Appendix A Structure Plan and Catchment Extent

NOTE: Topographic ICMP boundary is based on 2008 LiDAR. Fringe development may discharge to this or adjacent catchments as a result of earthworks and network design. In this case HCC shall be consulted to determine which ICMP shall apply.

Legend

Topographic Catchment

City Boundary

Rev.	By	App.	Description	Date

Notes:

Printed	26 May 2014 11:28		
Approved	-	Date	-
Designed	-	Checked	-
Drawn	-	Checked	-
File Name	001 TAOK ICMP Topo Catchment		

Map features depicted in terms of NZTM projection.

Data Sources:
NZ Topographical Features – LINZ NZ National Topo Dataset 2006
Cadastral Boundaries – LINZ NZ Cadastral Dataset 2007

AECOM

Project: TE AWA O KATAPAKI ICMP

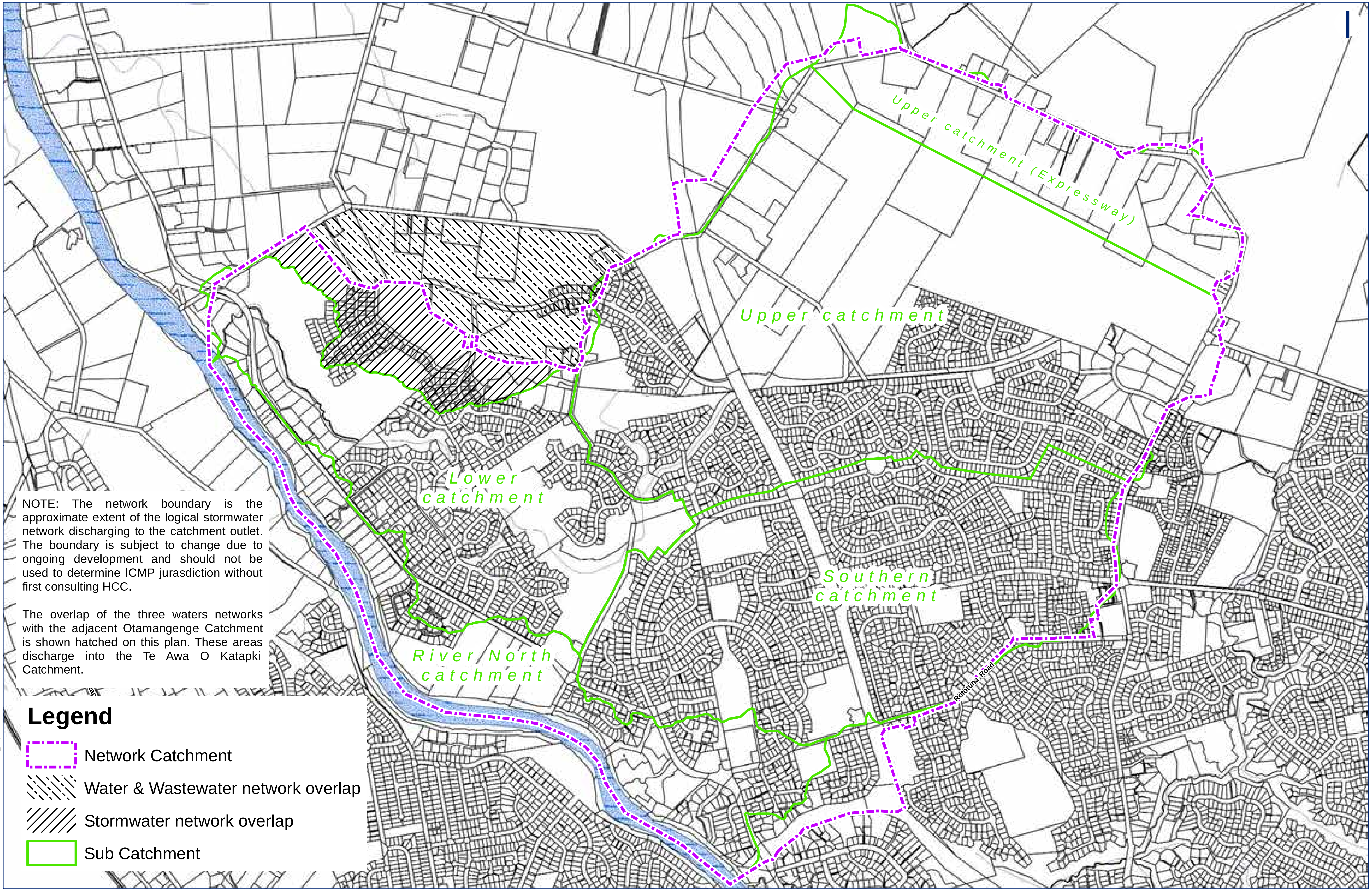
Title: Catchment Boundary Plan

Scale: Scale: 1:16,000 (A3 size) 200 100 0 200 400 Metres

Status: FINAL

Map No. 001

Rev. A



16 Mar 2015 16:32

P:\603X\60305986\4. Tech work area\4.99 GIS\02_Maps\01 General\TAOK\002 TAOK ICMP Sub Catchments.mxd

Rev.	By	App.	Description	Date

Notes:

Printed	26 May 2014 11:28		
Approved	-	Date	-
Designed	-	Checked	-
Drawn	-	Checked	-
File Name	002 TAOK ICMP Sub Catchments		

Map features depicted in terms of NZTM projection.

Data Sources:
NZ Topographical Features – LINZ NZ National Topo Dataset 2006
Cadastral Boundaries – LINZ NZ Cadastral Dataset 2007

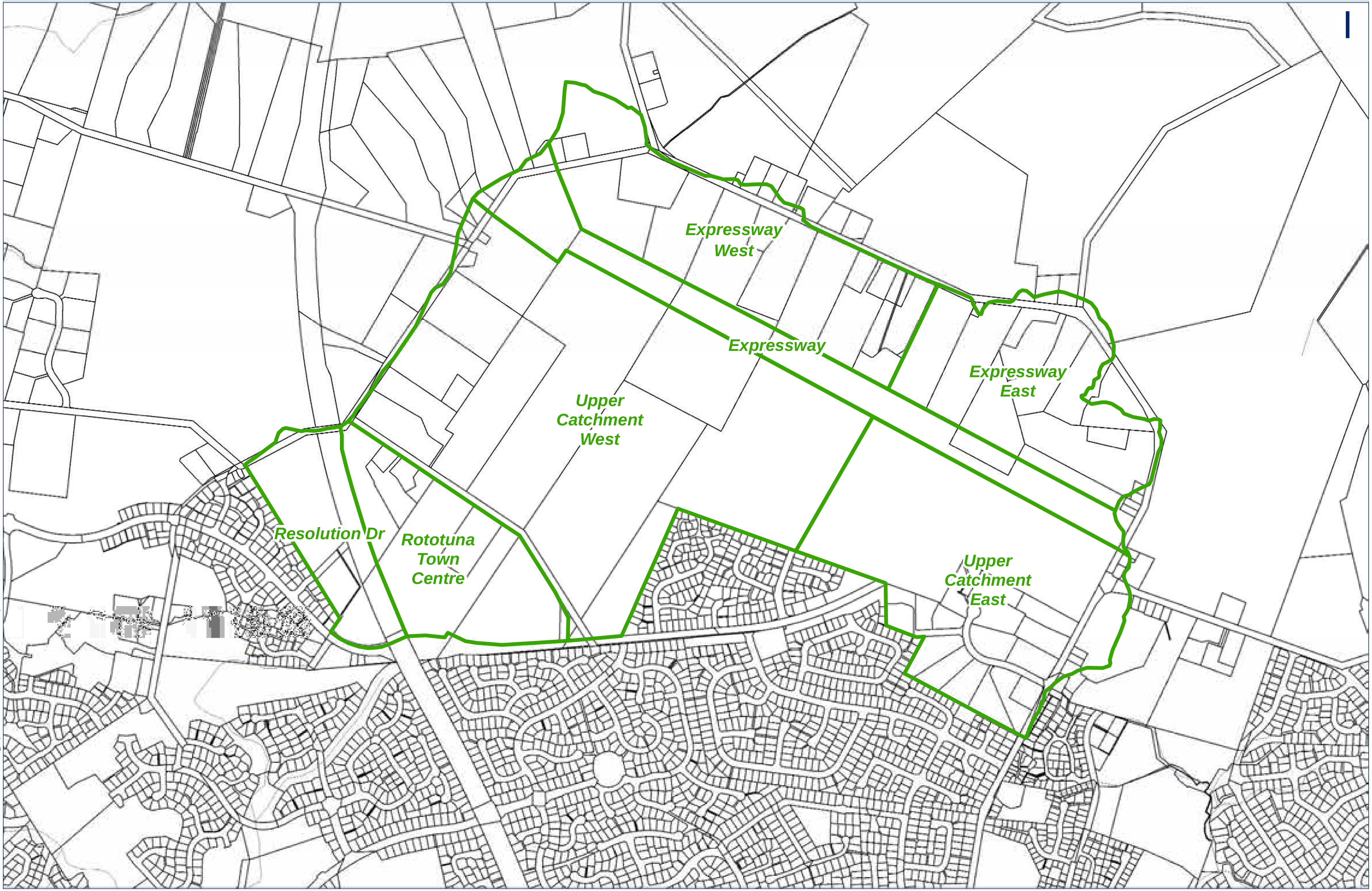
AECOM

Project: **TE AWA O KATAPAKI ICMP**

Title: **Subcatchment Boundary Plan**

Scale: Scale: 1:15,000 (A3 size) — 200 100 0 200 400 Metres

Status: FINAL | Map No. 002 | Rev. A



12 Mar 2015 13:41

P:\603X\60305986\4. Tech work area\4.99 GIS\02_Maps\01 General\TAOK\003 TAOK ICMP Undeveloped Catchments.mxd

Rev.	By	App.	Description	Date

Notes:

Printed	26 May 2014 11:28		
Approved	-	Date	-
Designed	-	Checked	-
Drawn	-	Checked	-
File Name	003 TAOK ICMP Undeveloped Catchments		

Map features depicted in terms of NZTM projection.

Data Sources:
NZ Topographical Features – LINZ NZ National Topo Dataset 2006
Cadastral Boundaries – LINZ NZ Cadastral Dataset 2007

AECOM

Undeveloped Catchments

Parcel

Project: TE AWA O KATAPAKI ICMP

Title: Undeveloped Stormwater Subcatchments Plan

Scale: Scale: 1:10,000 (A3 size)

200 100 0 200 Metres

Status: FINAL

Map No. 003

Rev. A

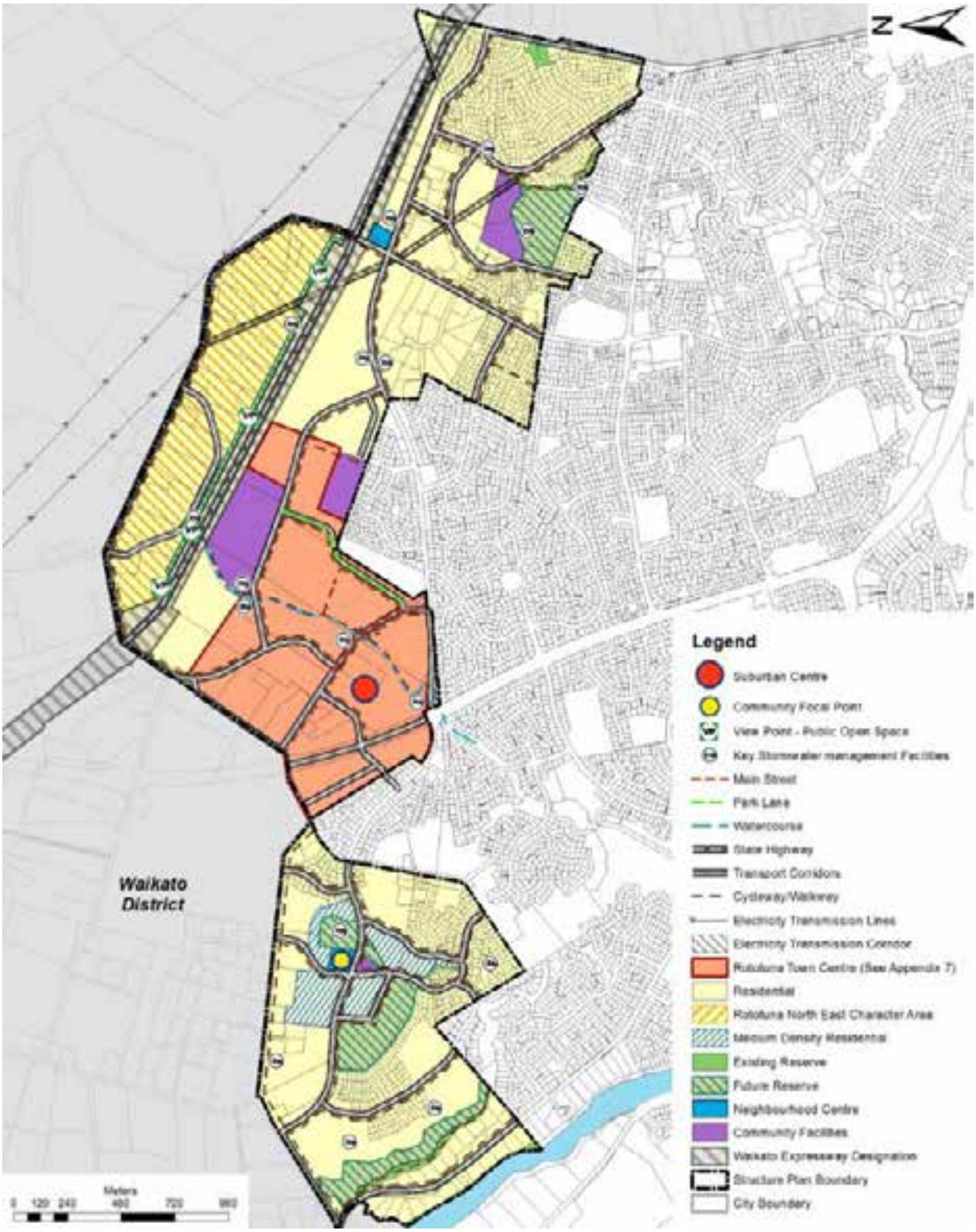
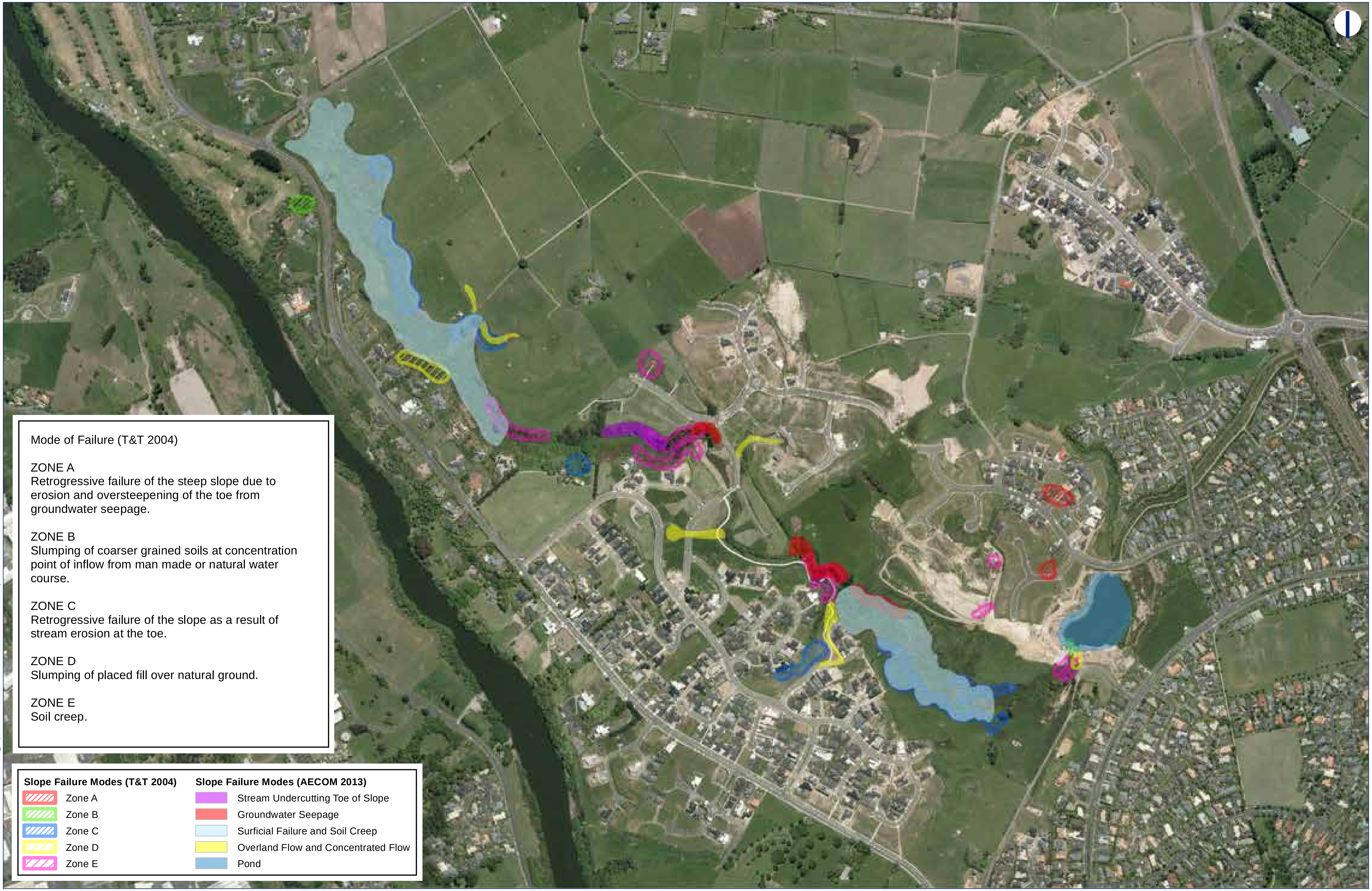


Figure 32 – Rototuna Structure Plan

Appendix B Catchment characteristics plans



27 Feb 2015 14:04

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Rev.	By	App.	Description	Date

Notes:

Printed	26 May 2014 11:28		
Approved	-	Date	-
Designed	-	Checked	-
Drawn	-	Checked	-
File Name	004 TAOK ICMP Erosion and stability		

Map features depicted in terms of NZTM projection.

Data Sources:
NZ Topographical Features – LINZ NZ National Topo Dataset 2006
Cadastral Boundaries – LINZ NZ Cadastral Dataset 2007

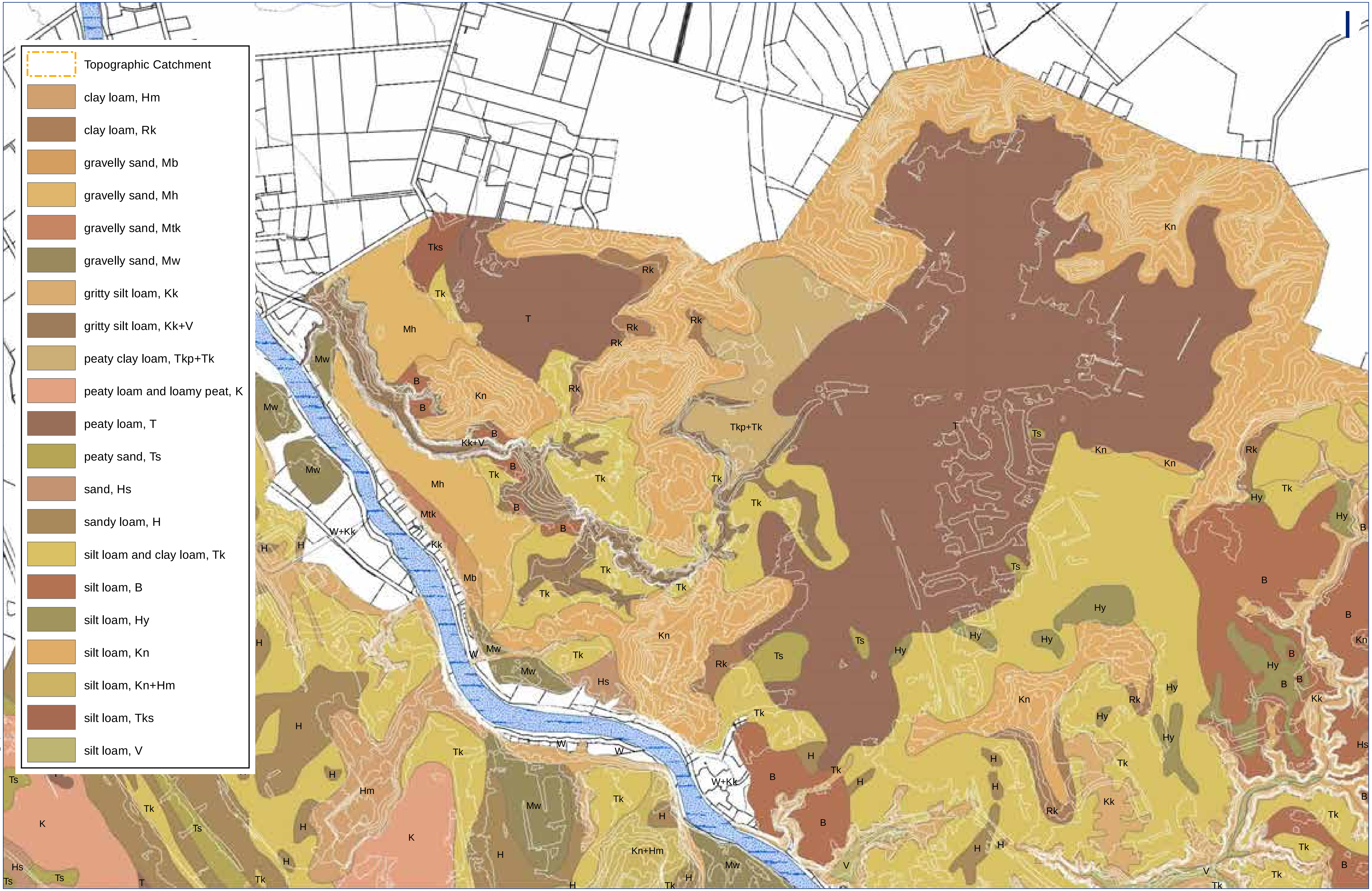
AECOM

Project: TE AWA O KATAPAKI ICMP

Title: Erosion & Stability Plan

Scale: Scale: 1:7,500 (A3 size) 200 100 0 Metres

Status: FINAL | Map No. 004 | Rev. A



26 Feb 2015 09:29

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Rev.	By	App.	Description	Date

Notes:

Printed	26 May 2014 11:28		
Approved	-	Date	-
Designed	-	Checked	-
Drawn	-	Checked	-
File Name	005 TAOK ICMP Soils		

Map features depicted in terms of NZTM projection.

Data Sources:
NZ Topographical Features – LINZ NZ National Topo Dataset 2006
Cadastral Boundaries – LINZ NZ Cadastral Dataset 2007

AECOM

Project: TE AWA O KATAPAKI ICMP

Title: Soil types Plan

Scale: Scale: 1:15,000 (A3 size) 200 100 0 Metres

Status: FINAL | Map No. 005 | Rev. A

13 Mar 2015 16:55

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Rev.	By	App.	Description	Date

Notes:

Printed	26 May 2014 11:28		
Approved	-	Date	-
Designed	-	Checked	-
Drawn	-	Checked	-
File Name	006 TAOK ICMP Velocity		

Map features depicted in terms of NZTM projection.

Data Sources:
NZ Topographical Features – LINZ NZ National Topo Dataset 2006
Cadastral Boundaries – LINZ NZ Cadastral Dataset 2007

AECOM

Project: TE AWA O KATAPAKI ICMP

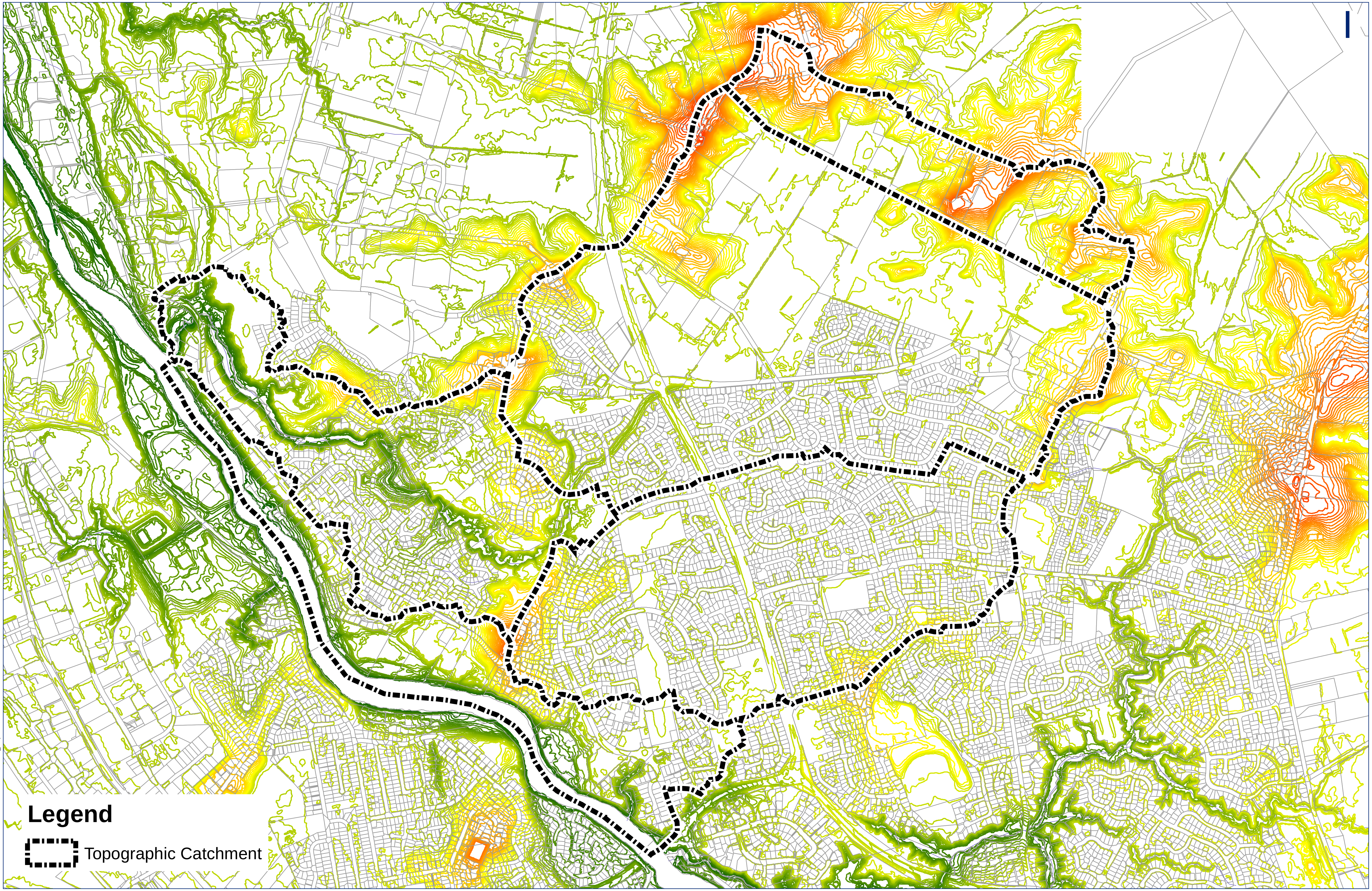
Title: Erosion & Stability Plan

Scale: Scale: 1:7,500 (A3 size) 200 100 0 Metres

Status: FINAL

Map No. 006

Rev. A



P:\603X\60305986\4. Tech work area\4.99 GIS\02_Maps\01 General\TAOK\008 TAOK ICMP Contours.mxd

12 Mar 2015 13:49

Rev.	By	App.	Description	Date

Notes:

Printed	26 May 2014 11:28		
Approved	-	Date	-
Designed	-	Checked	-
Drawn	-	Checked	-
File Name	008 TAOK ICMP Contours		

Map features depicted in terms of NZTM projection.

Data Sources:
NZ Topographical Features – LINZ NZ National Topo Dataset 2006
Cadastral Boundaries – LINZ NZ Cadastral Dataset 2007

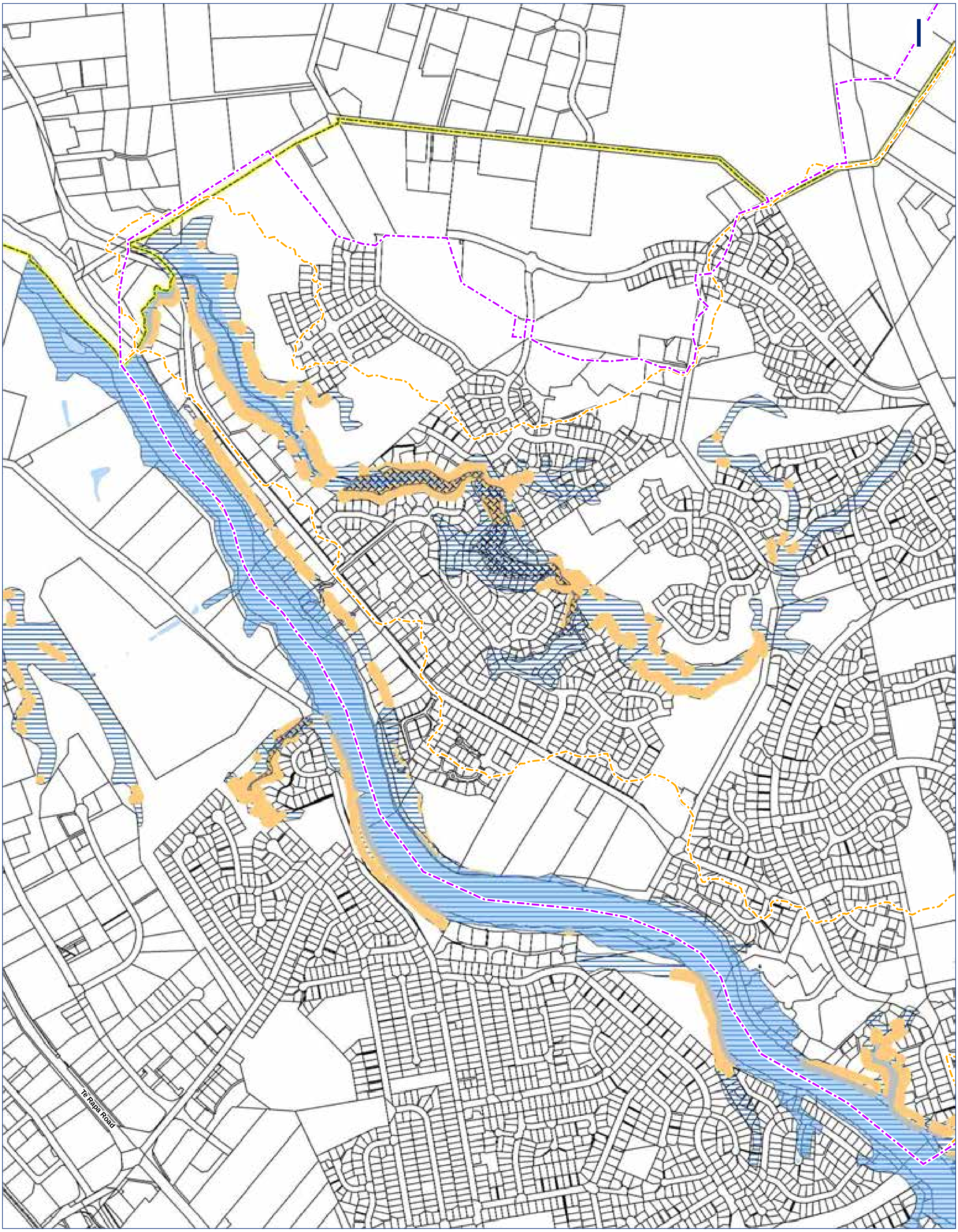
AECOM

Project: **TE AWA O KATAPAKI ICMP**

Title: **Topography Plan**

Scale: Scale: 1:16,000 (A3 size) 200 100 0 200 400 Metres

Status: FINAL | Map No. 008 | Rev. A



P:\603X\60305986\4. Tech work area\4.99 GIS\02_Maps\01 General\TAOK\009 TAOK ICMP Environmental Protection Overlay.mxd

27 Feb 2015 14:09

EPO - HCC Culvert Block and Associated Flooding Zones	Parcel
EPO - Flood Susceptibility Zone	Topographic Catchment
Gully Slopes <25	Network Catchment
Gully Slopes >25 (and 10m Buffer Zone)	City Boundary

Project: **TE AWA O KATAPAKI ICMP**

Title: **Environmental Protection Overlay - Component Layers Plan**

Scale: Scale: 1:10,000 (A3 size)   200 100 0 200 Metres

Status: DRAFT   Map No. 009   Rev. A

Rev.	By	App.	Description	Date

Notes:

Printed	26 May 2014 11:28		
Approved	-	Date	-
Designed	-	Checked	-
Drawn	-	Checked	-
File Name	009 TAOK ICMP Environmental Protection Overlay		

Map features depicted in terms of NZTM projection.

Data Sources:
NZ Topographical Features – LINZ NZ National Topo Dataset 2006
Cadastral Boundaries – LINZ NZ Cadastral Dataset 2007

AECOM

Appendix C Strategic infrastructure plans

31 Jul 2017 16:04

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Rev.	By	App.	Description	Date

Notes:

Printed	26 July 2017		
Approved	-	Date	-
Designed	-	Checked	-
Drawn	-	Checked	-
File Name	010 TAOK ICMP Water		

Map features depicted in terms of NZTM projection.

Data Sources:
NZ Topographical Features – LINZ NZ National Topo Dataset 2006
Cadastral Boundaries – LINZ NZ Cadastral Dataset 2007

AECOM

Project: TE AWA O KATAPAKI ICMP

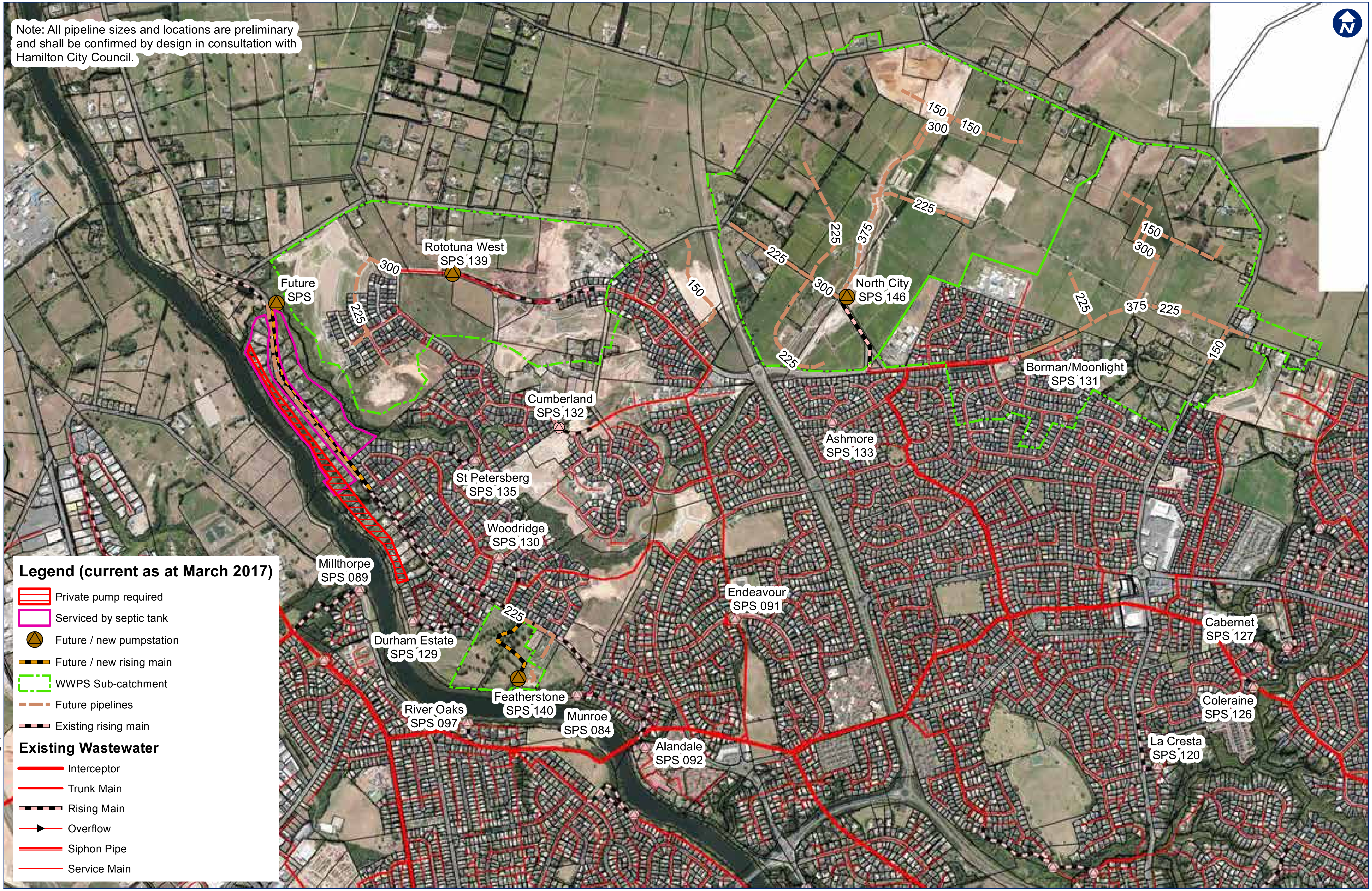
Title: Water Plan

Scale: Scale: 1:12,500 (A3 size) — 200 100 0 200 400 Metres

Status: FINAL

Map No. 010

Rev. A



Rev.	By	App.	Description	Date

Notes:

Printed	26 July 2017		
Approved	-	Date	-
Designed	-	Checked	-
Drawn	-	Checked	-
File Name	011 TAOK ICMP Wastewater		

Map features depicted in terms of NZTM projection.

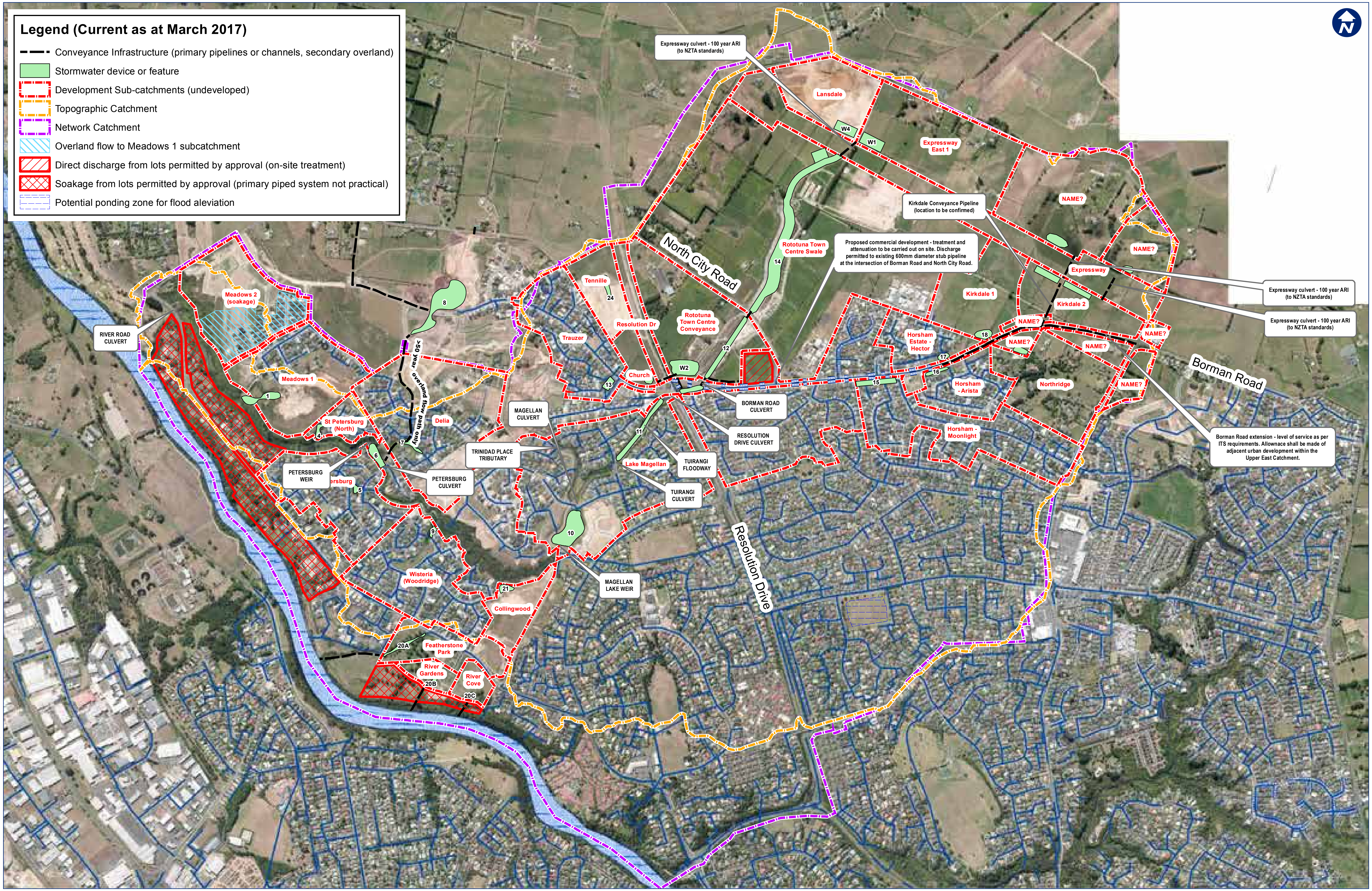
Data Sources:
NZ Topographical Features – LINZ NZ National Topo Dataset 2006
Cadastral Boundaries – LINZ NZ Cadastral Dataset 2007

Project: TE AWA O KATAPAKI ICMP

Title: Wastewater features Plan

Scale: Scale: 1:15,000 (A3 size) 200 100 0 200 400 Metres

Status: FINAL | Map No. 011 | Rev. A



16 Oct 2018 16:40

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Rev.	By	App.	Description	Date

Notes:

Printed	27 July 2017		
Approved	-	Date	-
Designed	-	Checked	-
Drawn	-	Checked	-
File Name	012 TAOK ICMP Stormwater		

Map features depicted in terms of NZTM projection.

Data Sources:
NZ Topographical Features – LINZ NZ National Topo Dataset 2006
Cadastral Boundaries – LINZ NZ Cadastral Dataset 2007

AECOM

Project: TE AWA O KATAPAKI ICMP

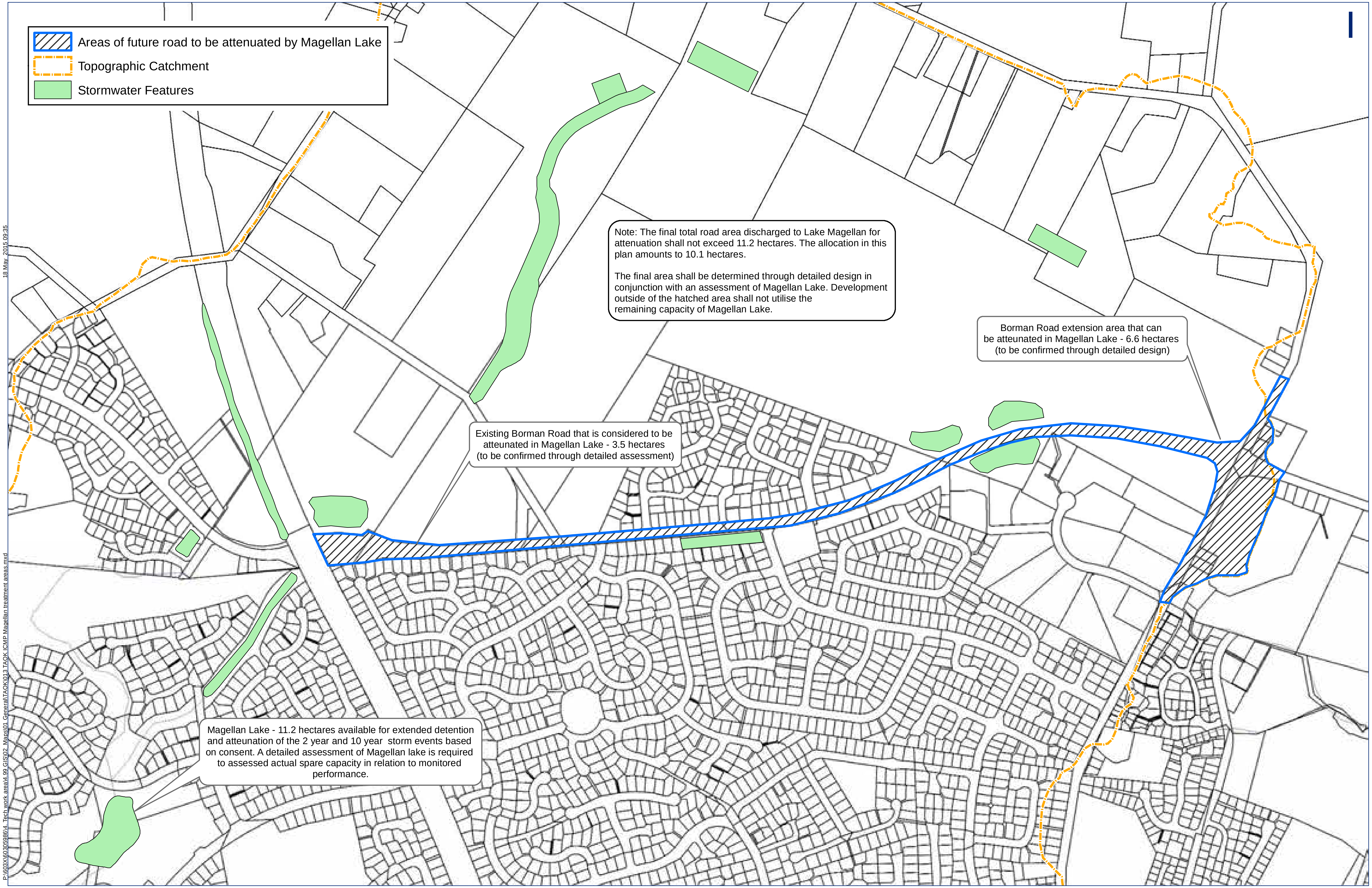
Title: Stormwater features Plan

Scale: Scale: 1:15,000 (A3 size) 200 100 0 200 Metres

Status: FINAL

Map No. 012

Rev. A



18 May 2015 09:35

P:\603X\60305986\4. Tech work area\4.99 GIS\02_Maps\01_General\TAOK\013 TAOK ICMP Magellan treatment areas.mxd

Rev.	By	App.	Description	Date

Notes:

Printed	26 May 2014 11:28		
Approved	-	Date	-
Designed	-	Checked	-
Drawn	-	Checked	-
File Name	013 TAOK ICMP Magellan treatment areas		

Map features depicted in terms of NZTM projection.

Data Sources:
NZ Topographical Features – LINZ NZ National Topo Dataset 2006
Cadastral Boundaries – LINZ NZ Cadastral Dataset 2007

AECOM

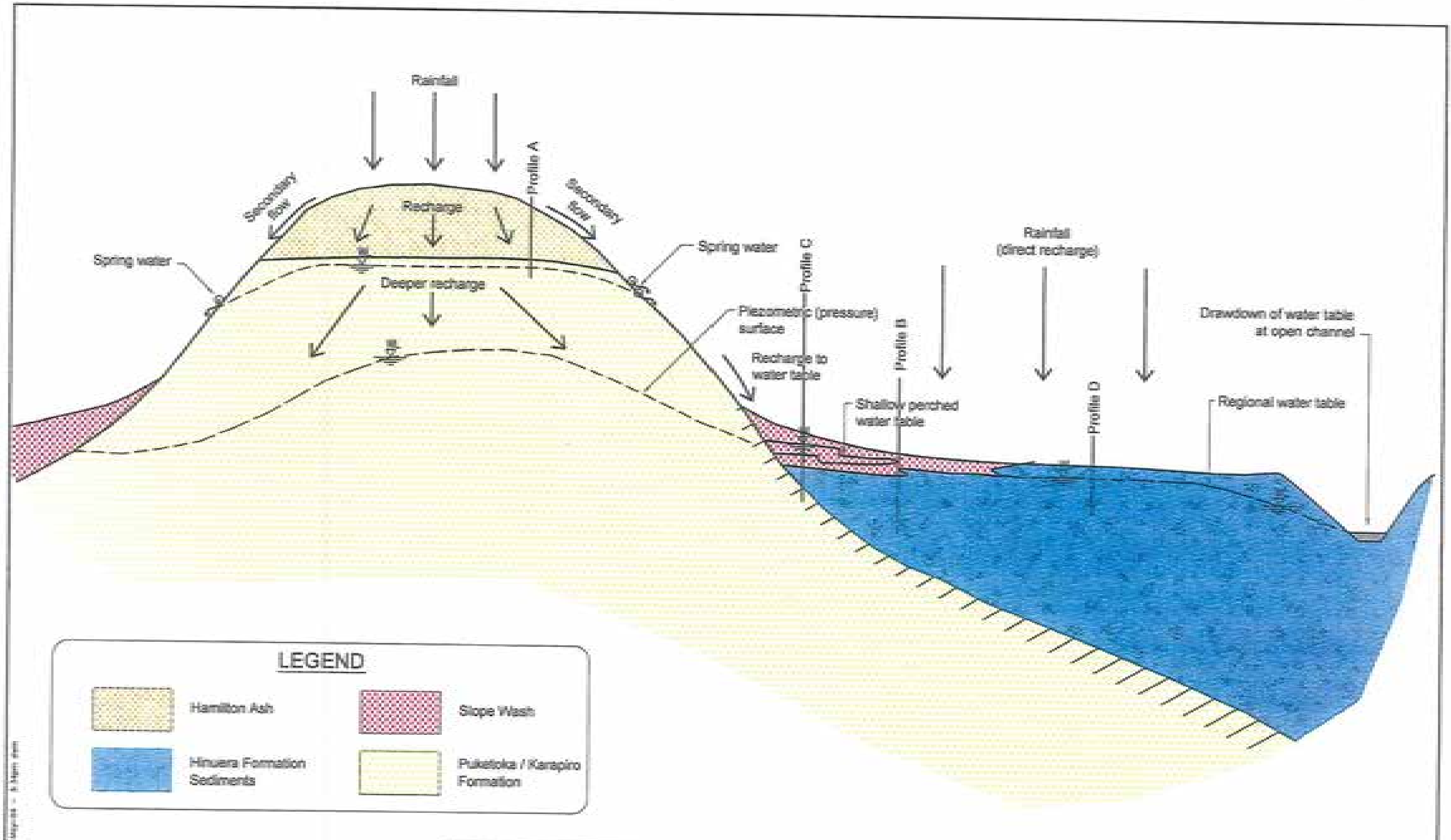
Project: **TE AWA O KATAPAKI ICMP**

Title: **Areas to be attenuated by Magellan Lake Plan**

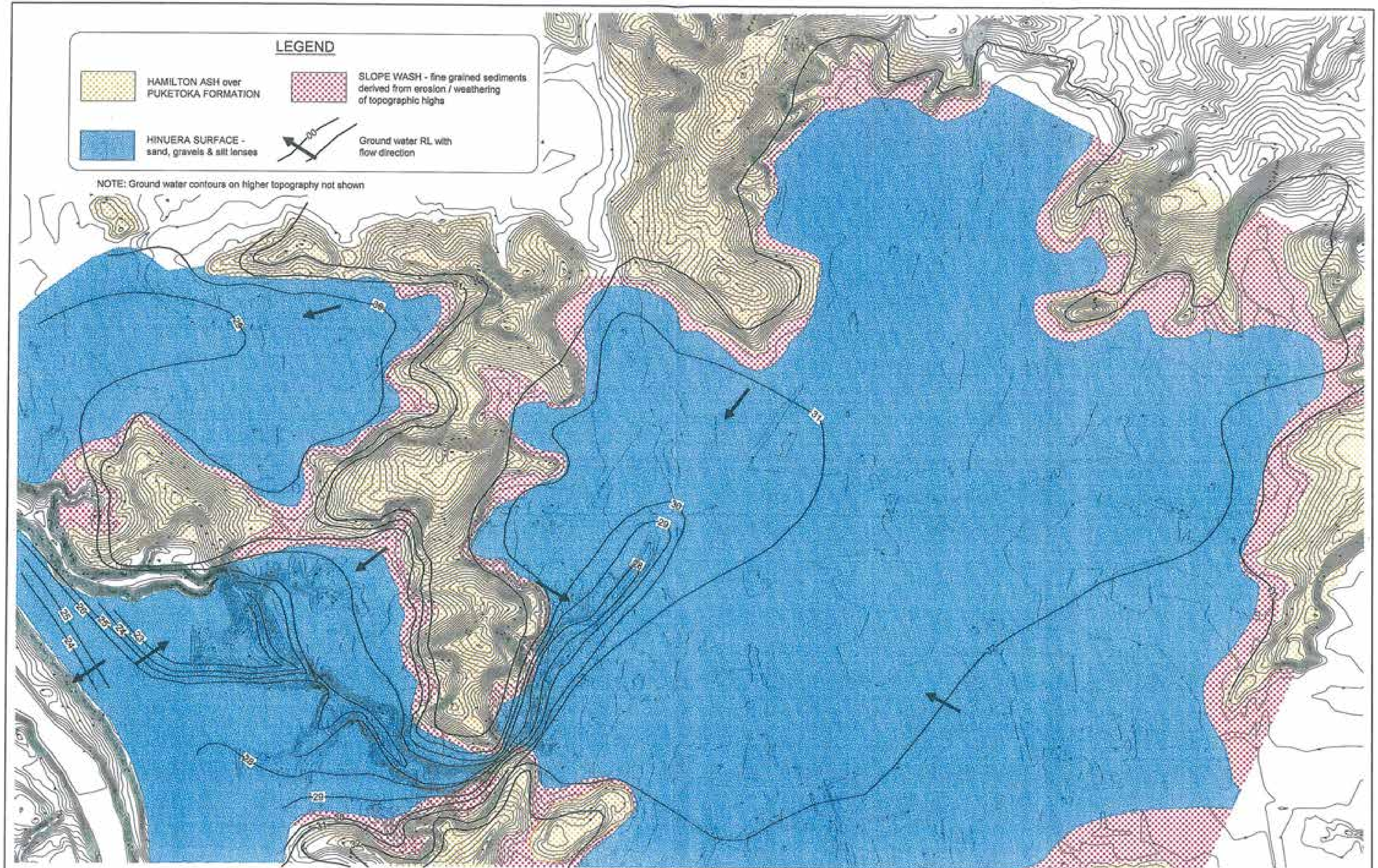
Scale: Scale: 1:7,500 (A3 size) 100 50 0 100 Metres

Status: FINAL | Map No. 013 | Rev. A

Appendix D Geology and hydrogeology



Tonkin & Taylor Environmental & Engineering Consultants ☐Auckland ☐Nelson ■Hamilton ☐Wellington ☐Christchurch ☐Whangarei	DRAWN: dwm Apr.04 DRAFTING CHECKED APPROVED CADFILE: L:\60645\60645-F04 SCALES (AT A4 SIZE) 1:500 PROJECT No. 60645	HAMILTON CITY COUNCIL Te Awa O Katapaki Catchment Assessment Typical Geohydrological Model FIG. No. Figure 4	REV. 0



SCALE 1: 10,000
0 100 200 300 400 500 (m)

Tonkin & Taylor Environmental & Engineering Consultants Hamilton Auckland Christchurch Nelson Wellington Whangarei	DRAWN dwm Apr.04 DRAFTING CHECKED APPROVED	HAMILTON CITY COUNCIL Te Awa O Katapaki Catchment Assessment	
	CADFILE: L:\60645\60645-F03 SCALES (AT A3 SIZE) 1: 10,000	Geology Map & Regional Ground Water Contours	
	PROJECT No. 60645	FIG. No. Figure 3	REV. 0

Appendix E Water quality modelling

Contaiminant Load Model - 2000 Baseline Scenario

	Site area (m²)			7563247	Source contaminant management train				Contaminant yields, loads, and load reduction efficiencies															
SOURCE	SOURCE TYPE								Sediment				Zinc				Copper				Total Petroleum Hydrocarbons			
			Length (m)	Source Area (m²)	First management option	Second management option	Third management option	Fraction of area draining to train	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Load reduction efficiency	Reduced load ($g\ a^{-1}$)	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Load reduction efficiency	Reduced load ($g\ a^{-1}$)	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Load reduction efficiency	Reduced load ($g\ a^{-1}$)	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Load reduction efficiency	Reduced load ($g\ a^{-1}$)
Roofs	Galvanised unpainted								5	0	0.00	0	2.200	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
	Galvanised steel poor paint			34492				0.5	5	172462	0.00	172462	1.600	55187.8	0.00	55187.84	0.0008	27.6	0.00	27.6				
Roof areas assumed at 55% c	Galvanised well painted								5	0	0.00	0	0.150	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Total area = 1,706,187 includi	Zinc/aluminium unpainted								5	0	0.00	0	0.300	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Residential = A11	Colorsteel/colorcote			324229				0.5	5	1621143	0.00	1621143	0.040	12969.1	0.00	12969.14	0.0008	259.4	0.00	259.4				
Roofs = A12	Concrete			172462				0.5	10	1724620	0.00	1724620	0.020	3449.2	0.00	3449.24	0.0013	224.2	0.00	224.2				
	Clay								5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
1254269	Slate								5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
689847.95	Copper								5	0	0.00	0	0.000	0.0	0.00	0.00	3.0000	0.0	0.00	0.0				
	Decramastic			158665				0.5	5	793325	0.00	793325	0.200	31733.0	0.00	31733.01	0.0017	269.7	0.00	269.7				
	Other materials								5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
	Unknown (no galvanised steel/copper)								7	0	0.00	0	0.200	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
			Length (m)																					
Roads		<1000	0					0.5	4	0	0.00	0	0.021	0.0	0.00	0.00	0.0070	0.0	0.00	0.0	0.11	0.0	0.00	0.0
Total area =		1000-5000	0	52310					30	1572375	0.00	1572375	0.107	5615.6	0.00	5615.62	0.0349	1825.1	0.00	1825.1	0.54	28078.1	0.00	28078.1
326937	*Vehicles/day*	5000-20000	0	156930				0.5	150	23585620	0.00	23585620	0.537	84234.4	0.00	84234.36	0.1744	27376.2	0.00	27376.2	2.68	421171.8	0.00	421171.8
		20000-50000	0	117697				0.5	299	35205852	0.00	35205852	1.068	125735.2	0.00	125735.19	0.3472	40863.9	0.00	40863.9	5.34	628675.9	0.00	628675.9
		50000-100000							300	0	0.00	0	2.281	0.0	0.00	0.00	0.7414	0.0	0.00	0.0	11.41	0.0	0.00	0.0
		>100000							300	0	0.00	0	3.532	0.0	0.00	0.00	1.1480	0.0	0.00	0.0	17.66	0.0	0.00	0.0
Paved Surfaces	Residential			188140.35				0.5	20	3762807	0.00	3762807	0.070	13169.8	0.00	13169.82	0.0100	1881.4	0.00	1881.4				
other than roads	Industrial								50	0	0.00	0	0.100	0.0	0.00	0.00	0.1300	0.0	0.00	0.0				
	Commercial								100	0	0.00	0	0.050	0.0	0.00	0.00	0.0500	0.0	0.00	0.0				
Urban Grass lands		<10		501261.7					35	17544160	0.00	17544160				614.0				122.8				
Reserves =	Slope	10-20							80	0	0.00	0				0.0				0.0				
124981		>20							160	0	0.00	0				0.0				0.0				
Urban Stream Channel	*length x width*			0					6000	0	0.00	0				0.0				0.0				
	Urban area without construction sites			**1706187**					**Totals**	**85982363**	**0.00**	**85982363**	**Totals**	**332094.2**	**0.00**	**332708.3**	**Totals**	**72727.5**	**0.00**	**72850.3**	**Totals**	**1077925.8**	**0.00**	**1077925.8**
Construction Site (1)		<10		33666	Dry pond			1	400	13466220	0.63	4982501				174.4				34.9				
open for 2 months/year	*Slope*	10-20							2500	0	0.00	0				0.0				0.0				
		>20							7000	0	0.00	0				0.0				0.0				
Construction Site (2)		<10		190771	Dry pond			1	1300	248002885	0.63	91761067				3211.6				642.3				
open for 6 months/year	*Slope*	10-20							7500	0	0.00	0				0.0				0.0				
		>20							20000	0	0.00	0				0.0				0.0				
Construction Site (3)		<10							2500	0	0.00	0				0.0				0.0				
open for 12 months/year	*Slope*	10-20							15000	0	0.00	0				0.0				0.0				
		>20							40000	0	0.00	0				0.0				0.0				
224437	**Urban area with construction sites**			**1930624**					**Totals**	**347451468**	**0.47**	**182725932**	**Totals**	**332094.2**	**-0.01**	**336094.3**	**Totals**	**72727.5**	**-0.01**	**73527.5**	**Totals**	**1077925.8**	**0.00**	**1077925.8**
Exotic production forest		<10							10	0	0.00	0				0.0				0.0				
		10-20							60	0	0.00	0				0.0				0.0				
	Slope	20-30							200	0	0.00	0				0.0				0.0				
		>30							500	0	0.00	0				0.0				0.0				
Stable bush		<10							5	0	0.00	0				0.0				0.0				
		10-20							30	0	0.00	0				0.0				0.0				
	Slope	20-30							100	0	0.00	0				0.0				0.0				
		>30							250	0	0.00	0				0.0				0.0				
Farmed pasture		<10							50	0	0.00	0				0.0				0.0				
		10-20							100	0	0.00	0				0.0				0.0				
	Slope	20-30							500	0	0.00	0				0.0				0.0				
		>30							1000	0	0.00	0				0.0				0.0				
Retired pasture		<10		5632623					20	112652460	0.00	112652460				3942.8				788.6				
		10-20							100	0	0.00	0				0.0				0.0				
	Slope	20-30							200	0	0.00	0				0.0				0.0				
		>30							500	0	0.00	0				0.0				0.0				
Horticulture		Volcanic							50	0	0.00	0				0.0				0.0				
	Soil type	Sediment							100	0	0.00	0				0.0				0.0				
		Unknown							100	0	0.00	0				0.0				0.0				
	Total area of sources (m²)			**7563247**					**Site totals**	**460103928**	**0.36**	**295378392**	**Site totals**	**332094.2**	**-0.02**	**340037.1**	**Site totals**	**72727.5**	**-0.02**	**74316.1**	**Site totals**	**1077925.8**	**0.00**	**1077925.8**

Site and source area's agree

Difference = 0

Bottom of Site contaminant management train				Bottom of Site out-fall Loads ($kg\ a^{-1}$)				Average yields				Average concentrations ($mg\ kg^{-1}$)			
First management option	**Second management option**	**Third management option**	**Fraction of area draining to train**	**TSS**	**Zn**	**Cu**	**TPH**	**TSS** $kg\ ha^{-1}\ a^{-1}$	**Zn** $g\ ha^{-1}\ a^{-1}$	**Cu** $g\ ha^{-1}\ a^{-1}$	**TPH** $g\ ha^{-1}\ a^{-1}$	**TSS**	**Zn**	**Cu**	**TPH**
				295378.4	**340.0**	**74.3**	**1077.9**	**391**	**450**	**98**	**1425**		**1151**	**252**	**3649**

Contaiminant Load Model - Existing Scenario (2013)

	Site area (m^2)		7563247	Source contaminant management train				Contaminant yields, loads, and load reduction efficiencies															
SOURCE	SOURCE TYPE							Sediment				Zinc				Copper				Total Petroleum Hydrocarbons			
			Source Area (m^2)	First management option	Second management option	Third management option	Fraction of area draining to train	Yield (g m^{-2}a^{-1})	Initial load (g a^{-1})	Load reduction efficiency	Reduced load (g a^{-1})	Yield (g m^{-2}a^{-1})	Initial load (g a^{-1})	Load reduction efficiency	Reduced load (g a^{-1})	Yield (g m^{-2}a^{-1})	Initial load (g a^{-1})	Load reduction efficiency	Reduced load (g a^{-1})	Yield (g m^{-2}a^{-1})	Initial load (g a^{-1})	Load reduction efficiency	Reduced load (g a^{-1})
Roofs	Galvanised unpainted							5	0	0.00	0	2.200	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
	Galvanised steel poor paint		94317	Wet pond			0.5	5	471585	0.77	290025	1.600	150907.1	0.10	143361.77	0.0008	75.5	0.15	69.8				
Roof areas assumed at 55% c	Galvanised well painted							5	0	0.00	0	0.150	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Total area = 1,706,187 includi	Zinc/aluminium unpainted							5	0	0.00	0	0.300	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Residential = A12	Colorsteel/colorcote		886579	Wet pond			0.5	5	4432897	0.77	2726232	0.040	35463.2	0.10	33690.02	0.0008	709.3	0.15	656.1				
Roofs = A13	Concrete		471585	Wet pond			0.5	10	4715848	0.77	2900246	0.020	9431.7	0.10	8960.11	0.0013	613.1	0.15	567.1				
	Clay							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
3429707	Slate							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
1886339	Copper							5	0	0.00	0	0.000	0.0	0.00	0.00	3.0000	0.0	0.00	0.0				
	Decramastic		433858	Wet pond			0.5	5	2169290	0.77	1334113	0.200	86771.6	0.10	82433.02	0.0017	737.6	0.15	682.2				
	Other materials							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
	Unknown (no galvanised steel/copper)							7	0	0.00	0	0.200	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
		Length (m)																					
Roads	<1000	0		Catchpits cleaned 1x/year			0.5	4	0	0.50	0	0.021	0.0	0.30	0.00	0.0070	0.0	0.40	0.0	0.11	0.0	0.20	0.0
Total area =	1000-5000	0	136452	Catchpits cleaned 1x/year				30	4101580	0.50	4101580	0.107	14648.5	0.30	14648.50	0.0349	4760.8	0.40	4760.8	0.54	73242.5	0.20	73242.5
852824	*Vehicles/day* 5000-20000	0	409355	Catchpits cleaned 1x/year			0.5	150	61523700	0.50	46142775	0.537	219727.5	0.30	186768.38	0.1744	71411.4	0.40	57129.2	2.68	1098637.5	0.20	988773.8
	20000-50000	0	307017	Catchpits cleaned 1x/year			0.5	299	91835377	0.50	68876533	1.068	327983.5	0.30	278785.97	0.3472	106594.6	0.40	85275.7	5.34	1639917.4	0.20	1475925.7
	50000-100000							300	0	0.00	0	2.281	0.0	0.00	0.00	0.7414	0.0	0.00	0.0	11.41	0.0	0.00	0.0
	>100000							300	0	0.00	0	3.532	0.0	0.00	0.00	1.1480	0.0	0.00	0.0	17.66	0.0	0.00	0.0
Paved Surfaces	Residential		514456.1134	Vegetative filter strips			0.5	20	10289122	0.40	8231298	0.070	36011.9	0.25	31510.44	0.0100	5144.6	0.30	4372.9				
other than roads	Industrial							50	0	0.00	0	0.100	0.0	0.00	0.00	0.1300	0.0	0.00	0.0				
	Commercial							100	0	0.00	0	0.050	0.0	0.00	0.00	0.0500	0.0	0.00	0.0				
Urban Grass lands	<10		1184944.429					35	41473055	0.00	41473055				1451.6				290.3				
Reserves =	Slope 10-20							80	0	0.00	0				0.0				0.0				
156032	>20							160	0	0.00	0				0.0				0.0				
Urban Stream Channel	*length x width*		35000					6000	210000000	0.00	210000000				7350.0				1470.0				
	Urban area without construction sites		**4473563.26**					**Totals**	**431012454**	**0.10**	**386075857**	**Totals**	**880945.0**	**0.10**	**788959.8**	**Totals**	**190046.7**	**0.18**	**155274.0**	**Totals**	**2811797.5**	**0.10**	**2537942.0**
Construction Site (1)	<10		31500	Wet pond with flocculation			1	400	12600000	0.90	1260000				44.1				8.8				
open for 2 months/year	*Slope* 10-20							2500	0	0.00	0				0.0				0.0				
	>20							7000	0	0.00	0				0.0				0.0				
Construction Site (2)	<10		178500	Wet pond with flocculation			1	1300	232050000	0.90	23205000				812.2				162.4				
open for 6 months/year	*Slope* 10-20							7500	0	0.00	0				0.0				0.0				
	>20							20000	0	0.00	0				0.0				0.0				
Construction Site (3)	<10							2500	0	0.00	0				0.0				0.0				
open for 12 months/year	*Slope* 10-20							15000	0	0.00	0				0.0				0.0				
	>20							40000	0	0.00	0				0.0				0.0				
210000	**Urban area with construction sites**		**4683563**					**Totals**	**675662454**	**0.39**	**410540857**	**Totals**	**880945.0**	**0.10**	**789816.0**	**Totals**	**190046.7**	**0.18**	**155445.2**	**Totals**	**2811797.5**	**0.10**	**2537942.0**
Exotic production forest	<10							10	0	0.00	0				0.0				0.0				
	10-20							60	0	0.00	0				0.0				0.0				
	Slope 20-30							200	0	0.00	0				0.0				0.0				
	>30							500	0	0.00	0				0.0				0.0				
Stable bush	<10							5	0	0.00	0				0.0				0.0				
	10-20							30	0	0.00	0				0.0				0.0				
	Slope 20-30							100	0	0.00	0				0.0				0.0				
	>30							250	0	0.00	0				0.0				0.0				
Farmed pasture	<10							50	0	0.00	0				0.0				0.0				
	10-20							100	0	0.00	0				0.0				0.0				
	Slope 20-30							500	0	0.00	0				0.0				0.0				
	>30							1000	0	0.00	0				0.0				0.0				
Retired pasture	<10		2879683					20	57593667	0.00	57593667				2015.8				403.2				
	10-20							100	0	0.00	0				0.0				0.0				
	Slope 20-30							200	0	0.00	0				0.0				0.0				
	>30							500	0	0.00	0				0.0				0.0				
Horticulture	Volcanic							50	0	0.00	0				0.0				0.0				
	Soil type Sediment							100	0	0.00	0				0.0				0.0				
	Unknown							100	0	0.00	0				0.0				0.0				
	Total area of sources (m^2)		**7563247**					**Site totals**	**733256121**	**0.36**	**468134524**	**Site totals**	**880945.0**	**0.10**	**791831.8**	**Site totals**	**190046.7**	**0.18**	**155848.4**	**Site totals**	**2811797.5**	**0.10**	**2537942.0**

Site and source area's agree

Difference = 0

Bottom of Site contaminant management train				Bottom of Site out-fall Loads (kg a^{-1})				Average yields				Average concentrations (mg kg^{-1})			
First management option	Second management option	Third management option	Fraction of area draining to train	TSS	Zn	Cu	TPH	TSS kg ha^{-1} a^{-1}	Zn g ha^{-1} a^{-1}	Cu g ha^{-1} a^{-1}	TPH g ha^{-1} a^{-1}	TSS	Zn	Cu	TPH
				468134.5	791.8	155.8	2537.9	619	1047	206	3356		1691	333	5421

Contaiminant Load Model - Future Unmanaged Scenario

	Site area (m^2)		**7563247**	**Source contaminant management train**				**Contaminant yields, loads, and load reduction efficiencies**															
SOURCE	**SOURCE TYPE**							**Sediment**				**Zinc**				**Copper**				**Total Petroleum Hydrocarbons**			
			Source Area (m^2)	**First management option**	**Second management option**	**Third management option**	**Fraction of area draining to train**	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Load reduction efficiency	Reduced load ($g\ a^{-1}$)	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Load reduction efficiency	Reduced load ($g\ a^{-1}$)	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Load reduction efficiency	Reduced load ($g\ a^{-1}$)	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Load reduction efficiency	Reduced load ($g\ a^{-1}$)
Roofs	Galvanised unpainted							5	0	0.00	0	2.200	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
	Galvanised steel poor paint		163922	Wet pond			0.287	5	819608	0.77	638483	1.600	262274.6	0.10	254747.36	0.0008	131.1	0.15	125.5				
Roof areas assumed at 55% o	Galvanised well painted							5	0	0.00	0	0.150	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Total area = 1,706,187 includi	Zinc/aluminium unpainted							5	0	0.00	0	0.300	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Residential = A11	Colorsteel/colorcote		1540863	Wet pond			0.287	5	7704317	0.77	6001740	0.040	61634.5	0.10	59865.63	0.0008	1232.7	0.15	1179.6				
Roofs = A12	Concrete		819608	Wet pond			0.287	10	8196082	0.77	6384830	0.020	16392.2	0.10	15921.71	0.0013	1065.5	0.15	1019.6				
	Clay							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
5960787	Slate							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
3278433	Copper							5	0	0.00	0	0.000	0.0	0.00	0.00	3.0000	0.0	0.00	0.0				
	Decramastic		754040	Wet pond			0.287	5	3770198	0.77	2937022	0.200	150807.9	0.10	146479.73	0.0017	1281.9	0.15	1226.7				
	Other materials							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
	Unknown (no galvanised steel/copper)							7	0	0.00	0	0.200	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
		Length (m)																					
Roads	<1000	0					0.5	4	0	0.00	0	0.021	0.0	0.00	0.00	0.0070	0.0	0.00	0.0	0.11	0.0	0.00	0.0
Total area =	1000-5000	0	240128	Catchpits cleaned 1x/year			0.287	30	7217971	0.50	6182192	0.107	25778.5	0.30	23558.94	0.0349	8378.0	0.40	7416.2	0.54	128892.3	0.20	121493.9
1500801	*Vehicles/day* 5000-20000	0	720385	Catchpits cleaned 1x/year			0.287	150	108269562	0.50	92732880	0.537	386677.0	0.30	353384.12	0.1744	125670.0	0.40	111243.1	2.68	1933385.0	0.20	1822408.7
	20000-50000	0	540288	Catchpits cleaned 1x/year			0.287	299	161612126	0.50	138420786	1.068	577186.2	0.30	527490.44	0.3472	187585.5	0.40	166050.7	5.34	2885930.8	0.20	2720278.4
	50000-100000							300	0	0.00	0	2.281	0.0	0.00	0.00	0.7414	0.0	0.00	0.0	11.41	0.0	0.00	0.0
	>100000							300	0	0.00	0	3.532	0.0	0.00	0.00	1.1480	0.0	0.00	0.0	17.66	0.0	0.00	0.0
Paved Surfaces	Residential		894118.085	Vegetative filter strips			0.287	20	17882362	0.40	15829467	0.070	62588.3	0.25	58097.56	0.0100	8941.2	0.30	8171.3				
other than roads	Industrial							50	0	0.00	0	0.100	0.0	0.00	0.00	0.1300	0.0	0.00	0.0				
	Commercial							100	0	0.00	0	0.050	0.0	0.00	0.00	0.0500	0.0	0.00	0.0				
Urban Grass lands	<10		1846894.772					35	64641317	0.00	64641317				2262.4				452.5				
Reserves =	Slope 10-20							80	0	0.00	0				0.0				0.0				
58659	>20							160	0	0.00	0				0.0				0.0				
Urban Stream Channel	*length x width*		43000					6000	258000000	0.00	258000000				9030.0				1806.0				
	Urban area without construction sites		**7563247**					**Totals**	**638113543**	**0.07**	**591768717**	**Totals**	**1543339.2**	**0.06**	**1450837.9**	**Totals**	**334285.9**	**0.11**	**298691.3**	**Totals**	**4948208.2**	**0.06**	**4664181.0**
Construction Site (1)	<10		0	Wet pond with flocculation			1	400	0	0.90	0				0.0				0.0				
open for 2 months/year	*Slope* 10-20							2500	0	0.00	0				0.0				0.0				
	>20							7000	0	0.00	0				0.0				0.0				
Construction Site (2)	<10		0	Wet pond with flocculation			1	1300	0	0.90	0				0.0				0.0				
open for 6 months/year	*Slope* 10-20							7500	0	0.00	0				0.0				0.0				
	>20							20000	0	0.00	0				0.0				0.0				
Construction Site (3)	<10							2500	0	0.00	0				0.0				0.0				
open for 12 months/year	*Slope* 10-20							15000	0	0.00	0				0.0				0.0				
	>20							40000	0	0.00	0				0.0				0.0				
0	**Urban area with construction sites**		**7563247**					**Totals**	**638113543**	**0.07**	**591768717**	**Totals**	**1543339.2**	**0.06**	**1450837.9**	**Totals**	**334285.9**	**0.11**	**298691.3**	**Totals**	**4948208.2**	**0.06**	**4664181.0**
Exotic production forest	<10							10	0	0.00	0				0.0				0.0				
	10-20							60	0	0.00	0				0.0				0.0				
	Slope 20-30							200	0	0.00	0				0.0				0.0				
	>30							500	0	0.00	0				0.0				0.0				
Stable bush	<10							5	0	0.00	0				0.0				0.0				
	10-20							30	0	0.00	0				0.0				0.0				
	Slope 20-30							100	0	0.00	0				0.0				0.0				
	>30							250	0	0.00	0				0.0				0.0				
Farmed pasture	<10							50	0	0.00	0				0.0				0.0				
	10-20							100	0	0.00	0				0.0				0.0				
	Slope 20-30							500	0	0.00	0				0.0				0.0				
	>30							1000	0	0.00	0				0.0				0.0				
Retired pasture	<10							20	0	0.00	0				0.0				0.0				
	10-20							100	0	0.00	0				0.0				0.0				
	Slope 20-30							200	0	0.00	0				0.0				0.0				
	>30							500	0	0.00	0				0.0				0.0				
Horticulture	Volcanic							50	0	0.00	0				0.0				0.0				
	Soil type Sediment							100	0	0.00	0				0.0				0.0				
	Unknown							100	0	0.00	0				0.0				0.0				
	Total area of sources (m^2)		**7563247**					**Site totals**	**638113543**	**0.07**	**591768717**	**Site totals**	**1543339.2**	**0.06**	**1450837.9**	**Site totals**	**334285.9**	**0.11**	**298691.3**	**Site totals**	**4948208.2**	**0.06**	**4664181.0**

Site and source area's agree

Difference = 0

Bottom of Site contaminant management train				**Bottom of Site out-fall Loads ($kg\ a^{-1}$)**				**Average yields**				**Average concentrations ($mg\ kg^{-1}$)**			
First management option	**Second management option**	**Third management option**	**Fraction of area draining to train**	**TSS**	**Zn**	**Cu**	**TPH**	**TSS** $kg\ ha^{-1}\ a^{-1}$	**Zn** $g\ ha^{-1}\ a^{-1}$	**Cu** $g\ ha^{-1}\ a^{-1}$	**TPH** $g\ ha^{-1}\ a^{-1}$	**TSS**	**Zn**	**Cu**	**TPH**
				591768.7	**1450.8**	**298.7**	**4664.2**	**782**	**1918**	**395**	**6167**		**2452**	**505**	**7882**

Contaiminant Load Model - Future Existing Areas Component for Future Option Scenarios

	Site area (m^2)		7563247	Source contaminant management train				Contaminant yields, loads, and load reduction efficiencies															
SOURCE	SOURCE TYPE							Sediment				Zinc				Copper				Total Petroleum Hydrocarbons			
			Source Area (m^2)	First management option	Second management option	Third management option	Fraction of area draining to train	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Load reduction efficiency	Reduced load ($g\ a^{-1}$)	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Load reduction efficiency	Reduced load ($g\ a^{-1}$)	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Load reduction efficiency	Reduced load ($g\ a^{-1}$)	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Load reduction efficiency	Reduced load ($g\ a^{-1}$)
Roofs	Galvanised unpainted							5	0	0.00	0	2.200	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
	Galvanised steel poor paint		94317	Wet pond			0.5	5	471585	0.77	290025	1.600	150907.1	0.10	143361.77	0.0008	75.5	0.15	69.8				
Roof areas assumed at 55% c	Galvanised well painted							5	0	0.00	0	0.150	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Total area = 1,706,187 includi	Zinc/aluminium unpainted							5	0	0.00	0	0.300	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Residential = A12	Colorsteel/colorcote		886579	Wet pond			0.5	5	4432897	0.77	2726232	0.040	35463.2	0.10	33690.02	0.0008	709.3	0.15	656.1				
Roofs = A13	Concrete		471585	Wet pond			0.5	10	4715848	0.77	2900246	0.020	9431.7	0.10	8960.11	0.0013	613.1	0.15	567.1				
Roofs 2013=A14	Clay							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
5759354	Slate							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
3167644	Copper							5	0	0.00	0	0.000	0.0	0.00	0.00	3.0000	0.0	0.00	0.0				
1886339	Decramastic		433858	Wet pond			0.5	5	2169290	0.77	1334113	0.200	86771.6	0.10	82433.02	0.0017	737.6	0.15	682.2				
Total new roofs=	Other materials							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
1281305	Unknown (no galvanised steel/copper)							7	0	0.00	0	0.200	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Residential 2013=																							
3429707																							
Roads		*Length (m)*																					
Total area=	<1000	0					0.5	4	0	0.00	0	0.021	0.0	0.00	0.00	0.0070	0.0	0.00	0.0	0.11	0.0	0.00	0.0
1500801	1000-5000	0	136452	Catchpits cleaned 1x/year			0.5	30	4101580	0.50	3076185	0.107	14648.5	0.30	12451.23	0.0349	4760.8	0.40	3808.6	0.54	73242.5	0.20	65918.3
Total area 2013=	*Vehicles/day* 5000-20000	0	409355	Catchpits cleaned 1x/year			0.5	150	61523700	0.50	46142775	0.537	219727.5	0.30	186768.38	0.1744	71411.4	0.40	57129.2	2.68	1098637.5	0.20	988773.8
852824	20000-50000	0	307017	Catchpits cleaned 1x/year			0.5	299	91835377	0.50	68876533	1.068	327983.5	0.30	278785.97	0.3472	106594.6	0.40	85275.7	5.34	1639917.4	0.20	1475925.7
Total new area=	50000-100000							300	0	0.00	0	2.281	0.0	0.00	0.00	0.7414	0.0	0.00	0.0	11.41	0.0	0.00	0.0
647978	>100000							300	0	0.00	0	3.532	0.0	0.00	0.00	1.1480	0.0	0.00	0.0	17.66	0.0	0.00	0.0
Paved Surfaces	Residential		514456	Vegetative filter strips			0.5	20	10289122	0.40	8231298	0.070	36011.9	0.25	31510.44	0.0100	5144.6	0.30	4372.9				
other than roads	Industrial							50	0	0.00	0	0.100	0.0	0.00	0.00	0.1300	0.0	0.00	0.0				
2013=	Commercial							100	0	0.00	0	0.050	0.0	0.00	0.00	0.0500	0.0	0.00	0.0				
514456																							
Total=																							
894118																							
Total new area=																							
379662																							
Urban Grass lands	<10		1184944					35	41473055	0.00	41473055				1451.6				290.3				
Reserves Total=	Slope 10-20							80	0	0.00	0				0.0				0.0				
268092	>20							160	0	0.00	0				0.0				0.0				
Reserves 2013=																							
156032																							
Reserves new=																							
112060																							
Urban Stream Channel	*length x width*		35000					6000	210000000	0.00	210000000				7350.0				1470.0				
	Urban area without construction sites		**4473563**					**Totals**	**431012454**	**0.11**	**385050462**	**Totals**	**880945.0**	**0.11**	**786762.5**	**Totals**	**190046.7**	**0.19**	**154321.8**	**Totals**	**2811797.5**	**0.10**	**2530617.7**
Construction Site (1)	<10		0				1	400	0	0.00	0				0.0				0.0				
open for 2 months/year	*Slope* 10-20							2500	0	0.00	0				0.0				0.0				
	>20							7000	0	0.00	0				0.0				0.0				
Construction Site (2)	<10		0				1	1300	0	0.00	0				0.0				0.0				
open for 6 months/year	*Slope* 10-20							7500	0	0.00	0				0.0				0.0				
	>20							20000	0	0.00	0				0.0				0.0				
Construction Site (3)	<10							2500	0	0.00	0				0.0				0.0				
open for 12 months/year	*Slope* 10-20							15000	0	0.00	0				0.0				0.0				
	>20							40000	0	0.00	0				0.0				0.0				
0	**Urban area with construction sites**		**4473563**					**Totals**	**431012454**	**0.11**	**385050462**	**Totals**	**880945.0**	**0.11**	**786762.5**	**Totals**	**190046.7**	**0.19**	**154321.8**	**Totals**	**2811797.5**	**0.10**	**2530617.7**
Exotic production forest	<10							10	0	0.00	0				0.0				0.0				
	10-20							60	0	0.00	0				0.0				0.0				
	Slope 20-30							200	0	0.00	0				0.0				0.0				
	>30							500	0	0.00	0				0.0				0.0				
Stable bush	<10							5	0	0.00	0				0.0				0.0				
	10-20							30	0	0.00	0				0.0				0.0				
	Slope 20-30							100	0	0.00	0				0.0				0.0				
	>30							250	0	0.00	0				0.0				0.0				
Farmed pasture	<10							50	0	0.00	0				0.0				0.0				
	10-20							100	0	0.00	0				0.0				0.0				
	Slope 20-30							500	0	0.00	0				0.0				0.0				
	>30							1000	0	0.00	0				0.0				0.0				
Retired pasture	<10							20	0	0.00	0				0.0				0.0				
	10-20							100	0	0.00	0				0.0				0.0				
	Slope 20-30							200	0	0.00	0				0.0				0.0				
	>30							500	0	0.00	0				0.0				0.0				
Horticulture	Volcanic							50	0	0.00	0				0.0				0.0				
	Soil type Sediment							100	0	0.00	0				0.0				0.0				
	Unknown							100	0	0.00	0				0.0				0.0				
	Total area of sources (m^2)		**4473563**					**Site totals**	**431012454**	**0.11**	**385050462**	**Site totals**	**880945.0**	**0.11**	**786762.5**	**Site totals**	**190046.7**	**0.19**	**154321.8**	**Site totals**	**2811797.5**	**0.10**	**2530617.7**

Bottom of Site contaminant management train				Bottom of Site out-fall Loads (kg a^{-1})				Average yields				Average concentrations (mg kg^{-1})			
First management option	Second management option	Third management option	Fraction of area draining to train	TSS	Zn	Cu	TPH	TSS kg ha^{-1} a^{-1}	Zn g ha^{-1} a^{-1}	Cu g ha^{-1} a^{-1}	TPH g ha^{-1} a^{-1}	TSS	Zn	Cu	TPH
				385050.5	786.8	154.3	2530.6	861	1759	345	5657		2043	401	6572

Contaiminant Load Model - Developed Scenario 1

	Site area (m^2)		7563247	Source contaminant management train				Contaminant yields, loads, and load reduction efficiencies															
SOURCE	SOURCE TYPE							Sediment				Zinc				Copper				Total Petroleum Hydrocarbons			
		Length (m)	Source Area (m^2)	First management option	Second management option	Third management option	Fraction of area draining to train	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Load reduction efficiency	Reduced load ($g\ a^{-1}$)	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Load reduction efficiency	Reduced load ($g\ a^{-1}$)	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Load reduction efficiency	Reduced load ($g\ a^{-1}$)	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Load reduction efficiency	Reduced load ($g\ a^{-1}$)
Roofs	Galvanised unpainted							5	0	0.00	0	2.200	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
	Galvanised steel poor paint		63845	Constructed wetland			1	5	319226	0.77	73422	1.600	102152.4	0.20	81721.95	0.0008	51.1	0.25	38.3				
Roof areas assumed at 55% (	Galvanised well painted							5	0	0.00	0	0.150	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Total area = 1,706,187 includ	Zinc/aluminium unpainted							5	0	0.00	0	0.300	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Residential = A12	Colorsteel/colorcote		600146	Constructed wetland			1	5	3000728	0.77	690167	0.040	24005.8	0.20	19204.66	0.0008	480.1	0.25	360.1				
Roofs = A13	Concrete		319226	Constructed wetland			1	10	3192264	0.77	734221	0.020	6384.5	0.20	5107.62	0.0013	415.0	0.25	311.2				
Roofs 2013=A14	Clay							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
5751354	Slate							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
3163244	Copper							5	0	0.00	0	0.000	0.0	0.00	0.00	3.0000	0.0	0.00	0.0				
1886339	Decramastic		293688	Constructed wetland			1	5	1468441	0.77	337741	0.200	58737.6	0.20	46990.12	0.0017	499.3	0.25	374.5				
Total new roofs=	Other materials							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
1276905	Unknown (no galvanised steel/copper)							7	0	0.00	0	0.200	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Residential 2013=																							
3429707																							
Residential New=																							
2321646																							
Roads		Length (m)																					
Total area=	<1000	0						4	0	0.00	0	0.021	0.0	0.00	0.00	0.0070	0.0	0.00	0.0	0.11	0.0	0.00	0.0
1500801	1000-5000	0	103676	Constructed wetland			1	30	3116391	0.77	716770	0.107	11130.0	0.54	5119.78	0.0349	3617.2	0.69	1121.3	0.54	55649.8	0.10	50084.9
Total area 2013=	*Vehicles/day* 5000-20000	0	311029	Constructed wetland			1	150	46745861	0.77	10751548	0.537	166949.5	0.54	76796.77	0.1744	54258.6	0.69	16820.2	2.68	834747.5	0.10	751272.8
852824	20000-50000	0	233272	Constructed wetland			1	299	69776749	0.77	16048652	1.068	249202.7	0.54	114633.23	0.3472	80990.9	0.69	25107.2	5.34	1246013.4	0.10	1121412.0
Total new area=	50000-100000							300	0	0.00	0	2.281	0.0	0.00	0.00	0.7414	0.0	0.00	0.0	11.41	0.0	0.00	0.0
647978	>100000							300	0	0.00	0	3.532	0.0	0.00	0.00	1.1480	0.0	0.00	0.0	17.66	0.0	0.00	0.0
Paved Surfaces	Residential		348247	Constructed wetland			1	20	6964939	0.77	1601936	0.070	24377.3	0.54	11213.55	0.0100	3482.5	0.69	1079.6				
other than roads	Industrial							50	0	0.00	0	0.100	0.0	0.00	0.00	0.1300	0.0	0.00	0.0				
2013=	Commercial							100	0	0.00	0	0.050	0.0	0.00	0.00	0.0500	0.0	0.00	0.0				
514456																							
Total=																							
862703																							
Total new area=																							
348247																							
Urban Grass lands	<10		808554	Constructed wetland			1	35	28299386	0.77	6508859				227.8				45.6				
Total=	Slope 10-20							80	0	0.00	0				0.0				0.0				
1993498	>20							160	0	0.00	0				0.0				0.0				
2013=																							
1184944																							
Reserves new=																							
808554																							
Urban Stream Channel	*length x width*		8000					6000	48000000	0.00	48000000				1680.0				336.0				
	Urban area without construction sites		**3089684**					**Totals**	**210883984**	**0.59**	**85463316**	**Totals**	**642939.9**	**0.44**	**362695.5**	**Totals**	**143794.6**	**0.68**	**45593.9**	**Totals**	**2136410.7**	**0.10**	**1922769.7**
Construction Site (1)	<10		0				1	400	0	0.00	0				0.0				0.0				
open for 2 months/year	*Slope* 10-20							2500	0	0.00	0				0.0				0.0				
	>20							7000	0	0.00	0				0.0				0.0				
Construction Site (2)	<10		0				1	1300	0	0.00	0				0.0				0.0				
open for 6 months/year	*Slope* 10-20							7500	0	0.00	0				0.0				0.0				
	>20							20000	0	0.00	0				0.0				0.0				
Construction Site (3)	<10							2500	0	0.00	0				0.0				0.0				
open for 12 months/year	*Slope* 10-20							15000	0	0.00	0				0.0				0.0				
	>20							40000	0	0.00	0				0.0				0.0				
0	**Urban area with construction sites**		**3089684**					**Totals**	**210883984**	**0.59**	**85463316**	**Totals**	**642939.9**	**0.44**	**362695.5**	**Totals**	**143794.6**	**0.68**	**45593.9**	**Totals**	**2136410.7**	**0.10**	**1922769.7**
Exotic production forest	<10							10	0	0.00	0				0.0				0.0				
	10-20							60	0	0.00	0				0.0				0.0				
	Slope 20-30							200	0	0.00	0				0.0				0.0				
	>30							500	0	0.00	0				0.0				0.0				
Stable bush	<10							5	0	0.00	0				0.0				0.0				
	10-20							30	0	0.00	0				0.0				0.0				
	Slope 20-30							100	0	0.00	0				0.0				0.0				
	>30							250	0	0.00	0				0.0				0.0				
Farmed pasture	<10							50	0	0.00	0				0.0				0.0				
	10-20							100	0	0.00	0				0.0				0.0				
	Slope 20-30							500	0	0.00	0				0.0				0.0				
	>30							1000	0	0.00	0				0.0				0.0				
Retired pasture	<10							20	0	0.00	0				0.0				0.0				
	10-20							100	0	0.00	0				0.0				0.0				
	Slope 20-30							200	0	0.00	0				0.0				0.0				
	>30							500	0	0.00	0				0.0				0.0				
Horticulture	Volcanic							50	0	0.00	0				0.0				0.0				
	Soil type Sediment							100	0	0.00	0				0.0				0.0				
	Unknown							100	0	0.00	0				0.0				0.0				
	Total area of sources (m^2)		**3089684**					**Site totals**	**210883984**	**0.59**	**85463316**	**Site totals**	**642939.9**	**0.44**	**362695.5**	**Site totals**	**143794.6**	**0.68**	**45593.9**	**Site totals**	**2136410.7**	**0.10**	**1922769.7**

2013 areas **4473563.26**

7563247

0

	Bottom of Site contaminant management train				Bottom of Site out-fall Loads ($kg\ a^{-1}$)				Average yields				Average concentrations ($mg\ kg^{-1}$)			
	First management option	Second management option	Third management option	Fraction of area draining to train	TSS	Zn	Cu	TPH	TSS $kg\ ha^{-1}\ a^{-1}$	Zn $g\ ha^{-1}\ a^{-1}$	Cu $g\ ha^{-1}\ a^{-1}$	TPH $g\ ha^{-1}\ a^{-1}$	TSS	Zn	Cu	TPH
Areas developed post 2013 scenario					85463.3	362.7	45.6	1922.8	277	1174	148	6223		4244	533	22498
Existing areas componement (unchanged from 2013 scenario)					385050.5	786.8	154.3	2530.6								
Total future scenario					470513.8	1149.5	199.9	4453.4	622	1520	264	5888				

Contaiminant Load Model - Developed Scenario 2

SOURCE	SOURCE TYPE	Length (m)	Source Area (m^2)	First management option	Second management option	Third management option	Fraction of area draining to train	Sediment Yield ($g\ m^{-2}a^{-1}$)	Sediment Initial load ($g\ a^{-1}$)	Sediment Load reduction efficiency	Sediment Reduced load ($g\ a^{-1}$)	Zinc Yield ($g\ m^{-2}a^{-1}$)	Zinc Initial load ($g\ a^{-1}$)	Zinc Load reduction efficiency	Zinc Reduced load ($g\ a^{-1}$)	Copper Yield ($g\ m^{-2}a^{-1}$)	Copper Initial load ($g\ a^{-1}$)	Copper Load reduction efficiency	Copper Reduced load ($g\ a^{-1}$)	Total Petroleum Hydrocarbons Yield ($g\ m^{-2}a^{-1}$)	Total Petroleum Hydrocarbons Initial load ($g\ a^{-1}$)	Total Petroleum Hydrocarbons Load reduction efficiency	Total Petroleum Hydrocarbons Reduced load ($g\ a^{-1}$)
Site area (m^2)			7563247																				
Roofs	Galvanised unpainted							5	0	0.00	0	2.200	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
	Galvanised steel poor paint		63845	Constructed wetland			1	5	319226	0.77	73422	1.600	102152.4	0.20	81721.95	0.0008	51.1	0.25	38.3				
Roof areas assumed at 55% (	Galvanised well painted							5	0	0.00	0	0.150	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Total area = 1,706,187 includ	Zinc/aluminium unpainted							5	0	0.00	0	0.300	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Residential = A12	Colorsteel/colorcote		600146	Constructed wetland			1	5	3000728	0.77	690167	0.040	24005.8	0.20	19204.66	0.0008	480.1	0.25	360.1				
Roofs = A13	Concrete		319226	Constructed wetland			1	10	3192264	0.77	734221	0.020	6384.5	0.20	5107.62	0.0013	415.0	0.25	311.2				
Roofs 2013=A14	Clay							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
5751354	Slate							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
3163244	Copper							5	0	0.00	0	0.000	0.0	0.00	0.00	3.0000	0.0	0.00	0.0				
1886339	Decramastic		293688	Constructed wetland			1	5	1468441	0.77	337741	0.200	58737.6	0.20	46990.12	0.0017	499.3	0.25	374.5				
Total new roofs=	Other materials							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
1276905	Unknown (no galvanised steel/copper)							7	0	0.00	0	0.200	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Residential 2013=																							
3429707																							
Residential New=																							
2321646																							
Roads		Length (m)																					
Total area=	<1000	0					0	4	0	0.00	0	0.021	0.0	0.00	0.00	0.0070	0.0	0.00	0.0	0.11	0.0	0.00	0.0
1500801	1000-5000	0	103676	Constructed wetland			1	30	3116391	0.77	716770	0.107	11130.0	0.54	5119.78	0.0349	3617.2	0.69	1121.3	0.54	55649.8	0.10	50084.9
Total area 2013=	*Vehicles/day* 5000-20000	0	311029	Constructed wetland			1	150	46745861	0.77	10751548	0.537	166949.5	0.54	76796.77	0.1744	54258.6	0.69	16820.2	2.68	834747.5	0.10	751272.8
852824	20000-50000	0	233272	Constructed wetland			1	299	69776749	0.77	16048652	1.068	249202.7	0.54	114633.23	0.3472	80990.9	0.69	25107.2	5.34	1246013.4	0.10	1121412.0
Total new area=	50000-100000							300	0	0.00	0	2.281	0.0	0.00	0.00	0.7414	0.0	0.00	0.0	11.41	0.0	0.00	0.0
647978	>100000							300	0	0.00	0	3.532	0.0	0.00	0.00	1.1480	0.0	0.00	0.0	17.66	0.0	0.00	0.0
Paved Surfaces	Residential		348247	Rain garden	Constructed wetland		1	20	6964939	0.90	696494	0.070	24377.3	0.79	5119.23	0.0100	3482.5	0.84	565.9				
other than roads	Industrial							50	0	0.00	0	0.100	0.0	0.00	0.00	0.1300	0.0	0.00	0.0				
2013=	Commercial							100	0	0.00	0	0.050	0.0	0.00	0.00	0.0500	0.0	0.00	0.0				
514456																							
Total=																							
862703																							
Total new area=																							
348247																							
Urban Grass lands	<10		808554	Constructed wetland			1	35	28299386	0.77	6508859				227.8				45.6				
Total=	Slope 10-20							80	0	0.00	0				0.0				0.0				
1993498	>20							160	0	0.00	0				0.0				0.0				
2013=																							
1184944																							
Reserves new=																							
808554																							
Urban Stream Channel	*length x width*		8000					6000	48000000	0.00	48000000				1680.0				336.0				
	Urban area without construction sites		**3089684**					**Totals**	**210883984**	**0.60**	**84557874**	**Totals**	**642939.9**	**0.45**	**356601.2**	**Totals**	**143794.6**	**0.69**	**45080.2**	**Totals**	**2136410.7**	**0.10**	**1922769.7**
Construction Site (1)	<10		0				1	400	0	0.00	0				0.0				0.0				
open for 2 months/year	*Slope* 10-20							2500	0	0.00	0				0.0				0.0				
	>20							7000	0	0.00	0				0.0				0.0				
Construction Site (2)	<10		0				1	1300	0	0.00	0				0.0				0.0				
open for 6 months/year	*Slope* 10-20							7500	0	0.00	0				0.0				0.0				
	>20							20000	0	0.00	0				0.0				0.0				
Construction Site (3)	<10							2500	0	0.00	0				0.0				0.0				
open for 12 months/year	*Slope* 10-20							15000	0	0.00	0				0.0				0.0				
	>20							40000	0	0.00	0				0.0				0.0				
0	**Urban area with construction sites**		**3089684**					**Totals**	**210883984**	**0.60**	**84557874**	**Totals**	**642939.9**	**0.45**	**356601.2**	**Totals**	**143794.6**	**0.69**	**45080.2**	**Totals**	**2136410.7**	**0.10**	**1922769.7**
Exotic production forest	<10							10	0	0.00	0				0.0				0.0				
	10-20							60	0	0.00	0				0.0				0.0				
	Slope 20-30							200	0	0.00	0				0.0				0.0				
	>30							500	0	0.00	0				0.0				0.0				
Stable bush	<10							5	0	0.00	0				0.0				0.0				
	10-20							30	0	0.00	0				0.0				0.0				
	Slope 20-30							100	0	0.00	0				0.0				0.0				
	>30							250	0	0.00	0				0.0				0.0				
Farmed pasture	<10							50	0	0.00	0				0.0				0.0				
	10-20							100	0	0.00	0				0.0				0.0				
	Slope 20-30							500	0	0.00	0				0.0				0.0				
	>30							1000	0	0.00	0				0.0				0.0				
Retired pasture	<10							20	0	0.00	0				0.0				0.0				
	10-20							100	0	0.00	0				0.0				0.0				
	Slope 20-30							200	0	0.00	0				0.0				0.0				
	>30							500	0	0.00	0				0.0				0.0				
Horticulture	Volcanic							50	0	0.00	0				0.0				0.0				
	Soil type Sediment							100	0	0.00	0				0.0				0.0				
	Unknown							100	0	0.00	0				0.0				0.0				
	Total area of sources (m^2)		**3089684**					**Site totals**	**210883984**	**0.60**	**84557874**	**Site totals**	**642939.9**	**0.45**	**356601.2**	**Site totals**	**143794.6**	**0.69**	**45080.2**	**Site totals**	**2136410.7**	**0.10**	**1922769.7**

2013 areas **4473563.26**

7563247

0

	Bottom of Site contaminant management train: First management option	Second management option	Third management option	Fraction of area draining to train	Bottom of Site out-fall Loads ($kg\ a^{-1}$): TSS	Zn	Cu	TPH	Average yields: TSS ($kg\ ha^{-1}\ a^{-1}$)	Zn ($g\ ha^{-1}\ a^{-1}$)	Cu ($g\ ha^{-1}\ a^{-1}$)	TPH ($g\ ha^{-1}\ a^{-1}$)	Average concentrations ($mg\ kg^{-1}$): TSS	Zn	Cu	TPH
Areas developed post 2013 scenario					84557.9	356.6	45.1	1922.8	274	1154	146	6223		4217	533	22739
Existing areas componement (unchanged from 2013 scenario)					385050.5	786.8	154.3	2530.6								
Total future scenario					469608.3	1143.4	199.4	4453.4	621	1512	264	5888				

Contaiminant Load Model - Developed Scenario 3

Site area (m^2): 7563247

SOURCE	SOURCE TYPE		Length (m)	Source Area (m^2)	First management option	Second management option	Third management option	Fraction of area draining to train	Sediment Yield ($g m^{-2}a^{-1}$)	Sediment Initial load ($g a^{-1}$)	Sediment Load reduction efficiency	Sediment Reduced load ($g a^{-1}$)	Zinc Yield ($g m^{-2}a^{-1}$)	Zinc Initial load ($g a^{-1}$)	Zinc Load reduction efficiency	Zinc Reduced load ($g a^{-1}$)	Copper Yield ($g m^{-2}a^{-1}$)	Copper Initial load ($g a^{-1}$)	Copper Load reduction efficiency	Copper Reduced load ($g a^{-1}$)	Total Petroleum Hydrocarbons Yield ($g m^{-2}a^{-1}$)	TPH Initial load ($g a^{-1}$)	TPH Load reduction efficiency	TPH Reduced load ($g a^{-1}$)
Roofs	Galvanised unpainted								5	0	0.00	0	2.200	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
	Galvanised steel poor paint			63845	Constructed wetland			1	5	319226	0.77	73422	1.600	102152.4	0.20	81721.95	0.0008	51.1	0.25	38.3				
Roof areas assumed at 55% (	Galvanised well painted								5	0	0.00	0	0.150	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Total area = 1,706,187 includ	Zinc/aluminium unpainted								5	0	0.00	0	0.300	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Residential = A12	Colorsteel/colorcote			600146	Constructed wetland			1	5	3000728	0.77	690167	0.040	24005.8	0.20	19204.66	0.0008	480.1	0.25	360.1				
Roofs = A13	Concrete			319226	Constructed wetland			1	10	3192264	0.77	734221	0.020	6384.5	0.20	5107.62	0.0013	415.0	0.25	311.2				
Roofs 2013=A14	Clay								5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
5751354	Slate								5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
3163244	Copper								5	0	0.00	0	0.000	0.0	0.00	0.00	3.0000	0.0	0.00	0.0				
1886339	Decramastic			293688	Constructed wetland			1	5	1468441	0.77	337741	0.200	58737.6	0.20	46990.12	0.0017	499.3	0.25	374.5				
Total new roofs=	Other materials								5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
1276905	Unknown (no galvanised steel/copper)								7	0	0.00	0	0.200	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Residential 2013=																								
3429707																								
Residential New=																								
2321646																								
Roads			Length (m)																					
Total area=		<1000	0						4	0	0.00	0	0.021	0.0	0.00	0.00	0.0070	0.0	0.00	0.0	0.11	0.0	0.00	0.0
1500801		1000-5000	0	103676	Constructed wetland	Catchpit filter		1	30	3116391	0.79	645093	0.107	11130.0	0.56	4863.80	0.0349	3617.2	0.71	1065.3	0.54	55649.8	0.15	47580.6
Total area 2013=	*Vehicles/day*	5000-20000	0	311029	Constructed wetland	Catchpit filter		1	150	46745861	0.79	9676393	0.537	166949.5	0.56	72956.93	0.1744	54258.6	0.71	15979.2	2.68	834747.5	0.15	713709.1
852824		20000-50000	0	233272	Constructed wetland	Catchpit filter		1	299	69776749	0.79	14443787	1.068	249202.7	0.56	108901.57	0.3472	80990.9	0.71	23851.8	5.34	1246013.4	0.15	1065341.4
Total new area=		50000-100000							300	0	0.00	0	2.281	0.0	0.00	0.00	0.7414	0.0	0.00	0.0	11.41	0.0	0.00	0.0
647978		>100000							300	0	0.00	0	3.532	0.0	0.00	0.00	1.1480	0.0	0.00	0.0	17.66	0.0	0.00	0.0
Paved Surfaces	Residential			348247	Constructed wetland	Rain garden		1	20	6964939	0.93	480581	0.070	24377.3	0.77	5606.78	0.0100	3482.5	0.86	485.8				
other than roads	Industrial								50	0	0.00	0	0.100	0.0	0.00	0.00	0.1300	0.0	0.00	0.0				
2013=	Commercial								100	0	0.00	0	0.050	0.0	0.00	0.00	0.0500	0.0	0.00	0.0				
514456																								
Total=																								
862703																								
Total new area=																								
348247																								
Urban Grass lands		<10		808554	Constructed wetland			1	35	28299386	0.77	6508859				227.8				45.6				
Total=	Slope	10-20							80	0	0.00	0				0.0				0.0				
1993498		>20							160	0	0.00	0				0.0				0.0				
2013=																								
1184944																								
Reserves new=																								
808554																								
Urban Stream Channel	*length x width*			8000					6000	48000000	0.00	48000000				1680.0				336.0				
	Urban area without construction sites			**3089684**					**Totals**	**210883984**	**0.61**	**81590264**	**Totals**	**642939.9**	**0.46**	**347261.2**	**Totals**	**143794.6**	**0.70**	**42847.7**	**Totals**	**2136410.7**	**0.15**	**1826631.2**
Construction Site (1)		<10		0				1	400	0	0.00	0				0.0				0.0				
open for 2 months/year	*Slope*	10-20							2500	0	0.00	0				0.0				0.0				
		>20							7000	0	0.00	0				0.0				0.0				
Construction Site (2)		<10		0				1	1300	0	0.00	0				0.0				0.0				
open for 6 months/year	*Slope*	10-20							7500	0	0.00	0				0.0				0.0				
		>20							20000	0	0.00	0				0.0				0.0				
Construction Site (3)		<10							2500	0	0.00	0				0.0				0.0				
open for 12 months/year	*Slope*	10-20							15000	0	0.00	0				0.0				0.0				
		>20							40000	0	0.00	0				0.0				0.0				
0	**Urban area with construction sites**			**3089684**					**Totals**	**210883984**	**0.61**	**81590264**	**Totals**	**642939.9**	**0.46**	**347261.2**	**Totals**	**143794.6**	**0.70**	**42847.7**	**Totals**	**2136410.7**	**0.15**	**1826631.2**
Exotic production forest		<10							10	0	0.00	0				0.0				0.0				
		10-20							60	0	0.00	0				0.0				0.0				
	Slope	20-30							200	0	0.00	0				0.0				0.0				
		>30							500	0	0.00	0				0.0				0.0				
Stable bush		<10							5	0	0.00	0				0.0				0.0				
		10-20							30	0	0.00	0				0.0				0.0				
	Slope	20-30							100	0	0.00	0				0.0				0.0				
		>30							250	0	0.00	0				0.0				0.0				
Farmed pasture		<10							50	0	0.00	0				0.0				0.0				
		10-20							100	0	0.00	0				0.0				0.0				
	Slope	20-30							500	0	0.00	0				0.0				0.0				
		>30							1000	0	0.00	0				0.0				0.0				
Retired pasture		<10							20	0	0.00	0				0.0				0.0				
		10-20							100	0	0.00	0				0.0				0.0				
	Slope	20-30							200	0	0.00	0				0.0				0.0				
		>30							500	0	0.00	0				0.0				0.0				
Horticulture		Volcanic							50	0	0.00	0				0.0				0.0				
	Soil type	Sediment							100	0	0.00	0				0.0				0.0				
		Unknown							100	0	0.00	0				0.0				0.0				
	Total area of sources (m^2)			**3089684**					**Site totals**	**210883984**	**0.61**	**81590264**	**Site totals**	**642939.9**	**0.46**	**347261.2**	**Site totals**	**143794.6**	**0.70**	**42847.7**	**Site totals**	**2136410.7**	**0.15**	**1826631.2**
	2013 areas		**4473563.26**																					
				7563247																				
				0																				

	Bottom of Site contaminant management train				Bottom of Site out-fall Loads ($kg a^{-1}$)				Average yields				Average concentrations ($mg kg^{-1}$)			
	First management option	Second management option	Third management option	Fraction of area draining to train	TSS	Zn	Cu	TPH	TSS $kg ha^{-1} a^{-1}$	Zn $g ha^{-1} a^{-1}$	Cu $g ha^{-1} a^{-1}$	TPH $g ha^{-1} a^{-1}$	TSS	Zn	Cu	TPH
Areas developed post 2013 scenario					81590.3	347.3	42.8	1826.6	264	1124	139	5912		4256	525	22388
Existing areas componement (unchanged from 2013 scenario)					385050.5	786.8	154.3	2530.6								
Total future scenario					466640.7	1134.0	197.2	4357.2	617	1499	261	5761				

Contaiminant Load Model - Developed Scenario 4

SOURCE	SOURCE TYPE		Length (m)	Site area (m²) 7563247 — Source Area (m²)	First management option	Second management option	Third management option	Fraction of area draining to train
Roofs	Galvanised unpainted							
	Galvanised steel poor paint			63845	Constructed wetland			1
Roof areas assumed at 55% (	Galvanised well painted							
Total area = 1,706,187 includ	Zinc/aluminium unpainted							
Residential = A12	Colorsteel/colorcote			600146	Constructed wetland			1
Roofs = A13	Concrete			319226	Constructed wetland			1
Roofs 2013=A14	Clay							
5751354	Slate							
3163244	Copper							
1886339	Decramastic			293688	Constructed wetland			1
Total new roofs=	Other materials							
1276905	Unknown (no galvanised steel/copper)							
Residential 2013=								
3429707								
Residential New=								
2321646								
Roads			Length (m)					
Total area=		<1000	0					
1500801		1000-5000	0	103676	Constructed wetland	Swale		1
Total area 2013=	*Vehicles/day*	5000-20000	0	311029	Constructed wetland	Swale		1
852824		20000-50000	0	233272	Constructed wetland	Swale		1
Total new area=		50000-100000						
647978		>100000						
Paved Surfaces	Residential			348247	Constructed wetland	Rain garden		1
other than roads	Industrial							
2013=	Commercial							
514456								
Total=								
862703								
Total new area=								
348247								
Urban Grass lands		<10		808554	Constructed wetland			1
Total=	Slope	10-20						
1993498		>20						
2013=								
1184944								
Reserves new=								
808554								
Urban Stream Channel	*length x width*			8000				
	Urban area without construction sites			**3089684**				
Construction Site (1)		<10		0				1
open for 2 months/year	*Slope*	10-20						
		>20						
Construction Site (2)		<10		0				1
open for 6 months/year	*Slope*	10-20						
		>20						
Construction Site (3)		<10						
open for 12 months/year	*Slope*	10-20						
		>20						
0	**Urban area with construction sites**			**3089684**				
Exotic production forest		<10						
		10-20						
	Slope	20-30						
		>30						
Stable bush		<10						
		10-20						
	Slope	20-30						
		>30						
Farmed pasture		<10						
		10-20						
	Slope	20-30						
		>30						
Retired pasture		<10						
		10-20						
	Slope	20-30						
		>30						
Horticulture		Volcanic						
	Soil type	Sediment						
		Unknown						
	Total area of sources (m²)			**3089684**				
	2013 areas		**4473563.26**					
				7563247				
				0				

Contaminant yields, loads, and load reduction efficiencies

SOURCE TYPE	Sediment Yield ($g\ m^{-2}a^{-1}$)	Sediment Initial load ($g\ a^{-1}$)	Sediment Load reduction efficiency	Sediment Reduced load ($g\ a^{-1}$)	Zinc Yield ($g\ m^{-2}a^{-1}$)	Zinc Initial load ($g\ a^{-1}$)	Zinc Load reduction efficiency	Zinc Reduced load ($g\ a^{-1}$)	Copper Yield ($g\ m^{-2}a^{-1}$)	Copper Initial load ($g\ a^{-1}$)	Copper Load reduction efficiency	Copper Reduced load ($g\ a^{-1}$)	Total Petroleum Hydrocarbons Yield ($g\ m^{-2}a^{-1}$)	TPH Initial load ($g\ a^{-1}$)	TPH Load reduction efficiency	TPH Reduced load ($g\ a^{-1}$)
Galvanised unpainted	5	0	0.00	0	2.200	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Galvanised steel poor paint	5	319226	0.77	73422	1.600	102152.4	0.20	81721.95	0.0008	51.1	0.25	38.3				
Galvanised well painted	5	0	0.00	0	0.150	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Zinc/aluminium unpainted	5	0	0.00	0	0.300	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Colorsteel/colorcote	5	3000728	0.77	690167	0.040	24005.8	0.20	19204.66	0.0008	480.1	0.25	360.1				
Concrete	10	3192264	0.77	734221	0.020	6384.5	0.20	5107.62	0.0013	415.0	0.25	311.2				
Clay	5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Slate	5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Copper	5	0	0.00	0	0.000	0.0	0.00	0.00	3.0000	0.0	0.00	0.0				
Decramastic	5	1468441	0.77	337741	0.200	58737.6	0.20	46990.12	0.0017	499.3	0.25	374.5				
Other materials	5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Unknown (no galvanised steel/copper)	7	0	0.00	0	0.200	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Roads <1000	4	0	0.00	0	0.021	0.0	0.00	0.00	0.0070	0.0	0.00	0.0	0.11	0.0	0.00	0.0
Roads 1000-5000	30	3116391	0.86	430062	0.107	11130.0	0.63	4095.83	0.0349	3617.2	0.77	841.0	0.54	55649.8	0.33	37563.6
Roads 5000-20000	150	46745861	0.86	6450929	0.537	166949.5	0.63	61437.42	0.1744	54258.6	0.77	12615.1	2.68	834747.5	0.33	563454.6
Roads 20000-50000	299	69776749	0.86	9629191	1.068	249202.7	0.63	91706.58	0.3472	80990.9	0.77	18830.4	5.34	1246013.4	0.33	841059.0
Roads 50000-100000	300	0	0.00	0	2.281	0.0	0.00	0.00	0.7414	0.0	0.00	0.0	11.41	0.0	0.00	0.0
Roads >100000	300	0	0.00	0	3.532	0.0	0.00	0.00	1.1480	0.0	0.00	0.0	17.66	0.0	0.00	0.0
Paved Residential	20	6964939	0.93	480581	0.070	24377.3	0.77	5606.78	0.0100	3482.5	0.86	485.8				
Paved Industrial	50	0	0.00	0	0.100	0.0	0.00	0.00	0.1300	0.0	0.00	0.0				
Paved Commercial	100	0	0.00	0	0.050	0.0	0.00	0.00	0.0500	0.0	0.00	0.0				
Urban Grass lands <10	35	28299386	0.77	6508859				227.8				45.6				
Urban Grass lands 10-20	80	0	0.00	0				0.0				0.0				
Urban Grass lands >20	160	0	0.00	0				0.0				0.0				
Urban Stream Channel	6000	48000000	0.00	48000000				1680.0				336.0				
Urban area without construction sites	**Totals**	**210883984**	**0.65**	**73335173**	**Totals**	**642939.9**	**0.51**	**317778.8**	**Totals**	**143794.6**	**0.76**	**34238.0**	**Totals**	**2136410.7**	**0.33**	**1442077.2**
Construction Site (1) <10	400	0	0.00	0				0.0				0.0				
Construction Site (1) 10-20	2500	0	0.00	0				0.0				0.0				
Construction Site (1) >20	7000	0	0.00	0				0.0				0.0				
Construction Site (2) <10	1300	0	0.00	0				0.0				0.0				
Construction Site (2) 10-20	7500	0	0.00	0				0.0				0.0				
Construction Site (2) >20	20000	0	0.00	0				0.0				0.0				
Construction Site (3) <10	2500	0	0.00	0				0.0				0.0				
Construction Site (3) 10-20	15000	0	0.00	0				0.0				0.0				
Construction Site (3) >20	40000	0	0.00	0				0.0				0.0				
Urban area with construction sites	**Totals**	**210883984**	**0.65**	**73335173**	**Totals**	**642939.9**	**0.51**	**317778.8**	**Totals**	**143794.6**	**0.76**	**34238.0**	**Totals**	**2136410.7**	**0.33**	**1442077.2**
Exotic production forest <10	10	0	0.00	0				0.0				0.0				
Exotic production forest 10-20	60	0	0.00	0				0.0				0.0				
Exotic production forest 20-30	200	0	0.00	0				0.0				0.0				
Exotic production forest >30	500	0	0.00	0				0.0				0.0				
Stable bush <10	5	0	0.00	0				0.0				0.0				
Stable bush 10-20	30	0	0.00	0				0.0				0.0				
Stable bush 20-30	100	0	0.00	0				0.0				0.0				
Stable bush >30	250	0	0.00	0				0.0				0.0				
Farmed pasture <10	50	0	0.00	0				0.0				0.0				
Farmed pasture 10-20	100	0	0.00	0				0.0				0.0				
Farmed pasture 20-30	500	0	0.00	0				0.0				0.0				
Farmed pasture >30	1000	0	0.00	0				0.0				0.0				
Retired pasture <10	20	0	0.00	0				0.0				0.0				
Retired pasture 10-20	100	0	0.00	0				0.0				0.0				
Retired pasture 20-30	200	0	0.00	0				0.0				0.0				
Retired pasture >30	500	0	0.00	0				0.0				0.0				
Horticulture Volcanic	50	0	0.00	0				0.0				0.0				
Horticulture Sediment	100	0	0.00	0				0.0				0.0				
Horticulture Unknown	100	0	0.00	0				0.0				0.0				
Total area of sources (m²)	**Site totals**	**210883984**	**0.65**	**73335173**	**Site totals**	**642939.9**	**0.51**	**317778.8**	**Site totals**	**143794.6**	**0.76**	**34238.0**	**Site totals**	**2136410.7**	**0.33**	**1442077.2**

	Bottom of Site contaminant management train				Bottom of Site out-fall Loads ($kg\ a^{-1}$)				Average yields				Average concentrations ($mg\ kg^{-1}$)			
	First management option	Second management option	Third management option	Fraction of area draining to train	TSS	Zn	Cu	TPH	TSS $kg\ ha^{-1}\ a^{-1}$	Zn $g\ ha^{-1}\ a^{-1}$	Cu $g\ ha^{-1}\ a^{-1}$	TPH $g\ ha^{-1}\ a^{-1}$	TSS	Zn	Cu	TPH
Areas developed post 2013 scenario					73335.2	317.8	34.2	1442.1	237	1029	111	4667		4333	467	19664
Existing areas componement (unchanged from 2013 scenario)					385050.5	786.8	154.3	2530.6								
Total future scenario					458385.6	1104.5	188.6	3972.7	606	1460	249	5253				

Contaiminant Load Model - Developed Scenario 5

SOURCE	Site area (m^2) / SOURCE TYPE	Length (m)	Source Area (m^2) 7563247	Source contaminant management train: First management option	Second management option	Third management option	Fraction of area draining to train	Sediment: Yield ($g\ m^{-2}a^{-1}$)	Sediment: Initial load ($g\ a^{-1}$)	Sediment: Load reduction efficiency	Sediment: Reduced load ($g\ a^{-1}$)	Zinc: Yield ($g\ m^{-2}a^{-1}$)	Zinc: Initial load ($g\ a^{-1}$)	Zinc: Load reduction efficiency	Zinc: Reduced load ($g\ a^{-1}$)	Copper: Yield ($g\ m^{-2}a^{-1}$)	Copper: Initial load ($g\ a^{-1}$)	Copper: Load reduction efficiency	Copper: Reduced load ($g\ a^{-1}$)	Total Petroleum Hydrocarbons: Yield ($g\ m^{-2}a^{-1}$)	Total Petroleum Hydrocarbons: Initial load ($g\ a^{-1}$)	Total Petroleum Hydrocarbons: Load reduction efficiency	Total Petroleum Hydrocarbons: Reduced load ($g\ a^{-1}$)
Roofs	Galvanised unpainted							5	0	0.00	0	2.200	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
	Galvanised steel poor paint		63845	Constructed wetland			1	5	319226	0.77	73422	1.600	102152.4	0.20	81721.95	0.0008	51.1	0.25	38.3				
Roof areas assumed at 55% (	Galvanised well painted							5	0	0.00	0	0.150	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Total area = 1,706,187 includ	Zinc/aluminium unpainted							5	0	0.00	0	0.300	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Residential = A12	Colorsteel/colorcote		600146	Constructed wetland			1	5	3000728	0.77	690167	0.040	24005.8	0.20	19204.66	0.0008	480.1	0.25	360.1				
Roofs = A13	Concrete		319226	Constructed wetland			1	10	3192264	0.77	734221	0.020	6384.5	0.20	5107.62	0.0013	415.0	0.25	311.2				
Roofs 2013=A14	Clay							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
5751354	Slate							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
3163244	Copper							5	0	0.00	0	0.000	0.0	0.00	0.00	3.0000	0.0	0.00	0.0				
1886339	Decramastic		293688	Constructed wetland			1	5	1468441	0.77	337741	0.200	58737.6	0.20	46990.12	0.0017	499.3	0.25	374.5				
Total new roofs=	Other materials							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
1276905	Unknown (no galvanised steel/copper)							7	0	0.00	0	0.200	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Residential 2013=																							
3429707																							
Residential New=																							
2321646																							
Roads		Length (m)																					
Total area=	<1000	0						4	0	0.00	0	0.021	0.0	0.00	0.00	0.0070	0.0	0.00	0.0	0.11	0.0	0.00	0.0
1500801	1000-5000	0	103676	Constructed wetland	Rain garden		1	30	3116391	0.93	215031	0.107	11130.0	0.77	2559.89	0.0349	3617.2	0.86	504.6	0.54	55649.8	0.60	22538.2
Total area 2013=	*Vehicles/day* 5000-20000	0	311029	Constructed wetland	Rain garden		1	150	46745861	0.93	3225464	0.537	166949.5	0.77	38398.39	0.1744	54258.6	0.86	7569.1	2.68	834747.5	0.60	338072.7
852824	20000-50000	0	233272	Constructed wetland	Rain garden		1	299	69776749	0.93	4814596	1.068	249202.7	0.77	57316.62	0.3472	80990.9	0.86	11298.2	5.34	1246013.4	0.60	504635.4
Total new area=	50000-100000							300	0	0.00	0	2.281	0.0	0.00	0.00	0.7414	0.0	0.00	0.0	11.41	0.0	0.00	0.0
647978	>100000							300	0	0.00	0	3.532	0.0	0.00	0.00	1.1480	0.0	0.00	0.0	17.66	0.0	0.00	0.0
Paved Surfaces	Residential		348247	Constructed wetland	Rain garden		1	20	6964939	0.93	480581	0.070	24377.3	0.77	5606.78	0.0100	3482.5	0.86	485.8				
other than roads	Industrial							50	0	0.00	0	0.100	0.0	0.00	0.00	0.1300	0.0	0.00	0.0				
2013=	Commercial							100	0	0.00	0	0.050	0.0	0.00	0.00	0.0500	0.0	0.00	0.0				
514456																							
Total=																							
862703																							
Total new area=																							
348247																							
Urban Grass lands	<10		808554	Constructed wetland			1	35	28299386	0.77	6508859				227.8				45.6				
Total=	Slope 10-20							80	0	0.00	0				0.0				0.0				
1993498	>20							160	0	0.00	0				0.0				0.0				
2013=																							
1184944																							
Reserves new=																							
808554																							
Urban Stream Channel	*length x width*		8000					6000	48000000	0.00	48000000				1680.0				336.0				
	Urban area without construction sites		**3089684**					**Totals**	**210883984**	**0.69**	**65080082**	**Totals**	**642939.9**	**0.60**	**258813.8**	**Totals**	**143794.6**	**0.85**	**21323.4**	**Totals**	**2136410.7**	**0.60**	**865246.3**
Construction Site (1)	<10		0				1	400	0	0.00	0				0.0				0.0				
open for 2 months/year	*Slope* 10-20							2500	0	0.00	0				0.0				0.0				
	>20							7000	0	0.00	0				0.0				0.0				
Construction Site (2)	<10		0				1	1300	0	0.00	0				0.0				0.0				
open for 6 months/year	*Slope* 10-20							7500	0	0.00	0				0.0				0.0				
	>20							20000	0	0.00	0				0.0				0.0				
Construction Site (3)	<10							2500	0	0.00	0				0.0				0.0				
open for 12 months/year	*Slope* 10-20							15000	0	0.00	0				0.0				0.0				
	>20							40000	0	0.00	0				0.0				0.0				
0	**Urban area with construction sites**		**3089684**					**Totals**	**210883984**	**0.69**	**65080082**	**Totals**	**642939.9**	**0.60**	**258813.8**	**Totals**	**143794.6**	**0.85**	**21323.4**	**Totals**	**2136410.7**	**0.60**	**865246.3**
Exotic production forest	<10							10	0	0.00	0				0.0				0.0				
	10-20							60	0	0.00	0				0.0				0.0				
	Slope 20-30							200	0	0.00	0				0.0				0.0				
	>30							500	0	0.00	0				0.0				0.0				
Stable bush	<10							5	0	0.00	0				0.0				0.0				
	10-20							30	0	0.00	0				0.0				0.0				
	Slope 20-30							100	0	0.00	0				0.0				0.0				
	>30							250	0	0.00	0				0.0				0.0				
Farmed pasture	<10							50	0	0.00	0				0.0				0.0				
	10-20							100	0	0.00	0				0.0				0.0				
	Slope 20-30							500	0	0.00	0				0.0				0.0				
	>30							1000	0	0.00	0				0.0				0.0				
Retired pasture	<10							20	0	0.00	0				0.0				0.0				
	10-20							100	0	0.00	0				0.0				0.0				
	Slope 20-30							200	0	0.00	0				0.0				0.0				
	>30							500	0	0.00	0				0.0				0.0				
Horticulture	Volcanic							50	0	0.00	0				0.0				0.0				
	Soil type Sediment							100	0	0.00	0				0.0				0.0				
	Unknown							100	0	0.00	0				0.0				0.0				
	Total area of sources (m^2)		**3089684**					**Site totals**	**210883984**	**0.69**	**65080082**	**Site totals**	**642939.9**	**0.60**	**258813.8**	**Site totals**	**143794.6**	**0.85**	**21323.4**	**Site totals**	**2136410.7**	**0.60**	**865246.3**
	2013 areas	**4473563.26**																					
			7563247																				
			0																				

	Bottom of Site contaminant management train: First management option	Second management option	Third management option	Fraction of area draining to train	Bottom of Site out-fall Loads (kg a^{-1}): TSS	Zn	Cu	TPH	Average yields: TSS kg $ha^{-1}\ a^{-1}$	Zn g $ha^{-1}\ a^{-1}$	Cu g $ha^{-1}\ a^{-1}$	TPH g $ha^{-1}\ a^{-1}$	Average concentrations (mg kg^{-1}): TSS	Zn	Cu	TPH
Areas developed post 2013 scenario					65080.1	258.8	21.3	865.2	211	838	69	2800		3977	328	13295
Existing areas componement (unchanged from 2013 scenario)					385050.5	786.8	154.3	2530.6								
Total future scenario					450130.5	1045.6	175.6	3395.9	595	1382	232	4490				

Contaiminant Load Model - Developed Scenario 6

	Site area (m^2)		7563247	Source contaminant management train				Contaminant yields, loads, and load reduction efficiencies															
SOURCE	SOURCE TYPE							Sediment				Zinc				Copper				Total Petroleum Hydrocarbons			
			Source Area (m^2)	First management option	Second management option	Third management option	Fraction of area draining to train	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Load reduction efficiency	Reduced load ($g\ a^{-1}$)	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Load reduction efficiency	Reduced load ($g\ a^{-1}$)	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Load reduction efficiency	Reduced load ($g\ a^{-1}$)	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Load reduction efficiency	Reduced load ($g\ a^{-1}$)
Roofs	Galvanised unpainted							5	0	0.00	0	2.200	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
	Galvanised steel poor paint		63845	Constructed wetland			1	5	319226	0.77	73422	1.600	102152.4	0.20	81721.95	0.0008	51.1	0.25	38.3				
Roof areas assumed at 55% (	Galvanised well painted							5	0	0.00	0	0.150	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Total area = 1,706,187 includ	Zinc/aluminium unpainted							5	0	0.00	0	0.300	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Residential = A12	Colorsteel/colorcote		600146	Constructed wetland			1	5	3000728	0.77	690167	0.040	24005.8	0.20	19204.66	0.0008	480.1	0.25	360.1				
Roofs = A13	Concrete		319226	Constructed wetland			1	10	3192264	0.77	734221	0.020	6384.5	0.20	5107.62	0.0013	415.0	0.25	311.2				
Roofs 2013=A14	Clay							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
5751354	Slate							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
3163244	Copper							5	0	0.00	0	0.000	0.0	0.00	0.00	3.0000	0.0	0.00	0.0				
1886339	Decramastic		293688	Constructed wetland			1	5	1468441	0.77	337741	0.200	58737.6	0.20	46990.12	0.0017	499.3	0.25	374.5				
Total new roofs=	Other materials							5	0	0.00	0	0.020	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
1276905	Unknown (no galvanised steel/copper)							7	0	0.00	0	0.200	0.0	0.00	0.00	0.0008	0.0	0.00	0.0				
Residential 2013=																							
3429707																							
Residential New=																							
2321646																							
Roads		*Length (m)*																					
Total area=	<1000	0						4	0	0.00	0	0.021	0.0	0.00	0.00	0.0070	0.0	0.00	0.0	0.11	0.0	0.00	0.0
1500801	1000-5000	0	103676	Constructed wetland	Swale	Catchpit filter	1	30	3116391	0.88	387056	0.107	11130.0	0.65	3891.04	0.0349	3617.2	0.78	799.0	0.54	55649.8	0.36	35685.5
Total area 2013=	*Vehicles/day* 5000-20000	0	311029	Constructed wetland	Swale	Catchpit filter	1	150	46745861	0.88	5805836	0.537	166949.5	0.65	58365.55	0.1744	54258.6	0.78	11984.4	2.68	834747.5	0.36	535281.8
852824	20000-50000	0	233272	Constructed wetland	Swale	Catchpit filter	1	299	69776749	0.88	8666272	1.068	249202.7	0.65	87121.26	0.3472	80990.9	0.78	17888.9	5.34	1246013.4	0.36	799006.1
Total new area=	50000-100000							300	0	0.00	0	2.281	0.0	0.00	0.00	0.7414	0.0	0.00	0.0	11.41	0.0	0.00	0.0
647978	>100000							300	0	0.00	0	3.532	0.0	0.00	0.00	1.1480	0.0	0.00	0.0	17.66	0.0	0.00	0.0
Paved Surfaces	Residential		348247	Constructed wetland	Rain garden		1	20	6964939	0.93	480581	0.070	24377.3	0.77	5606.78	0.0100	3482.5	0.86	485.8				
other than roads	Industrial							50	0	0.00	0	0.100	0.0	0.00	0.00	0.1300	0.0	0.00	0.0				
2013=	Commercial							100	0	0.00	0	0.050	0.0	0.00	0.00	0.0500	0.0	0.00	0.0				
514456																							
Total=																							
862703																							
Total new area=																							
348247																							
Urban Grass lands	<10		808554	Constructed wetland			1	35	28299386	0.77	6508859				227.8				45.6				
Total=	Slope 10-20							80	0	0.00	0				0.0				0.0				
1993498	>20							160	0	0.00	0				0.0				0.0				
2013=																							
1184944																							
Reserves new=																							
808554																							
Urban Stream Channel	*length x width*		8000					6000	48000000	0.00	48000000				1680.0				336.0				
	Urban area without construction sites		**3089684**					**Totals**	**210883984**	**0.66**	**71684155**	**Totals**	**642939.9**	**0.52**	**309916.8**	**Totals**	**143794.6**	**0.77**	**32623.6**	**Totals**	**2136410.7**	**0.36**	**1369973.4**
Construction Site (1)	<10		0				1	400	0	0.00	0				0.0				0.0				
open for 2 months/year	*Slope* 10-20							2500	0	0.00	0				0.0				0.0				
	>20							7000	0	0.00	0				0.0				0.0				
Construction Site (2)	<10		0				1	1300	0	0.00	0				0.0				0.0				
open for 6 months/year	*Slope* 10-20							7500	0	0.00	0				0.0				0.0				
	>20							20000	0	0.00	0				0.0				0.0				
Construction Site (3)	<10							2500	0	0.00	0				0.0				0.0				
open for 12 months/year	*Slope* 10-20							15000	0	0.00	0				0.0				0.0				
	>20							40000	0	0.00	0				0.0				0.0				
0	**Urban area with construction sites**		**3089684**					**Totals**	**210883984**	**0.66**	**71684155**	**Totals**	**642939.9**	**0.52**	**309916.8**	**Totals**	**143794.6**	**0.77**	**32623.6**	**Totals**	**2136410.7**	**0.36**	**1369973.4**
Exotic production forest	<10							10	0	0.00	0				0.0				0.0				
	10-20							60	0	0.00	0				0.0				0.0				
	Slope 20-30							200	0	0.00	0				0.0				0.0				
	>30							500	0	0.00	0				0.0				0.0				
Stable bush	<10							5	0	0.00	0				0.0				0.0				
	10-20							30	0	0.00	0				0.0				0.0				
	Slope 20-30							100	0	0.00	0				0.0				0.0				
	>30							250	0	0.00	0				0.0				0.0				
Farmed pasture	<10							50	0	0.00	0				0.0				0.0				
	10-20							100	0	0.00	0				0.0				0.0				
	Slope 20-30							500	0	0.00	0				0.0				0.0				
	>30							1000	0	0.00	0				0.0				0.0				
Retired pasture	<10							20	0	0.00	0				0.0				0.0				
	10-20							100	0	0.00	0				0.0				0.0				
	Slope 20-30							200	0	0.00	0				0.0				0.0				
	>30							500	0	0.00	0				0.0				0.0				
Horticulture	Volcanic							50	0	0.00	0				0.0				0.0				
	Soil type Sediment							100	0	0.00	0				0.0				0.0				
	Unknown							100	0	0.00	0				0.0				0.0				
	Total area of sources (m^2)		**3089684**					**Site totals**	**210883984**	**0.66**	**71684155**	**Site totals**	**642939.9**	**0.52**	**309916.8**	**Site totals**	**143794.6**	**0.77**	**32623.6**	**Site totals**	**2136410.7**	**0.36**	**1369973.4**
	2013 areas	4473563.26																					
			7563247																				
			0																				

	Bottom of Site contaminant management train				Bottom of Site out-fall Loads (kg a^{-1})				Average yields				Average concentrations (mg kg^{-1})			
	First management option	Second management option	Third management option	Fraction of area draining to train	TSS	Zn	Cu	TPH	TSS kg ha^{-1} a^{-1}	Zn g ha^{-1} a^{-1}	Cu g ha^{-1} a^{-1}	TPH g ha^{-1} a^{-1}	TSS	Zn	Cu	TPH
Areas developed post 2013 scenario					71684.2	309.9	32.6	1370.0	232	1003	106	4434		4323	455	19111
Existing areas componement (unchanged from 2013 scenario)					385050.5	786.8	154.3	2530.6								
Total future scenario					456734.6	1096.7	186.9	3900.6	604	1450	247	5157				

Appendix F Three Waters requirements (Existing and Future)

Stormwater

Refer to Plan 012 in Appendix C for locations of stormwater features. Final devices shall be wetlands unless stated otherwise, or specifically proposed and approved by Council prior to the submission of engineering plans.

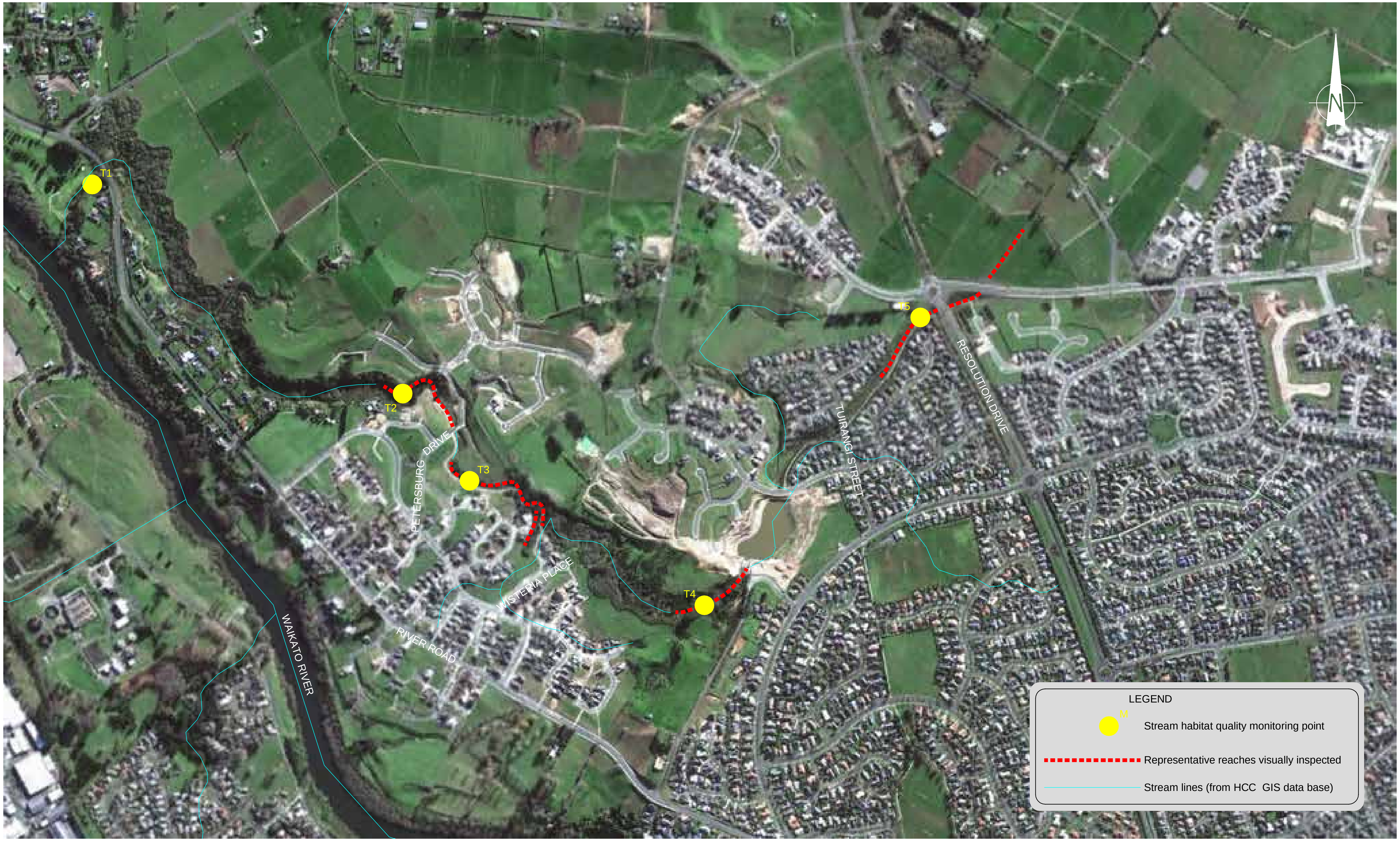
The required parameters are provided to inform design aspects for devices not yet consented. Pre 2004, device has existing use rights. Where a device is not consented developers will need to go through preferred device hierarchy appropriate for the area.

Device ID	Name / Development	Location	HCC Asset ID	Device Type and Purpose	Status	Design requirements	Consent Number/s
LOWER CATCHMENT							
1	Audrey Place Wetland (Meadows 1)	Cumberland Drive (part Otama-ngenge)		To mitigate stormwater from surrounding The Meadows residential development.	Built - Private – to be vested	- Water Quality Volume - Extended detention 24mm - Controlled discharge up to 100 year - Planted	Hamilton City Council consent 2009/20392 Waikato Regional Council consent 124726
2	Meadows soakage			Soakage only		- (on end of treatment train device) - Extended detention - Water quality (50%) - Attenuation not required - All events discharge direct to stream via setback	No consent required
4	Nicks way Wetland (Featherstone Park Development – North)	Cumberland Drive		To mitigate stormwater from surrounding Featherstone Park residential development.	Built - Council owned		HCC consent 2008/5012 Design detail plan (D-261203)
5	St Peterburg Wetland (Featherstone Park Development – south)	St Petersburg Drive		To mitigate stormwater from surrounding Featherstone Park residential development.	Built - Council owned	- Water Quality Volume (13.2ha, 863.6m) - Extended Detention 34.5mm, EDV 2745.9 - 2-year attenuation, will pass 10-year event - Flows exceeding wetland capacity flow into protected spillway - Plan shows southern catchment 7.7ha	HCC consent 2008/5012 Design (D-261101) Planting Plans D-261103 Pond, Fish pass D-261111
6	St Petersburg Lake (unofficial name)	St Petersburg Drive		Pond/Lake - aesthetic feature. previous culvert was capped, and weir and fish pass were installed.	Built - Land vested but consent obligations not passed to Council		HCC consent 2008/5012 Planting plan (D-261103) Pond, Fish pass (D-261111)
7	Delia Wetland (Eton Development)	Delia Court		To mitigate stormwater from Eton surrounding development including part of The Meadows, Magellan Heights	Built - Private – to be vested	- Design catchment 28.8 hectares - Primary treatment of first flush (considered to be 8.9mm of rainfall as described in the Waikato Regional Council evaluation) - Controlled discharge of up to 5-year event. - Emergency overflow of larger >50 year events	Hamilton City Council consent 2006/5394 Pond Design Report (D-261822) Waikato Regional Council consent 119119
8	Glaisdale Wetland **Overland flow path only** (Glaisdale West Development)	Borman Road Otama-ngenge Catchment		to mitigate stormwater from surrounding residential development. Overflows into the TAOK catchment	Consented	- Extended detention - Water quality (50%), - Attenuate 2- and 10-year flows to predevelopment levels, - Overland flows to TAOK 1 in 100-year event.	
9	Wisteria Place Wetland (Woodridge)	Wisteria Place off Te Huia Drive		To mitigate stormwater from surrounding Woodridge residential development.	Built - Council owned		
10	Magellan Lake (Major device)	Magellan Rise / The Link		Lake - to mitigate stormwater from surrounding CDL Development residential development.	Built - Land is vested, assets to be vested	Design under review To convey flows from Northern catchments only	117051, 48/1/M297 WRC consents 113670-113674
LOWER CATCHMENT							
11	Tuirangi Floodway	Magellan Rise		Stormwater floodway completed in 2006.	Built -Council owned	No treatment or attenuation capacity To convey flows from northern catchments only	
12	Redirection of stream (now piped)	Cumberland Drive		CDL Cumberland re-direction/replacement of the stream with overland flow path along road. Associated with the construction of the Tuirangi Floodway.	Built - Council owned		

13	Trauzer Place Wetland (Glaisdale and Sylvester Road Developments)	Trauzer Place		To mitigate stormwater from surrounding Glaisdale and apart of Sylvester Road residential development.	Future - consented	- Discharge the 2-year ARI critical duration storm at a rate that does not exceed the peak greenfield discharge - Water Quality Volume - Extended Detention 34.5mm - Includes sufficient capacity to capture the 5-year ARI critical duration storm and an emergency spillway that is sufficient to pass the 50-year ARI critical duration storm	Hamilton City Council consent 2005/5057 Waikato Regional Council consent 114008
14	Bourn Brook swale (Kimpton Farms)	Borman Road / North City Road (Upper catchment West)		Has consent to widen the drain (interim solution). Future development as part of the Rototuna Town centre includes a town centre lake feature, treatment swales and detention wetlands.	Future - consented	- Extended detention - Water quality (50%) - Attenuate 2- and 10-year flows to predevelopment levels – from Upper West catchment - Convey all flows from Upper West, Expressway and Expressway West catchments	Consented
15	Moonlight Wetland	Borman Road / Moonlight Drive (Horsham)		Stormwater detention pond to deal with the stormwater from surrounding residential development.	Built - Council owned	Catchment size – 28.83 ha D-1737113 - 2011/5066 Horsham Estate Stage 4 Stormwater Pond O&M	HCC consent 48/1/H261N and 48/1/B285C2
16	Arista Way Wetland	Borman Road (Horsham)		Stormwater management pond to mitigate stormwater from surrounding residential development.	Built - Private – to be vested		
17	Hector Drive Wetland	Borman Road (Horsham)		Stormwater management pond to mitigate stormwater from surrounding residential development.	Built - Private – to be vested		
18 A, B, C	Borman Road Catchment A, B and C)	Borman Road (Upper East)		Stormwater management pond to mitigate stormwater from surrounding residential development.	Built - Private – to be vested	- Extended detention - Water quality (50%) - Attenuate 2- and 10-year flows to predevelopment levels - Flows in excess of 10year and up to 50year – direct discharge to Borman Rd pipeline. - Flows in excess of 50 year – discharge via overland flow along Borman Road to Tuirangi Floodway.	
19	Resolution drive (treatment Device only) - Future			*Developers will need to go through preferred device hierarchy appropriate for the area*		- Extended detention - Water Quality (50%) - Attenuate 2- and 10-year flows to predevelopment levels - Flows in excess of 10year and up to 50year – direct discharge to Tuirangi Floodway - Provisional pipe to carry 2- & 10-year flows.	
21	Te Huia Drive Wetland	Te Huia Drive		Stormwater management pond to mitigate stormwater from future residential development.	Consented	- Extended detention - Water Quality (50%) - Attenuation not required - All events to flow direct to stream via setback.	
W1	Expressway West (Rototuna) - Future			*developers will need to go through preferred device hierarchy appropriate for the area*		- Extended detention - Water quality (50%) - Attenuate 2- & 10-year flows to pre-development levels - Overland flows in excess of 10 year – direct discharge to Bourn Brook swale via 100-year culvert (in accordance with NZTA requirements)	
W4	Landsdale Device Expressway West (Rototuna)						
E1	Expressway East Device (Rototuna)			*Developers will need to go through preferred device hierarchy appropriate for the area*		- Extended detention - Water quality (50%) - Attenuate 2- & 10-year flows to pre-development levels - Overland flows in excess of 2 year - direct discharge to Borman Road via a 100-year culvert sized in accordance with NZTA requirements. Open channel or pipeline to Borman Road to be determined by developer - note limitations on Borman Road pipeline stated below.	
W2	Bourn Brook swale Wetland (Future)	Rototuna Town centre Borman road				Wetland area – combined with Bourn Brook swale to achieve specified design requirements	
W3	Rototuna Wetland/Swale device (Town centre)	Proposed Rototuna Town Centre Borman road				- Extended detention - Water quality (50%) - Attenuate 2- & 10-year flows to pre-development levels - Overland flows in excess of 10 year – direct discharge to Tuirangi Floodway	
	Expressway					- Extended detention - Water quality (50%) - Attenuate 2- & 10-year flows to pre-development levels - Overland flows in excess of 10 year – direct discharge to Bourn Brook swale	

	Borman road					Stormwater pipeline capacity – 50 year Flows in excess of a 50-year event overland to Tuirangi floodway upstream of Resolution Drive	
24	Tennille Wetland	(Resolution sub catchment)		Wetland			
25	Church Wetland (future)			Wetland			
26	Detention (Atlantis) tanks	Borman road				Attenuation of 2-year event	
River North							
20 A	Featherstone Park A	River Road (River Gardens) Northern		Wetland/device to mitigate stormwater from future residential development.		- Extended detention - Water Quality (50%) - Attenuation not required subject to gully assessment. All events to flow direct to Waikato River via existing gully features (OLFP) - Centralised treatment may be replaced by at source treatment (i.e.) raingardens)	
20 B	Featherstone Park B	River Road		Wetland/device to mitigate stormwater from future residential development.	Built, Private – to be vested		
20 C	Featherstone Park C	River Road		Rain gardens	Built and vested		
Southern catchment – fully reticulated							

Appendix G Monitoring locations plan



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HAMILTON CITY COUNCIL
COMPREHENSIVE STORMWATER DISCHARGE CONSENT MONITORING
STREAM HABITAT AND SEDIMENT QUALITY MONITORING
Te Awa O katapaki Stream Stormwater Monitoring

FIG. No. Figure 3

REV. 0

Appendix H Magellan Lake and Concept Plan

Potential future works

The extent of CDL land is shown as catchments A-G in Figure 33. Enhancement works in the form of conversion of the lake to a wetland could provide the required WQV for up to 22 hectares which would comprise catchments A, B and C. The 22-hectare area is that is all that can be practically treated in Lake Magellan as the aforementioned catchments discharge directly to the lake.

Runoff from the remaining catchments D and E is mixed with water from the wider catchment that is be already treated before it reaches Lake Magellan[42] or is already mixed with partially treated catchment water prior to flowing into the Lake. It is not possible to isolate runoff from catchments D and E for treatment within the Lake.

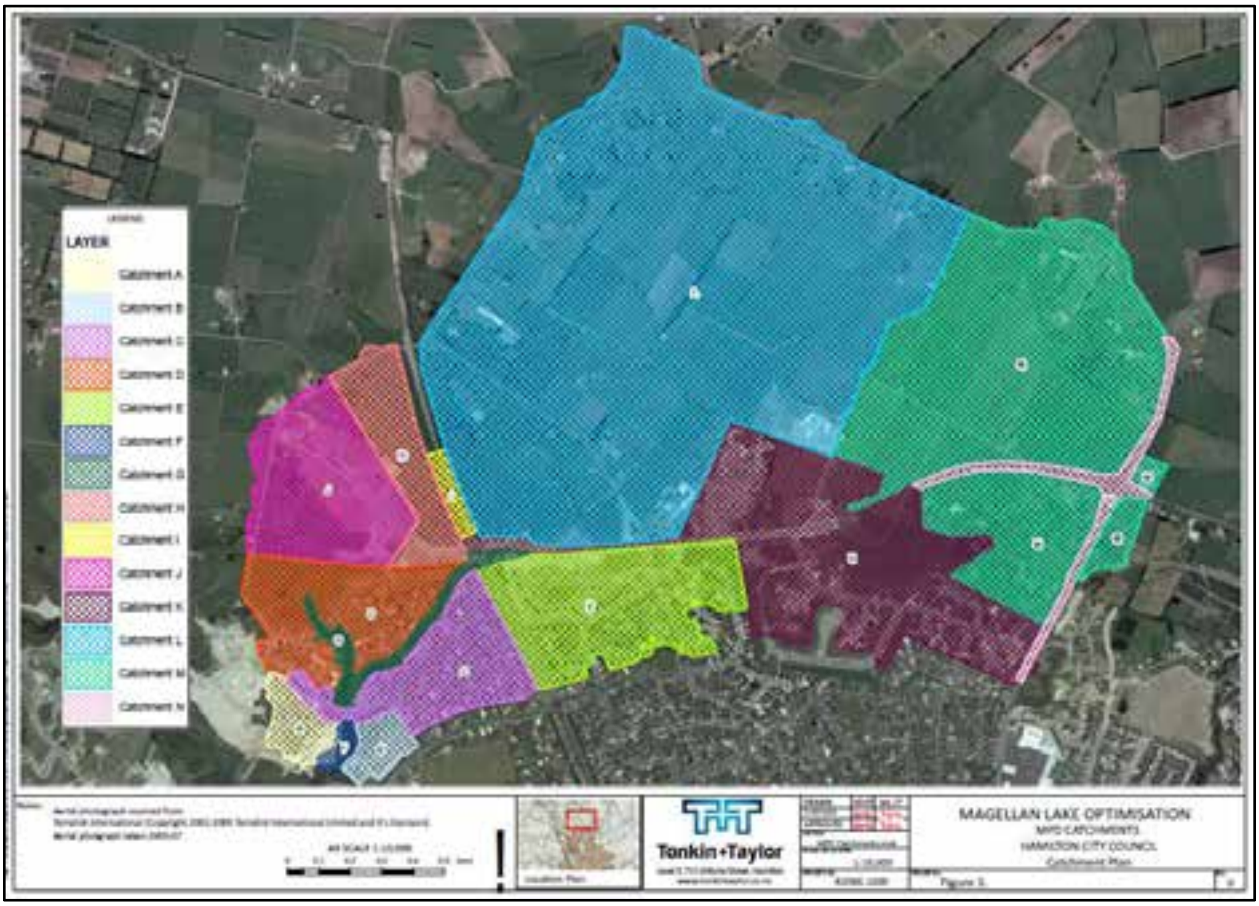

Figure 33 – Magellan Lake sub-catchment plan

CDL developed a portion of the area surrounding the Lake prior to the Lake development being consented (approximated as Area C). The aerial photos below illustrate the change in land development between January 2008 and March 2016. In the January 2008 photo the only areas of CDL land undeveloped were the areas immediately east and northwest of the Lake. No stormwater attenuation or treatment devices (other than the Lake and catchpits with gross pollutant traps) were installed in land developed by CDL.

[42] See D-2249822, D-2249820 and D-2322467

Figure 34 – Aerial image (courtesy Google Earth), January 2008

Figure 35 – Aerial image (courtesy Google Earth), March 2016

<u>Current Issues and Management Options</u>

A number of real and potential environmental issues have been identified by HCC notwithstanding compliance with resource consents. The issues are summarised below and discussed in more detail in the Lake O&M plan (T+T, 2013) and monitoring reports (T+T, 2013 and 2014).

- Water quality – predominantly in the form of downstream temperature and dissolved oxygen effects.

- Aquatic plants – predominantly failure to establish submerged macrophytes in the lake.
- Algal blooms – a potential issue only that has not been observed to date.
- Fish passage – no current issues.
- Pest fish – catfish are present and have the potential to impact on ecological values of the Lake.
- Waterfowl – periodic episodes of avian botulism.

WRC has noted that maintenance of base flows in the Te Awa O Kātāpaki Stream is another issue to address.

Flooding and velocity issues could be expected to arise as the catchment develops, if uncontrolled. Flood modelling for existing and future scenarios has been completed (AECOM, 2017) and a review of proposed peak flow attenuation based on modelling by T+T (2017) is discussed in a section on peak flow attenuation within the lake below.

<u>Lake Optimisation Concept</u>
HCC has progressed preliminary studies with respect to optimising the performance of the Lake. A potential opportunity has been identified to optimise the Lake to improve water quality and detention capabilities by altering the Lake.

The concept development is set out in detail in three reports prepared by T+T[43]. The current concept is summarised below:

- Construct a new low-level open channel, with suitable fish passage provisions, through the centre of the existing weir/dam structure. The normal water level will be reduced to enhance plant growth.
- Provide new treatment areas at the three existing stormwater inflow points. The new treatment areas will provide water quality improvement for approximately 22 hectares of developed land in total.
- Provide accessible forebays for sediment removal and maintenance.
- Plant the three new treatment areas and provide limited planting with the remaining lake area.

The three reports also update the previously reported constraints, risks and opportunities and key issues for further consideration by HCC and they are as follows:

- The provision of three treatment areas within the lake should provide water quality improvement for stormwater discharges from approximately 22 hectares of developed land in total.
- Converting the Lake into a segmented Lake with treatment areas and plantings may have positive effects on overall water quality in the Lake. It is noted that water quality within the Lake is in large part determined by upstream stormwater discharges and levels of treatment, and no amount of enhancement within the Lake will alter upstream conditions.
- Given the influence of upstream catchments, attempting to quantitatively assess if the proposed optimisation works would significantly change water quality within the body of the Lake would likely be expensive and may not reach a definitive or scientifically robust conclusion.
- Conversion to a segmented Lake could reduce the scale of, but not eliminate, the existing water temperature issues.

[43] Magellan Lake Optimisation Investigation, Phase 1, Phase 1 Addendum, and Phase 2 reports.

- Reconfiguring the Lake outlet and reducing static water levels would provide additional stormwater storage benefits and could potentially avoid the need for additional peak flow attenuation on some council roading projects including Resolution Drive.

A concept plan (T+T Figure 1, Rev. 2 dated February 20174) of the proposed Lake optimisation works is presented in Appendix H.

Environmental Effects
The effect of the proposed concept has not been specifically reviewed against all key issues identified for the Lake at the time of writing of the ICMP. A discussion of the expected effects is summarised below.

Water Quality
The stormwater treatment function in the Lake and in the upper catchment is a complex issue. Assessment would involve assumptions on current and future land use, the level of treatment in current and future developed lands, mixing and dilution of treated and untreated stormwater and the effect of additional treatment in the Lake.

Some water quality improvement is possible but the overall water quality in the Lake is largely governed by upstream stormwater treatment and associated discharges. The proposed enhancement will mitigate the impacts on water quality for the 22-hectare area targeted for treatment to a level compliant with the RITS (or another equivalent document).

Whole of Catchment TP10 Review
In order to assess the proposed enhancement, T+T (2017) have undertaken to estimate the rough order water quality effectiveness of the concept using TP10. The estimation is rough order for comparison purposes only and is not an accurate prediction of treatment levels. All assumptions and the methodology were kept consistent to enable comparison only and the quoted removal efficiencies should not be treated as absolute and achievable values.

Table 20-1 lists the estimated water quality volume required to achieve 75 % treatment in the maximum development with climate change scenario, the concept volume available at each of the proposed three treatment areas and the lake. The table has been summarised for clarity from the T&T Phase 2 (2017) report.

Table 20-1 – WQV summary in MPD +CC case

Treatment Area	Inflow from	TP10 Required WQV (m^3)	Available WQV (m^3)	% WQV Available	Indicative treatment (%)
Western	Catchment A	300	400	133%	80%
Eastern	Catchment B	200	400	200%	>82%
North East	Catchment C	1,300	1,400	108%	76%
Central Lake only	All catchments	40,000	5,200[44]	13%	42%

The table shows that the proposed treatment areas can provide adequate water quality volume and meet target treatment levels[45] for their contributing catchments.

[44] Excludes volume available in the three treatment areas.

[45] >75 % treatment efficiency as per TP10.

The percentage-based volume assessment method does not account for the potential to improve water quality by facilitating opportunities for increased planting density and associated water quality improvements via adhesion to vegetation, velocity and turbulence reduction, and biological uptake. In addition, the residual level of treatment in the central Lake is indicative given the small permanent water volume (water quality volume) provided in comparison to the amount which would be required to meet TP10 standards.

It is noted that much of the water discharging into the Central Lake area should already be treated in the fully developed scenario.

Other effects

1. Temperature – Conversion to a segmented Lake (with more plantings) could reduce the scale of, but not eliminate, the existing water temperature issues.
2. Dissolved oxygen – Significant changes are not expected to occur as a result of optimisation.
3. Aquatic plants – Modification to lower permanent and normal operating water depths and to create segmented treatment areas may provide improved conditions for aquatic plant establishment (different to wetland plants).
4. Algal blooms – Significant changes are not expected to occur as a result of optimisation.
5. Fish Passage – The proposed changes will maintain the existing weir type but will lower the slope so a slight improvement could be expected.
6. Pest Fish – Significant changes are not expected to occur as a result of optimisation.
7. Waterfowl – Significant changes are not expected to occur as a result of optimisation.
8. Base Flows – Significant changes are not expected to occur as a result of optimisation; T+T's 2014 monitoring report concludes that *"base flow in the Te Awa O Kātāpaki Stream downstream of the Lake footprint post the construction of Magellan Lake is of a similar order to the pre-Lake scenario"*.

Detailed Assessment of Environmental Effects

A full Assessment of Environmental Effects (AEE) of the proposed Lake optimisation work has not been undertaken at this stage. The proposed works will require resource consents to be applied for and an AEE will be completed as part of resource consent application documentation.

<u>CDL Extent Review</u>

The proposed optimisation will provide approximately 100 % AC TP10 level of treatment for 22 hectares of the 74-hectare CDL land area.

As part of future work, HCC will review potential options to provide additional treatment or offset opportunities within CDL land and/or similar sub-catchments that eventually discharge to the Lake. It is expected that the future work will review potential options and identify preferred options to implement.

<u>Peak Flow Attenuation in the Lake</u>

Peak flow attenuation targets related to CDL Lands, the future Resolution Drive extension and Borman Road is to attenuate to the 2 year and 10-year pre-development peak flow rate. Private development areas upstream of Borman Road where 100-year attenuation (80%) is required will be dealt with separately.

Modelling in 2009 (T+T) showed that the Lake attenuated peak flows, but flows exceeded pre-development rates by 5% and 7% for the 2 year and 10-year events respectively.
Peak flow attenuation results from T+T (2017) are summarised below with and without climate change respectively and represent the lake in its proposed optimised form.

Table 20-2 – Peak Flow Attenuation CDL Plus HCC Roads

Model scenario	Peak Flow, (% of rural greenfield flows)		
	2 year event	10 year event	100 year event
Without Climate Change	99.7 %	99.5 %	104.4 %
With Climate Change	102.0 %	104.5 %	103.7 %

When no climate change is considered it appears that the optimised Lake concept can achieve the attenuation target for CDL lands as well as the Borman Road and Resolution Drive extensions (future road projects). Peak flow rates downstream of the existing Lake in in the 2- and 10-year ARI events are attenuated to less than pre-development.

Attenuation of upstream road projects in Lake Magellan is subject to the ability to safely convey unattenuated stormwater to the Lake without increasing flood risk, which may not be possible for Borman Road.

When climate change is considered the optimised Lake concept does not achieve the attenuation target for CDL lands and future road projects in the 2, 10- and 100-year ARI events. However, the difference between peak flow rates between the undeveloped and developed cases is small at less than 5% in all scenarios considered.

The percent increase in peak flows is less than what was considered acceptable when the Lake was originally consented. The results are consistent with, or better than, what was achieved when the Lake was originally consented. The final outlet arrangement may be able to achieve improved attenuation, subject to final design. Aspects which could limit improvements in attenuation capacity include:

- A reduction in water quality outcomes resulting from attenuation improvements.
- Constraints on other enhancement aspects of the lake such as bunds, treatment areas and overall storage.
- Higher flood levels and flows than currently anticipated from upstream development.

Operations and Maintenance Plan

The Magellan Lake Operations and Maintenance Plan (O&MP) is a key management document. An updated version of the management plan, reflecting the optimisation proposal, will need to be prepared if it is progressed through to implementation. The proposed works will require resource consents to be applied for and a revised O&MP will be completed as part of resource consent application documentation.

HCC Funding Processes

Optimising Lake Magellan is subject to HCC securing funding under the Long-Term Plan funding process.

Reports on potential lake modification are discussed in section 10.5.4.

Figure 36 – Plan of Magellan Lake with planned lake planting areas in green

Appendix I Ecological Report

TE AWA O KATAPAKI STREAM

Assessment of Ecological Values to inform an Integrated Catchment Management Plan
Prepared for Hamilton City Council

26 May 2016

Document Quality Assurance

Bibliographic reference for citation: Boffa Miskell Limited 2016. *TE AWA O KATAPAKI STREAM: Assessment of Ecological Values to inform an Integrated Catchment Management Plan*. Report prepared by Boffa Miskell Limited for Hamilton City Council.		
Prepared by:	Kieran Miller Ecologist Boffa Miskell Limited	
Reviewed by:	Louise Saunders Principal / Ecologist Boffa Miskell Limited	
Status: FINAL	Revision / version: 1	Issue date: 26 May 2016
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Template revision: 20150724 0000

File ref: T14157_TAOK_Ecological_assessment_FINAL_20160526_LSA.docx

Cover photograph: Te Awa O Katapaki Stream, © Louise Saunders, 2015

CONTENTS

Appendices

Executive Summary

Hamilton City Council (HCC) has prepared a draft Integrated Catchment Management Plan (ICMP) for the Te Awa O Katapaki (TAOK) Stream catchment. TAOK Stream is a small tributary of the Waikato River located on the north-eastern boundary of Hamilton City. Most of the catchment is already urbanised, and the remaining rural areas are either currently under development or will be developed in the foreseeable future under the provisions of the Proposed Hamilton City District Plan and the Rototuna Structure Plan. An ICMP has also been prepared for the Resolution Drive sub-catchment to guide integrated three waters infrastructure in that part of the catchment.

This ecological assessment has been prepared to support ICMP development. The assessment characterises the state of the stream receiving environment in the context of the various land uses in the catchment. Based on water and habitat quality assessments, surveys of indigenous biodiversity, and observations of erosion dynamics, this assessment identifies the risks and sensitivities of the stream with respect to stormwater discharges.

Based on field surveys and review of existing information, the TAOK Stream has the following characteristics:

- The stream has a range of reach types including artificial drains, stormwater swales, on-line stormwater storage devices (Magellan Lake and Petersburg Drive lake), modified stream channels, and the natural stream channel within the gully floodplain with extensive riparian wetlands.
- Aquatic habitat provides very poor to moderate conditions for indigenous biota, and the diversity and distribution of native species is limited by fish passage barriers, poor water quality, and poor upper catchment habitat quality.
- Water quality is typical of all Hamilton streams with some water quality parameters exceeding the tolerances of aquatic species. Concentrations of copper, zinc, aluminium and nutrients exceed ANZECC guidelines. Some of these exceedances are related to high suspended sediment loads and others relate to long term land drainage, being common to most Hamilton waterways. Zinc, nitrate, and faecal pathogens are high throughout the catchment.
- Benthic sediment has elevated contaminant (arsenic and zinc) concentrations at three sampling locations. This is likely to be a localised issue and could be a risk to public safety from aquatic plant consumption (watercress).
- As well as shortfin eels, common smelt and common bully, the stream provides habitat for the threatened species giant kokopu and inanga which confers ecological significance on the catchment.

In the context of the above, and the Best Practical Options presented in the draft TAOK ICMP and Resolution Drive ICMP, the risks and sensitivities of the Te Awa O Katapaki Stream catchment have been identified with objectives and actions as follows:

- There is potential for existing water quality and native fauna effects of on-line stormwater devices to be improved by planting, retrofitting, or altering management of lakes. New open water devices should not be created on-line.

- Water quality can also be improved by improving the implementation and performance erosion and sediment control measures during and immediately post-construction to reduce suspended sediment loads and turbidity.
- Newly created stormwater swales are experiencing notable bank instability, sedimentation and impacts on water quality downstream, and currently provide very poor habitat for indigenous aquatic organisms. Requiring swales to be planted soon after construction will improve habitat quality, water treatment, water quality and bank stability.
- Existing bank instability between Magellan Lake and Petersburg Drive is causing similar impacts, and the most appropriate remedial measures will be green engineering devices that allow low-stature intensive riparian planting.

A monitoring regime is recommended to ensure that the objectives set to maintain and/or enhance the ecological values of the TAOK Stream are achieved.

The values of three small first order tributaries in the River North sub catchment could not be assessed. On the basis of records from similar catchments, these tributaries are assumed to provide habitat for threatened species and therefore have ecological significance. Their actual values should be established using field surveys.

1.0 Introduction

Boffa Miskell Ltd (BML) was engaged by Hamilton City Council (HCC) to assess the ecological values of the Te Awa O Katapaki (TAOK) Stream to support the development of an Integrated Catchment Management Plan (ICMP). The TAOK Stream catchment is located at the north-eastern periphery of Hamiton City and flows from east to west, draining into the Waikato River on its true right bank.

Apart from small areas at the northern extremities, the entire catchment is within the Hamilton City boundary incorporating the suburbs of Rototuna and Flagstaff. The adjacent catchments are Otama-ngenge Stream to the north-west and Kirikiriroa Stream to the south-east.

As described in the draft TAOK ICMP, the catchment is comprised of three main sub-catchments:

- Upper catchment of 411 hectares which was predominantly rural until recently, and is currently or proposed for development of a town centre, community facilities and residential and roading replacing the remaining rural land. This will include the Waikato Expressway and Resolution Drive extension.
- Southern catchment of 210 hectares which is a fully developed urban area with the typical mix of residential, open space, and small scale commercial areas.
- Lower catchment of 143 hectares which includes the main stem of the TAOK Stream within the incised gully system to the Waikato River confluence, with a small proportion of the area currently under development for residential land use.

In addition, there is the River North catchment located on the south-facing slopes between the TAOK catchment and the Waikato River, comprised of rural residential or residential development. The middle portion between Joseph Lovett Lane and Brywood Rise includes three small first order stream catchments flowing through land proposed for or currently under development and discharging directly into the River.

Within the framework provided by the Proposed Hamilton City District Plan and Rototuna Structure Plan, a draft ICMP has been prepared. An ICMP has also been prepared for the Resolution Drive sub-catchment upstream of Borman Road. The latter document reflects the draft Best Practicable Options (BPOs) contained in the former, and these documents provide guidance on the intended approach to Three Waters management and likely TAOK catchment outcomes in terms of water quality and physical effects.

The purpose of this assessment is to determine the existing values of the TAOK Stream and assumed values of the River North waterways, including ecological values and habitat. Further, the assessment evaluates whether stormwater discharges from existing and proposed urban areas are having actual or potential effects, and how far downstream those effects are being experienced.

This ecological assessment has been prepared to set clear objectives for the TAOK Stream catchment that will be achieved by implementing BPO set out in the ICMP. A monitoring programme can then determine whether the BPO have been effective at achieving these objectives.

1.1 Location and General Description

The TAOK Stream is a small tributary of the Waikato River located within the northern boundary of Hamilton City, south of Horsham Downs. Its catchment encompasses around 764ha[1] of rolling Waikato lowlands in the area generally defined by Borman, Kay, and River Roads in the lower catchment, Hukanui Road to the north, Rototuna Road to the east, and River Road to the south (see Figure 1 in Appendix 1). A full description of the catchment locations and land uses is provided in the draft TAOK ICMP.

Most of the TAOK Stream catchment is comprised of Waikato River alluvial plains which would originally have supported indigenous forest (Cornes *et al*. 2012). The topography, soils, and remnant vegetation indicates that the area would have included wetland areas, particularly in low-lying flood plains and gully floors. Some of these wetlands may have included highly organic and/or peat soils within incised gullies, intersected by dry gully slopes and plateaux.

Similar to almost all land in this area, by the mid-1900s, most wetland areas and remnant forest would have been removed to create farmland, and the vegetative cover changed from predominantly alluvial secondary native vegetation to exotic pasture (Nicholls 2002) and willow wetlands. Existing TAOK catchment vegetation is dominated by exotic pasture with shelterbelts and hedges in rural areas, while urban areas contain a mix of native and exotic amenity plants. Contiguous native and exotic shrubland and wetland vegetation is present along the riparian zones of the lower catchment.

Based on the sub-catchment areas, the TAOK stream is divided into three parts as follows:

- Upper catchment comprised of artificial farm drains being converted to swales, a small modified stream tributary, or artificial stormwater swales. Apart from the Tuirangi Floodway, there is very little riparian vegetation.
- Southern catchment comprised of the fully urbanised area from Hukanui Road west to the discharge point at The Link. The original stream tributaries have been piped and culverted and there are no surface waterways remaining.
- Lower catchment from Magellan Rise downstream comprised of two artificial lakes with detention structures, a modified stream reach between the lakes, and a relatively natural stream reach within the main gully system. The lower catchment gully system is the main topographical feature, with steep gully slopes, extensive riparian springs and wetlands, and well defined floodplain on the gully floor. The stream meanders west through the gully, before passing under River Road to the Waikato River confluence. Lower catchment riparian vegetation is extensive in parts, but highly modified where urban development (particularly walkway construction) has removed the vegetation.

The main surface stormwater features are:

- Headwater stormwater swales under development.
- The Tuirangi Floodway, an artificial stream reach created to move the stream to a location more conducive to development patterns.
- Magellan Lake, an online stormwater pond which has existing water quality problems and performance issues, and contains coarse fish species.

[1] Te Awa O Katapaki Integrated Catchment Management Plan, Draft: 21 October 2014.

- Petersburg Drive lake, an online stormwater pond created principally as an amenity feature.

The TAOK catchment also includes the River Road sub-catchment which is comprised of the south-west facing slopes between River Road and Waikato River. The sub-catchment is either rural-residential or residential with small areas between Joseph Lovett Land and Sylvester Road remaining to be developed. These areas discharge directly to the Waikato River via small first order waterways that satellite photography indicates have a mixture of exotic and native shrubland/treeland riparian cover.

1.2 Development Principles and Design

Based on the draft TAOK ICMP and Resolution Drive Sub-Catchment ICMP, stormwater design for new residential development will be based on the key design principles of:

- Roof water to soakage and tanks wherever possible.
- Overflow and impermeable runoff to conventional kerb and channel, road catch pits and piped reticulation, and discharge to raingardens and/or swales.
- All stormwater will then discharge to centralised stormwater detention and treatment devices that ultimately discharge into the TAOK Stream.
- The Waikato Expressway and Resolution Drive extension stormwater treatment is likely to consist of roadside swales connecting to detention and treatment wetlands that ultimately discharge into the TAOK main stem.

The urbanisation activities resulting from new and existing development most likely to affect aquatic ecological values are earthworks and stormwater (discharges and associated management).

Wastewater and water supply infrastructure are expected to be provided by way of conventional water mains from a HCC reservoir and wastewater pipelines and pump stations to the HCC wastewater treatment plant. Earthworks to construct these assets will occur within the catchment, but ongoing operation of water and wastewater infrastructure are not expected to have a direct effect on the waterways and are also not considered further.

Although detailed design is not available for all of the proposed development in the catchment, it is generally expected that all existing farm drains will be removed and replaced with pipes or open swales with continued connectivity, base flows, and fish passage to downstream habitats in the TAOK Stream.

Within the undeveloped portion of the River North sub-catchment, at the time of writing, the southern land parcel had resource consent for a stormwater design based on extensive use of rain gardens discharging into the stream. The design principles for stormwater management of the middle and northern land parcels was not available.

Construction-related earthworks effects on aquatic ecosystems throughout the TAOK catchment are expected to be addressed through regional resource consent applications and monitoring. While these would normally not be considered further in this assessment, previous studies acknowledge that there are existing effects occurring as a result of construction earthworks, principally increased sedimentation and turbidity in the stream.

This assessment focuses principally on stormwater infrastructure, the ongoing effects of post-development stormwater discharges and management, and existing effects of construction. The land uses that contribute to stormwater flows include:

- Existing residential land;
- Land under development for residential housing;
- Rural land proposed for urban development subject to resource consents; and
- Proposed roads.

For the proposed residential development, urban design parameters and stormwater management have been established broadly through district plan, Structure Plan and draft ICMP processes and these will be implemented and managed through subdivision and/or discharge consent processes. This means that post-development land cover and imperviousness, design and location of stormwater infrastructure, and discharge points are, for the most part, pre-determined.

However, identifying the particular risks and sensitivities of the catchment provides opportunities to influence the design performance of new infrastructure and consider retrofit or alternative management of existing stormwater treatment and storage devices.

The assessment is based on the following assumptions:

- The entire area of the TAOK Stream catchment within Hamilton City will be urbanised.
- Post-development residential imperviousness can be expected to reflect typical residential imperviousness of no greater than 60%, and that stormwater infrastructure has been, or will be, designed to accommodate stormwater volumes on that basis.
- Stormwater management for all development/roading areas is, or will be, designed to at least TP10[2] standards requiring an average removal of 75% of suspended sediment and associated contaminants.
- Stormwater attenuation requirements will vary across the catchment for new development on the basis of the means of compliance set out in the draft TAOK ICMP and Resolution Drive Sub-Catchment ICMP.
- Stormwater management for new residential areas in the TAOK sub-catchments includes a reticulated stormwater network, with raingardens and swales in suitable locations, discharging to conventional stormwater detention devices comprised of a sediment detention basin discharging into a storage basin with a low flow area planted as a wetland for stormwater treatment or a pond. These devices are expected to discharge to the TAOK Stream.
- Stormwater management for new urban area in the River North sub-catchment will be dependent on specific ecological assessment of the waterways, but are likely to include intensive treatment prior to discharge focused on maintaining cool temperatures and high standards of contaminant removal.
- The requirement for fish passage in new open stormwater devices will be dependent on the presence of fish habitat prior to development.

[2] Auckland Regional Council, 2003. Stormwater Management Devices: Design guidelines manual. Technical publication 10.

1.3 Stormwater Discharges

The quality, volume, and flow rate of stormwater discharged from a fully urbanised area is, or will be, different to the pre-development stormwater characteristics where the catchment is comprised of both rural and urban areas.

Rural catchments such as those present in the TAOK upper catchment are typically dominated by pervious pasture with small areas of less pervious farm tracks and impervious hardstands, buildings and roads comprising around 1-2% of the catchment. The TAOK Stream catchment has existing residential development throughout most of the catchment. Around half of the upper catchment and a small part of the lower catchment remain rural, with development proposed in the foreseeable future.

When fully developed, the new residential area is expected to have typical residential imperviousness of around 50-60%, while new commercial areas may have higher levels of imperviousness. This means the catchment's total impervious area will increase, and the incremental and cumulative increases in imperviousness will result in greater stormwater discharge volumes and flow rates than would be expected from pasture unless controlled.

Pre-development stormwater contaminants of concern from rural areas typically include nutrients, sediment, bacterial pathogens, and some metals associated with agricultural use (e.g. copper and zinc). Post-development stormwater contaminants typically include an increase in temperature, sediment, petroleum hydrocarbons, and metals, from concentrations/levels already present. Given that a high proportion of the catchment is already urbanised, much of this change can be expected to have already occurred, but new development will contribute to further incremental and cumulative changes in water quality.

It is important to note that the stormwater contaminant profile from residential land has changed in the last 10 years compared to that generated from older subdivisions due to changes in tyre and fuel composition, roof cladding, and stormwater technologies. In general, mass loads of the typical stormwater metals (cadmium, copper, lead, nickel, and zinc) have decreased[3]. This is particularly relevant to the TAOK catchment in which much of the urbanisation has occurred in the last ten years.

2.0 Assessment Purpose and Scope

The purpose of this assessment is to:

- Evaluate existing aquatic ecological values, water chemistry/quality, and sediment quality of the TAOK Stream; and
- Identify the risks and sensitivities of the TAOK Stream in relation to the actual and potential effects of stormwater discharges from new and existing urban development and roading.

To provide context to the assessment, it is important to note that:

[3] Brough, A., Brunton, R., England, M. & Eastman, R. 2012. Stormwater Quality – An analysis of runoff from modern subdivisions and the implications for stormwater treatment. Proceedings: Water New Zealand Stormwater Conference 2012.

- Urbanisation of land zoned future urban in the TAOK catchment, and particularly the Rototuna Structure Plan Area, is a foregone conclusion,
- Urbanised land will ultimately form a large proportion of the total catchment (approximately 85%), and
- Based on current District Plan zoning, residential will be the dominant land use within the catchment at 57%. The next most common land uses will be roading corridor (13%) and the Rototuna Town Centre commercial area (12.6%).

As set out in Table 1, this assessment has been based on surveys of riparian and aquatic habitat, biota, sediment quality and water quality present in the TAOK Stream. Existing information sources relating to aquatic ecology values were also evaluated.

Table 1: Data collection and methodology

Parameter	Methodology
Habitat values	Stream habitat assessment (instream and riparian qualitative assessments). Review of Land Cover Database. Review of Cornes *et al.* 2012 for identified sites of ecological significance. Review of Waikato Regional Council Regional Policy Statement and supporting technical reports regarding habitat evaluation for ecological significance.
Water quality	On-site measurement of temperature, pH, dissolved oxygen, and conductivity. Review of Waikato Regional Council water monitoring database.
Water contaminants	Water samples analysed for pH, suspended sediment, turbidity, metals, nutrients, carbonaceous biochemical oxygen demand, faecal bacteria and petroleum hydrocarbon compounds. Review of Waikato Regional Council water monitoring database.
Sediment contaminants	Sediment samples analysed for arsenic, cadmium, chromium, copper, lead, nickel, and zinc.
Aquatic macroinvertebrate fauna	Aquatic macroinvertebrate samples collected using Protocol C4 (MfE, 2001).
Fish fauna	Evaluation of Freshwater Fish Database records and previous fish survey information.

Access to the River North sub-catchment waterways was not possible so assessment of stream values is based on observations from HCC parks and public roads, satellite photography, and existing information on similar first order streams discharging into the Waikato River.

3.0 Methods

Prior to undertaking field surveys, existing data sources were collated and a gap analysis completed to determine the most appropriate sites for field surveys and the analyses/surveys to be undertaken at each site. To allow comparison with earlier survey results, sites close to earlier survey sites were given preference over other locations. Sites were also selected to provide ecological data on different reach types and different land uses.

On that basis, five survey sites were selected for field surveys. Four sites were along the main stem of the TAOK Stream and a further sampling site located on an adjoining tributary (see Figure 2 in Appendix 1). These sites were selected as being representative of the existing environment. Although a large proportion of the TAOK waterways was observed during field surveys, a full stream walkover was not undertaken.

The field surveys and habitat assessment of the TAOK Stream were completed on 22nd April 2015 as follows:

- Site habitat assessments including observations of riparian, bank and channel vegetation, water clarity, algal cover, structures, fencing, and adjacent land use.
- As part of the habitat assessment, the severity and extent of erosion and scour processes was noted at each site, within the context of the surrounding topography, vegetation, and land use. This included observing whether scour and erosion is active or historic, the location of the erosion or scour (undercutting at the waterline, bank failure, sloughing of bank materials, vegetation collapse, etc.) and the likely processes causing the erosion or scour (e.g. vegetation spraying, undersized or poorly placed culverts, etc.).
- Sediment and water quality samples were collected from all five sites. Samples were chilled and sent to Hill Laboratories for analysis with accompanying chain of custody documentation.
- Samples of aquatic macroinvertebrates were collected from four of the five sites using a 500 µm mesh net following Protocol C4 (soft-bottomed, Quantitative – Macrophytes) (Ministry for the Environment 2001), preserved in ethanol and analysed according to Protocol P1: coded abundance. Other protocols were not used because of inadequate suitable substrate (hard substrate, woody debris, or bank overhang) and dominance of aquatic macrophytes. The soft-bottom Semi-Quantitative Macroinvertebrate Community Index (SQMCI-sb) was calculated for each sample (Stark & Maxted 2007). Species richness and number of EPT[4] taxa were also calculated. Sample collection was not possible at one site due to insufficient suitable substrate of any kind.
- Existing Freshwater Fish Database records provide sufficient spatial coverage and are recent, so no further fish survey was considered necessary the TAOK catchment as part of this investigation.

Accessible reaches of the southern and northern River North tributaries were viewed on 3 July 2015 to provide information on the existing state of the sub-catchment and surrounding land.

Figure 2 shows the sample locations and extent of waterways observed.

[4] EPT: Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies), the most sensitive aquatic macroinvertebrate species indicative of good water quality and habitat.

4.0 Results

4.1 Habitat Values

4.1.1 Site Context

The TAOK Stream catchment is located within the Waikato Ecological Region and the Hamilton Ecological District. The indigenous vegetation of the Hamilton Ecological District is severely depleted, with only 1.6% of the original native vegetation remaining and at least 20% of its indigenous flora threatened or extinct (Clarkson & McQueen 2004). Almost all of the original alluvial floodplain vegetation and swamps of the Waikato lowlands have been cleared and drained for farming (Nicholls, 2002). Within Hamilton City, there is less than 20 hectares of high quality indigenous habitat remaining (Clarkson & McQueen, 2004), although substantial restoration is occurring.

The Lands Environments of New Zealand (LENZ) database classifies most of the low-lying parts of the upper catchment and almost all of the southern catchment as Environment A5.3 which is comprised of poorly-drained peat soils of low to very low fertility. The ridgelines of Horsham Downs, Kay and Sylvester Roads and portions of River Road and Discovery Drive are classified as Environment A7.2b which is very gently undulating hills with imperfectly drained soils of low fertility, comprised of volcanic soils, alluvium and peat. The main TAOK Stream gully is classified as Environment A7.2c which is comprised of imperfectly drained low fertility soils from tephra and alluvium with peat and greywacke.

4.1.2 Terrestrial Habitats

The terrestrial flora of the TAOK Stream catchment mirrors the situation in the surrounding areas. Historic vegetation cover was secondary succession alluvial vegetation (Nicholls 2002), most likely kahikatea swamp forest, with mixed conifer-broadleaf forest on higher ground (Clarkson *et al*. 2007, Cornes *et al*. 2012). Some small areas of peat bog vegetation (Clarkson *et al*., 2007) and larger areas of lowland swamp vegetation may also have occurred in the low lying areas in the upper catchment, depending on the type, depth, and drainage properties of the soils present. Extensive swamplands would have been present in the gully floors associated with large spring and high groundwater flows.

Today, the rural parts of the TAOK catchment are almost entirely vegetated in exotic pasture, with exotic trees and shrubs planted as shelterbelts, hedges, or for amenity and animal welfare purposes (livestock shade). This is confirmed by Land Cover Database analysis. Much of this vegetation is currently being removed to facilitate development. In developed and/or developing residential areas, the vegetation is comprised of a typical mix of native and exotic garden variety plants as well as open grass areas.

The River North sub-catchment is almost entirely in residential development except for an area south east of Joseph Lovett Lane. Part of this area is comprised of HCC reserve dominated by mown grassland. The middle land parcel is pasture with large exotic deciduous trees including poplar and a portion that has been partly developed with a formed road. The southern land parcel is under development at the time of writing.

4.1.3 Riparian and Aquatic Habitat

The following sections provide detailed descriptions of the riparian and aquatic habitat observed in the TAOK Stream catchment. This information is represented graphically in Figures 3 – 5, showing the waterway types and riparian vegetation observed.

4.1.3.1 Rural Upper Catchment

The waterways northeast of Borman Road and Resolution Drive consist almost entirely of artificial farm drains that form a network across the predominantly flat rural catchment south of the Kay Road and Horsham Downs Road ridgelines. The drains were excavated to drain historic wetlands and high groundwater/springs in the upper catchment to facilitate pasture development for farming. Current vegetation shows no evidence of peat wetlands, but it is likely that lenses of peat and/or highly organic soils are present as subsoil layers influencing pH and water chemistry.

The drains were being removed at the time of survey and aquatic habitat was not surveyed as part of this assessment. Based on assessments of similar habitats, the drains are/were likely to provide poor to moderate habitat for fish and aquatic macroinvertebrates, with modified or absent riparian vegetation, limited habitat diversity, and a lack of large organic material and coarse particulate matter.

Adjacent to the rural waterways, there is typically limited riparian vegetation where drains run through pasture, but some riparian cover is offered by hedgerows and the drains are likely to present stable, if highly modified, habitat. Few of the drains have natural surface drainage and most are likely to be fed predominantly by groundwater, with some overland flow occurring after heavy rainfall. It is likely that many of the drains dry up when groundwater levels drop, leaving the occasional deeper pools adjacent to culverts as potential habitat refuges.

The stormwater swales being constructed in the upper catchment to replace the drains (see Plate 1) currently present habitat equivalent to an open pipe rather than a swale, with poorer quality habitat than a rural drain. The swale upstream of North City Road is almost straight with no variation in depth or width and no constructed meanders or habitat features. The swale banks are lined with matting or geotextile (see Plate 2), but planting had not been undertaken at the time of the survey. Sediment deposition has occurred throughout the swale systems either as a result of collapsed banks or through stormwater inputs. Where riparian vegetation has re-established (see Plate 3), it consists of adventive pasture and weed species such as rank grass, red clover, fathen and dock. These swales are likely to offer lower habitat quality than the farm drains they replaced.

Plate 1: North City Road main swale.

Plate 2: North City Road tributary swale.

Plate 3: Established swales upstream of Resolution Drive.

4.1.3.2 Urban Upper Catchment

There are two urbanised waterways in the upper catchment, being the Tuirangi Floodway between Resolution Drive and Magellan Lake, and the tributary draining the area from north of Cumberland Drive to Magellan Lake.

The Tuirangi Floodway is an artificial channel created to replace the original TAOK channel to facilitate land development. Although mainly straight and uniform, the riparian margin and floodplain has been extensively planted and aquatic macrophytes are abundant in the channel in some places (see Plate 4). This has resulted in greater aquatic habitat diversity than would usually be expected in an artificial system, because water flow is creating meanders, pools, and eddies around the overhanging and in-stream vegetation.

The Trinidad Place tributary is a small modified waterway with headwater wetlands draining down a small gully system to a confluence with the Tuirangi Floodway (see Plate 5). It has little natural riparian vegetation but is somewhat protected by the very steep gully banks with weed species overhanging the channel. It has relatively natural meanders, and variation in water depth and flow. It may dry up or become intermittent in summer when flows and shallow groundwater levels drop, but it is likely that some pools remain as habitat refuges.

Plate 4: Tuirangi Floodway.

Plate 5: Trinidad Place tributary.

4.1.3.3 Southern catchment

Headwaters in the southern catchment have been piped and culverted, and drain into the TAOK main stem downstream of Lake Magellan. There are no surface waterways in the southern catchment to assess.

4.1.3.4 Lower Catchment Lakes

Lakes have been created as on-line stormwater devices and/or amenity features downstream of Petersburg Drive and Magellan Rise. Both lakes are artificial, have weirs at their outlets presenting potential fish passage barriers, and are significantly different from the stream aquatic habitat that would originally have been present.

Assessment of the lake at Petersburg Drive was not included in the scope of this work. However, planted vegetation observed around the lake riparian margins may eventually provide shade and woody debris. The lake appears to have variable depth, overhanging lake margin vegetation, and aquatic macrophyte beds. Although highly modified compared to the natural stream/wetland environment downstream, the lake appears to provide moderate to good quality aquatic habitat.

The riparian and aquatic habitat at Magellan Lake was assessed as being poor. Aquatic macrophytes consist only of small clumps of bamboo spike sedge (*Elecharis sphacelata*) and no other aquatic or riparian vegetation is present. The lake margins consist of vertical block walls. An assessment of the effect of the lake on water quality is provided in Section 4.2.3.

4.1.3.5 Lower Catchment - Middle Reach

The TAOK Stream between Magellan Lake and Petersburg Drive is a modified habitat with water depth and channel width varying considerably along the main stem. Active erosion and scour was common throughout the middle reach at the time of survey (see Plate 6), although subsequent observations in 2016 indicate bank stability has stabilised with development of bank vegetation.

Plate 6: Bentley Rise TAOK Stream main stem.

The stream reaches include modified and straightened channels, as well as reaches with more natural meanders. Through the middle reach, most stormwater discharges are likely to be point source discharges from treatment devices rather than overland flow. Scour and sediment deposition was observed at some of these discharge points.

Flows from the 18 April 2015 rainfall event were observed to have reached 2m above the channel based on debris deposition and vegetation flattening, and the force of the flow lifted and moved the manhole covers at the Bentley Rise stormwater pond. Well-developed riparian and wetland vegetation, particularly the willow canopy and sedgelands, appears to have prevented large scale erosion and bank failure along the stream reach.

Riparian vegetation along the true right bank is mostly intact but highly modified, comprising planted native areas and mixed native and exotic early succession shrubland and forest.

From the observable reaches, aquatic habitat diversity appears to increase with distance downstream, with pools and riffles present as well as undercut banks, logs, aquatic macrophytes and other organic debris. This middle reach of the stream provides moderate aquatic habitat.

4.1.3.6 Lower Catchment - Lower Reach

Downstream of the Petersburg Drive lake, the stream flows through a deeply entrenched gully system with steep gully slopes and a well-developed floodplain. The stream has a natural meander and habitat diversity is moderate to high, with a range of habitats present including undercut banks, pool, riffle and run sections, aquatic macrophytes, root mats and large amounts of instream woody debris and particulate matter (see Plate 7).

Riparian vegetation cover is present over a high proportion of the lower stream reach in the form of early succession native and exotic shrubland forest, and dense sedgeland and swamp vegetation.

As a result of the 18 April 2015 rainfall event, water depth was observed to have been approximately 1.5m above the channel based on debris deposition and vegetation flattening (see Plate 8), and parts of the *Carex* sedgeland had been scoured out and overturned. However, bank erosion and channel scour is likely to have been significantly worse had dense riparian and wetland vegetation not been present.

The most recent vegetation survey within Hamilton City identified one key ecological site of significance within the TAOK Stream catchment (Cornes *et al*. 2012). Cornes *et al*. identified the lower reach of the TAOK Stream gully system as a key ecological site, which is described as a mix of grey willow forest and kanuka/mahoe forest.

Plate 7: TAOK Stream upstream of River Road.

Plate 8: TAOK Stream upstream of River Road showing sedgeland vegetation.

4.1.3.7 River North sub-catchment

There are three small first order waterways located in the middle of the River North sub-catchment. Based on observations from HCC reserves, roads, and satellite photography, these waterways have shrubland or treeland riparian cover, but the condition of the riparian and aquatic habitat cannot be confirmed without field surveys.

All three waterways are likely to have been modified by past agricultural land use and current land development including impounding the waterway to create a pond, installation of stormwater infrastructure, vegetation clearance, channelization/diversion and livestock access.

The northern waterway is a small relatively steep catchment with a total waterway length of around 550m. The upstream reach of northern waterway has been piped east of River Road and stormwater from residential development and roads discharge into this waterway. The observable parts of the middle reach between the HCC reserve and River Road appear modified but generally follow natural topography, whereas the downstream reach around the HCC reserve perimeter does not appear to be natural and may have been diverted from its original channel location.

Riparian shrubland planting has been undertaken within the HCC reserve, providing shade, bank stability, and organic material to the waterway. However, based on the observed poorly formed channel and terrestrial vegetation, the waterway may be dry for part of the year.

The middle waterway is a small steep catchment of some 190m that appears to have been almost completely modified for stormwater conveyance and treatment. The channel has been armoured with rock riprap, covered geotextile or matting and planting, and part of the waterway has been converted to an on-line stormwater detention device. Sediment deposition into the riparian zone and/or channel from the adjacent earthworks has occurred. Riparian vegetation appears to be mixed shrubland and exotic trees.

The southern waterway is approximately 185m long and located in the base of a relatively unmodified gully. The riparian gully vegetation appears to consist of regenerating native riparian species with some weed vegetation, and the channel is likely to be largely natural. Urbanisation of the southern River North waterway catchment, including earthworks, stormwater design, and discharges, is subject to existing WRC resource consent conditions to manage effects on riparian and aquatic habitats. On that basis, the values of the southern River North waterway will be appropriately managed in respect of land development and are therefore not considered further in this assessment. However, using the criteria of Cornes *et al*., the southern waterway riparian vegetation could be considered significant.

Field survey is required on the upstream half of the northern waterway and the middle waterway to determine actual instream values and fish passage barriers at the outlet to the Waikato River.

4.1.4 Water Quality

4.1.4.1 Standards for water quality

The Waikato Regional Plan rules for stormwater discharges refer to the ANZECC 2000 Australian and New Zealand Guidelines for Fresh and Marine Water Quality as one of the standards against which hazardous substances in stormwater are to be assessed in order to achieve the conditions associated with the relevant rule.

HCC was granted a comprehensive consent from WRC for the discharge of stormwater from its urban areas. The comprehensive consent conditions refer to the USEPA (United States

Environmental Protection Agency) National Recommended Water Quality Criteria as the standard which the concentration of hazardous substances in discharges are required to meet.

Based on correspondence with WRC staff, we understand that the USEPA criteria are considered more appropriate than the locally derived ANZECC criteria because they reference the dissolved fraction of stormwater contaminants (specifically metals such as copper, lead and zinc) and provide standards for acute (short-term) exposure as well as chronic (long-term) exposure. NIWA and WRC considered the dissolved fraction of contaminants to be more relevant to the toxicity effects experienced by water column-dwelling biota exposed to stormwater discharges compared to total concentrations which includes the particulate fraction. Acute exposure is considered to be more relevant to the intermittent rain event-derived nature of stormwater discharges.

However, given that the purpose of this assessment is to establish the existing quality of the environment, not the impact of specific stormwater discharges at their outlets, it is appropriate to assess existing water quality against the ANZECC guidelines on the basis that they set thresholds for chronic exposure of aquatic organisms to existing contaminants.

4.1.4.2 Results

A results summary is presented below in Table 3 and laboratory reports are provided in Appendix 2. In Table 3, the results are compared against the guideline values noted in the footnotes. Results in bold and shaded exceed the guideline value. Results in bold only are values that are elevated but for which there is no guideline value.

Table 2: Water Quality Analysis

Analytes	**Units**	**Site 1** **River Rd**	**Site 2** **Bentley Rise**	**Site 3** **Tuirangi St**	**Site 4** **Trinidad Place**	**Site 5** **North City Rd**	**Guideline Values - ANZECC**
Water Quality							
Temperature	°C	11.8	12.0	12.4	12.3	13.9	
pH (Hills Laboratory)	pH Units	7.1	6.3	6.6	6.7	6.3	6-9[5]
pH (on site – April/June 2015)	pH Units	6.58	6.26	6.59	5.79	5.56	6-9[5]
Conductivity (on site – April/June 2015)	µs/cm	189.2	185.2	157.9	242.7	281.7	-
Dissolved oxygen (on site – April/June 2015)	mg/L	0.6	0.06	0.06	0.06	0.05	-
Turbidity	NTU	45	76	31	530	90	-
Total Suspended Solids	g/m^3	35	51	16	200	79	-
Carbonaceous Biochemical Oxygen Demand (CBOD5)	$g\ O2/m^3$	<2	< 2	< 2	< 2	< 2	-

[5] Australian and New Zealand Environment and Conservation Council; Agriculture and Resource Management Council of Australia and New Zealand. 2000. Australian and New Zealand Guidelines for Fresh and Marine Waters Quality. Trigger values for aquatic ecosystem protection at 90% protection of species, based on a highly disturbed system as indicated by the aquatic macroinvertebrate community composition.

Analytes	Units	Site 1 River Rd	Site 2 Bentley Rise	Site 3 Tuirangi St	Site 4 Trinidad Place	Site 5 North City Rd	Guideline Values - ANZECC
Faecal Coliforms	cfu/100mL	**3,700**	**9,000**	**4,700**	**3,800**	**500**	100[6] [7]
Metals							
Dissolved Aluminium	g/m3	**0.093**	0.018	0.021	0.069	0.017	0.08[5]
Total Aluminium	g/m^3	**1.30**	**3.6**	**1.33**	**19.4**	**3.4**	0.08[5]
Dissolved Arsenic	g/m^3	<0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.094[5]
Total Arsenic	g/m^3	0.0020	0.0025	0.0021	0.0059	0.0019	0.094[5]
Dissolved Cadmium	g/m^3	<0.00005	< 0.00005	0.00009	< 0.00005	0.00017	0.00040[5]
Total Cadmium	g/m^3	**0.00040**	0.000053	0.000079	0.000055	0.000153	0.00040[5]
Dissolved Chromium	g/m^3	0.0007	< 0.0005	< 0.0005	< 0.0005	< 0.0005	0.0060[5]
Total Chromium	g/m^3	0.00148	0.00142	0.00081	0.0050	0.0009	0.0060[5]
Dissolved Copper	g/m^3	0.0013	0.0014	0.0017	**0.0026**	**0.0020**	0.0018[5]
Total Copper	g/m^3	**0.0025**	**0.0032**	**0.0028**	**0.0132**	**0.0029**	0.0018[5]
Dissolved Iron	g/m^3	0.26	0.08	0.32	0.03	0.06	-
Total Iron	g/m^3	2.1	3.0	3.4	10.3	4.7	-
Dissolved Lead	g/m^3	<0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0056[5]
Total Lead	g/m^3	0.00111	0.00167	0.00040	**0.0123**	0.00169	0.0056[5]
Dissolved Nickel	g/m^3	0.0019	0.0020	0.0031	0.0018	0.0060	0.013[5]
Total Nickel	g/m^3	0.0024	0.0028	0.0036	0.0052	0.0064	0.013[5]
Dissolved Zinc	g/m^3	**0.0188**	**0.024**	**0.064**	0.0024	**0.111**	0.015[5]
Total Zinc	g/m^3	**0.024**	**0.035**	**0.066**	**0.036**	**0.115**	0.015[5]
Nutrients							
Total Nitrogen	g/m^3	**1.36**	**2.8**	**2.1**	**2.2**	**2.0**	0.04-0.10[8]
Total Kjeldahl Nitrogen	g/m^3	**0.47**	**0.97**	**1.09**	**1.04**	**1.01**	0.04-0.10[7]
Total Ammoniacal N	g/m^3	0.062	0.20	0.37	0.094	0.35	1.43[5]
Nitrite N	g/m^3	0.012	0.032	0.064	0.025	0.023	0.04-0.10[7]
Nitrate N	g/m^3	**0.88**	**1.85**	**0.92**	**1.16**	**0.99**	0.04-0.10[7]
Nitrate-N + Nitrite-N	g/m^3	**0.89**	**1.88**	**0.99**	**1.19**	**1.01**	0.04-0.10[7]

[6] Australian and New Zealand Environment and Conservation Council; Agriculture and Resource Management Council of Australia and New Zealand. 2000. Australian and New Zealand Guidelines for Fresh and Marine Waters Quality. Livestock drinking water guidelines – Faecal coliforms.

[7] Ministry for the Environment 2003. Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas. Ministry for the Environment, Wellington.

[8] Ministry for the Environment, 1992. Water Quality Guidelines No. 1: Guidelines for the Control of Undesirable Biological Growths in Water.

Analytes	Units	Site 1 River Rd	Site 2 Bentley Rise	Site 3 Tuirangi St	Site 4 Trinidad Place	Site 5 North City Rd	Guideline Values - ANZECC
Dissolved Reactive Phosphorus	g/m^3	0.008	0.010	**0.070**	0.012	< 0.004	0.015-0.03[7]
Total Phosphorus	g/m^3	**0.070**	**0.116**	**0.196**	**0.26**	**0.086**	0.015-0.030[7]
Hydrocarbons							
PAHs	g/m^3	ND	ND	ND	ND	ND	-
Total Petroleum Hydrocarbons C7-C36	g/m^3	<0.7	< 0.7	< 0.7	< 0.7	< 0.7	-

These water quality results were compared against[9]:

- 36 samples taken from waterways in the Mangaheka, Otama-ngenge, Kirikiriroa, Mangaonua, Waitawhiriwhiri, and Mangakotukutuku catchments analysed for the total and dissolved metals, nutrients, faecal coliforms, and petroleum hydrocarbons.
- 28 samples taken from 20 rural waterways close to Hamilton analysed for total copper, lead and zinc, nutrients, faecal coliforms, and petroleum hydrocarbons.

In general, TAOK Stream has similar water quality characteristics to other Hamilton waterways. CBOD and petroleum hydrocarbons were below the detection limit at all sampling sites.

Sediment/Turbidity

Suspended solids concentrations do not always reflect turbidity results within streams of this land type, indicating that turbidity is influenced by sources other than sediment. Orange staining and iron flocs are likely to be present throughout the catchment waterways and contributing (in part) to localised instances of elevated turbidity. This is supported by elevated iron concentrations as expected in waters draining shallow groundwater from wetland soils, at similar concentrations to other Hamilton waterways. There is no guideline value for total iron.

In addition to the effect of iron drainage, fine colloidal clay particles were observed contributing to turbidity throughout the catchment, particularly at Trinidad Place (see Plate 5). Suspended sediment and turbidity are elevated at sites 1-3 and 5, partly in response to the high rainfall event of 18 April 2015 and the resulting erosion effects. However, Trinidad Place has particularly high suspended sediment loads and turbidity that appear to be a result of construction site runoff. Sedimentation was observed in several locations throughout the catchment, with lobes of sediment present in newly constructed swales and the Trinidad Place tributary in addition to thick sediment coating vegetation in many places after the 18 April 2015 rainfall event.

There is no guideline value for turbidity. However, the ANZECC Guidelines refer to research into banded kokopu avoidance behaviour at turbidity of 20NTU, and WRC water quality scientists typically use turbidity of 10NTU or suspended sediment concentration of $10g/m^3$ as the threshold above which recreational and ecological effects occur. Turbidity was above

[9] BML unpublished data, 2016.

10NTU at all sites and observations of the riparian and channel environments indicate that sedimentation is an ongoing issue in the TAOK catchment.

The average TAOK suspended sediment and turbidity is almost 3 times greater than other Hamilton catchments.

Metals

TAOK's metals concentrations mirror that of other Hamilton catchments as follows:

- Arsenic, cadmium, chromium, lead, and nickel are generally below ANZECC guidelines.
- Aluminium, copper, and zinc exceed ANZECC guidelines.
- Iron is elevated.

Within the TAOK catchment, Trinidad Place stands out as having metals concentrations notably higher than other sites, along with turbidity and suspended sediments many times higher than elsewhere in the catchment.

Aluminium has elevated concentrations that are in orders of magnitude above ANZECC guidelines, with lower concentrations at River Road and the highest concentrations at Trinidad Place. Aluminium is also elevated above ANZECC guidelines in other Hamilton catchments, particularly in rural headwater tributaries, and appears to be higher where shallow groundwater is derived from wetland soils. It is therefore considered likely that elevated aluminium is a naturally occurring water quality component resulting from land drainage.

Although aluminium is known to be toxic to aquatic organisms if pH is acidic or alkaline, it is insoluble (and therefore has limited bioavailability) in peri-neutral waters and forms phosphates that settle out of the water column. Iron and manganese are also likely to form such complexes. Given that dissolved phosphorus concentrations are notably lower than total phosphorus, this appears to be occurring in the TAOK Stream. These phosphate complexes may contribute in part to elevated turbidity in water that is not associated with suspended sediment.

Across all TAOK sites, most metals are present in the water column adsorbed to sediment, organic material, or colloidal complexes except for copper, nickel, and zinc which have higher proportions present in the more bioavailable dissolved fraction.

Dissolved zinc concentrations exceed ANZECC guidelines throughout the catchment, whereas dissolved copper concentrations exceed ANZECC guidelines only at the two headwater sites (Trinidad Place and North City Road). These exceedances indicate potential for biological harm.

Nutrients

Elevated concentrations of nitrogen and phosphorus are ubiquitous in waterways around Hamilton, and generally far exceed the Ministry for the Environment water quality guidelines required to limit algal growth. However, TAOK has the lowest nitrogen concentrations of the Hamilton catchments for most parameters with concentrations of total nitrogen at or below the median concentration for Hamilton waterways. Total phosphorus concentrations are influenced by elevated sediment loads and exceed the median for Hamilton waterways, but dissolved reactive phosphorus concentrations are low.

However, with respect to algal growth, as noted earlier, the sequestration of phosphorus into metal phosphates and the predominance of particulate phosphorus may limit bioavailable phosphorus to concentrations below that required for algal growth. Filamentous algal growth was not observed at any of the sampling sites or observed waterway reaches.

Faecal pathogens

Faecal coliforms over all sampling sites exceed ANZECC guidelines for livestock watering, Ministry for the Environment guidelines for human contact, and the median for Hamilton rural streams (500cfu/100ml). There was also a trend of increasing faecal coliforms further downstream. While this may be a result of high rainfall prior to sampling and therefore may indicate a stormwater quality problem, it may also reflect the elevated faecal coliform load from Magellan Lake waterfowl and coarse fish inputs, pet inputs, and inputs from animals (possums, cats, rats, mustelids, waterfowl) present in the gully.

Water Quality

Water temperature was cool (11.8 – 13.9°C) and is expected to be in the range of 14-18°C during summer from Resolution Drive downstream assuming moderate macrophyte and riparian cover and predominantly groundwater-fed base flows. Temperature and dissolved oxygen will experience diurnal and seasonal fluctuations. However, the presence of online open water areas in swales and lakes, particularly when associated with the catchment's high turbidity, is likely to contribute to thermal storage causing temperatures exceeding 20 degrees during summer. This is likely to cause dissolved oxygen concentrations to drop below the tolerances of aquatic fauna in some locations. The more natural stream reaches downstream of Magellan Lake and Petersburg Drive will benefit from riparian vegetation and aquatic macrophytes maintaining lower temperatures and higher dissolved oxygen concentrations. The influence of metals complexes on dissolved oxygen concentrations may have localised impacts in small tributaries in the upper catchment.

4.1.4.3 River North

Due to lack of access, water quality samples were not collected in the River North waterways. Sampling of the middle and northern waterways is recommended to gain a better understanding of the water quality values and inform appropriate management approaches.

4.1.4.4 Magellan Lake Water Quality Effects

Analysis of the sample results from Site 4 at Trinidad Place, Site 3 at the Tuirangi floodway, and Site 2 downstream of Magellan Lake at Bentley Rise has been undertaken to provide an assessment of the lake's effect on water quality. The limitations on this analysis are:

- The southern catchment stormwater discharge enters TAOK Stream downstream of Lake Magellan, upstream of the Bentley Rise sampling site.
- No discharge quality information is available for the southern catchment.
- Water quality monitoring and samples were not taken from Lake Magellan itself.

However, bearing these limitations in mind, the key factors to note are:

- Faecal coliforms are present in almost double the numbers downstream of the Lake as upstream. Given the age of the southern catchment residential development, this is unlikely to be a result of sewer cross connections. The bacterial load is most likely a result of waterfowl and coarse fish presence within the Lake, combined with high turbidity reducing the natural attenuation of faecal pathogens from exposure to sunlight.
- The Trinidad Place tributary with very poor water quality is a proportionally small component of the lake inflows, but is likely to be providing a large proportion of the contaminant load to the lake, particularly turbidity, sediment, and possibly metals. These contaminants are unlikely to be a feature of discharges from the southern catchment.

- Given the approximate proportions of flow from the upstream sites, it appears that very little of the contaminant load is settled out in the lake. Likewise, very little nitrogen is being removed.
- There was no difference in water temperature or dissolved oxygen concentrations upstream and downstream of the lake at the time of the survey. However, there had been a significant rainfall event four days prior to the survey so the resulting freshwater inflow would have offset thermal storage and oxygen concentrations in the lake by flushing. Further, the downstream willow wetland area and southern catchment discharges are likely to reduce water temperatures as a result of shading and groundwater inflows. In comparison to upstream water quality, the lake can typically be expected to have a measurable impact on temperature and dissolved oxygen values during summer and autumn in base flow conditions.

As set out in Section 4.1, the lake has a significant detrimental impact on aquatic habitat values compared with the historic natural characteristics of the stream environment, and the existing aquatic values upstream and downstream of the lake. The lake offers very limited habitat value due to the lack of aquatic and riparian vegetation and the fish passage barrier of the weir structure.

Given the highly modified environment, poor habitat values, and lack of water quality treatment provided by the lake, on balance the lake as a stormwater device has an adverse effect. It does not deliver the treatment and ecological value HCC typically requires of on-line stormwater devices.

4.2 Contaminant Load Assessment

A contaminant load assessment (CLA) has been carried out by AECOM (22 May 2015). The contaminant inputs for residential land uses were based on the specific yields given in NIWA (2001), not modified to take account of the Brough *et al.* results for reduced metals concentrations from post-2000 subdivisions.

The results of the CLA indicate that use of the various means of compliance as set out in Table 3-5 to treat stormwater will result in a 50% increase in total contaminant loads of petroleum hydrocarbons, copper and zinc. This assumes that the devices perform as expected following development and are adequately maintained. The sediment load is expected to decrease slightly as a result of completion of earthworks and reduction in pasture area.

When compared with metals concentrations in fully urbanised, partly urbanised, and rural Hamilton catchments, TAOK metals concentrations can be expected to remain similar to existing concentrations and may decrease slightly as suspended sediment loads decrease.

4.3 Sediment Quality

A results summary is presented below in Table 4 and full laboratory reports are provided in Appendix 2. In Table 4, the results are compared against the ANZECC 2000 Interim Sediment Quality Guidelines (ISQG) as noted in the footnotes. Results in bold are shaded equal or exceed the guideline value.

Table 3: Sediment Sample Analysis

Analytes	Units	Site 1 River Rd	Site 2 Bentley Rise	Site 3 Tuirangi St	Site 4 Trinidad Pl	Site 5 North City Road	ISQG - Low Guideline Values[10]
Total Organic Carbon	g/100g	3.9	0.51	4.6	1.76	0.94	-
Total Recoverable Arsenic	mg/kg	**23**	7	**35**	10	7	20
Total Recoverable Cadmium	mg/kg	0.46	<0.10	0.29	0.25	0.13	1.50
Total Recoverable Chromium	mg/kg	8	4	11	8	9	80
Total Recoverable Copper	mg/kg	12	3	15	9	10	65
Total Recoverable Lead	mg/kg	10.6	3.7	6.9	19.9	7.1	50.0
Total Recoverable Nickel	mg/kg	19	4	7	7	8	21
Total Recoverable Zinc	mg/kg	**200**	49	109	72	**290**	200

All the metals analysed were detected at all sites, except cadmium which was below the detection level at Bentley Rise. The ISQG-Low trigger concentrations for arsenic were equalled or exceeded at River Road and Tuirangi Street. Zinc concentrations were exceeded at River Road and North City Road. The exceedances indicate the potential for these contaminants to cause adverse effects to benthic fauna and bioaccumulation in aquatic macrophytes. The elevated metal concentrations appears to be localised rather than a widespread issue on the basis of these results.

Due to lack of access, sediment quality samples were not collected in the River North waterways. Sampling of the middle and northern waterways is recommended to gain a better understanding of the sediment quality values and inform appropriate management approaches.

4.4 Aquatic Macroinvertebrates

The full macroinvertebrate analysis reports are provided in Appendix 3 and the summary table is shown below.

[10] Australian and New Zealand Environment and Conservation Council; Agriculture and Resource Management Council of Australia and New Zealand. 2000. Australian and New Zealand Guidelines for Fresh and Marine Waters Quality. Interim sediment quality guidelines.

Table 4: Macroinvertebrate Sample Analysis

Metric	Site 1 River Road	Site 2 Bentley Rise	Site 3 Tuirangi St	Site 4 Trinidad Pl
Taxonomic richness	15	8	9	8
No. of EPT Taxa	4	0	1	0
MCI-sb	88.4	54.3	60.9	41.0
SQMCI-sb	2.8	2.3	2.3	2.0

No sample was taken at North City Road because of the complete lack of suitable substrate for macroinvertebrate sampling.

Macroinvertebrate diversity was moderate at all sites. A total of 23 macroinvertebrate taxa were found across the sites surveyed. River Road comprised the highest species richness with 15 taxa, while the other three sites had similar taxa richness of 8 or 9.

The species composition varied between sites. The key points to note are:

- Mollusc taxa were most prominent at all sites except Trinidad Place, and *Potamopyrgus antipodarum* was particularly high in numbers at River Road.
- As well as having the highest species richness, River Road was the only site that contained sensitive EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa with four Trichoptera taxa identified. The only other site that recorded an EPT species was Tuirangi Street where *Oxyethira* was found although this species is more tolerant of disturbance and pollution.
- Broadly similar species composition across all sites, with molluscs, fly larvae, water boatmen, and oligochaete worms comprising most of the taxa. These taxa are typically associated with poor water and/or habitat quality.

No mayflies or stoneflies were recorded in any of the samples, but five species of caddisfly were present, four of which were found at River Road. The caddisfly species *Polyplectropus*, commonly found in slow flowing gravelly or soft bottom streams where woody debris is present, was the most sensitive species found. *Psilochorema* and *Triplectides* species and Oeconesidae were the three other caddisfly taxa also recorded at Site 2.

MCI scores for Bentley Rise, Tuirangi Street, and Trinidad Place were low and had a range of 41.0 to 61.9, indicating poor water and/or habitat quality. The MCI score was better at River Road scoring 88.4, indicating fair water and/or habitat quality (Stark & Maxted 2007). The SQMCI score takes into account the relative abundance of each taxa in the sample, and these results also consistently indicated ‘poor’ habitat or ‘severe’ pollution with a narrow range of 2.0 to 2.8. Site 2 had the highest SQMCI score, following a similar trend to the MCI index, with slightly improved downstream water and/or habitat quality.

These scores should be interpreted in the context of the rainfall event prior to sampling, as some taxa may have been removed as a result of high velocities after rainfall, and taxa diversity and abundance are likely to be improved with settled conditions. However, the scores also reflect the longer term influence of ongoing poor water quality including elevated turbidity, temperature, and dissolved metals concentrations and low dissolved oxygen. Regardless of the impact of an individual rainfall event, community composition is likely to remain dominated by species tolerant of disturbance and pollution, with a small proportion of more sensitive species where habitat quality is better.

Due to lack of access, aquatic macroinvertebrate samples were not collected in the River North waterways. Sampling of the middle and northern waterways is recommended to gain a better understanding of the habitat and water quality values and inform appropriate management approaches.

4.5 Fish

In the Waikato River catchment, 17 native fish species have been recorded (David & Speirs 2010).

The NIWA Freshwater Fish Database (FFDB) contains 14 records for fish surveys undertaken from 1984 to 2009 in the TAOK Stream. Survey locations included River Road, Bentley Rise, Tuirangi Street, the reach between Cumberland Drive and Trinidad Place, and the stream reach that is now Magellan Lake.

As shown in Figure 5, seven species were identified including two exotic species (mosquitofish and rainbow trout) and five native species (shortfin eel, common smelt, giant kokopu, common bully and inanga). Giant kokopu and inanga are classified at an At Risk – Declining species (Goodman et al. 2014).

Other than the weirs at Lake Magellan and the Petersburg Drive lake, none of the observed culverts and other structures appeared to present a barrier to fish passage and no debris jams were observed. Although a complete waterway walkover was not undertaken, debris jams would not normally be expected in a soft sediment waterway with little riparian cover or in the gully floor swamps.

Due to lack of access, fish surveys were not undertaken in the River North waterways and there is no existing FFDB data for these waterways. Fish surveys of the middle and northern waterways are recommended to gain a better understanding of the habitat values, confirm ecological significance status, and inform appropriate management approaches. The species likely to inhabit these streams are discussed in Section 5.4.

4.6 Erosion and Scour

An assessment of erosion and scour processes has been undertaken by AECOM as part of the development of the draft TAOK ICMP.

Observations of the erosion and scour at the survey sites indicate that recently constructed swales typically have moderate to poor bank stability, and sediment deposition resulting from bank slumping and scour continues to occur. The Tuirangi Floodway and Trinidad Place reaches appear to be relatively stable, with little bank slumping, toe undercutting or scour observed, but sedimentation was observed throughout the catchment.

At the time of survey, the middle reach of the lower catchment downstream of Magellan Lake was experiencing scour and bank slumping over areas where willow canopy is not present or riparian planting is absent or recent. Subsequent observations indicate that this instability has stabilised due to the growth of weeds along the true left bank below the silt curtain. The lower reach of the lower catchment below the Petersburg Drive lake is expected to be relatively stable based on observations of the dense sedgeland and willow vegetation upstream of River Road. This vegetation is expected armour bank and bed sediments, and was observed to be highly protective even after extreme rainfall events.

5.0 Discussion

5.1 Water Quality

Waterways with small catchments such as the TAOK Stream are particularly vulnerable to effects of urbanisation because new stormwater discharges make up a large proportion of post-development flows and therefore have a disproportionately large effect on water and habitat quality. Almost all of the TAOK catchment has now been urbanised or is under construction, so much of the baseflow conversion from groundwater/spring-fed to stormwater flows has already occurred, particularly in the southern and lower sub-catchments.

The TAOK Stream has water quality and water chemistry that is very similar to other Hamilton waterways. The stream receives ongoing inputs of suspended sediment, turbidity, nutrients, metals, and faecal pathogens. While most metals and phosphorus are in the particulate fraction and therefore have limited bioavailability, dissolved aluminium, copper, and zinc are present in dissolved concentrations that could cause harm to sensitive aquatic organisms.

However, an analysis of the water quality of Hamilton's rural, semi-urban, and urban waterways shows that although total contaminant loads may increase following urbanisation, contaminant concentrations can be expected to remain similar to pre-development. This is likely to be a result of pre-development stream baseflows sourced from shallow groundwater draining soils of historic wetlands which release continuously elevated metals loads. Analysis indicates that regardless of the proportion of urbanised catchment, concentrations of stormwater metals (copper, lead, zinc) do not change substantially. Some metals are uniformly high throughout the area (aluminium, iron, zinc). Source control may be required for stormwater from high intensity land uses (e.g. high traffic load intersections and roundabouts, industrial sites, etc.) to prevent effects from point sources. However, the results show that existing devices are maintaining metals concentrations at close to pre-development concentrations.

The most pervasive current water quality issue is elevated suspended sediment and turbidity throughout the catchment, and sedimentation and turbidity effects on the stream are visually apparent combined with long open water reaches in unplanted stormwater swales and poor water quality in lakes and stormwater ponds. As well as the obvious impacts on habitat quality, these conditions will create very poor water quality by raising temperature, reducing dissolved oxygen, and causing sedimentation and reduced water clarity. These conditions are likely to be adversely affecting the diversity and distribution of indigenous aquatic organisms.

The faecal pathogen load is very high (average higher than all other catchments) and makes the water unsuitable for human contact or livestock consumption from Resolution Drive downstream. Numbers peak downstream of Lake Magellan and are lowest in the rural headwaters. Given the close proximity of public parks, pathways, playgrounds and residential areas to the waterways, the high faecal pathogen load may present a public health risk for anyone in contact with the water or for fish consumption from Lake Magellan.

On balance, the water quality and water chemistry of the TAOK Stream catchment is considered to be moderate to poor, but similar to most Hamilton waterways.

5.2 Sediment Quality

In general, the value of TAOK Stream sediment for benthic fauna is likely to be acceptable, with localised areas of elevated contaminants. The toxicity of metals to benthic fauna will depend on the conditions in the sediment contributing to bioavailability. Although not analysed, based on the water quality results, concentrations of other metals such as aluminium and manganese in sediment may also be elevated.

Benthic fauna are likely to be limited to those species capable of withstanding ongoing smothering from suspended sediment loads that are experienced throughout the catchment. Contaminant concentrations are likely to have less important effects on benthic fauna diversity than factors such as suspended sediment inputs, benthic habitat quality, water temperature, and presence of aquatic macrophytes.

However, the concentrations of arsenic and zinc (and potentially lead and nickel) may present a risk for people collecting watercress or other plants for human consumption. Watercress was observed at River Road and there are many other suitable locations in the catchment where watercress could be present or may colonise. Watercress is known to bioaccumulate metals, particularly arsenic (Edmonds, 2001).

5.3 Aquatic Macroinvertebrates

Compared with the MCI /SQMCI scores and water quality results for other Hamilton catchments, the TAOK Stream macroinvertebrate community is most similar to those measured in the adjacent predominantly rural Otama-ngenge Stream catchment. Combined with water quality results, the MCI/SQMCI scores indicate TAOK has poorer habitat quality than the Mangakotukutuku Stream catchment (which has poorer water quality) but better habitat quality than the highly modified Waitawhiriwhiri Stream catchment. The TAOK macroinvertebrate community reflects the combined impacts of habitat modification and elevated sediment/turbidity, with the River Road site having the best values. All other sites have scores comparable to farm drains even where habitat values are moderate such as Tuirangi Street.

On the basis of these results, the aquatic macroinvertebrate community could be enhanced by:

- improved erosion and sediment control at construction phase and stormwater treatment devices designed for sediment removal to reduce sediment loads and turbidity throughout the catchment; and
- habitat enhancement of lakes and swales that currently have poor riparian and instream habitat quality.

In the upper catchment north of Resolution Drive, habitat quality is so poor that there was no suitable substrate to sample, and the aquatic macroinvertebrate community is likely to be largely absent. Fundamental changes to stormwater swale habitats are needed as set out in Section 5.4 below.

5.4 Fish

The factors to consider when assessing the fish diversity include aquatic and riparian habitat quality, water quality, community composition, and the presence of significant barriers to fish passage. The recorded fish diversity is less than what would be expected in natural conditions. In addition to those recorded, species that would naturally inhabit this type of lowland Waikato stream with peat influences could include black mudfish (*Neochanna diversus*), banded kokopu (*Galaxias fasciatus*), longfin eel (*Anguilla dieffenbachii*), Cran's bully (*Gobiomorphus basalis*) and koura (*Paranephrops planifrons*).

Given the extremely poor habitats upstream of Resolution Drive, none of these potential or previously recorded fish species could be expected to inhabit the stormwater swales that are replacing the farm drains.

Although further urbanisation and roading with stormwater management to TP10 standards may not reduce the existing fish community diversity, fish diversity and distribution across the catchment could be significantly enhanced if the existing constraints noted below are removed or improved.

- The presence of coarse fish species in Magellan Lake may present a notable barrier beyond the physical barriers of the lake weirs.
- The lakes themselves may create a thermal and dissolved oxygen barrier during summer high temperatures because neither has sufficient shading to prevent thermal storage in lake waters particularly given the observed elevated turbidity.
- Upstream of Resolution Drive, the stormwater swale habitats are fundamentally unsuitable for fish habitat. Without riparian or aquatic vegetation, habitat diversity, or instream features, these devices currently offer no opportunity to establish the food webs required for fish survival. However, these devices can easily be retrofitted, and new swales constructed, with fish habitat as the ultimate objective. Swale design to accommodate fish can also be expected to contribute to stormwater treatment, water quality enhancement, aquatic macroinvertebrate habitat, and stability of bank and bed sediments, achieving numerous environmental outcomes at once. This has been demonstrated in the Tuirangi Floodway.
- The key water quality issue is the high loads of suspended sediment and turbidity. Suspended sediment and turbidity are present at concentrations known to cause avoidance behaviour in native species. Improved performance of erosion and sediment control devices at construction sites is required to reduce this effect, and planting of new swales and detention basins immediately following construction to minimise bank instability and enhance sediment settlement.

The presence of threatened (At Risk: declining) giant kokopu and inanga means that the TAOK Stream has ecological significance under the provisions of the Proposed Waikato Regional Policy Statement. Under Policy 11.2.2, where activities will create unavoidable adverse effects on significant indigenous biodiversity, there are a range of potential remedies.

The continued discharge of stormwater contaminants into the ecologically significant habitat occupied by giant kokopu and inanga, including suspended sediment and turbidity, may impact on inanga spawning activity in suitable habitat in the lower reaches of the lower catchment, and may prevent future re-colonisation by these and other native species into the catchment post-construction.

Although there were no records for the River North tributaries, the FFDB has records for two similar first order tributaries discharging directly into the Waikato River located near the River North catchment. The fish recorded were shortfin and longfin eels, banded and giant kokopu, koura, and freshwater mussels. On this basis, the River North waterways can also be expected to provide habitat for threatened fish species depending on fish passage barriers at the outlets and along the waterways. As set out above, it is therefore likely that the River North waterways have ecological significance under the provisions of the Proposed Waikato Regional Policy Statement.

5.5 Erosion and Scour

Based on our observations from the survey sites and adjacent waterways, in the context of the urbanised catchment and Rototuna development proposal, there are three key issues with erosion and scour in the catchment.

First, swales in the upper catchment (and presumably at other development locations using swale infrastructure) have insufficient erosion control post-construction. Slumping and scour are common irrespective of erosion control methods (e.g. geotextile, coir matting). Where planting is present, clumping species are used instead of wetland plants with rhizomatous root systems. Post-construction planting is not of sufficient density, height, or proximity to the waterway to provide bank stability improvement or improve water quality in the short or medium term. This results in poor values for swale fish habitat, amenity, and stormwater treatment, particularly for sediment removal.

Second, the stream reach between Magellan Lake and Petersburg Drive has bank instability contributing to reduced habitat values and increased sedimentation, principally on the true left bank. The erosion and sediment control measures installed adjacent to the path are insufficient to mitigate this. Riparian grassland has stabilised the banks temporarily but will be insufficient to offset the expected increases in flow velocities and volumes that may result from increased urbanisation in the upstream catchment. The existing riparian shrubland planting may provide improved bank stability in the medium term but will be offset by increased erosion as ground cover grasses are shaded out. Further, in some places bank instability is likely to be a perennial issue in this reach because CPTED[11] issues associated with a public path will prevent planting of dense shrub vegetation that would typically be recommended.

Third, it is evident from observations of waterway clarity and the water quality results that the erosion and sediment control measures implemented on construction sites are not preventing adverse effects in TAOK Stream. Turbidity and suspended sediment are at concentrations that cause avoidance behaviour in fish and reduction in aquatic macroinvertebrate diversity, while also increasing the particulate metals (particularly from Trinidad Place) and nutrient loads discharged into the aquatic habitat. Sedimentation into downstream devices also has the potential to increase maintenance costs as well as having ongoing impacts on the ecologically significant TAOK Stream.

These erosion and instability effects can be reduced and improved by:

- requiring swale channels and stormwater wetlands to be planted as soon after construction as possible (preferably no longer than 3 months after construction has finished);
- using green engineering technology that allow riparian planting to be undertaken to stabilise stream banks with existing bank instability;
- planting indigenous riparian plants specifically chosen to improve bank stability and protect the channel bed (see Plant Selection Tool for Waikato Waterways); and
- HCC should also engage with and support Waikato Regional Council staff in strengthening the effectiveness of erosion and sediment control measures on construction sites, as well as strengthening its own regulatory methods for requiring improved erosion and sediment control performance.

[11] Crime Prevention Through Environmental Design.

6.0 Risks and Sensitivities

On the basis of Sections 2.0 – 5.0 above, there are a number of risks associated with stormwater management in the TAOK Stream catchment as a result of urbanisation and roading, based on the particular sensitivities identified. The following table sets out these risks and sensitivities, identifies objectives for catchment management, and makes recommendations for actions to achieve the objectives set.

Table 5: TAOK Catchment Management Approach

Environmental value	Existing state or values	Actual and potential effects of stormwater management?	Proposed objective
Riparian habitat	Variable. Low intrinsic values upstream of Resolution Drive and Lake Magellan, low to moderate values downstream of Lake Magellan, moderate to high values downstream of Petersburg Drive lake.	Yes – potential enhancement	<u>Explanation:</u> Existing riparian values will not be significantly changed by future stormwater discharges. Urbanisation will remove riparian vegetation and waterways as drains are replaced with swales/wetlands to accommodate increased stormwater flows. Riparian planting and/or enhancement can contribute to improved bank stability, water quality and instream values, especially where no riparian vegetation exists. Where bank instability is already present, principally downstream of Lake Magellan, green engineering is likely to be required in combination with riparian planting to stabilise banks. <u>Objective:</u> Riparian vegetation density and cover is established, maintained and/or enhanced along all waterways, including stormwater swales, to maintain habitat and bank stability and water quality (temperature and dissolved oxygen). <u>Recommendations:</u> 1. Dense riparian and/or wetland/aquatic vegetation cover must be established and maintained on all new surface stormwater systems (swales, floodways, wetlands) within 3 months of construction. Planting must consist of indigenous eco-sourced plant species appropriate to the lowland Waikato location, with a high proportion of rhizomatous species. 2. Green engineering solutions used to stabilise stream banks between Lake Magellan and Petersburg Drive to facilitate low stature riparian planting.

Environmental value	Existing state or values	Actual and potential effects of stormwater management?	Proposed objective
Aquatic habitat	Moderate ecological significance, habitat for threatened fish species	Yes	Explanation: In addition to water quality effects, on-line stormwater ponds and swales can create artificial aquatic habitat with very poor ecological values for indigenous fauna and may create barriers to fish passage. Objective: Habitat quality in on-line devices (wetlands, swales, lakes and ponds) accommodates native fish populations and distribution in the TAOK Stream catchment, does not release high sediment loads, and ensures fish passage is not impeded. Recommendations: 1. Dense riparian and/or wetland/aquatic vegetation cover must be established and maintained on all new surface stormwater systems (swales, floodways, wetlands) within 3 months of construction. Planting must consist of indigenous eco-sourced plant species appropriate to the lowland Waikato location. 2. Require existing and new open water devices to achieve >80% cover of wetland and/or riparian vegetation to maintain cool downstream temperatures. This may require alternative water level management to facilitate aquatic macrophyte establishment e.g. lowered water levels. 3. Undertake monitoring (Section 7.0) of weir structures to confirm whether these present a barrier to fish passage.
Water quality	Moderate to poor	Yes	Explanation: Stormwater discharges are impacting water quality with elevated faecal coliforms, suspended sediment, turbidity, and temperature. Existing devices and erosion and sediment control measures are not sufficient to protect water quality or are not achieving appropriate treatment performance. Objectives: Mass loads and concentrations of stormwater contaminants (namely sediment, turbidity, and faecal coliforms) in the TAOK Stream are progressively decreased. Temperature in the TAOK Stream is not above 20°C in summer and 14°C in winter downstream of Resolution Drive and the on-line lakes. Recommendations: 1. Dense riparian and/or wetland/aquatic vegetation cover must be established and maintained on all new surface stormwater systems (swales, floodways, wetlands) within 3 months of construction. Planting must consist of indigenous eco-sourced plant species appropriate to the lowland Waikato location.

Environmental value	Existing state or values	Actual and potential effects of stormwater management?	Proposed objective
			2. Avoid construction of new on-line open water devices. 3. Require existing open water devices to achieve >80% cover of wetland and/or riparian vegetation to maintain cool downstream temperatures. This may require alternative water level management or bathymetry changes to facilitate aquatic macrophyte and riparian vegetation establishment. 4. Undertake monitoring (Section 7.0) to confirm device performance, and detect changes in contaminant profile and temperature over time. 5. Encourage and coordinate with Waikato Regional Council consent processing officers and compliance officers to strengthen erosion and sediment control effectiveness during and immediately post-construction.
Sediment quality	Variable	No	Explanation: Localised accumulation of metals is likely to be a result of metals sourced from land drainage. On the basis of TP10 minimum design standards for treatment, there is unlikely to be a notable change in sediment quality as a result of stormwater discharges into TAOK Stream receiving waters. However, existing concentrations may present a public health risk for consumption of food collected from publicly accessible waterways. Objective: Concentrations of metals in aquatic sediment are maintained and/or reduced. Recommendations: 1. Undertake regular sediment quality monitoring at sites with accessible watercress to determine whether metals concentrations are increasing. 2. If metals concentrations increase, consider monitoring of plant material to define the level of public risk.
Aquatic macroinvertebrates	Variable	Yes	Explanation: Creation of new unvegetated stormwater devices replacing existing drains, ongoing stormwater discharges with high concentrations of suspended sediment and turbidity, and thermal storage raising temperatures in on-line open water devices is reducing the diversity and distribution of aquatic macroinvertebrates. See objectives and recommendations in Water Quality above and Erosion & Scour section below.

Environmental value	Existing state or values	Actual and potential effects of stormwater management?	Proposed objective
Indigenous fish	Moderate	Yes	<u>Explanation:</u> Removal of existing drains, creation of open swales with no riparian vegetation, and on-line ponds with poor aquatic habitat quality, potential fish passage barrier, and high temperatures are likely to be reducing the diversity and distribution of indigenous fish in the catchment, particularly from Lake Magellan upstream. Known fish diversity is lower than would be expected in the catchment without urbanisation. Objective: Native fish population diversity and distribution are enhanced in the TAOK Stream. <u>Recommendations:</u> 1. Dense riparian and/or wetland/aquatic vegetation cover must be established and maintained on all new surface stormwater systems (swales, floodways, wetlands) within 3 months of construction. Planting must consist of indigenous eco-sourced plant species appropriate to the lowland Waikato location. 2. Avoid construction of new on-line open water devices. 6. Require existing open water devices to achieve >80% cover of wetland and/or riparian vegetation to maintain cool downstream temperatures. This may require alternative water level management or bathymetry changes to facilitate aquatic macrophyte and riparian vegetation establishment. 3. Green engineering solutions used to stabilise stream banks between Lake Magellan and Petersburg Drive to facilitate low stature riparian planting. 4. Encourage and coordinate with Waikato Regional Council consent processing officers and compliance officers to strengthen erosion and sediment control effectiveness during and immediately post-construction. 5. Undertake monitoring (Section 7.0) of weir structures to confirm whether these present a barrier to fish passage.
Erosion & scour	Areas of bank instability	Yes	<u>Explanation:</u> Bank instability is present in recently established unvegetated swales and between Lake Magellan and Petersburg Drive. Post-development retrofitting of erosion control/planting is not appropriate, and all swales and wetlands should be densely planted immediately post-construction to avoid effects of sedimentation downstream. Preventative pre-

Environmental value	Existing state or values	Actual and potential effects of stormwater management?	Proposed objective
			development waterway management is the most appropriate method of avoiding erosion and scour effects in an ecologically significant habitat. <u>Objective:</u> The erosion and scour of the bed and banks of TAOK Stream downstream of Lake Magellan is reduced, and bank instability in recently established and new swales is remedied and/or avoided. <u>Recommendations:</u> 1. Dense riparian and/or wetland/aquatic vegetation cover must be established and maintained on all new surface stormwater systems (swales, floodways, wetlands) within 3 months of construction. Planting must consist of indigenous eco-sourced plant species appropriate to the lowland Waikato location. 2. Green engineering solutions used to stabilise stream banks between Lake Magellan and Petersburg Drive to facilitate low stature riparian planting. 3. Plant indigenous eco-sourced riparian and/or wetland/aquatic plant species with rhizome root systems and low stature appropriate to the lowland Waikato location to enhance bank stability while maintaining public safety along public paths,
River North tributaries	Unknown, assumed moderate ecological significance, habitat for threatened fish species	Yes	<u>Explanation:</u> Although the actual values of the River North tributaries have not been assessed, these waterways are assumed to provide habitat for threatened fish species and therefore have ecological significance. Until values have been assessed via field survey, modification of and discharges into these tributaries should be avoided. Online devices and direct discharges into these small first order tributaries is likely to be inappropriate. TP10 device performance standards for sediment removal and peak flow management will not be sufficient to preserve in stream values. Future objectives should be developed once ecological values are known. However, given the vulnerability of first order waterways to modification, objectives should focus on avoiding effects and on habitat restoration to support native fish populations.

7.0 Monitoring Programme

The purpose of monitoring to support an ICMP is to:

- Ensure that the assumptions on which objectives were based remain valid, and
- Determine whether implemented measures are effective at achieving the objectives.

The following monitoring parameters are recommended to meet the objectives.

1. At each of the sample sites, undertake water quality monitoring consistent with the HCC Comprehensive Stormwater Discharge Consent methodology and programme for the analytes set out in Table 2. The purpose of the analysis is to monitor water quality over time to determine whether water quality improvements are being achieved as a result of the recommendations set out in Section 6.0. Key analytes are suspended sediment, turbidity, nitrate-nitrogen, dissolved zinc, and faecal coliforms.
2. If dissolved zinc concentrations fail to decrease over time following development of rural areas, during storm flows, take an annual grab sample of stormwater at treatment device inlets and outlets to confirm the TP10 design (or alternative consented design) contaminant removal efficiency is being achieved.
3. At publicly accessible sites with watercress (i.e. where watercress collection could occur), undertake sediment quality sampling consistent with the HCC Comprehensive Stormwater Discharge Consent methodology and programme for the analytes set out in Table 3 to assess the risk to human health associated with aquatic plant consumption. Key analytes are arsenic and zinc.
4. Undertake monitoring (Section 7.0) of weir structures to confirm whether these present a barrier to fish passage.

In addition to the ICMP monitoring programme proposed above, site assessment and field survey of the River North tributaries is required to establish objectives for those catchments relative to their respective values.

8.0 Conclusion

Urbanisation of the TAOK Stream catchment will continue to occur in accordance with the Proposed District Plan and Structure Plan provisions, and the BPOs set out in the draft TAOK ICMP and Resolution Drive sub-catchment ICMP. The existing and new stormwater infrastructure and discharges, combined with ongoing construction activities, are likely to have an impact on the habitat quality, water quality, and indigenous biodiversity of the TAOK Stream. Fundamental changes are needed to new and existing swale and open water devices to enhance ecological values and reduce water quality impacts. Likewise, erosion and sediment control on construction sites requires changes to ensure that the existing impacts on turbidity and sedimentation in the TAOK Stream are reduced or prevented.

The TAOK Stream catchment provides existing habitat for a range of native fish species including threatened giant kokopu and inanga, conferring ecological significance on the waterway. Fish habitat and fish passage to upstream habitats must be maintained throughout the lower and upper catchments, and water and habitat quality must be enhanced to enable appropriate indigenous fish distribution and diversity.

To reduce potential for stormwater management resulting from existing stormwater discharges and future urbanisation to have adverse effects, objectives are provided for each of the main risks. On the basis of the information currently available regarding the ecological values of the TAOK Stream, actions have been recommended to prevent or mitigate effects on ecological values. Monitoring is recommended to ensure that the recommended actions have achieved the objectives.

9.0 References

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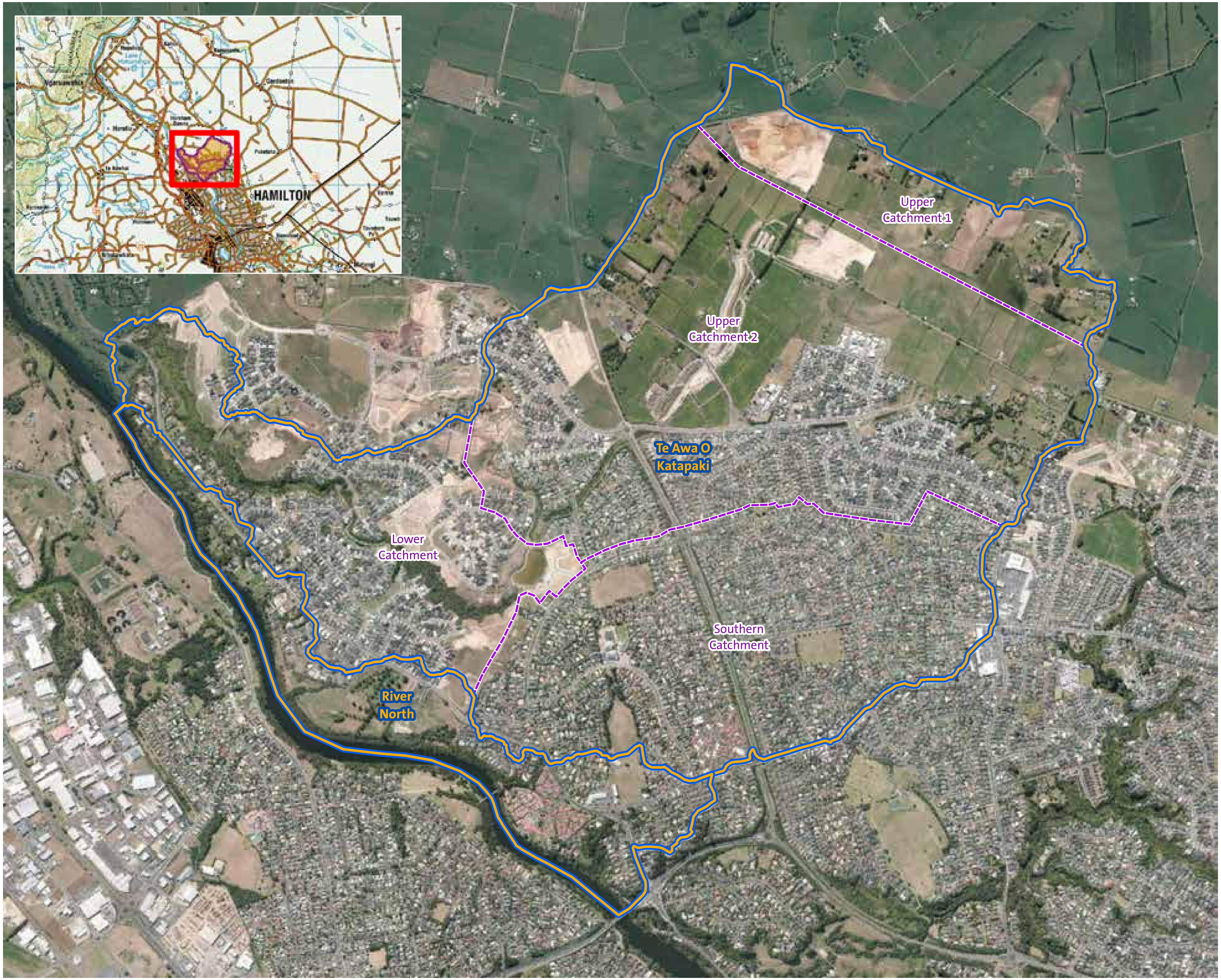
Appendix 1: Figures

File Ref: T14157_Figure1_CatchmentBoundary.mxd



Legend

- Topographic Catchment Boundary
- AECOM Topographic Sub-catchment Boundary

0 — 0.6 km

1:16,000 @ A3

Sources: Waikato Regional Council (WRAPS 2012), Land Information New Zealand, AECOM Limited.

Projection: NZGD 2000 New Zealand Transverse Mercator

TE AWA O KATAPAKI ICMP

Figure 1
Catchment Boundaries

Date: 16 May 2016
Revision: 0

Plan Prepared for the Hamilton City Council
by Boffa Miskell Limited
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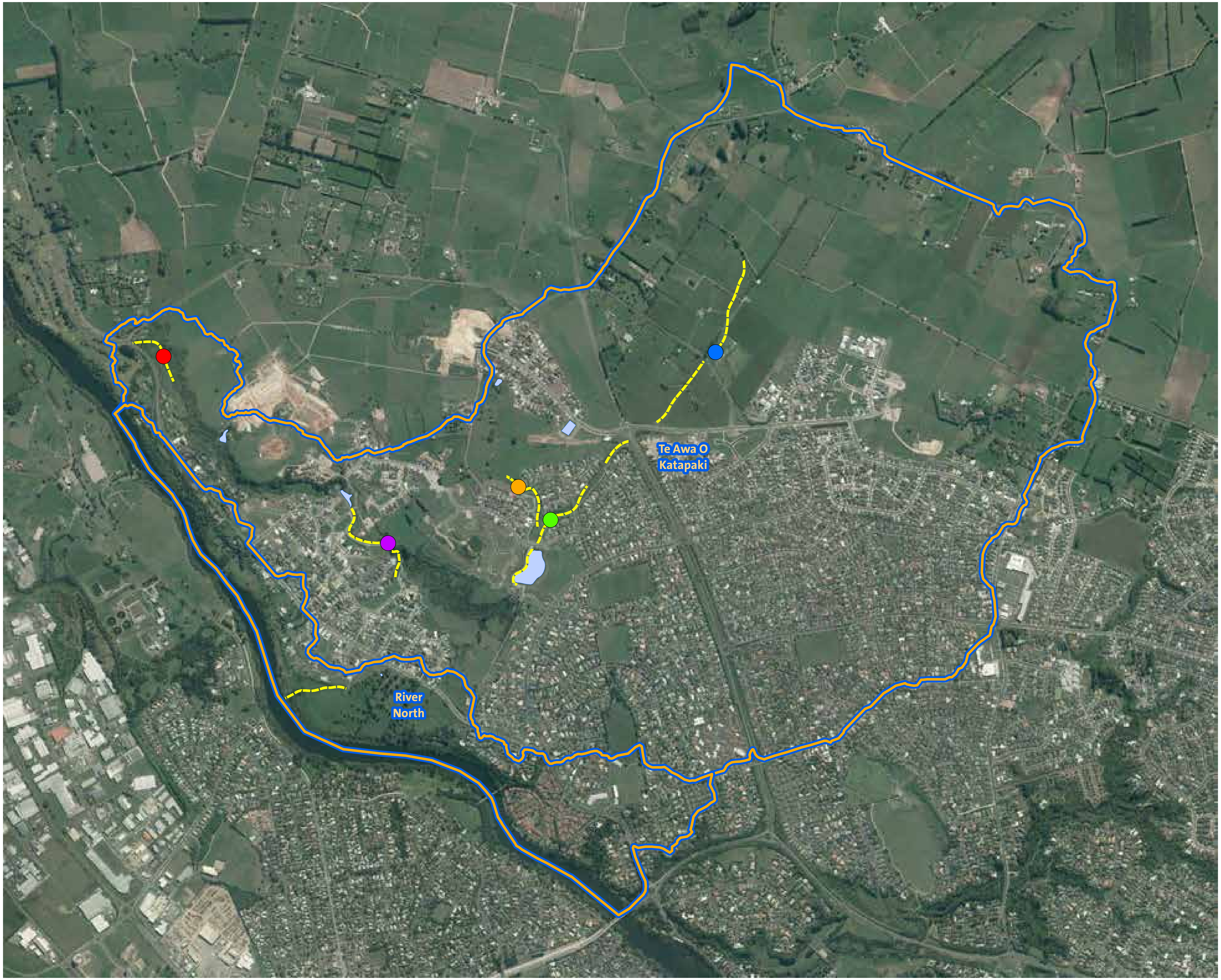
Drawn: JWa *Checked:* LSa

Boffa Miskell
www.boffamiskell.co.nz

File Ref: T14157_Figure2_SampleSites.mxd



Legend

Sample Site

- Area 1 - River Road
- Area 2 - Bentley Rise
- Area 3 - Tuirangi Street
- Area 4 - Trinidad Place
- Area 5 - North City Road
- Waterway Observations
- Artificial Ponds
- Topographic Catchment Boundary

0 0.5 km

1:16,000 @ A3

Sources: Waikato Regional Council (WRAPS 2012), Land Information New Zealand, AECOM Limited.

Projection: NZGD 2000 New Zealand Transverse Mercator

TE AWA O KATAPAKI ICMP

Figure 2
Sample Sites

Date: 16 May 2016
Revision: 0

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Drawn: JWa *Checked:* LSa

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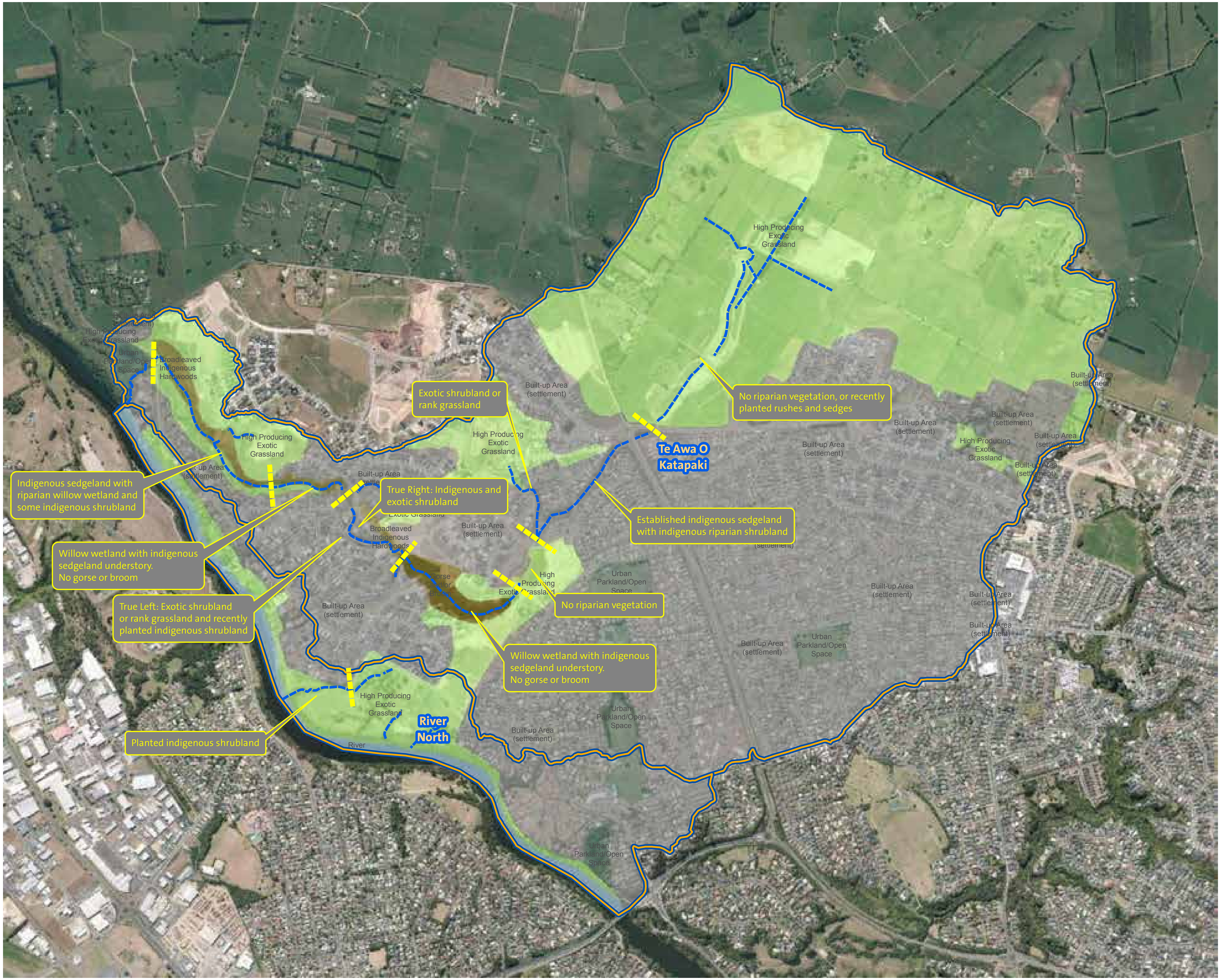

Legend

- Waterway
- Topographic Catchment Boundary

Landcover Classifiication (LCDB4)

- Built-up Area (settlement)
- Urban Parkland/Open Space
- River
- High Producing Exotic Grassland
- Gorse and/or Broom
- Broadleaved Indigenous Hardwoods

0 — 0.6 km

1:16,000 @ A3

Sources: Waikato Regional Council (WRAPS 2012), Land Information New Zealand, AECOM Limited.

Projection: NZGD 2000 New Zealand Transverse Mercator

TE AWA O KATAPAKI ICMP

Figure 3
Riparian Vegetation

Date: 16 May 2016
Revision: 0

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Drawn: JWa *Checked:* LSa

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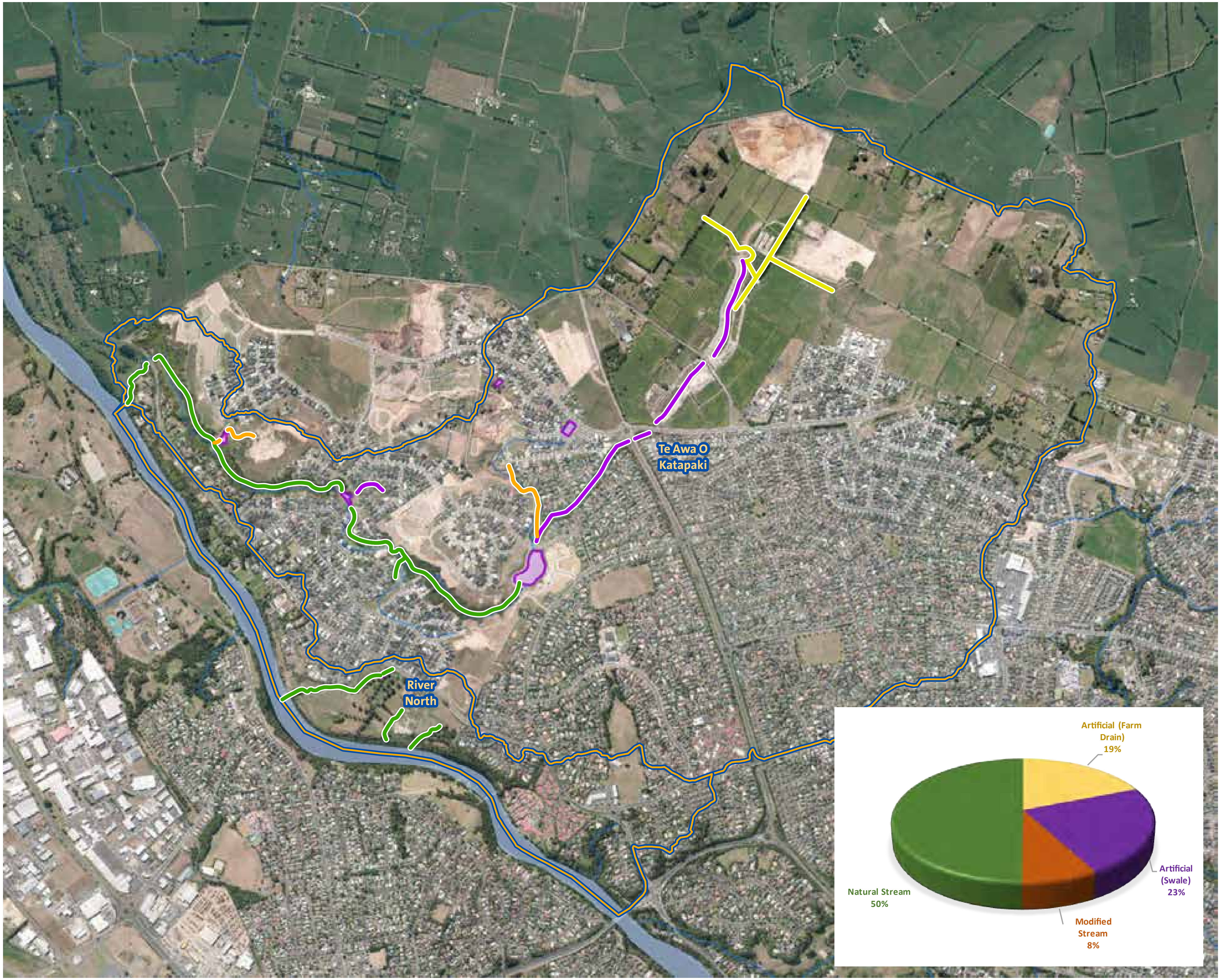
File Ref: T14157_Figure4_Hydrography.mxd



Legend

Waterway Classifications

- Artificial (Farm Drain)
- Artificial (Swale)
- Modified Stream
- Natural Stream
- Topographic Catchment Boundary
- Artificial Ponds
- River Centreline - NZTopo50
- Lake - NZTopo50
- Pond - NZTopo50
- River - NZTopo50

0 0.6 km

1:16,000 @ A3

Sources: Waikato Regional Council (WRAPS 2012), Land Information New Zealand, AECOM Limited.

Projection: NZGD 2000 New Zealand Transverse Mercator

TE AWA O KATAPAKI ICMP

Figure 4
Hydrography

Date: 16 May 2016
Revision: 0

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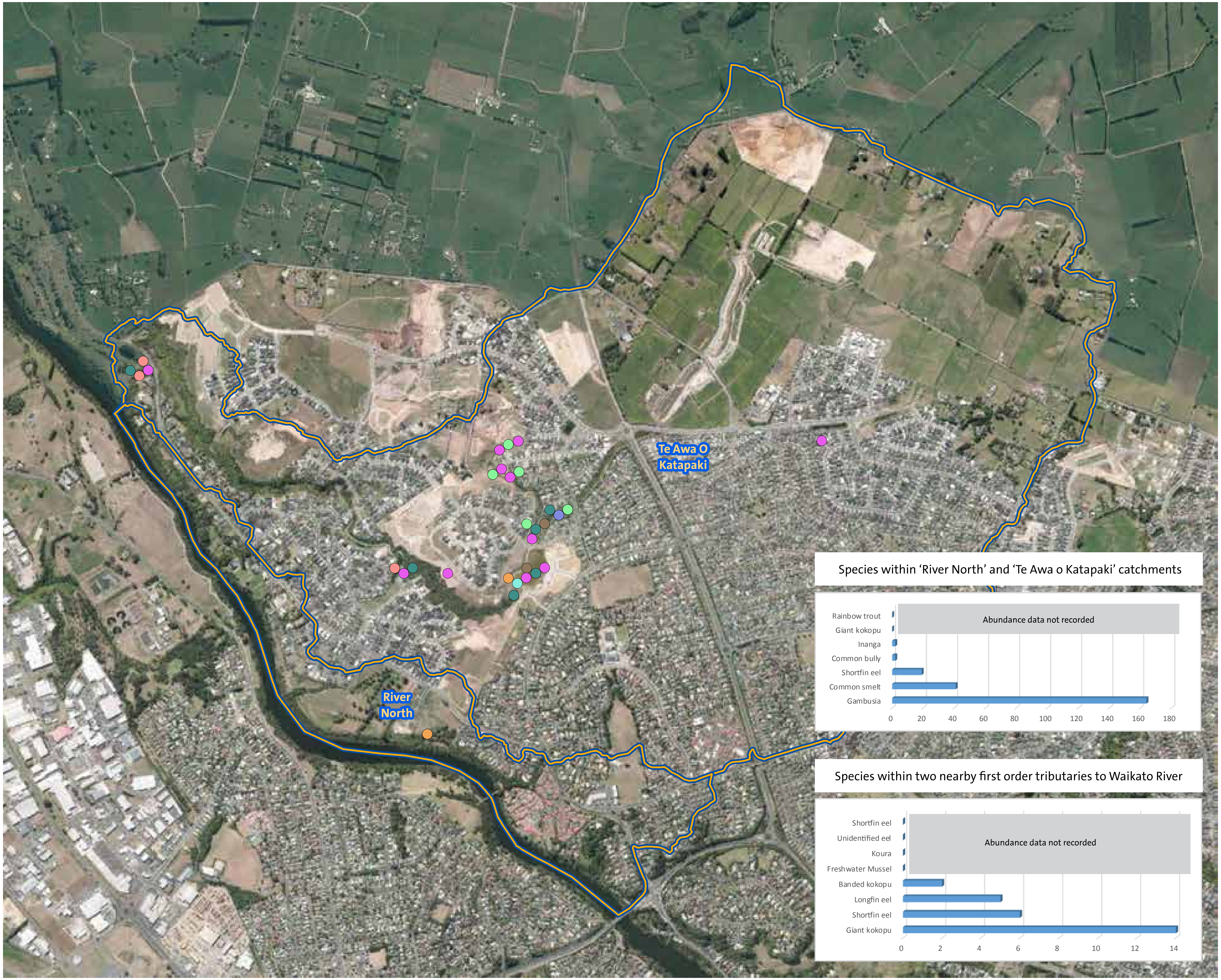

Legend

NIWA Freshwater Fish Database - 17 May 2016

- Catfish
- Shortfin eel
- Longfin eel
- Unidentified eel
- Goldfish
- Koi carp
- Giant kokopu
- Inanga
- Gambusia
- Common bully
- Grey mullet
- No species recorded
- Rainbow trout
- Koura
- Common smelt
- Rudd

0 0.6 km

1:16,000 @ A3

Sources: Waikato Regional Council (WRAPS 2012), Land Information New Zealand, AECOM Limited, NIWA.

Projection: NZGD 2000 New Zealand Transverse Mercator

TE AWA O KATAPAKI ICMP

Figure 5
Freshwater Fish Database Records

Date: 16 May 2016
Revision: 0

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Drawn: JWa *Checked:* LSa

Boffa Miskell
www.boffamiskell.co.nz

Appendix 2: Water and Sediment Analysis Reports

Hill Laboratories
BETTER TESTING BETTER RESULTS

R J Hill Laboratories Limited
1 Clyde Street
Private Bag 3205
Hamilton 3240, New Zealand

Tel +64 7 858 2000
Fax +64 7 858 2001
Email mail@hill-labs.co.nz
Web www.hill-labs.co.nz

ANALYSIS REPORT

Client:	Boffa Miskell Limited	**Lab No:**	1415249 SPv1
Contact:	L Saunders	**Date Registered:**	21-Apr-2015
	C/- Boffa Miskell Limited	**Date Reported:**	13-May-2015
	PO Box 13373	**Quote No:**	67004
	TAURANGA 3141	**Order No:**	T14157
		Client Reference:	Te Awa O Katapaki
		Submitted By:	L Saunders

Sample Type: Sediment

Sample Name:		TAOK Site 1 [Sediment] 20-Apr-2015 4:38 pm	TAOK Site 2 [Sediment] 20-Apr-2015 5:16 pm	TAOK Site 3 [Sediment] 21-Apr-2015 1:50 pm	TAOK Site 4 [Sediment] 21-Apr-2015 2:20 pm	TAOK Site 5 [Sediment] 21-Apr-2015 1:25 pm
Lab Number:		1415249.1	1415249.3	1415249.5	1415249.7	1415249.9
Individual Tests						
Total Organic Carbon*	g/100g dry wt	3.9	0.51	4.6	1.76	0.94
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	23	7	35	10	7
Total Recoverable Cadmium	mg/kg dry wt	0.46	< 0.10	0.29	0.25	0.13
Total Recoverable Chromium	mg/kg dry wt	8	4	11	8	9
Total Recoverable Copper	mg/kg dry wt	12	3	15	9	10
Total Recoverable Lead	mg/kg dry wt	10.6	3.7	6.9	19.9	7.1
Total Recoverable Nickel	mg/kg dry wt	19	4	7	7	8
Total Recoverable Zinc	mg/kg dry wt	200	49	109	72	290

Sample Type: Aqueous

Sample Name:		TAOK Site 2 20-Apr-2015 5:16 pm	TAOK Site 3 21-Apr-2015 1:50 pm	TAOK Site 4 21-Apr-2015 2:20 pm	TAOK Site 5 21-Apr-2015 1:25 pm	
Lab Number:		1415249.2	1415249.4	1415249.6	1415249.8	
Individual Tests						
Turbidity	NTU	76	31	530	90	-
pH	pH Units	6.3	6.6	6.7	6.3	-
Total Suspended Solids	g/m^3	51	16	200	79	-
Dissolved Aluminium	g/m^3	0.018	0.021	0.069	0.017	-
Total Aluminium	g/m^3	3.6	1.33	19.4	3.4	-
Dissolved Iron	g/m^3	0.08	0.32	0.03	0.06	-
Total Iron	g/m^3	3.0	3.4	10.3	4.7	-
Total Nitrogen	g/m^3	2.8	2.1	2.2	2.0	-
Total Kjeldahl Nitrogen (TKN)	g/m^3	0.97	1.09	1.04	1.01	-
Total Phosphorus	g/m^3	0.116	0.196	0.26	0.086	-
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	$g\ O_2/m^3$	< 2	< 2	< 2	< 2	-
Faecal Coliforms	cfu / 100mL	9,000 #2	4,700	3,800	500 #2	-
Heavy metals, dissolved, trace As,Cd,Cr,Cu,Ni,Pb,Zn						
Dissolved Arsenic	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010	-
Dissolved Cadmium	g/m^3	< 0.00005	0.00009	< 0.00005	0.00017 #1	-
Dissolved Chromium	g/m^3	< 0.0005	< 0.0005	< 0.0005	< 0.0005	-
Dissolved Copper	g/m^3	0.0014	0.0017	0.0026	0.0020	-
Dissolved Lead	g/m^3	< 0.00010	< 0.00010	< 0.00010	< 0.00010	-
Dissolved Nickel	g/m^3	0.0020	0.0031	0.0018	0.0060	-
Dissolved Zinc	g/m^3	0.024	0.064	0.0024	0.111	-

Sample Type: Aqueous						
Sample Name:		TAOK Site 2 20-Apr-2015 5:16 pm	TAOK Site 3 21-Apr-2015 1:50 pm	TAOK Site 4 21-Apr-2015 2:20 pm	TAOK Site 5 21-Apr-2015 1:25 pm	
Lab Number:		1415249.2	1415249.4	1415249.6	1415249.8	
Heavy metals, totals, trace As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Arsenic	g/m^3	0.0025	0.0021	0.0059	0.0019	-
Total Cadmium	g/m^3	0.000053	0.000079	0.000055	0.000153 [#1]	-
Total Chromium	g/m^3	0.00142	0.00081	0.0050	0.00090	-
Total Copper	g/m^3	0.0032	0.0028	0.0132	0.0029	-
Total Lead	g/m^3	0.00167	0.00040	0.0123	0.00169	-
Total Nickel	g/m^3	0.0028	0.0036	0.0052	0.0064	-
Total Zinc	g/m^3	0.035	0.066	0.036	0.115	-
Nutrient Profile						
Total Ammoniacal-N	g/m^3	0.20	0.37	0.094	0.35	-
Nitrite-N	g/m^3	0.032	0.064	0.025	0.023	-
Nitrate-N	g/m^3	1.85	0.92	1.16	0.99	-
Nitrate-N + Nitrite-N	g/m^3	1.88	0.99	1.19	1.01	-
Dissolved Reactive Phosphorus	g/m^3	0.010	0.070	0.012	< 0.004	-
Polycyclic Aromatic Hydrocarbons Screening in Water, By Liq/Liq						
Acenaphthene	g/m^3	< 0.00010	< 0.00010	< 0.00010	< 0.00010	-
Acenaphthylene	g/m^3	< 0.00010	< 0.00010	< 0.00010	< 0.00010	-
Anthracene	g/m^3	< 0.00010	< 0.00010	< 0.00010	< 0.00010	-
Benzo[a]anthracene	g/m^3	< 0.00010	< 0.00010	< 0.00010	< 0.00010	-
Benzo[a]pyrene (BAP)	g/m^3	< 0.00010	< 0.00010	< 0.00010	< 0.00010	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	g/m^3	< 0.00010	< 0.00010	< 0.00010	< 0.00010	-
Benzo[g,h,i]perylene	g/m^3	< 0.00010	< 0.00010	< 0.00010	< 0.00010	-
Benzo[k]fluoranthene	g/m^3	< 0.00010	< 0.00010	< 0.00010	< 0.00010	-
Chrysene	g/m^3	< 0.00010	< 0.00010	< 0.00010	< 0.00010	-
Dibenzo[a,h]anthracene	g/m^3	< 0.00010	< 0.00010	< 0.00010	< 0.00010	-
Fluoranthene	g/m^3	< 0.00010	< 0.00010	< 0.00010	< 0.00010	-
Fluorene	g/m^3	< 0.0002	< 0.0002	< 0.0002	< 0.0002	-
Indeno(1,2,3-c,d)pyrene	g/m^3	< 0.00010	< 0.00010	< 0.00010	< 0.00010	-
Naphthalene	g/m^3	< 0.0005	< 0.0005	< 0.0005	< 0.0005	-
Phenanthrene	g/m^3	< 0.0004	< 0.0004	< 0.0004	< 0.0004	-
Pyrene	g/m^3	< 0.0002	< 0.0002	< 0.0002	< 0.0002	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m^3	< 0.10	< 0.10	< 0.10	< 0.10	-
C10 - C14	g/m^3	< 0.2	< 0.2	< 0.2	< 0.2	-
C15 - C36	g/m^3	< 0.4	< 0.4	< 0.4	< 0.4	-
Total hydrocarbons (C7 - C36)	g/m^3	< 0.7	< 0.7	< 0.7	< 0.7	-

Analyst's Comments

Please interpret these microbiological results with caution as the sample temperature was > 8 °C on receipt in the lab. Samples are required to be less than 8 °C (but not frozen).

[#1] It has been noted that the result for the dissolved fraction was greater than that for the total fraction, but within analytical variation of the methods.

[#2] Statistically estimated count based on the theoretical countable range for the stated method.

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1, 3, 5, 7, 9
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, screen level.	0.10 - 4 mg/kg dry wt	1, 3, 5, 7, 9
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1, 3, 5, 7, 9

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Organic Carbon*	Acid pretreatment to remove carbonates if present, Elementar Combustion Analyser.	0.05 g/100g dry wt	1, 3, 5, 7, 9

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Heavy metals, dissolved, trace As,Cd,Cr,Cu,Ni,Pb,Zn	0.45µm filtration, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.00005 - 0.0010 g/m^3	2, 4, 6, 8
Heavy metals, totals, trace As,Cd,Cr,Cu,Ni,Pb,Zn	Nitric acid digestion, ICP-MS, trace level	0.000053 - 0.0011 g/m^3	2, 4, 6, 8
Nutrient Profile		0.0010 - 0.010 g/m^3	2, 4, 6, 8
Polycyclic Aromatic Hydrocarbons Screening in Water, By Liq/Liq	Liquid / liquid extraction, SPE (if required), GC-MS SIM analysis [KBIs:4736,2695]	0.00010 - 0.0005 g/m^3	2, 4, 6, 8
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m^3	2, 4, 6, 8
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	2, 4, 6, 8
Total Digestion	Boiling nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	2, 4, 6, 8
Total Kjeldahl Digestion	Sulphuric acid digestion with copper sulphate catalyst.	-	2, 4, 6, 8
Total Phosphorus Digestion	Acid persulphate digestion.	-	2, 4, 6, 8
Turbidity	Analysis using a Hach 2100N, Turbidity meter. APHA 2130 B 22nd ed. 2012.	0.05 NTU	2, 4, 6, 8
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012.	0.1 pH Units	2, 4, 6, 8
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D 22nd ed. 2012.	3 g/m^3	2, 4, 6, 8
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22nd ed. 2012.	-	2, 4, 6, 8
Dissolved Aluminium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.003 g/m^3	2, 4, 6, 8
Total Aluminium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012 / US EPA 200.8.	0.0032 g/m^3	2, 4, 6, 8
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	2, 4, 6, 8
Total Iron	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.021 g/m^3	2, 4, 6, 8
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m^3 is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m^3, the Default Detection Limit for Total Nitrogen will be 0.11 g/m^3.	0.05 g/m^3	2, 4, 6, 8
Total Ammoniacal-N	Filtered sample. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH_4-N = NH_4+-N + NH_3-N). APHA 4500-NH_3 F (modified from manual analysis) 22nd ed. 2012.	0.010 g/m^3	2, 4, 6, 8
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m^3	2, 4, 6, 8
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	2, 4, 6, 8
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m^3	2, 4, 6, 8
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D. (modified) 4500 NH_3 F (modified) 22nd ed. 2012.	0.10 g/m^3	2, 4, 6, 8
Dissolved Reactive Phosphorus	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 22nd ed. 2012.	0.004 g/m^3	2, 4, 6, 8
Total Phosphorus	Total phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P B & E (modified from manual analysis) 22nd ed. 2012. Also modified to include the use of a reductant to eliminate interference from arsenic present in the sample. NWASCA, Water & soil Miscellaneous Publication No. 38, 1982.	0.004 g/m^3	2, 4, 6, 8
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	Incubation 5 days, DO meter, nitrification inhibitor added, dilutions, seeded. Analysed at Hill Laboratories - Microbiology; 1 Clow Place, Hamilton. APHA 5210 B (modified) 22nd ed. 2012.	2 g O_2/m^3	2, 4, 6, 8
Faecal Coliforms	Membrane Filtration, Count on mFC agar, Incubated at 44.5°C for 22 hours, Confirmation. Analysed at Hill Laboratories - Microbiology; 1 Clow Place, Hamilton. APHA 9222 D, 22nd ed. 2012.	1 cfu / 100mL	2, 4, 6, 8

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Carole Rodgers-Carroll BA, NZCS
Client Services Manager - Environmental Division

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Hill Laboratories
BETTER TESTING BETTER RESULTS

ANALYSIS REPORT

SPv1

Client:	Boffa Miskell Limited	**Lab No:**	1435045
Contact:	L Saunders	**Date Registered:**	04-Jun-2015
	C/- Boffa Miskell Limited	**Date Reported:**	16-Jun-2015
	PO Box 13373	**Quote No:**	67004
	TAURANGA 3141	**Order No:**	T14157
		Client Reference:	
		Submitted By:	L Saunders

Sample Type: Aqueous

Sample Name:		T14157 04-Jun-2015 2:00 pm				
Lab Number:		1435045.1				
Individual Tests						
Turbidity	NTU	45	-	-	-	-
pH	pH Units	7.1	-	-	-	-
Total Suspended Solids	g/m^3	35	-	-	-	-
Dissolved Aluminium	g/m^3	0.093	-	-	-	-
Total Aluminium	g/m^3	1.30	-	-	-	-
Dissolved Iron	g/m^3	0.26	-	-	-	-
Total Iron	g/m^3	2.1	-	-	-	-
Total Nitrogen	g/m^3	1.36	-	-	-	-
Total Kjeldahl Nitrogen (TKN)	g/m^3	0.47	-	-	-	-
Total Phosphorus	g/m^3	0.070	-	-	-	-
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	g O_2/m^3	< 2	-	-	-	-
Faecal Coliforms	cfu / 100mL	3,700	-	-	-	-
Heavy metals, dissolved, trace As,Cd,Cr,Cu,Ni,Pb,Zn						
Dissolved Arsenic	g/m^3	< 0.0010	-	-	-	-
Dissolved Cadmium	g/m^3	< 0.00005	-	-	-	-
Dissolved Chromium	g/m^3	0.0007	-	-	-	-
Dissolved Copper	g/m^3	0.0013	-	-	-	-
Dissolved Lead	g/m^3	< 0.00010	-	-	-	-
Dissolved Nickel	g/m^3	0.0019	-	-	-	-
Dissolved Zinc	g/m^3	0.0188	-	-	-	-
Heavy metals, totals, trace As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Arsenic	g/m^3	0.0020	-	-	-	-
Total Cadmium	g/m^3	0.00040	-	-	-	-
Total Chromium	g/m^3	0.00148	-	-	-	-
Total Copper	g/m^3	0.0025	-	-	-	-
Total Lead	g/m^3	0.00111	-	-	-	-
Total Nickel	g/m^3	0.0024	-	-	-	-
Total Zinc	g/m^3	0.024	-	-	-	-
Nutrient Profile						
Total Ammoniacal-N	g/m^3	0.062	-	-	-	-
Nitrite-N	g/m^3	0.012	-	-	-	-
Nitrate-N	g/m^3	0.88	-	-	-	-
Nitrate-N + Nitrite-N	g/m^3	0.89	-	-	-	-
Dissolved Reactive Phosphorus	g/m^3	0.008	-	-	-	-
Polycyclic Aromatic Hydrocarbons Screening in Water, By Liq/Liq						
Acenaphthene	g/m^3	< 0.00010	-	-	-	-

Sample Type: Aqueous						
Sample Name:		T14157 04-Jun-2015 2:00 pm				
Lab Number:		1435045.1				
Polycyclic Aromatic Hydrocarbons Screening in Water, By Liq/Liq						
Acenaphthylene	g/m^3	< 0.00010	-	-	-	-
Anthracene	g/m^3	< 0.00010	-	-	-	-
Benzo[a]anthracene	g/m^3	< 0.00010	-	-	-	-
Benzo[a]pyrene (BAP)	g/m^3	< 0.00010	-	-	-	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	g/m^3	< 0.00010	-	-	-	-
Benzo[g,h,i]perylene	g/m^3	< 0.00010	-	-	-	-
Benzo[k]fluoranthene	g/m^3	< 0.00010	-	-	-	-
Chrysene	g/m^3	< 0.00010	-	-	-	-
Dibenzo[a,h]anthracene	g/m^3	< 0.00010	-	-	-	-
Fluoranthene	g/m^3	< 0.00010	-	-	-	-
Fluorene	g/m^3	< 0.0002	-	-	-	-
Indeno(1,2,3-c,d)pyrene	g/m^3	< 0.00010	-	-	-	-
Naphthalene	g/m^3	< 0.0005	-	-	-	-
Phenanthrene	g/m^3	< 0.0004	-	-	-	-
Pyrene	g/m^3	< 0.0002	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m^3	< 0.10	-	-	-	-
C10 - C14	g/m^3	< 0.2	-	-	-	-
C15 - C36	g/m^3	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m^3	< 0.7	-	-	-	-

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Heavy metals, dissolved, trace As,Cd,Cr,Cu,Ni,Pb,Zn	0.45µm filtration, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.00005 - 0.0010 g/m^3	1
Heavy metals, totals, trace As,Cd,Cr,Cu,Ni,Pb,Zn	Nitric acid digestion, ICP-MS, trace level	0.000053 - 0.0011 g/m^3	1
Nutrient Profile		0.0010 - 0.010 g/m^3	1
Polycyclic Aromatic Hydrocarbons Screening in Water, By Liq/Liq	Liquid / liquid extraction, SPE (if required), GC-MS SIM analysis [KBIs:4736,2695]	0.00010 - 0.0005 g/m^3	1
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m^3	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total Digestion	Boiling nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	1
Total Kjeldahl Digestion	Sulphuric acid digestion with copper sulphate catalyst.	-	1
Total Phosphorus Digestion	Acid persulphate digestion.	-	1
Turbidity	Analysis using a Hach 2100N, Turbidity meter. APHA 2130 B 22nd ed. 2012.	0.05 NTU	1
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012.	0.1 pH Units	1
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D 22nd ed. 2012.	3 g/m^3	1
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22nd ed. 2012.	-	1
Dissolved Aluminium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.003 g/m^3	1
Total Aluminium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012 / US EPA 200.8.	0.0032 g/m^3	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Total Iron	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.021 g/m^3	1

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m^3 is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m^3, the Default Detection Limit for Total Nitrogen will be 0.11 g/m^3.	0.05 g/m^3	1
Total Ammoniacal-N	Filtered sample. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH_4-N = NH_4+-N + NH_3-N). APHA 4500-NH_3 F (modified from manual analysis) 22nd ed. 2012.	0.010 g/m^3	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m^3	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m^3	1
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D. (modified) 4500 NH_3 F (modified) 22nd ed. 2012.	0.10 g/m^3	1
Dissolved Reactive Phosphorus	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 22nd ed. 2012.	0.004 g/m^3	1
Total Phosphorus	Total phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P B & E (modified from manual analysis) 22nd ed. 2012. Also modified to include the use of a reductant to eliminate interference from arsenic present in the sample. NWASCA, Water & soil Miscellaneous Publication No. 38, 1982.	0.004 g/m^3	1
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	Incubation 5 days, DO meter, nitrification inhibitor added, dilutions, seeded. Analysed at Hill Laboratories - Microbiology; 1 Clow Place, Hamilton. APHA 5210 B (modified) 22nd ed. 2012.	2 g O_2/m^3	1
Faecal Coliforms	Membrane Filtration, Count on mFC agar, Incubated at 44.5°C for 22 hours, Confirmation. Analysed at Hill Laboratories - Microbiology; 1 Clow Place, Hamilton. APHA 9222 D, 22nd ed. 2012.	1 cfu / 100mL	1

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Peter Robinson MSc (Hons), PhD, FNZIC
Client Services Manager - Environmental Division

Appendix 3: Aquatic Macroinvertebrate Results

T14157 (Te Awa O Katapaki)

Summary of Freshwater Macroinvertebrate Sample Processing & Results

April 2015

ryderconsulting
environment + planning + project management

T14157 (Te Awa O Katapaki)

Summary of Freshwater Macroinvertebrate Sample Processing & Results

April 2015

prepared for Boffa Miskell by Ryder Consulting Limited

Katie Blakemore, BSc. (Hons)

Ben Ludgate, MSc.

Document version: 27/05/15

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Table of Contents

1. Introduction

Preserved benthic macroinvertebrate samples were provided to Ryder Consulting Limited by Boffa Miskell. Boffa Miskell staff collected these samples in April 2015. Ryder Consulting Limited was engaged to process the samples, and report the results of taxonomic composition and abundance.

2. Laboratory Analysis

2.1 Processing

Macroinvertebrate samples were processed for macroinvertebrate species identification and their relative abundance using the semi-quantitative protocols outlined in the Ministry for the Environment's 'Protocols for sampling macroinvertebrates in wadeable streams' (Stark *et al.* 2001). Protocol 'P1: Coded abundance' was used, which is summarised briefly below.

In the laboratory, the samples were passed through a 500 µm sieve to remove fine material. Contents of the sieve were then placed in a white tray. Each taxon present in the sample was assigned to one of five coded abundance categories (Table 1). Up to 20 individuals representative of each taxon were removed from each sample to confirm identifications under a dissecting microscope (10-40x) using criteria from Winterbourn *et al.* (2006).

Table 1 *Coded abundance scores used to summarise macroinvertebrate data (after Stark 1998).*

Abundance	Coded Abundance	Weighting factor
1 - 4	Rare (R)	1
5 - 19	Common (C)	5
20 - 99	Abundant (A)	20
100 - 499	Very abundant (VA)	100
> 500	Very very abundant (VVA)	500

2.2 Data summaries and metric calculations

For each site, benthic macroinvertebrate community health was assessed by determining the following characteristics:

Number of taxa: A measurement of the number of taxa present.

Number of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa, and percentage of the total number of taxa comprising EPT taxa (% EPT taxa): These insect groups are generally dominated by pollution sensitive taxa. In stony bed rivers, these indexes usually increase with improved water quality and increased habitat diversity.

Macroinvertebrate Community Index for soft-bottomed streams (MCI-sb) and semi-quantitative MCI for soft-bottomed streams (SQMCI-sb) (Stark and Maxted 2007): These biotic indices have been developed specifically for use in soft-bottomed streams. The original MCI and SQMCI were developed for use in hard-bottomed streams based on sampling macroinvertebrates from riffle or run habitats, however their use has often been extended through a wide range of habitats including soft-bottomed areas. The soft-bottomed indices use the same principles as the hard-bottomed MCI and SQMCI indices, however new taxon-specific tolerance scores (between 1 and 10) have been derived specifically for soft-bottomed streams (Stark and Maxted 2007).

The MCI-sb site score is obtained by summing the scores of individual taxa and dividing this total by the number of taxa present at the site.

$$\text{MCI-sb} = \left(\frac{\text{Sum of taxa scores}}{\text{Number of scoring taxa}}\right) \times 20$$

The SQMCI-sb uses the same approach as the MCI-sb but weights each taxa score based on how abundant the taxa is within the community. Abundance of each taxon is converted into one of five coded abundance categories (Table 1).

$$\text{SQMCI-sb} = \frac{\text{Sum of (Taxa coded abundance x Taxa score)}}{\text{Sum of coded abundances for sample}}$$

As for MCI and SQMCI, MCI-sb and SQMCI-sb scores can be interpreted in the context of national standards (Table 2).

Table 2 *Interpretation of macroinvertebrate community index values from Boothroyd and Stark (2000) (Quality class A) and Stark and Maxted (2007) (Quality class B).*

Quality Class A	Quality Class B	MCI-sb	SQMCI-sb
Clean water	Excellent	≥ 120	≥ 6.00
Doubtful quality	Good	100 – 119	5.00 – 5.99
Probable moderate pollution	Fair	80 – 99	4.00 – 4.99
Probable severe pollution	Poor	< 80	< 4.00

3. Results

3.1 Macroinvertebrate results

The macroinvertebrate results are included below and have also been forwarded to Boffa Miskell in electronic form.

TAXON	MCI-sb score	Te Awa O Katapaki 1	2	3	4
COLEOPTERA					
Scirtidae	6.4			R	
CRUSTACEA					
Isopoda	4.5	R			
Paracalliope fluviatilis	5.5	R			
Talitridae	5.5			C	
DIPTERA					
Chironomus species	3.4	R	R		R
Orthocladiinae	3.2	R			
Polypedilum species	8.0	C	R		
Tanytarsini	4.5			R	
Zelandotipula species	3.6	R			
HEMIPTERA					
Anisops species	2.2		C		C
Sigara species	2.4				C
HIRUDINEA	1.2		R		R
MOLLUSCA					
Physa / Physella species	0.1	R	C	C	R
Potamopyrgus antipodarum	2.1	VA	R	R	R
Sphaeriidae	2.9	R		C	
ODONATA					
Xanthocnemis zealandica	1.2	C			C
OLIGOCHAETA	3.8	R	C	C	R
PLATYHELMINTHES	0.9		R	R	
TRICHOPTERA					
Oeconesidae	6.4	R			
Oxyethira albiceps	1.2			A	
Polyplectropus species	8.1	C			
Psilochorema species	7.8	R			
Triplectides species	5.7	C			
Number of taxa		15	8	9	8
Number of EPT taxa		4	0	1	0
% EPT taxa		27	0	11	0
MCI-sb score		88.4	54.3	60.9	41.0
SQMCI-sb score		2.8	2.3	2.3	2.0

4. References

Boothroyd, I.G. and Stark, J.D. 2000. Use of invertebrates in monitoring. Chapter 14 in Collier, K.J. and Winterbourn, M.J. eds. New Zealand stream invertebrates: ecology and implications for management. New Zealand Limnological Society, Christchurch. Pp. 344-373.

Stark, J.D. 1998. SQMCI: a biotic index for freshwater macroinvertebrate coded abundance data. *New Zealand Journal of Marine and Freshwater Research*. **32**: 55-66.

Stark, J.D. and Maxted, J.R. 2007. A biotic index for New Zealand's soft-bottomed streams. *New Zealand Journal of Marine and Freshwater Research*. **41**: 43-61.

Stark, J.D., Boothroyd, I.K.G., Harding, J.S., Maxted, J.R. and Scarsbrook, M.R. 2001. Protocols for sampling macroinvertebrates in wadeable streams. New Zealand Macroinvertebrate Working Group Report No. 1. Prepared for the Ministry for the Environment.

Winterbourn, M.J., Gregson, K.L.D. and Dolphin, C.H. 2006. Guide to the aquatic insects of New Zealand. *Bulletin of the Entomological Society of New Zealand*. **14**.

Appendix J Updated Ecological Findings

Tonkin+Taylor

Job No: 1014914
17 February 2021

Hamilton City Council
Private Bag 3010
Hamilton 3240

Attention: Andrea Phillips

Dear Andrea

Te Awa O Kātāpaki Integrated Catchment Management Plan - Review of Freshwater Ecology Information

This letter presents a brief review and update to the assessment of ecological values undertaken for the Te Awa O Kātāpaki (TAOK) Integrated Catchment Management Plan (ICMP)[1], hereafter the "ICMP Ecology Report" and presents an ongoing monitoring programme for the catchment.

1 Introduction

The ICMP Ecology Report was based on specific field investigations undertaken in 2015 covering habitat values, water quality, sediment quality, instream fauna (fish and macroinvertebrates) and erosion and scour. A review of available database information is also included.

There are a range of other studies and ecological data for the TAOK catchment that were undertaken or collected pre and post the ICMP Ecology Report that are relevant to establishing catchment ecological condition and values. The objectives of this report are to summarise the additional information available for the catchment and to provide an updated monitoring programme for the ICMP on the basis of the existing citywide monitoring programme. We have not covered the "River North" sub-catchment as we are not aware of any additional data to that presented in the ICMP Ecology Report.

2 Stream ecology values and information

The main sources of information used for this update are summarised as follows:

- Monitoring and assessment data collected by Tonkin & Taylor Ltd (T+T) in relation to Waikato Regional Council (WRC) resource consents for the construction and operation of Magellan Lake. Resource consents have been transferred to Hamilton City Council (HCC). This includes the 2013 Magellan Lake environmental monitoring report[2] and an NZ Stormwater Conference paper also presenting that data.

[1] Boffa Miskell Ltd, 2018. Te Awa O Katapaki Stream - Assessment of Ecological Values to inform an Integrated Catchment Management Plan.
[2] T+T, 2013. Magellan Lake 2013 Environmental Monitoring Report. Prepared for CDL Land (NZ) Ltd.

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- Monitoring data and reports prepared by T+T for HCC in accordance with its Comprehensive Stormwater Discharge Consent (CSDC, Consent number 105297) and associated monitoring plans.
- An ecological assessment prepared by Boffa Miskell Ltd (BML) for the proposed piping of an upper reach of the TAOK stream to the west of the Rototuna Town Centre[3].
- A black mudfish (*Neochanna diversus*) monitoring plan prepared by T+T for the CityEdge Alliance following the discovery and transfer of mudfish in the upper TAOK catchment around the Waikato Expressway: Hamilton Section[4].

2.1 Watercourse classification

The ICMP Ecology Report presented a high-level watercourse classification. Watercourses in the TAOK catchment downstream of Resolution Drive have been subject to a subsequent erosion focussed walkover survey and mapped (Morphum & T+T, 2016).

A network of modified swales and farm drains is present in the developing parts of the upper catchment (upstream of Resolution Drive). These watercourses have not been comprehensively assessed or mapped for the ICMP, although this will occur progressively by HCC or developers as part of resource consent processes. Black mudfish are known to be present in some upper catchment drains (see Section 2.4.3).

2.2 Water quality

The ICMP Ecology report presented the results of grab sample data (one or two sampling occasions) collected from four sites on the TAOK Stream. Additional data are available for the two online ponds present on the main TAOK stream (Magellan Lake and Petersburg pond). The data were collected for the purpose of assessing the effects of the ponds on stream water quality, primarily water temperature and dissolved oxygen.

2.2.1 Magellan Lake

Monitoring of the effect of Magellan Lake on TAOK Stream water temperature and dissolved oxygen was undertaken by T+T for the developer (CDL Land (NZ) Ltd). Continuous water temperature data were collected at locations upstream and downstream of the lake for two summer periods prior to and two summer periods after the lake was constructed. The results are presented in detail in the 2013 Magellan Lake environmental monitoring report[2] and in an NZ Stormwater Conference paper[5].

In summary, for the post lake scenario and as of 2013 the broad upstream to downstream trend based on mean temperatures were as follows. Magellan Lake resulted in an increase in temperature in the TAOK Stream of up to 5 °C in summer. TAOK stream temperature then reduced by around 2 °C when mixed with the cooler water entering the stilling basin from the southern catchment. Further cooling then occurred through the shaded reach of the stream to Wisteria Place around 750 m downstream of the lake (0.6 to 0.9 °C).

Continuous dissolved oxygen monitoring data collected by T+T downstream of the lake outlet indicated that while brief low levels in dissolved oxygen occurred, in general dissolved oxygen conditions were similar to or better in the post lake scenario (2012 and 2013 data) relative to the pre lake 2008 data. For example, the percentage of measurements below the slight effects threshold for

[3] Boffa Miskell Ltd, 2020. Rototuna Town Centre West – Watercourse Piping Ecological Impact Assessment Prepared for Hamilton City Council.
[4] T+T, 2019. Mudfish monitoring protocol for the Waikato Expressway – Hamilton Section. Prepared for CityEdge Alliance.
[5] Miller, D.C. 2014. Does a large on-line stormwater pond put the heat on the downstream environment. NZ Stormwater Conference Paper.

stream fauna of 6 mg/L (Maxted *et al.* 2005[6]) was less in 2012 and 2013 (a drought summer) compared to in 2008.

In order to assist in mitigating any effect of the lake on stream dissolved oxygen levels it was proposed to incorporate rock lining into the lake outlet channel to break up flow and aid in oxygenating the discharged lake water. Monitoring of dissolved oxygen concentrations and levels upstream and downstream of the rock lined outlet channel of Magellan Lake showed a small but consistent improvement in dissolved oxygen conditions as a result of aeration of water discharged from the lake. On average conditions improved by 0.29 mg/L and 3.6 % saturation.

2.2.2 Petersburg pond

Monitoring of the effect of Petersburg pond (see Figure 2.1) on TAOK Stream water temperature and dissolved oxygen was undertaken by T+T for HCC as part of its CSDC monitoring programme[7]. Continuous water temperature data were collected at locations upstream and downstream of the pond over the 2013/14 summer period with data sondes deployed to monitor dissolved oxygen for one week each month during December 2013, January, February and March 2014.

Figure 2.1: Location of Petersburg Drive online pond

Temperature results showed little difference between upstream and downstream temperatures with comparable temperature ranges, maximum and minimum values and similar peak and troughs

[6] Maxted, J.R; McCreedy, C.H.; Scarsbrook, M. R., 2005: Effects of small ponds on stream water quality and macroinvertebrate communities. New Zealand Journal of Marine and Freshwater Research, Vol. 39: 1069–1084.
[7] T+T, 2014. Comprehensive Stormwater Discharge Consent 105279 2013/14 Monitoring Report. Prepared for HCC.

with overlapping temperature data. This may be due to the small size of the pond resulting in a short residence time reducing the opportunity for water to be heated during the day. The dense beds of weeds (parrots feather) may also reduce the degree of mixing in the pond as there is generally a narrow and fairly direct flow path through the weed from upstream to the outlet. Essentially the stream flow may pass fairly quickly through the pond. Overall, the Petersburg Drive online pond appears to have little effect on water temperatures.

Dissolved oxygen levels increased slightly downstream, which is likely due to a combination of factors including, maintained water temperature and the rock lined fish pass at the outlet of the pond causing turbulent flows and water to become aerated. Small rainfall events also appeared to cause dissolved oxygen levels to improve slightly upstream and downstream of the pond. Upstream and downstream dissolved oxygen levels were generally below the 6 mg/L slight effects criterion and occasionally fell below the 4 mg/L moderate effects criterion[6]. This means that dissolved oxygen conditions were likely to be having a slight to moderate effect on aquatic life.

2.3 Habitat and sediment quality

Stream habitat and sediment quality data have been collected from five sites on the TAOK Stream since 2013 as part of HCC's CSDC monitoring programme. Site locations are shown as T1 to T5 on Figure 2.2. All five sites were monitored in 2013, with selected sites monitored in 2019 and 2020 following a change in monitoring approach and a shift to prioritised monitoring. Monitoring comprises a qualitative habitat assessment (QHA) undertaken over a 100 m reach in accordance with WRC's Regional Guidelines for Ecological Assessment of Freshwater Environments[8], collection of a single macroinvertebrate sample and collection of a composite sediment quality sample.

Figure 2.2: Location plan extracted from HCC's SREMP and showing existing TAOK monitoring site locations (Sites T1 to T5).

Stream habitat assessment and macroinvertebrate data for each site in the TAOK Stream catchment are summarised in Table 2-1. QHA scores have remained approximately similar over time at Sites T2, T4 and T5 while there has been a reduction at Site T1. There was some sign of improvement at Site T1 from 2019 to 2020. Macroinvertebrate data for Site T1 show variable trends although

[8] Waikato Regional Council, 2005. Regional Guidelines for Ecological Assessments of Freshwater Environments: Macroinvertebrate Sampling in Wadeable Streams. http://www.waikatoregion.govt.nz/PageFiles/3114/tr05-02.pdf

Macroinvertebrate Community Index (MCI) and Quantitative Macroinvertebrate Community Index (QMCI) scores were low in 2020 compared to the first CSDC monitoring round in 2013.

MCI and QMCI scores for TAOK catchment sites have been low in general over time and mostly fall within the "poor" water and habitat quality class (below 80 for MCI and below 4 for QMCI). Few sensitive Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa are encountered in samples, including in the parts of the stream with good physical habitat quality. This suggests an impact due to sedimentation and water quality issues.

QHA and macroinvertebrate data are also available for a site in the upper TAOK catchment which was investigated in June 2020 as part of a proposal to pipe the section of the TAOK Stream downstream of North City Road[3]. The QHA score for the site was 72 (out of a possible 180), MCI score was 73.6 and SQ-MCI was 2.2. Habitat conditions reflect the open nature of the site and macroinvertebrate data are indicative of reduced water and habitat conditions, consistent with the CSDC data for TAOK Stream.

Sediment quality testing results for samples collected as part of the CSDC monitoring programme are presented in Table 2-2. Results include extractible (E) and total recoverable (TR) copper (Cu) and zinc (Zn). Extractable metals (Cu and Zn) are for the <63 µm fraction following a weak acid digestion. The clay/silt (<63 µm) fraction is more likely to adsorb organic and metal contaminants and particles <63 µm are more common in the gut of sediment-ingesting biota. Concentrations have been compared to the ANZG 2018[9] default and upper guideline values.

Few exceedances of ANZG guideline values have been detected to date, other than at Site T1 for TR zinc in 2020 which is consistent with the data reported in the ICMP Ecology Assessment. However, most sites where repeat monitoring has been undertaken, and in particular Sites T1 and T2, show a pattern of increasing recoverable and extractable copper and zinc concentrations over time.

The ICMP Ecology Report identifies metal contamination of watercress as a potential human health risk (in particular arsenic). The report recommends that additional sediment quality monitoring is undertaken at publicly accessible sites with watercress (i.e. where watercress collection could occur). Key analytes are arsenic and zinc.

[9] Australian & New Zealand Guidelines for Freshwater and Marine Water Quality

Table 2-1: Macro-invertebrate sample results for TAOK Catchment habitat assessment sites

Site	T1			T2		T3	T4		T5		
Year	2013	2019	2020	2013	2019	2013	2013	2019	2013	2019	2020
Qualitative habitat assessment score*	116 (HB)	78 (HB)	83 (HB)	152 (SB)	151 (SB)	100 (SB)	154 (SB)	144 (SB)	69 (HB)	74 (SB)	79 (SB)
Number of taxa	9	15	12	5	16	8	7	8	6	17	17
Number of EPT taxa	0	1	0	1	0	0	0	0	0	0	0
MCI score	67	77	55	80	63	63	74	65	67	71	86
QMCI score	3.90	3.03	3.32	4.10	2.28	3.50	2.10	3.30	3.50	2.98	3.13

* HB = Hard Bottomed, SB = Soft Bottomed

Table 2-2: Copper and zinc concentrations in sediment collected at TAOK Catchment habitat assessment sites

Site	T1			T2		T3	T4		T5		
Year	2013	2019	2020	2013	2019	2013	2013	2019	2013	2019	2020
E Cu (mg/kg dry wt) [63um Fraction]	12.3	8.3	11.6	10.8	14.0	19.8	27.0	21.0	10.2	13.3	21.0
TR Cu (mg/kg dry wt) [500um Fraction]	7.6	8.7	15.6	6.8	6.8	8.3	5.2	10.4	5.0	8.1	12.7
E Zn (mg/kg dry wt) [63um Fraction]	137	76	168	126	160	199	174	101	83	82	102
TR Zn (mg/kg dry wt) [500um Fraction]	95	62	230	93	109	74	50	68	47	53	79

Orange text denotes values exceeding the ANZG 2018 default guideline values (DGV) of 65 mg/kg dry wt (copper) and 200 mg/kg dry wt (zinc).
Red text denotes values exceeding the ANZG 2018 upper guideline values (UGV) of 270 mg/kg dry wt (copper) and 410 mg/kg dry wt (zinc).

2.4 Fish

Some additional fish survey information is available for the TAOK catchment to that presented in the ICMP Ecology Report and is summarised below.

2.4.1 Online ponds

A fish survey was undertaken at Magellan Lake in early April 2014[10]. Native fish captured comprised shortfin eel (*Anguilla australis*) and banded kokopu (*Galaxias fasciatus*). Exotic species captured comprised catfish (*Ameiurus nebulosus*) and rudd (*Scardinius erythrophthalmus*). The presence of catfish and rudd were new records for the lake and the upper catchment at that time. Koi carp (*Cyprinus carpio*) and mosquitofish (*Gambusia affinis*) were not captured during the survey although both species are known to be present in Magellan Lake.

The smallest eels captured in the lake were 150 mm in length. Shortfin eels of this size are likely to be around 3 years old and their presence suggested that eel recruitment to the lake had occurred via the fish pass since the weir became operational (August 2010). The small size of the specimen (60 mm) suggests that the banded kokopu has entered the lake from the downstream catchment via the fish pass.

A similar fish survey was undertaken in Petersburg pond in April 2014 as part of HCC's CSDC monitoring programme[7]. Seven species of fish were caught during the online pond survey including four native species and three exotic species. Native species included shortfin and longfin eel (*Anguilla dieffenbachii*), giant kokopu (*Galaxias argenteus*) and smelt (*Retropinna retropinna*). Exotic (pest) species included catfish, rudd and gambusia.

2.4.2 Upper catchment

Fish survey data are also available for a site in the upper TAOK catchment which was investigated in June 2020 as part of a proposal to pipe the section of the TAOK Stream downstream of North City Road[3]. The only native fish species encountered was shortfin eel. Catfish and gambusia were also captured.

2.4.3 Mudfish

Mudfish were recently discovered in an upper tributary of the TAOK Stream as part of routine fish survey / rescue work for the Waikato Expressway: Hamilton Section construction project. The Project alignment crosses many watercourses, including known and previously unknown black mudfish (*Neochanna diversus* - At Risk: Declining[11]) habitat. As the project footprint crossed known black mudfish habitat, a Mudfish Management Plan (MMP) was required prior to construction to provide an approved approach to mudfish management. The MMP was approved by Waikato Regional Council (WRC) and finalised on 7 July 2016.

An unknown, and previously un-surveyed population of black mudfish were found inhabiting a watercourse (culvert L) bisecting the project alignment near Kay Road (WGS 1984 coordinates: -37.71225556, 175.2594389). Fishing pre-culverting works resulted in 45 black mudfish being relocated downstream of works between December 2017 and January 2018. The black mudfish discovery and relocation sites are shown on Figure 2.3. Mudfish were confirmed to be present at the relocation site in late 2020[12].

[10] T+T, 2014. Magellan Lake 2014 Environmental Monitoring Report. Prepared for CDL Land (NZ) Ltd.
[11] Dunn et al. (2018). Conservation status of New Zealand freshwater fishes, 2017 [New Zealand Threat Classification Series 24]. Department of Conservation, Wellington.
[12] Unpublished survey data collected as part of the Waikato Expressway: Hamilton Section MMP.

Figure 2.3: Mudfish fishing and relocation sites in an unnamed tributary of TAOK stream for the Waikato Expressway: Hamilton Section project.

2.5 Fish passage

Fish passage in the TAOK Stream system was assessed as part of a city wide investigation undertaken as part of HCC's CSDC monitoring programme[7]. A total of 7 structures were inspected in the TAOK Stream.

The culvert beneath River Road at the bottom end of the catchment was upgraded in 2013 to include a fish friendly design and is no longer a barrier. The next two in-stream structures are associated with on-line stormwater detention ponds (Petersburg Pond and Magellan Lake). The outlets for both ponds include specifically designed and consented fish passes. The Magellan Lake fish ramp was specifically designed to allow the passage of eels based on habitat conditions upstream of the lake.

Only 1 barrier was identified in The TAOK catchment and this comprises a gabion weir located in the bed of a drain upstream of Borman Rd. The weir includes a 1.5 m vertical drop and low flows pass through the structure rather than over it. Habitat upstream of the weir comprises around 2 km of straightened farm drain and modified swales that would represent low quality habitat for eel species. The presence of a remnant mudfish population in the upper catchment also means enhanced eel passage is less desirable. For these reasons the barrier was a low priority for remedial work.

Fish passage issues and priorities were more recently assessed by HCC in 2019 as part of the Stormwater Master Plan Version 2 project. There was no change to the priority for barrier remediation in the TAOK catchment. We note this is in contrast to the fish passage recommendations in the ICMP Ecology Report.

3 Ongoing monitoring

HCC holds Waikato Regional Council resource consents for stormwater discharges, water take, and wastewater discharges. HCC's CSDC) covers existing urban development. HCC was required to prepare a monitoring plan to assess the adverse effects of municipal stormwater diversion and discharge activities on the environment in accordance with the requirements of Condition 37 of the CSDC. The original monitoring plan was approved by Waikato Regional Council in 2013 (T+T 2012). The original monitoring plan has been updated and incorporated into a comprehensive citywide Stormwater and Receiving Environment Monitoring Plan (SREMP, T+T, 2019). The SREMP has the following purposes:

- To assist HCC to monitor and enable all relevant agencies to understand the effects of stormwater discharges and compliance with the CSDC;
- To assist HCC in determining if a response is required;
- To assist HCC in prioritising stormwater quality improvements; and
- To assist HCC in determining if catchment management initiatives are needed or successful.

The SREMP is an adaptive monitoring programme that includes regular review to capture any new monitoring requirements as they arise and monitoring site priorities and frequencies that change in response to observed data and catchment development. The general thrust for the updated plan is a strong focus on receiving environment monitoring (as opposed to device monitoring), with the development of catchment/stream specific targets. Exceedances of established targets would initiate a response, which could comprise further investigation or action.

The ICMP Ecology Report made a series of recommendations for ongoing monitoring, with reference to the city-wide CSDC monitoring plan for some aspects. The following sections outline the recommended monitoring programme for the TAOK catchment on the basis of HCC's SREMP while incorporating the ICMP Ecology Report recommendations as appropriate.

3.1 Catchment monitoring

The SREMP includes a network of monitoring sites throughout the TAOK stream network. The effects of existing and proposed stormwater discharges and stormwater improvement and management initiatives on freshwater receiving environments in the TAOK Catchment will be monitored primarily through the SREMP. Monitoring of the effects of development will also occur under any specific subdivision discharge consent monitoring requirements prior to those consents being transferred to HCC and captured under the CSDC and SREMP.

Monitoring site locations for the TAOK catchment are shown in Figure 2.2. TAOK monitoring site locations were established prior to the bulk of the development occurring upstream of Resolution Drive. Consideration should be given to adding a 6th stream ecological monitoring site is added to the ongoing monitoring programme in the upper catchment (Site T6).

3.1.1 Water quality monitoring

The SREMP (CSDC driven monitoring programme) includes visual inspection-based water quality monitoring in the TAOK. The water components of the SREMP that are relevant to the TAOK catchment are described in detail in the SREMP and summarised below. Site locations are shown on Figure 2.2. In all cases the monitoring is adaptive (site locations and frequency can be amended as needed) and there are triggered actions and responses. The SREMP should be referred to for detail.

- Visual monitoring: This programme involves visual monitoring of selected stream points and stormwater outlets within specific catchments to visually assess the health of the water courses and identify any visual signs of contaminants in stormwater (conspicuous oil or grease films, scums or foams, floatable suspended materials, conspicuous change in colour or visual clarity). Established sites at this stage comprise the main TAOK Stream at River Road (Site T1). A specific scoring system has been developed that results in increased monitoring frequency and or response as appropriate which may include follow up investigation, audits under the Stormwater Bylaw or immediate actions to address the identified issue.

- Stormwater runoff quality: Stormwater runoff quality and flow monitoring using flow proportional composite sampling methods will be undertaken as an investigative tool. This may be undertaken in response to receiving environment data, to determine the contaminant load from a specific outlet or to validate predictive modelling outputs and/or the performance of stormwater treatment infrastructure.
- Water quality monitoring: The ICMP Ecology Report recommends that water quality monitoring is undertaken at each of the survey sites included in that study according with HCC's CSDC methodology. We suggest this is undertaken in conjunction with the SREMP monitoring programme at Sites T1 and T4. The sampling includes testing for dissolved & total metals, (Cu, Zn) and nutrient parameters. The primary objective of this monitoring is to understand the contribution of the urban area on water quality and the duration and frequency of this monitoring will be reviewed annually.

3.1.2 Ecological monitoring

The SREMP (and previous CSDSC monitoring plan) has an established network of monitoring sites throughout Hamilton City, including 5 sites in the TAOK catchment. Ecological monitoring includes habitat quality using WRC's Regional Ecological Monitoring of Streams (REMS) protocol, macroinvertebrate and sediment quality sampling. Sites are visited and sampled annually, two yearly or four yearly depending on catchment development progress and data results and trends. Site locations are shown on Figure 2.2. with the key components of the monitoring summarised below.

- REMS: Standard WRC REMS habitat assessment protocol covering riparian and in-stream conditions that provides a semi-quantitative score.
- Macroinvertebrates: A single macro-invertebrate sample will be collected from each site (100 m reach) in accordance with the WRC Guidelines for Ecological Assessment of Freshwater Environments. Macroinvertebrate samples are processed following a 200 fixed count methodology in accordance with the guidelines.
- Sediment quality: A composite sediment quality sample is collected from surface sediments at each habitat quality monitoring site. Samples are tested for total organic carbon, polynuclear aromatic hydrocarbons (PAHs) (every fourth sampling occasion) and total recoverable (TR) and Extractable (E) copper and zinc (every sampling occasion).

The ICMP Ecology Report identifies metal contamination of watercress as a potential human health risk and report recommends that additional sediment quality (arsenic and zinc) monitoring is undertaken. We suggest that arsenic could be added to the sediment suite and that all six of the established (and proposed) TAOK ongoing monitoring sites are sampled for sediment quality as part the next monitoring round (scheduled for summer 2021). Subsequent response with respect to the watercress issue can be developed through the SREMP process.

3.1.3 Stream channel and erosion monitoring

HCC has developed an erosion susceptibility assessment for Hamilton City streams known as the Rapid Geomorphic Erosion Assessment (RGEA) Methodology. The RGEA method was developed at WRC's suggestion and aims to provide rapid baseline information on the bank and bed stability of a watercourse and susceptibility to erosion. The purpose is to aid decision making with regard to prioritising stream reaches requiring stabilisation interventions and therefore a concept programme of works to for LTP funding decisions, determine developer contributions and provide guidance for Project Watershed.

An erosion walkover of the TAOK stream has been undertaken using the Receiving Environment Module methodology in 2016 (Morphum & T+T). The SREMP has considered this assessment and captures ongoing monitoring requirements for the TAOK Stream network and should be consulted for detail. The monitoring will be undertaken at and along targeted stream sites and reaches and the focus will be on "Erosion hot spots" and stream reaches identified as having poor stability (high erosion susceptibility).

Hot spot monitoring will follow the methodology outlined in the ICMP receiving environment module along with recording the mechanism for erosion at the site.

For stream stability. On the first occasion that "poor" stability reaches are monitored the full RGEA methodology will be followed to ensure data for ongoing monitoring are consistent. Representative photographic monitoring points (photo points) within the reach will also be established and GPS coordinates collected. Subsequent monitoring visits will comprise the collection of photographs at established photo points and collection of the Bank Height and Bank Angle components of the RGEA.

3.2 Magellan Lake

HCC hold WRC resource consents 115069, 113670, 113673 and 113674 authorising the placement and operation of Magellan Lake. An operations and maintenance plan (O&M Plan) was prepared for Magellan Lake in accordance with the consents and approved by WRC in February 2014[13]. The approved O&M Plan includes monitoring requirements for ongoing monitoring. The ongoing monitoring will be undertaken as part of HCC's SREMP and include.

- Algal blooms (cyanobacteria) – primarily visual inspections during summer months with additional sampling undertaken if blooms are observed.
- Avian botulism – Routine inspections for avian botulism will be undertaken at the same frequency as algal bloom monitoring above. Dead ducks will be removed and disposed of as required.
- Macrophyte communities – Qualitative assessments of the lake macrophyte community will also be undertaken during the monthly or two monthly inspections. In general this monitoring will include observations on the diversity and abundance of macrophyte species from the lake edge and in particular the presence of any exotic species.
- Habitat structures and riparian planting downstream of the lake outlet. To be inspected annually and any issues reported.

3.3 Reporting

Monitoring reporting for the TAOK catchment will be undertaken as part of the Municipal Stormwater Network Operation Annual Report which is to be submitted to WRC by 1 July. The report will contain recommendations on any changes that may be needed to the monitoring plan for the following year in line with the adaptive approach set out in this SREMP. All raw data and monitoring assessments/reporting relevant to CSDC requirements or collected in conjunction with a WRC monitoring programme will be made available to WRC on request.

[13] T+T, 2014. Magellan Lake Operations and Maintenance Plan. Consultancy report prepared for CDL Land (NZ) Ltd.

4 Applicability

This report has been prepared for the exclusive use of our client Hamilton City Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that this report will be used by Waikato Regional Council in undertaking its regulatory functions in connection with Te Awa O Katapaki ICMP.

Tonkin & Taylor Ltd

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Report prepared by:

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Tonkin+Taylor

Job No: 1018379
14 December 2021

Hamilton City Council
Private Bag 3010
Hamilton 3240

Attention: Andrea Phillips

Dear Andrea

Hamilton City Council - Wetland and Watercourse Identification - Te Awa O Katapaki Integrated Catchment Management Plan

This report presents the results of watercourse and wetland classification mapping work in the Te Awa O Katapaki (TAOK) Catchment in north-east Hamilton. The work[1] has been undertaken to inform the TAOK Integrated Catchment Management Plan (ICMP) being prepared by Hamilton City Council (HCC).

1 Introduction

Watercourse classification has previously been undertaken in the TAOK catchment on behalf of HCC (Boffa Miskell Ltd, 2018[2]). That work classified and mapped watercourses within and around the main TAOK gully but included only indicative information for the northern portion of the catchment. The previous watercourse classification work was also undertaken prior to the National Policy Statement for Freshwater Management 2020 (NPS-FM) and Resource Management (National Environmental Standards for Freshwater) Regulations 2020 (NES-F) coming into force.

The objective of this work is to classify and map watercourses under the Waikato Regional Plan (WRP) definitions in the remaining part of the catchment, and to identify any wetlands areas that potentially meet the NPS-FM definition of a natural wetland. The purpose of including the watercourse and wetland map in the ICMP is to clearly signal where land development activities may need to consider the rules in the WRP and NES-F.

The wetland assessment work has focussed on the upper TAOK catchment outside the main TAOK gully, predominantly in North Rototuna. Ground truthing work has also covered the previously mapped 'wetland' areas associated with the main TAOK gully. We have provided preliminary wetland extents for the purpose of the ICMP. We note that the application of the Wetland Delineation Protocols as per NES-F was outside the scope of this work.

As part of this work, we have also visited watercourses present on HCC's GIS database but thought to be no longer present and updated the map layers accordingly. We have also assessed the maintenance status of known restoration planting areas around Magellan Lake.

[1] [1] This work has been undertaken in accordance with IFS Number PSP00001001/2021

[2] Boffa Miskell Ltd, 2018. Te Awa O Katapaki Stream - Assessment of Ecological Values to inform an Integrated Catchment Management Plan.

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2 Methods

2.1 Definitions

Definitions for watercourses and wetlands used in this assessment are provided in Appendix A Table 1 and Appendix A Table 2 respectively. We have used WRP definitions for watercourses and RMA and NPS-FM definitions for wetlands.

2.2 Watercourse and wetland assessment methods

The approach to the assessment has comprised an initial desktop mapping exercise followed by ground truthing. The desktop exercise involved a systematic assessment of aerial photographs and available GIS layers to produce preliminary maps for ground truthing. Detailed desktop assessment methods are provided in Appendix B.

Ground truthing was undertaken by way of a walkover field assessment on 19 and 20 November 2021. Field assessment methods are provided in the following sections.

2.3 Ground-truthing

Site visits were carried out by two appropriately experienced Tonkin & Taylor Ltd (T+T) ecologists. The site visits were carried out on 18 and 19 November 2021. There was 47.2 mm of rainfall during the 10 days leading up to the site visits, with much of that falling on 14 November (39.6 mm)[3].

2.3.1 Data capture

All data were collected in the field using the Collector App using the preliminary map generated through the desktop exercise as a baseline.

2.3.2 Watercourses

All mapped watercourses were walked to ground-truth the classification and extent. Some watercourses were deemed “swales” during the site assessment as they were shallower than the typical ‘farm drain’, and likely above the water table outside of rain events. But both swales and farm drains are artificial watercourses under the definition in the WRP (Appendix A Table 1). Any additional watercourse identified on site that had not been previously mapped was added. Any watercourses found to be no longer present, were removed as discussed in 2.3.4 below.

2.3.3 Wetlands

All locations of possible natural and constructed wetlands identified in Stage 1 were visited where possible. The exceptions to this include:

- The TAOK Stream gully area (including River Road North Gully SNA). This is on the basis that this area is mostly within reserve land and has been previously mapped.
- The north-east of the Waikato Expressway and south of Horsham Downs Road due to access restrictions.
- A small area along the true right bank of the Waikato River south of the mouth of the TAOK Stream due to access restrictions.

We note that the application of the Wetland Delineation Protocols (WDP)[4] was outside the scope of the project and was not carried out.

[3] https://cliflo.niwa.co.nz/

[4] Ministry for the Environment. 2020. Wetland Delineation Protocols. Landcare Research, Hamilton. Report prepared by Landcare Research for Ministry of the Environment.

Instead, the Wetland Classification system[5] was used to determine if an area was a 'wetland'. This classification system follows a nested hierarchy to classify the wetland (or each component of a wetland complex). To allow this classification to be undertaken, evidence of the following classification parameters were recorded in the field where possible:

1. Hydro system – based on general landform and broad hydrological setting.
2. Hydrology – site specific descriptor of the water regime, such as source, movement, drainage, fluctuation etc.
3. Wetland class – based on substrate type, water regime and consequent factors (such as nutrient status and pH).
4. Wetland form – based on the landforms the wetland areas occupy, and often related to fluvial or coastal geomorphic processes.

Structural class – based on the general growth form and structure of the vegetation occupying the wetland area. Notes were taken on the dominant species (plant species having 20 % or more cover, as set out on Johnson and Gerbeaux (2004)[5]) and their dependence on wetland environments (set out in Clarkson, 2014[6] and subsequent updates). A description of this dependency is provided below:

- Obligate (OBL): plant species that occur almost always in wetlands (estimated probability greater than 99 % in wetlands).
- Facultative Wetland (FACW): plant species that occur usually in wetlands (67 % to 99 %).
- Facultative (FAC): plant species equally likely to occur in wetlands or non-wetlands (34 % to 66 %).
- Facultative Upland (FACU): plant species that occur occasionally in wetlands (1 % to 33 %).
- Upland (UPL): plant species that rarely occur in wetlands (less than 1 %).

The wetland classification is then expressed as a descriptor of the area, combining all the elements above. In addition to this, general observations were taken of vegetation cover, hydric soils[7] (no soil samples were obtained as part of ground truthing) and wetland hydrology[8].

Any areas that met the above characteristics were delineated by walking around the margins of the features (where possible) and identified as possible natural wetlands.

A number of areas were confirmed as wetlands/ponds that were constructed by artificial means and these polygons were removed from the maps.

2.3.4 Other

Several previously mapped waterbodies either by Boffa Miskell in 2018 or on HCC's GIS database are now thought not to be present. These include some possible inlets/wetlands along the Waikato River bank as well as waterbodies within the lower and middle TAOK catchment. These areas were also ground-truthed and subsequently removed and/or added in the mapping exercise in accordance with what was observed.

Areas of previous riparian planting carried out by the developer, immediately downstream of Magellan Lake and of Cumberland Drive, respectively, were checked to broadly describe current maintenance status.

[5] Johnson, P., and Gerbeaux, P. 2004.Wetland types in New Zealand. Department of Conservation.
[6] Clarkson, B. 2014. A vegetation tool for wetland delineation in New Zealand. Landcare Research.
[7] Fraser S, Singelton P and Clarkson B, 2018. Hydric soils – field identification guide. Manaaki Whenua - Landcare Research. Prepared for Tasman District Council.
[8] Ministry for the Environment, July 2021. Wetland delineation hydrology tool for Aotearoa New Zealand.

3 Results and conclusions

This section provides the results of the ground-truthing work to classify watercourses and possible wetlands. These results have been mapped and are provided in Appendix C.

3.1 Watercourse classification

Watercourses were walked to ground-truth the extent and classification of each and mapped during the walkover. There were numerous artificial watercourses in the North Rototuna area, some being reasonably deep channels that would support standing and flowing water most of the year, and other shallow watercourses that would have water intermittently. These were distinguished by using the terms 'farm drains' for the deeper watercourses and 'swales' for the shallower ones. For clarity, both are artificial watercourses under the definition in the WRP (Table 1.2). All watercourse mapping is provided in Figure A.1, Appendix A.

3.2 Wetland identification and classification

Most of the North Rototuna area inspected was observed to have dark soils with visible organic matter, this included the soils observed at all the possible natural wetlands visited. Manaaki Whenua / Landcare Research describe the majority of the TAOK ICMP catchment, especially the North Rototuna area as imperfectly to poorly drained[9] and classified as having orthic gley and orthic podzol soils[10]. Orthic gley soils are chemically reduced soils that are strongly affected by waterlogging (chemical reduction is caused by high water tables that limit oxygen). Orthic podzols occur in areas of high rainfall and are usually associated with forest trees with an acid litter (possibly in this case, historic kahikatea stands) and are associated with slow permeability. These soils are typical of where wetlands have been located historically.

Land use within the areas that were visited was mainly farmland with pasture grassland and/or currently being planted for maize cropping. Some areas were also being developed with earthworks in progress at the time of the site visit.

There were eight areas (W1-8) that have been classified as natural wetlands in North Rototuna area. Classification, description and approximate area are provided in Table 3.1 for W1-7. All locations and the extent of each possible and confirmed natural wetlands are provided in Figure 3.1 below and also shown in the wider TAOK ICMP catchment provided in Figure A.1, Appendix C.

[9] https://smap.landcareresearch.co.nz/maps-and-tools/app/.
[10] https://soils-maps.landcareresearch.co.nz/.

Figure 3.1: Natural wetlands (possible and confirmed) located during Stage 2 ground-truthing of North Rototuna.

Natural wetlands in the upper catchment area, bounded by Horsham Downs Road were mapped using a document provided by Wainui Environmental in relation to resource consent applications for a property in this area[11]. From previous involvement in the Waikato Expressway construction works and previous visits to the constructed stormwater treatment wetlands in the area and knowledge of landforms, we are confident that this is the only natural wetland in this area. This is the only natural wetland that we have classified as confirmed as it has been assessed using the WDP as well as following consultation with Waikato Regional Council (WRC). It has an area of approximately 4532 m^2.

All the other areas have been categorised as possible natural wetlands due to not being delineated using the WDP.

Any development that may impact on possible natural wetlands W1 to W7 will require a further WDP assessment to confirm status under the NPS-FM, and potentially an ecological assessment to inform an assessment of effects under the NES-F.

[11] Wainui Environmental Limited. Lower basin concept layout (for discussion with HCC) 16/11/21. Drawing provided for Pragma Homes Limited application for resource consent at 247-269 Horsham Downs Road to Hamilton City Council.

Table 3.1: Descriptions (natural wetland classification[5], observations on wetland hydrology and hydric soils and area) of possible natural wetlands (W1-7) located in the upper Te Awa O Katapaki ICMP catchment.

Wetland ID	Description	Photo and Confidence Level
W1	Starwort (*Callitriche stagnalis*) (OBL) herb bog, situated on a plain; palustrine. Obvious surface water and soil saturation[12]. Probable hydric soils. 47 m^2	
W2	Mercer grass (*Paspalum distichum*) (FACW) grassland swamp, situated on a plain; palustrine. Obvious surface water and soil saturation[12]. Probable hydric soils. 2727 m^2	
W3	Juncus sp. (*Juncus prismatocarpus* or *fockei*) (FACW or OBL) reedland swamp; palustrine. This wetland is situated within a linear landform (swale) adjacent to the Waikato Expressway batter. Obvious surface water and soil saturation[12]. Probable hydric soils. 767 m^2	

[12] Primary indicators of wetland hydrology – MfE, July 2021. Wetland delineation hydrology tool for Aotearoa New Zealand.

W4	Water pepper (*Persicaria hydropiper*) (FACW) – mercer grass herb swamp; palustrine. Again, this wetland is situated within a linear landform (swale) adjacent to the Waikato Expressway batter. Obvious surface water and soil saturation[12]. Probable hydric soils. 447 m^2	
W5	Starwort – Water purslane (*Lythrum portula*) (OBL) herb bog, situated on a plain; palustrine. Obvious surface water and soil saturation[12]. Probable hydric soils. 1553 m^2	
W6	Mercer grass – Juncus sp. (OBL or FACW) – creeping buttercup (*Ranunculus repens*) (FAC) grassland swamp, situated on a plain; palustrine. Obvious surface water and soil saturation[12]. Probable hydric soils. 6082 m^2	

W7	Mercer grass grassland swamp, situated on a plain; palustrine. Obvious surface water and soil saturation[12]. Probable hydric soils. 2244 m^2	

3.3 Other

Ground-truthed watercourses in other areas of the wider catchment have been added or removed in the map provided in Appendix C as appropriate.

3.3.1 Magellan Lake downstream plantings

Riparian planting was undertaken by CDL along the reach of the TAOK Stream from the end of the stilling basin to the existing well shaded part of the stream (approximately 50 m) in April 2011. The stream reach immediately downstream of Magellan Lake was observed to be overgrown by exotic weed species. The immediate area downstream of the outlet of Magellan Lake (stilling basin) was overgrown with grey willow (*Salix cinerea*) (Photograph 3.1).

Photograph 3.1: Vegetation observed around the stilling basin downstream of Magellan Lake showing grey willow growing around the stilling basin.

In the area downstream of the stilling basin, there were sparse taller native species observed such as cabbage tree (*Cordyline australis*), *Comprosma robusta* and ponga/tree ferns. However, the area was mostly inundated with weeds and exotics of varying strata (herbs to tree species) (Photograph 3.2). There was also no evidence of any maintenance of the area. Because of the density of the large weeds and steep terrain, we did not access the understorey to assess the success of any understorey plantings.

Photograph 3.2: Vegetation observed south of the stilling basin downstream of Magellan Lake showing numerous exotic weed species.

3.3.2 Cumberland Drive downstream plantings

Planting work in this area was completed in August 2013. The riparian plantings of the watercourse immediately south of Cumberland Drive have been more successful than those downstream of Magellan Lake. Most of the native species have been able to prevent the invasion of larger exotic weeds (Photograph 3.3 and Photograph 3.4 below).

Photograph 3.3: Riparian planting along the watercourse immediately south of Cumberland Drive have been relatively successful (view from Cumberland Drive).

Photograph 3.4: Good growth of planted natives and few weed species.

However, at the southern end of the plantings, exotic grasses and species such as creeping buttercup are smothering plantings (Photograph 3.5). There is no evidence of any recent maintenance besides mowing of the grass immediately adjacent to the plantings.

Photograph 3.5: Southern end of riparian planting south of Cumberland Drive showing pasture grass species smothering plantings.

4 Applicability

This report has been prepared for the exclusive use of our client Hamilton City Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that this report will be used by Waikato Regional Council in undertaking its regulatory functions in connection with Te Awa O Katapaki Integrated Catchment Management Plan.

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

Report prepared by:	Authorised for Tonkin & Taylor Ltd by:
....	....
Tammy Valler Freshwater Ecologist	Bryn Quilter Project Director

Technical review by Dean Miller, Principal Environmental Scientist

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watercourse_and_wetland_classification.docx

Appendix A: Watercourse and wetland definitions

Appendix A Table 1: Definitions used to classify watercourses (WRP)

Definition	Description
River (RMA and WRP)	A continually or intermittently flowing body of fresh water and includes a stream and modified watercourse; but does not include any artificial watercourse (including an irrigation canal, water supply race, canal for the supply of water for electricity power generation, and farm drainage canal).
Modified watercourse	An artificial or modified channel that may or may not be on the original watercourse alignment and which has a natural channel at its headwaters.
Artificial watercourse	A watercourse that contains no natural portions from its confluence with a river or stream to its headwaters and includes irrigation canals, water supply races, canals for the supply of water for electricity power generation and farm drainage canals.

Appendix A Table 2: Wetland definitions (RMA and NPS-FM)

Definition	Description
Wetland (RMA) – "the Act"	includes permanently or intermittently wet areas, shallow water, and land margins that support a natural ecosystem of plants and animals that are adapted to wet conditions.
Natural wetland (NPS-FM)	a wetland (as defined in the Act) that is not: 1. a wetland constructed by artificial means (unless it was constructed to offset impacts on, or restore, an existing or former natural wetland); or 2. a geothermal wetland; or 3. any area of improved pasture that, at the commencement date, is dominated by (that is more than 50% of) exotic pasture species and is subject to temporary rain-derived water pooling.
Natural inland wetland (NPS-FM)	a natural wetland that is not in the coastal marine area.

Appendix B: Desktop methods

1. Watercourses

Watercourses within the study catchments were identified using ArcGIS Collector as well as using the WRP definitions (see Appendix A).

Watercourses were mapped using ESRI World Imagery (Updated: 13 May 2020), LiDAR contour lines and HCC 3 Waters map viewer[16] with the stormwater channel layer turned on. Watercourses were prescribed preliminary classifications from the WRP definitions.

2. Possible natural wetlands

Possible natural wetlands were identified and mapped considering RMA and NPS-FM definitions as provided in Appendix A. Identification was carried out using ESRI World Imagery (Updated: 13 May 2020) and several information layers (below) in a systematic approach including:

- Hamilton Significant Natural Areas (SNAs)[13].
- LiDAR contour lines.
- Locations of Hamilton rivers and lakes[14].
- Historical wetland extent[15].
- HCC stormwater management device layer[16] (updated 14 April 2021).

The systematic approach carried out included a visual search of the aerial, followed by adding the contour lines to observe depressions in the landscape. The remaining layers were then added to confirm the likelihood of wetland presence. A polygon was drawn around the extent of the possible wetland.

Potential natural wetlands were identified as the following:

- Gully systems containing a flow path.
- Depressions in the landscape.
- Gentle hillslopes that may contain seepages.
- Surface water present in a 'likely' non-constructed wetland.
- Possible wetland vegetation.
- An SNA that contains wetland (i.e., met Criteria 6 (Indigenous wetland habitat - contains or is likely to contain wetland habitat) and/or Criteria 8 (critical aquatic habitat))[17].

Confidence levels were assigned to the possible wetlands. These confidence levels indicate the likelihood of natural wetland presence and extent (see Appendix B Table 1). A conservative approach was taken to incorporate uncertain areas for ground-truthing.

Wetlands or ponds that appeared to be constructed by artificial means (and therefore falling under exemption '1' under the definition of a natural wetland – see Appendix A Table 2) were mapped using the same methods. Confidence levels for constructed wetlands were assigned as per Appendix B Table 1 below.

---

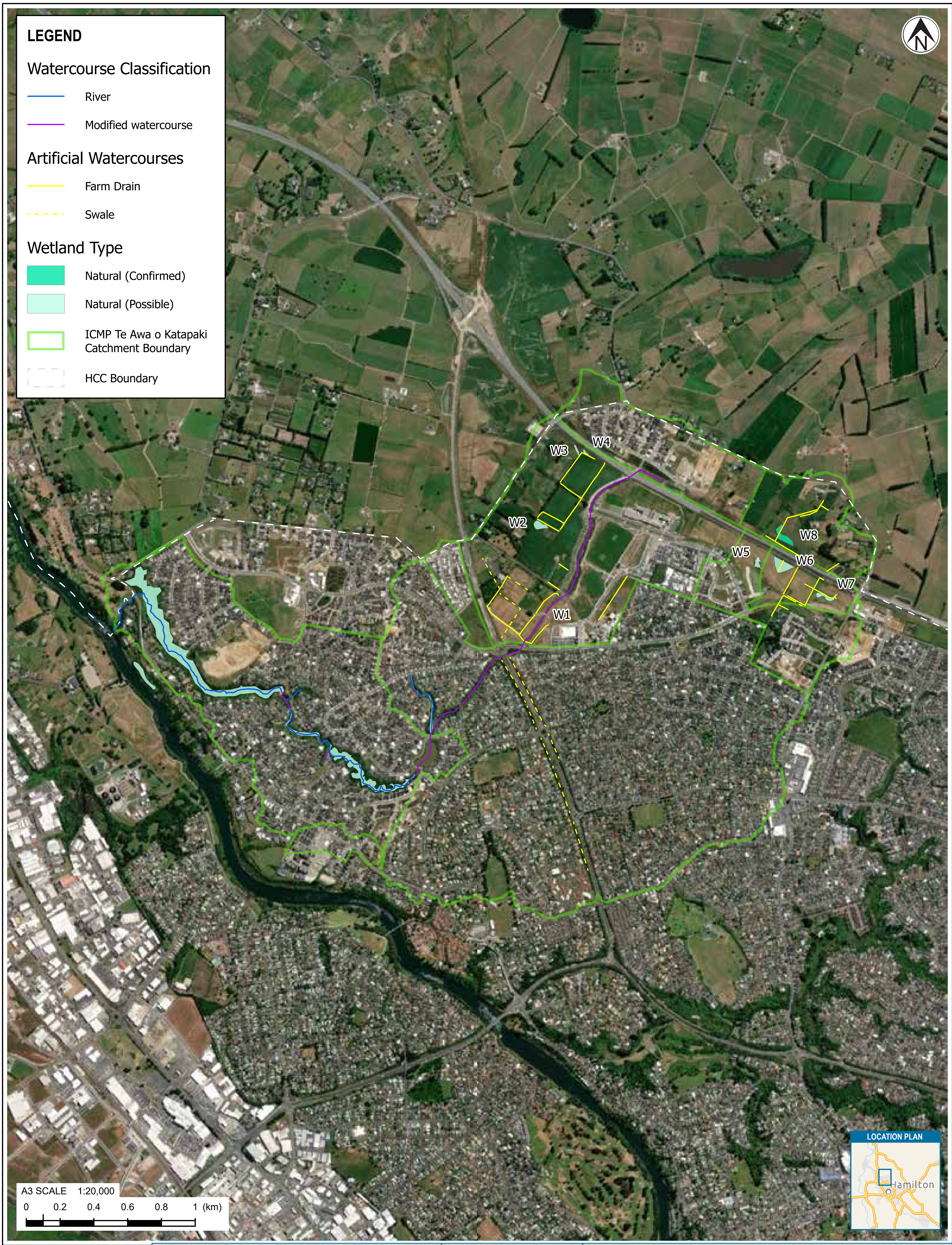
[13] Cornes, T. S., Thomson, R.E., and Clarkson, B.D. 2012. Key Ecological Sites of Hamilton City Volume I. Prepared for Hamilton City Council. CBER Contract Report No. 121. 58p.
[14] https://waikatomaps.waikatoregion.govt.nz/Viewer/
[15] Hamilton Ecological District Wetland Extent. Last updated 18/07/21.
[16] https://hcc.maps.arcgis.com/
[17] Cornes, T. S., Thomson, R.E., and Clarkson, B.D. 2012. Key Ecological Sites of Hamilton City Volume I. Prepared for Hamilton City Council. CBER Contract Report No. 121. 58p.

Stormwater management devices (for example treatment wetlands) on the HCC stormwater management layer[16] were excluded from this exercise. For clarity, any on-line devices (constructed within a watercourse) have not been highlighted as such in this mapping exercise, and only given the classification of the watercourse they are situated within.

Appendix B Table 1: Confidence levels assigned to natural wetlands and constructed wetlands

Confidence level	Description
High	Previously assessed / ground-truthed using wetland delineation protocols or can be obviously delineated from aerial imagery (e.g., a peat lake margin that abruptly transitions to improved pasture).
Medium	Previously assessed / ground-truthed (e.g., wetlands identified in SNA report), but extent not formally delineated using delineation protocols. Or wetlands not previously assessed but very obvious on aerial imagery. Boundaries will need to be defined via delineation on the ground.
Low	Wetlands identified largely based ancillary data such as LiDAR and historic imagery. Cannot be accurately assessed via desktop methods due to canopy cover in current aerials, i.e., all of the potential gully bottom wetlands (except ones previously identified via walk overs).
Unknown	Wetlands where it was not obvious if they were either constructed or natural.

Appendix C: TAOK watercourse and wetland map



\\ttgroup.local\corporate\Hamilton\Projects\1018379\WorkingMaterial\GIS\MapDocuments\TeRapa_WetlandWatercourse_ClassificationAssessment.aprx Layout: Figure A1 - Stage2 Te Awa o Katapaki 2021-Dec-08 2:45 pm Drawn by ANTH

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NOTES:
Basemap NZ Navigation Map: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors.. World Imagery: Maxar

REV	DESCRIPTION	GIS	CHK	DATE
0	First version	ANTH		26/11/21

PROJECT No.	1018379	
DESIGNED	ANTH	DEC.21
DRAWN	ANTH	DEC.21
CHECKED	JORB	DEC.21
APPROVED	BMQ	14/12/21

CLIENT HAMILTON CITY COUNCIL

PROJECT WATERCOURSE AND WETLAND IDENTIFICATION TE AWA O KATAPAKI ICMP CATCHMENT

TITLE NATURAL WETLANDS AND WATERCOURSE CLASSIFICATION FOR THE TE AWA O KATAPAKI ICMP CATCHMENT

SCALE (A3) 1:20,000 FIG No. FIGURE C1. REV 1

Appendix K TAOK Model Build Report

AECOM

Te Awa O Katapaki Catchment
Management Plan

Hamilton City Council

21-Aug-20155

Stormwater Model Build Report

Te Awa O Katapaki Catchment Management Plan

Stormwater Model Build Report

Te Awa O Katapaki Catchment Management Plan

Client: Hamilton City Council

Co No.: N/A

Prepared by

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21-Aug-2015

Job No.: 60288558

AECOM in Australia and New Zealand is certified to the latest version of ISO9001, ISO14001, AS/NZS4801 and OHSAS18001.

Quality Information

Document	Stormwater Model Build Report
Ref	60288558
Date	21-Aug-2015
Prepared by	Leighton Fletcher, Tracey Myers, Mike Summerhays, Chris Hardy
Reviewed by	Mike Summerhays, Natasha Ryan

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
C	21-Aug-2015	Final Draft (following updated modelling of Johnnybro & Raupo areas)	Natasha Ryan Project Manager	

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Executive Summary

Introduction

AECOM has been engaged by Hamilton City Council to undertake stormwater modelling for the Te Awa O Katapaki catchment. The purpose of the modelling is to identify flood hazards within the catchment for the 100 year storm event and to inform catchment management planning.

The Te Awa O Katapaki catchment is a mix of residential development and pasture. The pasture areas are predominantly in the north of the catchment and are zoned residential with some commercial development. The catchment area is about 700 hectares.

Model Build

The stormwater model was developed as a coupled model which includes pipe networks, streams, channels, and a ground surface model. A model was developed for both the existing scenario, and future scenario. The latter is based on maximum possible development.

The existing model includes all of the council known assets, along with developers work and consented proposals that occurred up to 2013 as well as additional unmanned aerial vehicle survey for a portion of the catchment undertaken in 2015. The model build was carried out using DHI software to represent the various hydraulic components of the model. The model was run for the 2 year, 10 year, and 100 year storm events. Flood hazard results were generated from the 100 year storm event (with climate change) for inclusion in the Proposed District Plan.

The future model included updating the existing scenario model to reflect consented future development, in terms of both the rainfall runoff (hydrology) and hydraulics (pipes and land topography). The Rototuna Structure Plan was used to determine the future development and impervious areas. The model was run for the 2 year, 10 year, and 100 year storm events and included climate change impacts of 16.8% over the existing rainfall.

Results

The flood hazard maps were generated and smoothed to produce results suitable for inclusion in the Proposed District Plan. The flooding extent within the catchment is generally limited to the stream and gully network, with some surface ponding and overland flow evident along road corridors and localised low-points. In the upper catchment, flood hazards generally follow drainage paths but more surface ponding is evident around undeveloped channels and farmland due to the flat topography.

An assessment of flow velocities downstream of the Magellan Lake stilling basin was undertaken. The basin reduces flow velocities through this portion of the catchment for the 2 year and 10 year storm events. A further reduction in velocities downstream of the basin would benefit the catchment and reduce the potential for erosion.

As part of catchment management planning, the viability of additional in stream control structures or off line attenuation will need to be determined. Either of these will have a positive effect on flow rates and velocities in the stream and is expected to be part of the final catchment management approach. A decision of how to apply one or both of these approaches should come out of the catchment planning process.

1.0 Introduction and Background

Hamilton City Council identified the Te Awa O Katapaki catchment as a priority catchment for integrated catchment planning. Stormwater modelling to predict flood hazard areas is a part of this. The catchment area is about 700 hectares and is a mix of residential land and pasture, which is zoned residential with some commercial.

Residential development has occurred in the south and is currently underway in the west and north of the catchment. The remaining farmland in the north-east is planned for future urban growth.

The catchment drains to the Waikato River via a series of open drains in the north-east, and the Te Awa O Katapaki Stream elsewhere. The catchment is shown below in Figure 1 and Te Awa O Katapaki Stream is shown in light blue flowing from the centre of the catchment to the Waikato River in the west.

Figure 1 Te Awa O Katapaki Catchment.

Note: Topographical Catchment boundary shown in light orange, Te Awa O Katapaki Stream shown in light blue

AECOM was engaged to model the catchment and produce stormwater Flood Hazard Maps (FHM) to supplement the Integrated Catchment Management Plan (ICMP). This includes modelling the existing and future scenarios in order to compare the magnitude of change for the 2, 10 and 100 year return period rainfall events.

2.0 Scope

The modelling undertaken for the Te Awa O Katapaki catchment included the following:

- Existing development (existing) scenario model build
- Future developed scenario model build based on the maximum possible development
- The optimisation of two proposed weirs upstream of Magellan Lake, if required, following analysis of the model results
- Stormwater flood hazard mapping for the District Plan (existing 100 year storm event with climate change).

3.0 Methodology

The modelling methodology used for the project was as follows:

1) **Model schematisation**. This involved identifying the extent of the stormwater network to be modelled, the major open channel systems to model, and the data sources to be used for the model.
2) **Existing development model build**. The existing model included all of council's known assets plus developers work and designs consented up to 2013. The model also includes 2015 drone survey data undertaken in 2015. This model build was carried out using DHI software to represent the various hydraulic components of the model.
3) **Existing model QA & QC**. The model was checked and reviewed internally and recommended changes were adopted where necessary.
4) **Run the existing model for 2 year and 10 year events without climate change, and the 100 year event with and without climate change**. The 100 year event with climate change adjusted rainfall was required to generate the District Plan flood hazard maps.
5) **Future development model build**. This included updating the existing scenario model to reflect future development in terms of rainfall runoff (hydrology) and consented hydraulics (pipes and land topography). The Rototuna Structure Plan was used as to determine the future development and impervious areas.
6) **Run the future model for 2 year, 10 year and 100 year rainfall events with climate change incorporated**. The future (MPD) rainfall included climate change impacts of 16.8% increase over the existing rainfall.
7) **Flood Hazard Mapping**. The model outputs were processed in accordance with the Council flood hazard matrix. The results were then smoothed to produce maps suitable for inclusion in the Proposed District Plan. The 100 year storm event with climate change was used for flood hazard mapping.
8) **Weir optimisation.** The optimisation of two proposed weirs was to be undertaken once the initial model results had been reviewed. There was little scope to construct additional weirs to attenuate flow and velocity upstream of Magellan Lake without causing additional flooding so the weirs were not assessed. This is discussed further in Section 5.3.

4.0 Model Development

4.1 Software Used

DHI (version 2011) software was used to build both the hydrology and hydraulic components of the model. The DHI packages used are as follows:

- Mike 21 – to represent flood plains and overland flow paths
- Mike 11 – to represent the Te Awa O Katapaki stream channel and Magellan Lake
- Mike Urban – to represent the council pipe networks within the catchment.

4.2 Assumptions and Limitations

The following assumptions and limitations apply to the flood hazard modelling process and outputs.

4.2.1 Hydrology

a) Rainfall has been taken from the HCC Infrastructure Technical Specifications (ITS) depth / duration / frequency tables with climate change effects. AECOM created nested storms from these tables.
b) The climate change effects assumed in the ITS are detailed in a report prepared by NIWA (NIWA Client Report WLG2008-010). The NIWA report provides for a medium range average temperature increase of 2.08 degrees Celsius by 2090.
c) Design hyetographs were developed so that peak flow and volume can be modelled at any point within the catchment, in a single model. A nested storm contains peaks for all durations and therefore, in theory,

generates storm flows when applied uniformly across a range of sub-catchments with varying times of concentration.

d) A sensitivity analysis completed by AECOM indicated that the 12 hour duration storm was critical for this catchment (i.e. the peak flow and water level was achieved in all locations). The 24 hour duration storm has been used for the flood hazard mapping in order to capture the peak at all locations within the time period.

e) To provide an appropriate boundary condition, the Waikato River water level has been set at RL15.46m for all events, based on the 1998 flood. This approach is consistent with Waikato Regional Council's determination of water levels for design purposes.

f) Hydrology was developed based on the Unit Hydrograph Method (UHM). The catchment was divided into sub-catchment areas of about 3 hectares, with losses, flow paths and time of concentration calculated for each. Each sub-catchment is made up of combined pervious and impervious areas so that the initial extraction and ground losses can be established based on the underlying soil type and land-use.

g) The curve number (CN) for the pervious sub-catchment is assumed to be the same for the existing scenario and the future scenario. The pervious and impervious sub-catchment areas add up to the total area for each sub-catchment. An impervious CN value of 98 was used and the pervious CN values vary by land type.

4.2.2 LiDAR and Terrain Development

a) LiDAR data supplied by council was used to develop the terrain that formed the base for the model. This data is assumed to be correct and no adjustments have been made other than those required to stabilise the model at the inlet and outlets of critical culverts or ponds. As LiDAR picks up the water level, the ground surface at ponds/inlets and outlets was lowered to known pipe invert levels. The LiDAR was flown in 2008 and changes to land after this are not included, with the exception of developers' terrain data, and a portion of the catchment where drone survey was undertaken in 2015.

b) Developers and their agents (surveyors) provided 3D terrain data for a number of areas throughout the catchment. This data was assumed to be correct and no quality checks were carried out. This data is laid over the LiDAR data to create a merged terrain surface comprising both LiDAR and as-built/design data where appropriate. Design surface data from the following developments has been used in the modelling:

Table 1 Development design data used in the models

Development Area	
Amokura	Magellan Heights
Cumberland Drive	Magellan Lake
Glaisdale	The Meadows
Glaisdale North	Woodridge Stage 4
Glaisdale South	Woodridge Stage 5
Horsham Estate	Woodridge Stage 6
Rototuna Town Centre	

c) Several areas within the catchment required site specific survey, including such things as stormwater ponds, outlets and manholes. This data was incorporated into the model build, and included the following areas:

Table 2 Surveyed data used in the models

Surveyed Area
River Road Culvert
Te Awa O Katapaki Stream cross sections at most confluences and outlets
Various stormwater ponds throughout the catchment

d) Design information and the O&M plan provided by S&L consultants was used along with drone survey data to model the pond north of Borman Road and immediately east of Hector Drive. This information is assumed to be accurate.

e) The flood hazard model uses a 2 metre x 2 metre grid, with the level of the grid cell being the average of the LiDAR points within the cell.

f) Water level was defined by adding together the ground level and the water depth at the relevant grid cell. The ground level was determined by interpolation of the surface DTM points and is therefore subject to inaccuracies (in the elevation of the LiDAR points and in the data processing to create the DTM). This is particularly true wherever the LiDAR DTM point density is sparse or in heavily vegetated areas. In such cases, it is assumed that the flood extent and the water depth give a good approximation of the flood risk even if the ground level is not accurate.

g) In urban areas the LiDAR data is stated to have an accuracy of about ± 0.25m with a 95% confidence interval. This relates to the spheroid height; additional error is introduced when the geodic height model is applied. As a result of the water level variability, the lateral extent of flood hazards may vary significantly from that shown.

h) The actual range of uncertainty as a result of the combined effect of LiDAR and other possible errors and inaccuracies, will in some situations, be in excess of 0.5 metres. Asset planners, consent planners and designers should take appropriate care in using the results and should apply a freeboard allowance that is appropriate for the situation, taking into account these limitations, assumptions and uncertainties including the compounding effects of uncertainties in the rainfall model.

i) The future model terrain for the areas that are currently pasture was developed by AECOM based on the Structure Plan showing where the road alignments are, and by connecting these to the existing roads. The new roads will become overland flow paths in extreme events. The future terrain model allowed for the ground to be contoured towards the roads to minimise property flooding and maximise the use of roads as secondary overland flow paths.

j) The bathymetry was adjusted with a new surface obtained from drone survey in 2015. This was in the region of Hector Drive, Johnnybro Place and Raupo Place where a new subdivision had been created after HCC's original LiDAR survey of 2008. This subdivision, with its roads and settlement ponds changed the hydrologic surface significantly.

k) After hydrological modelling, there was found to be a single ridge line in the new surface that had a significant effect on the hydrologic flow. The ridge line was an artificially created artefact, approximately 100 meters long and 24 centimetres high. It was created partially by the different vertical accuracies of the two surveys, the interpolations applied to adjust them to control points and by the edge used to join the two sets of processed data. As the ridge line was located crossing an open paddock, which had clearly defined drainage around the borders, it was appropriate to feather the change out across the open space. This feathering occurred across a distance of approximately 40 meters from the new survey to the matching contour from the old survey. Care was taken to ensure that the drainage from this feathered area drained to the expected drainage channels.

4.2.3 Land-use

a) The existing scenario impervious coverage were utilised for the District Plan Flood Hazard Mapping.

b) The land use types for the future scenario were taken from the Rototuna Structure Plan, with impervious and pervious coverage taken from the District Plan allowances.

c) The roughness of the surface model was averaged over each land use type. The following Manning's 'n' values were adopted:

Table 3 Development design data used to develop the models

Land Use Type	Manning's 'n' value
Roading	0.01575
Commercial	0.0185
Greenfield / pasture	0.030
Residential	0.0266

4.2.4 Model Setup and Boundary Conditions

a) Catchpits were assumed to have a maximum inletting capacity of 25 L/s.

b) Catchpits were assumed to be free flowing and unimpeded.

c) All culverts included in the model were assumed as free flowing and unimpeded.

d) Sub-catchments were connected directly to each identified loading node. That is, the flow hydrograph generated by each sub-catchment was connected directly to the sub-catchment outlet pipe. A weir was placed at ground level so that if the pipe does not have capacity, excess flow will spill to the ground surface model and become overland flow.

e) The next downstream manhole after the loading node (in the overland flow path) was regulated according to the number of catchpits located within the catchment (i.e. total number of catchpits multiplied by 25 L/s) with a minimum regulation of 100 L/s. This then allows overland flow back into the system should there be downstream pipe capacity.

f) All other manholes were sealed and only those manholes where water level surcharged above the ground level had weirs attached to allow flow out of the system (i.e. the pipe system was not pressurised).

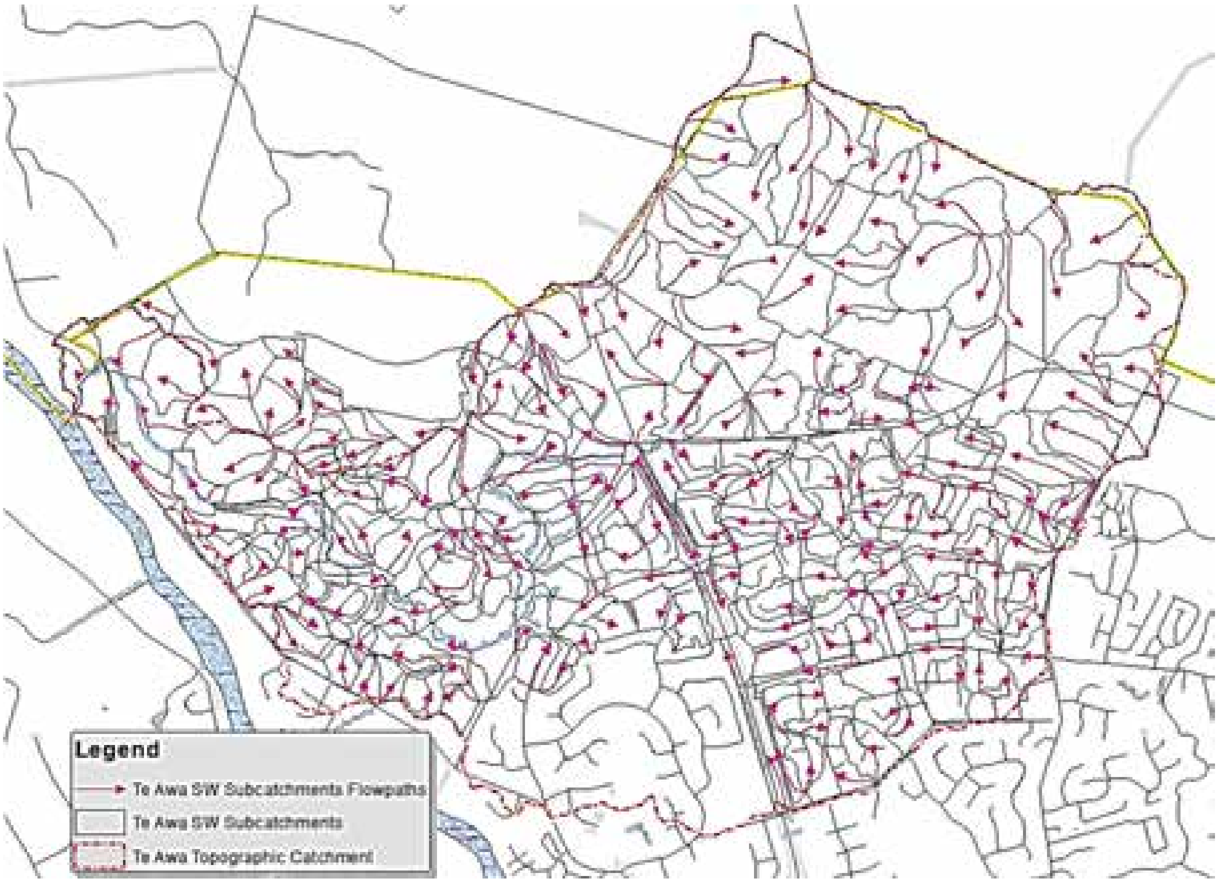
g) The manhole levels were set to the terrain model level to ensure that all couplings operated correctly.

h) The Waikato River formed the downstream boundary to the catchment. A river level of RL 15.46m was adopted based on the criteria discussed above.

4.3 Model Extent

The overall catchment was divided into sub-catchments based primarily on topography. The sub-catchments were limited to around 3 hectares and were used to calculate overland flow paths, time of concentrations and runoff hydrographs for each. The sub-catchments and flow paths are shown in Figure 2.

Figure 2 Existing and future model sub-catchments and flow paths



4.4 Hydraulic Model Build

4.4.1 Floodplain and Watercourse Schematisation

The terrain model was developed in Mike 21 and the main watercourse in Mike 11. A combination of LiDAR data and development data was used to generate a merged 2D surface. The stream channel cross sections were extracted from the merged surface.

The Te Awa O Katapaki stream has a number of significant stormwater features along its length, including culverts, an open floodway, and ponds at Magellan Lake and St Petersburg. The culverts act as hydraulic controls and are represented in the Mike 11 model. Information regarding the size and levels of the culverts was obtained from survey data and on-site measurements. The newly constructed River Road culvert was based on construction drawing dimensions and levels.

A major stormwater pond (Magellan Lake) was also modelled in Mike 11, with data obtained from a combination of LiDAR, survey, or as-built development information. LiDAR data does not pick up pond invert levels where there is standing water. A correction has been applied in the model to account for this and correctly represent the pond. The permanent water level picked up by LiDAR has been used as the initial water level.

4.4.2 Stormwater Drainage System

The model does not include any pipe systems upstream of loading nodes, which in most cases excluded pipes equal to or less than 225mm. No storage compensation has been carried out to allow for this minor pipe volume.

For the future model outside of the existing developed area, theoretical pipes were put into the model in the existing farmland areas to allow for residential development being able to cope with a 2 year return period storm event (including climate change).

4.4.2.1 Review of Existing Asset Data

Table 4 gives details of the asset data sources for the modelled pipes and manholes.

Table 4 Asset data modelled

Asset Data Type	No.	Data Sources
Manholes – Ground Levels	615	Mike 21 Ground Model
Manholes – Invert Levels	13	Estimated based on upstream and downstream pipe slopes
	17	Dummy nodes inserted at junctions or to connect existing systems
	67	Dummy nodes and outlets to model rural un-piped catchments
	510	Council GIS database
Culvert/Pipe Inlets and Outlets	92	Mike 21 ground model
	67	Dummy outlets to model rural un-piped catchments
	14	Mike 11/21 ground model coupling adjustment
	3	Survey
	8	Council GIS database
Pipes	492	Council GIS database
	67	Dummy links to model rural un-piped catchments
	42	Dummy links to connect dummy nodes inserted at junctions or to connect existing systems
	1	Estimated based on upstream and downstream pipe diameters

4.4.3 Hydraulic Model

4.4.3.1 Method Used

Nodes and links were imported into the Mike Urban model from council's GIS network. Ground levels were assessed against the ground model to be used in the Mike 21 model. About 70% of the levels were outside the allowable range of +/- 50mm.

As a result the ground levels in the model were amended to reflect the Mike 21 ground model. Some nodes were surveyed and these levels were included in the model. In some instances this affected the levels of pipes and so invert levels were amended accordingly.

One pipe diameter was missing from the GIS and this was inferred from the upstream and downstream pipe diameters.

Ten dummy nodes were modelled to connect pipes at junctions where no manhole exists in the GIS. One dummy node was modelled to connect two existing stormwater systems together where there is no information.

Sub-catchment loading nodes had a modelled weir added, set at ground level with a length of 1.35m. The nodes were then sealed and the downstream node was coupled to the Mike 21 model using Mike 21 regulation.

Just over 50% of the existing catchment is not currently connected to the city network as it is undeveloped farmland. This was modelled using Mike Urban dummy source points for the hydrographs developed for the 2, 10 and 100 year (with and without climate change) so that the existing scenario overland flow paths could be established. There were 67 sub-catchments modelled using this approach.

4.4.3.2 Hydraulic Model Extents

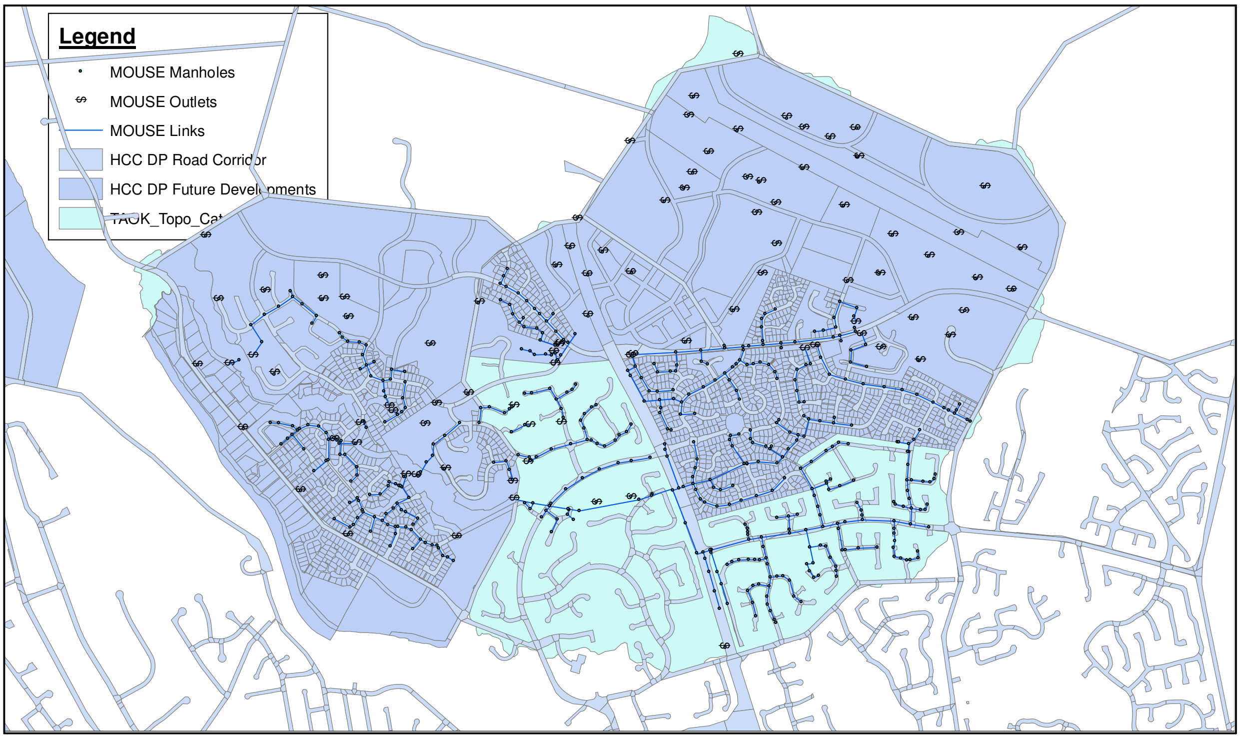
Table 5 gives details of the number of hydraulic model components.

Table 5 Hydraulic model components

Total Number of Hydraulic Model Components	Values
Stormwater network system nodes	515
Dummy nodes for catchment loading	88
Links	602
Stormwater network system pipes	514
Dummy links for catchment loading	88
Weirs	242
Outlets	96

The figure below shows the extent of the hydraulic model.

Figure 3 Extent of hydraulic model used for FHM



4.4.3.3 Energy Losses

Table 6 shows the modelled Manning's roughness values.

Table 6 Manning's roughness values

Link Type	MOUSE Link Material Type	Manning's "n" Value Used
Pipe and Culvert	Concrete (Normal)	0.015
	Concrete (Smooth)	0.005

Table 7 shows the modelled node head loss parameters.

Table 7 Head loss parameters

Node Type	MOUSE Node Head Loss Parameter
Physical Nodes	Mean Energy Approach, Km = 0.3
Dummy Nodes	No Cross-Section Changes
Pipe Outlet Nodes	Mean Energy Approach, Km = 0.3

4.4.3.4 Hydraulic Model Assumptions

Council provided much of the hydraulic information for the development of the stormwater model. This included GIS data and network asset data. A review of the data was undertaken, and anomalies or errors noted during the model build.

The GIS data was assumed to be accurate and correct for assets, without obvious errors in the GIS data supplied. Site survey was conducted where possible, or existing as-built data used to provide missing network data. Where survey data or as-built data was not available, data was interpolated from neighbouring assets. Interpolation has been made for cases such as assets without level information, or pipes grading uphill or where connectivity was not present or correct.

Developers and their agents (surveyors) provided updated topography by way of 3D surface information. The information was based on as-built or design information for developments undertaken or in the process of being constructed since LiDAR was flown in 2008/2009. It was agreed with council to use this information to update the

LiDAR in areas where development had occurred. The data was assumed to be correct and no changes were made to the information provided.

4.5 Final Coupled Model Representation

To establish relationships between pipe networks, the stream, sub-catchments and floodplains the following linkages were established in the coupled Mike Flood model:

a) **River/Urban link** – Mike Urban to Mike 11 (pipe flow into the Te Awa O Katapaki stream).

b) **Urban link** – Mike Urban to Mike 21 (pipe network overflowing to the floodplain).

Once the pipe network capacity is exceeded, the flows will surcharge onto the surrounding ground surface before finally discharging into the Te Awa O Katapaki stream.

c) **Lateral link** – Mike 11 to Mike 21 (Te Awa O Katapaki stream overflowing into the surrounding floodplain).

All sub-catchments discharge directly into the Te Awa O Katapaki stream via the catchment specific outlet discharge system. Once the flow overtops the stream bank, the water will flow into the surrounding floodplains.

4.6 Flood Hazard Mapping

The flood hazard mapping approach for existing development has been covered by the Flood Hazard Mapping Methodology developed by AECOM for Hamilton City Council in February 2013.

4.6.1 Existing and future scenarios – flood results

The results were provided in two parts and they are:

a) District Plan flood hazard outputs for the existing 100 year event plus climate change.

b) Results rasters for the 2, 10 and 100 year existing and MPD results. The raster results will have the following results in each 2 metre x 2 metre cell:

   i) Maximum depth and associated velocity

   ii) Maximum velocity and associated depth

   iii) Maximum depth x velocity

   iv) Maximum cell water level

   v) Cell hazard value

The 2 and 10 year results will be used for assessment of erosion potential and the 100 year results will be used to understand the existing and future flood risks.

The criteria and hazard classification methodology is discussed in Flood Hazard Report, City Wide Flooding Classification, AECOM, May 2012[1].

The hazard is classified with one of the following values in Table 8 below:

Table 8 Hazard classification category

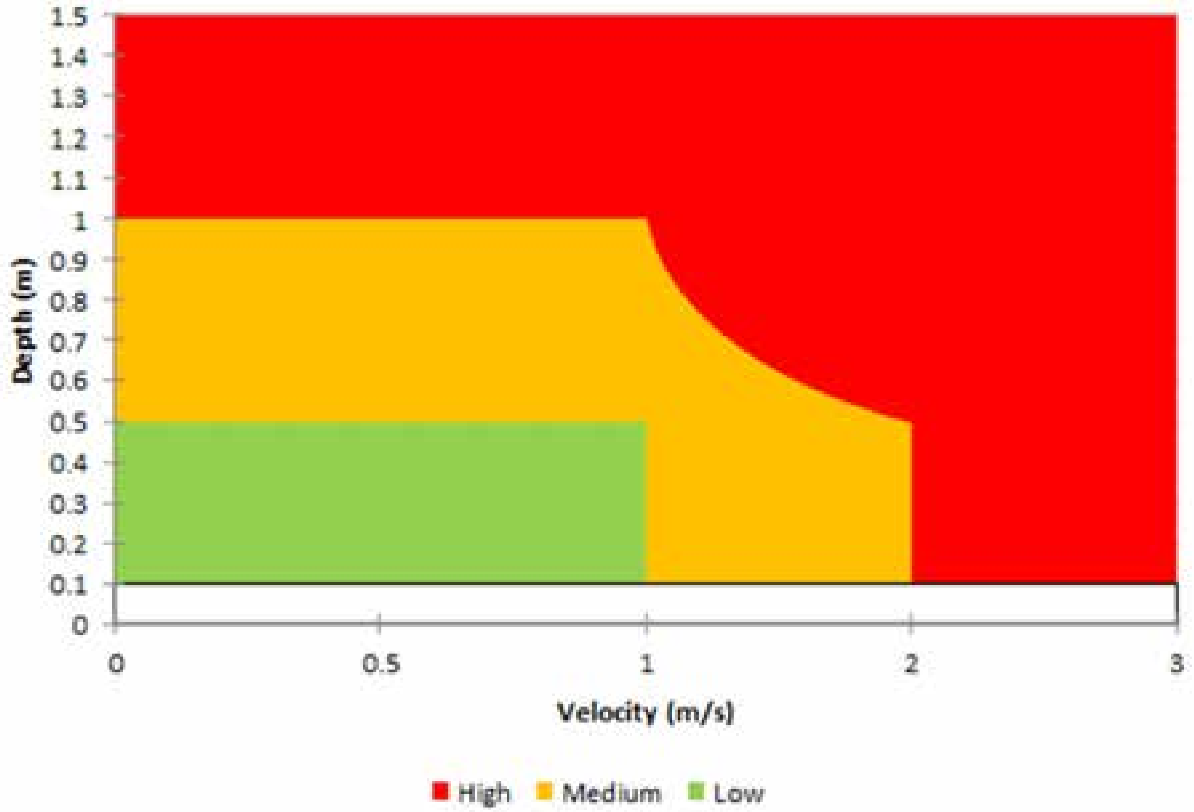
Hazard Classification	Description
3	High Risk Hazard
2	Medium Hazard
1	Low Hazard
0	No Hazard

[1] Flood Hazard Report, City Wide Flooding Classification. Three Waters Modelling Programme, Hamilton City Council, 3 May 2012. Report prepared by AECOM New Zealand Ltd.

The maximum value during the simulation for each grid cell is extracted from the result file and used to determine the hazard classification. This method evaluates the hazard classification at each time step and determines the maximum (worst case) hazard. The maximum value for velocity with associated depth, depth with associated velocity, and depth x velocity then produces the hazard classification for that cell.

The depth/velocity criteria for each hazard classification are shown in Figure 4 below. These classifications are then used for the raster output showing the colour scheme for each grid cell based on the model results.

Figure 4 Depth – velocity criteria for hazard classification



5.0 Results

Results were generated for the 2 year, 10 year, and 100 year storm events. Results were extracted for a number of locations throughout the catchment, including:

- Floodway upstream of Borman Road
- Culvert upstream of Magellan Lake
- Magellan Lake
- Magellan Lake outlet weir
- River Road culvert.

5.1.1 Culvert upstream of Borman Road

The results indicated that flood hazards through the culverts and floodway will likely be contained within the drainage reserve in the upper catchment. Some localised surface ponding is expected across the upper catchment due to the flat topography.

Figure 5 Hazard classifications for the 100 year existing scenario at the Borman Road underpasses

While the flows increase significantly for the future scenario, flows are predicted to be contained within the floodway extents. Future development in the upper catchment is expected to result in flows being re-directed along roadways. Some surface ponding is still predicted to occur in the upper catchment; however this is reduced compared to the existing scenario.

Table 9 FHM results for various storm events at the Borman Road underpass

ARI Storm Event	Existing			Future		
Results for ♦ shown	Q (m3/s)	v (m/s)	Elevation (RL m)	Q (m3/s)	v (m/s)	Elevation (RL m)
2 year	0.60	0.09	29.16	1.08	0.10	29.47

ARI Storm Event	Existing			Future		
Results for ♦ shown	Q (m3/s)	v (m/s)	Elevation (RL m)	Q (m3/s)	v (m/s)	Elevation (RL m)
10 year	1.16	0.13	29.39	2.33	0.19	29.69
100 year	2.23	0.19	29.63	3.89	0.29	29.79

5.1.2 Culvert upstream of Magellan Lake

The stream and floodway upstream of Magellan Lake carries flow through a well-defined floodway. Flood hazards through this area are predicted to be contained within the floodway.

Figure 6 Hazard classifications for the 100 year existing scenario upstream of Magellan Lake

Flow through this portion of the catchment is predicted to double for the future scenario. While flow depths increase about 200 mm, this is still predicted to be contained within the reserve area and just outside of private property boundaries.

Table 10 FHM results for various storm events upstream of Magellan Lake

ARI Storm Event	Existing			Future		
Results for ♦ shown	Q (m3/s)	v (m/s)	Elevation (RL m)	Q (m3/s)	v (m/s)	Elevation (RL m)
2 year	3.15	0.26	26.42	7.01	0.48	26.69
10 year	6.11	0.42	26.68	10.89	0.62	26.88
100 year	11.23	0.64	26.86	13.95	0.72	27.03

5.1.3 Magellan Lake

Magellan Lake is a significant stormwater feature within the catchment. The lake has a large storage volume available for managing runoff from the upstream catchment. Flood hazards are predicted to be contained within the lake.

Figure 7 Hazard classifications for the 100 year existing scenario through Magellan Lake

While flow rates through the lake are expected to double for the future scenario, the lake level is expected to increase by only about 300 mm. The additional flow volume is likely to be managed effectively through the lake due to the lake volume and the effect of the outlet control structure.

The velocity increase within the lake is expected to be negligible.

Table 11 FHM results for various storm events in Magellan Lake

ARI Storm Event	Existing			Future		
Results for ♦ shown	Q (m3/s)	v (m/s)	Elevation (RL m)	Q (m3/s)	v (m/s)	Elevation (RL m)
2 year	2.99	0.01	26.42	6.82	0.03	26.69
10 year	6.51	0.03	26.66	11.55	0.05	26.88
100 year	12.3	0.05	26.86	14.88	0.06	27.03

5.1.4 Magellan Lake outlet

The Magellan Lake outlet has been specifically designed to utilise the volume of the lake for storage and attenuation.

Figure 8 Hazard classifications for the 100 year existing scenario downstream of Magellan Lake

Flows across the outlet weir of Magellan Lake are expected rise about 700mm between the existing and future scenarios. Flood water is expected to be contained within the structure, however the flow velocities are likely to increase by about 20% as the discharge increases for larger storm events and development scenarios with more runoff.

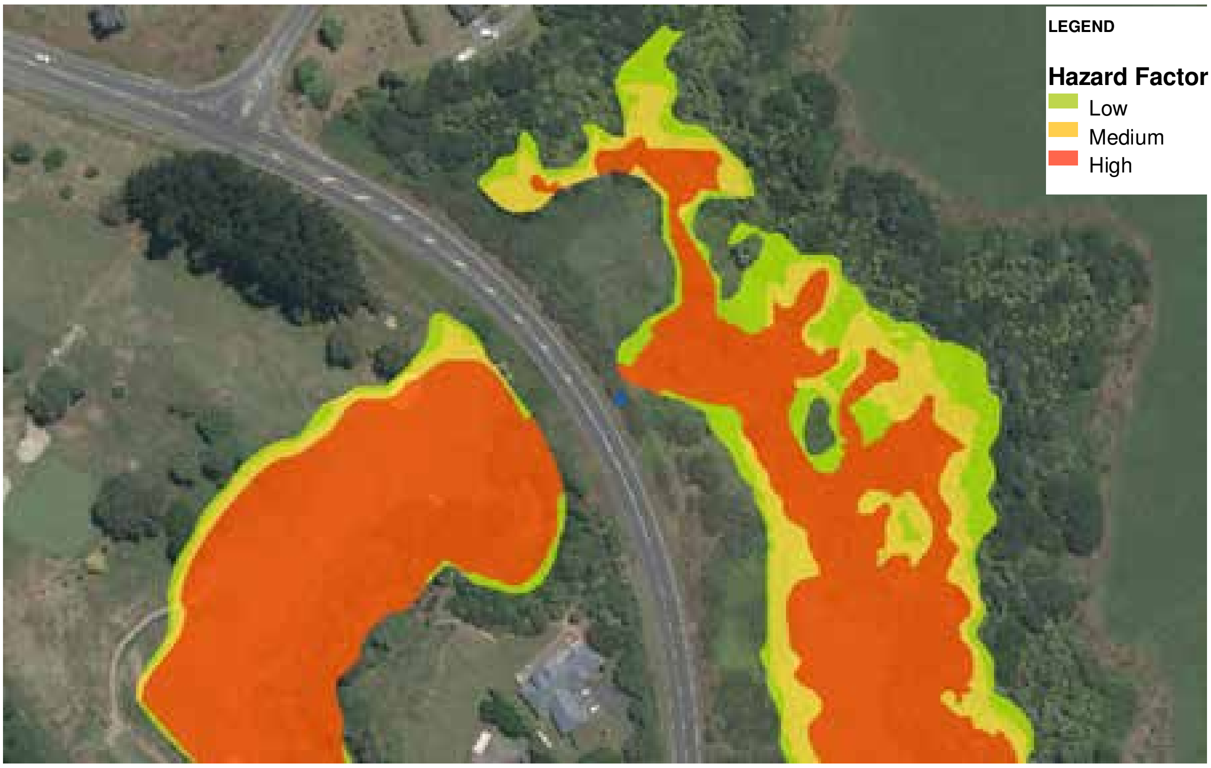
Table 12 FHM results for various storm events at Magellan Lake outlet weir

ARI Storm Event	Existing			Future		
Results for ♦ shown	Q (m3/s)	v (m/s)	Elevation (RL m)	Q (m3/s)	v (m/s)	Elevation (RL m)
2 year	2.93	0.56	25.26	10.43	1.02	25.87
10 year	6.29	0.81	25.58	17.96	1.19	26.42
100 year	12.66	1.08	26.05	21.95	1.25	26.69

5.1.5 River Road Culvert

Hamilton City Council recently installed a new box culvert under River Road to cater for large storm events. The culvert is shown to convey flows up to the 100 year ARI storm event (both existing and future) without overtopping River Road.

Figure 9 Hazard classifications for the 100 year existing scenario at River Road Culvert



At this location there is a large increase in flow rate between the existing and future scenarios for the 10 year and 100 year ARI storm events as can be seen in Table 13. At present the undeveloped land adjacent to the lower gully catchment drains via overland flow into the stream network and through the River Road culvert.

Once the land is fully developed, the topography of this land is expected to be significantly altered, as will the flow paths and directions. Overland flow from the developed land may follow new road alignments and through a stormwater pond adjacent to the stream. This change may result in a delayed response for the catchment, in effect lowering the peak flow rate through the culvert.

Table 13 FHM results for various storm events upstream of the River Road culvert

ARI Storm Event	Existing			Future		
Results for ♦ shown	Q (m3/s)	v (m/s)	Elevation (RL m)	Q (m3/s)	v (m/s)	Elevation (RL m)
2 Year	9.52	0.47	15.47	11.12	0.51	15.52
10 Year	10.2	0.48	15.49	21.24	0.48	15.65
100 Year	18.34	0.46	15.60	34.8	0.68	15.98

5.2 Magellan Lake Optimisation

Flows and water levels in Magellan Lake were derived as part of the stormwater modelling. This included Magellan Lake and the floodway upstream of the lake. The purpose was to determine relevant parameters which could be used for a more focussed assessment of the lake's performance.

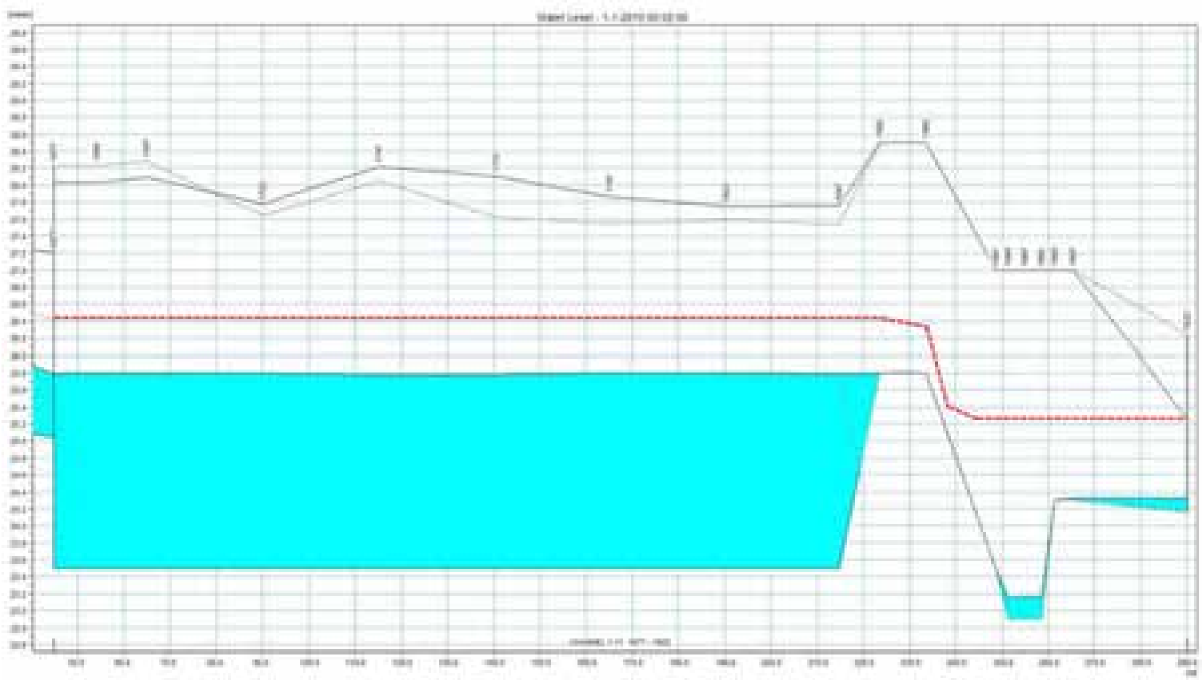
The 2 year and 10 year storm events were assessed because they are the storms for which attenuation is required. Lowering the outlet velocity reduces the potential for downstream bank erosion. To achieve this, additional volume needs to be stored which increases upstream water levels.

Hamilton City Council has advised that any changes to Magellan Lake will require discussion and approval from Waikato Regional Council. A number of consent conditions are in place relating the operation and maintenance of Magellan Lake, which will need approval for any changes.

Analysis has been undertaken to determine the lake level and flow velocity at the outlet of Magellan Lake. The analysis involved modelling of the lake and its outlet energy dissipation structure (stilling basin) using as-built plans for the 2 year and 10 year storm events.

Figure 10 below shows a portion of the model setup through the lake and spilling basin, with the left and right banks and chainage shown in the top two lines. The area shown in blue represents the water level at the very start of the 2 year event, while the red line indicates the maximum water level.

Figure 10 Long-section through Magellan Lake and downstream stilling basin



Model results with and without the stilling basin are provided in Table 14.

Table 14 Magellan Lake and stilling basin model data results

Model Location	Velocity (m/s)	
	2 year	10 year
Magellan Lake weir crest	4.47	4.99
Downstream end of stilling basin	0.23	0.35
100m downstream of stilling basin	1.49	2.15
200m downstream of stilling basin	1.47	1.81

The stilling basin downstream of Magellan Lake appears to provide adequate reduction in flow velocities for both the 2 year and 10 year storm events. Velocities at the downstream end of the basin appear to be low and should pose no erosion issue.

Downstream of the basin the velocities in the channel increase to around 1.4 - 2.2 m/s. This is not deemed to be a fault of the weir but the stream flow returning to normal velocities for the channel size and slope. There is potential for some erosion to occur at these velocities in sections where over-steep banks exist or undercutting is occurring.

The predicted flood levels in the lake and the upstream floodway reach the maximum permitted level in some locations. If the flood level was raised any further, the extent of flooding could increase and include private property. There is little potential to raise the existing Magellan Lake weir to create more storage because this could result in an increase in the extent of flooding.

5.3 Proposed Weir Optimisation

Optimisation of the floodway upstream of the Magellan Lake was proposed to be carried out depending on the results of the initial modelling. This optimisation was to include the Tuirangi floodway and the proposed Cate Floodway (now part of Rototuna Town Centre).

Two weirs were proposed on the 2006 catchment management plan for the purpose of attenuation and velocity reduction, primarily for the 2 year storm event. The proposed weir locations were as follows:

- Upstream of Magellan Rise and Magellan Lake on the Tuirangi Floodway
- Upstream of the Borman Road culvert crossing in the vicinity of the Resolution Drive roundabout.

Cate/Rototuna Floodway

Based on previous catchment management plans, a floodway was to be constructed upstream of the Borman Road culvert. Current plans are that this section will now be piped and the proposed Rototuna Town Centre floodway will be located upstream of the pipeline. There is a preliminary design for the Rototuna floodway and it will include its own attenuation structures.

The weir has not been modelled because the proposed weir location no longer exists in its planned form.

Tuirangi Floodway

A weir was planned to be installed in the Tuirangi Floodway to reduce the effective slope of the channel and to better utilise the volume of the floodway for attenuation.

Analysis of the results shows that in a 100 year event in the future scenario, in places the floodway is fully utilised up to the boundary of private property. This may preclude the construction of a weir at a height significant enough to provide a meaningful amount of attenuation and velocity control. A weir of a significant height is likely to increase the maximum predicted flood level and therefore the extent of flood water may enter private properties which are not previously affected.

Based on the above, the proposed weir has not been modelled. Although additional attenuation is beneficial, it cannot be at the expense of creating more flooding impact on private property. It is expected that the overall catchment attenuation philosophy will be discussed and address in an updated version of the catchment management plan.

Appendix A

Model Catchment Parameters

Rev.	By	App.	Description	Date

Notes:

Printed			
Approved		Date	18 Dec 2013
Designed		Checked	
Drawn		Checked	
File Name			

Map features depicted in terms of NZTM projection.

Data Sources:
NZ Topographical Features – LINZ NZ National Topo Dataset 2006
Cadastral Boundaries – LINZ NZ Cadastral Dataset 2007

AECOM

Project: **Te Awa O Katapaki Stormwater Modelling**

Title: **Model Build Report**
Catchment Overview

Scale: 1:10,000 (A3 size) 200 100 0 200 400 Metres

Status: For Information | Map No. **MB01** | Rev. **0**

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19 Sep 2013 11:39

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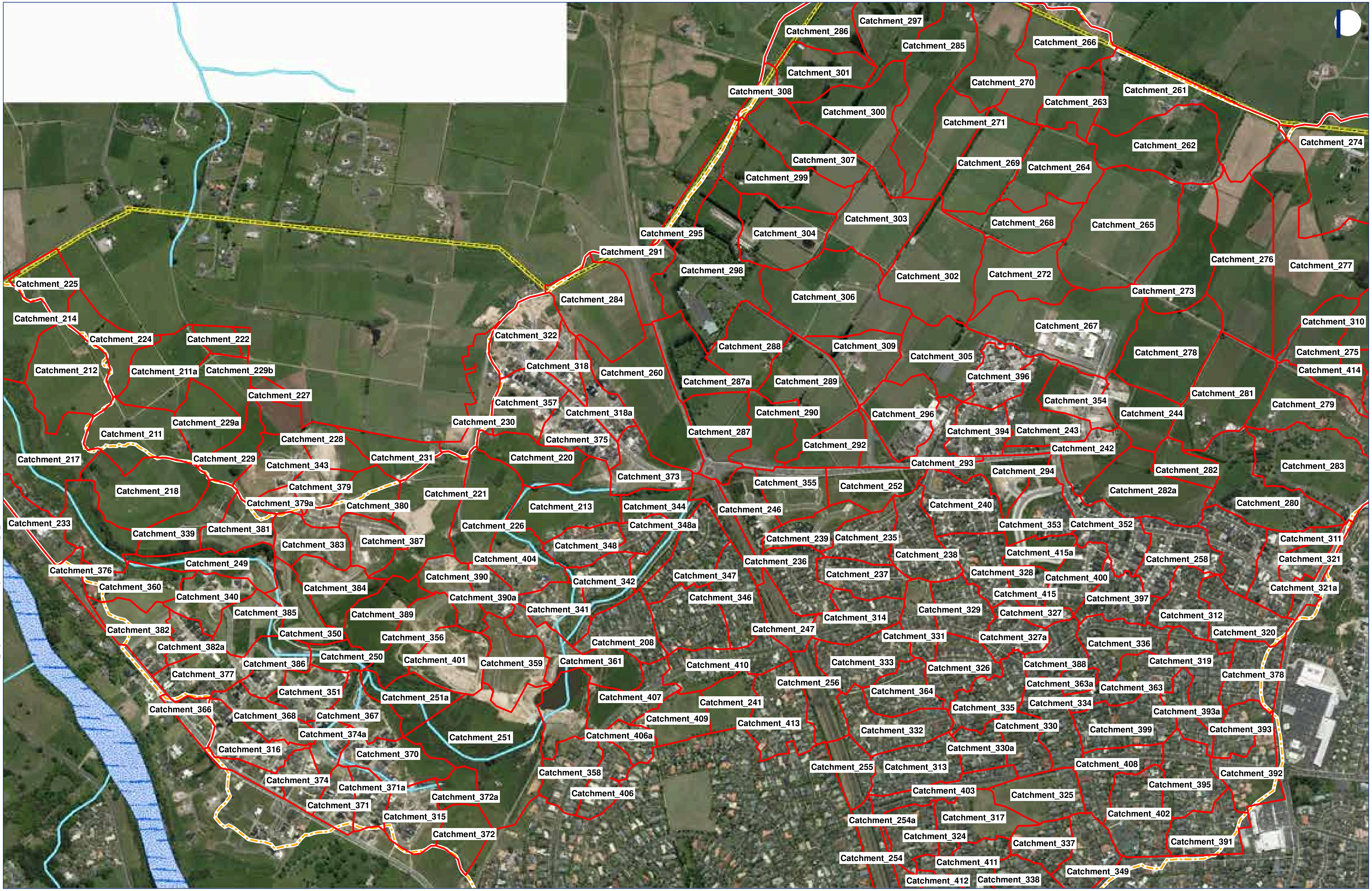


Rev.	By	App.	Description	Date

Notes:

Printed			
Approved		Date	18 Dec 2013
Designed		Checked	
Drawn		Checked	
File Name			

Map features depicted in terms of NZTM projection.

Data Sources:
NZ Topographical Features – LINZ NZ National Topo Dataset 2006
Cadastral Boundaries – LINZ NZ Cadastral Dataset 2007

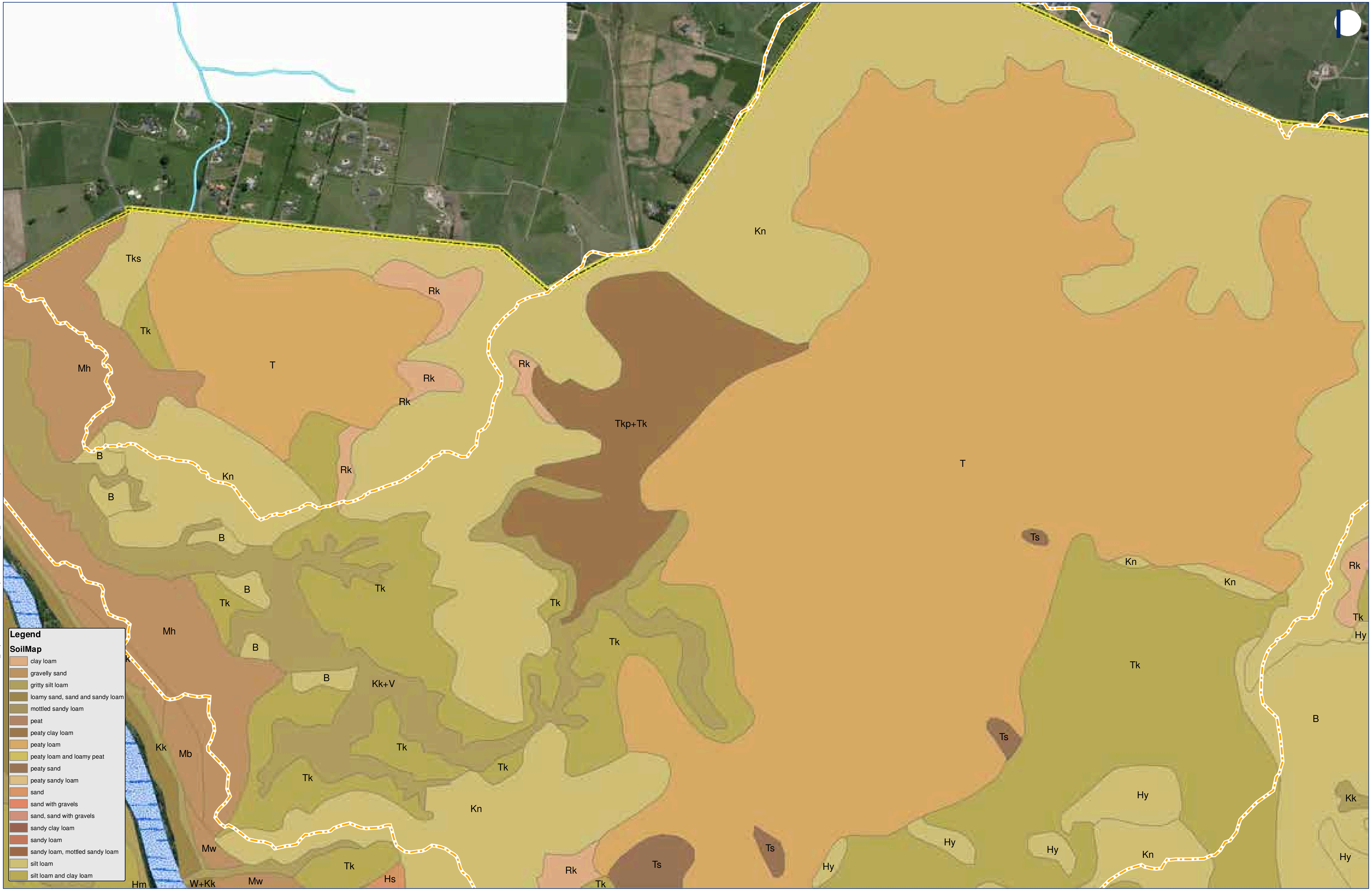
AECOM

Project: **Te Awa O Katapaki Stormwater Modelling**

Title: **Model Build Report**
Subcatchments

Scale: 1:10,000 (A3 size) 200 100 0 200 400 Metres

Status: For Information | Map No. MB02 | Rev. 0



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Rev.	By	App.	Description	Date

Notes:

Printed			
Approved		Date	18 Dec 2013
Designed		Checked	
Drawn		Checked	
File Name			

Map features depicted in terms of NZTM projection.

Data Sources:
NZ Topographical Features – LINZ NZ National Topo Dataset 2006
Cadastral Boundaries – LINZ NZ Cadastral Dataset 2007

AECOM

Project: **Te Awa O Katapaki Stormwater Modelling**

Title: **Model Build Report**
Soil Map

Scale: 1:10,000 (A3 size) 200 100 0 200 400 Metres

Status: For Information | Map No. MB03 | Rev. 0

Existing Development MIKE Urban Catchment Parameters

Catchment ID	Area	Hydrograph	Cp	Loss Model	Runoff Coef	Curve Number	Initial abstraction	Lag Time	LT Curve Number
Catchment_208	2.999	SCS Dimensionless	0.85	SCS Generalised	0.75	79.60	2.25	0.11	80
Catchment_211	4.275	SCS Dimensionless	0.85	SCS Generalised	0.75	64.23	4.93	0.16	64
Catchment_211a	4.036	SCS Dimensionless	0.85	SCS Generalised	0.75	56.64	4.96	0.13	57
Catchment_212	5.446	SCS Dimensionless	0.85	SCS Generalised	0.75	49.42	5.00	0.19	49
Catchment_218	5.609	SCS Dimensionless	0.85	SCS Generalised	0.75	71.25	5.00	0.11	71
Catchment_220	3.143	SCS Dimensionless	0.85	SCS Generalised	0.75	73.94	4.92	0.11	74
Catchment_221	5.490	SCS Dimensionless	0.85	SCS Generalised	0.75	64.63	4.80	0.15	65
Catchment_222	0.949	SCS Dimensionless	0.85	SCS Generalised	0.75	69.00	5.00	0.15	69
Catchment_224	2.866	SCS Dimensionless	0.85	SCS Generalised	0.75	49.15	4.99	0.30	49
Catchment_225	2.244	SCS Dimensionless	0.85	SCS Generalised	0.75	49.59	4.94	0.18	50
Catchment_226	4.341	SCS Dimensionless	0.85	SCS Generalised	0.75	73.47	4.73	0.11	73
Catchment_227	0.932	SCS Dimensionless	0.85	SCS Generalised	0.75	69.01	5.00	0.13	69
Catchment_228	3.101	SCS Dimensionless	0.85	SCS Generalised	0.75	62.84	4.99	0.26	63
Catchment_229	2.109	SCS Dimensionless	0.85	SCS Generalised	0.75	69.02	5.00	0.11	69
Catchment_229a	2.890	SCS Dimensionless	0.85	SCS Generalised	0.75	67.48	4.98	0.11	67
Catchment_229b	2.017	SCS Dimensionless	0.85	SCS Generalised	0.75	68.06	5.00	0.21	68
Catchment_230	2.605	SCS Dimensionless	0.85	SCS Generalised	0.75	73.24	4.27	0.11	73
Catchment_231	2.316	SCS Dimensionless	0.85	SCS Generalised	0.75	70.37	4.90	0.11	70
Catchment_233	2.475	SCS Dimensionless	0.85	SCS Generalised	0.75	64.80	3.39	0.26	65
Catchment_235	2.432	SCS Dimensionless	0.85	SCS Generalised	0.75	86.33	2.01	0.18	86
Catchment_236	2.909	SCS Dimensionless	0.85	SCS Generalised	0.75	85.42	2.17	0.13	85
Catchment_237	2.435	SCS Dimensionless	0.85	SCS Generalised	0.75	83.46	2.51	0.15	83
Catchment_238	3.402	SCS Dimensionless	0.85	SCS Generalised	0.75	85.53	2.15	0.11	86
Catchment_239	2.231	SCS Dimensionless	0.85	SCS Generalised	0.75	75.97	3.80	0.26	76
Catchment_240	3.613	SCS Dimensionless	0.85	SCS Generalised	0.75	85.98	2.07	0.11	86
Catchment_241	2.089	SCS Dimensionless	0.85	SCS Generalised	0.75	60.37	4.73	0.11	60
Catchment_242	2.738	SCS Dimensionless	0.85	SCS Generalised	0.75	77.58	3.52	0.11	78
Catchment_243	3.425	SCS Dimensionless	0.85	SCS Generalised	0.75	75.77	3.83	0.20	76
Catchment_244	3.019	SCS Dimensionless	0.85	SCS Generalised	0.75	73.19	4.28	0.21	73
Catchment_247	1.921	SCS Dimensionless	0.85	SCS Generalised	0.75	83.98	2.42	0.18	84
Catchment_248	0.949	SCS Dimensionless	0.85	SCS Generalised	0.75	82.16	1.85	0.11	82
Catchment_252	2.807	SCS Dimensionless	0.85	SCS Generalised	0.75	74.07	4.13	0.31	74
Catchment_253	0.408	SCS Dimensionless	0.85	SCS Generalised	0.75	84.55	2.26	0.12	85
Catchment_254	3.639	SCS Dimensionless	0.85	SCS Generalised	0.75	73.12	2.71	0.23	73
Catchment_254a	1.822	SCS Dimensionless	0.85	SCS Generalised	0.75	77.20	2.23	0.15	77
Catchment_255	1.865	SCS Dimensionless	0.85	SCS Generalised	0.75	81.65	2.82	0.14	82
Catchment_256	2.517	SCS Dimensionless	0.85	SCS Generalised	0.75	79.45	3.20	0.17	79
Catchment_258	3.454	SCS Dimensionless	0.85	SCS Generalised	0.75	83.64	2.06	0.18	84
Catchment_260	6.462	SCS Dimensionless	0.85	SCS Generalised	0.75	81.09	4.65	0.15	81
Catchment_261	8.050	SCS Dimensionless	0.85	SCS Generalised	0.75	70.45	4.75	0.11	70
Catchment_262	6.164	SCS Dimensionless	0.85	SCS Generalised	0.75	69.50	4.91	0.11	69
Catchment_263	2.561	SCS Dimensionless	0.85	SCS Generalised	0.75	69.01	5.00	0.11	69
Catchment_264	4.764	SCS Dimensionless	0.85	SCS Generalised	0.75	69.00	5.00	0.13	69
Catchment_265	9.304	SCS Dimensionless	0.85	SCS Generalised	0.75	69.06	4.99	0.11	69
Catchment_266	5.792	SCS Dimensionless	0.85	SCS Generalised	0.75	70.67	4.71	0.11	71
Catchment_267	8.667	SCS Dimensionless	0.85	SCS Generalised	0.75	74.49	4.05	0.11	74
Catchment_268	3.622	SCS Dimensionless	0.85	SCS Generalised	0.75	69.01	5.00	0.22	69
Catchment_269	4.936	SCS Dimensionless	0.85	SCS Generalised	0.75	69.00	5.00	0.21	69
Catchment_270	5.817	SCS Dimensionless	0.85	SCS Generalised	0.75	70.45	4.76	0.11	70
Catchment_271	3.453	SCS Dimensionless	0.85	SCS Generalised	0.75	69.01	5.00	0.22	69
Catchment_272	4.021	SCS Dimensionless	0.85	SCS Generalised	0.75	69.00	5.00	0.19	69
Catchment_273	5.431	SCS Dimensionless	0.85	SCS Generalised	0.75	69.29	4.95	0.11	69
Catchment_274	11.095	SCS Dimensionless	0.85	SCS Generalised	0.75	71.38	4.59	0.11	71
Catchment_275	4.239	SCS Dimensionless	0.85	SCS Generalised	0.75	69.09	4.98	0.13	69
Catchment_276	8.099	SCS Dimensionless	0.85	SCS Generalised	0.75	69.00	5.00	0.15	69
Catchment_277	10.089	SCS Dimensionless	0.85	SCS Generalised	0.75	69.14	4.98	0.18	69
Catchment_278	6.161	SCS Dimensionless	0.85	SCS Generalised	0.75	69.16	4.97	0.15	69
Catchment_279	8.507	SCS Dimensionless	0.85	SCS Generalised	0.75	71.07	4.64	0.16	71
Catchment_280	5.706	SCS Dimensionless	0.85	SCS Generalised	0.75	71.77	4.52	0.16	72
Catchment_281	5.914	SCS Dimensionless	0.85	SCS Generalised	0.75	70.05	4.82	0.23	70
Catchment_282	1.687	SCS Dimensionless	0.85	SCS Generalised	0.75	69.68	4.88	0.16	70
Catchment_282a	4.961	SCS Dimensionless	0.85	SCS Generalised	0.75	70.78	4.69	0.27	71
Catchment_283	6.812	SCS Dimensionless	0.85	SCS Generalised	0.75	72.57	4.38	0.13	73
Catchment_284	5.281	SCS Dimensionless	0.85	SCS Generalised	0.75	78.84	4.57	0.11	79
Catchment_285	6.644	SCS Dimensionless	0.85	SCS Generalised	0.75	69.11	4.98	0.13	69
Catchment_286	3.628	SCS Dimensionless	0.85	SCS Generalised	0.75	72.24	4.63	0.11	72
Catchment_287a	3.296	SCS Dimensionless	0.85	SCS Generalised	0.75	84.06	4.69	0.22	84
Catchment_288	3.619	SCS Dimensionless	0.85	SCS Generalised	0.75	79.39	4.88	0.11	79
Catchment_291	2.547	SCS Dimensionless	0.85	SCS Generalised	0.75	83.02	3.81	0.14	83
Catchment_292	2.283	SCS Dimensionless	0.85	SCS Generalised	0.75	69.08	4.99	0.17	69
Catchment_293	2.770	SCS Dimensionless	0.85	SCS Generalised	0.75	84.96	2.25	0.24	85
Catchment_294	2.409	SCS Dimensionless	0.85	SCS Generalised	0.75	83.10	2.57	0.11	83
Catchment_295	2.297	SCS Dimensionless	0.85	SCS Generalised	0.75	74.75	4.01	0.14	75
Catchment_296	3.721	SCS Dimensionless	0.85	SCS Generalised	0.75	75.23	3.93	0.16	75
Catchment_297	10.045	SCS Dimensionless	0.85	SCS Generalised	0.75	71.14	4.74	0.11	71
Catchment_298	8.548	SCS Dimensionless	0.85	SCS Generalised	0.75	75.27	4.47	0.16	75
Catchment_299	4.856	SCS Dimensionless	0.85	SCS Generalised	0.75	69.31	4.95	0.16	69
Catchment_300	6.032	SCS Dimensionless	0.85	SCS Generalised	0.75	69.00	5.00	0.16	69
Catchment_301	3.437	SCS Dimensionless	0.85	SCS Generalised	0.75	70.07	4.81	0.11	70
Catchment_302	7.122	SCS Dimensionless	0.85	SCS Generalised	0.75	69.17	4.97	0.22	69
Catchment_304	4.542	SCS Dimensionless	0.85	SCS Generalised	0.75	69.66	4.89	0.11	70
Catchment_305	4.751	SCS Dimensionless	0.85	SCS Generalised	0.75	72.98	4.31	0.21	73
Catchment_307	4.378	SCS Dimensionless	0.85	SCS Generalised	0.75	69.01	5.00	0.13	69
Catchment_308	0.717	SCS Dimensionless	0.85	SCS Generalised	0.75	77.28	3.57	0.18	77
Catchment_310	9.833	SCS Dimensionless	0.85	SCS Generalised	0.75	70.83	4.69	0.11	71

Existing Development MIKE Urban Catchment Parameters

Catchment ID	Area	Hydrograph	Cp	Loss Model	Runoff Coef	Curve Number	Initial abstraction	Lag Time	LT Curve Number
Catchment_311	2.402	SCS Dimensionless	0.85	SCS Generalised	0.75	80.71	2.72	0.11	81
Catchment_312	2.448	SCS Dimensionless	0.85	SCS Generalised	0.75	76.98	2.20	0.31	77
Catchment_313	3.321	SCS Dimensionless	0.85	SCS Generalised	0.75	85.62	2.14	0.16	86
Catchment_314	2.831	SCS Dimensionless	0.85	SCS Generalised	0.75	85.07	2.23	0.12	85
Catchment_315	2.871	SCS Dimensionless	0.85	SCS Generalised	0.75	76.38	3.52	0.11	76
Catchment_316	2.771	SCS Dimensionless	0.85	SCS Generalised	0.75	84.01	1.59	0.11	84
Catchment_317	3.259	SCS Dimensionless	0.85	SCS Generalised	0.75	62.02	3.75	0.24	62
Catchment_318	1.426	SCS Dimensionless	0.85	SCS Generalised	0.75	83.17	2.90	0.11	83
Catchment_318a	1.759	SCS Dimensionless	0.85	SCS Generalised	0.75	86.22	3.23	0.11	86
Catchment_319	3.108	SCS Dimensionless	0.85	SCS Generalised	0.75	77.38	2.10	0.19	77
Catchment_320	3.312	SCS Dimensionless	0.85	SCS Generalised	0.75	76.53	2.38	0.13	77
Catchment_321	1.598	SCS Dimensionless	0.85	SCS Generalised	0.75	79.11	3.26	0.11	79
Catchment_321a	1.136	SCS Dimensionless	0.85	SCS Generalised	0.75	88.15	1.70	0.11	88
Catchment_322	3.560	SCS Dimensionless	0.85	SCS Generalised	0.75	85.08	2.39	0.11	85
Catchment_323	3.311	SCS Dimensionless	0.85	SCS Generalised	0.75	85.14	2.07	0.11	85
Catchment_324	2.340	SCS Dimensionless	0.85	SCS Generalised	0.75	75.97	2.61	0.15	76
Catchment_325	3.051	SCS Dimensionless	0.85	SCS Generalised	0.75	61.25	3.75	0.11	61
Catchment_326	2.840	SCS Dimensionless	0.85	SCS Generalised	0.75	86.60	1.97	0.12	87
Catchment_327	1.044	SCS Dimensionless	0.85	SCS Generalised	0.75	86.61	1.63	0.15	87
Catchment_327a	1.767	SCS Dimensionless	0.85	SCS Generalised	0.75	85.68	1.95	0.11	86
Catchment_328	2.743	SCS Dimensionless	0.85	SCS Generalised	0.75	85.66	2.13	0.20	86
Catchment_329	2.533	SCS Dimensionless	0.85	SCS Generalised	0.75	85.59	2.14	0.11	86
Catchment_330	2.128	SCS Dimensionless	0.85	SCS Generalised	0.75	80.30	2.11	0.14	80
Catchment_330a	1.725	SCS Dimensionless	0.85	SCS Generalised	0.75	85.84	2.08	0.11	86
Catchment_331	2.031	SCS Dimensionless	0.85	SCS Generalised	0.75	81.47	2.85	0.11	81
Catchment_332	3.490	SCS Dimensionless	0.85	SCS Generalised	0.75	85.48	2.16	0.11	85
Catchment_333	3.435	SCS Dimensionless	0.85	SCS Generalised	0.75	85.68	2.12	0.14	86
Catchment_334	2.856	SCS Dimensionless	0.85	SCS Generalised	0.75	74.70	2.39	0.12	75
Catchment_335	2.985	SCS Dimensionless	0.85	SCS Generalised	0.75	85.68	2.05	0.11	86
Catchment_336	3.118	SCS Dimensionless	0.85	SCS Generalised	0.75	74.17	2.43	0.18	74
Catchment_337	2.086	SCS Dimensionless	0.85	SCS Generalised	0.75	70.70	2.79	0.11	71
Catchment_338	3.685	SCS Dimensionless	0.85	SCS Generalised	0.75	81.08	2.22	0.11	81
Catchment_340	2.598	SCS Dimensionless	0.85	SCS Generalised	0.75	62.70	3.89	0.12	63
Catchment_343	2.700	SCS Dimensionless	0.85	SCS Generalised	0.75	70.36	4.23	0.11	70
Catchment_345	3.535	SCS Dimensionless	0.85	SCS Generalised	0.75	80.51	2.24	0.18	81
Catchment_346	3.015	SCS Dimensionless	0.85	SCS Generalised	0.75	83.25	2.50	0.20	83
Catchment_347	3.501	SCS Dimensionless	0.85	SCS Generalised	0.75	83.12	2.33	0.23	83
Catchment_348a	1.176	SCS Dimensionless	0.85	SCS Generalised	0.75	91.92	2.17	0.11	92
Catchment_349	2.864	SCS Dimensionless	0.85	SCS Generalised	0.75	80.76	2.06	0.20	81
Catchment_351	2.419	SCS Dimensionless	0.85	SCS Generalised	0.75	82.04	1.94	0.11	82
Catchment_352	3.534	SCS Dimensionless	0.85	SCS Generalised	0.75	89.30	1.46	0.21	89
Catchment_353	2.996	SCS Dimensionless	0.85	SCS Generalised	0.75	82.50	2.67	0.11	82
Catchment_354	2.652	SCS Dimensionless	0.85	SCS Generalised	0.75	82.44	2.68	0.17	82
Catchment_355	2.687	SCS Dimensionless	0.85	SCS Generalised	0.75	73.85	4.16	0.11	74
Catchment_357	3.249	SCS Dimensionless	0.85	SCS Generalised	0.75	81.81	3.30	0.11	82
Catchment_358	2.727	SCS Dimensionless	0.85	SCS Generalised	0.75	80.01	2.57	0.11	80
Catchment_362	2.998	SCS Dimensionless	0.85	SCS Generalised	0.75	85.55	2.14	0.28	86
Catchment_363	2.832	SCS Dimensionless	0.85	SCS Generalised	0.75	77.35	2.11	0.15	77
Catchment_363a	0.724	SCS Dimensionless	0.85	SCS Generalised	0.75	78.63	1.98	0.11	79
Catchment_364	2.433	SCS Dimensionless	0.85	SCS Generalised	0.75	84.60	2.31	0.11	85
Catchment_366	1.213	SCS Dimensionless	0.85	SCS Generalised	0.75	84.37	1.39	0.11	84
Catchment_368	2.481	SCS Dimensionless	0.85	SCS Generalised	0.75	73.84	3.09	0.11	74
Catchment_370	3.279	SCS Dimensionless	0.85	SCS Generalised	0.75	75.52	2.62	0.15	76
Catchment_371	1.635	SCS Dimensionless	0.85	SCS Generalised	0.75	90.57	1.24	0.11	91
Catchment_371a	1.606	SCS Dimensionless	0.85	SCS Generalised	0.75	88.10	1.47	0.11	88
Catchment_372	2.079	SCS Dimensionless	0.85	SCS Generalised	0.75	69.54	4.91	0.11	70
Catchment_372a	1.139	SCS Dimensionless	0.85	SCS Generalised	0.75	67.66	4.99	0.11	68
Catchment_373	2.697	SCS Dimensionless	0.85	SCS Generalised	0.75	82.40	3.78	0.15	82
Catchment_374	1.770	SCS Dimensionless	0.85	SCS Generalised	0.75	85.53	1.41	0.11	86
Catchment_374a	1.452	SCS Dimensionless	0.85	SCS Generalised	0.75	89.63	2.62	0.11	90
Catchment_375	2.716	SCS Dimensionless	0.85	SCS Generalised	0.75	87.97	2.56	0.16	88
Catchment_376	0.914	SCS Dimensionless	0.85	SCS Generalised	0.75	64.15	3.45	0.14	64
Catchment_377	2.906	SCS Dimensionless	0.85	SCS Generalised	0.75	70.19	2.84	0.17	70
Catchment_378	2.874	SCS Dimensionless	0.85	SCS Generalised	0.75	84.35	2.02	0.17	84
Catchment_379	1.584	SCS Dimensionless	0.85	SCS Generalised	0.75	67.33	4.10	0.11	67
Catchment_379a	0.843	SCS Dimensionless	0.85	SCS Generalised	0.75	75.23	3.93	0.11	75
Catchment_380	2.749	SCS Dimensionless	0.85	SCS Generalised	0.75	70.63	4.49	0.11	71
Catchment_382	3.121	SCS Dimensionless	0.85	SCS Generalised	0.75	58.56	4.02	0.14	59
Catchment_382a	1.251	SCS Dimensionless	0.85	SCS Generalised	0.75	71.40	2.71	0.11	71
Catchment_387	2.308	SCS Dimensionless	0.85	SCS Generalised	0.75	66.45	3.77	0.11	66
Catchment_388	2.071	SCS Dimensionless	0.85	SCS Generalised	0.75	77.46	2.11	0.13	77
Catchment_389	3.098	SCS Dimensionless	0.85	SCS Generalised	0.75	51.77	4.72	0.15	52
Catchment_390	2.325	SCS Dimensionless	0.85	SCS Generalised	0.75	70.95	3.99	0.11	71
Catchment_390a	1.430	SCS Dimensionless	0.85	SCS Generalised	0.75	83.84	2.44	0.11	84
Catchment_391	3.001	SCS Dimensionless	0.85	SCS Generalised	0.75	77.93	2.30	0.11	78
Catchment_392	2.946	SCS Dimensionless	0.85	SCS Generalised	0.75	72.16	2.72	0.12	72
Catchment_393	1.949	SCS Dimensionless	0.85	SCS Generalised	0.75	77.85	2.43	0.11	78
Catchment_393a	1.530	SCS Dimensionless	0.85	SCS Generalised	0.75	77.14	2.13	0.34	77
Catchment_394	2.426	SCS Dimensionless	0.85	SCS Generalised	0.75	79.98	3.11	0.28	80
Catchment_395	3.330	SCS Dimensionless	0.85	SCS Generalised	0.75	77.64	2.08	0.11	78
Catchment_396	2.382	SCS Dimensionless	0.85	SCS Generalised	0.75	82.50	2.67	0.24	82
Catchment_397	2.482	SCS Dimensionless	0.85	SCS Generalised	0.75	74.20	2.43	0.11	74
Catchment_399	3.747	SCS Dimensionless	0.85	SCS Generalised	0.75	77.19	2.12	1.05	77
Catchment_400	2.388	SCS Dimensionless	0.85	SCS Generalised	0.75	70.01	3.03	0.15	70
Catchment_401	3.339	SCS Dimensionless	0.85	SCS Generalised	0.75	79.12	2.49	0.11	79

Existing Development MIKE Urban Catchment Parameters

Catchment ID	Area	Hydrograph	Cp	Loss Model	Runoff Coef	Curve Number	Initial abstraction	Lag Time	LT Curve Number
Catchment_402	4.042	SCS Dimensionless	0.85	SCS Generalised	0.75	80.20	2.23	0.11	80
Catchment_403	2.190	SCS Dimensionless	0.85	SCS Generalised	0.75	85.39	1.99	0.17	85
Catchment_406	1.968	SCS Dimensionless	0.85	SCS Generalised	0.75	84.20	2.09	0.11	84
Catchment_406a	1.309	SCS Dimensionless	0.85	SCS Generalised	0.75	80.29	2.47	0.11	80
Catchment_407	2.817	SCS Dimensionless	0.85	SCS Generalised	0.75	72.71	3.16	0.15	73
Catchment_408	2.893	SCS Dimensionless	0.85	SCS Generalised	0.75	78.05	2.04	0.17	78
Catchment_409	2.282	SCS Dimensionless	0.85	SCS Generalised	0.75	68.86	4.78	0.11	69
Catchment_410	3.512	SCS Dimensionless	0.85	SCS Generalised	0.75	81.22	2.63	0.22	81
Catchment_411	2.504	SCS Dimensionless	0.85	SCS Generalised	0.75	76.88	2.20	0.28	77
Catchment_412	2.420	SCS Dimensionless	0.85	SCS Generalised	0.75	76.01	2.24	0.13	76
Catchment_413	3.941	SCS Dimensionless	0.85	SCS Generalised	0.75	83.55	2.44	0.15	84
Catchment_414	5.375	SCS Dimensionless	0.85	SCS Generalised	0.75	74.27	4.09	0.11	74
Catchment_415	1.272	SCS Dimensionless	0.85	SCS Generalised	0.75	79.13	3.25	0.11	79
Catchment_415a	1.632	SCS Dimensionless	0.85	SCS Generalised	0.75	76.04	3.65	0.11	76

Future Development MIKE Urban Catchment Parameters

Catchment ID	Area	Cp	Runoff Coef	Curve Number	Initial abstraction	Lag Time	LT Curve Number
Catchment_208	2.999	0.85	0.75	84.62	1.63	0.11	85
Catchment_211	4.275	0.85	0.75	85.43	1.83	0.12	85
Catchment_211a	4.036	0.85	0.75	74.97	2.76	0.11	75
Catchment_212	5.446	0.85	0.75	77.40	2.12	0.13	77
Catchment_218	5.609	0.85	0.75	87.37	1.99	0.11	87
Catchment_220	3.143	0.85	0.75	89.01	1.55	0.11	89
Catchment_221	5.490	0.85	0.75	87.13	1.87	0.11	87
Catchment_222	0.949	0.85	0.75	88.92	1.57	0.11	89
Catchment_224	2.866	0.85	0.75	89.29	1.50	0.12	89
Catchment_225	2.244	0.85	0.75	89.29	1.50	0.15	89
Catchment_226	4.341	0.85	0.75	87.82	1.75	0.12	88
Catchment_227	0.932	0.85	0.75	86.59	1.97	0.13	87
Catchment_228	3.101	0.85	0.75	86.42	2.00	0.13	86
Catchment_229	2.109	0.85	0.75	87.97	1.73	0.19	88
Catchment_229a	2.890	0.85	0.75	89.71	1.43	0.13	90
Catchment_229b	2.017	0.85	0.75	88.62	1.62	0.22	89
Catchment_230	2.605	0.85	0.75	88.06	1.71	0.11	88
Catchment_231	2.316	0.85	0.75	89.41	2.05	0.11	89
Catchment_233	2.475	0.85	0.75	88.10	1.71	0.11	88
Catchment_235	2.432	0.85	0.75	96.48	0.26	0.11	96
Catchment_236	2.909	0.85	0.75	96.11	0.63	0.20	96
Catchment_237	2.435	0.85	0.75	94.67	0.87	0.11	95
Catchment_238	3.402	0.85	0.75	95.84	0.49	0.12	96
Catchment_239	2.231	0.85	0.75	86.39	2.00	0.14	86
Catchment_240	3.613	0.85	0.75	90.01	1.38	0.23	90
Catchment_241	2.089	0.85	0.75	89.42	1.48	0.11	89
Catchment_242	2.738	0.85	0.75	88.59	1.62	0.12	89
Catchment_243	3.425	0.85	0.75	83.17	2.56	0.14	83
Catchment_244	3.019	0.85	0.75	88.24	1.68	0.11	88
Catchment_247	1.921	0.85	0.75	86.66	2.23	0.14	87
Catchment_248	0.949	0.85	0.75	84.76	2.28	0.13	85
Catchment_252	2.807	0.85	0.75	87.28	1.85	0.13	87
Catchment_253	0.408	0.85	0.75	89.15	1.53	0.11	89
Catchment_254	3.639	0.85	0.75	72.88	4.33	0.21	73
Catchment_254a	1.822	0.85	0.75	84.52	2.32	0.11	85
Catchment_255	1.865	0.85	0.75	78.04	3.44	0.20	78
Catchment_256	2.517	0.85	0.75	85.15	2.22	0.11	85
Catchment_258	3.454	0.85	0.75	94.67	0.57	0.15	95
Catchment_260	6.462	0.85	0.75	90.05	1.37	0.11	90
Catchment_261	8.050	0.85	0.75	87.25	1.69	0.11	87
Catchment_262	6.164	0.85	0.75	82.44	1.63	0.29	82
Catchment_263	2.561	0.85	0.75	87.49	1.81	0.16	87
Catchment_264	4.764	0.85	0.75	90.25	1.34	0.11	90
Catchment_265	9.304	0.85	0.75	90.24	1.27	0.11	90
Catchment_266	5.792	0.85	0.75	88.36	1.09	0.11	88
Catchment_267	8.667	0.85	0.75	67.65	3.16	0.23	68
Catchment_268	3.622	0.85	0.75	91.76	1.22	0.11	92
Catchment_269	4.936	0.85	0.75	92.40	1.53	0.11	92
Catchment_270	5.817	0.85	0.75	82.11	1.62	0.18	82
Catchment_271	3.453	0.85	0.75	83.41	1.62	0.12	83
Catchment_272	4.021	0.85	0.75	88.32	1.67	0.11	88
Catchment_273	5.431	0.85	0.75	93.27	0.82	0.11	93
Catchment_274	11.095	0.85	0.75	90.94	1.31	0.11	91
Catchment_275	4.239	0.85	0.75	86.90	1.79	0.11	87
Catchment_276	8.099	0.85	0.75	81.72	1.93	0.14	82
Catchment_277	10.089	0.85	0.75	67.11	3.15	0.11	67
Catchment_278	6.161	0.85	0.75	89.63	1.44	0.12	90
Catchment_279	8.507	0.85	0.75	89.19	1.26	0.15	89
Catchment_280	5.706	0.85	0.75	87.09	1.73	0.11	87
Catchment_281	5.914	0.85	0.75	89.22	1.51	0.19	89
Catchment_282	1.687	0.85	0.75	89.57	1.45	0.11	90
Catchment_282a	4.961	0.85	0.75	83.83	1.69	0.14	84
Catchment_283	6.812	0.85	0.75	87.75	1.76	0.11	88
Catchment_284	5.281	0.85	0.75	84.05	2.40	0.11	84

Future Development MIKE Urban Catchment Parameters

Catchment ID	Area	Cp	Runoff Coef	Curve Number	Initial abstraction	Lag Time	LT Curve Number
Catchment_285	6.644	0.85	0.75	89.13	1.53	0.11	89
Catchment_286	3.628	0.85	0.75	89.12	1.53	0.13	89
Catchment_287a	3.296	0.85	0.75	80.75	1.77	0.11	81
Catchment_288	3.619	0.85	0.75	89.01	1.50	0.11	89
Catchment_291	2.547	0.85	0.75	78.08	2.03	0.17	78
Catchment_292	2.283	0.85	0.75	75.76	2.27	0.11	76
Catchment_293	2.770	0.85	0.75	84.45	1.78	0.11	84
Catchment_294	2.409	0.85	0.75	85.33	1.39	0.11	85
Catchment_295	2.297	0.85	0.75	84.76	2.03	0.11	85
Catchment_296	3.721	0.85	0.75	83.98	1.80	0.17	84
Catchment_297	10.045	0.85	0.75	86.32	1.98	0.20	86
Catchment_298	8.548	0.85	0.75	85.93	1.89	0.22	86
Catchment_299	4.856	0.85	0.75	92.76	1.87	0.11	93
Catchment_300	6.032	0.85	0.75	84.36	1.63	0.19	84
Catchment_301	3.437	0.85	0.75	89.25	1.06	0.11	89
Catchment_302	7.122	0.85	0.75	91.90	1.02	0.21	92
Catchment_304	4.542	0.85	0.75	89.62	1.44	0.11	90
Catchment_305	4.751	0.85	0.75	89.92	1.39	0.15	90
Catchment_307	4.378	0.85	0.75	90.22	1.34	0.11	90
Catchment_308	0.717	0.85	0.75	90.18	1.59	0.11	90
Catchment_310	9.833	0.85	0.75	85.61	1.77	0.11	86
Catchment_311	2.402	0.85	0.75	83.98	1.43	0.11	84
Catchment_312	2.448	0.85	0.75	89.80	1.41	0.26	90
Catchment_313	3.321	0.85	0.75	79.46	1.89	0.14	79
Catchment_314	2.831	0.85	0.75	80.36	1.80	0.11	80
Catchment_315	2.871	0.85	0.75	88.17	1.69	0.11	88
Catchment_316	2.771	0.85	0.75	89.03	0.92	0.11	89
Catchment_317	3.259	0.85	0.75	87.74	1.31	0.11	88
Catchment_318	1.426	0.85	0.75	85.56	1.45	0.13	86
Catchment_318a	1.759	0.85	0.75	93.07	0.82	0.11	93
Catchment_319	3.108	0.85	0.75	90.03	1.18	0.11	90
Catchment_320	3.312	0.85	0.75	86.40	2.00	0.11	86
Catchment_321	1.598	0.85	0.75	87.46	1.73	0.11	87
Catchment_321a	1.136	0.85	0.75	92.19	1.41	0.14	92
Catchment_322	3.560	0.85	0.75	89.34	0.98	0.11	89
Catchment_323	3.311	0.85	0.75	92.81	1.62	0.11	93
Catchment_324	2.340	0.85	0.75	92.82	1.32	0.16	93
Catchment_325	3.051	0.85	0.75	86.89	1.13	0.11	87
Catchment_326	2.840	0.85	0.75	82.91	1.54	0.15	83
Catchment_327	1.044	0.85	0.75	86.32	1.73	0.16	86
Catchment_327a	1.767	0.85	0.75	83.20	1.98	0.11	83
Catchment_328	2.743	0.85	0.75	89.01	1.55	0.11	89
Catchment_329	2.533	0.85	0.75	87.03	1.80	0.11	87
Catchment_330	2.128	0.85	0.75	85.98	1.23	0.11	86
Catchment_330a	1.725	0.85	0.75	86.13	1.42	0.11	86
Catchment_331	2.031	0.85	0.75	81.99	1.64	0.13	82
Catchment_332	3.490	0.85	0.75	78.16	2.02	0.11	78
Catchment_333	3.435	0.85	0.75	88.00	1.47	0.11	88
Catchment_334	2.856	0.85	0.75	89.42	1.48	0.11	89
Catchment_335	2.985	0.85	0.75	81.37	1.91	0.11	81
Catchment_336	3.118	0.85	0.75	84.39	1.43	0.11	84
Catchment_337	2.086	0.85	0.75	83.21	1.78	0.11	83
Catchment_338	3.685	0.85	0.75	82.19	1.61	0.32	82
Catchment_340	2.598	0.85	0.75	89.58	1.45	0.25	90
Catchment_343	2.700	0.85	0.75	80.27	1.81	0.11	80
Catchment_345	3.535	0.85	0.75	91.36	1.14	0.22	91
Catchment_346	3.015	0.85	0.75	83.97	1.43	0.11	84
Catchment_347	3.501	0.85	0.75	81.50	1.68	1.00	82
Catchment_348a	1.176	0.85	0.75	85.12	1.40	0.12	85
Catchment_349	2.864	0.85	0.75	84.84	1.73	0.11	85
Catchment_351	2.419	0.85	0.75	82.96	1.88	0.11	83
Catchment_352	3.534	0.85	0.75	90.63	1.16	0.16	91
Catchment_353	2.996	0.85	0.75	87.13	1.65	0.11	87
Catchment_354	2.652	0.85	0.75	84.08	1.94	0.11	84

Future Development MIKE Urban Catchment Parameters

Catchment ID	Area	Cp	Runoff Coef	Curve Number	Initial abstraction	Lag Time	LT Curve Number
Catchment_355	2.687	0.85	0.75	81.88	2.01	0.14	82
Catchment_357	3.249	0.85	0.75	83.59	1.47	0.16	84
Catchment_358	2.727	0.85	0.75	71.46	4.35	0.11	71
Catchment_362	2.998	0.85	0.75	84.63	2.10	0.22	85
Catchment_363	2.832	0.85	0.75	82.37	1.63	0.26	82
Catchment_363a	0.724	0.85	0.75	79.96	1.84	0.12	80
Catchment_364	2.433	0.85	0.75	87.13	1.84	0.15	87
Catchment_366	1.213	0.85	0.75	90.48	1.30	0.11	90
Catchment_368	2.481	0.85	0.75	88.77	1.59	0.11	89
Catchment_370	3.279	0.85	0.75	88.43	1.59	0.11	88
Catchment_371	1.635	0.85	0.75	88.20	2.00	0.11	88
Catchment_371a	1.606	0.85	0.75	84.46	1.95	0.12	84
Catchment_372	2.079	0.85	0.75	71.90	4.50	0.15	72
Catchment_372a	1.139	0.85	0.75	79.91	1.85	0.20	80
Catchment_373	2.697	0.85	0.75	79.26	1.91	0.12	79
Catchment_374	1.770	0.85	0.75	87.18	2.09	0.11	87
Catchment_374a	1.452	0.85	0.75	74.10	4.12	0.12	74
Catchment_375	2.716	0.85	0.75	76.54	3.05	0.22	77
Catchment_376	0.914	0.85	0.75	82.64	2.65	0.11	83
Catchment_377	2.906	0.85	0.75	81.83	2.64	0.11	82
Catchment_378	2.874	0.85	0.75	71.09	4.49	0.21	71
Catchment_379	1.584	0.85	0.75	86.78	1.93	0.11	87
Catchment_379a	0.843	0.85	0.75	86.97	1.95	0.11	87
Catchment_380	2.749	0.85	0.75	82.33	1.60	0.21	82
Catchment_382	3.121	0.85	0.75	89.83	1.41	0.17	90
Catchment_382a	1.251	0.85	0.75	89.62	1.44	0.12	90
Catchment_387	2.308	0.85	0.75	88.29	1.67	0.14	88
Catchment_388	2.071	0.85	0.75	88.95	1.56	0.11	89
Catchment_389	3.098	0.85	0.75	90.01	1.38	0.22	90
Catchment_390	2.325	0.85	0.75	89.64	1.44	0.11	90
Catchment_390a	1.430	0.85	0.75	64.10	4.26	0.11	64
Catchment_391	3.001	0.85	0.75	85.74	2.11	0.11	86
Catchment_392	2.946	0.85	0.75	86.40	2.00	0.18	86
Catchment_393	1.949	0.85	0.75	88.92	1.56	0.18	89
Catchment_393a	1.530	0.85	0.75	94.14	0.67	0.16	94
Catchment_394	2.426	0.85	0.75	88.26	1.14	0.11	88
Catchment_395	3.330	0.85	0.75	87.17	1.87	0.27	87
Catchment_396	2.382	0.85	0.75	89.94	1.35	0.11	90
Catchment_397	2.482	0.85	0.75	90.95	0.77	0.19	91
Catchment_399	3.747	0.85	0.75	82.59	1.65	0.14	83
Catchment_400	2.388	0.85	0.75	93.09	0.85	0.12	93
Catchment_401	3.339	0.85	0.75	93.08	0.85	0.15	93
Catchment_402	4.042	0.85	0.75	89.90	1.16	0.16	90
Catchment_403	2.190	0.85	0.75	91.71	1.73	0.13	92
Catchment_406	1.968	0.85	0.75	88.32	1.67	0.11	88
Catchment_406a	1.309	0.85	0.75	87.54	1.80	0.11	88
Catchment_407	2.817	0.85	0.75	87.64	1.79	0.11	88
Catchment_408	2.893	0.85	0.75	85.70	2.12	0.11	86
Catchment_409	2.282	0.85	0.75	87.91	1.74	0.11	88
Catchment_410	3.512	0.85	0.75	87.51	1.81	0.11	88
Catchment_411	2.504	0.85	0.75	82.64	2.65	0.11	83
Catchment_412	2.420	0.85	0.75	77.90	3.47	0.19	78
Catchment_413	3.941	0.85	0.75	81.13	2.91	0.18	81
Catchment_414	5.375	0.85	0.75	88.11	1.70	0.11	88
Catchment_415	1.272	0.85	0.75	83.91	2.43	0.18	84
Catchment_415a	1.632	0.85	0.75	79.75	3.15	0.17	80

Existing Development MIKE 11 Catchment Parameters

Name	Area	RunoffCoef	LossCurveNum	LagTime
CATCHMENT 209	0.018	0.75	80	0.16
CATCHMENT 213	0.047	0.75	85	0.28
CATCHMENT 214	0.055	0.75	69	0.11
CATCHMENT 215	0.038	0.75	86	0.11
CATCHMENT 216	0.030	0.75	70	0.11
CATCHMENT 217	0.079	0.75	75	0.11
CATCHMENT 219	0.035	0.75	76	0.11
CATCHMENT 246	0.023	0.75	79	0.19
CATCHMENT 249	0.029	0.75	85	0.11
CATCHMENT 250	0.013	0.75	83	0.11
CATCHMENT 251	0.096	0.75	72	0.13
CATCHMENT 251A	0.026	0.75	78	0.11
CATCHMENT 287	0.036	0.75	74	0.14
CATCHMENT 289	0.054	0.75	71	0.15
CATCHMENT 290	0.027	0.75	71	0.24
CATCHMENT 303	0.049	0.75	69	0.21
CATCHMENT 306	0.080	0.75	70	0.14
CATCHMENT 309	0.032	0.75	71	0.13
CATCHMENT 339	0.029	0.75	74	0.11
CATCHMENT 341	0.025	0.75	84	0.11
CATCHMENT 342	0.023	0.75	89	0.19
CATCHMENT 344	0.032	0.75	80	0.16
CATCHMENT 348	0.021	0.75	91	0.11
CATCHMENT 350	0.025	0.75	80	0.11
CATCHMENT 356	0.030	0.75	65	0.11
CATCHMENT 359	0.034	0.75	74	0.11
CATCHMENT 360	0.030	0.75	58	0.17
CATCHMENT 361	0.037	0.75	74	0.11
CATCHMENT 367	0.024	0.75	77	0.11
CATCHMENT 381	0.023	0.75	72	0.15
CATCHMENT 383	0.026	0.75	67	0.30
CATCHMENT 384	0.030	0.75	62	0.45
CATCHMENT 385	0.026	0.75	73	0.40
CATCHMENT 386	0.024	0.75	75	0.44
CATCHMENT 404	0.031	0.75	83	0.31
CATCHMENT 405	0.028	0.75	82	0.44

Future Development MIKE 11 Catchment Parameters

Name	Area	RunoffCoef	LossCurveNum	LagTime
CATCHMENT 209	0.018	0.75	80	0.16
CATCHMENT 213	0.047	0.75	85	0.28
CATCHMENT 214	0.055	0.75	69	0.11
CATCHMENT 215	0.038	0.75	86	0.11
CATCHMENT 216	0.030	0.75	70	0.11
CATCHMENT 217	0.079	0.75	75	0.11
CATCHMENT 219	0.035	0.75	76	0.11
CATCHMENT 246	0.023	0.75	79	0.19
CATCHMENT 249	0.029	0.75	85	0.11
CATCHMENT 250	0.013	0.75	83	0.11
CATCHMENT 251	0.096	0.75	72	0.13
CATCHMENT 251A	0.026	0.75	78	0.11
CATCHMENT 287	0.036	0.75	74	0.14
CATCHMENT 289	0.054	0.75	71	0.15
CATCHMENT 290	0.027	0.75	71	0.24
CATCHMENT 303	0.049	0.75	69	0.21
CATCHMENT 306	0.080	0.75	70	0.14
CATCHMENT 309	0.032	0.75	71	0.13
CATCHMENT 339	0.029	0.75	74	0.11
CATCHMENT 341	0.025	0.75	84	0.11
CATCHMENT 342	0.023	0.75	89	0.19
CATCHMENT 344	0.032	0.75	80	0.16
CATCHMENT 348	0.021	0.75	91	0.11
CATCHMENT 350	0.025	0.75	80	0.11
CATCHMENT 356	0.030	0.75	65	0.11
CATCHMENT 359	0.034	0.75	74	0.11
CATCHMENT 360	0.030	0.75	58	0.17
CATCHMENT 361	0.037	0.75	74	0.11
CATCHMENT 367	0.024	0.75	77	0.11
CATCHMENT 381	0.023	0.75	72	0.15
CATCHMENT 383	0.026	0.75	67	0.30
CATCHMENT 384	0.030	0.75	62	0.45
CATCHMENT 385	0.026	0.75	73	0.40
CATCHMENT 386	0.024	0.75	75	0.44
CATCHMENT 404	0.031	0.75	83	0.31
CATCHMENT 405	0.028	0.75	82	0.44

Appendix B

Model Results and Maps

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Rev.	By	App.	Description	Date

Notes:

Printed		GIS File	
Approved		Date	07/08/2015
Designed		Checked	
Drawn		Checked	
	Name		

Map features depicted in terms of NZTM projection.

Data Sources:
LINZ National Topographic Dataset 2006.
Watercare GIS Data 2008.
Metrowater GIS Data 2008.

AECOM

Project: **Te Awa O Katapaki Stormwater Modelling**

Title: **ED 2 Year ARI Model Results**
Maximum Water Depth

Scale: Scale: 1:6,000 (A1 size)

0.06 0.03 0 0.06 0.12 0.18 0.24 0.3 Kilometres

Map No. **MR01**

Rev. **B**

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Rev.	By	App.	Description	Date

Notes:

Printed		GIS File	
Approved		Date	07/08/2015
Designed		Checked	
Drawn		Checked	
	Name		

Map features depicted in terms of NZTM projection.

Data Sources:
LINZ National Topographic Dataset 2006.
Watercare GIS Data 2008.
Metrowater GIS Data 2008.

AECOM

Project: Te Awa O Katapaki Stormwater Modelling

Title: ED 2 Year ARI Model Results
Maximum Flow Velocities

Scale: 1:6,000 (A1 size)

0.06 0.03 0 0.06 0.12 0.18 0.24 0.3 Kilometres

Map No. MR01

Rev. B

07 Aug 2015 16:16

Rev	By	App	Description	Date

Notes:

Printed		GIS File	
Approved		Date	07/08/2015
Designed		Checked	
Drawn		Checked	
	Name		

Map features depicted in terms of NZTM projection.

Data Sources:
LINZ National Topographic Dataset 2006.
Watercare GIS Data 2008.
Metrowater GIS Data 2008.

AECOM

Project: **Te Awa O Katapaki Stormwater Modelling**

Title: **ED 10 Year ARI Model Results**
Maximum Water Depth

Scale: 1:6,000 (A1 size)

0.06 0.03 0 0.06 0.12 0.18 0.24 0.3 Kilometres

Map No. **MR01** Rev. **B**

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Rev.	By	App.	Description	Date

Notes:

Printed		GIS File	
Approved		Date	07/08/2015
Designed		Checked	
Drawn		Checked	
	Name		

Map features depicted in terms of NZTM projection.

Data Sources:
LINZ National Topographic Dataset 2006.
Watercare GIS Data 2008.
Metrowater GIS Data 2008.

AECOM

Project: **Te Awa O Katapaki Stormwater Modelling**

Title: **ED 10 Year ARI Model Results**
Maximum Flow Velocities

Scale: 1:6,000 (A1 size)

0.06 0.03 0 0.06 0.12 0.18 0.24 0.3 Kilometres

Map No. **MR01**

Rev. **B**

07 Aug 2015 16:16

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Rev.	By	App.	Description	Date

Notes:

Printed		GIS File	
Approved		Date	07/08/2015
Designed		Checked	
Drawn		Checked	
	Name		

Map features depicted in terms of NZTM projection.

Data Sources:
LINZ National Topographic Dataset 2006.
Watercare GIS Data 2008.
Metrowater GIS Data 2008.

AECOM

Project: **Te Awa O Katapaki Stormwater Modelling**

Title: **ED 100 Year ARI (including climate change) Model Results Maximum Water Depth**

Scale: Scale: 1:6,000 (A1 size)

0.06 0.03 0 0.06 0.12 0.18 0.24 0.3 Kilometres

Map No. **MR01** Rev. **B**

07 Aug 2015 16:16

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Rev.	By	App.	Description	Date

Notes:

Printed		GIS File	
Approved		Date	07/08/2015
Designed		Checked	
Drawn		Checked	
	Name		

Map features depicted in terms of NZTM projection.

Data Sources:
LINZ National Topographic Dataset 2006.
Watercare GIS Data 2008.
Metrowater GIS Data 2008.

AECOM

Project: **Te Awa O Katapaki Stormwater Modelling**

Title: **ED 100 Year ARI (including climate change) Model Results Maximum Flow Velocities**

Scale: Scale: 1:6,000 (A1 size)

0.06 0.03 0 0.06 0.12 0.18 0.24 0.3 Kilometres

Map No. **MR01**

Rev. **B**

07 Aug 2015 16:16

C:\Users\granwall\Desktop\TAOK_MAP.mxd

Rev.	By	App.	Description	Date

Notes:

Printed		GIS File	
Approved		Date	07/08/2015
Designed		Checked	
Drawn		Checked	
	Name		

Map features depicted in terms of NZTM projection.

Data Sources:
LINZ National Topographic Dataset 2006.
Watercare GIS Data 2008.
Metrowater GIS Data 2008.

AECOM

Project: **Te Awa O Katapaki Stormwater Modelling**

Title: **ED 100 Year ARI (including climate change) Model Results Smoothed Hazard Factors**

Scale: 1:6,000 (A1 size)

0.06 0.03 0 0.06 0.12 0.18 0.24 0.3 Kilometres

Map No. **MR01** Rev. **B**

Rev.	By	App.	Description	Date

Notes:

Printed		GIS File	
Approved		Date	07/08/2015
Designed		Checked	
Drawn		Checked	
	Name		

Map features depicted in terms of NZTM projection.

Data Sources:
LINZ National Topographic Dataset 2006.
Watercare GIS Data 2008.
Metrowater GIS Data 2008.

AECOM

Project: **Te Awa O Katapaki Stormwater Modelling**

Title: **MPD 2 Year ARI (including climate change) Model Results Maximum Water Depth**

Scale: 1:6,000 (A1 size)

0.06 0.03 0 0.06 0.12 0.18 0.24 0.3 Kilometres

Map No. **MR01** Rev. **B**

07 Aug 2015 16:16

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Rev.	By	App.	Description	Date

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	Name		

Map features depicted in terms of NZTM projection.

Data Sources:
LINZ National Topographic Dataset 2006.
Watercare GIS Data 2008.
Metrowater GIS Data 2008.

AECOM

Project: **Te Awa O Katapaki Stormwater Modelling**

Title: **MPD 2 Year ARI (including climate change) Model Results**
Maximum Flow Velocities

Scale: 1:6,000 (A1 size)

0.06 0.03 0 0.06 0.12 0.18 0.24 0.3 Kilometres

Map No. **MR01** Rev. **B**

07 Aug 2015 16:16

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Rev.	By	App.	Description	Date

Notes:

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Approved		Date	07/08/2015
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Map features depicted in terms of NZTM projection.

Data Sources:
LINZ National Topographic Dataset 2006.
Watercare GIS Data 2008.
Metrowater GIS Data 2008.

AECOM

Project: Te Awa O Katapaki Stormwater Modelling

MPD 10 Year ARI (including climate change) Model Results
Maximum Water Depth

Scale: 1:6,000 (A1 size)

Map No. MR01 Rev. B

07 Aug 2015 16:16

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Rev.	By	App.	Description	Date

Notes:

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Approved		Date	07/08/2015
Designed		Checked	
Drawn		Checked	
	Name		

Map features depicted in terms of NZTM projection.

Data Sources:
LINZ National Topographic Dataset 2006.
Watercare GIS Data 2008.
Metrowater GIS Data 2008.

AECOM

Project: Te Awa O Katapaki Stormwater Modelling

Title: MPD 10 Year ARI (including climate change) Model Results
Maximum Flow Velocities

Scale: 1:6,000 (A1 size)

0.06 0.03 0 0.06 0.12 0.18 0.24 0.3 Kilometres

Map No. MR01

Rev. B

07 Aug 2015 16:16

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Rev.	By	App.	Description	Date

Notes:

Printed		GIS File	
Approved		Date	07/08/2015
Designed		Checked	
Drawn		Checked	
	Name		

Map features depicted in terms of NZTM projection.

Data Sources:
LINZ National Topographic Dataset 2006.
Watercare GIS Data 2008.
Metrowater GIS Data 2008.

AECOM

Project: **Te Awa O Katapaki Stormwater Modelling**

Title: **MPD 100 Year ARI (including climate change) Model Results**
Maximum Water Depth

Scale: 1:6,000 (A1 size)

0.06 0.03 0 0.06 0.12 0.18 0.24 0.3 Kilometres

Map No. **MR01** Rev. **B**

07 Aug 2015 16:16

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Rev.	By	App.	Description	Date

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Printed		GIS File	
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	Name		

Map features depicted in terms of NZTM projection.

Data Sources:
LINZ National Topographic Dataset 2006.
Watercare GIS Data 2008.
Metrowater GIS Data 2008.

AECOM

Project: **Te Awa O Katapaki Stormwater Modelling**

Title: **MPD 100 Year ARI (including climate change) Model Results Maximum Flow Velocities**

Scale: 1:6,000 (A1 size)

0.06 0.03 0 0.06 0.12 0.18 0.24 0.3 Kilometres

Map No. **MR01** Rev. **B**

Appendix L Model Build Peer Review

410 Colombo Street, Sydenham
PO Box 13960, Christchurch 8141, New Zealand
T: +64 3 366 3521 // **F:** +64 3 366 3188
E: info@beca.com // **www.beca.com**

Hamilton City Council
Private Bag 3010
Hamilton 3240
New Zealand

27 May 2016

Attention: Raewyn Simpson

Dear Rae

TAOK Stormwater Model Build Report - Review

We have carried out our initial review of AECOM's report titled ***Stormwater Model Build Report*** (the Report) prepared to inform the Te Awa o Katapaki Catchment Management Plan, and dated 21 August 2015.

The review has been undertaken using a 0-3 scoring system (described in the table below) which flags up issues that will affect the use and acceptability of the report and underlying modelling. Please note that we have not yet reviewed the models, input data, or detailed results/outputs (currently underway). This report will be revised once this subsequent work has been completed.

Review rating scheme

Description	Review rating
No issue: The element or information being reviewed is acceptable, but may include a suggestion to improve understanding.	0
Minor issue: There is an issue, but it is unlikely to significantly affect results or conclusions.	1
Major issue: Failure to resolve the issue compromises the report or model, and should be rectified. It may be resolved by explanation or acceptance of limitations.	2
Fatal flaw: Failure to resolve this issue severely compromises the report or model, and must be rectified.	3

The following table contains the review.

Report item	Findings & Comments	Rating
Front page	The date at the top of the front page shows the year as "20155", rather than '2015"	1
1.0 Introduction and Background		
Text	The text for this section reads well, and explains the catchment and context within the ICMP process.	0
Figure 1	The map should be annotated to identify the location of various roads, culverts, ponds, and other features referenced later in the report. Alternatively, additional location maps could be provided at the appropriate location in the report (see later comments).	1

Report item	Findings & Comments	Rating
2.0 Scope		
Existing development	The existing scenario should be clearly defined. I assume that it is the catchment ground model and development in 2013, but it is unclear. Re-naming the scenario as 'Baseline 2013' would solve the problem.	**2**
Future scenario	Would this be better re-named as the Maximum Probable Development (MPD) scenario? We note that there is no mitigation that would affect flood depths or extents (the only mitigation is the stilling basin at the Magellan Lake outfall, which only has a local effect on velocities), and so mitigation model runs are not required	**1**
Add a bullet point	The list includes the optimisation of two proposed weirs (Report section 5.3), but doesn't include the optimisation of the Magellan Lake outlet (Report section 5.2).	**1**
3.0 Methodology		
2)	If the 2015 drone survey been added to existing model build, then what is the baseline year for the existing scenario? Is it 2015, rather the 2013 that I have assumed. *Note the comments under 4.2.2 regarding how different data are tied together.*	**2**
7)	Reference Figure 4	**0**
4.0 Model Development		
4.1	It's worth a sentence or two to confirm whether there are any bugs in MIKE version 2011 or subsequent changes in the software that might affect the model results.	**0**
4.2.1 a) to c)	Should reference Hamilton City Council's ***Standard Stormwater Modelling Methodology*** (HCC 2013) for these items	**0**
4.2.1 d)	The way that this paragraph is written implies that the critical duration storm for all parts of the catchment is 12 hours, whereas I assume that this it is meant to imply that a nested 12 hour storm profile will include the critical durations for all parts of the catchment.	**1**
4.2.1 e)	Are any parts of the modelled catchment sensitive to the downstream water level?	**1**
4.2.1 f)	What unit hydrograph method is used; SCS, Clark, etc?	**1**

Report item	Findings & Comments	Rating
4.2.2	It is unclear which bullet points refer to development of the existing terrain and which to the future terrain.	1
	The LiDAR and information provided by developers is “assumed to be correct”. I am aware of issues in other parts of the country where flood hazard maps are not accepted by the local community, in part because of uncertainty over survey and LiDAR accuracy. Would sensitivity to lidar accuracy range effect any results on hazards? If checks have been made on survey accuracy, then they should be reported as such. This may prevent difficulties further into the ICMP process. How have data from different sources been joined together, and has this been quality checked.	2
4.2.2 a)	The 2nd sentence refers to changes made to account for LiDAR picking up water surface rather than channel invert. That’s correct, but it is probably worth referring to 4.2.2 c) as well.	1
4.2.2 b)	Are these developments included in both the existing and future terrain models? Similar issue as raised under 2.0. What is the baseline year for the existing model? Clarification also required for 4.2.2 j).	2
4.2.2 f)	Were any checks for anomalies undertaken?	1
4.2.2 k)	A map and (before & after) cross-sections of the affected area should be included.	1
4.2.3	Maps of existing and future imperviousness, and roughness should be provided	1
Table 3	Manning’s ‘n’ values are normally shown to 3 decimal places.	1
4.2.4 a)	Worth referencing the source of the inlet capacity figure.	0
4.2.4 b) & c)	Was an assessment done as to the susceptibility to blockage of culverts in this catchment, in order to confirm the approach of not using blockage?	1
4.3 and Figure 2	Only one sub-catchment map is provided. Were the sub-catchment boundaries and outlet locations the same for both the existing and future model scenarios, or were there any changes in catchment size or re-direction of outlet?	2
4.4.1	1st paragraph – Table 2 implies that stream channels were also defined by survey. Please confirm	1
	As noted with reference to Figure 1, key locations mentioned in the text should be identified on catchment maps for reference	1
4.4.2	Was a minimum pipe size of 225 mm assumed for the future model areas that are still to be developed? Please confirm	1
Table 4	Is there any change in the number of asset data types between the existing and future models?	1

Report item	Findings & Comments	Rating
	There are 615 manhole ground levels, but 607 manhole invert levels. Should they be the same number?	1
4.4.3.1	2nd paragraph – How significant are the discrepancies between the GIS and model terrain ground levels (GL)? Was it generally found that inverts were OK and GL wrong, or was it that both were incorrect?	2
	5th paragraph – Does the 1.35 m weir length represent the circumference of the manhole grate?	1
Table 6	How was it decided whether pipes/culverts were normal or smooth?	1
	N=0.005 looks low. What is the reference for this?	1
	A map may assist in identifying which pipes/culverts are smooth or normal.	1
4.6	There are various flood hazard standards, depending on whether it is hazard to life or property. I assume that this relates to life.	0
4.6.1	Have flood hazard maps for future scenarios been modelled? The previous sentence under 4.6 only mentions existing, but the 4.6.1 sub-heading mentions both.	1
5.0 Results		
5.0	A catchment map should be provided to identify the five locations listed.	1
5.1.1 to 5.1.5	Only an existing flood hazard maps is shown. Future maps should also be provided, so that the change in flood hazard can be identified. The change in flood hazard is not reported for any of the five locations.	2
	All maps should be annotated to clearly identified locations being referred to in the text.	1
	Though it is reasonably clear that Figure 5 and Table 9 relate to Borman Road, the figure and table are not referenced in the text. This issue applies to 5.1.2 to 5.1.5 as well.	1
Table 9	A small table such as this shouldn't be spilt over two pages.	0
Tables 10 and 11	The elevations are the same for both tables. This implies that water is ponded through the culvert, with no flow (as there is no headloss) under max elevation conditions. Yet, this is not commented on in the text.	1
5.1.5	The elevations suggest that this reach is influenced by the downstream boundary (Waikato water level). If that is the case, I would expect some commentary on the sensitivity of the reach to the boundary condition. Given the doubling of 100-year flow, this could be significant.	1
Figure 10	The text in Figure 10 is unreadable. As such, it has limited value. If plots are to be included, then it would be worth having plots showing with and without the stilling basin.	1

Report item	Findings & Comments	Rating
Table 14	The sentence above the table indicates that Table 14 will include results for with and without the stilling basin, but only one set of results is provided. I assume that they are the ‘with basin’ results, but a comparison cannot be made.	1
5.2	The last sentence of the last paragraph is a key conclusion, to which attention should be drawn.	1
5.3	A map is needed to locate the two potential weir sites (and the attenuation areas behind the weirs)	1
	Rejection of the feasibility of providing storage/attenuation at either of the weir sites means that ‘hydrological neutrality’ is not achieved within the catchment in terms of matching pre- and post-development peak flows. No mention is made in the report of changes in flood volumes, or consideration given to providing storage/attenuation in parts of the catchment still to be developed. Are there any effects of increasing peak flows and flood volumes into the Waikato River? While increases from one 700 ha catchment are unlikely to have noticeable effects flood risk downstream, the potential cumulative effects of increases from multiple catchments should be acknowledged and assessed, even if the not attenuating runoff is a conscious decision to discharge runoff out of the catchment prior to the arrival of the peak water levels in the Waikato.	2
Report Conclusions	There is not a Conclusions or Summary section to the report, though there is an Executive Summary that fulfils some of the same roles. It is recommended that a Conclusions or summary section is included. This could include an explanation as to why mitigation measures were not pursued further, and commentary on the accuracy of the modelling.	2

From the information provided in the model report, it appears that the modelling generally meets appropriate standards and provides a useful tool to inform the ICMP. The review of the model itself (which is underway) is required to confirm that view. However, the review of the report has raised a number of questions about what has been modelled and how. We suggest that most of these questions and issues will be resolved through clarification and additional explanation.

In its current state, the model report merely describes the modelling and presents some results. As noted in the last point in the table, there should be an attempt to explain the results of the modelling, particularly where:

- The modelling approach or range of modelled scenarios raise questions
- Results are particularly sensitive to assumptions or boundary conditions.

We assume that the ICMP is not recommending any measures such as Extended Detention for downstream watercourse scour control that would then feed back into flood hazard modelling. If controls are needed for this reason it will impact on the flood modelling. This could be confirmed in a Conclusions section of the report.

In the 2nd to last point in the table, we raise the issue of hydrological neutrality. This has not been met. We are not aware of how HCC would deal with this (exemption to standards given etc) and the implications on downstream communities along the Waikato River. This may be dealt with through explanation from the modellers or by HCC either in the report or, more likely, in the ICMP.

If you have any questions, I would be happy to discuss them with you, or the modellers.

Yours sincerely

Michael Law
Associate - Water Resources

on behalf of

CH2M Beca Ltd

Direct Dial: +64 3 371 3666
Email: michael.law@beca.com

Copy

Iain Smith, Beca Ltd
Andrea Phillips, HCC

Appendix M Stormwater Quantity Beca Memo 2021

Memorandum

To:	Andrea Phillips	**Date:**	31 March 2021
From:	Ari Craven	**Our Ref:**	3414272
Copy:	Melissa Slatter		
Subject:	TAOK Consent Review Final		

1 Introduction

Hamilton City Council (HCC) are currently in the process of finalising the Te Awa O Kata (TAOK) Integrated Catchment Management Plan (ICMP). The ICMP has existed in draft format for a number of years and during this time a number of developments have been consented (and constructed) within the TAOK catchment. Beca Ltd have been engaged to undertake the following:

- Review of the consents granted since the TAOK ICMP was drafted (approximately circa 2012). Assessment of the consented stormwater quantity management approached against the proposed mean of compliance in the ICMP.
- Review of the management of two major overland flowpaths within the upper TAOK catchment; the Bourne Brook Swale and the Borman Road overland flowpath.
- Provide an overview of the TAOK flood model peer review process. This has been undertaken in a number of stages, with no final documentation previously produced summarising all stage sof the review.

2 Consent Review

Development consent data (stormwater reports) for the TAOK catchment was extracted by HCC Develop Engineering (DE) staff and supplied for use in this assessment. Each consent application was reviewed against the attenuation components of the stormwater means of compliance tables in the draft TAOK ICMP (refer Chapter 11 of the ICMP). Table 1 summarises management requirements for the 2y, 10y and 100y ARI events. Figure 1 shows a spatial representation of the consent supplied and reviewed as part of this process. The ICMP sub-catchments indicated in pink corelate to unique means of compliance requirements in the ICMP.

Table 1 – Summary of ICMP compliance requirements

ICMP Sub-Catchment	2y ARI Attenuation	10y ARI Attenuation	100y ARI Attenuation
Expressway West	Yes	Yes	No
Expressway East	Yes	Yes	Yes
Upper West	Yes	Yes	No
Upper East Pipeline	Yes	Yes	Yes
Upper East	Yes	Yes	Yes
Resolution Drive	N/A – under separate sub-catchment ICMP		

Southern	Yes	Yes	No
Lower[1]	No	No	No
Featherstone Park[1]	No	No	No
River North[1]	No	No	No

1. Extended detention required only

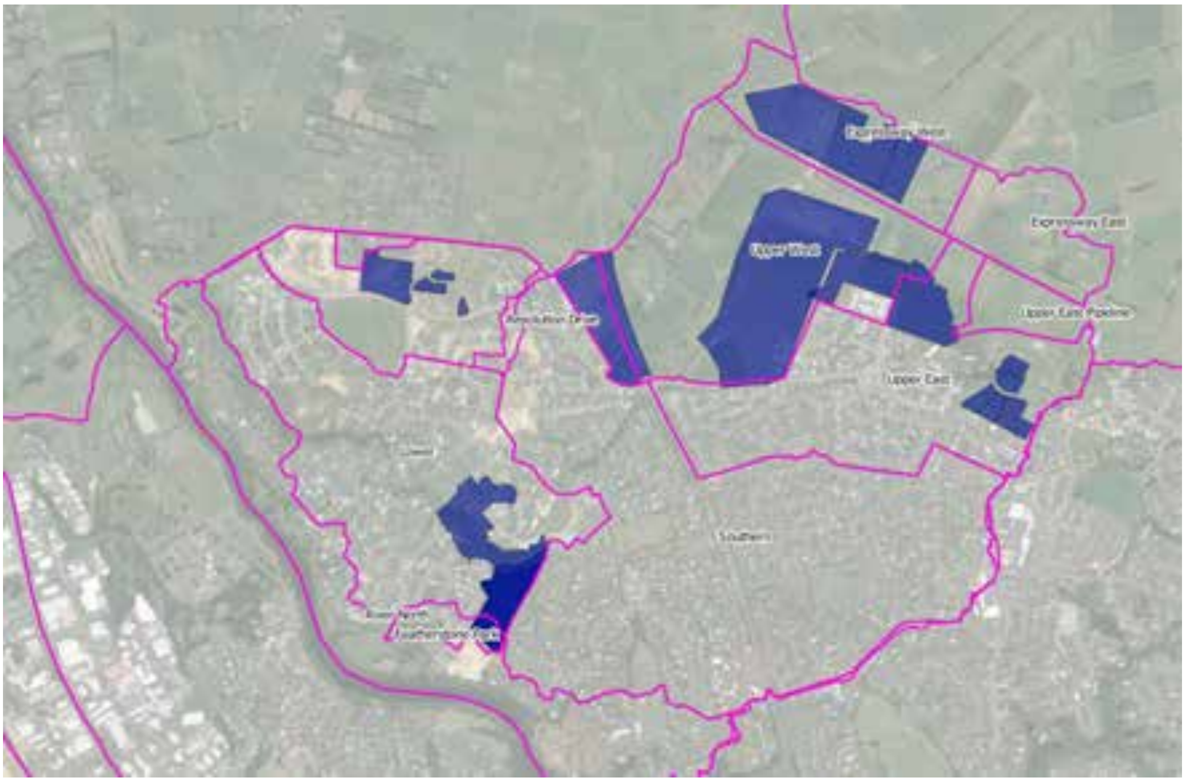

Figure 1 – Consents made available for review

2.1 Summary

A summary of the key findings is as follows:

- Consents reviewed that drain to Borman Road (Upper East catchment) align with the outcomes in the means of compliance tables in the ICMP.
- Consents reviewed in the Expressway West catchment align with the outcomes in the means of compliance tables in the ICMP.
- Consents reviewed in the Lower catchment align with the outcomes in the means of compliance tables in the ICMP.
- Consents reviewed that drain to the Bourne Brook swale (Upper West Catchment) align with the outcomes in the means of compliance tables in the ICMP. Refer to discussion below for additional context.

Initially, review of consents in the 'Upper West' catchment suggested that consented stormwater infrastructure for the Rototuna Town Centre did not align with the ICMP means of compliance. The proposed Bourne Brook Swale arrangement provides flood attenuation to a level greater than 80% of the 100 year ARI (ED) scenario. Subsequent communications with AECOM (per comms

21/11/19) indicated that the proposed Rototuna Town Centre infrastructure had been incorporated into the modelling for the TAOK ICMP.

It is recommended that the ICMP document is updated to clarify what infrastructure was included in MPD scenarios modelled and that the requirement for no flood attenuation in the upper west catchment refers to no attenuation beyond the centralised attenuation in the Bourne Brook Swale.

3 Management of Overland Flows

The TAOK ICMP identifies four key overland flowpaths within the TAOK catchment. These flowpaths are shown in Figure 2. Two OLFPs within the TAOK catchment have been focused on in this review:

- Downstream of the Bourne Brook Swale, which has not been identified as a key overland flowpath in the draft ICMP report; and
- The Borman Road overland flowpath. Development since the drafting of the ICMP has caused some uncertainty around the current OLFP alignment.

Figure 2 – Overland flowpath figure from ICMP draft report

3.1 Bourne Brook Swale

No overland flowpath was documented in the draft TAOK ICMP downstream of the Bourne Brook Swale area – refer Figure 2. The draft ICMP proposed a conveyance channel between North City Road and Borman Road. The latest consent information for the Rototuna Village area indicates that the reach between North City Road and Borman Road will be piped. The current version of the

Regional Infrastructure Technical Specification (RITS) indicates an allowance for an overland flowpath should be made (to allow for blockage of the inlet structure). An indicative alignment is shown in Figure 3. It is understood that the Rototuna Village area is currently undergoing a re-consenting process.

It is recommended that HCC ensure that this overland flowpath is incorporated into the updated consent and the flowpath is recognised in the final ICMP.

Figure 3 – Proposed alignment for Bourne Brook overland flowpath

3.2 Borman Road Flowpath

The stormwater modelling undertaken in support of the TAOK ICMP suggests that the pipe below Borman Road has adequate capacity to convey the 100y MPD+CC mitigated scenario (although ponding in various sag points along the road are observed in the results). This scenario assumes flood attenuation in all new developments discharging to the Borman Road pipe.

It is noted that the final review of the TAOK stormwater modelling undertaken by Beca Ltd observed that the calculated flows reporting to this pipe were being under-predicted, which was acknowledged by AECOM (refer Item 5, *Te Awa O Katapaki Stormwater Model Review* dated 2 June 2017). Insufficient reporting currently exists to assess whether this would result in overland flow along Borman Drive under 'normal' network operating conditions.

An overland flowpath along Borman Road is still required under the current revision of the RITS to allow for failure of the pipe system, and this is currently reflected in the ICMP. The alignment of the Borman Road overland flowpath in the current draft ICMP is shown in Figure 2.

A high-level assessment was undertaken to confirm the current alignment of the Borman Road overland flowpath. The following data was used in this assessment:

- Permanent level information supplied by HCC for North City Road (AECOM drawing number 60532091-SHT-00-0000-C-0051)
- Engineering plans for Turakina Rise supplied by HCC (AECOM drawing number 60507030-SHT-00-0000-C-0101)
- Detailed ground survey of Borman Road (dated 30/11/2016) supplied by HCC.
- 2019 LiDAR supplied by HCC (capture date October 2019).

Based on interpretation of the data listed above the alignment of the secondary flowpath along Borman Road is presented in Figure 4. Any secondary flows travelling westward along Borman Road will report to one of three locations:

- The sag on North City Road approximately 30m from the intersection with Borman Road. A raised pedestrian platform at the intersection with Borman Road has an elevation of 31.55 mRL.
- The sag on Turakina Rise approximately 70m from the intersection with Borman Road. Entrance to Turakina Rise at 31.30 mRL.
- Private properties fronting Borman Road between North City Road and Turakina Rise at 31.50 mRL.

Partially due to stockpiling of fill material west of Turakina Rise, no flowpath currently exists between the sag on Turakina Rise and the TAOK channel. Once the volumes within Turakina Rise sag is exceeded, any additional flow would flow through the footpath adjacent to the private properties, generally in the vicinity of 10 – 16 Welwyn Place and then pond at the North City Road sag location.

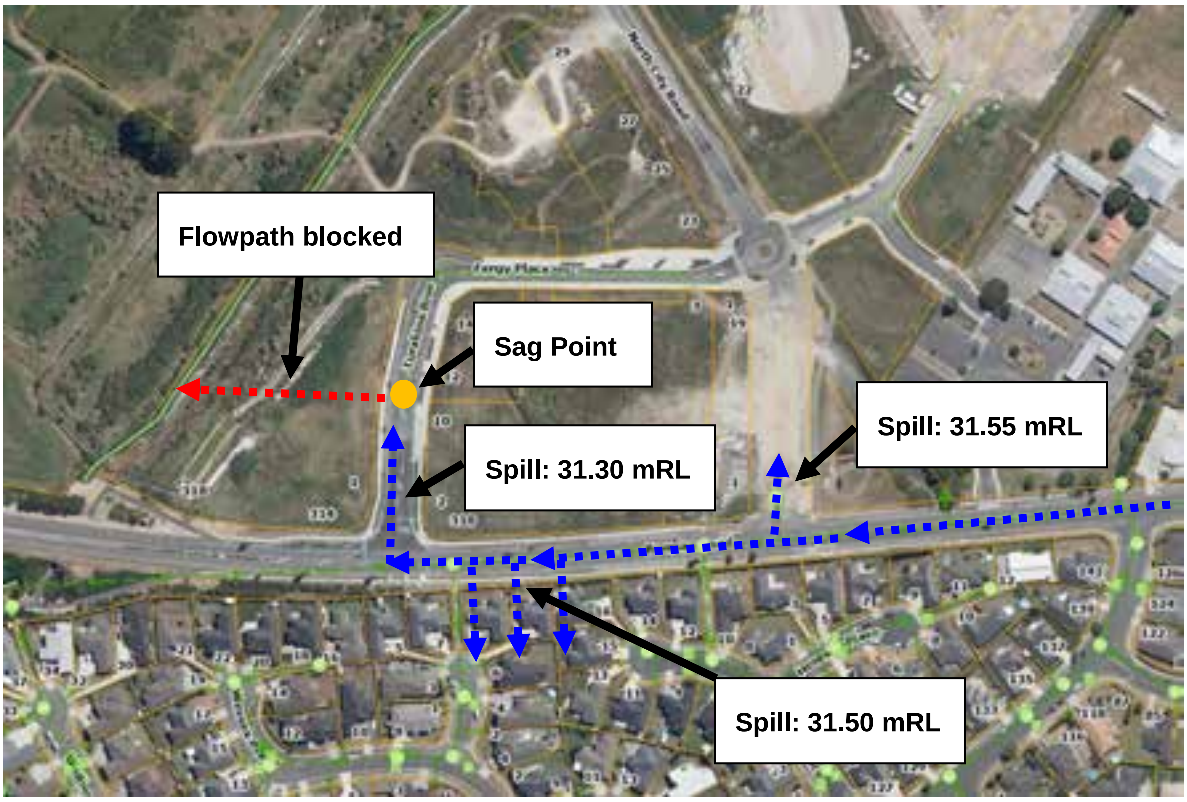

Figure 4 – Current Borman Road overland flowpath location

It is recommended that the alignment of the Borman Road overland flowpath be updated in the final ICMP to reflect an outcome consistent with RITS requirements.

Options that could be considered to ensure that an overland flowpath alignment exists for Borman Road that does not impact private properties include the following:

- Raise the footpath along a section of Borman Road and lower verge levels at the northern end of Turakina Rise to allow flow into the drain constructed in this area. (Option 1).
- Raise the footpath along a section of Borman Road and maintain an overland flowpath adjacent to the sag point in Turakina Rise. (Option 2).
- Raise the footpath along a section of Borman Road and adjust ground levels on the opposite side of Borman Road to allow overland flow into the pedestrian underpass below Borman Road. (Option 3).

At this stage it is recommended that the Option 2 alignment be incorporated in the final TAOK ICMP. This option will retain the OLFP at a location that minimises ponding on Turakina Rise. It is recommended that HCC make some allowance for minor civil works along the Borman Road footpath and/or intersection with Turakina Rise. Only minor elevation differences exist between the sag points and regrading works may be required for the function of the flow path.

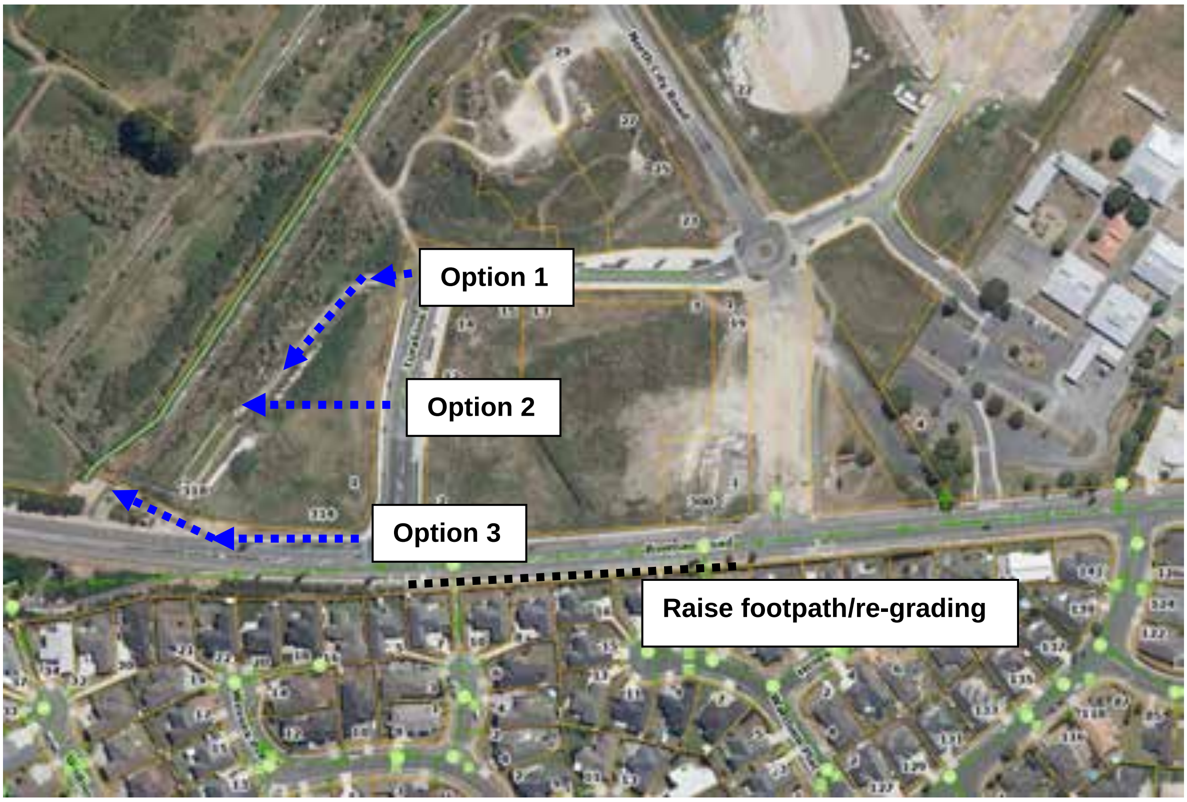

Figure 5 – Potential concept options for Borman Road overland flowpath locations

3.3 Summary

Based on the findings of the review process undertaken in the TAOK catchment the following recommendation are made:

- It is recommended that the proposed Bourne Brook overland flowpath is incorporated into the final ICMP and any future Rototuna Town Centre consents.

It is recommended that the alignment of the Borman Road overland flowpath be updated in the final ICMP. Three options have been proposed in this memorandum, with 'Option 2' suggested. It is noted that no detailed modelling or design considerations have been undertaken in preparing these options.

4 Summary of Flood Modelling Results

4.1 Purpose

The purpose of this section of the memorandum is to summarise the final state of flood attenuation modelling to support the ICMP. Multiple models were developed during the process with no final documentation on the overall modelling process and outcomes.

The intent is not to provide a technical review of the models or modelling outputs. Peer review was undertaken by Beca as part of the ICMP process.

4.2 Relevant Flood Modelling Documents

- Model build report
- 2017 letter *2017-06-28 LTR Remodelling upper TAOK* (AECOM, 2017)
- Original Beca peer review
- Final Beca Peer review

4.3 Overview of Results

Flood modelling to support the ICMP was undertaken by AECOM through the period 2015 – 2017. Two phases of modelling were undertaken during this period. Ultimately, AECOM concluded that the proposed MPD flood mitigation measures would result in flooding effects that were less than minor.

Beca were engaged by HCC to undertake a peer review of the modelling and associated technical report. A summary of the peer review approach and chronology has been extracted from the final peer review report (Beca, 2017):

- *A review meeting held on the 23/6/2016 with Beca/HCC/AECOM.*
- *Review of the model files and associated result files.*
- *Reviewing of AECOM responses to our comments received on 16/9/2016.*
- *To address some of the comments we raised, HCC decided to truncate the MIKE model removing parts of the upper, undeveloped catchment. The hydrology for these areas was developed in a separate HEC-HMS model to produce hydrographs that were them used back in the in MIKE model to determine flood effects.*
- *Comments were made on the revised model arrangement and comments were received back from HCC including a selection of updated flood maps, dated 11/4/2017.*

The original MIKE model was truncated primarily to address identified issues with MPD flood storage representation in the Upper West catchment (refer Figure 1). The truncated model was used to determine flood attenuation requirements in catchments draining to Borman Road and sizing of strategic stormwater infrastructure.

The truncated MIKE model was reviewed by the peer reviewer and was deemed fit-for-purpose (subject to the limitations identified in the peer review). The following additional limitations of the truncated model are noted:

- The truncated model does not include flood attenuation effects of the Bourne Brook Swale so will produce conservative estimates of outflows from this part of the catchment.
- The 100y ARI ED scenario does not incorporate allowance for climate change.

Based on the outcomes of their modelling, AECOM identified that the critical area of potential flood hazard to private properties along the main TAOK channel (due to greenfield MPD development) is located immediately upstream of the Petersburg Drive bridge crossing (refer Figure 6).

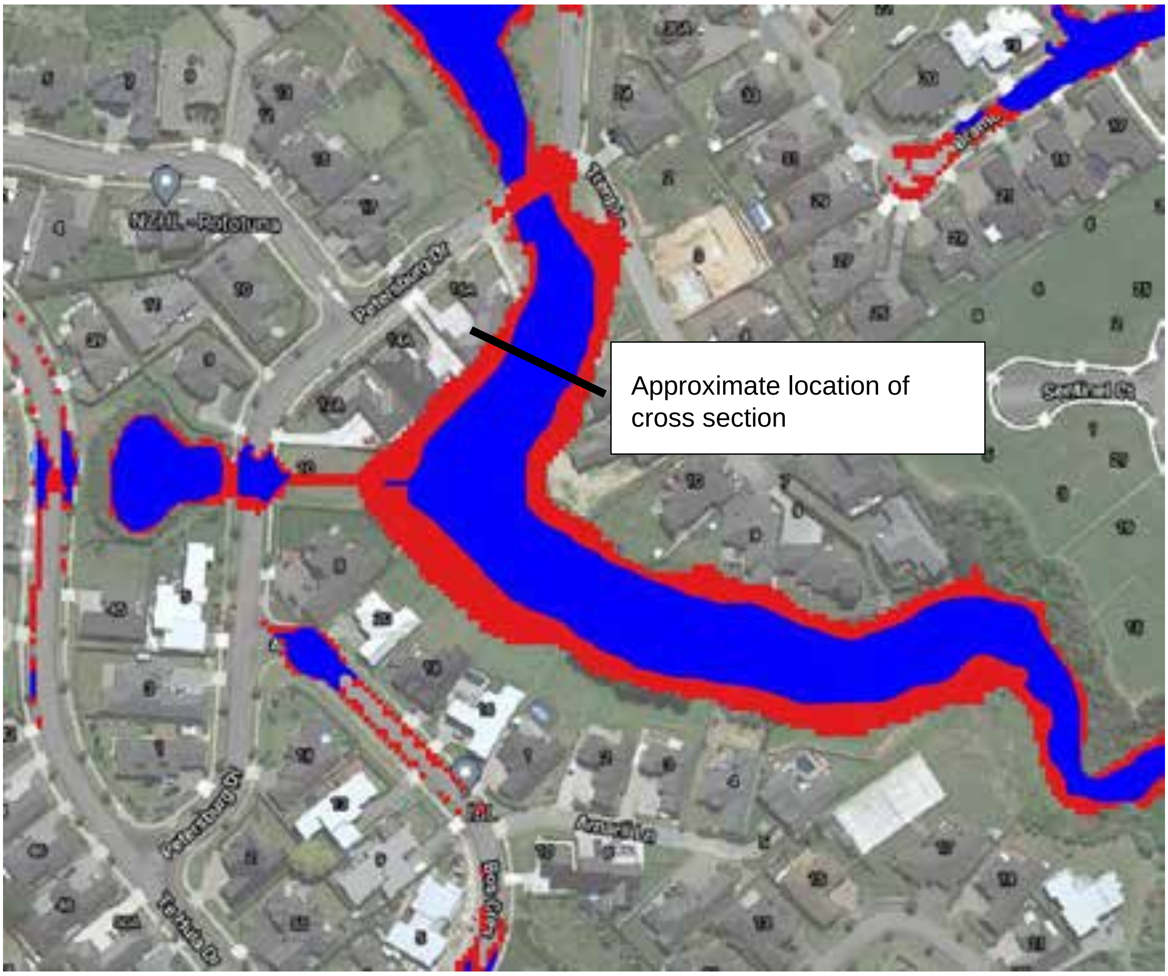

Figure 6 Flood hazard extents upstream of Petersburg Drive. ED+CC results shown in blue (2015 model), MPD+CC results shown in red (2017 model).

Peak flood depths from the truncated model and channel bathymetry data were used to interpret peak water surface elevation at a section upstream of the Petersburg Bridge (Figure 7) to confirm the AECOM conclusions. Based on Figure 7 the 100y ARI MPD peak water level is approximately 1 m below building pad levels in this location, i.e. while the MPD scenario predicts an increase in flood depths, private properties are not impacted.

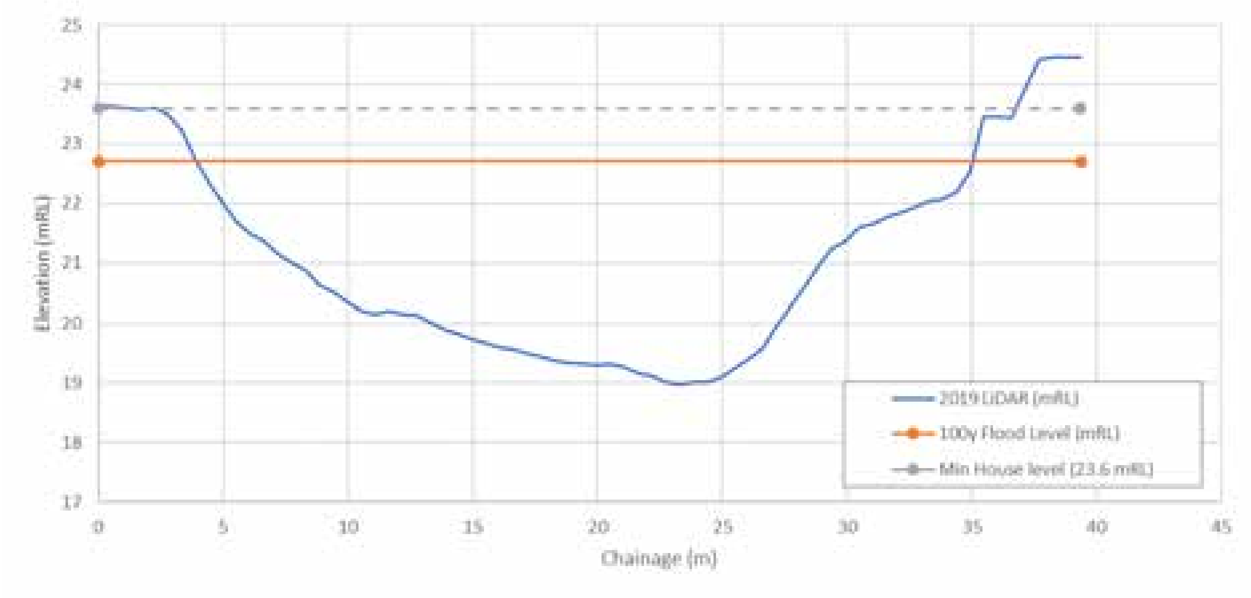

Figure 7 TAOK Creek section, upstream of Petersburg Drive bridge crossing.

Increases in brownfield flood extent are observed in several locations throughout the catchment. This appears to be driven by an increase to brownfield impervious assumptions in the MPD scenario when compared with the ED scenario (to simulate in-fill development). This increase in extent therefore represents the effects of in-fill development without mitigation. The most significant area of increase in extent is shown below in Figure 8. In this location Resolution Drive presents as a blockage to overland flow and thus exacerbates the additional runoff volumes cause an increase in ponding in this location. The increase in ponding results in an increase of flood hazard extent on approximately 6-7 private properties. Most of these properties were impacted to some extent in the ED scenario.

For the increase in brownfield urban hazard extents to be realised, significant amounts of single-lot scale intensification would likely need to occur. This is considered to be unlikely given that the Rototuna area has only been relatively recently developed (circa 2008) and current lot sizes are likely to prohibit this scale of re-development. This generally seems to support the AECOM conclusions that these effects should be considered less than minor.

Figure 8 Flood hazard extents at the intersection of Resolution Drive and Thomas Road. ED+CC results shown in blue (2015 model), MPD+CC results shown in red (2017 model).

4.4 Summary

Flood modelling to support the TAOK ICMP was undertaken by AECOM with peer review provided by Beca Ltd. Modelling was undertaken over a number of years, with two versions of the TAOK flood model being developed (2015 & 2017). Ultimately the peer review process deemed the flood modelling fit for purpose, subject to limitations that are documented by the peer review.

Based on the results of the flood modelling undertaken, AECOM concluded that the proposed MPD flood mitigation measures would result in flooding effects that were less than minor. Available flood modelling results have been reviewed to confirm that they support this conclusion. This review focused around increases within the TAOK channel downstream of greenfield development areas and increases in flood hazard extents in brownfield urban areas. The available modelling results appear to support the AECOM ICMP conclusions that the proposed MPD scenario results in flooding effects that are less than minor.

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