TONGAAT HULETT DEVELOPMENTS

Sibaya Nodes 1-5

Wetland Rehabilitation Plan

Issue date: October 2015
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SPECIALIST REPORT DETAILS

This report has been prepared as per the requirements of Section 32 of Government Notice No. R. 543 dated 18 June 2010 (Environmental Impact Assessment Regulations) under sections 24(5), 24M and 44 of the National Environmental Management Act, 1998 (Act 107 of 1998).

I, **Stephen Burton** declare that this report has been prepared independently of any influence or prejudice as may be specified by the Department of Economic Development, Tourism and Environmental Affairs (EDTEA).

Signed: Date: 05/10/2015

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DISCLAIMER

Original Wetland Delineation and Completed Assessments

This rehabilitation plan is based on findings of the Wetland Delineation Assessment (2001) and Current and Post-Development Wetland Assessment (2008) both compiled by LRI. This plan should also be read in conjunction with the Sibaya Ecological Report (SiVEST, 2012), and the Sibaya Wetland Functional Assessment (SIVEST, 2015).

Applicability of the Rehabilitation Plan

Due to the current and proposed land use changes within the study area, this wetland rehabilitation plan should only be considered to be valid for a year after the issue of this report.

Designs

Due to the fact that SiVEST has no control over the construction phase of the project we will incur no liability or consequential liability as a result of the implementation of the plans and designs contained in this document. In addition, designs for the rehabilitation interventions have been developed for site conditions as at the time of the planning site visits. Should site conditions change before the designs are implemented, changes to the design may be necessary. In this case, project implementers may require the assistance of a professional engineer.

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SIBAYA NODES 1-5

WETLAND & OPEN SPACE REHABILITATION PLAN

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Glossary of Important Terms

Base Flow: The minimum discharge in a steam or river that occurs as a result of the deep (subsurface) percolation of water.

Berm: A mound or bank of earth used as a barrier against the flooding of land.

Biodiversity: The number and variety of living organisms on earth, the millions of plants, animals, and micro-organisms, the genes they contain, the evolutionary history and potential they encompass, and the ecosystems, ecological processes, and landscapes of which they are integral parts.

Buffer Zone: A strip of vegetated/un-developed land surrounding a wetland that is maintained to protect and screen wetland flora and fauna from the disturbances associated with neighbouring land uses with the aim of maintaining the ecological integrity of the wetland.

Coppice: Growth of trees from shoots or suckers after the cutting of the main stem.

Crimping: To compress into small folds or ridges.

Culvert: An artificial, covered channel that diverts the flow of water underneath a road or railway line.

Ecology: The scientific study of the relations that living organisms have with respect to each other and their natural environment.

Ecotone: A region of transition between two different biological communities.

Floodplain (inundated by annual flood): A relatively level alluvial (sand or gravel) area lying adjacent to the river channel, which has been constructed by the present river in its existing regime. Distinction should be made between active flood plains and relic flood plains.

Gabion: A structure made of wire mesh baskets filled with regularly sized stones, and used to prevent and/ or repair erosion. They are flexible and permeable structures which allow water to filter through them. Vegetation and other biota can also establish in/around the habitat they create.

Geomorphology: The study of the origin and development of landforms of the earth.

Graminoid: Technical term for grasses.

Habitat: The natural home and range of species of plants or animals.

Hydrology: The study of the properties, distribution and circulation of water on earth.

Hydrophyte: A plant that grows in water or on a substratum that is at least periodically deficient in oxygen as a result of soil saturation or flooding.

Intervention: An engineered structure such as a concrete or gabion weir, earthworks or re-vegetation that that achieves identified objectives within a wetland e.g. raising of the water table within a drainage canal.

Marsh: A frequently or continually inundated wetland characterized by emergent herbaceous vegetation adapted to saturated soil conditions.

Weir: A dam-type structure placed across a watercourse to raise the water table of the surrounding ground and trap sediment on the upstream face without preventing water flow. Weirs are generally used to prevent erosion from progressing up exposed gullies.

Rehabilitation: Refers to re-instating the driving ecological forces (including hydrological, geomorphological and biological processes) that underlie a wetland, so as to improve the wetland’s health and the ecological services that it delivers.

Spreader Canal: An artificial canal excavated on the contour in order to receive runoff in a concentrated form (e.g. in an artificial channel or gulley) and to spread it over a wide area when the water in the artificial channel or gulley fills and overtops its banks.

Swamp: A frequently or continually inundated wetland dominated by trees and shrubs adapted to saturated soil conditions.

Thalweg: A line connecting the lowest points of successive cross-sections along the course of a valley or river.

Transpiration: The transfer of water from plants into the atmosphere as water vapour.

Water Table: The level below which the ground is saturated with water.

Wetland: Land that has water on the surface or within the root zone for long enough periods through the year to allow for the development of anaerobic conditions. These conditions create unique soil conditions (hydromorphic soils) and support vegetation adapted to these flood conditions.

TONGAAT HULETT DEVELOPMENTS

SIBAYA NODES 1-5

WETLAND & OPEN SPACE REHABILITATION PLAN

1 INTRODUCTION

SiVEST has been appointed by Tongaat Hulett Developments to compile a wetland rehabilitation plan for Wetland Units that are going to be conserved within the Sibaya Node 1-5 Mixed-Use Development (**Figure 1**). These wetlands units were delineated by LRI (**2001** and **2008**), and there functionality was assessed by SiVEST (**2015**).

2 OBJECTIVES

The objectives of the wetland rehabilitation plan are to:

- Identify the problems undermining the hydrological, geomorphological and vegetative integrity of each wetland unit;
- Identify appropriate rehabilitation goals;
- Identify the most appropriate rehabilitation interventions utilising the WET-Rehab Methods tool developed by **Russell (2009);**
- Provide detail on the design of the rehabilitation interventions selected to achieve the rehabilitation goals;
- Provide a detailed bill of quantities for the rehabilitation of each wetland unit;
- Provide detailed measures for the ongoing management of each wetland unit; and
- Design a monitoring programme for assessing the success of the rehabilitation interventions.

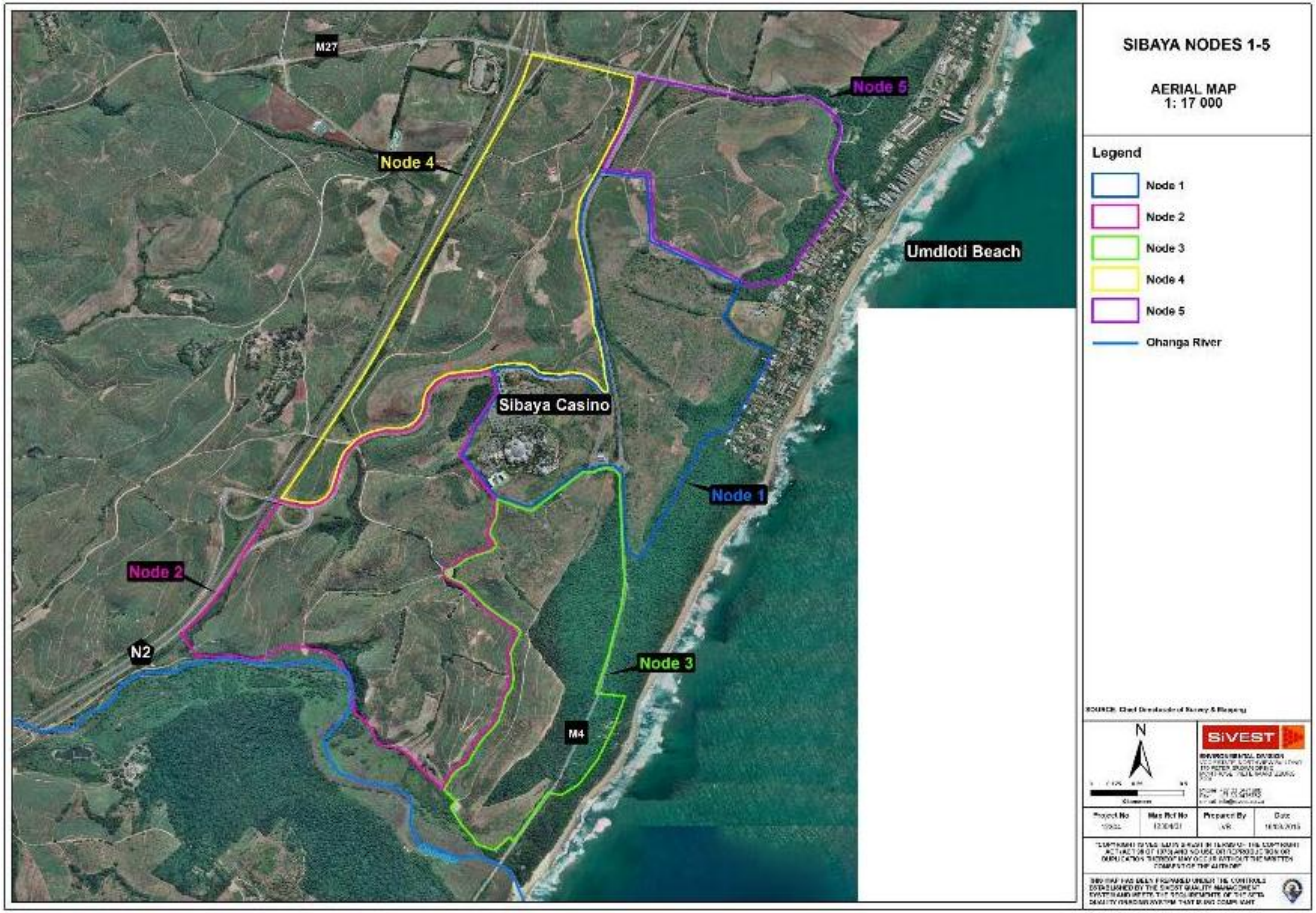


Figure 1: Sibaya Node 1-5 Overview.

3 STUDY AREA

3.1 Overview

Sibaya Nodes 1-5 covers some 625 ha, of which most is planted to sugar cane with the exception of the most prevalent drainage lines, or where soil or topography is unsuitable for sugar cane production. The site also includes limited stands of woody vegetation and some forestry plantations.

3.2 Climate

The site falls within the KwaZulu-Natal Coastal Belt (CB 3) vegetation unit as defined by **Mucina and Rutherford (2006)**. This vegetation unit experiences summer rainfall with some rain in winter. The area is characterised by high air humidity and no frost. Mean annual precipitation is approximately 973 mm and mean annual potential evaporation is 1650 mm. The rainfall average is 973 mm of rainfall. The mean temperature is 20.5 ^{0}C and the climate rating is C1, which has a none to slight limitation on crop growing (**Camp, 1995**).

3.3 Geology and Soils

The ENPAT GIS Database (**DEAT, 2001**) indicates that Sibaya Nodes 1-5 are predominantly underlain Red Dune Cordon Sand of the Berea formation. This has given rise to the formation of red apedal soils. Apedal soils lack well formed peds other than porous micro-aggregates and are weakly structured. Apedal soils tend to be freely drained, and due to overriding climatic conditions, these soils will tend to be dystrophic (low base status). The soils across most of the estate have been highly disturbed for as long as it has been utilised as a commercial sugar cane farm. Regular ploughing along with the sugar cane production cycle has resulted in extensive disruption to the wetland soils. Some compaction of soils has occurred in those wetland areas with roads or tracks running through them. According to the BRU Unit Information the erosion rating for the site translates to a very high risk of erosion (**Camp, 1995**).

3.4 Topography and Drainage

The Sibaya site is undulating with rounded hilltops and ridge lines separated by broad, moderately sloping valleys and valley heads. Elevation ranges from around 130 m down to 58 m amsl. Mean average slope within Node 4, is approximately 12% and a maximum slope of 30%. The southern half of the site drains towards the Ohlanga River, to the south. The north eastern and western portions drain towards the M4 and N2 respectively Artificial drainage channels have been established within the valley thalwegs (lowest elevation of a valley bottom) to lower the local water table and drain the wetlands within the valley bottom areas for use as sugar cane cultivation areas.

At present, the drainage within the Sibaya has been modified in order to maximise the cultivated area. This modification stems from the diversion and canalisation of flow into central channels through the formation of artificial drainage channels, gully formation or channel incision. Unnatural channels are identified as straight or angular lines following the courses of valleys, as opposed to the usually sinuous, irregular lines made by natural channels. Drainage channels are also associated with the N2 and M4 road servitudes.

Hydro-geomorphic (HGM) units within this land use class include channelled and un-channelled

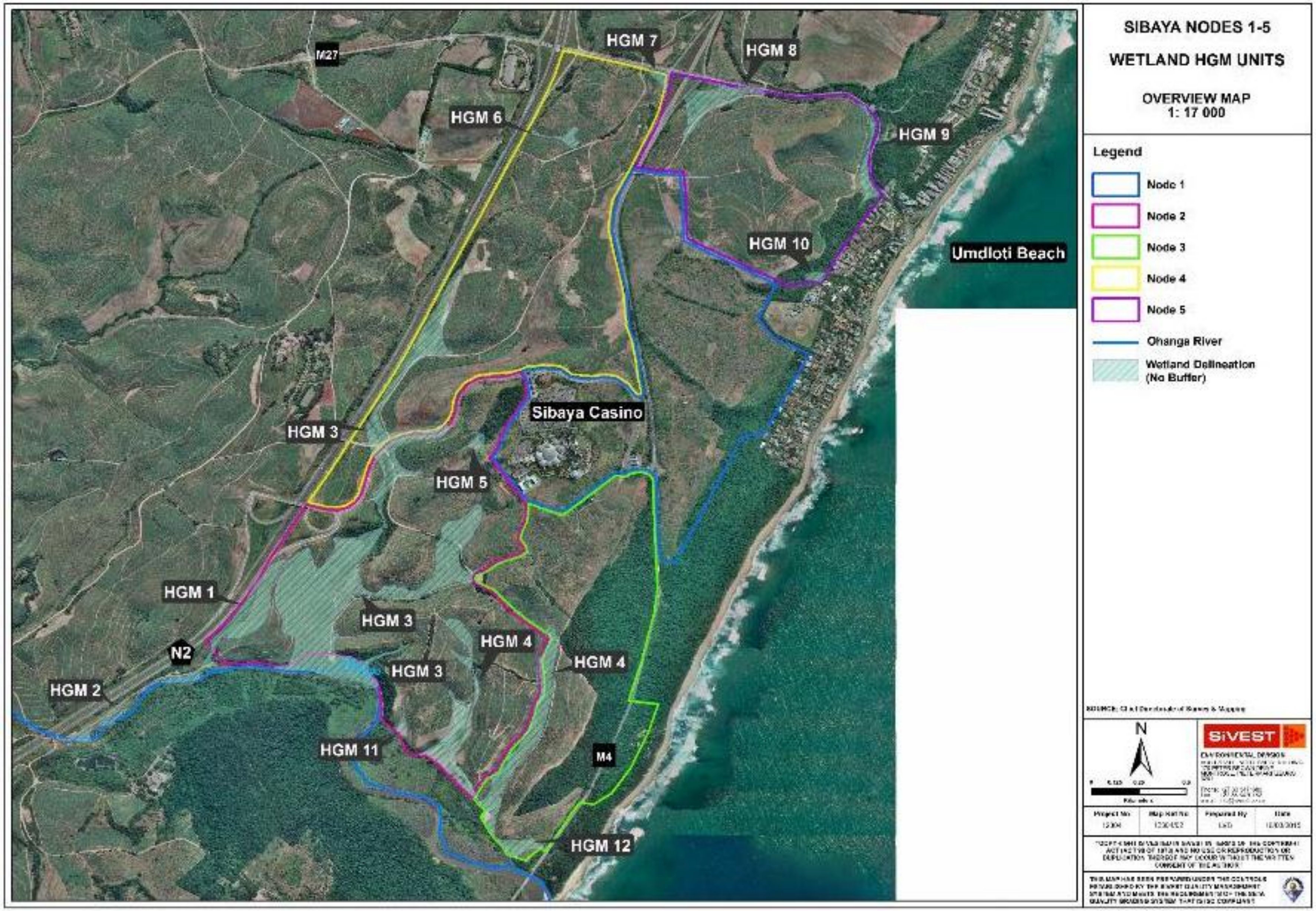


Figure 2: Wetland Map

3.5 Vegetation Cover

At a broad-scale, the site is situated within the KZN Coastal Belt vegetation unit, as defined by Mucina and Rutherford (2006). The KwaZulu-Natal Coastal Belt is distributed in a long, and in places broad, coastal strip along the KwaZulu-Natal coast, from near Mtunzini in the north, via Durban to Margate and just short of Port Edward in the south. Altitude ranges from about 20–450 m.

This vegetation unit predominantly comprises subtropical coastal forest with patches of primary grassland prevailing in hilly, high rainfall areas where pressure from natural fire and grazing regimes prevailed (Mucina and Rutherford, 2006).

This vegetation unit is considered endangered by Mucina and Rutherford (2006) with only a very small part conserved in Ngoye, Mbumbazi and Vernon Crookes Nature Reserves. About 50% of this veld type has already been transformed for cultivation and by urban sprawl. In these areas much of the remaining vegetation has been severely encroached upon by alien invasive species that include *Chromolaena odorata, Lantana camara, Melia azedarach* and *Solanum mauritianum.* At present, the majority of the site has been cleared for sugar cane cultivation. Remnants of invaded and highly disturbed coastal and riparian bush remain where cane cultivation was not feasible. These areas include the lowest portion of the identified drainage lines and bottomlands. Natural communities that still exist appear to be maintained annually, as part of the estates maintenance. The wetlands to be rehabilitated have all been cleared for cane cultivation. Typical wetland species such as of *Typha capensis, Phragmites australis* and *Cyperus textilis* are confined to the beds and banks of the artificial drainage channels dug along these in-land wetlands units.

4 WETLANDS AFFECTED BY THE CONSTRUCTION OF ANCILLARY INFRASTRUCTURE, OUTSIDE OF SIBAYA NODES 1-5

In addition to the development that is to take place within the Sibaya Nodes 1-5, a number of ancillary services will be constructed over the site, and specifically, these will include the construction of a water supply pipeline, and sewer reticulation to service the Sibaya Nodes. These ancillary services affect areas within the Sibaya Nodes, as well as areas outside of the boundary of the Sibaya Nodes. The proposed infrastructure is highlighted in **Figure 3** below, and affects a number of wetlands within Cornubia North, and along the Ohlanga Floodplain. Given the nature of pipeline and sewer installation, it is recommended that the installation of these services be undertaken at the start of wetland rehabilitation on site. Since the installation of pipes in wetlands does not lead to the permanent loss of wetland habitat, the impact of these installations is likely to be minimal, and revegetation of affected wetlands is likely to occur naturally. However, a number of best practise guidelines must be adhered to ensure that affected wetlands have the best chance of rehabilitating:

- The working servitude in all wetland areas should be kept to a minimum, and should only include enough space for the trench, a working machine, and a small buffer;
- All wetland material excavated for the trench should be stockpiled outside of the wetland area, in a laydown agreed with the ECO beforehand;
- A road should not be created, and instead, bogmats should be used to disperse machinery weight. Bogmats cause minimal impacts on wetland soils, and will allow the vegetation to recover naturally post construction; and
- Care must be taken to replace wetland soils in the correct sequence once construction is completed.

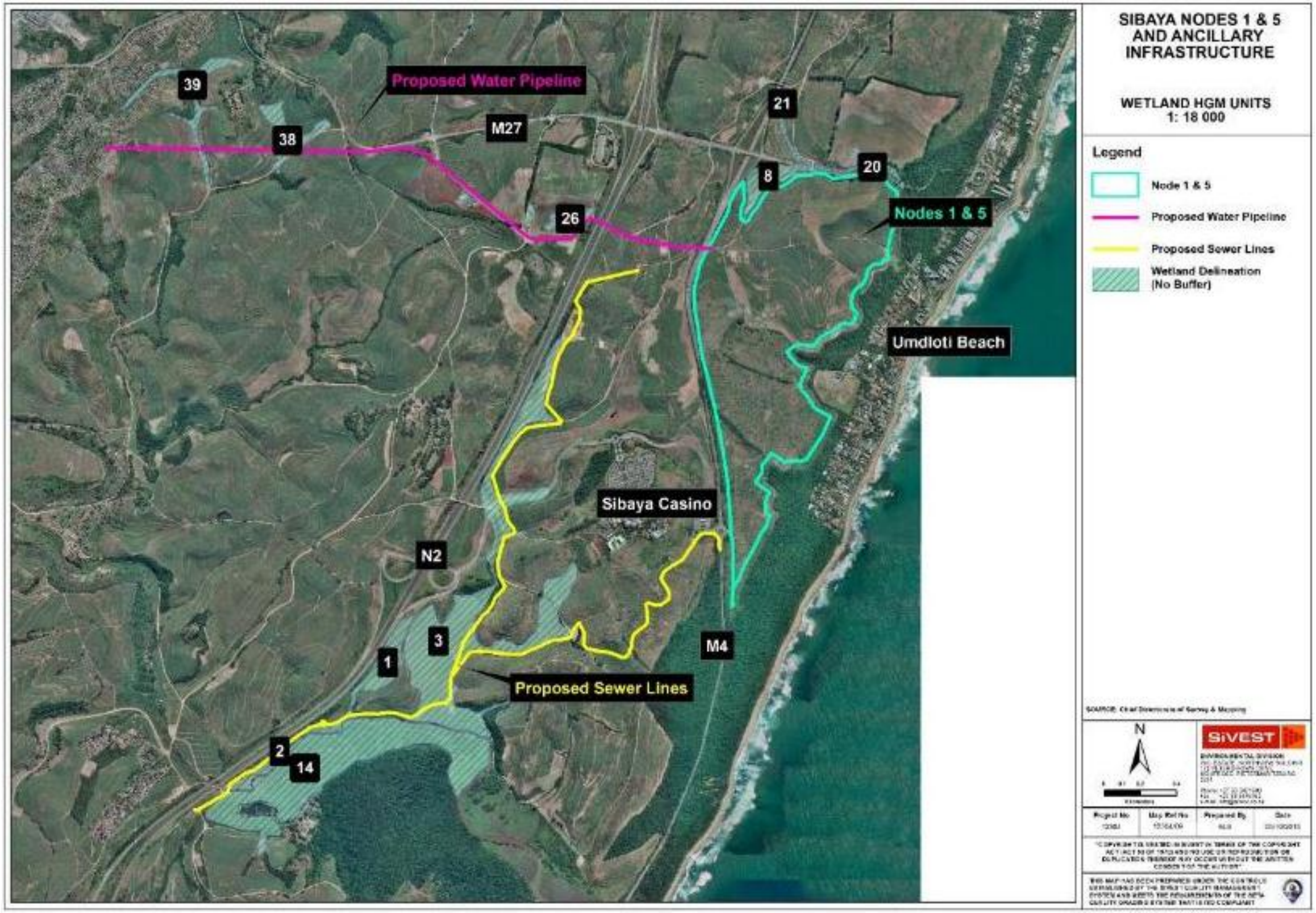


Figure 3: Proposed ancillary services for the Sibaya Nodes Development

5 METHODS

5.1 Wetland Rehabilitation Plan

5.1.1 Intervention Selection and Design

The causation of degradation within each wetland unit was determined by a rapid assessment during field visits of the state of the wetland units in conjunction with an assessment of the state of their catchments using AcrView GIS 10 software.

A site visit to each wetland unit was undertaken by the wetland specialist, ecologist and civil engineer to identify the causes of degradation requiring rehabilitation. During the site visits, physical disturbances to each wetland unit were identified, documented, photographed and measured. Thereafter, rehabilitation goals for each wetland unit were established and appropriate interventions for each wetland unit selected utilising the WET-Rehab Methods tool developed by **Russell (2009)**. The hydrological and/or geomorphological rehabilitation interventions for each wetland unit were then designed in conjunction with the civil engineer using ArcGIS and CAD software packages.

The wetland management programme for the operational phase of the Sibaya Nodes 1-5 development involved the design of a long term disturbance monitoring programme. Taking into account the surrounding land uses, the potential disturbance impacts to the wetland were identified and measures for the mitigation of these impacts implemented.

5.1.2 Re-vegetation Intervention

Soil saturation in wetlands, most often occurs along a wetness continuum. This creates a distinct zonation of vegetation from the permanently saturated areas outwards towards the temporarily saturated areas. This zonation is controlled by soil wetness and hydrology and in turn contributes to habitat diversity. Therefore, the planting approach will be to match plant species assemblages to the degree of soil saturation expected within the wetlands. The expected wetness zones across the wetland units are:

1. **Permanent zone** - Constant and permanent standing water throughout the year. The water table is at or near the ground surface during all seasons of the year. Dominated by emergent hydrophytes, typically referred to as marshes or vleis;
2. **Semi-permanent zone** - Saturated for most of the year, but does occasionally dry out for a few weeks to a month. Dominated by a mix of emergent hydrophytes, sedges and rushes, typically referred to as marshes or vleis;
3. **Seasonal zone** - Consistently saturated for 6 to 10 months of the year, but does occasionally dry out for a couple of months during the dry season. Dominated by a mix of sedges, rushes and water-loving grasses that are tolerant of cyclical wet and dry conditions (e.g. sedge meadows);
4. **Temporary wetland zone** - Hygrophilous to semi-terrestrial grassland. Saturated for 3 to 5 months of the year. Dominated by water tolerant grasses and some sedges.
5. **Dry stormwater attenuation ponds** - These areas comprise all four of the abovementioned wetness zones but will be subject to unnatural permanent flooding during storm events.

Within each one of these hydrological wetness zones, the nature of water flow into, through and out of the particular wetness zone varies according to the hydro-geomorphic setting of the different wetland units. In general, the following distinct "hydrological habitats" can be present within the different wetness zones at any one time:

- Diffuse subsurface flow fed areas
- Diffuse surface flow fed areas e.g. un-channelled sheet flow

- Sheet surface flow fed areas i.e. seasonal overtopping on floodplain
- Surface flow/channel fed areas

5.1.3 Wetness zone identification

Areas labelled "Dry season water surface" (permanent wetness zone) were determined by drawing a contour along the weir elevation, upstream of the structure (see **Figure 4**). This area designates the water surface that would be dammed upstream of the structure when the dam is full, but not overflowing.

The semi-permanent zone was defined as the zone in which; if one were to dig a trial pit, groundwater would be encountered at a depth of between 0 and 500 mm. The diagram below (**Figure 3**) shows how the extents of this zone were determined. An imaginary plane, 500 mm higher than the water surface was created. Where this plane intersects the ground, a contour was drawn, representing the extent of the wetness zone. An example of the overarching wetness zonation is shown in **Figure 4**. This zonation was repeated for all wetland units located within Sibaya Nodes 1-5.

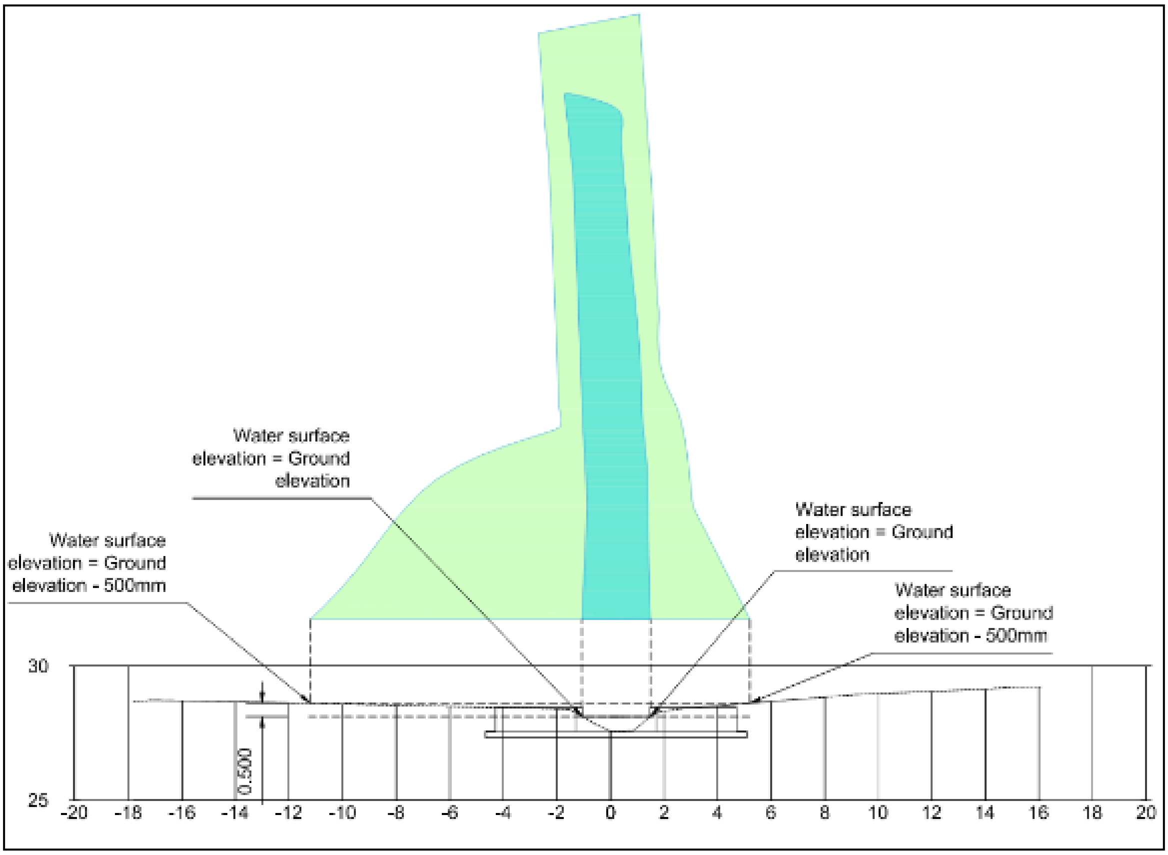


Figure 4: A schematic diagram showing how the post-rehabilitation extent of the permanent and semi-permanent wetland zones was predicted

Figure 5: Example of wetland and open space zonation completed for the entire Sibaya site

6 OFFSETTING WETLAND LOSS VIA REHABILITATION

The proposed Sibaya Development will result in a permanent loss of some wetland areas. For wetland offsets, the no-net wetland loss principle is generally accepted as best practice when dealing with the issues of wetland loss. This means that wetland loss must be replaced by wetland gain so that the net wetland loss is zero. The replacement of wetlands at a ratio of 1:1 is generally regarded as being insufficient to mitigate wetland loss as wetland rehabilitation cannot reproduce pristine wetlands. Internationally, a minimum ratio of 1:1.5 is generally required to achieve 1:1 compliance on the ground. However, this minimum ratio is only considered appropriate in situations where rehabilitation has a low risk of failure, especially if the wetlands in question are degraded and of low conservation value from an ecosystem services perspective. Following a review of the NFEPA wetland database, an appropriate offset calculation was undertaken after the method outlined by Macfarlane *et al* (2014). This calculation noted that HGM unit 8 is classified as being an Indian Ocean Coastal Belt Group 2 wetland, and these wetlands are considered as critically endangered. The offset is therefore calculated by multiplying the area being lost by 15, and corrected by a multiplier of 1. The functional offset ratio is therefore 1:15. The area for area approach involves rehabilitating or reinstating an area of wetland equal to the wetland area being lost at the required offset ratio.

Given the above, this Rehabilitation Plan aims to guide the rehabilitation of wetlands across the site, and thus fulfil the offset requirements mentioned above. **Table 1**, below summarises the current wetland losses and rehabilitation potential for the entire Sibaya Project.

The current layout for Sibaya Nodes 1 & 5 indicates that **3.48 ha** of wetland area is required to be rehabilitated to offset the direct loss of wetland area, whilst the total wetland area available for rehabilitation is **68.29 ha,** this is some **64.81 ha** more than the required minimum. This equates to a

1:297 offset ratio, which is greater than the calculated 1:15 offset ratio. Thus the overall wetland losses can be considered to be adequately offset and the significance of the impact reduced to acceptable levels.

Table 1. Wetland Loss and Offset Calculations for Sibaya

Phase	Wetland Area (ha)	Wetland Loss (ha)	Required Wetland Area to be Rehabilitated at the 1:15 offset Ratio (ha)	Wetland Area Available for Rehabilitation
Sibaya	68.52	0.23	3.48	68.29

Figure 6: Wetland Loss Map

7 CAUSES OF WETLAND DEGRADATION

Table 2. Summary of the impacts on wetland hydrology, geomorphology and vegetation for each HGM Unit

Wetland Unit	HGM	Impacts on Wetland Hydrology	Impacts On Wetland Geomorphology	Impacts On Wetland Vegetation
1	Channelled Valley Bottom	• Cultivation in wetland • Road Runoff (Cane and Highway) • Channel incisement • Change in runoff characteristics • Artificial drainage • Decrease in wetland saturation (zonation)	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • Dirt Roads (Source of Sediment) • Scour • Bare soils (increased erosion and sediment yield) • General disturbance, crossings	• Moderate prevalence of alien vegetation (thalweg) • Cultivation (removal and reduction number of spp.)
2	Un-Channelled Valley Bottom	• Road Runoff, • Change in runoff characteristics	• Roads (hardening) • Dirt Roads (Source of Sediment) • General disturbance, crossings	• High prevalence of alien vegetation (road enbankment)
3	Channelled Valley Bottom	• Cultivation in wetland • Road Runoff (Cane and Highway) • Channel incisement • Change in runoff characteristics • Artificial drainage • Decrease in wetland saturation (zonation)	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • Roads (hardening) • Dirt Roads (Source of Sediment) • Scour • Bare soils (increased erosion and sediment yield) • General disturbance, crossings	• Moderate prevalence of alien vegetation (thalweg) • Cultivation (removal and reduction number of spp.)
4	Channelled Valley Bottom	• Cultivation in wetland • Flow Confinement (Culverts) • Road Runoff (Cane) • Channel incisement • Change in runoff characteristics • Artificial drainage • Decrease in wetland saturation (zonation)	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • Roads (hardening) • Scour • Bare soils (increased erosion and sediment yield) • General disturbance, crossings	• Moderate prevalence of alien vegetation (thalweg) • Cultivation (removal and reduction number of spp.)
5	Un-Channelled Valley Bottom	• Cultivation in wetland • Change in runoff characteristics • Decrease in wetland saturation	• Bare soils (increased erosion and sediment yield) • General disturbance, crossings	• Moderate prevalence of alien vegetation (thalweg) • Cultivation (removal and

Wetland Unit	HGM	Impacts on Wetland Hydrology	Impacts On Wetland Geomorphology	Impacts On Wetland Vegetation
		(zonation)		reduction number of spp.)
6	Un-Channelled Valley Bottom	• Cultivation in wetland • Flow Confinement (Culvert under road) • Artificial drains • Scour • Road Runoff • Steep road embankments (increased runoff)	• Roads (Hardening and source of sediment) • Road embankment (source of sediment) • Scour • General disturbance	• Moderate prevalence of alien vegetation (thalweg) • Cultivation (removal and reduction number of spp.)
7	Channelled Valley Bottom	• Cultivation in wetland • Flow Confinement (Culvert under road) • Artificial drains • Scour • Road Runoff • Steep road embankments (increased runoff)	• Roads (Hardening and source of sediment) • Road embankment (source of sediment) • Scour • General disturbance	• Moderate prevalence of alien vegetation (thalweg) • Cultivation (removal and reduction number of spp.)
8	Channelled Valley Bottom	• Cultivation in wetland • Flow Confinement (Culvert under road) • Artificial drains • Scour • Road Runoff • Steep road embankments (increased runoff)	• Roads (Hardening and source of sediment) • Road embankment (source of sediment) • Scour • General disturbance	• Moderate prevalence of alien vegetation (thalweg) • Cultivation (removal and reduction number of spp.)
9	Channelled Valley Bottom	• Cultivation in wetland • Flow Confinement (Culvert under road) • Artificial drains • Scour • Road Runoff • Steep road embankments (increased runoff)	• Roads (Hardening and source of sediment) • Road embankment (source of sediment) • General disturbance	• Moderate prevalence of alien vegetation (thalweg) • Cultivation (removal and reduction number of spp.)
10	Un-Channelled Valley Bottom	• Change in runoff characteristics • Decrease in wetland saturation (zonation)	• General disturbance	• Moderate prevalence of alien vegetation

Wetland Unit	HGM	Impacts on Wetland Hydrology	Impacts On Wetland Geomorphology	Impacts On Wetland Vegetation
11	Channelled Valley Bottom	• Cultivation in wetland • Artificial drains • Scour • Decrease in wetland saturation (zonation)	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • Dirt Roads (Source of Sediment) • Bare soils (increased erosion and sediment yield) • General disturbance, crossings	• Moderate prevalence of alien vegetation (thalweg) • Cultivation (removal and reduction number of spp.)
12	Channelled Valley Bottom	• Cultivation in wetland • Artificial drains • Scour • Decrease in wetland saturation (zonation) • Road Runoff	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • Dirt Roads (Source of Sediment) • Bare soils (increased erosion and sediment yield) • General disturbance, crossings	• Moderate prevalence of alien vegetation (thalweg) • Cultivation (removal and reduction number of spp.)

8 WETLAND REHABILITATION VISION AND GOALS

8.1 Valley Bottom Wetland Units

The vision for these wetland units is to reinstate them as an un-channeled marsh environments characterized by a diffuse semi-permanent wetland zone along the lowest lying portions of the wetland colonised by a range of common emergent hydrophytes like *Phragmites australis* and *Cyperus latifolius*; and a diffuse seasonal wetland zone surrounding the semi-permanent zone colonised by a mix of sedges (e.g. *Cyperus sphaerospermus*, *Cyperus textilis*) and water loving/tolerant grasses (e.g. *Imperata cylindrica*, *Ischaemum fasciculatum*).

The rehabilitation goals to achieve this vision are:

1. Raise the local water table within the portions of the wetland unit that have been drained to within 50cm of the surface of the wetland during low flows by plugging the artificial drainage channels.
2. Where the longitudinal slope of the wetland units make Goal 1 above impractical, the goal will be to stabilise and arrest erosion within the channel.
3. Remove the existing cane road crossings and culverts that are not going to be incorporated into the proposed development and re-vegetate the disturbed areas.
4. Remove all of the sugarcane from the wetland unit and its buffers and re-vegetate the seasonal and temporary wetland areas and buffers with appropriate plant species to 'kick start' succession.
5. Eradicate all of the alien plants within the wetland unit on an ongoing basis for the lifetime of the project.

9 WETLAND REHABILITATION ENGINEERING INTERVENTION SELECTION AND DESIGN

Degraded wetlands within Sibaya Nodes 1-5 were identified during the site visit. Of the degraded wetlands identified, five wetlands were deemed suitable for rehabilitation by engineering interventions. The aim of the intervention is to reinstate the wetland to its original functionality.

9.1 Introduction

Historically, wetland areas within Sibaya have been artificially drained, by excavating channels through wetlands or deepening of existing streams. These activities have lowered the local water table and increased the effective farming area. These activities have also unfortunately resulted in a direct loss of wetland habitat and have reduced the functionality of the affected wetland units. The intention of the proposed structural interventions is to rehabilitate the degraded wetlands by reducing erosion, encouraging deposition and raising the local water table.

9.2 Methodology

The following methodology was used to position the proposed interventions and to determine the appropriate type and size of structure. The proposed interventions were positioned in consultation with the wetland and vegetation specialists. The overarching factors considered when positioning the interventions are listed below:

- Geomorphic conditions of the channel,
- Hydrological conditions at the proposed location,
- Slope of the streambed and surrounding area, and
- Subsequently select and size the most appropriate intervention to determine the newly resulting permanent and semi-permanent wetland zones.

9.2.1 Geomorphic Conditions

Weirs are positioned in areas where the stream channel has become incised as a result of poor farming practices. An example of an incised channel is shown in **Figure 6** below.

Figure 7: Example of a man-made channel

9.2.2 Hydrological Conditions

Floodpeaks for the proposed weir locations were determined using the Rational Method (**SANRAL 2006**)[1]. The Rational Method is suitable for catchments smaller than 15 km² and therefore this method could be used on all the contributing catchments within Sibaya Nodes.

9.2.2.1 Rainfall Data Analysis

The representative rainfall station selected for the floodpeak analysis was Mt Edgecombe situated at the South African Sugar Research Institute, SAWB Code 241042. The station has a mean annual precipitation of 927 mm with a data set spanning 62 years.

9.2.2.2 Contributing Catchment Delineation and River Reach Analysis

The representative rainfall station selected for the floodpeak analysis was Blackburn, SAWB Code 241131. The station has a mean annual precipitation of 922 mm with a data set spanning 62 years.

The design point rainfall depth was calculated using *The Estimation of Design Rainfall for Durban Unicity* (Smithers, 2002)[2]. Linear interpolation was used to determine the design rainfall depth for storm durations not explicitly shown in the data set.

[1] Drainage Manual, The South African Roads Agency Limited (SANRAL), 5th edition, 2006
[2] Smiters, JC. The Estimation of Design Rainfall for Durban Unicity, eThekwini Municipality, 2002.

9.2.2.3 Land Use

For all new developments the eThekwini Municipality stipulates that pre- and post-development flood peaks shall be the same and the developers are obliged to provide storm water attenuation in order to comply. Therefore, the current land use of sugarcane was used to determine the runoff coefficients for each catchment. The resultant runoff coefficients generated are considered appropriate for sugarcane farmland.

9.2.2.4 Design Flood Determination

WET-Rehab Methods (**Russell, 2009**) recommends that small structures with a catchment area of less than 50 ha should be able to pass a design flood peak with a 1 in 10 year recurrence interval. A flood peak with a 1 in 20 year recurrence is required for a moderately sized structure with a catchment area of 50 - 500 ha. The peak flows for the 1 in 10 year flood event were calculated for each weir position as stipulated.

9.2.2.5 Slope of Streambed and Surrounding Area

A spatial analysis of the topology was undertaken to determine areas where slopes were less than 5 %. This revealed areas where the greatest gains in wetland reestablishment could be found.

9.2.2.6 Intervention Selection

The type of intervention selected is important when rehabilitating a wetland. Using the decision tree for choosing a mechanism to stabilise a degraded wetland, WET-RehabMethods[3] recommends the use of a gabion weir with a central spillway.

The flow capacity of the weirs were calculated using the broad crested spillway formula. The length of weir was determined based on the floodpeak calculated for each location. A maximum weir length of 15 m (7 m + 4 m + 4 m box weir) was selected based on the typical size of the channels within Sibaya Node 4 and a floodpeak of 10 m^3/s.

The water surface area created by inundation behind the weir was calculated using the sill elevation in conjunction with the topographical survey. An additional 500 mm was added to the sill elevation to determine the area of semi-permanent wetland.

9.3 Results

To reinstate the hydrology of the wetland units, sixteen gabion weirs are proposed. These are to be located within the artificial drainage channels, as shown in the layout plan 12304-5400. A typical detail of the concrete weir is shown in Drawing 12304-5601.

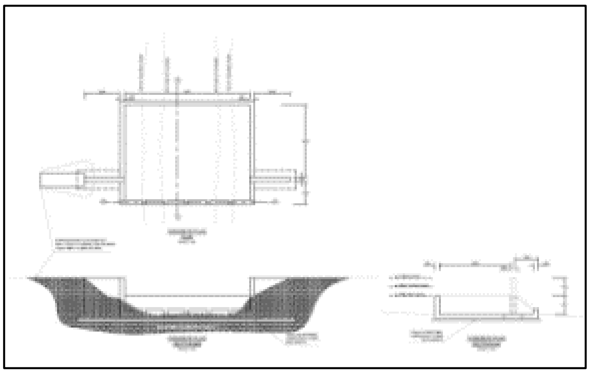
These weirs will effectively dam flow within the artificial drainage channels during low flows and allow for overtopping during mean to high flows. This will raise the local water table to near the top of the artificial channel banks and create a shallow water table environment within the wetland areas outside of the drainage channel. Damming of the flow will create a stilling basin, where deposition is encouraged. Eventually the channel should fill up with wetland soils approximately to its former level.

9.4 Notes for the construction of the gabion plugs and spreader canals

- Gabion baskets are to be installed to manufacturer specifications.

[3] Russell, W. WET-RehabMethods, National guidelines and methods for wetland rehabilitation. Water Research Commission. March 2009.

- Foundations are to be constructed from 100mm in-situ material compacted to 90% MOD AASHTO density.
- Geofabric (Bidim U40 or similar approved) lining to be installed on all earth-facing sides
- Gabion baskets shall be woven together as per the manufacturer's recommendations.
- An earthen berm (spreader canals) must be constructed from the edge of the wing walls outwards, at grade. Detail shown on drawing 12304-5601.



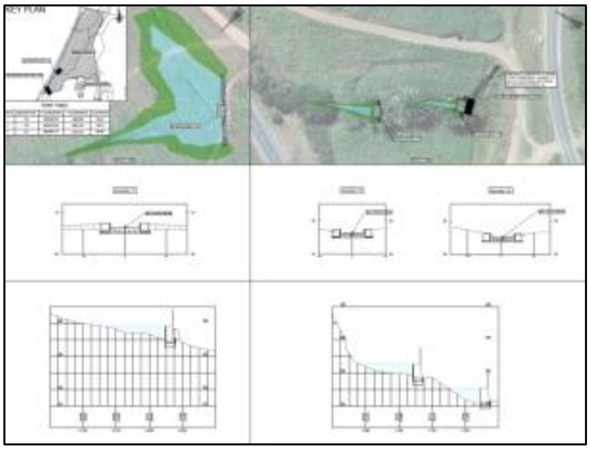


Figure 8: Screen captures of the supporting engineering designs (see supporting drawings)

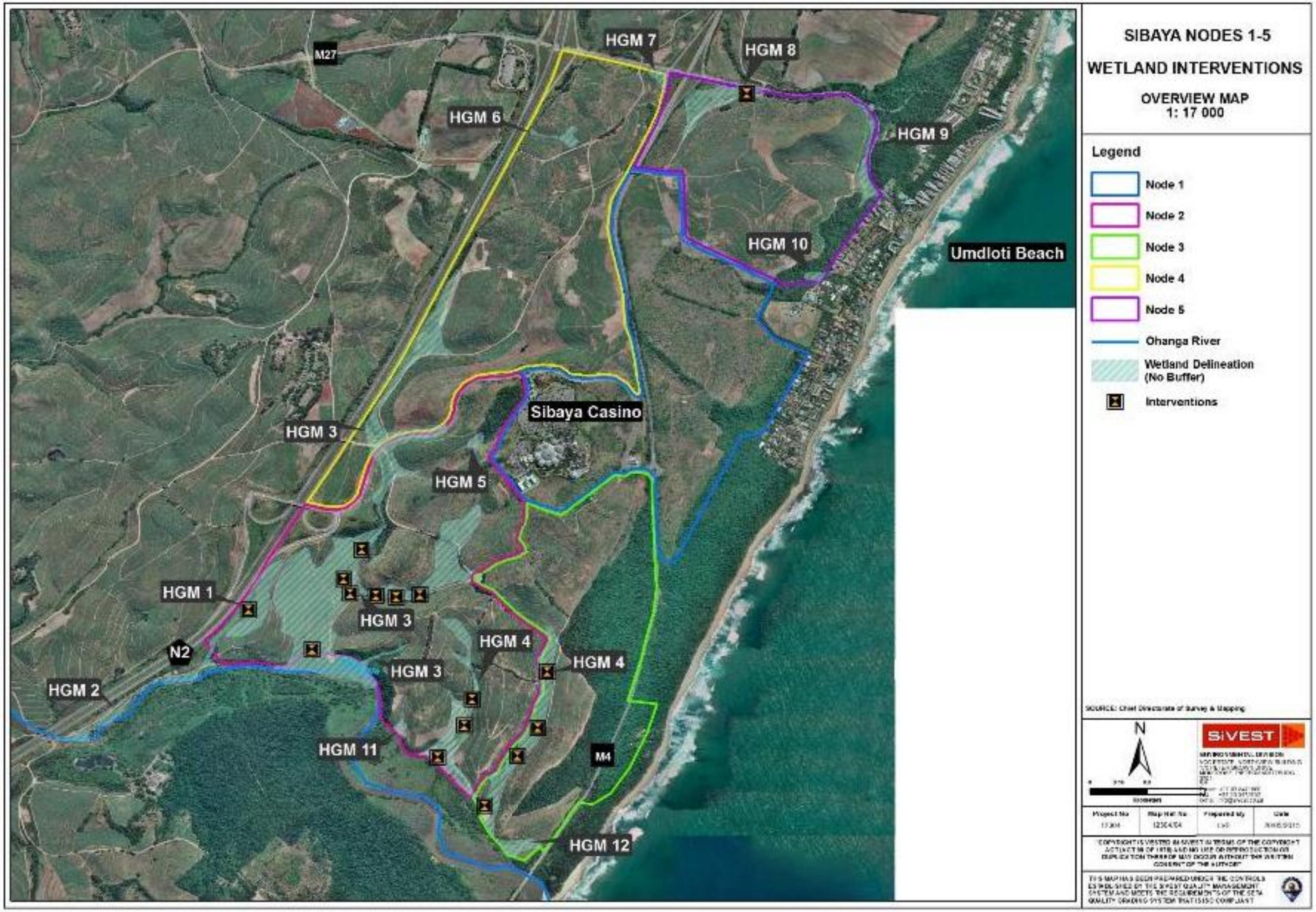


Figure 9: Locations of the proposed engineering interventions

10 BACKGROUND TO THE RE-VEGETATION PROGRAMME

Sibaya is a large area which is currently under almost complete sugar cane cultivation. The pockets of vegetation that remain within the cultivated areas are: small, isolated, dominated for the most part by aliens and have little or no ecological or biological value. In terms of the Wetland Rehabilitation proposed the current area of each of the types of wetland is included in **Table 3** below. Due consideration must be taken that the proposed wetland areas may currently be under intensive sugar cane cultivation and therefore no requirement exists for these areas to be included in the initial alien clearing exercise. However, once the Rehabilitation Plan is implemented, the need will arise for all of these areas to be maintained and alien free.

Table 3. The various categories of Wetland Identified within the Sibaya Development Footprint.

WETLAND CATEGORY	AREA (HA)	PROPORTION (%)
Permanent	2.56	4%
Seasonal	21.73	34%
Semi-Permanent	5.11	8%
Temporary Wetland	34.51	54%
TOTAL	**63.91**	**100.00%**

11 PLANTING METHODOLOGY

In terms of the vegetative rehabilitation of the proposed wetland areas located within Sibaya Nodes 1-5, it is envisaged that the rehabilitation would be a two tiered approach.

The first tier or phase would be to establish a robust and relatively species diverse basal cover, which would ensure that once the cultivated sugarcane is removed; the land form would be re-landscaped where required and the necessary wetland interventions constructed to facilitate the correct hydrological regime and thus functioning of the wetland areas.

It must be clarified that in terms of the vegetative component of the wetland rehabilitation, i.e. areas that will exhibit conditions ranging from total inundation through to temporary and seasonally elevated soil moisture conditions can only be created post-intervention construction. The reason is that the proposed species assemblages are driven by the underlying hydrological regime. The soils which have been impacted upon by previous land use need to "recover" and provide the correct conditions for the establishment of these plant species. Thus, the stabilisation of the hydrological regime will be critical in the success of these proposed plantings.

The stabilisation of the hydrological regime will assist in promoting the succession of the species assemblage to a position where these systems will superficially mirror the pre-cultivation community assemblage.

In terms of the Buffer Zones; establishment of these areas as soon as the sugar cane has been removed must be undertaken. Our recommendation that these areas are established prior to the removal of the sugarcane within the wetland areas is paramount to avoid sedimentation of the wetlands. This approach will ensure additional protection of these systems during the removal of the sugarcane.

11.1 Methodologies for the Re-Establishment of Terrestrial Buffer Zone Grasslands

In terms of the areas that will require rehabilitation from existing sugarcane fields back to their original grassland form, the approach would be to establish indigenous vegetation within these areas.

The first and most important step in the transition and return of the sugarcane fields to grasslands would be the land preparation to receive the adopted method of re-establishment.

The preparation of the soils is as important as the application of the intended re-vegetation methodology. Numerous areas are relatively large, accessible and have been commercially farmed. Within these areas, the use of machinery in land preparation is possible and advisable. This will result in a rapid rate and a potentially more accurate method of preparation.

The soil should be ripped to a depth of 500 mm. This will remove the majority of the existing sugar cane ratoons and ensure that the soil is not compacted and no plough sole exists that may impact on the rooting potential and survival of the replanted material.

Once the soil has been ripped, a lightweight roller should be utilised to level the soil surface removing any high points that may impact on seed distribution. Grass seed will be used as the basis for the establishment of the grassland areas.

Following the soil preparation one or all of the techniques expanded upon below may be utilised to establish the base grass layer. The use of the techniques provided below will depend on the terrain, slope and accessibility into the intended rehabilitation zone.

11.1.1 Broadcasting

Broadcasting involves using a simple hand spinner or tractor drawn implements to spread seed over an area. This type of seed distribution is traditionally used for seeding very small areas (<1 ha) or lands that are inaccessible to conventional implements. Generally, broadcasting should be limited to slopes no steeper than 1:3. Broadcasting should not occur in high wind conditions. Even cover can be best achieved by applying half of the total mix in one direction and the second half of the mix in a direction perpendicular to first half. Sand can be added to the mix to assist with even spread and prevent blockages of the implements. Soil should be harrowed after seed has been applied.

Germination and establishment will be assisted by applying a mulch or weed-free straw at a rate of four tons per hectare immediately after applying the seed. In order to prevent the winnowing out of the straw cover, it should be crimped into the ground to a depth of 50 mm using a crimping disc or similar device. As an alternative to crimping, a tackifying or bonding agent may be applied using hydro-seed equipment at a rate of 30 kg / hectare, or at the manufacturer's advised specification.

11.1.2 Drill seeding

Drill seeding is carried out by tractor. Seed (and fertiliser) are injected into the ground via a disc or tine in a single pass application to a depth of about 7 to 15 millimetres. This provides better establishment, and reduced seed loss to birds and insects. This is usually the most cost effective method of establishing plants from seed.

11.1.3 Hydraulic seeding / Hydro-seeding

This method of seeding is quick and effective especially on steep, critical slopes and in inaccessible areas that cannot practically be seeded by other more traditional methods. Hydro-seeding includes seed, water, fertilizer and a small amount of mulch in a slurry transported in a tank, either truck or trailer mounted and sprayed under pressure over prepared ground in a uniform layer. A tracking dye may be included to visually aid uniform distribution, which is an advisable inclusion. The mulch in the hydro-seed mixture helps maintain the moisture level of the seed and seedlings, thus resulting in improved germination rates.

Although hydraulic planting is more expensive than manual seeding and mulching, it has many benefits. Compared to broadcasting, the seed blend can be distributed uniformly, the added mass increases accuracy and throw distance, especially in exposed, windy areas, while presoaking and water accelerates germination and enhances the chance of survival. Compared to hydro-mulching (see below) it is better suited to flatter land. Like other forms of seeding it should be carried out in suitable weather conditions.

11.1.4 Cut Grass Placement

This option may prove to be too time consuming and costly, however, we have included this option as it may prove to be very successful, as the rehabilitation of the grass layer will be such that it mirrors more closely the grassland areas in close proximity. In addition, the potential exists for herbaceous species and geophytes seed to be included when the grass is cut.

Two methods of collection are possible. Firstly, members of the local community could be utilised to go and cut grass and bundle the grass, on existing grassland sites in small blocks, during early to late summer, this would provide limited unskilled labour opportunities. The sites for harvesting would need to be identified by a suitable grassland ecologist prior to the cutting taking place. The second method would be to utilise a slasher on a tractor which will cut the grass. The cut grass can be raked up and collected.

The cut material can then be taken to the sites identified and laid out on the prepared soil surface. This material, if placed on relatively steep slopes maybe covered with some form of geotextile, such as Biojute® to hold it in place. The use of Geotextiles will be extremely useful in areas where the buffer zones are on steep slopes.

The benefits of the above technique include;

- High seed diversity;
- Re-established area will potentially resemble surrounding grassland areas;
- The vegetation that has been cut acts as a water reservoir, will prevent soil erosion, both resulting from wind and water action;
- The seed will be protected to a certain extent from predation;
- The grass material will degrade, forming a indigenous mulch which will promote vigourous growth and sustain the established grass seed.
- Soil Stabilisation Techniques using various products.

11.2 Soil Stabilisation Techniques using Various Products

11.2.1 Hydro-mulching

Hydro-mulching is essentially the same operation as hydro-seeding, but includes a much higher mulch rate and usually has other ingredients including fertilizer, dye and tackifying agents (water soluble binders) which bond the application to the soil surface.

Hydro-mulching is useful where:

- Areas cannot be accessed by machinery, such as tractors.
- Slopes are steeper than 1:3 or otherwise are of such gradient and consistency that they cannot receive adequate seedbed preparation and mulch is difficult to anchor.
- Slopes have irregular surfaces, with large clods, stones or a high percentage of rock.
- Conditions such as irregular soil surfaces, existing vegetation and shallow soils preclude the installation of erosion control blankets and mats.
- Soil stabilization, seeding, and mulching will cause unacceptable levels of disturbance.
- It is desirable to apply water, seed, mulch and tackifiers in one or more quick operations.
- Dust control is also needed.

Before applying, the soil surface should be roughened without removing topsoil, such as by careful scarifying with a grader comb blade, before the soil is saturated with water. The mulch should be mixed with seed, water and any other additives as specified and applied at a rate recommended by the manufacturer/s in order to achieve uniform, effective coverage.

Mulches used in these operations typically include wood or paper fibre or combinations of both, vegetative mulches such as from sugar cane or flax, or polyester and/or polypropylene fibres. Paper and wood based mulch is generally inferior to vegetative and polyester/polypropylene products, with vegetative mulches offering superior biodegradability.

A robust class of products is designated as Bonded Fibre Matrix. This is a term used within the erosion control industry to categorize hydraulically applied products which are designed to match or exceed the performance of erosion control blankets.

After application the matrix dries as a continuous layer of elongated fibre strands held together by a water-resistant bonding agent, with a tackifier which binds the cover to the soil surface. The matrix has no holes greater than one millimetre and so prevents raindrops from hitting the soil, while allowing water to percolate through. It has high water-holding capacity, does not form a crust that inhibits plant growth, and harmlessly biodegrades.

Fertilizer and seed are accommodated into the mix at the manufacturer's specification and may need to be applied at rates of 6 tons/hectare. Two applications may be needed to prevent shadowing on rough ground.

11.2.2 Turfing

Turfing should be applied where immediate cover is required for stabilisation. Particular areas identified are areas where potential outfall from storm water pipes is proposed and very steep banks are created such as road embankments. Please note that in terms of turfing, only indigenous species may be utilised and these comprise species such as *Cynodon dactylon*

Turf should be:

- Placed on a bed of fertilised topsoil of a minimum depth of 75 mm;
- Laid parallel to the contour on sites with steep slope gradients;
- Under or over a pegged artificial mesh (e.g. a light polypropylene, UV stabilised mesh with about 20 mm openings) in areas of very high water velocity;
- Tamped immediately as laid;
- Where necessary, pegged to the soil at 1 to 2 metre centres;
- Watered immediately to enhance establishment;
- Watered regularly for the first seven days or as required to effect establishment.

11.2.3 Geotextiles

Geotextiles (also referred to as erosion control blankets or mats) are any permeable textile material that is used to holding seed, fertilizers and/or topsoil in place, or holding disturbed soil on steep slopes and graded sites, in order to prevent erosion.

Good surface preparation is critical, as the soil surface should be relatively smooth and without projections. The blanket or mat should extend beyond the edge of the area to be covered, with the top end buried in a trench at least 10 cm deep by 20 cm wide. The mat or blanket will need to be further secured with stakes. There must be maximum soil contact to prevent erosion underneath.

Although geotextiles have historically been made of natural plant materials, geotextiles are increasingly made from a synthetic polymer or a composite of natural and synthetic material.

Plant fibre-based geotextiles are subject to decomposition and have a limited durability. However they may be left in place to form an organic mulch to help in the establishment of vegetation. Different fibres will degrade at different rates. Coir geotextiles degrade in 2-3 years while jute degrades in 1-2 years. Coir is therefore useful in situations where vegetation will take longer to establish, and jute is useful in low rainfall areas because it absorbs more moisture.

One of the recommended products is Biojute®, which is produced by a company called Maccaferri. The synthetic polymers have the advantage of not decaying under biological and chemical processes, but being a petrochemical-based product if left to decay may cause environmental pollution. In areas where the proposed rehabilitation zone is on a slope and will be exposed to on-going contact with water, be it overland flow or storm water discharge, the use of Hyson® Cells would be promoted. These cells come as a flat roll that is opened up and stretched over the area identified and staked into position. The cells that are created as a result of the stretching are to be filled with soil and thereafter lightly compacted.

Ideally, vegetation is the best form of erosion control, with geotextiles only used for temporary stabilization purposes until vegetation cover is established. In coastal areas, geotextiles are only superior to hydro-mulching in the following situations:

- When the growing season is short or unfavourable and plants cannot stabilize a slope quickly;
- When surfaces are so unstable or contours so channelled that a heavy rain could result in significant and costly erosion damage.

Geotextiles can be ineffective when flows can get beneath the blanket/mat, and they may also mask slope failures until erosion is too far advanced to effectively and cheaply remediate the slope. In contrast where hydraulic applications fail damage is visible early.

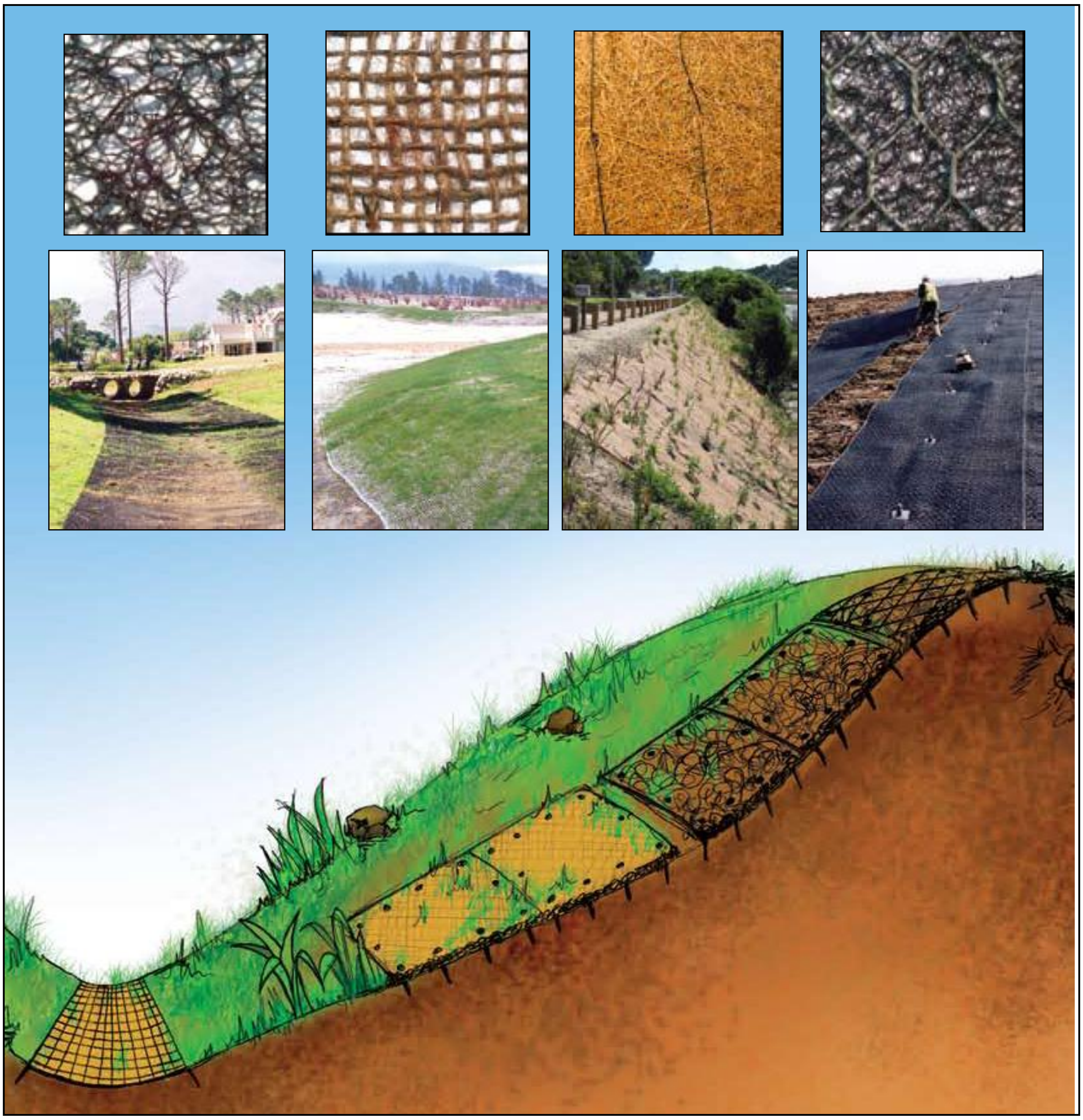


Figure 10. The various types of Geotextile fabrics commonly utilised in soil stabilisation and their position and application within the landscape at for which they are best suited. The insets are the differing geofabrics, and are named from left to right as follows (MacMat™, BioJute™, BioMac™, MacMat™R) with a plate of their successful utilisation below each sample plate. (Representation courtesy of Maccaferri, Promotional Literature, 2003).

The buffer zone will comprise predominantly graminoid species. The species selected require that the soils exhibit terrestrial properties for the entire year. The role of the buffer zone and the vegetation that will comprise said area is required to aid in the attenuation of overland flow prior to it entering the wetland systems, beyond in the valley bottoms. In terms of the buffer zones they are important as a large amount of the storm water that accumulates within the individual erven of the site will be discharged onto these areas, which will act as a dissipater and retarder of water flows and volumes, from the storm water discharge structures.

As with the permanently wet areas and the temporary seasonally wet areas, there will be an area of interface that will see the establishment of species along the ecotone, which are able to withstand both high soil moisture levels, for limited periods, and completely terrestrial conditions. The following species of graminoid would be best suited to be grown along these ecotones, or the “fringe” of the overarching wetland area.

11.2.4 Terrestrial / Wetland Ecotone or Fringe

- *Setaria sphacelata*
- *Ischaemum fasciculatum*
- *Imperata cylindrica*
- *Andropogon appendiculatus*
- *Bothriochloa insculpta*
- *Eragrostis racemosa*
- *Eragrostis capensis*

Beyond the ecotonal zone the following graminoid species would be the ideal species to perform the function of establishing a graminoid dominated species assemblage in the terrestrial environment. The species that have been selected are all species which occur in grassland areas in and around Durban. The species proposed are as follows;

11.2.5 Terrestrial Environment

- *Melinis repens*
- *Themeda triandra*
- *Aristida junciformis*
- *Melinis nerviglumis*
- *Monocymbium ceresiiforme*
- *Alloteropsis semialata*
- *Brachiaria serrata*
- *Tristachya leucothrix*

The above species are predominantly species which are referred to as Decreaser[4] species. These species proliferate in good quality veld and under the correct management are able to dominate the grassland species assemblage, which will result in extremely high basal cover. Additionally, this will result in higher levels of rainfall infiltration, retard overland flow during peak flows and from a biodiversity perspective provide the ideal graminoid assemblage for the establishment of herbaceous and geophyte species. The establishment of these species is significant in as much as they will provide significant habitat heterogeneity as well as opportunities for pollinators, especially Lepidoptera to thrive and make use of these open spaces as dispersal corridors. The improved habitat heterogeneity and diversity will contribute to the management and sustainability of the grassland buffer zones.

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[4] Grasses that are abundant in good veld, but that decrease in number when the veld is over-grazed or under-grazed. These grasses are palatable climax grasses.

11.3 Wetlands

It must be stated that even though the sugarcane is being cultivated in the wetland areas, its removal will have an effect on the potential for erosion to occur, and resultant sedimentation of lower lying areas. The provision of a buffer around the wetland will significantly reduce the velocity and volumes of water entering these areas. Once the interventions have been constructed the planting up of the wetlands can occur. We would suggest that the interventions are constructed in a stepwise manner, i.e. starting at the head of the catchment and moving down the catchment. The removal of sugarcane should follow the same strategy, with it only being removed once the intervention construction is completed. This proposed programme will have two benefits. First and foremost the wetland areas will be protected from erosion and damage. Secondly, once the hydrology changes, after intervention construction, it will aid in the prevention of the sugarcane from re-emerging (resulting from the change in the soil hydrology), reducing costs of clearing areas, once planting has been completed.

In terms of the actual design of the planting we would propose the following strategy be adopted to ensure good coverage and protection of the re-establishing wetland. **Figure 10** below illustrates what we would propose as the correct methodology for the establishment of wetland vegetation within the rehabilitated zones. In brief, we would recommend the planting of the vegetation in rows with a single plant being placed at one (1) metre centres, and ranging between 1.5 and 3 metre intervals along the wetland, depending on the position within the wetland where the planting will take place.

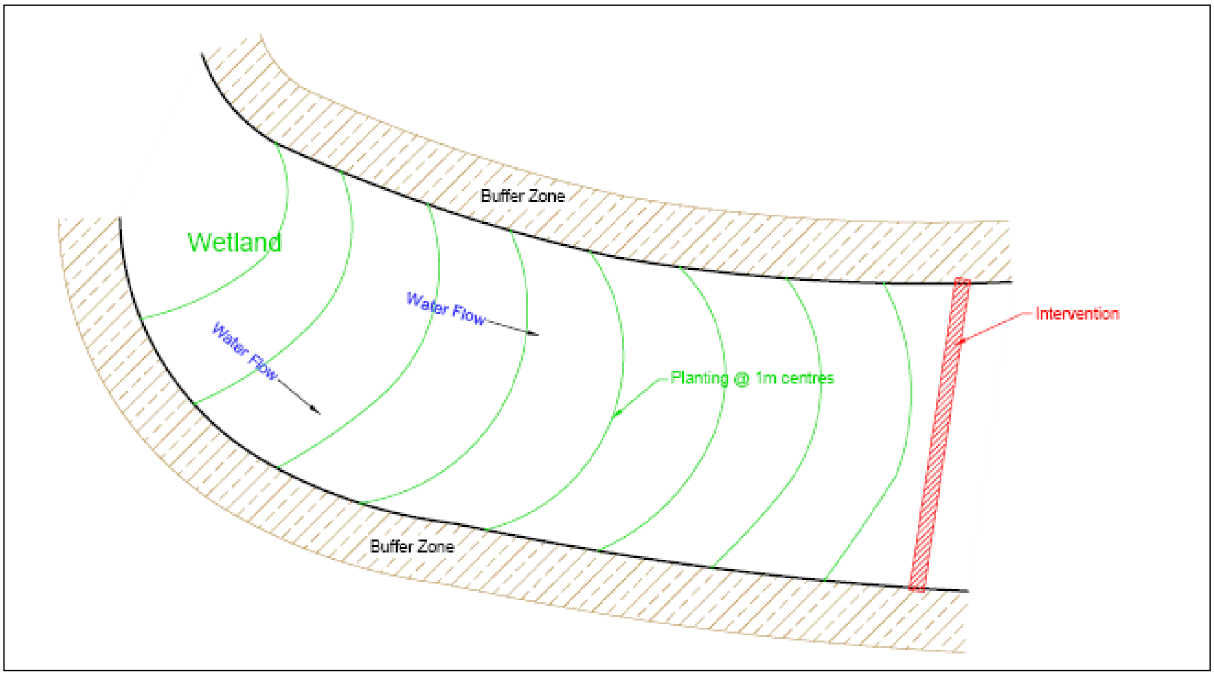

Figure 11: A schematic diagram representing the proposed planting methodology to be adopted when rehabilitating wetland areas (Kinvig, 2011).

11.3.1 Wetland Areas

In terms of the replanting of wetland areas, numerous suggestions or methodologies have been utilised in order to obtain the required outcome in terms of the plant species assemblage that would be representative of the original wetland plant species assemblage. This is the ultimate successional state that would be striven towards. However there are numerous factors which need to be considered and catered for in the rehabilitation efforts as outlined in this document, in order to obtain a state that will superficially reflect the climax state.

We must consider very carefully the approach to the rehabilitation efforts when deciding on the methodology that is required in order to rehabilitate wetlands and return the most valuable of the Ecological Goods and Services afforded by wetland systems. The approach has to be a fine balance that will deliver returns on all of the EG&S. However, the returns in certain areas will be more significant than in others. The optimal outcome for the rehabilitated wetland areas will see the delivery of:

- Improved storm water management
- Reduced sedimentation of the Ohlanga River
- Improved flood control
- Increased removal of nutrients
- Increased removal of toxicants

and to a lesser extent an opportunity around the establishment of a heterogeneous habitat matrix that will contribute to species diversity and niche development. The habitat heterogeneity will contribute to the vegetation continuum, which in turn will elevate the number and diversity of habitats available for colonisation.

As a result of the proposed development of relatively large areas of hardened surfaces and the potential for relatively high flow rates, during heavy rainfall, we have decided to take the following approach in order to achieve the delivery of the above mentioned outcomes.

11.3.2 Seasonal & Semi Permanent Areas

- *Phragmites australis*

Please note that with the rehabilitation of the wetland areas adjoining the floodplain, other species of Sedge will enter the system and form relatively pure stands where the conditions are suitable. It would be expected that the more robust species would establish themselves in these areas, simply as a function of their ability to compete with the *P. australis.*

11.3.3 Riverbanks and low lying areas requiring additional protection

- *Barringtonia racemosa*
- *Voacanga thouarsii*
- *Ficus sur*
- *Syzygium cordatum*

11.3.4 Permanently Saturated and Inundated Wetland

These areas will comprise the priority flow channels that will still exist post rehabilitation. As a result of the nature and action of water these channels will be the most susceptible to erosion and/or damage, resulting from a high volume rainfall event. It is therefore proposed that these areas should be rehabilitated using a certain limited suite of species that are robust and capable of being able to provide protection to the soils, filter the water, retard flow rates and remove sediment.

The following species are proposed for these areas:

- *Mariscus solidus*
- *Cladium mariscus*
- *Cyperus dives*
- *Cyperus latifolius*
- *Phragmites australis*
- *Juncus lomatophyllus*

All of the above mentioned species are considered to be of a pioneer nature and able to withstand change and certain levels of disturbance. These species are extremely hardy and reproduce vegetatively at an exceptionally high rate. The desired outcome therefore is achieved rapidly and in a cost effective manner. The proposed planting density for this area is one plant per every 3 m^2.

11.3.5 *Semi-permanent Wetland (water table never lower than 50 cm)*

These areas identified on the relevant attached maps are going to be exposed to water which is at the natural ground level, up to a depth of approximately 50 cm. In these areas the attenuation of flow is not the most important variable that needs to be taken into account, rather the removal of sediment, toxicants and excess nutrients.

In order for the nutrients and toxicants to be removed, the choice of species is important. The species that have been selected and listed below, all produce high volumes of above ground vegetative matter and will be able to remove significant levels of toxicants and nutrients. The proposed planting density for this area is one plant per every 2 m^2.

- *Cyperus latifolius*
- *Cyperus dives*
- *Cyperus fastigiatus*
- *Eleocharis limosa*
- *Schoenoplectus erectus*
- *Carex cognata*
- *Juncus lomatophyllus*
- *Cyperus denudatus*
- *Berula erecta*
- *Persicaria attenuata*
- *Persicaria decipiens*

11.3.6 *Seasonal Wetland (water table lower than 50 cm during low flows)*

The seasonal zones of the wetland outside of the semi-permanent/seasonal zone mentioned above may be seasonally inundated with water during very high flow events but in general experiences diffuse soil saturation within the top 50 cm of soil during the wet season and dries out in the dry seasons where the water table is at a depth lower than 50 cm.

The soils are usually moist but the top 20-30 cm centimetres dry out for 2 to 3 months during winter. The species that grow in this area generally prefer saturated rooting conditions but can tolerate dry soil conditions for short periods during the dry months. The proposed planting density for this area is one plant per 1.5 m^2.

In order to establish these areas during the rehabilitation of the wetlands, post interventions, the following species or subgroup thereof would be the ideal for the establishment of the vegetative component.

- *Cyperus dives*
- *Cyperus laevigatus*
- *Cyperus sexangularis*
- *Cyperus solidus*
- *Cyperus sphaerospermus*
- *Pycreus nitidus*
- *Juncus dregeanus*
- *Bulbostylis hispidula*

11.3.7 *Temporary Wetland*

The temporary zone of a wetland is very seldom inundated with water, and if this does occur it will only be for a very short period of time during very high flow events. The soils are generally saturated for around 3 months of the year during the wettest months and are dry for the remainder of the year. Generally, the species that grow in this area prefer moist conditions but do not tolerate permanently saturated rooting conditions, thus this area is usually dominated by a mix of facultative wetland sedges and grasses and terrestrial grasses tolerant of moist conditions during the wet season.

In order to establish these areas during the rehabilitation of the wetlands, post interventions, the following species or subgroup thereof would be the ideal for the establishment of the vegetative component. Given that this class of area is relatively terrestrial we would propose that the area be hydro-seeded and the more hygrophilous species of sedge and other wetland plants will establish themselves over time in the areas where the conditions will suit their establishment.

Grasses:

- *Setaria sphacelata*
- *Andropogon appendiculatus*
- *Aristida junciformis*
- *Imperata cylindrica*

Sedges:

- *Cyperus congestus*
- *Bulbostylis hispidula*
- *Cyperus sphaerospermus*

11.3.8 Interventions

In areas of wetland where interventions have been proposed, we would suggest that either of the following methodologies be adopted. The first option would be to plant the area to Sedge dominated species, or alternatively, select certain woody species, whose roots will not interfere with the functioning or integrity of the intervention, to stabilise the soils at the interface between the intervention and wetland soils. It is a commonly occurring problem that where interventions have been constructed, that the soils at the interface can and do become eroded. It is with this in mind that we would suggest that deep rooting tree species be planted in this contact zone to further stabilise the soil to prevent water from eroding the soils around the intervention and thus making it redundant. It is of paramount importance that the correct species are selected, with all species of *Ficus* being excluded due to their extremely aggressive root system.

The following species of tree would be ideal in performing the stabilisation of these intervention areas;

- *Bridelia micrantha*
- *Syzygium cordatum*
- *Cassipourea gummiflua*
- *Rauvolfia caffra*
- *Macaranga capensis*
- *Barringtonia racemosa*
- *Voacanga thouarsii*

In terms of the overall design aspect, the wetland ecologist has suggested that he is of the opinion that trees may not be a suitable option for around the interventions. The wetland ecologist is of the opinion that *Phragmites australis* is able to play a very important role in stabilising soils and therefore it is his opinion to plant *P. australis* in lieu of the trees.

It is also his concern that the trees may result in shading which could impact on the under storey and may lead to issues in the future around the interventions. We therefore submit that the option is available to make use of the trees. From an ecological perspective we would like to plant trees as it will significantly improve habitat heterogeneity and will provide islands for motile species to move through and utilise.

12 BILL OF QUANTITIES

12.1 Areas identified for rehabilitation

Table 4. Areas proposed to undergo rehabilitation through the planting of indigenous vegetation.

Re-vegetation Areas	Area (m^2)	Area (ha)	Plant No.	Planting Density
Permanent zone	25600	2.56	8533	1 plant / 3 m^2
Semi-permanent zone	51100	5.11	25550	1 plant / 2 m^2
Seasonal zone	217300	21.73	144867	1 plant / 1.5 m^2
Temporary zone	345100	34.51	1035	30 kgs seed / hectare
Total Re-vegetation Area	**639100**	**63.91**	**178950***	

***Excludes kgs of grass seed required, which equates to 1035 kgs of seed.**

12.2 Bill of quantities for each category of re-vegetated area

Table 5. The proportions and kgs of grass seed required for each hectare of Temporary Zone to be rehabilitated.

Temporary Zone	No. /kgs/ha	Proportions	Kgs
Setaria sphacelata	4.00	13%	134.55
Ischaemum fasciculatum	5.00	17%	175.95
Imperata cylindrica	4.00	13%	134.55
Andropogon appendiculatus	4.50	15%	155.25
Bothriochloa insculpta	4.00	13%	134.55
Eragrostis racemosa	4.00	13%	134.55
Eragrostis capensis	4.50	15%	155.25
TOTAL	**30.00**	**100%**	**1035**

Table 6. The proportions and total plant numbers required for the category – Seasonal Zone

Seasonal Zone	Proportions	Individuals
Cyperus dives	30	43461
Cyperus laevigatus	10	14487
Cyperus sexangularis	10	14487
Cyperus solidus	10	14487
Cyperus sphaerospermus	20	28976
Pycreus nitidus	10	14487
Juncus dregeanus	5	7243
Bulbostylis hispidula	5	7243
TOTAL	**100**	**144867**

Table 7. The proportions and total plant numbers required for the category – Semi-permanent Zone

Semi-Permanent	Proportions	Individuals
Cyperus latifolius	25	6387
Cyperus dives	25	6387
Cyperus fastigiatus	10	2556
Eleocharis limosa	7.5	1917
Schoenoplectus erectus	10	2556
Carex cognata	5	1278
Juncus lomatophyllus	5	1278
Cyperus denudatus	5	1278
Berula erecta	2.5	639
Persicaria attenuata	2.5	639

Persicaria decipiens	2.5	639
TOTAL	**100**	**25550**

Table 8. The proportions and total plant numbers required for the category – Permanent Zone

Permanent Zone	Proportions	Individuals
Mariscus solidus	15	1278
Cladium mariscus	5	427
Cyperus dives	25	2130
Cyperus latifolius	15	1278
Phragmites australis	35	2982
Juncus lomatophyllus	5	427
TOTAL	**100**	**8533**

12.3 The Combined Bill of Quantities

Table 9. The quantities of grass seed and individual plants required for the re-vegetation of the wetlands and open spaces.

GRAMINOID SPECIES	KILOGRAMS
Andropogon appendiculatus	155.25
Bothriochloa insculpta	134.55
Eragrostis capensis	155.25
Eragrostis racemosa	134.55
Imperata cylindrica	134.55
Ischaemum fasciculatum	175.95
Setaria sphacelata	134.55
Total Kilograms of Grass Seed Required	**1035**
SEDGE SPECIES	**INDIVIDUALS**
Berula erecta	639
Bulbostylis hispidula	7243
Carex cognata	1278
Cladium mariscus	427
Cyperus denudatus	1278
Cyperus dives	51978
Cyperus fastigiatus	2556
Cyperus laevigatus	14487
Cyperus latifolius	7665
Cyperus sexangularis	14487
Cyperus solidus	14487
Cyperus sphaerospermus	28976
Eleocharis limosa	1917
Juncus dregeanus	7243
Juncus lomatophyllus	1705
Mariscus solidus	1278
Persicaria attenuata	639
Persicaria decipiens	639
Phragmites australis	2982
Pycreus nitidus	14487
Schoenoplectus erectus	2556
Total Sedge Individuals Required	**178950**

13 ALIEN PLANT ERADICATION AND CONTROL PROGRAMME

This alien eradication and control program comprises the following three steps:

13.1 Step 1

The first step of the Alien Plant Eradication Programme will be to undertake an inception and educational meeting, where the people employed to undertake this activity are able to identify the correct species as aliens and the manner in which to remove and control them. We would suggest the development of a series of flip cards to help with alien plant identification or utilise a company which has people available that already know which species are alien and require removal and management.

13.2 Step 2

The second step will be to identify the Alien Invasive Species and start a process of removing the individuals that occur on the site. The removal of the alien species must be in a stepwise manner and be undertaken within a single area at a time. This will ensure that all individuals are removed at the same time to reduce re-infestations. Further, the co-ordination of a single removal will mean that all seed that has not germinated will be of a similar age class when they do. This will provide significant benefit in aiding the control and management of these species. There are a number of methods that may be employed to undertake the activity of removing alien plant species and are listed in limited detail below.

13.2.1 Mechanical Methods

Hand-pulling

This method of removal is only really an option during the summer months and when the alien plant species that are requiring removal are very small, and their root system is not very well established. The only precautionary note here is that many alien plant species may look similar to indigenous species when they emerge, so the labour force must be extremely well versed in the individuals that will require removal.

Up-rooting

This method is similar to hand-pulling but is undertaken on slightly older individuals of the target species. It only has one drawback; a relatively large area can be disturbed with the soils being altered and opening the area up to re-infestation.

Lasso & Winch

This method is the upgraded version of the up-rooting, with the same principles applying, that is of trying to remove the entire plant with all the root system attached, to prevent re-growth. This can have a serious destabilizing effect on the receiving environment and should definitely not be undertaken on slopes or sandy soils.

Cutting / Slashing

This method is not a suitable method for control and long term management if used as a stand-alone technique because many of the alien plant species will simply coppice or re-sprout during the summer periods. Many, if not most, alien plants species are annual species, and through their natural life strategy (r-selected) are able to withstand disturbance, even extreme disturbance as in this instance.

Ring-barking

This involves the removal of bark in a 30 centimetre band. This technique is used to desiccate the plant through killing the phloem and xylem and thus preventing transpiration. Further it also facilitates pathogen infestation. It is very effective on large trees if undertaken correctly. This technique and two of the following techniques will be best suited for species growing within the flood plain, most notably *Melia azedarach, Schinus terebinthifolius, Eucalyptus* spp., and any other large alien invasive species, which requires removal.

Strip-barking

As with ring-barking, just at a larger scale.

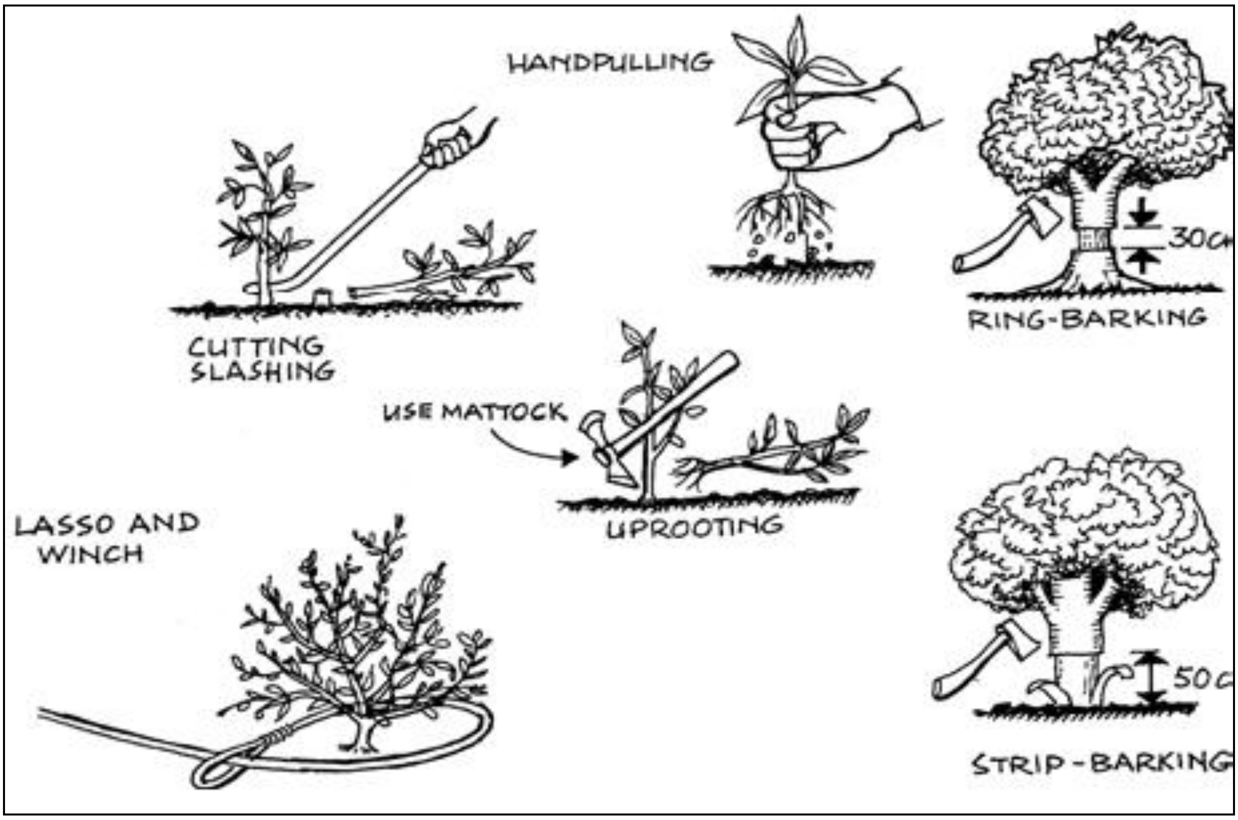

Figure 12: Schematic representation of six techniques used to remove alien invasive plant species.

Frilling / Girdling

Girdling and frilling are methods of killing standing trees that may be done with or without an herbicide. Girdling involves cutting a groove or notch into the trunk of a tree to interrupt the flow of sap between the roots and crown of the tree. The groove must completely encircle the trunk and should penetrate into the wood to a depth of at least 1.5 centimetres on small trees, and 2.5 to 4 centimetres on larger trees. Girdling can be done with an axe, panga or chain saw. When done with an axe or panga, the girdle is made by striking from above and below along a line around the trunk so that a notch of wood and bark is removed. The width of the notch varies with the size of the tree. Effective girdles may be as narrow as 2.5 to 5 centimetres on small-diameter trees, and as wide as 15 to 20 centimetres on very large-diameter trees. When a chain saw is used to girdle, two horizontal cuts between 5 and 10 centimetres apart are usually made completely around the tree when no herbicide is used and one horizontal cut is made completely around the tree when herbicide is used.

Frilling is a variation of girdling in which a series of downward angled cuts are made completely around the tree, leaving the partially severed bark and wood anchored at the bottom (**Fig. 17**). Frilling is done with an axe or panga.

By themselves, girdling and frilling are physical methods to deaden trees that require very little equipment and may be done without herbicides. Both techniques require considerable time to carry out, particularly with an axe or panga. Girdling with a chain saw is much faster. The effectiveness of girdling and frilling depends on the tree species and on the size and completeness of the girdle or frill. To be effective, girdles and frills must completely encircle the tree. Because frills can heal-over more easily, girdling is usually more effective.

The effectiveness of both girdling and frilling can be increased by using herbicides. With frilling and girdling, water soluble forms of herbicides are most commonly used to get maximum movement of herbicide within the plant. When using water-soluble herbicides, the herbicide/water mixture is commonly applied by squirting it on the girdle or frill until the cut surface is wet. Hand-held, spray bottles, such as those available at local garden stores, are ideal for applying herbicide to the girdle. Again, note that a single, rather than double chain saw girdle is used when a water soluble herbicide is to be applied.

We would recommend that certain individuals once frilled and or girdled are left as standing material, as these species will be utilised extensively by species of Egret and Heron for roosting and as hunting perches, feeding perches and potential nest sites for the numerous Fish Eagles which inhabit the Ohlanga River and Estuary.

13.2.2 Chemical Methods

The use of chemicals in controlling and removing of alien plant species should not be excluded as a possible option. Once the alien plant species are more manageable the use of chemicals should be reduced or excluded completely. The best option would be to pursue a combination of mechanical and chemical control in the early stages, especially when dealing with *Solanum mauritianum, Chromolaena odorata* and the numerous creeper species growing along the Ohlanga River and associated floodplain. The following creeper species require significant effort and control; *Cardiospermum grandiflorum, Passiflora* spp*., Ipomoea purpurea* and *Pereskia aculeata* growing in the wooded areas associated with the flood plain.

The best available herbicides that are currently utilised for the control of the above species are; Ranger®, Mamba®, Hatchet® and Roundup®. The only negative impact of the use of chemicals is that if used incorrectly may result in plant species being able to develop some form of resistance to the herbicide. If herbicides are used as a foliar spray, drift will cause non-target species to be impacted upon. The only method we would prescribe is the cutting of the plants prior to the treatment of the remaining stems using a “stem painting” technique.

It is imperative that the herbicides used are dye treated or that the end-user add a dye to ensure that all stems that have been treated are easily identified. Note, the application of the chemical solution must follow directly after the cutting of the vegetation. Therefore, a small area should be selected and all cutting and stem painting be undertaken on that area prior to moving to the next area.

It must also be ensured that should chemicals be used on site they must be;

- Stored in a secure and covered area, or off-site.
- The correct protective clothing is to be used in line with manufacturer’s instructions and / or the Occupational Health & Safety Act, Act 85 of 1993 (and amendments) and,
- All MSDS sheets are to be made available on site along with a Medical First Aid Kit.

The information below has been generated by the Working for Water programme, during extensive work at many sites in South Africa, and has been adapted for use in this alien eradication programme.

Person day norms have been derived based on results from the activity sampling exercises. They have been grouped into categories, based on:
- Treatment stage (initial or follow-up)
- Species type,
- Treatment type (cut stump, frill, spray etc.)

The norms below <u>do not</u> take local environmental constraints into account, i.e. slope, accessibility. The norm provided is the maximum number of person days it should take to clear a flat, accessible area. In areas that are unusually steep or inaccessible, local production norms must be applied. The species covered in the report is not reflective of all species currently being cleared by WFW, further activity sampling will improve on this list. Should a species in your area not be listed, but which could easily fit into, or is similar too, one of the categories provided in the tables, the production norm given in this document must be applied.

Should a species not be listed and which cannot easily fit into one of the categories or treatment methods, then local production norms should be applied.

The following categories & treatment types are covered in this report:

Table 10. Categories and treatment types for the various Alien Plant Management requirements as identified on site

CATEGORY		TREATMENT TYPED	
INITIAL CLEARING			
Herbaceous Species		Stacking	No stacking
Trees		Frill, no stacking	Frill, fell, stacking
Small Trees	Multi-stem	No stacking	Stacking
Mixed Species	Predominantly Herbaceous	No stacking	Stacking
	Predominantly Woody	No stacking	Stacking
FOLLOW-UP		Slashing & herbicide	Spray

The following is the maturity classification used:

Table 11. Description of the various categories of trees based on stems diameter (trunk) or a combination of height and Stem diameter.

TREES		
Maturity Class	**Stem Diameter (Ø)**	**Height**
Seedlings	0 – 1.5 cm	N/A
Young	1.6 – 5 cm	N/A
Adult	6 – 15 cm	<10 m
Mature Adult	16 – 30 cm	>10 m
X Large Adult	> 30 cm	>10 m

Person Day Norms – Herbaceous Species

Table 12. No stacking

Species	Size Class	Number of person days per hectare					
Chromolaena, Lantana, Rubus etc.		**Occasional**	**Very Scattered**	**Scattered**	**Medium**	**Dense**	**Closed**
	Seedling	1 (Spray)	1 (Spray)	2 (Spray)	3 (Spray)	4 (Spray)	4 (Spray)
Method:	**Young**	1	1	2	2.6	6	6
Plants are cut off at ground level and only the stem is treated. The brush is not cut up or stacked.	**Adult**	1.1	1.1	2	3	8	8
	Mature Adult	1.1	1.1	2	3	10	10

Table 13. Stacked

Species	Size Class	Number of person days per hectare					
Chromolaena, Lantana, Rubus etc.		**Occasional**	**Very Scattered**	**Scattered**	**Medium**	**Dense**	**Closed**
	Seedling	1 (Spray only)	1 (Spray only)	2 (Spray)	3 (Spray)	6 (Spray)	6 (Spray)
Method:	**Young**	1	1	2	3	6	6
Plants are cut off at ground level, the stem is treated, the brush cut up and stacked into heaps or brush lines.	**Adult**	2	2	2.7	6.8	18	18
	Mature Adult	2	2	2.7	7	20	20

Recommended Treatment Method – Herbaceous Species

Chromolaena, *Lantana* and other herbaceous species

- Plan the clearing work beforehand. Mark out what needs to be cleared in a day for the number of people in the team, depending on the density and method (see relevant table).

- Each person must carry their own small hand held herbicide applicator and must apply herbicide to cut stump of slashed plants.
- Keep the team working in a line, with the daily tasks pegged out where possible.
- Cut plants as low to ground as possible and apply herbicide to all cut surfaces and exposed roots.

When stacking:
- Stack/move the slashed brush off the stumps to aid herbicide application and re-establishment of indigenous plant species.

Person Day Norms – Trees

Table 14. Frill, no stacking

Species	Size Class	Number of person days per hectare					
Eucalyptus, Schinus, Acacia, Pinus, Melia, Morus, etc.		Occasional	Very Scattered	Scattered	Medium	Dense	Closed
	Seedlings	1 (Spray only)	1 (Spray only)	2 (Spray)	3 (Spray)	5 (Spray)	5 (Spray)
Method:	Young	1.5	1.5	3.6	10	26	26
>5 cm Frill and apply herbicide; <5 cm Slash and apply herbicide.	Adult	2.5	2.5	3.6	10	26	26
	Mature Adult	2.5	2.5	4	12	30	30
	X Large Adult	2.5	2.5	4	12	30	30

Table 15. Frill, Fell & Stack

Species	Size Class	Number of person days per hectare					
Eucalyptus, Schinus, Acacia, Pinus, Melia, Morus, etc.		Occasional	Very Scattered	Scattered	Medium	Dense	Closed
	Seedlings	1 (Spray only)	1 (Spray only)	2 (Spray)	3 (Spray)	5 (Spray)	5 (Spray)
Method:	Young	3	3	4	10	28	28
>5 cm Frill and apply herbicide; <5 cm Slash and apply herbicide.	Adult	3	3	4	12	28	28
	Mature Adult	3	3	4	12	28	28
All material must be removed from near watercourses, wetlands and 20m from any roadside. The rest of the area must be slashed and frilled.	X Large Adult	3	3	6	15	40	40

Recommended Treatment Method – Trees

- Plan the clearing work beforehand. Mark out what needs to be cleared in a day for the number of people in the team, depending on the density and method (see relevant table).
- Where possible, each person must carry their own small hand held herbicide applicator and must apply herbicide
- to cut stump of slashed plants or frilled trees.
- Send slashers through the area first and remove all the small, thin plants.
- Treat larger trees (50mm or greater) standing, frill.
- If brush cutters are used as part of the team, ensure they work a safe distance from the manual slashers.
- Keep the team working in a line, with the daily tasks pegged out where possible.
- If burning is planned, do not stack.
- If no burning is planned, stack the brush into brush lines on the contour 5m apart with a break in between each brush line
- Brush line of 5m every 20m in length. Stacking can take place underneath the frilled trees.
- Those sites where the trees must be felled, remove the brush out of the 20-year flood line from a river or 20 m from a roadside. The rest of the stand can be frilled.

Person Day Norms – Small Trees

Table 16. Multi-stems, no stacking

Species	**Size Class**	**Number of person days per hectare**					
Solanum, Psidium, small *Schinus* tree		**Occasional**	**Very Scattered**	**Scattered**	**Medium**	**Dense**	**Closed**
	Seedlings	1 (Spray only)	1 (Spray only)	2 (Spray)	3 (Spray)	5 (Spray)	5 (Spray)
Method:	**Young**	2	2	5	12	12	12
>5 cm frill and apply herbicide; <5 cm slash and apply herbicide	**Adult**	3	3	6	12	13	13
	Mature Adult	4	4	7	12	15	15

Recommended Treatment Norms – Small Trees

- Plan the clearing work beforehand. Mark out what needs to be cleared in a day for the number of people in the team, depending on the density (see relevant table).
- Send slashers through the area first, if possible, and remove all the small, thin plants.
- Keep the team working in a line, with the daily tasks pegged out where possible.
- Cut plants as low to ground as possible and apply herbicide to all cut surfaces, bark and exposed roots.
- Stack/move the slashed brush off the stumps to aid herbicide application and re-establishment of indigenous plant species
- Stack the brush into brush lines on the contour 5m apart with a break in the brush line of 5m every 20 m in length.
- If brush cutters / chainsaws used as part of the team, ensure they work a safe distance from the manual slashers.

Person Day Norms – Mixed Species

Table 17. Predominantly herbaceous, no stacking

Species	**Size Class**	**Number of person days per hectare**					
Mixed species, predominantly herbaceous		**Occasional**	**Very Scattered**	**Scattered**	**Medium**	**Dense**	**Closed**
	Seedlings	1 (Spray only)	1 (Spray only)	2 (Spray)	3 (Spray)	4 (Spray)	4 (Spray)
Method:	**Young**	1.1	1.1	2	2.6	7	7
Plants are cut off at ground level and only the stem is treated. The brush is not cut up or stacked. >5 cm frill and apply herbicide; <5 cm Slash and apply herbicide	**Adult**	1.1	1.1	2	2.6	7	7
	Mature Adult	1.1	1.1	2	2.6	7	7

Table 18. Predominantly herbaceous, stacking

Species	**Size Class**	**Number of person days per hectare**					
Mixed species, predominantly herbaceous		**Occasional**	**Very Scattered**	**Scattered**	**Medium**	**Dense**	**Closed**
	Seedlings	1 (Spray only)	1 (Spray only)	2 (Spray)	3 (Spray)	4 (Spray)	4 (Spray)
Method:	**Young**	1.3	1.3	2.7	6.8	18	18
Plants are cut off at ground level, the stem is treated, the brush cut up and stacked into heaps or brush lines. Where necessary, brush is removed from river areas and roadsides. >5 cm Frill and apply herbicide; <5 cm Slash and apply herbicide.	**Adult**	1.3	1.3	3	6.8	18	18
	Mature Adult	1.3	1.3	3	6.8	18	18

Table 19. Predominantly woody, no stacking

Species	**Size Class**	**Number of person days per hectare**					
Mixed Spp, predominantly woody		**Occasional**	**Very Scattered**	**Scattered**	**Medium**	**Dense**	**Closed**
	Seedlings	1 (Spray only)	1 (Spray only)	2 (Spray)	3 (Spray)	4 (Spray)	4 (Spray)
Method:	**Young**	3	3	3.6	9	24	24
No removal of material from river courses or roadsides. >5 cm Frill and apply herbicide; <5 cm Slash and apply herbicide.	**Adult**	3	3	3.7	10	26	26
	Mature Adult	3.5	3.5	3.9	10	26	26

Table 20. Predominantly woody, stacking

Species	**Size Class**	**Number of person days per hectare**					
Mixed Spp, predominantly woody		**Occasional**	**Very Scattered**	**Scattered**	**Medium**	**Dense**	**Closed**
	Seedlings	1 (Spray only)	1 (Spray only)	2 (Spray)	3 (Spray)	4 (Spray)	4 (Spray)
Method:	**Young**	3	3	4.2	10.5	28	28
All material is removed from the agreed flood line or 20m from any roadside. The rest of the area must be slashed and frilled. >5 cm Frill and apply herbicide; <5 cm Slash and apply herbicide	**Adult**	4	4	6	15	28	28
	Mature Adult	4	4	6	15	40	40

Recommended Treatment Methods – Mixed Species

Mixed species, predominantly herbaceous

- Plan the clearing work beforehand. Mark out what needs to be cleared in a day for the number of people in the team, depending on the density and method (see relevant table).
- Each person to carry own small hand held herbicide applicator, to apply herbicide to cut stump of slashed plants.
- Keep the team working in a line, with the daily tasks pegged out where possible.
- Cut plants as low to ground as possible and apply herbicide to all cut surfaces and exposed roots.
- Stack/move the slashed brush off the stumps to aid herbicide application and re-establishment of indigenous plant species.

Treat larger trees (50 mm or greater) standing, frill.

- Those sites where the trees must be felled, remove the brush out of the 100-year flood line from a river or 30 m from a roadside. The rest of the stand can be frilled.

Mixed species, predominantly woody

- Plan the clearing work beforehand. Mark out what needs to be cleared in a day for the number of people in the team, depending on the density and method (see relevant table).
- Where possible, each person to carry their own small hand held herbicide applicator, to apply herbicide to cut stump of slashed plants or frilled trees.
- Send slashers through the area first and remove all the small, thin plants.
- Treat larger trees (50 mm or greater) standing, frill.
- If brush cutters used as part of the team, ensure safe working distance from the manual slashers.
- Keep the team working in a line, with the daily tasks pegged out where possible.
- If burning is planned, do not stack. If no burning, stack the brush into brush lines on the contour 5m apart with a break in the brush line of 5 m every 20 m in length. Stacking can take place underneath the frilled trees.
- Those sites where the trees must be felled, remove the brush out of the 100-year flood line from a river or 30 m from a roadside. The rest of the stand can be frilled.

Follow up Person Day Norms

Follow-up norms have not been grouped per species, but rather by treatment type:

- Slash, herbicide & Spray
- Spray only

If the operation is carried out timeously, the follow-up method used will be similar no matter which species was initially treated. If follow-up is not carried out timeously and the norms below cannot be used, the norms for initial clearing should be used. An explanation must be provided as to why the site was lost to follow-up.

Table 21. Slash & herbicide

Species	Size Class	Number of person days per hectare					
All		Occasional	Very Scattered	Scattered	Medium	Dense	Closed
	Seedlings	3	3	3	6	8	8
Method:	Young	3	3	3	6	8	8
Some plants are slashed and herbicide applied to cut stump where needed. Those plants not needed to be slashed are sprayed.	Adult	3	3	3	6	8	8
	Mature Adult	3	3	3	6	8	8

Table 22. Spray Only

Species	Size Class	Number of person days per hectare					
All		Occasional	Very Scattered	Scattered	Medium	Dense	Closed
	Seedlings	1	1	2	3	5	5
Method:	Young	1	1	2	3	5	5
All re-growth or regeneration is sprayed	Adult	1	1	2	3	5	5
	Mature Adult	1	1	2	3	5	5

Some of the more commonly available herbicides, which are considered to be safe to the environment if correctly utilised.

Table 23. Commonly available registered Herbicides

Active ingredient	Name of herbicide
Metsulfron-methyl	Brushoff / Climax
Imazapyr	Chopper / Hatchet
Triclopor	Garlon / Tricion / Timbrel
Glycophosphate @ 360gm/L	Roundup / Mamba / Springbok

13.3 Step 3

The third step in the management of alien invasive species is to assess the degree of success that is being achieved with the current management plan and style of removals. The monitoring of the alien invasive species should be undertaken yearly, and at the same time each year. The monitoring should encompass the following:

- Establishing species identity;
- Whether the species has been recorded in this area previously or not;
- Counting the number of stems per unit area
- Assessing the general health of the plants, and;
- Assess whether natural succession of indigenous plants is occurring in response to the removal of alien vegetation and on-going management.

14 WETLAND CONSERVATION MANAGEMENT PLAN

The wetland conservation management plan should focus on two aspects: measures to reduce human disturbances to the wetland and the design of a burning regime for the wetland conservation areas.

14.1 Human Disturbance Minimisation Measures

To minimize human disturbances to the wetlands and buffer zones (e.g. illegal dumping, informal path creation, vegetation clearing and trampling), the wetland conservation area needs to be clearly demarcated for the benefit of the local residents and businesses. Prohibition and educational signs should be established at strategic places along the fence and buffer zones to clearly demarcate the conservation area for the benefit of the local residents and businesses as well as educate the local residents on the value of the wetlands. A caveat to this is the need to ensure that controlled access to these areas is still maintained to make management of these areas possible.

14.2 Fire Management Plan

As the wetland buffers and temporary wetland areas are proposed to be grass dominated areas, fire is recommended as a management tool to both maintain the health of the grasslands and control bush encroachment, especially in the form of alien invasive bush encroachment.

The wetland buffers and temporary zones must be divided into 8 burning compartments or blocks and two different compartments should be burnt every year until the cycle starts again. Ideally each burning compartment should include a representative area of buffer zone and temporary wetland. The burning method should be a head burn and should be undertaken between late autumn (May) and early spring (September). Furthermore, a compartment burnt in late autumn in one year should not be burnt in the same season when it is next burnt.

Appropriately sized fire breaks must be designed and established around the wetland and its buffers to reduce the risk of unplanned burns from crossing into the wetland. The fire breaks must be burnt annually between autumn and early winter.

Emergency response measures must be draw up in the cases of runaway fires within the wetland conservation area. These measures should be finalised in more detail as part of the scope of works of the contractor commissioned by the applicant to do the burning.

If burning is not feasible, then mowing must be used as an alternative management tool to burning. If mowing is proposed, the buffers and temporary wetland areas should also be divided into 8 compartments and two different compartments should be mowed every year until the cycle starts again. The grass should be mowed to a length no shorter than 15cm.

15 CONSTRUCTION MANAGEMENT PLAN

15.1 Road Crossing Removal

Existing pipe and box culverts wetland crossings and their associated fill material not included in the proposed Phase 2 development must be removed prior to rehabilitation commencing. The following measures must be implemented and adhered to during the removal of the culverts and road fill material:

- The removal of the culverts and fill from the wetland crossings should be undertaken during the winter months (between the months of April and August).
- The area to be disturbed during construction i.e. the construction footprint or right-of way (ROW), must be as narrow as possible and must be demarcated prior to construction commencing using 'snow fencing'.
- Areas outside of the construction footprint must not be disturbed and considered 'no-go' zones.

- The running track must be as narrow as possible (approximately the width of the excavator within safety limits).
- The demarcated ROW must be approved by the ECO prior to construction within the wetland commencing.
- Once the culverts and fill have been removed, the compacted soils within the construction ROW must be ripped to a depth of 30cm as the excavator is working backwards out of the wetland.
- The wetland areas must be grassed immediately after the completion of shaping and ripping as per the re-vegetation programme.

15.2 Intervention Construction

The Working for Wetlands Standard Construction Environmental Management Plan for Wetland Rehabilitation Projects should be used to guide the construction of the interventions by the appointed contractor.

In addition, the following measures must be implemented and adhered to during the construction of the concrete weirs, gabion weirs and earthen plugs within the wetlands:

- The construction of the rehabilitation interventions should be undertaken during the winter months (between the months of April and August).
- The area to be disturbed during construction i.e. the construction footprint or right-of way (ROW), must be as narrow as possible and must be demarcated prior to construction commencing using 'snow fencing'.
- Areas outside of the construction footprint must not be disturbed and considered 'no-go' zones.
- The running track must be as narrow as possible (approximately the width of the excavator within safety limits).
- The demarcated ROW must be approved by the ECO prior to construction within the wetland commencing.
- Once construction is completed, the compacted soils within the construction ROW must be ripped to a depth of 30cm as the excavator is working backwards out of the wetland.
- The wetland areas must be grassed immediately after the completion of shaping and ripping as per the re-vegetation programme.

16 MONITORING PROGRAMME

All rehabilitation sites within a wetland, no matter how small, will require some form of monitoring for at least the lifespan of the project. This is to ensure that the rehabilitation interventions selected to achieve the rehabilitation goals set out for the wetland have been implemented effectively and more importantly to determine whether the rehabilitation interventions are achieving the rehabilitation goals and improving the health and functionality of the system over time. Regular monitoring also allows one to identify the need for corrective action for problems that may arise during the course of rehabilitation programme.

Given the nature of the surrounding land use, monitoring is even more important in ensuring that disturbance impacts associated with local settlements do not take place.

This monitoring programme includes the following information:

- indicators to be measured;
- frequency, interval and timing of monitoring; and
- evaluation procedure.

16.1 Indicators to be Measured

16.1.1 Construction and Implementation

During the construction and implementation of the various rehabilitation interventions and measures, monitoring will need to take place to ensure that the interventions are being implemented as per the designs and programmes of this plan.

16.1.2 Structural integrity

Following construction and implementation, the structures must be monitored to ensure their stability in the long term.

16.1.3 Fixed-point photography

To illustrate the improvement in the wetland habitat associated with the rehabilitation interventions, fixed-point photography monitoring should be used.

Locating Photo Points:

The following guidelines should be followed when locating photographic points across the wetland units for fixed-point photographs:

- photo-points should be selected at various locations throughout the rehabilitation site and at points that will be easily accessible at all times;
- record the geographical co-ordinates of each point using a GPS, preferbly accurate to within 3m. This provides any individual with the information required to navigate to the exact location of each photo point; and
- a permanent field marker should be placed in the ground at each point, to ensure that photos are always taken from exactly the same point. If possible the orientation of the photo at the point should be recorded on the marker.

Taking Fixed-Point Photographs:

The following guidelines should be followed when implementing fixed-point photography for monitoring purposes:

- the orientation of the photographer should be recorded;
- use of the same zoom ratio each time. If this is not possible, record the settings used. The camera should preferably be located on a tripod at a fixed height;
- when the frequency of monitoring increases to an annual interval, photographs should be taken at roughly the same time of year and at the same time of the day, and under similar weather conditions. This would limit the variability of the wetland habitat associated with vegetative and hydrological changes linked to seasons;
- a standard object, such as a soil auger or a metre rule should be included in the photograph as a reference for scale; and
- record relevant information about factors that may influence features in the photograph (e.g. a recent fire, late or early rains, etc.), especially those relating to the appearance of the site.

16.1.4 Wetland Health

To substantiate the argument that the rehabilitation of the wetland units has offset the impacts associated with the proposed Sibaya development, an assessment of the wetland unit's health using the WET-Health tool developed by Macfarlane *et al* (2009) should be undertaken a year and three years after the completion of the rehabilitation.

16.2 Frequency, Interval and Timing of Monitoring

It is important that a baseline for both the fixed-point photographs and a WET-Health Assessment be undertaken for all the wetland units before the construction of the interventions for comparative evaluation purposes.

With regards to time frames for monitoring it is important that monitoring take place during the initial construction stages of the rehabilitation project as well as operational / recovery phase. During the construction phase, monitoring should be more regular to identify issues quickly and have them remedied. Once excavation and construction activities are complete in the wetland, and these areas have been ripped and replanted, then assessments can become less frequent as distinct changes will take longer to manifest.

The frequency and nature of the monitoring will allow for accurate assessment of the various stages of the project to help guide the long term success of the rehabilitation. Frequent initial monitoring will ensure that a solid base is formed and that the wetland is given the best opportunity to improve. During the recovery phase, monitoring will make sure that the various structures are performing well and that there are no fundamental flaws in the rehabilitation process. The final, long term monitoring will assess the overall success of the rehabilitation program, once the system has had time to stabilise. A monitoring programme is provided in Table 25 below.

Table 24. : A basic framework for monitoring of the wetland rehabilitation plan

Phasing	Frequency	Assessment	Duration
Pre-Construction Phase	Before intervention construction commences	• Baseline fixed-point photography • Baseline WET-Health Assessment	
Intervention Construction and Implementation Phase	Weekly	• Intervention construction management monitoring • Alien plant removal • Re-vegetation	Duration of remediation activities (monthly report)
Recovery Phase	Monthly	• Structural integrity monitoring • Alien plant re-emergence monitoring and removal • Re-vegetation success monitoring	6 x 1 month visits (monthly report)
Operational Phase	Annual	• 2 x WET-Health Assessments (first and third years after construction) • Alien plant re-emergence monitoring and removal • Fence integrity monitoring and repair	Annual visits (report per visit)

16.3 Evaluation Procedure

In order to demonstrate that the proposed rehabilitation interventions will result in a gain in wetland integrity and functional habitat for the wetland being rehabilitated, it is recommended that the hectare equivalents concept be used to measure this gain in healthy and functional wetland habitat. The hectare equivalents must be derived for the current scenario and then used as the baseline to measure the hectare equivalent gains for the specific wetlands as well as ensure that the gain in functional wetland is sufficient offset mitigation for the loss of wetlands proposed across the Phase 2 site.

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