INVESTIGATION OF THE REHABILITATION POTENTIAL OF THE BAAKENS RIVER,GQEBERHA,EASTERN CAPE, SOUTH AFRICA
REPORT 1: CURRENT STATE OF THE RIVER

Amanda Uys, Anton Bok, James MacKenzie, Patsy Scherman and Nonopha Kanise

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TT 910/1/23

An Investigation of the Rehabilitation Potential of the Baakens River, Gqeberha

Part 1: Current state of the river

Report to the
Water Research Commission

by

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Laughing Waters & Associates

WRC Report No. TT 910/1/23
ISBN 978-0-6392-0350-8

April 2023

Obtainable from
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This report forms part of a set of five reports emanating from WRC project no. C2022/2023-01121. The other reports are:

- An investigation of the rehabilitation potential of the Baakens River, Gqeberha. Part 2: River rehabilitation scenarios. (WRC Report No. TT 910/2/23)
- An Investigation of the rehabilitation potential of the Baakens River. Part 3: Cost benefit analysis. (WRC Report No. TT 910/3/23)
- Rehabilitation Potential of the Baakens River, Gqeberha. Part 4: Recommendations. (WRC Report No. TT 910/4/23)
- Rehabilitation potential of the Baakens River, Gqeberha. Part 5: Summary Report. (WRC Report No. TT 910/5/23)

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'One of the penalties of an ecological education is that one lives alone in a world of wounds. Much of the damage inflicted on land is quite invisible to laymen. An ecologist must either harden his shell and make believe that the consequences of science are none of his business, or he must be the doctor who sees the marks of death in a community that believes itself well and does not want to be told otherwise.

The government tells us we need flood control and comes to straighten the creek in our pasture. The engineer on the job tells us the creek is now able to carry off more flood water, but in the process, we lost our old willows where the cows switched flies in the noon shade, and where the owl hooted on a winter night. We lost the little marshy spot where our fringed gentians bloomed.

Some engineers are beginning to have a feeling in their bones that the meanderings of a creek not only improve the landscape but are a necessary part of the hydrologic functioning. The ecologist sees clearly that for similar reasons we can get along with less channel improvement on Round River.

Leopold, Aldo: Round River, Oxford University Press, New York, 1993.

"The time has come for science to busy itself with the earth itself.
The first step is to reconstruct a sample of what we had to start with."

Aldo Leopold: The Arboretum and the University, The River of the Mother of God.

ACKNOWLEDGEMENTS

The Project Team would like to thank the Mandela Bay Development Agency (MBDA) for the funding for this project, and hold the sincere hope that the Baakens River rehabilitation work continues under their good guidance. Mr Bonani Madikizela of WRC is appreciated for the integral part he played in this project, and for accompanying the team on the field survey. Mr Madikizela is also acknowledged for the role he continues to play in leading South Africa into an active river restoration future. Ms Singathwa Posma, Ms Tamlynn David and Ms Pumza Tshebe of the MBDA are thanked for their support and assistance during the project.

We are grateful to the members of the Reference Group for their time, expertise and support:

Dr Liz Day, Dr Nikite Muller, Dr Julie Coetzee, Ms Thwala Mmaphefo, Ms Duduzile Soginga, Prof Antony Palmer, Prof Nelson Odume, Prof Nadine Strydom, Mr Mbulelo Dopolo, Ms Ellen Paasche and Mr Gary Koekemoer.

Thanks to Ms Leah Jacobs, Mr Japie Buckle, Mr Adrian Grobler and Ms Rosemary Buchanan for their explanations of the work and reports they had done on aspects of the Baakens River catchment. Thanks to Prof Nadine Strydom who made time to go through her recommendations for the restoration of the Baakens estuary. More thanks to Ms Gerda Kruger, our *uber* WRC Project Administrator, and to Ms Anja van der Merwe of the WRC who designed the report covers.

Historian and writer extraordinaire Mr Dean McCleland gave the Project Leader material to mull over and read, providing deep insights into the history of the Baakens River and the city. A broad historic perspective is what makes for sound rehabilitation goals. That input was valuable and greatly appreciated.

The Project Leader thanks her A-Team, James MacKenzie, Anton Bok, Patsy Scherman, Micah Moynihan and Nonopha Kanise, who worked willingly and for long hours to get the work, planning and thinking done. Healthy rivers really are our Life Mission, it's a privilege to work with you all.

Mr Renzo Driussi and members of the Nelson Mandela Bay Business Chamber are thanked for their time, their interest in the project, and their ongoing work and endeavours to keep their City well maintained, functional, attractive, and clean.

A few members of the community and from civic organisations stepped forward to assist with information and context on this project and are gratefully acknowledged: Ms Ellen Paasche, founder of the Community Crime Awareness group in the valley (we wish all South Africans understood community and ecology the way she does); Mr Gary Koekemoer who wears many hats, including the Chairmanship of the Wildlife and Environment Society, Algoa Bay Branch, and who inspires us with his relentless commitment to reversing degradation in the Metro; Mr Johan Gerryts, and Ms Candy Boonzaaier, who were the first to meet us on-site, and who are thanked for their time, insights, information and enthusiastic trail-guiding.

EXECUTIVE SUMMARY

CHAPTER 1: INTRODUCTION

The Mandela Bay Development Agency (MBDA) is tasked with the conceptualisation and implementation of projects on behalf of the Nelson Mandela Bay Metropolitan Municipality ('the Metro') in the Eastern Cape city of Gqeberha. The MBDA has entered into an agreement with the country's primary water research funding organisation, the Water Research Commission (WRC), to facilitate water-related studies in areas in which information is needed for development decision-making by the Development Agency (DA).

In the case of this project, the DA sought a study which would provide information on the Baakens River, which occupies a central locality in the city and is a critical component of the city's future development plans. Over the 200 years since the arrival of settlers in the area, the river has been subjected to a suite of impacts including development of its floodplain, clearing of its riparian zone, flow impoundment, water quality impairment, and dense urbanisation, and as a result the river is degraded. Nonetheless, it occupies a central position in the life and heart of the city, provides a safe green space for the people of Gqeberha, and has significant biodiversity and natural-capital value which requires regeneration and protection.

As 'current state' overview of the system is required as a starting point and as a base from which decisions regarding the possible rehabilitation of the river can be made. A cost-benefit analysis of a river rehabilitation exercise is also a necessity for the Metro. These requirements serve as the rationale for this project.

A Memorandum of Understanding (MOU) was signed between the WRC and the DA to facilitate this and other research. The WRC Research Manager for this study is Mr Bonani Madikizela, and the study coordinator for the DA is Research, Innovation and Sustainability Manager Ms Singathwa Poswa.

The project team, led by Laughing Water & Associates, comprises four senior aquatic scientists and a senior resource economist, each with over 20 years in their respective fields, and an MSc level GIS/RS student.

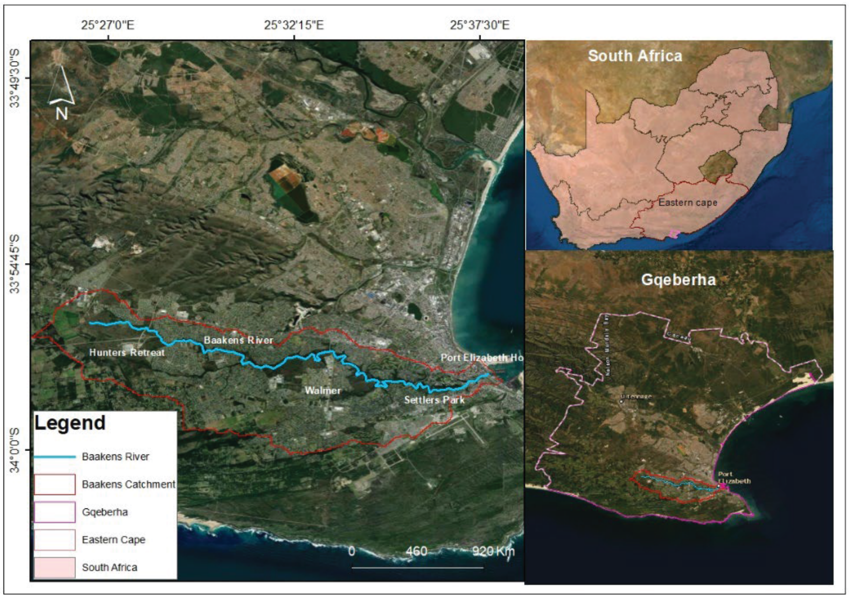
The study aims are:

a. To determine, using accepted current South African methods, the Present Ecological State (PES) of the Baakens River, with respect to its water quality, fauna and flora.
b. To develop a rehabilitation vision and broad strategy for the Baakens catchment and apply these in 3 or 4 different rehabilitation scenarios, in consultation with key stakeholders.
c. To do a cost-effectiveness analysis on the rehabilitation scenarios.
d. To present the results and to engage with the stakeholder forum to prioritise scenarios.
e. To provide more detail on the prioritised scenario.
f. To make recommendations to the MBDA regarding the feasibility of rehabilitation for the Baakens River, and the most cost-effective starting point.

This report represents the first project deliverable and provides the preliminary information on the current state of the Baakens River, based on findings to date.

CHAPTER 2: THE BAAKENS RIVER

The Baakens River is a small, urbanised river, about 23 km in length and with a catchment size of 85 km^2. The river flows from west to east, bisecting the city of Gqeberha, and providing the catchment community with a green corridor and a literal breathe of fresh air. The catchment is situated in Ecoregion II 20.01 (South Eastern Coastal Belt) and in quaternary catchment M20A. The estuary flows into the ocean at the Port of Gqeberha.



Locality of the Baakens River, Gqeberha

Climatically, the area is transitional between a subtropical and a temperate climate, with bimodal (spring and autumn) peaks in rainfall, and runoff with a high coefficient of variability. The naturalised Mean Annual Runoff (MAR) from the Baakens River (1920-2009) was 5.3 million cubic metres (approximately 0.17 m^3/s or 170 litres per second), with baseflows comprising approximately 15.4% of total flows. Under natural conditions and on average, the months with the lowest flows were January and February. The ‘Water Resources of South Africa’ study (WR2012) estimates that under natural conditions, the river would have been intermittent, ceasing to flow for approximately one-quarter of the time in the two lowest-flow months (viz. January and February).

The Baakens catchment is underlain largely by weather-resistant Peninsula Formation sandstones and quartzites of the Table Mountain Series (TMS) of the Cape Supergroup. The geology is responsible for the acidity of the Baakens River and its poor, shallow and stony soils, which also provide the ideal conditions for fynbos and thicket vegetation. Due to its marine origins, it is also thought to be the cause of the relatively high electrical conductivity (EC) of the river water.

The vegetation of the catchment is fynbos-dominated, with thicket and forest elements in the steeper forested areas. The river occupies an important locality from a biodiversity perspective, at the confluence between two vegetation biodiversity hotspots, the Cape Floristic Region and the Pondoland-Maputaland-Albany Biome. Numerous Critical Biodiversity Areas (CBAs) have been identified in the Baakens Valley. The catchment is categorized as a Freshwater Ecosystem Protected Area (FEPA), a Fish Sanctuary area (as it supports two threatened fish species) and a Fish Support Area (FSA). It is also home to a wide array of plant Species of Special Concern, including endemic and critically endangered species.

Important seep wetlands are located in the source area of the river, in the Hunters Retreat area to the west of the city. Aside from their intrinsic ecosystem value, these wetlands offer the services of water purification, flood protection, groundwater recharge and baseflow maintenance. They are also home to the seep-dependant plant *Cyclopia pubescens* (Honeybush), which is critically endangered. The valley is home to several other plant species of special concern (SSCs), which have been at the core of certain of the Systematic Conservation Planning initiatives for the Metro.

The estuary has been built into, onto and over since the 1860s, and its remnant channel is now confined to a narrow concrete canal up to its confluence with the ocean in the Port of Gqeberha. Nonetheless, the system still retains some functionality as a link between the freshwater and marine environments and serves as a corridor for the movement of indigenous migratory fish and eel species.

The 75Ha Settlers Reserve in the lower section of the valley catchment is the only formally protected element of this catchment. Dodd's Farm area and Robert Searle Reserve are two other areas with Public or Private Open Space Zoning. Both areas are popular with walkers and mountain bikers.

CHAPTER 3: HISTORY OF THE RIVER

The Baakens has played a central role in the city's history and development. Prior to European visitors to these shores, Khoisan hunter-gatherers roamed this valley, which provided a plentiful source of water, fruit, and small animals to hunt. Of the many words inherited from the Khoisan, those still in relation to the river are Kragga Kamma, which probably means 'sweet' or 'fresh' water, and 'Kabega' (abundance of reeds) – the name of the rivers which form the Baakens at Frame Park.

Portuguese ships docking in Algoa Bay in the 1690s used a small spring near the mouth of the river, 'Baatjes Fonteyn', as a source of fresh water. The British took control of Algoa Bay in the late 18th century, and the development of Port Elizabeth commenced, north and south of the Baakens River. During those days, the estuary was a wide shallow lagoon, with a bedrock sill across the mouth that served to back-up incoming tidal water while allowing the river to flow to the ocean. For decades the lagoon was used as a recreational area, as small boats could also access it, however as development progressed, factories were built along the left (northern) bank of the lower river, and the system was slowly degraded to the point that it became unusable for recreation.

In the 1860s it was the site of several factories and wool washing operations on its bank. In 1864 the city was granted the right to fill a portion of the lagoon with rock from a nearby area which had been quarried for development. Over time the lagoon was gradually 'reclaimed' and declined in size and condition until eventually there was no hint that it had ever been there. The lower sections of the river were eventually confined to a canal to make space for more development. This canal still carries the water of the Baakens River to the ocean, via the city's Port.

In the 1950s the City formally protected the area, which is now known as Settlers Valley, upstream of the upper limit of the estuary. An area of approximately 75 ha was cleared and fenced to create Settlers Park. A network of walking trails was created and Settlers Park became a well-loved recreational area. It is only in the past decade that this area has become overgrown and is now considered unsafe to walk alone in.

Note: This section is a summary of the Baakens History as variously told by Dean McCleland (2017, 2018).

CHAPTER 4: APPROACH AND METHODS

This study had four main tasks:

1. A description of current state: The river, in terms of its water quality, flora and fauna, using the method of Ecoclassification.
2. The development of rehabilitation scenarios: The formulation of an overall vision and broad strategy for the catchment, and three rehabilitation scenarios each associated with numerous interventions.
3. A cost-benefit analysis: The analysis of the cost-effectiveness and cost-benefit of these options.
4. A series of recommendations regarding prioritisation of rehabilitation interventions: The interaction with key stakeholders in the setting of the vision and objectives, and in discussing and prioritising rehabilitation scenarios.

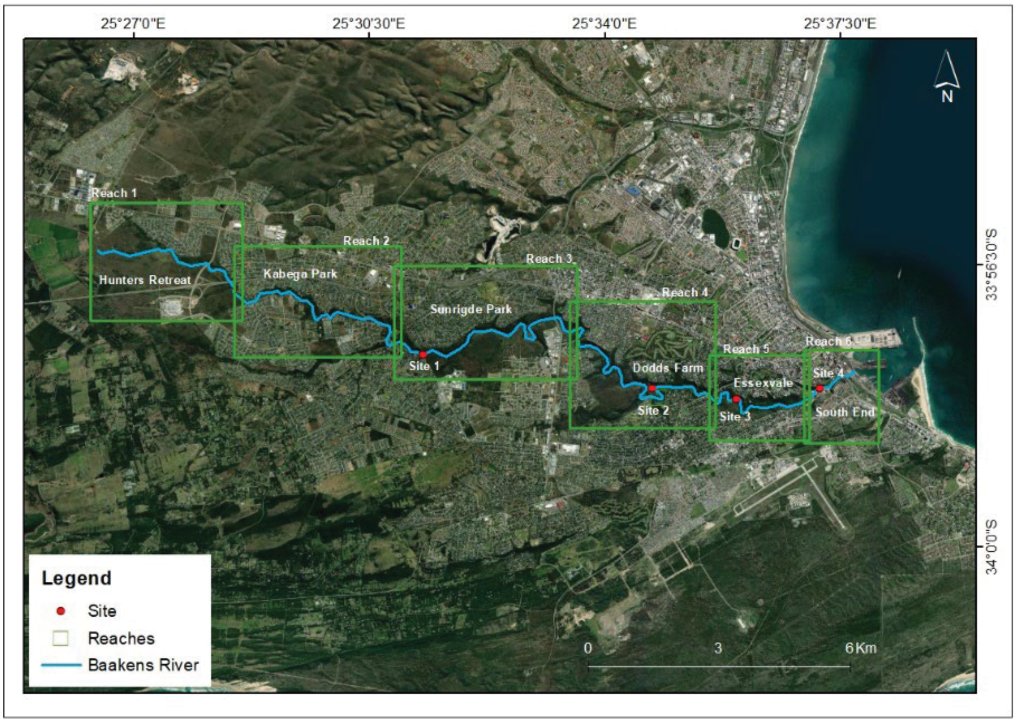
This report (Part 1 of the series) deals with the first of these phases, determination of Current State. The approach followed is the standard South African stepwise method of Ecoclassification, somewhat tailored to the resources available in the project. The following are the steps taken to determine Present Ecological State, in this case based on water quality, riparian vegetation, fish and aquatic macroinvertebrates:

- Divide the river into manageable units for analysis (reaches), and select one site within each of four reaches.
- Determine reference conditions for each component, i.e. create an informed picture of how your component of the river system (e.g. fish), and the river, is likely to have looked prior to anthropogenic influence.
- This is a desktop exercise and relies on existing information, data and anecdote -
  - Determine the Present Ecological State for each component as well as for the EcoStatus. The EcoStatus refers to the integration of physical changes, as reflected by biological responses.
- This involved a single site survey planned for May 2022, at which the relevant sampling methods would be applied at each of four sites.
  - Component-specific Excel spreadsheet-based models (PAI, VEGRAI, FRAI, MIRAI) were used to calculate the extent of deviation of condition of that component from reference condition. The output is the PES for the component. The component PES were then used to determine the Ecostatus for the site. The Ecostatus is expressed as a category from A to E (pristine to critically degraded). Each subsequent category represents 10-20% greater deviation from reference condition, which is set at 100%. Thus, a C category represents a deviation of 30-50% from reference.
  - Determine the trend (i.e. is the site improving or deteriorating) for each component as well as for the EcoStatus.
  - Determine causes for the PES and whether these are flow or non-flow related.
  - Determine the Ecological Importance and Sensitivity (EIS) of the biota and habitat.

CHAPTER 5: DIVISION OF THE CATCHMENT INTO UNITS

For the purposes of assessment and analysis, the river length was divided into six relatively homogenous reaches on the basis of a range of considerations: ecosystem type (wetland, river or estuary) and morphology, geology and topography, land-use zoning, protected area status, linkage to previous studies' river divisions, extent of degradation and accessibility.

A single river site for survey/sampling was selected within each of the four lower reaches. Where possible these sites corresponded with existing or historic sites (water quality, fish sampling) so that historic data could be consulted.



Map of the Baakens showing the 6 river reaches and 4 sites for PES determination.

Photographs of one portion of each of the four sampling sites (Clockwise from Left Top: Sites 1-4)

CHAPTER 6: REFERENCE CONDITIONS

Water Quality

The Reference Condition or natural state would be described by slightly salty water with high dissolved oxygen levels, low nutrients and low toxins. It is assumed that instream temperatures would be low due to overhanging vegetation.

The natural geology of Peninsula Formation shales underlying the catchment is expected to be the reason for the somewhat 'salty' (high electrical conductivity) character of the overlying waters. It is assumed that although there has been an anthropogenic increase in salinity levels, the natural or reference state would still be higher than 30 mS/m. The baseline condition was therefore recalibrated to 55 mS/m to account for these 'natural' salts. Note that this is an assumption, as no data exists for unimpacted systems.

Riparian Vegetation

Within the Baakens River catchment the two dominant Vegetation Units are Algoa Sandstone Fynbos and Bethelsdorp Bontveld which belongs to the Albany Thicket Bioregion and follows the contours of the Baakens River along its incised valley.

Under Reference Condition, sites in the Fynbos are expected to not be dominated by tall woody species, with lower to small shrubs at most and characterised by a marginal zone dominated by non-woody riparian obligates such as sedges, grasses and hydrophilic herbaceous forbs. Algoa Sandstone Fynbos is described as "flat to slightly undulating plains supporting grassy shrubland (mainly graminoid fynbos). Grasses become dominant especially in wet habitats".

Sites within the Albany Thicket on the other hand are expected to have a well-defined and tall woody component, but one that does not dominate to the extent of exclusion of marginal zone non-woody specialists. Bethelsdorp Bontveld is described as "a mosaic of low thicket (2-3 m) consisting of bush clumps in a matrix of low, succulent-rich shrubland comprising renosterveld and succulent karroid elements, e.g. *Smelophyllum capense*.

Fish

The indigenous fish species expected under natural or reference condition in the Baakens River are tabulated below.

FISH SPECIES			
SCIENTIFIC NAME	**COMMON NAME**	**SCIENTIFIC NAME**	**COMMON NAME**
Pseudobarbus afer	Eastern Cape redfin	*Monodactylus falciformis*	Cape moony
Sandelia capensis	Cape kurper	*Anguilla mossambica*	Longfin eel
Enteromius pallidus	Goldie barb	*Eleotris fusca*	Dusky sleeper
Myxus capensis	Freshwater mullet	*Awaous aeneofuscus*	Freshwater goby
Mugil cephalus	Flathead mullet	Stenogobius ?polyzona	Banded goby

Invertebrates

The invertebrate taxa expected to be present in the middle and lower reaches of the Baakens River under natural conditions are tabulated below. Note that to account for the naturally high Electrical Conductivity (EC) or 'saltiness' of the water, taxa scoring over 10/15 (higher sensitivity to water quality) have been removed from the derived reference condition.

TAXON	Family	Common name	TAXON	Family	Common name
PORIFERA		Sponges	MEGALOPTERA	Corydalidae	Dobsonflies
COELENTERATA		Freshwater polyp	TRICHOPTERA	Ecnomidae	Caseless caddisfly
TURBELLARIA		Flatworms		Hydropschychidae	Net-spinning caddisfly
ANNELIDA	Oligochaeta	Aquatic worms	COLEOPTERA	Hydroptilidae	Purse-case caddisflies
HIRUDINEA		Leeches		Leptoceridae	Micro-caddis
CRUSTACEA	Potamonautidae	Crabs		Dytiscidae	Predaceous diving beetles
	Palaeomonidae	Freshwater prawns		Elmidae	Riffle beetles
HYDRACARINA		Water mites		Gyrinidae	Whirligig beetles
EPHEMEROPTERA	Baetidae 2 sp	Small minnow mayflies		Haliplidae	Crawling water beetles
	Caenidae	Cainflies (mayflies)		Hydraenidae	Minute moss beetles
	Leptophlebiidae	Prongills (mayflies)		Hydrophilidae	Water scavenger beetles
ODONATA	Synlestidae	Malachite dragonfly	DIPTERA	Ceratopogonidae	Biting midges
	Coenagriidae	Narrow-winged damsel		Chironomidae	Midges
	Lestidae	Spreadwing damselfly		Culicidae	Mosquito larva
	Protoneuridae	Hawker dragonflies		Dixidae	Meniscus midges
	Aeshnidae	Darner dragonflies		Empididae	Dagger flies
	Gomphidae	Skimmers		Muscidae	House fly larvae
	Libellulidae	Common skimmers		Psychodidae	Moth fly larvae
HEMIPTERA	Belostomatidae	Giant water bugs		Simuliidae	Blackfly larvae
	Corixidae	Water boatmen		Syrphidae	Rat tailed maggot larvae
	Gerridae	Pond skaters		Tabanidae	Horsefly larvae
	Hydrometridae	Marsh treaders		Tipulidae	Cranefly larvae
	Naucoridae	Creeping water bugs	GASTROPODA	Ancylidae	Freshwater limpets
	Nepidae	Water scorpions		Lymnaeidae	Pond snails
	Notonectidae	Backswimmers		Physidae	Pouch snails
	Pleidae	Pygmy backswimmers		Planorbinae	Orb snails
	Veliidae	Riffle bugs			

CHAPTER 7: SURVEY RESULTS

Site 1: Hawthorne Ave, Upper River

WATER QUALITY (WQ)
The river at Site 1 is significantly transformed from natural. There was a risk of high turbidity levels if the fine sediment were to be mobilized during high flows, for example. Hawthorne Sewage Pump Station located directly below the sampling point at Site 1 Is reportedly non-compliant with discharge standards and dysfunctional at times. Load-shedding will exacerbate this situation, and backup, temporary storage, or bypass protocols may be inconsistently applied according to reports. *E*. *coli* levels were very high at this site, indicating sewage pollution.
RIPARIAN VEGETATION
Most of the reach has been invaded by perennial alien species which has resulted in the exclusion of indigenous flora. Portions of the reach have been cleared and landscaped by river front and replanted banksand constructed some in-channel pools and habitats. These in-channel areas support some in-channel marginal zone vegetation.
FISH
Five individuals of the indigenous goldie barb *Enteromiu*s (ex *Barbus) pallidus* were captured within the upper section among marginal vegetation and under the rocks on the substrate.
AQUATIC INVERTEBRATES
The invertebrate fauna was a resilient, low diversity one, comprising mostly taxa scoring ≤8 out of 15 on the sensitivity score, except for the baetid mayflies (>2 species present, scoring 12). The SASS5 score was 76, with 19 taxa, giving an ASPT of 4.

Site 2: Dodd's Farm, Middle River:

WATER QUALITY (WQ)
Despite the aesthetics of the surrounding area, the odour and visible water quality clues at the weir on Dodd's Farm indicated poor water quality. A pipe built into the weir was discharging raw effluent, possibly from the Mangold Park sewage pump station upstream. Dissolved oxygen at this point was extremely low but increased with distance downstream. DWS results indicate that on average, *E. coli* levels are extremely high (exceed limits) in this section.
RIPARIAN VEGETATION
Marginal Zone Riparian and aquatic vegetation associated with pools at this site is mostly indigenous, but the alien *Myriphyllum* (Parrots Feather) has started encroaching in some areas and may invade. Indigenous riparian species occur in pools. Most of the marginal zone is not in the backup areas however and comprises runs with overhanging vegetation and less aquatic representation. Here *Phragmites australis* are present. **Non-marginal zone** This zone is characterised by high aerial cover and dense vegetation, both woody and non-woody and the patchiness of this appears to be maintained by mowing and clearing of certain areas for public access. Open areas are dominated by grasses while woody areas range from bush clumps with dense shrubs to more open understorey areas dominated by tall trees to shrub and succulent-dominated Fynbos as one leaves the valley. Perennial alien species comprising dense shrub and tall trees exist at moderate levels and pose a threat to longer-term integrity of natural vegetation.

Site 2: Dodd's Farm, Cont…

FISH
No indigenous fish species were found during the present survey at Site 2, with only low numbers of alien banded tilapia and southern mouthbrooder captured.
AQUATIC INVERTEBRATES
The SASS5 score was 68, with 15 taxa, giving an ASPT of 4.5. The highest scoring taxon was the single Platycnemid damselfly larva (scoring 10/15). The stones-in-current fauna was dominated by baetid mayflies and sImuliid (blackfly) larvae, and the marginal vegetation by simuliid larvae and physid snails. Notably absent were a variety of Hemiptera (bugs) and Coleoptera (beetles).

Site 3: Essexvale (in Settlers Park), Lower River:

WATER QUALITY (WQ)
Discharges from Essexvale Pump Station are reported to overflow directly into the river in this reach. At the time of the site survey a significant rupture in the rising main off Lloyd Road was responsible for the impacts seen at Site 3, e.g. low oxygen levels (3.36 mg/L) even in fast-flowing water. *E. coli* levels were very high and serve as an indicator of pollution by sewage discharges.
RIPARIAN VEGETATION
Marginal zone Essexvale is very similar to Dodd's Farm: The two main habitat forms in the marginal zone are pools or backup zones and natural channel forms, mostly runs with a linear nature. Riparian and aquatic vegetation associated with pools is mostly indigenous, but Parrots Feather has started encroaching in some areas and may invade. **Non-marginal zone** The non-marginal zone is characterised by high aerial cover and dense vegetation, both woody and non-woody. The patchiness of woody to non-woody appears to be maintained by mowing and clearing. Open areas are dominated by grasses, while woody areas range from bush clumps with dense shrubs to more open understorey areas dominated by tall to shrub and succulent dominated Fynbos as one leaves the valley. Perennial alien species comprising dense shrub and tall trees exist at moderate levels and pose a threat to longer-term integrity of natural vegetation.
FISH
In addition to the alien banded tilapia and southern mouthbrooder captured at this site, four endangered Eastern Cape redfin and one large (ca. 45 cm long) longfin eel were captured. It is important to note that Site 3 is located in the same river reach and approximately 800 m upstream from the only site in the Baakens River where this endangered Eastern Cape redfin was captured by Strydom in 2014.
AQUATIC INVERTEBRATES
Despite increasing sample effort, the SASS5 total sample was extremely poor, with only four taxa collected. This is attributed to the water quality impacts related to the upstream raw sewage overflow, and the associated low oxygen conditions. The SASS5 score was 9, with 4 taxa, giving an ASPT of 2.25. The only taxa collected were river crabs, notonectids, hemipterans, and chironomid and culicid dipteran larvae.

Site 4: Alchemy, Lower river (estuarine influence)

WATER QUALITY (WQ)
The river water appears clear in this section of the river, although *E. coli* levels are very high and serve as an indicator of pollution by sewage discharges. This would be expected as the site is at the bottom of an urban catchment. It is clear that poor water quality, primarily linked to sewage discharges rather than industrial waste, is of primary concern in the mid and lower catchment. Any recreational use in the lower catchment would be severely constrained by the high *E. coli* levels in the water.
RIPARIAN VEGETATION
Left Bank The marginal zone comprises a linear bank along a concrete canal, broken in places, with seeps into the zone from the upland areas. Aerial cover is 100%, dense vegetation that is mostly non-woody with overhang from woody shrubs, mostly the alien *Cestrum laevigatum* (Inkberry). The canal has some snags and a pulse of sediment moving through the system. Indigenous species dominate but aliens present include *Ricinus communis* and *Arundo donax* . The non-marginal zone is characterised by high aerial cover and dense vegetation, both woody and non-woody, and comprises a linear bank along a cliff or urban area. **Right Bank** The right bank is landscaped for public use and comprises mown lawns with some scattered plantings of Fig trees, although there is some recruitment of the invasive alien *Sesbanea punicea* nearer the channel. The right bank has little ecological value, with negligible ability to function as a corridor or for flood attenuation and virtually no contribution to biodiversity.
FISH
The only fish species captured during the present survey (freshwater mullet, *Myxus capensis*) was a secondary freshwater species with a catadromous life history. The absence of preferred slow-deep habitats favoured by this species indicates that the fish captured were using Site 4 as a migration corridor.
AQUATIC INVERTEBRATES
The river in this section of Reach 5 is considered estuarine interface, although the EC did not suggest highly salty water at this site (possibly due to dilution by rain). The river was canalised here, however there were habitat elements that could be sampled. The SASS5 score was 66, with 14 taxa and an ASPT of 4.7. Taxa present in the SASS5 sample were nonetheless the less sensitive, lower-scoring ones. The lack of more sensitive taxa is attributed to the overall paucity of good habitat in this section of the river, and to the chronic upstream deterioration in water quality.

CHAPTER 8: PRESENT ECOLOGICAL STATE, ECOSTATUS AND EIS

The PES results are presented as a summary of Present Ecological State (PES) percentages, Ecological Categories (ECs) and confidence values out of 5 (Conf) for each of the four sites, for water quality (PAI results), riparian vegetation (VEGRAI), fish (FRAI) and macroinvertebrates (MIRAI).

REACH	SITE	PAI	EC	Con	VEGRAI	EC	Con	FRAI	EC	Con	MIRAI	EC	Con
3	**1**	64.1%	C	3	13.7%	F	3	44.2%	D	2	48.9%	D	2
4	**2**	66.5%	C	3	66.7%	C	4	45.3%	D	2	43.5%	D	2
5	**3**	26.5%	E	4	62.0%	C	4	59.0%	C/D	2	14.5%	F	2
6	**4**	68.8%	C	3.5	35.9%	E	3	46.3%	D	2	40.9%	D/E	2

The final integrated results per site are presented below. These are the Ecostatus percentages (Eco %) and associated Ecological Categories (EC) together with the Ecological Importance and Sensitivity values (EIS), site Trajectory (Traj; Neg – negative), and Recommended Ecological Category (REC). IN the case of an Ecostatus of E or lower, remediation is considered a requirement.

REACH.	SITE	Eco %	EC	EIS	Traj	REC
1	**-**	-	-	HIGH	-	-
3	**1**	29.2%	E	HIGH	Neg	Remediation
4	**2**	57.8%	C/D	VERY HIGH	Neg	C
5	**3**	53.8%	D	VERY HIGH	Neg	C/D
6	**4**	39.8%	D/E	VERY HIGH	Neg	D

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ACRONYMS, ABBREVIATIONS AND NOMENCLATURE

approx.	Approximately
AR	Annual Runoff
BGIS	Biodiversity GIS
dec. deg.	decimal degrees
DHSWS	Department of Human Settlements, Water and Sanitation (historic name)
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry (historic name)
DWS	Department of Water and Sanitation (current name)
EC	Ecological Category
EIS	Ecological Importance & sensitivity
FRAI	Fish Response Assessment Index
GIS	Geographical Information System
ha	hectares (10 000 m^2 or 0.01 km^2)
IHAS	Integrated Habitat Assessment System
IHI	Index of Habitat Integrity
km^2	square kilometres
mamsl	metres above mean sea level
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MBDA	Mandela Bay Development Agency
mcm	Million cubic metres
MIRAI	Macroinvertebrate Response Assessment Index
mm	Millimetres
m^3/s	cubic metres per second
m^3/a	cubic metres per annum
na	not applicable
NMBM	Nelson Mandela Bay Metro
NWA	National Water Act
PAI	Physico-chemical Assessment Index
PES	Present Ecological State
REC	Recommended Ecological Category
SANBI	South African National Biodiversity Institute
SASS5	South African (Aquatic Macroinvertebrate) Scoring System (Version) 5
spp.	several species
VEGRAI	Vegetation Response Assessment Index
WRC	Water Research Commission
WR2012	Water Resources of South Africa, 2012

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1 INTRODUCTION TO THE STUDY

1.1 BACKGROUND

The Mandela Bay Development Agency (MBDA, hereinafter MBDA) is a special purpose development company which receives its mandate from the Nelson Mandela Bay Municipality ('NMBM') in the Eastern Cape city of Gqeberha. The MBDA has entered into an agreement with the Water Research Commission (WRC), to facilitate water-related studies in areas in which information is needed for development decision-making by the MBDA. In the case of this project, the information requirements relate to the Baakens River catchment.

The MBDA sought a study which would provide information on the current condition of the Baakens River in terms of its water quality, fauna and flora, and assess the feasibility and cost effectiveness of rehabilitating areas of the river. A Memorandum of Understanding (MOU) was signed between the WRC and the MBDA to facilitate this and other research. The WRC Research Manager involved was Mr Bonani Madikizela and the MBDA selected the Research, Innovation and Sustainability Manager, Ms Singathwa Poswa.

Laughing Waters and Associates were awarded the project and commenced work in April 2022.

1.2 RATIONALE

The United Nations Development Programme (UNDP) has declared the decade from 2021 to 2031 the UN Decade of Ecosystem Restoration ('the Decade'). In alignment with this, the international Society for Ecological Restoration (SER) has established chapters around the world, including Africa. It is critical that South Africa is equipped with adequate information, skills, resources, and tools to engage fully in the restoration of degraded ecosystems around the country, and to make their contribution to global restoration efforts in this Decade. The importance of restoration being underpinned by sound science and planning cannot be understated. This is the 'big picture' rationale behind this project.

Working from this high-level vision, this project represents the initiation of such a restoration or rehabilitation exercise on a degraded urban catchment in the Eastern Cape. The Baakens River is a small, impacted urban river with a catchment of approximately 85 km^2, and a length of approximately 23 km. This is a potentially manageable scale for a source-to-sea rehabilitation plan, with implementation phased over a decade.

Despite the various types of alteration of form and function to which the river and its estuary have been exposed in the past almost two centuries, the remaining undeveloped areas of the catchment remain ecologically connected and represent a corridor of biodiversity and conservation value, worthy of both rehabilitation and protection.

The Baakens River is central to the NMBDA plans for the South-End Precinct Development and as such, there is a need for its rehabilitation, in part to assist with the reactivation of tourism and development in the area While the Water Research Commission (WRC) has stated that it has most, if not all, the tools required to turn the degraded catchment into a green one, local contextualization in the form of a 'current state' overview of the system is required as a starting point and as a base from which decisions regarding the rehabilitation can be made. A cost-benefit analysis of the rehabilitation exercise is also a necessity. These requirements serve as the rationale for this project.

1.3 AIMS

The study aims are:

a. To determine, using accepted current South African methods, the Present Ecological State (PES) of the Baakens River, with respect to its water quality, fauna and flora, at four sites in the mid to lower catchment. From this information, the integrated Ecostatus of the sites, and the Ecological Importance and Sensitivity (EIS) is to be determined.
b. On the basis of this information, to develop a rehabilitation vision and broad strategy for the catchment, and apply these in three or four different rehabilitation scenarios, in consultation with the NMBDA and other key stakeholders.
c. To do a cost-effectiveness analysis on the scenarios.
d. To present the results of the current state and the outcomes of the cost-effectiveness analysis to a stakeholder forum, and to engage with this forum to prioritise scenarios.
e. To provide more detail on the top priority rehabilitation scenario.
f. To generate a set of recommendations to the NMB Metro regarding the feasibility and cost-effectiveness of the rehabilitation of one or more reaches of the Baakens River, as a basis for further decision-making by the MBDA and the Metro.

1.4 STUDY TEAM

The study team comprises four senior Aquatic Scientists representing different disciplines in river science, a senior Resource Economist, and a Masters of Science GIS student. The senior members of the team each have over 20 years of experience in their specialist fields. The summary details of all team members are provided in Table 1.1.






Anton Bok	James MacKenzie	Patsy Scherman	Micah Moynihan	Mandy Uys	Nonopha Kanise

Table 1.1 Names, details and roles pertaining to the six members of the study team (alphabetical).

NAME	NAME AND LOCALITY OF ORGANISATION	QUALIFICATION AND YEARS OF EXPERIENCE	ROLE ON THE PROJECT
Dr Anton Bok	Anton Bok and Associates, Gqeberha	PhD Freshwater Fish >25 years experience	Fish PES, fishway concepts and designs, rehabilitation interventions, local specialist
Dr Jackie Crafford	Prime Africa, Gauteng	PhD Resource Economics >20 years experience	Cost-benefit analysis of rehabilitation options
Ms Nonopha Kanise	University of Fort Hare, Alice	BSc Hons GIS & RS	GIS
James MacKenzie	MacKenzie Ecological and Development Services, Gauteng	MSc Riparian Vegetation, >20 years experience	Riparian vegetation PES, wetland overview, rehabilitation interventions
Dr Patsy Scherman	Scherman Environmental, Makhanda	PhD Biochemistry >20 years experience	Water quality PES, stakeholder interventions
Dr Mandy Uys	Laughing Waters & Associates, East London	PhD River Ecology >20 years' experience	Study leader and manager, aquatic Invertebrate PES, river rehabilitation, stakeholder engagement, reporting.

1.5 STUDY APPROACH

The study approach was as modular as possible for the sake of efficiency. The overall approach is described briefly here and relevant detail is provided in the Study Methods section of this report.

1.5.1 Inception

This is the project initiation phase, during which the representatives of all three parties, the WRC, the MBDA and the study team, meet and engage to familiarise themselves with the study approach and ensure expectations from both sides could be met and managed appropriately.

1.5.2 Determination of current state

The survey- and workshop-based determination of Present Ecological State (PES) for water quality, riparian vegetation, fish and invertebrates; and determination of integrated Ecostatus (based on PES) for each of four sites selected in the different, pre-determined, reaches of the river.

1.5.3 Rehabilitation scenarios, prioritisation and detailed planning

Development of a broad scale rehabilitation vision and strategy for the catchment with the inputs of the key Stakeholders. Development of a set of rehabilitation options or scenarios for the river, based on the current state and the acquired understanding of impacts and constraints.

1.5.4 Cost-benefit analysis

Analysis of the cost-benefit of the various scenarios relative to a 'do nothing' scenario. The relevant mitigation options or scenarios will then be compared against one another.

1.5.5 Stakeholder engagement

Engagement with key stakeholders, during which the rehabilitation options or scenarios will be presented and discussed, providing the Development Agency, stakeholders and the river community an opportunity to play a role in setting a vision and objectives for the catchment. The rehabilitation scenarios will be prioritized.

1.5.6 Recommendations

In line with the Aims of this project, the final stage is the drafting of a set of recommendations to the NMB Development Agency regarding the cost-effectiveness of rehabilitating the prioritised reaches of the Baakens River.

1.5.7 Capacity building

The intention of having a student on the project is to train new young capacity under the mentorship of senior practitioners, to empower the student and to share information. The student accompanied the river team into the field for both training and exposure to current and tested methods and interacted closely with the team during the Ecoclassification workshop.

1.6 CLARIFYING TERMINOLOGY

A number of terms should be clarified for the reader's information. The mixed use of the terms 'restoration' and 'rehabilitation' in the global literature leads to some confusion. In most of the contemporary literature, both terms aim for the same outcome: the return of the structure and function of a degraded ecosystem to the closest achievable approximation of its natural (pre-impact) state.

The term 'rehabilitation' is preferred by many, and by this project, because that it is felt that 'restoration' implies a return to natural pre-impact state and is thus aspirational and seldom achievable, while 'rehabilitation' aims for achievable objectives and focusses on improvement and protection. Rutherfurd et al (2000) argue that, in the case of rivers, to achieve true 'restoration', the following objectives would need to be fulfilled: the restoration of the natural range of water quality functioning; restoration of the natural sediment and flow regime; restoration of a natural channel geometry and stability; restoration of the natural riparian communities; and restoration of native aquatic plants and animals. This is seldom likely to be achievable. The goal of rehabilitation, on the other hand, is the improvement of important aspects of the stream environment and ecology, with the aim of the system eventually resembling its pre-impact state (Rutherfurd et al. 2000).

The term 'remediation' is appropriate in cases where it is not possible to rehabilitate due to a river system being irretrievably degraded, or where a system has been fundamentally altered in character but has, over time, adjusted and achieved a state of dynamic 'stability' or equilibrium. This is often the case of a river channel in a degraded catchment, or downstream of a dam or weir. The aim of remediation is to improve the ecological condition of the river, while not aiming for an endpoint which resembles its original condition (Breen and Walsh, 1999).

For the purposes of this report, the terms are used as described in Table 1.2.

Table 1.2 Definitions of terms used in this report

Description	Source
Rehabilitation	
Actions aimed at the improvement of important aspects of the stream environment and ecology, with the aim of the system eventually resembling its pre-impact state.	Rutherfurd et al. 2000
Restoration	
Actions which aim to achieve a return to natural, pre-impact state.	Rutherfurd et al. 2000
Remediation	
The aim of remediation is to improve the ecological condition of the river, while not aiming for an endpoint which resembles its original condition.	Breen and Walsh 1999

1.7 LIMITATIONS OF THE STUDY

It should be noted that this study is a scoping level, feasibility study and not a rehabilitation planning exercise. This study was initiated as a first step in the DA's decision-making process regarding the future of the Baakens River. Recommendations will include the need for extensive further studies and for a full rehabilitation plan.

The background information on which sections of this report are based is that which has been sourced or made available to the Team at the time of review, survey and analysis. Some of the more relevant information could not be sourced, as Officials were not available or did not respond to email requests for information. As information is shared by these sources, including the Metro, this information may be updated.

2 THE BAAKENS RIVER

2.1 LOCALITY

The Baakens River runs from west to east through the city of Gqeberha (formerly Port Elizabeth) in the Eastern Cape Province of South Africa, serving as the backbone of its natural systems and providing a 'green lung' to the city (Figure 2.1).

The river rises in a series of seep wetlands in the west, in the areas of Sherwood, Hunters Retreat and Rowallan Park, and flows eastwards through largely urban areas, with a total mainstream length of approximately 27 km and 15 km of tributaries (SRK 2014). The catchment size is approximately 85 km^2, and it is located within Water Management Area 7 (Mzimvubu to Tsitsikamma), quaternary catchment M20A and Ecoregion (level 2) 20.01, the South Eastern Coastal Belt. The characteristics of this ecoregion are presented in Appendix 1. The river flows into the Indian Ocean at the Port of Gqeberha in Algoa Bay.

Figure 2.1 Baakens River locality within the Eastern Cape, sub-quaternary M20A.

2.2 PHYSICAL SETTING

2.2.1 Climate, rainfall and runoff

Nelson Mandela Bay Metro is at the confluence of a number of climatic zones, and principally at the transition between subtropical and temperate climates. The region has a warm temperate climate, with average monthly temperatures ranging from 18 to 25°C in summer and 9 to 20°C in winter. Berg wind conditions preceding westerly cold fronts can cause very high temperatures during autumn and winter, and summer temperatures can also be extreme (SRK 2013).

Rainfall follows a bimodal pattern, with peaks in spring and autumn and a wide variation between years, ranging from 350-200 mm (Lear 2013). Outside of drought periods, convective rainfall can occur at any time during the year, associated with the passing of frontal troughs.

2.2.2 Geology, topography and soils

The geology of the Baakens catchment is chiefly Peninsula formation, comprising sandstones and quartzites of the Table Mountain Series (TMS) of the Cape Supergroup. This weather-resistant rock is grey to white-coloured and fine-grained with thin subordinate layers of shale. It is responsible for the acidity of the Baakens River and its poor, shallow and stony soils which provide the ideal conditions for fynbos and thicket vegetation (Buchanan 2014).

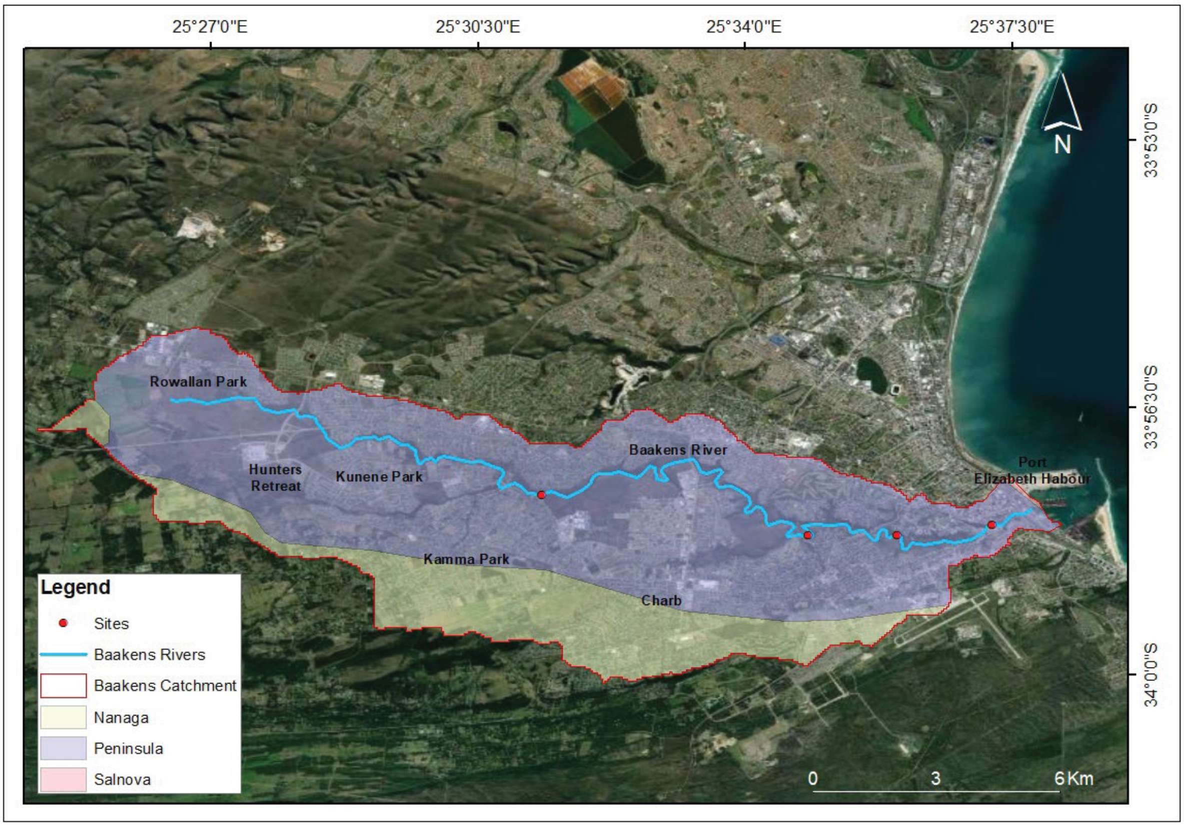

Figure 2.2 Geology of the Baakens River catchment. Source: Scherman Environmental

From the source area which is characterized by seep wetlands (Sherwood, Hunters Retreat and Rowallan Park areas) to the upper reaches of the river, the geology is dominated by Peninsula formation, though this is not as visible as in lower reaches. Soil depth is 450-750 mm, and the valley is wide and shallow. In the upper river, in the vicinity of Sunridge Park, topography is typically not as steep as in the middle and lower areas, and the river has long, gentle curves with valley sides reaching a height of about 10 m (McCallum 1981).

The slopes of the valley gradually increase in height and are at their highest and steepest towards the lower river at Dodd's Farm and Target Kloof. The south-facing slopes are generally steeper and include more cliffs, while the north-facing slopes, although more rounded, have a harder appearance as a result of rocky outcrops and a sparser, more succulent type of vegetation (McCallum 1981).

The lower reaches, closer to the coast, differ from the middle and upper reaches, as they are dominated by Salnova Formation geology. This is associated with the Algoa Group geology and is characterised by marine and estuarine calcareous sand and siltstone. Here in the lower river, the topography is steeper on the northern side, with cliffs up to 40 m high above the river. In this lower area, the river also forms the most meanders, each with a different orientation, configuration and character (Buchanan 2014). The Salnova Formations are reportedly often characterized by abundant and diverse invertebrate faunas that are dominated by various groups of mollusks, particularly bivalves and gastropods (Almond 2010).

Figure 2.3 The topography of the middle and lower catchment. Looking towards the sea from Dodd's Farm, from a high point looking downstream. North-facing slopes located on the left, south-facing slopes on the right of the image.

The predominant soil forms found in the Baakens catchment originate from the quartzitic sandstones of the TMS. They are the Valley, Upland and Plateau soils, which are shallow and of poor quality, and tend to be stony on the sides and upper reaches of the Valley (McCallum 1981). Due to their TMS origins, they tend to be acidic. Colluvial soils of the Valley form are found along the sides of the river bed where they have been deposited by the river (McCallum 1981). These are deep, sandy soils that become waterlogged quickly after heavy rains.

Grey, siliceous and rocky soils of the Upland form are located along the slopes of the Valley and its tributaries. These are well-drained soils, and vegetation on them is sparse. The shallow, grey soils of the Plateau form are located on the higher and more level sections of the study area (McCallum 1981). The drainage of these soils is impeded by underlying ferricrete, and they are thus subject to waterlogging after heavy rains.

2.2.3 Hydrology

The Scope of Work for this project excluded hydrological analyses, but basic information is available from the 2012 'Water Resources of South Africa' study (WR2012), and is provided here to give some limited context. The naturalised monthly flow time-series is available for Quaternary M20A for the period 1920 to 2009. Flow is expressed in millions of cubic metres per month.

The Baakens River sub-catchment is approximately 23.2% of quaternary M20A, and this area-scaling factor was used to provide an estimate of the naturalised time-series[1] at the outflow of the Baakens River. Statistical analyses were carried out using the SPatial And Time Series Information Modelling (SPATSIM; Hughes, 2004) software; baseflow separation applied regionalised parameters as described by Hughes and Watkins (2002). The 1920 to 2009 flow time-series, expressed as monthly flow rates, is illustrated in Figure 2.4. Flow rates (in cubic metres per second) are used on the y-axes rather than a monthly volume (in millions of cubic metres), as it is generally easier to comprehend how much water this is.

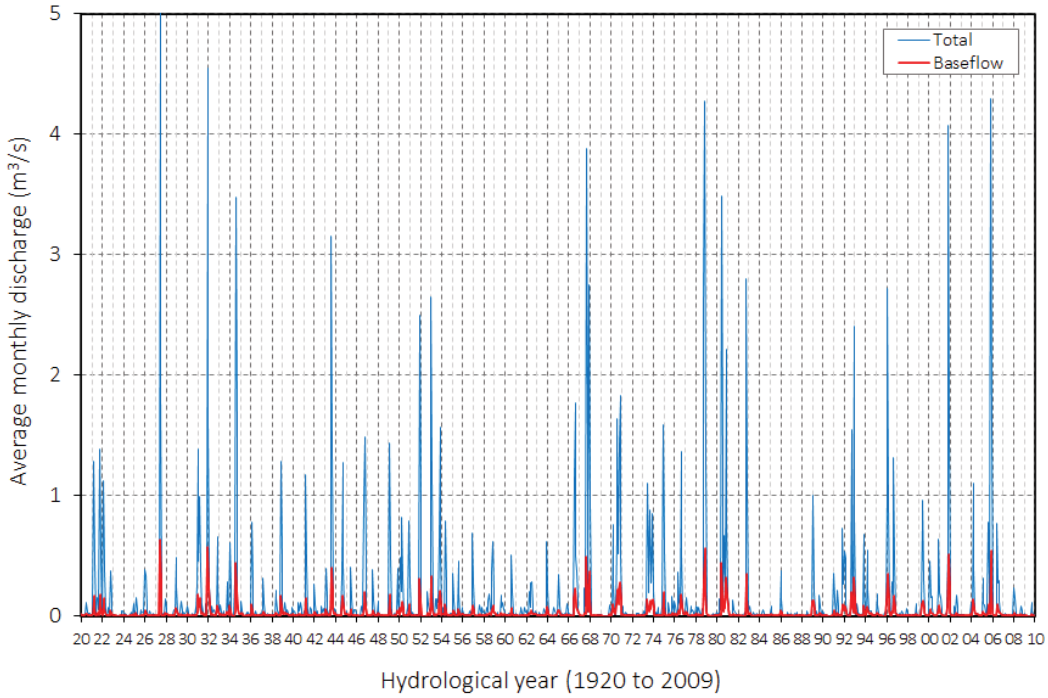

Figure 2.4 Time-series of monthly average total and baseflow discharge from 1920 to 2009 from WR2012

The naturalised Mean Annual Runoff (MAR) from the Baakens River was approximately 0.17 m^3/s or 170 litres per second (5.3 million cubic metres per annum), with a standard deviation of 0.20 m^3/s. The naturalised mean annual baseflow was 0.027 m^3/s, with a standard deviation of 0.028 m^3/s. The high standard deviations relative to the means signify a (naturalised) river with a variable flow regime (hydrological variability index of 38.2). Baseflows comprised about 15.4% of total flows (naturalised situation).

Some further monthly statistics are provided in Table 2.1.

[1] A naturalized flow time series is one that excludes any anthropogenic influences on hydrology

Table 2.1 shows that under natural conditions and on average, the months with the lowest flows were January and February, and with the highest flows were August and September. WR2012 estimates that under natural conditions, the river was intermittent, and ceased to flow for approximately one-quarter of the time in the two lowest-flow months (viz. January and February).

Table 2.1 Average monthly naturalised total (WR2012) and separated baseflows (according to Hughes and Watkins 2002) for the Baakens River catchment

Month	Mean (m^3/s)		% zero months
	Total	Baseflow	
Jan	0.051	0.010	17
Feb	0.038	0.007	28
Mar	0.162	0.022	8
Apr	0.102	0.016	8
May	0.183	0.026	3
Jun	0.191	0.028	2
Jul	0.198	0.030	1
Aug	0.311	0.045	0
Sep	0.297	0.045	0
Oct	0.191	0.032	1
Nov	0.161	0.027	1
Dec	0.118	0.021	0
Annual	0.167	0.026	

2.2.3.1 Floods

The valley was in the years 1867, 1897, 1908, 1968, 1981 and 2006, 2012 and 2015 the scene of severe floods. The months in which floods occurred vary (e.g. May 1897, November 1908, September 1968, October 2012, July 2015). There are numerous anecdotes of the resulting flood devastation and loss of lives in a number of these events. The biggest threat during flooding seems to be in the lower sections of the river. (see Section 3: History).

Figure 2.5 Water levels at the Baakens lower bridge during the 'Great Flood' of 16.11.1908. Source: McCleland 2018

Figure 2.6 Water levels alongside the Tramways building during the 1908 'Great Flood'. Source: McCleland 2018.

Figure 2.7 Water levels in the lower Baakens River during floods in July 2015. Looking upstream towards Brickmakerskloof Road Bridge. Source: Herald Newspaper online.

2.2.3.2 Floodlines

The most recent floodlines for the Baakens focus on the lower river (Figure 2.8) and were produced in 2014 (SRK 2014). As is clear (and well known), there are numerous historic developments in this lower section which are located in the floodplain, and well within the 1:100 floodline. An example of the water level in this lower area, during the flood of July 2016, is shown in Figure 2.7. Any new developments – or indeed rehabilitation plans – in the valley need to take account of this serious and as yet unmitigated threat. To this end, updated floodline studies are to be commissioned in the foreseeable future (Davids, pers. comm. 2022)

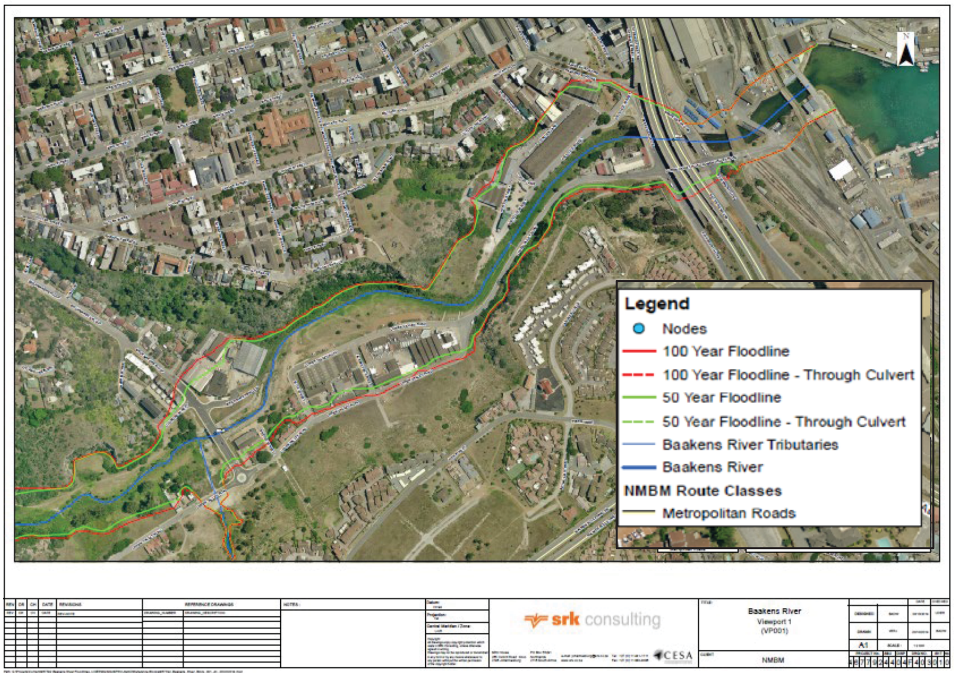

Figure 2.8 1:50 and 1:100 year floodlines for the Lower Baakens produced by SRK Engineers in 2014

2.2.4 Terrestrial vegetation

The vegetation map of South Africa is a model of the historical extent of the vegetation types prior to the year 1750 and incorporates data from the SA National Vegetation Database. Vegetation types are nested within a hierarchy. At the highest level there are nine distinct Biomes of South Africa and a tenth of Azonal vegetation which represents vegetation that crosses climatic and geographic boundaries. Nested within the Biomes are Bioregions. This level is linked more strongly to management units and broad ecoregions. The 3rd level of the hierarchy and the core of the vegetation map is the vegetation type. These units represent groups of communities that share similar biotic and abiotic features, and although these may or may not be applicable to riparian zones or wetlands, they are taken to represent the terrestrial context in which the riparian ecotone occurs.

Within the Baakens River catchment, there are 4 Vegetation Units (Figure 2.9). Algoa Sandstone Fynbos dominates the catchment spanning 94% of the catchment area, with 5% Bethelsdorp Bontveld which belongs to the Albany Thicket Bioregion and follows the contours of the Baakens River along its incised valley. Only 1% of the vegetation is represented by St Francis Dune Thicket and 0.1% is Cape Seashore Vegetation.

Detailed descriptions of the two dominant vegetation units are replicated from the NBA database (SANBI, 2018) in Appendix 2 (Section 10.2).

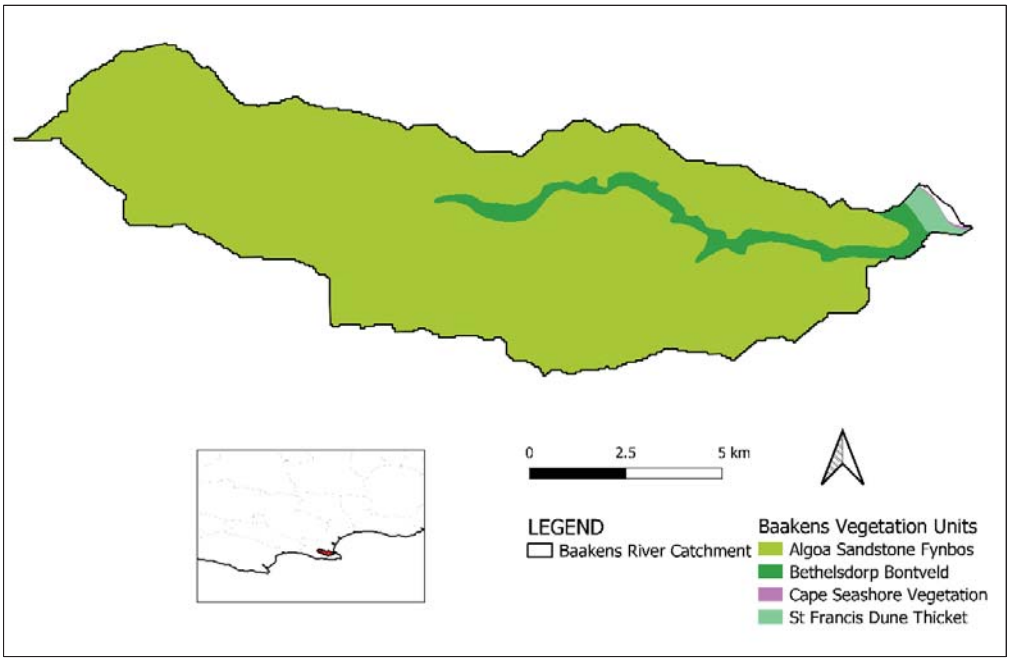

Figure 2.9 Vegetation Units within the Baakens River Catchment (Mucina & Rutherford, 2006, 2018; NBA update shown; SANBI 2018).

2.3 WETLANDS

Following the National Biodiversity Assessment (2018) the resultant new wetland map (NWM 5) is the current national wetland coverage (SANBI 2018). Based on this map and its underlying data, the wetlands within the Baakens River catchment are shown in Figure 2.10

The most extensive wetland is the Baakens estuary, albeit in a heavily modified current state, although there are also notable unchanneled valley bottom wetlands and a fair density of seep and depressional wetlands in the headwaters of the catchments. The seep and depressional wetlands all occur in Algoa Sandstone Fynbos and provide critical habitat for one of the last remaining populations of the Eastern Cape endemic *Cyclopia pubescens*, a critically endangered shrub that is a seepage wetland specialist. At least 80% of this species' habitat is already transformed as a result of urban expansion, agriculture and alien plant invasion. Further urban expansion threatens at least two remaining subpopulations, and alien invasive plants are present in the locality of three subpopulations (Raimondo et al. 2011).

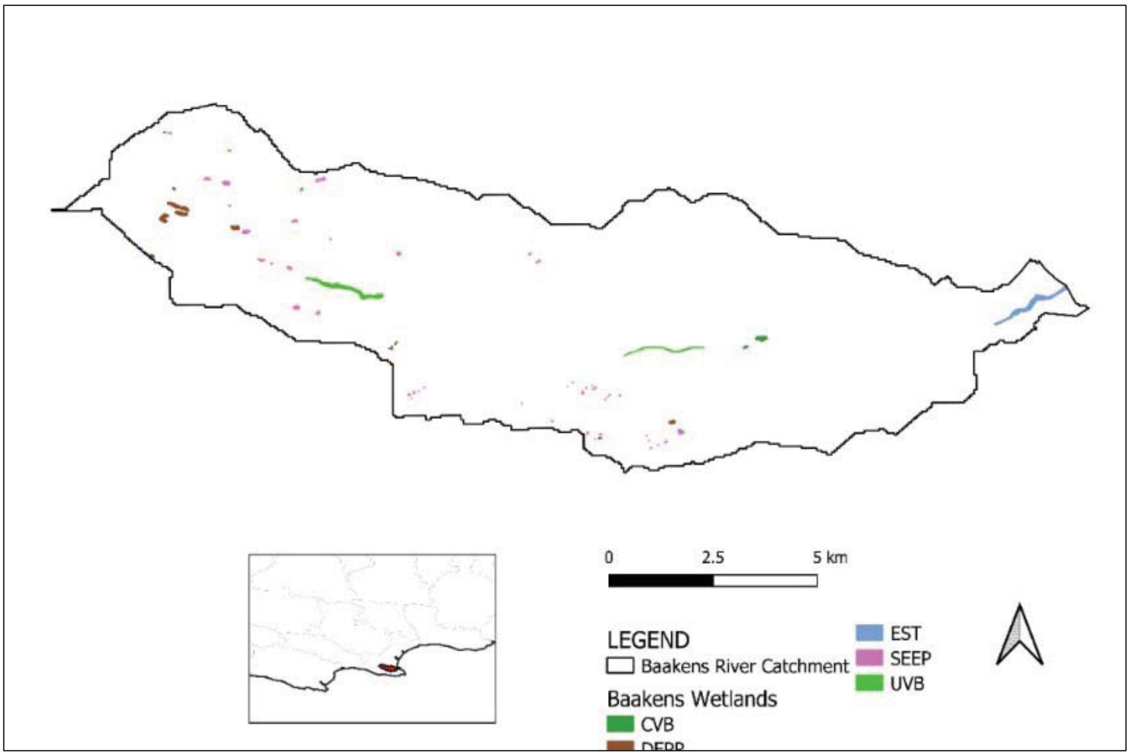

Figure 2.10 Wetland Hydrogeomorphic Units within the Baakens River Catchment (SANBI, 2018).

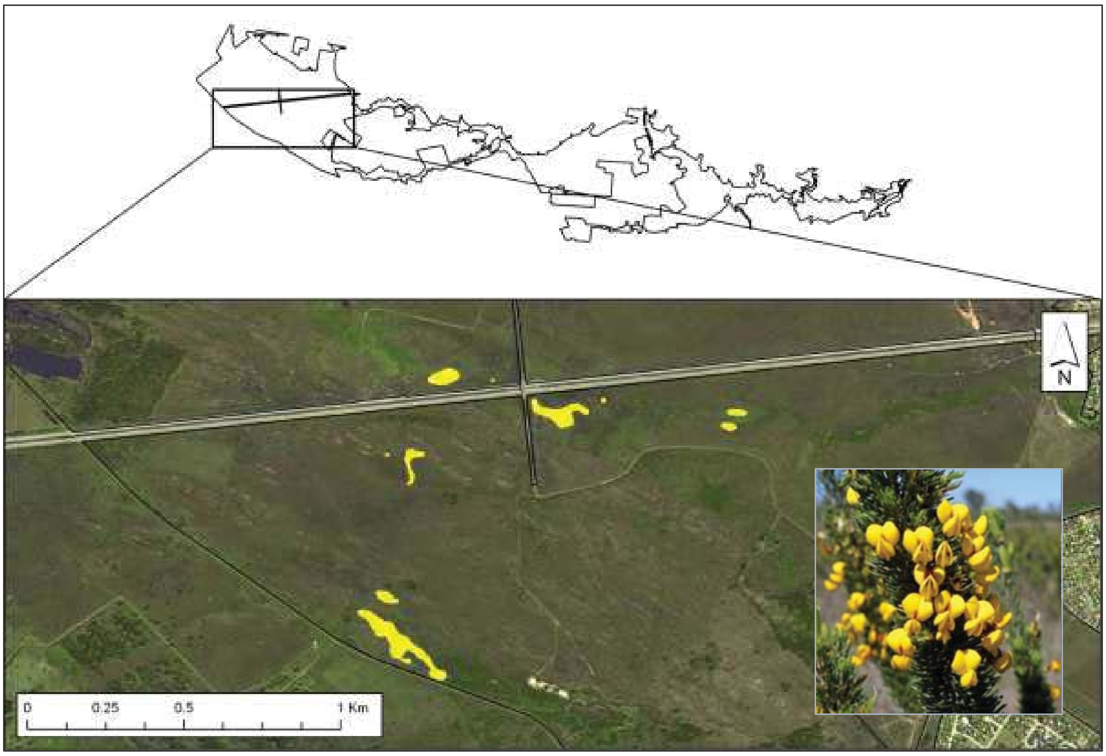

Figure 2.11 Yellow areas indicate the distribution of *Cyclopia pubescens* in the upper Baakens River Valley. Inset: *Cyclopia pubescens.* Source: Grobler 2012

2.4 ESTUARY

Extensive alterations to the lower sections of the river started in 1850, and by 1900 the whole area of the river and its floodplain downstream of Brickmakers Kloof had been completely transformed by development (McCallum 1981). This lower estuarine area of the Baakens was largely reclaimed for development, and the remainder confined into a narrow, shallow canal. Towards the Port, where the canal opens to a more natural width, highways have been constructed directly overhead, and this portion of the system has been degraded by deposition of concrete and rubble, shading, and the invasive presence of large piers. Despite the loss of functionality that this resulted in, the National Estuarine map indicates that in these lower reaches, the Baakens is still classified as an estuary, and this delineation extends up to the Brickmakerskloof bridge. According to Strydom (2014), 'this is still an important nursery area for juvenile marine fishes, particularly the catadromous River mullet*, Myxus capensis,* Flathead mullet*, Mugil cephalus,* and Cape moony*, Monodactylus falciformis*. These species naturally penetrate farther upstream to take advantage of the rich food resources in the form of aquatic insect larvae, on which they are known to feed (Strydom et al. 2014). The catadromous Longfin eel, *Anguilla mossambica* was also recorded in the current study. These species spawn their eggs in the sea and then the larvae and juveniles migrate through estuaries and into rivers*.'*

A bedrock sill is located at the lower end of the estuary. This is no longer visible except as the foundation for the present-day freeway piers across the estuary. Prior to the substantial changes inflicted on the estuary, the bedrock sill was the major hydraulic control, and resulted in the formation of a tidal lagoon. High tides would flow in, and at low tide, the bedrock sill behaved like a dam wall, retaining a raised water body upstream of it until the next high tide. At that time, the flow of the river was still unimpeded at low tide, and it could still flow over this sill. The columns of the freeway bridge that crosses the estuary are founded on the bedrock sill (Figure 2.12, McCleland 2017).

Figure 2.12 Degradation of the lower Baakens. L: The canalised estuarine section to the west of the Tramways building. R: The estuary below the freeway (low tide).

Historically during high tide, small sailing vessels with a very shallow draft could make it over the bedrock sill and sail into the lagoon. Larger vessels were not able to enter, and for this reason, the estuary was never dredged as a harbour, and one was built in the ocean just beyond the river (Figure 2.13, McCleland 2017).

Figure 2.13 The Baakens estuary just upstream of its entry to the Port of Gqeberha

2.5 PROTECTION STATUS OF THE BAAKENS

2.5.1 Land use zoning

A large portion of the undeveloped Baakens valley is zoned as Public Open Space, and there are limited areas of Private Open Space (see Figure 5.1). Here, the valley remains scenic and relatively natural, and home to diverse indigenous and non-indigenous fauna and flora. In many areas of the upper catchment however, alien vegetation has encroached and has become well established (Grobler 2014).

In 1957, the area just to the west of the lower, developed section of river, between 3rd Ave Newton Park and Brickmakerskloof Road was declared a nature reserve. This forms the current Settlers Park (McCallum 1981). The park, occupying over 75 ha is landscaped and has not retained its natural character (Grobler 2014). The 7.5 km Guineafowl hiking Trail runs through the park. While this trail was in the past very popular with walkers, it is now overgrown and poorly maintained in the lower section, and is not considered safe.

The Dodd's Farm and Robert Searle Ledger Park areas, west of Settlers Park Reserve, are zoned as Private Open Space, but are not formally protected. In this area, trails have been extended to a network that is managed and maintained by a private mountain bike (MTB) club. These tracks are widely used by MTB enthusiasts, and the area is also used to host sporting events.

2.5.2 Status in conservation planning

In 2003, the NMB Metro agreed to the following vision for biodiversity conservation in the municipal area (Stewart 2010):

"By the year 2014, a representative proportion of all biodiversity within Nelson Mandela Bay is effectively conserved, in a manner that is embraced by local communities, endorsed by government and recognised internationally".

In order to achieve this vision, a systematic conservation assessment and planning study was carried out to assess the extent to which various natural features in the Metro including vegetation types, ecological processes, and species of conservation concern (SCCs), had been irreversibly lost due to land use pressures.

This led to the identification of the critical biodiversity areas (CBAs) and critical ecological process areas (CEPAs) which are the minimum areas required to meet conservation objectives in the NMBM (Figure 2.14 and Figure 2.15). CBA maps divide the landscape into five main categories: protected areas, CBAs, ESAs, other natural areas and areas where no natural habitat remains (Table 2.2). Each category has a different desired state, which in turn determines which land uses are compatible with that category (SANBI 2018).

In order to facilitate the efficient implementation of the plan, the CBAs and CEP areas were amalgamated into 29 implementation sites and prioritised via an implementation site prioritisation framework. The Baakens River Valley was identified as one of these implementation sites and was ranked sixth on the priority rating of implementation sites (Stewart 2010).

The Baakens catchment has also been identified as a National Freshwater Ecosystem Priority Area (FEPA[1]), and has been listed as a 'fish sanctuary' primarily due to the presence of the endangered Eastern Cape redfin *Pseudobarbus afer*, which is classified as endangered (IUCN, 2013); the Goldie barb (*Entoromius pallidus*) and Cape Kurper (*Sandelia capensis*). The Southern Mouthbrooder (*Pseudocrenilabrus philander*; Bok, 1994) and Banded Tilapia (*Tilapia sparmanii*) pose a significant threat to the indigenous fish.

In terms of the Eastern Cape Biodiversity Freshwater Conservation Plan (ECBCP), quaternary M20A is also categorised as a CBA2 (A2a). These are important sub-catchments, considered to be support zones required for the prevention of degradation of A1 rivers. These areas require moderate or high protection.

Table 2.2 Description of the CBA map categories, desired state for each, and examples of compatible land uses. Source: SANBI 2018

CBA Map category	Description	Desired state	Examples of compatible land uses
Protected area	Areas that are formally protected in terms of the Protected Areas Act. Each protected area has a management plan.	As per each protected area's management plan.	• Conservation-related land uses
Critical Biodiversity Area 1 (CBA 1)	Areas that are irreplaceable for meeting biodiversity targets. There are no other options for conserving the ecosystems, species or ecological processes in these areas.	Maintain in natural or near natural ecological condition.	• Open space • Low impact ecotourism or recreation
Critical Biodiversity Area 2 (CBA 2)	Areas that are the best option for meeting biodiversity targets, in the smallest area, while avoiding conflict with other land uses.		
Ecological Support Area 1 (ESA 1)	Areas that support the ecological functioning of protected areas or CBAs, or provide important ecological infrastructure.	Maintain in at least semi-natural ecological condition.	• Low impact ecotourism or recreation • Sustainably managed rangelands • Certain forms of low density housing
Ecological Support Area 2 (ESA 2)		No further intensification of land use.	• Intensive agriculture
Other natural area (ONA)	Natural or semi-natural areas that are not required to meet biodiversity targets or support natural ecological processes.	Best determined through multi-sectoral planning processes.	From a biodiversity perspective, these areas can be used for a range of intensive land uses
No natural remaining (NNR)	Areas in which no natural habitat remains.		

[1] The National Freshwater Ecosystem Priority Areas (NFEPA) project provides strategic spatial priorities for conserving South Africa's freshwater ecosystems and supports sustainable use of water resources. These priority areas are called Freshwater Ecosystem Priority Areas, or 'FEPAs'

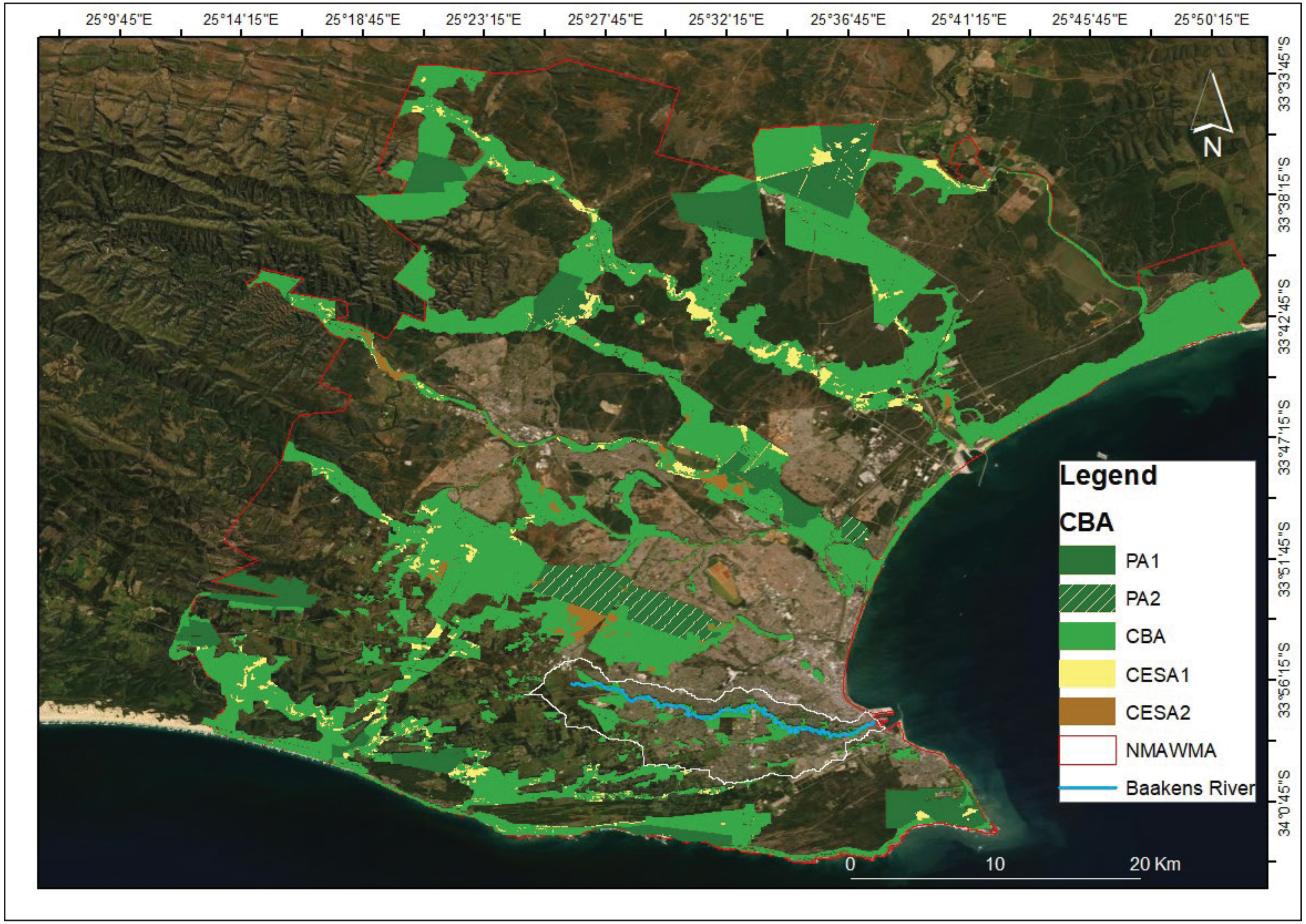

Figure 2.14 The Eastern Cape Biodiversity Conservation Plan conservation priority areas (see Table 2.2 for explanation of categories)

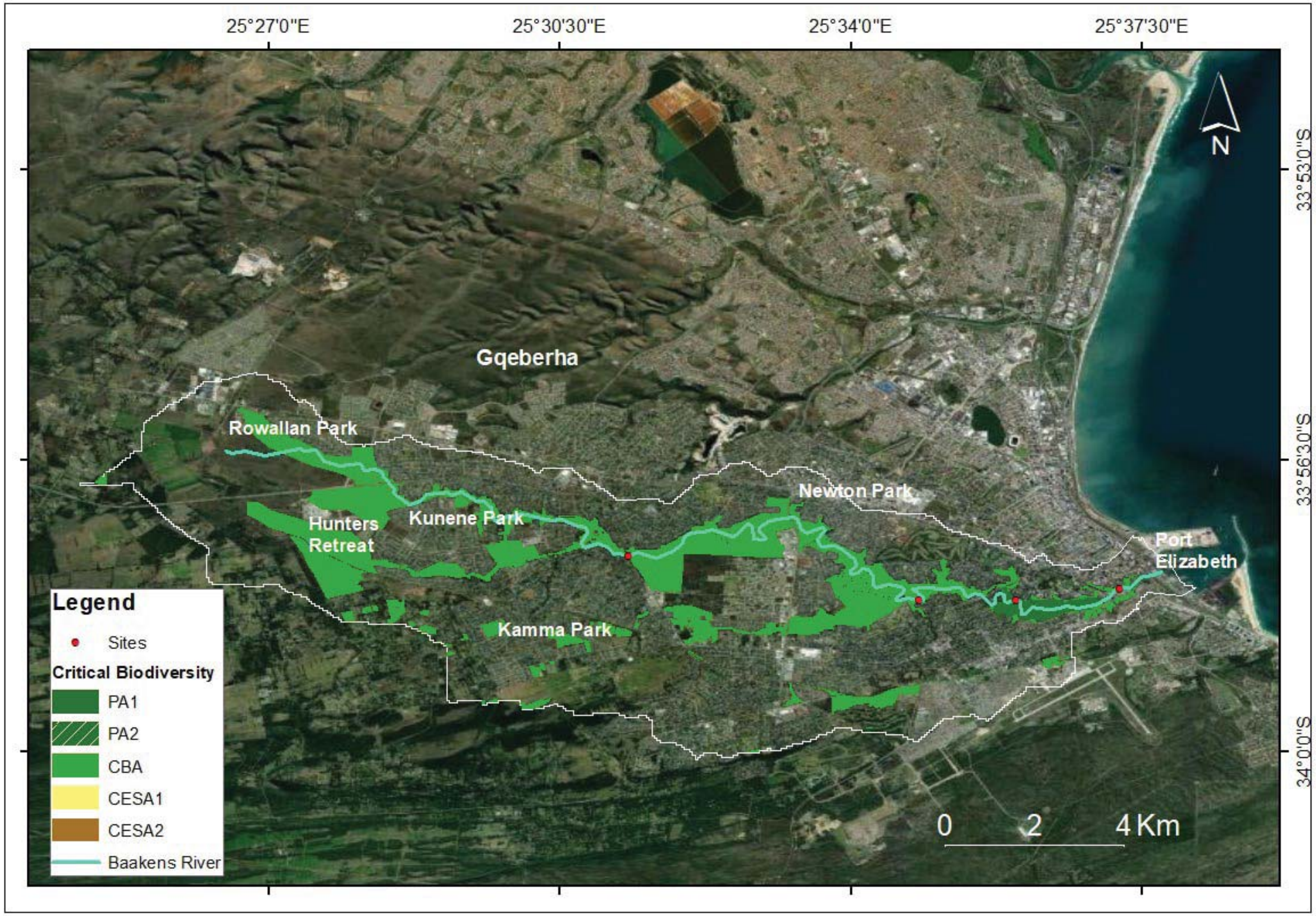

Figure 2.15 The Critical Biodiversity Areas (CBAs) identified in the Baakens River Valley areas (see Table 2.2 for explanation of categories)

3 HISTORY OF THE RIVER

This section is included to provide a background context to the Baakens, and a reference point for the rehabilitation planning process. The history to the end of the 1800s is covered here. This is summarised from the writings of McCleland (2017, 2018). Pictures: McCleland (2017, 2018, 2020).

The Baakens River in its lowest section and estuary have been altered dramatically since the 1820s. Prior to the first ships of the Dutch East India company (VOC) docking in the Port in 1690, the Baakens river and its catchment supplied freshwater and food to hunter-gatherer Khoisan coastal dwellers, and was known by the name Kragga Kama (McCleland 2018), which seems to translate broadly to the 'sweet fresh waters'.

The freshwater from the Baakens River and the sheltered bay were what that attracted the Dutch sailors to first use Algoa Bay. Evidence of this has been found in a 1789 Dutch map, indicating the "Baakjes Fonteyn". This they claimed rights to with a beacon erected on a prominent cliff in 1752 by ensign August Frederik Beutler on behalf of the VOC (McCleland 2017). The beacon is still standing.

In 1799 the first British troops took possession of the Lower Baakens. They built a fort on the current site of Fort Frederick (see Figure 3.2) reportedly to protect themselves from the Xhosa, Khoisan and the French who were providing support to the trekboers (Dutch famers who had trekked from the Cape and were trying to establish themselves in the area).

Figure 3.1 Baakens River and View of the Anchorage 1847. Artist unknown AN 094. Source: McCleland 2018

The city historically developed north and south of this important small river. However, the value of the river was clearly not apparent to the Settlers. McCleland (2018) writes:

"From a pristine lagoon in 1820 to a commercial area in forty years, is how long it took to destroy this once virgin wilderness. Unlike the Settlers, the previous inhabitants of this area, the Khoisan, without any discernible talent at building permanent structures, left no detectable evidence of their presence in the area over eons."

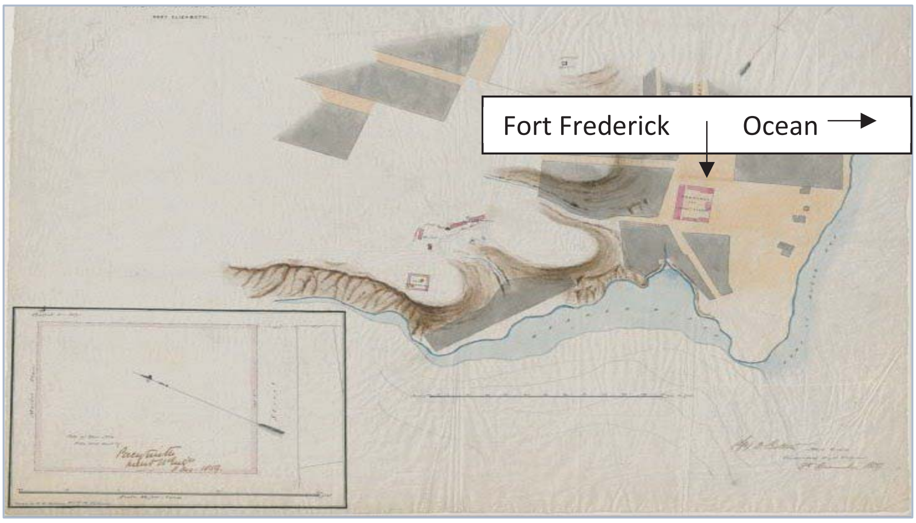

Figure 3.2 1859 map of the lower Baakens River and estuary by the Royal Engineers. Source: McCleland 2018

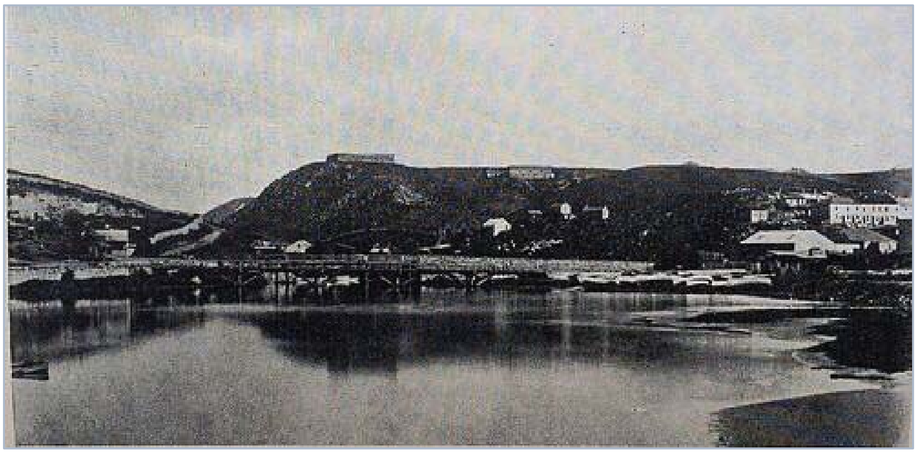

Figure 3.3 Baakens Lagoon in 1860s (looking from the mouth towards Fort Frederick). Source: McCleland 2018

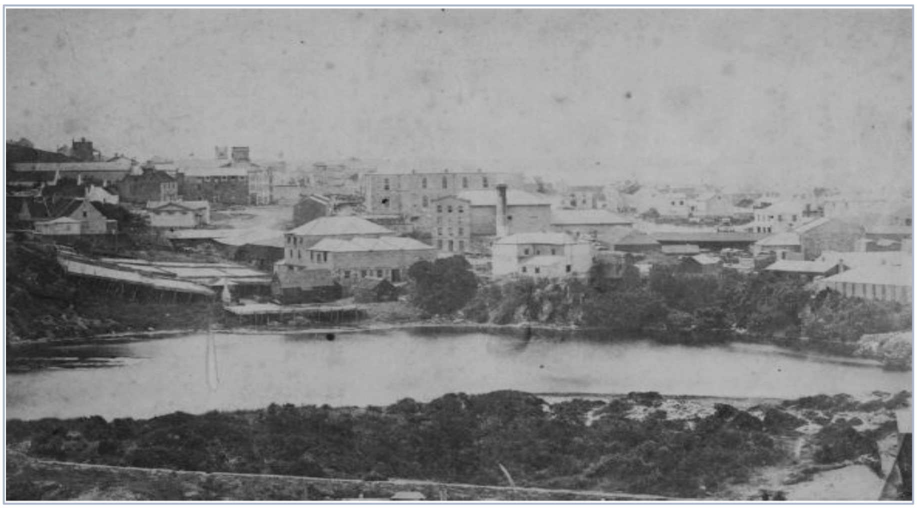

Figure 3.4 Baakens Lagoon in 1860s during the time of woolwashing operations (looking from right to left bank in the lower river). Source: McCleland 2018

The lagoon was for many years a recreational haven, and a venue for boaters. However, long before it vanished, it became unusable for pleasure activities due to various industrial activities along its banks, including wool washing operations (McCleland 2017). Probably the first of many factories and businesses established in the valley was a steam mill which became operational in 1851. The next operation was the Algoa Bay Mooring and Watering Company which piped water from a spring on the southern side of the Baakens River to a water boat at anchor beyond the surf (McCleland 2018).

During July 1864, the Municipality narrowed the channel of the Baakens River near the mouth and were granted permission to sell plots of the reclaimed land and create gardens with the proceeds. The gardens apparently did not materialise, and the money was used to purchase what is now Victoria Park (McCleland 2017).

Figure 3.5 The Baakens lagoon being filled in during the 1880s. Source: McCleland 2018

During the 1880s, a steep rocky bank behind what was then Main Street had to be excavated. Vast quantities of rock were disposed of into the Baakens Lagoon, which was at that stage in a poor condition. The Town Council consented to the dumping on the northern fringe of the lagoon (McCleland 2017). Other industries followed suit. In addition, as roads were unpaved, rains led to debris washouts down steep roads. Once again, the easiest place to dump the debris was the Baakens lagoon. In this way, the Town Council also created for themselves a land surface (which was of value to them).

By 1900 the whole area of the river and its floodplain downstream of Brickmakers Kloof had been completely transformed by development (McCallum 1981). The lower estuarine area was largely reclaimed for development, and the remainder confined into a narrow, shallow concrete canal. Where the canal opens to a more natural-width estuary, highways have been constructed overhead, and the estuarine quality and functionality has been diminished by deposition of concrete and rubble, shading, and the presence of the large piers.

Figure 3.6 Late 1800s after the river had been confined into a canal. The Tramways Building is visible with its 3 chimneys. (Source: McCleland 2018)

'Soon the Baakens was reduced to its present attenuated stream and the fact that once the Baakens River had possessed a stunning lagoon is now erased from its memory' (McCleland 2017)

The Tramways Building, which now houses the NMBDA, was built in 1897 in the middle of the right bank floodplain (Figure 3.6). The building has survived a suite of floods. Adjacent to the Tramways runs the river confined to a narrow concrete canal. The flood of 1908 caused severe damage at the lower end of the Baakens (see Figure 2.6 and Figure 2.7), and proved the constrained channel was too narrow at the mouth of the Baakens River. In January 1913, the Ratepayers accepted a scheme to widen and improve the channel of the Baakens River and to build a new bridge to provide a proper outlet in case of future floods (McCleland 2017). However, the bridges were sequentially destroyed by floods, until the concrete bridges replaced them (Figure 2.12).

'*With the benefit of hindsight, would it not have been preferable to preserve the Baakens River as a park close to the centre of town. A grave wrong was committed in not retaining the original lagoon as a pleasure resort and boating facility. The death throes of this pristine wilderness were long and painful yet no civic figure, citizen or the Council sought to protect it.*

Development of industrial concerns proceeded apace on the valley floor over the first half century, dooming this area to destruction …

Imagine seabirds skimming the water, seagulls screeching overhead and flamingos gracing its shores parading around on their long legs, as if on stilts, sieving minute creatures with their curved reddish hued beaks.

Instead of swearing undying loyalty to progress and development, consider the environment too. Don't destroy the gems of nature. Treasure them & preserve them. One can only sigh "What could have been!" (McCleland 2018).

Figure 3.7 The lower section of the canal, where the estuary opens up slightly. The Tramways building is on the left of the picture. Photo: Uys 2022

4 STUDY APPROACH & METHODS

4.1 INTRODUCTION

This study had four main focus areas:

- **Description of current state:** The determination of the current state of the river, in terms of its water quality, flora and fauna, using the method of Ecoclassification.
- **Rehabilitation scenarios:** The formulation of an overall vision and broad strategy for the catchment, and a series of rehabilitation actions in the form of options or scenarios;
- **Cost-benefit analysis:** The analysis of the cost-effectiveness and cost-benefit of these options;
- **Consultation:** The interaction with key stakeholders in the setting of the vision and objectives, and in discussing and prioritising rehabilitation actions.

In the first phase of the project, which is reported here, the intention was to get a broad overview of the catchment and its current condition. The methods that relate specifically to this objective are presented here. An additional step of setting an initial vision for the Baakens River has been added.

4.2 SETTING AN INITIAL VISION FOR THE RIVER

Although the setting of the vision for the catchment and river has been planned for the consultative phase later in the project, it is felt to be important to set a first-level goal to align the rehabilitation thinking with (Figure 2.14). This is based on our understanding of the system to date, and the rationale for the project. While it is aspirational (and may take decades to achieve), it provides a point on the horizon towards which to steer. The ultimate vision for the catchment will be set consultatively, with stakeholders and the community of the river.

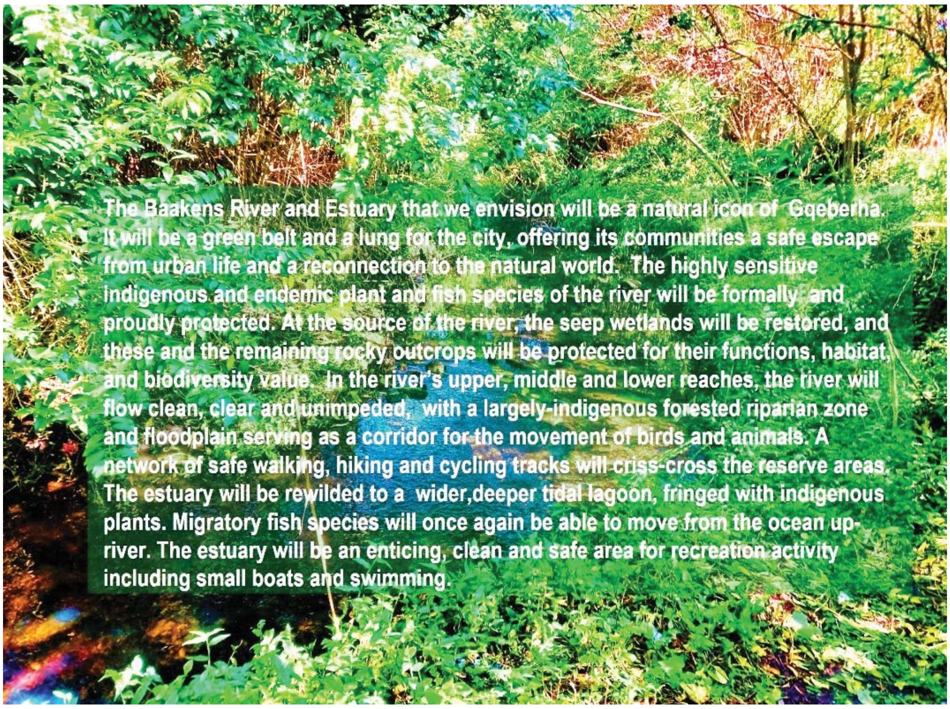

Figure 4.1 A first level vision for the Baakens River and Estuary

4.3 DIVISION OF RIVER INTO UNITS

The description of current state is assisted by dividing the river into units for analysis.

For this study, the unit of choice was the river reach. The term 'reach' can be variously defined. The USGS (2022) defines a reach as 'a section of a stream or river along which similar hydrological conditions exist, such as discharge (flow), depth, area, and slope', but also states that where this is not possible, it can be defined as 'any length of a stream or river, used when it is necessary to refer to a small section of a stream or river rather than its entire length' (USGS 2022).

For practical purposes, and for the purposes of this project, in which the stream is un-gauged and there is little information on hydrology, the reach selection took into account the following characteristics: position along river, morphology, predominant geology, slope, channel width and cover, urban context and major impacts, land-use zoning, current and future usage, and access.

Each 'river site' is located within the river reach, and is a point or length of river at which samples or surveys are taken.

4.4 ECOCLASSIFICATION

In South African water resource management under the Department of Water and Sanitation (DWS), the system in use to determine the current state of a river is known as Ecoclassification. The state of a river is expressed in terms of biophysical components:

· The physical system 'drivers' (physico-chemical/water quality, geomorphology, hydrology) which provide a particular habitat template; and

· The biological 'responses' (fish, riparian vegetation and aquatic invertebrates).

The PES is a statement of condition relative to the natural, pre-impact, or reference condition. The purpose of the EcoClassification process is to develop insights into what has caused the attribute in question to deviate from the reference condition. This provides the information needed to derive desirable and attainable future ecological objectives for the river (Kleynhans & Louw 2007).

The steps followed in the EcoClassification process are as follows (Kleynhans and Louw 2007):

- Determine **reference conditions** for each component.
- Determine the **Present Ecological State** for each component as well as for the **EcoStatus**. The EcoStatus refers to the integration of physical changes by the biota and as reflected by biological responses.
- Determine the **trend** (i.e. moving towards or away from the reference condition) for each component as well as for the EcoStatus.
- Determine **causes** for the PES and whether these are flow or non-flow related.
- Determine the Ecological Importance and Sensitivity **(EIS)** of the biota and habitat.
- Considering the PES and the EIS, suggest a realistic and practically attainable Recommended Ecological Category **(REC)** for each component as well as for the EcoStatus.
- Determine alternative Ecological Categories (**AECs**) for each component as well as for the EcoStatus for the purposes of providing various scenarios. This was not done in this project phase.

For this project, which is a scoping exercise with limited resources, the Ecostatus Level 2 method was followed. For Level 2, the system driver component is Instream Habitat Integrity (IHI), and the biotic response components are fish, invertebrate and riparian vegetation (Kleynhans & Louw 2007).

4.4.1 Determination of Reference Condition

Present state of a river is a relative measure: the deviation of river state from the pre-impact, natural, or 'reference' state. To quantify this deviation, one must reconstruct a picture of how the river would have looked before human impact. The reference condition describes the condition of the site, river reach or delineation prior to anthropogenic change and is formulated for each component considered in EcoStatus determination (in the case of this study, fish, aquatic invertebrates, riparian vegetation, and water quality) following the process described by Kleynhans & Louw (2007):

- Locate the least-impacted sites, either in the same or in ecologically comparable river zones.
- Use the results of historical ecological surveys done prior to major human impacts.
- If this is not possible, consider the use of survey information from ecologically comparable rivers. Use historical aerial photographs and land cover data to get an indication of the degree of catchment changes. The Internal Strategic Perspective (ISP) reports of the Department of Water and Sanitation (DWS) also provide relevant information.
- Use expert knowledge to derive an approximation of expected natural reference conditions.

Historical information and data, and/or data from reference sites (minimally impacted sites) are then used to describe the reference conditions for the biota and the water quality. Where there are data limitations and/or the absence of any existing reference sites, the reference condition may not represent an actual natural river state, but rather the best estimate of a minimally impaired baseline state. If the river has not changed, then the PES can be described as being in a natural condition (Category A, see following section). Ideally, both qualitative and quantitative data are available either from historical origin or from other representative geographical regions. If only qualitative data are available, these can still be used, although this places limitations on the type of metrics that can be calculated and used in the assessment of the ecological quality.

The type of information that can be used in setting up a reference condition is presented in Table 4.1.

Table 4.1 The type of information that can be sourced to develop a reference condition. Where relevant to the component, blocks are shaded. Source: James MacKenzie

TYPE OF INFORMATION SOURCED IN DETERMINATION OF REFERENCE CONDITION	Water quality	Riparian vegetation	Fish	Inverts.
Historic data from the same or a similar site at a similar position in a catchment Water quality: a long data record is required				
Background knowledge of the catchment being assessed, e.g. the climate, geology and hydrology.				
Published or unpublished **scientific papers, reports, theses**, etc.				
Historic, and therefore expected, distribution For plants**:** Vegetation biomes, bioregions and types (Mucina & Rutherford, 2006, 2012; SANBI, 2018).				
Current and historic species distribution patterns For plants: POSA; SANBI 2009, especially known riparian and wetland species.				
Past reports or assessments, although these may be of limited value in terms of historic time covered.				
Anecdotal information from any available source, be it published or by interview with people who have a long term experience of the site. This includes photographs that provide context, especially if they are dated. Plants: Skead 2009				

TYPE OF INFORMATION SOURCED IN DETERMINATION OF REFERENCE CONDITION	Water quality	Riparian vegetation	Fish	Inverts.
Acquisition of **historic aerial photographs** for time comparisons of change at the site.				
Comparison of current satellite coverages with historic aerial photographs and between timelines within the dataset, e.g. exploring Google Earth coverages across all available time frames.				
Assessment of on-site impacts and applying specialist understanding of what the relevant variable may be like in the absence of said impacts.				
Knowledge of background conditions in the catchment				
Species assemblages and aquatic habitats found in adjacent, relatively natural coastal streams of similar size				

4.4.2 Determination of Present Ecological State

The PES represents the current state of the river compared to the river in its natural (pre-impact or reference) state. It is expressed as a percentage similarity to the natural condition (natural taken to be 100%).

The PES for each Driver or Response component is determined as an index, using a rule-based modelling approach. The names of the models refer to these indices. In the case of this project, the physical driver components were water quality and habitat, and the response components were riparian vegetation, fish and macroinvertebrates.

- Physicochemical Assessment Index (PAI)
- Riparian Vegetation Response Assessment Index (VEGRAI)
- Fish Response Assessment Index (FRAI).
- Macroinvertebrates Response Assessment Index (MIRAI).

As discussed, for this study, resources allowed for the inclusion of water quality, riparian vegetation, aquatic macroinvertebrates and fish.. The PES result is expressed as a category. Each category is linked to a percentile range which represents the proximity to a natural (pre-impact) condition, which is set at 100%, as listed below and described in Table 4.2, and so-called 'half' or 'mid-range' categories such as A/B, B/C, etc. (Figure 4.2).

- A: near natural (>89% to 100%)
- B: largely natural (> 80% to 89%)
- C: moderately modified (> 60% to 79%)
- D: largely modified (>40% to 59%)
- E: seriously modified (>20% to 39%)
- F: critically modified (<20%)

The boundary between two categories is relative and the A→F scale represents a continuum. There may therefore, be cases where there are uncertainty as to which category a particular entity belong. This situation falls within the concept of a fuzzy boundary where a particular entity may potentially have membership of both classes (Robertson et al., 2004). For practical purposes these situations are referred to as boundary categories and denoted as B/C, C/D, etc. The B/C boundary category is for example indicated as the light green to blue area in Figure 3.1.

4.4.3 Ecostatus

The EcoStatus represents an ecologically integrated state. At its most detailed, this represents the physical system 'drivers' (hydrology, geomorphology, physico-chemical) and the biotic system 'responses' (fish, aquatic invertebrates and riparian vegetation).

Ecostatus can be done at four levels of increasing detail and confidence (Levels 1-4). For the purposes of this project, and with the available resources, Level 2 was appropriate, as discussed.

Ecostatus is usually determined in a workshop situation attended by specialists responsible for the different components. It is indirectly informed by the present state of the river system 'driver' variables: hydrology, geomorphology and water quality; and directly (numerically) informed by the various PES values of the system 'response' variables: fish, invertebrates and riparian vegetation of the site in question.

Table 4.2 Descriptive categories used to describe the present ecological status (PES) of biotic components (adapted from Kleynhans 1999).

CATEGORY	BIOTIC INTEGRITY	DESCRIPTION OF GENERALLY EXPECTED CONDITIONS
A	Excellent	Unmodified, or approximates natural conditions closely. The biotic assemblages compares to that expected under natural, unperturbed conditions.
B	Good	Largely natural with few modifications. A change in community characteristics may have taken place but species richness and presence of intolerant species indicate little modifications. Most aspects of the biotic assemblage as expected under natural unperturbed conditions.
C	Fair	Moderately modified. A lower than expected species richness and presence of most intolerant species. Most of the characteristics of the biotic assemblages have been moderately modified from its naturally expected condition. Some impairment of health may be evident at the lower end of this class.
D	Poor	Largely modified. A clearly lower than expected species richness and absence or much lowered presence of intolerant and moderately intolerant species. Most characteristics of the biotic assemblages have been largely modified from its naturally expected condition. Impairment of health may become evident at the lower end of this class.
E	Very Poor	Seriously modified. A strikingly lower than expected species richness and general absence of intolerant and moderately tolerant species. Most of the characteristics of the biotic assemblages have been seriously modified from its naturally expected condition. Impairment of health may become very evident.
F	Critical	Critically modified. Extremely lowered species richness and an absence of intolerant and moderately tolerant species. Only tolerant species may be present with complete loss of species at the lower end of the class. Most of the characteristics of the biotic assemblages have been critically modified from its naturally expected conditions. Impairment of health generally very evident.

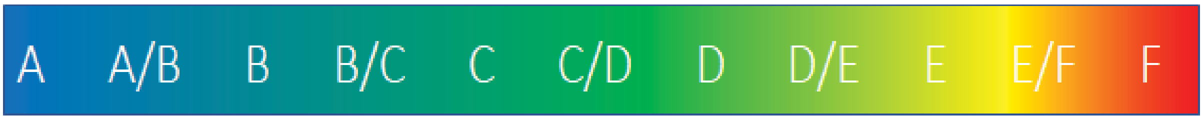

Figure 4.2 Graphic illustration of Ecological Categories from A to F using a cold to hot graduated colour scheme

4.4.4 Ecological Importance and Sensitivity

The Ecological Importance (EI) is an expression of the importance of a water resource to the maintenance of ecological diversity and functioning on local and wider scales. Ecological Sensitivity (ES) refers to the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred (Kleynhans 1999). These are combined to provide an Ecological Importance and Sensitivity (EIS) rating. Categories used to describe Ecological Importance and Sensitivity (EIS) are described in Table 4.3, and are determined by scoring certain abiotic and abiotic components of the ecosystem. The overall PES and EIS values for the Baakens River at the sub-quaternary scale, drawn from the National PES/EIS database (DWS 2014), are given in Table 4.4.

Table 4.3 Ecological importance and sensitivity (EIS) categories (Kleynhans 1999)

EIS CATEGORIES	GENERAL DESCRIPTION
VERY HIGH	Quaternaries/delineations that are unique on a national or even international level based on unique biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) are usually very sensitive to flow modifications and have no or only a small capacity for use.
HIGH	Quaternaries/delineations that are unique on a national scale due to biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) may be sensitive to flow modifications but in some cases, may have a substantial capacity for use.
MODERATE	Quaternaries/delineations that are unique on a provincial or local scale due to biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) are usually not very sensitive to flow modifications and often have a substantial capacity for use.
LOW/MARGINAL	Quaternaries/delineations that are not unique at any scale. These rivers (in terms of biota and habitat) are generally not very sensitive to flow modifications and usually have a substantial capacity for use.

Table 4.4 National database results for PES, EI and ES for the Baakens River (DWS 2014)

Quaternary Catchment	River	PES	EI	ES
M20A	Baakens	C	Moderate	High

4.4.5 Water Quality Sampling and PES

The approach to the river water quality task is to gather information from a wide range of sources and provide an assessment of present state for the four sites within the delineated reaches of the Baakens River.

Information from the PES/EIS study (DWS 2014), which includes a desktop assessment of water quality impacts in the area, is the first information source used to inform a water quality assessment for rivers. This overview is then built on, through information and data collection and analysis. Data used for this assessment were from four points in the catchment monitored by the DWS (2014-2019) and a single sample taken from each site and analysed by Talbot & Talbot analytical laboratories in Gqeberha in May 2022.

Methods as outlined in DWAF (2008) were used for the present state assessment, i.e. data analysis to provide summary statistics, and use of the Physico-chemical driver Assessment Index (PAI) Excel model to provide an integrated water quality category.

The following water quality parameters and associated summary statistics are required by the PAI method:

- pH: 5th and 95th percentiles.
- Electrical Conductivity, ions, metals, toxics: 95th percentiles. *Metals and toxics include those listed in the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996), which include ammonia and toxic metal ions.*
- Nutrients, i.e. Total Inorganic Nitrogen (TIN) and ortho-phosphate: 50th percentile.
- Chlorophyll-a (phytoplankton): average or mean of values – not available for this study.
- Diatoms: average or mean of values – not available for this study.
- Turbidity, dissolved oxygen (DO), temperature: narrative descriptions when no data are available, as for this study.

Water quality data were utilised in the following way: Nutrients, pH, turbidity, DO, temperature and Electrical Conductivity data were compared to values in DWAF (2008), while ionic data (i.e. macro-ions and salt ions) were compared to benchmark tables in DWAF (2008) and the Target Water Quality Ranges (TWQR) of the aquatic ecosystem guidelines (DWAF 1996) where available.

The PAI model is used to generate an integrated a present state category for instream water quality. Data from DWAF (2008) is used to compare summary statistics per variable to benchmark tables. The selected rating is then inserted into the PAI model. The output of the PAI model is therefore the physico-chemical category (P-C category) or Ecological Category (EC) for water quality.

Note that the rule applied from DWAF (2008) is to use the most recent five years of data to represent present state. As only one or two data points were collected by DWS in 2020 and 2021, and recent data could not be sourced from NMB Metro, data used to represent PES were generally those from 2014-2019. Water quality issues noted in the literature and by catchment residents appear to be consistent throughout this period, and already appeared in articles pre-2014.

4.4.6 Vegetation Survey and PES

The PES of riparian vegetation at all sites within the Baakens River catchment wase assessed using the Riparian Vegetation Response Assessment Index (VEGRAI) level 3 (Kleynhans et al. 2007), using the metrics presented in Table 4.5. Since all VEGRAI assessments are relative to the natural unmodified conditions (reference state) it is necessary and important to define and describe the reference state for each site. This is done in part before going into the field, with the use of historic aerial imagery, present and historic species distributions, general vegetation descriptions of the area, any anecdotal data available, knowledge of the area and comparison of the site characteristics to other comparable sections of river that might be in a better state. Armed with this information the reference (and present state) is quantified on site. The assessor reconstructs and quantifies the reference state from the present state by understanding how visible impacts have caused the vegetation to change and respond.

Impacts on riparian vegetation at the site are then described and rated. It is important to distinguish between a visible / known impact (such as flow manipulation) and a response of riparian vegetation to the said impact. If there is no response by riparian vegetation, the impact is noted but not rated since it has no visible / known effect. This is often the case with water quality for example.

Ratings of impacts are as follows:
- No Impact = 0
- Small impact = 1
- Moderate impact = 2
- Large Impact = 3
- Serious impact = 4
- Critical impact = 5

Once the riparian zone has been delineated, the reference and present states have been described and quantified (aerial cover is used) and a species checklist for the site has been compiled, the VEGRAI metrics are rated and qualified, to deliver a PES category.

Table 4.5 Metrics that were assessed using VEGRAI 3, with modification.

Vegetation Components	**Level 3**	**Level 3 (Modification)**
Woody	Cover	Cover
	Species composition	Species composition
		Vertical structure
Non-woody (grasses, sedges, herbaceous vegetation)	Cover	Cover
	Species composition	Species composition
Specialized category (reeds; palmiet)	Cover	Cover

Table 4.6 Illustration of the distribution of Ecological Categories on a continuum.

4.4.7 Fish Survey and PES

Fish surveys

Fish surveys were undertaken at the four sampling site/s on the Baakens on 15 and 16 May 2022. The equipment used was an electro-fisher (Samus 725G) fixed into a back-pack and fitted with a cathode dip-net and anode cable (Figure 4.3).

During these surveys, all instream habitat types and depth-velocity classes present in the river channel, up to a maximum depth of 1.5 m, were sampled. The electro-fishing effort at each site was approximately 45 to 60 minutes. The temporarily stunned fish were placed in containers filled with river water, identified to species level on site (according to Skelton 2001), examined for deformities, photographed for record purposes, counted, and the fork length of a sub-sample measured. All captured fish were returned alive and unharmed to the water at the capture sites.

A visual assessment of the extent and condition of the various aquatic habitat types present at the surveyed site, as well as within the river reach under consideration, was undertaken.

Figure 4.3 Dr Bok samples fish in the Baakens River using electro-fishing equipment, May 2022

The Velocity- Depth classes assessed are:
a) Fast-Deep (velocity >0.3 m/s; depth >0.3 m),
b) Fast-Shallow (velocity >0.3 ms; depth <03 m),
c) Slow-Deep (velocity <0.3 m/s; depth >0.5 m) and
d) Slow-Shallow (velocity <0.3 m/s; depth <0.5 m).

The Cover Metrics assessed include:
a) overhanging vegetation,
b) undercut banks and root wads,
c) stream substrate types (e.g. rocks, boulders, cobbles, etc. that provide cover for fish,
d) aquatic macrophytes, and
e)water column / depth.

In addition, the extent of any identified anthropogenic impacts on the aquatic habitat integrity at the various sampling sites and the potential impacts these could have on the natural fish assemblage, were noted.

Fish Response Assessment Index (FRAI)

The fish assemblage (species composition, frequency of occurrence, species population structure) within any river system is a reflection of the preferred conditions and instream habitats available in the river in relation to the requirements of the fish species expected at the particular site. Any changes in important riverine ecosystem drivers (e.g. river flow, water quality and geomorphology) will impact on instream habitat condition, and will be accompanied by changes in the natural fish assemblage. The relationship between drivers and fish metric groups is given in
Figure 4.4.

The fish assemblage expected under reference conditions is then compared with the existing assemblage found (or expected at the site based on recent fish surveys) under current instream conditions. The output of this exercise gives an indication of the present ecological state (PES) category of the system. The response of the fish assemblage to changing environmental conditions is assessed by undertaking fish surveys and/or is inferred from the observed changes to the instream habitat and knowledge of species' ecological requirements.

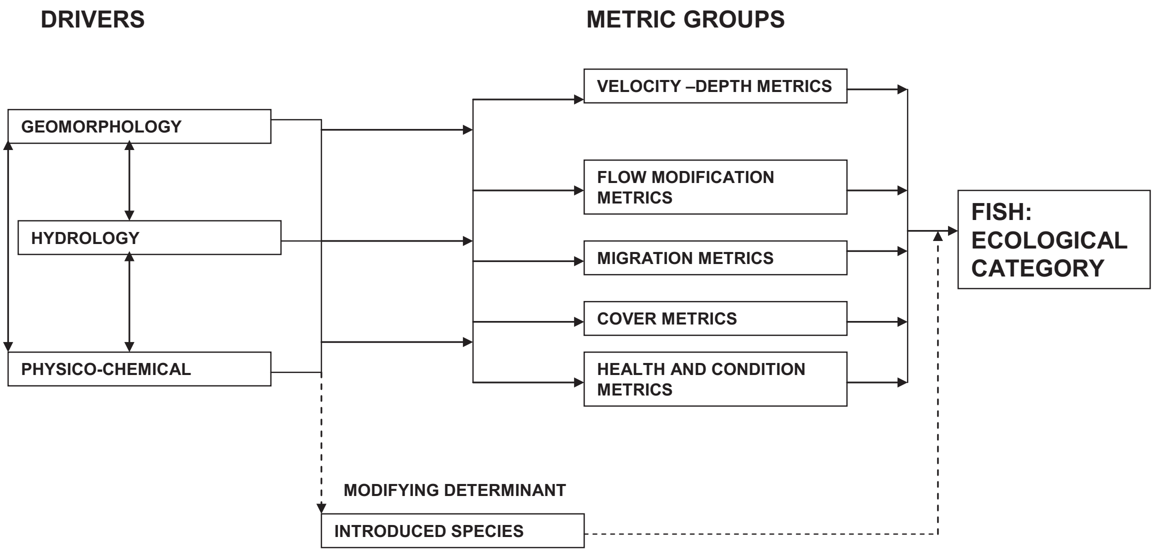

Figure 4.4 The relationship between drivers and fish metric groups (from Kleynhans 2008) as used in the Fish Response Assessment Index (FRAI).

However, it is recognised that it is difficult and time-consuming to accurately measure responses of fish populations to environmental disturbances. This is particularly problematic when limited time is allocated to fish surveys and a limited variety of fish capture gear is used. This concern is applicable to the present survey of the Baakens River as only one fish capture gear (an electro-fisher in this instance) was used to sample for fish at the four sites.

Thus, a method to determine the PES of a river reach based on a qualitative combination of fish species attributes, currently available instream habitat resulting from driver changes, and distribution data from both previous surveys and the fish distribution information from a current survey, has been developed (Kleynhans 2008). This method, termed the Fish Response Assessment Index (FRAI) developed by Kleynhans (2008) is recognized by the Department of Water and Sanitation (DWS) as the preferred tool to determine the PES of river reaches in terms of fish. The reference condition used for the FRAI, as discussed earlier, is based on the fish distribution data from historical fish data and extrapolation from similar adjacent river systems.

Summaries of data from the FRAI Excel spreadsheets used to determine the FRAI at each site are given in Appendix 9.

4.4.8 Aquatic macroinvertebrate survey and PES

Field Survey

The surveys were done at the four sites on 15 and 16 May 2022. At each site a section of river 50-100 m was sampled, and where suitable habitats were not available, sampling was done further up- or downstream.

The sampling method used was the South African (Aquatic Macroinvertebrate) Scoring System Version 5 (SASS5). This is a biological monitoring (biomonitoring) method used in the assessment of river water quality and river health. It is based on the composition of the macroinvertebrate fauna occupying the different habitats of the river system. It was developed for use in flowing South African rivers by Chutter (1994), and is considered by Roux (1997) to be suitable for the following uses:

- Assessment of the ecological state of aquatic ecosystems
- Assessment of the spatial and temporal trends in ecological state
- Assessment of emerging problems
- Setting objectives for rivers
- Assessment of the impact of developments
- Prediction of changes in the ecosystems due to developments
- Contribution to the determination of the Ecological Reserve (National Water Act 1998).

The assessment is based on aquatic macroinvertebrate taxa, generally at the Family level of classification. Each taxon is assigned a sensitivity score ranging from 1 to 15 (scaled from lowest to greatest sensitivity to water quality deterioration).

The equipment required is a soft, 1 mm^2 mesh net on a 30 cm square frame on a stout handle, white or cream flat-bottomed tray/s (approximately 30x45 cm size and 10 cm deep), forceps, soft plastic wide-mouth pipettes, timer, magnifying lens, SASS scoring sheets, or other means of capturing data.

The following habitats are sampled (where available): Stones (in and out of current, bedrock); Vegetation (marginal and aquatic, in and out of current); Gravel/Sand/Mud; and hand-picking, using standard sampling techniques. The sampling period is standardised for different habitats and conditions. The samples are then carefully tipped into separate trays by inverting the net and flushing it with water to ensure that biota do not remain in it. A period of 15 minutes is spent identifying the live invertebrates present in each tray, assessing their abundance, and recording this information. Following the identification, the live sample is carefully returned to the river.

Figure 4.5 A SASS5 sample underway

The sample's Total Score is a simple addition of the sensitivity value of all taxa present, and the Average Score per Taxon (ASPT), which is a measure of the sensitivity of the aquatic macroinvertebrate community, is the Total Score divided by the number of families present.

Macroinvertebrate Present Ecological State (PES)

The SASS5 results and data serve as inputs to the Excel spreadsheet-based Macroinvertebrate Response Assessment Index (MIRAI) of Thirion (1997), to determine the Invertebrate Ecological Category (EC) of the river site.

The MIRAI works on the basis of comparing the sampled invertebrate community to the reference (expected) community in terms of four different metric groups in which the deviation of the sampled invertebrate assemblage from the reference (expected) assemblage: flow modification, habitat modification, water quality modification, and system connectivity and seasonality.

The following information from the field sheets is used. The first step in determining the PES is the completion of the field sheets with information including the abundance and frequency of occurrence of the different invertebrate taxa under natural (reference) conditions, as well as the abundance and frequency of occurrence (if possible) of the invertebrate taxa present in the sample. For this index, an increase in abundance and/or frequency of occurrence, as well as a decrease in abundance and/or frequency of occurrence, is scored as an impact or change when compared to the natural or reference condition. The six point rating system (0-6) starts at 0 – no change from reference and goes up to 5 – extreme change from reference. For example, if the community of invertebrates sampled in the stones-in-current habitat has changed substantially from the one expected under natural conditions (reference), then the deviation would be scored a 4 or 5. In this way the spreadsheet is populated.

In addition to the rating of the different metrics, each metric and metric group is also ranked and weighted according to its importance in determining the EC of the invertebrates of that site. Each metric is ranked in terms of which metric (if it changed from worst to best) would best indicate good integrity in terms of the metric group. In other words, which metric is the most important in determining the present state of the invertebrates. The ranking procedure is only used to guide the weighting and is not used in any calculation. A weighting system is in place to provide a range of priorities to each metric group.

Habitat assessment

The main aim of a habitat assessment is to evaluate the template on which the invertebrates exist. An organism can only live where there is suitable habitat, so it is essential to assess habitat quality and quantity , and diversity of available biotopes.

For this study, two rapid methods were used. These assess different aspects of the habitat, and together provide a good sense of the habitat quality at both a micro scale (actual habitat availability at the sampling site) and a macro scale (upstream influences which may affect the instream habitat). These are, respectively:

- Integrated Habitat Assessment (IHAS version 2) method of MacMillan (1998), a rapid assessment of the specific habitat suitability for the survival of aquatic macro-invertebrates, designed to and aid in the interpretation of the SASS5 results. IHAS scores as a percentage and is divided into two sections, the sampling habitat (comprising 55% of the total score) and the general stream characteristics (comprising 45% of the total score). Summation of the scores obtained for the two sections will provide an overall habitat percentage. The IHAS field-sheet is shown in Appendix 8;
- The (Quick) Index of Habitat Integrity Assessment (QHI) of Kleynhans (1999) which rates the habitat according to a scale of 0 (close to natural) to 5 (critically modified) according to the following metrics:
    - Bed modification
    - Flow modification
    - Introduced Instream biota
    - Inundation
    - Riparian / bank condition
    - Water quality modification

  Where the QHI is used, the metrics serve as a substitute for the driver variables (Kleynhans & Louw 2007) – in the case of this project, the hydrology and geomorphology.

4.5 DEVELOPMENT OF REHABILITATION SCENARIOS

A series of rehabilitation scenarios will be developed based on the information acquired in the surveys, the eco-classification process, and informed by discussions with MBDA and Baakens community members. This is the subject of the next phase of the study and will be discussed in more depth in the upcoming report.

4.6 COST-BENEFIT ANALYSIS

Analysis of the cost-benefit of the various scenarios will be done relative to a ‘do nothing’ scenario. The relevant mitigation options or scenarios will then be compared against one another. The mitigation costing will be informed by case study estimates and desktop analyses of published mitigation interventions in similar settings.

The ecosystem services valuation will be conducted in two phases, first, the causal linkages between mitigation interventions and ecosystem services benefits will be quantified using comparative risk assessment methodology and second, the resultant benefits will be quantified in monetary terms using benefit transfer methods. The approach to the valuation will be to conduct rapid, evidence-based work relying on data generated by the projects, expert knowledge and secondary data.

4.7 STAKEHOLDER ENGAGEMENT

Engagement with key stakeholders is of primary importance in this project, particularly in the setting of a rehabilitation vision, objectives and priorities. From the outset of the project, key stakeholders were to be identified, with the assistance of the NMBDA, key community groups active in the catchment, and online media.

The intention wherever possible is to engage directly and face-to-face with individuals and groups, and to get an idea of which authorities or agencies are responsible for managing different sections and aspects of the river, which community and other groups were active in the catchment, what roles they were playing, and how to engage these separate groups and encourage interaction, synergies and partnerships. This engagement is seen as critical to the effective rehabilitation of the river, and the maintenance of any such initiatives.

The intention is that once the various rehabilitation scenarios are available, and a cost-benefit analysis has been done, there will be engagement with the key role players and stakeholders. Here the findings to date and the scenarios will be presented and discussed, providing the Development Agency and stakeholders a role in setting a vision and objectives for the catchment, and prioritising one rehabilitation scenario.

4.8 RECOMMENDATIONS

In line with the Aims of this project, the final stage is the drafting of a set of recommendations to the NMBDA regarding the cost-effectiveness of rehabilitating the prioritised reaches or reaches of the Baakens River.

5 DIVISION OF THE RIVER INTO STUDY UNITS

5.1 SELECTION OF REACHES

The land-use zoning map is presented in Figure 5.1 for easy reference. The river reaches are described in Tables 5.1 and 5.2 and mapped in Figure 5.2.

Table 5.1 Description of the six river reaches and reason for selection

Reach	Reason for selection
1	This is the source area where the seep wetlands and numerous rocky outcrops are located. It is currently extensively invaded largely by *Acacia cyclops* (wattle). The source is a critical focal area from a rehabilitation point of view from its biodiversity and functional point of view. Aside from their intrinsic ecosystem value, the wetlands serve as sponges. Holding and slowly releasing rainfall water to provide a baseflow to the upper sections of the river. They also serve a flood attenuation purpose. This is currently envisaged a high priority area for rehabilitation.
2	This upper river reach is highly urbanised with a narrow band of public open space zoning on either side of the river, flanked by residential zones on both banks. It is extensively invaded with alien vegetation including alien Acacia species (largely wattle) and old, well established Eucalypts (bluegums). The channel is narrow and shallow with a sandy substrate, and not suitable for sampling biota. In Public Open Space areas of the lower section the right floodplain has been entirely cleared of indigenous vegetation and is mowed (maintained) and already serves as a recreational area for runners, cyclists and walkers with dogs. Currently not envisaged as a high priority area for rehabilitation.
3	This is the middle river where the topography steepens. The channel is wider and somewhat steeper and the floodplain constrained due to development. The area is extensively invaded by alien vegetation including large old Eucalypts. This section is highly urbanised with limited Public Open Space on either bank. Currently not envisaged as a high priority area for rehabilitation, however *Pseudobarbus afer* have been collected here previously. Site 1 is in this reach.
4	This is the lower section of the middle river, which includes a large area of Private Open Space. Here the Robert Searle Private Nature Reserve and Dodd's Farm are open to the public, and extensive walking and cycling trails are well maintained (privately). Here the river channel is wider, and the river meandering, with a riffle-run-pool morphology. On the north side, large rugged cliffs loom, and the riparian zone is densely forested, with alien elements. The south bank riparian area is forested, and though not natural does have indigenous elements. This area is considered a priority for rehabilitation and maintenance. Site 2 is in Dodd's Farm area.
5	This is the lower river in the Settlers Park Reserve area which is formally protected. The river is wide and deeper, with a riffle-run-pool morphology. The forested riparian zone is not natural but also not extensively invaded. The Guinea Fowl trail is maintained but not considered safe. There are a number of impounding structures (largely created for river crossings) in this section of the river. As it is protected and has the potential for usage, it is considered a priority for rehabilitation. Site 3 is located here.
6	This is the Estuarine interface and Estuary area. The system is highly transformed and degraded, with a small band of the south (right) bank and floodplain still undeveloped but cleared and mowed in the lower section. The only undeveloped area is the south bank of the middle portion of this reach, all other areas are developed into the floodplain. The river is canalised through the mid and lower sections of the reach. Land-use zoning in the remaining open areas of the floodplain is largely Public Open Space and Assembly. A high priority for rehabilitation as a natural area within the South End Precinct Development.

5.2 SELECTION OF SURVEY SITES

The four sites were selected in four different river reaches. The intention was to use sites which where possible corresponded to sites where there were existing data on water quality, riparian or terrestrial vegetation, fish, or invertebrates, or any other salient river related information. At the same time, it was necessary to represent as much of the river length and character as possible with the sites, and to work in areas considered to have the greatest rehabilitation potential. Access to sites was also an important consideration for the site surveys. The sites were selected at a desktop level and were ground-truthed during late April 2022 to whittle the original selection to the four options best meeting these criteria. The sites are presented in Table 5.2.

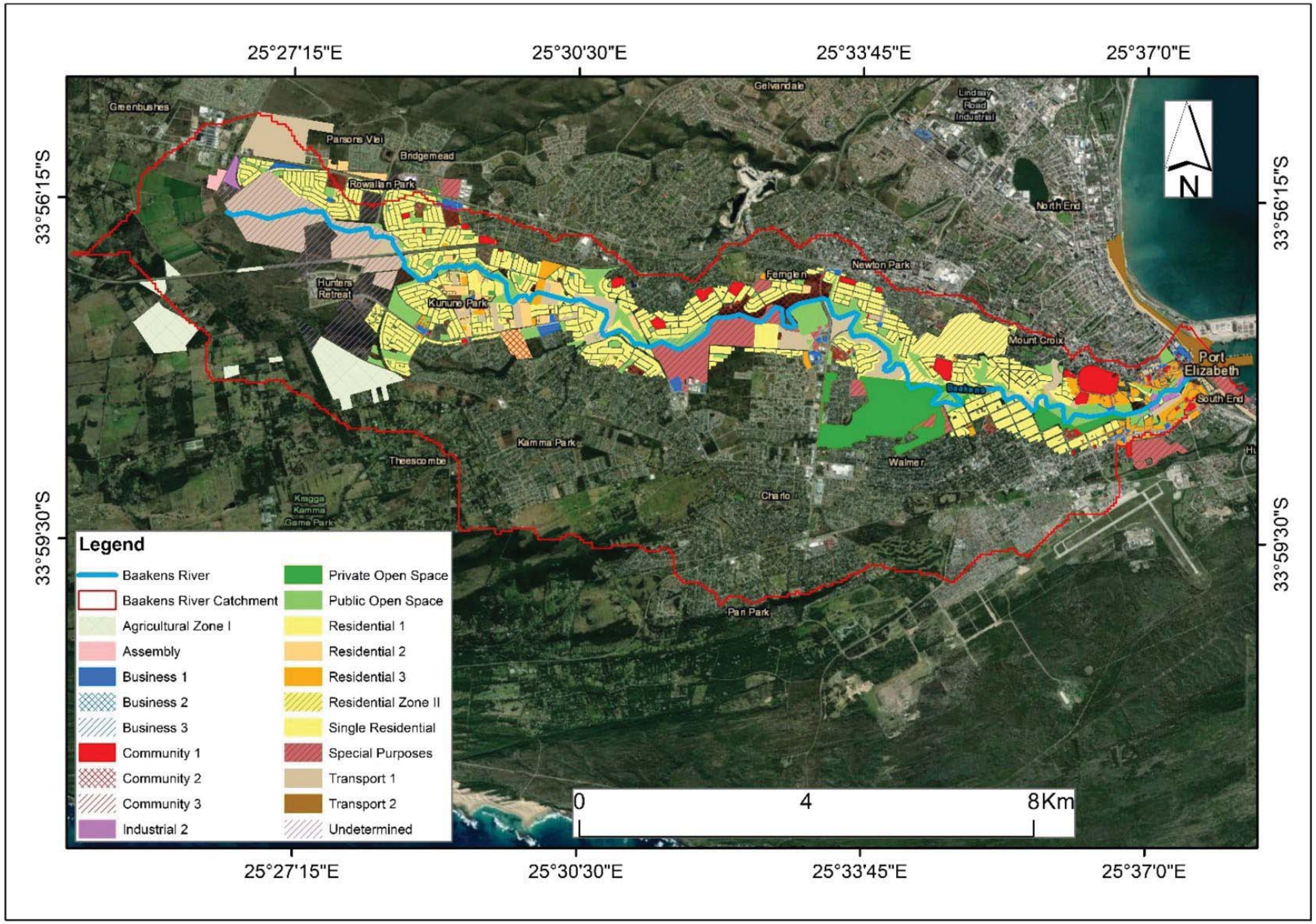

Figure 5.1 Land use Zoning for the Baakens River. Source: NMB Metro data, dated 2017.

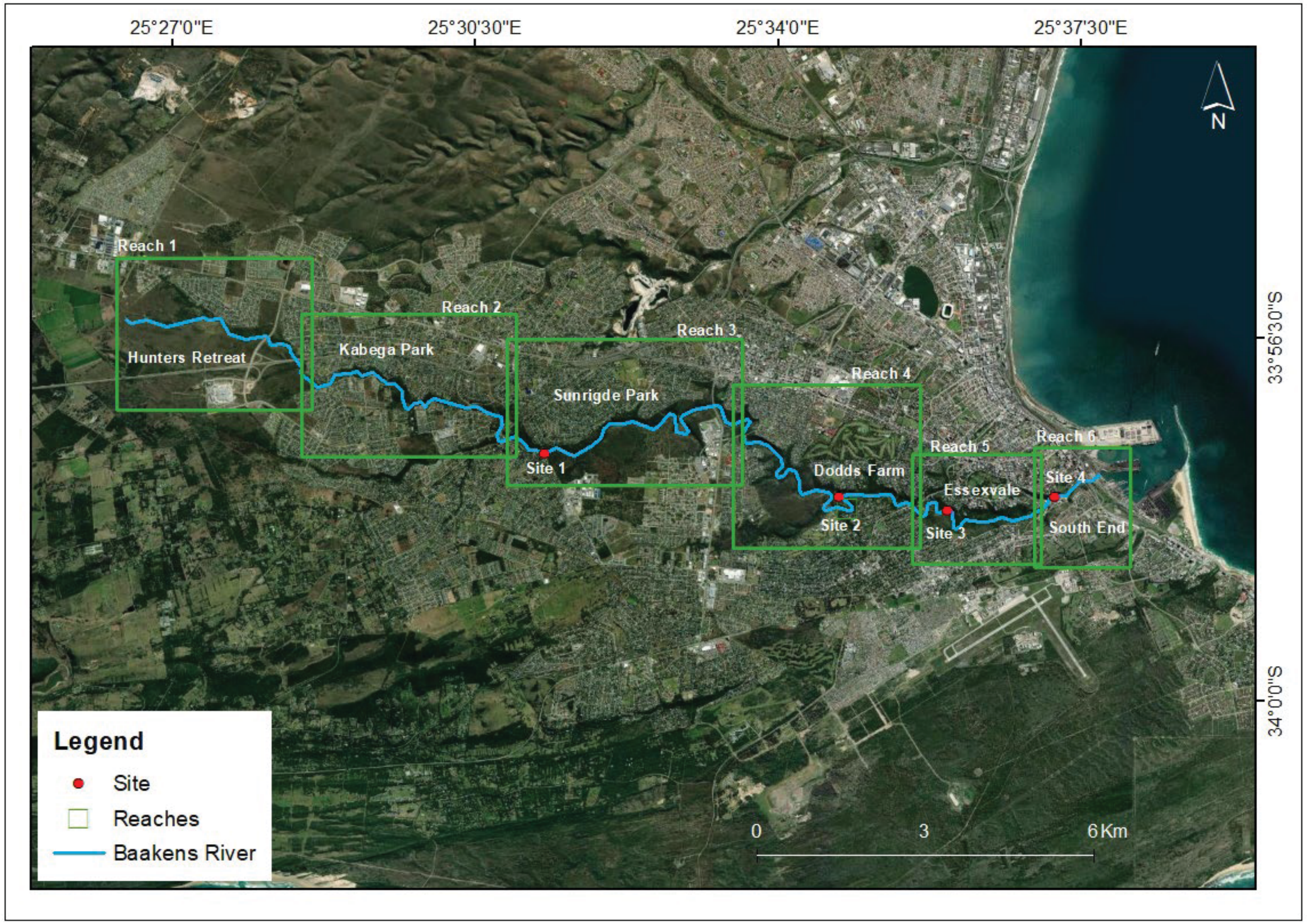

Figure 5.2 Map of the Baakens River showing the division of the river into six reaches, and the four survey sites selected

Table 5.2 The localities and descriptions of the river reaches and four sites

ZONE	REACH	URBAN MARKERS (ACCESS POINTS)	NATURAL CHARACTERISTICS	Coordinates of upper boundary	Channel length
			(Buchanan 2014)	Latitude/ Longitude	km
Source	1	Source area to Headingly Road crossing.	Peninsula formation geology (TMS). Seep wetlands and narrow shaded channel within shallow wide valley. Large areas of floodplain remain undeveloped. Dominated by fynbos. Unique fynbos elements.	33°56'25.53"S 25°26'28.16"E	4.3
Upper	2	Headingly Road crossing to Kabega Road crossing	Channel width increases and valley is somewhat steeper. Both floodplains highly developed. No formal protected areas.	33°57'1.94"S 25°28'47.21"E	4.3
Middle	3	Kabega Rd crossing to 3rd Avenue Dip crossing (Newton Park). Formal access point to upper Guinea Fowl Trail (GFT).	Topography begins to change. Slopes become steeper towards the top of Reach 4. TMS is visible in places on the steeper south facing slopes. The more rounded north-facing slopes are where rocky outcrops occur. These support more succulent vegetation	33°57'30.87"S 25°30'55.02"E	6.4
Middle	4	3rd Avenue Dip crossing to Targetkloof Road (middle GFT). Formal access to GFT. Includes Dodd's Farm and Robert Searle Private Reserve.		33°57'29.09"S 25°33'36.29"E	5.4
Lower	5	Targetkloof Road to Brickmakerskloof. Access to Settlers Park and lower GFT at Chelmsford Ave.	The lower reaches are characterised by more dramatic topography. Steeper cliffs occur mainly on the northern side with an increase in river meandering. This results in a greater variety of orientation and micro-climates. In some parts the cliffs reach 40 m above the level of the river. On the steeper slopes the natural habitat has been maintained to a large degree. As geology changes towards the sea, natural vegetation type differs (no longer visible).	33°58'9.24"S 25°35'35.81"E	3
Estuarine Interface and Estuary	6	Brickmakerskloof Road to Port	Estuarine interface and estuary, downstream of the final impounding structure. The topography in this section remains fairly steep for a lowland system. The river channel in this section transitions from a natural deep open channel to a gabion-stabilised one, to a canalised final estuarine confinement shortly upstream of the Port.	33°58'9.58"S 25°37'5.86"E	1.3

Table 5.3 Information pertaining to the four selected survey sites

Site No	Name	Description	Coordinates		Position along river	Reach
			South	East		
No Site					Source Area	1
No Site					Upper River	2
1	Hawthorne Ave	Lower extension of Hawthorn Avenue, Sunridge Park. Degraded section of river, however critically endangered *Pseudobarbus after* collected here previously.	33°57'39.03"S	25°31'19.33"E	Upper River, outside of Guineafowl trail, downstream of confluence with tributary	3
2	Dodd's Farm	Middle Baakens River Private open space. Recreational area of Dodds Farm.	33°58'3.44"S	25°34'43.67"E	Middle River, in protected recreational area on Guineafowl trail. MTB trails still active.	4
3	Essexvale	Lower Baakens River. Essexvale section of Settlers Park, at Chelmsford Ave	33°58'11.01"S	25°35'58.72"E	Lower River. Protected area. Likely to be high priority for rehab. Lower Guinea Fowl Trail	5
4	Alchemy	Lower Baakens River. Estuarine interface. Right floodplain completely cleared.	33°58'2.68"S	33°58'2.68"S	Lower River, area of urban revitalisation and South Precinct Development. Estuarine interface in upper section, estuarine in lower section	6

5.3 SITE DESCRIPTIONS & PHOTOS

Brief site descriptions and photographs of the sites are presented here. Survey-relevant site details are provided in the Specialist Results (Chapter 7).

5.3.1 Site 1: Hawthorne Ave

The upper section of this site is highly modified (Figure 5.3), while the lower section has low accessibility due to large woody debris and the extent of alien invasion. Nonetheless it was considered necessary to situate the site here as there was the possibility of collecting the critically endangered *Pseudobarbus. after* fish, as they had been previously collected here. The site is also a DWS water quality sampling point.

The upper portion of the site has been modified by the land-owner, and the channel is flanked by electrical fencing which also extends across a low-level weir and crossing. Sandbags have been installed across part of the channel in an attempt to create deeper areas upstream. Instream habitat is further degraded by the presence of rubble and other building materials in the channel. The site is described further in specialist results.

Figure 5.3 The upper portion of the Hawthorne Road Site 1 (see Figure x for downstream view)

Figure 5.4 Site 1 looking downstream to the small weir and downstream channel.

5.3.2 Site 2: Dodd's Farm

In this reach (Reach 4), sampling for fish was done at two localities, sampling for invertebrates was done at the selected site, and vegetation assessment involved a scan of the entire area and included the terrestrial vegetation. This is detailed in the various specialist results.

At the selected site (Figure 5.6 and Figure 5.7), the channel was narrow and deeper than in upstream and downstream reaches, due to confinement by dense fringing reeds and sedges. Substrates comprised packed medium-sized rocks and cobbles, with occasional sands and gravels. The water was fast-flowing, and significantly less odorous than the upstream river at the main weir on this section of river where raw sewage was discharging into the river (Figure 5.5).

Figure 5.5 The large weir at Dodd's farm, upstream of the sample site. At the time of sampling raw sewage was discharging from a pipe on the downstream wall (circled).

Figure 5.6 Site 2 at Dodd's Farm, looking downstream from the small bridge crossing the river

Figure 5.7 Site 2 at Dodd's farm, looking upstream from the small bridge crossing the river

5.3.3 Site 3: Essexvale

Site 3 in the Protected Area of Settlers Park is located upstream and downstream of a low-level crossing point. Upstream of the crossing, the flow backup has created a deep pool section, edged on both banks by reeds. Downstream, the river is wide and shallow and deeply shaded, with substrates comprising boulders, rocks, and cobbles.

At the time of sampling, two juvenile otters, assumed to be Cape Clawless Otters, were seen playing in this pool at sunset despite the extremely poor water quality.

Further details are provided in specialist results.

Figure 5.8 Site 3 at Essexvale in Settlers Park looking upstream to the pooled section. Note the causeway which impounds upstream water and prevents upstream fish migration.

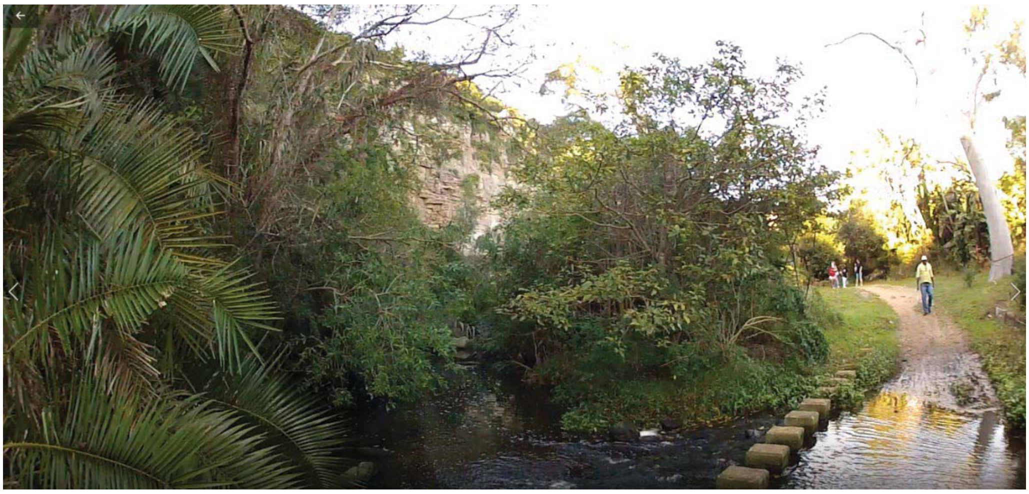

Figure 5.9 Site 3 at Essexvale looking across the low-level crossing and downstream.

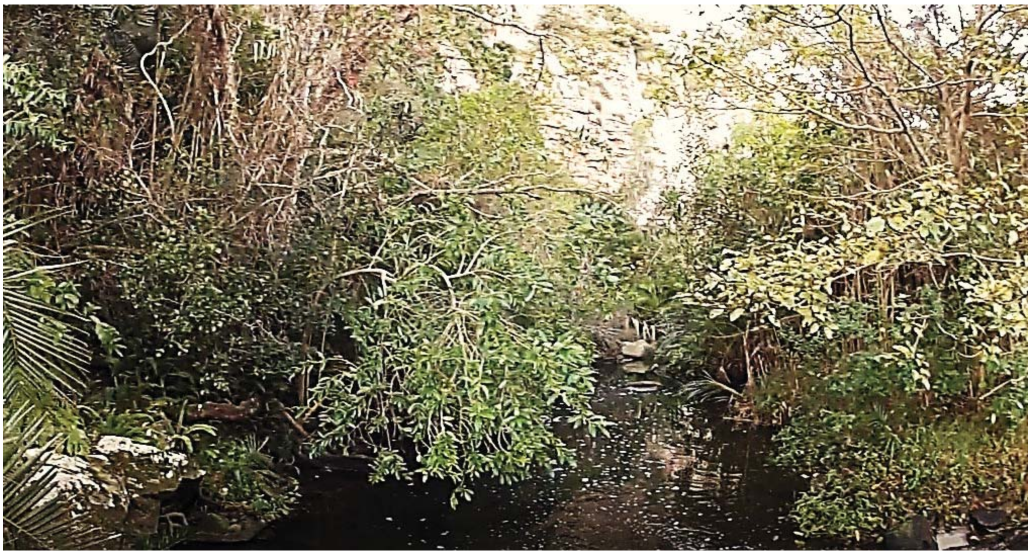

Figure 5.10 Site 3 at Essexvale showing detail of the site downstream of the crossing.

5.3.4 Site 4: Alchemy

In this lower portion of the river, in Reach 5, Site 4 was selected in the area which has been set aside for development as a recreational area linked to the South End Precinct development (currently in various phases of planning by the Development Agency). The site is considered to be an estuarine interface, as catadromous fish species (which migrate from the ocean up-river) have been collected here. The site is downstream of that at which DWS collect water quality samples.

The river in this section is confined to a narrow gabion-clad canal. In some sections of the canal, cobble and stone substrates are present, these possibly originate from damaged gabion baskets. On the left bank, the topography is steep and well vegetated, and provides habitat to a suite of indigenous and alien plants. The right bank and floodplain have been cleared of trees and other riparian plants and is maintained as a lawn. This is the area set aside for a picnic and recreational area within the South-End Precinct development plans.

Figure 5.11 The left bank and right floodplain at Site 4

Figure 5.12 The area upstream of Site 4, showing the steep topography of both sides of the valley in this area. Note also the cleared floodplain on the right bank.

Figure 5.13 The sampling area at Site 4, where the channel is confined to a gabion-stabilised canal

6 REFERENCE CONDITION FOR THE BAAKENS RIVER

This Chapter focusses on the determination of Reference Condition at each of the four sites. The Reference Condition is described for water quality, riparian vegetation, fish and macroinvertebrates for each site.

6.1 BACKGROUND INFORMATION AVAILABLE

6.1.1 Water quality

Water quality state is assessed using standard methods for South African rivers, according to the methods outlined in DWAF (2008). Data used for this assessment relied on data collected from four points in the catchment monitored by the DWS (see Determination of Reference Condition), and a single sample selected from each site and analysed by Talbot & Talbot analytical laboratories in May 2022.

DWS data collection started in 2008, meaning that there are not adequate quantitative data available for an assessment of Reference Condition (RC) or pre-impact state. DWAF (2008) makes provision for such a case and recommends the use of the benchmark boundary tables in DWAF (2008) for an A category (or unimpacted) river.

Note that any background knowledge of the catchment which may impact on water quality, for example natural geology which may result in naturally elevated salinity levels, must be taken into consideration when assigning RC. Should natural background levels not be taken into consideration, present state may be assigned to be significantly worse than it is in reality.

Table 6.1 lists the monitoring points where data were routinely collected by DWS from 2008-2019; generally quarterly per year, with approximately 119 samples in the data record. Figure 6.1 shows the location of DWS monitoring points in relation to the sites surveyed in this study.

Table 6.1 DWS monitoring points on the Baakens River, indicating use for analysis

Site no. (this study)	DWS monitoring point ID	Site description	Latitude	Longitude
1	1000011174	Baakens River @ Low water bridge at Third Avenue, Newton Park	33° 57' 28.17"S	25° 33' 36.29"E
2	Extrapolated from 1000011174	Baakens River @ Low water bridge at Third Avenue, Newton Park	33° 57' 28.17"S	25° 33' 36.29"E
3	1000008833	Baakens River @ Targetkloof d/s Chelmsford Ave Bridge	33° 58' 8.04"S	25° 35' 50.32"E
4	1000008838	Baakens River d/s Brickmakerskloof Bridge	33° 58' 4.08"S	25° 37' 11.21"E
-	1000008839	Baakens River @ Tramway Building	33° 57' 54.72"S	25° 37' 28.99"E

d/s: downstream

Figure 6.1 DWS monitoring points in relation to the Study Sites 1-4. Image: Google Earth ©

6.1.2 Riparian vegetation

The following sources of data / information were available and applicable to determination of RC for riparian zones and wetlands:

- National Biodiversity Assessment (new wetland map, 2018):
    - Diversity of wetland Hydrogeomorphic types (HGMs) within quinary catchment – this is a count of different HGMs within the sub-quaternary reach or SQR, excluding estuaries.
    - Overall extent of wetlands within quinary catchment (Hectares per SQR).
- NFEPA (2011):
    - Wetland FEPA status
    - Wetland Clusters
    - Habitats for rare and endangered species including:
        - Cranes – wetlands (excluding dams) with the majority of its area within a sub-quaternary catchment that has sightings or breeding areas for threatened Wattled Cranes, Grey Crowned Cranes and Blue Cranes.
        - Amphibians – wetlands within 500 m of an IUCN threatened frog / toad point locality.
        - Water Birds – wetlands within 500 m of a threatened waterbird point locality.
- Known important peatland sites.
- Important Birding Areas (2015) – The Important Bird and Biodiversity Areas (IBA) Programme is a BirdLife International Programme set up to conserve habitats that are important for birds. These areas are defined according to a strict set of guidelines and criteria based on the species that occur in the area. The Important Bird Areas of Southern Africa directory was first published in 1998, and identified within South Africa 122 IBAs. In September 2015 a revised IBA Directory was published by BirdLife South Africa. All these IBAs were objectively determined using established and globally accepted criteria. An IBA is defined by the presence of any of the following bird species in a geographic area: Bird species of global or regional conservation concern, assemblages of restricted-range bird species, assemblages of biome-restricted bird species, and concentrations of numbers of congregatory bird species.

- Regions / Centres of Plant Endemism (Van Wyk & Smith, 2001) – sites that occur in regions or centres of plant endemism
- Regional Conservation Plans including:
    - Eastern Cape
- PES-EI-ES Assessment (DWS, 2014)
- National Spatial Biodiversity Assessment (2005): notable wetlands, springs, thermal springs, oxbows
- Updated vegetation map (Mucina & Rutherford, 2006, 2012, 2018 updates): spatial data and metadata with detailed vegetation type descriptions.
- Level 1 and 2 Ecoregions.
- Threatened riparian / wetland species distribution data, especially plants.
- In 2012 Adrian Grobler submitted an MSC Thesis entitled "A systematic conservation assessment and plan for the Baakens River Valley, Port Elizabeth". The thesis is a detailed treatment of the biodiversity, biodiversity hotspots and bioregional conservation planning of the Baakens River valley. It outlines detail pertaining to vegetation at multiple scales and also highlights species of conservation concern.

6.1.3 Fish

The reference condition in terms of the fish fauna naturally occurring in the Baakens River was reconstructed using historical fish distribution records obtained from various historical fish surveys. Data on the changes to the natural fish assemblage in the Baakens over the last 30 years was obtained from fish surveys, scientific papers and unpublished reports as listed below.

- Heard, H.W. & King, M.(1981). A report on the fish populations and ecology of the Baakens River. Internal Report for Dept. of Nature and Environmental Conservation, Grahamstown. 9pp
- King, M. J. & Bok, A. H. (1984). Report on the ichthyofaunal and ecology of the Baakens River. Internal Report for Dept. of Nature and Environmental Conservation, Grahamstown. 9pp
- Bok, A. H. (1994) Report on a fish survey of the Baakens River: December 1994. Internal Report for the Eastern Cape Dept. of Nature and Environmental Conservation, Grahamstown. 23pp
- Bok, A.H. (1997) Necessity for and conceptual design of fishways in the Baakens River, Settlers Park. Unpublished. Report for the City of Port Elizabeth. 28pp.
- Department of Water and Sanitation (DWS) (2014). A Desktop Assessment of the Present Ecological State, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa. Secondary: N1. Compiled by RQIS-RDM.
- Strydom, N. (2014). Status of fishes in the Baakens River, Port Elizabeth, with notes on rehabilitation. Unpubl. Report to CEN Integrated Environmental Management, Port Elizabeth.
- Muller, C, Strydom N.A. & Weyl, O. (2015). Fish community of a small, temperate urban river in South Africa. Water SA 41 (5), 746-752.
- Muller, C, Weyl, O. & Strydom, N.A. (2015). Introduction, establishment and spread of southern mouthbrooder *Pseudocrenilabrus philander* in the Baakens River, Port Elizabeth, South Africa. African Zoology 2015, 1-4.

6.1.4 Aquatic Invertebrates

There are few known historic data sources for aquatic macroinvertebrates for the Baakens River. The following information, together with expert knowledge of Eastern and Southern Cape rivers and their invertebrates, was used in compiling a likely natural or reference condition for the invertebrates of the river:

- South African Ecoregion Level 1 and Level 2 reports. Source: Kleynhans et al. 2015, Department of Water and Sanitation website: https://www.dws.gov.za/iwqs/gis_data/ecoregions
- Invertebrate data from the following rivers in quaternary catchments M20A and M20B: Papenskuilsrivier, Maitland River, and Van Stadens River. These data are sourced from Department of Water and Sanitation. 2014. A Desktop Assessment of the Present Ecological State, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa. Secondary: M2. Compiled by RQIS-RDM: https://www.dwa.gov.za/iwqs/rhp/eco/peseismodel.aspx accessed May 10 2022.
- Data from an Expert System (ExSys) developed for 1782 subquaternary catchments in the Eastern Cape, for the purposes of the National PES EI ES (DWS 2014) project. Each subquaternary was also assessed at desktop level (Google Earth) to check the outputs of the ExSys. Developed in 2013/2014 by Dr A.L. Birkhead with inputs from Dr M. Uys (Birkhead et al. 2014).

The following data could not be located or made available in time for this report:

- Data from the River Ecosystem Monitoring Programme, Department of Water and Sanitation (DWS) Gqeberha.
- Baakens River Adopt-A-River Programme: The Eastern Cape River Health Programme (RHP) Team has initiated the Adopt-A-River Programme with Kabega Primary School, within the Chris Hani District Municipal area. The School adopted the Baakens River. Grade 6 pupils were taken to the Baakens River seasonally where they assessed the ecological health of a river reach.
  Source: National aquatic ecosystem health monitoring programme (NAEHMP). September 2008. River Health Programme E-communication.

Figure 6.2 Kabega Primary School, who adopted the Baakens River and has done a number of assessments, clean-ups and other projects at the river (up to 2019: see school Facebook page)

6.2 REFERENCE CONDITION

6.2.1 Longitudinal connectivity

The longitudinal connectivity relates to both the aquatic and riparian environment's ability to act as a conduit or corridor that facilitates upstream/downstream movement of biota and materials. As far as we know, the instream longitudinal connectivity under natural conditions would have been maintained throughout the length of the river under natural conditions, with the possibility of reduced connectivity in areas where bedrock chutes occur (these are not mapped). This is now threatened by low-level stream crossings and weirs that act as barriers to flow, and canalisation of the main channel in the lowest sections of the river/estuary. The riparian longitudinal connectivity is threatened by invasive alien plant species that form dense clumps or stretches of "green barriers" to upstream/downstream corridor function along the river, and result in a loss of biodiversity.

6.2.2 Lateral connectivity

The lateral connectivity relates to the riparian environment's ability to act as a conduit that facilitates lateral movement of biota and materials between the aquatic and terrestrial environments. The riparian lateral connectivity is also threatened by invasive alien plant species that form dense clumps or stretches along the river of "green barriers" to lateral movement.

6.2.3 Water quality

The maps shown in Figure 2.2 and Figure 6.3 indicate that the underlying geology in the area is the Peninsula Formation, which consists of quartzitic sandstone, minor conglomerate and shale. The elevated salinity levels seen throughout the catchment are therefore assumed to be of natural geological origin, as elevated electrical conductivity levels (as compared to guideline values in DWAF, 2008) are seen from the estuary interface through to Site 1 in the upper catchment.

Electrical conductivity levels for the average unimpacted (or A category) river is <30 mS/m, which is significantly lower than the values seen for the Baakens River. As the natural geology would result in more 'salty' overlying waters, it is assumed that although there has been an anthropogenic increase in salinity levels, the natural or reference state would be higher than 30 mS/m. The baseline condition was therefore recalibrated to 55 mS/m to account for the 'natural' salts in the water due to shales underlying the catchment. Note that this is an assumption, as no data exists for unimpacted systems.

The RC or natural state would therefore be described by slightly salty water with high DO levels, low nutrient levels (i.e. nitrogen and phosphorous; elevated levels lead to eutrophication[1]) and low toxins (such as metal ions, and Persistent Organic Pollutants such as fertilizers and herbicides). It is assumed that instream temperatures would be low due to overhanging vegetation. The confidence in the perceived RC is moderate-high, score 4.

[1] Eutrophication is the explosive growth of plants, including phytoplankton (minute photosynthesising organisms suspended in the water column), resulting from contamination of water with excessive quantities of nutrients, normally nitrogen and phosphorus.

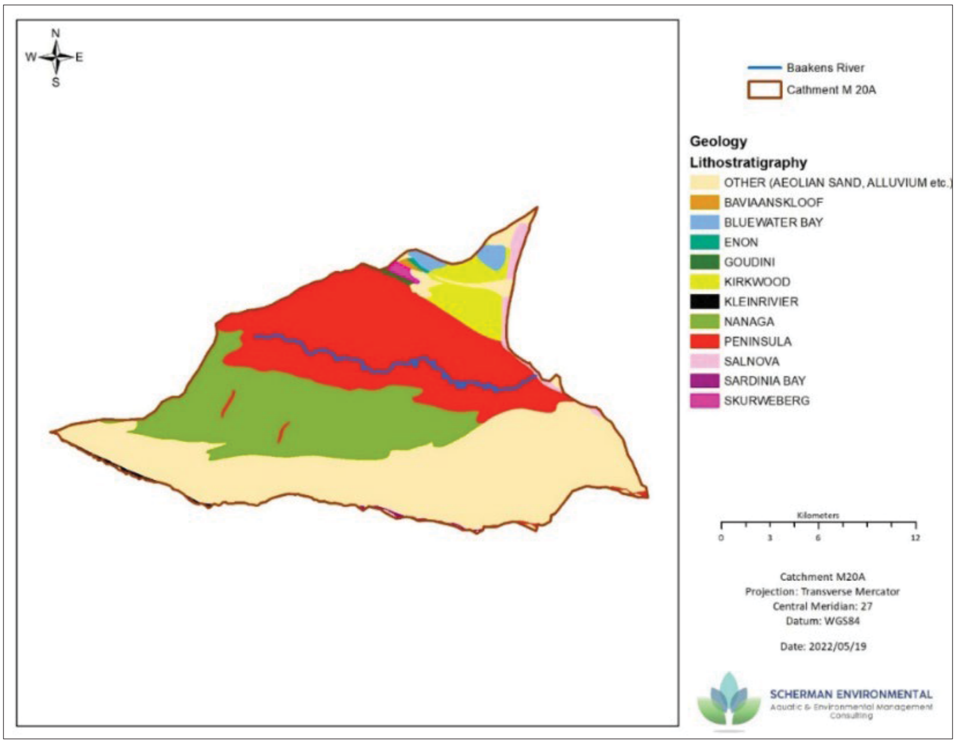

Figure 6.3 Geology of the Baakens River Valley

6.2.4 Riparian vegetation

The vegetation units within which sites occur will, to some extent at least, also determine the general structure of vegetation found within the riparian zone. Within the Baakens River catchment the two dominant Vegetation Units are Algoa Sandstone Fynbos and Bethelsdorp Bontveld which belongs to the Albany Thicket Bioregion and follows the contours of the Baakens River along its incised valley (Figure 2.9).

Sites in the Fynbos are therefore expected to not be dominated by tall woody species, with lower to small shrubs at most and characterised by a marginal zone dominated by non-woody riparian obligates such as sedges, grasses and hydrophilic herbaceous forbs. Algoa Sandstone Fynbos is described as "flat to slightly undulating plains supporting grassy shrubland (mainly graminoid fynbos). Grasses become dominant especially in wet habitats". Sites within the Albany Thicket on the other hand are expected to have a well-defined and tall woody component, but that does not dominate to the extent of exclusion of marginal zone non-woody specialists. Bethelsdorp Bontveld is described as "a mosaic of low thicket (2-3 m) consisting of bush clumps in a matrix of low, succulent-rich shrubland comprising renosterveld and succulent karroid elements, e.g. *Smelophyllum capense*". Historic photographs taken in 1994 at the Dodd's Farm crossing outline this best (Figure 6.4). The mosaic of woody and non-woody elements is clearly visible in photographs taken 28 years ago and just is clear is the woody encroachment since then.

A number of extracts from Skead (2009) pertaining to the Baakens River valley and the Port Elizabeth (Gqeberha) vicinity shed some light on the reference state of vegetation, albeit often in a broad sense. These are presented in Appendix 3 (Section 10.3). Overall confidence is the understanding of what the reference state is: 3/5.

Figure 6.4 L (top and bottom): Photographs of Dodd's Farm weir crossing taken in 1994 (Source: Anton Bok, 1994) and R (top and bottom): In 2022 (Source: J MacKenzie).

6.2.5 Fish

Under near pristine conditions, the fish listed in

Table 6.2 would be expected in the Baakens River. The primary freshwater fish species present (Eastern Cape redfin, Cape kurper, and goldie barb) should occur naturally in suitable habitats throughout the Baakens River System, from just above the estuary to the headwaters. The catadromous species (freshwater mullet, flathead mullet and Cape Moony) would naturally be more common in the lower reaches of the river, apart from longfin eel that penetrates into the very upper reaches of coastal rivers. No alien fish would be expected.

6.2.6 Aquatic Invertebrates

Under pre-development conditions, the following differences (from current state) would support the 'expected' aquatic invertebrate community, which is listed in Table 6.3.

- Clean clear slightly salty water with a low sediment load;
- Absence of alien fish species;
- Healthy, mobile instream habitat (differing in size-class along the river length);
- Low incidence of fines overlaying instream habitat;
- Absence of alien vegetation instream and in the marginal and riparian zones;
- Absence of instream flow modification (including: instream barriers to flow, runoff from agriculture in upper reaches and urbanised catchment in middle and lower reaches, canalisation in the estuarine section);
- Intact marginal vegetation and riparian zone supporting only appropriate indigenous species;
- Natural shading in the middle reaches (i.e. less than present).

Table 6.2 An annotated list of indigenous fish species found in the Baakens River.

FISH SPECIES		CONSERVATION STATUS AND DISCUSSION
SCIENTIFIC NAME	**COMMON NAME**	
Pseudobarbus afer	Eastern Cape redfin	*IUCN Status: Endangered.* This so-called "Mandela lineage" is confined to the Baakens, Swartkops and Sundays rivers; redfin populations to the west are considered different species; The Baakens population may be a district lineage, but genetic analysis is needed to confirm this.
Sandelia capensis	Cape kurper	*IUCN Status: Data Deficient*. Considered by local scientists as a species of special concern, and the Baakens River population may have a distinct genetic lineage (Swartz 2008) and warrants special protection.
Enteromius pallidus	Goldie barb	*IUCN Status: Least Concern*. Local expert opinion (Swartz 2008) considers populations within the Eastern Cape (*E. pallidus South*) a distinct species and under threat. Baakens River population may form a unique genetic lineage.
Myxus capensis	Freshwater mullet	*IUCN Status: Least Concern*. Marine spawning catadromous species penetrating far upstream in the absence of instream barriers. This species is considered locally threatened due to construction of instream barriers in coastal rivers.
Mugil cephalus	Flathead mullet	*IUCN Status: Least Concern*. Marine spawning, partially catadromous species penetrating upstream into freshwater, but more common in estuaries.
Monodactylus falciformis	Cape moony	*IUCN Status: Least Concern*. Marine spawning catadromous species common in estuaries, penetrating upstream into freshwater
Anguilla mossambica	Longfin eel	*IUCN Status: Least Concern*. Marine spawning obligatory catadromous species able to negotiate (climb over) instream barriers and penetrates into the upper reaches of most coastal rivers. Found throughout Baakens system
Eleotris fusca	Dusky sleeper	*IUCN Status: Least Concern.* Marine / estuarine migrant usually found near freshwater-estuarine interface in coastal rivers, rare in this region
Awaous aeneofuscus	Freshwater goby	*IUCN Status: Least Concern.* Estuarine migrant found in lower reaches of coastal rivers in low numbers, but rare in this region.
Stenogobius ?polyzona	Banded goby	*IUCN Status: Data Deficient.* Estuarine migrant found in lower reaches of coastal rivers, specimen found is a new distribution record and may be a new undescribed species. More specimens required for genetic analyses.

The invertebrates listed in Table 6.3 (in the 'REF' column) would be expected to occur under these pre-impact conditions in the freshwater portion of the Baakens River in its middle and lower reaches. Note that due to the high EC (electrical conductivity) of the water, which is considered natural and related to the underlying TMS geology (see Section 6.2.3), invertebrate taxa scoring over 10 were excluded from the reference condition due to their high sensitivity to water quality.

Table 6.3 The macro-invertebrate fauna expected to occur under natural or reference conditions in the Baakens River. REF = present under reference (with relevant score) Ab = abundance.

TAXON	Family	Common name	REF.	Ab
PORIFERA		Sponges	5	A
COELENTERATA		Freshwater polyp	1	A
TURBELLARIA		Flatworms	3	A
ANNELIDA	Oligochaeta	Aquatic worms	1	A
HIRUDINEA			3	A
CRUSTACEA	Potamonautidae	Crabs	3	A
	Palaeomonidae	Freshwater prawns	10	A
HYDRACARINA		Water mites	8	A
EPHEMEROPTERA	Baetidae 2 sp	Small minnow mayflies	6	B
	Caenidae	Cainflies (mayflies)	6	A
	Leptophlebiidae	Prongills (mayflies)	9	B
ODONATA	Synlestidae	Malachite dragonfly	8	A
	Coenagriidae	Narrow-winged damselfly	4	B
	Lestidae	Spreadwing damselfly	8	A
	Protoneuridae	Hawker dragonflies	8	A
	Aeshnidae	Darner dragonflies	8	A
	Gomphidae	Skimmers/Dropwing	6	B
	Libellulidae	Common skimmers	4	B
HEMIPTERA	Belostomatidae	Giant water bugs	3	A
	Corixidae	Water boatmen	3	C
	Gerridae	Pond skaters	5	B
	Hydrometridae	Marsh treaders	6	A
	Naucoridae	Creeping water bugs	7	A
	Nepidae	Water scorpions	3	A
	Notonectidae	Backswimmers	3	B
	Pleidae	Pygmy backswimmers	4	B
	Veliidae/	Dobsonflies	5	A
MEGALOPTERA	Corydalidae	Caseless caddisfly	8	A
TRICHOPTERA	Ecnomidae	Net-spinning caddisfly	8	A
	Hydropschychidae	Purse-case caddisflies	4	B
	Hydroptilidae		6	A
	Leptoceridae	Predaceous diving beetles	6	A
COLEOPTERA	Dytiscidae	Riffle beetles	5	B
	Elmidae	Whirligig beetles	8	A
	Gyrinidae	Crawling water beetles	5	B
	Haliplidae		5	A

Table 6.3 Cont....

TAXON	Family	Common name	REF.	Ab
COLEOPTERA cont	Hydraenidae	Minute moss beetles	8	A
	Hydrophilidae	Water scavenger beetles	5	A
DIPTERA	Ceratopogonidae	Biting midges	5	B
	Chironomidae	Midges	2	B
	Culicidae	Mosquito larva	1	B
	Dixidae	Meniscus midges	10	A
	Empididae		6	A
	Muscidae	House fly larvae	1	A
	Psychodidae	Moth fly larvae	1	B
	Simuliidae	Blackfly larvae	5	B-
	Syrphidae	Rat tailed maggot larvae	1	A
	Tabanidae	Horsefly larvae	5	B
	Tipulidae	Cranefly larvae	5	A
GASTROPODA	Ancylidae	Freshwater limpets	6	B
	Lymnaeidae	Pond snails	3	B
	Physidae	Pouch snails	3	B
	Planorbinae	Orb snails	3	B

Note: The expected abundances (Ab) refer to the number of invertebrates of that taxon one would expect to occur in a SASS5 sample, where A= 1-10, B=10-100, and C=>100.

7 FIELD SURVEY RESULTS

7.1 SOURCE AREA AND OTHER WETLANDS

There wasn't a formal evaluation done in the upper reaches of the river, nor of the wetlands, however a short comment is included here for the purposes of highlighting the importance of these wetlands and their ecosystem services (especially flood attenuation, baseflow conservation and biodiversity value) when going forward to the rehabilitation strategy and scenario development stage.

The unchannelled valley bottom wetlands in the catchment are critically threatened (CR threat status in the National Biodiversity Assessment/NBA database 2018) and are poorly protected, while the seep and depressional wetlands in the headwaters and upper catchment are vulnerable (VU threat status in the NBA database, 2018) and are also poorly protected.

Some of the seep dependent wetland plants are also threatened, notably *Cyclopia pubescens* (CR, NMBM endemic, seep dependent), which is being threatened by urban sprawl and invasion of the upper catchment by Port Jackson Willow (*Acacia saligna).*

IUCN Categories for Species of Special Concern

Extinct (EX) –	No known individuals remaining.
Extinct in the wild (EW) –	Known only to survive in captivity, or as a naturalized population outside its historic range.
Critically endangered (CR) –	Extremely high risk of extinction in the wild.
Endangered (EN) –	High risk of extinction in the wild.
Vulnerable (VU) –	High risk of endangerment in the wild.
Near threatened (NT) –	Likely to become endangered soon.
Least concern (LC) –	Lowest risk. Does not qualify for a more at-risk category. Widespread and abundant taxa are included in this category.
Data deficient (DD) –	Not enough data to assess its risk of extinction.
Not Evaluated (NE) –	Has not yet been evaluated against the criteria.

Figure 7.1 The various categories of threatened species, and their abbreviations (Source: International Union of Conservation of Nature or IUCN)

7.2 SITE 1 HAWTHORNE AVE (REACH 3)

7.2.1 Discharge, width and depth

Discharge at the site was measured as 0.03 m^3/s (30 litres/second). Depth ranged from 10-15 cm and channel width from 2-4 m.

7.2.2 Water quality

Water quality data for Site 1 are presented in Table 7.1 and Table 7.2. Summary statistics used per variable according to DWAF (2008) are shown in bold on Table 7.2. Talbot & Talbot results for samples collected on 4 May 2022 are attached as Appendix 4.

The river at Site 1 is significantly transformed from what would be expected naturally. The flow at the site was low, with a risk of high turbidity levels if the fine sediment were to be mobilized during high flows, for example. A sewerage pump station, Hawthorne Pump Station, is located within the reach directly below the sampling point at Site 1. Reports of non-compliance with discharge standards and the Pump Station being dysfunctional at times were provided by members of the public. Note that load-shedding would significantly impact on functionality of the pump station, and backup, temporary storage, or bypass systems need to be implemented. It is assumed that these operational mechanisms are in place, although reported impacts suggest that implementation of protocols may be inconsistent. Litter was also found in the urban area, which would further impact on instream water quality. *E. coli* levels were very high and serve as an indicator of pollution by sewage discharges.

Table 7.1 *In situ* water quality data taken in mid-May 2022.

Site	Electrical conductivity (mS/m)	DO (mg/L)	pH	Temperature (ºC)	Notes
1	123.3	6.87: slow flow 8.54: fast flow	6.61	17.5	DO levels assessed in both a fast and slow-flowing section of river below the weir.

d/s: downstream

Table 7.2 Statistics for DWS data at Sites 1 and 2

Site number	Statistic	COD (mg/L)	*E. coli* (cfu/ml)	Electrical conductivity (mS/m)	Ammonia (NH_3-N; mg/L)	Total Inorganic Nitrogen (TIN-N; mg/L)	PO_4-P (mg/L)	pH
SITE 1 & 2	Count	24	22	24	23	23	24	24
	5th percentile	12.1	81.2	85.2	0.001	0.3	0.05	7.1
	50th percentile	38.5	500	134	0.007	1.2	0.05	7.5
	95th percentile	56.2	315 500	177	0.089	11.5	0.94	7.8
	Average	38	1 026 413	132.5	0.021	2.5	0.20	7.5

Cfu: colony forming units
COD: Chemical Oxygen Demand
Note: Guideline standards for these variables are shown in Appendix 6, Table 10.2.

7.2.3 Riparian vegetation

Most of the area upstream and downstream of the site has been invaded by perennial alien species comprising dense shrub and tall trees, notably *Eucalyptus camuldulensis* and *Acacia saligna,* which has resulted in the exclusion of indigenous flora (Figure 7.2 and Figure 7.3)

Portions of the reach have been landscaped by river front landowners who have cleared and replanted banks (both alien and indigenous species) and constructed some in-channel pools and habitats. These in-channel areas support some marginal zone vegetation, notably *Cyperus dives* and *Floscopa glomerata*, but introduced substrates are not alluvial in origin (i.e. not deposited by the river) and are clogging habitats with anoxic deposits. Prevalent impacts at the time of the site visit are listed and noted in Table 7.3. Aerial cover (%) of vegetation components for a woody and non-woody assessment are shown in Figure 7.9 for both the marginal and non-marginal zone. For a full list of expected and observed species, refer to Appendices 2 and 7 respectively.

Table 7.3 Ratings of intensity and extent of impacts at Site 1 on a scale of 0-5, where 0 represents no impact and 5 extreme / extensive impact.

IMPACTS	INTENSITY	EXTENT	NOTES
Marginal Zone			
Vegetation Removal	3	3	Portion of the channel has been landscaped by landowners and substrates are mostly non-alluvial. Large stretches of the reach have been shaded by tall woody aliens and supports no marginal zone vegetation.
Alien Species Invasion	5	4.5	Extensive, mostly woody shrub and tall trees.
Water Quantity	1	5	Altered hydrograph due to hardened surfaces and increase in flashiness.
Water Quality	3	5	Elevated nutrients from sewer spills, high quantities of litter in the stream.
Erosion	2	2.5	Unconsolidated fine sediments introduced by landscaping are eroding.
Non-marginal Zone			
Vegetation Removal	3	2	Near complete removal along properties with river frontage, and shading / exclusion by tall dense alien tree species.
Alien Species Invasion	5	4	Extreme, the zone is dominated by *Eucalyptus* species and *Acacia saligna.*
Water Quantity	0	5	No impact discernible.
Water Quality	0	5	No impact discernible.
Erosion	3	4	Due to landscaping and lack of understorey, sediments are scouring,

Figure 7.2 Photographs of Site 1 taken in May 2022 looking upstream

Figure 7.3 Photographs of Site 1 taken in May 2022 looking downstream.

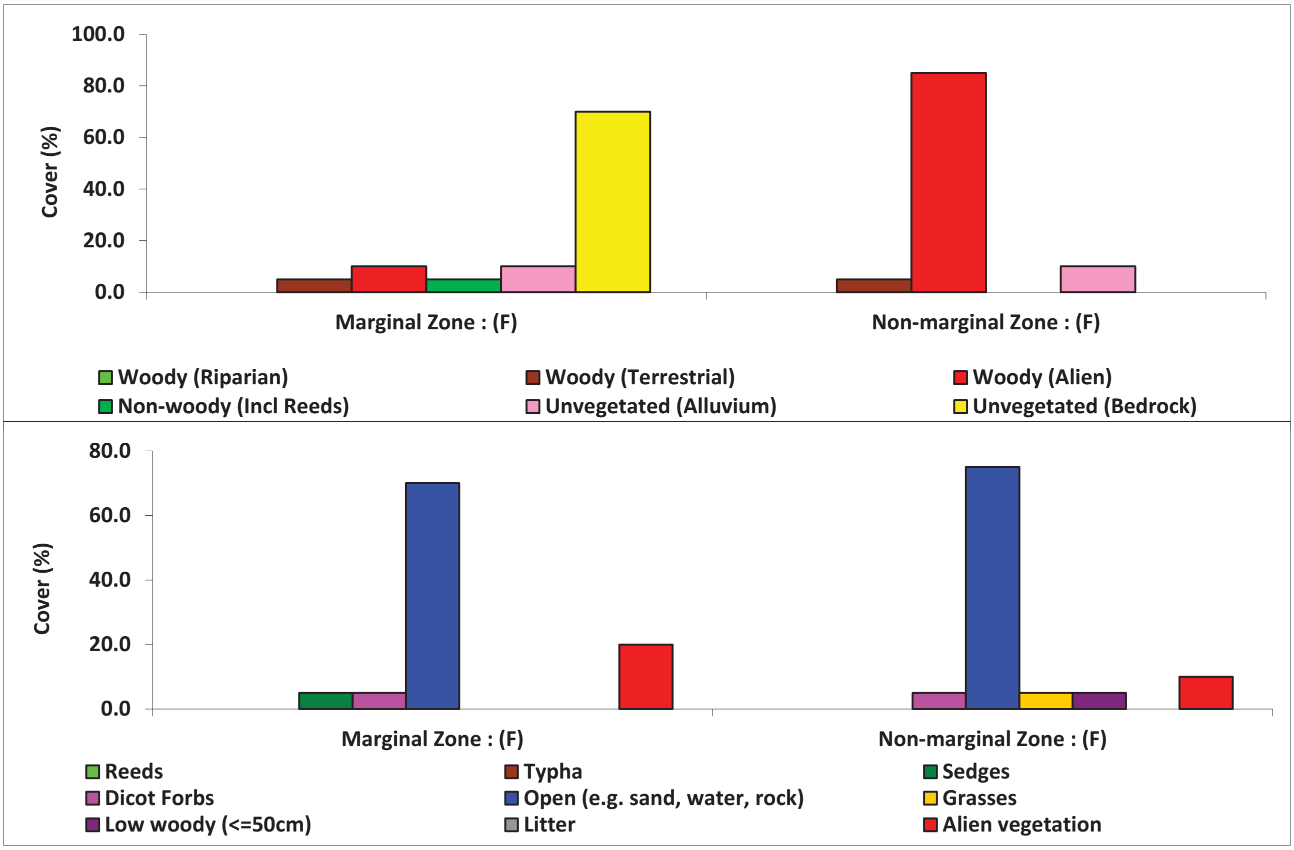

Figure 7.4 Aerial cover (%) of vegetation components at Site 1 for a woody (top) and non-woody (bottom) assessment.

7.2.4 Fish

Fish sampling was undertaken both upstream and downstream of a low weir in the Baakens River adjacent to the Hawthorne Avenue sewer pump station – see Figure 7.5 and Figure 7.6 As can be seen, the river channel upstream of the low weir has been 'cleaned out and rehabilitated' by the landowner on the one bank.

A variety of slow-deep and slow-shallow habitats with aquatic macrophytes and rocky substrate (upstream site) were sampled. The indigenous goldie barb *Enteromius* (ex *Barbus) pallidus* recorded at this site were all captured within the upper section among marginal vegetation and under the rocks on the substrate.

Figure 7.5. The downstream (L) and upstream (R) sections of Site 1 sampled for fish.

The fish species captured at Site 1 during this survey and the fish species that should be present based on the most recent fish surveys (Strydom 2014, Muller et al. 2014) are given in Table 7.4 below. The only indigenous fish captured during the present survey at Site 1 were five adult goldie barb, *Enteromius pallidus.*

Figure 7.6 Adult goldie barb (*Enteromius pallidus*) captured at Site 1 during the present survey.

Table 7.4. Presence and absence of fish expected and found at Site 1.

FISH SPECIES EXPECTED	FOUND THIS SURVEY	PREVIOUS RECENT SURVEYS
INDIGENOUS SPECIES		
Enteromius pallidus	Yes	Yes
Pseudobarbus afer	No	No
Sandelia capensis	No	Yes
Anguilla mossambica	No	Yes
ALIEN SPECIES		
Tilapia sparrmanii	Yes	Yes
Pseudocrenilabrus philander	Yes	Yes

7.2.5 Aquatic Invertebrates

The invertebrates collected at Site 1 are presented in Table 7.5 The taxa collected at Site 1, their scores and abundances, and the site score. The SASS5 score was 76, with 19 taxa, giving an ASPT of 4. The Instream Habitat Assessment System (IHAS) scored 51% while the Integrated Habitat Integrity Assessment (IHI) instream scored 38 (Category E). The difference in these scores is explained by the difference in variables measured by each. Both reflect the poor habitat resulting from modifications to the stream bed and banks in this section, and the presence of fines overlaying the coarse substrates.

Table 7.5 The taxa collected at Site 1, their scores and abundances, and the site score.

Invertebrate Taxon		Score	Ab
TURBELLARIA		3	A
ANNELIDA	Oligochaeta	1	A
HIRUDINEA		1	A
CRUSTACEA	Potamonautidae	3	A
EPHEMEROPTERA	Baetidae >2sp	12	C
	Caenidae	6	A
ODONATA	Coenagriidae	4	A
	Aeshnidae	8	A
HEMIPTERA	Belostomatidae	3	1
	Corixidae	3	1
	Gerridae	5	A
	Nepidae	3	1
	Notonectidae	3	
	Pleidae	4	B
	Veliidae/ M…veliidae	5	
TRICHOPTERA	Hydropschychidae 1 sp	4	
DIPTERA	Chironomidae	2	B
	Culicidae	1	A
	Simuliidae	5	B
	SASS5 Score	**76**	
	No of taxa	**19**	
	ASPT	**4**	

The temperature taken in the afternoon on site was 17.5°C, pH 6.61, EC 123 mS/m, and DO 8.54 mg/L in slow flow and 6.87 mg/L in fast flow. Water clarity pre-disturbance was 100 cm, however this declined rapidly as the river water was disturbed. The habitats sampled at Site 1 were stones (in and out of current), marginal vegetation, and sand. The Instream Habitat Assessment System (IHAS) for the site scored 51%, reflecting the presence of largely non-alluvial sediments and fines smothering the natural habitat, the paucity of a robust 'stones' habitat and the poor diversity of habitat overall.

The invertebrate fauna was a resilient, low diversity one, comprising mostly taxa scoring ≤8 out of 15 on the sensitivity score, except for the Baetid mayflies (>2 species present, scoring 12). Other families collected included Oligochaete worms, leeches, potamonautid river crabs, Baetid and Caenid mayflies, Gerrid; Belostomatid and Notonectid bugs; Dytiscid; Elmid and Hydrophilid beetles; Coenagriid and Aeshnid dragonflies; Ancylid and Physid snails; and Culicid, Simuliid and Chironomid fly larvae. Certain of the expected aerial taxa (particularly beetle and true bug families) were notably absent.

The naturally high EC (attributed by Scherman to the underlying Table Mountain Sandstone group geology) and the low dissolved oxygen, together with the poor instream habitat and sequential sewage spills in this area, provides some context for the low diversity and sensitivity of the invertebrate fauna.

7.3 SITE 2: DODD'S FARM (REACH 4, MIDDLE RIVER)

7.3.1 Discharge, width and depth

Discharge at the site was measured as 0.07 m^3/s (71 litres/second). Channel depth ranged from 1 0-15 cm, with greater depth in the downstream pooled sections. Channel width ranged from 2-3 m (at the site).

7.3.2 Water quality

Water quality data are presented in Table 7.6 and Table 7.7. Summary statistics used per variable according to DWAF (2008) are shown in bold on Table 7.7. Talbot & Talbot results for samples collected on 4 May 2022 are attached as Appendix 4.

Despite the aesthetics of the surrounding area, the odour and visible water quality clues at the weir on Dodd's Farm indicated poor water quality. A pipe built into the weir was discharging effluent which coated the weir downstream of the discharge point with a white layer; later explained to be toilet paper discharging down the system. The filamentous algae and periphyton present instream were evidence of high enrichment at this site, particularly at the large weir-crossing (upstream of the sampling site).

The Mangold Park Pump Station is located downstream of this site. It has been reported that when this pump station stops working, effluent is discharged directly into the river (this was not observed, hence not photographed). This effluent reportedly includes industrial waste.

Table 7.6 *In situ* water quality data taken in mid-May 2022

Site	Electrical conductivity (mS/m)	DO (mg/L)	pH	Temperature (ºC)	Notes
2	75.4	7.93	6.70	Approx. 18.5	Delay between taking sample and measuring temperature. Sampled at the large weir.
2	102.6	2.25	6.70		Sample taken at effluent discharge pipe in large weir.
2		7.5-8.4			Sample taken d/s weir at Site 2

d/s: downstream

Table 7.7 Summary statistics for DWS data at Sites 1 and 2

Site number	Statistic	COD (mg/L)	*E. coli* (cfu/ml)	Electrical conductivity (mS/m)	Ammonia (NH_3-N; mg/L))	Total Inorganic Nitrogen (TIN-N; mg/L)	PO_4-P (mg/L)	pH
SITE 1 + 2	Count	24	22	24	23	23	24	24
	5th percentile	12.1	81.2	85.2	0.001	0.3	0.05	7.1
	50th percentile	38.5	500	134	0.007	**1.2**	**0.05**	7.5
	95th percentile	56.2	**315 500**	**177**	**0.089**	11.5	0.94	**7.8**
	Average	38	**1 026 413**	132.5	0.021	2.5	0.20	7.5

Cfu: colony forming units
COD: Chemical Oxygen Demand
Note: Guideline standards for these variables are shown in Appendix 6, Table 10.2.

7.3.3 Riparian vegetation

Marginal zone:

The two main habitat forms in the marginal zone in the vicinity of Site 2 are pools or backup zones and natural channel forms, mostly runs with a linear nature. Most of the pool areas are artificial and associated with weirs or river crossings, but natural pool areas do exist. Riparian and aquatic vegetation associated with pools is mostly indigenous (see inset in Figure 7.7) but Parrots Feather (*Myriophyllum aquaticum*) has started encroaching in some areas and may invade. Dominant species in pools include *Floscopa glomerata*, *Berula erecta*, *Cyperus dives*, *Potomogeton pectinatus*, *Persicaria lapathifolia* and *Typha capensis* (which is favoured by slow flowing backup areas and elevated nutrient levels). Most of the marginal zone is not in the backup areas however (Figure 4 6) and comprises runs with overhanging vegetation and less aquatic representation. Similar species dominate with the inclusion of *Phragmites australis*.

Figure 7.7 Photographs of in-channel habitats at Site 2 taken in May 2022 looking upstream (top) and downstream (bottom). Inset indicates pool habitats (not natural) in the backup zone of weirs / river crossings.

Non-marginal zone

The non-marginal zone is characterised by high aerial cover and dense vegetation, both woody and non-woody, and the patchiness of woody to non-woody appears to be maintained by mowing and clearing of certain areas for public access, a task that naturally would have been performed by much higher grazing and browsing pressure (Figure 7.7, also refer to Figure 6.4).

Open areas are dominated by grasses, mainly *Panicum maximum,* while woody areas range from bush clumps with dense shrubs (mainly *Carissa bispinosa, Scutia myrtina, Diospyros dichrophylla, Searsia lucida,* and *Pterocelastrus tricuspidatus*) to more open understorey areas dominated by tall trees (mainly *Olea europaea subsp. africana, Pittosporum viridiflorum, Searsia rehmanniana, Schotia latifolia, Sideroxylon inerme* and *Erythrina caffra*) to shrub and succulent-dominated Fynbos as one leaves the valley. Perennial alien species comprising dense shrub and tall trees exist at moderate levels and pose a threat to longer-term integrity of natural vegetation. Invading species are mainly *Acacia saligna, A. mearnsii, Solanum mauritianum, Mellia azedarach, Arundo donax* and *Eucalyptus* species. For a full list of expected and observed species refer to Appendix 2 and 7 respectively.

Prevalent impacts at the time of the site visit are listed and noted in Table 7.8, and aerial cover (%) of vegetation components for a woody and non-woody assessment are shown in Table 7.9 for both the marginal and non-marginal zone.

Table 7.8 Ratings of intensity and extent of impacts at Site 2 on a scale of 0-5 where 0 represents no impact and 5 extreme / extensive impact.

IMPACTS	INTENSITY	EXTENT	NOTES
	Marginal Zone		
Vegetation Removal	1	1	Small impact, limited to low-level crossings and barriers to flow.
Alien Species Invasion	1	1	Isolated pockets of *Myriophyllum aquaticum*.
Water Quantity	1	5	Altered hydrograph due to hardened surfaces and increase in flashiness as well as backup at weirs / barriers.
Water Quality	3	5	Elevated nutrients from sewer spills promotes primary productivity of aquatic and marginal zone vegetation.
Erosion	0	5	No visible impact.
	Non-marginal Zone		
Vegetation Removal	1	2	Low intensity removal at low-level crossings and maintenance of some park / grassed areas. Some clearing for paths and tracks and open public spaces.
Alien Species Invasion	2.5	2.5	Moderately invaded with the potential for increase without management: Mainly *Acacia saligna, A. mearnsii, Solanum mauritianum, Mellia azedarach, Arundo donax, Eucalyptus* species.
Water Quantity	0	5	No visible impact.
Water Quality	0	5	No visible impact.
Erosion	1	1	Minimal, localised areas along tracks.

Figure 7.8 Photographs of valley habitats at site 2 taken in May 2022 showing (L) a landscape view and (R) bank habitats.

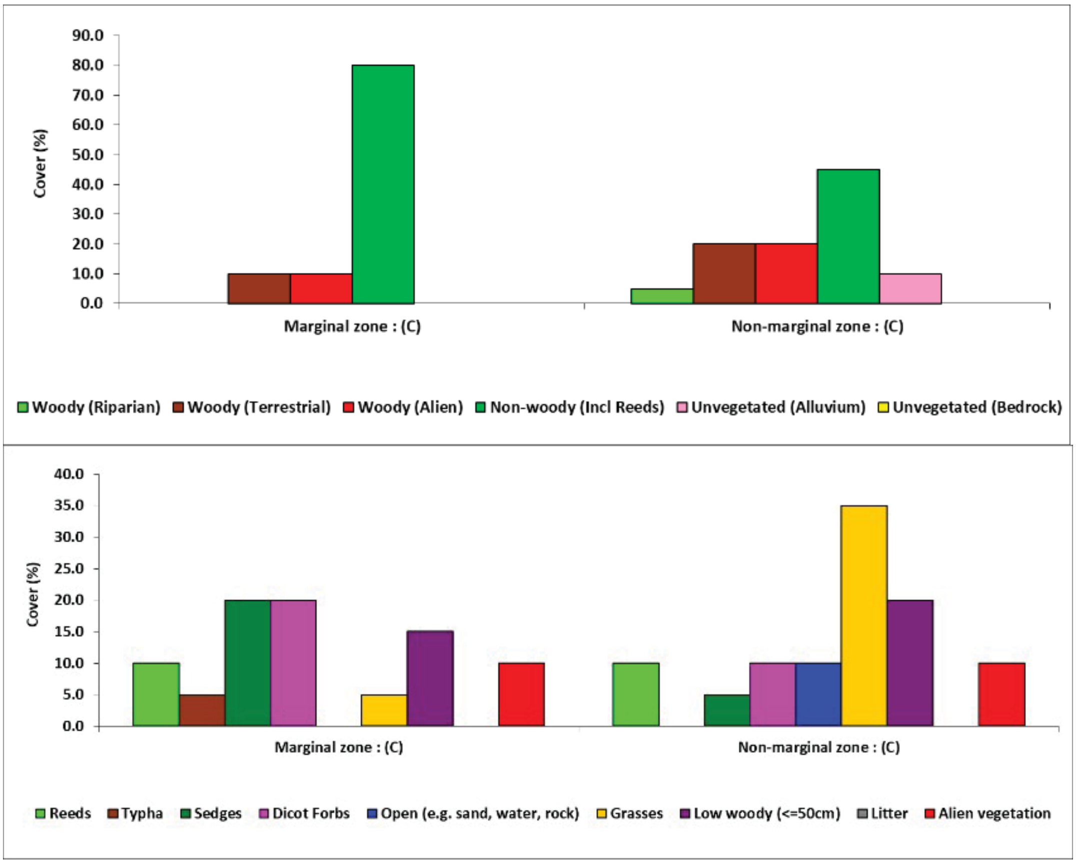

Figure 7.9. Aerial cover (%) of vegetation components at Site 2 for a woody (top) and non-woody (bottom) assessment

7.3.4 Fish

Fish sampling was undertaken upstream and downstream of the Ninth Avenue bridge over the Baakens River (33^0 58' 09.8" S; 25^0 34' 39.1" E), as well as at a pedestrian gabion causeway (33^0 58' 02.9" S; 25^0 34' 38.4" E) located about 490 m upstream of the bridge. Habitats consisted of slow-deep and slow-shallow habitats with dense marginal and overhanging vegetation with soft sand and mud substrate.

Figure 7.10 Fish sampling for Site 2 at the 9th Avenue Bridge, (left) downstream and (right) upstream

The fish species captured at Site 2 during this survey, and the fish species that should be present based on the most recent fish surveys (Strydom 2014, Muller et al. 2014), are presented in Table 7.9. No indigenous fish species were found during the present survey at Site 2, with only low numbers of alien banded tilapia and southern mouthbrooder captured.

Table 7.9 Presence and absence of fish expected and captured in the present survey at Site 2.

FISH SPECIES EXPECTED	FOUND THIS SURVEY	PREVIOUS RECENT SURVEYS-2014
INDIGENOUS SPECIES		
Enteromius pallidus	No	Yes
Pseudobarbus afer	No	No
Sandelia capensis	No	No
Anguilla mossambica	No	Yes
ALIEN SPECIES		
Tilapia sparrmanii	Yes	Yes
Pseudocrenilabrus philander	Yes	Yes

7.3.5 Aquatic invertebrates

The river was sampled at the site, which is located 520 m downstream of the large weir crossing at which raw sewage was being discharged. Sampling was done upstream and downstream of a narrow crossing bridge (see Figure 7.7). The invertebrate taxa collected at Site 2 are presented in Table 7.10. The SASS5 score was 68, with 15 taxa, giving an ASPT of 4.5. The IHAS score for the instream habitat was 87%, and the IHI score instream was 60 (Category C).

Table 7.10 The aquatic invertebrates collected at Site 2 at Dodd’s Farm, with their scores and abundances, and the site score.

INVERTEBRATE TAXON		Score	Ab
TURBELLARIA	TURBELLARIA	3	A
ANNELIDA	Oligochaeta	1	A
CRUSTACEA	Potamonautidae	3	A
EPHEMEROPTERA	Baetidae 2sp	6	C
	Caenidae	6	A
ODONATA	Chlorolestidae	8	A
	Coenagriidae	4	B
	Platycnemidae	10	1
HEMIPTERA	Gerridae	5	A
	Hydrometridae	6	A
	Veliidae	5	B
DIPTERA	Chironomidae	2	C
	Culicidae	1	A
	Simuliidae	5	C
GASTROPODA	Physidae	3	C
	SASS5 Score	**68**	
	No of taxa	**15**	
	ASPT	**4.5**	

The river in this section is a narrow channel 3-5 m in width, with a riffle-run-pool morphology, situated upstream of a large natural pool (Mermaid's pool). Instream habitat included packed cobbles ('stones in and out of current'), marginal vegetation (in flow) and small areas of gravels. The marginal vegetation was mostly overhanging, and did not provide a great deal of habitat, due to the low level of inundation of stems. There was no introduced non-alluvial sediment in this section. The Instream Habitat Assessment System (IHAS) for the site scored 87%, an improvement from Site 1.

Water quality was measured upstream at the large weir crossing, as this was the 'original' site selected, and at which the water quality sample analysed by Talbot and Talbot was taken earlier in May. The downsteam site was selected for SASS5 sampling as it was considered more natural and more representative of the Reach in general. In addition, the odour of the water at the large weir (due to the sewage discharge) was no longer present at the lower site and it was expected that a better SASS5 sample would be collected there.

At the upstream weir site, the temperature was 18.5 C, pH 6.71, EC 75.4 mS/m, and DO 7.93 mg/L. Water clarity at the sampling site was approximately 100 cm. The invertebrate fauna was sparse and largely tolerant to water quality change, with the ASPT of 4. The highest scoring taxon was the single Platycnemid damselfly larva (scoring 10/15). The stones-in-current fauna was dominated by Baetid mayflies and SImuliid (blackfly) larvae, and the marginal vegetation by Simuliid larvae and Physid snails. Notably absent was a variety of Hemipteran bugs and Coleopteran beetles.

Other families collected included Oligochaete worms, leeches, river crabs, Caenid mayflies, Gerrid, Hydrometrid and Veliid hemipterans; and Coenagriid and Synlestid dragonflies.

As with Site 1, the naturally high EC (attributed by Scherman to the underlying TMS Group geology) and the low dissolved oxygen, together with the lack of leafy marginal vegetation habitat, and the sequential sewage spills in this area, provides some context for the low diversity and sensitivity of the invertebrate fauna.

7.4 SITE 3: ESSEXVALE, SETTLERS PARK (REACH 5, LOWER RIVER)

7.4.1 Discharge, width and depth

Based on the previous two sites, and the position of this site in the catchment, it is estimated that discharge at the site was in the vicinity of 0.07 m^3/s to 0.1 m^3/s. Average channel depth was 10-20 cm.. Average channel width was 5-7 m (at the site).

7.4.2 Water quality

Data are presented in Table 7.11 and Table 7.12. Summary statistics used per variable according to DWAF (2008) are shown in bold on Table 7.12. Talbot & Talbot results for samples collected on 4 May 2022 are attached as Appendix 5. .

Discharges from Essexvale Pump Station are reported to overflow directly into the river in this reach. At the time of the site survey (16 May 2022), a significant rupture in the rising main (i.e. the line that pumps sewage away) off Lloyd Road was responsible for the impacts seen at Site 3, e.g. low oxygen levels even in fast-flowing water. Issues such as these are managed by switching off the pump station and employing a contractor to remove sewage by tanker while repairs can be undertaken. The impact of this rupture seemed significant, although action by the Metro was rapid.

Six sewage lines at Little Walmer Golf Course would also impact in this river reach. According to (unverified) land-owner reports, these lines are often blocked and overflow, assumedly via the manholes.

E. coli levels were very high and serve as an indicator of pollution by sewage discharges.

Table 7.11 *In situ* water quality data taken at Site 3 in mid-May 2022

Site	Electrical conductivity (mS/m)	DO (mg/L)	pH	Temperature (ºC)	Notes
3	83	3.66	6.80	15.5	Low DO levels even d/s the weir in fast flow. Site downstream of a ruptured sewer line.

d/s: downstream

Table 7.12 Summary statistics for DWS data at Site 3

Site number	Statistic	COD (mg/L)	*E. coli* (cfu/ml)	Electrical conductivity (mS/m)	Ammonia (NH_3-N; mg/L))	Total Inorganic Nitrogen (TIN-N; mg/L)	PO_4-P (mg/L)	pH
SITE 3	Count	25	24	25	25	25	25	25
	50th percentile	10	70.15	99	0.001	**0.2**	**0.05**	7.2
	Median	32	435	131	0.003	1.0	0.05	7.5
	95th percentile	49	**5 870**	**172.6**	**0.044**	4.0	1.65	**7.9**
	Average	29.8	**2 458.5**	130.5	0.012	1.4	0.40	7.5

Cfu: colony forming units
COD: Chemical Oxygen Demand

7.4.3 Riparian vegetation

Marginal zone

Essexvale is very similar to Dodd's Farm: The two main habitat forms in the marginal zone are pools or backup zones and natural channel forms, mostly runs with a linear nature. Most of the pool areas are artificial and associated with weirs or river crossings, but natural pool areas do exist. Riparian and aquatic vegetation associated with pools is mostly indigenous (see inset in Figure 4 9) but Parrots Feather (*Myriophyllum aquaticum*) has started encroaching in some areas and may invade. Dominant species in pools include *Floscopa glomerata, Berula erecta, Cyperus dives, Potomogeton pectinatus, Persicaria lapathifolia* and *Typha capensis* (which is favoured by slow-flowing backup areas and elevated nutrient levels). Most of the marginal zone is not in backup areas however (Figure 4 9) and comprises runs with overhanging vegetation and less aquatic representation. Similar species dominate with the inclusion of *Phragmites australis.* Much of the marginal zone overhanging vegetation is comprised of the alien shrub *Cestrum laevigatum* (Inkberry).

Non-marginal zone
The non-marginal zone is characterised by high aerial cover and dense vegetation, both woody and non-woody. The patchiness of woody to non-woody appears to be maintained by mowing and clearing of certain areas for public access, a task that naturally would have been performed by much higher grazing and browsing pressure (Figure 7.12,

Figure 2.1). Open areas are dominated by grasses, mainly *Panicum maximum*, while woody areas range from bush clumps with dense shrubs (mainly *Carissa bispinosa, Scutia myrtina, Diospyros dichrophylla, Searsia lucida*, and *Pterocelastrus tricuspidatus*) to more open understorey areas dominated by tall trees (mainly *Olea europaea subsp. africana*, *Pittosporum viridiflorum, Searsia rehmanniana, Schotia latifolia, Sideroxylon inerme* and *Erythrina caffra*) to shrub and succulent dominated Fynbos as one leaves the valley. Perennial alien species comprising dense shrub and tall trees exist at moderate levels and pose a threat to loner-term integrity of natural vegetation. Invading species are *mainly Acacia saligna, A. mearnsii, Solanum mauritianum, Mellia azedarach, Arundo donax* and *Eucalyptus species*. For a full list of expected and observed species refer to Appendix 2 and 7 respectively.

Prevalent impacts at the time of the site visit are listed and noted in Table 7.13, and aerial cover (%) of vegetation components for a woody and non-woody assessment are shown in Table 7.14.

Table 7.13. Ratings of intensity and extent of impacts at Site 3 on a scale of 0-5 where 0 represents no impact and 5 extreme / extensive impact.

IMPACTS	INTENSITY	EXTENT	NOTES
Marginal Zone			
Vegetation Removal	0.5	0.5	Small impact, limited to low-level crossings and barriers to flow.
Alien Species Invasion	1.5	4	Isolated pockets of *Myriophyllum aquaticum* and overhanging Inkberry.
Water Quantity	1	5	Altered hydrograph due to hardened surfaces and increase in flashiness as well as backup at weirs / barriers.
Water Quality	2	5	Elevated nutrients from sewer spills promotes primary productivity of aquatic and marginal zone vegetation.
Erosion	0	5	No visible impact.
Non-marginal Zone			
Vegetation Removal	1.5	1.5	Low intensity removal at low-level crossings and maintenance of some park / grassed areas. Some clearing for paths and tracks and open public spaces.
Alien Species Invasion	2.5	2	Moderately invaded with the potential for increase without management: Mainly *Cestrum laevigatum, Acacia saligna, A. mearnsii, Solanum mauritianum, Mellia azedarach, Arundo donax, Eucalyptus* species.
Water Quantity	0	5	No visible impact.
Water Quality	0	5	No visible impact.
Erosion	0.5	5	Minimal, localised areas along tracks.

Table 7.14 Aerial cover (%) of vegetation components at Site 3 for a woody (top) and non-woody (bottom) assessment.

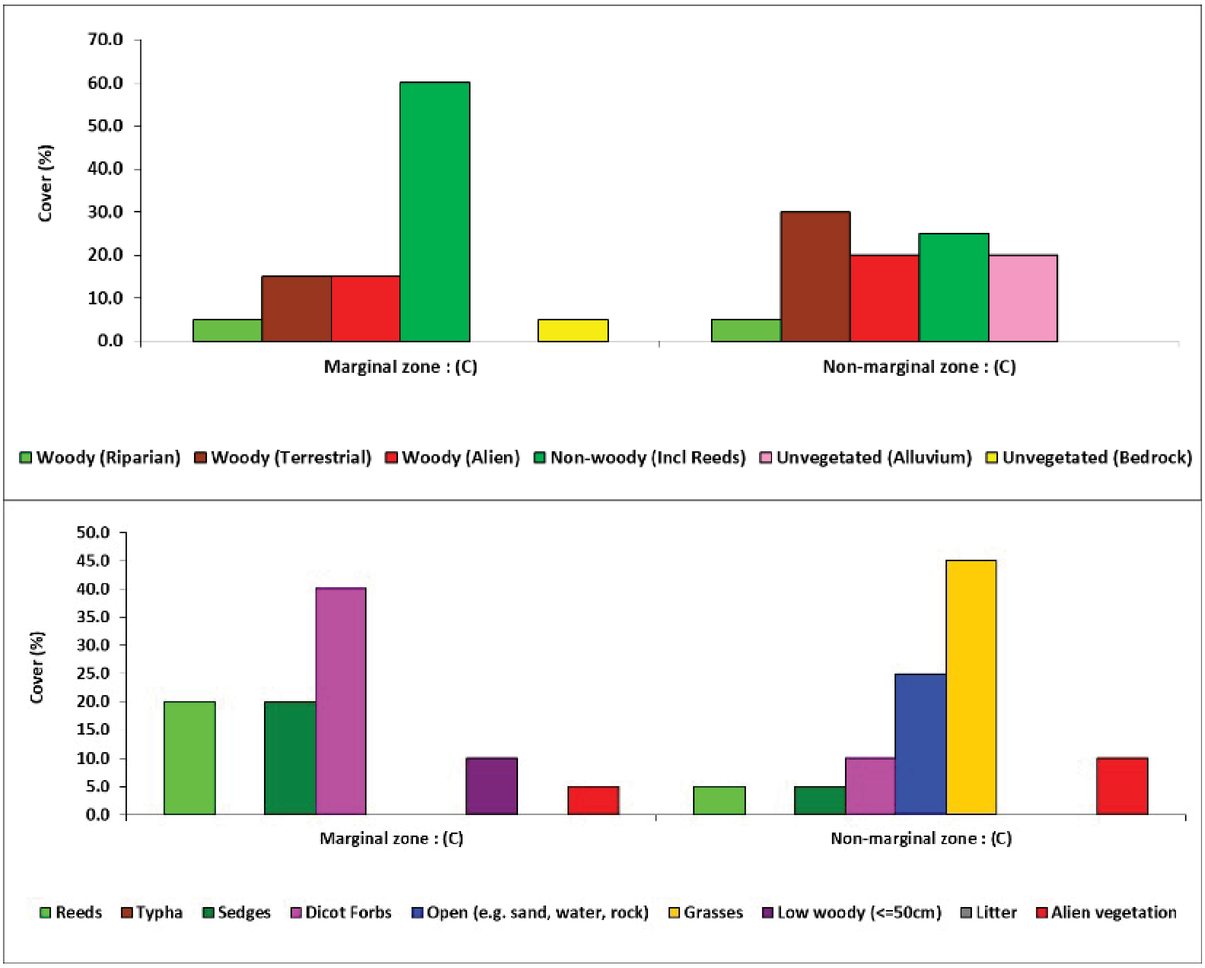

Figure 7.11 Photographs of in-channel habitats at Site 3 taken in May 2022 looking upstream (top) and downstream (bottom). Inset indicates pool habitats (not natural) in the backup zone of weirs / river crossings.

Figure 7.12. Photographs of valley habitats at site 3 taken in May 2022 showing a landscape view (top) and bank habitats (bottom).

7.4.4 Fish

Fish sampling was undertaken at a road causeway over the Baakens River in Settlers Park, located about 40 m downstream from the car park off Chelmsford Avenue, Essexvale (33° 58’ 10.7” S; 25° 35’ 58.9” E). Marginal and instream vegetation were limited, but large rocks and cobbles provided good fish cover in water depths up to 60 cm (Figure 7.13 and Figure 7.11).

The fish species captured at Site 3 during this survey and the fish species that should be present based on the most recent fish surveys (Strydom 2014, Muller et al. 2014) are given in Table 7.15. In addition to the alien banded tilapia and southern mouthbrooder captured, four endangered Eastern Cape redfin *Pseudobarbus afer* (Figure 7.14) and one large (ca. 45 cm long) longfin eel *Anguilla mossambica* (Figure 7.15) were captured. It is important to note that Site 3 is located in the same river reach and approximately 800 m upstream from the only site in the Baakens River where this endangered Eastern Cape redfin was captured by Strydom in 2014.

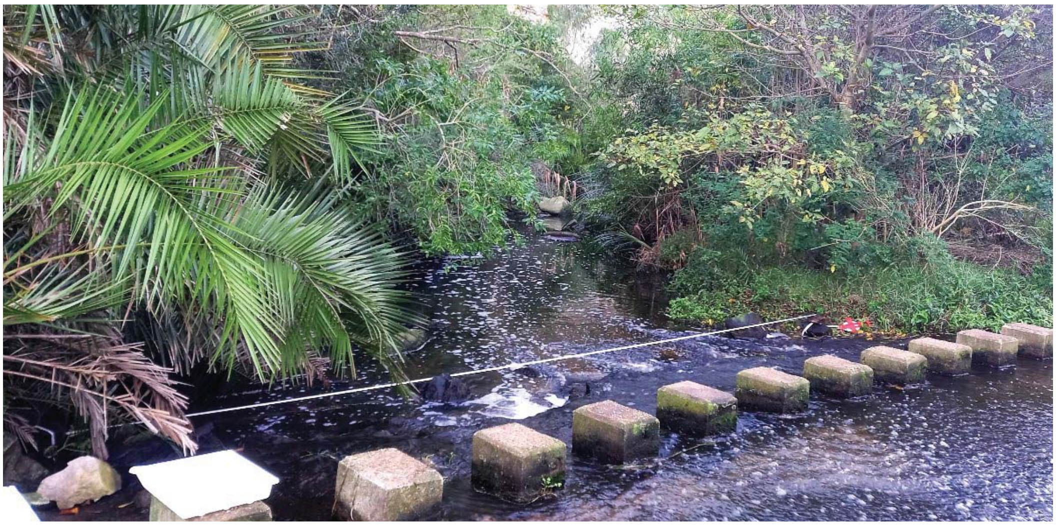

Figure 7.13 Fish sampling at Site 3 within riffle area downstream of a road causeway in Settlers Park

Figure 7.14 Eastern Cape redfin captured at Site 3 in Baakens River.

Figure 7.15 Longfin eel *Anguilla mossambica* captured at Site 3 in the Baakens River.

Table 7.15 Presence and absence of fish expected and captured in the present survey at Site 3.

FISH SPECIES EXPECTED	FOUND THIS SURVEY	PREVIOUS RECENT SURVEYS
INDIGENOUS SPECIES		
Enteromius pallidus	No	Yes
Pseudobarbus afer	Yes	Yes
Sandelia capensis	No	Yes
Anguilla mossambica	Yes	Yes
ALIEN SPECIES		
Tilapia sparrmanii	Yes	Yes
Pseudocrenilabrus philander	Yes	Yes

7.4.5 Aquatic Invertebrates

The site was sampled at the first low-level crossing after the Chelmsford Ave entrance to the Park. Sampling was both upstream and downstream of the crossing within a distance of approximately 100 m. Habitats sampled included stones, in the form of boulders and rocks (in and out of current), marginal vegetation (in pool and flow areas) and limited gravels. The temperature was 15.5°C, with a pH of 6.8, EC of 83 mS/m and DO of 3.66 mg/L. Water clarity pre-disturbance was 100 cm, however this declined rapidly as the river water was disturbed and fines were mobilised.

The SASS5 total sample was extremely poor at this site, with only four taxa being collected (Table 7.16). This is attributed to the sewage spill upstream, and the associated low oxygen conditions, as discussed in Section 7.4.2. The SASS5 score was 9, with 4 taxa, giving an ASPT of 2.25. The only taxa collected were river crabs, notonectid hemipterans, and chironomid and culicid dipteran larvae. The Instream Habitat Assessment System (IHAS) for the site scored 86% on account of the diversity of habitat types available (and the lack of more qualitative elements in the assessment). The IHI scored 40% (D) as this assessment takes account of water quality and flow modification. .

Table 7.16 The aquatic invertebrates collected at Site 3, their scores and abundances, and the site score.

INVERTEBRATE TAXA		Site 3	Ab
CRUSTACEA	Potamonautidae	3	A
HEMIPTERA	Notonectidae	3	A
DIPTERA	Chironomidae	2	C
	Culicidae	1	B
	SASS5 Score	**9**	
	No of taxa	**4**	
	ASPT	**2.25**	

7.5 SITE 4: ALCHEMY (LOWER RIVER, REACH 6)

7.5.1 Discharge, width and depth

It was not possible to measure flow at this site. Based on the two upper sites, and the position of this site in the catchment, it is estimated that discharge at the site was in the vicinity of 0. 07-0. 12 m^3/s. Average depth in the gabion-lined canal was 10-15 cm . Average channel width was 1-2 m (wider upstream where there is no canalisation).

7.5.2 Water quality

Data are presented in Table 7.17 and Table 7.18. Summary statistics used per variable according to DWAF (2008) are shown in bold on Table 7.18. Talbot & Talbot results for samples collected on 4 May 2022 are attached as Appendix 5.

The river water appears clear in this section of the river, although *E. coli* levels are very high and serve as an indicator of pollution by sewage discharges. This would be expected as the site is at the bottom of an urban catchment.

It is clear from the conditions seen throughout the catchment, literature accessed, and reports from residents and stakeholders living in the catchment that poor water quality, primarily linked to sewage discharges rather than industrial waste, is of primary concern. Any recreational use in the lower catchment would be severely constrained by the high *E. coli* levels in the water.

Table 7.17 *In situ* water quality data taken in mid-May 2022

Site	Electrical conductivity (mS/m)	DO (mg/L)	pH	Temperature (ºC)	Notes
4	42.3	8.5	6.85	15.8	24 mm rain had fallen the previous night. Fast flow.

d/s: downstream

Table 7.18 Summary statistics for DWS data at Site 4

Site number	Statistic	COD (mg/L)	*E. coli* (cfu/ml)	Electrical conductivity (mS/m)	Ammonia (NH_3-N; mg/L))	Total Inorganic Nitrogen (TIN-N; mg/L)	PO_4-P (mg/L)	pH
SITE 4	Count	21	21	21	21	21	21	21
	50^{th} percentile	10	150	101	0.001	**0.8**	**0.05**	7.2
	Median	28	3 500	140	0.004	1.4	0.05	7.5
	95^{th} percentile	39.7	**300 000**	**167**	**0.037**	7.5	0.25	**7.7**
	Average	25.1	**197 836**	136	0.013	1.7	0.08	7.5

Cfu: colony forming units
COD: Chemical Oxygen Demand

7.6 RIPARIAN VEGETATION

Left Bank

The marginal zone comprises a linear bank along a concrete canal, broken in places, with seeps into the zone from the upland areas. Aerial cover is 100%, dense vegetation that is mostly non-woody with overhang from woody shrubs, mostly the alien *Cestrum laevigatum* (Inkberry). The canal has some snags and a pulse of sediment moving through the system. Dominant species *include Floscopa glomerata, Berula erecta, Cyperus dives, Persicaria lapathifolia*, *Phragmites australis and Typha capensis* (only in snag areas where it is favoured by slow flowing backup and elevated nutrient levels). Alien species include *Ricinus communis* and *Arundo donax* (Figure 4 12).

The non-marginal zone is characterised by high aerial cover and dense vegetation, both woody and non-woody and comprises a linear bank along a cliff or urban area (Figure 4 12). Dominant species include *Erythrina caffra, Phragmites mauritianus* and the aliens included *Solanum mauritianum, Mellia azedarach, Arundo donax, Ricinus communis,Cestrum laevigatum* and *Cardiospermum grandiflorum* (Balloon Vine). For a full list of expected and observed species refer to Appendices 4 and 6 respectively.

Right Bank

The right bank is landscaped for public use and comprises mown lawns with some scattered plantings of Fig trees, although there is some recruitment of the invasive alien *Sesbanea punicea* nearer the channel. The right bank has little ecological value due to loss of ability to function as a corridor or for flood attenuation and virtually no contribution to biodiversity.

Prevalent impacts at the time of the site visit are listed and noted in Table 7.19, and aerial cover (%) of vegetation components for a woody and non-woody assessment are shown in for both the marginal and non-marginal zone on the left bank only.

Table 7.19. Ratings of intensity and extent of impacts on the left bank at Site 4 on a scale of 0-5 where 0 represents no impact and 5 extreme / extensive impact.

IMPACTS	INTENSITY	EXTENT	NOTES
Marginal Zone			
Vegetation Removal	0.5	0.5	Minimal removal on the LB and localised to areas where people have walked pathways.
Alien Species Invasion	3	3	Invasion by alien species is high, mainly *Nasturtiam officinale, Ricinus communis, Sesbanea punicea* and *Ipomoea cairica*, but also overhang from Inkberry
Water Quantity	1	5	Altered hydrograph due to hardened surfaces and increase in flashiness
Water Quality	1	5	No impact discernable, mostly due to the canalized nature of the main channel.
Erosion	0	0	No evidence of impact.
Non-marginal Zone			
Vegetation Removal	1	1	Minimal removal on the LB and localised to areas where people have walked pathways.
Alien Species Invasion	2	2.5	Invasion by alien species is high, *mainly Ricinus communis, Sesbanea punicea Cestrum laevigatum* and *Arundo donax.*
Water Quantity	0	5	No evidence of impact.
Water Quality	0	5	No evidence of impact.
Erosion	0	5	No evidence of impact.

Figure 7.16 Photograph of in-channel habitats at Site 4 taken in May 2022 looking upstream.

Figure 7.17 Photographs of in-channel habitats at Site 4 taken in May 2022 looking downstream. Inset indicates canalised stream farther downstream towards the estuary.

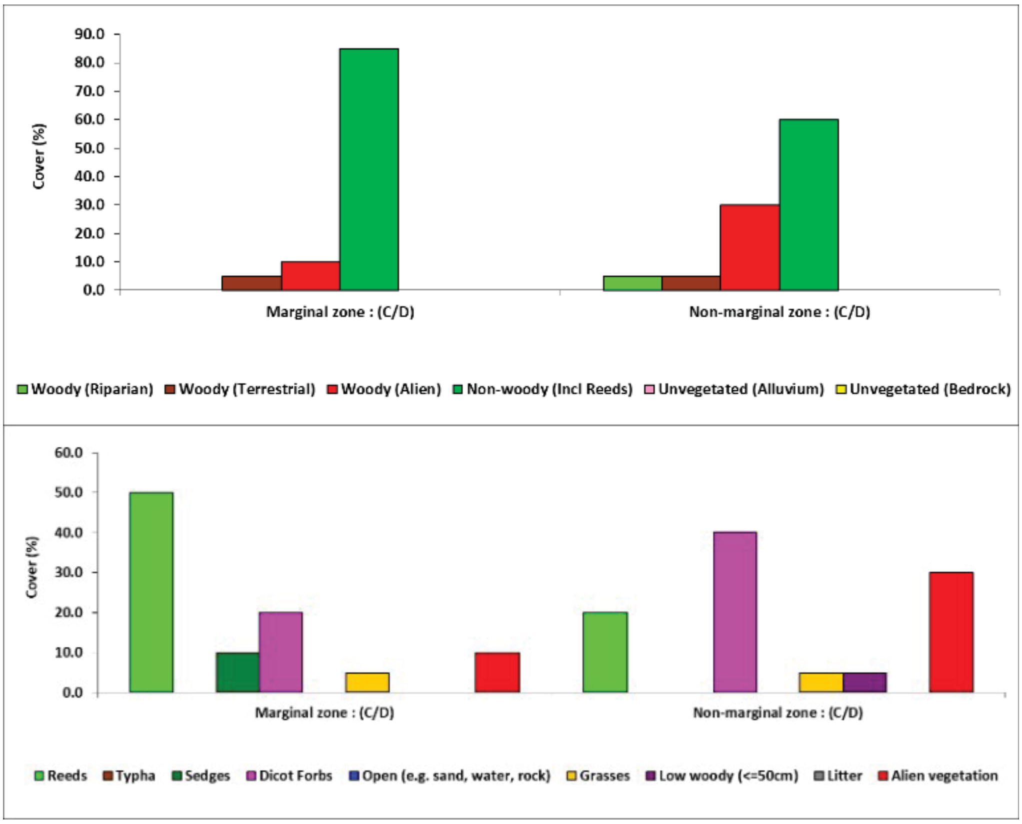

Figure 4.1 Aerial cover (%) of vegetation components at Site 4 for a woody (top) and non-woody (bottom) assessment on the left bank.

7.6.1 Fish

Fish sampling was limited to a 100 m section of the canalised river bed in the lower Baakens River where there was suitable habitat for fish (33^{0} 58' 02.7" S; 25^{0} 37' 13.4" E). The original ca. 2 m wide concrete channel is semi-intact in this area with marginal vegetation growing on the sides providing some cover for fish, with limited substrate cover for fish in the form of a few rock and gravel.

Figure 7.18 L,R: Fish sampling area in the canalised river, Site 4

The only fish species captured during the present survey (freshwater mullet, *Myxus capensis*) was a secondary freshwater species with a catadromous life history. The absence of preferred slow-deep habitats favoured by this species indicates that the fish captured were using Site 4 as a migration corridor. The fish data used in the FRAI assessment were therefore supplemented by fish distribution from previous surveys by Strydom (2014), that included habitats upstream of the concrete canal.

Table 7.20 Presence and absence of fish expected and captured in the present survey at Site 4.

FISH SPECIES EXPECTED	FOUND THIS SURVEY	PREVIOUS RECENT SURVEYS
INDIGENOUS SPECIES		
Enteromius pallidus	No	Yes
Pseudobarbus afer	No	No
Sandelia capensis	No	Yes
Myxus capensis	Yes	Yes
Anguilla mossambica	No	Yes
ALIEN SPECIES		
Tilapia sparrmanii	No	Yes
Pseudocrenilabrus philander	No	Yes

7.6.2 Aquatic Invertebrates

The river in this section of Reach 5 is canalised, however there were habitat elements that could be sampled. Invertebrates were sampled within 30-40 m of the site, where suitable instream habitat was available. In some areas, it is thought that the gabion baskets stabilising the canal had disintegrated or been destroyed by large flows, releasing cobbles into the channel, which provided invertebrates with some cover and habitat. The marginal vegetation on either side of the channel was leafy and dense, serving as good habitat and cover for invertebrates with a preference for this type of habitat.

Temperature at the site was 15.8°C, pH 6.85, EC 42.3 mg/L and DO 8.5 mg/L. The EC was likely reduced by the preceding rainfall, and the DO was likely increased by the resultant flow at the site (see Table 7.17). Note that this site is within the zone delineated as estuarine (Strydom 2014), however EC here was low relative to the other 3 sites. This could be due to the preceding rainfall. The low EC was adequate reason to continue with sampling (normally one would not use SASS 5 in an estuary).

The invertebrates collected at Site 4 are presented in Table 7.21. The SASS5 score was 66, with 14 taxa and an ASPT of 4.7. This is a significant improvement on the sample collected at Site 3, only 2.4 km upstream, and just a day earlier. This provides some indication of the ability of the river and its biota to recover over a short distance, where there is good riparian and instream vegetation to assist this process through bioremediation. Taxa present in the SASS5 sample were nonetheless the less sensitive, lower scoring ones, including Oligochaetes, Potamonautid crabs, leeches, Baetid and Caenid mayflies, Coenagriid, Lestid and Gomphid Odonata, Gerrid and Veliid hemipterans, and a number of dipteran larvae. The lack of more sensitive taxa is attributed to the overall paucity of good habitat in this section of the river, and to the water quality condition of inflows.

Table 7.21 The aquatic invertebrates collected at Site 4, their scores and abundances, and the site score.

Invertebrate Taxa		Score	Ab
TURBELLARIA		3	A
ANNELIDA	Oligochaeta	1	A
CRUSTACEA	Potamonautidae	3	
EPHEMEROPTERA	Baetidae >2sp	12	C
	Caenidae	6	1
ODONATA	Coenagriidae	4	B
	Lestidae	8	A
	Gomphidae	6	A
HEMIPTERA	Gerridae	5	
	Veliidae/ M...veliidae	5	
DIPTERA	Chironomidae	2	C
	Culicidae	1	B
	Simuliidae	5	C
	Tabanidae	5	A
	SASS5 Score	66	
	No of taxa	14	
	ASPT	4.71	

8 PRESENT ECOLOGICAL STATE & ECOSTATUS OF THE BAAKENS

8.1 SITE 1: HAWTHORNE AVE

8.1.1 Water quality

The PAI model scores water quality as a low C category (64.1%). Primary contributors are high nutrient levels, elevated salinity, anoxic fine sediments and a low toxicant load. The confidence is 3.

8.1.2 Riparian vegetation

The riparian vegetation at this site has been critically altered, with an overall PES score of 13.7% (category F), which is critically modified from reference condition. This is attributed to an extremely lowered species richness and an absence of intolerant and moderately tolerant species. Only intolerant species may be present, with complete loss of species at the lower end of the class. Most of the characteristics of the biotic assemblages have been critically modified from naturally expected conditions. Impairment of health at this site is generally very evident.

Table 8.1 outlines a summary of the PES ratings, score and ecological category of zones, and provides the most notable reasons for the perturbation.

Table 8.1 PES score and category for riparian vegetation at Site 1, with main reasons for the score.

LEVEL 3 ASSESSMENT		Baakens River Site 1		17 May 2022	
RIPARIAN VEGETATION EC METRIC GROUP	CALCULATED RATING	WEIGHTED RATING	CONFIDENCE	RANK	WEIGHT
Marginal Zone	15.2	1.6	2.9	1.0	10.7
Non-marginal Zone	13.5	12.1	2.9	2.0	89.3
LEVEL 4 VEGRAI (%)-					13.7
VEGRAI Ecological Category (PES)					F
AVERAGE CONFIDENCE					2.9
	ZONE				
	Marginal Zone	Non-marginal Zone		0.0	0.0
VEGRAI % (Zone)	15.2	13.5		not assessed	not assessed
EC (Zone)	F	F			
Confidence (Zone)	2.9	2.9			
Main cause of **PES** of **F**					
The most notable impacts resulting in the ecostatus score, as observed at site, are domination by invasive alien plant species, notably *Eucalyptus lehmannii,* but also *Acacia saligna* and *A. mearnsii* to the extent that little to no indigenous flora remain in large stretches of river and marginal zone non-woody species have been shaded out. Secondary to this, was localized manipulation of the channel structure and bed with additional sediment inputs and planting of non-local flora.					

8.1.3 Fish

The PES results, causes and sources and trend for the fish at Site 1 are presented in Table 8.2 (see also Appendix 9).

Table 8.2 The present ecological state (PES) for Site 1 in the Baakens River, reasons for this category and the anticipated trend.

PES	CAUSES AND SOURCES	TREND	CONF. /5
44.2% D	Deterioration in water quality due to organic pollution from sewage spills and contaminated run-off from urban catchment	Negative – due to increased sewage loads, poor sewer maintenance and population growth	2
	Impact of alien fish species, including competition for food and space and predation, particularly on eggs and larvae by banded tilapia and southern mouthbrooder	Negative – distribution and population density of alien fish appear to be increasing	2
	Increased sedimentation due destabilization of river banks by alien plants and increased catchment erosion due to disturbance by man	Negative – rapid spread of alien trees, increased disturbance of catchment	2
	Changes to natural hydrology, including flash floods due hardened catchment and base-flow reduction due to alien trees and extensive groundwater abstraction	Negative – increased urbanization and increased alien plants and boreholes	2

8.1.4 Aquatic Invertebrates

The PES for the aquatic invertebrates for Site 1 is 49%, which is a D category (Table 8.3). This is described as follows: *'**Largely modified**. A clearly lower than expected species richness and absence or much lowered presence of intolerant and moderately intolerant species. Most characteristics of the biotic assemblages have been largely modified from their naturally expected condition. Impairment of health may become evident at the lower end of this class'* (Kleynhans 1999).

Table 8.3 The PES for invertebrates at Site 1

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC GROUP	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	FM	37.5	*0.250*	9.375	1	100
HABITAT	H	43.8	*0.250*	10.9375	1	100
WATER QUALITY	WQ	54.7	*0.250*	13.6842	1	100
CONNECTIVITY & SEASONALITY	CS	60.0	*0.250*	15	1	100
						400
INVERTEBRATE EC				**48.9967**		
INVERTEBRATE EC CATEGORY-PES				D		
>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F						
Main causes: Alteration of instream habitat; altered hydrology; introduced barriers to flow; non-natural backup of water; introduction of non-alluvial sediments which smother habitat; water quality deterioration; absence of natural riparian zone and leaf-fall. Confidence in PES: 3/5						

>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F

8.1.5 Trend

Table 8.4 The trend for each component for Site 1, with reasons

Parameter	Trend (Negative, Stable, Positive)	Reasons
WQ	Negative	Failing infrastructure, with load-shedding putting additional strain on an already constrained system.
RV	Negative	Invasive alien plant species will continue to invade
FISH	Negative	Due to increased pollution and escalating changes in natural hydrology and increase in numbers and distribution of aggressive, predatory alien fish species
INVERT	Negative	Water quality will continue to deteriorate with forecast loadshedding; instream habitat unlikely to recover without intervention.

8.1.6 Ecostatus

The Ecostatus for Site 1 is informed by the system's driver variables (in this case, water quality, with background information on hydrology and geomorphology), and based on the PES outputs of the response variables, riparian vegetation, fish and invertebrates.

The EC for the site is 29.2%, a Category E (Figure 8.1,Table 8.5, Appendix 10). This is described by Kleynhans 1999 as: ***Critically modified**. Extremely lowered species richness and an absence of intolerant and moderately tolerant species. Only intolerant species may be present, with complete loss of species at the lower end of the class. Most of the characteristics of the biotic assemblages have been critically modified from its naturally expected conditions. Impairment of health generally very evident.* The major causes for this EC are presented per component.

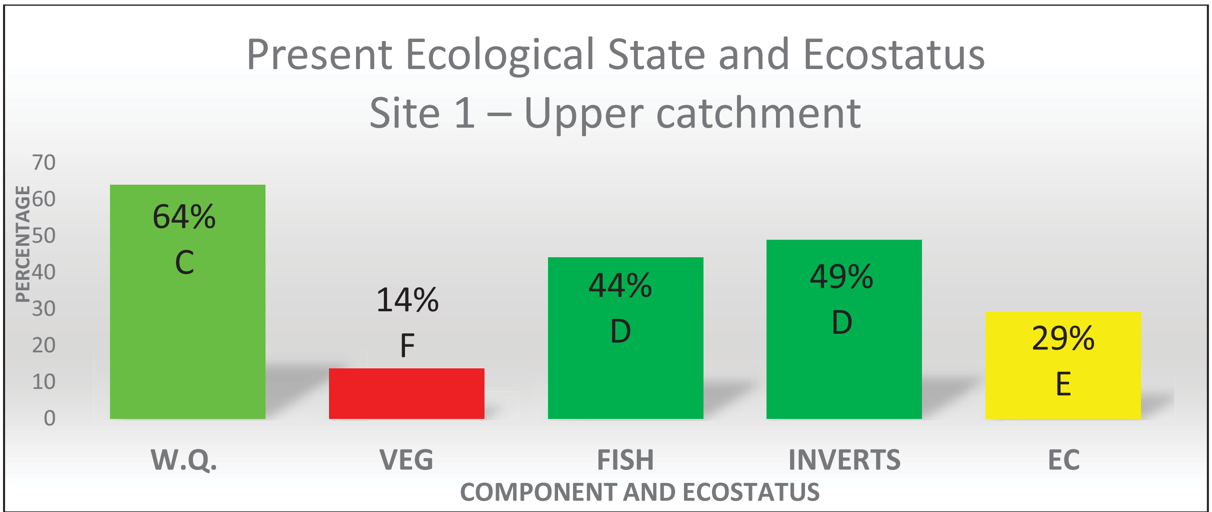

Figure 8.1 PES and Ecostatus graphic: Site 1. (WQ – water quality, VEG – riparian vegetation, FISH – Fish, INVERTS – invertebrates, EC – Ecostatus).

8.1.7 Trend

The overall trend for Site 1 is negative (deteriorating). Reasons are provided in Table 8.5.

Table 8.5 Summary Table for Site 1, showing trend and reasons

SITE 1				
COMPONENT	**PES %**	**CAT.**	**TREND**	**REASONS**
WATER QUALITY	64.1	C	↓	Failing infrastructure; load-shedding impacts; urban stream; litter.
RIPARIAN VEG	13.7	F	↓	Alien vegetation
FISH	44.2	D	↓	Increase in intensity of all existing negative impacts described above
INVERTEBRATES	48.9	D	↓	Habitat and flow alteration, water quality deterioration, alien fish species, sedimentation.
ECOSTATUS	**29.2**	**E**	↓	

Red down-arrow: Deteriorating

8.2 PES SITE 2: DODD'S FARM

8.2.1 Water quality

The assessment is for conditions where instream sampling was undertaken. Conditions at the weir would be considered worse due to the obvious discharges seen at the time of sampling. Note that the significant impact on DO was at the point of discharge. Levels had stabilised downstream of the weir. The PAI model scores water quality as a C category (66.5%). Primary contributors are high nutrient levels, elevated salinity and a low toxicant load. The confidence is 3.

8.2.2 Riparian vegetation

The present state at this site has been moderately altered, with an overall PES score of 66.7%. This is a category C, described as: *Moderately modified from reference condition, with a lower than expected species richness and presence of most intolerant species. Most of the characteristics of the biotic assemblages have been moderately modified from its naturally expected condition. Some impairment of health may be evident at the lower end of this class*.

Table 8.6 outlines a summary of the PES ratings, score and ecological category of zones, and provides most notable reasons for the perturbation.

Table 8.6. PES score and category for Riparian vegetation at Site 2, Dodd's Farm, with main reasons for the score.

LEVEL 3 ASSESSMENT	Baakens River Site 2 (Dodd's Farm)			17 May 2022	
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**
Marginal zone	66.7	6.1	3.0	1.0	9.1
Non-marginal zone	66.8	60.7	3.0	2.0	90.9
LEVEL 4 VEGRAI (%)					66.7
VEGRAI EC					**C**
AVERAGE CONFIDENCE					3.0
		Zone			
	Marginal zone	**Non-marginal zone**		**0.0**	**0.0**
VEGRAI % (Zone)	66.7	66.8		not assessed	not assessed
EC (Zone)	**C**	**C**			
Confidence (Zone)	3.0	3.0			

Main causes of PES of C:
The most notable impacts resulting in the ecostatus score, as observed at site, are invasion by alien plant species, notably *Eucalyptus lehmannii* and *Cestrum laevigatum*, but also *Acacia saligna, A. mearnsii, Solanum mauritianum* and *Mellia azedarch,* amongst others. There are also alterations to the aquatic and marginal zone vegetation with an increase in productivity due to nutrient loading and barriers to flow.

8.2.3 Fish

The Fish ES for Site 2, together with causes, sources and trend, are presented in Table 8.7.

Table 8.7 The Fish present ecological state (PES) for Site 2 in the Baakens River, causes and sources, and trend.

PES	CAUSES AND SOURCES	TREND	CONF
D (45.3%)	Deterioration in water quality due to organic pollution from sewage spills and contaminated run-off from urban catchment	Negative – due to increased sewage loads, poor sewer maintenance and population growth	2
	Impact of alien fish species, including competition for food and space and predation, particularly on eggs and larvae by banded tilapia and southern mouthbrooder	Negative – distribution and population density of alien fish appear to be increasing	2
	Increased sedimentation due destabilization of river banks by alien plants and increased catchment erosion due to disturbance by man	Negative – rapid spread of alien trees, increased disturbance of catchment	2
	Changes to natural hydrology (flash floods) due hardened catchment and base-flow reduction by alien trees and extensive groundwater abstraction	Negative – increased urbanization and increased alien plants and boreholes	2

8.2.4 Aquatic invertebrates

The PES for the invertebrates at Site 2 is calculated as 43%, a D category, the description for which is provided in Section 8.1.4. The PES calculations and the main causes for it are given in Table 8.8.

Table 8.8 The PES for the invertebrates at Site 2 (from MIRAI), with main causes

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC GROUP	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	FM	41.3	*0.270*	11.1486	1	100
HABITAT	H	55.0	*0.270*	14.8649	1	100
WATER QUALITY	WQ	36.8	*0.270*	9.95733	1	100
CONNECTIVITY & SEASONALITY	CS	40.0	*0.189*	7.56757	2	70
						370
INVERTEBRATE EC				43.5384		
INVERTEBRATE EC CATEGORY				D		
Main causes: Water quality deterioration; altered hydrology; alien fish, poor marginal vegetation habitat. Confidence in PES: 2/5						
>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F						

8.2.5 Trend

The overall trend for each component for Site 2, and the reasons for this, are presented in Table 8.9.

Table 8.9 Trend for Site 2 and reasons for this

Parameter	Trend (Negative, Stable, Positive)	Reasons
WQ	Negative	Failing infrastructure, with load-shedding putting additional strain on an already constrained system.
RV	Negative	Invasive alien plant species will continue to invade
FISH	Negative	Due to increased pollution and increasing changes in natural hydrology and increase in numbers and distribution of aggressive, predatory alien fish species
INVERTS	Negative	Anticipated increase in impacts particularly water quality (due to loadshedding) and flow modification.

8.2.6 Ecostatus at Site 2

The EC for Site 2 is 57.8%, a category C/D (Figure 8.2, Table 8.10, Appendix 10). This falls between moderately and largely modified, C category is described by Kleynhans (1999) as: ***Moderately modified*** *from reference condition, with a lower than expected species richness and presence of most intolerant species. Most of the characteristics of the biotic assemblages have been moderately modified from theirs naturally expected condition. Some impairment of health may be evident at the lower end of this class*. A category D is described by Kleynhans (1999) as: ***'Largely modified****. A clearly lower than expected species richness and absence or much lowered presence of intolerant and moderately intolerant species. Most characteristics of the biotic assemblages have been largely* *modified from their naturally expected condition. Impairment of health may become evident at the lower end of this class'.*

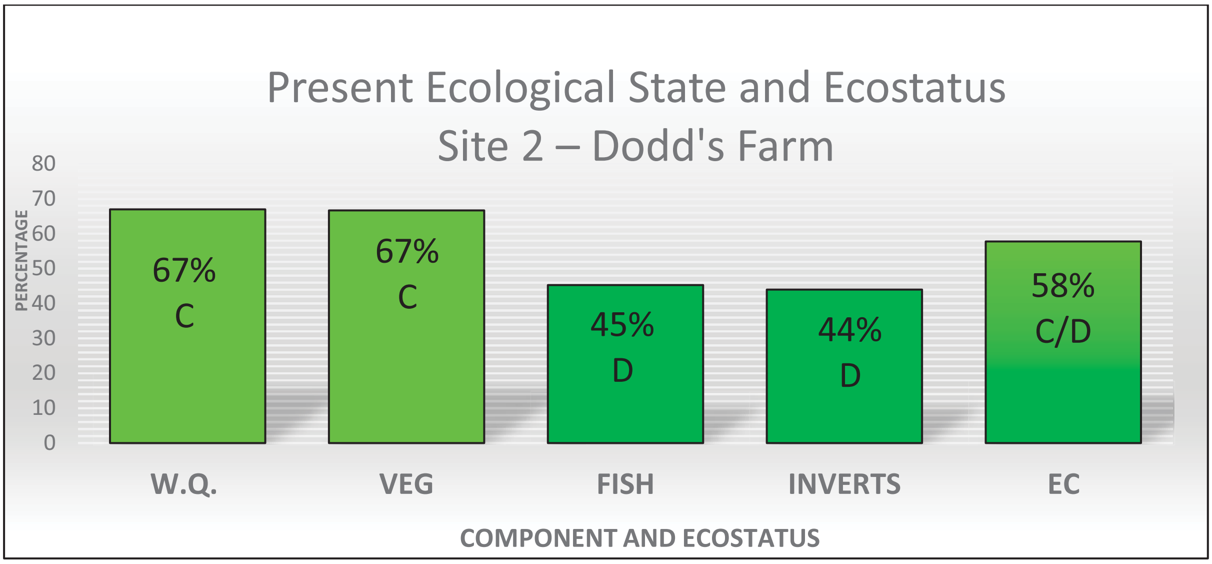

Figure 8.2 Graphic illustration of the PES and Ecostatus for Site 2. (WQ – water quality, VEG – riparian vegetation, FISH – Fish, INVERTS – invertebrates, EC – Ecostatus)

Table 8.10 Summary Table Site 2

SITE 2				
COMPONENT	**PES %**	**CAT.**	**TREND**	**REASONS**
WATER QUALITY	66.5	C	↓	Failing infrastructure; impacted upper urban environment; load-shedding an additional strain.
RIPARIAN VEG	66.7	C	↓	Alien species
FISH	45.3	D	↓	Increase in intensity of all existing negative impacts described for Site 1
INVERTEBRATES	43.5	D	↓	Poor water quality, flow modification, alien fish, poor marginal vegetation. Water quality deterioration is likely to increase with loadshedding forecast.
ECOSTATUS	57.8	C/D	↓	

Red down-arrow: Negative trend (Deteriorating)

8.3 PES SITE 3: ESSEXVALE

8.3.1 Water quality

The upstream impact of the ruptured sewerage line had a significant impact at this site, with extremely low oxygen levels recorded and poor invertebrate scores. Due to the poor DO levels, the threshold for DO in the PAI method was reached, and the integrated water quality category is an E (26.5%). Confidence is 4.

8.3.2 Riparian vegetation

The present state at this site has been moderately altered, with an overall PES score of 62.3% (category C), which is moderately modified from reference condition. There is a lower than expected species richness and presence of most intolerant species. Most of the characteristics of the biotic assemblages have been moderately modified from its naturally expected condition. Some impairment of health may be evident at the lower end of this class. Table 8.11 outlines a summary of the PES ratings, score and ecological category of zones, and provides most notable reasons for the perturbation.

Table 8.11 PES score and category for Riparian vegetation at Site 3, with main reasons for the score.

LEVEL 3 ASSESSMENT		**Baakens River Site 3 (Essexvale)**			**16 May 2022**
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**
Marginal zone	62.9	4.4	3.0	1.0	7.0
Non-marginal zone	62.3	57.9	3.0	2.0	93.0
LEVEL 4 VEGRAI (%)					62.3
VEGRAI EC					**C**
AVERAGE CONFIDENCE					3.0
	Zone				
	Marginal zone	**Non-marginal zone**		**0.0**	**0.0**
VEGRAI % (Zone)	62.9	62.3		not assessed	not assessed
EC (Zone)	**C**	**C**			
Confidence (Zone)	3.0	3.0			
Main cause of PES of C:					
The most notable impacts resulting in the ecostatus score, as observed at site, are invasion by alien plant species, notably *Eucalyptus lehmannii* and *Cestrum laevigatum*, but also *Acacia saligna, A. mearnsii* and *Solanum mauritianum*, amongst others. There are also alterations to the aquatic and marginal zone vegetation with an increase in productivity due to nutrient loading and barriers to flow.					

8.3.3 Fish

The PES for the Fish at Site 3 is provided in Table 8.12 (see also Appendix 9), together with the causes and sources, and the trend for the site.

Table 8.12 The present ecological state (PES) for Site 3 in the Baakens River, reasons for this category and the anticipated trend.

PES	CAUSES AND SOURCES	TREND	CONF
C/D (59.0%)	Deterioration in water quality due to organic pollution from sewage spills and contaminated run-off from urban catchment	Negative – due to increased sewage loads, poor maintenance and population growth	2
	Impact of alien fish species, including competition for food and space and predation, particularly on eggs and larvae by banded tilapia and southern mouthbrooder	Negative – distribution and population density of alien fish appear to be increasing	2
	Increased sedimentation due destabilization of river banks by alien plants and increased catchment erosion due to disturbance by man	Negative – rapid spread of alien trees, increased disturbance of catchment	2
	Changes to natural hydrology including flash floods due hardened catchment and base-flow reduction by alien trees and extensive groundwater abstraction	Negative – increased urbanization and increased alien plants and boreholes	2

8.3.4 Aquatic invertebrates

The PES for the invertebrates at Site 3 is 14.5%, an F category (Table 8.13). This is described as '*Critically modified. Extremely lowered species richness and an absence of intolerant and moderately tolerant species. Only intolerant species may be present with complete loss of species at the lower end of the class. Most of the characteristics of the biotic assemblages have been critically modified from its naturally expected conditions. Impairment of health generally very evident*' (Kleynhans 1999).

Table 8.13 PES Score and Category for Site 3 invertebrates, with reasons

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC GROUP	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	FM	12.5	*0.250*	3.125	1	100
HABITAT	H	12.5	*0.250*	3.125	1	100
WATER QUALITY	WQ	7.4	*0.250*	1.84211	1	100
CONNECTIVITY & SEASONALITY	CS	25.7	*0.250*	6.42857	1	100
						400
INVERTEBRATE EC				14.5207		
INVERTEBRATE EC CATEGORY				F		
Reasons for EC: Water quality impairment (particularly, low dissolved oxygen) caused by failing sewerage infrastructure. Consequent habitat degradation. Flow modification. Alien fish.						
>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F						

8.3.5 Trend

The trend for each of the components at Site 3 is negative (deteriorating). The reasons for this are provided in Table 8.14.

Table 8.14 Trend for each component for Site 3, together with reasons.

Parameter	Trend (Deteriorating, Stable, Improving)	Reasons
WQ	Negative	Failing infrastructure, with load-shedding putting additional strain on an already constrained system. Ruptured line upstream on the sewage system had a significant impact at the site.
RV	Negative	Invasive alien plant species will continue to invade.
FISH	Negative	Due to increased pollution and increasing changes in natural hydrology and increase in numbers and distribution of aggressive, predatory alien fish species (see above).
INVERT	Negative	With predicted increases in loadshedding the water quality situation is likely to deteriorate further, also affecting habitat quality negatively.

Red down-arrow: Deteriorating

8.3.6 Ecostatus at Site 3

The Ecostatus for Site 3 is 53.8%, an EC of D (Figure 8.3, Table 8.14, Appendix 10) which is described by Kleynhans (1999) as: ***Largely modified****. A large loss of natural habitat, biota and basic ecosystem functions has occurred.*

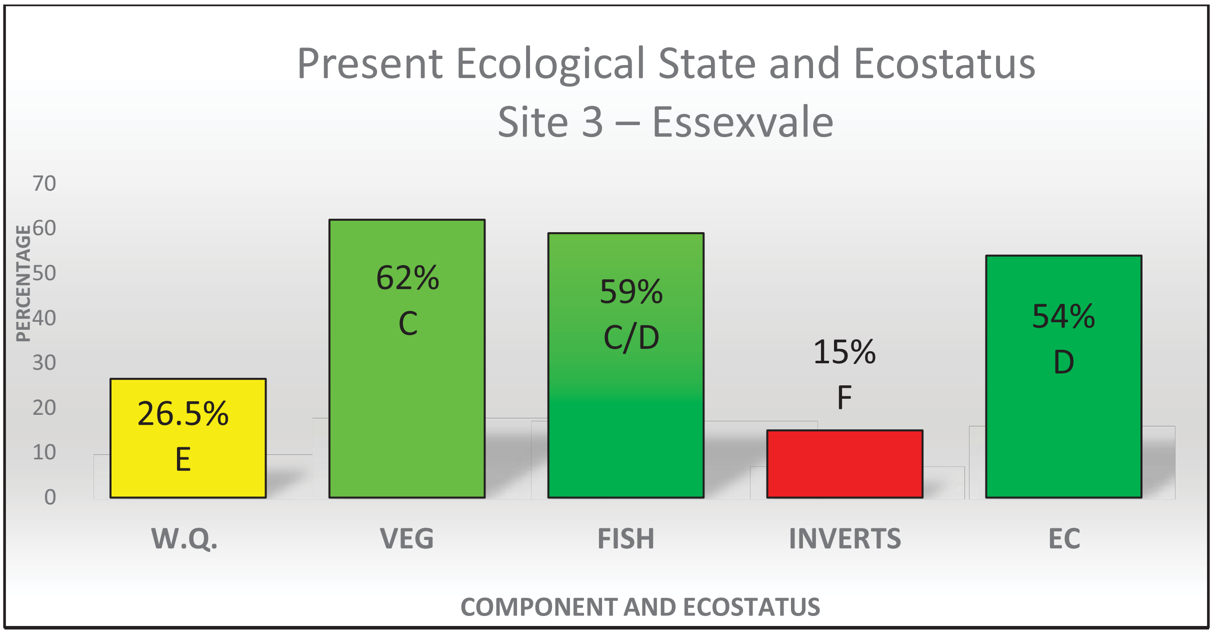

Figure 8.3 Graphic illustration of the PES and Ecostatus for Site 3 (WQ – water quality, VEG – riparian vegetation, FISH – Fish, INVERTS – invertebrates, EC – Ecostatus)

Table 8.15 Summary Table for Site 3

SITE 3				
COMPONENT	**PES %**	**CAT.**	**TREND**	**REASONS**
WATER QUALITY	26.5	E	↓	Failing infrastructure and damages to upstream sewer lines with significant immediate impacts on instream water quality conditions.
RIPARIAN VEG	62.3	C	↓	Alien plant species
FISH	59.0	C/D	↓	Increase in intensity of all existing negative impacts described for Sites 1 and 2
INVERTEBRATES	14.5	F	↓	Continued threat of water quality deterioration which will also lead to habitat deterioration.
ECOSTATUS	53.8	D	↓	

Red down-arrow: Negative (deteriorating)

8.4 PES SITE 4: ALCHEMY (LOWER RIVER)

8.4.1 Water quality

Upstream urban impacts result in a C (68.8%) water quality state. Conditions in this stretch are better than expected (other than high *E. coli* levels which will constrain recreational use of the river). It is assumed there has been some regeneration of the system. The upper part of this section is well vegetated, possibly acting as a water quality filter. Confidence 3.5.

8.4.2 Riparian vegetation

The left and right bank (LB, RB) at Site 4 are dramatically different from each other where the RB comprises mown lawns with little ecological value and the LB comprises structured vegetation, albeit modified and manipulated but with both indigenous and alien species. The two banks were therefore assessed separately to make the results more meaningful so that each may be managed in the appropriate way, which may result in different management regimes for each bank.

The present state of the left bank at this site has been moderately to largely altered, with an overall PES score of 57.6%, category C/D, which is '*moderately to largely modified from reference condition (A lower than expected species richness and presence of most intolerant species. Most of the characteristics of the biotic assemblages have been moderately modified from its naturally expected condition. Some impairment of health may be evident at the lower end of this class*). Table 8.16 outlines a summary of the PES ratings, score and ecological category of zones, and provides most notable reasons for the perturbation.

Table 8.16 PES score and category for riparian vegetation at Site 4 (Left Bank), with main reasons for the score.

LEVEL 3 ASSESSMENT		**Baakens River Site 4 LB**			**16 May 2022**
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**
Marginal zone	58.3	8.3	3.0	1.0	14.3
Non-marginal zone	57.5	49.3	3.0	2.0	85.7
LEVEL 4 VEGRAI (%)					57.6
VEGRAI EC					**C/D**
AVERAGE CONFIDENCE					3.0
			Zone		
	Marginal zone	**Non-marginal zone**		**0.0**	**0.0**
VEGRAI % (Zone)	58.3	57.5		not assessed	not assessed
EC (Zone)	**C/D**	**C/D**			
Confidence (Zone)	3.0	3.0			
Main cause of PES of C/D: The most notable impacts resulting in the ecostatus score, as observed at site, are channel modification, straightening and invasion by alien plant species, *notably Cestrum laevigatum, Arundo donax, Sesbanea punicea* and *Ricinus communis*, amongst others. There are also drastic alterations to the aquatic and marginal zone vegetation with a lack of lateral connectivity due to the insertion of a concrete canal as the main channel as well as stream straightening.					

Table 8.17 PES score and category for Riparian vegetation at site 4 (Right Bank), with main reasons for the score.

LEVEL 3 ASSESSMENT		**Baakens River Site 4 (RB)**			**16 May 2022**
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**
Marginal zone	29.4	4.2	3.0	1.0	14.3
Non-marginal zone	11.7	10.0	3.0	2.0	85.7
LEVEL 4 VEGRAI (%)					14.2
VEGRAI EC					**F**
AVERAGE CONFIDENCE					3.0
			Zone		
	Marginal zone	**Non-marginal zone**		**0.0**	**0.0**
VEGRAI % (Zone)	29.4	11.7		not assessed	not assessed
EC (Zone)	**E**	**F**			
Confidence (Zone)	3.0	3.0			
Main cause of PES of E/F: The most notable impacts resulting in the ecostatus score, as observed at site, are channel modification, straightening and near complete removal of all natural vegetation to be replaced with mown lawns and scattered planted trees.					

The PES of the right bank riparian vegetation at this site has a score of 14.2%, a category F, described as '*critically modified from reference condition, with extremely lowered species richness and an absence of intolerant and moderately tolerant species. Only intolerant species may be present with complete loss of species at the lower end of the class. Most of the characteristics of the biotic assemblages have been critically modified from its naturally expected conditions. Impairment of health generally very evident* (Kleynhans 1999). Table 8.17 outlines a summary of the PES ratings, score and ecological category of zones for the right bank of Site 4, and provides most notable reasons for the perturbation.

The integrated PES for Riparian Vegetation (LB and RB) is 35.9%, which is an E category, described as 'Seriously modified, with an extensive loss of natural habitat, biota and basic ecosystem functions'.

8.4.3 Fish

The PES, causes and sources, and trend for Site 4 are presented in Table 8.18.

Table 8.18 The present ecological state (PES) for Site 4 in the Baakens River, reasons for this category and the anticipated trend.

PES	CAUSES AND SOURCES	TREND	CONF
D (46.3)	Large-scale modification of natural morphology of the river channel due to infilling and canalization and destruction of natural instream habitats	Stable – no further physical modifications of the river channel anticipated	2
	Deterioration in water quality due to organic pollution from sewage spills and contaminated run-off from urban catchment	Negative – due to increased sewage loads, poor maintenance and population growth	2
	Impact of alien fish species, including competition for food and space and predation, particularly on eggs and larvae by banded tilapia and southern mouthbrooder	Negative – distribution and population density of alien fish appear to be increasing	1
	Changes to natural hydrology increased flash floods due hardened catchment and base-flow reduction by alien trees and extensive groundwater abstraction	Negative – increased urbanization and increased alien plants and boreholes	2

8.4.4 Aquatic invertebrates

The PES for the aquatic invertebrates at Site 4 is 40.9%, a D/E category (Table 8.19). This fits between two descriptions: D being '*Largely modified. A clearly lower than expected species richness and absence or much lowered presence of intolerant and moderately intolerant species. Most characteristics of the biotic assemblages have been largely modified from their naturally expected condition. Impairment of health may become evident at the lower end of this class'* , and E being '*Seriously modified. A strikingly lower than expected species richness and general absence of intolerant and moderately tolerant species. Most of the characteristics of the biotic assemblages have been seriously modified from its naturally expected condition. Impairment of health may become very evident*' (Kleynhans 1999).

Table 8.19 The PES for the invertebrates of Site 4, with main causes

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC GROUP	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	FM	23.8	*0.237*	5.625	2	90
HABITAT	H	39.2	*0.237*	9.27632	2	90
WATER QUALITY	WQ	38.9	*0.263*	10.2493	1	100
CONNECTIVITY & SEASONALITY	CS	60.0	*0.263*	15.7895	1	100
						380
INVERTEBRATE EC				40.9401		
INVERTEBRATE EC CATEGORY				D/E		
Main causes: Canalisation and lack of instream habitat. Alien fish species. Modified baseflows and high flows. As this site is at the lower end of the catchment, impacts likely to be cumulative despite apparent recovery of water quality.						
>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F						

8.4.5 Trend

The trend for Site 4 for each component is presented in Table 8.20, together with the reasons for this.

Table 8.20 The trend for Site 4 for each component, together with reasons

Parameter	Trend (Deteriorating, Stable, Improving)	Reasons
WQ	Negative	Failing infrastructure, with load-shedding putting additional strain on an already constrained system.
RV	Negative	Invasive alien plant species will continue to invade
FISH	Negative	Due to increased pollution and increasing changes in natural hydrology and increase in numbers and distribution of aggressive, predatory alien fish species
INVERT	Negative	In the absence of strong interventions in this section of the river, it is likely to degrade further as it is receiving all upstream impacts

8.4.6 Ecostatus

The Ecostatus at Site 4, taking into account the integrated RV score, is 39.8%, a D/E category (Figure 8.4, Table 8.21, Appendix 10). For a description of this category see Section 8.4.4.

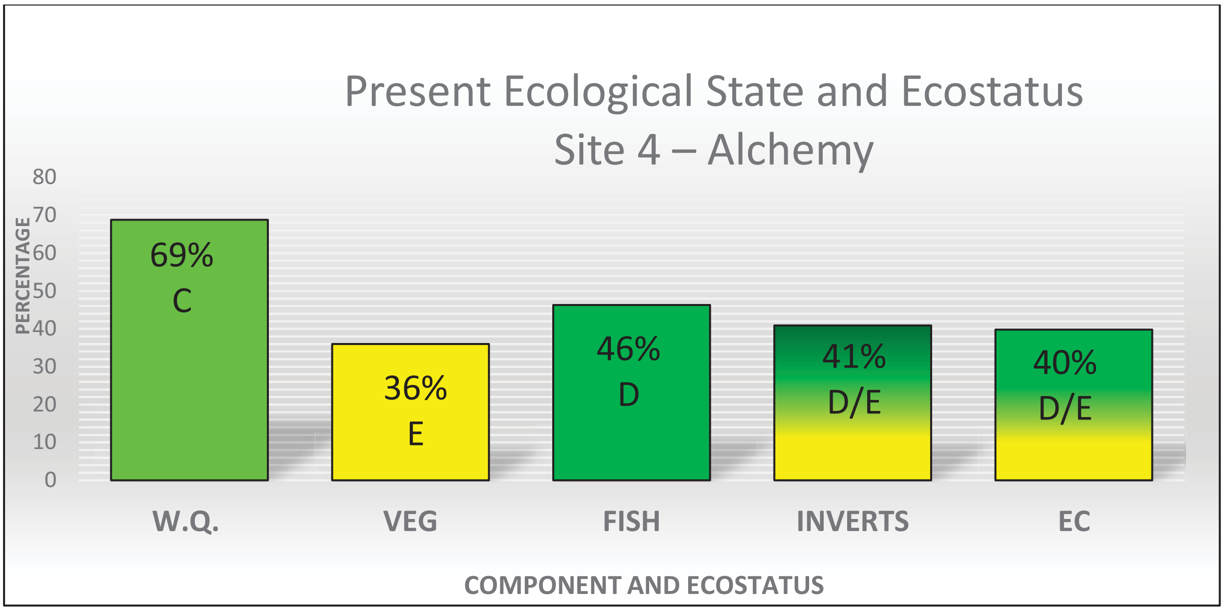

Figure 8.4 Graphic illustration of the PES and Ecostatus for Site 4. (WQ – water quality, VEG – riparian vegetation, FISH – Fish, INVERTS – invertebrates, EC – Ecostatus)

Table 8.21 Summary Table Site 4

SITE 4				
COMPONENT	**PES %**	**CAT.**	**TREND**	**REASONS**
WATER QUALITY	68.8	C	↓	Until sewage infrastructure problems can be addressed and water quality issues rectified, the overall trend will be to deteriorate.
RIPARIAN VEG	LB:57.6 RB:14.2 INT:35.9	LB: C/D RB:F INT:E	↓	Invasive alien plant species will continue to invade. LB: Left bank, RB: Right Bank Int: Integrated
FISH	46.3	D	↓	Increase in intensity of existing negative impacts described earlier
INVERTEBRATES	41	D/E	↓	Water quality impacts likely to get worse as loadshedding worsens
ECOSTATUS	39.8	D/E	↓	

Red down-arrow: Deteriorating

8.4.7 Summary of PES and Ecostatus for all sites

A summary of the PES per component and the Ecostatus for each site is provided in Table 8.24.

8.5 ECOLOGICAL IMPORTANCE AND SENSITIVITY (EIS)

The EIS for the four sites was calculated in a specialist workshop setting in Gqeberha during May 2022. The outputs of that process are documented in Table 8.22, with the scores assigned per site presented in Table 8.23.

Table 8.22 EIS for Sites 1-4 and Contributing factors. RV: Riparian Vegetation

Site 1: HAWTHORNE AVE	
EIS	**HIGH**
Contributing Factors:	
RV	The following threatened and / or endemic plant species potentially occur (including terrestrial vegetation): *Cyrtanthus obliquus* (Declining), *Haworthia fasciata* (NT, EC endemic), *Erica zeyheriana* (VU, EC endemic), *Eucomis autumnalis* (Declining), *Rapanea melanophloeos* (Declining).
FISH	Both indigenous fish species *Enteromius pallidus* and *Sandelia capensis* found at this site may have distinct genetic lineages and are considered rare and unique. The indigenous fish species present (*Enteromius pallidus* and *Sandelia capensis)* are relatively sensitive to water quality and flow changes, particularly to low or no flows
Site 2: DODDS FARM	
EIS	**VERY HIGH**
Contributing Factors:	
RV	The following threatened and / or endemic plant species occur at Dodd's Farm (including terrestrial vegetation): *Apodolirion macowanii* (VU, EC endemic), *Cyrtanthus spiralis* (EN, MBM endemic), *Agathosma gonaquensis,* (CR, NMBM endemic), *Boophone disticha* (Declining), *Brunsvigia litoralis* (EN, EC endemic), *Crinum lineare* (VU, EC endemic), *Aloe micracantha* (NT, SA endemic), *Erica zeyheriana* (VU, EC endemic), *Rapanea melanophloeos* (Declining),
FISH	Both indigenous fish species *Enteromius pallidus* and *Sandelia capensis* present may have distinct genetic lineages and are considered rare and unique. The indigenous fish species present are relatively sensitive to water quality and flow changes, particularly to low or no flows
Site 3: ESSEXVALE	
EIS	**VERY HIGH**
Contributing Factors:	
RV	The following threatened and / or endemic plant species occur at Essexvale (including terrestrial vegetation): *Apodolirion macowanii* (VU, EC endemic), *Cyrtanthus spiralis* (EN, MBM endemic), *Haworthia fasciata* (NT, EC endemic), *Pelargonium reniforme* (DDD, EC endemic), *Corpuscularia lehmannii* (CR, NMBM endemic), *Agathosma gonaquensis,* (CR, NMBM endemic).
FISH	
SITE 4: ALCHEMY	
EIS	**VERY HIGH**
Contributing Factors:	
FISH	The *Pseudobarbus afer* present is endangered and together with the other two indigenous fish species *Enteromius pallidus* and *Sandelia* present may have distinct genetic lineages and would thus be considered rare and unique. The indigenous fish species present (*Pseubarbus afer* and *Enteromius pallidus*) are relatively sensitive to water quality and flow changes, particularly to low or no flows

Table 8.23 The EIS spreadsheet in which a number of metrics (e.g. Biota) are assigned a number of relevant indices (e.g. Rare and Endangered) which are scored 1-4 (low to high) on the basis of criteria provided in the method, survey data, and the Specialists' understanding of the site and catchment.

EIS Baakens River		INSTREAM									RIPARIAN/WETLAND									RESULTS		CONFIDENCE (1-5)
		BIOTA					HABITAT				BIOTA				HABITAT							
REACH	SITE	RARE & ENDANGERED	UNIQUE	INTOLERANT NO FLOW	INTOLERANT PHYSICO-CHEMICAL CHANGES	SPECIES/ TAXON RICHNESS	DIVERSITY OF TYPES AND FEATURES	REFUGIA AND CRITICAL	SENSITIVITY TO FLOW CHANGES	MIGRATION ROUTE	RARE AND ENDANGERED	UNIQUE	INTOLERANT	SPECIES/ TAXON RICHNESS	DIVERSITY OF TYPES AND FEATURES	REFUGIA AND CRITICAL	SENSITIVITY TO FLOW CHANGES	MIGRATION CORRIDOR	NAT PARKS, WILDERNESS AREAS, RESERVES, HERITAGE SITES, NATURAL AREAS	MEDIAN SCORE	IMPORTANCE	
1	Reach 1: Seep wetlands										4.0	4.0	3.0	3.0	2.0	3.5	1.0	2.0	2.0	3.0	HIGH	3
3	Site 1: Hawthorne Ave	4.0	4.0	2.5	2.5	3.0	3.0	3.0	4.0	3.0	4.0	4.0	2.0	3.0	1.5	1.5	1.0	4.0	1.0	3.0	HIGH	3
4	Site 2: Dodds Farm	4.0	4.0	2.5	2.5	3.0	4.0	4.0	4.0	4.0	3.0	4.0	2.0	3.0	2.0	3.0	1.0	4.0	4.0	3.5	VERY HIGH	4
5	Site 3: Essexvale	4.0	4	2.5	2.5	3.5	4.0	4.0	3.5	4.0	3.0	4.0	2.0	3.0	2.0	3.0	1.0	4.0	4.0	3.5	VERY HIGH	3
6	Site 4: Alchemy	4.0	4	2.5	2.5	4.0	4.0	4.0	4.0	4.0	3.0	4.0	2.0	3.5	3.0	3.0	2.0	4.0	1.0	3.8	VERY HIGH	3

Note that in this Table, the scoring for 'Biota' applies specifically to fish species rather than invertebrates (as the latter are not highly sensitive in this system)

Table 8.24 Summary Table for PES, Ecostatus and EIS for the Reaches and Sites

REACH	SITE	PAI	Cat	Con	VEGRAI	Cat	Con	FRAI	Cat	Con	MIRAI	Cat	Con	Ecostatus	Cat	EIS	Traj
1																HIGH	
3	1	64.1%	C	3	13.7%	F	3	44.2%	D	2	48.9%	D	2	29.2%	E	HIGH	Neg
4	2	66.5%	C	3	66.7%	C	4	45.3%	D	2	43.5%	D	2	57.8%	C/D	VERY HIGH	Neg
5	3	26.5%	E	4	62.0%	C	4	59.0%	C/D	2	14.5%	F	2	53.8%	D	VERY HIGH	Neg
6	4	68.8%	C	3.5	35.9%	E	3	46.3%	D	2	40.9%	D/E	2	39.8%	D/E	VERY HIGH	Neg

EC – Ecological Category Con – Confidence out of 5; Traj – trajectory Neg – negative

8.6 CONSIDERATION OF RECOMMENDED ECOLOGICAL CATEGORY (REC)

The following applies to the setting of a Recommended Ecological Category (REC) for the four sites along the Baakens River:

'The *modus operandi* followed by DWAF's Directorate: Resource Directed Measures (RDM), is that, if the EIS is high or very high, the ecological aim should be to improve the condition of the river. However, the causes related to a particular PES should also be considered to determine if improvement is realistic and attainable. This relates to whether the problems in the catchment can be addressed and mitigated. If the EIS evaluated as moderate or low, the ecological aim should be to maintain the river in its PES.

'Within the Ecological Reserve context, Ecological Categories A to D can be recommended as future states (REC – the Recommended Ecological Category) depending on the EIS and PES. Ecological Categories E and F PES are regarded as ecologically unacceptable, and remediation is needed'. (Kleyhans and Louw 2007).

In this instance, then, Site 1 (Ecostatus E) would be requiring remediation, while an REC could be set for Sites 2-4. It is generally considered pragmatic to set an REC only half a class higher than the PES, particularly where there are constraints to achieving that REC, such as there are in the Baakens River.

Thus, the REC for the Sites would be set as follows:

SITE	PES EC	EIS	REC
1	E	HIGH	D
2	C/D	VERY HIGH	C
3	D	VERY HIGH	C/D
4	D/E	VERY HIGH	D

In the case where rehabilitation is the objective, and the conservation, protection and regeneration of parts of the catchment is as vitally important as it is in the Baakens, it may be possible to aim higher than this, for example to have an REC of a B/C for Site 2, a C for Site 3, and a C for Site 4. Rehabilitation scenarios would then be set accordingly, and over a time period over which such change may be achievable.

8.7 DISCUSSION

The results of the Ecostatus and EIS determination are enlightening and conflicting. While the Baakens Catchment EIS is High to Very High at all sites, and it is a known area of significant biodiversity and conservation value (NFEPA river, Fish Sanctuary, Fish Passage Area, Critical Biodiversity Area, home to numerous critically endangered species and endemics, etc.). the current state of the river is poor to critical. This signals an issue with the management of the resource, which will need to be addressed before any form of rehabilitation is possible..

This Present Ecological State study has established that the major causes of deterioration in the Baakens River are:

- **Water quality deterioration**: caused by both failing infrastructure and poor management of infrastructure;
- **Increasing alien invasive vegetation:** particularly in the upper catchment and in the vicinity of the important seep wetlands;
- **Major alteration of river morphology and function**, caused by largescale development along its banks and floodplains, clearing of the floodplain, canalisation of the lower river/estuary, and a suite of impounding structures and crossings along its length.
- **Likely reduction in baseflows**: associated with invasive alien vegetation, and potentially with abstraction of groundwater (boreholes).
- **Altered runoff patterns and increased flood risk** due to urbanisation, increased hardened surfaces and
- **Presence of alien fish** which impact and threaten rare indigenous fish, and consume indigenous aquatic invertebrates
- **Habitat alteration (instream, riparian and terrestrial):** Resulting from clearing, development, alien vegetation, alien fish, modification of river continuity.
- **Impoundment and prevention of fish passage** caused by various impounding structures (mostly river crossings);
- **Decrease in safety and security** of those wishing to use the recreational areas.

The next phase of this study will develop a vision for rehabilitation of the Baakens River, and rehabilitation scenarios to address these issues.

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10 APPENDICES

10.1 APPENDIX 1: CHARACTERISTICS OF ECOREGIONS LEVEL II 20.01 (DWAF 2005B)

Main Attributes	**South Eastern Coastal Belt 20.01**
Terrain Morphology:	Broad division Plains; moderate relief, Closed hills, mountains; moderate and high relief, Plains; low relief Terrain Morphology Strongly Undulating Plains, Undulating Hills, Moderately Undulating Plains, Slightly Undulating Plains, Hills, Low Mountains.
Vegetation types (dominant types in bold) (Primary) :	Mesic Succulent Thicket, Xeric Succulent Thicket, Eastern Thorn Bushveld, **Coastal Grassland, Coastal Forest, Valley Thicket, Grassy Fynbos, Dune Thicket, South and South-west Coast Renosterveld, Afromontane Forest.**
Altitude (mamsl)	0-300 MAP (mm). 300-700
Coefficient of variation (% of annual precipitation)	20-35
Rainfall concentration index:	<15-30
Rainfall seasonality.	All year, Very late Summer.
Mean annual temp (°C).	16-20
Mean daily max temp (°C)	February. 24-30
Mean daily max temp (°C)	July. 18-22
Mean daily min temp (°C)	February. 14-18
Mean daily min temp (°C)	July. 6-10
Median annual simulated runoff (mm) for quaternary catchment:	10-200

10.2 APPENDIX 2: VEGETATION UNITS OF THE BAAKENS RIVER CATCHMENT

Contributed by James MacKenzie

Excerpt from Mucina & Rutherford (2006) and updated from the National Biodiversity Assessment (2018)

FFs 29 Algoa Sandstone Fynbos

VT 70 False Macchia (74%), VT 2 Alexandria Forest (26%) (Acocks 1953). South Coast Renosterveld (28%) (Moll & Bossi 1983). LR 63 South and Southwest Coast Renosterveld (75%), LR 65 Grassy Fynbos (23%) (Low & Rebelo 1996). BHU 22 Algoa Grassy Fynbos (62%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Eastern Cape Province: Coastal flats at Port Elizabeth from Van Stadens River in the west to Southdene-Summerstrand in the east, located mostly some kilometres from the coast and close to the coast at only Maitland River Mouth and urbanised Summerstrand. Altitude 20-300 m.

Vegetation & Landscape Features Flat to slightly undulating plain supporting grassy shrubland (mainly graminoid fynbos). Grasses become dominant especially in wet habitats. In the south this fynbos unit borders on AT 9 Albany Coastal Belt and AZs 1 Algoa Dune Strandveld and forms transitional mosaics with both. It also borders on patches of FOz 6 Southern Coastal Forest in this area.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Db and Ha.

Climate MAP 560-890 mm (mean: 680 mm), evenly throughout the year, with a slight peak in March and October. Mean daily maximum and minimum temperatures 25.2°C and 7.6°C for February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFs 29 Algoa Sandstone Fynbos (Figure 4.21).

Important Taxa Tall Shrubs: *Protea eximia*, *P. neriifolia*, *P. repens*. Low Shrubs: *Agathosma hirta*, *A. ovata*, *Erica zeyheriana*, *Euryops ericifolius*, *Helichrysum appendiculatum*, *H. teretifolium*, *Leucadendron salignum*, *L. spissifolium* subsp. *phillipsii*, *Leucospermum cuneiforme*, *Protea cynaroides*, *P. foliosa*, *Tephrosia capensis*. Succulent Herb: *Crassula pellucida* subsp. *marginalis*. Graminoids: *Andropogon eucomus*, *Brachiaria serrata*, *Cymbopogon pospischilii*, *Cynodon dactylon*, *Digitaria eriantha*, *Ehrharta calycina*, *Eustachys paspaloides*, *Ischyrolepis capensis*, *Pentaschistis heptamera*, *P. pallida*, *Thamnochortus cinereus*, *Themeda triandra*, *Tristachya leucothrix*.

Endemic Taxa ([W]Wetlands) Low Shrubs: *Agathosma gonaquensis*, *Cyclopia pubescens*[W], *Erica etheliae*. Geophytic Herb: *Holothrix longicornu*.

Conservation Endangered. Target 23%. About 2% conserved in the Van Stadens Wild Flower Reserve, The Island Nature Reserve as well as in several private nature reserves. More than 50% transformed (cultivation, urban sprawl of the Nelson Mandela Metropolitan Area). Several Australian *Acacia* species occur as invasive aliens, but only to a limited extent. Erosion moderate and very low.

Reference Vlok & Euston-Brown (2002).

AT 20 Bethelsdorp Bontveld

(Type history: STEP map – Bethelsdorp Bontveld (100%); 2012 VEGMAP – AT 3 Groot Thicket (100%))

Distribution This vegetation type occurs in the Eastern Cape Province, northwest of Port Elizabeth; mainly in valleys incising the plateau along the southern margin of the Swartkops River basin, but also in the Baakens River valley.

Vegetation & Landscape Features A mosaic of low thicket (2-3 m) consisting of bush clumps in a matrix of low, succulent-rich shrubland comprising renosterveld and succulent karroid elements. Several of the tree and shrub species that make up the bush clumps (e.g. *Smelophyllum capense*) are shared with AT19 Baviaans Valley Thicket. Found on steep slopes of deeply incised valleys.

Geology and Soils Predominantly on the Goudini, Peninsula and Skurweberg Formations, typically on shallow, sandy lithosols derived from quartzose sandstone. Found on Land Types Db and Fa.

Climate Non-seasonal rainfall dominates the region with MAP between 530 mm and 586 mm. Frost is present for approximately 3 days per year. The mean monthly maximum temperature is 25.4°C in February and the mean monthly minimum is 7.6°C in July. Altitude ranges from 15-215 masl.

Important Taxa (d=dominant, e=South African endemic, et=possibly endemic to a vegetation type)

Growth form	Species
Small tree	*Smelophyllum capense* (d), *Pittosporum viridiflorum* (d), *Schotia latifolia* (d), *Sideroxylon inerme* (d)
Succulent shrub	*Aloe striata* (e), *Cotyledon woodii* (e), *Crassula perfoliata* var. *minor* (e), *Crassula rubricaulis* (e), *Crassula rupestris, Crassula tetragona, Euphorbia clava* (e), *Euphorbia polygona* (e), *Ruschia orientali* (e)*s, Plectranthus spicatus, Portulacaria afra*
Succulent herb	*Bulbine latifolia* (d), *Crassula pellucida* subsp. *marginalis, Curio crassulifolius* (d), *Gasteria nitida* (e), *Haworthia cymbiformis* (d)
Succulent Herbaceous Climber	*Pelargonium peltatum* (e), *Senecio angulatus* (e)
Succulent tree	*Aloe ferox* (d), *Aloe lineata* (e), *Aloe pluridens* (e)
Herb	*Aizoon rigidum* (e), *Hypoestes aristata, Plectranthus verticillatus, Tephrosia capensis*
Low Shrub	*Asparagus suaveolens, Berkheya angustifolia, Elytropappus rhinocerotis, Eriocephalus africanus* (e), *Hermannia velutina, Phylica axillaris* (e), *Phylica gnidioides* (e)
Epiphytic Geophytic Herb	*Apodolirion macowanii* (e), *Cyrtanthus spiralis* (e), *Drimia ciliata* (e), *Eulophia parviflora*
Semiparasitic Shrub	*Colpoon compressum*
Graminoid	*Cymbopogon marginatus* (d), *Ehrharta calycina, Panicum deustum, Panicum maximum, Pentameris curvifolia, Themeda triandra* (d)
Tall Shrub	*Euclea undulata* (d), *Hippobromus pauciflorus* (d), *Canthium spinosum, Capparis sepiaria, Carissa bispinosa, Diospyros scabrida* var. *cordata* (d), *Euclea schimperi, Maerua cafra, Mystroxylon aethiopicum, Ochna serrulata, Psydrax obovata* (d), *Pterocelastrus tricuspidatus* (e), *Putterlickia pyracantha* (e), *Searsia longispina, Searsia lucida, Searsia pallens*
Woody Succulent Climber	*Cynanchum viminale*
Leaf-succulent Dwarf Shrub	*Corpuscularia lehmannii* (e), *Euphorbia stellata* (e), *Haworthiopsis fasciata* (e)
Woody Climber	*Asparagus aethiopicus*
Naturalised	*Corpuscularia lehmanii* (d)

Conservation (Status can be found on BGIS in September 2019)

Conservation Target	19%
Conserved in	None listed
Area transformed	40.7%
Threat activities	Mining, overgrazing, urban sprawl, small stock grazing, overharvesting, altered fire regime, roads
Protection Level	Not protected

Remarks This thicket type is not comparable to any of the other local Baviaans Thicket or Sundays Thicket types. The dominant thicket species (e.g. *Smellophyllum capense*) strongly suggest a link to the Baviaans Thicket types, although it is distantly located in the Swartkops River basin. The most plausible explanation for its existence is that it is a relic of a vegetation type — in which woody species such as *Atalaya capensis, Smellophyllum capense*, and *Sterculia alexandri* were once abundant — that once extended from the present Baviaanskloof eastward to the mouth of the Swartkops River. This thicket type may have contained endemic species, but has been transformed by urban development to such an extent that it is difficult to determine its original condition (Vlok & Euston-Brown 2002).

Citation: Grobler, A., Vlok, J., Cowling, R, van der Merwe, S., Skowno, A.L., Dayaram, A. 2018. Technical Report: Integration of the Subtropical Thicket Ecosystem Project (STEP) vegetation types into the VEGMAP national vegetation map 2018***.***

References: Vlok, J.H.J. and Euston-Brown, D.I.W. 2002. The patterns within, and the ecological processes that sustain, the Subtropical Thicket vegetation in the planning domain for the Subtropical Thicket Ecosystem Planning (STEP) Project. Terrestrial Ecology Research Unit. Report 40. University of Port Elizabeth, Port Elizabeth.

Vlok, J.H.J., Euston-Brown, D.I.W., Cowling, R.M., 2003. Acocks' Valley Bushveld 50 years on: New perspectives on the delimitation, characterisation and origin of subtropical thicket vegetation. South African J. Bot. 69, 27-51.

*All taxonomic names are the latest names as they were listed in the Biodiversity Database of South Africa (BODATSA) on the 11 January 2019)

10.3 APPENDIX 3: CONTRIBUTION TO RIPARIAN REFERENCE CONDITION

EXTRACTS OF HISTORIC WRITINGS, BY SKEAD (2009)

Contributed by James MacKenzie

These extracts from Skead (2009) pertaining to the Baakens River valley and the Port Elizabeth (Gqeberha) vicinity shed some light on the reference state of vegetation, albeit often in a broad sense.

Lichtenstein (1815)

In January 1804: En route to Port Elizabeth from the west:

"The nearer we got to the coast the more the country resumed its former waste and dreary appearance: the road lay over a flat plain as destitute of woods as it was of hills. In the latter part of the way are some sandhills... On the last hill which goes down to the shore is Fort Frederic built by the English in 1799 ..." Mentions the Baakens River in the valley below. [p. 286] "The country about Algoa Bay is by nature so fertile that, even if uninhabited, it would produce wood, game, salt and grass for feeding cattle in abundance ..." [p. 288]

Bethelsdorp, 13 km northwest of Port Elizabeth:

"It is scarcely possible to describe the wretched situation in which this establishment appeared to us... On a wide plain without a tree, almost without water fit to drink... For a great way round not a bush is to be seen, for what there might have been originally, have long ago been used for firewood: the ground all about is perfectly naked and hard trodden down ..." [p. 294]

Bunbury, C.J.F. (1848)

9 April 1838: Port Elizabeth:

"It is an ugly, dirty, ill-scented, ill-built hamlet, resembling some of the worst fishing villages on the English coast; backed by low stony hills of the most barren character while long ranges of sandhills extend along the shore on both sides of it. [p. 120]

"This unpromising neighbourhood produces many curious plants, particularly of the fleshy kind. Aloes of several species, crassulas and cotyledons with fine scarlet flowers, and euphorbias whose fluted columnar stems are beset with formidable prickles, flourish in the crevices of the sandstone rocks and among loose fragments of stone exposed to the full glare of the sun. "In company with these are some beautiful everlastings, and various kinds of a hard, rigid, stunted character but with handsome blossoms. "The sandhills along the coast are partially covered with dwarfish evergreen bushes seldom more than 3 feet high intermixed with succulent plants of the strangest shapes The boerboontje, Schotia speciosa [Schotia afra] with its hard knotty twisted branches, its scanty dark green foliage and brilliant carmine-coloured flowers, is plentiful here, but in the form of a low scrubby bush; whereas on the banks of the Gamtoos it grows to the size of an apple tree. It is a very general plant in the eastern province. "The little stream which comes down to the sea at Port Elizabeth [Baakens River] is covered with beautiful blue water-lilies. [p. 121]

Delegorgue, A. (1990)

In May 1838, Port Elizabeth:

"From the few walks I took in the vicinity I realised that birds were very rare there, probably because the forests were composed chiefly of stinck out [sic, the true stinkhout, Ocotea bullata, does not occur in the Port Elizabeth forests, e.g. Baakens River], that is to say with trees with strong-smelling wood. These trees, garlanded with five or six foot strands of moss, have a very strange bearded look; this moss seems to hinder them in their growth for beneath it the branches are twisted as if in agony. The few leaves they have turn mouldy while still alive. The humidity in these forests is great; grass is rare and ferns abundant. Several naturalists have made use of this parasitic moss-like plant which they first dry in the oven and then use to stuff birds. Because of its lightness it is used for all sorts of packing; it does not attract insects and has the advantage of being economical. I particularly recommend it, and if I have used it very little myself, this is because I did not remain long in those parts where it is found. “The plains of this country are remarkable for their sour pasturage, suren vlaacke, the Dutch say. They are beautiful to the eye, bad for cattle and only fair for horses.” [p. 42]

Baines, T. in Kennedy (1961)
In 1848, Port Elizabeth, Fort Frederick, on the hill above the Baakens River:
“At the base of these hills is a small but rather picturesque cemetery with several tombs covered with slabs of bluish stone similar to that procured from Robben Island, and some of them neatly enclosed by iron rails. The ground had formerly been surrounded by a hedge of aloes but of these only a few remained to guard, like solitary sentinels, the city of the dead. [1: 22] “This plant, the Aloe spicata [actually Aloe ferox], as well as many other varieties, is scattered in wild profusion on the hills around the Bay, adorning their barren crags or rough acclivities with its scarlet flowers; and many thousand cases of its juice, the Bitter or Hepatic Aloes of commerce, are annually shipped from Port Elizabeth; but its valuable properties seem to have been unknown to the Dutch colonists till revealed, by a Negro slave, to one of them named De Witt who obtained in consequence the exclusive privilege of supplying the East India Company, and appointed his slave inspector of the work, naming the aloe after him, the ‘coree bosch’ [goreebosch = Aloe ferox (Smith 1966)]. In 1850, 155 166 lbs of Aloes valued at one thousand five hundred and fifty-four pounds were exported from Cape Town and 72 446 lbs at one thousand five hundred and fifty-nine pounds from Algoa Bay. “The preparation of the sap affords a livelihood to many Hottentots and other persons, and is still conducted very nearly as described by Sparrman in 1776. A tub, or sometimes a skin, is sunk into a hole in the ground and the leaves of the Aloe are cut off and placed in it with their points upwards; the juice or sap which exudes from them is then boiled and poured while still hot into the cases in which it is left to harden. “Its price varies according to the care bestowed upon its preparation, the inferior kind fetching not more than three halfpence while that which has been well boiled, and is consequently much harder, is worth as much as fourpence per lb. “The juice, which at first is clear and limpid, and, it need hardly be said, bitter in the extreme, soon becomes thick and viscous, and besides its medicinal uses is frequently employed by the frontier farmers as a varnish for partitions, ceilings, or articles of furniture, to which it imparts a beautiful polish and a rich brown colour.” [p. 23]

Redgrave, J.J. (1947)
<u>In 1870 / 1880s: The Baakens River:</u>
“… at high tide was very deep and penetrated up as far as the old wooden stores, and extended in width from the narrow valley road to the back of the Markham Hotel, forming a high lagoon which was crossed at the lower end by a narrow footbridge ...” [p. 538]

10.4 APPENDIX 4: EXPECTED PLANT SPECIES OF THE BAAKENS RIVER CATCHMENT

Contributed by James MacKenzie

Expected Species

Acacia karroo	*Cyperus glaucophyllus*	*Isopterygium strangulatum*	*Protea neriifolia*
Adromischus cristatus var. schonlandii	*Cyperus longus*	*Juncus acutus*	*Protea repens*
Agathosma gonaquensis	*Cyperus michelianus*	*Juncus bufonius*	*Psilocaulon junceum*
Agathosma hirta	*Cyperus rotundus*	*Juncus capensis*	*Pterocelastrus tricuspidatus*
Agathosma ovata	*Cyperus textilis*	*Juncus dregeanus*	*Pteronia adenocarpa*
Aizoon glinoides	*Digitaria eriantha*	*Juncus effusus*	*Pteronia incana*
Albuca cremnophila	*Dodonaea viscosa var. angustifolia*	*Juncus hybridus*	*Pulicaria scabra*
Aloe ferox	*Ehrharta calycina*	*Juncus inflexus*	*Putterlickia pyracantha*
Aloe pictifolia	*Ekebergia Capensis*	*Juncus lomatophyllus*	*Rhigozum obovatum*
Alternanthera sessilis	*Eleocharis geniculata*	*Juncus oxycarpus*	*Rhoicissus digitata*
Andropogon eucomus	*Elytropappus rhinocerotis*	*Juncus punctorius*	*Rhus longispina*
Aponogeton desertorum	*Encephalartos lehmannii*	*Landoltia punctata*	*Rhus lucida*
Aponogeton junceus	*Enneapogon desvauxii*	*Lemna gibba*	*Riella capensis*
Aponogeton natalensis	*Eragrostis curvula*	*Lepidium africanum*	*Rosenia humilis*
Aponogeton rehmannii	*Eragrostis obtusa*	*Leucadendron salignum*	*Ruppia maritima*
Aponogeton stuhlmannii	*Erica etheliae*	*Leucadendron spissifolium subsp. phillipsii*	*Samolus porosus*
Aptosimum elongatum	*Erica zeyheriana*	*Leucas capensis*	*Sansevieria hyacinthoides*
Aristida adscensionis	*Eriocephalus africanus*	*Leucospermum cuneiforme*	*Sarcostemma viminale*
Aristida congesta	*Eriocephalus capitellatus*	*Limeum aethiopicum*	*Schoenoplectus decipiens*
Asparagus burchellii	*Eriocephalus ericoides*	*Limnophyton obtusifolium*	*Schoenoplectus litoralis*
Asparagus mucronatus	*Euclea undulata*	*Lobelia quadrisepala*	*Schotia afra var. afra*
Asparagus racemosus	*Euphorbia ledienii*	*Lycium oxycarpum*	*Selago albida*
Asparagus subulatus	*Euphorbia mauritanica*	*Marsilea coromandelina*	*Selago fruticosa*
Asplenium cordatum	*Euphorbia polygona*	*Marsilea ephippiocarpa*	*Senecio junceus*
Bacopa monnieri	*Euphorbia tetragona*	*Marsilea schelpeana*	*Setaria lindenbergiana*
Boophone disticha	*Euryops ericifolius*	*Merxmuellera stricta*	*Sideroxylon inerme*
Boscia albitrunca	*Euryops spathaceus*	*Monechma spartioides*	*Smelophyllum capense*
Brachiaria serrata	*Eustachys paspaloides*	*Moraea pallida*	*Solanum tomentosum*
Bulbine cremnophila	*Felicia filifolia*	*Myriophyllum spicatum*	*Sporobolus fimbriatus*

Capparis sepiaria var. citrifolia	*Felicia muricata*	*Najas marina*	*Stachys aethiopica*
Carex clavata	*Fimbristylis bisumbellata*	*Nymphaea nouchali*	*Stapelia kougabergensis*
Carissa bispinosa	*Fimbristylis complanata*	*Nymphoides forbesiana*	*Stuckenia pectinata*
Carpha glomerata	*Fimbristylis dichotoma*	*Nymphoides indica*	*Tarchonanthus camphorates*
Cenchrus ciliaris	*Fimbristylis ferruginea*	*Nymphoides rautanenii*	*Tephrosia capensis*
Chrysocoma ciliata	*Fuirena coerulescens*	*Olea capensis*	*Thamnochortus cinereus*
Cissampelos capensis	*Gasteria ellaphieae*	*Olea europaea sub africana*	*Themeda triandra*
Cladium mariscus	*Gasteria glomerata*	*Oryza longistaminata*	*Tragus berteronianus*
Cotyledon tomentosa subsp. tomentosa	*Gasteria rawlinsonii*	*Oryza punctata*	*Trapa natans*
Crassula cultrata	*Glottiphyllum oligocarpum*	*Osyris compressa*	*Tristachya leucothrix*
Crassula expansa	*Glottiphyllum salmii*	*Ozoroa mucronata*	*Troglophyton capillaceum*
Crassula inanis	*Grewia robusta*	*Pachypodium succulentum*	*Tromotriche baylissii*
Crassula muscosa	*Gymnosporia polyacanthus*	*Panicum gilvum*	*Tromotriche longii*
Crassula orbicularis	*Haworthia glauca var. herrei*	*Pappea capensis*	*Typha capensis*
Crassula ovata	*Haworthia pungens*	*Pentaschistis heptamera*	*Typha domingensis*
Crassula pellucida subsp. marginalis	*Haworthia zantneriana var. minor*	*Pentaschistis pallida*	*Vachellia karroo*
Crassula perforata	*Helichrysum appendiculatum*	*Podocarpus falcatus*	*Vallisneria spiralis*
Crassula rupestris subsp. commutata	*Helichrysum teretifolium*	*Pollichia campestris*	*Viscum rotundifolium*
Crassula tetragona subsp. robusta	*Hermannia gracilis*	*Portulacaria afra*	*Wolffia arrhiza*
Crinum campanulatum	*Hermannia pulverata*	*Potamogeton crispus*	*Wolffia globosa*
Cussonia spicata	*Holothrix longicornu*	*Potamogeton nodosus*	*Zannichellia palustris*
Cyclopia pubescens	*Huernia brevirostris subsp. baviaana*	*Potamogeton schweinfurthii*	*Zantedeschia aethiopica*
Cymbopogon pospischilii	*Huernia echidnopsioides*	*Potamogeton trichoides*	*Zantedeschia albomaculata*
Cynodon dactylon	*Hygrophila senegalensis*	*Prionium serratum*	*Zostera capensis*
Cynodon incompletus	*Indigofera denudata*	*Protea cynaroides*	*Zygophyllum foetidum*
Cyperus amabilis	*Ischyrolepis capensis*	*Protea eximia*	
Cyperus compressus	*Isolepis prolifera*	*Protea foliosa*	

10.5 APPENDIX 5: WATER QUALITY RESULTS SITES 1-4, FROM TALBOT AND TALBOT

TALBOT
A Level 2 B-BBEE company

[003581/22], [2022/05/13]

Certificate of Analysis

Project details

Customer Details

Company name:	LAUGHING WATERS
Contact address:	PO BOX 889, GONUBIE 5256
Contact person:	MANDY UYS

Sampling Details

Sampled by:	CUSTOMER
Sampled date:	2022/05/04

Sample Details

Sample type(s):	SURFACE WATER SAMPLES
Date received:	2022/05/05
Delivered by:	CUSTOMER - PORT ELIZABETH LAB
Temperature at sample receipt (°C):	21.8

Report Details

Testing commenced:	2022/05/05
Testing completed:	2022/05/12
Report date:	2022/05/13
Our reference:	003581/22

Talbot Laboratories (Pty) Ltd Reg: 2016/334237/07
P.O Box 22598 Pietermaritzburg 3203 South Africa
+27 (0) 33 346 1444 www.talbot.co.za

Analytical Results

Methods	Determinands	Units	011679/22 BAAKENS RIVER SITE 1 - HAWTHORN ROAD 04.05.2022 12:15	011680/22 BAAKENS RIVER SITE 2 - DODDS FARM 04.05.2022 12:15
Chemical				
65	Dissolved Calcium	mg Ca/ℓ	54	37
65	Potassium	mg K/ℓ	6.77	5.69
65	Dissolved Magnesium	mg Mg/ℓ	31	16.2
64	Sodium	mg Na/ℓ	311	138
94	Dissolved Silver*	µg Ag/ℓ	<5	<5
94	Dissolved Aluminium*	µg Al/ℓ	22	20
92	Dissolved Arsenic*	µg As/ℓ	<10	<10
94	Dissolved Boron*	µg B/ℓ	134	82
94	Dissolved Barium*	µg Ba/ℓ	39	26
94	Dissolved Beryllium*	µg Be/ℓ	<1	<1
94	Dissolved Cadmium*	µg Cd/ℓ	<5	<5
94	Dissolved Cobalt*	µg Co/ℓ	<5	<5
94	Dissolved Chromium*	µg Cr/ℓ	<5	<5
94	Dissolved Copper*	µg Cu/ℓ	<5	<5
94	Dissolved Iron*	µg Fe/ℓ	66	63
92	Dissolved Mercury*	µg Hg/ℓ	<10	<10
94	Dissolved Lithium*	µg Li/ℓ	6.7	5.7
94	Dissolved Manganese*	µg Mn/ℓ	<5	<5
94	Dissolved Molybdenum*	µg Mo/ℓ	<5	<5
94	Dissolved Nickel*	µg Ni/ℓ	5.3	<5
94	Dissolved Lead*	µg Pb/ℓ	7.6	<5
92	Dissolved Antimony*	µg Sb/ℓ	<10	<10
92	Dissolved Selenium*	µg Se/ℓ	<10	<10
94	Dissolved Tin*	µg Sn/ℓ	<10	<10
94	Dissolved Strontium*	µg Sr/ℓ	453	261
94	Dissolved Titanium*	µg Ti/ℓ	<5	<5
94	Dissolved Thallium*	µg Tl/ℓ	<10	<10
94	Dissolved Uranium*	µg U/ℓ	<25	<25
94	Dissolved Vanadium*	µg V/ℓ	<10	<10
94	Dissolved Zinc*	µg Zn/ℓ	<5	<5
Calc.	Sum dissolved metal concentration*	µg/ℓ	674	609
10G	Total Alkalinity	mg $CaCO_3$/ℓ	128	97
16G	Chloride	mg Cl/ℓ	357	190
18G	Fluoride	mg F/ℓ	0.16	0.11

Methods	Determinands	Units	011679/22	011680/22
			BAAKENS RIVER SITE 1 - HAWTHORN ROAD 04.05.2022 12:15	BAAKENS RIVER SITE 2 - DODDS FARM 04.05.2022 12:15
64G	Total Ammonia	mg N/ℓ	<1.5	<1.5
65Gc	Nitrate	mg N/ℓ	0.4	0.55
65Gb	Nitrite	mg N/ℓ	<0.05	0.29
4	Turbidity	NTU	3.3	5.1
1	pH at 25°C	pH units	7.4	7.3
66G	Orthophosphate	mg P/ℓ	<0.1	0.21
67G	Sulphate	mg SO_4/ℓ	76.3	31.6
41	Total Dissolved Solids at 180°C	mg/ℓ	858	480
Calc.	Total Hardness*	mg $CaCO_3$/ℓ	260	159

Methods	Determinands	Units	011681/22	011682/22
			BAAKENS RIVER SITE 3 - ESSEXVALE 04.05.2022 12:15	BAAKENS RIVER SITE 4 - CONCRETE 04.05.2022 12:15
Chemical				
85	Dissolved Calcium	mg Ca/ℓ	39	46
85	Potassium	mg K/ℓ	7.22	6.36
85	Dissolved Magnesium	mg Mg/ℓ	17.5	18.6
84	Sodium	mg Na/ℓ	193	204
94	Dissolved Silver*	µg Ag/ℓ	<5	<5
94	Dissolved Aluminium*	µg Al/ℓ	14	22
92	Dissolved Arsenic*	µg As/ℓ	<10	<10
94	Dissolved Boron*	µg B/ℓ	97	108
94	Dissolved Barium*	µg Ba/ℓ	21	22
94	Dissolved Beryllium*	µg Be/ℓ	<1	<1
94	Dissolved Cadmium*	µg Cd/ℓ	<5	<5
94	Dissolved Cobalt*	µg Co/ℓ	<5	<5
94	Dissolved Chromium*	µg Cr/ℓ	<5	<5
94	Dissolved Copper*	µg Cu/ℓ	<5	<5
94	Dissolved Iron*	µg Fe/ℓ	111	30
92	Dissolved Mercury*	µg Hg/ℓ	<10	<10
94	Dissolved Lithium*	µg Li/ℓ	6.2	<5
94	Dissolved Manganese*	µg Mn/ℓ	5.3	<5
94	Dissolved Molybdenum*	µg Mo/ℓ	<5	<5
94	Dissolved Nickel*	µg Ni/ℓ	<5	<5
94	Dissolved Lead*	µg Pb/ℓ	<5	<5
92	Dissolved Antimony*	µg Sb/ℓ	<10	<10
92	Dissolved Selenium*	µg Se/ℓ	<10	<10

Talbot Laboratories (Pty) Ltd

Methods	Determinands	Units	011681/22 BAAKENS RIVER SITE 3 - ESSEXVALE 04.05.2022 12:15	011682/22 BAAKENS RIVER SITE 4 - CONCRETE 04.05.2022 12:15
94	Dissolved Tin*	µg Sn/ℓ	<10	<10
94	Dissolved Strontium*	µg Sr/ℓ	284	336
94	Dissolved Titanium*	µg Ti/ℓ	<5	<5
94	Dissolved Thallium*	µg Tl/ℓ	<10	<10
94	Dissolved Uranium*	µg U/ℓ	<25	<25
94	Dissolved Vanadium*	µg V/ℓ	<10	<10
94	Dissolved Zinc*	µg Zn/ℓ	<5	<5
Calc.	Sum dissolved metal concentration*	µg/ℓ	685	674
10G	Total Alkalinity	mg $CaCO_3$/ℓ	102	101
16G	Chloride	mg Cl/ℓ	222	228
18G	Fluoride	mg F/ℓ	0.13	0.12
64G	Total Ammonia	mg N/ℓ	4.46	<1.5
65Gc	Nitrate	mg N/ℓ	<0.25	2.74
65Gb	Nitrite	mg N/ℓ	0.06	0.15
4	Turbidity	NTU	2.7	1.2
1	pH at 25°C	pH units	7.3	7.2
66G	Orthophosphate	mg P/ℓ	0.64	0.37
67G	Sulphate	mg SO_4/ℓ	38.4	46.6
41	Total Dissolved Solids at 180°C	mg/ℓ	546	614
Calc.	Total Hardness*	mg $CaCO_3$/ℓ	168	192

Refer to the "Notes" section at the end of this report for further explanations.

Specific Observations

None

10.6 APPENDIX 6: WATER QUALITY RESULTS SUMMARY, ALL SITES

Summary data are presented in Table 10.1 below for all sites assessed. Summary statistics used **per variable** and according to methods outlined in DWAF (2008) and Section 4.4.5, are shown in bold on Table 10.2.

All summary statistics are shown, however, for information purposes. Talbot & Talbot results for samples collected on 4 May 2022 are attached as Appendix 5.

Table 10.1 *In situ* water quality data taken in mid-May 2022

Site	Electrical conductivity (mS/m)	DO (mg/L)	pH	Temperature (ºC)	Notes
1	123.3	6.87: slow flow 8.54: fast flow	6.61	17.5	DO levels assessed in both a fast and slow-flowing section of river below the weir.
2	75.4	7.93	6.70	Approx. 18.5	As there was a delay between taking the sample and measuring temperature, an approximate value is used. Sampled at the weir.
2	102.6	2.25	6.70		Sample taken at effluent discharge pipe in weir.
2		7.5-8.4			Sample taken d/s weir.
3	83	3.66	6.80	15.5	Low DO levels even d/s the weir in fast flow. Site downstream of a ruptured sewer line.
4	42.3	8.5	6.85	15.8	24 mm rain had fallen the previous night. Fast flow.

d/s: downstream

Table 10.2 Summary statistics for DWS data for all sites

Site number	Statistic	COD (mg/L)	*E. coli* (cfu/ml)	Electrical conductivity (mS/m)	Ammonia (NH_3-N; mg/L))	Total Inorganic Nitrogen (TIN-N; mg/L)	PO_4-P (mg/L)	pH
SITE 1 + 2	Count	24	22	24	23	23	24	24
	5th percentile	12.1	81.2	85.2	0.001	0.3	0.05	7.1
	50th percentile	38.5	500	134	0.007	**1.2**	**0.05**	7.5
	95th percentile	56.2	**315 500**	**177**	**0.089**	11.5	0.94	**7.8**
	Average	38	**1 026 413**	132.5	0.021	2.5	0.20	7.5
SITE 3	Count	25	24	25	25	25	25	25
	50th percentile	10	70.15	99	0.001	**0.2**	**0.05**	7.2
	Median	32	435	131	0.003	1.0	0.05	7.5
	95th percentile	49	**5 870**	**172.6**	**0.044**	4.0	1.65	**7.9**
	Average	29.8	**2 458.5**	130.5	0.012	1.4	0.40	7.5
SITE 4	Count	21	21	21	21	21	21	21
	50th percentile	10	150	101	0.001	**0.8**	**0.05**	7.2
	Median	28	3 500	140	0.004	1.4	0.05	7.5
	95th percentile	39.7	**300 000**	**167**	**0.037**	7.5	0.25	**7.7**
	Average	25.1	**197 836**	136	0.013	1.7	0.08	7.5
Guideline values		75 mg/L: limit in wastewater discharged into a water resource (DWAF, 2004)	TWQR: 0-130 cfu (full contact recreational use, e.g. swimming). DWAF, 1996b.	Re-benchmarked A category: 55 mS/m (DWAF, 2008)	TWQR (DWAF, 1996a): 0.007 mg/L	0.2-0.7 mg/L: B category. 0.7-1.0 mg/L: C category. 1.0-4.0 mg/L: D category (DWAF, 2008)	0.005: B category (DWAF, 2008)	6.5-8.0; A category (DWAF, 2008)

Cfu: colony forming units
COD: Chemical Oxygen Demand

Note the explanations below for the summary statistics used in the table.
Note the explanations below for the summary statistics used in the table.

- Count: number of samples in the data period (2014-2019)

- Percentiles: a percentage of values in a set of data scores that fall below a given value, for example, a 95th percentile of 24 means that 95% of the data falls below 24.
- Median: the 50th percentile
- Average: the mean

10.8 APPENDIX 7: OBSERVED PLANT SPECIES LIST FOR ALL FOUR SITES.

Family	Species	Common Name/s	Alien	Site 1	Site 2	Site 3	Site 4	Threat status
ANACARDIACEAE	*Harpephyllum caffrum*	Wild Plum			y			LC
ANACARDIACEAE	*Searsia lucida*	Glossy Currant			y	y	y	LC
ANACARDIACEAE	*Searsia rehmanniana*				y	y		LC
APIACEAE	*Centella asiatica*	Pennywort					y	LC
APIACEAE	*Berula thunbergii*	Toothache Root			y	y	y	LC
APOCYNACEAE	*Carissa bispinosa* subsp. *bispinosa*	Num-num			y	y		LC
ARACEAE	*Zantedeschia aethiopica*	White Arum Lily			y		y	LC
ARALIACEAE	*Cussonia thyrsiflora*					y		LC
ARECACEAE	*Phoenix reclinata*	Wild date palm				y		LC
ASPARAGACEAE	*Asparagus suaveolens*	Wild Asparagus		y	y	y		LC
ASPHODELACEAE	*Aloe ferox*				y	y	y	LC
ASTERACEAE	*Bidens pilosa*	Black Jack	*	y	y	y	y	
ASTERACEAE	*Senecio tamoides*				y	y	y	LC
ASTERACEAE	*Tarchonanthus littoralis*	Coast Camphor-bush					y	LC
BRASSICACEAE	*Nasturtium officinale*		*	y	y	y	y	
CACTACEAE	*Opuntia ficus-indica*		*		y			
CANNACEAE	*Canna indica*		*		y		y	
CASUARINACEAE	*Casuarina equisetifolia*	Horsetail Tree	*	y				
CELASTRASEAE	*Pterocelastrus tricuspidatus*	Candlewood			y	y	y	LC
CERATOPHYLLACEAE	*Ceratophyllum demersum var. demersum*	Water Hornwort			y	y		LC

Family	Species	Common Name/s	Alien	Site 1	Site 2	Site 3	Site 4	Threat status
COMMELINACEAE	*Floscopa glomerata*			y	y	y	y	LC
CONVOLVULACEAE	*Ipomoea carnea subsp. fistulosa*	Morning Glory Bush	*				y	
CUPRESSACEAE	*Widdringtonia nodiflora*				y	y		LC
CYATHEACEAE	***Alsophila capensis***					**y**		**Declining**
CYPERACEAE	*Cyperus dives*	Giant sedge		y	y	y	y	LC
CYPERACEAE	*Cyperus textilis*	Tall star sedge		y	y	y		LC
EBENACEAE	*Diospyros dicrophylla*	Common star apple			y	y		LC
EUPHORBIACEAE	*Ricinus communis*		*	y	y	y	y	
FABACEAE	*Acacia dealbata*	Silver Wattle	*	y	y	y		
FABACEAE	*Acacia mearnsii*	Black Wattle	*	y	y	y		
FABACEAE	*Acacia saligna*	Port Jackson Willow	*	y	y	y		
FABACEAE	*Erythrina caffra*	Coast coral tree, Kuskoraalboom		y	y	y	y	LC
FABACEAE	*Schotia latifolia*	Forest Boer-bean			y	y		LC
FABACEAE	*Senna didymobotrya*		*	y				
FABACEAE	*Sesbania punicea*	Red Sesbania	*				y	
FABACEAE	*Vachellia karroo*	Sweet Thorn				y		LC
HALORAGACEAE	*Myriophyllum spicatum*	Spiked Water-milfoil	*		y			
HYDROCHARITACEAE	*Egeria densa*	Water Weed	*			y	y	
IRIDACEAE	*Dietes butcheriana*					y		LC
IRIDACEAE	*Watsonia pillansii*					y		LC
LAMIACEAE	*Plectranthus verticillatus*				y	y		LC

Family	Species	Common Name/s	Alien	Site 1	Site 2	Site 3	Site 4	Threat status
LEMNACEAE	*Lemna gibba*	Duckweed			y	y		LC
LENTIBULARIACEAE	*Utricularia stellaris*	Star Bladderwort			y			LC
MALVACEAE	*Sida dregei*				y	y	y	LC
MELIACEAE	*Melia azedarach*	Syringa	*		y	y	y	
MORACEAE	*Ficus sur*	Broomcluster Fig			y	y	y	LC
MORACEAE	*Ficus thonningii*	Strangler Fig			y		y	
MYRTACEAE	*Eucalyptus camaldulensis*	River Red Gum	*	y	y	y		
MYRTACEAE	*Eucalyptus grandis*		*	y	y	y		
MYRTACEAE	*Eucalyptus lehmannii*		*	y	y			
MYRTACEAE	*Syzygium cordatum subsp. cordatum*	Waterberry				y	y	LC
NYMPHAEACEAE	*Nymphaea nouchali*	Blue Water Lily			y			LC
OLEACEAE	*Olea europaea subsp. africana*	Wild Olive			y	y		LC
PINACEAE	*Pinus radiata*		*		y	y	y	
PITTOSPORACEAE	*Pittosporum viridiflorum*	Cheesewood			y	y		LC
PLANTAGINACEAE	*Plantago lanceolata*	Narrow-leaved ribwort					y	LC
PLUMBAGINACEAE	*Plumbago auriculata*				y		y	
POACEAE	*Arundo donax*	Spanish Reed	*		y	y	y	
POACEAE	*Cortaderia selloana*	Pampass Grass	*		y			
POACEAE	*Leersia hexandra*	Rice Grass			y	y		LC
POACEAE	*Panicum maximum*	Guinea Grass		y	y	y	y	LC
POACEAE	*Phragmites australis*	Common Reed		y	y	y	y	LC

Family	Species	Common Name/s	Alien	Site 1	Site 2	Site 3	Site 4	Threat status
POACEAE	*Setaria megaphylla*	Broad-leaved bristle grass		y	y	y	y	LC
POACEAE	*Sporobolus fimbriatus*	Dropseed Grass			y	y		LC
POACEAE	*Thamnocalamus tessellatus*				y			LC
PODOCARPACEAE	*Afrocarpus falcatus*	Outeniqua yellowwood			y	y		
POLYGONACEAE	*Persicaria lapathifolia*	Spotted Knotweed; Hanekam	*	y	y	y	y	
POLYGONACEAE	*Persicaria senegalensis*	Silver snake root			y	y	y	LC
POTAMOGETONACEAE	*Potamogeton pectinatus*	Sago Pondweed			y			LC
RHAMNACEAE	*Scutia myrtina*				y	y		LC
ROSACEAE	*Cliffortia strobilifera*	Cone Rice Bush			y	y		LC
ROSACEAE	*Rubus fruticosus*	European Blackberry	*	y	y			
SAPINDACEAE	*Cardiospermum grandiflorum*	Ballon Vine	*				y	
SAPOTACEAE	*Sideroxylon inerme*	White milkwood			y	y		LC
SOLANACEAE	*Cestrum laevigatum*	Inkberry	*	y	y	y	y	
SOLANACEAE	*Solanum mauritianum*	Bugweed	*	y	y	y	y	
STILBACEAE	*Nuxia floribunda*			y		y		LC
STRELITZIACEAE	*Strelitzia juncea*				?	?		VU
STRELITZIACEAE	*Strelitzia nicolai*				y	y	y	LC
THELYPTERIDACEAE	*Cyclosorus interruptus*						y	LC
THYMELAEACEAE	*Dais cotinifolia*	Pompom Tree				y		LC
TYPHACEAE	*Typha capensis*	Bulrush			y	y	y	LC
VERBENACEAE	*Lantana camara*	Bird's Brandy	*	y	y	y	y	

10.9 APPENDIX 8: SUMMARY OF SASS5, REFERENCE CONDITION, IHI AND IHAS FOR EACH SITE.

IHI: Instream Habitat Integrity Assessment (IHI) **IHAS:** Instream Habitat Assessment System

Invertebrate Taxa		Score	SITE 1	Ab	SITE 2	Ab	SITE 3	Ab	SITE 4	Ab	REF	Ab
PORIFERA	PORIFERA	5									5	A
COELENTERATA	COELENTERATA	1									1	A
TURBELLARIA	TURBELLARIA	3	3	A	3	A			3	A	3	A
ANNELIDA	Oligochaeta	1	1	A	1	A			1	A	1	A
	HIRUDINEA	3	1	A								
CRUSTACEA	Potamonautidae	3	3	A	3	A	3	A	3		3	A
HYDRACARINA	HYDRACARINA	8									8	A
	Baetidae 1sp	4										
EPHEMEROPTERA	Baetidae 2 sp	6			6	C					6	B
	Baetidae >2sp	12	12	C					12	C		
	Caenidae	6	6	A	6	A			6	1	6	A
	Leptophlebiidae	9									9	B
ODONATA	Chlorolestidae	8			8	A					8	A
	Coenagriidae	4	4	A	4	B			4	B	4	B
	Lestidae	8							8	A	8	A
	Platycnemidae	10			10	1						
	Protoneuridae	8									8	A
	Aeshnidae	8	8	A							8	A
	Gomphidae	6							6	A	6	B
	Libellulidae	4									4	B
HEMIPTERA	Belostomatidae	3	3	1							3	A
	Corixidae	3	3	1							3	C
	Gerridae	5	5	A	5	A			5		5	B
	Hydrometridae	6			6	A					6	A
	Naucoridae	7									7	A
	Nepidae	3	3	1							3	A
	Notonectidae	3	3				3	A			3	B
	Pleidae	4	4								4	B
	Veliidae/ M…veliidae	5	5		5	B			5		5	A
MEGALOPTERA	Corydalidae	8									8	A
	Ecnomidae	8									8	A
	Hydropschychidae 1 sp	4	4								4	B
	Hydroptilidae	6									6	A
	Leptoceridae	6									6	A
COLEOPTERA	Dytiscidae	5									5	B
	Elmidae	8									8	A
	Gyrinidae	5									5	B

Invertebrate Taxa		Score	SITE 1	Ab	SITE 2	Ab	SITE 3	Ab	SITE 4	Ab	REF	Ab
	Haliplidae	5									5	A
	Hydraenidae	8									8	A
	Hydrophilidae	5									5	A
DIPTERA	Athericidae	10									10	A
	Ceratopogonidae	5									5	B
	Chironomidae	2	2	B	2	C	2	C	2	C	2	B
	Culicidae	1	1	A	1	A	1	B	1	B	1	B
	Dixidae	10									10	A
	Empididae	6									6	A
	Muscidae	1									1	A
	Psychodidae	1									1	B
	Simuliidae	5	5	B	5	C			5	C	5	B-C
	Syrphidae	1									1	A
	Tabanidae	5							5	A	5	B
	Tipulidae	5									5	A
GASTROPODA	Ancylidae	6									6	B
	Lymnaeidae	3									3	B
	Physidae	3			3	C					3	B
	Planorbinae	3									3	B
	SASS5 Score		76		68		9		66			
	No of taxa		19		15		4		14			
	ASPT		4		4.9		2.3		4.7			
	HABITAT:											
	IHAS %		51%		87%		86%		54%			
	IHI %		38 E		60 C		40 D		31 E			

RESULTS FOR INSTREAM HABITAT INTEGRITY ASSESSMENT (IHI) (KLEYNHANS 1999)

INSTREAM HABITAT INTEGRITY EVALUATION	R1	R2 Unrated	R3 S1	R4 S2	R5 S3	R6 S4
DELINEATION:			SITE 1	SITE 2	SITE 3	SITE 4
PRIMARY						
WATER ABSTRACTION	1		4	2	2	2
FLOW MODIFICATION	10		12	8	16	18
BED MODIFICATION	5		13	7	9	20
CHANNEL MODIFICATION	11		14	10	10	25
WATER QUALITY	19		20	18	25	16
INUNDATION	10		19	11	16	6
TOTAL (OUT OF 150)						
SECONDARY						
EXOTIC MACROPHYTES	5		6	6	8	8
EXOTIC FAUNA	10		11	11	11	11
SOLID WASTE DISPOSAL	0		5	3	4	4
TOTAL (OUT OF 75)						
INSTREAM HABITAT INTEGRITY SCORE	60		38	60	40	31
CATEGORY	C		E	C	D	E

R: REACH

IHAS FIELDSHEET (McMIllan 1998)

SAMPLING HABITAT	0	1	2	3	4	5
Stones in Current (SIC)						
Total length of white water rapids (ie: bubbling water) (in metres)	none	0-1	>1-2	>2-3	***>3-5***	>5
Total length of submerged stones in current (run) (in metres)	none	0-2	>2-5	***>5-10***	>10	
Number of separate SIC ***area's*** kicked (not individual stones)	0	1	2-3	***4-5***	6+	
Average stone size's kicked (cm's)(<2 *or* >20 is '<2>20')(gravel is <2; bedrock is >20).	none	<2>20	2-10	11-20	***2-20***	
Amount of stone surface clear (of algae, sediment etc.) (in percent %) *.	n/a	0-25	26-50	51-75	>75	
PROTOCOL: time spent actually kicking SIC's (in minutes)(gravel/bedrock = 0 min)	0	<1	>1-2	***2***	>2-3	>3
(* ***NOTE***: up to 25% of stone is usually embedded in the stream bottom)					*max. 20*	
SIC Score:						
Vegetation						
Length of fringing vegetation sampled (river banks) (PROTOCOL - in metres)	none	0-½	>½-1	>1-2	***2***	>2
Amount of aquatic vegetation/algae sampled (underwater) (in square metres)	none	0-½	***>½-1***	>1		
Fringing vegetation sampled in: ('still'=pool/still water only; 'run'=run only)	none		run	still		***mix***
Type of veg. (percent leafy veg. as opposed to stems/shoots) (aq. veg. only=49%) . .	none		1-25	26-50	***51-75***	>75
					max. 15	
Vegetation Score:						
Other Habitat / General						
Stones Out Of Current (SOOC) sampled: (PROTOCOL - in square metres)	none	0-½	>½-1	***1***	>1	
Sand sampled: (PROTOCOL – in minutes) ('under' = present, but only under stones) .	none	under	0-½	>½-1	***1***	>1
Mud sampled: (PROTOCOL – in minutes) ('under' = present, but only under stones). .	none	under	0-½	***½***	>½	
Gravel sampled: (PROTOCOL – in minutes) (*if all gravel, SIC stone size = '<2'*)**. . . .	none	0-½	***½***	>½**		
Bedrock sampled: ('all'=no SIC, sand, or gravel; *then SIC stone size ='>20'*)**	none	***some***			all**	
Algal presence: ('1-2m²'=algal bed; 'rocks'=on rocks; 'isol.'=isolated clumps) ***	>2m²	rocks	1-2m²	<1m²	***isol.***	none
Tray identification: (PROTOCOL – using time: 'corr' = correct time)		under		***corr***		over
(** ***NOTE***: you must still fill in the SIC section)					*max. 20*	
Other Habitat Score:						
					max. 55	
Habitat Total:						

STREAM CONDITION						
Physical						
River make up: ('pool'=pool/still/dam only; 'run' only; 'rapid' only; '2mix'=2 types etc.)	pool		run	rapid	2 mix	3 mix
Average width of stream: (metres)		>10	>5-10	<1	1-2	>2-5
Average depth of stream: (metres)	>1	1	>½-1	½	<½-¼	<¼
Approximate velocity of stream: ('slow'=<½m/s; 'fast'=>1m/s) (use twig etc. to test).	still	slow	fast	med.		mix
Water colour: ('disc.'=discoloured with visible colour but still transparent)	silty	opaque		disc.		clear
Recent disturbances due to: ('constr.'=construction; 'fl/dr'=flood or drought) *** . .	fl/dr	fire	constr.	other		none
Bank / riparian vegetation is: ('grass'=includes reeds; 'shrubs'=includes trees)	none		grass	shrubs	mix	
Surrounding impacts: ('erosn'=erosion/shear bank; 'farm'=farmland/settlement)***.	erosn.	farm	trees	other		open
Left bank cover (rocks and vegetation): (in percent %)	0-50	51-75	75-95	>95		
Right bank cover (rocks and vegetation): (in percent %)	0-50	51-75	75-95	>95		
(*** ***NOTE***: if more than one option, choos ethe lowest)					*max. 45*	
Stream Conditions Total:						

Total IHAS Score: %

10.10 APPENDIX 9: SUMMARY OF FISH RESPONSE ASSESSMENT INDEX (FRAI) RESULTS

Site 1: Hawthorn Avenue (33^0 57’ 39.0” S; 25^0 31’ 19.3.1” E)

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	SCIENTIFIC NAMES: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE	EC:OBSERVED & HABITAT DERIVED FREQUENCY OF OCCURRENCE
PAFE	PSEUDOBARBUS AFER (PETERS, 1864)	2.00	0.00
BPAL	BARBUS PALLIDUS SMITH, 1841	3.00	2.00
SCAP	SANDELIA CAPENSIS (CUVIER, 1831)	3.00	0.00
AMOS	ANGUILLA MOSSAMBICA PETERS 1852	1.00	1.00

WEIGHT OF METRIC GROUPS	
METRIC GROUP	**WEIGHT (%)**
VELOCITY-DEPTH	39.47
COVER	44.74
FLOW MODIFICATION	44.74
PHYSICO-CHEMICAL	100.00
MIGRATION	73.68
IMPACT OF INTRODUCED	86.84

FRAI – Present Ecological State (PES)

ADJUSTED	
FRAI (%)	**44.2**
EC: FRAI	**D**

SITE 2: Dodds Farm (33^0 58’ 09.8” S; 25^0 34’ 39.1” E

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	SCIENTIFIC NAMES: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE	EC:OBSERVED & HABITAT DERIVED FREQUENCY OF OCCURRENCE
BPAL	BARBUS PALLIDUS SMITH, 1841	3.00	1.00
AMOS	ANGUILLA MOSSAMBICA PETERS 1852	1.00	1.00

WEIGHT OF METRIC GROUPS	
METRIC GROUP	**WEIGHT (%)**
VELOCITY-DEPTH	39.47
COVER	44.74
FLOW MODIFICATION	44.74
PHYSICO-CHEMICAL	100.00
MIGRATION	73.68
IMPACT OF INTRODUCED	86.84

FRAI – Present Ecological State (PES)

AUTOMATED	
FRAI (%)	**45.3**
EC: FRAI	**D**

SITE 3: Essexvale (33^0 58’ 10.7” S; 25^0 35’ 58.9” E).

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	SCIENTIFIC NAMES: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE	EC:OBSERVED & HABITAT DERIVED FREQUENCY OF OCCURRENCE
PAFE	PSEUDOBARBUS AFER (PETERS, 1864)	3.00	2.00
BPAL	BARBUS PALLIDUS SMITH, 1841	2.00	1.00
SCAP	SANDELIA CAPENSIS (CUVIER, 1831)	3.00	1.00
AMOS	ANGUILLA MOSSAMBICA PETERS 1852	1.00	1.00

WEIGHT OF METRIC GROUPS	
METRIC GROUP	WEIGHT (%)
VELOCITY-DEPTH	44.12
COVER	50.00
FLOW MODIFICATION	50.00
PHYSICO-CHEMICAL	100.00
MIGRATION	94.12
IMPACT OF INTRODUCED	97.06

FRAI – Present Ecological State (PES)

ADJUSTED	
FRAI (%)	**59.0**
EC: FRAI	**C/D**

SITE 4: River-estuary interface (33^0 58’ 02.7” S; 25^0 37’ 13.4” E).

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	SCIENTIFIC NAMES: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE	EC:OBSERVED & HABITAT DERIVED FREQUENCY OF OCCURRENCE
MCAP	MYXUS CAPENSIS (VALENCIENNES, 1836)	4.00	2.00
BPAL	BARBUS PALLIDUS SMITH, 1841	3.00	1.00
AMOS	ANGUILLA MOSSAMBICA PETERS 1852	3.00	1.00

WEIGHT OF METRIC GROUPS	
METRIC GROUP	**WEIGHT (%)**
VELOCITY-DEPTH	52.31
COVER	72.31
FLOW MODIFICATION	58.46
PHYSICO-CHEMICAL	100.00
MIGRATION	86.15
IMPACT OF INTRODUCED	92.31

FRAI – Present Ecological State (PES)

AUTOMATED	
FRAI (%)	**46.3.0**
EC: FRAI	**D**

10.11 APPENDIX 10: ECOSTATUS DETERMINATION FOR THE FOUR SITES

10.11.1 Site 1 Hawthorne Ave

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	3	80		
2.What is the natural diversity of **fish** species with a preference for different cover types	4	100		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	4	100		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	2	60		
FISH ECOLOGICAL CATEGORY	13	340	**44.2**	**D**
AQUATIC INVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	3	90		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	3	90		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	3	100		
AQUATIC INVERTEBRATE ECOLOGICAL CATEGORY	**9**	280	**48.99**	**D**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		620	**46.8**	**D**

INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	Confidence rating	Proporitons	Modified weights
Confidence rating for **fish** information	2	0.40	17.68
Confidence rating for **macro-invertebrate** information	3	0.60	29.39
	5	1.00	47.07
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**D**

RIPARIAN VEGETATION	EC %	EC
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**13.7**	**F**

ECOSTATUS	Confidence rating	Proporitons	Modified weights
Confidence rating for instream biological information	2.6	0.46	21.86
Confidence rating for riparian vegetation zone information	3	0.54	7.34
	5.6	1.00	29.20
ECOSTATUS	**EC**		**E**

10.11.2 Site 2: Dodd's Farm

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	3	100		
2.What is the natural diversity of **fish** species with a preference for different cover types	3	80		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	2	40		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	3	60		
FISH ECOLOGICAL CATEGORY	11	280	**45.3**	**D**
AQUATIC INVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	3	90		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	3	80		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	3	100		
AQUATIC INVERTEBRATE ECOLOGICAL CATEGORY	**9**	270	**43.5**	**D**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		550	**44.3**	**D**

INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	Confidence rating	Proporitons	Modified weights
Confidence rating for **fish** information	2	0.40	18.12
Confidence rating for **macro-invertebrate** information	3	0.60	26.10
	5	1.00	44.22
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**D**

RIPARIAN VEGETATION	EC %	EC
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**66.7**	**C**

ECOSTATUS	Confidence rating	Proporitons	Modified weights
Confidence rating for instream biological information	2.6	0.39	17.42
Confidence rating for riparian vegetation zone information	4	0.61	40.42
	6.6	1.00	57.84
ECOSTATUS	**EC**		**C/D**

10.11.3 Site 3: Essexvale

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	3	100		
2.What is the natural diversity of **fish** species with a preference for different cover types	3	80		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	2	60		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	3	40		
FISH ECOLOGICAL CATEGORY	11	280	**59.0**	**C/D**
AQUATIC INVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	4	90		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	3	80		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	3	100		
AQUATIC INVERTEBRATE ECOLOGICAL CATEGORY	**10**	270	**14.5**	**F**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		550	**31.6**	**E**

INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	Confidence rating	Proporitons	Modified weights
Confidence rating for **fish** information	2	0.50	29.50
Confidence rating for **macro-invertebrate** information	2	0.50	7.25
	4	1.00	36.75
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**E**

RIPARIAN VEGETATION	EC %	EC
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**62.3**	**C**

ECOSTATUS	Confidence rating	Proporitons	Modified weights
Confidence rating for instream biological information	2	0.33	12.25
Confidence rating for riparian vegetation zone information	4	0.67	41.53
	6	1.00	53.78
ECOSTATUS	**EC**		**D**

10.11.4 Site 4: Alchemy

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	3	100		
2.What is the natural diversity of **fish** species with a preference for different cover types	3	80		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	3	60		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	3	40		
FISH ECOLOGICAL CATEGORY	12	280	**46.3**	**D**
AQUATIC INVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	4	90		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	3	85		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	3	100		
AQUATIC INVERTEBRATE ECOLOGICAL CATEGORY	**10**	275	**41**	**D/E**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		555	**43.1**	**D**

INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	Confidence rating	Proporitons	Modified weights
Confidence rating for **fish** information	2	0.50	23.15
Confidence rating for **macro-invertebrate** information	2	0.50	20.50
	4	1.00	43.65
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**D**

RIPARIAN VEGETATION	EC %	EC
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**35.9**	**E**

ECOSTATUS	Confidence rating	Proporitons	Modified weights
Confidence rating for instream biological information	2	0.50	21.83
Confidence rating for riparian vegetation zone information	2	0.50	17.95
	4	1.00	39.78
ECOSTATUS	**EC**		**D/E**