exceeding the resource base may be allowed. Risk to the well-being and survival of intolerant biota depending on (the nature of the disturbance) may be allowed to generally increase substantially with resulting low abundances and frequency of occurrence, and a reduction of resilience and adaptability at a large number of localities. However, the associated increase in the abundance of tolerant species must not be allowed to assume pest proportions. The impact of local and acute disturbances must at least to some extent be mitigated by refuge areas.
21 – 40	E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.
0 – 20	F	Critically modified. Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

Step 3b: Determine the **Estuary Importance Score (EIS[1])** that takes account the size, the rarity of the estuary type within its biographical zone, habitat, biodiversity and functional importance of the estuary into account (Table 1.3 and Table 1.4).

Table 4.11 Estuary Importance scoring system

Criterion	Score	Weight	Weighted Score
Estuary Size	…	15	…
Zonal Rarity Type	…	10	…
Habitat Diversity	…	25	…
Biodiversity Importance	…	25	…
Functional Importance	…	25	…
Weighted Estuary Importance Score			…

Box 1. Continued.

Table 4.12 Estuarine Importance rating system

EIS	Importance rating
81 – 100	Highly important
61 – 80	Important
0 – 60	Of low to average importance

Step 3c: Set the **Recommended Ecological Category (REC)** which is derived from the PES and EIS (or the protection status allocated to a specific estuary) flowing the guidelines listed in Table 1.5.

Table 4.13 Guidelines to assign REC, based on protection status and importance, and PES of an estuary

Protection Status and Importance	REC	Policy basis
Protected area	A or BAS*	Protected and desired protected areas should be restored to and maintained in the best possible state of health.
Desired Protected Area (based on complementarity)		
Highly important	PES + 1, min B	Highly important estuaries should be in an A or B Category.
Important	PES + 1, min C	Important estuaries should be in an A, B or C Category.
Of low to average importance	PES, min D	The remaining estuaries can be allowed to remain in a D Category.

* Best Attainable State

An estuary cannot be allocated an REC below a Category "D". Therefore systems with a PES in Categories 'E' or 'F' needs to be managed towards achieving at least a REC of "D".

Step 4: **Quantify the ecological consequences of various runoff scenarios** (including proposed operational scenarios) where the predicted future condition of the estuary is assessed under each scenario. As with the determination of the PES, the EHI is used to assess the predicted condition in terms of the degree of similarity to the reference condition.

Step 5: Quantify the (recommended) **Ecological Water Requirements (EWR)**, which represent the lowest flow scenario that will maintain the resource in the REC.

Step 6: Estimate (recommended) **Resource Quality Objectives (Ecological Specification)** for the REC, as well as future **monitoring requirements** to improve the confidence of the EWR.

Impacts of changes in flow on the uMkhomazi estuary under Scenario MK2 on the occurrence of different abiotic states (State 1: Closed mouth, State 2: Tidal with intermittent mouth closure, State 3: Tidal, State 4: Freshwater dominated) and on water quality were also assessed as being very severe. The occurrence of State 1 (closed mouth) and State 2 (Tidal with intermittent mouth closure) were both projected to rise dramatically (from 1 to 19% and from 13 to27% respectively), while the occurrence of State 3 (Tidal) and State 4 (Freshwater dominated) declined in a corresponding manner (from 17 to 7% and from 70 to 47%, respectively) (Table 4.14).

Table 4.14 Occurrence of the abiotic states under Scenario MK2 relative to Present and Reference conditions. Source: DWS (2014).

Abiotic State	Reference	Present	MK2
State 1: Closed mouth	0	1	19
State 2: Tidal with intermittent mouth closure	1	13	27
State 3: Tidal	12	17	7
State 4: Freshwater dominated	87	70	47

Changes in water quality were also predicted to be very severe, especially for salinity and nutrient levels in the lower and middle reaches of the system (Table 4.15). The overall water quality health score for the uMkhomazi estuary was predicted to drop from 67% at present to 61% in future (Table 4.16). Impacts on physical habitat health were described as moderate and limited to some loss of exposed intertidal habitat due to intermitted mouth closure and greater mouth restriction. Habitat health score under the MK2 scenario is projected to drop from 78 to 70% (Table 4.17).

Changes to the microalgae communities in the estuaries under the MK2 scenario as follows (DWS 2014): "…open water area is increased which will allow more volume in which the microalgae can proliferate. At the same time there is some nutrient enrichment which will result in an increase in both phytoplankton and MPB biomass. This compensates for the loss of intertidal sand and mudflats. There is a big loss of area in reed and swamp vegetation which will have an overall negative effect. The changes in area of forest, mangroves floodplain are not relevant to the microalgae scores. Only small changes in salinity appear and these to levels that will be unlikely to adversely affect microalgae." Microalgae health score was projected to change from 90% at present to 75% as a result of these changes (Table 4.18).

Impacts on macrophytes were described by DWS (2014) as follows: "…drastically reduced base flow causes the mouth to close. This will result in an increase in open water area thereby reducing area for reeds and sedges to occupy. Higher salinity will reduce reed and sedge growth. Salinity at times will be 30 in Zone A, 20 in Zone B and 10 in Zone C. Reeds, sedges and swamp forest grow best at salinity less than 15. Saline conditions would encourage the growth and expansion of mangroves, with a possible increase from 1 to 2 ha. Some change (15% lower than present) in species and community composition in response to salinity change expected. The decline in open fresh state (State 4), which was dominant under natural conditions would impact the offshore marine habitats."

Table 4.15 **Estimated changes in water quality in different zones under Scenario MK2 relative to Present and Reference conditions. Source: DWS (2014).**

Zones in Estuary	Volume weighting for Zone	Estimated SALINITY concentration based on distribution of abiotic states under a range of Scenario Groups		
		Reference	Present	MK2
A: Lower	0.4	4	9	14
B: Middle	0.3	3	6	11
C: Upper	0.2	1	3	7
D: Upper (H)	0.1	0	0	0

Zones in Estuary	Volume weighting for Zone	Estimated DIN concentration (µg/l) based on distribution of abiotic states under a range of Scenario Groups		
		Reference	Present	MK2
A: Lower	0.4	97	207	180
B: Middle	0.3	97	222	197
C: Upper	0.2	97	230	201
D: Upper (H)	0.1	97	237	224

Zones in Estuary	Volume weighting for Zone	Estimated DIP concentration (µg/l) based on distribution of abiotic states under a range of Scenario Groups		
		Reference	Present	MK2
A: Lower	0.4	10	17	15
B: Middle	0.3	10	17	15
C: Upper	0.2	10	18	15
D: Upper (H)	0.1	10	18	15

Zones in Estuary	Volume weighting for Zone	Estimated TURBIDITY (NTU based on distribution of abiotic states under a range of Scenario Groups		
		Reference	Present	MK2
A: Lower	0.4	175	143	99
B: Middle	0.3	175	143	99
C: Upper	0.2	175	143	99
D: Upper (H)	0.1	175	143	99

Zones in Estuary	Volume weighting for Zone	Estimated DISSOLVED OXYGEN concentration (mg/l) based on distribution of abiotic states under a range of Scenario Groups		
		Reference	Present	MK2
A: Lower	0.4	6	6	6
B: Middle	0.3	6	6	6
C: Upper	0.2	6	6	5
D: Upper (H)	0.1	6	6	6

Table 4.16 EHI scores for water quality under Scenario MK2 relative to Present and Reference conditions. Source: DWS (2014).

Variable		Scenario	
		Present	MK2
1	Salinity		
	Similarity in salinity	66	45
2	General water quality in the estuary		
A	N and P concentrations	67	74
B	Turbidity	90	72
C	Dissolved oxygen	99	98
D	Toxic substances	75	75
Water quality score*		67	61

$* \text{ Score } = (0.6 * \text{S} + 0.4 * (\min(\text{a to d}))$

Table 4.17 EHI scores for physical habitat under Scenario MK2 relative to Present and Reference conditions. Source: DWS (2014).

Variable	Scenario	
	Present	MK2
1a. Intertidal areas and sediments	70	50
1b.Similarity in sand fraction	80	80
2. Subtidal area and sediments	80	75
Physical habitat score	78	70

Table 4.18 EHI scores for microalgae component under Scenario MK2 relative to Present and Reference conditions. Source: DWS (2014).

Variable	Scenario	
	Present	MK2
1. Species richness	95	90
2 Abundance	90	75
3. Community composition	95	90
Biotic component score	90	75

Impacts on macrophyte health score were modest though (change from 21 to 20%) due to the existing poor state (Table 4.18).

Changes in flow under the MK2 scenario are predicted to result in an increase in zooplankton and benthic invertebrate community diversity and abundance (linked to an increase in mouth closure, especially during winter, reduced river flows, and higher water retention times (DWS 2014). Loss of intertidal habitat and intertidal microphytobenthos is also expected to reduce food availability for some species. Overall numbers of species were not expected to change but total abundance was expected to drop significantly, and community composition to change markedly. Invertebrate health score was predicted to drop from 75 to 60% (Table 4.19).

Table 4.6 **EHI scores for macrophyte component under Scenario MK2 relative to Present and Reference conditions. Source: DWS (2014).**

Variable	Scenario	
	Present	MK2
1. Species richness	80	65
2 Abundance	21	20
3. Community composition	51	47
Biotic component score	21	20

Table 4.19 **EHI scores for invertebrates component under Scenario MK2 relative to Present and Reference conditions. Source: DWS (2014).**

Variable	Scenario	
	Present	MK2
1. Species richness	95	95
2. Abundance	75	60
3. Community composition	80	60
Biotic component score	75	60

Impacts on fish were described by DWS (2014) as follows: "Flow reductions cause a significant increase in mouth closure, especially in late winter and early spring. This impacts recruitment of many of the main (and important) estuarine dependent marine fishes. Increased occurrence on State 1 and State 2 might results in depressed oxygen concentrations in Zone C of the estuary, an important nursery area for estuarine dependent marine species. Most of these species will undergo population reductions despite salinities in the estuary being conducive to the use of the whole system. Reduced river flows, higher water retention and increased zooplankton productivity will benefit the estuarine resident component of the fish assemblage. Detritivores are also likely to benefit from lower flows and increased detrital productivity. Loss of intertidal habitat and intertidal microphytobenthos reduces food availability for some mullet species. Overall numbers of species and total fish abundance is likely to be reduced, and community composition changes markedly." Fish health score was anticipated to drop dramatically from 60% at present to 35% (Table 4.20).

Table 4.20 EHI scores for fish component under Scenario MK2 relative to Present and Reference conditions. Source: DWS (2014).

Variable	Scenario	
	Present	MK2
1. Species richness	95	55
2. Abundance	60	35
3. Community composition	75	40
Biotic component score	60	35

Impacts of changes in flow on avifauna of the estuary were described by DWS (2014) as follows: "Mouth closure would increase, with increased back-flooding (which was observed during this study to have positive impacts on the aquatic avifauna). There would be increased salinity in the estuary and the possibility of enhanced development of inter-tidal sandbanks and mudflats to the possible advantage of small invertebrate-feeding waders. Back-flooding and increased salinity would have a negative impact on macrophytes but this would likely have little impact on waterbirds. Low flows would be to the detriment of swimming piscivores, a major component of the relatively impoverished waterbird avifauna, during open-mouth conditions but would be to their benefit during closed-mouth, deeper-water conditions." Changes in the bird health score were predicted to be modest (down from 60% at present to 50% under scenario MK2, Table 4.21).

Table 4.21 EHI scores for bird component under Scenario MK2 relative to Present and Reference conditions. Source: DWS (2014).

Variable	Scenario	
	Present	MK2
1. Species richness	80	70
2. Abundance	60	50
3. Community composition	70	60
Biotic component score	60	50

Overall impacts on health status of the uMkhomazi estuary under the MK2 scenario are summarised in Table 4.22. The overall health of the system is projected to decline from 68 to 54% and will drop from a "C" category to a "D" category. The recommended ecological category (REC) for the uMkhomazi estuary is a "B" owing it being rated as "Very Important" from a biodiversity perspective and the fact that it also forms part of the core set of priority estuaries in need of protection to achieve biodiversity targets in the National Estuaries Biodiversity Plan for the NBA (DWS 2014, Turpie *et al*., 2013).

The impacts of the proposed development were thus assessed as having a very high significance negative impact on the uMkhomazi estuary (Table 4.23).

Table 4.22 EHI score and corresponding Ecological Categories under Scenario MK2 relative to Present and Reference conditions. Source: DWS (2014).

Variable	Weight	Scenario Group	
		Present	MK2
Hydrology	25	66.8	**45**
Hydrodynamics and mouth condition	25	95	**75**
Water quality	25	66.6	**61**
Physical habitat alteration	25	78	**70**
Habitat health score		**76**	**63**
Microalgae	20	80	**65**
Macrophytes	20	21	**20**
Invertebrates	20	75	**60**
Fish	20	60	**35**
Birds	20	60	**50**
Biotic health score		**59**	**46**
ESTUARY HEALTH SCORE		**68**	**54**
ECOLOGICAL STATUS		**C**	**D**

Table 4.23 Impact 1: Abstraction of water during periods of high flow.

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	Regional 2	High 3	Long-term 3	**Very high 8**	Probable	**VERY HIGH**	**- ve**	Medium
Essential mitigation measures: • Implement alternative flow scenarios (MK21, MK22, MK23 or MK42) as identified in the Mvoti to Umzimkulu Classification study (DWA 2012) • Implement the following additional offset measures identified in the Mvoti to Umzimkulu Classification study (DWA 2012): ○ Remove sand mining from the upper reaches below the Sappi Weir to increase natural function, i.e. restore intertidal area. ○ Restoration of vegetation upper reaches and along the northern bank, e.g. remove aliens and allow disturbed land to revert to natural land cover (is already on upwards trajectory). ○ Curb recreational activities in the lower reaches through zonation and improve compliance. ○ Reduce/remove castnetting in the mouth area through estuary zonation or increase compliance; and ○ Relocate upstream, or remove, the Sappi Weir to restore upper 15% of the estuary.								
With mitigation	Local 1	Low 1	Long-term 3	**Medium 6**	Probable	**MEDIUM**	**- ve**	Medium

In the Mvoti to Umzimkulu Classification study, DWS (2014) evaluated a number of alternative flow scenarios in an effort to ascertain whether it was possible to achieve the REC for the uMkhomazi system and also to meet future projected water demands. There investigations suggested that it was not possible to achieve the REC and to meet water demands through flow manipulation alone and that this would require a combination of flow and non-flow related interventions.

They identified five possible flow scenarios (identified as MK21, MK22, MK23, and MK42) which, in combination with the following management interventions, could achieve the REC for this system:

- Remove sandmining from the upper reaches below the Sappi Weir to increase natural function, i.e. restore intertidal area.
- Restoration of vegetation upper reaches and along the northern bank, e.g. remove aliens and allow disturbed land to revert to natural land cover (is already on upwards trajectory).
- Curb recreational activities in the lower reaches through zonation and improve compliance.
- Reduce/remove castnetting in the mouth area through estuary zonation or increase compliance; and
- Relocate upstream, or remove, the Sappi Weir to restore upper 15% of the estuary.

It is thus recommended that one of the alternative flow scenarios identified in the Mvoti to Umzimkulu Classification study (DWS 2014) be adopted in place of MK2 (MK21, MK22, MK23, or MK42) and that the additional management interventions identified in this study be implemented as mitigation and offset measures.

A description of each of these scenarios is provided below (DWS 2014):

- Scenarios MK21, 22 and 23 were all based on Scenario MK2 where the flows at the EWR sites will be assessed for the following EWR flows:
    - Total flow EWRs (Mk_I_EWR2) set to achieve the REC (**MK21**).
    - Low flow EWRs (Mk_I_EWR2) set to achieve the REC (**MK22**).
    - Total Flows for January, February, March and Low Flows remaining months (Mk_I_EWR2) set to achieve the REC (**MK23**).

  The purpose of these scenarios was to determine to what degree the total flow, low flow and the in between flow EWRs together with the dam spills and tributary inflows from the dam will achieve the REC at Mk_I_EWR2.
- Scenario MK42 was also based on **MK2** but flows at the EWR sites but low flow EWRs (Mk_I_EWR2) were set to achieve the REC. The purpose of this scenarios was to determine if the total flow and low flow EWRs (Mk_I_EWR2) together with the dam spills and tributary inflows from the dam could achieve the REC at EWR sites.

In terms of these flow requirements, the minimum flow at the head of the estuary should not drop below 1.2 m^3/s even under extreme drought conditions (flows should exceed this level 99.9% of the time). This translates to a minimum monthly flow rate of 3.2 Mm^3. This is designed to ensure that the mouth of the estuary remains open as was the case historically.

Table 4.24 Summary of the monthly flow (in m3/s) distribution under Scenario MK21 and MK41. Source: DWS (2014).

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	198.0	129.1	174.9	200.2	240.4	247.5	132.3	126.9	82.9	32.4	32.3	226.7
99	78.4	126.7	131.5	197.8	215.7	221.7	110.9	98.2	39.5	22.3	27.0	79.9
90	12.3	32.9	77.8	112.8	133.2	106.1	60.6	18.0	7.2	7.8	4.5	4.1
80	9.5	21.0	55.6	80.7	105.1	76.8	42.1	11.6	6.2	4.7	3.9	3.8
70	8.0	17.8	39.2	68.0	81.9	58.3	28.7	10.6	5.6	4.0	3.4	3.5
60	6.8	14.3	27.1	52.3	69.3	52.0	25.7	9.5	5.1	3.6	3.0	3.1
50	5.7	12.5	20.2	39.9	60.0	44.0	24.1	8.5	4.7	3.0	2.3	2.5
40	4.6	10.5	16.3	29.6	46.7	40.3	19.0	7.1	3.8	2.5	1.7	2.0
30	3.8	8.2	12.0	22.0	41.6	36.4	12.7	5.8	3.1	1.9	1.5	1.7
20	2.8	5.6	8.2	13.9	32.9	28.8	10.0	4.5	2.2	1.5	1.4	1.5
10	1.6	3.1	3.8	8.1	19.6	21.3	6.6	3.5	1.8	1.3	1.3	1.3
1	1.3	1.6	1.9	3.3	4.5	7.9	5.2	2.0	1.4	1.2	1.2	1.2
0.1	1.3	1.6	1.9	2.9	2.1	6.5	4.7	1.6	1.3	1.2	1.2	1.2

Table 4.25 Summary of the monthly flow (in m3/s) distribution under Scenario MK22 and 23. Source: DWS (2014).

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	197.7	128.9	178.3	199.9	240.1	247.3	132.1	126.7	82.7	31.6	32.2	225.4
99	78.1	126.4	131.9	197.6	215.5	221.4	110.6	97.9	39.0	22.0	26.8	79.7
90	9.7	33.4	82.5	114.3	132.9	105.8	60.4	17.8	7.2	7.8	4.5	4.1
80	5.7	16.9	61.1	87.8	107.1	76.5	41.8	11.6	6.2	4.7	3.9	3.8
70	4.9	10.4	43.6	69.2	82.0	58.0	28.5	10.6	5.6	4.0	3.4	3.5
60	4.1	7.5	30.9	55.6	69.0	51.7	25.4	9.5	5.1	3.6	3.0	3.1
50	3.4	6.3	19.9	43.4	59.7	43.7	23.8	8.5	4.7	3.0	2.3	2.5
40	2.9	4.8	10.8	34.0	48.2	40.7	18.8	7.1	3.8	2.5	1.7	2.0
30	2.2	3.5	6.9	22.9	41.6	36.1	12.4	5.8	3.1	1.9	1.5	1.7
20	1.8	3.1	5.1	12.6	32.7	29.0	9.4	4.5	2.2	1.5	1.4	1.5
10	1.5	2.5	3.4	6.6	19.3	21.3	6.4	3.5	1.8	1.3	1.3	1.3
1	1.3	1.6	1.9	3.3	4.5	7.9	5.2	2.0	1.4	1.2	1.2	1.2
0.1	1.3	1.6	1.9	2.9	2.1	6.5	4.7	1.6	1.3	1.2	1.2	1.2

4.2.2 Decrease in sediment load

According to the project description (Nemai Consulting 2017) water for the project will be drawn directly from the Mkomazi River and hydrocyclones will be employed to remove excess sediment during "higher flow and turbidity periods". This suggests that this will not be undertaken on a continuous basis and that a reduction in sediment levels in the river can be anticipated during flow periods at least.

Sediment starvation is often caused by man-made structures such as dams, though natural barriers can also limit sediment transport. Without sediment transport and deposition, new habitats cannot be formed, and without some nutrient enrichment (carried with sediment into the water), submerged vegetation growth is stunted (EPA 2012). Too little sediment can alter an ecosystem to the point that indigenous species cannot survive. In addition to the effect on aquatic life, the loss of sediment transport and deposition can cause physical changes to the terrain. Downstream of dammed rivers, it is common to see receding riparian zones and wetlands due to the loss of transported sediment. Erosion downstream of a barrier is common, as is coastline erosion when there is not a large enough sediment load currently carried by the water. The flowing water will pick up new sediment from the bottom and banks of a waterway (eroding instead of refreshing habitats) as it attempts to adjust to a uniform flow rate (EPA 2012, USCOP 2004). The duration of the impact is long term, the significance of this impact is rated as **Medium** (Table 4.26). Further detail in sediment transport volumes, impacts and management of this system will be addressed in the Sediment Specialist Report.

Table 4.26 Impact 2: Decrease in sediment load.

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	Regional 2	Medium 2	Long-term **3**	**High 7**	Possible	**MEDIUM**	**- ve**	Low
Essential mitigation measures: • Return sediment to system guided by an appropriate specialist management scenario								
With mitigation	Regional 2	Low 1	Long-term **3**	**Medium 6**	Possible	**LOW**	**- ve**	Low

4.3 Decommissioning Phase

There will be no decommissioning phase.

4.4 Summary of potential impacts

Table 4.27 Summary of potential impacts resulting from the construction of the proposed LUBWSS in the uMkhomazi River catchment area.

Phase	Impact identified	Consequence	Probability	Significance	Status	Confidence
Construction	Impact 1: Alteration of Water Flow	Low	Definite	Low	-ve	Low
	With Mitigation	Very low	Definite	Very low	-ve	Low
	Impact 2: Decrease in sediment load	Low	Definite	Low	-ve	Low
	With Mitigation	Very Low	Definite	Very low	-ve	Low

Table 4.28 Summary of potential impacts resulting from the operation of the proposed LUBWSS in the uMkhomazi River catchment area.

Phase	Impact identified	Consequence	Probability	Significance	Status	Confidence
Operation	Impact 1: Water abstraction	High	Definite	Very High	-ve	Medium
	With Mitigation	Medium	Definite	Medium	-ve	Medium
	Impact 2: Decreased sediment load	High	Definite	High	-ve	Medium
	With Mitigation	Medium	Definite	Medium	-ve	Medium

5 RECOMMENDATIONS & MONITORING PROGRAMME

It is recommended that projected water requirements for the Lower uMkhomazi Bulk Water Supply Scheme (LUBWSS) should be achieved through implementation of one of the flow scenarios identified in the Mvoti to Umzimkulu Classification study (DWS 2014) that enabled the uMkhomazi estuary to achieve the Recommended Ecological Category (REC) for the system of a "B" (viz. MK21, MK22, MK23, and MK42). The Mvoti to Umzimkulu Classification study (DWS 2014) also included a number of additional non-flow related environmental offset interventions that should be implemented in conjunction with the recommended flow scenario. While it is recognised that most of these interventions are not within the power of Umgeni Water to implement these are nonetheless included here for completeness:

- Remove sand mining from the upper reaches below the Sappi Weir to increase natural function, i.e. restore intertidal area.
- Restoration of vegetation upper reaches and along the northern bank, e.g. remove aliens and allow disturbed land to revert to natural land cover (is already on upwards trajectory).
- Curb recreational activities in the lower reaches through zonation and improve compliance.
- Reduce/remove cast netting in the mouth area through estuary zonation or increase compliance; and
- Relocate upstream, or remove, the Sappi Weir to restore upper 15% of the estuary.

Detailed baseline and long term monitoring requirements to ascertain impacts of changes in freshwater flow to the uMkhomazi estuary and any improvement or reductions therein are listed in Mvoti to Umzimkulu Classification study (DWS 2014) and are replicated in Table 5.1 and Table 5.2 below. Ultimate responsibility for implementing these monitoring activities resides with the Department of Water and Sanitation (DWS). However, given that Umgeni Water will be the primary recipients of the water abstracted from the uMkhomazi River, they should be expected to fund the baseline (Year 1) monitoring costs at least (Table 5.1).

Table 5.1 Recommended baseline monitoring requirements

Ecological Component	Monitoring Action	Temporal Scale (Frequency And When)	Spatial Scale (No. Stations)
Hydrodynamics	Record water levels	Continuous	At bridge
	Measure freshwater inflow into the estuary	Continuous	Above the estuary
	Aerial photographs of estuary (spring low tide)	Every 3 years	Entire estuary
Sediment dynamics	Bathymetric surveys: Series of cross-section profiles and a longitudinal profile collected at fixed 500 m intervals, but in more detailed in the mouth (every 100m). The vertical accuracy should be about 5 cm.	Every 3 years	Entire estuary
	Set sediment grab samples (at cross section profiles) for analysis of particle size distribution (PSD) and origin (i.e. using microscopic observations)	Every 3 years (with invert sampling)	Entire estuary (6 stations)
Water quality	Measurements of organic content and toxic substances	Every 3 - 6 years	Focus on sheltered,

Ecological Component	Monitoring Action	Temporal Scale (Frequency And When)	Spatial Scale (No. Stations)
	(e.g. trace metals and hydrocarbons) in sediments along length of the estuary, where considered an issue (must also include sediment grain size analysis of samples).		depositional areas
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. ▪ Intertidal and subtidal benthic chlorophyll-a measurements.	Monthly sampling for 2 years (seasonal trends)	Entire estuary (5 stations)
Fish	Record species and abundance of fish, based on seine net and gill net sampling. The data will establish Zone specific baselines and provide a measure of natural variability. They should be based on replicate sampling of stations and wet and dry seasons.	Late spring, summer and two winter survey every year for 3 years	Entire estuary (9 stations) (increase to 12 to include Zone D)
Birds	Undertake counts of all water associated birds, identified to species level.	A series of monthly counts for a yea	Entire estuary (3 sections)

Table 5.2 Recommended long-term monitoring requirements for the uMkhomazi estuary.

Ecological Component	Monitoring Action	Temporal Scale (Frequency And When)	Spatial Scale (No. Stations)
Hydrodynamics	Record water levels	Continuous	At bridge
	Measure freshwater inflow into the estuary	Continuous	Above the estuary
	Aerial photographs of estuary (spring low tide)	Every 3 years	Entire estuary
Sediment dynamics	Bathymetric surveys: Series of cross-section profiles and a longitudinal profile collected at fixed 500 m intervals, but in more detailed in the mouth (every 100 m). The vertical accuracy should be about 5 cm.	Every 3 years	Entire estuary
	Set sediment grab samples (at cross section profiles) for analysis of PSD and origin (i.e. using microscopic observations).	Every 3 years (with invert sampling)	Entire estuary (6 stations)
Water quality	Water quality (e.g. system variables, nutrients and toxic substances) measurements on river water entering at the head of the estuary.	Monthly continuous	DWS WQ monitoring station(U1H006)
	Longitudinal salinity and temperature profiles ((and any other in situ measurements possible e.g. pH, DO, turbidity) collected during high and low tide at: End of low flow season (i.e. period of maximum seawater intrusion/closed mouth). Peak of high	Seasonally every year	Entire estuary (9 stations)

Ecological Component	Monitoring Action	Temporal Scale (Frequency And When)	Spatial Scale (No. Stations)
	flow season (i.e. period of maximum flushing by river water).		
	Water quality parameters (i.e. system variables, and inorganic nutrients) taken along the length of the estuary (at least surface and bottom samples).	Coinciding with biotic surveys or when significant change in quality expected	Entire estuary (9 stations)
	Measurements of organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary, where considered an issue (must also include sediment grain size analysis of samples).	Every 3 - 6 years	Focus on sheltered, depositional areas
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 every 3 years	Entire estuary (5 stations)
Macrophytes	Map the area covered by the different macrophyte habitats during a field survey. Compile a species list and check for expansion of invasive plants, reed, sedge and grass areas.	Summer survey every 3 years	Entire estuary
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	Winter/low flow survey every year	Entire estuary (6 stations) include extra upper station if weir removed
Fish	Record species and abundance of fish, based on seine net and gill net sampling.	Late spring/ summer and winter survey every year. Repeated within season if any Ecospec is not met	Entire estuary (9 stations) (increase to 12 to include Zone D)
Birds	Undertake counts of all water associated birds, identified to species level.	Winter and summer surveys every year Coordinated Waterbird Counts (CWAC)	Entire estuary

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7 IMPACT RATING METHODOLOGY

The significance of all potential impacts that would result from the proposed project is determined in order to assist decision-makers. The **significance** of an impact is defined as a combination of the **consequence** of the impact occurring and the **probability** that the impact will occur. The significance of each identified impact was thus rated according to the methodology set out below:

Step 1 – Determine the **consequence** rating for the impact by determining the score for each of the three criteria (A-C) listed below and then **adding** them. The rationale for assigning a specific rating, and comments on the degree to which the impact may cause irreplaceable loss of resources and be irreversible, must be included in the narrative accompanying the impact rating:

Rating	Definition of Rating	Score
A. ***Extent – the area over which the impact will be experienced***		
Local	Confined to project or study area or part thereof (e.g. limits of the concession area)	1
Regional	The region (e.g. the whole of Namaqualand coast)	2
(Inter) national	Significantly beyond Saldanha Bay and adjacent land areas	3
B. ***Intensity – the magnitude of the impact in relation to the sensitivity of the receiving environment, taking into account the degree to which the impact may cause irreplaceable loss of resources***		
Low	Site-specific and wider natural and/or social functions and processes are negligibly altered	1
Medium	Site-specific and wider natural and/or social functions and processes continue albeit in a modified way	2
High	Site-specific and wider natural and/or social functions or processes are severely altered	3
C. ***Duration – the time frame for which the impact will be experienced and its reversibility***		
Short-term	Up to 2 years	1
Medium-term	2 to 15 years	2
Long-term	More than 15 years (state whether impact is irreversible)	3

The combined score of these three criteria corresponds to a **Consequence Rating**, as follows:

Combined Score (A+B+C)	**3 – 4**	**5**	**6**	**7**	**8 – 9**
Consequence Rating	Very low	Low	Medium	High	Very high

Example 1:

Extent	Intensity	Duration	Consequence
Regional 2	Medium 2	Long-term 3	High 7

Step 2 – Assess the **probability** of the impact occurring according to the following definitions:

Probability– the likelihood of the impact occurring	
Improbable	< 40% chance of occurring
Possible	40% - 70% chance of occurring
Probable	> 70% - 90% chance of occurring
Definite	> 90% chance of occurring

Example 2:

Extent	Intensity	Duration	Consequence	Probability
Regional 2	Medium 2	Long-term 3	High 7	Probable

Step 3 – Determine the overall **significance** of the impact as a combination of the **consequence** and **probability** ratings, as set out below:

		Probability			
		Improbable	Possible	Probable	Definite
Consequence	Very Low	**INSIGNIFICANT**	**INSIGNIFICANT**	**VERY LOW**	**VERY LOW**
	Low	**VERY LOW**	**VERY LOW**	**LOW**	**LOW**
	Medium	**LOW**	**LOW**	**MEDIUM**	**MEDIUM**
	High	**MEDIUM**	**MEDIUM**	**HIGH**	**HIGH**
	Very High	**HIGH**	**HIGH**	**VERY HIGH**	**VERY HIGH**

Example 3:

Extent	Intensity	Duration	Consequence	Probability	Significance
Regional 2	Medium 2	Long-term 3	High 7	Probable	HIGH

Step 4 – Note the **status** of the impact (i.e. will the effect of the impact be negative or positive?)

Example 4:

Extent	Intensity	Duration	Consequence	Probability	Significance	Status
Regional 2	Medium 2	Long-term 3	High 7	Probable	HIGH	– ve

Step 5 – State the level of **confidence** in the assessment of the impact (high, medium or low).

Impacts are also considered in terms of their status (positive or negative impact) and the confidence in the ascribed impact significance rating. The prescribed system for considering impacts status and confidence (in assessment) is laid out in the table below. Depending on the data available, a higher level of confidence may be attached to the assessment of some impacts than others. For example, if the assessment is based on extrapolated data, this may reduce the confidence level to low, noting that further ground-truthing is required to improve this.

Confidence rating	
Status of impact	+ ve (beneficial) or – ve (cost)
Confidence of assessment	Low, Medium or High

Example 5:

Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Regional 2	Medium 2	Long-term 3	High 7	Probable	HIGH	– ve	High

The significance rating of impacts is considered by decision-makers, as shown below. Note, this method does not apply to minor impacts which can be logically grouped into a single assessment.

INSIGNIFICANT: the potential impact is negligible and **will not** have an influence on the decision regarding the proposed activity.

VERY LOW: the potential impact is very small and **should not** have any meaningful influence on the decision regarding the proposed activity.

LOW: the potential impact **may not** have any meaningful influence on the decision regarding the proposed activity.

MEDIUM: the potential impact **should** influence the decision regarding the proposed activity.

HIGH: the potential impact **will** affect a decision regarding the proposed activity.

VERY HIGH: The proposed activity should only be approved under special circumstances.

Step 6 – Identify and describe practical **mitigation** and **optimisation** measures that can be implemented effectively to reduce or enhance the significance of the impact. Mitigation and optimisation measures must be described as either:

- **Essential**: must be implemented and are non-negotiable; and
- **Best Practice**: must be shown to have been considered and sound reasons provided by the proponent if not implemented.

Essential mitigation and optimisation measures must be inserted into the completed impact assessment table. The impact should be re-assessed with mitigation, by following Steps 1-5 again to demonstrate how the extent, intensity, duration and/or probability change after implementation of the proposed mitigation measures.

Example 6: A completed impact assessment table

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	Regional **2**	Medium **2**	Long-term **3**	**High 7**	Probable	**HIGH**	**– ve**	High
Essential mitigation measures: xxxxx xxxxx								
With mitigation	Local 1	Low 1	Long-term 3	**Low 5**	Improbable	**VERY LOW**	**– ve**	High

Step 7 – Prepare a summary table of all impact significance ratings as follows:

Impact	***Consequence***	***Probability***	**Significance**	***Status***	***Confidence***
Impact 1: XXXX	Medium	Improbable	LOW	–ve	High
With Mitigation	Low	Improbable	VERY LOW		High
Impact 2: XXXX	Very Low	Definite	VERY LOW	–ve	Medium
With Mitigation:	*Not applicable*				

Indicate whether the proposed development alternatives are environmentally suitable or unsuitable in terms of the respective impacts assessed by the relevant specialist and the environmentally preferred alternative.

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