Engineers & Consultants

Mangaheka Watercourse Assessment and Programme of Works

Final

Prepared for Hamilton City Council by Morphum Environmental Ltd
22/05/2017

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Document Control

Client Name: Hamilton City Council

Project Name: Mangaheka

Project Number: P01282

Document: Mangaheka Watercourse Assessment and Programme of Works

Revision History

Status	Date Issued	Author	Reviewed By	Released By
Draft	02/03/2017	Sam McArthur	Emily Reeves	Damian Young
Final	17/03/2017	Sam McArthur, Emily Reeves		Damian Young
Version 2 (Following Wainui Consulting Review on behalf of WRC)	22/05/2017	Emily Reeves		Damian Young

Reviewed by:

Reviewer: Emily Reeves **Signature:**

Released by:

Reviewer: Damian Young **Signature:**

Executive Summary

Hamilton City Council is currently preparing integrated catchment management plans (ICMPs) for several catchments within the city boundary. One of the objectives of an ICMP is to identify effects on the receiving environment and to propose mitigation solutions. This process is critical in catchments where growth pressure is changing Greenfield land to Brownfield and the focus to date has largely been around erosion. To get a better understanding of existing condition and future impacts a number of assessments have been undertaken focusing on the downstream receiving environments of greenfield areas to assess existing erosion and erosion susceptibility. These assessments (to date in Kirikiriroa and Te Awa O Katapaki catchments) have led to a programme of works being developed to provide resilience against erosion including both exacerbation of existing erosion issues, and potential erosion in currently stable (or artificially stabilised) reaches associated with growth areas.

A large portion of the HCC catchments are either developed or has HCC and WRC consents. These assessments are designed to address the residual effect of increased volumes from the growth areas on the receiving environment channels. Although these growth areas are assumed to be mitigating all onsite requirements for treatment and attenuation, it is acknowledged that this is not always possible and the gully systems and current farm drains may need restoration and management.

Erosion in watercourses, although a natural process, can be intensified due to increased flow rates and volumes from urbanisation. Increased sediment mobilisation and deposition within a watercourse can have detrimental effects on fish and macroinvertebrate populations and channel erosion can result in the loss of private and public land.

Morphum Environmental Limited (Morphum) was engaged by Hamilton City Council (HCC) to undertake an assessment of the Mangaheka Stream from the HCC boundary to the upstream boundary of the Tanirau Wetland. The assessment is aiming to inform concept projects and management options that are required to mitigate ongoing erosion within the Mangaheka Stream including the portion of the stream that is located within Waikato Regional Council's administered Ngaruawahia Drainage Area. The portion of the stream outside the WRC administered drainage area is managed by Waikato District Council and Waikato Regional Council's Waipa Zone catchment programme..

Morphum undertook an assessment on Wednesday the 22nd February 2017 which consisted of a walkover survey of the 5 km reach and collection of data using the ArcGIS application Collector. Following this assessment, four scenarios have been developed with varying mitigation works and actions. These scenarios have been developed in consideration of the fact the works are proposed on private land and both WRC and HCC want to minimise any impacts to landowners including the loss of grazing land.

The final costings should be considered as indicative only. A pricing activity of erosion mitigation works should occur during detailed designs. The following details and costs form the four scenarios:

Scenario One: Do nothing.
No mitigation works will likely result in increased erosion, bank slumping and loss of land through the Mangaheka Stream network. There is no capital cost associated with this scenario.

Scenario Two: Low Level Mitigation.
This scenario provides the minimum mitigation works that Council should consider for the Mangaheka Stream network. The works include planting that aim to support top of bank stability and isolated reinforcement with toe protection. It should be noted that overall bank erosion for the reach may still increase given the lack of bank stabilisation works however, there is potential for seed dispersal to occur on the banks which would provide some bank resilience. The total physical works cost including

20% contingency for this scenario is $1.2M and could be implemented over a 5 year period, with a 5 year maintenance period following completion.

Scenario Three: Medium Level Mitigation.
This scenario provides the mitigation options that should be considered by council to further protect the watercourse from erosion and provide better stability to erosion prone banks while providing a larger ecological corridor and buffer for flora and fauna. The works include further planting, installation of toe protection and riprap for isolated areas and the battering back of some banks. The total physical works cost including 20% contingency for this scenario is $1.9M and could be implemented across a 5-10 period, with a 5 year maintenance period following completion.

Scenario Four: High Level (Best Practice) Mitigation.
This scenario provides the mitigation works that would provide the banks with further protection from erosion and while providing sufficient shade and habitat for flora and fauna. The works include retiring a total of 10m either side of the channel for staged planting and installing erosion protection such as riprap along extended reaches of the upper network. The total physical works cost including 20% contingency for this scenario is $4.3M and could be implemented over a 10 period, with a 5 year maintenance period following completion.

Based on the scenarios described above, it is recommended that Scenario 3 is the chosen option and the described works to be considered for inclusion into the ICMP. Option 4 should be considered for its restorative value and as a longer term solution subject to landowner consent.

Operation and maintenance costs are considered further in this report and vary with each scenario.

Contents

1.0 Assessment Methodology

The assessment was undertaken on Wednesday the 22nd February and consisted of a walkover survey of the 5 km reach. The ArcGIS application Collector was used to collect data in the field. Ecolines (as per the HCC ICMP receiving environment module, HCC 2015) were recorded for reaches of streams that were similar in morphology. The ecoline data schema includes the assessment of upper bank stability using the Pfankuch Bank Stability Assessment (Pfankuch, 1975). The ICMP Data schema does not include the Lower Bank and Bottom (channel) erosion susceptibility assessments. During the assessments the erosion susceptibility of lower banks were assessed with consideration of previous photos (Boffa Miskell, 2015) and previous studies (Coffeys Geotechnics, 2012). Locations were also identified where localised erosion hotspots or bank slumping was observed and GPS photos points recorded.

A total of 10 reaches were identified, based on changes in bank morphology and landform e.g. roads. Figure 1 shows subject reaches and overview.

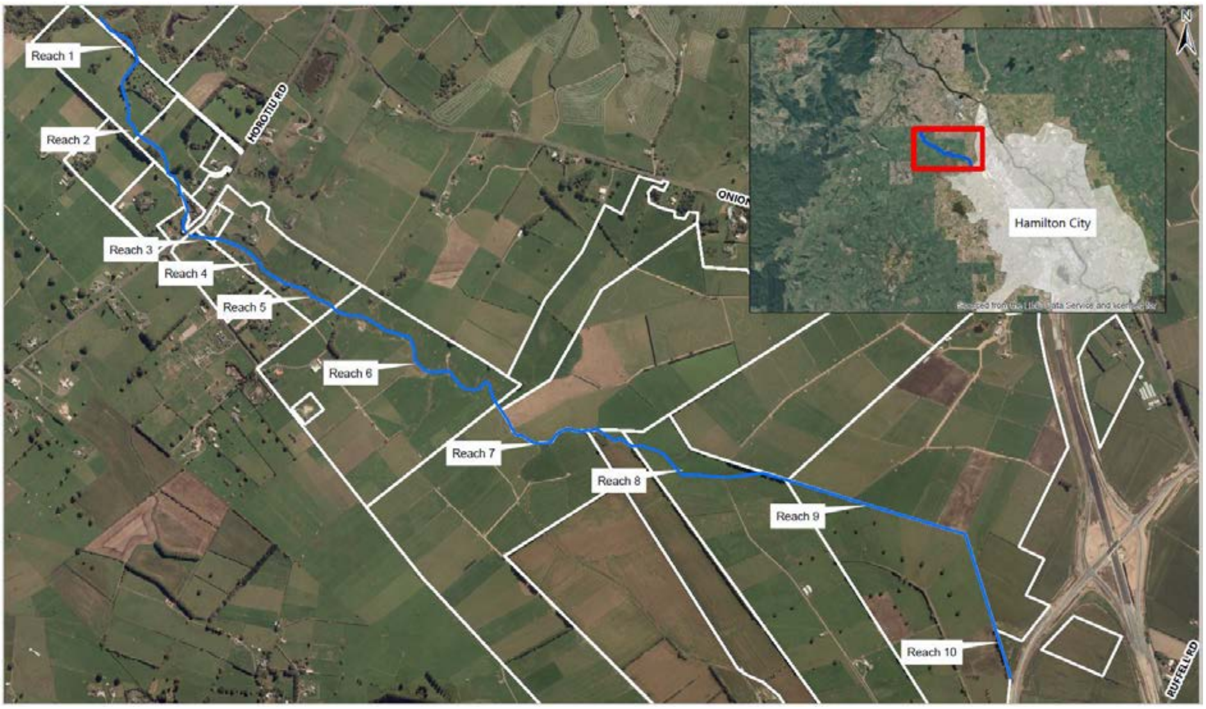

Figure 1 Overview of assessment area and reaches

2.0 Watercourse Function and Capacity

According to NZWERF, the primary function of farm drainage waterways is to lower the water table 30 cm below the soil surface within 24 hours, or 50 cm within 48 hours of a one-year return period, to improve pasture health (NZWERF, 2005). The portion of the Mangaheka Stream located in the Ngaruawahia Drainage Area is administered by WRC's Integrated Catchment Management Directorate (ICM) with a Drainage Board (comprising local land owners within the drainage area) in place to make decisions about operation and maintenance requirements for the drainage system. Maintenance is often undertaken by WRC contractors and will include spraying and the digging out of drains within the drainage area. Weed management is generally undertaken annually within the channel located in the drainage area with aquatic species being targeted by the spray programme that includes spraying the base of the channel (additional spraying maybe undertaken by individual landowners). Blanket spraying can occur which results in the loss of desirable vegetation. It is recommended that for any further spraying required, a spot spraying method should be considered. Furthermore, drain maintenance in the form of channel substrate removal should be limited to 20% of the total stream length per year and rotated over a 5 year period.

Farm drainage systems have ecological value even when they are highly impacted. During the assessment a single 110 mm Longfin eel (*Anguilla dieffenbachii*) was observed, as well as a number of coarse fish species such as Koi carp (*Cyprinus carpio)* and Mosquito fish (*Gambusia affinnis)* along reach 7.

Within the drainage area in the Mangaheka Stream catchment, the primary level of service is to manage groundwater levels to a level to enable rural activities to occur. The secondary level of service is to drain ponded water from a 10 year ARI event within 3 days, so as to ensure pasture damage is avoided. The Mangaheka ICMP – Stormwater 1-D Modelling report (February 2017) carried out by Beca Group (Beca) investigated the effects of development on stream water levels, peak flows and flooding duration at 12 locations along the Mangaheka channel, 3 of which were within the scope of this report (locations 8, 9 and 10; Figure1: Reporting Locations, pg 4 of Beca Report).

2.1 Existing Development Modelled with Climate Change

The results of the Beca modelling indicate that with the existing level of development there will be a 30% increase in flows at the top of Morphum study reach 10 during a 100 year rainfall event as a result of climate change (Table 3: pg 5, Beca Report). When modelled on a 10 year rainfall event at the same location (Location 8 of Beca model), it is expected that there will be an increase of 14% in maximum flow rate in response to climate change.

2.2 Maximum Probable Development Modelled with Climate Change

The results of this modelling show that during a 100 year rainfall event (factoring in climate change), there will be a 39% increase in maximum flow at the top of reach 10 following the completion of proposed developments (Table 3: pg 5, Beca Report). During a 10 year post-development flow increases by 45% of existing development levels to 2.52 m^3/s at the top of reach 10. The drain down times (post maximum probable development and mitigation) for these events at the bottom of the study reaches (Horotui Rd) are 11 hours and 5.5 hours for a 100 year and 10 year event respectively. The current drain down times for the existing development scenario are 8.8 hours and 4.2 hours for a 100 year and 10 year event respectively.

These results show that implementing all proposed mitigation techniques, outlined on page 7 of the Beca Report, will result in peak flows which are at or below existing development water levels. However, there are likely to be residual ongoing effects, of the development on the drainage network, such as increased annual flow volumes and extended duration of peak flows which may exacerbate downstream erosion and scour effects.

2.3 Restoration Vision 2012

The Draft Mangaheka Stream and Drain Network Restoration vision was developed by Boffa Miskell in August 2012 and will be considered for adoption by WRC's ICM directorate and inclusion in the Waipa Zone Management Plan depending on zone prioritisation and availability of budget and resources. . It was intended by the authors of the restoration vision that implementation of the vision would occur within 10 years of 2012. The vision was first developed through the consenting process for the Rotokauri Industrial Development which identifies targeted rates as the primary source of funding. The purpose of the vision is to guide regional and district councils, Tangata whenua and public efforts to help restore and enhance the ecology of the Mangaheka Stream network. Funding for the implementation of the restoration vision has not been determined.

The Restoration vision statement is:

"To restore the lowland stream values of the Mangaheka Stream to a high quality aquatic environment, thereby providing for the long term availability of the stream for existing and potential uses consistent with the concept of sustainable management."

The works described in this report take into account the restoration vision and provide an additional resolution by providing concepts, design geometry and dimension.

3.0 Limitation for assessing costs for remediation works

The following specific limitations are provided as follows:

- Volumes for proposed excavations are approximate for each reach as bank height and channel width are averages for the study reaches as per the walkover assessment and did not involve survey levels just inferred bank angles and lengths to determine volumes.
- Detailed surveying of significant erosion hotspots will be required to accurately cost the proposed remediation works outlined in this memorandum.
- Dimensions for planting areas are approximate and based on:
    - Planting area for Scenario 2 will begin at the margin of the top of bank.
    - Planting areas for Scenarios 3 and 4 will begin on the lower bank margins following any proposed excavations.
    - Fence lines are indicative only. Best practise fencing may lead to straightening of proposed fence lines.

Please note the Reach Percentages are for both banks i.e. 30% of total reach. The supporting other details for costs are included in unit rates Table 2.

4.0 Reach Summaries

The following section provides a high level summary of each reach. Table 1 provides a summary of the reaches assessed.

Table 1 Reach Summary

Reach #	Reach Length (m)	Average Bank Height (m)	Average Erosion Scarring (%)	Erosion Susceptibility	District	Area Management
1	330	0.5	<20	Low	Waipa	Waipa River Zone
2	633	0.5	<20	Low	Waipa	Waipa River Zone
3	20	0.6	<20	Low	Waipa	Waipa River Zone
4	260	0.6	<20	Low	Waipa	Waipa River Zone
5	276	0.6	<20	Low	Waipa	Waipa River Zone
6	800	1.6	<20	Low-Moderate	Waipa	WRC Land Drainage
7	521	1.9	20-40	Moderate	Waipa	WRC Land Drainage
8	458	0.9	<20	Low-Moderate	Waipa	WRC Land Drainage
9	917	1.1	<20	Low-Moderate	Waipa	WRC Land Drainage
10	551	1.5	<20	Low-Moderate	Waipa	WRC Land Drainage

4.1 Reach 1, 2 and 3

Reach 1, 2 and 3 are characterised as low energy, highly depositional wetland environments. The reaches are characterised as wide cushiony floodplains that have approximately 0.5 m of water below the surface. The reaches were assessed to have low susceptibility to erosion given the proximity to upstream development and relatively low grade. The most likely process resulting in erosion is from the disturbance of soil and bank structure caused by stock during grazing of these wetland areas. This is due to the lack of exclusion fences in most of these wetland type areas.

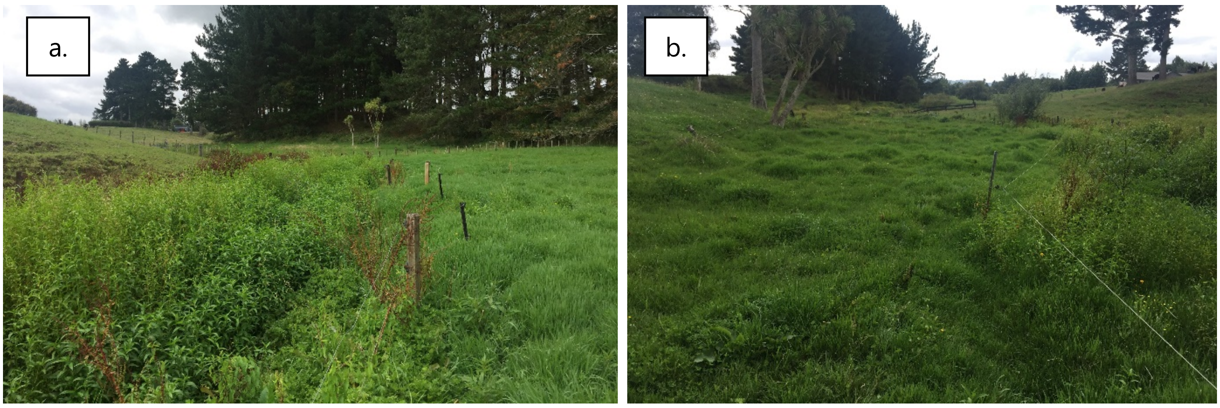

Figure 2: Figure 2a and 2b illustrate the fencing off of the channel along reach 2 however, the surrounding low lying pasture land that is not encompassed within this fence has been identified as a floating wetland type as described above. Figure 2c shows the wetland in panorama.

4.2 Reach 4 and 5

Reach 4 and 5 are both considered as low energy, transport reaches due to the low grade of the incised channel. The low bank height and complete vegetation cover on the flood plain minimise the risk of erosion during inundation from high flows. The susceptibility of these reaches to erosion is therefore considered low as there is little evidence of erosion scarring under current conditions. The lack of fencing along these reaches is a concern as stock are evidently grazing right up to the bank, again increasing the likelihood that bank structure may be compromised and increase localised erosion along these reaches.

Figure 3: Illustration of the grazing pressure along the unfenced reach 5. The far bank (TLB) is not grazed, while the near bank (TRB) has been grazed. Grazing pressure was observed right up to the channel edge.

4.3 Reach 6 and 8

Reach 6 spans the width of the Hancock property and was identified by the Coffey Geotechnic assessment as one of the worst affected areas. This report identifies reach 6 (*Figure 4a and c*) and reach 8 (*Figure 4b*) as low – moderate energy systems as there is an increase in channel grade and localised confinement relevant to the downstream reaches. There is little concern for widespread bank instability under normal conditions however; the proximity of fence posts to the upper bank has become a focal point for localised erosion, mainly caused by overland flow paths during heavy rainfalls. Concentrated stress at these points during high magnitude events could be the source of weak points. In the upstream segments of Reach 6 the bank height increases to 1.6 m and the bank steepens. The changes in bank geometry have resulted in increased signs of bank instability such as slumping of both the upper and lower bank, exacerbating the weak points associated with post positioning at the top of the bank which is likely to require toe protection and bank stabilisation works.

Figure 4: Figures 4a and 4b demonstrate the close proximity of the fencing along reaches 6 and 8 respectively. Figure 4c highlights the issues of fences located too close to the waterways.

4.4 Reach 7

Although not highlighted by the Coffey Geotechnics report as an erosion hotspot, this report notes that Reach 7 is considered a moderate energy system, as the channel grade and proximity to the upstream catchment increase the susceptibility of the channel banks to further erosion. Reach 7 has a highly-incised channel with steep banks. The channel appears to have had the channel excavated which has resulted in banks that are now exposed and in places near vertical and undercut. The bank erosion of this reach can be attributed to removal of channel bed substrate although instabilities have been exacerbated by an increase of ash within the soil. As a result, there are multiple points where bank stabilisation methods may need to be implemented to reduce increased sediment loss in the future and reduce erosion susceptibility.

4.5 Reach 9 and 10

Reach 9 and 10, although highly incised, have been classified as having low to moderate erosion susceptibility due to a stable bank structure and a decrease in channel grade in comparison to reach 7. The drain erosion assessment carried out by Coffey Geotechnics in 2012 identifies these reaches as one of the worst affected areas of the Mangaheka Stream, which aligns with the findings of this report. Slumping of the upper bank is evident in some locations, although the primary cause of this instability appears to be the alignment of the fence in relation to the bank edge in conjunction with very steep near vertical channel banks. Steep banks may have been exacerbated by spraying or where the steepness in the bank has resulted in conditions where grass has not been able to establish in the summer months. The instabilities of the upper bank are extensive along both reaches and may require a high level of remediation in the form of channel reshaping due to the proximity of the reach to the upstream development.

Figure 5: Figure 5a and 5c indicate the typical channel form along reaches 9 and 10 respectively. Figure 5b and 5d illustrate upper bank instabilities along reaches 9 and 10 caused by steep bank angles and poor fence alignment.

5.0 Programme of Works Scenarios and Costs

Four scenarios are developed as part of this programme of works with varying mitigation efforts. Planting in the scenarios are supported by Figure 6. All scenarios will need to be designed to allow the continued function of the drainage system by lowering the water table of surrounding fields to ensure the pasture health of these fields is not compromised during high magnitude rainfalls that may result in surface flooding.

These scenarios have been developed with the consideration that the works are proposed on private land and both WRC and HCC want to minimise any impacts to landowners including the loss of grazing land. Additionally this is not detailed design but high level costs of scenarios only and it is anticipated a detailed design process should be undertaken prior to any works being undertaken.

5.1 Do nothing (Scenario 1)

Maintain current management regime. No mitigation works will likely result in increased erosion, bank slumping and loss of land through the Mangaheka Stream network.

5.2 Low level Mitigation (Scenario 2)

This scenario provides the minimum mitigation works that Council should consider for the Mangaheka Stream network. The works include planting that aim to support top of bank stability and isolated reinforcement with toe protection using appropriately sized riprap. It should be noted that overall bank erosion for the reach may still increase given the lack of bank stabilisation works however, there is potential for seed dispersal from the newly planted areas to occur on the banks which would provide some bank resilience.
The works include:

1. Retiring 3 m either side of the stream from farm land to riparian buffer.
2. Plant retired land using type 1a as per Table 2.
3. Fencing the outer perimeter of the planted area.
4. Installing erosion protection for isolated areas identified during the site visit.

5.3 Medium Level Mitigation (Scenario 3)

This scenario provides the mitigation options that should be considered by council to further protect the watercourse from erosion and provide better stability to erosion prone banks while providing a larger ecological corridor and buffer for flora and fauna. The works include:

1. Retiring 5 m either side of the stream from rural land to riparian buffer.
2. Plant first 3 m of retired land using planting type 1b as per Table 2.
3. Plant remaining 2 m strip of retired land using planting type 2 as per Table 2.
4. Fencing the outer perimeter of the planted area.
5. Installing erosion protection for isolated areas identified during the site visit.
6. Battering back banks for sections of reaches that require increased stabilisation.

5.4 High Level (Best Practice) Mitigation (Scenario 4)

This scenario provides the mitigation works that would provide the banks with further protection from erosion and while providing sufficient shade and habitat for flora and fauna. The works include:

1. Retiring a total of 10 m (or where the natural floodplain extends to, such as the upper banks of reaches 1, 2 and 3) from rural to riparian buffer.
2. Plant first 3 m of retired land using planting type 1b as per Table 2.

3. Plant 2 m of retired land strip using planting type 2 as per Table 2.
4. Plant the remaining 5 m outer strip of retired land using planting type 3 as per Table 2.
5. Fencing the outer perimeter of the planted area.
6. Battering back banks for sections of reaches that require increased stabilisation.
7. Installing erosion protection for extended areas of reach 7, 9 and 10 and isolated areas of reach 6 and 8.

6.0 Cost and unit rates for mitigation options

The following rates are based on schedules of works and quotes from the last 5 years in the Auckland market. The rates are therefore considered conservative but should take into account upwards price pressure in the immediate future. The final costings should be considered as indicative only. A pricing activity of erosion mitigation works should occur during detailed designs. It is anticipated that these costs are considered by council to inform a funding request and are limited in that no detailed design work was done.

Table 2 Cost and unit rates

Mitigation	Unit	Cost	Assumptions and exclusions
Erosion Protection	m	$50	Assumes use of 0.25m^3 of rock per linear metre. At $200 per m^3; This includes isolated toe protection and bank stabilisation using riprap.
Type 1a Carex Planting at 3 plants per m^2	m^2	$21.40	Includes boom spray of glyphosate single application; Planting at 4 plants per m^2. Carex and Juncas; Plant grade PB3s; Assumes team of 6 planting 350 plants each per day; Cost includes portaloo hire, quad and trailer hire, and fertiliser.
Type 1b Carex Planting at 4 plants per m^2	m^2	$28.50	Includes boom spray of glyphosate single application; Planting at 3 plants per m^2. Carex and Juncas; Plant grade PB3s; Assumes team of 6 planting 350 plants each per day; Cost includes portaloo hire, quad and trailer hire, and fertiliser.
Type 2 Monocot* Planting at 1 plant per m^2	m^2	$7.25	Includes boom spray of glyphosate single application; Planting at 1 plant per m^2, Carex, toetoe, flax and cabbage tree; Plant grade: PB3s; Assumes team of 6 planting 350 plants each per day; Cost includes portaloo hire, quad and trailer hire, and fertiliser.
Type 3 Native Planting at 1 plant per m^2	m^2	$7.25	Includes boom spray of glyphosate single application; Planting at 1 plant per m^2, Carex, toetoe, flax and cabbage tree; Plant grade: PB3s; Assumes team of 6 planting 350 plants each per day; Cost includes portaloo hire, quad and trailer hire, and fertiliser.
Fencing	m	$7.50	7 wire fence with 5m posting.
Bank batter	m^3	$70	$50/m^3 for excavation; $20/m^3 for haulage away from site and disposal to clean fill; Does not include setting up diversions/erosion and sediment control; Assumes 45° banks.
Grazing land lost	m^2	$0.38	Based on 10% of average land sale cost in Waikato Region as reported by REINZ 2016; 10% assumes land lease rather than sale; http://www.interest.co.nz/rural/resources/farm-sales.

*Indicative Monocot species include Flax and ToeToe.

Figure 6 provides the indicative planting arrangements using the types in for Scenario 2, 3 and 4.

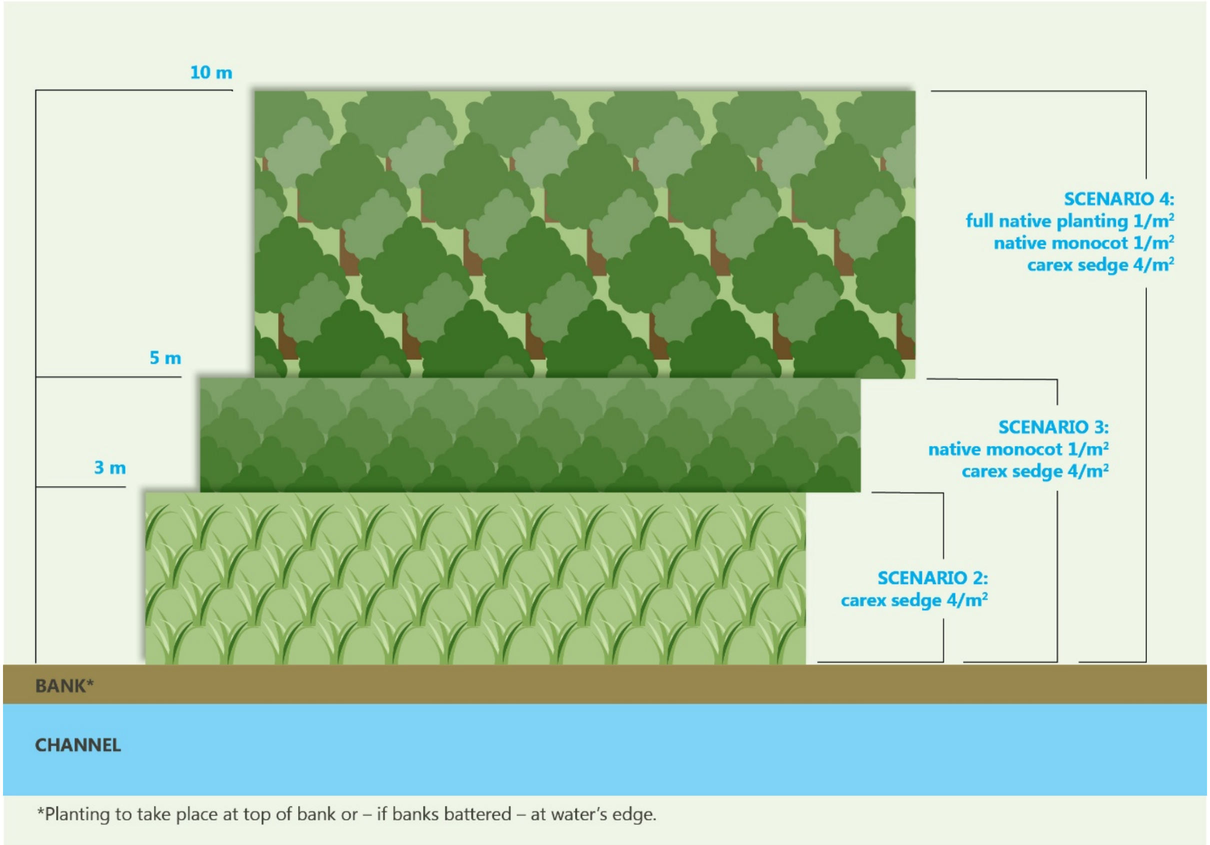

Figure 6 Scenario 2, 3 and 4 Planting Plan

Table 3, Table 4 and Table 5 provide the cost estimates for scenarios 2, 3 and 4 respectively.

Table 3 Scenario 2 Erosion Mitigation Works and Costs

Reach number	Planting Total	Fencing Perimeter	Erosion Protection		Batter Banks		Grazing Land Cost	Detailed Design	Totals
			%	Cost	%	Cost			
1	$ 57,120	$ 5,110		$ -		$ -		$60,000	
2	$ 108,946	$ 9,645		$ -		$ -			
3	$ 14,309	$ 1,361		$ -		$ -			
4	$ 44,735	$ 4,038		$ -		$ -			
5	$ 47,889	$ 4,303		$ -		$ -			
6	$ 137,482	$ 12,152	5%	$ 2,000		$ -			
7	$ 89,798	$ 7,979	10%	$ 2,605		$ -			
8	$ 79,387	$ 7,060	10%	$ 2,290		$ -			
9	$ 157,482	$ 13,911	10%	$ 4,585		$ -			
10	$ 95,127	$ 8,443	10%	$ 2,755		$ -			
Sub total	**$ 832,273**	**$ 74,001**		**$ 14,235**				**$60,000**	**$ 920,509**
Total including contingency 20%									**$1,176,611**

Table 4 Scenario 3 Erosion Mitigation Works and Costs

Reach number	Planting Total	Fencing Perimeter	Erosion Protection		Batter Banks		Grazing Land Cost	Detailed Design	Totals
			%	Cost	%	Cost			
1	$ 85,856	$ 5,181		$ -		$ -		$80,000	
2	$ 219,253	$ 10,643		$ -		$ -			
3	$ 47,153	$ 2,401		$ -		$ -			
4	$ 67,111	$ 4,091		$ -		$ -			
5	$ 71,941	$ 4,377		$ -		$ -			
6	$ 206,355	$ 12,208	10%	$ 4,000	10%	$ 4,298			
7	$ 134,792	$ 8,039	30%	$ 7,815	50%	$ 48,190			
8	$ 119,195	$ 7,131	10%	$ 2,290	10%	$ 779			
9	$ 236,454	$ 13,987	30%	$ 13,755	30%	$ 12,436			
10	$ 142,920	$ 8,518	30%	$ 8,265	30%	$ 19,059			
Sub total	**$ 1,331,030**	**$ 76,575**		**$ 36,125**		**$ 84,760**		**$80,000**	**$1,608,490**
Total including contingency 20%									**$1,930,188**

Table 5 Scenario 4 Erosion Mitigation Works and Costs

Reach number	Planting Total	Fencing Perimeter	Erosion Protection %	Erosion Protection Cost	Batter Banks %	Batter Banks Cost	Grazing Land Cost	Detailed Design	Totals
1	$ 254,828	$ 5,977		$ -		$ -	$ 5,752	$100,000	
2	$ 235,094	$ 10,711		$ -		$ -	$ 11,323		
3	$ 105,668	$ 2,486		$ -		$ -	$ 2,416		
4	$ 156,998	$ 5,015		$ -		$ -	$ 4,886		
5	$ 260,472	$ 5,039		$ -		$ -	$ 4,056		
6	$ 376,867	$ 14,075	30%	$ 12,000	50%	$ 21,489	$ 13,485		
7	$ 180,899	$ 8,212	30%	$ 7,815	90%	$ 86,741	$ 3,940		
8	$ 278,077	$ 7,291	30%	$ 6,870	50%	$ 3,893	$ 3,582		
9	$ 260,101	$ 14,143	30%	$ 13,755	90%	$ 37,307	$ 6,993		
10	$ 1,201,855	$ 8,724	50%	$ 24,795	90%	$ 57,176	$ 4,898		
Sub total	**$ 3,310,860**	**$ 81,674**		**$ 54,215**		**$ 206,606**	**$ 61,331**		**$ 3,608,080**
Total including contingency 20%									**$ 4,329,696**

6.1 Capital Cost Summary

The costs outlined in Tables 2,3 and 4 are summarised by costs below:

- The physical works costs (including a 20% contingency) for Scenario 2 is $1,176,611.
- The physical works costs (including a 20% contingency) for Scenario 3 is $1,930,188.
- The physical works costs (including a 20% contingency) for Scenario 4 is $4,329,696.

These costs are physical works costs with additional 20% contingency. They do not include design and feasibility, resource consents, defects liability or operations and maintenance fees. These additional costs have been included in the scenario 3 costing table (Table 7) in Appendix B.

6.2 Operation and Maintenance Costs

Years 1 and 2 (post works completion) should be included as part of the capital works defects liability. It is assumed this would include:

- 10% of capital projects cost,
- Annual plant maintenance costs as per Table 6,
- Post works sign off walkover,
- Six months follow up walkover,
- Annual walkover assessment.

Years 3 and 4 costs should include:

- Annual plant maintenance costs as per Table 6 with reduced visit frequency to 3 per year,
- Annual walkover assessment,
- Full assessment of reach in the third year and update the concept programme of works.

Years 5 + cost should include:

- Annual plant maintenance costs as per Table 6 with reduced visit frequency to 2 per year,
- Annual walkover assessment,
- Full assessment of reach every three years and update the concept programme of works.

Table 6 Annual Planting Maintenance per year

Scenario	Area (m^2)	Days per visit	Year 1 and 2		Year 2 and 3		Years 5 +	
			visits per year	Cost per year	visits per year	Cost per year	Visits per year	Visits per year
Scenario 2	38,891	**4**	4	$23,040	3	$17,280	2	$11,520
Scenario 3	69,599	**7**	4	$40,320	3	$30,240	2	$20,160
Scenario 4	171,049	**17**	4	$97,920	3	$73,440	2	$48,960

Assumptions of costs in Table 6 include:

- 10,000m^2 per day;
- Team of 4 spot spraying and hand releasing;

- $45 per hour per person;
- 4 visits per year;
- Totals are for one year only.

6.3 Implementation Timeline

It is understood that implementation may occur over a long term period given that the development of the Mangaheka industrial area is due to be completed over 20 years. The following gives an indication on timeframes for implementation:

- Scenario 2 – 5 year implementation plus 5 year maintenance;
- Scenario 3 – 5-10 year implementation plus 5 year maintenance;
- Scenario 4 – 10 year implementation plus 5 year maintenance.

7.0 References

Boffa Miskell (2015). Images provided following August 2015 Site Visit.

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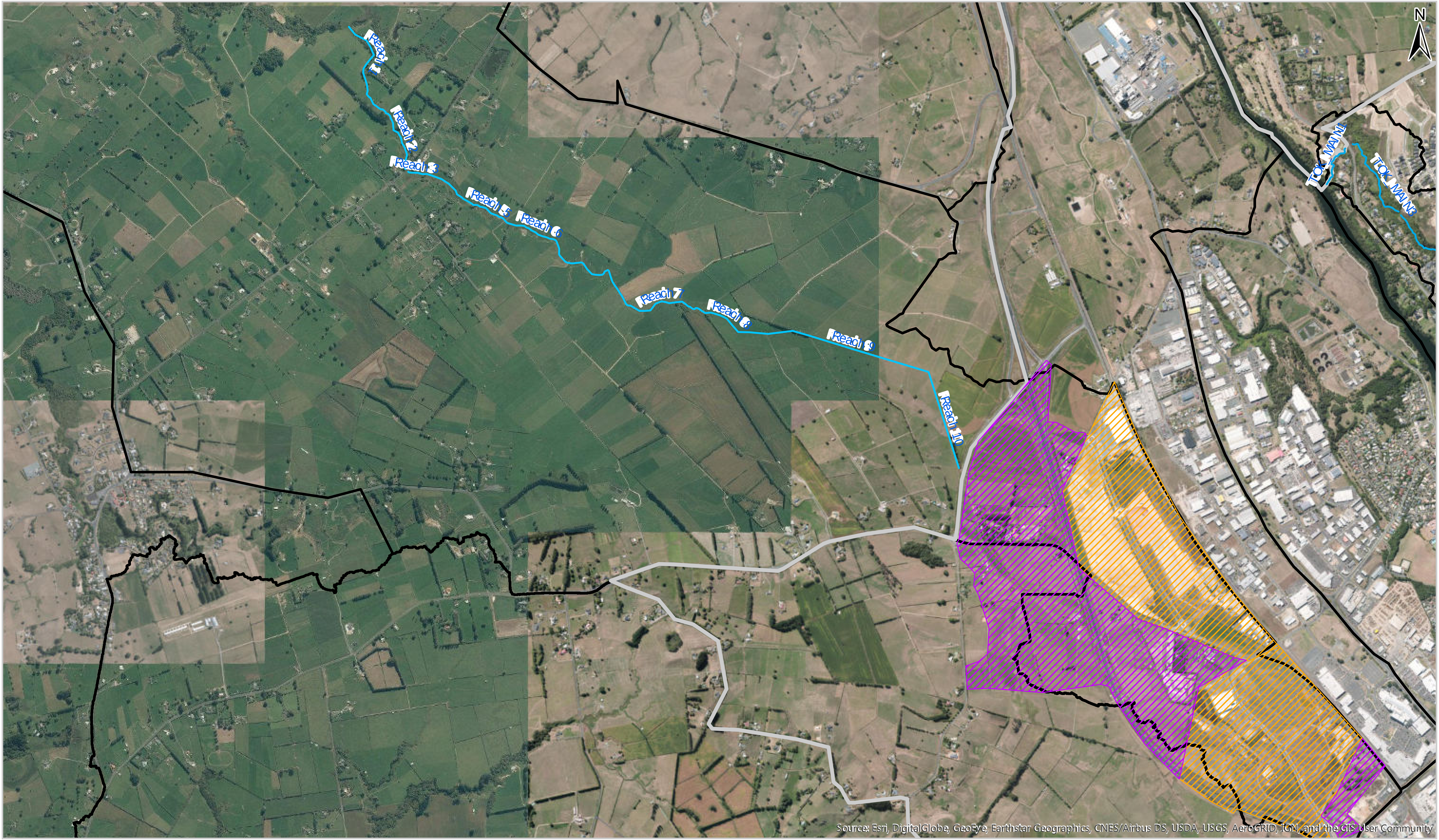
Appendix 1 Greenfields and Assessment Map

Mangakeha Assessment Reaches and Greenfield Areas



Mangaheka Greenfields

- Consented
- Unconsented

- Hamilton City Boundary
- Hamilton City Catchments
- Mangaheka Ecoline

0 1 2 km

Client Hamilton City Council

Project **Mangaheka Erosion Assessment**

Project no. P01103

Date 16 May 2017

Drawn ER

Approved CU

Appendix 2 Greenfields Development Contribution

The projects are intended to provide a high level cost of identified remedial and restoration works within the subject reaches. Proportional cost estimates are provided to assist in calculating appropriate financial contributions to mitigate stormwater effects within the stream associated with new development. The subject of this memo is specifically the residual effects of the development in Mangaheka.

The project contribution costs have been estimated for Scenario 3.

The total cost of projects identified in the subject reaches of the Mangaheka Stream is $2,437,491. Proportional cost estimates (based on contributing catchment area of the greenfields site) associated with effects of the proposed development for remediation and prevention is $1,554,143 which accounts for 2,856 per Ha.

Limitations

Project identification was restricted to existing and potential erosion issues and does not include additional water quality, ecological enhancement, or amenity value aspects of identified projects or of any separate projects. It should be noted that some erosion mitigation physical works may result in a net adverse impact on ecological values.

A planning assessment has not been undertaken and the following have not been considered in the identification of projects:

- HCC and WRC objectives and policies;
- Consent requirements to implement identified projects;
- Legislative framework regarding financial contributions;
- Other HCC strategic plans (including Gully Management).

Projects identified are intended for consideration of offset of any residual impacts and all appropriate measures should be taken on site to avoid, or minimise potential downstream impacts (in accordance with the appropriate consented stormwater treatment design).

These projects are also not intended to be used as offset mitigation for the loss of any stream values on site.

It is recommended that a detailed options analysis and planning assessment is conducted at a later date including ecological assessment and concept design of remediation and prevention options to inform capital works, which will require site assessment.

Growth and Development Proportions

The projects identified aim to support resilience against erosion including both exacerbation of existing erosion issues, and potential erosion in currently stable (or artificially stabilised) reaches associated with upstream development.

The extent of influence from increased stormwater volume from Mangaheka Catchment within the HCC boundary on erosional effects downstream reduces with distance downstream due to increasing influence from the wider catchment.

A summary of the total cost for each identified project and potential contributing costs is provided below.

Table 7 Apportioning Cost Based on Contributing Catchment

Tributary Name	Physical Works Cost	Total Cost*	Upstream Catchment Area (Ha)**	Upstream Greenfield Area (Ha)***	% Greenfield as Total Area	Cost Proportional to Greenfield Area
Reach 1	$91,036	$144,536	1124	544.2	48%	$69,991
Reach 2	$229,896	$381,864	1068	544.2	51%	$194,668
Reach 3	$49,554	$86,411	1068	544.2	51%	$44,051
Reach 4	$71,202	$112,992	1007	544.2	54%	$61,085
Reach 5	$76,318	$121,157	1007	544.2	54%	$65,499
Reach 6	$226,860	$359,158	1007	544.2	54%	$194,164
Reach 7	$198,835	$309,374	916	544.2	59%	$183,795
Reach 8	$129,394	$205,065	740	544.2	74%	$150,863
Reach 9	$276,632	$436,187	740	544.2	74%	$320,896
Reach 10	$178,762	$280,748	568	544.2	96%	$269,131
Total	**$1,528,490**	**$2,437,491**				**$1,554,143**
				Per Ha Rate		**$2,856**

**Cost includes Design and Feasibility (10% of physical works), Resource Consent fees (3% of physical works), defects liability (10% of physical works), 20% contingency and 5 year maintenance costs.*

***Upstream catchment areas are taken from the Beca Mangaheka Integrated Catchment Management Plan - Stormwater 1D Modelling Report.*

****This is based on 544.2 ha of greenfields land in upper Mangaheka catchment which includes consented and unconsented land.*