NZ TRANSPORT AGENCY
WAKA KOTAHI

Auckland Motorways

Stormwater Swale Planting Improvements

2010

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Revision Schedule

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Contents

Executive Summary

Road Network Operators own and maintain a variety of stormwater treatment devices to treat stormwater runoff from the road surfaces and protect the environment. Due to nature of the road assets, Swales form a significant component of the stormwater treatment systems on road networks including NZTA's Auckland Motorway Network. For these Swales to function effectively, it is necessary to construct and maintain them in a proper manner.

The current practices of NZTA and other network operators in Auckland region are based on ARC's TP10. TP10 has been used since 1992 in the Auckland Region and is lately being used as a design standard or the basis for the design standard by many other regions in New Zealand. TP 10 focuses on the design of stormwater devices and does not provide much guidance about construction or of planting Swales.

At least 25km of formalised Swales exist on the Auckland Motorway Network, and significant time and cost is incurred in maintaining these Swales. More extensive use of Swales can be expected with new capital projects. Network complaints are often received relating to concerns about maintenance of the corridor asset and often relate to Swale maintenance procedures.

Alternative vegetation methods will deliver value (e.g. resilient and low maintenance requirements), as well as water quality improvements. The objective of this study is to trial implementation of suitable plant species (e.g. low growth grasses, and or native ground cover vegetation, etc) in Swales along the motorway and monitor for the water quality outcomes achieved.

This study reviews and captures the industry's best practice for planting and maintenance of vegetation in Swales. It also includes field trials to identify three species of vegetation suitable for the common soil conditions and climate along the Auckland Motorway Network.

Three sites were selected for the study, Silverdale, Newton and Alfriston, which are located on North, Central and South sections of the Auckland Motorway Network.

The plant species being trialled are Apodasmia similis (Leptocarpus similis), Ficinia nodosa and Cyperus ustulatus. At each of the sites a section of 30m was planted with each of the species.

The objectives of this study are to review and capture the industry's best practice for planting and maintenance of vegetation in Swales, and to trial and identify three species of vegetation suitable for the common soil conditions and climate along the Motorway network. At the end of Stage 1 of this study, a total industry review of potential alternative to grass stormwater treatment swales has been completed. Planting of three trial species in three contextually different trial sites each with three trial bands of plan species has also been completed. To date, monitoring was done initially by weekly visit then fortnightly visits and finally only monthly visits over a 4 month period. The key findings at this stage are:

- No damage to the swale cross-section indicating clear demarcation of the sites;
- Limited Weed intrusion on all sites. This shows that the weed suppression mat and native species are functioning well as weed suppressors;
- Significant water ponding caused by initial construction. Further review of construction techniques is required;
- The three selected species are surviving and flourishing in the different micro-climates;

Further monitoring of the sites and an expansion into the water quality aspect of the Swales is required in the next stage. It is essential to undertake a robust performance monitoring over a period of one year so that the actual holistic performance outcomes can be determined. Water quality aspects need to be include in the study as they are significant component in fulfilling the Water Resource Objectives under the NZTA Environmental Plan of 2008.

Introduction

In the Auckland Motorway network, a key purpose of the stormwater management systems is to collect stormwater runoff from the motorway corridor and provide treatment via vegetated Swales, ponds, sand filters etc., prior to discharge to the receiving environments.

Swales and Filter Strips use vegetation in conjunction with slow and shallow-depth flow for stormwater treatment. As stormwater is conveyed through the vegetation, contaminants are removed by the combined effects of filtration, infiltration, adsorption, and biological uptake. Vegetation also decreases the velocity of flow and allows for coarse sediment removal to occur (ARC 1992; GCCC 2007).

At least 25km of formalised Swales exist on the Auckland Motorway Network, and significant time and cost is incurred in maintaining these sites (e.g. mowing grass, repairs to damaged Swales and maintaining coverage). Network complaints are often received relating to concerns about maintenance of the corridor assets and often relate to vegetation maintenance procedures (including Swales). Swales are damaged by excessive flows and birds eating the plants. Damage to the Swales is also often caused by drivers stopping on them to answer the phone or in an accident and by inappropriate vegetation maintenance, mowing and spraying.

The current practices by AMA and other network operators in Auckland region are based on ARC's TP10. TP10 was originally produced by the ARC in the early 1990's (revised in 2003) to assist in the design of stormwater treatment devices. The publication was the first real design guide in New Zealand for stormwater treatment devices and was largely based on overseas experience and design standards (Healy et al. October 2009).

This Water Quality project is for Stormwater Swale Planting Improvements under NZTA's 2009/10 Strategic Plan Initiative funding for Water Quality projects. The NZTA has commissioned AMA to undertake a study to trial suitable planting alternatives to grass that will deliver improved outcomes such as value for money water quality improvements.

Scope of Works

The scope of this trial includes:

- Review of current and potential Swale planting practices.
- Identify the preferred trial plant solutions
- Identify a range of potential as well as the three preferred Swale panting trial sites.
- Investigate and design the trial test sites,
- Construction and planting,
- Monitoring of the planting establishment and
- Reporting including options, trial findings, and recommended preferred planting option/s.

Objectives and Benefits

Objectives

The objectives of this study are to review and capture the industry's best practice for planting and maintenance of vegetation in Swales, and to trial and identify three species of vegetation suitable for the common soil conditions and climate along the Motorway network. Using alternative types of vegetation will deliver value providing resilience, requiring minimum maintenance, better delineation of asset and providing water quality improvements.

Benefits to NZTA

This investigation reinforces NZTA's commitment to being socially and environmentally responsible and to improving the contribution of its networks to the environmental and social well being of New Zealand. This project also fulfils NZTA'S goal under the Environmental Plan to, *"improve the contribution of state highways to the environmental and social well being of New Zealand and prioritise and address environmental and social issues"* by developing approaches and implementation of plans for various categories of the environmental and social impact.

This study provides positive linkage to the 2008 Transit New Zealand's Environmental Management Plan (EMP) with target alignment to Water Resources objectives (W1, W2, W3 & W4), as well as considered linkage to Ecological Resources objectives (E1 & E2), Social Responsibility objective (SR1) and two of the EMP listed Visual Quality objectives (VQ1 & VQ2).

Water Resources Objective

- **W1 = Ensure run-off from state highways complies with RMA requirements.**– One of NZTA's requirements under the RMA is to comply with the Resource Consent Conditions for Stormwater Diversion and Discharge, usually to comply with TP10 guidelines. This study is focused on identifying the most efficient native species of wetland plant that will provide bother water quantity and quality control. This ensures that planted Swales are functioning as required by the Consent Conditions.
- **W2 = Limit the adverse effects of run-off from state highways on sensitive receiving environments.** – There are numerous sections of existing state highways in Auckland that are close to sensitive receiving environments. By planting the right kind of plant species in Swales effective treatment can be provided before discharge into the environment.
- **W3 = Ensure stormwater treatment devices on the network are effective.** – Already widely used on the network, Swales are an important part of maintaining stormwater on the Motorways. This study will help to provide effective maintenance of existing Swales and provide effective designs for future Swales.
- **W4 = Optimise the value of water management through partnerships with others.** – This study draws on the experience and knowledge of network operators, local authorities, landscape designers and Engineering Consultants. The recommendations draw from the industry's best practice and highlight the benefit of working in partnership with others.

Ecological Resources Objective

- **E1 = Promote biodiversity on the state highway network.** – By planting native plant species in Swales this provides habitat to encourage the growth of native species. The plants selected are also chosen to act as a natural weed suppressant encouraging further propagation of other natural vegetation.
- **E2 = No net loss of native vegetation, wetlands, critical habitat or endangered species.** – The Plant species identified in this study were selected specifically to be native wetland species. This study will provide an increase in the amount of native vegetation, wetlands and habitat.

Social Responsibility Objective

This study fulfils the social objective **SR1 – Enhance and contribute to community cohesion** by considering social cost alongside technical, safety and economic issues associated with stormwater treatment devices. This is achieved by reducing the cost from unforeseen environmental damages due to poor functioning of these devices.

Visual Objective

- **VQ1 = Incorporate multi-purpose landscaping as an integral part of all new state highway construction projects.** – The vegetation planted in these Swales will provide numerous visual benefits to the highway. Firstly they are designed to be aesthetically appealing, by their very presence but also by providing a visual barrier to litter on the highways. Secondly they provide a visual barrier; this will prevent weed spraying (which will damage vegetation) and also help to prevent vehicles damaging the Swale when they pull off the motorway. Finally the vegetation serves the purpose of attenuating and treating stormwater from the network.

VQ2 = Improve the visual quality of the existing state highway network. – The vegetation is selected specifically to improve the aesthetics of the network and provide delineation of the asset.

Figure 1: Before and after pictures of the Newton site

This research will also help NZTA by.

- Ensuring the technique is aligned with the prescribed stormwater management guideline (ARC TP10).
- Providing a positive link to the NZTA Environmental Management Plan.
- Ensuring that the work ties into institutional knowledge of monitoring SW devices on the NZTA research.
- Reducing work by external contractors on the network.

Figure 2: Well grassed Swale

Figure 3: Well planted Swale

Figure 4: Poorly maintained Swale

Review of Current Practices

Swale Design

A TP10 Swale typically consists of inflow points, side slopes, bottom channel, vegetation and soil, erosion protection and an outlet. Swales can also have underdrains and design enhancements such as check-dams. The purpose of this study includes a review of the current practices in regard to the following three components of a Swale:

- Swale Vegetation
- Soil and Planting Bed Preparation
- Erosion Protection

The objective of reviewing the above components is to ensure that alternative vegetation being trialled is planted following the best industry practice.

Literature Review

Both, local and international practices have been reviewed as a part of this study to identify the current Swale planting and maintenance practices. As a part of reviewing the local practices, discussions have been held with the AMA, North Shore City Council (NSCC) and Waitakere City Council (WCC) and reviewed the following documents:

- LB205 Swales Filter Strips by NSCC
- LB301 Stormwater Treatment for Roads by NSCC
- LB302 Conditioning of Surface Soil by NSCC
- On Site Stormwater Management Guideline by NZWWA
- Stormwater Solutions for Residential Sites by WCC
- ARC's Technical Publication 10
- The report from the Reforming Watertable Drains in Waitakere City study of 2004 by Jan Weaver of Waitakere City Council,
- The draft of the Low Impact Design Manual prepared by Waitakere City Council
- The draft of the Stormwater Treatment Devices – Operation & Maintenance Technical Report and Constructions Reports prepared by AECOM for Auckland Regional Council,
- The draft of TP10 Landscape & Ecology Values within Stormwater Management – Prepared by Boffa Miskell for ARC, and
- A number of policy and practice documents published by overseas Local Authorities and Network Operators.

A summary of the findings is as follows:

ARC TP10

ARC developed TP10 in the early 1990s to assist stormwater treatment designers. TP10 has been used since 1992 in the Auckland Region and is lately being used as a design standard or the basis for the design standard by many other regions in New Zealand. TP 10 focuses on the design of stormwater devices and does not provide much guidance about construction or planting of treatment devices such as Swales.

The version of TP10 currently being used was published in 2003. Chapter 14 of the document focuses on landscape values, including aspects of economic values, visual mitigation and recommendations for the establishment of plants. TP10 encourages the use of native plants in stormwater management practices where appropriate due to their distinct genetic advantages over non-native species. TP10 also acknowledges

that people often plant exotic species for their ornamental value. In this document, perennial Rye grass is noted to be the most common grass used for Swales in the Auckland Region.

In terms of soil preparation, TP10 suggests loosening of soils to an approximate depth of 150mm and disking of hard clays to deeper depth for planting success and increase in germination rates.

ARC's TP 10 does not provide a list of appropriate or recommended list of species for planting in Swales. It however stipulates a typical height of 150mm but, not less than 100mm of vegetation for selection of suitable species.

Local Authorities in Auckland Region

The Operation and Maintenance team at Waitakere City Council (WCC), North Shore City Council (NSCC) and Manukau City Council were approached to discuss and note their current Swale planting and maintenance practices. WCC and NSCC were consulted on their current practices. Below is a summary of their practices:

WCC vegetated Swales are predominantly turf grassed and maintained by their Parks Department. WCC's Low Impact Design (LID) Code of Practice November 2009 does not specify a list of preferred plant species but only stipulates a typical height consistent with the ARC's TP10 for selection of suitable species.

WCC recommends a minimum of 150mm thick topsoil layer in the Swales for planting as a part of soil and planting bed preparation.

Jan Weaver of WCC completed a study in 2004 called, Reforming Watertable Drains in Waitakere City. The objective of this study was to trial an alternative maintenance method to their current practices of blanket herbicide spraying and/or mechanical clearance by planting native wetland plants in the Swales. The plant species used in this study were Eleocharis acuta (sharp spike-sedge), Isolepis prolifer ('Isolepis' has changed name to 'Ficinia') (knobby clubrush), Microlaena stipoides (meadow rice grass, patiti) and Cotula coronopifolia (bachelor's button). The most successful species in this study were Eleocharis acuta (sharp spike sedge) and Isolepis prolifer. Further trial of these species was recommended by this study for use as preferred species for planting in Swales.

NSCC practices the recommendations of ARC's TP10 for their Swale construction. Currently Rye grass is used predominantly by NSCC in their Swales. NSCC have found Apodasmia similis (Oioi or Jointed Wire Rush) to capture hydrocarbons effectively when used in Rain Gardens. However, Apodasmia similis is currently not being used in the Swales by NSCC.

NSCC has published two guidance notes LB205 – Swale and filter Strips and LB 302 – conditioning of Surface soils for implementing Low Impact Design options in Long Bay that apply to Swales in Long Bay. In these guidance notes, NSCC recommends use of Underdrains in Swales constructed in clay soils and conditioning of the top 200mm of topsoil. The recommended conditioning method is scarifying, adding gypsum and using fertilisers.

NZTA Practices

NZTA currently uses the recommendations in ARC's TP10. As a part of the Northern Busway Project, NZTA is currently trialling Apodasmia similis (Oioi), Ficinia nodosa (knobby clubrush), Juncus maritimus (Wiwi) and Eleocharis acuta on the Motorway edges and coastal shore edges.

NZTA currently is using 50mm to 100mm of topsoiling as a part of soil and planting bed preparation. This practice is consistent with ARC's TP10.

International Practices

The species of planting material being used in Swales overseas range from *Loium sp. (Rye Grass)* and Stenotaphrum Secandantum (Buffalo Grass) to other native species. In many countries, a combination of plant species is being used in Swales for visual enhancement.

Gold Coast City Council in Australia has published a Land Development Guidelines that includes a section for Plant Selection for Water Sensitive Urban Design (WSUD) Systems. This policy document provides one of the

most comprehensive lists of plant species suitable for planting in Swales. The table in this document that includes this list of plant species also outlines the zone in the Swales that it is suitable for, the form, the height to which a particular species grows, recommended density for planting and some useful comments. A copy of this table is attached to this report as Appendix A.

The United States (US) Environmental Protection Agency (EPA) has a Vegetated Swale technology fact sheet freely available to download[1]. It summarises the key results of several American studies on Swales. The document contains many of the key points for design and construction of Swales. In the appendices of this document there is a detailed cost break-down for a Swale for both construction and maintenance. A 4.5m (top width) Swale costs US$16-$30 per linear meter to construct. Maintenance costs of Swales are around US$1.90 per linear meter (based on a 0.5m deep Swale). A more detailed cost breakdown is provided in the appendices of this document.

The soils preparation used overseas consists of conditioning of soil and using topsoil. The thickness of topsoil being used in Swales ranges from as low as 50mm to as high as 300mm.

Recent Developments in New Zealand

Below is a summary of the recent developments in the stormwater treatment and maintenance practices in New Zealand:

- In 2007 AECOM New Zealand (then Maunsell AECOM) was engaged to develop guidelines for supervisors/foremen, labourers and for maintenance staff for the construction, operation and maintenance of stormwater treatment devices included in TP10.
- In 2004, Jan Weaver of WCC completed the Reforming Watertable Drains in Waitakere City study to trial an alternative maintenance method to their current practices of blanket herbicide spraying and/or mechanical clearance by planting four species of native wetland plants in the Swales.
- WCC is in the process of publishing a Low Impact Design Manual (currently in Draft format) that includes various details for construction and maintenance of Swales. AECOM is currently preparing an Operation and Maintenance Technical Report and Constructions Report for ARC that is currently in draft format.
- Boffa Miskell is currently reviewing TP 10 for ARC, with specific regard to promoting values for landscape and ecology in the design of stormwater management devices. The document summarising this review is in draft format and is called the Landscape & Ecology Values within Stormwater Management.

Even though the draft of the Stormwater Treatment Devices – Operation & Maintenance Technical Report and Constructions Reports being prepared by AECOM for ARC does not provide a list of plant species for use in Swales, it provides comprehensive guidance for construction and maintenance of Swales. This document recommends 100mm of topsoil as a part of planting bed preparation.

The draft report of Landscape & Ecology Values within Stormwater Management being prepared by Boffa Miskell for ARC is one of the most comprehensive documents being developed in New Zealand that includes recommendations to guide habitat enhancement, a detailed plant schedule, and an operation and maintenance programme. This document provides a list of over 200 plant species (Appendix B) for use in stormwater treatment devices, 47 of which are for specific use in Swales. The list of these 47 species is attached to this report as Appendix C.

[1] Sourced from *www.**epa**.gov/owm/mtb/veg**swale**.pdf*

Trial Sites

Site Selection

Site selection is an important criterion for the success of the trials. A number of potential sites for the trial were identified in consultation with AMA. The basis upon which the sites were selected is as follows:

- Desired level of contamination loading;
- Easy access for planting and study with no or low temporary traffic management requirements;
- Resource Consent conditions so these trials or study do not compromise the Resource Consent AMA holds for the site;
- Preferably a site that is due for re-planting under the maintenance plan or a new Swale that is being constructed;
- A selection of soil conditions and microclimates and
- Adequate length of site being available for the trials

The initial plan was to select three trial sites on the North Shore to reduce trial times for implementation and monitoring. This approach was cast aside in favour of an approach that would consider the diversity of microclimates and soil condition/types of Auckland.

To consider microclimate and soil types in the trials the following five locations were chosen for further short listing:

- Southern Motorway section in Ramarama
- North-Western Motorway
- Newton Gully
- Southern Motorway section in Manurewa
- Northern Motorway section in Silverdale

The Ramarama site was not given further consideration due to cost associated with the commute to the site during the trial period. The North-Western Motorway was ruled out due to widening projects about to commence which will interfere with the reliability of the results.

The remaining three sites offer varying microclimates and soil conditions for this trial.

- Newton Gully site consists of Lithic tuff mainly sandstone, mudstone, alluvium, micaceous sand or borrowed fill material from the motorway construction. There are a number of special issues with the Newton site compared to the other selected sites. Firstly the overhead Newton Bridge covers a portion of the site. This means that the light availability for the plant species will be reduce for some portion of the site. While not ideal for perfect planting conditions it will provide a measure of the resilience of the plants to more stressful conditions.
- The Manurewa site is near the Botanical Gardens and consists of alternating muddy sandstone and mudstone with interbedded lenses of grit. This site offers a relatively colder micro-climate with little or no frost during the winter months.
- Silverdale site is more exposed to frost during the winter months and consists of Hukerenui Mudstone (Institute of Geological & Nuclear Sciences Ltd Maps).

The sites are also selected such that the existing Swales can easily be transformed to the ARC TP10 design standards (see section "Swale Design" under the introduction for details of standards). Each of the selected sites measure more than 90m in length so that 3 sets of 30m planting strips can be maintained. 30m is the minimum length of a Swale to ensure sufficient hydraulic residence time and useful results as set out in the ARC TP10.

Locality Plan

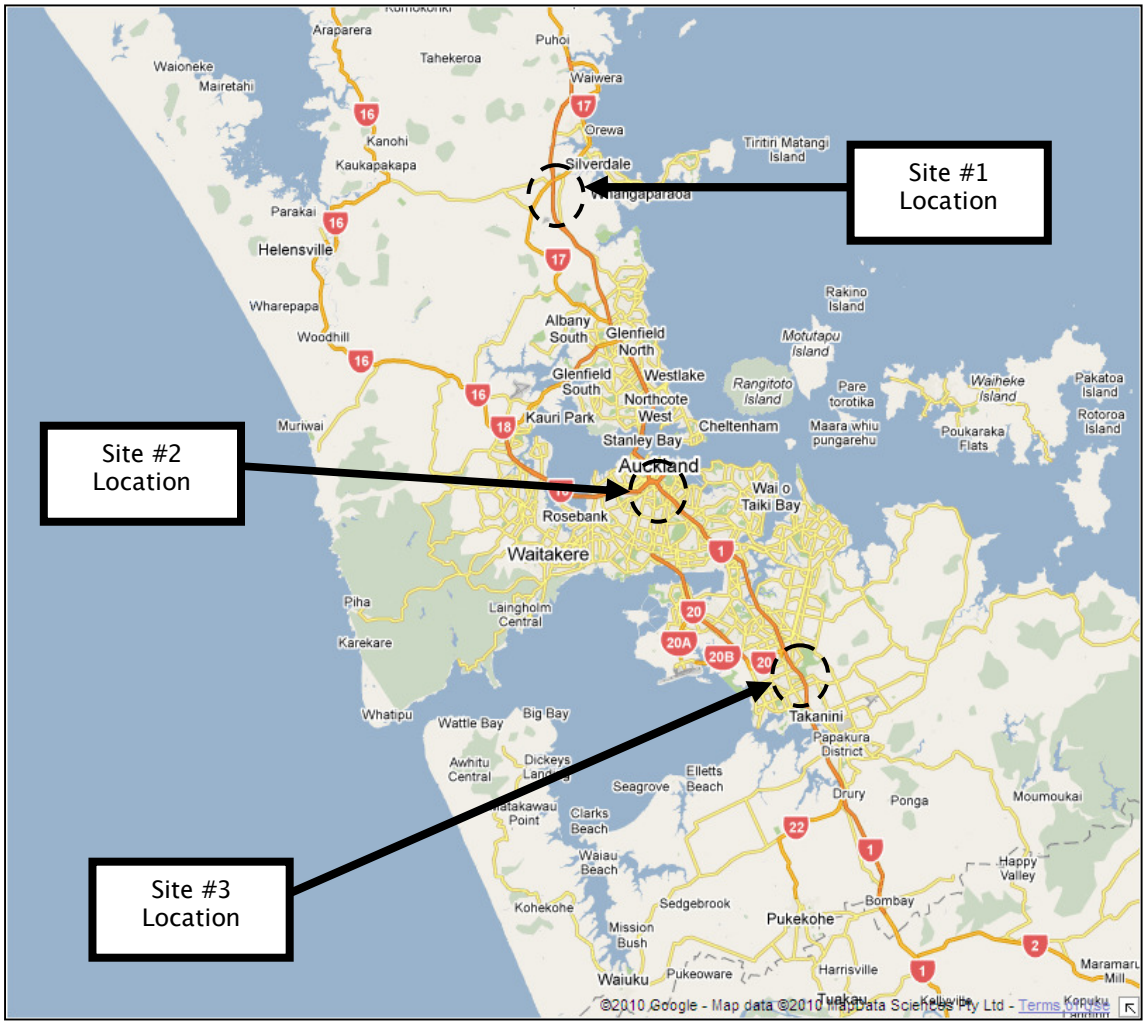

Figure 5: Locality Plan

(Source: http://maps.google.co.nz, MapData © 2010 Sciences Pty Ltd)

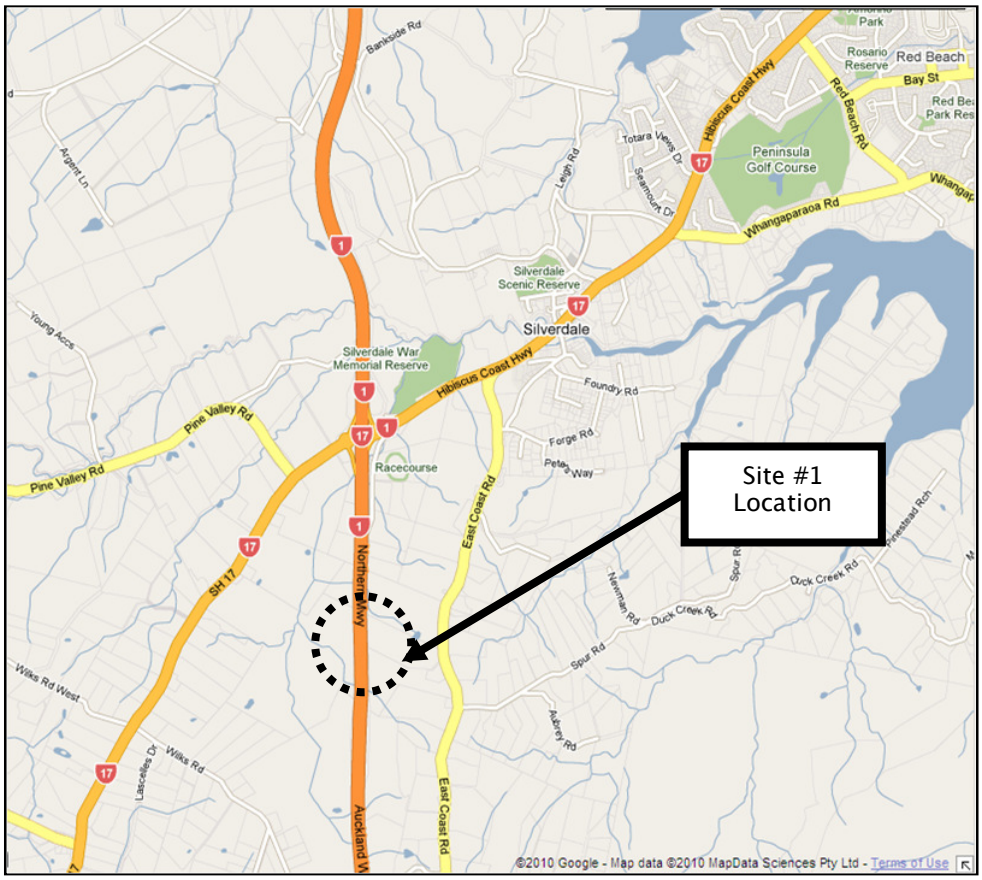

Figure 6: Locality Plan site #1 (Zoom)

(Source: http://maps.google.co.nz, MapData © 2010 Sciences Pty Ltd)

The first Swale site is located in the berm of the South bound motorway of SH1, south of the Silverdale southbound on-ramp in Rodney District opposite to the indoor ski field "Snowplanet" (Figure 7). The area is mainly farmland with a scattering of trees and scrub.

Figure 7: Photo of Silverdale site before construction

Figure 8: Locality Plan site #2 (Zoom)

(Source: http://maps.google.co.nz, MapData © 2010 Sciences Pty Ltd)

Site two (#2) is located beneath Newton Bridge between the North and South bound carriageways of SH16 (Figure 9). The area is predominantly residential with some light commercial industry in the nearby vicinity.

Figure 9: Photo of Newton site before construction

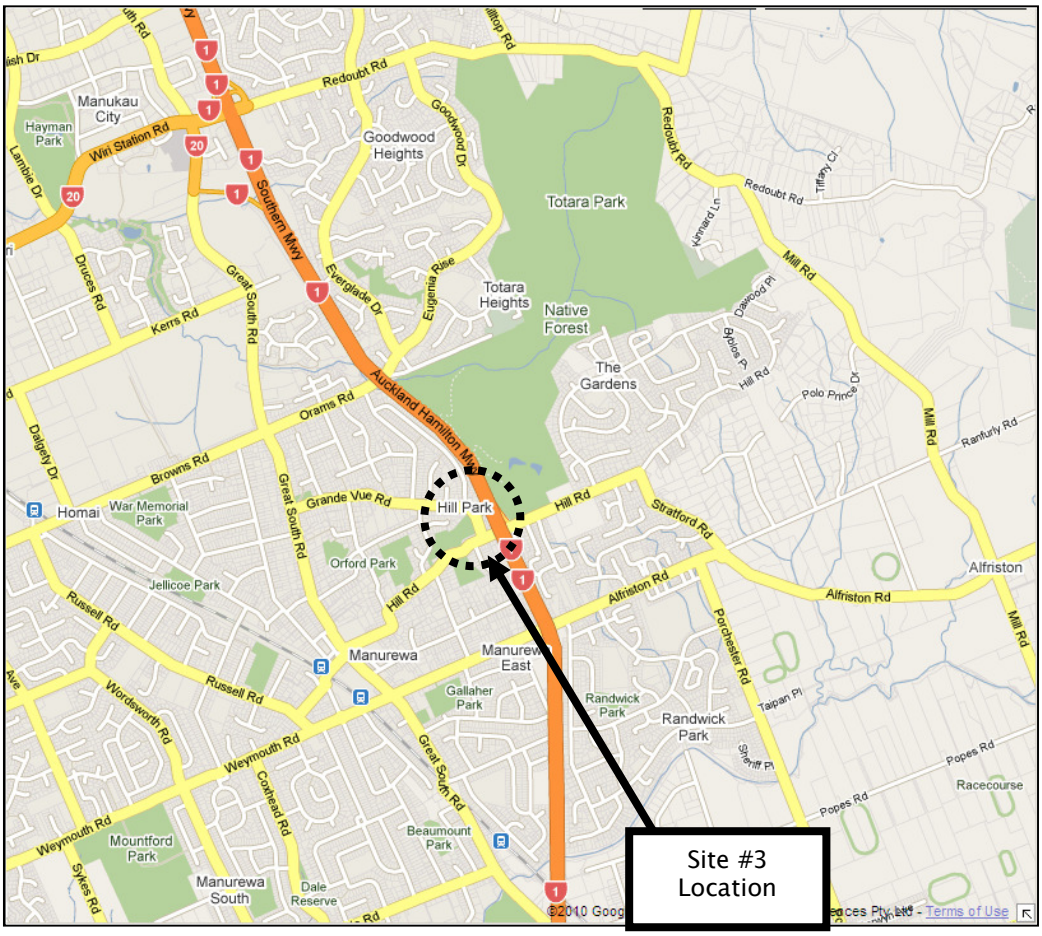

Figure 10: Locality Plan site #3 (Zoom)

(Source: http://maps.google.co.nz, MapData © 2010 Sciences Pty Ltd)

Site three (#3) is located in the berm of the South bound motorway of SH1, just north of the Manurewa motorway off-ramp in Mankukau District adjacent to the Botanical gardens (Figure 11). The area mainly consists of Urban residential to the west and the gardens to the east.

Figure 11: Picture of Alfriston site before construction

Trial Plant Species

Background

The Landscape and Ecological Values within Stormwater Management report being prepared by Boffa Miskell follows an extensive research of wetland species for inclusion into Stormwater treatment devices. Results from the research have been compiled into a list of 200 species (see appendix B) which are suitable for inclusion in wetland environments to satisfy treatment and conveyance requirements. Out of these 200 species, 47 are noted to be suitable for planting in Swales (See Appendix C). This study and report was compiled by Boffa Miskell with support from Landcare Research. Discussions were held with Landcare Research and two different nurseries to isolate four species from Boffa Miskells report for the trials. The selection of planting for the trials was based on experience working with various species within the Auckland area.

Selection criteria

Being located next to a motorway in Auckland provides some specific hazards to plant species as well as supply and maintenance requirements. As such the 4 species selected were based upon the following criteria:

- Native – Appropriate to the Auckland character
- Aesthetics – Present a visually attractive feature and delineate the asset
- Plant stems that will allow water passage through the Swale and not impede water flow
- Tolerance to varying environmental conditions (wet and dry) – Given Auckland's diverse and varying climate and microclimates extreme tolerances are required
- Availability from nurseries
- Plant height – This will provide visual delineation of the sites, which help to prevent weed spraying and vehicle encroachment. Also maintenance costs are reduced if mowing is not required to maintain the Swales.
- Establishment – A high density of plant growth (especially at stem level) will provide a tortuous path for stormwater through the Swale which will increase residence time, treatment efficiency and erosion protection.
    - The speed at which the plants become firmly established will provide accuracy for maintenance time and cost during the establishment period

Plant Species

Apodasmia similis (Leptocarpus similis), Ficinia nodosa, Carex lessoniana and Carex lambertiana are the four plant species originally selected for the trials. Apodasmia similis and Ficinia nodosa were picked particularly for their tolerance to extreme environmental conditions at Shoal Bay and Manakau. Both of the Carex species were selected specifically because of the prevalence of these species on the banks of streams throughout the Auckland area. Subsequent to discussions with the nurseries identified to supply the plants, it was noted that the Carex species were not available in required numbers at the time of planting for this study. As a consequence Cyperus ustulatus was selected instead of Carex because of similar benefits. Cyperus has shown good survival rates and is appropriate to natural water channel locations.

Other plant species on the list also fit the above criteria. However those working on this study have personal experience and in-depth knowledge of the capabilities of the selected species.

Hence the final three species were selected for this trial as below:

1. *Apodasmia similis* (*Leptocarpus similis*),

Figure 12: Apodasmia similis aka "Oioi"

2. *Ficinia nodosa*,

Figure 13: Ficinia nodosa aka "Knobby Club Rush"

3. *Cyperus ustulatus.*

Figure 14: Cyperus ustulatus

Trial Implementation

This section outlines the methods used for planting bed preparation, and planting methods at the three chosen sites.

Swale Design

The three trial Swales were designed in accordance with TP10 to (ARC 1992):

- To treat one third of the 50% AEP storm, also referred as the Water Quality Volume storm (WQV).
- To remove seventy-five percent (75%) of the incoming suspended sediment on a long-term basis.
- To provide at least a nine minute (9min) residence time for all stormwater runoff from the new and existing impervious areas within each Swales catchment.
- To provide a maximum WQV storm discharge velocity of 0.80 m/s.

Soil Preparation and Planting

All weed pests and nuisance weeds were removed from the areas identified for the construction of Swales. The ground was profiled as necessary to form Swales with 2m base width and either 4m or 5m top width. The cross-sections of the Swales were ensured to be consistent with the recommendation of TP10. A contract herbicide appropriate to the weed species was sprayed in accordance with the manufacturers' recommendations. The extent of spraying was marked by a spray marker dye in all sites. All dead material and debris was removed off site and appropriately disposed of.

Once existing grass was sprayed and removed off site, 50mm of fertile free draining topsoil was spread consistently over the entire extents of the trial Swales (Figure 15). The spreading of topsoil was to ensure the new layer of topsoil sits within the ground profile of the Swale and the new level of topsoil was flush with adjacent ground.

Figure 15: Photo of topsoil application at the Alfriston site

Macaferri's Biomac 300 was spread over the entire extents of the Swales as an erosion protection and weed control measure and secured to the ground as per the manufacturer's directions. New plants were inserted into 300mm length cuts made into the mat and each cut pinned by high tensile ground staples.

The 90m trial Swales were divided into three sections of 30m each and planted with 1 litre grade trial plant species i.e., Apodasmia similis (Oioi), Cyperus ustulatus (Umbrella sedge) and Ficinia nodosa (Knobby club rush) with each section being planted with a particular species.

Figure 16: Picture of the Silverdale site just after planting

The plants were planted in well prepared free draining holes with one tablet of Agrifarm plant fertiliser tablet. The holes for planting were 1.5 times the depth and 2 times the width of the existing rootball without removing the container until planting. The rootballs were scored on the sides with a sharp instrument before planting. Plants were planted to the depth of the original soil level on the stem. All plants were well watered prior to planting.

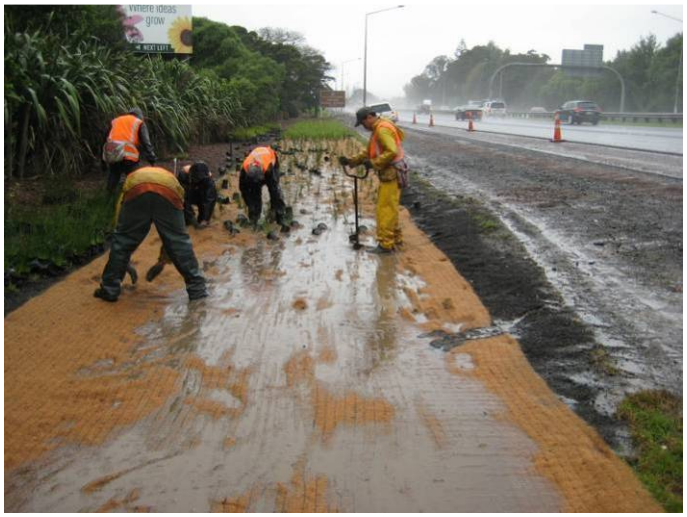

Figure 17: Picture of Alfriston site during planting

Sketches of the planting layout are in Appendix D.

Inspections and Maintenance

The plant species chosen for this trial take up to 1 year to grow to a size when they can be effective Swales. These species will continue to grow up to 3 years when they reach their final size. The Biomac 300 weed mats used in the trial usually take 2 months to 1.5 years to completely disintegrate. To monitor and assess the effectiveness of the trial plant species, it is necessary to monitor trial Swales/Plants for at least a period of 3 years. Since the plants became effective in 1 year a formal trial period of 1 year was chosen in this project. AMA operators will continue to monitor the plants for up to 3 years. Based on the plant growth during different seasons of the year, the following frequency was chosen for the inspections in the first year:

First month – Weekly

1 August to 30 November – Fortnightly

1 December to 31 March – Monthly

1 April to 30 May – Fortnightly

Inspection

The following data is being collected for this study from the trial Swales in the three sites chosen:

1. Establishment
- Deaths
- Rate of Growth
- Health of Plants
- Density/coverage
2. Appearance
- Visual Demarcation
- Enhancement of aesthetics
- Entrapment of litter
3. Maintenance
- Moving requirement
- Ease of removing litter
- Erosion repairs

Each species plot has been marked out with string lines to demarcate a 50 cm wide by 200 cm long plots, as measured from the centre. Each line is then divided by one lengthwise and seven crosswise evenly spaced string lines to create a grid of 16 quadrats measuring 0.0625 m^2 (x 16 = total area of 1 m^2). This created 48 quadrats (or 3 m^2) for each species and 144 quadrats (9 m^2) overall, i.e. 16 x 3 species plots = 48 quadrats per species, x 3 drain sections = 144 quadrats in total. The growth is being measured by placing a ruler in the centre of each quadrat and recording height of the nearest blade (for Apodasmia similis, Ficinia nodosa and Cyperus ustulatus) and the height of the upright portion of the nearest stolon (for Cotula). The percentage coverage of the planted species in each quadrat is visually estimated. The rate of occurrence, species and percentage coverage of any weeds present recorded too.[2]

[2] Methodology as adopted in a Swale monitoring study by Waitakere City Council (Weaver, J. (2009). "Reforming watertable drains in Waitakere City.")

Maintenance

All planted Swales need to be maintained. All dead, defective or unhealthy plants and those lost due to vandalism were replaced as soon as possible. Replacement plants were of the same specification as the original plants planted.

During the maintenance period, sediment, debris and trash which threaten the ability of the stormwater management system to treat or convey water need to be removed and properly disposed of in order to restore proper function of the system. This also included trash that could make the system unsightly.

The maintenance schedule for a 12 months maintenance period is in the table below:

Activity	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	As Required
Fortnightly Inspection	✓	✓	✓	✓					✓	✓	✓		
Monthly Inspection					✓	✓	✓	✓					
Weed Removal													✓
Litter Removal													✓
Plant Replacement													✓
Channel Reshaping													✓

Table 1: Maintenance Timing of Activities

Field Evaluation

Multi-criteria Analysis

The data collated during the trial period will be analysed using a robust multi-criteria analysis model. The aspects considered in the multi-criteria analysis are as below:

Assessment Criteria

Establishment – This is considered the most important aspect of the new species being trialled. This aspect forms the core objective of this trial. For an alternative vegetation species to be shortlisted as ideal it needs to have a high rate of survival (low rate of Plant deaths) in a given micro-climatic condition, a high rate of growth/re-growth, the plants need to remain healthy and have a good and dense coverage. A total of 47% weighing has been applied for this aspect of the trialled species.

Appearance – The most common causes of damage to vegetation in Swales is the accidental spraying or inappropriate mowing of plants by maintenance staff or damage by errant vehicles. For an alternative vegetation species to be suitable, it needs to provide a good visual demarcation between the Swale Planting and the general turf in the motorway berm. A total of 10% weighting has been given for this aspect of the trailed species.

Maintenance – This aspect of Swale vegetation has a significant bearing on the acceptance of the alternative vegetation species by the Operators and Maintenance staff. This aspect also has an implication on the overall cost of maintaining a stormwater asset. Mowing requirement, ability of the plant species to suppress weed growth (thereby reducing the need for frequent weed removal), ease with which litter could be removed from the swales and the reduction in the need to carry out repairs in swales due to erosion damages has been considered. A total of 25% weighting was given to this aspect of the trailed species.

Capital Cost – The cost of planting and watering the plants was also considered in the multi-criteria analysis. The objective of including this aspect in the analysis is to ensure that the alternative vegetation being trailed and recommended is not substantially more expensive than those presently being used by AMA and other network operators.

Method of Evaluation

All aspects of the plant species to be monitored for the multi-criteria analysis are measurable except of the assessment of the 'Health of plant' (a part of the Establishment aspect with 10% weighting) and the 'Enhancement of aesthetics' (a part of the Appearance aspect with a weighting of 2.5%). The appearance has low weighing the analysis. Hence any error in the assessment of this aspect will have a negligible implication on the overall assessment result. On the other hand, the Establishment aspect has a very high weighting. Errors in assessing this aspect could skew the results. To ensure the results of this trial are not skewed, it is suggested that the site inspections be carried out by one person with the assessment of the plant health verified by a second person (an NZTA operator). The scores for this aspect to be considered for the multi-criteria assessment will be a score mutually agreed by the two inspectors.

A template for completing the multi-criteria analysis is outlined Appendix F.

Summary of findings

General

Overall all three of the sites are operating adequately during the establishment period.

Key results:

- No plant deaths
- No damage to the swale cross-section
- Litter trapped and screened
- Limited Weed intrusion
- Significant water ponding
- Newton site catchpit surcharge

Litter has been trapped by all three trial species at all three of the sites. Early stages of monitoring show favourably that the plant species are effective at screening litter from passing motorists. Cyperus is particularly good at screening litter; this is mainly due to the large surface area which the leaves cover. Once the other two species completely establish a comparison can be made as to which species performs best. This implies that these Swales will require less frequent litter removal. This in turn implies a more efficient maintenance schedule and less maintenance cost for the NZTA and AMA.

The Biomac mattress has had both positive and negative results. The positive is that it took three months before the first weed species appeared on site (Figure 18). There was very limited intrusion on all sites, particularly the Newton site, but this is most likely due to the high oil content (discussed in detail below). Also the intrusions mostly originated from the stems of the wetland species.

Figure 18: Photo of weed establishment

The negative finding for the Biomac mattress is that the mat tended to bulge. This caused pools of water to form (Figure 19), which in turn formed channels for the water to flow through. These channels meant that the entire base of the swale was not being utilised. This was more evident in the Silverdale and Newton site, the Alfriston site tended to drain away any pools of water much better. The Biomac mattress is designed to disintegrate in 2 months to 1.5 years. Once this occurs a conclusion can be drawn as to the best approach for the construction of Swales in the future.

Figure 19: Photo of Silverdale site showing pooling of water

Silverdale

The Silverdale site quite often had pools of water forming throughout its length. This is most likely due to the high frequency of rainfall throughout the trial period and the low permeable Hukerenui Mudstone in the area.

Sludge was beginning to form in some of the pools of water (Figure 20). The sludge was only evident at the upstream end of the swale amongst the "Oioi" species. It is too early at this stage to draw conclusions as to the formation of the sludge except that it is at least in part due to the standing pools of water. This has implications on the water quality functionality of these swales, and whether it is a construction or plant species fault needs to be established.

Figure 20: Photo of sludge forming at the Silverdale site

Newton

Of all the sites Newton has the most ponding of water. A catchpit connected to the above bridge drainage has been surcharging, causing water and oil to pond in the swale (Figure 21). This issue is currently being addressed and will not be a factor in the future. On a positive note the plants affected by the oil appear to still be in good health and continue to grow.

Figure 21: Picture of surcharging catchpit

Alfriston

The Alfriston site at this stage has not had any unique problems or points of interest. Apart from the weed intrusion and pooling of water, which is also evident on the other two sites, the Swale appears to be functioning as per design. Further monitoring is required to firmly establish why this Swale is performing so well, which in turn will provide improved design and construction methodologies.

Recommendations

It has become apparent through this study that there is limited review or field trials of planting alternative vegetation in Swales. It is only in the recent past that the stormwater industry in New Zealand has started looking into this aspect of Swales. By commissioning this study NZTA has placed itself in the forefront of the research in the Swale Planting Area. The results of this study will help NZTA, TLAs and other network operators optimise the maintenance of stormwater devices and save thousands of dollars in maintenance costs and money lost by constructing Swales that do not function satisfactorily. By commissioning this study NZTA is leaving a Positive Legacy in the industry. Hence, NZTA may wish to publish the outcomes of this investigation for the wider benefit of the industry.

To be elaborated after the field trials.

The field trials have been monitored for just over 3 months at this stage. We recommend that NZTA commission further monitoring during the 2010/2011 financial year to complete the monitoring over a total period of one year and assessment the performance of the tested plants using a robust multi-criteria analysis like the one suggested in this report.

Appendices

Appendix A: Planting Species List from Gold Coast City Council

Appendix B: Plant Species List in Landscape & Ecological Values within Stormwater Management

Appendix C: Swale Planting Species List

Appendix D: Planting Layout

Appendix E: US EPA Swale Cost Breakdown

Appendix F: Multi-criteria Analysis