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Volume 2D

RESOURCE CONSENT APPLICATION FOR THE STAGE 4 EXTENSION OF THE SOUTHERN LANDFILL, WELLINGTON

August 2013

Absolutely Positively Wellington
Me Heke Ki Pōneke
Wellington City Council

Report

Southern Landfill Ecological Assessment

AUGUST 2013

Prepared for

Wellington City Council

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Introduction

1.1 Introduction

Wellington City Council (WCC) has operated the Southern Landfill, located in Carey's Gully since 1975. WCC have evaluated alternatives for future waste disposal and the currently preferred option is the extension of the existing landfill further up Carey's Gully (Stage 4). WCC are applying for resource consent for this extension and require ecological information to support the consent application.

The objective of this report is to establish the overall ecological "health" of the aquatic and terrestrial environments within the proposed Stage 4 landfill extension. The evaluation is based upon recently completed (May 2011) field investigations and historic ecological data from the surrounding area.

The objectives of this ecological evaluation are to provide information for Greater Wellington Regional Council (GWRC) to evaluate applications for resource consent to complete the Stage 4 expansion. The report will be summarised for inclusion in the Assessment of Environmental Effects for the project.

1.2 Site Description

1.2.1 Site Location

The Site is located in Carey's Gully, in rugged hill country approximately 5 km to the southwest of central Wellington City. **Figure 1-1** shows the Site location.

1.2.2 Site Ownership

The WCC owns the Site and a substantial area of adjoining land. It is part of a block of land that runs down to the Southern Coast near the Owhiro Bay Quarry. The legal description of the land is Lot 1 DP29398 on certificate of title 21D/612.

1.2.3 Site Layout

The Site is located in a steep sided gully, with existing stages of the landfill having been constructed in the mid-section of the valley. The Site is partially surrounded by a ring of high scrub-covered ridges, which generally separate the Site from residential and commercial land uses. Access to the Site is via Landfill Road, which climbs up Carey's Gully from Happy Valley Road (connecting the suburbs of Brooklyn and Owhiro Bay).

Figure 1-2 shows the existing stages of the landfill and the proposed Stage 4 area.

1.2.4 Stream Catchment

Carey's Stream is the surface water course that drains the Carey's Gully. The Carey's Stream (including approximately four small tributaries) runs down the gully before it is diverted though a tunnel beneath the current landfill, reverting to natural water course downstream from the landfill. Carey's Stream flows into the Owhiro Stream at the corner of the landfill access road and Happy Valley Road. Owhiro Stream continues a further 1.5 km south to reach the coast at Owhiro Bay.

The Owhiro Stream arises from three main tributaries - draining Carey's Gully, Kowhai Park Gully and urban Brooklyn (which is largely culverted). The majority of the Owhiro catchment (around 85%) is in gorse scrubland, with 7% urban, 4% pastoral and 4% bare ground and landfill (MWH, 2002). The main tributaries of the Owhiro stream are affected by urban development. Only the upper reaches of

1 Introduction

Carey's gully remain undeveloped, in a relatively natural condition, with the steep gully covered in a dense vegetation of scrub and regenerating native bush (MHW, 2002).

No surface water takes are reported for Carey's Stream or Owhiro Stream.

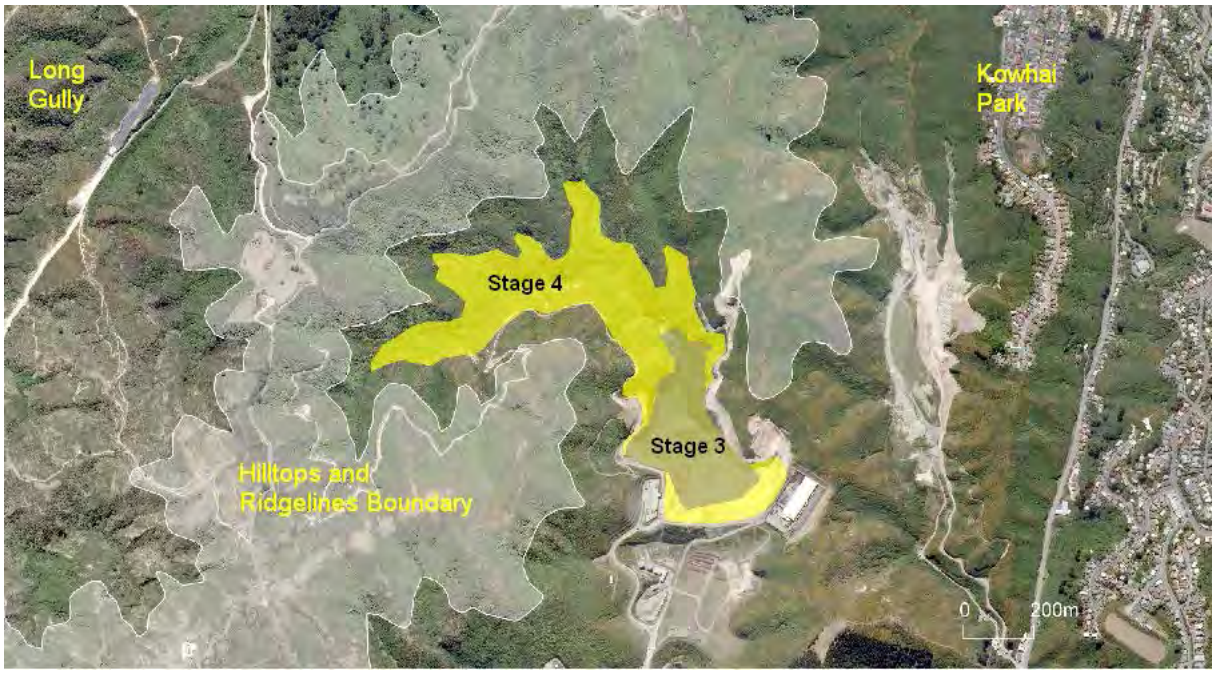
1.2.5 Setting

Carey's Gully is adjacent to the predominantly residential suburbs of Happy Valley, Owhiro Bay Kowhai Park and Mornington. The nearest residential dwellings are located approximately 650 m to the northeast of the site on Mitchell Street, in the suburb of Kowhai Park, with the nearest suburb to the east being Kingston approximately 1 km away, with Owhiro Bay almost 2 km to the south.

The Site was gazetted in 1972 for Sanitary Works and is designated in the District Plan for landfill purposes. The landfill site and the area immediately surrounding it have an underlying zoning of Open Space B.

The Carey's Gully area, including the Site, is within Wellington's Outer Green Belt Management Plan[1] (Outer Green Belt Management Plan) area. The Outer Green Belt Management Plan indicates that the Carey's Gully area provides ecological and recreational linkages with the South Coast and southern parts of the Inner Town Belt. However, it also notes that the "Council's position is that the landfill land has a primary purpose as a site to dispose of waste, and that this fundamental purpose will not be compromised by its position within the Outer Green Belt." The site is situated adjacent to but below the WCC Ridgelines and Hilltops plan area. Refer to **Plate 1-1** for the setting of the existing Stage 3 landfill and proposed Stage 4 extension.

Plate 1-1 Setting of existing Stage 3 and proposed Stage 4 landfill[2]



[1] Wellington City Council, May 2004
[2] Adapted from Southern Landfill – Stage IV Development, Landscape and Visual Assessment, Boffa Miskell

1 Introduction

There are several commercial/industrial facilities located on Landfill Road. Land use in the immediate area of the landfill site includes the following:

- Carey's Gully Sanitary Landfill Sludge Treatment Facility.
- C&D Demolition Landfill
- Bay of Plenty Electricity Limited, Southern Landfill Generation Plant
- The Capital Trout Centre.
- Second Treasure Shop / Recycling Centre.
- Former Living Earth Composting Facility (*facility decommissioned in 2008*)
- Wellington City Council CitiOperations Offices

The landuse beyond the ridgeline surrounding the proposed Stage 4 extension of the landfill is summarised in **Table 1-1**.

Table 1-1 Landuse Beyond Ridgeline Surrounding Proposed Stage 4 Landfill Extension

Direction	Landuse
North	Zealandia Wildlife Sanctuary Waterhouse Drive and Ashton Fitchett Street (residential) Meridian Energy Brooklyn Wind Turbine
West	"Long Gully Station" 48B,F,R,G,H,J,K,L and M; Ashton Fitchett Drive The "Ostrich Farm"48A Ashton Fitchett Drive The "Castle" 48F Ashton Fitchett Drive Other privately held sections, which are lightly or undeveloped
South	Te Kopahou Reserve
East	Bush with T&T landfill in adjacent valley

The following tracks, used for recreational purposes, are located along the ridgeline above the Site:

- Wind Turbine to Hawkins Hill Track
- Red Rocks Track
- Tip Track
- Zealandia Wildlife Sanctuary Predator Fence Loop Track

1.2.6 Climate

Wellington has a temperate climate with mild daytime temperatures and infrequent frosts. The area generally tends to get high rainfall in winter and low rainfall in summer, but is prone to high-intensity rainfall and wind, which can occur at any time of the year. Annual rainfall is approximately 1240 mm around Carey's Gully.

1.3 Scope of Work

The scope of the ecological assessment was developed in consultation with the Greater Wellington Regional Council (GWRC). The objective was to describe the existing communities (based on site investigations and previous work) and predict ecological impacts from the proposed Stage 4 landfill extension. Each of the ecological study tasks is described as follows:

Literature Review

Literature review of ecological information pertaining to the Carey's Gully and Owhiro Stream catchments and surrounding area.

Terrestrial Assessment

Site walkover to assess the general status of the terrestrial environment and provide information on native and exotic plant and animal (in particular bird and lizard) species found within the footprint of the proposed Stage 4 expansion.

Aquatic Assessment

Stream assessment at locations within the proposed Stage 4 expansion and immediately upstream and downstream of the current landfill extent, including:

- Stream ecological valuation (SEV) following protocols outlined by Auckland Council (Rowe et al., 2008) and updated for use by the GWRC (Storey, 2009);
- Aquatic macroinvertebrate sampling following NZ protocols (Stark et al., 2001). Samples analysed to MCI taxa level and species presence/abundance recorded along with Macroinvertebrate Community Index (MCI) and Ephemeroptera, Plecoptera and Trichoptera (EPT) values; and
- Fish survey by electrofishing and spotlighting following methods and protocols outlined in Bruno et al. (2010).

Reporting

Preparation of this report to provide:

- a summary of results of the ecological investigation (historical and updated baseline information); and,
- an evaluation of the effects of the proposed landfill expansion.

Project:	Southern Landfill Ecology
Title:	Southern Landfill Overview Plan
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Date Created:	30 May 2011
Designed:	SS
Scale:	1:25,000
Drawn:	SS
Original Size:	A3
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Client:

Wellington City Council

Drawing Number: Figure 1-1

Rev: A

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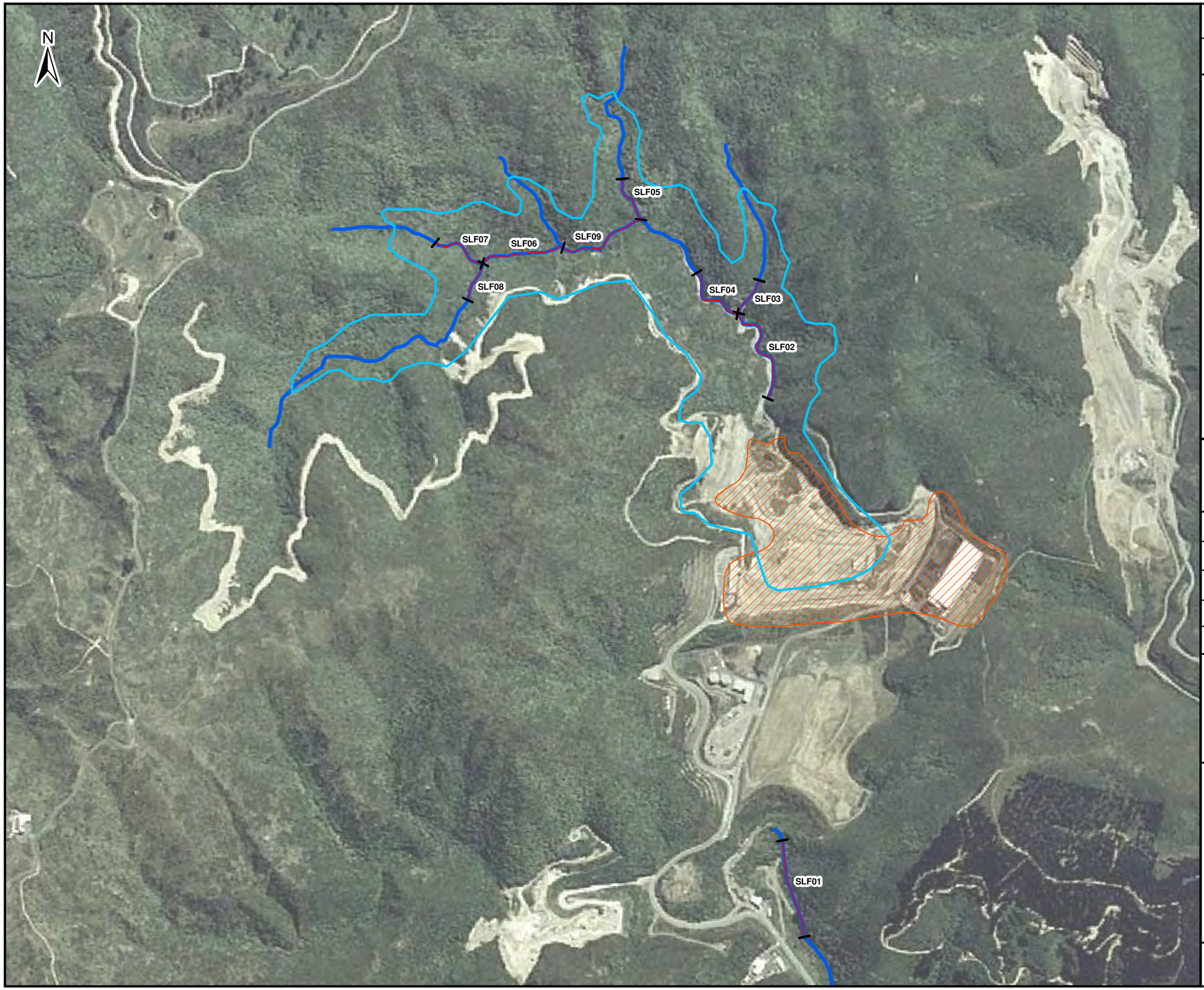

Project: Southern Landfill Ecology

Title: Site Location Map

Legend:

- Reach Sections
- Extent of Stage IV Landfill
- Carey's Gully Stream
- Current Landfill

File: 42035544\ SITE_PLAN.MXD

Date Created:	30 May 2011	Designed:	SS
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Original Size:	A3	Checked:	JH
Status	FINAL	Approved:	JH

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Client: Wellington City Council

Drawing Number: Figure 1-2

Rev: A

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2

Background

A literature review was undertaken of ecological information pertaining to the Carey's Gully and Owhiro Stream catchments and the surrounding area.

An ecological assessment of the Owhiro Stream catchment was carried out in November 2002 by MWH on behalf of Wellington City Council (MWH, 2002). The study included two sites on the Owhiro Stream, one upstream and one downstream of the confluence with Carey's Stream, as well as one site each above and below the Southern Landfill within Carey's Gully. Information from the MWH (2002) study, along with historical monitoring data undertaken by GWRC and WCC, as well as data from the NZ Freshwater Fish Data Base (NZFFD) have been used as the basis for the information summarised and presented in this section.

The WCC and GWRC water quality / MCI sampling locations are shown in **Figure 2-1**. Locations C1/CAREUS and CAREDS are the same as the sample locations SLF02 and SLF01 (immediately up and downstream of the current landfill) used in this study.

2.1 Terrestrial Ecology

No recent vegetation surveys are known to have been carried out within the Owhiro catchment. MWH (2002) stated that the majority of the catchment (around 85%) is in gorse scrubland, with 7% urban, 4% pastoral and 4% bare ground and landfill. These figures were derived from the GWRC Land Cover Database, 2001. As described previously, the upper reaches of Carey's Gully represent the main undeveloped area within the total catchment.

A botanical survey was carried out in Carey's Stream Middle Branch by members of the Wellington Botanical Society in 1992 and 1994. A diverse range of indigenous vascular species were identified during this survey. All species identified are currently classed as 'non-threatened' by the New Zealand Plant Conservation Network with the exception of Stellaria decipiens, which is classified as 'naturally uncommon – range restricted'.

2.2 Aquatic Ecology

2.2.1 Benthic Invertebrates

Macroinvertebrate sampling has been periodically carried out within Carey's Gully from 1989 to 2011 and from 1993 to 2003 within the Owhiro Stream. A summary of this data, giving calculated MCI results, is provided in **Table 2-1**. Stark and Maxted (2007) provide the following interpretation of New Zealand MCI results: "excellent – clean water" >120, "good - doubtful quality or possible mild pollution" 100-119, "fair - probable moderate pollution" 80-99, "poor - probable severe pollution" <80.

The MCI results show that macroinvertebrate communities at both Carey's Gully sites (upstream and downstream of the existing landfill) are generally healthy and diverse, indicating water quality that is good-to-excellent. Macroinvertebrate communities in Owhiro Stream are less diverse, indicating poor-to-fair water quality, which likely to reflects the modified nature of the larger Owhiro Stream catchment.

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Table 2-1 Summarised MCI data

Sample Location Description	Sample Location (Figure 2-1)	1989	1992	1993	1994	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Upper Owhiro Stream[2]	Unknown	---	---	---	---	---	---	---	92	---	---	---	---	---	---	---	---	---
Lower Owhiro Stream [3, 4]	O5	---	---	75	66	68-88	54-80	53-60	71-82	69-84	---	---	---	---	---	---	---	---
Upper Carey's Gully (Stage 4 Area)[1, 4]	CAREUS / C1	---	---	---	125-139	119-134	128	103-128	129-137	109-123	133-133	127-131	---	127	117	113-131	123	114
Carey's Gully – Downstream of existing landfill[1]	CAREDS	---	---	---	96	102-122	96-106	86-114	123-125	108-117	113-132	110-116	---	97	126	105-120	114	117
Carey's Gully –(at confluence w/ Owhiro Stm at Happy Valley and Landfill Road)[4]	C3	26	64	64	70	---	---	---	---	---	---	---	---	---	---	---	---	---

[1] Data provided by WCC

[2] From MWH, 2002

[3] Data provided by GWRC

[4] Data provided by GWRC (reported in WCC, 1994)

Note: Figures given are for minimum and maximum concentrations recorded during period. A single figure refers to just one sample.

2 Background

2.2.2 Fish

A review of NIWA's NZ Freshwater Fish Data Base (NZFFD) shows field surveys were undertaken within the Owhiro catchment in 1965, 1974, 1979, 1982 and 2005. The 1965 and 1982 surveys were conducted within Carey's Gully within the proposed Stage 4 area (1965 survey) and below the existing landfill (1982 survey). The rest of the field surveys have been grouped into Upper Owhiro Stream sites (locations above the confluence of Carey's Stream and Owhiro Stream) and Lower Owhiro Stream sites (locations below the confluence of Carey's Stream and Owhiro Stream). A summary of the species observed during these field surveys from these defined areas is presented in **Table 2-2**.

The fish inhabiting the Owhiro Stream are typical of New Zealand urban/rural catchment including a range of indigenous galaxiids, bullies and eels. There are also brown trout reported in the lower Owhiro Stream area.

Table 2-2 Fish species historically observed in Owhiro catchment

Location	Surveys Undertaken	Scientific Name	Common Name
Upper Owhiro Stream	1979, 2005	Gobiomorphus huttoni	Redfin bully
		Galaxias maculatus	Inanga
		Galaxias brevipinnis	Koaro
		Galaxias postvectis	Shortjaw kokopu
		Galaxias argenteus	Giant kokopu
		Anguilla australis	Shortfin eel
		Galaxia fasciatus	Banded kokopu
		Anguilla dieffenbachii	Longfin eel
Lower Owhiro Stream	1965, 1974, 1979, 1982, 2005	Gobiomorphus huttoni	Redfin bully
		Galaxias maculatus	Inanga
		Anguilla australis	Shortfin eel
		Anguilla dieffenbachii	Longfin eel
		Galaxia fasciatus	Banded kokopu
		Galaxias brevipinnis	Koaro
		Gobiomorphus cotidianus	Common bully
		Salmo trutta	Brown trout
Upper Carey's Gully (Stage 4 Area) (SLF02)	1965	Galaxias postvectis	Shortjaw kokopu
		Galaxia fasciatus	Banded kokopu
		Galaxias brevipinnis	Koaro
		Gobiomorphus huttoni	Redfin bully
		Anguilla dieffenbachii	Longfin eel
Carey's Gully – Downstream of existing landfill (SLF01)	1982	Anguilla dieffenbachii	Longfin eel
		Gobiomorphus huttoni	Redfin bully
		Galaxias brevipinnis	Koaro

2 Background

2.2.3 Aquatic Habitats and water quality

The annual freshwater quality and biological monitoring report for the Wellington region (Perrie and Cockeram, 2010) does not present any information pertaining to the Owhiro Stream and/or its tributaries. However, the ecological assessment of the Owhiro Stream in 2002 (MWH, 2002) and stormwater monitoring data from 2005 and 2006 (Milne and Watts, 2008) provide habitat and water quality data for the area.

Habitat

MWH (2002) reports the upper reach of the Carey's Gully tributary has 100% overhead cover with the streambed dominated by cobbles and boulders. The streambed immediately upstream of the landfill is reported to be partially in-filled, approximately 0.7 m wide, 0.05 - 0.25 m deep, with very little macrophyte or periphyton development. The lower reach of Carey's Gully is reported to have between 10 and 80% overhead cover, a streambed of predominantly cobbles with an average width of 0.9 m, 0.06-0.25 m deep, with the stream bed supporting macrophyte and periphyton development.

The upper reaches of the Owhiro Stream receive drainage from urban areas (parks, stormwater drains and culverts), have overhead vegetation from 0% to 50% with steep banks and moderate levels of macrophyte and periphyton development (MHW, 2002). The lower reaches of the Owhiro Stream have a streambed of predominantly small to medium cobbles with areas of soft sediment. The stream flows through a run / pool / riffle channel morphology past residential properties with an overhead riparian vegetation cover of <10%, is approximately 1-3 m wide, 0.05 - 0.4 m deep and has extensive macrophyte and periphyton cover (MWH, 2002).

Water quality

The majority of historic water quality data from Carey's Stream and Owhiro Stream is from two main survey periods undertaken by GWRC (1987-1994 and 1997-2002). This data is presented and summarised in two reports (Wellington City Council, 1994 and MWH, 2002, respectively). GWRC has also provided data for the Owhiro Stream mouth sampling site for the period 1987–2003. In addition, samples were analysed for metals from 2005 to 2006 from the lower Owhiro Stream, the data of which is presented in Milne and Watts (2008). Selected data has been collated from this data and is summarised in **Table 2-3**. Note that the data for sampling site C2 is not necessarily representative of the influence of Southern Landfill as this site is downstream of the confluence with a tributary from the C&D Landfill catchment. Furthermore, for water quality sampling purposes, sample location SLF01 is located approximately 2 to 3 metres upstream of this confluence, and therefore sample results are not indicative of reasonable mixing at the discharge location. MCI samples at this location are collected downstream of the confluence with the Demolition Gully discharge and as a result reflect water quality associated with activities at Carey's Gully complex (i.e., the former Living Earth composting facility, sludge dewatering facility, and the landfill) and also activities at the C&D landfill.

Table 2-4 provides a summary of data collected on behalf of WCC for sites upstream and downstream of the landfill for the period between 2005 and 2010. Median values for the reported water quality parameters generally did not differ significantly between upstream and downstream locations. Exceptions include ammonia and manganese, which exhibited median concentration increases of approximately one-to-two orders of magnitude from upstream to downstream, respectively. These constituents may be associated with activities of the Carey's Gully complex. Given the proximity of the downstream sample location to the Demolition Gully discharge it is possible that discharges from the

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C&D landfill may impact on sample results downstream of the Southern Landfill, either through surface discharge impacts or through groundwater impacts discharging to Carey's Stream.

The reported median constituent concentrations from samples collected from above and below the landfill are generally at or below the ANZECC[3] trigger level for 95% level of protection for freshwater species, and in many cases, particularly for the metals, below detection limits for the analysis.

The main exception is nitrate, which was measured at concentrations in excess of the ANZECC trigger in all sampling events (2005 to 2010) both up and downstream from the landfill. Nitrate has been detected in shallow groundwater upgradient from the landfill at wells located at the ridgeline above the landfill (approximately 1,000 metres upgradient from the active landfill), at the valley slopes (approximately 400 metres upgradient from the active landfill) and at the base of the valley (approximately 100 metres upgradient from the active landfill). Based on the presence of nitrate in samples collected from shallow groundwater *upgradient* from the landfill, and in samples collected from surface water *upstream* of the landfill it is inferred that there is an upgradient source of nitrate not related to activities at the Carey's Gully complex. However, there is also a nominal increase in nitrate concentrations from the upstream-to-downstream sample locations, which may be a result of activities at the Carey's Gully complex.

Concentrations of ammonia have also been detected in Carey's Stream downstream of the Southern Landfill nominally in excess of the 95% trigger level on two occasions out of 64 sampling events (0.94 and 1.2 mg/l versus a trigger of 0.9 mg/l). One of those exceedances was associated with an overflow from the form Living Earth Composting Facility sewer[4].

Exceedances of the ANZECC 95% trigger level were reported for aluminium (2 of 9 sampling events) and manganese (1 of 65 sampling events) in samples collected upstream from the landfill and aluminium was detected in excess of the trigger level in one of nine samples collected downstream from the landfill. In data going back to 2001, no other exceedances of the 95% trigger value have been reported for manganese either upstream or downstream from the landfill in over 200 samples analysed; and as a result, it is inferred that the one elevated manganese concentration is a result either of sampling error or a one-off event.

Aluminium concentrations in samples collected from Carey's Stream both upstream and downstream of the landfill generally increase and decrease in unison, with upstream concentrations generally higher than downstream concentrations. Based on this it is inferred that the aluminium exceedances are not related to activities at Southern Landfill. This is further supported by leachate sample results, which indicate that aluminium is not a major component with only 2 of 17 samples exceeding (nominally) the ANZECC 95% trigger over the period between 2001 and 2010. Groundwater results for monitoring wells upstream and upgradient of the landfill indicate aluminium concentrations of the same order as those detected in Carey's Stream.

The results show that the overall water quality in the Carey's Stream is good, with some moderately elevated faecal coliforms and also nutrient levels downstream of the landfill. It is inferred that contaminants from historic and current activities at the Carey's Gully complex enter the stream and cause infrequent ephemeral impacts to Carey's Stream. The water quality in the Owhiro Stream is

[3] Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000, Australian and New Zealand Environment and Conservation Council (ANZECC).
[4] WCC report that a sewer overflow occurred from the former Living Earth composting facility, which caused anomalously high results.

2 Background

similarly characterised by elevated nutrient levels, and fluctuating and in some cases high, faecal coliform levels.

2 Background

Table 2-3 Summary of Historic Water Quality Data for Carey's Stream and Owhiro Stream

Analyte	Carey's Gully, Upstream of Southern Landfill (SLF02)		Carey's Gully, Downstream of Southern Landfill (SLF01)		Upper Owhiro Stream		Lower Owhiro Stream		
Sample Location (refer **Figure 2-1**)	**C1**	**Unknown**	**C2**	**Unknown**	**O4**	**Unknown**	**O5**	**Unknown**	**O5**
Dates sampled	**1987-1994**	**1997-2002**	**1987-1994**	**1997-2002**	**1987-1994**	**1997-2002**	**1987-1996**	**1997-2003**	**2005 2006**
pH	7.2 - 7.8	7.7[2] – 7.8	6.7 – 7.4	7.4[2] – 7.8			7.0 – 10.0	7.5 – 10.2	
Temp (°C)							5.8 – 17.3	7.9 – 20.0	
Dissolved O2 (% Sat.)								77 - 122	
Biochemical Oxygen Demand, 5 Day	<5 - 32		<5 – 32						
Chemical Oxygen Demand		<1 – 5		1.5[2] – 2			0.3 – 7.8	1.0 – 7.1	
Conductivity (us/cm)	258	244[2] - 268	457		479	302 - 325	4 - 497	206 - 555	
Visibility (m)								0.04 – 4.3	
Faecal Coliforms (per /100ml)		250[2] - 760		150[2] – 2000			100 - 14600	100 - 19500	
Arsenic[1]	nd	0.002[2] – 0.002	0.00077	0.003[2] – 0.003	nd		nd	0.001	nd
Iron[1]	<0.1 - 0.35	0.030[2] – 0.030	0.51 -1.24	0.050[2] – 0.770				nd	
Zinc[1]	nd	0.005[2] – 0.005	<0.05 – 0.29	0.009[2] – 0.013				0.024	0.002-0.011
Lead[1]	nd	nd	nd	0.003[2] – 0.005				0.0008	<0.001- 0.0005
Manganese[1]	nd	0.001[2] – 0.001	0.15 – 2.9	0.190[2] – 0.320				nd	
Cadmium[1]	nd	nd	nd	nd				nd	nd
Chromium[1]	nd		nd					0.0010	<0.0005-0.0005
Copper[1]	nd	nd	nd	0.003[2] – 0.004				0.0040	0.001-0.006
Nitrate	nd		nd						
NH4-N	nd	0.04[2] – 0.180	1.6	0.04[2] – 1.38	nd		0.06 – 0.52	<0.05 – 0.25	

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Analyte	Carey's Gully, Upstream of Southern Landfill (SLF02)		Carey's Gully, Downstream of Southern Landfill (SLF01)		Upper Owhiro Stream		Lower Owhiro Stream		
NO3-N	0.66		0.77		1.04		1.1 – 3.7	0.7 – 3.4	
Dissolved Reactive Phosphorous	nd		nd		nd		0.01 – 0.04	<0.01 – 0.06	
Suspended solids	<1-23	4 - 9	<2 - 42	4 - 19					

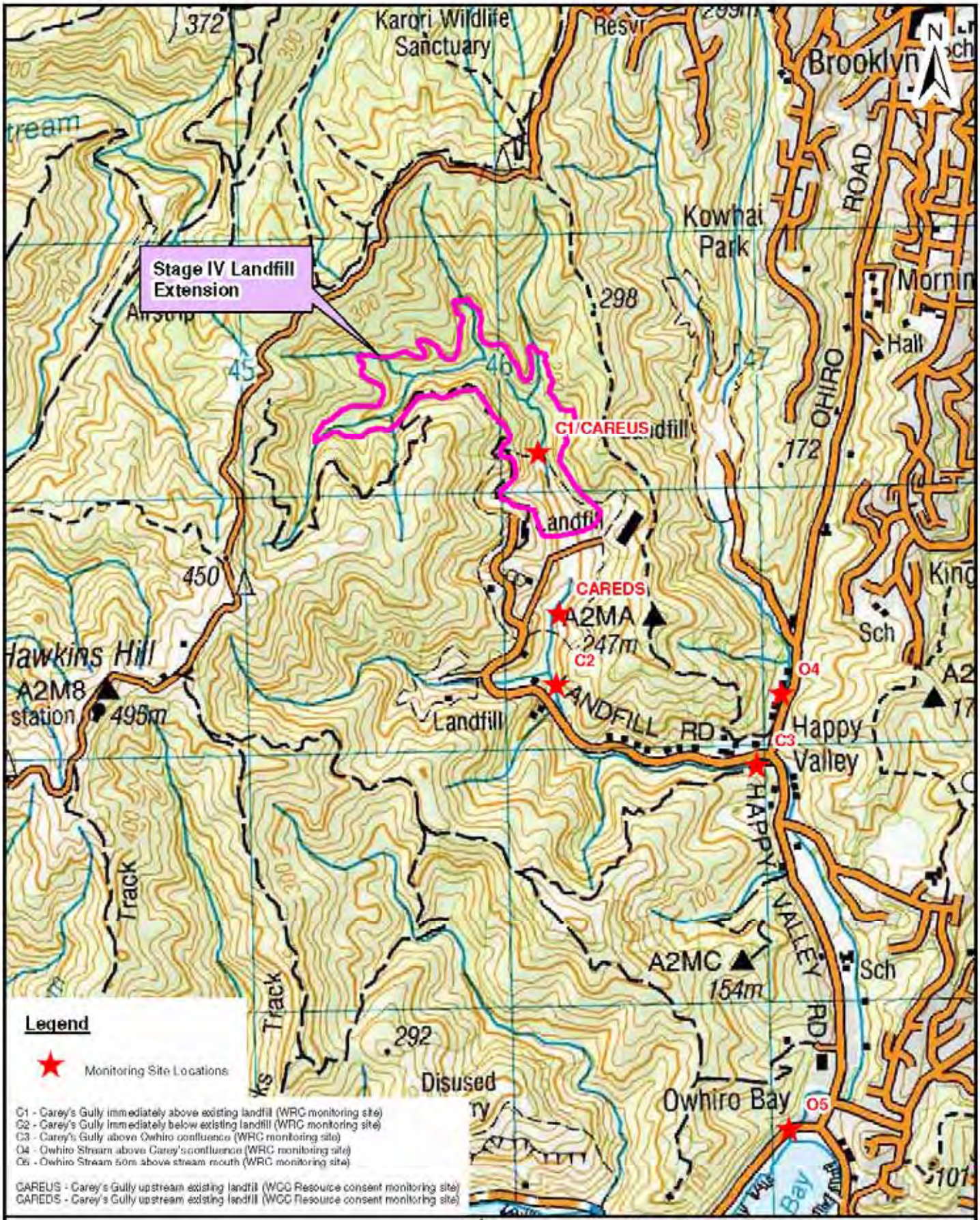
Concentrations/values in mg/l unless stated otherwise
Tabulated values are for minimum and maximum concentrations recorded during period. A single value refers to just one sample.
[1] Given concentrations are for total concentrations (1987 – 1994) and dissolved concentrations (1997 – 2006)
[2] Minimum concentrations unknown, Median concentration given
nd = Not detected throughout sampling period.
Blank cell = not analysed

2 Background

Table 2-4 Summary of Historic Water Quality Data Collected on Behalf of WCC for Carey's Stream adjacent to the Southern Landfill, Median Values[5], 2005-2010

Analyte	Carey's Gully Upstream of Southern Landfill CAREUS/C1/SLF01	Carey's Gully Downstream of Southern Landfill (CAREDS/SLF02)[6]
Nitrate- nitrogen (mg/l)	0.55	0.81
Total Suspended Solids (mg/l)	5	5
pH	7.6	7.5
Conductivity (mS/m)	25.6	30.9
Ammonia - nitrogen (mg/l)	0.01	0.09
Faecal Coliform per 100ml	23.5	20
Biochemical Oxygen Demand, 5 Day (mg/l)	1	1
Chemical Oxygen Demand (mg/l)	15	15
Iron (mg/l)	0.085	0.1
Manganese (mg/l)	0.0052	0.1435
Dissolved Reactive Phosphorous (mg/l)	0.01	0.011
Chloride (mg/l)	45.9	51.3
Aluminium (mg/l)	0.033	0.012
Arsenic (mg/l)	0.001	0.001
Boron (mg/l)	0.03	0.03
Cadmium (mg/l)	0.0002	0.0002
Chromium (mg/l)	0.001	0.001
Copper (mg/l)	0.0005	0.0005
Nickel (mg/l)	0.0005	0.001
Lead (mg/l)	0.0005	0.0005
Zinc (mg/l)	0.002	0.002

[5] When reported concentrations are less than the method detection limit the detection limit was used to calculate the median.
[6] Data collected from November 2006 not included in summary. WCC report that a sewer overflow occurred from the former Living Earth composting facility, which caused anomalously high results



Southern Landfill Ecology
Location of Ongoing Water Quality/MCI Sampling Locations

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			Status: FINAL
			Figure 2-1

3

Methodology – 2011 Investigations

3.1 Terrestrial Ecology

3.1.1 Flora

Main habitats and significant land features within the site were initially inspected from aerial photographs. This was followed by site inspections on the 2 through 4 May 2011. Distinct floral habitats were noted during this walkover as were dominant and rare species (indigenous and exotic).

3.1.2 Fauna

During fieldwork qualitative data was collected for bird, mammal and/or lizard species observed and/or heard. Detailed observations of habitat characteristics were recorded to provide a basis for estimating the likely nature of terrestrial faunal communities. The likely nature (species diversity and abundance) of terrestrial communities is commonly inferred from habitat interpretation rather than isolated quantitative metrics; (e.g. five-minute bird counts or pitfall trapping) which potentially miss many of the resident species.

3.2 Aquatic Ecology

3.2.1 Study Design and Location of Sampling Sites

In order to provide an assessment of ecological health of the Carey's Stream in the vicinity of the proposed Stage 4 landfill extension, nine survey sites were established in the stream. Eight of these sites were within the footprint of the proposed Stage 4 extension, and one was immediately downstream of the existing landfill. Survey sites were located to provide a spatial snapshot of Carey's Stream ecology upstream of the landfill with sites located at major tributaries and downstream of the confluence of tributaries. Given the relatively small reach of stream below the landfill prior to merging with the tributary from the C&D Landfill a single sample site was selected upstream of this confluence.

Each survey site comprised a stream reach up to 150 m in length. The locations of these sites are shown on **Figure 1-2** and are described in **Table 3-1**. Photographs are provided in **Figure 3-1** to **Figure 3-8**. All field work and associated sampling was carried out between 2 through 4 May 2011.

3 Methodology – 2011 Investigations

Table 3-1 Survey sites

Site	Location Description	Easting	Northing	SEV Assessment	Water Quality Monitoring	Macroinvertebrate Sampling	Electric Fishing	Spot Lighting
SLF01	Carey's Stream, downstream of the landfill.	1746183	5423254	√	√	√	√	
SLF02	Carey's Stream, immediately upstream of the landfill. (Stage 4 area)	1746136	5424287	√	√	√	√	√
SLF03	Tributary of Carey's Stream. (Stage 4 area)	1746135	5424435	√	√	√		
SLF04	Carey's Stream, upstream of the landfill.	1746113	5424400	√	√	√	√	√
SLF05	Tributary of Carey's Stream. (Stage 4 area)	1745895	5424610	√	√	√		
SLF06	Carey's Stream, upstream of the landfill. (Stage 4 area)	1745708	5424489	√	√	√	√	
SLF07	Tributary of Carey's Stream. (Stage 4 area)	1745575	5424495	√	√	√		
SLF08	Carey's Stream, upstream of the landfill. (Stage 4 area)	1745625	5424420	√	√	√		
SLF09	Carey's Stream, upstream of the landfill. (Stage 4 area)	1745864	5424528				√	

A Stream Ecological Valuation (SEV) assessment, water quality monitoring and MCI sampling were carried out at sites SLF01 – SLF08. Due to insufficient flow, electric fishing could not be undertaken at all locations, with surveys completed at sites SLF01, SLF02, SLF04 and SLF06. An additional site (SLF09) within the main channel of Carey's Stream was selected and electric fished to provide additional data. As far as possible all stream sections within the landfill extension were characterised as per Table 3.2 of Auckland Regional Council's TP313 Small headwater streams of the Auckland region Volume 1: Spatial extent (Parkyn and Wilding, 2006) that contains the method for characterising headwater streams.

3 Methodology – 2011 Investigations

The field work was carried out after 5 days without a rainfall event. Considering typical weather for the autumn/winter season this window of dry weather was considered the best opportunity to undertake the field work. The majority of the survey sites within Carey's Stream are located within the upper reach of the catchment and the return to stream base flow rates is relatively quick. Therefore this time frame without rain was considered adequate to provide results that are representative of stable stream conditions.

3.2.2 Stream Ecological Valuation (SEV)

The SEV (Rowe et al, 2008) is a method for scoring the ecological performance of streams, and has been identified by the GWRC as the best practice for assessing stream ecological value. The methodology has been specifically modified for use within the Wellington region (Storey, 2009) and also adopted for use to support resource consent applications to the GWRC. The aim of the assessment is to provide a comparable and repeatable assessment that scores the stream based on current and potential ecological characteristics.

The SEV assessment is broken into the following four functions:

- Hydraulic functions
  - natural flow regime
  - connectivity to flood-plain
  - connectivity for species migrations
  - connectivity to groundwater
- Biogeochemical functions
  - water temperature control
  - dissolved oxygen maintenance
  - organic matter input
  - instream particle retention
  - decontamination of pollutants
  - flood-plain particle retention
- Habitat provision functions
  - fish spawning habitat
  - habitat for aquatic fauna
- Biotic functions
  - fish fauna intact
  - invertebrate fauna intact
  - aquatic biodiversity intact
  - riparian vegetation intact

Specific methods associated with the SEV assessment are given below and are further detailed within Rowe et al (2008), modified by Storey (2009).

Water Quality

Spot measurements of basic water quality parameters were measured at each site using a Yellow Springs Instrument (YSI) Pro Plus handheld Multi-parameter. The parameters that were recorded from each site included temperature, pH, conductivity, dissolved oxygen and oxidation reduction potential (ORP). Visual clarity was measured with by using a 0.6 m clarity tube.

Benthic Invertebrates

Aquatic macroinvertebrate samples were collected at each monitoring site in order to obtain semi-quantitative data in accordance with the Ministry for the Environments standards as outlined in (Stark et al., 2001). Protocol C1 for hard-bottomed semi-quantitative analysis was used and samples were collected over a 50 m stream reach by kick sampling until approximately 1.0 m^2 of riffle habitat had been sampled.

Samples were immediately preserved in isopropyl alcohol in 1 litre plastic containers and dispatched to Landcare Research for analysis. Macroinvertebrates were identified to the lowest practicable level to enable biotic indices to be counted.

The macroinvertebrate abundance categories given are based on those recommended in Stark et al. (2001). These are the percentage of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) recorded in a sample (%EPT) and the MCI. EPT are three orders of insect that are generally sensitive to organic and nutrient enrichment, while MCI is based on the average sensitivity score for individual taxa within a sample.

3.2.3 Fish

In accordance with GWRC's recommended stream reach lengths from David et al. (2010), approximately 150 m of the Carey's Stream and all accessible habitat within the selected tributaries were electric fished. Electric fishing was undertaken using an EFM 300 backpack electric fishing machine. This machine temporarily stuns the fish, allowing them to be captured by a net downstream. Spotlighting was also undertaken at two of the sites (SLF02 and SLF04) during night time, as a method to capture and identify fish species that may have been missed during the day. All fish captured were identified, measured and counted before being returned to their habitats.

3 Methodology – 2011 Investigations

Figure 3-1 SLF01 looking downstream

Figure 3-2 SLF02 looking downstream

Stage III of landfill is visible in the background. Note manmade barrier on the true right and concrete barrier in the stream.

3 Methodology – 2011 Investigations

Figure 3-3 SLF03 looking upstream

Note shaded conditions and abundant periphyton.

Figure 3-4 SLF04 looking upstream

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Figure 3-5 SLF05 looking downstream

Figure 3-6 SLF06 looking downstream

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Figure 3-7 SLF07 looking downstream

Figure 3-8 SLF08 looking downstream

4

Results and Discussion

4.1 Terrestrial Ecology

4.1.1 Flora Habitat and Diversity

The area of the proposed Stage 4 landfill is characterised by a regenerating native forest located within the steep sided Carey's Gully. It is presumed that historically the land was cleared for farming. The current second-generation forest/scrub vegetation is likely to be a result of wind and avifaunal dispersal from areas of native vegetation in the surrounding area and pockets of native vegetation left in-situ within Carey's Gully during initial pastoral clearing.

The forest is currently dominated by the primary successional species mahoe (Melicytus ramiflorus), with kawakawa (Macropiper excelsum) also abundant in the lower reaches of the valley. Gorse (Ulex europaeus) is common on the valley sides, particularly on the steep exposed ridges and on the southern upper sides on the southern side of Carey's Stream. Several mature pockets of black tree ferns (Cyathea medullaris) were present on the northern side of Carey's Gully as were a few small stands of kanuka (Kunzea ericoides) on the elevated ridges. Hebe parviflora was common on the southern side of Carey's Gully in the vicinity of sampling point SLF02. A dense thicket of the weed Buddleia (Buddleja davidii) was also present in the stream bed to the north of sampling location SLF04.

The vegetation understory was found to be extensively grazed, being devoid of vegetation in most parts. Based on anecdotal information, it is likely that goats and to a lesser extent wild pigs and deer have grazed the understory. Plant species that are tolerant to heavy grazing, such as five-finger (Pseudopanax arboreus), harakeke (Phormium tenax) and various crown ferns (Blechnum sp.), were present at different densities within the stream margins, as were unidentified species of grasses and smaller ferns. The narrow side streams feeding into the main branch of Carey's Stream had more abundant vegetation than areas within the immediate area of the main tributary.

Photos of the general floral habitat are shown in **Figure 4-1 to Figure 4-6**.

Figure 4-1 Characteristic mahoe (*Melicytus ramiflorus*) stand

Carey's Gully tributary above SLF03. Note lack of understory.

Figure 4-2 View looking down on Carey's Gully – SLF02

SLF02 in foreground of picture and Stage III limit of landfill in background.

4 Results and Discussion

Figure 4-3 Upper Carey's Gully

View down into Carey's Gully from southern side of catchment (upstream extent of proposed Stage 4 extension). Note dense gorse (*Ulex europaeus*) in foreground.

Figure 4-4 View looking down on Carey's Gully – SLF06

View from southern side of Carey's Gully. Note stands of black tree ferns (*Cyathea medullaris*).

Figure 4-5 Carey's Stream tributary

Typical vegetation of side stream within the Stage 4 extension.

Figure 4-6 View looking down on Carey's Gully - SLF04

View from southern side of Carey's Gully. Road depicts approximate vertical extent of Stage 4 extension. Note strips of gorse (*Ulex europaeus*) on exposed ridges.

4.1.2 Fauna Diversity

Within the Stage 4 area, fantail (Rhipidura fuliginosa placabilis) and tui (Prosthemadera novaeseelaniae) were observed in the overhead canopy. Feral goats (Capra hircus) were noted on the access road on the northern border of the proposed Stage 4 outline and it is understood that their presence in the area is common. Wild pigs (Sus scrofa) and deer (species unknown) are also rare visitors to the area, although none were seen during the field investigations.

No Herpetofauna was observed during the site walkover.

4.2 Aquatic Ecology

4.2.1 Stream Ecological Survey

The SEV assessment produces a score out of one as an indicator of stream ecological value. As summarised in **Table 4-1**, the overall SEV scores for the sites surveyed at Carey's Gully reflect generally 'medium' ecological value with two sites evaluated as having 'high' ecological values. The SEV scores for each function category are presented in **Appendix A**[7]**.**

The calculated average SEV for all survey sites (SLF01 – 08) within the Carey's Stream and tributaries was 0.75, with the sites within the proposed Stage 4 extension only (SLF02 – 08) averaging 0.74. Site SLF02 (immediately upstream of the existing landfill) recorded the lowest SEV score throughout all the sites with a medium score of 0.62. Influencing factors contributing to the lower score of this reach include the modified channel with reduced shading, the number of total barriers present and a lower invertebrate diversity. The SEV score for the Carey's Stream site downstream of the landfill (SLF01) was 0.79 which reflects "medium" ecological value. Rowe et al. (2008) lists the main ecological functions that contribute to the SEV assessment and their relative importance. Those of high relative importance include: natural flow regime, water temperature control, fish spawning habitat, habitat for aquatic fauna, fish fauna, invertebrate fauna, aquatic biodiversity and riparian vegetation. All of these individual ecological functions scored between 0.73 and 0.93 across the survey sites, with the exception of aquatic biodiversity, which scored on average 0.65.

The reported SEV scores are high in the Wellington context, which reflects the relatively non-modified nature of the Carey's Gully catchment and the resultant high-quality aquatic habitat in particular the riparian cover and "clean" (i.e. silt free) cobble/pebble substrate. Reference site data used in the SEV calculation were from the Auckland region as GWRC does not currently maintain Wellington-specific reference data. The use of an Auckland reference site may have impacted the scores for specific ecological functions but the effect on the overall SEV is not likely to be significant.

General site characteristics and observations are summarised in **Table 4-1** and photos of the sites are provided in **Figure 3-1 to Figure 3-8**. In general the sites were well confined and incised having a flood plain width of between approximately 1.0 and 3.0 metres and a wetted width of between approximately 1.0 and 2.0 metres. The channel shape was generally sinuous characterised by a riffle/run/pool structure except for the side streams (SLF03 and SLF07) which had a riffle/pool structure. The banks were well vegetated and stable (except for the true right bank of SLF02, which was stabilised by a concrete structure). The banks were not undercut.

In-stream bed substrate at the surveyed locations was dominated by gravels with some cobbles, sand and bedrock present. Macrophytes were observed at all sites and were predominantly emergent. Periphyton was present at all sites although more dominant in the side streams SLF03 and SLF04. Woody material was present at most sites, and leaf litter was found at all sites. Sites were well shaded except for site SLF02, which was adjacent to the access road and had overhead shading from the true left bank only.

The riparian environment was generally forested with regenerating native forest. There was little ground cover (understory), although; small ferns and grasses were present at all sites. Assorted wind-

[7] The SEV values reported in **Table 4-1** and discussed in this report are based on a 2006 methodology. Since the initial finalisation of this report a revised 2011 SEV methodology has since been produced. Revised SEV scores based on 2011 methodology are provided in **Appendix C**.

4 Results and Discussion

blown refuse was observed at sites closest to the existing Southern Landfill (SLF01 and SLF02) and along the stream banks adjacent to these sites.

Approximately 1.8 km of Carey's Stream within the Stage 4 landfill extension was characterised as '1A' (Channel incised, no terrestrial vegetation; Obvious water flow) as per the Auckland Regional Council Headwater Characterisation description (Parkyn and Wilding, 2006). This included all survey sites within the proposed extension (approximately 1km in total). The western extent of the stream (past survey site SLF08) was characterised as '5B' (No Banks, bed vegetated; Dry). However the exact length could not be calculated due to the terrain being inaccessible.

Adjacent land uses to the downstream survey site (SLF01) include the Southern landfill (north), the T & T landfill and regenerating native forest and scrub (east), the C&D Landfill and regenerating forest to the west and south. Several commercial premises are located on Landfill Rd. approximately 400 m downstream of SLF01. Sites within the proposed Stage 4 extension are surrounded by regenerating native forest and scrub. The northern extent of the Southern Landfill (current Stage 3) is located immediately to the south of survey site SLF02.

4 Results and Discussion

Table 4-1 Stream Habitat parameters

Site	Floodplain width (m)	Wetted channel width (m)	Depth of water (m)	Shaded proportion	Leaf litter present	Periphyton present	Roots and emergent vegetation present	Woody material present	Dominant streambed substrate	General Observations	Calculated SEV Score
SLF01*	2.0-4.1	1.2 – 3.0	0.01 – 0.20	0.85	Y	Y	Y	Y	Gravels	---	0.79
SLF02	1.3 – 6.0	1.65 – 5.75	0.01 – 0.29	0.50	Y	Y	Y	Y	Gravels and bedrock	Barriers to migration present	0.62
SLF03	0.9 – 2.4	0.4 – 2.2	0.01 – 0.21	0.90	Y	Y	Y	Y	Gravels and bedrock	---	0.70
SLF04	1.7 – 3.6	1.1 – 1.8	0 – 0.40	0.60	Y	Y	Y	N	Gravels	---	0.74
SLF05	1.6 – 3.0	0.95 – 1.9	0.01 – 0.26	0.90	Y	Y	Y	Y	Gravels, sand and bedrock	---	0.76
SLF06	1.5 – 3.0	0.85 – 1.6	0 – 0.12	0.90	Y	Y	Y	Y	Gravels	---	0.81
SLF07	0.8 – 2.1	0.6 - 1.1	0 – 0.11	0.90	Y	Y	Y	Y	Gravels and sand	---	0.77
SLF08	1.8 - 2.9	0.9 – 1.5	0.01 – 0.18	0.90	Y	Y	Y	Y	Gravels	Stream ran dry at far end of reach	0.82

* Downstream monitoring site.

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4.2.2 Water Quality

The results of the in-stream water quality measurements undertaken at each monitoring site are given in **Table 4-2**.

Table 4-2 Measured water quality parameters

Site	Temperature (ºC)	pH	Conductivity (µS/cm)	Dissolved oxygen (mg/l)	Dissolved oxygen (% saturation)	Oxidation reduction potential (mv)	Clarity (m)
SLF01*	13.2	7.31	318.5	10.8	105.1	22.7	> 0.6
SLF02	11.9	7.88	174.0	13.1	123.9	83.2	> 0.6
SLF03	11.5	7.91	178.1	12.5	116.9	71.4	> 0.6
SLF04	11.8	7.97	170.7	12.6	119.0	59.6	> 0.6
SLF05	11.8	7.63	151.1	11.3	106.7	64.2	> 0.6
SLF06	11.9	7.53	170.4	11.9	112.4	78.7	> 0.6
SLF07	11.7	7.38	135.3	11.7	110.3	99.9	0.59
SLF08	11.8	7.30	175.1	12.0	112.5	121.4	> 0.6
SLF02 – SLF08 (Average)	11.8	7.7	165	12.2	114.5	82.6	> 0.6

* Downstream monitoring site

The water quality results were relatively consistent across all of the sites located upstream of the existing landfill within the proposed Stage 4 footprint (SLF02 – SLF08). The sampled water from SLF01 (downstream from the landfill) was warmer, with higher conductivity and lower dissolved oxygen and oxidation reduction potential, in comparison to the other sites. Water clarity measured across all of the sites was very similar, with all sites recording greater than 60 cm clarity, except for SLF07 which had a clarity of 59 cm.

4.2.3 Benthic Invertebrates

A total of 62 benthic invertebrate taxa were identified from the eight sites sampled in Carey's Stream on the 2nd and 3rd of May 2011. A full list of species collected from each site is provided in **Appendix B**.

Sites SLF03 to SLF08 were characterised by an abundant and varied taxa of mayfly (Deleatidium sp.), stonefly (Plecoptera sp.) and caddisfly (Trichoptera sp.). Site SLF01 had a less varied taxa in these three main insect groups, whereas taxa from site SLF02 had very limited genera of mayflys, stoneflys and caddisflys.

Summarised macroinvertebrate data from each of the sites are presented in **Table 4-3**.

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Table 4-3 Macroinvertebrate indices from survey sites

	SLF01*	SLF02	SLF03	SLF04	SLF05	SLF06	SLF07	SLF08
Number of Taxa	26	23	22	40	40	30	38	34
Number of individuals	1240	787	786	1480	748	926	1454	893
EPT Value	14	7	11	22	22	17	19	17
% EPT (taxa number)	53.8	30.4	50.0	55.0	55.0	56.7	50.0	50.0
MCI Value	114.6	92.2	120.0	123.5	133.5	135.3	127.9	130.0

* Downstream monitoring site.

The greatest number of taxa were collected at sites SLF04 and SLF05 within the footprint of the proposed Stage 4 extension. The lowest number of taxa were collected from SLF02 which is also within the proposed Stage 4 extension, immediately upstream of the current landfill. It is likely that this result is directly related to the quality of habitat at this site, including decreased overhead shading and the concrete structure on the true right of the stream at this location resulting in a modified and less desirable invertebrate habitat.

The EPT value was highest in sites in the headwaters of Carey's Stream (SLF04-SLF08) and lowest in sites closest to the current landfill (SLF01-SLF03). Reasonably large numbers of the mayfly Coloburiscus at sites SLF03 - SLF06 (inclusive) reflect in particular the clean low-nutrient water and riffle habitat with cobble/small boulder substrate.

MCI values show a similar pattern to the EPT values. Reported MCI values for Sites SL04-SL08 are very high, ranging from 123.5 to 135.3. As noted earlier, MCI values above 119 reflect excellent water quality (Stark and Maxted, 2007). Site SLFO2 with an MCI value of 92.2 indicates a water quality of 'fair – probable mild pollution' and SLF01 downstream of the current landfill is categorised as 'good – doubtful quality or possible mild pollution' with an MCI value of 114.6.

The slightly less healthy (as evidenced by the MCI and EPT values) benthic invertebrate communities at the site immediately upstream of the current landfill operation is mostly likely a result of the modified stream channel at this location. For the downstream site, it is possible that activities at the Carey's Gully complex and the C&D Landfill may have impacted invertebrate communities.

The MCI results for the immediately upstream and downstream sites (SLF02 and SLF01 respectively) are consistent with recent previous MCI monitoring results for the upper and lower Carey's Stream survey sites (CAREUS/C1 and CAREDS respectively). This indicates that stream conditions were fairly stable during the sampling period, despite the shorter period of dry weather prior to sampling than generally recommended[8].

[8] GWRC recommends 14 days of dry weather prior to stream surveying

4.2.4 Fish

The results from the electric fishing and spotlighting surveys are presented in **Table 4-4**.

Table 4-4 Fish species and numbers observed at survey sites

Scientific Name	Common Name	SLF01	SLF02*	SLF04*	SLF06	SLF09
Galaxias brevipinnis	Koaro	11	47 (7)	43 (*)	8	5
Galaxia fasciatus	Banded kokopu	9	10 (*)	5 (1)	4	4
Anguilla dieffenbachii	Longfin eel	7	(3)			1

() Numbers in brackets denote number of individuals seen during evening spotlighting.

(*) Indicates a large (unquantified) number of individuals seen in pools during spotlighting.

Koaro and banded kokopu were abundant throughout the proposed Stage 4 area, with numbers reducing further up the catchment. The size range for these species in the Stage 4 area varied from 60 to 150 mm for koaro and 50 to 200 mm for banded kokopu.

Both koaro and banded kokopu are very aggressive upstream migrants (McDowall, 1984). Although both species are diadromous (spend juvenile life cycle stages at sea); “land-locked” populations are common throughout the North Island of New Zealand. Koaro are able to climb damp vertical faces and are common in streams in well forested catchments. Banded kokopu also penetrate substantial distance inland and reach locations that seem inaccessible.

Eels were abundant at site SLF01 (7 caught ranging in size from 120 – 300 mm), whereas they appeared rare and absent in the Stage 4 area, with only a few mature species present (size range 500 – 600 mm).

The New Zealand population sizes for all three fish species recorded during the electric fishing survey have been declining steadily over recent decades, due primarily to loss of habitat.

4.3 Conclusion

The ecological survey results generally agree with observations and measurements from previous monitoring undertaken immediately upstream and downstream of the existing Stage 3 Landfill. The upper reaches of Carey’s Stream within the Stage 4 extension supports diverse healthy freshwater invertebrate and fish communities (as indicated by SEV, MCI, EPT and electric fishing results), with a healthy canopy of regenerating native forest providing habitat for diverse and abundant terrestrial communities.

There is a lack of understory within the Carey’s Gully forested area and this is most probably caused by extensive browsing by mammalian pests within the area. Vegetation on the upper slopes of the catchment is a mixture of regenerating native plants and scrub dominated by invasive pest species.

Native fish species are present throughout Carey’s Gully area, although their diversity appears limited by downstream barriers. There is a varied size range of fish in the Carey’s Stream upper catchment suggesting recruitment through the existing landfill is occurring for these species. However, only larger eels were found to be present in the Stage 4 extension compared to downstream of the landfill

4 Results and Discussion

suggesting the landfill may be a barrier to eel migration. The landfill and other structures further down Carey's and Owhiro Stream are also likely barriers to bullies (Gobiomorphus sp.), which were not recorded at any sites.

Stream locations immediately upstream and downstream of the existing landfill are more ecologically impacted than sites further upstream of the landfill. This may be due to the impacts associated with the activities at the Carey's Gully complex and activities associated with the C&D landfill. For example, decreased water quality has historically been observed at site SLF01, and reduced quality habitat at SLF02 during this investigation.

5

Assessment of Effects

5.1 Terrestrial

The proposed Stage 4 landfill extension when completed would result in the loss of approximately 25 hectares of regenerating native bush and terrestrial habitat within the proposed landfill footprint. The proposed landfill footprint is located in the lower part of Carey's Gully and represents approximately 16% of the total Carey's Gully catchment area above the existing Stage 3 landfill.

Based on qualitative field observations completed during this investigation, the area within the proposed landfill footprint appears unlikely to support ecologically significant New Zealand terrestrial faunal species. Evidence of substantial understorey grazing suggests significant pest communities (both herbivorous and carnivorous) exist within the regenerating forest. These species would hinder the establishment and/or survival of indigenous high ecological value terrestrial fauna within this area through degraded habitat and direct predation. It is likely that isolated indigenous faunal species do exist within the valley; however, the presence of these individuals in numbers that would be considered a viable community is considered unlikely.

It is likely that the overall area provides an important ecological corridor link to neighbouring areas of significant ecological value, e.g. Zealandia (Karori Wildlife Sanctuary). The value of the Carey's Gully regenerating forest area has been recognised in Wellington's Outer Green Belt Management Plan (Wellington City Council, 2004), which supports the maintenance of a continuous regenerating forest corridor between Wellington City and the Southern Coast. However, the habitat loss would be restricted to the lower reaches of the gully, which are less critical with respect to the wildlife corridor than the upper reaches. This is the due to the relatively discontinuous nature of the lower reaches versus the continuous nature of the relatively unmodified terrestrial habitat in the upper reaches of the valley

The entire area has been designated in the District Plan for landfill purposes, which from a planning perspective, provides some region-wide "context" for the loss. This is acknowledged in the Outer Green Belt Management Plan, which states that "Council's position is that the landfill land has a primary purpose as a site to dispose of waste, and that this fundamental purpose will not be compromised by its position within the Outer Green Belt."

Overall the loss of terrestrial ecological habitat is considered significant enough to warrant compensation/mitigation.

Compensation would be provided through proposed improvements to the terrestrial habitat in the upper reaches of Carey's Gully and through provision of native planting in Stage 4 areas with final cover.

Improvements would largely be focused on controlling pest species, primarily possums, rats, goats and stoats in an effort to improve the understory of the upper parts of Carey's Gully and reduce predation by these introduced pest species on native avifauna and herpetofauna. A pest management plan will be included as part of the Stage 4 landfill management plan. The proposed Stage 4 pest management plan would include similar provisions to the Stage 3 pest management plan, and would include the key measures summarised below:

- Implementation of a goat culling programme to be undertaken on a monthly basis;
- Implementation of a baiting and trapping programme for seagulls, rats, stoats and possums;
- Reduction of the "attractive nuisance" of landfilling operations primarily through controls at the tip face, such as compaction of waste and provision of daily cover, and litter abatement through litter fencing and policing/pickup.

Final cover would be provided in those areas where the final capping level is reached. Initially final cover areas would be grassed to allow for maintenance and operation of drainage and landfill gas systems. Upon completion of landfill gas operations, some areas would be redeveloped to include both recreational areas and select native plantings (native plants would be selected such that they would not compromise the final cover). Such redevelopment would be progressive and over the long-term and would be undertaken in accordance with a landscaping plan. Refer to the Stage 4 Upper Carey's Gully Indicative Ecological Plan[9] (*Indicative Ecological Plan*) included as **Appendix D** for additional detail.

5.2 Aquatic

5.2.1 Water Quality

As presented in Section 4.2.2, the water quality between the sites is very consistent and indicative of a stream of good water quality (ANZECC 2000). To maintain the quality of Carey's Stream, a number of engineering and operational controls are proposed to protect the water quality. Stormwater would generally be diverted around the Stage 4 landfill operations. Stormwater from the catchment above the landfill footprint would be conveyed around the Stage 4 footprint through a cleanwater diversion system and ultimately discharge to Carey's Stream downstream of the overall landfill. Stormwater from areas of the Stage 4 landfill with final cover would also report to this cleanwater diversion. Within the landfill footprint, cutoff drains would be provided around the active landfill area (cells), and report to Carey's Stream downstream of the landfill. Additional controls would include the following:

- Provision of engineering controls to limit erosion and consequent sediment transport (within the cutoff and diversion drain systems and at the point of discharge to Carey's Stream);
- Development and implementation of environmental and erosion and sediment control management plans for both the construction and operational phases of the landfill;
- Minimising areas of cleared vegetation to the extent practical;
- Provision of intermediate or final cover and establishment of vegetation growth, as soon as practical;
- Provision of robust leachate and containment systems, which would limit discharges to groundwater and consequent discharges to surface water.

Although, there is the potential for the proposed Stage 4 landfill to adversely influence surface water conditions, such as dissolved oxygen (DO), conductivity, turbidity, pH and temperature, these impacts will be mitigated through the measures described above. As a result, the effects associated with the proposed Stage 4 landfill on resident downstream aquatic communities, which are already typical of partially modified urban catchments in New Zealand, are expected to be no more than minor.

5.2.2 Aquatic Habitat

Once completed, the Stage 4 landfill extension would result in the progressive net loss of approximately 1.5 km to the Carey's Stream habitat (including tributaries), which is the stream area directly within the proposed extension footprint.

The macroinvertebrate communities in the vicinity of the proposed Stage 4 extension are healthy and diverse, which reflects the relatively non-modified nature of the largely regenerating forest catchment.

[9] Stage 4 Upper Carey's Gully Indicative Ecological Plan, June 2013, Boffa Miskell

5 Assessment of Effects

As described in **Section 4.2.3** a total of 40 different taxa were collected from Sites SLF04 and SLF05 within the footprint of the landfill Stage 4 extension. Many of these species, in particular stoneflies and mayflies, will only inhabit non-modified stream environments. The macroinvertebrate communities within the Stage 4 footprint are typical of those inhabiting non-modified stream environments throughout New Zealand. The reported SEV scores are high in the Wellington context, which reflects the relatively non-modified nature of the Carey's Gully catchment and the resultant high-quality aquatic habitat, in particular the riparian cover and "clean" (i.e. silt free) cobble/pebble substrate.

The fish species recorded as inhabiting Carey's Stream (long-finned eel, banded kokopu and koaro) are generally widespread throughout most of New Zealand; although, habitat degradation and competition from introduced species has seen a reduction in the range and abundance of these species (McDowall, 2000). Populations of all of the Carey's Stream fish species also inhabit both the upper and lower sections of the Owhiro Stream (NZFFD, NIWA).

The loss of habitat would have a direct impact on the macroinvertebrate and fish populations inhabiting this section of Carey's Stream. The landfill extension is also likely to further limit, upstream migration of the banded kokopu and koaro fish species, which inhabit Carey's Stream.

5.2.3 Conclusion

The proposed landfill extension would ultimately eliminate the upstream Carey's Gully aquatic ecosystem altogether within the extension footprint. The existing upstream ecosystem is generally healthy and supports a diverse range of native species, all of which are relatively abundant in similar habitat conditions throughout New Zealand. The loss of a high value aquatic ecological habitat in such close proximity to an urban area represents a significant impact and as such is considered to warrant compensation.

The Stage 4 extension would be designed to minimise further negative effects to water quality downstream from the landfill operations. The Owhiro Stream water quality and ecological communities downstream of the existing landfill are highly modified from the primarily urban landuses within the tributary catchments. With the proposed engineering controls in place, it is expected that discharges would be minimised, and that the incremental effect of the discharges from the Stage 4 landfill to the Owhiro Stream would be less than minor.

5.2.4 Compensation

An evaluation of compensation options is provided in the *Ecological Compensation Feasibility Assessment*[10] (**Appendix C)** and in the *Indicative Compensation Plan* included as **Appendix D**.

As described in *Ecological Compensation Feasibility Assessment*, an area of approximately 3,000 m^2 of ecological enhancement would be required to compensate for the infilling of streams within the Stage 4 landfill expansion footprint. Options for compensation have been identified within the Carey's Gully catchment, which include riparian planting and other ecological enhancements along the cleanwater diversion (CWD) at the northern perimeter of the landfill extension, the creation of a wetland within the Carey's Gully catchment, and adding ecological value to the existing Lower Carey's Gully stream.

[10] Ecological Compensation Feasibility Assessment Stage 4 Extension of Southern Landfill, URS, August 2013.

5 Assessment of Effects

The CWD around the northern perimeter of the proposed landfill expansion has been identified as the most feasible option for ecological compensation. This option would be supplemented as required, by the other options based on detailed landfill cell design and ecological compensation planning/design. To ensure that the timeframe between stream infilling and providing the ecological compensation is acceptable, it is proposed that the compensation would be provided progressively with the development of each cell and the overall Stage 4 expansion.

To provide sufficient ecological compensation for the loss of the upper Carey's Gully stream, the CWD would need to be modified to provide ecological enhancements and native habitat regeneration. The modifications would include habitat improvements and riparian planting. These modifications are described in greater detail in the *Indicative Ecological Plan*.

Ecological compensation for each cell of the Stage 4 expansion would be based on the detailed design for that cell, the actual as-built conditions and final configuration of the landfill access roads along the CWD, and supplemental ecological and hydrological assessments, if required, of the streams being infilled for each cell. If sufficient compensation area is not available along the northern CWD, then additional compensation could be undertaken along the southern CWD or at lower Carey's Stream.

6

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A

Appendix A SEV Scores

Function category	Report section	Function	Worksheet #	Variable (code)	SLF001	SLF002	SLF003	SLF004	SLF005	SLF006	SLF007	SLF008
				Length of Reach surveyed (m)	150	150	80	150	150	150	150	70
			1	Vbed	0.86	0.79	0.55	0.91	0.91	1.00	1.00	1.00
			2	Verosn	1.00	0.70	1.00	1.00	1.00	1.00	1.00	1.00
			30	Vimper	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Hydraulic	**5.1**	**NFR**		**=**	**0.93**	**0.74**	**0.78**	**0.96**	**0.96**	**1.00**	**1.00**	**1.00**
			14	Vfpwidth	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
			3	Vfreq	0.10	0.40	0.10	0.10	0.10	0.10	0.10	0.10
Hydraulic	**5.2**	**CFP**		**=**	**0.25**	**0.40**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**
			4	Vbarr	1.00	0.00	0.30	0.30	0.30	1.00	0.30	1.00
			31	Vcatch	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Hydraulic	**5.3**	**CSM**		**=**	**1.00**	**0.00**	**0.30**	**0.30**	**0.30**	**1.00**	**0.30**	**1.00**
			1	Vhypo	0.86	0.79	0.55	0.91	0.91	1.00	1.00	1.00
Hydraulic	**5.4**	**CGW**		**=**	**0.86**	**0.79**	**0.55**	**0.91**	**0.91**	**1.00**	**1.00**	**1.00**
		Hydraulic function mean score			**0.76**	**0.48**	**0.47**	**0.60**	**0.60**	**0.81**	**0.64**	**0.81**
			18	Vshade	0.83	0.48	0.88	0.68	0.91	0.92	0.91	0.91
			15	Vdepth	0.60	0.70	0.60	0.60	0.60	0.50	0.50	0.60
			22	Vveloc	0.60	0.80	0.70	0.60	1.00	1.00	1.00	1.00
			21	Vlength	0.90	0.90	0.80	0.90	0.90	0.90	0.90	0.80
biogeochemical	**5.5**	**WTC**		**=**	**0.76**	**0.64**	**0.79**	**0.69**	**0.87**	**0.86**	**0.85**	**0.86**
			5	Vdod	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
biogeochemical	**5.6**	**DOM**		**=**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
			19	Vcanop	0.69	0.10	0.72	0.27	0.89	0.92	0.89	0.91
			20	Vdecid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
biogeochemical	**5.7**	**OMI**		**=**	**0.69**	**0.10**	**0.72**	**0.27**	**0.89**	**0.92**	**0.89**	**0.91**
			23	Vtrans	0.70	1.00	1.00	1.00	1.00	1.00	1.00	1.00
			24	Vretain	0.92	0.94	0.66	0.92	0.73	0.85	0.65	0.78
biogeochemical	**5.8**	**IPR**		**=**	**0.65**	**0.94**	**0.66**	**0.92**	**0.73**	**0.85**	**0.65**	**0.78**
			16	Vsurf	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
biogeochemical	**5.9**	**DOP**		**=**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
			14	Vfpwidth	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
			6	Vrough	0.55	0.70	0.40	0.61	0.40	0.40	0.40	0.40
			3	Vfreq	0.10	0.40	0.10	0.10	0.10	0.10	0.10	0.10
biogeochemical	**5.10**	**FPR**		**=**	**0.35**	**0.50**	**0.30**	**0.37**	**0.30**	**0.30**	**0.30**	**0.30**

		Biogeochemical function mean score		0.74	0.70	0.74	0.71	0.80	0.82	0.78	0.81
			9	Vgalspwn	1.00	1.00	1.00	1.00	0.25	0.50	1.00	1.00
			10	Vgalqual	1.00	0.75	0.25	1.00	0.25	0.25	0.25	0.25
			17	Vgobspwn	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
habitat provision	**5.11**	**FSH**		**=**	**1.00**	**0.88**	**0.63**	**1.00**	**0.53**	**0.56**	**0.63**	**0.63**
			7	Vphyshab	0.81	0.69	1.00	0.84	1.00	1.00	1.00	1.00
			8	Vwatqual	0.91	0.49	0.94	0.84	0.95	0.96	0.95	0.96
			30	Vimper	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
habitat provision	**5.12**	**HAF**		**=**	**0.89**	**0.72**	**0.99**	**0.88**	**0.99**	**0.99**	**0.99**	**0.99**
		Habitat provision function mean score			0.94	0.80	0.81	0.94	0.76	0.78	0.81	0.81
			28	Vfish	0.80	0.80	0.80	0.70	0.80	0.70	0.80	0.80
Biodiversity	**5.13**	**FFI**		**=**	**0.80**	**0.80**	**0.80**	**0.70**	**0.80**	**0.70**	**0.80**	**0.80**
			25	Vmci	1.00	0.30	1.00	1.00	1.00	1.00	1.00	1.00
			26	Vept	1.00	0.28	0.84	1.00	1.00	1.00	1.00	1.00
Biodiversity	**5.14**	**IFI**		**=**	**1.00**	**0.29**	**0.92**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
			29	Vvert	0.80	0.80	0.80	0.70	0.80	0.70	0.80	0.80
			27	Vinvert	0.44	0.38	0.38	0.65	0.66	0.52	0.60	0.52
Biodiversity	**5.15**	**ABI**		**=**	**0.62**	**0.59**	**0.59**	**0.68**	**0.73**	**0.61**	**0.70**	**0.66**
			11	Vripcond	0.60	0.60	0.60	0.60	0.70	0.70	0.70	0.70
			12	Vripconn	1.00	0.50	1.00	1.00	1.00	1.00	1.00	1.00
			13	Vripar	1.00	0.50	1.00	1.00	1.00	1.00	1.00	1.00
Biodiversity	**5.16**	**RVI**		**=**	**0.87**	**0.53**	**0.87**	**0.87**	**0.90**	**0.90**	**0.90**	**0.90**
		Biodiversity function mean score			0.82	0.55	0.79	0.81	0.86	0.80	0.85	0.84
Sum of scores (maximum value 16)					**12.66**	**9.91**	**11.13**	**11.78**	**12.16**	**12.94**	**12.26**	**13.06**
Overall mean SEV score (maximum value 1)					**0.791**	**0.619**	**0.696**	**0.736**	**0.760**	**0.809**	**0.766**	**0.817**

B

Appendix B Macroinverterbrate Results

Macroinvertebrate Sample Results									
Taxa	**MCI**	**SLF01**	**SLF02**	**SLF03**	**SLF04**	**SLF05**	**SLF06**	**SLF07**	**SLF08**
	TV	**3/05/11**	**2/05/11**	**2/05/11**	**2/05/11**	**3/05/11**	**3/05/11**	**3/05/11**	**3/05/11**
Mayfly *Acanthophlebia*	7				10	12	30		4
Mayfly *Ameletopsis*	10				6	4	2		2
Mayfly *Arachnocolus*	8								
Mayfly *Atalophlebioides*	9								
Mayfly *Austroclima*	**9**								
Mayfly *Austronella*	**7**								
Mayfly *Coloburiscus*	**9**	8			230	65	140	80	5
Mayfly *Deleatidium*	**8**	490	1	140	590	60	120	1	80
Mayfly *Ichthybotus*	**8**								
Mayfly *Isothraulus*	**8**								
Mayfly *Mauiulus*	**5**								
Mayfly *Neozephlebia*	**7**	25			1	3	80	1	2
Mayfly *Nesameletus*	**9**			20		25	14	11	22
Mayfly *Oniscigaster*	**10**								
Mayfly *Rallidens*	**9**								
Mayfly *Siphlaenigma*	**9**								
Mayfly *Tepakia*	**8**								
Mayfly *Zephlebia*	**7**	4		25	2	80	80	180	40
Stonefly *Acroperla*	**5**								
Stonefly *Austroperla*	**9**				1			1	
Stonefly *Cristaperla*	**8**								
Stonefly *Megaleptoperla*	**9**								
Stonefly *Nesoperla*	**5**								
Stonefly *Spaniocerca*	**8**	1		30	6	30	3	60	18
Stonefly *Stenoperla*	**10**	4	1	7	12	35	18	10	16
Stonefly *Taraperla*	**7**								
Stonefly *Zelandobius*	**5**			14	30	85	90	2	120
Stonefly *Zelandoperla*	**10**		3	1	1	2	3	2	2
Caddisfly *Alloecentrella*	**9**								
Caddisfly *Aoteapsyche*	**4**	40	40	25	55				
Caddisfly *Beraeoptera*	**8**								
Caddisfly *Confluens*	**5**								
Caddisfly *Costachorema*	**7**				3				
Caddisfly *Diplectrona*	**9**			140		120	65	160	235
Caddisfly *Ecnomina*	**8**								
Caddisfly *Edpercivalia*	**9**								
Caddisfly *Helicopsyche*	**10**				2				
Caddisfly *Hudsonema*	**6**								
Caddisfly *Hydrobiosella*	**9**			35	25	6	95	35	14

Caddisfly *Hydrobiosis*	**5**	12	5		4	1	2		
Caddisfly *Hydrochorema*	**9**			3	3	25	1		1
Caddisfly *Kokiria*	**9**								
Caddisfly *Neurochorema*	**6**					1	12	1	2
Caddisfly *Oecetis*	**6**								
Caddisfly Oeconesidae	**9**	1						6	
Caddisfly *Olinga*	**9**	2			40				
Caddisfly *Orthopsyche*	**9**	7			1	45	90	1	35
Caddisfly *Oxyethira*	**2**	1	330		1				
Caddisfly *Paroxyethira*	**2**		1						
Caddisfly *Philorheithrus*	**8**				2	2			1
Caddisfly *Plectrocnemia*	**8**								
Caddisfly *Polyplectropus*	**8**	80				1		1	
Caddisfly *Pseudoeconesus*	**9**							1	
Caddisfly *Psilochorema*	**8**	3			3	3		1	
Caddisfly *Pycnocentrella*	**9**								
Caddisfly *Pycnocentria*	**7**					1		3	
Caddisfly *Pycnocentrodes*	**5**								
Caddisfly *Tiphobiosis*	**6**								
Caddisfly *Triplectides*	**5**					2			
Caddisfly *Zelandoptila*	**8**								
Caddisfly *Zelolessica*	**10**								
Damselfly *Austrolestes*	**6**								
Damselfly *Ischnura*	**6**								
Damselfly *Xanthocnemis*	**5**								
Dragonfly Aeshnidae	**5**								
Dragonfly *Antipodochlora*	**6**								
Dragonfly *Diplacodes*	**5**								
Dragonfly *Hemicordulia*	**5**								
Dragonfly *Procordulia*	**6**								
Bug *Anisops*	**5**								
Bug *Diaprepocoris*	**5**								
Bug *Hydrometra*	**5**								
Bug *Mesovelia*	**5**								
Bug *Microvelia*	**5**								
Bug Saldidae	**5**								
Bug *Sigara*	**5**								
Dobsonfly *Archichauliodes*	**7**	90	18		45	1	30		8
Scorpionfly *Nannochorista*	**7**								
Lacewing *Kempynus*	**5**								
Lacewing *Sisyra*	**5**								
Beetle *Antiporus*	**5**								

Beetle *Berosus*	**5**								
Beetle Dytiscidae	**5**								
Beetle Elmidae	**6**		2	6	5	22	8	40	25
Beetle Hydraenidae	**8**								
Beetle Hydrophilidae	**5**								
Beetle *Lancetes*	**5**								
Beetle *Liodessus*	**5**								
Beetle *Onychohydrus*	**5**								
Beetle Ptilodactylidae	**8**		1		1	5	2	2	1
Beetle *Rhantus*	**5**								
Beetle Scirtidae	**8**					1			
Beetle Staphylinidae	**5**								
True Fly *Aphrophila*	**5**								
True Fly *Austrosimulium*	**3**	5	8		3				
True Fly Blephariceridae	**7**								
True Fly Ceratopogonidae	**3**								
True Fly *Chironomus*	**1**								
True Fly *Corynoneura*	**2**								
True Fly Culicidae	**3**								
True Fly Dolichopididae	**3**								
True Fly Empididae	**3**								
True Fly Ephydridae	**4**								
True Fly Eriopterini	**9**					2			1
True Fly Forcipomyiinae	**3**								
True Fly *Harrisius*	**6**								
True Fly Hexatomini	**5**			3	1	4		1	
True Fly *Limonia*	**6**								
True Fly *Lobodiamesa*	**5**								
True Fly *Maoridiamesa*	**3**		85		4				
True Fly *Mischoderus*	**4**								
True Fly *Molophilus*	**5**								
True Fly Muscidae	**3**		3	1	1	1		1	1
True Fly *Nothodixa*	**4**		1		1			2	1
True Fly Orthocladiinae	**2**	260	90		6	1		2	2
True Fly *Paradixa*	**4**								
True Fly *Paralimnophila*	**6**	1		1		10		5	
True Fly *Paucispinigera*	**6**								
True Fly Pelecorhynchidae	**9**								
True Fly Podominae	**8**					1			
True Fly *Polypedilum*	**3**	2		3	1	5	3	10	
True Fly Psychodidae	**1**								
True Fly Sciomyzidae	**3**								

True Fly *Stictocladius*	**8**				2	2	1	5	1
True Fly Stratiomyidae	**5**								
True Fly Syrphidae	**1**								
True Fly Tabanidae	**3**								
True Fly Tanypodinae	**5**						1	1	1
True Fly Tanytarsini	**3**			1		50	1	1	
True Fly Thaumaleidae	**9**								
True Fly *Zelandotipula*	**6**								
Moth *Hygraula*	**4**								
Collembola	**6**	2			1		5	1	
Crustacea Cladocera Chydorida	**5**								
Crustacea Cladocera Daphniida	**5**								
Crustacea Cladocera Llyocrypti	**5**								
Crustacea Cladocera Moinidae	**5**								
Crustacea Copepoda Calanoids	**5**								
Crustacea Copepoda Cyclopoid	**5**								
Crustacea Copepoda Harpactic	**5**								
Crustacea *Amarinus* crabs	**3**								
Crustacea *Helice* crabs	**3**								
Crustacea Isopoda	**5**		1						
Crustacea Mysid shrimps	**5**								
Crustacea Ostracoda	**3**	16	90		1				3
Crustacea *Paracalliope*	**5**		60	3				35	
Crustacea *Paraleptamphopus*	**5**								2
Crustacea *Paranephrops*	**5**							1	
Crustacea *Paranthura*	**5**								
Crustacea *Paratya*	**5**								
Crustacea *Phreatogammarus*	**5**								
Crustacea Talitridae	**5**			2	1	2	10	18	1
Crustacea Tanaidacea	**4**								
MITES	**5**	3	1			1	2	2	1
SPIDERS *Dolomedes*	**5**								
TARDIGRADES	**4.5**								
Mollusc *Ferrissia*	**3**								
Mollusc *Glyptophysa*	**5**								
Mollusc *Gyraulus*	**3**								
Mollusc *Echyridella*	**3**								
Mollusc *Latia*	**3**								
Mollusc Lymnaeidae	**3**								
Mollusc *Melanopsis*	**3**								
Mollusc *Physella = Physa*	**3**								
Mollusc *Potamopyrgus*	**4**	40	35	320	350	28	10	760	230

Mollusc Sphaeriidae	**3**								
OLIGOCHAETES	**1**	140	7	2	1	3		4	1
LEECHES	**3**								
PADDLEWORMS	**3**								
FLATWORMS	**3**	1	3	4	25	1	6	6	14
Rhabdocoel Flatworms	**3**				3		2		1
NEMATODES	**3**		1						
NEMERTEANS	**3**	2							
NEMATOMORPHS	**3**								
HYDROIDS	**3**								
TARDIGRADA	**4.5**								
BRYOZOA	**4**								
Number of Taxa		**26**	**23**	**22**	**40**	**40**	**30**	**38**	**34**
Number of individuals		**1240**	**787**	**786**	**1480**	**748**	**926**	**1454**	**893**
EPT Value		**14**	**7**	**11**	**22**	**22**	**17**	**19**	**17**
% EPT (taxa number)		**53.8%**	**30.4%**	**50.0%**	**55.0%**	**55.0%**	**56.7%**	**50.0%**	**50.0%**
%EPT (numbers of individuals)		**54.7%**	**48.4%**	**56.0%**	**69.5%**	**81.3%**	**91.3%**	**38.3%**	**67.1%**
MCI Value		**114.6**	**92.2**	**120.0**	**123.5**	**133.5**	**135.3**	**127.9**	**130.0**
QMCI Value		**5.47**	**2.86**	**6.31**	**6.85**	**7.33**	**7.75**	**5.72**	**6.69**

Galaxiid eggs

C

Appendix C Ecological Compensation Feasibility Assessment Stage 4 Extension of Southern Landfill

Report

Ecological Compensation Feasibility Assessment

Stage 4 Extension of Southern Landfill

AUGUST 2013

Prepared for

Wellington City Council

PO Box 2199
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42787470

URS

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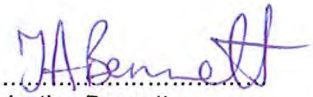

Justine Bennett
Principal Environmental Scientist

Date: **August 2013**
Reference: 42787470/R014/F
Status: FINAL

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1

Introduction

URS New Zealand Limited (URS) have been engaged by Wellington City Council (WCC) to assess potential compensation for the loss of streams associated with the Stage 4 expansion of the Southern Landfill (SLF).

Approximately 2,900 m^2 of stream network exists within the proposed Stage 4 landfill footprint, comprising approximately 2,300 m^2 of permanent (perennial) and 600 m^2 of intermittent streams. This report provides a high-level assessment of the feasibility of ecological compensation for the infilling of these stream areas through enhancements/restoration within the upper Carey's Gully catchment.

This assessment is based on the concept design for the Stage 4 landfill expansion and the findings of the *Southern Landfill Ecological Assessment*[1]. It is anticipated that for each cell of the Stage 4 landfill, including the first cell, an updated and detailed ecological compensation plan would be developed based on the detailed landfill cell design and additional ecological assessments (as and if required).

This report includes the following:

- A summary of the proposed concept for the Stage 4 expansion as it relates to ecological compensation options.
- A description of the existing Carey's Gully stream within the Stage 4 landfill footprint.
- A discussion of the Stream Ecological Valuation (SEV) scores for the existing Carey's Stream within the Stage 4 footprint.
- Evaluation and description of ecological compensation options.
- Estimate of the Environmental Compensation Ratio (ECR) based on the SEV score for the existing streams and the proposed compensation.
- Conclusions and discussion related to the feasibility of providing ecological compensation in the upper part of Carey's Gully.

Figures referenced in this report are included at the end of each section.

[1] Southern Landfill Ecological Assessment Report, URS New Zealand Limited, 2013.

2

Background

2.1 Stage 4 Concept Design

Progressive development and filling of the proposed Stage 4 landfill is proposed from the upper portion of Stage 4 area downwards to the existing Stage 3 landfill. The concept design proposes that the Stage 4 landfill expansion would be developed in five (indicative) major cells with the first cell developed at the upper extent of the Stage 4 footprint.

The concept design for the Stage 4 landfill expansion includes a clean water diversion (CWD) system that flows around the perimeter of both the northern and southern sides of the landfill. The northern and southern CWDs would combine to the southwest of the existing Stage 3 landfill. From this point flow would be conveyed through a series of open channels and culverts before discharging to Carey's Stream to the south of the overall Southern Landfill complex (i.e., to the south of the existing Stage 1 and Stage 2 landfills). The CWD system would be developed at the outset of the Stage 4 landfill development (i.e. during development of the first cell of Stage 4).

An existing tunnel beneath the Stage 3 landfill currently conveys flow from the upper Carey's Gully catchment before discharging to Carey's Stream below the Southern Landfill complex. During development and operation of the Stage 4 expansion there is potential that flow from the CWD could be re-diverted back to Carey's Stream below the active fill cell. During development of the last cell of the Stage 4 landfill, flow would be completely diverted around the landfill and the tunnel would no longer be used to divert Carey's Stream. As the CWD system would be constructed at the outset of the Stage 4 landfill, should circumstances require (e.g., a failure of the tunnel), the CWD would allow for complete diversion of storm flows from the catchment above the Stage 4 landfill.

2.2 Description of Carey's Stream

The *Southern Landfill Ecological Assessment (2012)* produced SEV scores for sections of the existing stream network within the upper catchment. The overall SEV scores for the sites surveyed at Carey's Gully reflect a habitat of medium-to-high[2] ecological value, and are summarised in **Table 2-1**. The locations of the streams surveyed in 2011 are presented in **Figure 2-1**.

Storey et al. (2011)[3] lists the ecological functions that contribute to the SEV assessment, which include:

- Hydraulic functions
  - natural flow regime
  - floodplain effectiveness
  - connectivity for natural species migrations
  - natural connectivity to groundwater
- Biogeochemical functions
  - water temperature control
  - dissolved oxygen levels
  - organic matter input
  - instream particle retention
  - decontamination of pollutants

[2] As described in Rowe et al. (2008). Scores from 0 - 0.4 represent streams of low functional value, 0.4 - 0.8 represent streams of medium functional value and > 0.8 represent streams of high functional value.
[3] Stream Ecological Valuation (SEV): a Method for Assessing the Ecological Functions of Auckland Streams, Storey et al., 2011

- Habitat provision functions
  - fish spawning habitat
  - habitat for aquatic fauna
- Biodiversity provision functions
  - fish fauna intact
  - invertebrate fauna intact
  - riparian vegetation intact

The majority of these ecological functions scored high across all of the survey sites. However, the species migration, floodplain effectiveness, fish spawning habitat, and riparian vegetation intact ecological functions did score moderate to poor for some of the reaches assessed.

In general the sites were well confined and incised, having a flood plain width of between approximately 1.0 and 3.0 metres and a wetted width of between approximately 1.0 and 2.0 metres. The channel shape was generally sinuous, characterised by a riffle/run/pool structure. The banks were well vegetated and stable (except for the true right bank of SLF02, which was stabilised by a concrete structure). The banks were not undercut.

The riparian environment was generally forested with regenerating native trees. There was little ground cover (understory); although, small ferns and grasses were present at all sites.

Approximately 2,300 m^2 of existing Carey's Stream within the Stage 4 landfill expansion is characterised as '1A' (Channel incised, no terrestrial vegetation; Obvious water flow) as per the Auckland Regional Council Headwater Characterisation description[4]. The western extent of the stream (beyond survey site SLF08), and sections of the upper tributaries (approximately 600 m^2) are characterised as '5B' (No Banks, bed vegetated; Dry), or as an intermittent stream.

2.3 Comparison of SEV Methodologies

The *SLF Ecological Assessment* evaluated reaches of stream/tributaries throughout the upper Carey's Gully catchment above the existing Stage 3 landfill, and calculated SEV scores using a 2006 methodology[5]. A revised 2011 methodology[6] has since been produced and these SEV scores are summarised in **Table 2-1** along with the scores utilising the 2006 methodology.

Scores produced by the 2006 and the 2011 SEV methodologies are understood to be generally consistent. However, the range of extreme scores for the spectrum of streams (very poor to pristine) produces a greater discriminatory weighting in the 2011 SEV. This may result in poor scoring streams decreasing in value, with pristine scoring streams increasing in value. Therefore, because the streams within the footprint of the proposed Stage 4 SLF expansion are mostly of high quality, there has been an overall increase in the SEV score.

[4] Small Headwater Streams of the Auckland Region Volume 1: Spatial Extent, Parkyn.S., Wilding.T., 2006
[5] Stream Ecological Valuation (SEV): a Method for Scoring the Ecological Performance of Auckland Streams and for Quantifying Mitigation, Rowe et al., 2006.
[6] Stream Ecological Valuation (SEV): a Method for Assessing the Ecological Functions of Auckland Streams, Storey et al., 2011

2 Background

Table 2-1 Summary of Ecological Values for Stream Reaches within the Stage 4 Footprint

Site	Floodplain width (m)	Wetted channel width (m)	Depth of water	Chanel Modification	Shaded proportion	Dominant streambed substrate	Calculated SEV Score (Original 2006)	Calculated SEV Score (Revised 2011)
SLF02	1.3 – 6.0	1.65 – 5.75	0.01 – 0.29	Yes	Moderate	Gravels and bedrock	0.62	0.63
SLF03	0.9 – 2.4	0.4 – 2.2	0.01 – 0.21	No	High	Gravels and bedrock	0.70	0.76
SLF04	1.7 – 3.6	1.1 – 1.8	0 – 0.40	No	Moderate-High	Gravels	0.74	0.82
SLF05	1.6 – 3.0	0.95 – 1.9	0.01 – 0.26	No	High	Gravels, sand and bedrock	0.76	0.81
SLF06	1.5 – 3.0	0.85 – 1.6	0 – 0.12	No	High	Gravels	0.81	0.87
SLF07	0.8 – 2.1	0.6 -1.1	0 – 0.11	No	High	Gravels and sand	0.77	0.83
SLF08	1.8 -2.9	0.9 – 1.5	0.01 – 0.18	No	High	Gravels	0.82	0.87

Project: Southern Landfill – Stage IV Extension

Title: Location of Existing Stream Reaches within the Stage 4 Footprint

Legend:

- Reach Sections
- Extent of Stage IV Landfill
- Carey's Gully Stream
- Current Landfill

File: 42787470\ SITE_PLAN.MXD

Date: 25/10/2012		Designed:	SS
Scale:	1:6,500	Drawn:	SS
Original Size:	A3	Checked:	JH
Status	FINAL	Approved:	JH

URS

Client: Wellington City Council

Drawing Number FIGURE 2-1 Rev A

Created with ESRI ArcGIS

3

Ecological Compensation

Summarised below are the following:

- A description and evaluation of the options considered for best practicable ecological compensation.
- A more detailed description of the preferred ecological compensation option.
- An estimate of the SEV scores for the preferred ecological compensation option.

3.1 Alternatives Considered

Various options and locations for ecological compensation were considered, including: the clean water diversion (CWD) along the landfill perimeter; development of wetlands within the Cary's Gully catchment; and enhancing the lower Carey's Gully stream. A summary of these options is provided below:

1. Clean Water Diversion (CWD):
   - The CWD would be constructed at the outset of the Stage 4 expansion; therefore, there is potential to add features to the engineering design to enhance the ecological value of the CWD.
   - Provides an ecological stream corridor that would connect the upper and lower catchments of Carey's Gully.
   - Provides sufficient stream replacement length as defined under the justification for use of environmental compensation[7].
   - Attenuation areas would be designed along the CWD system to maintain flow during baseline conditions/summer and would be designed to allow for fish passage.
   - Limited riparian margin opportunity throughout the CWD due to topographical and landfill design constraints.
   - The final CWD with ecological compensation would remain a highly modified stream.
2. Development of large wetland within the Carey's Gully catchment:
   - Provides areas of high ecological value.
   - Does not provide linkage between upper and lower catchment of Carey's Gully.
   - Inconsistencies when comparing the ecological value of wetlands with streams.
   - This type of compensation is not "like for like", as there will be an overall loss of stream edge habitat.
3. Enhancing the Lower Carey's Gully stream:
   - The *SLF Ecological Assessment* found that an upper section of the lower Carey's Gully stream produced a moderate to high SEV score of 0.79. Therefore, it is unlikely that significant enhancement of this stream could be achieved, as the stream is already considered to be of relatively high quality.

Consideration has been given to each of the above options in regards to the predicted ECR score, the best ecological outcome, and cost/benefit along with the SEV requirements. It is considered that the best practical approach for compensation would involve providing enhanced ecological value along the CWD.

Based on the relative size of the catchments, the northern exposure, and the presence of permanent tributary streams, the focus for the restoration/compensation option is along the northern perimeter of the landfill, which has the highest likelihood of permanent water. Compensation along the southern perimeter of the landfill would be utilised for intermittent streams.

[7] Stream Ecological Valuation (SEV): a Method for Assessing the Ecological Functions of Auckland Streams. Section 6.5.1; Storey et al., 2011

3.2 Preferred Ecological Compensation Option

A brief description of the proposed enhancement is described below with corresponding ECR calculations included in **Section 4**. A more detailed description of the proposal is provided in the *Indicative Ecological Plan*

Figure 3-1 provides indicative locations for the proposed ecological compensation. **Figure 3-2** presents a high-level cross-section of the proposed CWD ecological enhancement. To achieve the required SEV score, the following key elements of the CWD design would be included to increase the regeneration of the native habitat:

- Banks within the channel should incorporate a floodplain/spawning area (flat land < 10°).
- Appropriate plantings on the floodplains, such as dense flaxes, sedges and long grasses.
- Avoid the use of culverts, concrete linings and gabion baskets.
- Boulders/cobbles/gravels should be used along the length of the CWD, to incorporate areas of hydraulic variation (riffle, run, pool, and chute).
- Riparian banks should be planted with native species at a minimum width of 5 m, and extending these widths in flatter and wider areas of the CWD.
- Attenuation areas should be designed to allow for fish passage to migrate up the length of the CWD.
- Connection should be maintained between the CWD and lower Carey's Stream or a fish relocation plan implemented.
- Importation and placement of soil for planting along the CWD.

It is proposed that the ecological compensation work along the CWD would occur progressively upon completion of filling and final capping of each cell of the Stage 4 expansion. This would reduce the time between infilling of the streams and provision of the compensation.

In order to provide compensation for the first cell development, a large area of compensation has been identified on **Figure 3-1** (highlighted green). It is proposed that this compensation ('a CWD meander') be provided in parallel with the development of the first cell. Compensation for the second cell would be provided at the CWD adjacent to cell one, and compensation for subsequent cells would be provided at the CWD adjacent to immediately preceding cells. In this manner the compensation would be provided in parallel with cell development.

There is potential for water attenuation areas to be established along the CWD and at locations of existing tributaries discharging to the CWD. These areas would be designed to maintain permanent water and regular flow in the CWD as required. It is envisaged that the attenuation areas would also incorporate elements such as wider riparian margins, hydrological variability and floodplain spawning areas; therefore, adding to the overall ecological value of the CWD. **Figure 3-1** shows indicative locations for those water attenuation areas along tributaries to the CWD

3.3 Hydrology

As indicated in **Figure 3-1**, approximately 600 m^2 of the proposed stream infill area is defined as an intermittent stream (*those that contain flowing water for most of the year, but cease flowing or dry completely for a period of days or weeks in a year of average rainfall)*[8]. It is an expectation within the 2011 SEV methodology that mitigation should compensate "like for like". For this assessment, the

[8] Applicability of the Stream Ecological Valuation (SEV) to intermittent streams: Report prepared for Hawkes Bay Regional Council, NIWA, 2010.

SEV for the intermittent portions of the stream have been calculated, and indicative areas of intermittent stream compensation have been shown in **Figure 3-1**. The applicability of the SEV and ECR methodology to intermittent streams would be reviewed during detailed design of the compensation.

Based on the following it is considered that similar flows and flow variations could be maintained in the CWD in relation to a similar position along Carey's Stream and its tributaries.

- As described above (and shown in **Figure 3-1**) attenuation areas are proposed at certain tributaries, which would allow for a slow release of flow to the CWD system.
- As filling progresses from cell to cell the surface water catchment contribution increases as a result of the larger catchment above the landfill footprint but also because the increased catchment associated with completed sections of the landfill (with final cover), which would also drain to the CWD.
- The proposed landfill cover system includes a drainage provision beneath the vegetative cover. This drainage would ultimately discharge to the CWD. The nature of this discharge would likely be something akin to a continuous seep providing flow to the CWD long after surface runoff from the landfill had abated. In effect the drainage provision would act as a large attenuation system. The cuts along the CWD would be high and long. It is inferred that numerous seeps would be encountered along the cuts and collected by the CWD at the toe of the cuts. In addition, it is anticipated that there would be seeps from the colluvium above the rock cuts, which would be collected by the CWD.

The ECR/SEV compensation methodology considers the wetted width of the stream as a surrogate for flow. While constraints to the compensation area wetted width may be present in some areas, due to variable topography of the site, there will likely be other areas where the wetted width of the CWD can be expanded (e.g., in wider sections of the former access road such as pullouts).

During progressive development of the landfill, portions of Carey's Stream would remain between the active Stage 4 landfill cell and the toe of the Stage 3 landfill. Within this section, Carey's Stream would receive flow from the catchment beneath the CWD and also from groundwater, as the Carey's Stream is a groundwater gaining/seasonally gaining stream. Flow from the CWD system could be re-diverted back to the remaining sections of Carey's Stream below the active Stage 4 cell to maintain flow conditions.

3.4 SEV Score for the Proposed CWD Enhancements

Table 3-1 presents a breakdown of the functions of the SEV (using the 2011 methodology) applied to the enhanced CWD. This analysis highlights the scores of each function, and indicates what features would be required to enhance the CWD to achieve the appropriate SEV scores. Considering the enhancement features shown on **Figure 3-2**, the SEV scores for the permanent and intermittent CWD along the northern side of the proposed landfill expansion were estimated to be 0.82 based on the design and compensation input by Boffa Miskell.

Boffa Miskell advise that it is reasonable to assume that the new CWD waterway will be able to achieve an SEV score similar to the existing stream reaches and this is the key assumption in the assessment presented below.

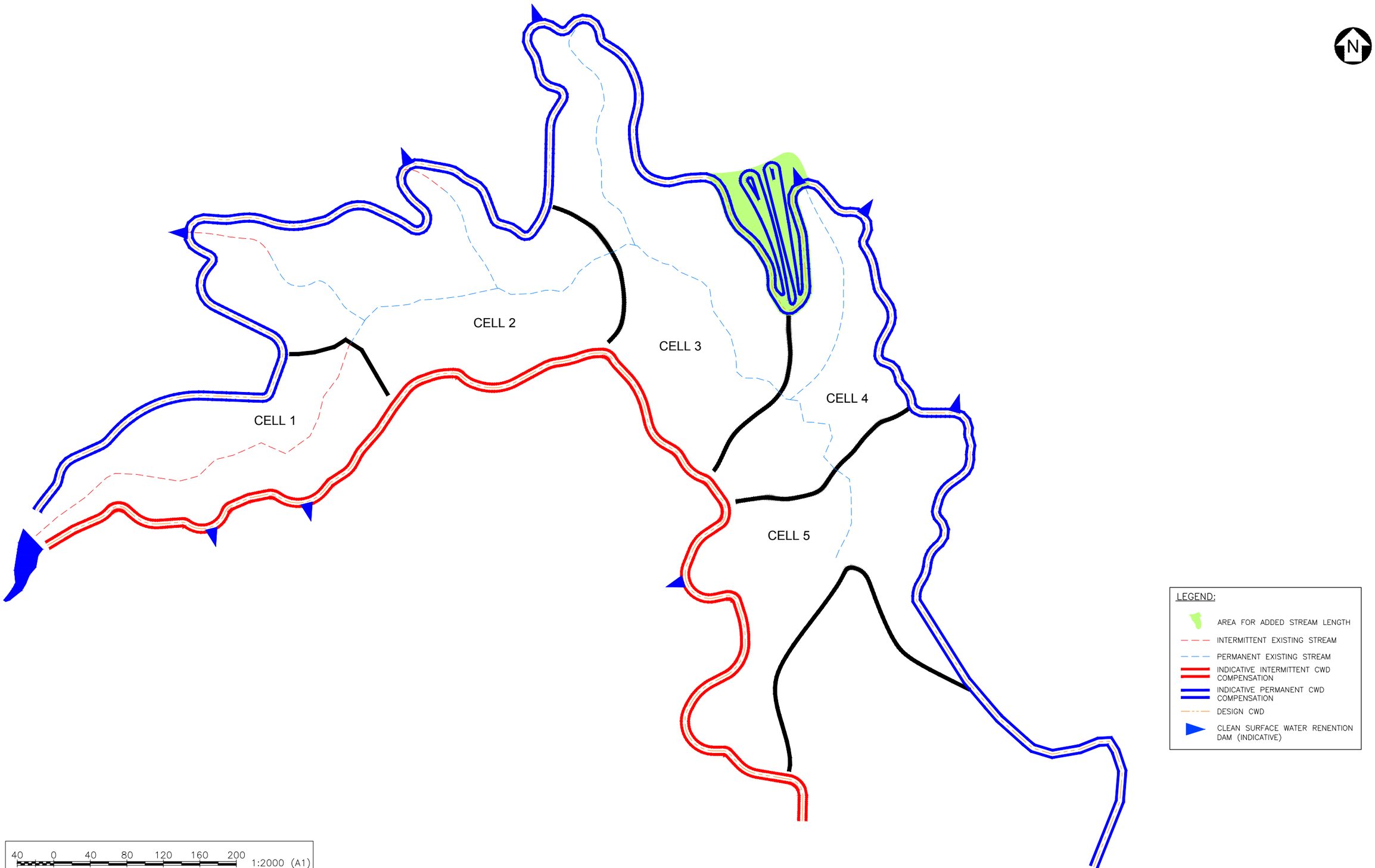
3 Ecological Compensation

Table 3-1 SEV Summary of Clean Water Diversion using 2011 Methodology

Function	Permanent CWD	Intermittent CWD	Typical Score	Comments/Reasoning
Channel	0.90	0.90	**High**	Proposed CWD will be constructed with natural and local materials to simulate a natural stream channel
Lining	1.00	1.00	**High**	Banks and channel will be constructed from natural and local materials
Pipe inflow	1.00	1.00	**High**	No piped inflows
Bank	0.48	0.48	**Low - Moderate**	Floodplain present, but connectivity to the full flood plain is restricted by modification
Flood Plain Vegetation	0.80	0.80	**High**	Natural diverse wetland vegetation to be planted on banks
Fish Barriers	1.00	1.00	**High**	Fish passage to be provided
Channel Shape	0.80	0.80	**High**	Natural channel with no modification, but flow patterns may be affected by reduction in roughness elements
Lining	1.00	1.00	**High**	Banks and channel will be constructed from natural materials
Shade	0.85	0.85	**High**	Most of shade owing to topographic features (steep cut natural wall) and similar to existing stream shade
Oxygen Demand	1.00	1.00	**High**	Optimal oxygen demand - no anaerobic sediment, no odours or bubbling, little or no macrophytes
Riparian Zone	0.75	0.75	**Moderate - High**	Opportunity for increased riparian margins from removal of service road and vegetating the hillside cut
Deciduous proportion	1.00	1.00	**High**	No deciduous tree cover; native plantings only
Macrophytes	0.85	0.85	**High**	Limited macrophytes
Channel Modification	0.85	0.85	**High**	Natural channel with no modification, but flow patterns may be affected by reduction in roughness elements
Surface Substrate	1.00	1.00	**High**	Wide variety of substrate types, including gravels, cobbles, boulders with a presence of wood and leaf litter to enhance this
Riparian Filtering capacity	0.70	0.70	**Moderate - High**	Slightly less filtering capacity due to the modified steep cut banks which will limit the potential for surface water to interact with the vegetation. There are no external activities/inputs affecting the stream given the locations of works is occurring at the top of the catchment, and the landfill discharges will be directed elsewhere.
Galaxiid Spawning Habitat	0.75	0.75	**Moderate - High**	Moderate proportion of spawning ground inundated by high rainfall events.

3 Ecological Compensation

Function	Permanent CWD	Intermittent CWD	Typical Score	Comments/Reasoning
Galaxiid Spawning Quality	1.00	1.00	**High**	Near flat floodplain will be located under dense tree canopy. Heavy cover of dense stemmed, low growing vegetation twigs or gravels.
Gobiidae Spawning Habitat	1.00	1.00	**High**	Suitable surface substrate for spawning provided - large boulders, cobbles and wood
Physical Habitat	0.82	0.82	**Overall – High** **High** **High** **High**	A range of scores were produced for the Physical Habitat section, with an overall rating of High. Detailed below is a breakdown. High scores due to habitat diversity, abundance, mixture of hydraulic conditions High scores due to high channel shading from steep terrain and canopy cover. High score due to Riparian integrity being designed, planted and maintained to portray a natural environment
Water Quality	0.93	0.93	**High**	Shading of stream catchment upstream provide optimal oxygen demand.
Impervious surface upstream	1.00	1.00	**High**	Low percentage of catchment above site that is impervious surface
Riparian Condition	0.58	0.58	**Moderate**	Minimal mature tree canopy, and majority of understory consisting of flax, long grasses, sedges with regenerating low diversity native trees
Riparian Connectivity	1.00	1.00	**High**	The riparian margins will be well connected with the proposed CWD.
Permanent CWD	0.82		The invertebrate and fish functions were removed from the calculation as they are too difficult to predict.	
intermittent CWD	0.82			



Rev	Revision Description	Designed	Drawn	Checked	Approved	Date
C	FINAL	RC	IMM	GH	GH	08/2013
B	DRAFT	JH	IMM	JH	JH	5/03/13
A	DRAFT	JH	IMM	JH	JH	19/10/12

Tab Figure 3-1

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Original Size A1

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Absolutely Positively Wellington
Me Heke Ke Ponoke
Wellington City Council

SOUTHERN LANDFILL - STAGE 4 EXTENSION

STAGE 4 LANDFILL
INDICATIVE LOCATION OF ECOLOGICAL COMPENSATION

Status FINAL

Drawing Number Figure 3-1

Revision C

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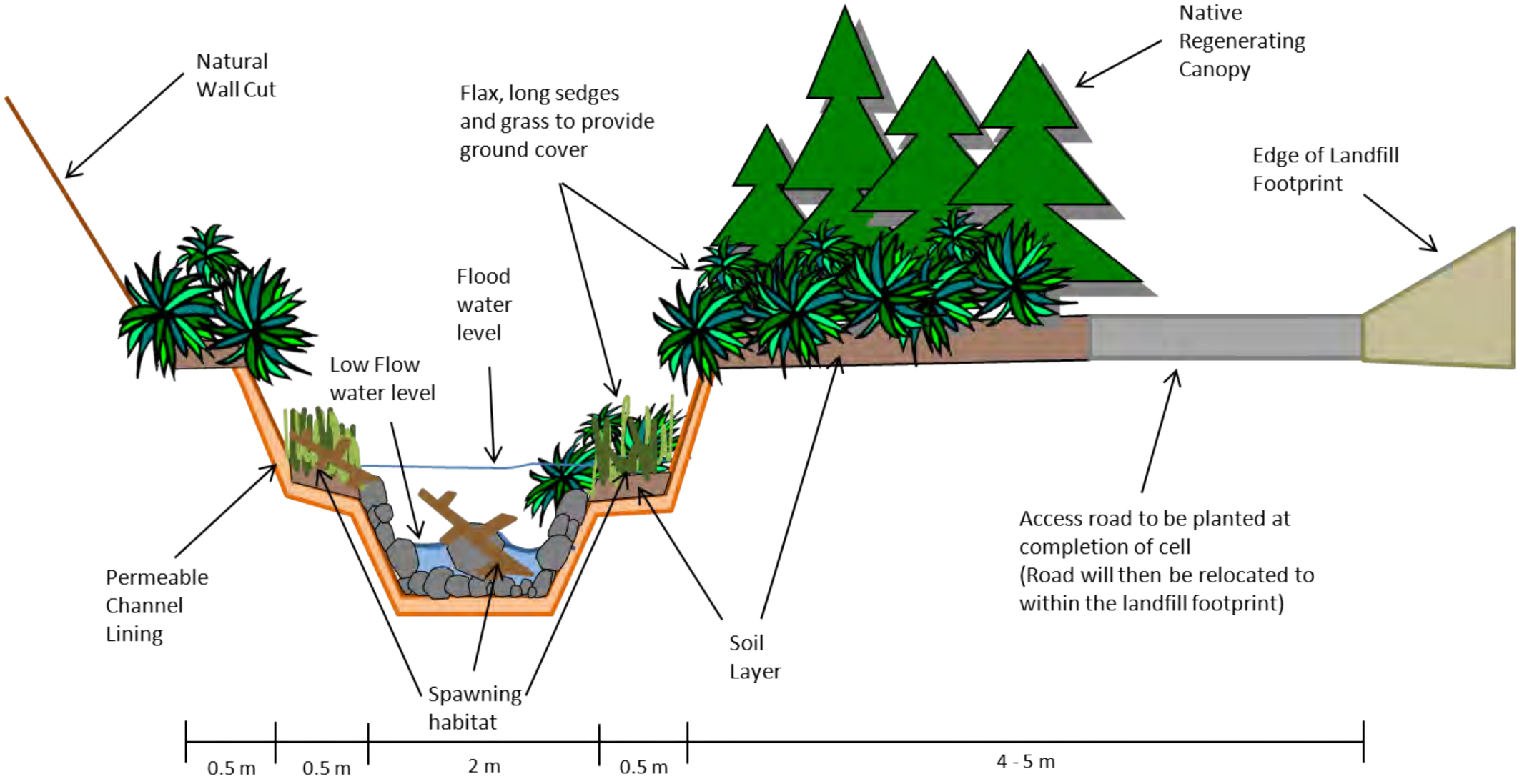
Figure 3-2 Indicative Cross-Section Showing Enhancement Features of Proposed CWD



4

Ecological Compensation Ratio

4.1 ECR Methodology

To derive the ECR for the loss/degradation of a waterway, Auckland Council have recommended the following calculation.

ECR = [(SEVi-P – SEVi-I) / (SEVm-P – SEVm-C)

- SEVi-P is the potential (P) value of the existing impacted (i) /lost stream,
- SEVi-I is the impacted (I) value of the existing impacted (i) /lost stream,
- SEVm-P is the potential (P) value of the mitigation (m) /compensation stream assuming the enhancement features are successfully completed.
- SEVm-C is the current (C) value of the mitigation (m) /compensation stream,

Auckland Council (2011 SEV methodology) recommends a multiplication factor of 1.5 is applied to the above calculation. The purpose of this factor is to account for the fact that compensation often fails to achieve what is expected, and that some environmental compensation measures may take years before reaching their full effect. This is a conservative approach and in this case not considered appropriate.

Boffa Miskell recommended that, due to the early mitigation works (i.e. the CWD meander) and immediate compensation after each landfill cell is started, the multiplication factor is not required as there should be no lag in compensation, and mitigation can be proven to be successful in a timely fashion. Therefore, for the purposes of this assessment, it is proposed not to apply the multiplication factor.
In order to provide more certainty on this issue a sensitivity analysis was carried out by Boffa Miskell and as a result, it is noted that should the 1.5 factor be required, the total length of perennial stream being proposed for mitigation (1966m) will still meet the needs of this more conservative approach and as such provide an appropriate level of mitigation.

Values used for this study are presented in **Table 4-1**.

Table 4-1 SEVs Used to Calculate the ECR

SEVi-P	0.63 – 0.87 (The SEV of streams to be impacted by the SLF are high for all reaches, with minimal opportunity for enhancement. Therefore the SEVi-P is taken as the current SEV calculated for the subject streams).
SEVi-I	0 (The stream network will be completely removed).
SEVm-P	0.82 (based on input from Boffa Miskell Limited regarding success of proposed restoration)
SEVm-C	0 (CWD does not currently exist).

It should be noted that ECR calculations have the potential for variability due to the subjectivity related to the prediction of future SEV values. The ECR values provided within this report should therefore be viewed as a guide rather than an absolute compensation requirement.

4.2 ECR for the Clean Water Diversion

The concept design indicates that the Stage 4 landfill would be developed progressively in five cells. Therefore, the SEV and area of stream lost for the permanent and intermittent streams within each cell of the proposed landfill expansion were calculated based on the indicative cell development proposed in the concept design. The ECR was then applied to determine the total area of stream that would require compensation. This has been calculated using both the original 2006 and revised 2011 SEV methodologies, in order to estimate the worst-case compensation required. This is presented in Error! Reference source not found.**Table 4-2**.

Table 4-2 Compensation for Clean Water Diversion

Landfill Cell	Stream type	Stream Area Lost (m^2)	2006 SEV Methodology			2011 SEV Methodology		
			SEV Score	ECR	Area of Compensation (m^2)[1]	SEV Score	ECR	Area of Compensation (m^2)[1]
1	Intermittent	460	0.82	1.08	500	0.87	1.06	500
	Permanent	0	-	-	-	-	-	-
	Total	460	0.82	1.08	500	0.87	1.06	500
2	Intermittent	140	0.77	1.01	150	0.83	1.01	150
	Permanent	650	0.79	1.04	675	0.85	1.04	675
	Total	790	0.79	1.04	825	0.85	1.03	825
3	Intermittent	-	-	-	-	-	-	-
	Permanent	700	0.75	1.00*	700	0.82	1.00	700
	Total	700	0.75	1.00	700	0.82	1.00	700
4	Intermittent	-	-	-	-	-	-	-
	Permanent	620	0.68	1.00*	625	0.72	1.00*	625
	Total	620	0.68	1.00	625	0.72	1.00	625
5	Intermittent	-	-	-	-	-	-	-
	Permanent	330	0.62	1.00*	350	0.63	1.00*	350
	Total	330	0.62	1.00	350	0.63	1.00	350
ALL CELLS	Intermittent	600	0.81	1.06	650	0.86	1.05	650
	Permanent	2300	0.72	1.01	2325	0.77	1.01	2325
	TOTAL	2900	0.74	1.02	2975	0.79	1.02	2975

[1] Areas are rounded up to the nearest 25m.

* Calculated ECR are < 1. Scores have been rounded up to 1 so that no net loss of stream occurs.

The 2006 and 2011 SEV methodologies project the same replacement areas of stream. To compensate for the loss of the existing stream, a total area of approximately 3000 m^2 would require restoration with a SEV potential of 0.82 for the intermittent and permanent CWD enhancements.

4 Ecological Compensation Ratio

Error! Reference source not found. summarises an estimate of the area of compensation required for each cell of development.

Table 4-3 Estimated Compensation Summary for each Cell of the SLF Development

Cell	Stream Type	Area of Compensation required for CWD (m^2)	Length of Compensation Required for CWD (m)*
1	Intermittent	500	500
	Permanent	-	-
2	Intermittent	150	150
	Permanent	675	338
3	Intermittent	-	-
	Permanent	700	350
4	Intermittent	-	-
	Permanent	625	313
5	Intermittent	-	-
	Permanent	350	175
TOTAL	Intermittent	650	650
	Permanent	2325	1163
	TOTAL	2975	1813

* Based upon compensation wetted width of 1 m and 2 m for intermittent and permanent CWD, respectively.

The compensation lengths presented in Error! Reference source not found. are based on indicative widths for the CWD of approximately 2 m for the permanent and 1 m for the intermittent. It is considered likely that there would be opportunity to widen the CWD in areas, which would result in an overall decrease in the compensation length required.

5

Conclusions

Based on the information presented in the concept design and the *Southern Landfill Ecological Assessment (2012),* and input from Dr Keesing of Boffa Miskell Limited on the SEV and compensation analysis presented in this ECR report, an area of approximately 3,000 m^2 of ecological enhancement would be required to compensate for the infilling of streams within the Stage 4 landfill expansion footprint.

Options for compensation have been identified within the Carey's Gully catchment, which include the development of a CWD along the northern perimeter of the landfill extension, the creation of a wetland within the Carey's Gully catchment, and adding ecological value to the existing Lower Carey's Gully stream.

The CWD around the northern perimeter of the proposed landfill expansion has been identified as the most feasible option for ecological compensation. This option would be supplemented as required, by the other options based on detailed landfill cell design and ecological compensation planning/design. To ensure that the timeframe between stream infilling and providing the ecological compensation is acceptable, it is proposed that the compensation would be provided progressively with the development of each cell and the overall Stage 4 expansion.

To provide sufficient ecological compensation for the loss of the upper Carey's Gully stream, the CWD would need to be modified to provide ecological enhancements and native habitat regeneration. It is considered that modifications would include the following:

- Removal of the CWD liner (if any) and localised widening relocation of the CWD to provide sufficient width and riparian planting margins.
- Importation and placement of soil for planting along the CWD.
- Establishment and maintenance of riparian planting.
- Boulders/cobbles/gravels provided along the length of the CWD, to incorporate areas of hydraulic variation (riffle, run, pool, and chute).

These modifications are described in greater detail in the *Indicative Ecological Plan.*

This ECR assessment assumes that the enhancement features detailed in **Figure 3-2** are consistently applied across the compensation area. This may not be possible, given constraints in places; therefore, the final ECR score may vary along the length of the CWD. Consequently, if the proposed compensation SEV is not achievable, a larger area of stream compensation may be required. While it is inferred that constraints to the compensation area wetted width may be present in some areas, there will likely be other areas where the wetted width of the CWD can be expanded (e.g., in wider sections of the former access road such as pullouts).

Based on the above it is considered that ecological compensation for infilling streams within the Stage 4 landfill expansion footprint is feasible along the northern CWD. It is estimated that there is sufficient area adjacent to the northern cleanwater diversion (including the added stream length area shown on **Figure 3-1**) to provide this compensation. Ecological compensation for each cell of the Stage 4 expansion would be based on the detailed design for that cell, the actual as-built conditions and final configuration of the landfill access roads along the CWD, and supplemental ecological and hydrological assessments, if required, of the streams being infilled for each cell. If sufficient compensation area is not available along the northern CWD, then additional compensation could be undertaken along the southern CWD or at lower Carey's Stream.

5 Conclusions

A peer review of the SEV and ECR outcomes was carried out by River Lake Limited (RLL) and following further discussions with Dr Keesing it was concluded that:

- The variance between the SEV function scores used in the assessment and those suggested by RRL were generally small.
- A sensitivity analysis on the SEV scores resulted in a difference of only 125m of stream compensation length (ECR multiplier of 1.0) and a total stream compensation length still within the indicative 1,966m for the CWD waterway presented in the *Indicative Ecological Plan*.
- Using a conservative multiplication factor of 1.5, and the less optimistic SEV scores, resulted in a total stream compensation length of 1,932 metres. Again this length is within the 1,966 m indicative compensation length presented in the *Indicative Ecological Plan*.
- Construction of the CWD meander and monitoring of its performance will alleviate uncertainty around the stream restoration.
- Overall the level of mitigation was considered to be appropriate.

Limitations

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Appendix D Stage 4 Upper Carey's Gully Indicative Ecological Plan

D

SOUTHERN LANDFILL

Stage 4 Upper Carey's Gully

Indicative Ecological Plan

Submitted to

Wellington City Council

July 2013

Front cover:
Upper section of Carey's Gully on the route of the northern access road looking south from the proposed clear water diversion meander. This is the start of permanent water from side tributaries for the north clear water diversion.

Bibliographic reference:
Boffa Miskell (2012). Upper Carey's Gully Stream Restoration Plan. Prepared by Boffa Miskell Ltd for Wellington City Council

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CONTENTS

Introduction

The Southern Landfill is located in Carey's Gully, approximately 5 km to the southwest of central Wellington city. The gully is surrounded by a ring of high scrub-covered ridges and slopes, with tributaries flowing into Carey's Gully Stream from these slopes, which in turn drains into Owhiro Stream.

Wellington City Council is proposing an extension (Stage 4 extension) of the landfill further up the gully, which will involve infilling parts of the upper Carey's Gully Stream and its tributaries. This *Upper Carey's Gully Indicative Ecological Plan* (Plan) outlines the land development and planting works that would be implemented for ecological improvements as compensation for infilling portions of the stream and tributaries.

This plan should be considered in association with the report Ecological Compensation Feasibility Assessment, Stage 4 Extension of Southern Landfill (URS February 2013) (*Ecological Compensation Feasibility Assessment*), which outlines the Stream Ecological Valuation (SEV) data collection and analysis as part of the assessment of ecological effects associated with the proposed landfill extension.

The proposed focus for ecological compensation is on the upper part of Carey's Gully above and adjacent to the proposed landfill extension. In particular, the compensation focus is on the proposed clean water diversion (CWD) system, which would run along the periphery of the northern and southern sides of the Stage 4 extension.

The CWD would be constructed during the enabling phase of the Stage 4 extension, and consist of a system of diversions channels and attenuation structures to divert surface water flows from the head of Carey's Gully Stream and its tributaries around the periphery of the landfill. The CWD system would divert the water to the remaining portion of Carey's Gully Stream to either downstream from the active landfill fill stage or downstream from the overall Carey's Gully Complex (i.e., downstream from the first three stages of the Southern Landfill, the sludge dewatering facility, and former composting facility).

During consultation GWRC have requested that the compensation for infilling be provided on an Ecological Compensation Ratio (ECR) basis utilising the methodology developed by Auckland Council. Therefore, this Plan has been developed to provide indicative compensation for stream infilling, on an ECR basis, for the Stage 4 extension. It is anticipated that the compensation would be implemented progressively, and the compensation plan would be finalised during detailed design of each cell of the Stage 4 development based on the following:

- Size, extent and phasing of each cell of the Stage 4 extension development;
- Additional ecological assessments (if required) supporting compensation design for landfill cells, including development of SEVs and determining whether ephemeral/perennial.
- As built information around development of the site access roads, CWDs and other overall landfill enabling works that may provide opportunities or constraints around compensation.
- Actual ground and site conditions encountered during construction of the enabling works.

Due to the unknowns presented above, this Plan is by necessity indicative. However, it is anticipated that the indicative concepts presented in this plan would be incorporated as the primary basis for compensation. This Plan is developed around the compensation SEV scores presented in the *Ecological Compensation Feasibility Assessment*.

GWRC would be provided the opportunity to approve the compensation plan for each cell of the Stage 4 landfill extension prior to development of the cell.

1.0 SITE CONTEXT

1.1 Upper Carey's Gully

The upper reach of the Carey's Gully Stream, upstream of the landfill operation, runs through a steep gully under a dense vegetation of scrub and regenerating native bush. This area is difficult to access and largely undeveloped. MWH (2002) describe the reach as having 100% overhead cover with a streambed formed predominantly of large cobbles and boulders. The stream flow is approximately 0.7m wide, 0.05-0.25m deep, with very little macrophyte or periphyton development (MWH 2002). Refer Appendix 1 for site photos.

Access roads have been cut on the north and south sides of the gully toward the headwaters. The cut batters, some of which are now up to ten years old, are a good indicator of the ground material that will be exposed and the vegetation that might naturally establish itself on the exposed batters.

Based on observations of cut faces that have been constructed many years ago at the landfill, it is evident that there will be limited vegetation natural establishment. Often, only grasses, gorse and exotic weeds that are able to handle the dry, often hard rocky ground conditions are able to colonise and survive the exposed ground. There is little woody growth and in places bare rock is exposed without any vegetation at all. Even on the cooler south side, the low fertility and free draining nature of the ground does not facilitate plant growth. Native regrowth observed on these faces has been limited to Hebe sp. on the southern track. At toes of slopes where rockfall and detritus combine to give a suitable growing environment, some plant growth has established. Similarly at seep locations where free water is available to plants and some erosion gives loose material as a growing medium, plants readily establish and thrive.

1.2 Lower Carey's Gully

A description of the lower reach of Carey's Gully and proposed restoration concepts are provided in the Boffa Miskell (2012) Lower Carey's Gully Stream Restoration Plan, prepared for Wellington City Council. The concepts presented in this plan would be implemented in whole or in part, if sufficient compensation area is not available in the upper reaches of Carey's Gully, which is the primary focus of this Plan.

2.0 ENABLING WORKS

As outlined in the *Ecological Compensation Feasibility Assessment*, the upper section of Carey's Gully will be progressively filled as a series of cells with controls on leachate from the landfill and the interception and diversion of the stormwater that currently enters the Carey's Gully Stream via tributaries and seeps from the

hillsides. In general, the concept design is to divert clean water around the active filling areas, and to separate/manage any stormwater coming in direct contact with active landfill as leachate.

As part of enabling works two access roads would be constructed along the hillsides, roughly following the finish landfill design levels. On the northern side, a single carriageway will be cut into the hillside to provide maintenance access and to allow for construction of the CWD (Refer BML W12099_301_Section B). On the southern side, a dual carriageway will be cut into the hillside to service the filling operation, allowing vehicles to go up and return on the same road and be the primary route for vehicles. (Refer BML W12099_301 section C).

At the head of the gully, an attenuation dam would be constructed to intercept the headwaters and divert them through CWD channels that follow the access roads and down to the lower Carey's Gully Stream below the overall landfill. The CWD channel on the southern side would have an optional concrete liner at the base and sides, with the base roughly 1.5m wide. On the northern side, the CWD channel would be unlined and vary in width, starting at 1.0m wide, at the head of the gully, and increasing to 1.5m wide lower down the gully as more water is collected from side tributaries and seeps.

The primary purpose of both channels is to divert surface water, and as such, the unmodified CWDs would not contribute significantly as ecological compensation. Prior to the compensation planting proposed in the Plan, plant establishment along the CWDs would be limited to any natural regrowth that occurs on the cut hillside batters and along the channel banks.

3.0 INITIAL COMPENSATION CONCEPT

This Plan presents indicative compensation on both the northern and southern sides of the Stage 4 landfill extension. It is proposed the primary compensation for infilling of the ephemeral/intermittent portions of the stream and tributaries would be at the southern side of the Stage 4 extension. Compensation for infilling of portions of the stream and tributaries that have permanent flow would be along the northern periphery of the extension, primarily along the CWD. As such the CWD attenuation system would be managed to provide flow to the northern side of the CWD system.

It is not until the first section (Cell 1) of the landfill reaches its final design level, that planting and compensation improvements can begin along the edges of the CWD channel. To compensate for the infilling of the stream the footprint of the first cell of the Stage 4 extension, it is proposed that a section of hillside spur on the north side be removed to form a roughly flat section where channel meanders can be formed and planted. Areas between the meanders would have groundforms shaped to support new planting. The ground would initially be ripped, base fill placed up to 2m high with a layer of topsoil 300mm deep over and enriched with compost, and then all covered in bark chip mulch. This would provide suitable growing conditions for planting riparian species that will grow and overhang the waterway to give an enhanced waterway environment at this section of the channel.

The planting for the meander will be riparian species that grow and overhang the waterway. Water edge species would primarily be native grasses and flax. Further from the edge, taller growing hardy woody species would be planted as pioneer plants to take exposed conditions and planted close together to quickly form a

mass that gives mutual protection from wind. In the longer term, enrichment species that require a modified sheltered environment, would be added to broaden the plant types. Refer to the Schedule of plant species in the Appendix 3.

Should additional compensation area be required as a result of the detailed design ECR calculations or should it be required to assist with phasing of the landfill development (i.e., to reduce the lag between compensation development and development of the landfill cell) additional meander areas could be created either in wide sections along the northern access road or through creation of additional flat area through removal of hillside spurs as described above. The improvements presented in the *Lower Carey's Gully Stream Restoration Plan* could also be implemented, as required, to provide additional compensation and to assist in phasing.

Refer Boffa Miskell Drawing W12099_200 showing the road construction and channel meander on the north side and W12099_201 showing the planting to the meander, that together outline the work for Stage 4

To facilitate populating the new stream environs, a fish relocation programme could be implemented, if required, to link the Lower Carey's Stream and the upper reaches, which are currently interrupted by the tunnel under the existing landfill.

4.0 FIRST STAGE COMPENSATION CONCEPT

Once Cell 1 has been completed i.e. the cell has been filled to the design levels and capped; compensation measures can be provided along the CWD adjacent to Cell 1. Refer to BML W12099_202 Phase 1 Planting, for the landscape planting and finishes of the completed Cell 1 works together with W12099_401 that details the work.

1 Modification of the CWD channel – the primary focus would be the northern channel, which is an unlined channel running beside the access road. Secondary compensation may be along the southern CWD, additional meander areas along the southern and /or northern access roads, or at the Lower Carey's Gully stream.

Once filling activities are complete, a number of modifications to the CWD would be undertaken to create a more variable shape and profile to simulate a natural system. These modifications would include the following:

- Localised widening of the CWD
- Placement of cobbles and stones in the bottom of the CWD
- Provision of check dams with pools, riffles, log or rock overhangs that provide a habitat for fish and microcorganisms
- Relocation of the CWD in areas to the centre of the access track to provide a bank on both sides of the CWD for riparian planting.

Indicative details for the formation and components of the channel waterway and meander are shown on BML W12099_402. Such work can only be described generally and is best determined on site after construction of the access road and once design details for first Cell have been confirmed. Additional investigation and

confirmation of water flows (ephemeral, intermittent and permanent) and seeps along the cut batters, will assist with design of attenuation dams for water management.

2 Riparian planting to the CWD channel edge – The carriageway on the north side will be phased out and a new access road formed on the constructed landfill (if required). This will allow a riparian planting zone to be created immediately beside the channel. (Refer BML W12099_301 section B1). The dual carriageway on the southern side will be reduced to a single carriageway with the redundant carriageway reconstructed to form a planting zone immediately beside the channel, if required based on ECR calculations. (Refer BML W12099_301 section C1)

As part of ground preparation, where new planting is to be established over redundant carriageway, any seal would first be removed and the compacted constructed basecourse ripped with tines to loosen the top and facilitate some water and root ingress to the subgrade. A 500mm layer of soil mix would then be placed over the prepared ground and only lightly compacted to a profile shaped to shed excess water to the CWD channel. The soil mix would comprise approved subsoil with a mixture of small rock particles and clay that has been recovered from site or imported. The material would be clean and be free of extraneous material such as wood that could decompose and break down, large rock and noxious weed rhizomes that would be an issue for plant establishment.

The top of the finished formation would have a top horizon for planting composed of 300mm of topsoil that has had a 300mm deep layer of compost laid over and cultivated into it. Incorporating compost will provide microbes and humus to give a friable soil mix that will assist in the establishment of plants and hold moisture. On completing the soil layer formation, a 100mm thick layer of woodchip mulch will further assist in retaining soil moisture as well as control weed growth. An alternative method, not included in this Plan, is to hydroseed the formation to establish a vegetation cover, then spot spray planting locations and plant into them. Additional maintenance (releasing) may be required to ensure that the plants are not swamped by lush grass growth that can grow then fall over in the wind, smothering the desirable plants.

The planting for the CWD channel edge will be riparian species that grow and overhang the waterway. Water edge species would primarily be native grasses and flax. Further from the edge, taller growing hardy woody species that are used as pioneer plants to take exposed conditions and would be planted close together to quickly form a mass that gives mutual protection from wind. In the longer term, enrichment species that require a modified sheltered environment, would be added to broaden the plant types and provide additional bird habitat. Refer to the Schedule of plant species in Appendix 3.

3 Planting on the completed landfill – At the interface between the permanent carriageway and the completed landform, an intercept channel to collect stormwater from the grassed surface of the capped formation would follow the carriageway. Water would be directed to the CWD channel at regular intervals along the route. Initially the channels would be grassed to control silt runoff. Permanent, larger plants including sedges, flax and toe toe would then be planted in a 2 – 5m wide strip around beside the carriageway to provide ecological and amenity values.

The final landform is proposed to be shaped and crowned to give a positive fall to the outer edges. The final landform cover will include a topsoil layer underlain by a drainage layer, all above a capping/ gas control layer. The capping layer should not be compromised by the action of large roots penetration. Accordingly, plant

species on the landfill cover are limited to grasses with shallow, fibrous root types rather than woody, invasive roots associated with tall trees. Alternatively, areas of deeper topsoil cover may be provided in locations to allow for a wider diversity in plantings. Refer to the Schedule of plant species in Appendix 3.

The remaining top of the landform would be grassed. Ground conditions that could be encountered may be similar to those at the Tawatawa Reserve which was once the Preston's Gully landfill. This is an indication of what planting could be established in top of the landfill without compromising the capping layer. Refer Appendix 1 for site photos. Planting to the top of the landfill is not included in this Plan but ground conditions would be reviewed over the longer term to determine if additional plantings can be incorporated on the landfill cover to give a variety of environments in the centre of the gully. The overall vision for the completed landfill is that it will be used for general recreation. Any planting would be done in conjunction with an overall development plan and plant selection would use plants that are generally fibrous rooting that would not penetrate or compromise the capping seal layer. This is likely to be a mix of small native shrubs and grasses planted after the closure of each cell and after gas collection is complete.

5.0 COMPENSATION FOR SUBSEQUENT CELLS

Compensation for subsequent landfill cells shall be provided in a similar manner to that described for Cell 1 and shall consist primarily of improvements to the northern CWD. The proposed extent of the compensation for the entire Stage 4 extension is shown on BML_W12099_203. The compensation would be progressive, working downward in the direction of landfill cell development and filling.

A detailed compensation plan would be submitted to GWRC prior to development of each cell. The plan would be based on the detailed design of the proposed landfill cell, actual enabling works and site conditions/configurations. Additional ecological assessments may also be completed within the footprint of each cell to confirm SEV values of the actual stream length and tributaries to be infilled and the flow conditions (i.e., ephemeral or permanent). These assessments would be utilised to confirm ECRs for the cell and develop the compensation plan.

To manage the lag time between ecological compensation for and development of a cell, it is proposed that compensation be provided within six months of physical works associated with development of a cell. This will primarily be accomplished by providing compensation at the CWD along the previous landfill cell to that currently being developed (i.e., compensation for Cell 2 would be provided at the CWD adjacent to Cell 1, etc). Initial compensation would be provided through compensation at the meander described above (refer BML Drawing W12099_400. In some instances compensation may be required in other locations to manage the phasing of cell development and ecological compensation. Alternate locations may include the lower part of Carey's Gully Stream downstream from the overall landfill complex, additional meander areas adjacent to the landfill, and/or improvements to the CWD on the south side of the Stage 4 extension.

In some instances the proposed cell area may require a larger compensation area than is available along the CWD for the previous landfill cell. In such cases, additional compensation would be provided through improvements at the alternate locations described above.

6.0 ECOLOGICAL COMPENSATION EVALUATION

Under the URS Ecological Compensation Feasibility Assessment, for Cell 1, the compensations for Clean Water Diversions, being an Intermittent Stream Type with a SEV score of 0.82 and ECR value of 1.06; the required compensation is estimated to be = 500m. This can be achieved based on the following calculations.

To establish the Stream Ecological Values and relative Ecological Compensation, the relative lengths of waterways was measured along the centreline of the CWD waterways on plan:

For the enabling works for Cell 1, the CWD meander (perennial water flow) = 577m with planting both sides plus 142m and 127m at beginning and end of the meander with planting one side = 846m. The base would be nominal 1.5m wide

The total North CWD (perennial water flow) = 1120m, width varies 1.0. to 1.5, unlined channel. This total sum sufficiently equates to the URS calculated total ECR requirement of 1163m perennial stream and the 650m of intermittent stream over the entire project. Allow a nominal 1.0m for most of Cell 1 length. Planting is on one side but this can be varied – CWD channel can be relocated away from the toe of the batter to allow formation of flattish banks both sides of the waterway and planted. Maintenance access track would be reconstructed on landfill, if required.

Together the total length of perennial flow = 1966m made up of the CWD meander (846m) plus the North CWD (1120m).

South CWD (intermittent water flow) = 721m, width nominal 1.0m, lined channel. Planting on one side but this can be varied – CWD channel can be relocated away from the toe of the batter to allow formation of flattish banks both sides of the waterway and planted. Maintenance access track would be reconstructed on landfill, if required.

These assumptions are made on an indicative plan and represent an estimate of what might be expected. They could be varied and updated during the detailed design of each cell for the Stage 4 landfill to include actual ecological conditions and the site / ground conditions, programme phasing and design conditions. In addition, there is option to relocate the waterway away from the toe of the cut batter to allow the formation of flattish banks on both sides that can be planted, rather than having a cut batter that has limited vegetation growth.

Phasing of the landfill works and planting to give ecological compensation would be included in the overall programme. As each of the landfill cells are progressively filled, the planting works along the edge of the previous cell gives ecological compensation. As part of the enabling works that creates the north and south access carriageways, the meander would be created to provide mitigation for the stream environs lost as Cell 1 is developed. The planting along the north access track CWD beside the completed Cell 1 landform would compensate for Cell 2 development. This would continue down the gully until the final stage links to the lower Carey's gully environs.

In summary, URS predict the need for 650m of intermittent stream and 1163m of perennial stream as compensation. The restorations proposed in this report for waterways, severally meet the requirements in that they are 71m in excess of the intermittent stream and 803m in excess of the perennial stream requirements. Given the indicative nature only of an SEV ECR, we consider that the compensation indicated as being required is successfully met by the restorations proposed.

7.0 MAINTENANCE

The establishment of planting is reflected in the ground preparation, timing of planting and ongoing maintenance of the plants. Ground improvements are described above. Planting smaller grade plants (pb 3, 0.5litre and 1 litre grades) are a common method of revegetating large areas but must be implemented when there is adequate soil moisture levels and warm ground conditions. Planting in autumn is the ideal time to allow some root growth to establish the plant in the relatively warm, moist soil. The plant would then be established and produce vegetative growth in the spring. Ongoing maintenance includes release weeding, fertilising and control of pests and diseases. Wild goats are present in the area and could be a problem by grazing on new plants. They are not fully controlled and present a risk in the establishment of plants. Possums can have an effect on young growth but are currently well controlled in the area.

8.0 WEED CONTROL

Weed species can permanently alter the structure and ecological processes of native riparian and aquatic communities. As such, a weed control programme forms an important component of most restoration projects. In general it is preferable to remove weeds prior to planting the desired (native) plants. The proposed ground formation will leave modified ground clear of weeds but the intervening time between completion of the ground formation and planting at a suitable season could result in the establishment of grasses and woody weeds. Established weeds on hillsides in the area include gorse, broom, Darwin's barberry and buddleia. These species could colonise newly formed planting areas and must be controlled prior to planting.

8.1 Planning

Prior to the commencement of a weed control programme it is important to consider the following:

1) Limit the extent of clearance to manageable areas to prevent new weed species establishing where developing new planting areas in established weed zones.
2) Work in stages, controlling outlying weed patches first to slow the rate of weed spread before starting on the worst areas. Replace weeds with natives or non-weedy plants as work progresses.
3) Timing of control operations to occur before weeds fruit or seed. Ideally control operations should be undertaken during the main growing season of weeds (i.e. between October to May).
4) Prevent the spread of seeds or fragments that could resprout. Decide on the best disposal method before commencement of work.

In instances where chemical control is used, there will be a minimum period of time (recommended by the herbicide manufacturer) between herbicide application and enhancement planting; in all cases, a minimum of

at least 3 weeks after application. When cleared patches cannot be planted promptly, mulching the cleared ground will reduce weed invasion and conserve soil moisture.

Critical to any weed control operation is the subsequent surveillance which allows new invasions to be caught and controlled early. Thus, ongoing weed control will required after revegetation planting in order to ensure the long-term success of a planting programme.

8.2 Control Methods

Weed control may be carried out by hand, machine, herbicide or a combination of the three. In all instances where chemical control is used, care will need to be taken to ensure that no unwanted effects on native vegetation or waterbodies occur. The appropriate method will vary according to the growth form of the weed, the level of infestation, and the context in terms of existing habitat and vegetation:

- **Herbs or ground cover weeds** may be pulled, especially where there is the risk of overspray to adjacent desirable plants, or sprayed using chemicals recommended for control of that particular weed species.
- **Shrub weeds** may be sprayed, usually with metsulfuron or Tordon Brushkiller (if it is desired to retain grass growing around the target weed) applied at label rates, or cut and stump swabbed with the same chemicals.
- **Vines** may be controlled by cutting the stems near the ground and painting the stump with herbicide within 30 seconds of cutting.
- **Tree weeds** may be felled by an accredited operator and stump swabbed if there is a risk of sprouting. Note that if trees are felled, it will be done so in a manner that will minimise the risk of damaging any surrounding native vegetation. Alternatively, methods including frilling or drilling and poisoning.

Weed management will generally be limited to the control of weed seedlings that germinate in the planting zones. Gorse can be used as a nurse crop and native seedlings allowed to grow through, where there is an established patch that is interplanted with native plants but this situation is unlikely given the proposal is to place new material in planting zones. A full schedule of weed plant species present in established areas and their method of control is in the lower Carey's Gully Stream Restoration Plan (Boffa Miskell Feb 2012).

9.0 ANIMAL PEST CONTROL

Grazing damage from feral goats and pigs are a risk in the establishment of new plants. GWRC implements a pest control programme in agreement with WCC. It is important that a high level of control on a regular basis is maintained both now and in the future to ensure existing and the establishment of new vegetation is not compromised by populations of pest animals. The planting contractor would monitor any damage done by pest animals and be responsible for reporting any damage. Quick action to control pest populations would be needed to limit ongoing damage.

10.0 RIPARIAN VEGETATION MANAGEMENT

Riparian vegetation management is a key tool used in stream restoration as the riparian zone forms the interface zone between the stream proper and the land. There are many forms of riparian planting, all of which are likely to have some ecological benefit. Riparian planting comprising trees and shrubs provide the following benefits:

- Increases the amount of stream shading, regulating water temperature and thereby associated variables such as dissolved oxygen, as well as reducing light levels and preventing the growth of algae;
- Provides a consistent input of organic matter in the freshwater system;
- Provides woody debris to the stream, providing habitat diversity and cover for fish and insects;
- Reduces erosion and inputs of find sediments, and stabilises the stream banks;
- Reduces surface flow velocities (due to increased hydraulic roughness of the buffer zone vegetation);
- Act as a biological filter or buffer zone between streams and their surrounding lands, intercepting much of the nutrients that would otherwise end up in waterways. Where nutrients enter the streams unchecked, eutrophication reduces water quality and degrades habitat.
- Creates a corridor and breeding area required for adult life phases of many aquatic invertebrate fauna.

In contrast, low riparian vegetation also has benefits. Riparian edges comprising sedges and grasses are effective due to the following reasons:

- They typically form dense cover over the ground which slows down the passage of water;
- Their many fine leaves are ideal filters or sieves, reducing the velocity of water and encouraging the settling out of solids;
- They grow well in saturated soils and can tolerate periods of immersion;
- They can tolerate and grow through accumulated sediment;
- They are tolerant of dry periods;
- They are generally tolerant of both low and high fertility;
- They tend to accumulate organic matter and help create anaerobic conditions.

The width of the planting zone (and whether to plant on one or both banks) will be determined to some extent by stream morphology, bank steepness, existing cover and land ownership factors. The general aim should be to achieve a 5-10m planted width on each bank, with greater width where practicable (MWH 2002).

10.1 Revegetation Principles

- Manage weed growth that competes with existing native vegetation and can infest new areas.
- Plant open flat areas with hardy pioneer species to establish a microclimate for enrichment species. Plant types are selected for their hardiness and appropriateness to site conditions, as a means of attracting birdlife and for relative vigour to establish a closed vegetation cover that limits weed ingress and establishment.

- Plant sloping banks at edges to stream sides with hardy riparian plants. Riparian plant types are selected for the cool sloping aspect with the aim to give an overhanging vegetation canopy over the stream and bank edges.
- Infill existing vegetation with 'enrichment species' that require a more sheltered environment to establish and will ultimately grow to a larger stature to become emergent canopy vegetation.

10.2 Riparian Planting Guidelines

In order to achieve the best possible results from the planting programme, we advise that the following points should be adhered to:

- Follow a planting scheme which outlines composition and spacing of plants. This will ensure that plants will be placed in accordance with their environmental tolerances
- Adopt high planting density rates (0.5-1 m spacings) to help to combat weed invasion and reduce maintenance requirements for weed removal
- Planting times vary according to environmental conditions. In the Wellington region, the planting season is typically from May to September. This will generally achieve optimal plant establishment and survival, with reduced maintenance
- Careful timing of planting at the right season will reduce the need for watering. However, in dry spells young plants may require watering to assist with their establishment
- All planting should be of approved species, based on the list provided
- All plants should be sourced from the Wellington Ecological Region
- All supplied plants should have a habit of growth that is normal to the species and are of sound, healthy, vigorous nursery grown stock
- All plants should be free of insect pests, plant disease, sun scalds, abrasions and other disfigurement
- All plants should have normal and well-developed branch systems, and vigorous and fibrous root system, which are neither root nor pot bound
- All plants should be hardened off to suit the local conditions
- Given that the act of planting is crucial to the survival of plants, planting should be undertaken by experienced and proven contractors.

11.0 PHYSICAL HABITAT ENHANCEMENT

11.1 Long-Term Potential

Providing a walking track adjacent to the stream will encourage people to use this area. This may in turn instil a sense of ownership and encourage people to maintain an area free of rubbish. Long term such a track and picnic/open space area will be part of the wider Carey's Gully redevelopment concept after closure of the landfill. Following the closure of the landfill operations, public access to the site may be possible, including such possibilities as a walking area about the up-stream reach and a picnic / passive use area at the "head water". In addition, this restoration concept and activities outlined in the Lower Carey's Gully Stream Restoration could be extended into the Upper Carey's Gully. Refer to the End term development concept plan

The vision of the completed landfill, once it is closed for landfill operations, is for it to be a natural environment for passive recreation with associated ecological values in the stream and riparian plantings. A network of tracks could access the area and link to other recreation activities or points of interest in the wider area.

The primary focus of this ecological plan is to establish a native lowland broadleaf stream riparian canopy that completes the edge of the surrounding hillsides and overhangs the diverted waterway. Water flows would be managed and the physical habitat would be improved and could be the basis for wider recreation opportunities in the distant future.

12.0 REFERENCES

MWH (2002): An Ecological Assessment of Owhiro Stream. Report prepared for Wellington City Council by MWH New Zealand Ltd.

URS (2011): DRAFT Southern Landfill Ecological Assessment. Prepared for Wellington City Council by URS, June 2011. 35 p. + Appendices.

BML (2012) Lower Carey's Gully Stream Restoration Plan (Boffa Miskell Feb 2012)

URS (2013) Ecological Compensation Feasibility Assessment, Stage 4 Extension of Southern Landfill

APPENDIX 1: SITE PHOTOS

APPENDIX 1: Site photos

North access track Cut batter about 2 years old

Mahoe vegetation with limited understory at tributary near proposed meander

View south down Carey's Gully to current landf ll operations.
Cut batters on right about 10 years old colonised with gorse.

South access cuts with gorse and regrowth on debris fans

Upper Carey’s Gully Stream - downstream

Old cut batter by transfer station with Hebe (parvif ora?), gorse and exotic grass regrowth

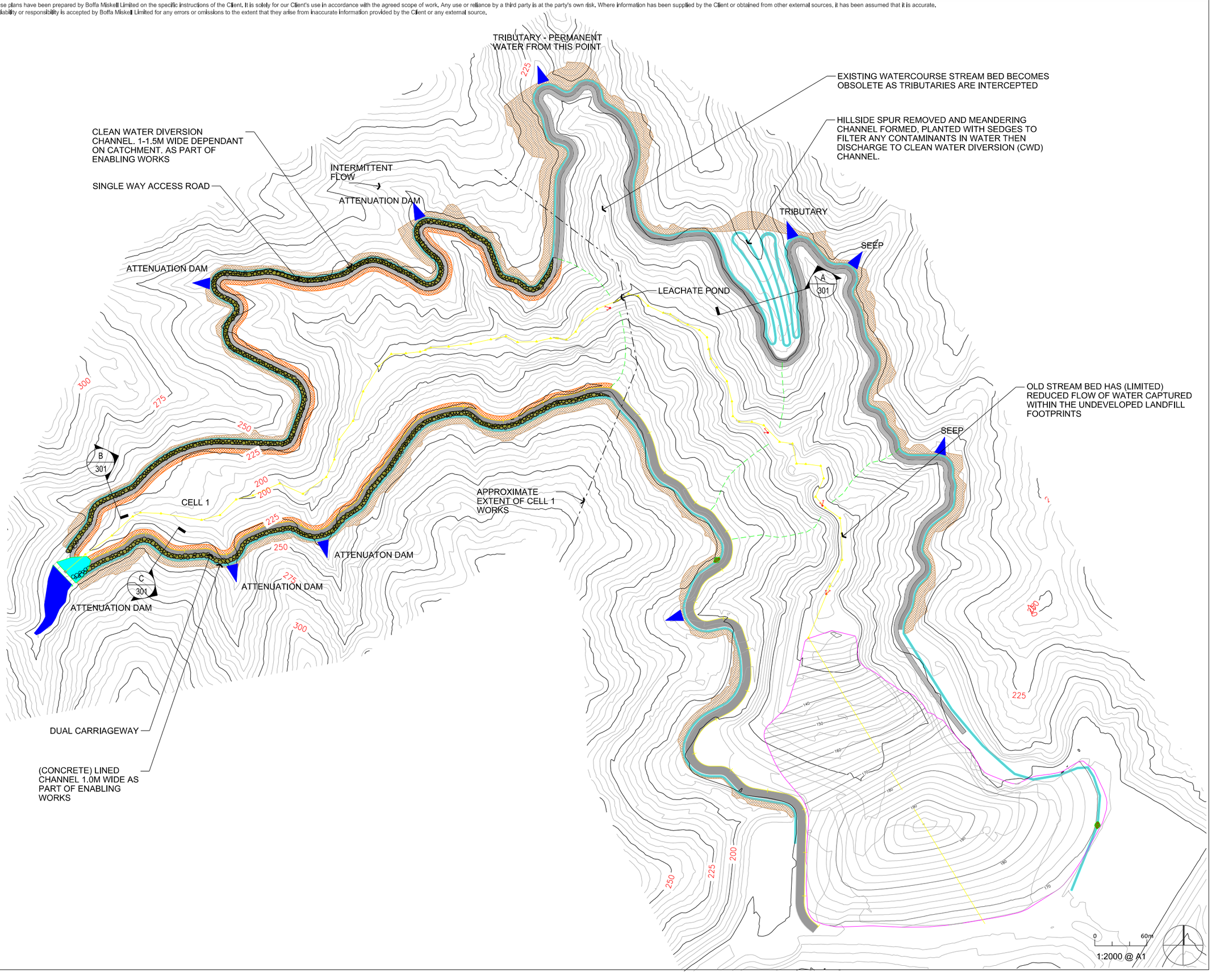
North access road old cut batter colonised with Hebe (stricta?), Ozothamnus leptophylla and gorse

Upper Carey’s Gully Stream - upstream

Tawatawa Reserve with f ax planting around ephemeral wetland in centre foreground

Wetland channel (Christchurch) - meander precedent

APPENDIX 2: DRAWINGS



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OVERALL DEVELOPMENT

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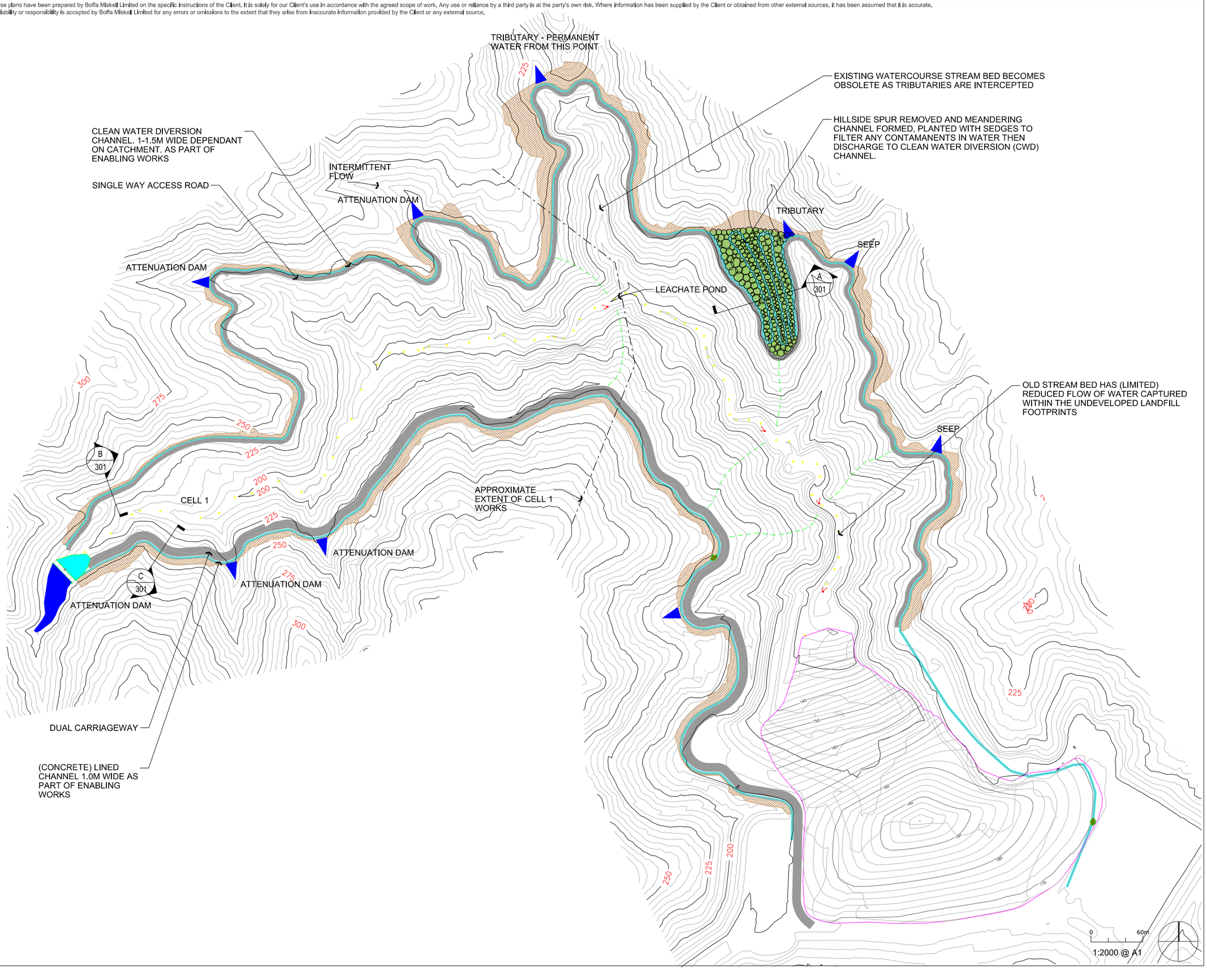

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ENABLING - OVERALL PLANTING

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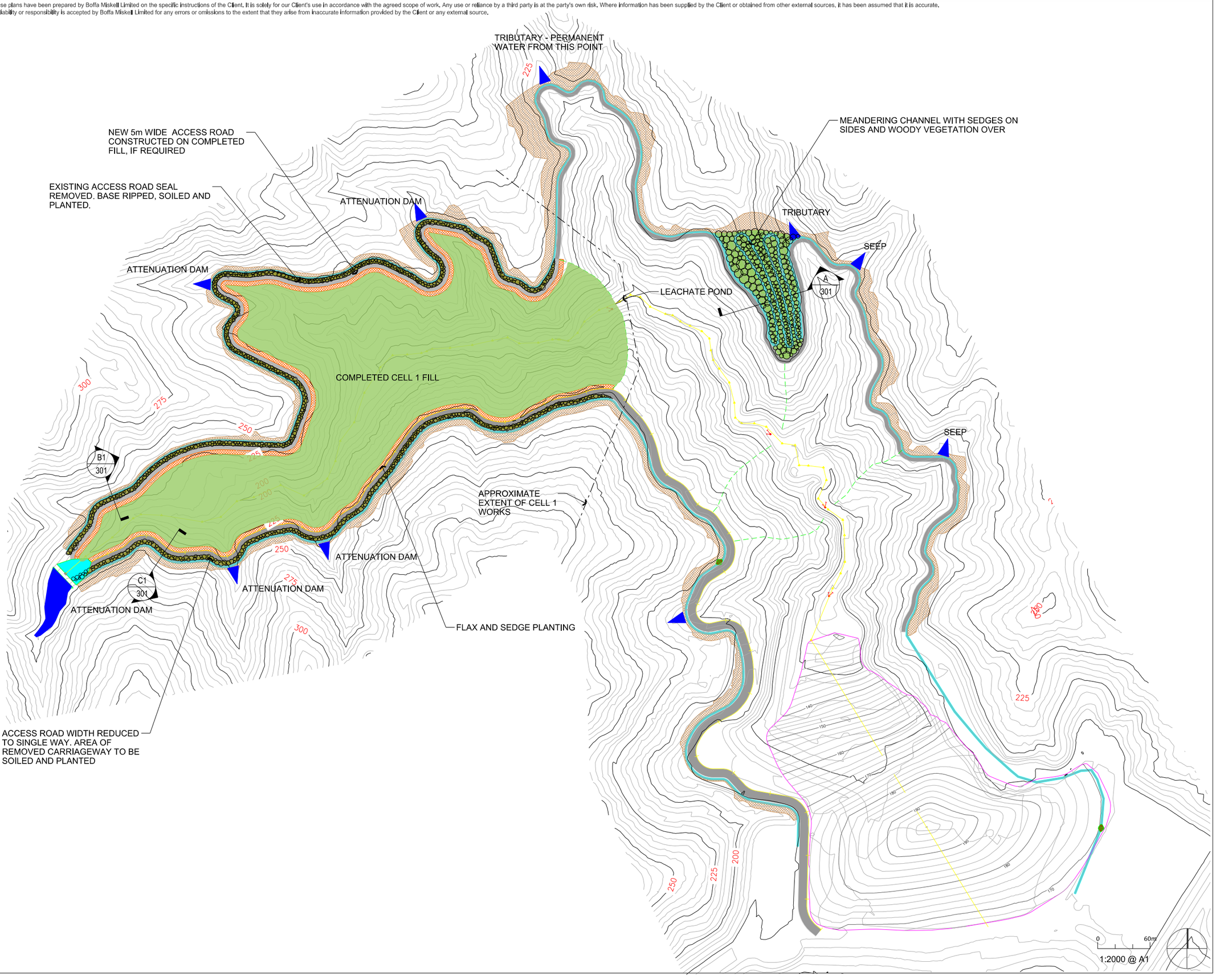

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PHASE 1 - PLANTING

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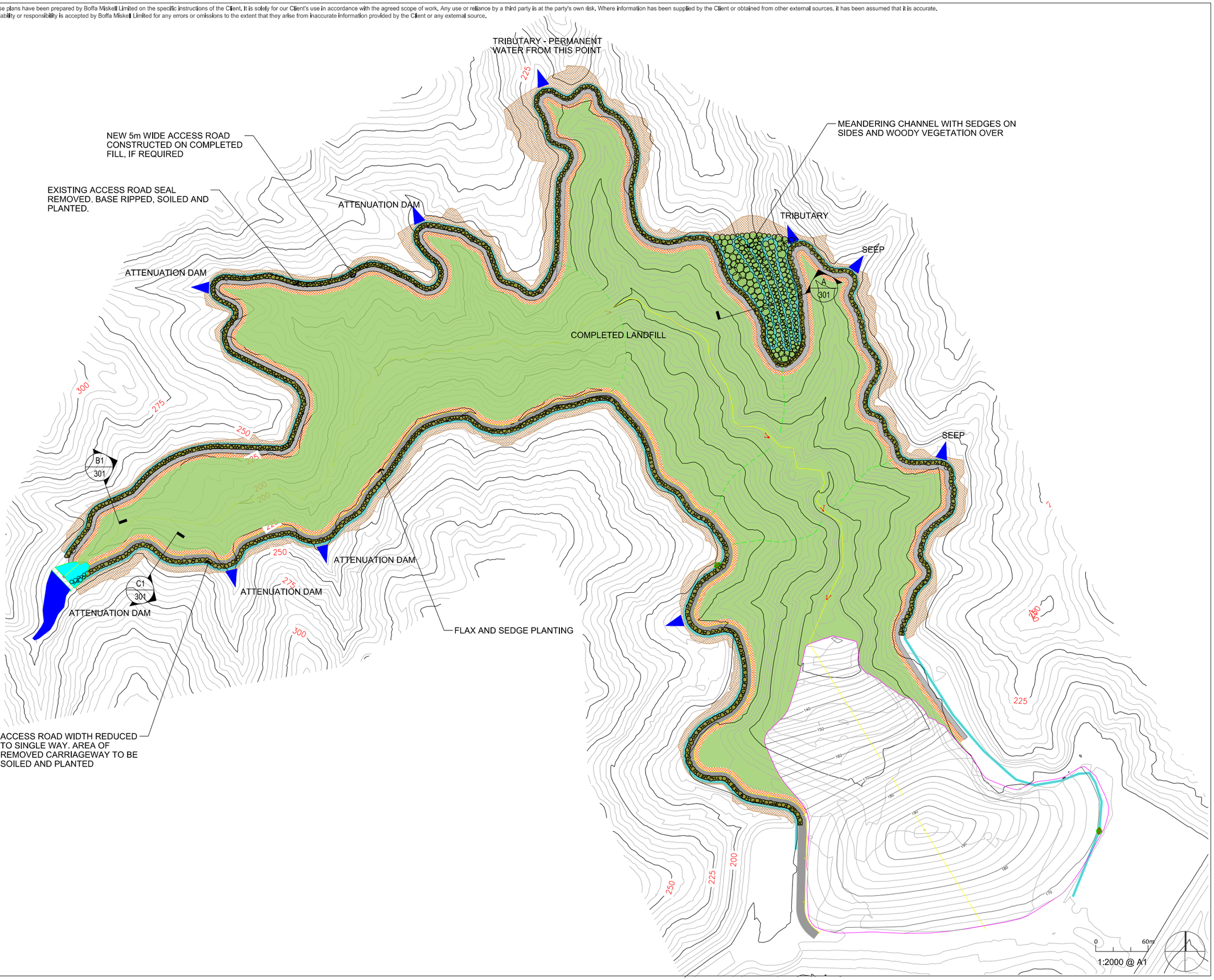

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FINAL LANDFILL

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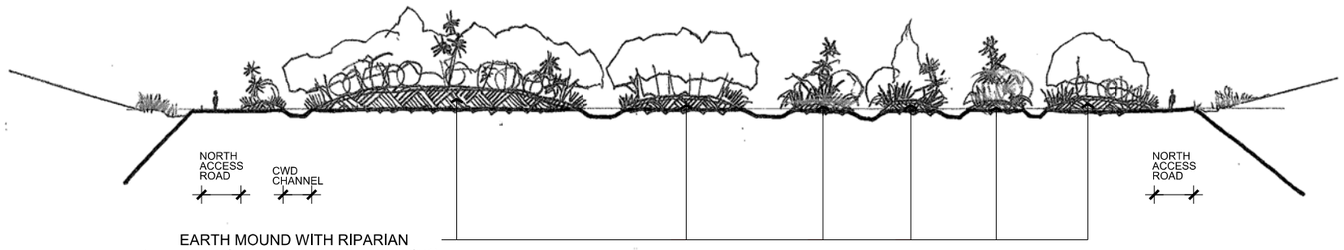
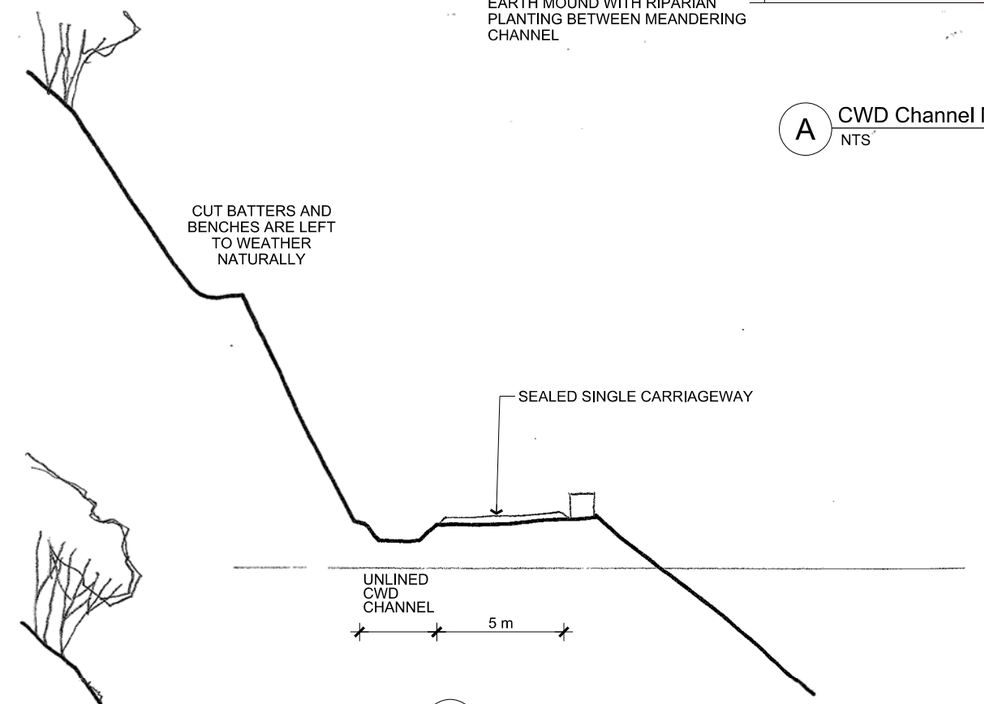


EARTH MOUND WITH RIPARIAN PLANTING BETWEEN MEANDERING CHANNEL

A CWD Channel Meander
NTS



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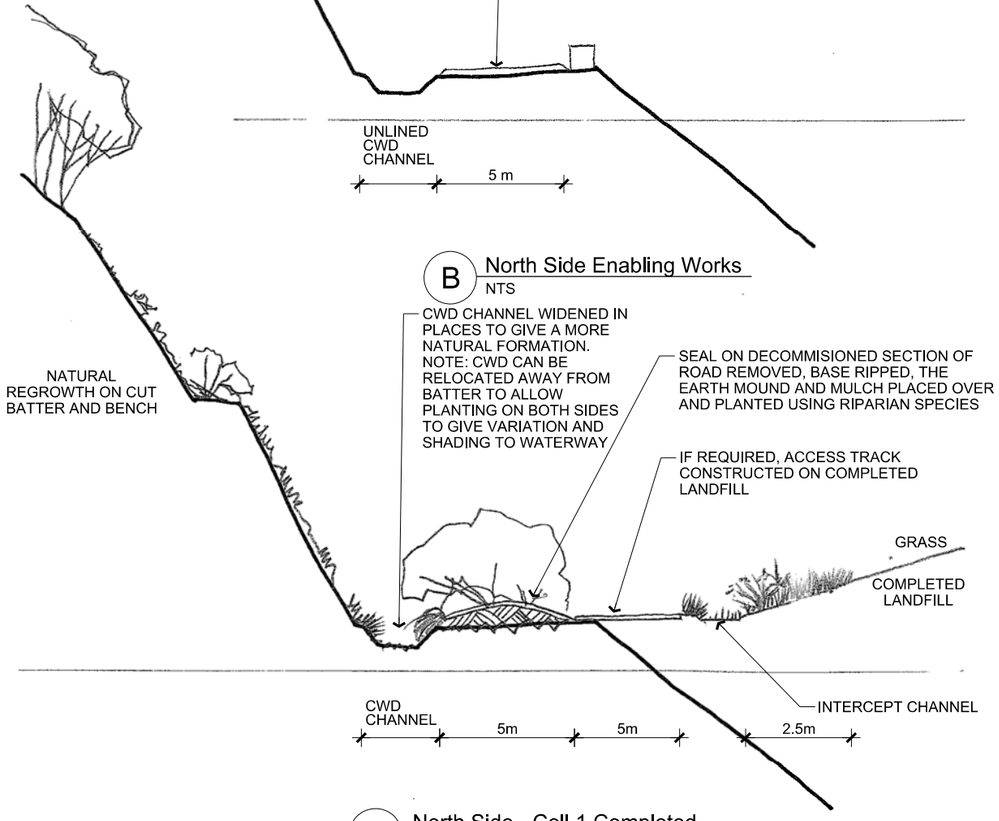

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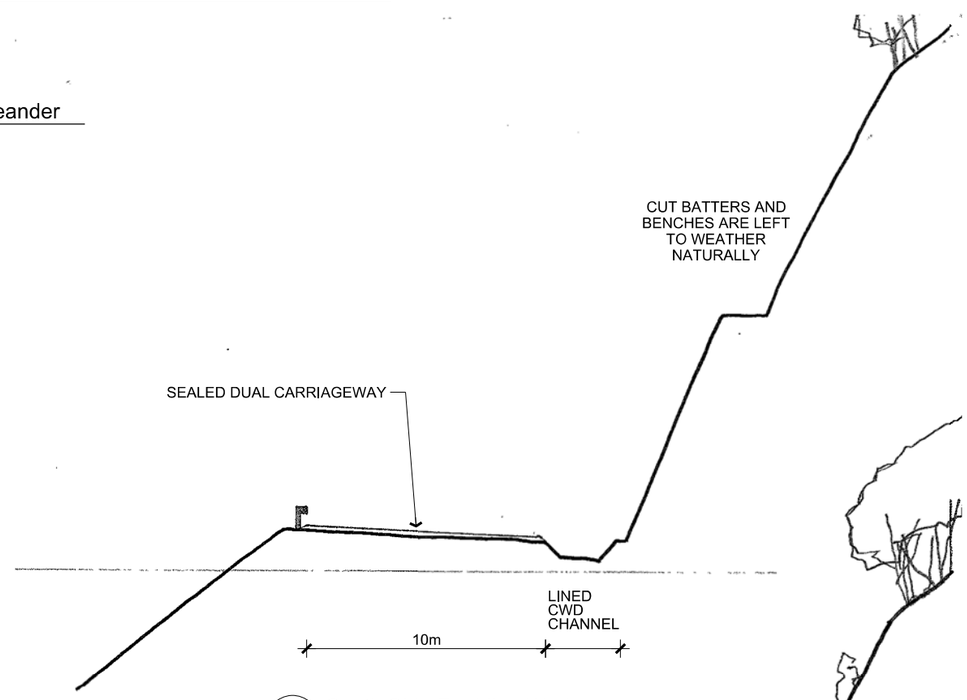

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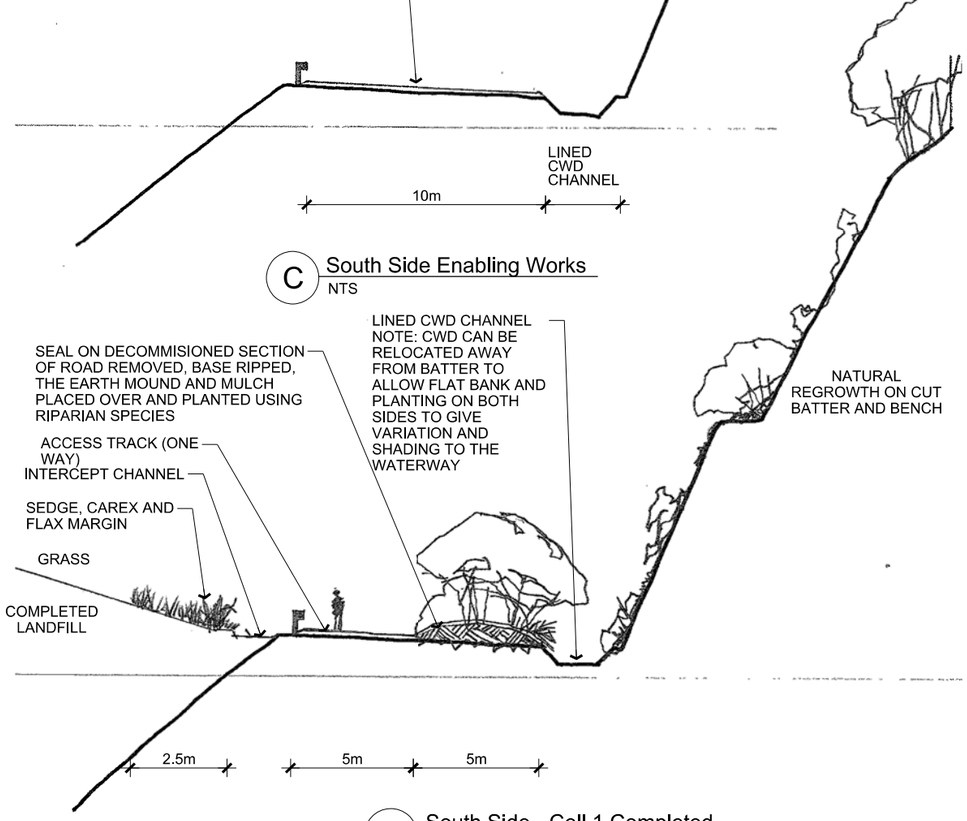

C1 South Side - Cell 1 Completed
NTS

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PHASE 1 - CROSS SECTIONS

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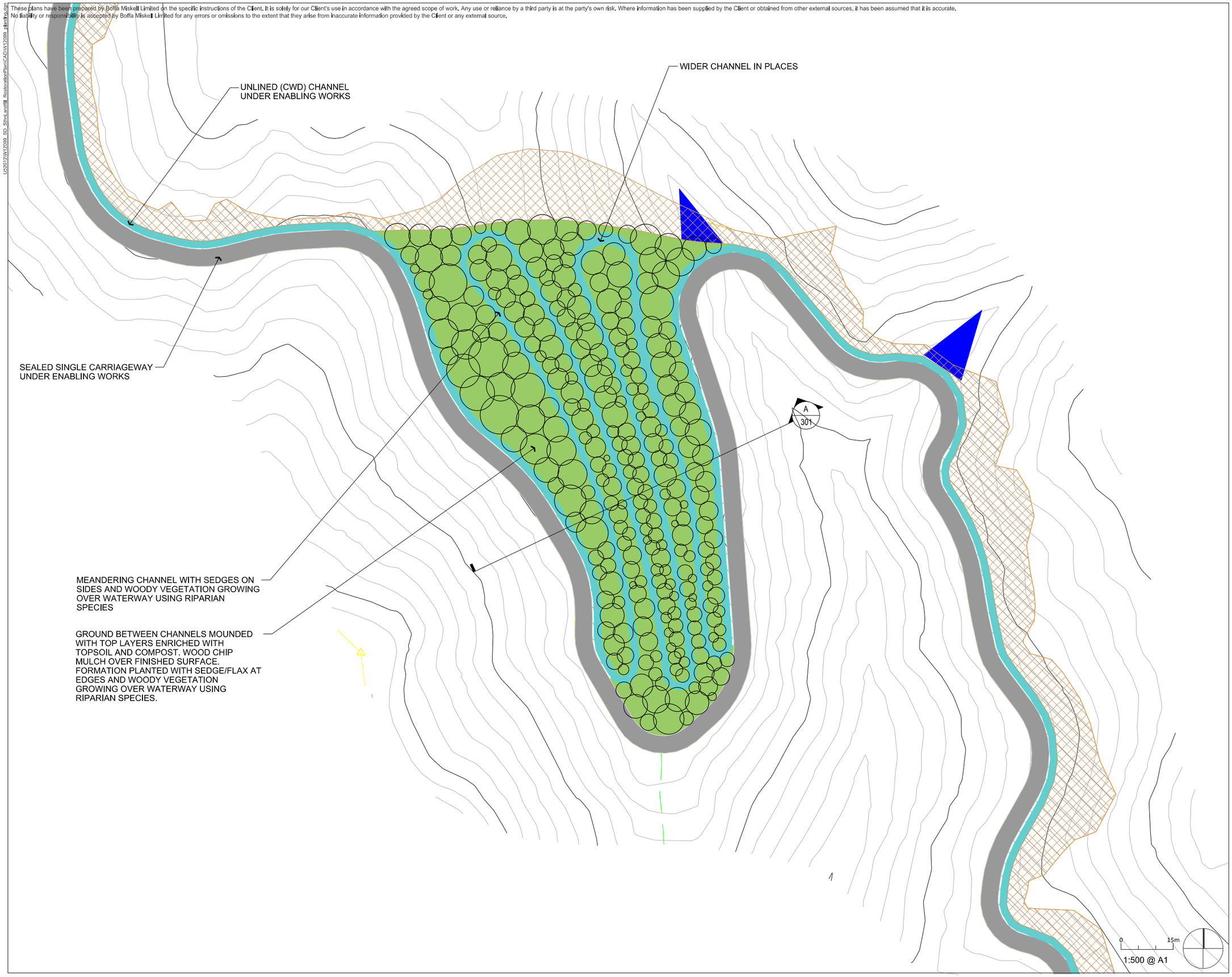

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ENABLING WORKS
CHANNEL MEANDER

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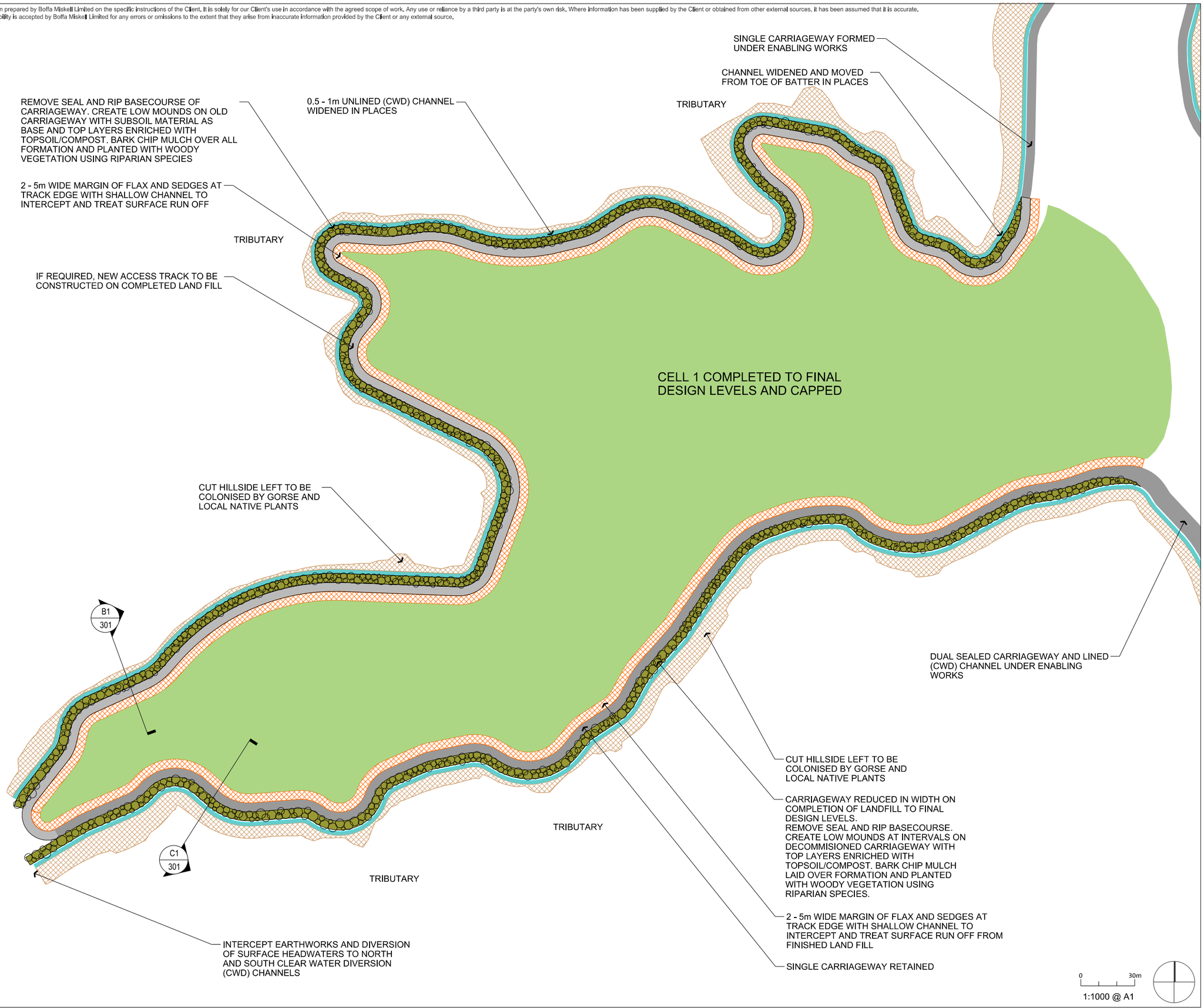

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PHASE 1
ECOLOGICAL RESTORATION
(CELL 1 COMPLETED)

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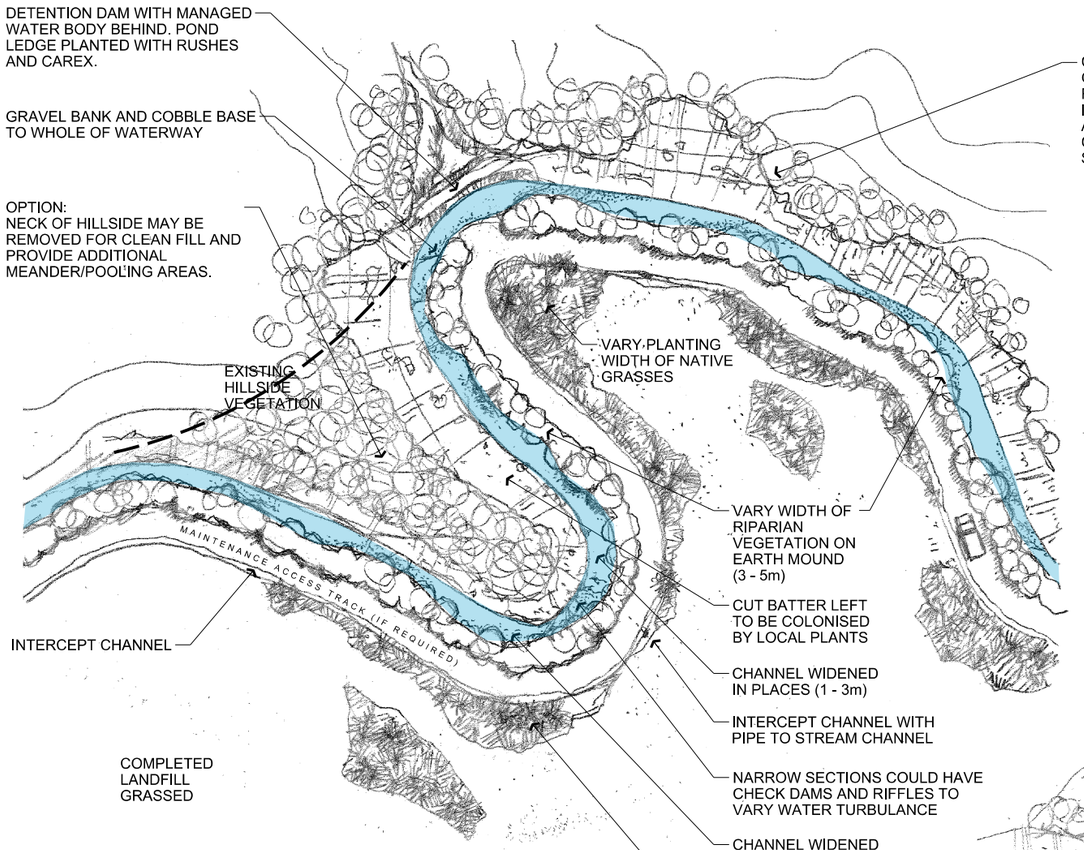

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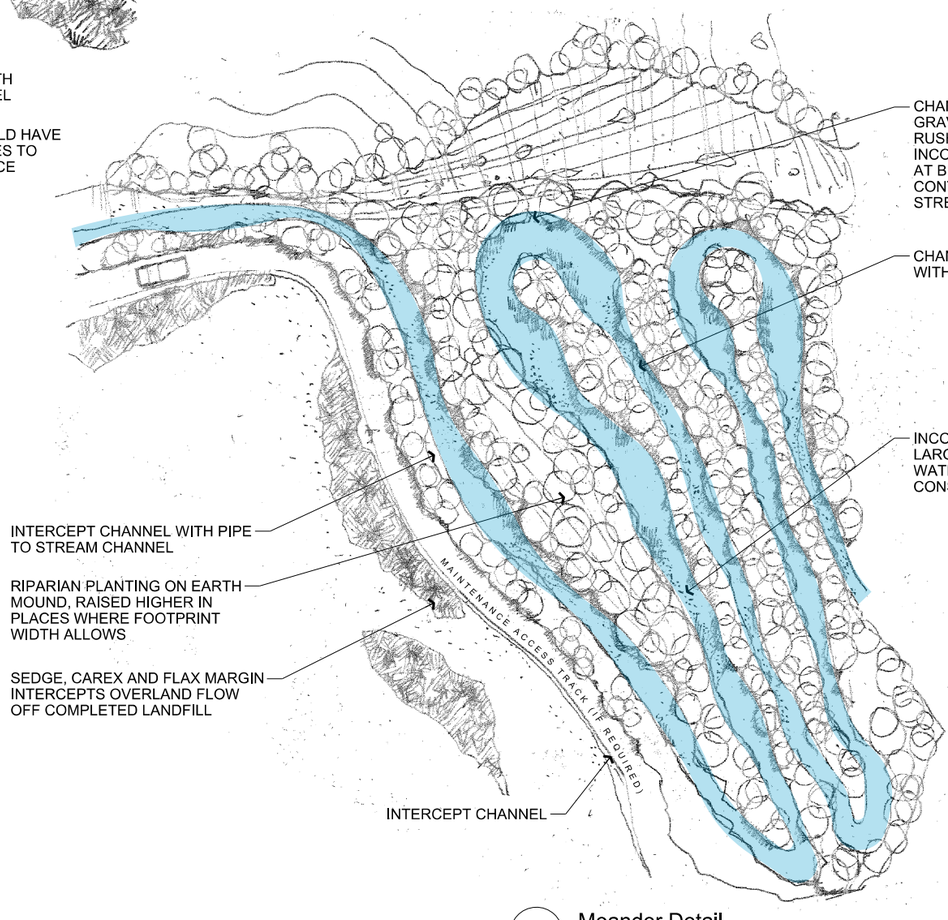

E Meander Detail
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0 15m
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CHANNEL IMPROVEMENT STRATEGY

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APPENDIX 3: PLANT SPECIES LIST

		Meander Area (6433m2)	North Phase 1 road edge (5589m2)	South Phase 1 road edge (3583m2)	North landfill edge (5636m2)	South landfill edge (3630m2)	
Botanical name (common)	Grade	Plant number	Plant number	Plant number	Plant number	Plant number	Total plants
Area (m2)		6,433	5,589	3,583	5,636	3,630	
Sedges and grasses at .75m spacing		1,447	1,258	806	10,020	6,453	19,984
Woody veg at 1m spacing		3,860	3,353	2,150			9,363
Total plants		5,307	4,611	2,956	10,020	6,453	29,347
Pioneer plants							
Coprosma robusta (Karamu)							
Hebe stricta (Koromiko)							
Melicytus ramiflorus (Mahoe)							
Olearia paniculata (Akiraho)							
Olearia solandri							
Phormium cookianum (Whararikí)							
Riparian banks species							
Aristotelia serrata (Makomako)							
Carpodetus serratus (Putaputaweta)							
Fuchsia excorticata (Kotukutuku)							
Phormium tenax (Harakeke)							
Pittosporum tenuifolium (Kohuhu)							
Plagianthis regius (Manatu, ribbonwood)							
Pseudopanax arboreus (Five finger)							

Enrichment species							
Alectryon excelsus (Titoki)							
Beilschmiedia tawa (Tawa)							
Eleocarpus dentatus (Hinau)							
Eleocarpus hookerianus (Pokaka)							
Knightia excelsa (Rewarewa)							
Metrosideros robusta (Northern rata)							
Vitex lucens (Puriri)							

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