TONGAAT HULETT DEVELOPMENTS

Cornubia Mixed Use Development (Phase 2) in the eThekwini Municipality

Final Wetland & Open Space Rehabilitation Plan

Issue date: 20th February 2015
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Project No.: 12154

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: 20/02/2015

Date:	20th February 2015
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For:	Tongaat Hulett Developments

DISCLAIMER

Original Wetland Delination and Completed Assessments

This rehabilitation plan is based on findings of the original wetland delineation assessment, compiled by NMH Consulting in 2005. It is also recommended that this document is read in conjunction with the numerous completed wetland assessment reports for the overarching Cornubia Development.

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.

TONGAAT HULETT DEVELOPMENTS

CORNUBIA MIXED USE DEVELOPMENT - PHASE 2
IN THE ETHEKWINI MUNICIPALITY

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 an 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 a 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

CORNUBIA MIXED USE DEVELOPMENT - PHASE 2 IN THE ETHEKWINI MUNICIPALITY

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 Phase 2 of the proposed Cornubia Mixed-Use Development (**Figure 1**). These wetlands units were delineated by NMH Consulting in December 2005.

In addition, SiVEST have also been appointed to compile a rehabilitation and management plan for the proposed Open Spaces within Phase 2. The Open Space rehabilitation plan has been included in this report.

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.

The objectives of the open space rehabilitation plan are to:

- Compile a re-vegetation programme for the open spaces not included as part of the wetland rehabilitation plan;
- Incorporate these open spaces into the wetland alien eradication programme;
- Provide a detailed bill of quantities for the rehabilitation of the open spaces; and
- Incorporate these open spaces into the wetland conservation management plan.

Figure 1: Cornubia Phase 2 Overview

3 STUDY AREA

3.1 Overview

Cornubia Phase 2 covers some 926 ha of which most is planted to sugar cane with the exception of the most prevalent drainage lines, Ohlanga River flood plain, or where soil or topography is unsuitable for sugar cane production.The site also includes limited stands of woody vegetation along with the Dube East Settlement (Blackburn) near the N2 Highway.

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 989 mm and mean annual potential evaporation is 1659 mm.

3.3 Geology and Soils

The ENPAT GIS Database (DEAT, 2001) indicates that Phase 2 is predominantly underlain by Pietermaritzburg Shale with the northern parts underlain by alluvium associated with the Ohlanga River floodplain. Small areas of tillite of the Dwyka Formation, sandstone of the Vryheid Formation, dolerite and dune cordon sand are also expected. It is expected that the soils overlying the shales and dolerites comprise silty clay and the alluvial soils within the Ohlanga River floodplain comprise loamy sand to well sorted sand. 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.

3.4 Topography and Drainage

The Phase 2 site is undulating with broad and rounded hilltops and ridge lines separated by broad, moderately sloping valleys and valley heads. Elevation ranges from around 150 m down to 8 m amsl (**Figure 2**). Mean average slope within Phase 2, is approximately 13% and a maximum slope of 77% (**Figure 3)**. The majority of the site drains towards the Ohlanga River, to the north with a small catchment area that contributes to Marshall Dam being the most notable exception. Artificial drainage channels have been established within all of 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 Phase 2 has been severely 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.

For ease of assessment and discussion Phase 2 has been delineated into smaller sub-catchments and for consistency have been labelled, as far as possible, based on the original Wetland Delineation Report (**NMH, 2005**) (**Figure 4**).

Of the 926 ha which constitute Cornubia Phase 2, 123.3 ha (13.3%) is defined as wetland (**Figure 5**). Hydro-geomorphic (HGM) units within this land use class include floodplain, channelled and un-channelled valley bottoms and hillside seeps. Again for consistency these units have been labelled based on their contributing catchment as well as on names used in previous assessments.

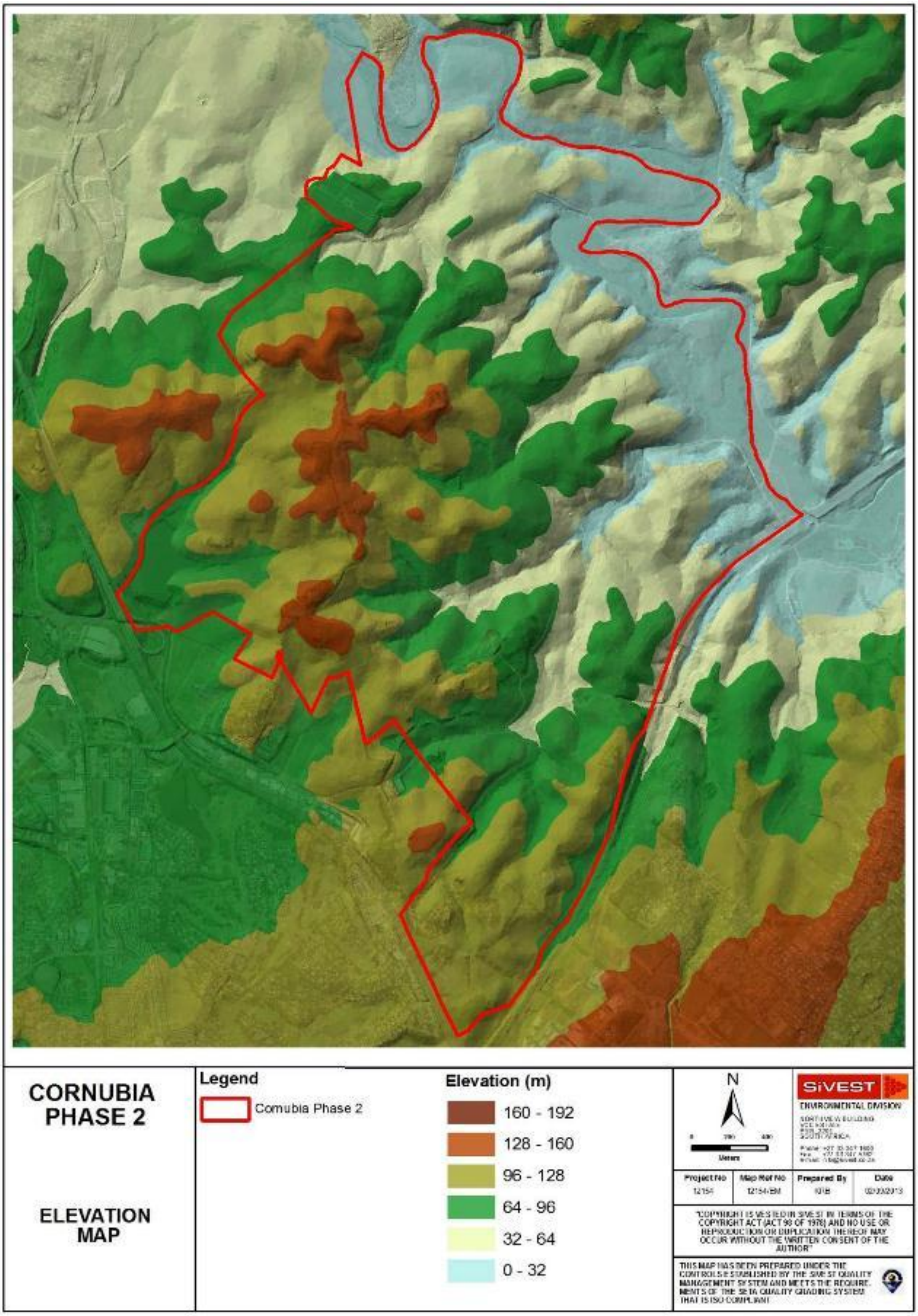

Figure 2: Elevation Map

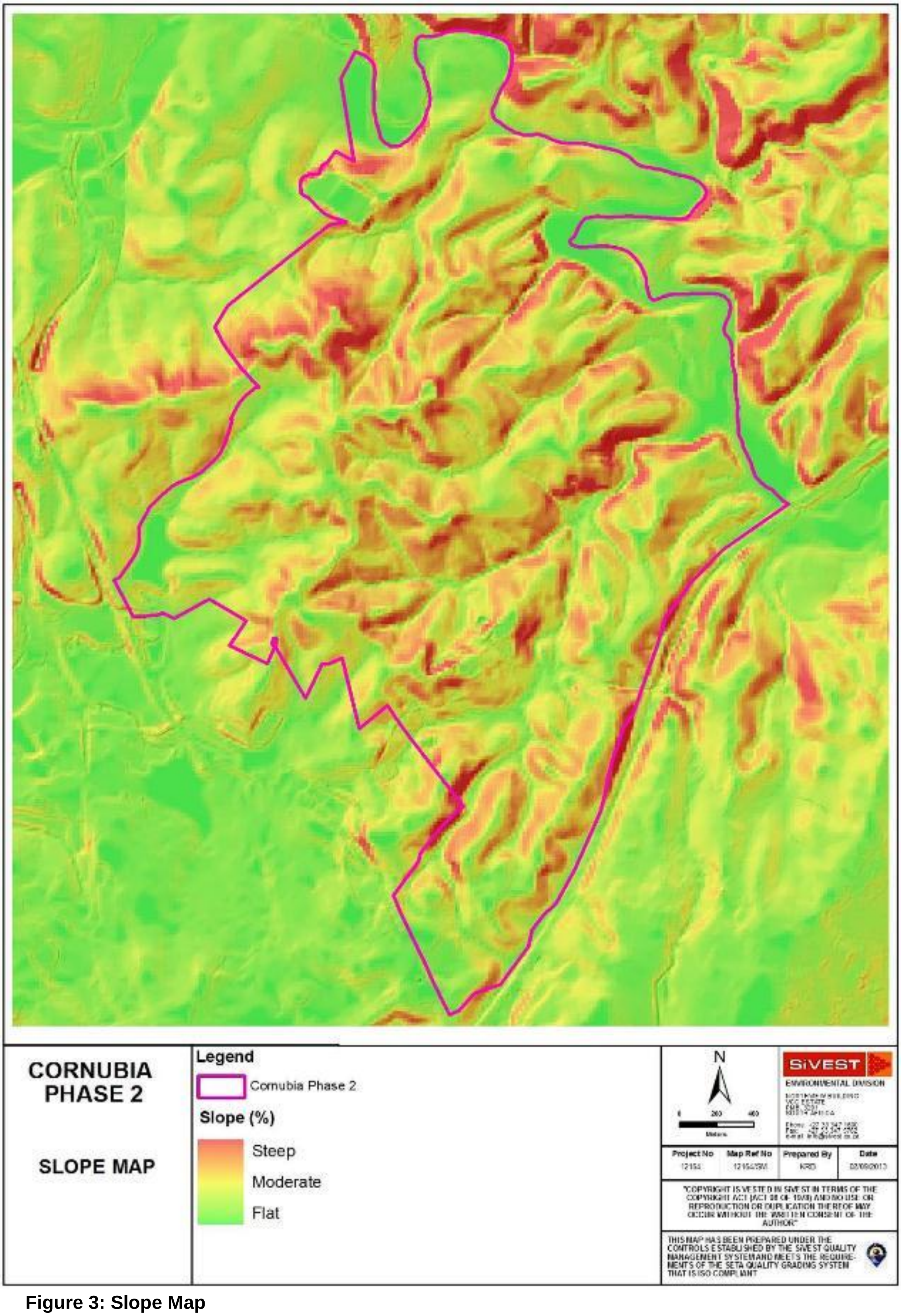

Figure 3: Slope Map

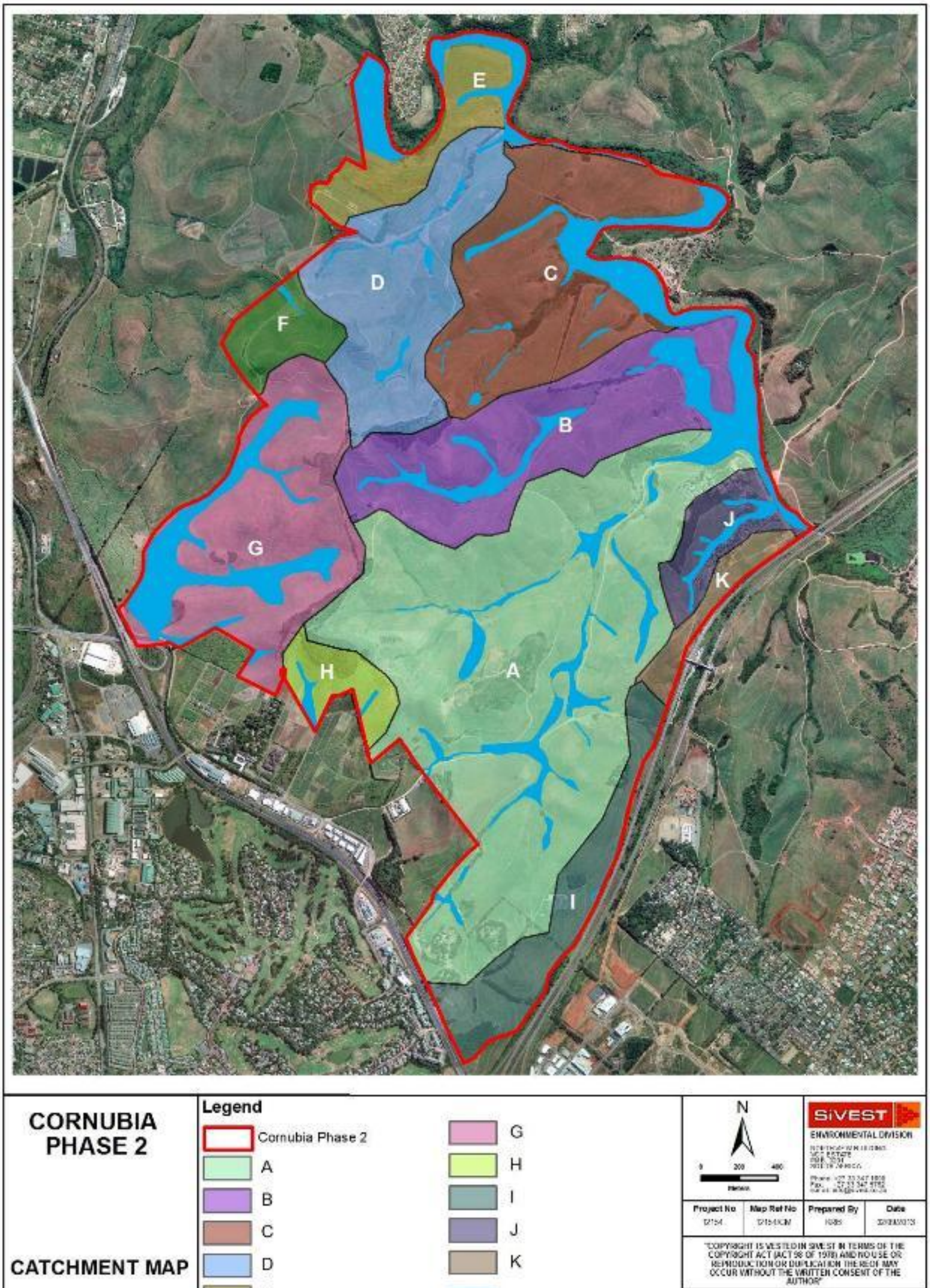

Figure 4: Catchment Map

Figure 5: 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). 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*. Erosion within this veld type is low to moderate.

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 riparian area of the Ohlanga River, fragments along some of the existing streams and on hilltops characterised by shallow soils. Natural communities that still exist appear to be maintained annually, as part of the estates maintenance. With the exception of the floodplain wetland immediately bordering the Ohlanga River, 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 METHODS

4.1 Wetland Rehabilitation Plan

4.1.1 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 9.3 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 Cornubia Phase 2 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.

4.1.2 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

4.1.3 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 6**). 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 6**) 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 7**. This zonation was repeated for all wetland units located within Cornubia Phase 2.

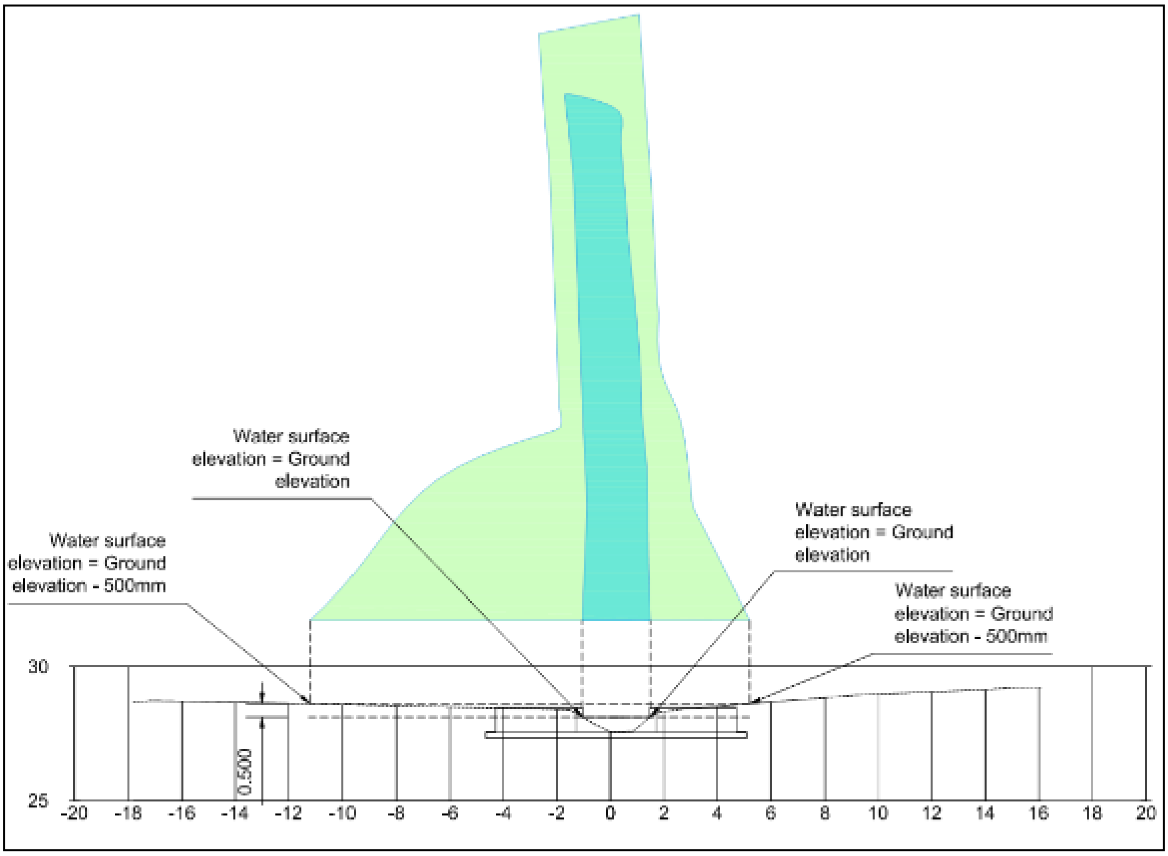

Figure 6: A schematic diagram showing how the post-rehabilitation extent of the permanent and semi-permanent wetland zones was predicted

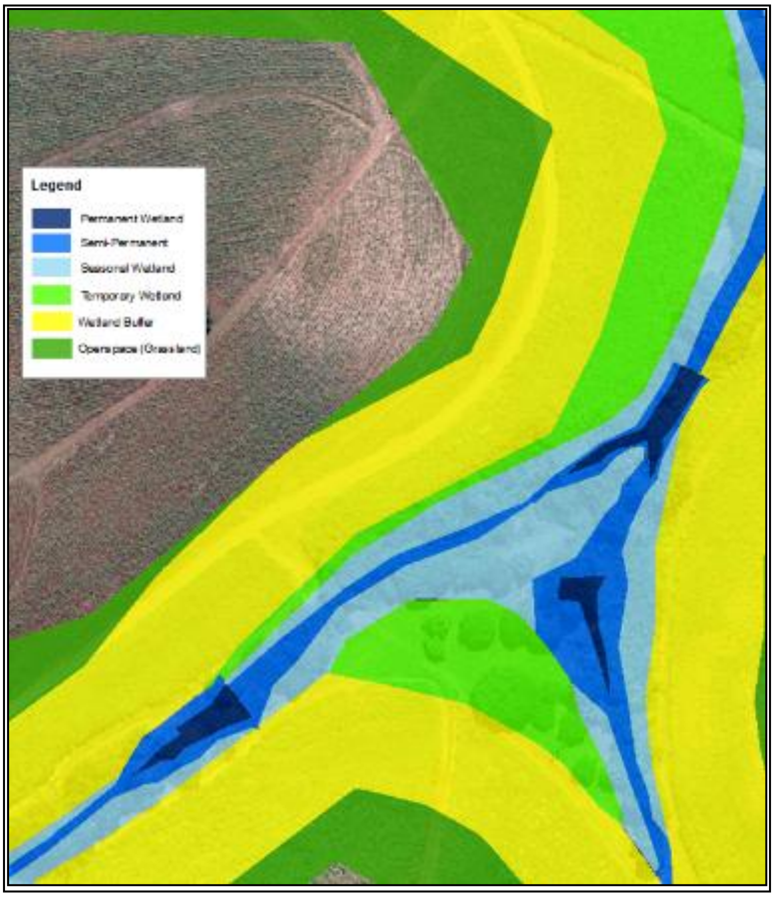

Figure 7: Example of wetland and open space zonation completed for the entire Phase 2

5 OFFSETTING WETLAND LOSS VIA REHABILITATION

The proposed Greater Cornubia Development (Phase 1, Phase 2 and Retail Park) 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. After receiving comments from key stake holders it has been decided to implement an area for area approach using a 1:3 offset ratio, as recommended by *Ezemvelo* KZN Wildlife. 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.

Although the overarching Greater Cornubia Development has been phased, the impacts, losses and potential rehabilitation of all wetland areas must be considered in order to adequately assess the cumulative impacts. **Table 1**, below summarises the current wetland losses and rehabilitation potential for the entire Cornubia Project.

All wetland units within the Retail Park Development Footprint will be lost and thus there is no opportunity to offset the loss of wetlands within Retail Park Site. As a result the wetland loss associated with the Retail Park must be offset within Phase 2 (**Figure 8**). Even though greater development has been phased, from an environmental perspective the Cornubia Site and particularly the Retail Park needs to be viewed as a single entity. This holistic view will allow improved management of wetland resources and will also encourage consistency in terms of rehabilitation and management techniques. The wetland units, which will be rehabilitated to offset the loss associated with the retail park have already been of nominated as part of the Retail Park Impact Assessment (**SiVEST, 2013**). These nominated units are shown in **Figure 9** and total **12 ha**.

The current layout for Phase 2 and the Retail park indicates that **91.59 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 **96.31 ha,** this is some **4.72 ha** more than the required minimum. This equates to a **1:3.15** offset ratio, which is greater than the stipulated 1:3 offset ratio. Thus the overall wetland losses can be 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 Cornubia (LUM, October 2014)

Phase	Wetland Area (ha)	Wetland Loss (ha)	Required Wetland Area to be Rehabilitated at the 1:3 offset Ratio (ha)	Wetland Area Available for Rehabilitation
Cornubia Phase 1	53.9	7.54	22.62	46.36
Cornubia Phase 2	123.3	24.05	72.15	99.25
Cornubia Retail Park	3.54	3.54	10.62	0
Combined Cornubia Phase 2 and Retail Park	126.84	30.53	91.59	96.31

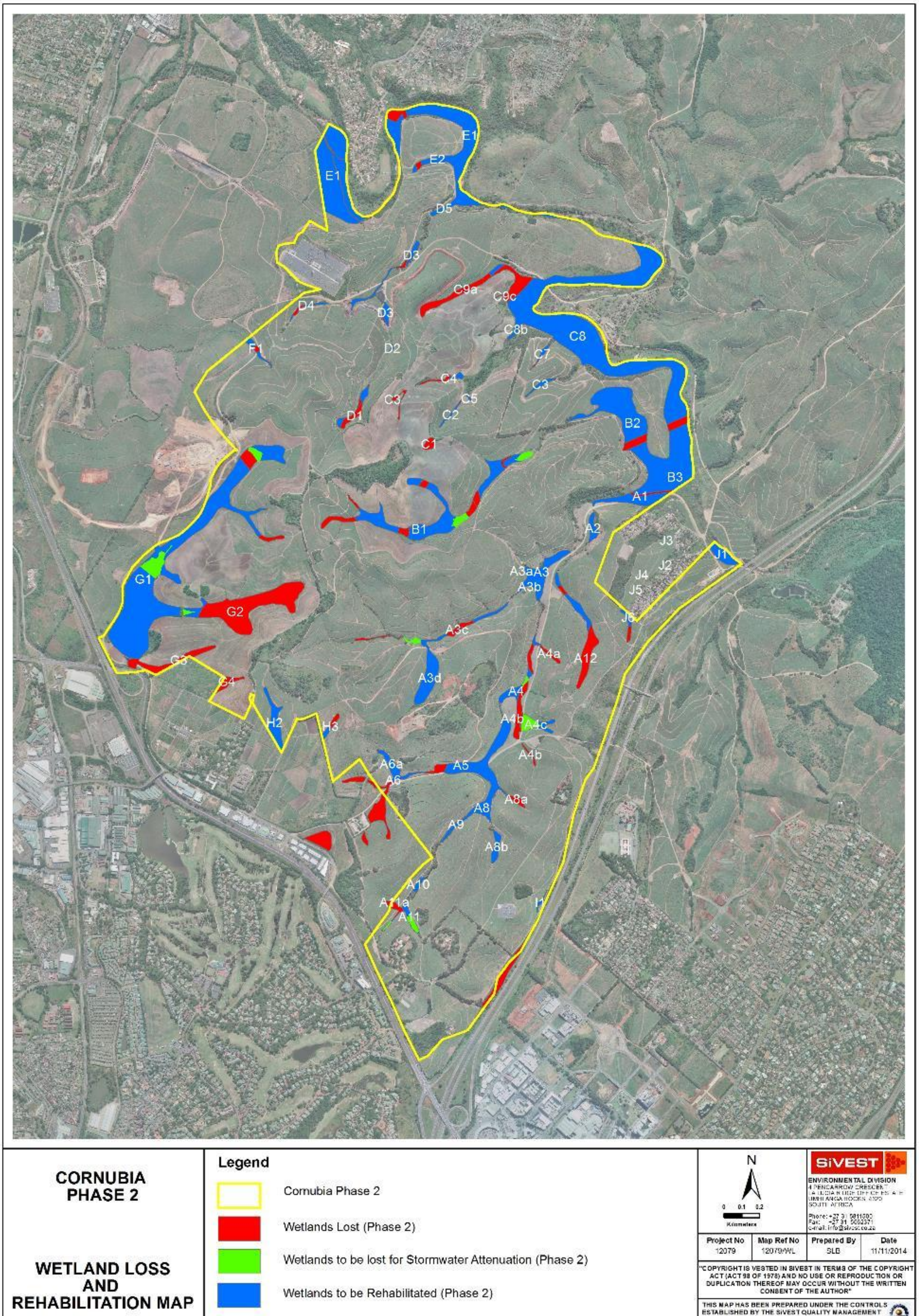

Figure 8: Wetland Loss Map

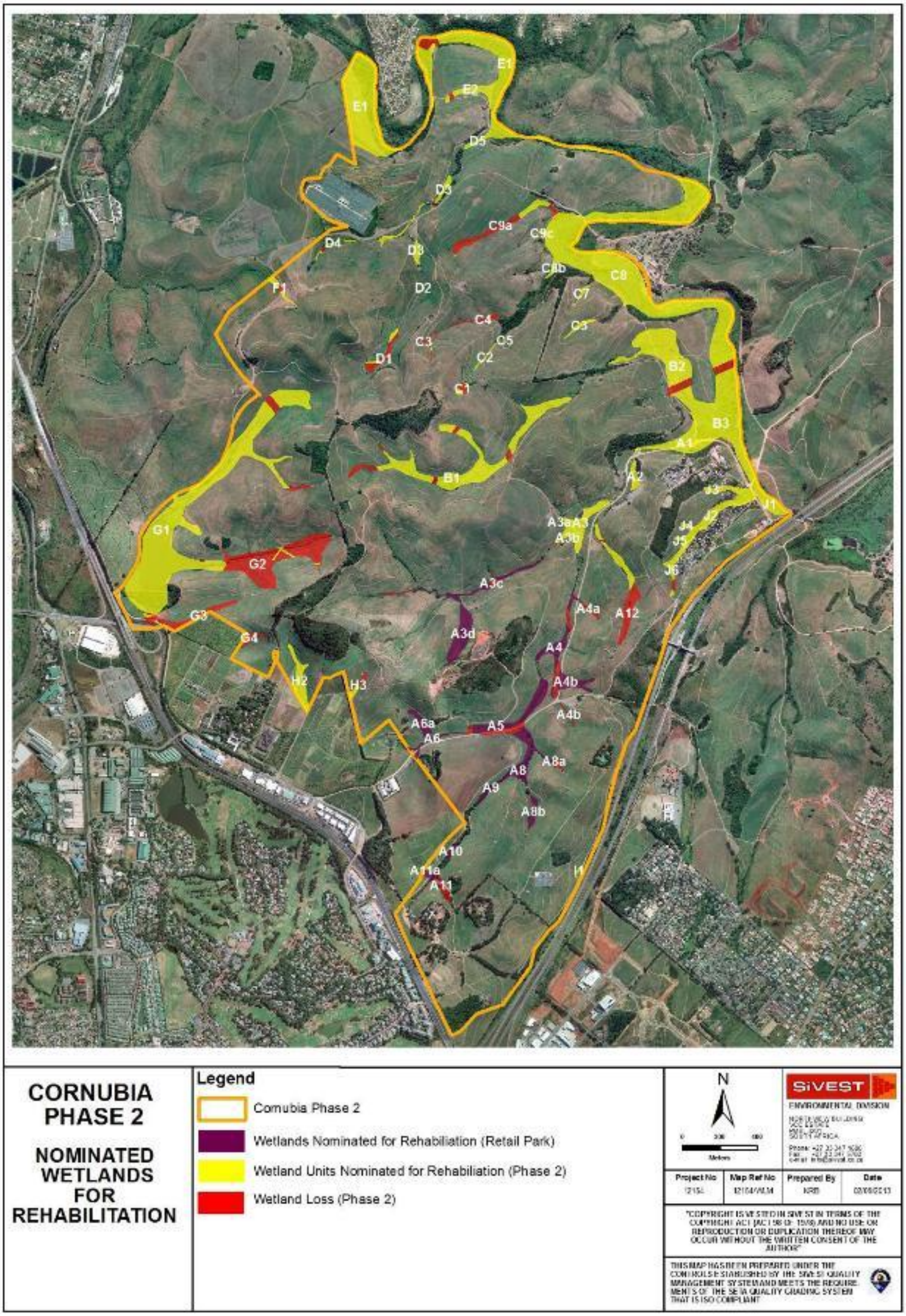

Figure 9: Nominated Wetlands for Rehabilitation

6 CAUSES OF WETLAND DEGRADATION

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

Catchment	Wetland Unit	HGM	Impacts on Wetland Hydrology	Impacts On Wetland Geomorphology	Impacts On Wetland Vegetation
A	A1	Channelled Valley Bottom	• Cultivation • Flow Confinement (Culvert) • Road Runoff, and loss of wetland • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • Roads (Hardening) • Scour • General disturbance, crossings	• High prevalence of alien vegetation • Cultivation (removal and reduction number of spp.)
	A10	Channelled Valley Bottom	• Cultivation • Flow Confinement • Road Runoff, and loss of wetland • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • Roads (Hardening) • Scour • General disturbance, crossings	• Low prevalence of alien vegetation • Cultivation (removal and reduction number of spp.)
	A11	Channelled Valley Bottom	• Cultivation in channel • Flow Confinement (Culvert) • Road Runoff • Incisment • Artificial drainage • Decrease in wetland saturation (zonation)	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • Roads (Hardening and source of sediment) • Scour	• Modprevalence of alien vegetation • Cultivation (removal and reduction number of spp.)
	A11a	Valley Head Seep	• Cultivation • Artificial drainage •	• Canalisation (increased erosion in the channel)	• Cultivation (removal and reduction number of spp.)
	A12	Channelled Valley Bottom	• Cultivation • Flow Confinement (Culvert) • Road Runoff • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • Roads (Hardening) • Scour	• Moderate prevalence of alien vegetation • Cultivation (removal and reduction number of spp.) • Stabilising plant species planted on banks
	A2	Channelled Valley Bottom	• Cultivation • Flow Confinement (Culvert) • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel)	• Moderate prevalence of alien vegetation • Cultivation (removal and reduction number of spp.) •
	A3	Channelled Valley Bottom	• Cultivation • Flow Confinement (Culvert) • Road Runoff • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • Roads (Hardening) • General disturbance, crossings	• Low prevalence of alien vegetation • Cultivation (removal and reduction number of spp.)
	A3a	Valley Head Seep	• Cultivation • Artificial drainage • Decrease in wetland saturation (zonation)	• Canalisation (increased erosion in the channel)	• Cultivation (removal and reduction number of spp.)
	A3b	Channelled Valley Bottom	• Cultivation • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment	• Low prevalence of alien vegetation • Cultivation (removal and reduction number of spp.)
	A3c	Channelled Valley Bottom	• Cultivation • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment	• High prevalence of alien vegetation • Cultivation (removal and reduction number of spp.)
	A3d	Channelled Valley Bottom	• Cultivation • Flow Confinement (Culvert) • Road Runoff • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • Roads (Hardening) • General disturbance	• Low prevalence of alien vegetation • Cultivation (removal and reduction number of spp.)
	A4	Channelled Valley Bottom	• Cultivation • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment •	• Low prevalence of alien vegetation • Cultivation (removal and reduction number of spp.)
	A4a	Valley Head Seep	• Artificial drainage • Decrease in wetland saturation (zonation)	• Canalisation (increased erosion in the channel)	• Cultivation (removal and reduction number of spp.)
	A4b	Channelled Valley Bottom	• Cultivation • Flow Confinement (Culvert) • Road Runoff • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • Roads (Hardening) • General disturbance	• Low prevalence of alien vegetation • Cultivation (removal and reduction number of spp.)
	A4c	Valley Head Seep	• Cultivation • Flow Confinement (Culvert) • Road Runoff • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment	• Cultivation (removal and reduction number of spp.) •
	A5	Channelled Valley Bottom	• Cultivation • Flow Confinement (Culvert) • Road Runoff • Incisment	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment	• Moderate prevalence of alien vegetation • Cultivation (removal and reduction number of spp.)

Catchment	Wetland Unit	HGM	Impacts on Wetland Hydrology	Impacts On Wetland Geomorphology	Impacts On Wetland Vegetation
			• Artificial drainage • Decrease in wetland saturation	• Roads (Hardening) • Scour • General disturbance, crossings	• Stabilising plant species planted on banks
	A6	Channelled Valley Bottom	• Cultivation • Flow Confinement (Culvert) • Road Runoff • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • Roads (Hardening) • Scour • General disturbance, crossings	• High prevalence of alien vegetation • Cultivation (removal and reduction number of spp.)
	A6a	Channelled Valley Bottom	• Cultivation • Flow Confinement (Culvert) • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment •	• Mod prevalence of alien vegetation • Cultivation (removal and reduction number of spp.)
	A8	Channelled Valley Bottom	• Cultivation • Flow Confinement (Culvert) • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment	• Low prevalence of alien vegetation • Cultivation (removal and reduction number of spp.) • Stabilising plant species planted on banks
	A8a	Channelled Valley Bottom	• Cultivation • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment	• Low prevalence of alien vegetation • Cultivation (removal and reduction number of spp.)
	A8b	Channelled Valley Bottom	• Cultivation • Flow Confinement • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • Limited scour	• Low prevalence of alien vegetation • Bamboo • Cultivation (removal and reduction number of spp.) • Stabilising plant species planted on banks
	A9	Channelled Valley Bottom	• Cultivation • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment	• Low prevalence of alien vegetation • Cultivation (removal and reduction number of spp.) • Stabilising plant species planted on banks
B	B1	Channelled Valley Bottom	• Cultivation • Flow Confinement (Culverts) • Road Runoff • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • Roads (Hardening) • Scour • General disturbance	• High prevalence of alien vegetation • Cultivation (removal and reduction number of spp.)
	B2	Channelled Valley Bottom	• Cultivation • Flow Confinement (Culverts) • Road Runoff • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • Roads (Hardening) • Limited scour • General disturbance, crossings	• Moderate prevalence of alien vegetation • Cultivation (removal and reduction number of spp.)
	B3	Flood Plain	• Cultivation • Flow Confinement (Culverts) • Road Runoff • Crossings • Artificial drainage • Increase in flood peaks • Effluent from upstream • Increase in nutrient load • Pollution	• General disturbance, crossings • Alteration of erosion and deposition regime • Roads crossings (deactivation of processes)	• Cultivation (removal and reduction number of spp.) • Decrease in ecological complexity. • Moderate alien prevalence • Fragmentation
C	C1	Channelled Valley Bottom	• Cultivation • Artificial drainage • Decrease in wetland saturation • Road runoff	• Canalisation (increased erosion in the channel) • General disturbance, crossings • Roads (Hardening and source of sediment)	• Cultivation (removal and reduction number of spp.)
	C2	Channelled Valley Bottom	• Cultivation • Artificial drainage • Decrease in wetland saturation • Road runoff	• Canalisation (increased erosion in the channel) • General disturbance, crossings • Roads (Hardening and source of sediment)	• Cultivation (removal and reduction number of spp.)
	C3	Un-Channelled Valley Bottom	• Cultivation • Artificial drainage • Decrease in wetland saturation • Road runoff	• Canalisation (increased erosion in the channel) • General disturbance, crossings • Roads (Hardening and source of sediment)	• Cultivation (removal and reduction number of spp.)
	C4	Channelled Valley Bottom	• Cultivation • Artificial drainage • Decrease in wetland saturation • Road runoff	• Canalisation (increased erosion in the channel) • General disturbance, crossings • Roads (Hardening and source of sediment)	• Cultivation (removal and reduction number of spp.)
	C5	Channelled Valley Bottom	• Cultivation • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel)	• Cultivation (removal and reduction number of spp.) • Moderate alien prevalence

Catchment	Wetland Unit	HGM	Impacts on Wetland Hydrology	Impacts On Wetland Geomorphology	Impacts On Wetland Vegetation
	C7	Un-Channelled Valley Bottom	• Cultivation • Artificial drainage • Decrease in wetland saturation • Road runoff	• Canalisation (increased erosion in the channel) • General disturbance, crossings	• Cultivation (removal and reduction number of spp.) • Moderate alien prevalence
	C8	Flood Plain	• Cultivation • Flow Confinement (Culverts) • Road Runoff • Crossings • Artificial drainage • Increase in flood peaks • Effluent from upstream • Increase in nutrient load • Pollution	• General disturbance, crossings • Alteration of erosion and deposition regime • Roads crossings (deactivation of processes)	• Cultivation (removal and reduction number of spp.) • Decrease in ecological complexity. • Moderate alien prevalence • Fragmentation
	C8b	Channelled Valley Bottom		• Canalisation (increased erosion in the channel)	• Cultivation (removal and reduction number of spp.) • Moderate alien prevalence
	C9a	Channelled Valley Bottom	• Cultivation • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel)	• Cultivation (removal and reduction number of spp.) • Moderate alien prevalence
	C9c	Channelled Valley Bottom	• Cultivation • Flow Confinement • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • General disturbance, crossings	• Low prevalence of alien vegetation • Cultivation (removal and reduction number of spp.)
	D1	Channelled Valley Bottom	• Cultivation • Flow Confinement • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • General disturbance, crossings	• Cultivation (removal and reduction number of spp.)
	D2	Channelled Valley Bottom	• Cultivation • Flow Confinement • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • General disturbance, crossings	• Cultivation (removal and reduction number of spp.)
D	D3	Channelled Valley Bottom	• Cultivation • Flow Confinement • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • General disturbance, crossings	• Cultivation (removal and reduction number of spp.)
	D4	Channelled Valley Bottom	• Cultivation • Flow Confinement • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • General disturbance, crossings	• Low prevalence of alien vegetation • Cultivation (removal and reduction number of spp.)
	D5	Channelled Valley Bottom	• Cultivation • Flow Confinement • Incisment • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • General disturbance, crossings	• Low prevalence of alien vegetation • Cultivation (removal and reduction number of spp.)
	E1	Flood Plain	• Cultivation • Flow Confinement (Culverts) • Road Runoff • Crossings • Artificial drainage • Increase in flood peaks • Effluent from upstream • Increase in nutrient load • Pollution	• General disturbance, crossings • Alteration of erosion and deposition regime • Roads crossings (deactivation of processes)	• Cultivation (removal and reduction number of spp.) • Decrease in ecological complexity. • Moderate alien prevalence • Fragmentation
E	E1	Flood Plain	• Cultivation • Flow Confinement (Culverts) • Road Runoff • Crossings • Artificial drainage • Increase in flood peaks • Effluent from upstream • Increase in nutrient load • Pollution	• General disturbance, crossings • Alteration of erosion and deposition regime • Roads crossings (deactivation of processes)	• Cultivation (removal and reduction number of spp.) • Decrease in ecological complexity. • Moderate alien prevalence • Fragmentation
	E2	Channelled Valley Bottom	• Cultivation • Flow Confinement • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • General disturbance	• Cultivation (removal and reduction number of spp.)
F	F1	Channelled Valley Bottom	• Cultivation • Flow Confinement • Artificial drainage • Decrease in wetland saturation	• Canalisation (increased erosion in the channel) • General disturbance	• Cultivation (removal and reduction number of spp.)
G	G1	Channelled Valley Bottom	• Cultivation • Flow Confinement (Culvert) • Road Runoff, and loss of wetland • Incisment • Artificial drainage • Decrease in wetland saturation • Dam (change in flow patterns,	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • General disturbance, crossings • Alteration of erosion and deposition regime	• Moderate prevalence of alien vegetation • Cultivation (removal and reduction number of spp.)

Catchment	Wetland Unit	HGM	Impacts on Wetland Hydrology	Impacts On Wetland Geomorphology	Impacts On Wetland Vegetation
			deposition)		
	G2	Channelled Valley Bottom	• Cultivation • Flow Confinement (Culvert) • Road Runoff, and loss of wetland • Incisment • Artificial drainage • Decrease in wetland saturation • Dam (change in flow patterns, deposition)	• Canalisation (increased erosion in the channel) • Areas outside channel starved of sediment • General disturbance, crossings • Alteration of erosion and deposition regime	• Moderate prevalence of alien vegetation • Cultivation (removal and reduction number of spp.)
	G3	Lost	Lost	Lost	Lost
	G4	Lost	Lost	Lost	Lost
H	H2	Channelled Valley Bottom	• Cultivation • Artificial drainage • Decrease in wetland saturation	• General disturbance	• Cultivation (removal and reduction number of spp.)
	H3	Channelled Valley Bottom	• Cultivation • Artificial drainage • Decrease in wetland saturation	• General disturbance	• Cultivation (removal and reduction number of spp.)
I	I1	Channelled Valley Bottom	• Cultivation	• General disturbance	• Cultivation (removal and reduction number of spp.)
J	J1	Flood Plain	• Cultivation • Flow Confinement (Culverts) • Road Runoff • Crossings • Artificial drainage • Increase in flood peaks • Effluent from upstream • Increase in nutrient load • Pollution	• General disturbance, crossings • Alteration of erosion and deposition regime • Roads crossings (deactivation of processes)	• Cultivation (removal and reduction number of spp.) • Decrease in ecological complexity. • Moderate alien prevalence • Fragmentation
	J2	Channelled Valley Bottom	• Cultivation • Road Runoff, and loss of wetland • Incisment • Artificial drainage • Decrease in wetland saturation • Waste water discharge • Increase in nutrient load • Pollution	• Canalisation (increased erosion in the channel) • Roads (Hardening) • Scour • General disturbance, crossings	• High prevalence of alien vegetation • Cultivation (removal and reduction number of spp.)
	J3	Valley Head Seep	• Artificial drainage • Decrease in wetland saturation (zonation)	• Canalisation (increased erosion in the channel)	• Cultivation (removal and reduction number of spp.)
	J4	Valley Head Seep	• Cultivation • Artificial drainage • Decrease in wetland saturation (zonation)	• Canalisation (increased erosion in the channel)	• Cultivation (removal and reduction number of spp.)
	J5	Valley Head Seep	• Cultivation • Artificial drainage • Decrease in wetland saturation (zonation)	• Canalisation (increased erosion in the channel)	• Cultivation (removal and reduction number of spp.)
	J6	Valley Head Seep	• Cultivation • Artificial drainage • Decrease in wetland saturation (zonation)	• Canalisation (increased erosion in the channel)	• Cultivation (removal and reduction number of spp.)

7 WETLAND REHABILITATION VISION AND GOALS

7.1 Flood Plain Units

The vision for these wetland units are to reinstate and improve the range of wetland and riparian habitats on the floodplain similar to that that would have existed under natural conditions. It is very difficult to predict what habitats would have naturally existed on the now cleared floodplain areas. However, it is expected that there would have been a mix of seasonally to semi-permanently saturated marshes dominated by plant species like *Cyperus latifolius*, *Typha capensis* and *Phragmites australis*; seasonally and temporarily saturated grasslands dominated by short sedges and water loving/tolerant grasses; and riparian woody communities dominated by tree species like *Bridelia micrantha*, *Syzygium cordata*, *Phoenix reclinata* and *Rauvolfia caffra*.

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 50 cm of the surface of the wetland during low flows by plugging the artificial drainage channels.
2. Remove the existing cane road crossings and culverts that are not going to be incorporated into the proposed development and rehabilitation.
3. Eradicate all of the alien plants within the existing and future reinstated wetland and riparian habitats in the floodplain wetland unit for the lifetime of the project.
4. Remove all of the sugarcane from the wetland units and their buffers and re-vegetate the seasonal and temporary wetland areas and buffers with appropriate plant species to 'kick start' succession.

7.2 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.

7.3 Hillside Seeps

1. 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.
2. 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.

3. Eradicate all of the alien plants within the wetland unit on an ongoing basis for the lifetime of the project.
4. Re-vegetate using the with seasonal and temporary vegetation palette (**cf. Section 10**).

8 WETLAND REHABILITATION ENGINEERING INTERVENTION SELECTION AND DESIGN

A number of degraded wetlands were identified during the original wetland delineation and subsequent field visits. With the selection of appropriate interventions, these wetlands are to be rehabilitated to improve their overall health and functionality.

8.1 Introduction

The current land use at Cornubia is primarily sugarcane cultivation. Historically, wetland areas within Cornubia, 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 farmable areas. 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.

8.2 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.

8.2.1 Geomorphic Conditions

Weirs are positioned in areas where the stream channel has become incised as a result of artificial drainage channels being created (**Figure 11**).

Figure 10: Example of a man-made channel

8.2.2 Hydrological Conditions

Floodpeaks for the proposed weir locations were determined using the Rational Method (**SANRAL 2006**). The Rational Method is suitable for catchments smaller than 15 km² and therefore this method could be used on all the contributing catchments within Phase 2.

8.2.3 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.

8.2.4 Contributing Catchment Delineation and River Reach Analysis

The contributing catchments were delineated using survey data provided by **messrs. SMEC**. The 1085-slope method[1] was used to determine the average slope for each river reach. River length and elevation at points of interest were calculated from topographical maps and the survey dataset.

8.2.5 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.

8.2.6 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.

8.2.7 *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.

8.2.8 *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-Rehab Methods recommends the use of a concrete or 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 flood peak 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 Cornubia and a flood peak of 10 m³/s. A weir larger than 15 m was deemed unviable in lower reaches were the flood peaks are in excess of 15 m³/s.

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

In addition, stabilisation (not restoration) should apdoted for the upper reaches of drainage lines. It was deemed impractical to fully rehabilitate the upper reaches because of the expected small gains in wetland habitat associated with the large costs of constructing many gabion weirs.

8.3 Results

To reinstate the hydrology of the wetland units, a series of concrete mass gravity and gabion weirs are proposed. These are to be located within the artificial drainage channels, as shown in the layout plan 12154-5401. The location of each of the weir structures is shown in Drawings 12154-5402 to 12154-5417 attached as **Appendix A** of this document and also illustrated in **Figure 12**. The typical design of the concrete and gabion weirs is shown in Drawings 12154-5601 and 12154-5602 respectively, both of which are attached as **Appendix B** of this document.

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. The extent of the re-instated permanent and semi-permanent wetland zones areas where the water table will be reinstated to the ground surface and within 50 cm of the ground surface respectively. The permanent zone is shown as the blue hatching and the semi-permanent zone as the light green hatching in Drawings 12154-5402 to 12154-5417.

Damming of the flow will create a stilling basin, where deposition is encouraged. Overtime the channel should fill up with wetland soils to its historical/pre-development level.

8.4 Notes for the construction of the concrete weirs and spreader canals

- The drawings issued as part of this report specify the dimensions of structures as required from a hydraulic perspective. A full structural analysis has not yet been performed. Prior to construction, full structural details including reinforcing schedules will have to be produced.

- The surface preparation required for the structures has not been shown on the drawings. For estimation purposes, this may be assumed to be 150 mm thick G2 material compacted to 93% MOD AASHTO density.
- Geofabric (Bidim U40 or similar approved) lining is to be installed on all earth-facing sides.
- 25mm diameter weep-holes shall be cast in to the concrete walls at 750mm spacing, in vertical and horizontal directions.
- An earthen berm (spreader canals) must be constructed from the edge of the wing walls outwards, at grade. Detail shown on drawing 12154-5601.

8.5 Notes for the construction of the gabion weirs, gabion plugs and spreader canals

- Gabion baskets are to be installed to manufacturer specifications.
- 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 12154-5602.
- Earthen plugs are proposed to be used to plug the offline artificial drainage ditches and there position will be should be finalised during the implementation of the rehabilitation interventions.

8.6 Bill of Quantities

The following bill of quantities is based on 12 x 15 m concrete weirs and 15 x 6 m gabion basket weirs.

Table 3. Bill of quantities for the proposed engineering interventions.

Concrete Plugs	**Quantities**
Structural Concrete	183 m^3
Excavation	251 m^3
Embankments	122 m^3
Gabion Plugs	
Reno Mattresses	713 m^3
Gabion Baskets	210 m^3
Geofabric	585 m^2
Excavation	837 m^3
Embankments	153 m^3

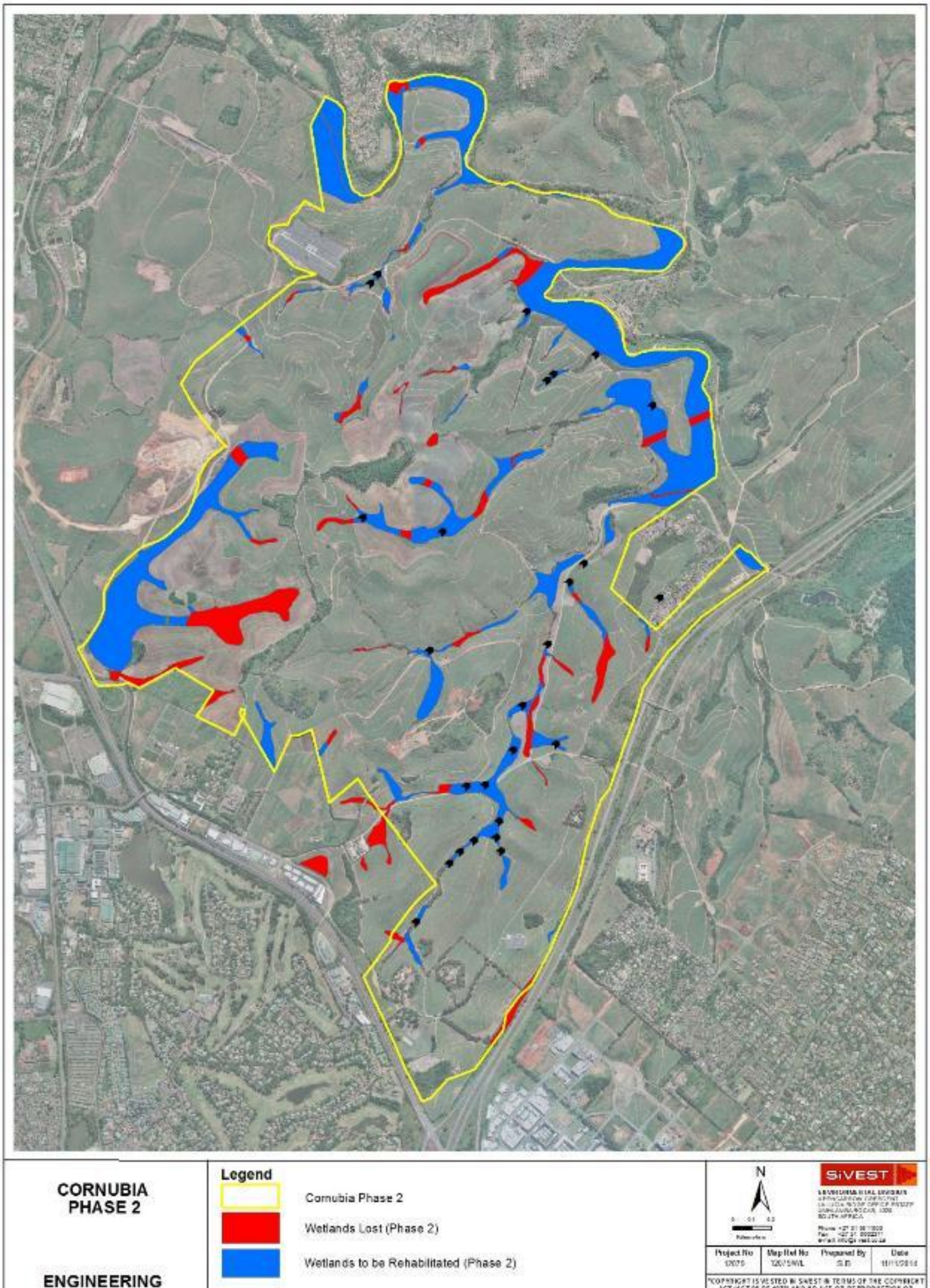

Figure 11: Locations of the proposed engineering interventions

9 BACKGROUND TO THE RE-VEGETATION PROGRAMME

Cornubia Phase 2 is an extremely large area, totalling **926 hectares**, with the current layout proposing that **392.5 hectares** as the total area of Open Space and Servitudes that will exist within the various development typologies and infrastructural requirements proposed. Cornubia Phase 2 follows on from the original Phase 1 and Pilot study undertaken within the context of the Greater Cornubia Framework Development. Cornubia Phase 2 incorporates the Retail Park Development and due to its size and its design lay out and thus its inability to contribute to the overall rehabilitation opportunities and Open Spaces has been incorporated into the Phase 2 Rehabilitation process, where loses that have been incurred as a result of the proposed development have been offset within the Phase 2 assessment and rehabilitation document. This comprises a variety of vegetation types, with large portions of the area proposed being currently under sugar cane cultivation. In terms of the Open Spaces proposed the current area of each of the types of Open Space is included in **Table 4** below. Due consideration must be taken that the proposed Open Spaces 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 4. The various categories of Open Space Identified within the Cornubia LUMS for Phase 2.

OPEN SPACE CATEGORY	AREA (HA)	PROPORTION (%)
Terrestrial Environment	**289**	**74%**
Parks (recreation)	11.5	3%
Servitude (Grassland)	55	14%
Indigenous Woody Vegetation	8	2%
Buffer	103	27%
Open Space (Grassland)	111.5	28%
Constructed Environment	**4**	**1%**
Dry Ponds	4	1%
Wetlands (excl. buffers)	**99**	**25%**
Open Water	8	2%
Permanent	3	0.5%
Riparian	2	0.5%
Seasonal	32	8%
Semi-Permanent	19	5%
Temporary Wetland	35	9%
TOTAL	**392**	**100%**

It must be noted that of the total 392 ha 11.5 hectares of Open Space are parks, which may not link into the Greater Open Space System; however, these areas provide critical space for recreation, as well as valuable community areas, which are required for human well-being. Therefore, they may not provide significant functional Ecological Goods and Services; however, their social value cannot be disputed, and given that the vegetation within these units will be indigenous they have been included in the overall calculations. The area contributed by these areas is not that significant as it equates to a total of 3%.

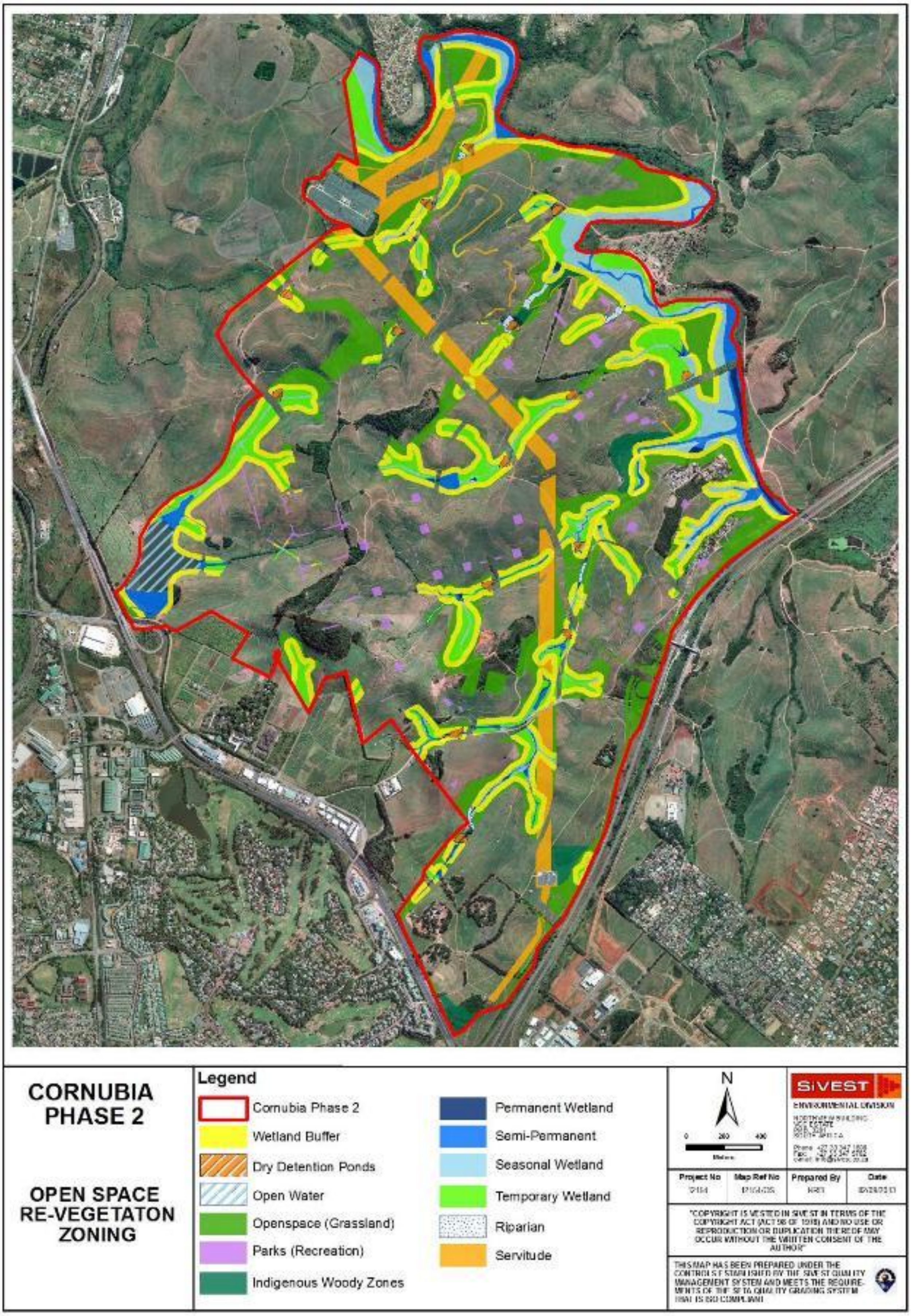

Figure 12: Open Space Re-Vegetation Zoning

10 PLANTING METHODOLOGY

In terms of the vegetative rehabilitation of the proposed Open Space Areas, comprising;

- Grassland Areas (predominantly wetland terrestrial buffers and electrical servitudes);
- Wooded Areas (Forest);
- Wetland areas, and;
- Buffer zones

located within Phase 2 of the proposed Cornubia Development, 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.

10.1 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.

10.1.1 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.

10.1.2 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.

10.1.3 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 pre-soaking 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.

10.1.4 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.

10.2 Soil Stabilisation Techniques using Various Products

10.2.1 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.

10.2.2 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.

10.2.3 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 13. 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.

10.2.4 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;

10.2.5 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[1] 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.

10.3 Linking Riparian Zones

The linking riparian zones (currently not included within wetlands) represent areas that should be rehabilitated to areas typical of riparian zones (the riparian zones should occur on the upper reaches of the drainage lines and wetlands where the wetlands are more canalized, narrower, thus prone to erosion).

[1] 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.

The goal of riparian habitat restoration should be the creation of a mosaic of different habitats, ranging from dense, large clumps of well-established riparian forest to open drainage lines maintained by the same burning regime as the grassland areas. There are a number of criteria that determine riparian habitat integrity (**Kleynhans, 1996**) namely:

- Indigenous vegetation removal;
- Exotic vegetation encroachment;
- Bank erosion;
- Channel modification;
- Water abstraction;
- Inundation;
- Flow modification; and
- Water quality

Most of these are determined by impacts within the riparian catchments, with indigenous vegetation removal and alien invasive vegetation control the two main aspects that can be influenced on site.

Hence riparian habitat rehabilitation should mainly centre around the initial clearing and subsequent control of alien invasive plants. In addition, riparian vegetation may be planted to accelerate the natural recovery process. In those areas where the expansion of riparian forest is to be encouraged, it is recommended that a width of approximately 4 adult trees on either side of the channel is deemed appropriate to restore a measure of the fundamental riparian ecological processes (**Geoff Nichol**, ***personal communication***).

Riparian areas should comprise a stratified structure that comprises an under-storey, an intermediate storey (comprising shrubs and small trees as well as creepers) and the tree canopy. In addition, these areas will be buffered through the development of an ecotone and the width of the buffer is as per the determination made by the wetland ecologists. The ecotone will provide a spatial continuum between the various ecosystem units.

It must be clearly stated that rehabilitation or restoration is a methodical process that will be driven by the ecological conditions that prevail. The plant species listed in **Table 5** are species capable of withstanding the environmental conditions and are not necessarily pioneer species in the truest interpretation of pioneer species. The species listed have been given a positional distribution through the riparian zone, illustrating their requirements, either drier side slopes a little removed from the actual drainage channel and the associated temporary or seasonally wet soils, to species which will survive in both, or species which require their roots to be permanently wet all year round.

The presence of woody vegetation within the Cornubia Phase 2 Development Area is limited to areas which have as a result of past actions by the farm managers, whom have planted up a number of the drainage lines, particularly the drainage lines in Catchment A It must be stated that the vegetation is not remnant vegetation and it has all been planted or has established as a result of the planted vegetation. The vegetation that has been planted is typical of moist conditions, with species such as *Syzigium cordatum, Ficus trichopoda, Barringtonia racemosa, Tabernaemontana ventricosa, Ficus lutea, Ficus burkei, Ficus natalensis, Clerodendrum glabrum, Acacia robusta* and *Bridelia micrantha* being most prevalent.

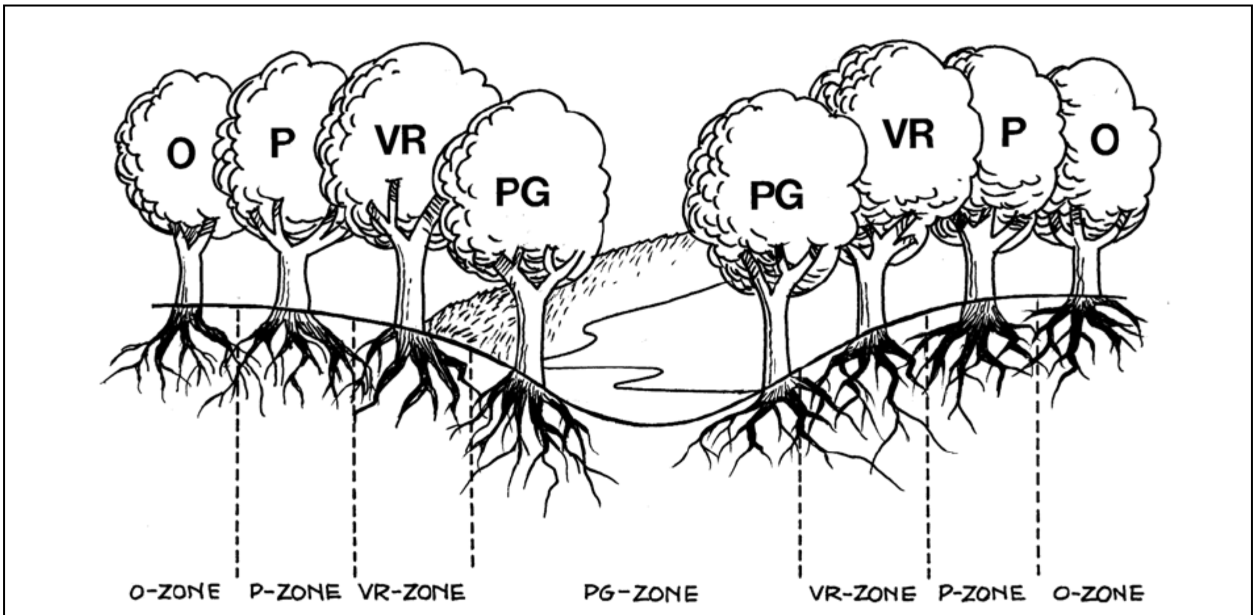

Figure 14. Graphical representation of the differing abiotic conditions that will be experienced by trees in Riparian Zones. Taken from the Ethekwini EMP Revegetation specification. The interpretations of the zones are a variation on the Ethekwini illustration, as the O – Zone is the ecotonal edge that will provide the linkage between various land uses, be it the built environment or other ecosystem units. PG – Zone = Plug Zone (trees which will act as plugs to reduce flow, preventing erosion of the drainage line or riparian zone. VR – Zone = Vigorous Rooting Zone (trees utilised will contribute to the stabilisation of the drainage line / riparian zone banks, additional create the primary canopy of the riparian zone). P – Zone = Pioneer Zone (trees that will protect the "core species, i.e. the VR and PG zone tree species, and facilitate the development of the O- Zone or ecotonal edge).

Table 5. Tree species identified for the Riparian Zone Planting.

Species	Position	Species	Position
Acacia robusta	dry	*Searsia chirindensis*	dry
Allophylus natalensis	dry	*Searsia natalensis*	dry
Brachylaena discolor	dry	*Strychnos gerrardii*	dry
Canthium inerme	dry	*Ziziphus mucronata*	dry
Carissa bispinosa	dry	*Bridelia micrantha*	dry / wet
Celtis africana	dry	*Halleria lucida*	dry / wet
Chaetachme aristata	dry	*Maesa lanceolata*	dry / wet
Clausena anisata	dry	*Syzygium guineense*	dry / wet
Clerodendrum glabrum	dry	*Trema orientalis*	dry / wet
Cordia caffra	dry	*Anastrabe integerrimum*	dry/ wet
Croton sylvaticus	dry	*Antidesma venosum*	dry/ wet
Diospyros natalensis	dry	*Baphia racemosa*	dry/ wet
Dovyalis longispina	dry	*Ficus burtt-davyi*	dry/ wet
Dovyalis rhamnoides	dry	*Ficus natalensis*	dry/ wet
Drypetes arguta	dry	*Harpephyllum caffrum*	dry/ wet
Ekebergia capensis	dry	*Macaranga capensis*	dry/ wet
Erythrina lysistemon	dry	*Maytenus undata*	dry/ wet
Erythroxylum emarginatum	dry	*Syzygium cordatum*	dry/ wet
Euclea natalensis	dry	*Ficus lutea*	dry/ wet

Eugenia capensis	dry	*Barringtonia racemosa*	wet
Grewia occidentalis	dry	*Ficus burkei*	wet
Pavetta revoluta	dry	*Ficus sur*	wet
Psydrax obovata	dry	*Hibiscus tiliaceus*	wet
Putterlickia verrucosa	dry	*Phoenix reclinata*	wet
Rhoicissus digitata	dry	*Protorhus longifolia*	wet
Rhoicissus tridentata	dry	*Rauvolfia caffra*	wet
Sapium integerrimum	dry	*Voacanga thouarsii*	wet

10.4 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 15** 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.

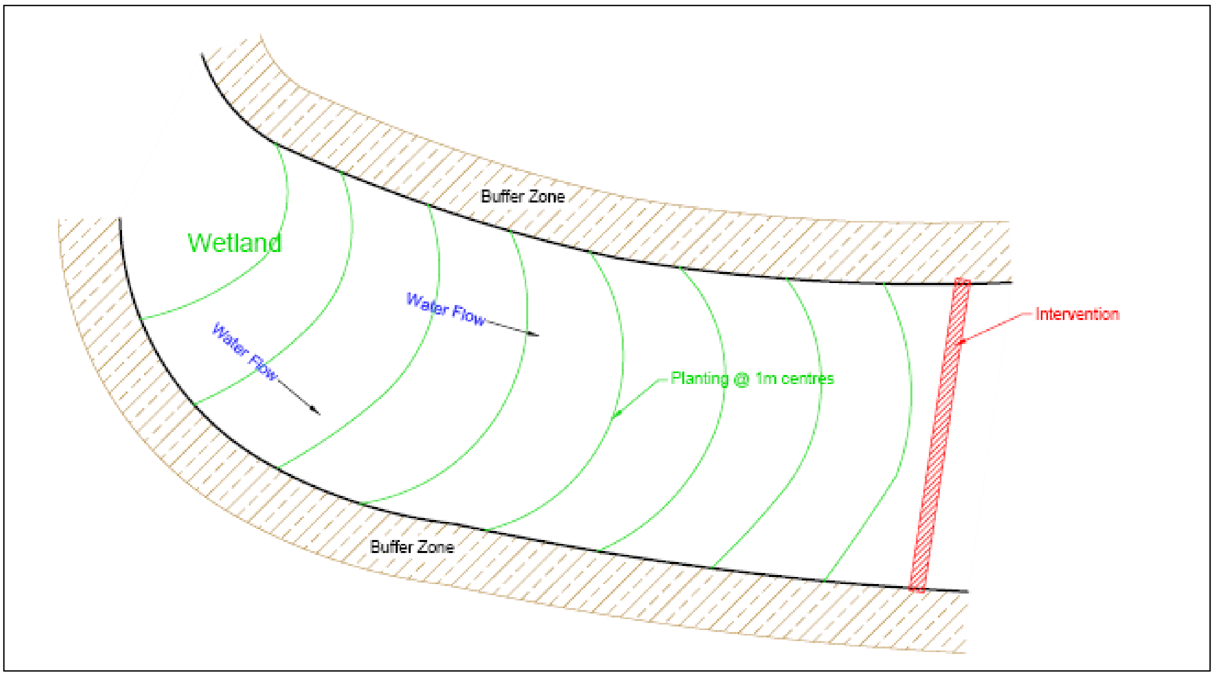

Figure 15: A schematic diagram representing the proposed planting methodology to be adopted when rehabilitating wetland areas (Kinvig, 2011).

10.4.1 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. As stated in the Vegetation Document compiled by **SiVEST (Rev 7.3)** 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.

10.4.2 Floodplain Areas

In terms of the Ohlanga floodplain we would propose that the following species are utilised in the rehabilitation. The reason for the selection of the following species is twofold. Firstly, due to the presence of the WWTW up-stream, the nutrient loading in the river is high. This is evidenced from the extremely high abundance of *Phragmites australis* down-stream at the estuary mouth. These *Phragmites* beds are therefore crucial in removing a large amount of the suspended nutrients and sediments from the water, improving the general health of the Ohlanga River. Secondly, *P. australis* is extremely robust and is able to withstand regular flooding thus stabilising the flood plain to a very high degree. Similarly, the current levels of water in the Ohlanga River are elevated due to the presence of the WWTW and the development that is occurring up-stream. We can therefore postulate that the Ohlanga River will regularly overtop onto the floodplain. *P. australis* is extremely well adapted to growing in conditions where regular or permanent inundation occurs, or where intermittent overtopping occurs, with the soil moisture fluctuating from 100% saturation to conditions where the soil moisture content is approximately 30%.

In terms of the current floodplain area, portions of the floodplain are at a slightly higher elevation that their surroundings. This will provide an ideal opportunity for the establishment of woody vegetation within the designated flood plain. In these areas we would propose the establishment of trees. Further along the current River bed and associated fringe, we would propose that trees which are able to grow in permanently wet conditions are planted. This will have two significant benefits. Firstly, the riverbank will be stabilised to a greater degree than by the simple presence of *Phragmites australis.* Secondly, the planting of trees will mimic the conditions that would have occurred pre-development and alteration of the river channel and floodplain.

10.4.3 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.*

10.4.4 Elevated Areas on the floodplain and fringes of the floodplain

- *Bridelia micrantha*
- *Syzygium cordatum*
- *Cassipourea gummiflua*
- *Rauvolfia caffra*
- *Phoenix reclinata*
- *Ficus natalensis*
- *Ficus burkei*
- *Macaranga capensis*

10.4.5 Riverbanks and low lying areas requiring additional protection

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

10.4.6 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.

10.4.7 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*

10.4.8 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*

10.4.9 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*

10.4.10 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.

10.5 Dry Storm water detention ponds

A number of relatively large storm water detention ponds are planned within the wetland units receiving rehabilitation as shown in **Figure 12.** The areas of wetland affected by the ponds have not received rehabilitation in the form of the plugging of the drains because of the creation of the large dam wall and the extent of back-flooding during large rainfall events. However, it has been decided that these areas be re-vegetated once the sugarcane has been removed. Due to the unnaturally high seasonal flooding of the wetlands and the fact that during low flows the existing drains will likely draw down the water table and the soils dry out, the plants for re-vegetation will need to be hardy and withstand long dry spells punctuated by seasonal permanent flooding and possibly submersion. Due to these extreme conditions, the storm water detention pond area will be susceptible to weed growth and alien plant invasion where indigenous species struggle to cope and are unable to compete against the generalist pioneer and alien species.

In light of the need for both a wide variety of hardy terrestrial and facultative wetland plants, it is proposed that the area be hydro-seeded with a similar plant species mix to that for the temporary wetland zone with a few hardy seasonal species included in the mix for the lowest lying areas of the wetland in the vicinity of the channel. It is important that the vegetation communities have established themselves before the storm water detention ponds are operational. The following species should be part of the mix:

Grasses:

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

Sedges:

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

10.6 Power Line Servitudes

Currently there is a major power line servitude that is registered over the Phase 2 Property. The servitude runs in an Easterly direction to two small distribution substations east south east of the Ottawa Sub Station and in close proximity to the N2 highway. In terms of the current utilisation, the rehabilitation needs to best mirror the existence of sugarcane below the power line in terms of potential risk and management requirements. Eskom specifies that no trees are allowed to be planted in the servitude and all vegetation which occurs in the servitude and becomes woody is continually managed and / or removed.

Further Eskom specifies that there is a specific clearance requirement (distance between the belly of the line and the ground or any protrusion there from) depending on the Voltage of the power line. In the Code of Practice for Clearances for Electrical Systems – Eskom specifies the relevant clearances as reflected in Table 2 below. The power lines in question belong to the Ethekwini Municipality Electrical Department. However, it is recommended that the rehabilitation and management of these areas comply with the Eskom Standards, if they differ.

Table 6. Eskom Clearance guidelines for 132 kV and 275 kV power line servitudes in terms of metres AGL.

Land Use below Power Lines	Voltage	
	132 kV	275 kV
Vegetation	6.3 m	7.0 m
Roads	7.5 m	8.2 m
Railway Lines	10.9 m	11.2 m

The above mentioned restrictions to utilisation and clearances results in the most desirable ecosystem type being a short grass dominated sward that is easily managed. The other factor which requires attention is what management of the grassland will be utilised. It is important that ash and burnt material resulting from the annual / biannual burning of the grasslands does not come into contact with the conductor and that this does not cause electrical flashover and resultant outages.

The current scenario is that Tongaat Hulett Sugar burn the sugarcane under these power lines. It is unknown whether the power lines are “switched off” for the period of the burning event. However, in most cases, and from our past experiences with Eskom, these arranged “Switch-Offs” are not that common. Further new research has shown that burning under power lines does not cause electrical faults that regularly and that by increasing the clearances of the conductor, reduces the chance of outages significantly. Therefore, the most suitable vegetation type for the servitude areas is grassland and thus the Open Space that will be created will be grassland.

10.7 Marshall Dam Buffer Zone

The banks and fringes of Marshall Dam currently comprise woodland and bush dominated by a mix of alien invasive species, the most prominent of which are: *Schinus terebinthifolius*, *Syzygium cumini*, *Litsea glutinosa* and *Arundo donax*. In between the matrix of alien trees few indigenous trees occur, the most prominent of which are *Phoenix reclinata* and *Trema orientalis*. Other indigenous species that are present within this wooded zone are; *Kraussia floribunda*, *Pavetta lanceolata*, *Clerodendrum glabrum* and *Ficus burkei*. The under storey is dominated by species such as *Setaria megaphylla*, *Stenotaphrum secundatum*, *Ageratum houstonianum*, *Lantana camara* and *Chromolaena odorata*.

10.7.1 Westerly Fringe Zone (Interface between Phase 1 and 2)

The individual tree species planted along the banks on the westerly side of the dam comprise predominantly of *Syzygium cumini* (Jambolam Plum) trees. These trees were utilised historically because of their rapid growth rate, shading properties and the fruit. In certain Hindu cultures, it is referred to as the fruit of the gods, particularly by people emanating from Gujarat in India[2].

Many of the *Syzygium cumini* trees are large and potentially there may be some use for the wood. The wood can be planked and used in landscaping or as bridge structures / board walks for footpaths which will be created in order to provide recreational usage of the Open Space Areas within the Phase 1 and Phase 2 of the Greater Cornubia Development Plan.

Along the westerly boundary of the Dam is an access road which is currently utilised as a haulage road for sugarcane production and the accessing of the Ottawa Sub Station. In terms of the Phase 1 approved layout plan, this road will be removed and access will be obtained through the newly designed road network, which will be created further away from the current alignment along the property boundaries of the Medium Density Housing Zone. The result is that the entire Marshall Dam Fringe and adjacent road bed will require rehabilitation through the planting of indigenous species.

The only concern regarding the rehabilitation and the manner in which it is undertaken may cause significant impacts if not undertaken correctly. Most of the species mentioned respond well to foliar spray treatments, followed up with a mechanical removal process. This however, may pose to be contentious as the infestations are directly adjacent the water’s edge and any mechanical removal may result in sediment entering Marshall Dam.

Therefore, it is recommended that the plants are carefully removed during the winter period with immediate re-vegetation of the area with a creeping turf grass such as *Dactyloctenium australe*. In addition, it is also recommended that the area to be rehabilitated be planted with numerous trees, which will create a park-like setting and create an opportunity for residents to utilise the area for passive recreation activities, and be able to access Marshall Dam. The ideal tree species to plant would be *Albizia adianthifolia*. Their growth form will create shade, but not to an extent that will preclude grass growth underneath the trees, if planted at suitable distances from one another.

10.7.2 Area below the Marshall Dam Wall

The closed canopy area along the Marshall Dam wall is heavily infested by alien invasive tree species namely, *Litsea glutinosa*. The majority of the *L. glutinosa* are relatively spindly saplings that have grown rapidly in order to access light. Further they have not been able to grow extremely large due to the relatively dense numbers of the trees competing for nutrients

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[2] **http://en.wikipedia.org/wiki/Jambul**

in soils which are relatively sandy and leached. The result of this is that once all of these individuals, as well as the numerous *Schinus terebinthifolius* individuals are removed, the densely wooded area will form an open canopied woodland mosaic, with an under-storey devoid of any vegetation. *L. glutinosa* releases allelopathic chemicals into the soil, which inhibit other plant species' growth, contributing to the difficulties of rehabilitating the area post removal, until all the chemicals have been leached out of the soil. Of the most concern will be the potential for erosion to occur as there is no plant material to prevent the upper layers of topsoil being washed away or eroded by wind action.

As the main purpose of the rehabilitation plan is to restore indigenous vegetation communities and ecosystem processes, and not necessarily to increase biodiversity, the following planting methodology is recommended for the rehabilitation of this area.

On the Dam wall banks it is recommended that all the indigenous trees remain in-situ and the under storey be planted with *Dactyloctenium australe*, to continue the "park like" effect that is proposed for the westerly boundary of the Dam. At the base of the dam wall the conditions are such that we would consider this area to be a permanent wetland. For this portion, the following is recommended:

- Remove and control alien invasive species;
- Allow the existing *Typha capensis* and other wetland vegetation to naturally re-colonise the area;
- Leave all the existing indigenous trees to create some habitat heterogeneity, as well as to stabilise the area.

The creation of coastal or riverine forest in this area is deemed impractical and a waste of resources for the following reasons:

- The area will remain small.
- The forest fragment will never proceed beyond a successional stage in forest development to a state where it will be a self-sustaining unit.
- Management of the area will be on-going and relatively intensive, particularly in light of the large number of alien invasive plant stands in the surrounding off-site Open Space Areas.
- Seeds of alien invasive species will be vectored in by birds and monkeys.
- No 'interior' or core area will be established,
- The species composition will remain in a low successional state, with the plant species being of a pioneer nature (i.e. they occur of forest edges or are able to establish new areas as a result of their life history;
- Forest edges and their associated plant architecture / structure are the ideal areas for the establishment of alien invasive plant species, and the lack of a core area will result in the alien species spreading throughout the fragment, continually eroding its biodiversity value.

10.7.3 Sedimentation Dam above the main Marshall Dam

A monotypic *Typha capensis* wetland plant community is well established within this area. Thus, it is recommended that this community be retained and the alien invasive plants are removed and controlled. Following the removal of alien plants, natural processes should result in the establishment of indigenous vegetation in the areas where the alien plants have been removed. Therefore, no planting will take place in this area.

10.8 Enlargement of Existing Indigenous Woody Zones

In order for the disturbance that has been created as a result of the existing agricultural practices and the on-going management of non-cultivated areas, it is important that the remaining areas are expanded to provide additional habitat as well as improve the functionality and the sustainability of these remaining areas.

A plant species list which only considers species that are common to the coastal forest areas, particularly in close proximity to the site of disturbance will be considered for re-introduction.

The plants listed in **Table 7**, are all suitable species for the rehabilitation and restoration of the forest that has been removed as a result of agricultural practices.

The process of restoration is known as restoration ecology[3]. It is important that in any restoration; undertaking the restored area should try and recreate what was initially removed. The areas proposed for expansion are identified on in **Figure 12**.

Table 7. Trees, creepers, bulbs, herbaceous plants and shrubs species ideally suited to the establishment and successional development of sugar cane fields into lowland forest.

SPECIES	GROWTH FORM	ECOLOGICAL POSITION	PIONEER	FIRST PLANTING	SECOND PLANTING
Drimiopsis maculata	Bulb	Throughout Forest	N		✓
Resnova humifusa	Bulb	Throughout Forest	N		✓
Scadoxus puniceus	Bulb	Throughout Forest	N		✓
Behnia reticulata	Climber	Throughout Forest	N		✓
Distephanus angulifolius	Climbing Shrub	Ecotone	N		✓
Adenia gummifera	Creeper	Throughout Forest	N		✓
Adenopodia spicata	Creeper	Ecotone	Y/N		✓
Asparagus falcatus	Creeper	Ecotone	Y/N		✓
Asystasia gangetica	Creeper	Ecotone	Y/N	✓	
Cynanchum ellipticum	Creeper	Throughout Forest	Y		✓
Dioscorea cotinifolia	Creeper	Ecotone	Y		✓
Melanthera scandens	Creeper	Ecotone	Y/N		✓
Mikania natalensis	Creeper	Ecotone	Y	✓	
Secamone alpini	Creeper	Ecotone	N		✓
Secamone filiformis	Creeper	Ecotone	N		✓
Senecio tamoides	Creeper	Ecotone	Y	✓	
Dalbergia armata	Creeping Tree	Throughout Forest	Y		✓
Dietes iridoides	Herb	Throughout Forest	N		✓
Justicia protracta	Herb	Ecotone	Y	✓	
Phaulopsis imbricata	Herb	Throughout Forest	Y		✓
Plectranthus fruticosus	Herb	Throughout Forest	N		✓
Commelina africana	Prostrate Creeper	Ecotone	Y	✓	
Commelina erecta	Prostrate Creeper	Ecotone	Y	✓	
Pupalia lappacea	Scrambling Shrub	Ecotone	Y	✓	
Acokanthera oblongifolia	Shrub	Throughout Forest	N	✓	
Canthium ciliatum	Shrub	Throughout Forest	Y		✓

[3] ***"Restoration Ecology is a process of repairing damage caused by natural or anthropogenic forces to the diversity and dynamics of indigenous ecosystems. The science of Restoration Ecology is focused on developing the tools and practices necessary to help rehabilitate impaired ecosystems and return them to a level of greater ecological functioning. To achieve this, an interdisciplinary approach is necessary which incorporates several areas of study including hydrology, soil science, plant and animal ecology, forestry, conservation biology, and landscape ecology. Because it is difficult to predict exact outcomes, restoration ecology in itself becomes an actual experiment".***

SPECIES	GROWTH FORM	ECOLOGICAL POSITION	PIONEER	FIRST PLANTING	SECOND PLANTING
Dracaena aletriformis	Shrub	Throughout Forest	N		✓
Cissampelos torulosa	Slender Twiner	Throughout Forest	Y		✓
Albizia adianthifolia	Tree	Throughout Forest	Y	✓	
Allophylus africanus	Tree	Throughout Forest	Y	✓	
Allophylus dregeanus	Tree	Throughout Forest	Y	✓	
Antidesma venosum	Tree	Ecotone	Y	✓	
Baphia racemosa	Tree	Throughout Forest	N	✓	
Bersama lucens	Tree	Throughout Forest	N	✓	
Brachylaena discolor	Tree	Ecotone	Y	✓	
Bridelia micrantha	Tree	Throughout Forest	Y	✓	
Canthium inerme	Tree	Ecotone	Y	✓	
Celtis africana	Tree	Throughout Forest	N	✓	
Clausena anisata	Tree	Throughout Forest	N		✓
Clerodendrum glabrum	Tree	Ecotone	Y	✓	
Cordia caffra	Tree	Throughout Forest	N		✓
Crotalaria capensis	Tree	Ecotone	2-3 YR		
Croton sylvaticus	Tree	Throughout Forest	Y	✓	
Cussonia sphaerocephala	Tree	Throughout Forest	N	✓	
Diospyros villosa	Tree	Throughout Forest	N		✓
Drypetes arguta	Tree	Core Forest	N		✓
Drypetes gerrardii	Tree	Core Forest	N		✓
Ekebergia capensis	Tree	Throughout Forest	N	✓	
Englerophytum natalense	Tree	Core Forest	N		✓
Erythroxylum emarginatum	Tree	Throughout Forest	Y		✓
Ficus lutea	Tree	Throughout Forest	Y	✓	
Ficus natalensis	Tree	Throughout Forest	Y	✓	
Ficus sur	Tree	Mainly near water	Y	✓	
Grewia occidentalis	Tree	Throughout Forest	Y	✓	
Gymnosporia nemorosa	Tree	Ecotone	Y	✓	
Halleria lucida	Tree	Ecotone	Y	✓	
Harpephyllum caffrum	Tree	Core Forest	N	✓	
Lagynias lasiantha	Tree	Throughout Forest	N		✓
Maerua racemulosa	Tree	Under storey	N		✓
Maytenus acuminata	Tree	Ecotone	Y	✓	
Maytenus peduncularis	Tree	Under storey	N		✓
Maytenus procumbens	Tree	Throughout Forest	N		✓
Mimusops caffra	Tree	Throughout Forest	N	✓	
Neonotonia wightii	Tree	Ecotone	Y		✓
Ochna natalitia	Tree	Throughout Forest	N		✓
Pavetta lanceolata	Tree	Ecotone	Y	✓	

SPECIES	GROWTH FORM	ECOLOGICAL POSITION	PIONEER	FIRST PLANTING	SECOND PLANTING
Peddiea africana	Tree	Ecotone	Y	✓	
Protorhus longifolia	Tree	Throughout Forest	Y	✓	
Psychotria capensis	Tree	Under storey	Y		✓
Psydrax obovata	Tree	Throughout Forest	Y	✓	
Putterlickia verrucosa	Tree	Throughout Forest	Y		✓
Rauvolfia caffra	Tree	Mainly near water	Y	✓	
Rothmannia globosa	Tree	Throughout Forest	Y	✓	
Sclerocroton integerrimum	Tree	Ecotone	Y	✓	
Scutia myrtina	Tree	Throughout Forest	Y	✓	
Searsia chirindensis	Tree	Ecotone	Y	✓	
Shirakiopsis elliptica	Tree	Throughout Forest	Y	✓	
Sideroxylum inerme	Tree	Throughout Forest	N	✓	
Teclea gerrardii	Tree	Throughout Forest	N		✓
Trema orientalis	Tree	Ecotone	Y	✓	
Tricalysia sonderiana	Tree	Throughout Forest	N		✓
Trichilia emetica	Tree	Throughout Forest	Y	✓	
Trimeria grandifolia	Tree	Throughout Forest	Y		✓
Turraea floribunda	Tree	Throughout Forest	Y		✓
Vepris lanceolata	Tree	Throughout Forest	Y	✓	
Ctenomeria capensis	Twining herb	Throughout Forest	N		✓
Rhoicissus tomentosa	Woody Climber	Throughout Forest	Y		✓
Rhoicissus tridentata	Woody Climber	Ecotone	Y		✓
Capparis sepiaria	Woody Creeper	Throughout Forest	Y		✓
Capparis tomentosa	Woody Creeper	Ecotone	N		✓
Acalypha glabrata	Woody herb	Throughout Forest	N		✓
Isoglossa woodii	Woody Herb	Ecotone	N		✓
Carissa bispinosa	Woody Shrub	Ecotone	Y	✓	
Carissa macrocarpa	Woody Shrub	Ecotone	Y	✓	

10.8.1 Planting Density

In order for the forest to be restored to mirror superficially what may have been lost as a result of the previous cultivation practices and infrastructural projects that have been applied to the area historically, an assessment of the stem densities needs to be considered in order to ensure that a continuous closed canopy forms as rapidly as possible. It is important to note that the densities must not be such that a hedge is created, i.e. the plants grow together and are unable to form a canopy due to their proximity to one another. In addition, if they are planted too closely to one another it will result in extreme competition for resources, which given the sandy nature of the soils, will be quite low. It is therefore with this in mind that a distance between trees of 2.25 metres is allowed for. The following planting distances will allow for *inter alia*:

- Access into the area for monitoring and alien maintenance;

- Natural processes of ecological (successional) development to occur, where the surrounding vegetation will provide propagules and will assist in ensuring that the new area that is restored mirrors it surroundings as closely as possible.;
- Higher planting densities will exclude recruitment from the surrounding woody vegetation
- Higher light intensities will promote rapid growth and the development of under-storey vegetation, which by its own presence will have significant benefits, not to mention:
  - reduction in soil loss through wind and water action;
  - promote nitrification of the soils
  - promote water infiltration during and after rainfall events;
  - Reduce the opportunity for the establishment of alien invasive species;
  - Promote utilisation of the area at a multiple-level by faunal and avi-faunal species.

10.8.2 Distribution of individuals across species

The replication of northern coastal forest, in terms of, the relative abundances of the different tree species is important. We therefore look to **Mucina and Rutherford, 2006** as well as our own experience to identify the dominant species and propose the varying abundances of each. In addition, it must be considered that the re-creation of forest is for functional reasons, and it must be able to function as a forest in future, with no on-going management interventions. A list of the preferential plant species that would prove to be ideal for the rehabilitation are included at **Table 7**.

In terms of the large and tall dominant species we would propose the following:

- *Albizia adianthifolia* – Quick growing
- *Sideroxylum inerme* – Quick growing
- *Trichilia emetica* – Quick growing
- *Croton sylvaticus* – Quick growing
- *Ficus burkei* – Quick growing
- *Mimusops caffra* – Grow well but not rapidly
- *Psydrax obovata* – Depending on their position they are able to grow rapidly
- *Vepris lanceolata* – Relatively slow growing
- *Protorhus longifolia* – Quick growing
- *Cordia caffra* – Dependent on the conditions, however, should grow well

These species are all species which are relatively well adapted to growing in isolation or being exposed to the elements, and therefore they will form the basis for the later successional forest.

Species such as *Drypetes reticulata* are core forest species and will probably succumb to the elements and conditions of newly established areas. In addition to these large tree species we would propose that the bulk of the planting would comprise smaller trees and shrubs. The following tree and shrub species are also rapid growing species, however they are restricted in their size, i.e. they naturally only attain a certain size and height. These species will comprise the intermediate level of the forest structure.

- *Rothmannia globosa* – Rapid growing tree
- *Brachylaena discolor* – Rapid growing tree (quite competitive so plant with caution)
- *Ptaeroxylon obliquum* – Fairly slow growth
- *Eugenia capensis* – Relatively slow
- *Searsia chirindensis* – Rapid growth
- *Kraussia floribunda* – Rapid growth
- *Pavetta lanceolata* – Rapid growth
- *Sclerocroton integerrimum* – Quick growing

Smaller tree species such as *Englerophytum natalense, Erythroxylum emarginatum* may not fare well in exposed conditions, as they prefer to grow in well protected environments where they are not exposed to high light intensities and are not damaged by wind action. Bearing this in mind we propose a first and second planting regime. A list of the species as well as the numbers of individuals to be planted is included in **Table 7.**

10.8.3 First Planting

The first planting would involve the preparation of the receiving area, the planting of the large trees, which in time will establish the forest canopy and the smaller trees which will form the intermediate level of the forest structure. Please note that it is important that a range of tree sizes are planted concurrently. It has been shown in other places where rehabilitation has been undertaken that planting trees all of the same age / cohort will result in significantly higher mortality rates as well as create a uniform stand of trees which is not the ideal outcome when considering that a natural forest is layered / stratified. It is therefore bearing this in mind that we would suggest that plants in 10, 20 and 40 litre bags are planted, as they will respond differently to being planted out and will thus create the natural stratification that is required in order to recreate Coastal Forest. A schematic diagram of development of Lowland Forest is included below at **Figure 16**.

Species to be planted in first planting

The species which should be planted initially are listed in **Table 7**.

Preparation for planting

The preparation of the site for planting is exceedingly important. A number of steps will be required in order to ensure that the proposed restoration / rehabilitation of the site is a success.

Access

Firstly, the control of access onto the site will be important, as the trees once planted out will be susceptible to damage.

We would recommend that the area to be restored / rehabilitated must be cordoned off to prevent people from entering the area and preventing the natural successional process from occurring. Once the vegetation is well established the area can be integrated back into the surrounding areas, by removing the physical barriers erected.

Soil Preparation & Planting

As the soils for the most part are relatively sandy, and as a result of agricultural activities having compacted them, we would suggest that the entire area identified for recreation of forest, be ripped to a depth of approximately 500 mms in order to loosen the soils. Further the sandy nature of the soils alludes to their inability to retain nutrients and resources required by the plants to establish and grow well. In preparing the holes for planting we would recommend the following inputs and additives to ensure that the trees will establish quickly and show rapid growth.

Planting guidelines

Mix a third compost, with two thirds soil, this will provide some additional structure to the soils and aid in retaining the valuable nutrients and prevent the rain from leaching these soils so rapidly. The addition of the compost will provide a basis that will be supplemented once the trees have established and they start to drop leaves and fruit and create their own organic matter. We would also suggest that 250 grams of Bounce® be spread into the soil that will be used to backfill the hole around the individual trees.

In terms of the hole size we would suggest the following, that a 600 mm X 600 mm hole be dug. The soil must be mixed with the compost and the Bounce® and returned to the hole once the tree has been placed inside of it. Prior to placement of the tree, the roots should be gently loosened from the confinement of the bag. This must be undertaken carefully in order to ensure that no root damage is caused.

The soil should be gently compacted in layers as it is returned to the hole. Any additional soil should be shaped into a bowl around the tree which will aid in containing water when the tree is watered. Once all the soil has been returned, the tree should get approximately ten litres of water poured around the base so as to further settle and remove any remaining air pockets that would have developed as a result of the planting exercise. In addition, the water will aid in maintaining the plant during its acclimatisation period.

Once the trees have been planted, they should receive a good drenching every five days during dry spells, for the first two months of having been planted out.

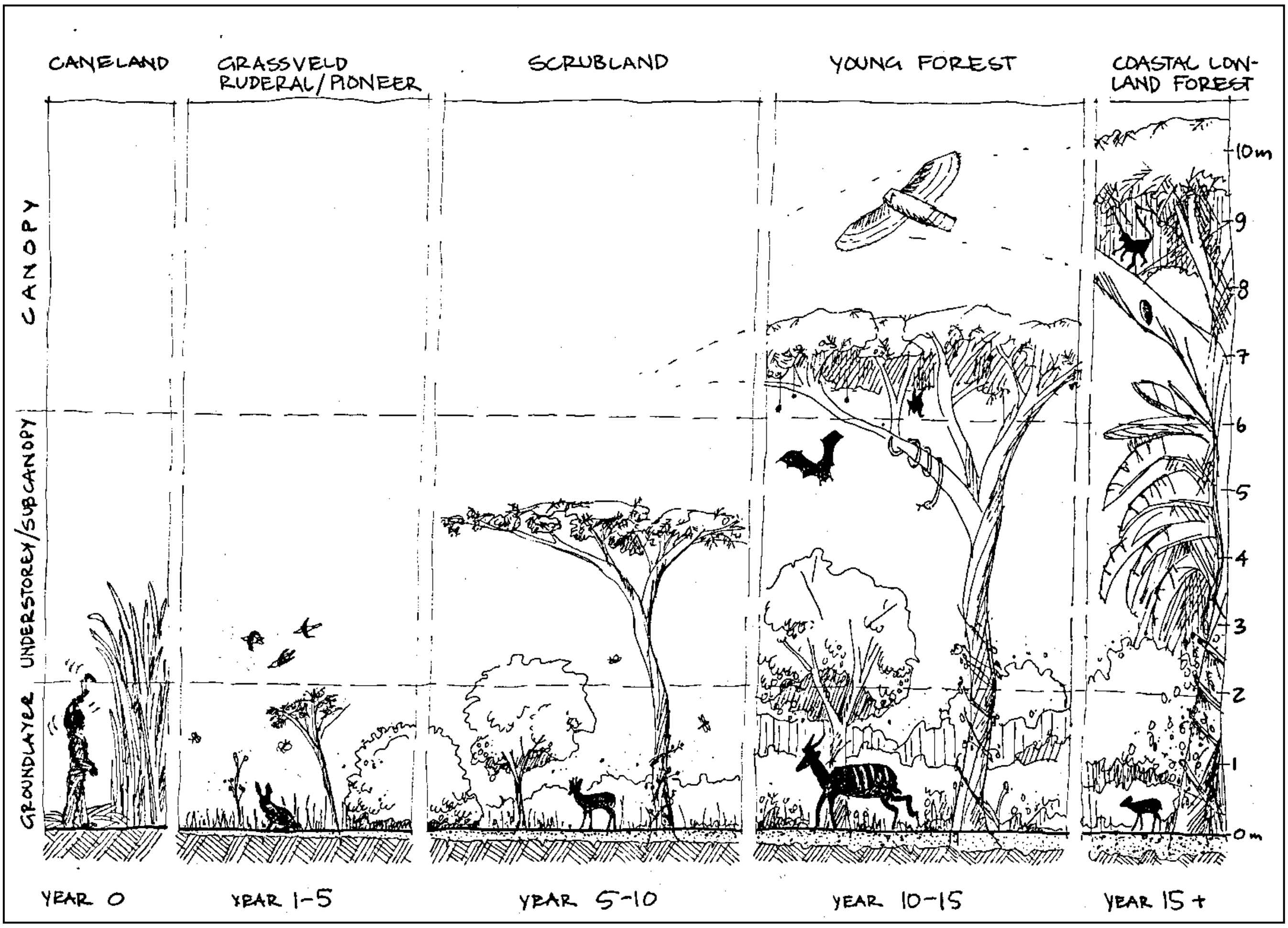

Figure 16. Schematic representation of Succession from Cane land to Lowland Forest (Image courtesy of G. Nicholls, 2003)

10.8.4 Second Planting

Plant species identified under the second planting, are species which are considered by the author to be more susceptible to damage as well as the elements. These species will, if introduced at the same time as the other species, probably not survive and will result in wasted expenditure. Secondly, many of the plants that will be planted in the second planting are considered to be the intermediate and under-storey plants that require higher levels of protection against the elements. It is our submission that many of the herbaceous plant species, as well as the creeper species, will probably be re-introduced relatively easily through natural processes, such as re-colonisation. We base this on the grounds that a number of these species already occur in the surrounding vegetation, as well as at other sites in close proximity to this particular area. Further, it was evidenced during the site survey that there were large agglomerations of white-eared barbets, a frugivorous species that will provide plenty of propagules into the rehabilitation area.

The timing of the second planting will depend on the success of the first planting, in addition, the speed at which growth is occurring. Should the growth be rapid, we would suggest that a second planting would potentially be successful within five years. Again, we need to stipulate that the requirement for a second planting depends on the natural ability of the surrounding vegetation to provide propagules to the rehabilitation area. Concomitant, whether the second plantings of the rarer species, which are considered core species, will mirror what was lost originally.

11 BILL OF QUANTITIES

11.1 Areas identified for rehabilitation

Table 8. 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	27500	2.75	9167	1 plant / 3 m^2
Semi-permanent zone	192600	19.26	96300	1 plant / 2 m^2
Seasonal zone	319600	31.96	213067	1 plant / 1.5 m^2
Temporary zone	351000	35.10	1053	30 kgs seed / hectare
Dry ponds in wetlands	41200	4.12	27467	1 plant / 1.5 m^2
Buffer zones	1030800	103.08	3092	30 kgs seed / hectare
Parks	115000	11.50	345	30 kgs seed / hectare
Servitudes	550300	55.03	1651	30 kgs seed / hectare
Indigenous Woody (new)	29900	2.99	13300	1 tree / 2.25 m^2
Open Space Grassland	1114800	111.48	3344	30 kgs seed / hectare
Open Water	N/A			
Riparian	19200	1.92	8500	1 tree / 2.25 m^2
Total Re-vegetation Area	**3791900**	**379.19**	**359301***	

***Excludes kgs of grass seed required, which equates to 9485 kgs of seed.**

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

Table 9. 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%	136.89
Ischaemum fasciculatum	5.00	17%	179.01
Imperata cylindrica	4.00	13%	136.89
Andropogon appendiculatus	4.50	15%	157.95
Bothriochloa insculpta	4.00	13%	136.89
Eragrostis racemosa	4.00	13%	136.89
Eragrostis capensis	4.50	15%	157.95
TOTAL	**30.00**	**100%**	**1053**

Table 10. The proportions and kgs of grass seed required for each hectare of Buffer Zone to be rehabilitated.

Buffer Zone	No. /kgs/ha	Proportions	Kgs
Themeda triandra	12	40%	1236.96
Aristida junciformis	2	7%	206.16
Melinis nerviglumis	3	10%	309.24
Monocymbium ceresiiforme	3	10%	309.24
Alloteropsis semialata	2	7%	206.16
Brachiaria serrata	1.5	5%	154.62
Tristachya leucothrix	2	7%	206.16
Eragrostis capensis	4.5	15%	463.86
TOTAL	**30**	**100%**	**3092.4**

Table 11. The proportions and total plant numbers required for the category – Seasonal Zone

Seasonal Zone	Proportions	Individuals
Cyperus dives	30	63921
Cyperus laevigatus	10	21307
Cyperus sexangularis	10	21307
Cyperus solidus	10	21307
Cyperus sphaerospermus	20	42614
Pycreus nitidus	10	21307
Juncus dregeanus	5	10653
Bulbostylis hispidula	5	10653
TOTAL	**100**	**213067**

Table 12. The proportions and total plant numbers required for the category – Semi-permanent Zone

Semi-Permanent	Proportions	Individuals
Cyperus latifolius	25	24075
Cyperus dives	25	24075
Cyperus fastigiatus	10	9630
Eleocharis limosa	7.5	7223
Schoenoplectus erectus	10	9630
Carex cognata	5	4815
Juncus lomatophyllus	5	4815
Cyperus denudatus	5	4815
Berula erecta	2.5	2407
Persicaria attenuata	2.5	2407
Persicaria decipiens	2.5	2407
TOTAL	**100**	**96300**

Table 13. The proportions and total plant numbers required for the category – Permanent Zone

Permanent Zone	Proportions	Individuals
Mariscus solidus	15	1375
Cladium mariscus	5	458
Cyperus dives	25	2292
Cyperus latifolius	15	1375
Phragmites australis	35	3208
Juncus lomatophyllus	5	458
TOTAL	**100**	**9167**

Table 14. The proportions and total tree numbers required for the establishment of Linking Riparian Zones

Linking Riparian Zones**	Proportions	Individuals
Wet	25	2125
Dry / Wet	25	2125
Dry	50	4250
TOTAL	**100**	**8500**

****Please note that given the significant number of tree species that are deemed suitable and where possible should be incorporated into the overall planting, we would state that the above is a simple example of the proportions that are to be utilised. We would propose that once the rehabilitation has commenced that the final number of trees as well as the ratios thereof are considered and thereafter implemented. Therefore the above is for indicative purposes only. Wetland Buffer Zones that fall within Linking Riparian Zones, must be planted with the woody vegetation in the proportions as provided above.**

Table 15. The proportions and total plant numbers required for the category – Dry Ponds The Dry Ponds have been broken up on a proportional basis with the Sedge dominated area being 1 hectare, and the graminoid component being approximately 3.12 hectares.

Dry Ponds	Proportions	Individuals
Sedges		
Cyperus sexangularis	10	667
Cyperus sphaerospermus	20	1333
Bulbostylis hispidula	40	2667
Cyperus congestus	30	2000
TOTAL (individuals)	**100**	**6667**
Graminoids		
Setaria sphacelata	13	12
Andropogon appendiculatus	30	27
Aristida junciformis	15	13.5
Imperata cylindrica	27	24
Eragrostis capensis	15	13.5
TOTAL (kilograms)	**1.00**	**90**

Table 16. The proportions and kgs of grass seed required for each hectare of Servitude to be rehabilitated.

Servitudes	Kg/Ha	Proportions	Kgs/Sp.
Themeda triandra	12	40%	660.40
Aristida junciformis	2	7%	115.57
Melinis nerviglumis	3	10%	165.10
Monocymbium ceresiiforme	3	10%	165.10
Alloteropsis semialata	2	7%	115.57
Brachiaria serrata	1.5	5%	82.55
Tristachya leucothrix	2	7%	115.57
Eragrostis capensis	4.5	15%	247.65
TOTAL	**30**	**100%**	1651

Table 17. The proportions and kgs of grass seed required for each hectare of Open Space to be rehabilitated.

Open Space	Kg/Ha	Proportions	Kgs/Sp.
Themeda triandra	12	40%	1337.60
Aristida junciformis	2	7%	234.08
Melinis nerviglumis	3	10%	334.40
Monocymbium ceresiiforme	3	10%	334.40
Alloteropsis semialata	2	7%	234.08
Brachiaria serrata	1.5	5%	167.20
Tristachya leucothrix	2	7%	234.08
Eragrostis capensis	4.5	15%	501.6
TOTAL	**30**	**100%**	**3344**

Table 18. The tree species and the proportions required to recreate Coastal Woody Vegetation to expand the existing areas on site and contribute to the overall diversity of the site.

Indigenous Woody Areas	Proportions (%)	Individuals
Albizia adianthifolia	2	267
Allophylus africanus	2	267
Allophylus dregeanus	2	267
Antidesma venosum	2	267
Baphia racemosa	2	267
Bersama lucens	1	133
Brachylaena discolor	1	133
Bridelia micrantha	2	267
Canthium inerme	2	267
Celtis africana	3	400
Clausena anisata	2	267
Clerodendrum glabrum	2	267
Cordia caffra	3	400
Crotalaria capensis	1	133
Croton sylvaticus	3	400
Cussonia sphaerocephala	1	133
Diospyros villosa	1	133
Drypetes arguta	1	133
Drypetes gerrardii	1	133
Ekebergia capensis	2	267
Englerophytum natalense	1	133
Erythroxylum emarginatum	1	133
Ficus lutea	2	267
Ficus natalensis	2	267
Ficus sur	2	267
Grewia occidentalis	2	267
Gymnosporia nemorosa	2	267
Halleria lucida	2	267
Harpephyllum caffrum	2	267
Lagynias lasiantha	2	267
Maerua racemulosa	1	133
Maytenus acuminata	2	267
Maytenus peduncularis	2	267
Maytenus procumbens	2	267
Mimusops caffra	3	400
Neonotonia wightii	1	133
Ochna natalitia	1	133
Pavetta lanceolata	1	133
Peddiea africana	2	267
Protorhus longifolia	3	400
Psychotria capensis	1	133
Psydrax obovata	2	267

Indigenous Woody Areas	Proportions (%)	Individuals
Putterlickia verrucosa	2	267
Rauvolfia caffra	2	267
Rothmannia globosa	2	267
Sclerocroton integerrimum	2	267
Scutia myrtina	2	267
Searsia chirindensis	2	267
Shirakiopsis elliptica	2	267
Sideroxylum inerme	2	267
Teclea gerrardii	1	133
Trema orientalis	1	133
Tricalysia sonderiana	1	133
Trichilia emetica	1	133
Trimeria grandifolia	1	133
Turraea floribunda	2	267
Vepris lanceolata	2	267

11.3 The Combined Bill of Quantities

Table 19. The quantities of grass seed and individual plants required for the re-vegetation of the wetlands and open spaces.

GRAMINOID SPECIES	KILOGRAMS
Alloteropsis semialata	556
Andropogon appendiculatus	185
Aristida junciformis	569
Bothriochloa insculpta	137
Brachiaria serrata	404
Eragrostis capensis	1385
Eragrostis racemosa	137
Imperata cylindrica	161
Ischaemum fasciculatum	179
Melinis nerviglumis	809
Monocymbium ceresiiforme	809
Setaria sphacelata	149
Themeda triandra	3235
Tristachya leucothrix	556
Cynodon dactylon / Dactyloctenium australe	345
Total Kilograms of Grass Seed Required	**9616**
SEDGE SPECIES	**INDIVIDUALS**
Berula erecta	2407
Bulbostylis hispidula	13320
Carex cognata	4815
Cladium mariscus	458
Cyperus congestus	2000
Cyperus denudatus	4815
Cyperus dives	90288
Cyperus fastigiatus	9630
Cyperus laevigatus	21307
Cyperus latifolius	25450
Cyperus sexangularis	21974

Cyperus solidus	21307
Cyperus sphaerospermus	43947
Eleocharis limosa	7223
Juncus dregeanus	10653
Juncus lomatophyllus	5273
Mariscus solidus	1375
Persicaria attenuata	2407
Persicaria decipiens	2407
Phragmites australis	3208
Pycreus nitidus	21307
Schoenoplectus erectus	9630
Total Sedge Individuals Required	**325201**
TREE SPECIES	**INDIVIDUALS**
Wet Tree Species	2125
Dry Tree Species	4250
Dry / Wet Tree Species	2125
Albizia adianthifolia	267
Allophylus africanus	267
Allophylus dregeanus	267
Antidesma venosum	267
Baphia racemosa	267
Bersama lucens	133
Brachylaena discolor	133
Bridelia micrantha	267
Canthium inerme	267
Celtis africana	400
Clausena anisata	267
Clerodendrum glabrum	267
Cordia caffra	400
Crotalaria capensis	133
Croton sylvaticus	400
Cussonia sphaerocephala	133
Diospyros villosa	133
Drypetes arguta	133
Drypetes gerrardii	133
Ekebergia capensis	267
Englerophytum natalense	133
Erythroxylum emarginatum	133
Ficus lutea	267
Ficus natalensis	267
Ficus sur	267
Grewia occidentalis	267
Gymnosporia nemorosa	267
Halleria lucida	267
Harpephyllum caffrum	267
Lagynias lasiantha	267
Maerua racemulosa	133
Maytenus acuminata	267
Maytenus peduncularis	267
Maytenus procumbens	267
Mimusops caffra	400

Neonotonia wightii	133
Ochna natalitia	133
Pavetta lanceolata	133
Peddiea africana	267
Protorhus longifolia	400
Psychotria capensis	133
Psydrax obovata	267
Putterlickia verrucosa	267
Rauvolfia caffra	267
Rothmannia globosa	267
Sclerocroton integerrimum	267
Scutia myrtina	267
Searsia chirindensis	267
Shirakiopsis elliptica	267
Sideroxylum inerme	267
Teclea gerrardii	133
Trema orientalis	133
Tricalysia sonderiana	133
Trichilia emetica	133
Trimeria grandifolia	133
Turraea floribunda	267
Vepris lanceolata	267
Total Number of Individual Trees Required	**21838**

12 ALIEN PLANT ERADICATION AND CONTROL PROGRAMME

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

12.1 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.

12.2 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.

12.2.1 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.

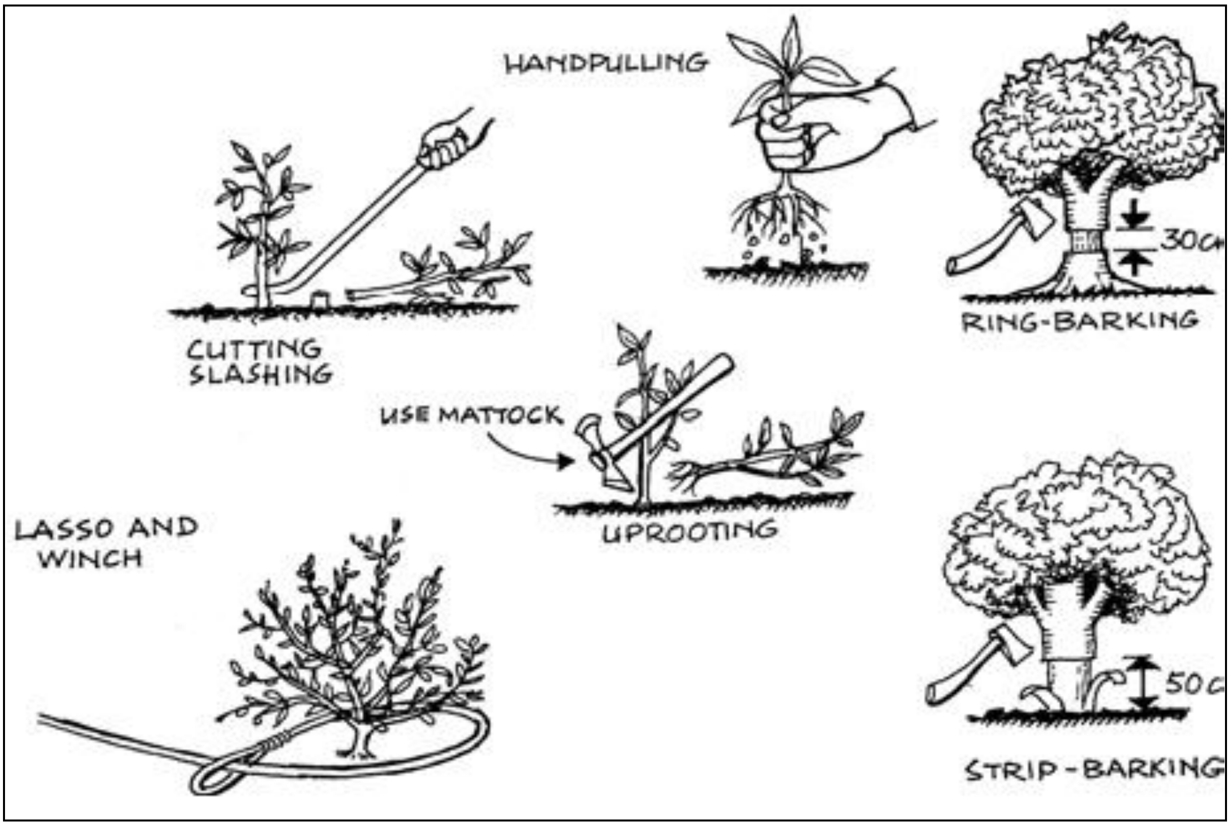

Figure 17: Schematic representation of six techniques used to remove alien invasive plant species.

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.

12.2.2 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 20. 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 21. 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 22. 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 23. 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 24. 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 25. 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 26. 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 27. 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 28. 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 29. 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 30. 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 31. 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 32. 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 33. 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

12.3 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.

13 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.

13.1 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.

13.2 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.

14 CONSTRUCTION MANAGEMENT PLAN

14.1 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.

14.2 Intervention Construction

The Working for Wetlands Standard Construction Environmental Management Plan for Wetland Rehabilitation Projects attached as **Appendix D** 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.

15 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.

15.1 Indicators to be Measured

15.1.1 *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.

15.1.2 *Structural integrity*

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

15.1.3 *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.

15.1.4 *Wetland Health*

To substantiate the argument that the rehabilitation of the wetland units has offset the impacts associated with the posed Phase 2 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.

15.2 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 16 below.

Table 16: 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)

15.3 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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