



TONGAAT HULETT DEVELOPMENTS

TINLEY MANOR SOUTH DEVELOPMENT, KWAZULU-NATAL PROVINCE

Wetland & Open Space Rehabilitation Plan

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SPECIALIST REPORT DETAILS

This report has been prepared as per the requirements of Section 13 of Government Notice No. R. 326 dated 7 April 2017 (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: 19/05/2017

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DISCLAIMER

Original Wetland Delineation and Completed Assessments

This rehabilitation plan is based on findings of the original wetland delineation assessment, compiled by SiVEST. It is also recommended that this document is read in conjunction with the numerous completed wetland assessment reports for the 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 two years 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
TINLEY MANOR SOUTH DEVELOPMENT
WETLAND & OPEN SPACE REHABILITATION PLAN

Contents	Page
1 INTRODUCTION.....	1
2 OBJECTIVES.....	1
3 STUDY AREA	2
3.1 OVERVIEW	2
3.2 CLIMATE.....	2
3.3 GEOLOGY AND SOILS	2
3.4 TOPOGRAPHY AND DRAINAGE	2
3.5 VEGETATION COVER	3
4 METHODS	4
4.1 WETLAND REHABILITATION PLAN.....	4
4.1.1 <i>Intervention Selection and Design</i>	4
4.1.2 <i>Re-vegetation Intervention</i>	4
4.1.3 <i>Wetness zone identification</i>	5
5 OFFSETTING WETLAND LOSS VIA REHABILITATION	6
6 WETLAND REHABILITATION VISION AND GOALS.....	8
6.1 FLOOD PLAIN UNITS.....	8
6.2 VALLEY BOTTOM WETLAND UNITS.....	8
6.3 HILLSIDE SEEPS	8
7 WETLAND REHABILITATION ENGINEERING INTERVENTION SELECTION AND DESIGN.....	9
7.1 INTRODUCTION.....	9
7.2 METHODOLOGY	9
7.2.1 <i>Geomorphic Conditions</i>	9
7.2.2 <i>Hydrological Conditions</i>	10
7.2.3 <i>Contributing Catchment Delineation and River Reach Analysis</i>	10
7.2.4 <i>Land Use</i>	10
7.2.5 <i>Design Flood Determination</i>	10
7.2.6 <i>Slope of Streambed and Surrounding Area</i>	11
7.2.7 <i>Intervention Selection</i>	11
7.3 NOTES FOR THE CONSTRUCTION OF THE CONCRETE WEIRS AND SPREADER CANALS	12
7.4 NOTES FOR THE CONSTRUCTION OF THE GABION WEIRS, GABION PLUGS AND SPREADER CANALS.....	12
8 BACKGROUND TO THE RE-VEGETATION PROGRAMME	13
9 PLANTING METHODOLOGY.....	13
9.1 METHODOLOGIES FOR THE RE-ESTABLISHMENT OF TERRESTRIAL BUFFER ZONE GRASSLANDS.....	14
9.1.1 <i>Broadcasting</i>	14
9.1.2 <i>Drill seeding</i>	14

9.1.3	<i>Hydraulic seeding / Hydro-seeding</i>	15
9.1.4	<i>Cut Grass Placement</i>	15
9.2	SOIL STABILISATION TECHNIQUES USING VARIOUS PRODUCTS	15
9.2.1	<i>Hydro-mulching</i>	15
9.2.2	<i>Turfing</i>	16
9.2.3	<i>Geotextiles</i>	16
9.2.4	<i>Terrestrial / Wetland Ecotone or Fringe</i>	19
9.2.5	<i>Terrestrial Environment</i>	19
9.3	WETLANDS	19
9.3.1	<i>Floodplain Areas</i>	20
9.3.2	<i>Seasonal & Semi Permanent Areas</i>	21
9.3.3	<i>Elevated Areas on the floodplain and fringes of the floodplain</i>	21
9.3.4	<i>Riverbanks and low lying areas requiring additional protection</i>	21
9.3.5	<i>Permanently Saturated and Inundated Wetland</i>	21
9.3.6	<i>Semi-permanent Wetland (water table never lower than 50 cm)</i>	21
9.3.7	<i>Temporary Wetland</i>	22
9.3.8	<i>Interventions</i>	22
10	BILL OF QUANTITIES	24
10.1	AREAS IDENTIFIED FOR REHABILITATION	24
10.2	BILL OF QUANTITIES FOR EACH CATEGORY OF RE-VEGETATED AREA	24
10.3	THE COMBINED BILL OF QUANTITIES	25
11	ALIEN PLANT ERADICATION AND CONTROL PROGRAMME	27
11.1	STEP 1	27
11.2	STEP 2	27
11.2.1	<i>Mechanical Methods</i>	27
11.2.2	<i>Chemical Methods</i>	29
11.3	STEP 3	34
12	WETLAND CONSERVATION MANAGEMENT PLAN	35
12.1	HUMAN DISTURBANCE MINIMISATION MEASURES	35
12.2	FIRE MANAGEMENT PLAN.....	35
13	CONSTRUCTION MANAGEMENT PLAN	35
13.1	ROAD CROSSING REMOVAL	35
13.2	INTERVENTION CONSTRUCTION	36
14	MONITORING PROGRAMME	36
14.1	INDICATORS TO BE MEASURED	36
14.1.1	<i>Construction and Implementation</i>	37
14.1.2	<i>Structural integrity</i>	37
14.1.3	<i>Fixed-point photography</i>	37
14.1.4	<i>Wetland Health</i>	37
14.2	FREQUENCY, INTERVAL AND TIMING OF MONITORING	38
14.3	EVALUATION PROCEDURE.....	38
15	REFERENCES	39

Appendix A: General Layout of Engineering Interventions

Appendix B: Typical Detail for Concrete and Gabion Intervention Structures

List of Figures

Figure 1: Tinley Manor South Wetland Overview 2

Figure 2: A schematic diagram showing how the post-rehabilitation extent of the permanent and semi-permanent wetland zones will be predicted 5

Figure 3: Example of wetland and open space zonation to be completed for the entire development. . 6

Figure 4: Wetland Loss Map..... 7

Figure 5: Example of a man-made channel 10

Figure 6: Proposed interventions and associated flood back..... 12

Figure 7. 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). 18

Figure 8: A schematic diagram representing the proposed planting methodology to be adopted when rehabilitating wetland areas (Kinvig, 2011). 20

Figure 9: Schematic representation of six techniques used to remove alien invasive plant species.... 28

Glossary of Important Terms

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

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

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

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

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

Crimping: To compress into small folds or ridges.

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

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

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

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

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

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

Graminoid: Technical term for grasses.

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

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

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

Intervention: An engineered structure such as a concrete or gabion weir, earthworks or re-vegetation that 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 gully) and to spread it over a wide area when the water in the artificial channel or gully 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
TINLEY MANOR SOUTH DEVELOPMENT
WETLAND & OPEN SPACE REHABILITATION PLAN

1 INTRODUCTION

SiVEST has been appointed by Tongaat Hulett Developments to compile a wetland rehabilitation plan for Wetland Units that are going to be conserved within the Tinley Manor South Development (**Figure 1**). These wetlands units were delineated by SiVEST.

In addition, SiVEST have also been appointed to compile a rehabilitation and management plan for the proposed Open Spaces within Tinley Manor South Development. 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.

IT MUST BE NOTED THAT WHILE THE METHOD OF REHABILITATION WILL NOT CHANGE, THE PLANTING PALETTES PROPOSED IN THIS DOCUMENT ARE CONSTANTLY BEING REFINED, AND GIVEN THE RECENT REHABILITATION EFFORTS UNDERTAKEN AT CORNUBIA AND THE KING SHAKA INTERNATIONAL AIRPORT, THERE MAY BE CHANGES MADE TO THE ACTUAL SPECIES COMPOSITION AS LESSONS ARE LEARNT FROM THESE REHABILITATION EFFORTS.

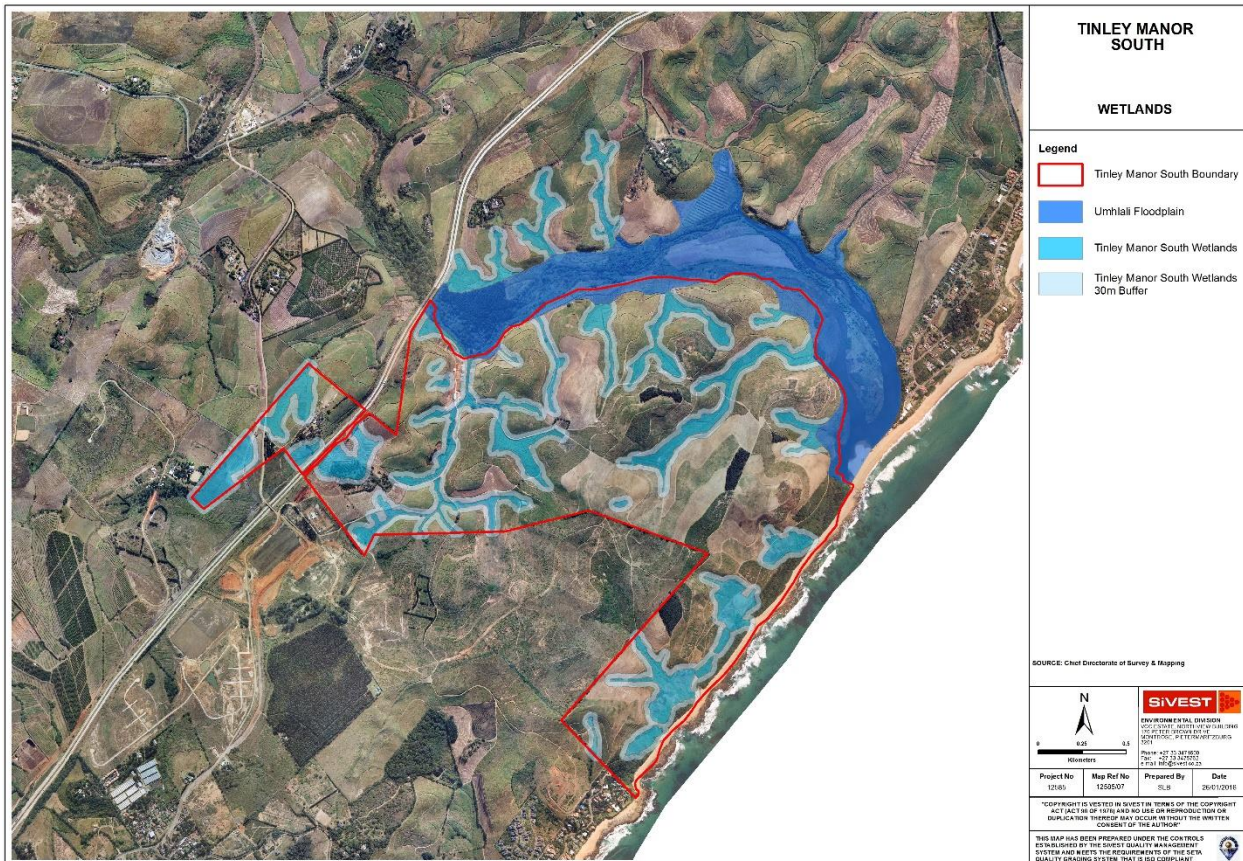


Figure 1: Tinley Manor South Wetland Overview

3 STUDY AREA

3.1 Overview

As previously mentioned, the study area is approximately 485 ha in size and lies predominantly on the southern bank of the Umhlali River near the coastline, east of the N2 freeway. A small portion of the site straddles and lies to the west of the N2 (**Figure 1**).

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 two broad geologies dominate the site. The western portion of the property is underlain by shale and this has led to the development of generally narrow, steeply incised drainage features across this portion. The eastern portion of the site by contrast is characterised by deep sands and the valleys tend to be broader and shallower.

3.4 Topography and Drainage

The study area falls within the Mkomazi Primary catchment. More specifically, the study area is situated in quaternary catchment U30E. The study area is characterised by a series of undulating ridges and steep valleys. Drainage from the site is towards the Umhlali River.

The secondary dunes on site are very high and slope steeply down towards the coast. Seepage from the base of these features has formed a band of wetlands between the dunes and the sea.

The portion of the property to the west of the N2 consists of both shale and sand derived elements.

The Umhlali River Floodplain dominates much of the river frontage of the site and the meandering stream has over time created a series of channels and islands across the broad flat floodplain. This portion of the site is characterised by unconsolidated sediments deposited during flood events.

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 Umhlali 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 Umhlali 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 ArcView GIS 9.3 software.

A site visit to each wetland unit was undertaken by the wetland specialist and ecologist 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 will be 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 will then be designed in conjunction with the civil engineer using ArcGIS and CAD software packages.

The wetland management programme for the operational phase of the Tinley Manor South development involves the design of a long term disturbance monitoring programme. Taking into account the surrounding land uses, the potential disturbance impacts to the wetland will be 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 management facilities** - 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) will be determined by drawing a contour along the weir elevation, upstream of the structure (see **Figure 2**). 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 will be 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 2**) shows how the extents of this zone will be determined. An imaginary plane, 500 mm higher than the water surface will be created. Where this plane intersects the ground, a contour will be drawn, representing the extent of the wetness zone. An example of the overarching wetness zonation is shown in **Figure 3**. This zonation will be repeated for all wetland units located within Tinley Manor South Development.

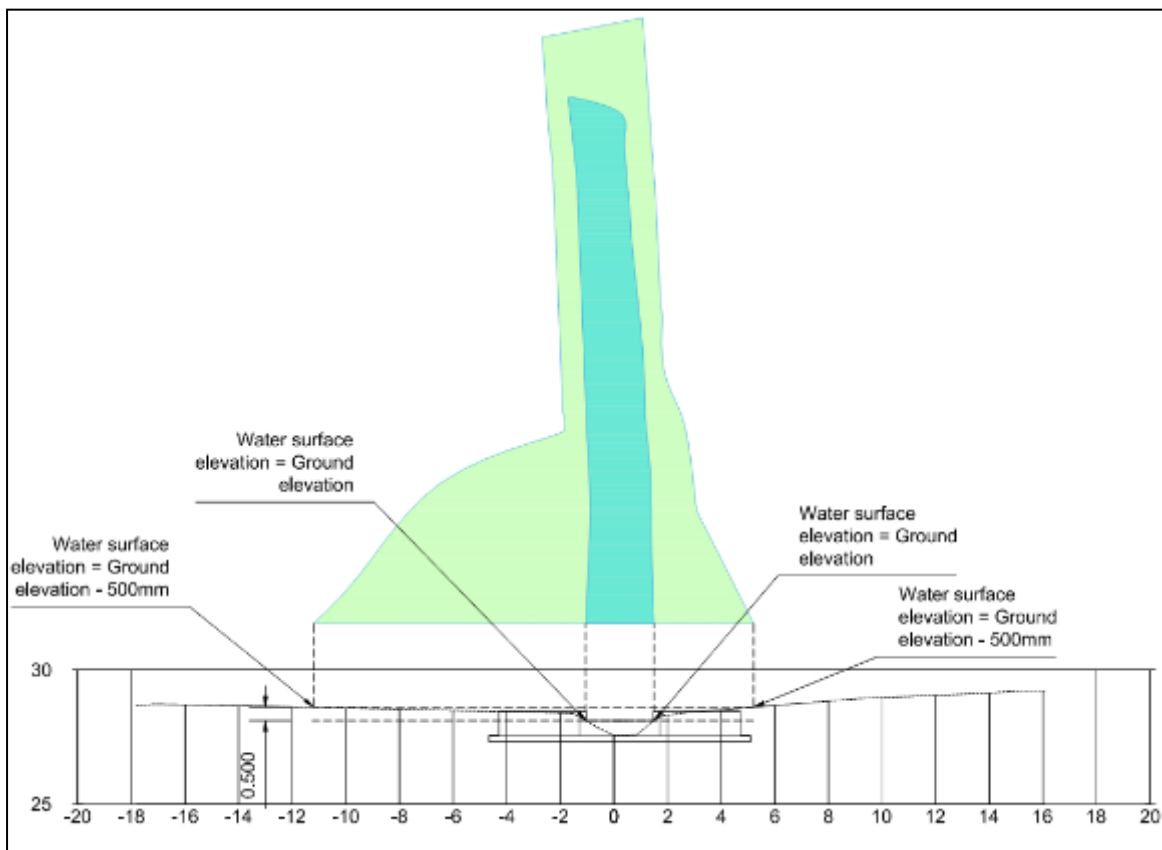


Figure 2: A schematic diagram showing how the post-rehabilitation extent of the permanent and semi-permanent wetland zones will be predicted

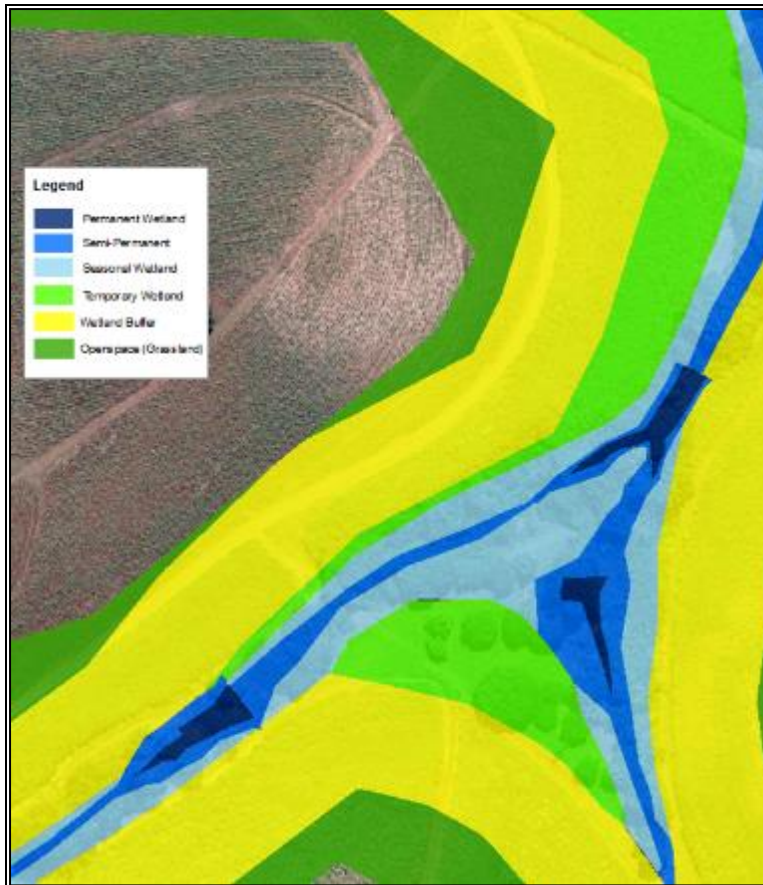


Figure 3: Example of wetland and open space zonation to be completed for the entire development.

5 OFFSETTING WETLAND LOSS VIA REHABILITATION

The proposed Tinley Manor South Development will result in a permanent loss of some wetland areas. For wetland offsets, the no-net wetland loss principle is generally accepted as best practice when dealing with the issues of wetland loss. This means that wetland loss must be replaced by wetland gain so that the net wetland loss is zero. The replacement of wetlands at a ratio of 1:1 is generally regarded as being insufficient to mitigate wetland loss as wetland rehabilitation cannot reproduce pristine wetlands. Internationally, a minimum ratio of 1:1.5 is generally required to achieve 1:1 compliance on the ground. However, this minimum ratio is only considered appropriate in situations where rehabilitation has a low risk of failure, especially if the wetlands in question are degraded and of low conservation value from an ecosystem services perspective. 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. The offset ratios for each wetland will be determined using the standard wetland offset guidelines, as published by the South African Biodiversity Institute and the Department of Water Affairs (2014)

The current layout for Tinley Manor South indicates that **24.87 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 **75.98 ha**, this is some **51.11 ha** more than the required minimum. This equates to a **1:9.17** offset ratio, which is significantly greater than the minimum 1:3 offset ratio. Thus the overall wetland losses can be considered to be adequately offset and the significance of the impact reduced to acceptable levels.

Table 1. Wetland Loss and Offset Calculations for Tinley Manor South

	Wetland Area (ha)	Wetland Loss (ha)	Required Wetland Area to be Rehabilitated at the 1:3 offset Ratio (ha)	Wetland Area Available for Rehabilitation
Tinley Manor South	84.27	8.29	24.87	75.98

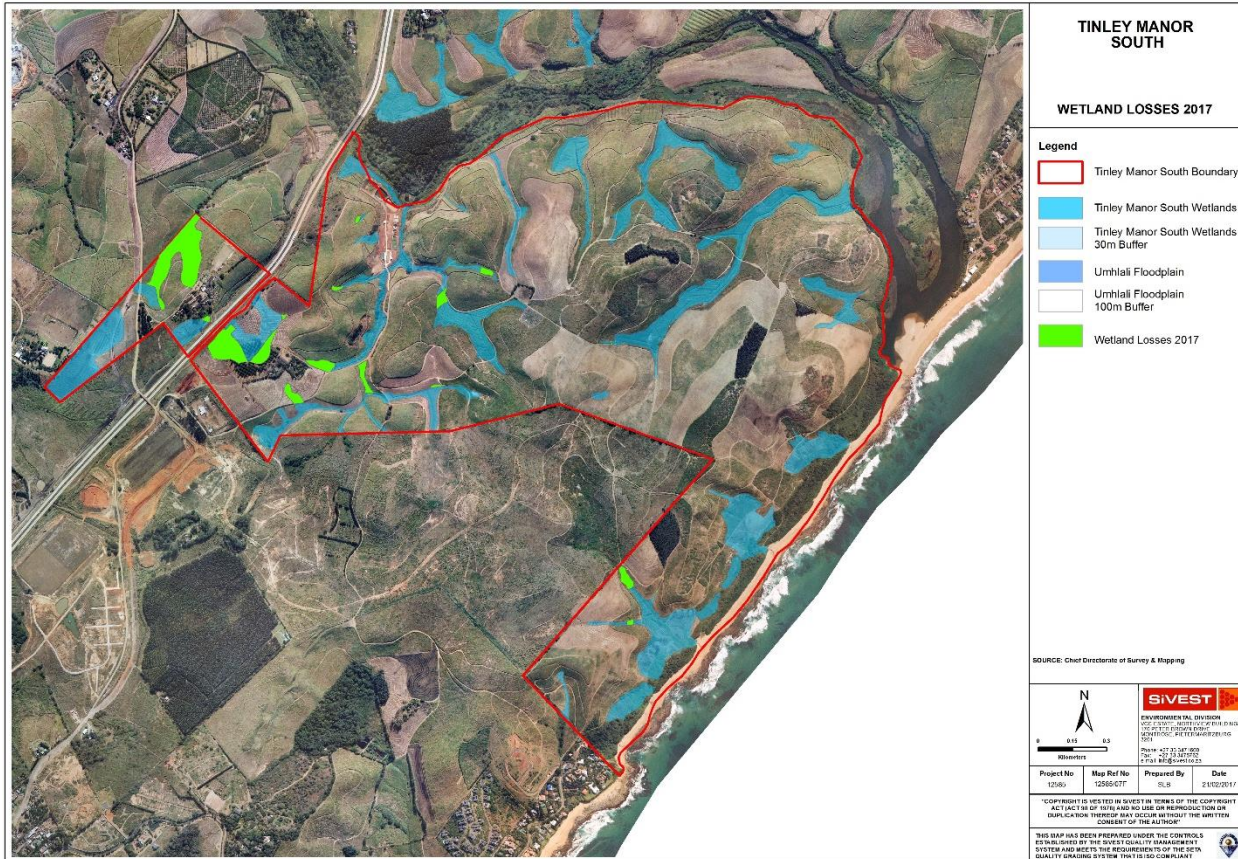


Figure 4: Wetland Loss Map

6 WETLAND REHABILITATION VISION AND GOALS

6.1 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.

6.2 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.

6.3 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**).

7 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.

7.1 Introduction

The current land use at Tinley Manor South (TMS) is primarily sugarcane cultivation. Historically, wetland areas within Tinley Manor South, 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.

7.2 Methodology

The following methodology has been used to position the proposed interventions and to determine the appropriate type and size of structure. The proposed interventions have been 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.

7.2.1 Geomorphic Conditions

Weirs have been positioned in areas where the stream channel has become incised as a result of artificial drainage channels being created (**Figure 5**).



Figure 5: Example of a man-made channel

7.2.2 *Hydrological Conditions*

Floodpeaks for the proposed weir locations have been 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 Tinley Manor South.

7.2.3 *Contributing Catchment Delineation and River Reach Analysis*

The contributing catchments have been delineated using survey data. The 1085-slope method¹ has been used to determine the average slope for each river reach. River length and elevation at points of interest have been calculated from topographical maps and the survey dataset.

7.2.4 *Land Use*

For all new developments the pre- and post-development flood peaks should be the same and the developers are obliged to provide storm water management in order to comply. Therefore, the current land use of sugarcane will be used to determine the runoff coefficients for each catchment. The resultant runoff coefficients generated have been checked to determine that they are appropriate for sugarcane farmland.

7.2.5 *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 have been calculated for each weir position as stipulated.

7.2.6 *Slope of Streambed and Surrounding Area*

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

7.2.7 *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 has been calculated using the broad crested spillway formula. The length of weir has been 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) has been used based on the typical size of the channels within Tinley Manor South and a flood peak of 10 m³/s. A weir larger than 15 m is 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 has been calculated using the sill level in conjunction with the topographical survey. An additional 500 mm has been added to the sill level to determine the area of semi-permanent wetland.

In addition, stabilisation (not restoration) should be adopted for the upper reaches of drainage lines. It is 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.

The intervention sites are determined through the above methodology are shown in **Figure 6** below, and in Appendix A.

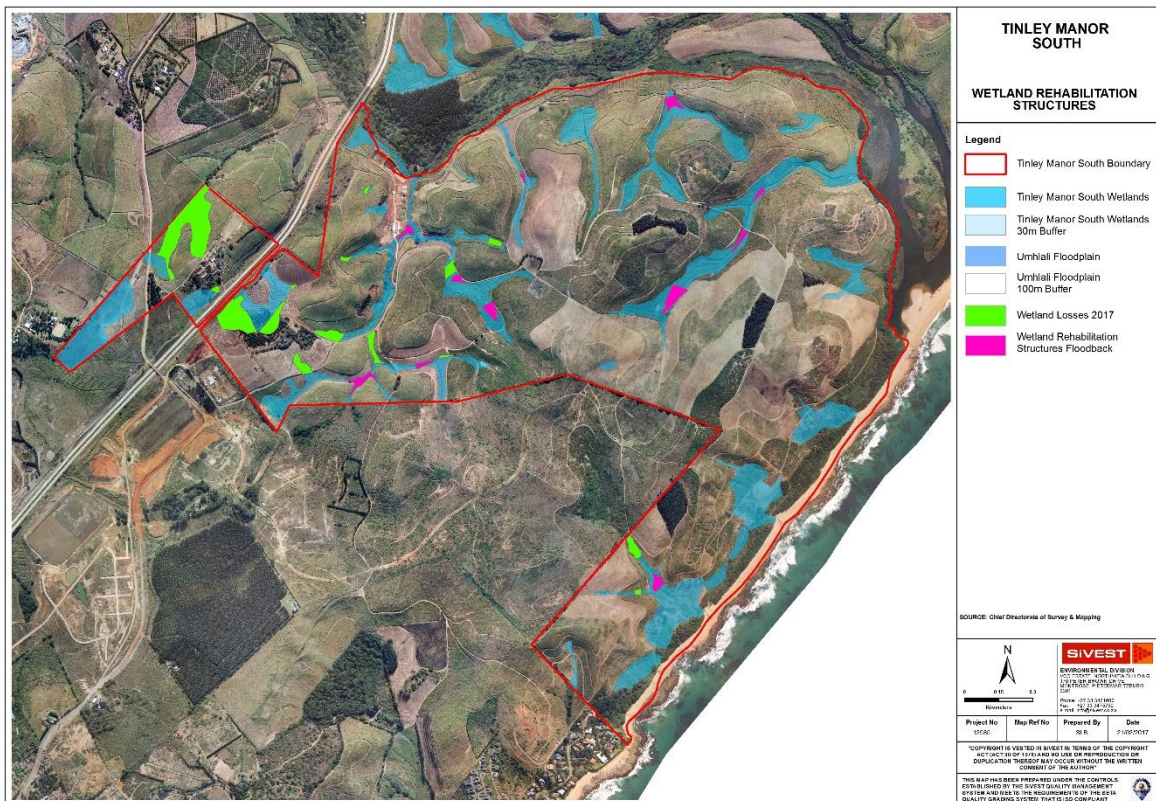


Figure 6: Proposed interventions and associated flood back.

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

- The drawings issued as part of the final version 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 will not be 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.

7.4 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.
- Earthen plugs are proposed to be used to plug the offline artificial drainage ditches and their position will be finalised during the implementation of the rehabilitation interventions.

8 BACKGROUND TO THE RE-VEGETATION PROGRAMME

Tinley Manor South is an extremely large area, totalling **485 hectares**, with the current layout proposing that the Open Space will exist within the various development typologies and infrastructural requirements proposed. 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 still to be finalised during the detailed design. 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 2. The various categories of Open Space Identified within the Tinley Manor South Layout.

OPEN SPACE CATEGORY	AREA (HA)	PROPORTION (%)
Terrestrial Environment	170.45	69.2%
Buffer	75.26	30.6%
Open Space (Grassland)	95.19	38.6%
Wetlands (excl. buffers)	75.9	30.8%
Permanent	3.1	1.2%
Semi-Permanent	4.7	2%
Temporary Wetland	68.1	27.6%
TOTAL	246.35	100%

9 PLANTING METHODOLOGY

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

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

located within the proposed 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.

9.1 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.

9.1.1 *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.

9.1.2 *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.

9.1.3 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.

9.1.4 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 vigorous growth and sustain the established grass seed.
- Soil Stabilisation Techniques using various products.

9.2 Soil Stabilisation Techniques using Various Products

9.2.1 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.

9.2.2 *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.

9.2.3 *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.

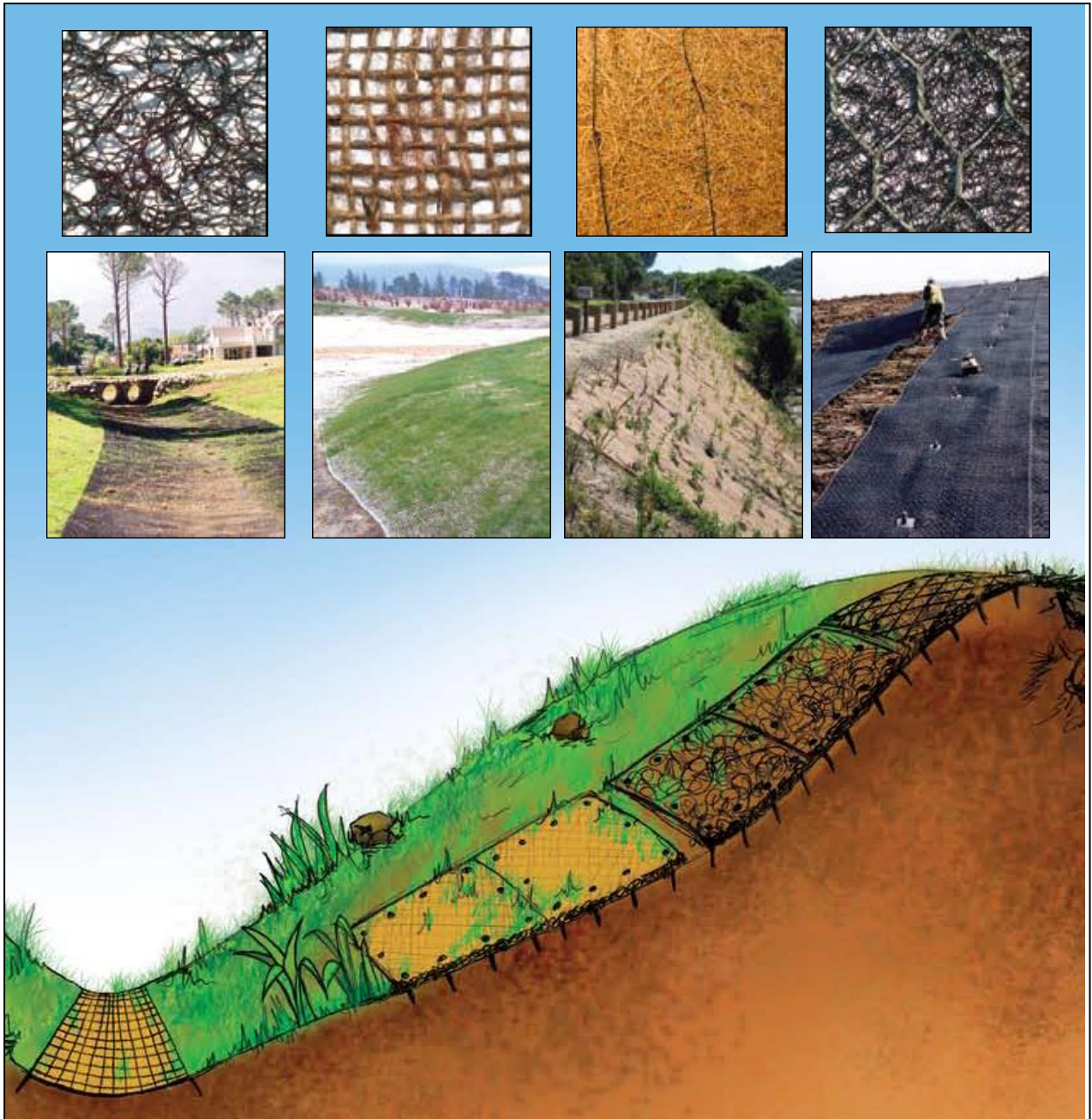


Figure 7. The various types of Geotextile fabrics commonly utilised in soil stabilisation and their position and application within the landscape at for which they are best suited. The insets are the differing geofabrics, and are named from left to right as follows (MacMat™, BioJute™, BioMac™, MacMat™R) 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 management 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.

9.2.4 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 along the north coast of KwaZulu Natal. The species proposed are as follows;

9.2.5 Terrestrial Environment

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

The above species are predominantly species which are referred to as Decreaser¹ 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.

9.3 Wetlands

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

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.

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 9** 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.

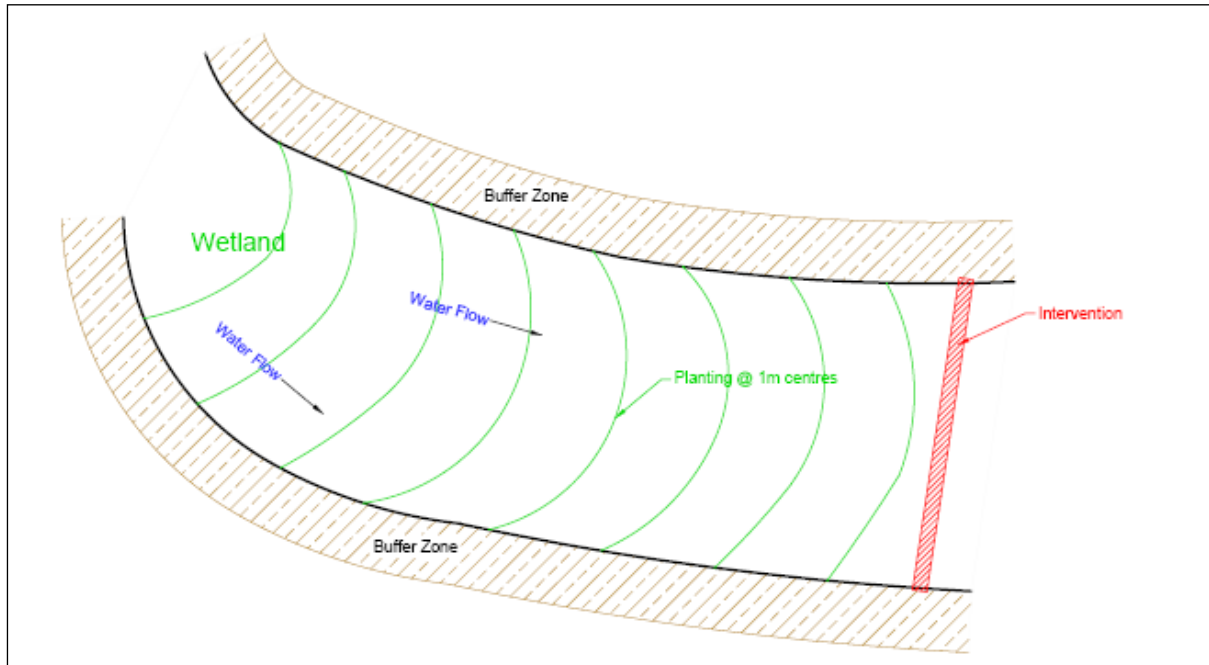


Figure 8: A schematic diagram representing the proposed planting methodology to be adopted when rehabilitating wetland areas (Kinvig, 2011).

9.3.1 Floodplain Areas

In terms of the Umhlali 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 Umhlali 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 Umhlali River are elevated due to the presence of the WWTW and the development that is occurring up-stream. We can therefore postulate that the Umhlali 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 than 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.

9.3.2 Seasonal & Semi Permanent Areas

- *Phragmites australis*

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

9.3.3 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*

9.3.4 Riverbanks and low lying areas requiring additional protection

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

9.3.5 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 m².

9.3.6 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 management 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 m².

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

9.3.7 Temporary Wetland

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

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

Grasses:

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

Sedges:

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

9.3.8 Interventions

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

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

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

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

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

10 BILL OF QUANTITIES

10.1 Areas identified for rehabilitation

Table 3. 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	31000	3.1	10333	1 plant / 3 m ²
Semi-permanent zone	47000	4.7	23500	1 plant / 2 m ²
Temporary zone	680105	68.1	2043	30 kgs seed / hectare
Buffer zones	753000	75.3	2258	30 kgs seed / hectare
Open Space Grassland	951900	95.19	2856	30 kgs seed / hectare
Total Re-vegetation Area			33833*	

*Excludes kgs of grass seed required, which equates to 7157 kgs of seed.

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

Table 4. The proportions and kgs of grass seed required for each hectare of Temporary Zone to be rehabilitated.

Temporary Zone	No. /kgs/ha	Proportions	Kgs
<i>Setaria sphacelata</i>	4.00	13%	266
<i>Ischaemum fasciculatum</i>	5.00	17%	367
<i>Imperata cylindrica</i>	4.00	13%	266
<i>Andropogon appendiculatus</i>	4.50	15%	306
<i>Bothriochloa insculpta</i>	4.00	13%	266
<i>Eragrostis racemosa</i>	4.00	13%	266
<i>Eragrostis capensis</i>	4.50	15%	306
TOTAL	30.00	100%	2043

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

Buffer Zone	No. /kgs/ha	Proportions	Kgs
<i>Themeda triandra</i>	12	40%	880
<i>Aristida junciformis</i>	2	7%	158
<i>Melinis nerviglumis</i>	3	10%	226
<i>Monocymbium ceresiiforme</i>	3	10%	226
<i>Alloteropsis semialata</i>	2	7%	158
<i>Brachiaria serrata</i>	1.5	5%	113
<i>Tristachya leucothrix</i>	2	7%	158
<i>Eragrostis capensis</i>	4.5	15%	339
TOTAL	30	100%	2258

Table 6. The proportions and total plant numbers required for the category – Semi-permanent Zone

Semi-Permanent	Proportions	Individuals
<i>Cyperus latifolius</i>	25	5875
<i>Cyperus dives</i>	25	5875
<i>Cyperus fastigiatus</i>	10	2350
<i>Eleocharis limosa</i>	7.5	1764
<i>Schoenoplectus erectus</i>	10	2350
<i>Carex cognata</i>	5	1175
<i>Juncus lomatoophyllus</i>	5	1175
<i>Cyperus denudatus</i>	5	1175
<i>Berula erecta</i>	2.5	587
<i>Persicaria attenuata</i>	2.5	587
<i>Persicaria decipiens</i>	2.5	587
TOTAL	100	23500

Table 7. The proportions and total plant numbers required for the category – Permanent Zone

Permanent Zone	Proportions	Individuals
<i>Mariscus solidus</i>	15	1550
<i>Cladium mariscus</i>	5	516
<i>Cyperus dives</i>	25	2636
<i>Cyperus latifolius</i>	15	1550
<i>Phragmites australis</i>	35	3565
<i>Juncus lomatophyllus</i>	5	516
TOTAL	100	10333

Table 8. The proportions and kgs of grass seed required for each hectare of Open Space to be rehabilitated.

Open Space	Kg/Ha	Proportions	Kgs/Sp.
<i>Themeda triandra</i>	12	40%	1140
<i>Aristida junciformis</i>	2	6.7%	191
<i>Melinis nerviglumis</i>	3	10%	286
<i>Monocymbium cerasiiforme</i>	3	10%	286
<i>Alloteropsis semialata</i>	2	6.7%	191
<i>Brachiaria serrata</i>	1.5	5%	142
<i>Tristachya leucothrix</i>	2	6.7%	191
<i>Eragrostis capensis</i>	4.5	15%	429
TOTAL	30	100%	2856

10.3 The Combined Bill of Quantities

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

GRAMINOID SPECIES	KILOGRAMS
<i>Alloteropsis semialata</i>	349
<i>Andropogon appendiculatus</i>	306
<i>Aristida junciformis</i>	349
<i>Bothriochloa insculpta</i>	266
<i>Brachiaria serrata</i>	255
<i>Eragrostis capensis</i>	1074
<i>Eragrostis racemosa</i>	266
<i>Imperata cylindrica</i>	266
<i>Ischaemum fasciculatum</i>	367
<i>Melinis nerviglumis</i>	512
<i>Monocymbium cerasiiforme</i>	512
<i>Setaria sphacelata</i>	266
<i>Themeda triandra</i>	2020
<i>Tristachya leucothrix</i>	349
Total Kilograms of Grass Seed Required	7157
SEDGE SPECIES	INDIVIDUALS
<i>Berula erecta</i>	587
<i>Carex cognata</i>	1175
<i>Cladium mariscus</i>	516
<i>Cyperus denudatus</i>	1175
<i>Cyperus dives</i>	8511
<i>Cyperus fastigiatus</i>	2350
<i>Cyperus latifolius</i>	7425

<i>Eleocharis limosa</i>	1764
<i>Juncus lomatophyllus</i>	1691
<i>Mariscus solidus</i>	1550
<i>Persicaria attenuata</i>	587
<i>Persicaria decipiens</i>	587
<i>Phragmites australis</i>	3565
<i>Schoenoplectus erectus</i>	2350
Total Sedge Individuals Required	33833

11 ALIEN PLANT ERADICATION AND CONTROL PROGRAMME

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

11.1 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.

11.2 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.

11.2.1 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.

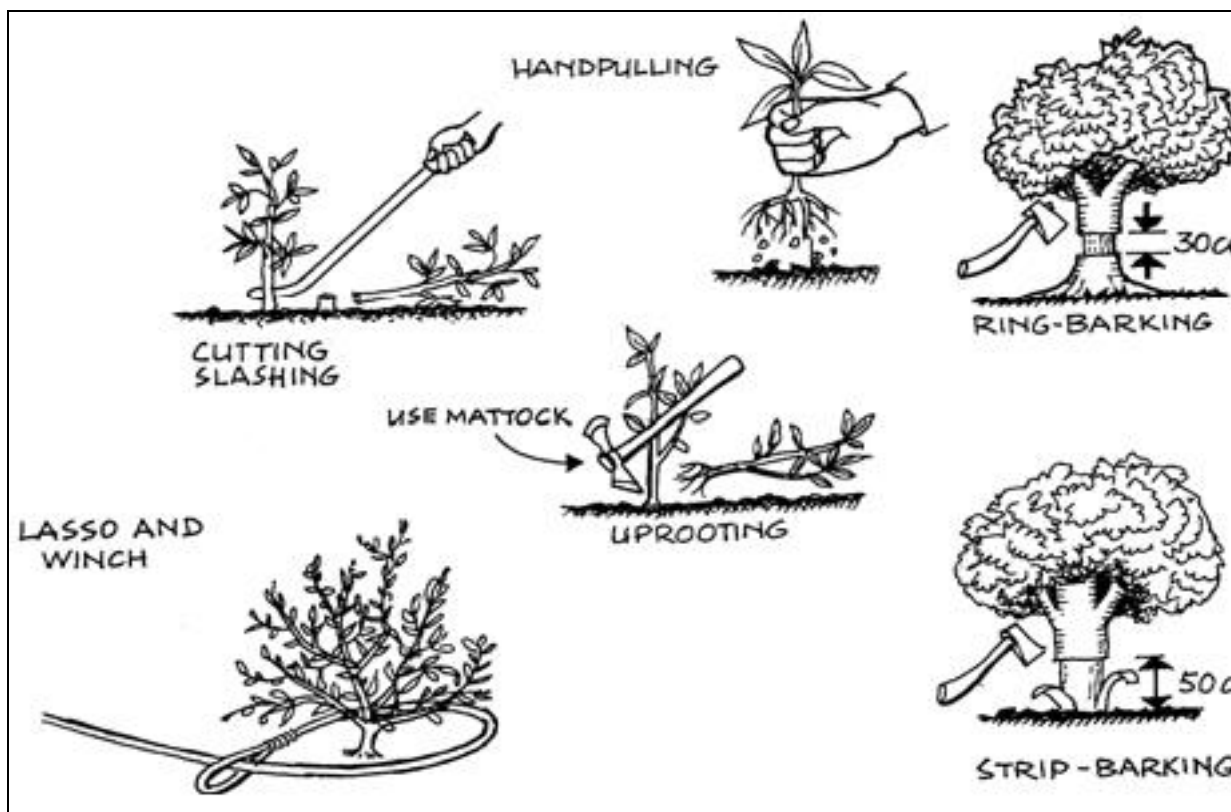


Figure 9: Schematic representation of six techniques used to remove alien invasive plant species.

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 Umhlali River and Estuary.

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

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

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

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

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

The following is the maturity classification used:

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

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

Person Day Norms – Herbaceous Species

Table 12. No stacking

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

Table 13. Stacked

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

Recommended Treatment Method – Herbaceous Species

Chromolaena, Lantana and other herbaceous species

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

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

When stacking:

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

Person Day Norms – Trees

Table 14. Frill, no stacking

Species	Size Class	Number of person days per hectare					
		Occasional	Very Scattered	Scattered	Medium	Dense	Closed
<i>Eucalyptus, Schinus, Acacia, Pinus, Melia, Morus, etc.</i>	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
>5 cm Frill and apply herbicide; <5 cm Slash and apply herbicide.	Adult	2.5	2.5	3.6	10	26	26
	Mature Adult	2.5	2.5	4	12	30	30
	X Large Adult	2.5	2.5	4	12	30	30

Table 15. Frill, Fell & Stack

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

Recommended Treatment Method – Trees

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

Person Day Norms – Small Trees

Table 16. Multi-stems, no stacking

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

Recommended Treatment Norms – Small Trees

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

Person Day Norms – Mixed Species

Table 17. Predominantly herbaceous, no stacking

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

Table 18. Predominantly herbaceous, stacking

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

Table 19. Predominantly woody, no stacking

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

Table 20. Predominantly woody, stacking

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

Recommended Treatment Methods – Mixed Species

Mixed species, predominantly herbaceous

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

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

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

Mixed species, predominantly woody

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

Follow up Person Day Norms

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

- Slash, herbicide & Spray
- Spray only

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

Table 21. Slash & herbicide

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

Table 22. Spray Only

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

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

Table 23. Commonly available registered Herbicides

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

11.3 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.

12 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.

12.1 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.

12.2 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 drawn 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.

13 CONSTRUCTION MANAGEMENT PLAN

13.1 Road Crossing Removal

Existing pipe and box culverts wetland crossings and their associated fill material not included in the proposed 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.

13.2 Intervention Construction

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

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

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

14 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.

14.1 Indicators to be Measured

14.1.1 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.

14.1.2 Structural integrity

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

14.1.3 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, preferably 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.

14.1.4 Wetland Health

To substantiate the argument that the rehabilitation of the wetland units has offset the impacts associated with the proposed 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.

14.2 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 28: A basic framework for monitoring of the wetland rehabilitation plan

Phasing	Frequency	Assessment	Duration
Pre-Construction Phase	Before intervention construction commences	<ul style="list-style-type: none"> Baseline fixed-point photography Baseline WET-Health Assessment 	
Intervention Construction and Implementation Phase	Weekly	<ul style="list-style-type: none"> Intervention construction management monitoring Alien plant removal Re-vegetation 	Duration of remediation activities (monthly report)
Recovery Phase	Monthly	<ul style="list-style-type: none"> Structural integrity monitoring Alien plant re-emergence monitoring and removal Re-vegetation success monitoring 	6 x 1 month visits (monthly report)
Operational Phase	Annual	<ul style="list-style-type: none"> 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)

14.3 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 site.

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