DARVILL CONSTRUCTED WETLAND REHABILITATION PLAN

Final Report

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SPECIALIST REPORT DETAILS

This report has been prepared as per the requirements of Section 32 of Government Notice No. R. 983 dated December 2014 (Environmental Impact Assessment Regulations) under sections 24(5), 24M and 44 of the National Environmental Management Act, 1998 (Act 107 of 1998).

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

Signed:… … …… …… Date: 19th August 2016

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PROPOSED CONSTRUCTED WETLAND, DARVILL WASTE WATER TREATMENT WORKS, PIETERMARITZBURG, KWAZULU-NATAL
REHABILITATION PLAN

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Glossary of Important Terms

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.

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.

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.

Graminoid: Technical term for grasses.

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

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.

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.

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.

PROPOSED CONSTRUCTED WETLAND, DARVILL WASTE WATER TREATMENT WORKS, PIETERMARITZBURG, KWAZULU-NATAL
DRAFT REHABILITATION PLAN

1. INTRODUCTION

SiVEST Environmental Division has been appointed by Umgeni Water (PTY) LTD, to provide a Rehabilitation Plan for the proposed construction, in terms of the Regulations compiled in terms of Chapter 3 of the Environmental Impact assessment Regulations (2014) of the National Environmental Management Act, 1998 (Act 107 of 1998) as amended December 2014. The Competent Authority (CA) for this project will be the Department of Environmental Affairs (DEA).

A project of this nature requires a slow and methodical approach to ensure that all aspects of the project are correctly undertaken, and that the implementation and eventual outcomes are aligned with the vision that was conceived when the project was authorised, and construction commenced.

2. BACKGROUND & MOTIVATION

The Darvill Waste Water Treatment Plant (WWTP) in Pietermaritzburg, KwaZulu-Natal (Appendix 1), is currently being upgraded. However, the completed upgrade of the WWTP will still be unable to accommodate the periodic high storm water flow volumes. To alleviate the impacts associated with these storm flow events, Umgeni Water (UW) have considered the use of wetland habitat to partially treat the overflows from the storm flow storage dam. The proposed constructed wetland is 17 hectares in extent.

3. DEFINITION OF REHABILITATION

The act of returning land to some degree of functioning by implementing best management practices without the intention of fully restoring it to the existing levels of ecosystem functioning, prior to perturbations and land use changes having taken place.

Rehabilitation therefore is the act of trying to return the land cover / vegetation at a level that superficially mirrors what was there prior to the construction of the wetland.

This is extremely pertinent as it is not possible to fully restore an ecosystem. The act of restoration ecology[1] is a new science which is fundamentally an ideological approach to trying to obtain a successional level and functional level which is superior to the previous functional level, prior to the perturbation. The reason that restoration is not being pursued is that the receiving environment, in particular the vegetation, is considered to be disturbed and will be continually disturbed as it falls along existing conduits of disturbance (the river). Further, the area small by ecological standards and therefore would have limited functional value. Maintaining high levels of biodiversity and areas of conservation value would require significant management and reserves in terms of financial inputs and commitments. All of which will not provide any significant value given the nature of the receiving environment and adjacent land use. These areas will be managed with regards to alien plant control and will be used as rescue areas for indigenous flora and fauna.

The three (3) key elements proposed in this rehabilitation process will be:

1) Objective Identification & Management to Achieve Objective:

Identify the vegetation architecture, structure and composition which are currently in existence. Active and dynamic management will be required to change the successional path of the site if the vegetation type is not the ideal end point in terms of

- the rehabilitation,
- the benefits accrued by its current state will not contribute towards the Ecological Goods and Services
- and the biodiversity of the site

In other words, if the project area is currently under alien invasive vegetation, then it would not be best practice or ideal to return this area to said cover. The professional team would need to look at the surrounding areas and based on experience and land form select the correct vegetative cover to be utilised in the rehabilitation process.

2) Rescue:

Indigenous plant and desired animal species will be rescued from these areas on an on-going basis and stored / housed in appropriate conditions until they can be relocated to suitably rehabilitated areas on the site. Should it be identified that there are significant[2] plant species or species that are afforded

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

[2] The species may be rare, endemic, of limited distribution and is not covered by legislation, but is deemed conservation worthy, they must be protected.

protection by provincial or national legislation, they must be uplifted prior to the commencement of clearing and / or construction, and housed in an area of protection for re-introduction post construction.

3) Alien plant removal and control:

This may be defined as the removal, monitoring and ongoing maintenance control of alien plants which fall within the areas designated as rehabilitation areas. A full description of the method, and legislative requirements of this phase of the project can be found in **Section 5.5** below, and **Appendix A**.

4.1 Broad Rehabilitation Objectives

- Removal of alien vegetation, within the project area;
- Replace crop lands once construction is complete;
- In waste areas select the correct vegetation type and select plant species equivalent with the vegetation type;
- Utilise, where necessary, mechanical means to reduce erosion and to remediate erosion at the project area;
- Dove tail the use of vegetation and eco-friendly techniques to ensure best practice and reduced costs in terms of the rehabilitation effort;
- Plant trees, plant and grass species to ensure that erosion is minimised, and the systems disturbed by constructed wetland are rehabilitated to create a diverse self-sustainable indigenous vegetation composition that provides tangible ecosystem goods and services.

4. SPECIFICS OF THE PROPOSED IMPLEMENTATION OF REHABILITATION PLAN

5.1. Proposed Sequence of Rehabilitation

The Programme for the proposed rehabilitation will follow a number of steps.

- Management of the working area during construction;
- Preliminary planting of graminoid base cover;
- Restoration of wetlands, (unless planted to sugar cane), will be carried out using approved wetland restoration procedures to return hydrological functionality;
- Alien Plant Control.

5.2. Management of Working Area During Construction

In order to ensure that the rehabilitation to be undertaken post construction is effective, it is paramount that the working area is managed correctly during the construction phase. The most important aspect

of this management will be the careful preservation and management of soil stockpiles, the correct method of which is detailed below, and should be implemented from the start of the project.

Soil samples will be taken to determine the depth of topsoil. It is expected to usually be 150mm deep. Topsoil must be removed from the full construction area and is not to be spoiled. Top and sub-soil stockpiles to be on adjacent sides of the trench. Top- and subsoil stockpiles must not be stockpiled within 100m or within the 1:100 year floodplain of a water course.

Naturally occurring vegetation removed by site clearance operations may be grubbed in with the topsoil for stockpiling. The topsoil shall not be buried or rendered in any other way unsuitable for future use. All precautions must be taken to prevent unnecessary handling and compaction of the topsoil. Topsoil stripping shall not occur in wet weather. During stripping and stockpiling, the topsoil shall not be subject to a compaction force greater than 1 500kg/m² and shall not be pushed for more than 50 m. Topsoil shall also only be handled twice, once to strip and stockpile, and secondly to replace, level, shape and scarify.

The top soil stockpiles must be protected against erosion and a record shall be kept of all top soil quantities and should there be shortfalls of topsoil required for rehabilitation, adequate replacement material from commercial sources should be obtained as approved by the Engineer (preferably from areas identified with sourced excess topsoil). Conversely, excess topsoil shall be landscaped and stabilized in accordance to the requirements of the Engineer and in consultation with the Contractor's Land Rehabilitation Specialist.

Topsoil stockpiles shall preferably not be stockpiled for longer than 3 months. Should this be unavoidable, these will need to be enriched or upgraded prior to replacement to ensure its effectiveness for rehabilitation. The objective of enhancement shall be to ensure that the condition of the topsoil replaced should correspond as closely as possible to pre-construction conditions in terms of soil profiles, soil chemistry and soil microbiology, as determined for the varying conditions along the route in the pre-construction survey. The Contractor shall consult with the Engineer with regards to matching preconstruction conditions or existing adjacent conditions.

All stockpiles left for extended periods of time shall be stabilized using approved vegetation cover or other erosion control measures. Topsoil stockpiles may not exceed 2m in height. Subsoil must be removed and stockpiled separately from topsoil stockpiles and these stockpiles must be adequately demarcated as such. Subsoil stockpiles may not be permitted to overflow and contaminate topsoil stockpiles. All stockpiles must be kept free of invasive vegetation.

Any excess subsoil must be removed from site and spoiled at an agreed spoil site (spoil sites to be agreed between landowner, ECO and Engineer).

5.3. Re-establishment of Graminoid Assemblage

The preparation of the soils is as important as the application of the intended re-vegetation methodology. 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 150mm. This will 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 pad foot roller should be utilised to nominally compress and homogenise the soil surface by 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 (**Table 2** below).

There are several methods / techniques available for employment in re-establishing the graminoid base layer. Through understanding the site and the problems posed, options have been identified as the correct methods to employ graminoid re-establishment. The three methods are expanded upon below. Please note that re-vegetation planting must be undertaken in spring to ensure that establishment is successful. Oats may be used as a winter crop to stabilise areas that require immediate rehabilitation.

5.3.1. Hydraulic seeding / Hydro-seeding

This method of seeding is quick and effective especially on steep, critical slopes and inaccessible areas that cannot practically be seeded by other 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 over prepared ground in a uniform layer. A tracking dye may be included to visually aid uniform distribution. 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. With hydraulic planting, 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.

5.3.2. Plugs

Plugs should be applied where immediate cover is required for stabilisation. Particular candidates are drainage channels and very steep slopes.
Plugs should be:

- Planted at 10 centimetre centres (100 plugs/m^2)
- Over a pegged artificial mesh (e.g. a light polypropylene, UV stabilised mesh with about 20mm openings) in areas of very high water velocity;

- Watered immediately to enhance establishment;
- Watered regularly for the first seven days or as required to effect establishment.

In areas where steep slopes require stabilisation a requirement may arise for the soils to be stabilised through the use of Geotextiles. Ideally, vegetation is the best form of erosion control, with Geotextiles only used for temporary stabilization purposes until this can establish. 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.

5.3.3. Hand Seeding

Compared to hydro-mulching, manual mulching and seeding is better suited to flatter land. Like other forms of seeding it should be carried out in suitable weather conditions.

5.3.4. 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 10cm deep by 20cm 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. We do not support the usage of synthetic Geotextiles. 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 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*.

Precautionary Note: 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 with hydraulic applications where fail damage is visible early.

Figure 1: 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 (MacMatTM, BioJuteTM, BioMacTM, MacMatTMR) with a plate of their successful utilisation below each sample plate. (Representation courtesy of Maccaferri, Promotional Literature, 2003).

5.3.5. Vegetation Species Composition

It was determined that the species assemblage comprised of degraded grassland, some natural riparian areas interspersed with pockets of alien vegetation scrub.

Of the alien species identified, some are more significant in terms of their invasive potential, whilst others are not as invasive. However, as they are alien, they and will require effort to remove them. A list of alien invasive species is included below in **Table 1**. Please be aware that other species may be

present, and have not been included, but once they are identified during the implementation phase of the project they will be removed.

Table 1.A list of alien species recorded during the vegetation survey with their relevant Categories and Growth forms.

Species name	**Common name**	**Status**	**Growth form**	**Category**
Tithonia rotundifolia (Mill.) S.F.Blake	Red Sun Flower	Alien	Shrub	1
Solanum mauritianum Scop.	Bugweed	Alien	Tree	1
Ricinus communis L. var. *communis*	Castor oil plant	Alien	Shrub	2
Populus L. sp.	Poplar	Alien	Tree	2
Passiflora subpeltata Ortega	Wild granadilla	Alien	Climber	1
Morus alba L. var. *alba*	White mulberry	Alien	Tree	3
Melia azedarach L.	Syringa	Alien	Tree	1
Macfadyena unguis-cati (L.) A.H.Gentry	Cats claw creeper	Alien	Creeper	1
Lantana camara L.	Tick berry	Alien	Shrub	1
Cirsium vulgare (Savi) Ten.	Spear Thistle	Alien	Herb	1
Cardiospermum grandiflorum Sw.	Balloon vine	Alien	Creeper	1
Cannabis sativa L.	Native Hemp	Alien	Herb	1
Canna indica L.	Canna	Alien	Herb	1
Argemone ochroleuca Sweet	Mexican poppy	Alien	Shrub	1
Argemone mexicana L.	Mexican poppy	Alien	Herb	1
Ageratum houstonianum Mill.	Garden Ageratum	Alien	Shrub	1
Ageratum conyzoides L.	Billy goat-weed	Alien	Herb	1
Achyranthes aspera L.	Burweed	Alien	Herb	1

Table 2.Grass Species selected for the baseline Graminoid assemblage, proportions and position in the landscape.

GRASS SPECIES	**PROPORTIONS**	**Kgs/hectare**	**LANDSCAPE POSITION**
Bothriochloa insculpta	10%	3	
Melinis repens	7.5%	2.25	
Themeda triandra	20.00%	6	
Eragrostis capensis	10.00%	3	
Imperata cylindrica	15.00%	4.5	Ecotone & Wetland Areas Only
Melinis nerviglumis	10.00%	3	
Monocymbium ceresiiforme	7.5%	2.25	
Sporobolus africanus	10%	3	
Miscanthus capensis	10%	3	Ecotone & Wetland Areas Only
Total	**100%**	**30**	

Some of the above mentioned species are not commonly available commercially, and therefore the sourcing of the seed is going to be difficult but not insurmountable. It is possible to source seed from companies such as Top Crop Nursery that prepare plugs, which may be required in difficult terrain which is steep and requires instant cover.

Should the seed mix stated above not be available, the following species may be included, as they are commercially available.

- *Eragrostis tef* 3kg/ha
- *Digitaria eriantha* 6kg/ha
- *Panicum maximum* 4 kg/ha
- *Chloris gayana* 6kg/ha
- *Cynodon dactylon* 6kg/ha[3]

Note:

There is no *E. curvula* in this mix as the commercially available seed produces a steroidal, "floppy leaved" grass which shades out and kills off all surrounding grasses and looks "incorrect".

There are some provincially protected plants which occur on site, some fall within the working area or on the cusp and therefore will require some actions to protect them, relocate them or off-set their loss.

- Provincially protected
  - *Scadoxus puniceus*

Indigenous trees and large shrubs planted within the works area are to be removed unless otherwise stated. Trees and large shrubs that require removal from the works area should be replanted, where possible, outside of the works area using the following method:

- Moisten the soil around the tree thoroughly about 3 to 4 days prior to the move.
- Use a sharp spade to dig a trench around the tree's base at its roots. The trench needs to be approximately 650 mm deep.
- Dig out the tree with a spade, and leave the roots and surrounding soil intact (form a root ball). The ideal amount of root and soil is a 1 m diameter clump around the base of the trunk.
- Pull the tree out of the hole, and round out the bottom of the root ball using the spade. Cut beneath the roots as necessary to form a ball.
- Place a piece of hessian cloth large enough to wrap around the root ball underneath the upended side.
- Wrap the hessian cloth around the root ball tightly, and secure it around the base of the trunk.
- Lift and carry the tree by the root ball, not the trunk. Transport it to the identified relocation point outside the working area.
- Dig a hole in the tree's new location. The hole should be 2 to 3 times the size of the root ball.
- The depth of the hole should be approximately 600mm.
- Pack the soil into the hole and around the root ball to provide stability.
- Cut and remove the twine holding the hessian to the trunk with scissors once the hole is 2/3 full.

[3](provided that it is at least 50m from the nearest cane field as the cane farmers have problems with it invading cane fields)

- Fill in the remainder of dirt removed from the hole, ensuring that the soil level is as it was when removed, i.e. do not place soil up against the trunk of the tree to a level higher than its current level.
- Water the newly replanted tree thoroughly.
- Tree species should receive water every 10 to 14 days for a period of two months, post planting, if it has not rained.

5.4. Riparian area

5.4.1. Description of current scenario

The constructed wetland is proposed to be developed on the ox-bow of the Msunduzi River directly North of the existing Canal and settling ponds (**Figure 2** below). The ox-bow was modified historically by man-made drainage channels to alleviate high flows originating from the existing storage dam during storm events. It is evident from the alien species composition and indigenous pioneer herbaceous species present that the site is degraded, most attributable to the presence of the sewer treatment works which result in substantial leaching of nitrogen and phosphorus into the soil, both essential for plant growth. The majority of the site is comprised of degraded grassland (16.4 ha) with a small patch of woodland (0.6 ha) at the east boundary of the site. The riparian vegetation is comprised mainly of *Phragmites australis* and alien species.

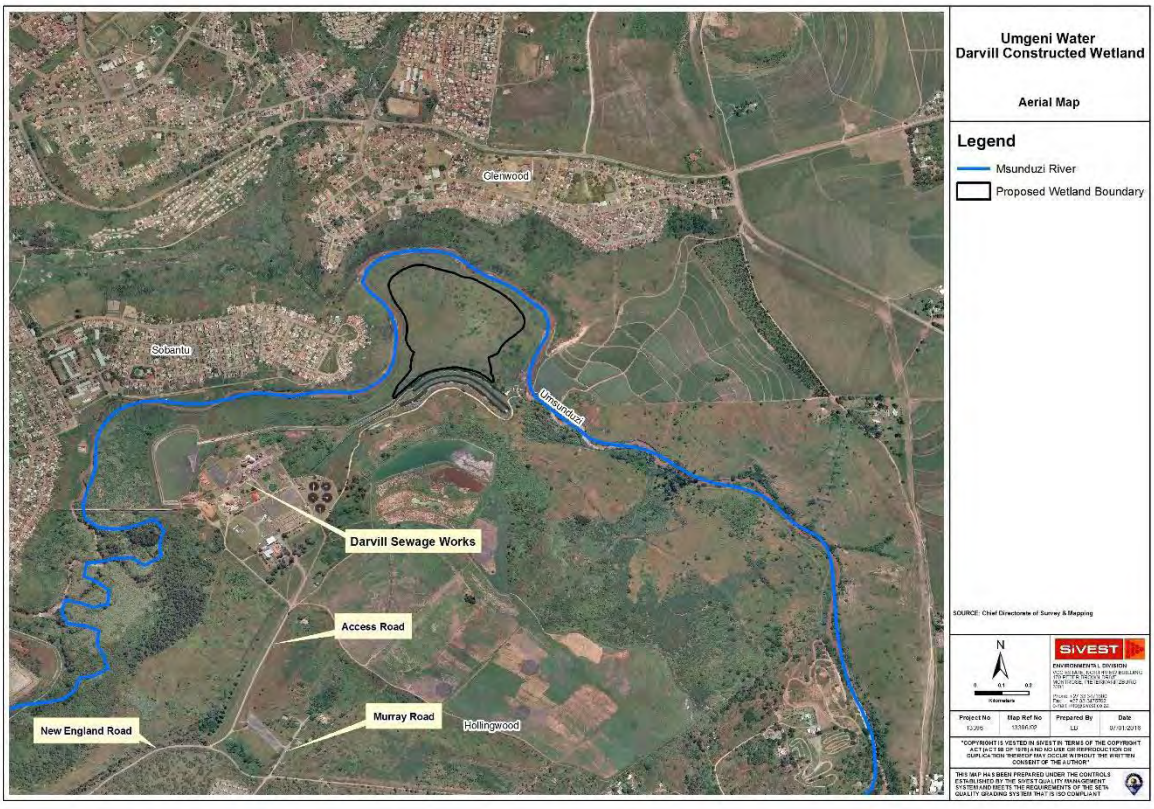

Figure 2: Overview map indicating the proposed development boundary on the ox-bow.

5.4.2. Objectives of riparian restoration & rehabilitation

The objective of the rehabilitation is to restore the riparian area to a condition as close as possible to the pre- construction state. The result of degradation, disturbance, and loss of wetland plant species, causes cumulative impacts with regards to the EG&S, which are hugely diminished or lost altogether.

Further, any physical alteration incurred as a result of the wetland being eroded, requires that significant works are required to return hydrological flow patterns and thereafter improve functionality. These will be achieved through a process of rehabilitating the area. The best chance of success in achieving the rehabilitation objective is to replace these components in their natural form. This requires that the management of wetland components during construction is planned to achieve this.

The objectives of Rehabilitation are to return or improve Ecological Goods and Services delivery, through;

- Restore indigenous vegetation;
- Reduce sediment source in the catchment;
- Minimise risk of erosion;
- Improve the vegetation component of riparian integrity;
- Deactivate the potential head-cut erosion identified;
- Improve the stability of the system,

5.4.3. Planting Methodology

With the removal of alien vegetation, it has been identified that these landscape features be returned to a scenario where they would represent their past vegetation assemblage. In order to recreate this vegetation mosaic, the following general guidelines have been adopted to drive the restoration process.

- Non-woody portions must be returned to either hygrophilous vegetation (sedges, bulrushes) or to graminoid assemblages which favour relevant specific habitats.

All plantings in riparian and wetland areas should occur in consultation with the relevant wetland and vegetation ecologists, whom have sufficient knowledge of habitat requirements of the different species to ensure best placement, within the wetland areas.

In addition to the wetland specific mitigation measures:

- Removal of existing alien species must be consistently undertaken.
- Rehabilitation of disturbed areas after the construction of the wetland must be completed as soon as possible after construction is concluded.
- If it is necessary to import soil onto the site the material; must be checked to ensure that it is not contaminated by weeds or invasive plants.

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 3** 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.

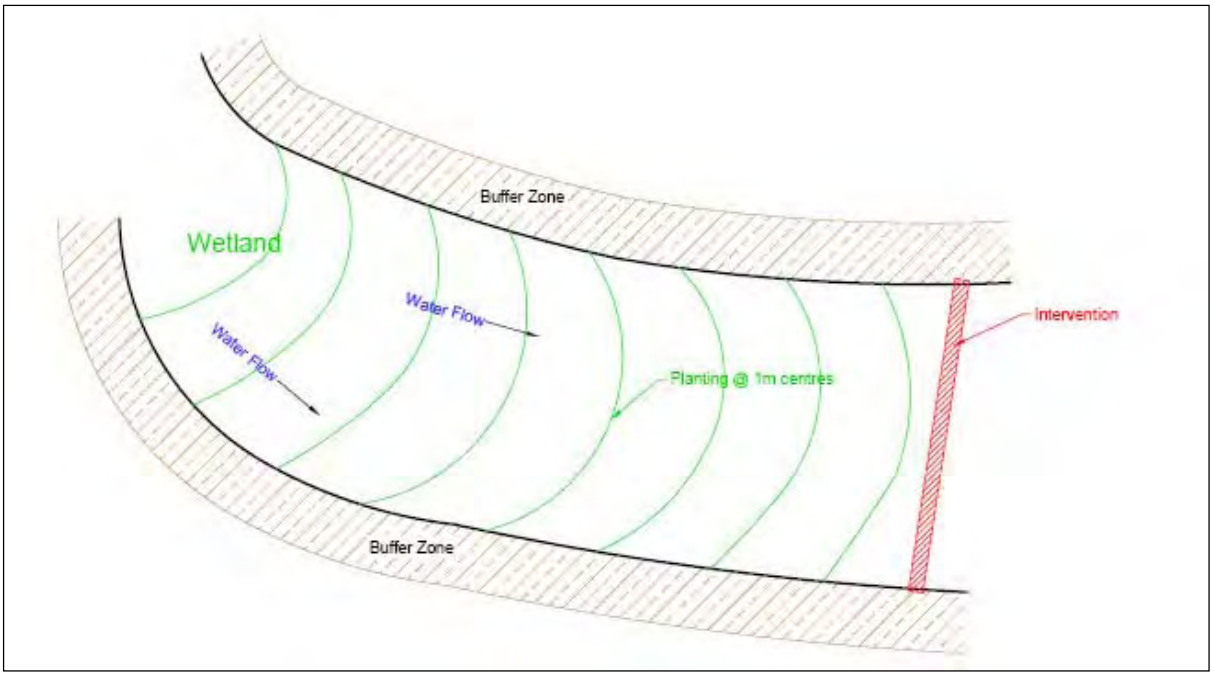

Figure 3. A schematic diagram representing the proposed planting methodology to be adopted when rehabilitating wetland areas (Kinvig, 2011).

5.5. Alien Plant Control

Invasive and other noxious plants are to be managed as per the requirements of the Conservation of Agricultural Resources Act (Act 43 of 1983, as amended in March 2001) Regulations (Notice No. R. 1048 of 25 May 1984, as amended by Government Notice No. R. 2687 of 6 December 1985) pertaining to weeds and invader plants control. As such, the following measures shall apply:

- All growth forms of **Category 1 weeds and invader plants**[4] shall actively be removed from all works areas, at all times; and
- All **Category 2 and 3 weeds and invader plants**[5] shall be actively removed all prior to flowering (See **Appendix A** for Alien Plant Removal and Control Methodology).

It must be noted however, that the maintenance period for this project is limited, and thereafter the Umgeni Water will be responsible for maintaining the site. In addition, the area to be rehabilitated is confined to the site, and any areas directly affected by construction activity, which may include but not be restricted to; lay down areas, site camps, construction camps and temporary access points.

5.6. CONCLUSION

Given that the nature of the existing vegetation that occurs at the constructed wetland site is largely alien, we feel that the above proposed rehabilitation measures will return the affected areas to natural vegetation once the project has been completed. While the rehabilitated areas may never reach climax status, the removal of alien species, and the replanting with appropriate vegetation will achieve a successional level and functional level which superficially mirrors the existing ecosystem type. This will be an improvement on some of the existing status of the alien and degraded natural vegetation units along surrounding the constructed wetland site.

[4]Section 15A of the amended Act.

[5]Section 15B and 15C of the amended Act.

Appendix A: Alien Plant Removal and Control Methodology

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 (See **Figure 3** below).

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.

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. 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 cutsurface 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.

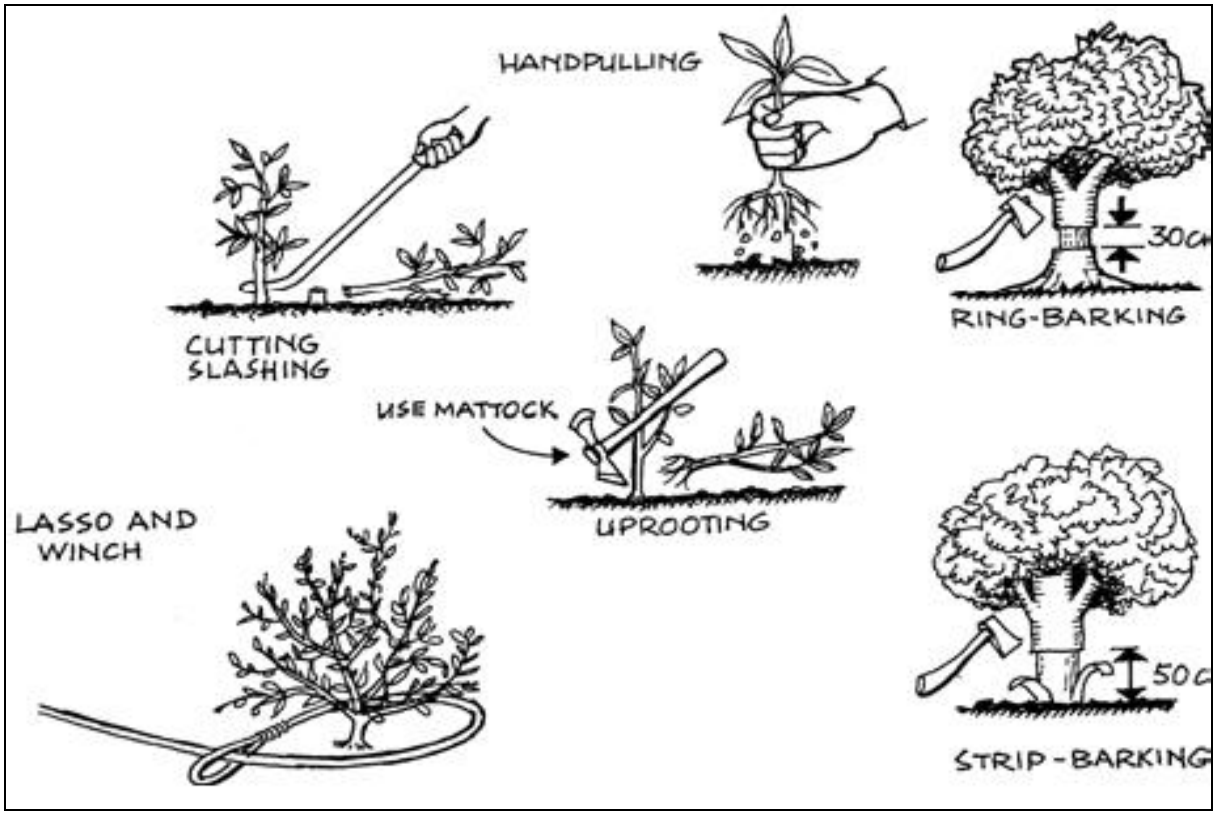

Figure 4: Schematic representation of six techniques used to remove alien invasive plant species.

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 species such as *Solanum mauritianum*, *Schinus terebinthifolius*, *Chromolaena odorata,* and the numerous creeper species. The following creeper species require significant effort and control; *Cardiospermum grandiflorum* and the *Ipomoea* spp.

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 3. 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 4.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 5. No stacking

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

Table 6. Stacked

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

Recommended Treatment Method – Herbaceous Species

Chromolaena, *Lantana* and other herbaceous species

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

When stacking:

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

Person Day Norms – Trees

Table 7. Frill, no stacking

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

Table 8. Frill, Fell & Stack

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

Recommended Treatment Method – Trees

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

- Those sites where the trees must be felled, remove the brush out of the 20-year flood line from a river or 20 m from a roadside. The rest of the stand can be frilled.

Person Day Norms – Small Trees

Table 9.Multi-stems, no stacking

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

Recommended Treatment Norms – Small Trees

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

Person Day Norms – Mixed Species

Table 10. 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)
Method:	**Young**	1.1	1.1	2	2.6	7	7
Plants are cut off at ground level and only the stem is treated. The brush is not cut up or stacked. >5 cm frill and apply herbicide; <5 cm Slash and apply herbicide	**Adult**	1.1	1.1	2	2.6	7	7
	Mature Adult	1.1	1.1	2	2.6	7	7

Table 11. 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)
Method:	**Young**	1.3	1.3	2.7	6.8	18	18
Plants are cut off at ground level, the stem is treated, the brush cut up and stacked into heaps or brush lines. Where necessary, brush is removed from river areas and roadsides. >5 cm Frill and apply herbicide; <5 cm Slash and apply herbicide.	**Adult**	1.3	1.3	3	6.8	18	18
	Mature Adult	1.3	1.3	3	6.8	18	18