Middle Waikato Bed Degradation Investigation Stages III & IV.

Contract number: AM2004/5-30

Proposed Middle Waikato River Bed Degradation Management Strategy - Appendices

May 2006

Environment Waikato
REGIONAL COUNCIL

Beca

Appendices

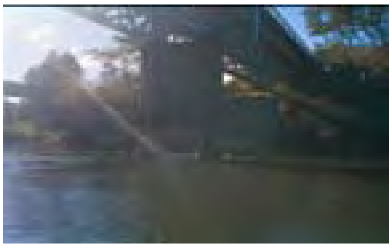
▪ Appendix A

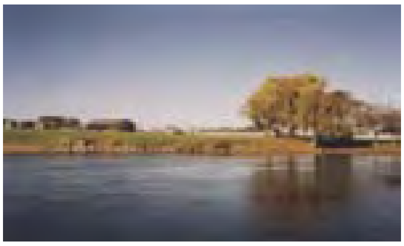
Photos

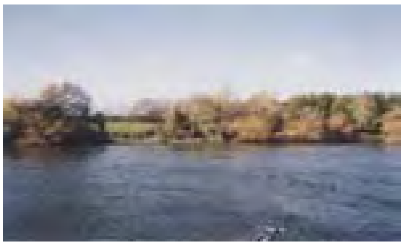
Mid-Waikato Bed Degradation Investigation Stages III and IV
River Bank and Infrastructure Condition Photographs - May 2005


km 95.5L

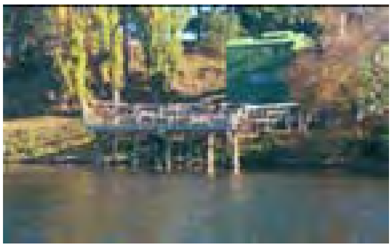

km 95.7a


km 95.7b


km 96.1R


km 97.3R


km 100.6L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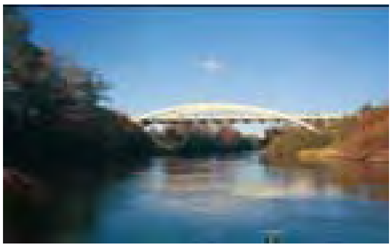
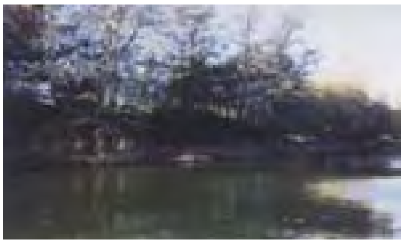

km 102.5


km 102.5aL


km 102.5bR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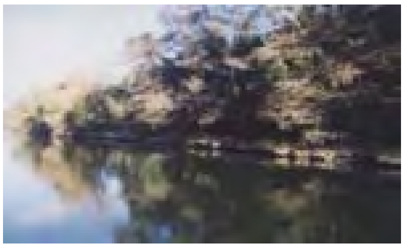
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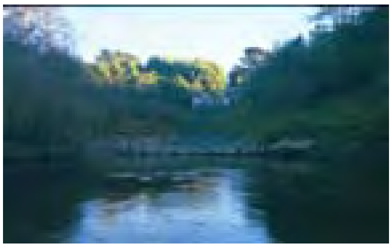
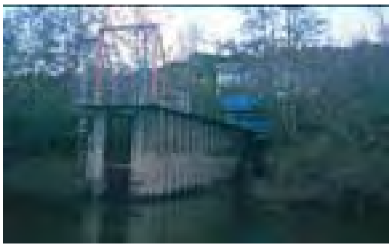

km 104.6L


km 104.8L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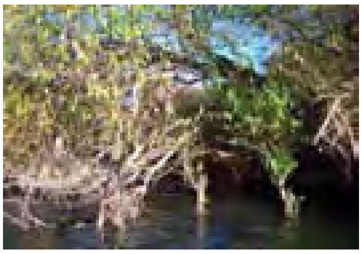
km 106.3L


km 106.3aL


km 106.3bL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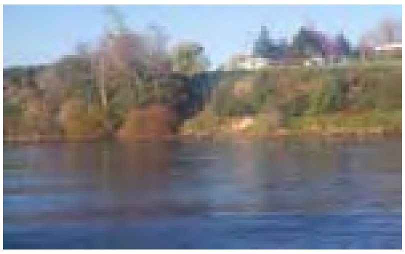
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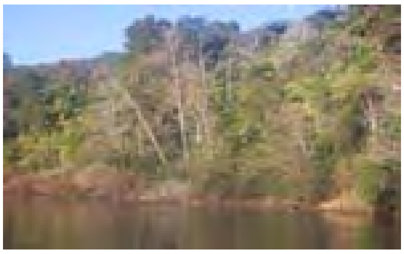
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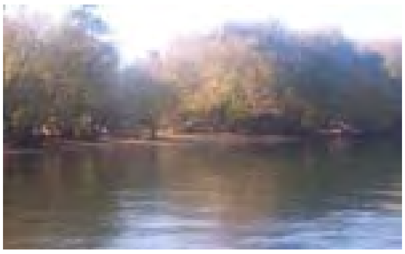
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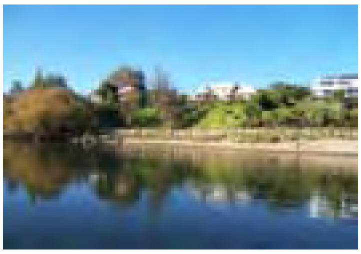
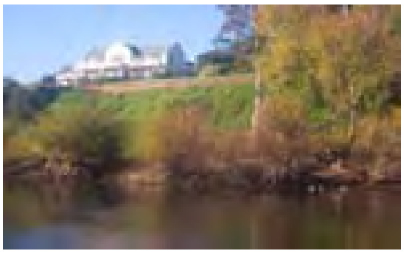
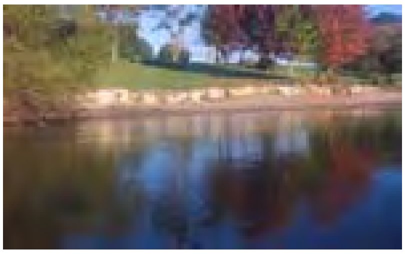

km 107.9 - 108.0L


km 108.1L


km 108.2L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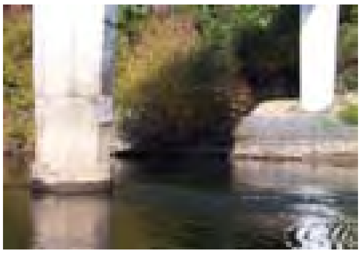
km 108.7a


km 108.7bL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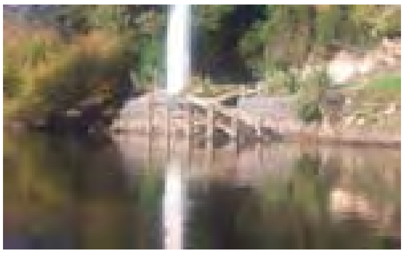
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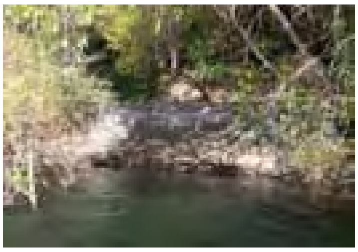
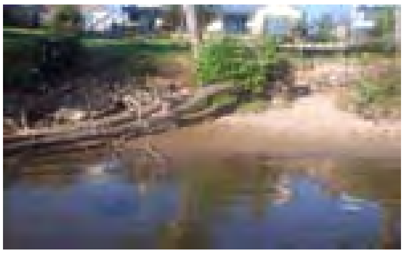

km 108.8aL


km 108.8bL


km 108.9R


km 109.1L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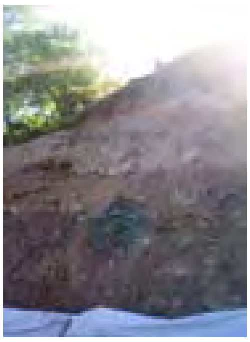
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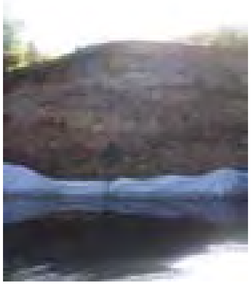
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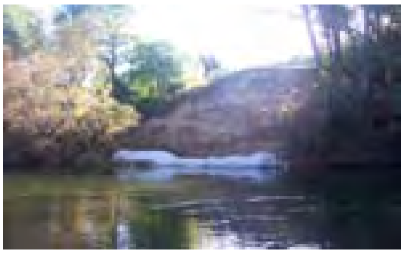
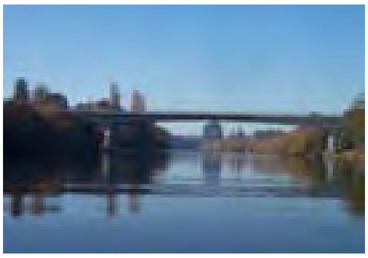

km 109.1dR


km 109.2aL


km 109.2bL


km 109.2cL


km 109.2dL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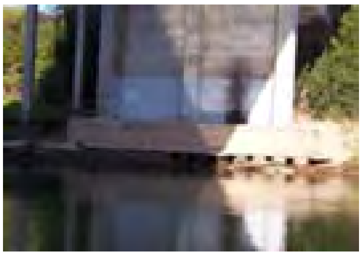
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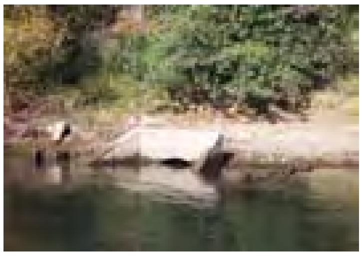
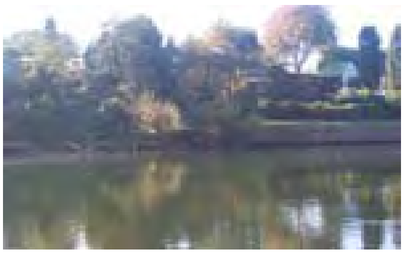

109.6cL


km 110.2L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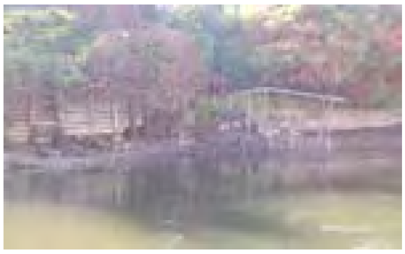
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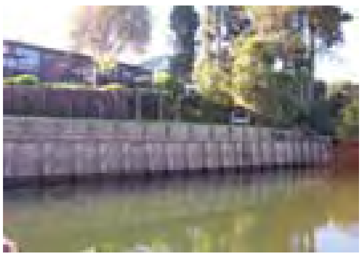
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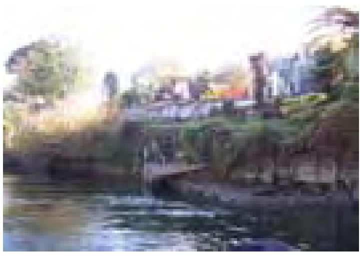
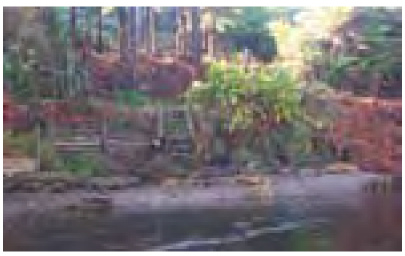

km 110.4R


km 110.4aR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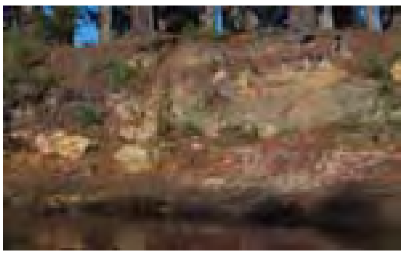
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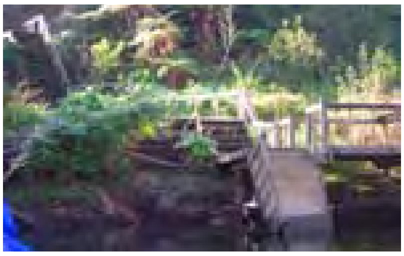
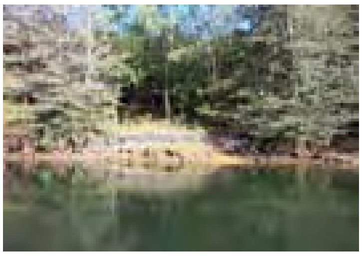

km 110.8R


km 110.8aR


km 110.0L


km 111.1R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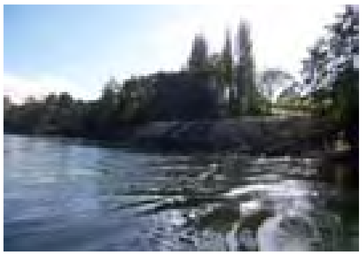
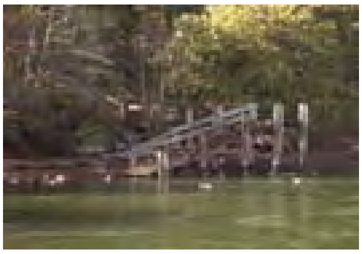

km 111.1bR


km 111.1cR


km 111.2R


km 111.2aR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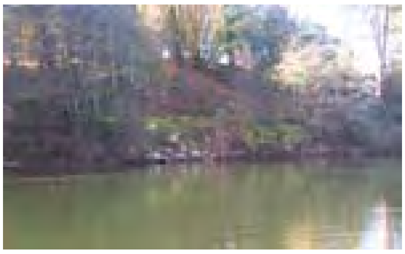
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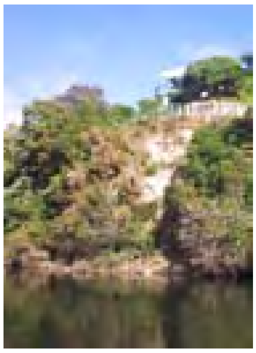
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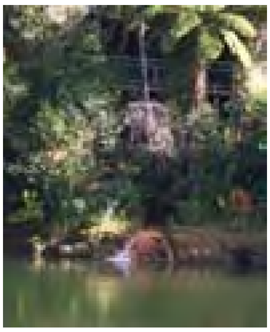
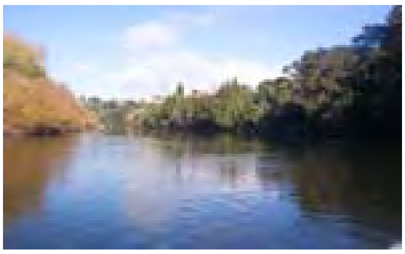

km 111.9L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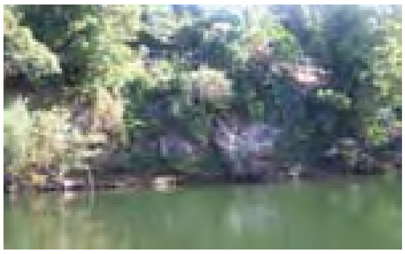
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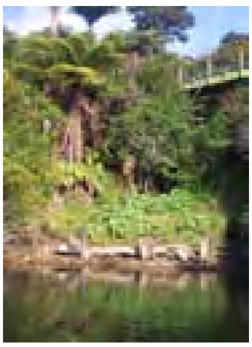
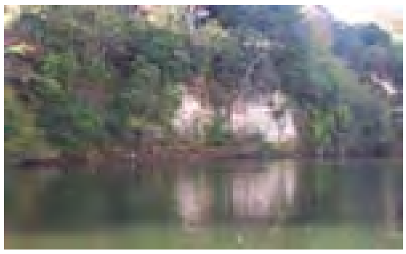

km 112.05cL


km 112.1L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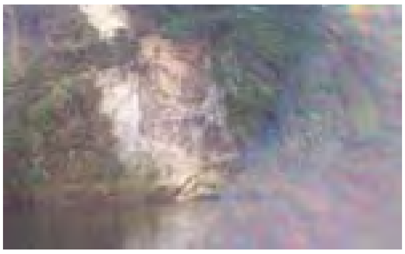
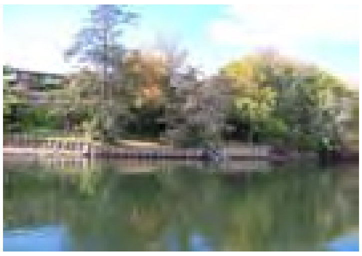

km 112.3bL


km 112.5L


km 112.7aR


km 112.7bR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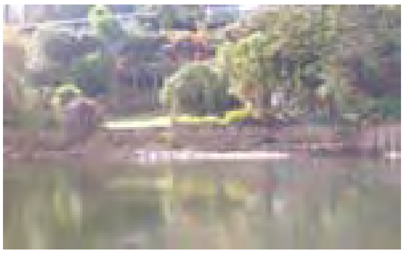
km 112.8aL


km 112.8bL


km 112.8cL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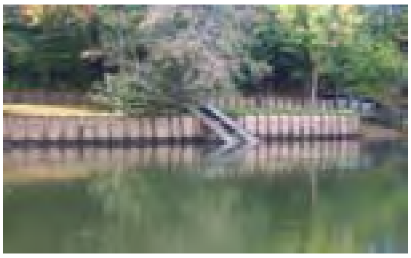
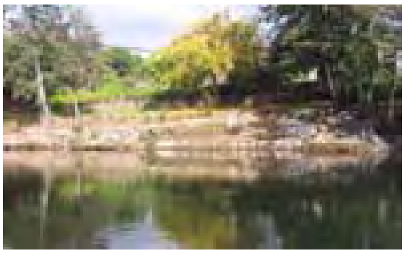

km 112.8bR


km 112.9aL


km 112.9bL


km 112.9cL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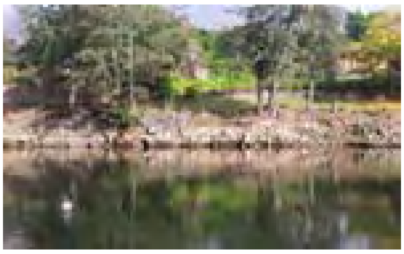
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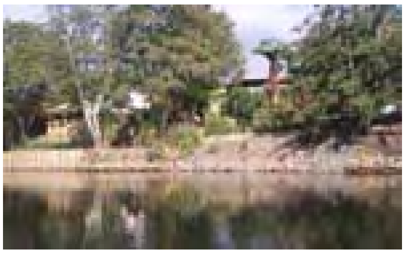
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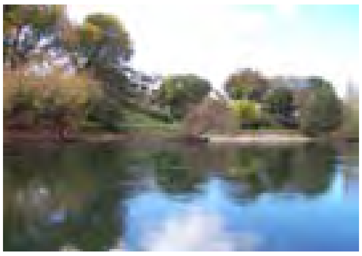
km 112.9gL


km 113.2R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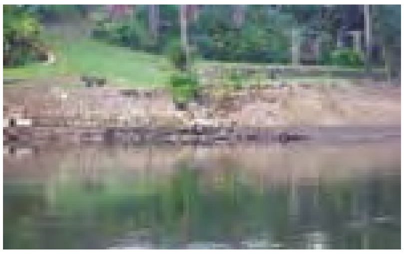
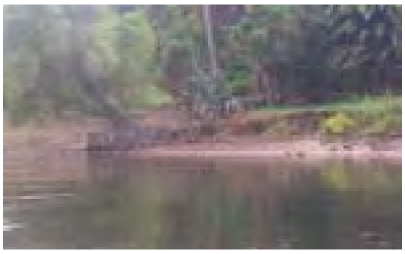
113.4aR


113.4bR


km 113.4cR

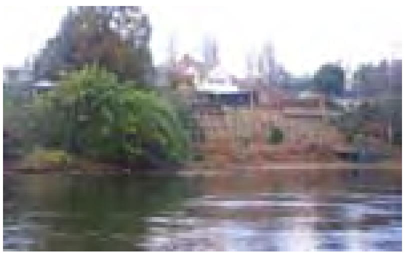

km 113.4dL


km 113.5a

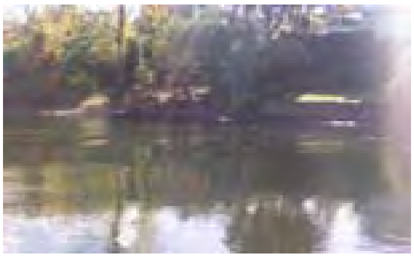

km 113.5bL


km 113.5cR

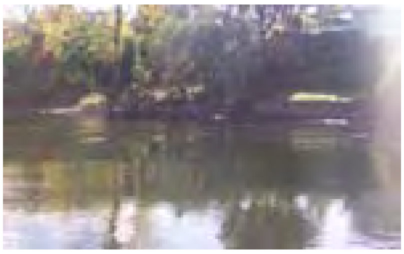

km 113.6L


km 113.6R


km 113.7R


km 113.9aR


km 113.9bL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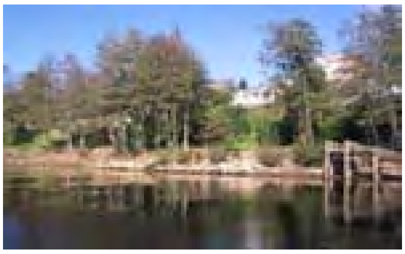
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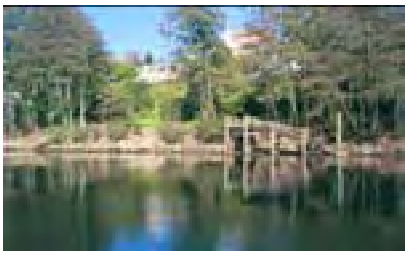
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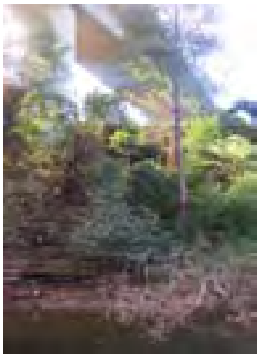
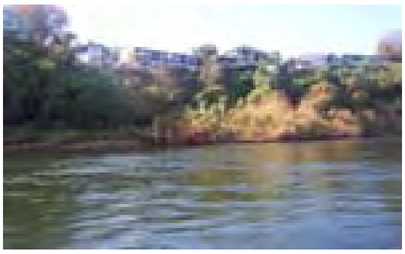

km 114.4R


km 114.5R

Mid-Waikato Bed Degradation Investigation Stages III and IV
River Bank and Infrastructure Condition Photographs - May 2005


km 114.5aR

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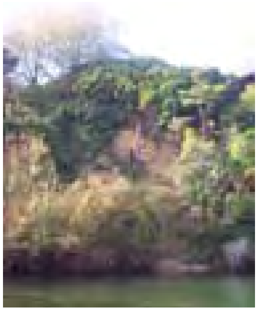
km 114.5bR


km 114.85L


km 115.4a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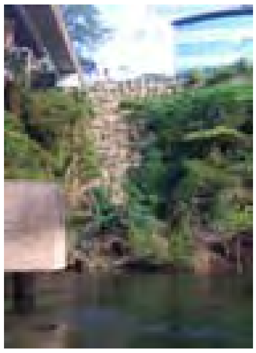
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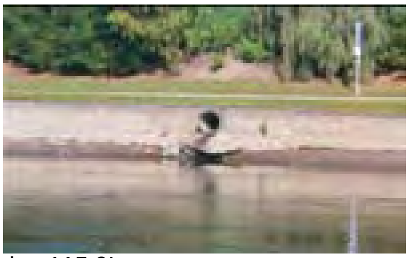
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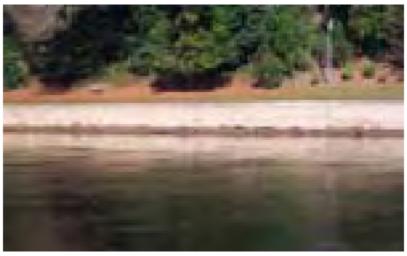
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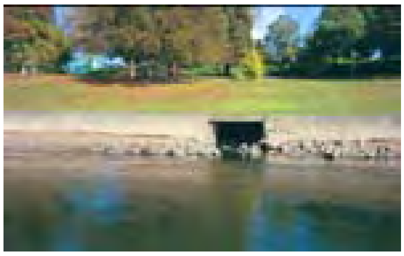
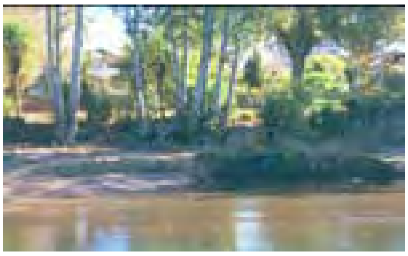

km 116.2L


km 116.3a


km 116.3bL


km 116.6R


km 116.7L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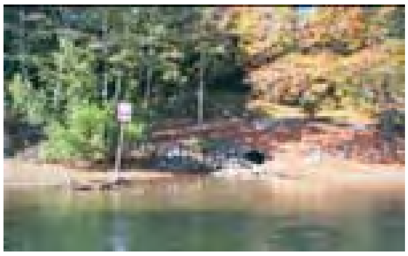
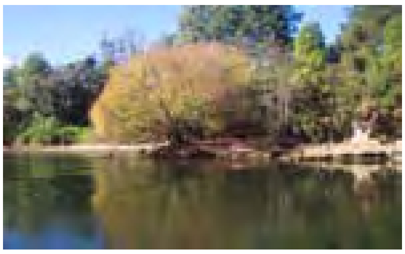
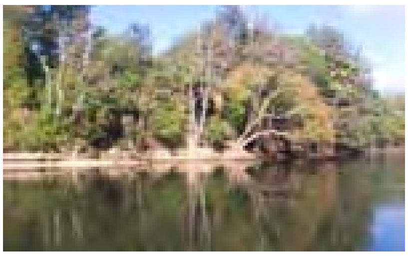

km 116.9R


km 117.3aR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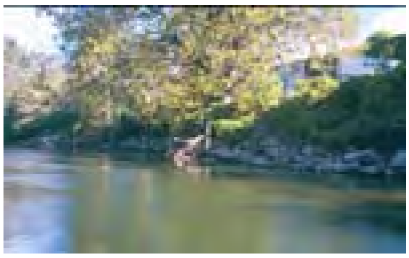
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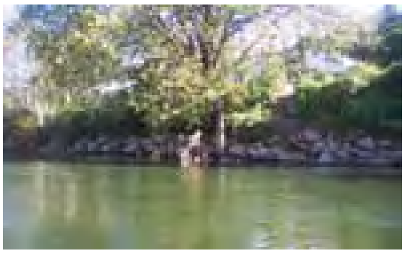
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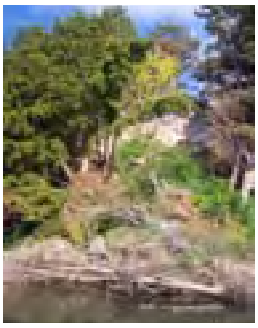
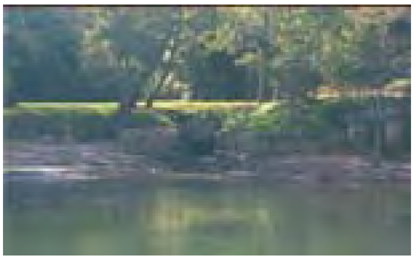
km 117.7L


km 117.9L


km 118.5L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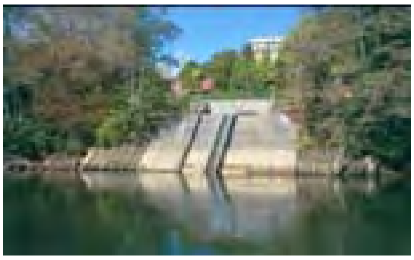
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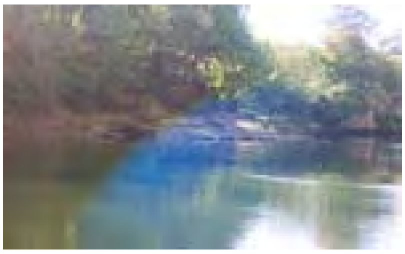
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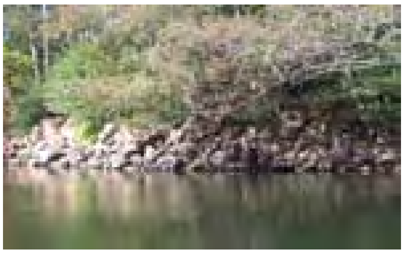
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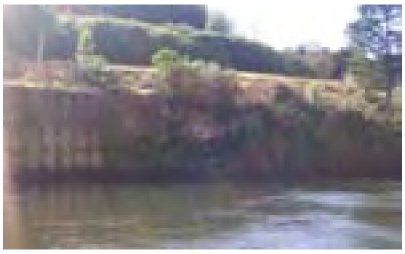
km 119.4L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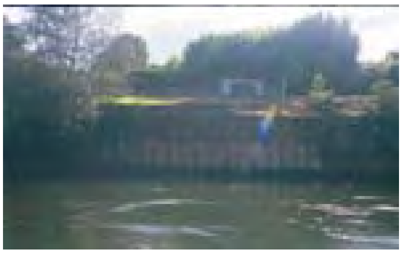
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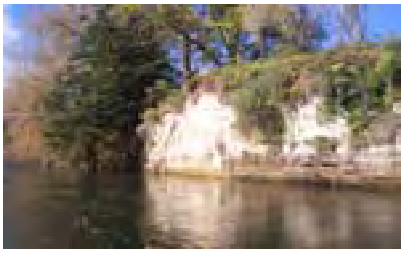
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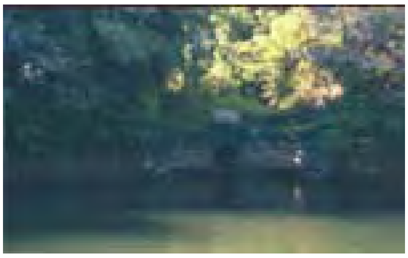
km 119.5R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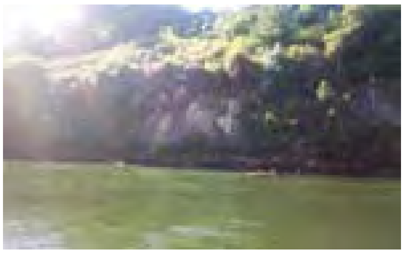
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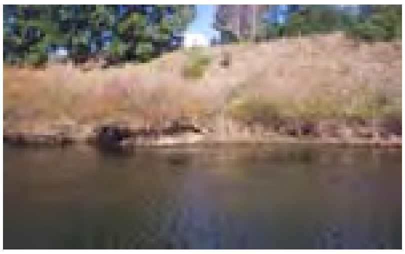
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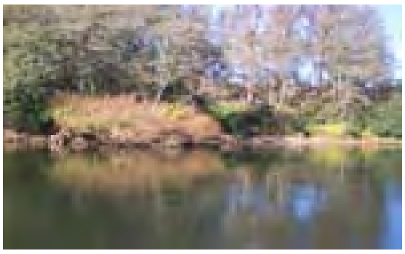
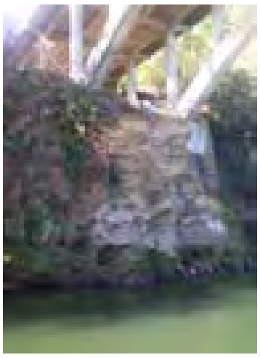

km 126.2R


km 126.4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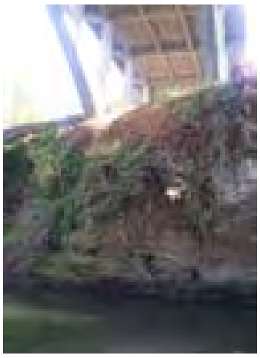
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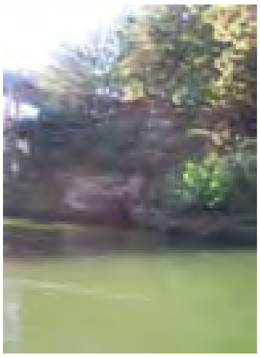
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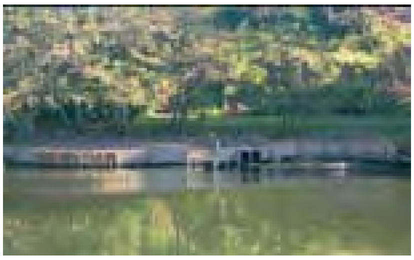
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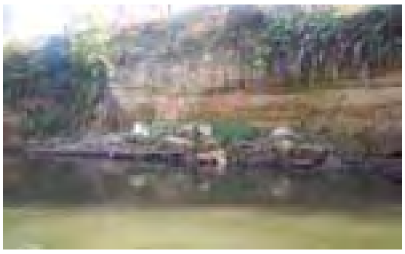
km 126.8L


km 126.9L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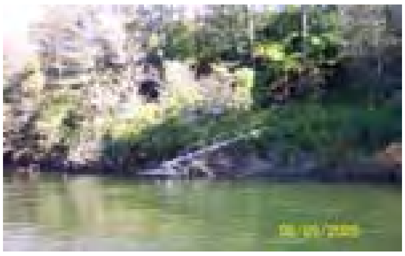
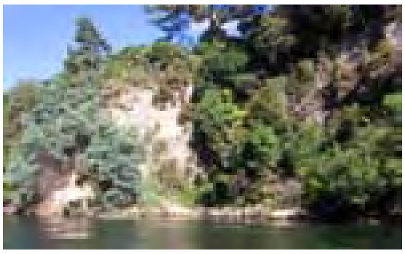

km 129.2L


km 132.5L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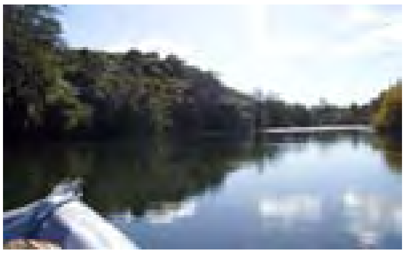
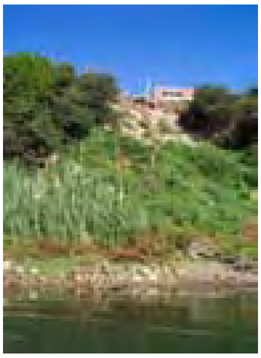

km 134.05L


km 135.65R


km 137.0L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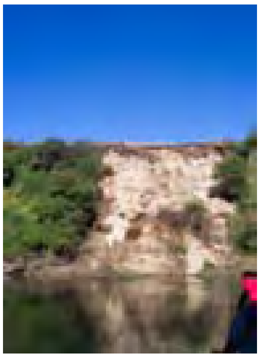
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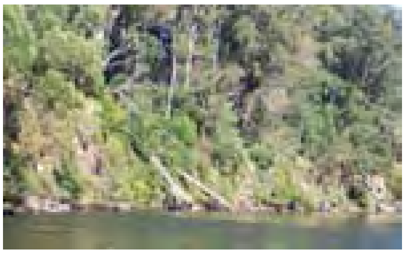
km 140.5a


km 140.5bL


km 142.0


km 142.0L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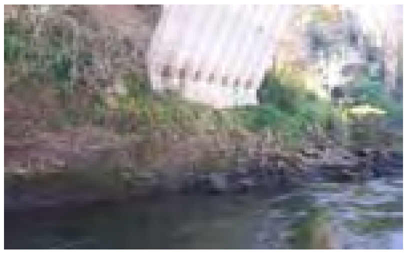
km 142.8a


km 142.8b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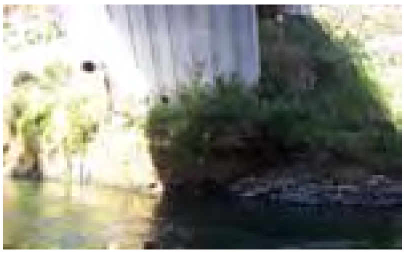
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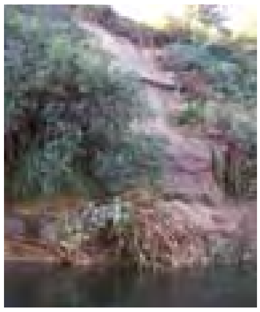
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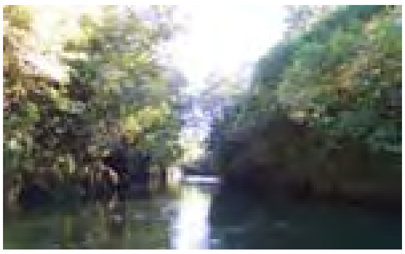
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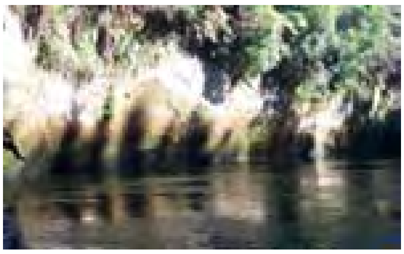
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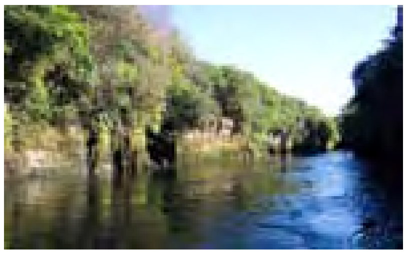
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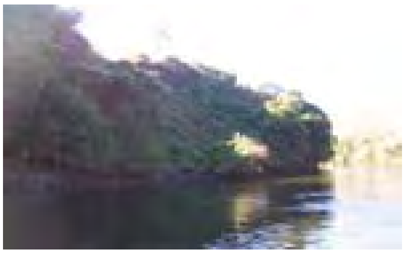
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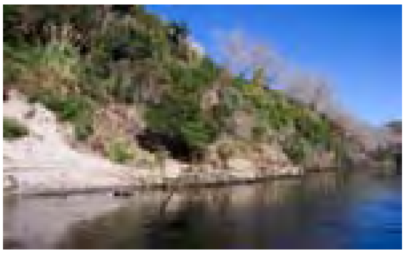
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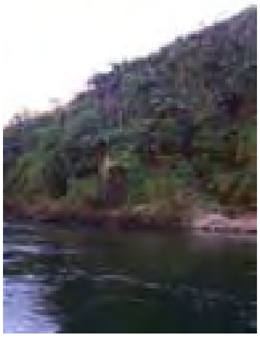
km 146.1bL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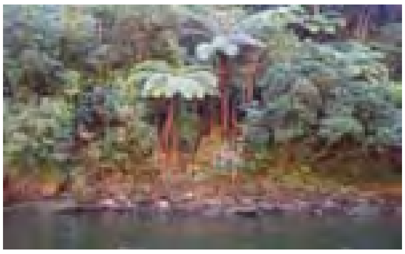
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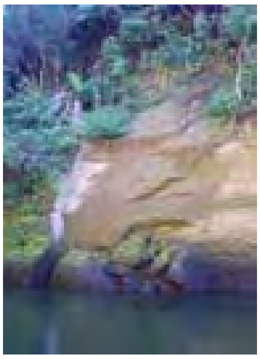
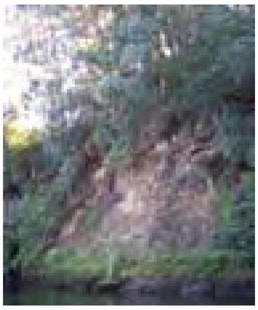

km 146.8aR


km 146.8bL


km 147.0aR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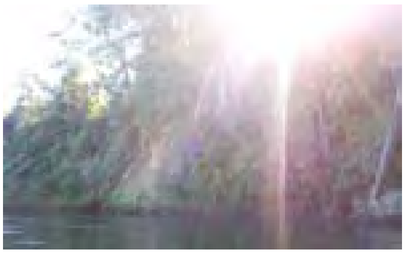
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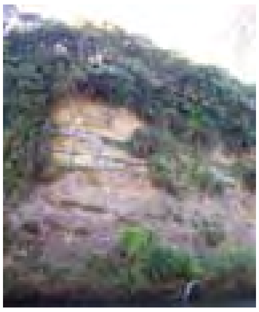
km 147.4aL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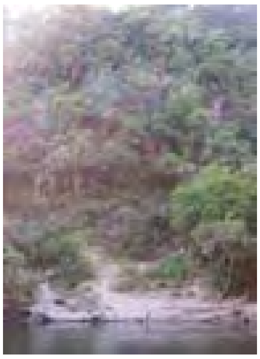
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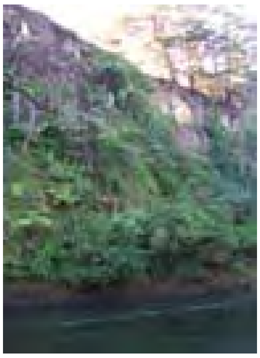
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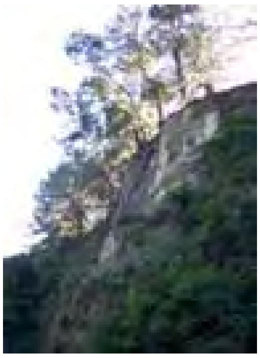
km 148.8dR

▪ Appendix B

Infrastructure (by River distance)

Distance from river mouth, km	Projected 100-years bed degradation, m	Beca waypoint/ cross-section No.	Photos	Bank	Feature	Land/ Property/ Infrastructure	Subjective risk assessment	Comments and Options to address bed degradation
95.3	*3.7*		No		Waipa confluence			
95.5	*3.7*	WP302	Yes	L	50-m length of riprap revetment	Property	Slight	
95.7	*3.7*		Yes		NIMT Railway Bridge 267 and SH1 Road Bridge, Ngaruawahia	Infrastructure	Severe	Two piers in river, two piers close to top of bank. Review record drawings for impact of any bed degradation.
96.1	*3.6*	WP308	J-17	R	200 dia outfall with rubble protection	Infrastructure	Slight	
96.5	*3.6*	WP309	No	L	Slips down steep bank; rock protection at base	Property		
101.0	*3.4*	CS81	Yes	L	Meatworks water intake	Infrastructure	Moderate	Review record drawings for impact of lower bed and water levels
102.5	*3.4*	CS82	Yes		Horotiu Road Bridge	Infrastructure	Slight	Arch springs from foundations set back from river edge
104.6	*3.3*	WP369	Yes	L	Overflow from dairy factory?	Infrastructure	Slight	Structure is set back from river. Riprap at river bank may need to be extended.
104.8	*3.3*	WP370	Yes	L	Overflow from dairy factory tanks?	Infrastructure	Moderate	Improved scour protection may be required
105.0	*3.3*	WP371	Yes	L	Dairy factory water intake	Infrastructure	Slight	Review record drawings for impact of lower bed and water levels
106.3	**3.23**	CS50	Yes	L	Pukete Boat Ramp	Infrastructure	Moderate	Water depth already too shallow at landing. Ramp will need extending or lowering.
106.3	3.2	CS50	Yes	L	300 dia stormwater outlet	Infrastructure	Moderate	Outlet is well above water level, and erosion protection is being undermined.
106.8	3.2	WP127	Yes	L	Waste Water Outlet	Infrastructure	Moderate	Hidden within willows, possibly piled. Review record drawings
107.9-108.0	3.2	WP134	Yes	L	Timber retaining wall for walkway	Infrastructure	Slight	
108.2	3.2	WP137	Yes	L	750 dia outfall	Infrastructure	Moderate	Gabions may need extending
108.7	3.1	CS54	Yes		Pukete Sewer Bridge	Infrastructure	Severe	Piers in river. Review record drawings for impact of lower bed and water levels
108.7	3.1	CS54	Yes	L	25-m long gabion revetment and timber steps	Infrastructure	Moderate	Gabions (which appear to be to protect walkway, rather than to protect bridge pier) may need extending. Timber steps will need extending.
108.8	3.1	WP143	Yes	L	15-m long gabion revetment below walkway	Infrastructure	Moderate	Toe of gabions is protected by rubble. Will need extended toe protection.
108.9	3.1	WP144	Yes	R	450 dia outlet structure	Infrastructure	Moderate	Gabion mattress scour protection needs extending.
109.1	3.1	WP145	Yes	L	600 dia outlet structure	Infrastructure	Slight	Rubble provides adequate scour protection
109.2	3.1	CS55	Yes	L	Ad-hoc 25-m long retaining structure, with localised gabions at toe.	Property	Moderate	Gabions already failing due to shallow foundation depth. Uneconomic to provide engineered solution.
109.6	3.1	CS56	Yes		Pukete Traffic Bridge (Wairere Drive)	Infrastructure	Severe	One pier in river, one at water's edge; piles exposed 0.4m below pile cap. Review record drawings for impact of lower bed and water levels
109.6	3.1	CS56	Yes	L	1 m dia outlet structure	Infrastructure	Slight	Outlet is largely submerged, so unlikely to be affected by bed degradation in the medium term.
110.2	3.1	WP160	Yes	L	1 m dia outlet structure	Infrastructure	Slight	Outlet is has sheet-piled toe protection.
110.3	3.1	WP161	Yes	R	40-m long timber retaining wall	Property	Moderate	Recently installed wall in good condition. Lower wall may be needed as bed degrades.
110.4	3.1	WP162	Yes	R	Timber retaining wall and landing	Property	Moderate	Landing has failed. Timber retaining wall scheduled to be replaced by sheet pile wall in near future.
110.8	3.0	WP169	Yes	R	Private landing	Property	Moderate	Steps failing, would need extending.
111.0	3.0	WP170	Yes	L	50-m long gabion wall below covered walkway at golf course	Property	Moderate	Gabion mattress toe protection will need extending.
111.1	3.0	WP171	Yes	L	10-m long gabion wall below walkway	Property	Slight	May need gabion mattress toe protection
111.1	3.0	WP171	Yes	R	30-m long riprap revetment, with concrete steps to above water level	Property	Moderate	Riprap will need top-up, and steps extending as river degrades.
111.2	3.0	WP172	Yes	R	1.5 m dia outfall with timber-piled headwall	Infrastructure	Moderate	Rock toe protection needs upgrading
111.3	3.0	WP173	Yes	R	Swarbricks Landing	Property	Moderate	Timber steps will need extending
111.9	3.0	WP174	Yes	L	Footbridge across tributary stream	Infrastructure	Slight	No issues
112.1	3.0	CS59	Yes	L	Vardon Road stormwater outlet	Infrastructure	Slight	Outlet below water level at piled structure. Review record drawings, but probably no action required.
112.5	3.0	CS60	Yes	L	Wastewater pump station and 300 dia outfall (Ann St)	Infrastructure	Slight	Located on inside of bend
112.7	3.0	WP184	Yes	R	50-m length timber retaining walls, including boat ramp	Property	Slight	Probably no action required
112.8	3.0	WP185	Yes	L	150-m long revetment below walkway, using rock and rubble	Property	Moderate	Riprap will need top-up
112.9	3.0	WP186	Yes	L	75-m long timber retaining wall and walkway	Property	Slight	Probably no action required
113.2	2.9	WP187	Yes	R	Failed timber jetty	Property	Moderate	Needs reconstruction

Distance from river mouth, km	Projected 100-years bed degradation, m	Beca waypoint/ cross-section No.	Photos	Bank	Feature	Land/ Property/ Infrastructure	Subjective risk assessment	Comments and Options to address bed degradation
113.3	2.9	WP188	Yes	R	75-m long timber retaining wall, set back from water's edge	Property	Slight	Probably no action required
113.5	2.9	CS61	Yes		Fairfield Bridge	Infrastructure	Severe	Two piers in river. Review record drawings for impact of bed degradation
113.6	2.9	WP195	Yes	L	Waitawhiriwhiri Stream outfall under Victoria Street	Infrastructure	Moderate	Review record drawings for impact of bed degradation. Will need more riprap for scour protection.
113.7	2.9	WP196	Yes	L	1200 dia outlet structure	Infrastructure	Slight	Possible need for scour protection in future
113.9	2.9	CS62	Yes	R	20-m long revetment using old tyres	Property	Slight	
113.9	2.9	CS62	Yes	L	ad-hoc rubble protection below walkway	Property	Moderate	
114.0	2.9	WP203	Yes	L	Rubble revetment and timber landing	Property	Moderate	Revetment will need top-up. Timber steps will need extending.
114.3	2.9	WP204	No	R	Timber steps	Property	Slight	Will need extending
114.4	2.9	CS63	No		Whitiora Bridge (Boundary Road)	Infrastructure	Severe	Two piers in river, with pile caps just above water level. Review record drawings for impact of bed degradation. Slope protection will be required to protect right bank pier on terrace.
114.5	2.9	WP209	Yes	R	Timber landing	Property	Moderate	In dilapidated state
114.7	2.9	WP210	No	L	Timber steps	Property	Slight	Will need extending
115.4	2.9	CS64	Yes		ECMT Railway Bridge 6 and Claudelands Bridge	Infrastructure	Severe	Left bank slip immediately downstream of rail bridge has been retained; bridge abutment assumed to be safe on bored piles. Two piers in river, rail bridge pile caps about 0.5 m above water level. Review record drawings for impact of bed degradation
115.55	2.9	WP219	No	R	20-m long timber wall below private garden	Property	Slight	
115.65	2.8	WP220	No	R	20-m long rock revetment below private garden	Property	Slight	
115.90	2.8	WP222	Yes	L	450 dia outfall through sprayed concrete revetment	Infrastructure	Moderate	Toe of revetment is already being undermined. Alternative detail required (flexible, or with deeper cutoff).
115.90	2.8	WP222	No	R	200-m long concrete block revetment	Property	Slight	
116.20	2.8	WP224	Yes	L	Square outlet through sprayed concrete revetment	Infrastructure	Moderate	Additional rock protection will be required.
116.3	**2.82**	CS65	Yes		Victoria Bridge (Bridge Street)	Infrastructure	Moderate	Arch bridge. Left abutment is protected by a concrete block wall which is likely to need new toe protection. Right abutment looks OK at present. Review record drawings for impact of bed degradation
116.6 - 117.0	2.8	WP229 - WP234	Yes	R	400-m long rubble and riprap revetment (below walkway at New Memorial Park).	Property	Moderate	On outside of bend; additional rock protection will be required.
116.7	2.8	WP230	Yes	L	Boat ramp with masonry walls	Property	Moderate	Boat ramp is already too shallow: will need lowering and/or extension.
116.8	2.8	WP232	Yes	L	300 dia outlet above water level, scouring	Infrastructure	Moderate	Erosion protection required.
116.9	2.8	WP233	Yes	R	900 dia outlet	Infrastructure	Slight	Possible need for scour protection in future
117.2	2.7	WP236	No	R	Timber steps	Property	Slight	Will need extending
117.4	2.7	WP239 CS66	Yes	L	50-m length of riprap revetment at Old Pumping Station	Property	Slight	Possible need for additional riprap in future
117.7	2.7	CS67	Yes	L	Hospital Drain outfall	Infrastructure	Moderate	Outfall structure is "hanging" with sheet pile downstream protection. Review record drawings for impact of bed degradation
118.5	2.6	CS68	Yes		Cobham Bridge	Infrastructure	Severe	Two piers in river, with pile caps just above water level. Review record drawings for impact of bed degradation
118.7	2.6	WP258	No	R	300 dia outfall	Infrastructure	Slight	No issues evident
118.8	2.5	WP259	Yes	R	750 dia outfall with gabions	Infrastructure	Moderate	Gabions will need extending
119.0	2.5	WP260	No	L	Mangakotukutuku Stream confluence, crossed by twin 450 dia water mains on pipe bridge	Infrastructure	Moderate	Monitor pipe bridge piers for effects of downcutting
119.3	2.5	WP263	Yes	L	Water Treatment Plant intake	Infrastructure	Slight	Review record drawings for impact of lower bed and water levels
119.4	2.5	WP264	Yes		20-m lengths of riprap on LB and sheet piling on RB at a buried water pipe crossing	Infrastructure	Severe	Review record drawings for impact of lower bed level
119.5	2.5	WP265	Yes	R	50-m long gabion wall and timber landing	Property	Moderate	Timber steps will need extending. Gabions are set back from river edge, so unlikely to be affected by bed degradation
121.3	2.3	WP272	Yes	R	900 dia outfall through gabion headwall	Infrastructure	Moderate	Outfall is only 3-4 years old, but gabions are already being undercut. Gabion mattress toe protection is an option.
126.0	**1.73**	CS73						
126.4	*1.7*	CS74	Yes		Narrows Bridge	Infrastructure	Moderate to high	Arch bridge springs from vertical weak rock faces. Slopes fronting abutments on both banks will require protection.
126.7	*1.7*	CS75	Yes	L	20-m long timber wall and landing below private garden	Property	Slight	Steps will need to be extended

Distance from river mouth, km	Projected 100-years bed degradation, m	Beca waypoint/ cross-section No.	Photos	Bank	Feature	Land/ Property/ Infrastructure	Subjective risk assessment	Comments and Options to address bed degradation
126.8	*1.7*		Yes	L	Floating pontoon with access walkway	Property	Slight	Pontoon cannot go lower without excavating bed near bank.
129.2	*1.5*	CS39	Yes	L	Water intake	Infrastructure	Slight	Intake on floating pontoon
137.0	*0.9*	WP88	No	L	Water intake	Infrastructure		
138.1	*0.8*		No	L	Water intake	Infrastructure		
140.5	*0.7*	WP67	Yes	(L)	Pipe bridge	Infrastructure	Slight	Supports clear of river, but left bank pipe parallel to top of slope
142.0	*0.6*	CS18	Yes		Victoria Bridge, Cambridge	Infrastructure	Slight	Arch bridge, abutments clear of river
142.8	*0.5*	CS16	Yes		Fergusson Bridge, Cambridge	Infrastructure	Moderate	Piers founded in river banks of alluvial sandy Hinewera Formation. Rock fall in zone fronting piles triggered by deepening of bed may expose piles and require remediation
149.6	***0.00***		No		Karapiro Dam			

NOTES

1. Projected bed degradation figures between Narrows and Pukete boat ramp are interpolated from figures in Smart, August 2003. Projections beyond this reach are less reliable, and shown in italics.
   The projected bed degradation is at a steady rate (I.e. projected bed degradation after 50 years is half that projected for 100 years).

2. Water levels are projected to decrease at a reducing rate.
   Projected water level lowering at Victoria Bridge Hamilton during low flows (110 m^3/s) is 0.7 m after 50 years, and 1.1 m after 100 years.
   There are no projections for elsewhere in the reach.

▪ Appendix C

Bank Condition (by River distance)

Distance from river mouth, km	Beca waypoint/ cross-section No.	Photo Filename	Bank	Feature	Bank Condition Comments
95.50	WP302	km 95.5L.jpg	L	Carpark and clubrooms	Riprap, grassed
95.50	WP302		R		Riprap protection extends about 1 m up from base of slope. Trees and scrub for about 100 m, then grassed.
95.70	CS77		L	Ngaruawahia rail and road bridges	Steep to sub-vertical bank, actively eroding; trees falling into river. Process likely to be ongoing but not direct result of bed degradation.
95.70	CS77	km 95.7b.jpg	R	Ngaruawahia rail and road bridges	Hummocky planted terrace approximately at river level, may require protection as bed degrades. Bank near vertical in places; indications of past slope movement.
95.95	WP307		L	Marae	Trees curved indicating soil creep; falling into river. Drainage outfalls causing significant erosion of beach. Eroded face will require protection with bed degradation.
95.95	WP307		R		Couple of metres high, small beach (sandy).
96.10	WP308		L	Outlet	~1 - 1.5 m high, grassed bank, increasing to ~3m high. Fronted by willow trees which are holding sediment and so protecting slope in behind. Some near vertical banks, vegetation slipping. Irregular concrete slab protection to stormwater discharge.
96.10	WP308	km 96.1R.jpg	R	Outlet	Becoming steep, about 4m high. Densely vegetated. Discharge through riprap.
96.50	WP309		L		Arcuate feature in bank.
96.80	CS78		L		Bank ~2 - 3 m high, fronted by willows. River level terrace. Local loss of grass cover, exacerbated by stock tracks to river.
96.80	CS78		R		~4 - 5 m high sub-vertical bank fronted by ~2 m wide flattish terrace. Generally trees hold soil around roots, locally tree and soil fall has occurred.
96.80	CS78		R		Loss of grass cover.
97.30	WP314		L		Shallow erosion/ creep in soil.
97.30	WP314	km 97.3R.jpg	R		
97.55	WP315		L		Sandy beach developed, grades to mud downstream.
97.75	WP316		L		Slope rises, tree form suggestive of creep.
97.75	WP316		R		Creep/ slide movement in grassed area; extends downstream. Frontal terrace increasing in width to 10m + (?) with 1 - 2 m wide short slope and flat ground behind.
98.00			L/R		Low slopes with trees bending toward river; small sandy beaches.
98.70	WP317		R	Private property	Beach with willow trees; sediment caught in roots is retained. Where trees absent, beach eroded. Creeping slope above with large home beyond.
98.90	CS79		L		Bank split by intermediate bench. Erosion occurring around trees (roots holding soil), likely to be exacerbated by bed degradation.
98.90	CS79		R		Exposed grassed bank.
99.15	WP325		L	Private property	Slope movement and gully erosion. Slopes fronting home subject to ongoing movement.
99.15	WP325		R		Root 'stacks' remain elevated while surrounding ground lowered by erosion. Active creep/slide/erosion occurring in grassed slope behind. South of here slope retaining works present, creep occurring below.
100.35	WP326		L		Active slope movement: fallen trees, soil creep/ fall.
100.35	WP326		R		Loss of vegetation exposes silty sediment at top of short bank.
100.40	CS80		L		Small scarps and vegetation loss.
100.60	WP331	km 100.6L.jpg	L	Property fences, at bank crest. Homes behind.	Slipping and slumping, trees moving, scarps behind.
100.80	WP332		R	Homes very close to crest.	
101.00	CS81	km101.0L.jpg	L	Horotiu meatworks intake.	Minor rock riprap protection - will require reconstruction.
101.60	WP335		L		Very hummocky, marginal slope. Loss of vegetation to expose sub-vertical soil faces in tall slopes. Minor creep in upper slope.
102.50	CS82	km 102.5aL.jpg	L	Horotiu Road Bridge	Geotextile used to protect present slope; must be maintained to avoid increasing problems as bed degrades. Very little space available for further retreat without significant consequences.
102.50	CS82	km102.5bR.jpg	R	Horotiu Road Bridge	Minor slabbing and formation of platform in riverbed. Sandy beach developed on silt downstream.
102.50	WP348	km 102.5cR.jpg	R		Significant retreat between willow trees (roots retaining soil).
102.55			L		Bank becoming higher, with some curved trees indicating soil creep.
102.55			R		Tree roots, but no soil, 'blanket of grass' remains with soil washed out from underneath.
103.50	WP349	km 103.05L.jpg	L		Rock undermined. Past silt beach level is being undercut.
103.65	WP357		R		Large homes on the terraces above slope ~20 - 30 degrees. Beach fronting the slope provides protection against the effects of bed degradation.
103.70	CS83		L/R		Partially undercut banks.
104.15	CS85		L		Slope actively creeping; soil lost from beneath tree roots.
104.15	CS85		R		Steep marginal bank.
104.55	WP368		L	Dairy factory overflow (?)	Rock riprap and geofabric protection; will require extension/ redesign with bed degradation.
104.55	WP368		R		Creep mid-slope.
104.65	WP369		R		Cliff: scarp at top of slope; trees with curved form at base.
104.80	WP370		L	Dairy factory tanks on terrace, overflow (?) below tanks.	Concrete slabs and minor riprap protection.
105.00	WP371		L	Dairy factory intake, chamber in riverbed (sheetpiled).	Water discharge adjacent to downstream side of bank. Erosion will be significantly exacerbated by bed degradation. Depth of sheetpiles not known.
105.30	WP372		L	Houses close to top of bank.	Bank actively failing.
105.50	CS86		L	Golf course.	Steep marginal banks with actively eroding toe platform.
105.50	CS86		R	Buildings close to edge of bank.	Steep, vegetated. Large trees cut down but stumps remain. Fallen trees small.

Distance from river mouth, km	Beca waypoint/ cross-section No.	Photo Filename	Bank	Feature	Bank Condition Comments
106.30	CS50	km 106.3L.jpg	L	Pukete boat ramp.	Vegetation retaining short banks (up to 4m high), some trees bent to horizontal. Wooden retaining wall at boatramp. Rocks and material entrained from beneath planks, cement already exposed ~0.5 m above beach level. Erosion beyond jetty, some willow protection at toe, very hummocky slope above. Slumping timber and tyre wall just downstream. Bank will be undermined with degradation. Small beach a short distance further south; trees bent over at bank edge.
106.30	CS50		R		Cut platforms and reasonably flat-lying area, unlikely to be significantly affected by bed degradation. Moderately steep terraced slope behind, trees holding it; no major instability observed.
106.60	WP126		L		Hummocky, vegetated, moderately steep slope.
106.60	WP126		R		Shallow fall/ slabbing failures (1-3m high cut).
106.80	WP127	km106.8L.jpg	L	Spillway from WWTP.	Protected by willow trees.
106.80	WP127		R	Houses.	Riprap bank protection. Evidence of ongoing active erosion. Houses set back from river.
107.25	WP128	km 107.25L.jpg	L	Wide road reserve.	Soil failure; shallow beach with high terrace behind. Benched slope.
107.25	WP128		R	Houses close to river.	Active erosion; tree roots exposed in river. Fenceline midway up cliff. Small beach developed at base of bank.
107.50	CS51	km 107.5bL.jpg, km 107.5aL.jpg	L		Slightly further south the shallow beach platform is lost, slope steepens, becomes sub-vertical (~5 m high), bush clad. Further south, few trees bent over; much regeneration of vegetation; pumiceous white soil in bank. Slightly further south again, active slope movement, trees bent over.
107.50	CS51		R		Gentle to moderately sloping beach with willows fronting 2 - 3 m slope. Upstream into curve of river, dead trees and fallen material, followed by recently slabbed faces with low scrub.
107.90	WP134		L		Timber pole retaining wall, beach developed in front, houses in behind on terrace. Wall undermined in several places.
107.90	WP134	km 107.9-108.0L.jpg	R		Slope steepens; creep. Beach fronting terraces.
108.10	CS53	km 108.1L.jpg	L		Timber retaining wall, steep grassed slopes fronting large homes. Hummocky to flat bench ~1.5 - 3 m wide. Willows. Slope cleared and grassed in front of houses, active creep.
108.10	CS53		R		Very hummocky slope.
108.20	WP137	km 108.2L.jpg	L	Piped outfall, private properties.	Degradation likely to activate failures further upslope. Private properties close to top of bank. Bench will be too narrow to maintain stability if river degrades. Short steep slope in front of reserve.
108.20	WP137		R		Unstable; degradation likely to trigger deeper-seated instability.
108.45			L		Retaining wall curves, beach in front, trees bent to horizontal.
108.45			R		Moderately steep actively moving slope; large scale movement expected with degradation.
108.50	WP138	km 108.5L.jpg	L		Shallow soil failure; small gravely beach.
108.50	WP138		R	Private property	Houses at top of steep arcuate scarp. Slope tree covered; trees will need to be maintained to maintain stability.
108.70	CS54	km 108.7L.jpg	L	Pukete Sewer Bridge	Pumiceous silt/ sand bluff. Gabions fronting abutment appear already above surface of beach. Gabion baskets also around pier of bridge. Jetty access, abutment and in-river piers will be vulnerable as a result of bed degradation.
108.70	CS54		R	Pukete Sewer Bridge	Housing close to edge of bank. Gentle slope with small bench for walking track. Shallow soil flow/creep occurring. Bank protection needed. Irregular timber retaining wall and blocks distributed to protect right bridge abutment; appears sufficient land to limit effects of bed degradation. Designed retaining structure recommended.
108.80	WP143	km 108.8aL.jpg km108.8bL.jpg	L		Rock riprap protection continues south, then more gabion baskets with concrete riprap in front. Willows becoming dry. Protection likely to be undermined if trees lost.
108.90	WP144		L	Private property	Terraced (shallow), few bent trees and minor soil erosion. Beach in front. Actively eroding riverbank, especially where trees lost. Wide berm (~4m) in front of properties, but rapidly diminishes.
108.90	WP144	km 108.9R.jpg	R	Stormwater drain	Drain discharging onto mattress and rock, scoured and undermined by 0.2 - 0.3 m.
109.10	WP145	km 109.1aL.jpg	L	Outfall, boardwalk	Concrete block protection for outfall. Trees lost, and sandy bank exposed. Already 'high and dry'.
109.10	WP145	km 109.1bR.jpg, km 109.1cR.jpg, km 109.1dR.jpg	R		Fallen trees. Recent cut prepared for walkway; bench too narrow to maintain stability if lower slope lengthened due to degradation.
109.20	CS55	km 109.2dL.jpg	L		Broken retaining wall with gabion baskets, bent trees, active movement. To South, short bank gently sloping with terrace behind; soil creep in terrace slope.
109.20	CS55	km 109.2cR.jpg	R	Walkway, private properties.	Steep, bush covered. Walkway bench being cut resulting in loss of bush. Platform (~4m wide) developed beyond toe of slope providing protection to bank and homes. Small timber retaining structure below private property, insufficient in the event of degradation, but house itself is retained.
109.60	CS56		L	Pukete Traffic Bridge	Bridge piles exposed below pile cap, 7 visible. Will require support. Piled outfall (sheetpiles) upstream. Bare soil on terrace - creep? Slope cleared of vegetation for view?
109.60	CS56	km 109.6bL.jpg	R	Pukete Traffic Bridge	Bridge piles exposed (2), encased by pile cap. Sandy bank about 50 degrees down to beach. Bush should be maintained for future protection. Slope south of bridge at shallower angle; houses close to edge of actively moving bank. Large flat area adjacent to river associated with stream.
109.75	WP159		L	Private property	Flat/ gentle sloping platform below slope and houses.
109.75	WP159		R	Private property	Homes very close to top of bank. Slope will need to be maintained (by planting?). Wide road reserve upstream.
110.20	WP160	km 110.2aR.jpg, km 110.2bR.jpg	R	Private property, jetty.	Retaining wall may be undermined by bed degradation.
110.30	WP161	km 110.3R.jpg	R		Timber retaining wall, 2 tiers - lower tier likely to be undermined as a result of bed degradation.

Distance from river mouth, km	Beca waypoint/ cross-section No.	Photo Filename	Bank	Feature	Bank Condition Comments
110.40	WP162	km 110.4aR.jpg, km 110.4bR.jpg	R	Retaining wall and jetty.	Adhoc retaining structures undermined by about 0.5 m at present. To be sheetpiled? Soils appear fairly competent in bank toe. Gabions in lower slope. Just upstream banks steep, vegetated, fallen rocks at toe.
110.50	CS57		L	St Andrews Golf Course	Hummocky; pine trees; bank ~4m high. Soil exposed in banks. Willows provide protection.
110.50	CS57	km 110.5aR.jpg	R		
110.50	CS57	km 110.5bR.jpg	R-L		Steep slope, active movement, trees falling downslope, houses immediately behind trees. Fallen rock blocks at toe. To south, retaining wall at top of slope with houses behind.
110.80	WP169	km 110.8R.jpg	R		Steep slopes with active movement, trees bent. Adhoc bank protection.
111.00	WP170		L		Retaining wall in front of golf course. Rock riprap and gabions.
111.00	WP170		R		Steep slope, houses at top, grading into gentler slopes.
111.10	WP171		L		Riprap toe of slope; active movement.
111.10	WP171	km 111.1R.jpg	R	Outflow	Small rock riprap and some bouldery riprap toward toe. Material/fabric exposed below trees where rock cover lost.
111.20	WP172		L		(Natural) rock platform. Beach formed in gentle eroding slopes.
111.20	WP172	km 111.2aR.jpg	R	Outflow	Riprap; steps extend down to 1-2 m above river level.
111.30	WP173		L	Jetty	Low gently sloping banks.
111.30	WP173	km 111.3aR.jpg	R	Walkway	Local riprap and concrete block protection of lower slope.
111.90	WP174		L	Outfall with piled walkway about 0.8 m up cliff.	Steep high banks. Tree form indicates creep; spalling and slabbing failures.
111.90	WP174	km 111.9aL.jpg	R-L		
112.05	CS59	km 112.05aL.jpg, km 112.05bL.jpg	L		Hummocky slope failing next to sheet-piled outfall (3 sheetpiles at 2 m spacing and timber). Loss of material below; walkway above; houses beyond. Bare of vegetation.
112.05	CS59	km 112.05cL.jpg	L	Stormwater outfall.	Steep slopes. Active slumping. Trees curved; vegetation obscures slope.
112.05	CS59		R		Bushclad; rockfall in places. Low slope overall, gentle parkland in behind.
112.30	WP181	km 112.3aL.jpg, km 112.3bL.jpg	L		Soils pumiceous, current bedded. Trees falling down gentle slopes.
112.30	WP181		R		Vertical cliff with arcuate scarps.
112.50	CS60	km 112.5L.jpg	L		Flat terraced reserve with active eroding face.
112.50	CS60		R	Private property	Debris at toe; steep subvertical slopes, curved tree form.
112.70	WP184-185		L		Riprap retaining wall; much rock lost. Supplemented with concrete paving slabs, sandbags, concrete blocks and timber.
112.70	WP184-185		R		Timber retaining structures.
112.80	WP185	km 112.8aR.jpg, km 112.8bR.jpg	R		Retaining structures.
112.90	WP186	km 112.9cL.jpg - km 112.9gL.jpg	L	Private property	Substantial timber retaining wall (depth of piles unknown, degradation may affect it). Much loose rubble debris at bank face, houses behind. Becomes willow protected.
112.90	WP186		R		Presently protected by willow trees.
113.20	WP187	km 113.2R.jpg	R		Adhoc attempts to maintain bank; loss of jetty.
113.30	WP188	km 113.3R.jpg	R		Low timber retaining wall, fronted by beach.
113.40	WP189	km 113.4dL.jpg	L	Bridge abutment and pier.	
113.40	WP189	km 113.4aR.jpg - km 113.4dR.jpg	R		Paved slope face?
113.50	CS61	km 113.5bL.jpg	L	Fairfield Bridge.	Adhoc protection downstream of abutment. Needs attention to maintain.
113.50	CS61	km 113.5cR.jpg	R	Fairfield Bridge, private properties.	Shallow beach fronting abutment. Upstream of bridge, slope becomes hummocky and houses close to top of slope.
113.60	WP195	km 113.6L.jpg	L	Outfall and walkway bridge.	Flattish terrace behind bank; failure of front of bank. Riprap protection; bush lost and cut away.
113.60	WP195	km 113.6R.jpg	R	Jetty	Significant 5 tiered timber retaining wall. May become undermined with bed degradation. Active movement/ slide/ flow/ creep upstream.
113.70	WP196	km 113.7R.jpg	R		Concentrated outfall - beach is paved with fine riprap and scattered boulders.
113.90	CS62	km 113.9cL.jpg	L		Erratic use of riprap on bank; slope movement evident; curved trees; debris. Slope benched for walking track. Tree roots exposed. Likely to fail in response to bed degradation.
113.90	CS62	km 113.9dR.jpg	R	Private property	Tyre wall; riprap; concrete slabs (home owner efforts to preserve property).
114.00	WP203		R		Scrub; tree roots exposed; active erosion. Needs maintenance.
114.30			L		Steep.
114.30			R		Moderate slope; small bench for path.
114.40	CS63		L	Boundary Road Bridge	Piles and pier okay. Bed degradation may expose piles. Moderately steep bank, soil failure at toe.
114.40	CS63	km 114.4R.jpg	R	Boundary Road Bridge	Adhoc protection of pier - will require support. Moderately steep with frontal bench and soil movement at toe.
114.50	WP209	km 114.5aR.jpg, km 114.5bR.jpg	R	Private properties.	Retained private properties at top of slope. Steep slope; arcuate feature; slipping trees; loss of material off bank. Need to maintain vegetation.
114.70	WP210		L	Jetty and outfalls.	Moderate slopes with gentle frontal slope. Riprap protection. Cliff set back from terrace.
114.85	WP211	km 114.85L.jpg	L	Urban	Steep unretained bank with road close to cliff. Concrete slab riprap where reserve meets river. Bank height increases from 4 to 10 m.
114.85	WP211		R		New concrete wall constructed at top of subvertical slope about 5 m high. Banks increase to about 10 m high.
115.25	WP212				Fallen trees, erosion.
115.40	CS64	km 115.4bL.jpg km 115.4aL.jpg	L	Claudelands Bridge	Moderate to subvertical slopes obscured by vegetation; small beach in front. Remedial works in place for slip on northern side of bridge. Main pile at abutment close to slope face, but probably not exacerbated by bed degradation. Vegetated slopes, but actively eroding. Water discharges from mid-slope just downstream of instability.
115.40	CS64	km 115.4aR.jpg	R	Claudelands Bridge	Slope in front of abutment pile has been subject to rockfall and loss of vegetation. Unlikely to be worsened by bed degradation. Slip with debris mostly washed away just north of bridge.
115.55	WP219		L	Buildings	Weak rock; fallen trees and active slope movement; many buildings above. Timber retaining wall tipping; riprap placed to reduce loss of material from beneath wall in two places.

Distance from river mouth, km	Beca waypoint/ cross-section No.	Photo Filename	Bank	Feature	Bank Condition Comments
115.55	WP219		R		Shallow slope; active soil failure. Wooden retaining wall would be undermined by bed degradation.
115.65	WP220		R		Riprap and boulder protection; unlikely to be affected by bed degradation.
115.90	WP222	km 115.9aL.jpg	L		Concrete retaining wall already undermined. Slopes flattish to moderate behind.
115.90	WP222		R	Waipa Delta Jetty	Concrete, hexagonal style 2-layer retaining wall and jetty. Undermining possible.
116.30	CS65	km 116.3bL.jpg	L	Bridge Street Bridge, outflow, rowing club.	Outflow tunnel with rock riprap in water. Fine gravel beach fronts rowing club. Concrete slab wall upslope, needs repair.
116.30	CS65		R	Bridge Street Bridge	Slopes ~5 m, vegetated but actively eroding and regular attempts at protection by riprap. Retaining wall where bridge struts enter bank. Willow and small gravel protection below. Need to support soils in front of bridge abutment.
116.60	WP229		L		Riprap, mesh and fabric. Actively eroding.
116.70	WP230	km 116.7L.jpg	L		Cemented rock wall retaining carpark. Will be redundant with bed degradation.
116.70	WP230		R		Riprap.
116.80	WP232	km 116.8L.jpg	L		Outfall onto flat sandy to gravelly beach; significant scour; will be high and dry with bed degradation. Slopes in behind are showing signs of movement.
116.80	WP232		R		Rip rap, concrete and boulders - erratic bank protection.
116.90	WP233	km 116.9R.jpg	R	Outfall	Riprap protection of 1.5 - 2 m slope below walkway.
117.00	WP234		R		Cessation of riprap protection.
117.10	WP235		R	Outfall	Concrete cone protects outfall.
117.20	WP236		L		Rock riprap protecting slabbing cliff.
117.20	WP236		R	Jetty	
117.20			R	Wellington Street Beach	Low to moderate slope; sandy beach.
117.30	WP237	km 117.3aR.jpg, km 117.3bR.jpg	R		Silt exposed below past beach, about 0.3 m erosion. Trees moving down bank.
117.40	WP239	km 117.4aL.jpg	L	Skills Centre	Riprap protection; slope 4 - 5m.
117.40	CS66	km 117.4L.jpg	L		Riprap protection; disused outflow. Slopes below road bush and willow protected, but some loss of trees to river.
117.40	CS66		R		Slope debris at toe; active loss of vegetation to the river. Willows provide protection to slope toe upstream.
117.55	WP245		L		Tree form indicative of creep; bedded soils/weak rock outcropping at water edge; ongoing loss of large trees at top of slope anticipated with bed degradation.
117.70	CS67		L	Outfall	Fallen trees at base of slope; dense scrubby vegetation.
117.70	CS67		R		Low terrace, moderately steep; if willows lost, bank will fail. Bank becomes vertical and prone to slabbing toward Cobham Bridge.
117.90	WP250	km 117.9L.jpg	L		Slope movement: sliding of weathered soils and vegetation. Arcuate headscarps extend along bank. Upper soils saturated and slide on underlying low permeability weak rock; rock fails by spalling and slabbing. Slope becomes subvertical cliff with gorse; active slabbing.
117.90	WP250		R		Low lying terrace with established willows; unlikely to be affected by bed degradation.
118.00	WP251		L		Movement of porous soils on low permeability layer below; slabbing of weak rock.
118.00	WP251		R		Shallow beach; slope behind moderate.
118.50	CS68	km 118.5L.jpg	L	Cobham Bridge	Beach elevated. Protection may be required downstream of pile slab if bed degradation occurs.
118.50	CS68		R	Cobham Bridge	Open fractures allow water to percolate into slope behind face causing slabbing of bank; continues upstream. Loss of vegetation below walkway above stormwater outfall. Pile will be vulnerable if bed degradation occurs. Active bank erosion.
118.70	WP258		L	Stormwater outfall	Beach of sand. Becoming flat terrace.
118.70	WP258		R		Cliff with trees. Debris and vegetation at toe.
118.80	WP259	km 118.8R.jpg	R	Stormwater outfall, Hamilton Gardens.	Erosion behind gabions.
119.00	WP260		L	Water supply pipe	Water supply pipe on concrete piles in bank; may be compromised by degradation. Runs parallel to river along top of bank for a distance; may necessitate bank protection. Rock exposure in middle of river.
119.00	WP260		R		Adhoc protection - dense scrub, but actively eroding.
119.15	WP261		L		Saturated zone discharging above low permeability sub-horizontal bedded weak rock.
119.30	WP262		R	Hamilton Gardens - building	Small beach with shallow eroding bank behind (creeping).
119.35	WP263	km 119.35aL.jpg	L	Water treatment plant flow gate structure	Gate structure will be elevated if bed degradation occurs. 50 m upstream; riprap protection.
119.35	WP263	km 119.35bR.jpg	R		
119.40	WP264	km 119.4aL.jpg	L		Riprap on slopes about 3 m high. Weak 'rock' platform formed in lower slope. Water discharging over bank.
119.40	WP264	km 119.4R.jpg	R	Hamilton Gardens	Sheetpile wall. Rockfall along discontinuities.
119.50	WP265	km 119.5L.jpg	L		Spalling and slabbing of subvertical cliff.
119.50	WP265	km 119.5R.jpg	R	Cemetery	Gabion protection below road. Beach developed. Slope steepens and lengthens; well vegetated but susceptible to spalling/ slabbing/ oversteepening. Terraced next to cemetery/ walking track.
120.20	CS70		L		Terrace about 1m high, 3 - 4 m across bank about 4 - 5 m. Fronting beach, partly gravel covered.
120.20	CS70		R		Headscarps; regrowth on lost face.
120.80	WP271		L		Steep slope with debris at toe; pumiceous soil with weathered crust. Trees moving downslope. Spalling and slabbing.
120.80	WP271		R		Bank becoming less steep.
121.00		km 121.3R.jpg	R		Moderate slope eroding above vertical bank susceptible to slabbing.

Distance from river mouth, km	Beca waypoint/ cross-section No.	Photo Filename	Bank	Feature	Bank Condition Comments
121.30	WP272		R	Outfall and walkway bridge.	Outfall with gabion protected walkway; timber bridge above cut in cliff. Slabbing of slope fronting piles; may require mitigation in future.
121.60	WP273		L	Riverglade Drive area.	Short vertical faces, actively eroding. Gully/stream tributary.
121.60	WP273		R	Riverglade Drive area.	Slope movement may be initiated by bed degradation. Bank gains willow protection and becomes flattish beach/ terrace.
122.75	CS71		L		4 - 5 m high, willow fronted; active slumping.
122.75	CS71	km 122.75R.jpg	R		Slabbing; tree roots overhang; tree fall into river.
122.85	WP276				Old slip.
123.40	WP277		L		Gentle slopes with creep in behind.
123.40	WP277		R		Moderate slope. Tree form suggests creep.
123.80	WP278		R		Debris at toe forming beach at inside bend; creep of slope occurring behind.
124.10	WP279		L		Low terrace with moderate slope behind; vegetation moving downslope. Erosion of soil into river.
124.10	WP279		R		Moderate slope; small slips.
124.55	WP280		L		Slope flattens.
124.65	WP281		L	Private property	Home made timber retaining wall. Slopes susceptible to shallow sliding.
124.65	WP281		R	Boat ramp	Retaining structure undermined.
125.10	WP282		L		Vegetation moving down moderate slope, with small beach in front. Susceptible to slumping.
125.10	WP282		R		Fallen trees.
125.30	WP283		L		Loss of trees has resulted in active soil erosion and spalling/ slabbing of bank. Arcuate scarps. Dense vegetation.
126.00	CS73	km 126.0L.jpg	L		Cleared bank: toe maintained by root systems; bank incised 2m+ where trees absent.
126.20	WP286	km 126.2R.jpg	R		Actively eroding subvertical slope below houses, ~ 5m high.
126.40	CS74	km 126.4aL.jpg	L	Narrows Bridge	Abutment extends to edge of slope; may require attention.
126.40	CS74	km 126.4bR.jpg, km 126.4cR.jpg	R	Narrows Bridge	Abutment piles extend to edge of top of slope; may require mitigation irrespective of bed degradation. Erosion upstream may lead to loss of bank.
126.70	WP291	km 126.7L.jpg	L		Active sliding/ creep on old landslide surface.
126.70	CS75		L		Timber retaining wall facing with riprap in behind; private effort, no value on bed degradation.
126.70	CS75		R		Lower terrace 2 - 3 m wide and slope increasing.
126.90	WP295	km 126.9L.jpg	L		Shallow slide movements extend several 10's of metres along bank.
127.10	CS76	km 127.1L.jpg	L		Loss of all trees over sections of bank of about 10 m length each. Evidence of slabbing/ rockfall. Water ~8.5 m deep.
127.10	CS76		R		Recent loss of trees; subvertical bank; fractures open.
127.10	WP296	km 127.1L.jpg	L		Slabbing. ~13 m water depth (gorge).
129.20	CS39	km 129.2L.jpg	L	Private water intake	
129.20	CS39		R	Private property	Creeping slope.
129.40	CS38		L		Creeping slope, unlikely to be exacerbated by bed degradation.
129.40	CS38		R		
129.85	WP116		L		Bank ~3 m high. Pines planted together with Willows, obscure slope profile.
131.00	CS36		L	Mystery Creek	Water discharges from bank above low permeability materials about 2/3 way down the slope. Limited private slope protection attempts. Beyond Mystery Creek, Willow margin developed.
131.00	CS36		R		Bank strongly vegetated; willows at margin. Saturated short steep slopes; rock and vegetation fall.
132.50	WP107	km 132.5L.jpg	L		Active tree fall from top of subvertical "sandstone" bank. Bank fails by slabbing through the rockmass. Low slopes at edge both sides.
132.50	WP107		R		Landslide zone.
133.50	WP102		R		Large scallop/amphitheatre above river; evidence of tree fall downslope.
133.60	CS31	km 133.6L.jpg	L	Pipe discharge (?)	Waterfall in bank (discharging from pipe?) in natural gully in rock; rockfall.
133.60	CS31		R		More gentle slopes (~40 degrees). Willows at water's edge on low shallow toe platform.
134.05	CS30	km 134.05L.jpg	L		Shorter hummocky slope. Large scallop just above slope.
134.05	CS30		R		Longer hummocky creeping slope.
135.65	CS28		L		Large residence above overhanging bank. Slope marginal. Vegetation regenerating; may assist in maintaining margin of stability.
135.65	CS28	km 135.65R.jpg	R		Bank just beyond pine plantation has scalloped form sloping down toward the beach. Frontal low shelf offers protection.
136.80	CS26		L		Low strength sandy soils exposed in bank.
136.80	CS26		R		Bush-clad tall slopes with evidence of historic movement. Trees curving toward river indicating some movement.
137.00	WP88	km 137.0L.jpg	L	Heritage Farm water intake	Water supply intake already subject to loss of material.
137.90	CS24		L	Private property	Tall slopes actively eroding, slightly over-steepened. Bench forms in places. Just past here is a large replanted zone - old landslide? Bench adjacent to river protects upslope property. However, tree fall continues to impact bank stability.
137.90	CS24		R		Bank more gentle and irregular.
138.55	WP79		L/R		Gorge'; erosion occurring by spalling and slabbing. Estimated 3 -4m high banks.
138.70	WP78		L		Abundant tree movement on bank.
138.70	WP78		R		Opens out to more gentle slopes; evidence of slope movement in farmland.
138.90	WP77		L-R		Entering broad 'gorge' with subvertical (more resistant) beds forming lower part of bank 0.5 to 1.0 m above water level; instability above these beds.
139.30	CS21		L-R		Slopes reducing in height. Abundant tree, soil and rock block fall. Large shallow bowls formed on both banks.
139.90	CS20	km 139.9L.jpg	L		Instability on both sides of river. Strong laminations in geology picked out by water/ weathering. Blocky failures in lower slope with more gentle instability above.
140.20	WP68	km 140.2L.jpg	L		Sandy soils over lower permeability weak rock; bank fails at interface both sides of river.
140.50	WP67	km 140.5a.jpg km 140.5bL.jpg	L-R	Pipe bridge	Pipe extends close to top of L bank crest. Log protection. Check - may get quite close to incised gully.
141.20	WP66		L		Slide and flow movement.

Distance from river mouth, km	Beca waypoint/ cross-section No.	Photo Filename	Bank	Feature	Bank Condition Comments
141.20	WP66		R	Private property	Significant arcuate scarps; slides undermine slopes.
141.30	CS19		L		Bank well vegetated with minor ongoing movement; scalloped morphology downstream toward the corner.
141.30	CS19		R		Bank bush-clad. Bench in bank (sharp) ~3 m above waterline.
141.70	WP61		L		Clearing trees at top of bank, leading to failures downslope.
142.00	CS18	km 142.0L.jpg	L	Victoria Bridge (Cambridge)	Appears clear of river.
142.25	CS17	km 142.25bL.jpg, km 142.25aL.jpg	L		Next 100 m trees falling into river. Path and fence lost into river.
142.25	CS17		R		Willows adjacent to river, low slope.
142.80	CS16	km 142.8bL.jpg km 142.8a.jpg	L	Fergusson Bridge	Front rock bulge may be vulnerable to loss exposing buttress piles on bed degradation. Crib wall and riprap protection at present. Resistant lower section of slope. If this continues at depth degradation may not have significant effect.
142.80	CS16	km 142.8aR.jpg	R	Fergusson Bridge	
143.10	WP51		L-R		Subvertical bedding entering "gorge".
143.25	WP50	km 143.25L.jpg	L	Private properties.	Slopes cleared of vegetation below Cambridge houses.
143.70	WP45	km 143.7R.jpg	R		Slope bare of vegetation; moderate to steep slopes ~45 deg.
143.80	CS14-15		R		Much rock and vegetation fall by slabbing.
144.10	CS13		L-R		Widened river. Slopes ~5 -8 m tall. Evidence of significant rockfall, tree fall and revegetation. 10 m further downstream, rock outcrops in riverbed with fallen boulders on top.
144.30	WP40		L-R		River widens from about 50 m upstream of here.
144.75	CS12	km 144.75L.jpg	L		Tall steep slope back beyond gorge. 17 - 18 m water depth shallows to 12 m.
144.75	CS12		R		Joint controlled 'ignimbrite' with open fractures. Some weak sandy lenses within.
145.00		km 145.0bL.jpg, km 145.0aL.jpg	L		Just past intersection with river branch, 13 m depth to riverbed; 'ignimbrite gorge', then sediment banks once more.
145.50	CS9		L		Upper 1.5 m of bank failing above a more resistant gravely river deposit.
145.50	CS9		R		Dense vegetation; scalloped bank inferred to occur behind.
145.65	WP32	km 145.65L.jpg	L		Very low banks, 2.5 - 3.0 m.
145.65	WP32		R		Slope movement on cleared face of about 45 deg.
146.10	CS8	km 146.1bL.jpg, km 146.1aL.jpg	L		Sandy gravel beach developed;plants regenerating. Amphitheatre nearby planted in pines. Water held up on a low permeability zone causing sediments above to fail.
146.10	CS8		R		Erosion occurring in behind a frontal block of the bank; block will eventually be lost.
146.40	CS7-8	km 146.4R.jpg	R		
146.60	CS7		L		Subvertical bank, gorse covered; coarse sub-horizontal sandstone beds. Slabbing and loss of trees and rock downstream.
146.60	CS7	km 146.6R.jpg	R		Loss of vegetation and rock blocks with debris accumulating at toe. Some large arcuate scarps. Slopes decreasing in height.
146.80	WP23	km 146.8bL.jpg	L		
146.80	WP23	km 146.8aR.jpg	R		Active slabbing of bank.
146.90	CS6		L		Rockfall fan fronts slopes, providing protection.
146.90	CS6		R		Rock falls straight into river.
147.00	WP18	km 147.0cR.jpg, km 147.0bR.jpg, km 147.0aR.jpg	R		Low point in riverbank; sub vertical trees actively falling in the river. Waterfall incised in rock. Between this and next site, banks becoming better vegetated and appear relatively stable.
147.40	CS5	km 147.4aL.jpg	L		Steep beach developed. Rockfall. Boulders to coarse gravel.
147.40	CS5	km 147.4bR.jpg	R		Clean face, with current bedded sandy-gravely deposits. Slope height is reduced. Next 50 m has many trees falling downslope.
147.60	CS4-5	km 147.6R.jpg	R		
148.20	WP13		R		Rockfall accumulating at slope base via spalling and slabbing. Steep beach at toe of bank formed from river sediments trapped between fallen rock blocks. Undercutting in places.
148.30	CS3		L		Tall slopes with small beach developed (~40 degrees bank in behind).
148.80	CS2		L		Water discharging down bank.
148.80	CS2	km 148.8dR.jpg, km 148.8cR.jpg	R		Falling trees facilitating building up of toe zone.
148.90	WP4		R		Pumiceous near top; sandy gravel toward base. Slabbing. Active erosion of bank with roots crawling downslope.
149.00	WP3		L		
149.10	WP2		R		
149.50			R		Greywacke exposed in bank; pines falling into river. Rock blocks and debris at base of slope.

- Appendix D

Geotechnical Assessments

1 Introduction

The middle reaches of the Waikato River (between the Karapiro Dam and the Waipa confluence at Ngaruawahia) are undergoing bed degradation. Over the next 100 years bed degradation is predicted to reach around 3 m at Hamilton, (Smart, 2003). It is expected that bed degradation will impact on the stability of the existing, marginally stable, riverbanks (the causes of this degradation are not considered in this study).

The affected stretch of the Waikato River passes through the urban areas of Cambridge, Hamilton and part of Ngaruawahia, and is crossed by more than ten bridges (including traffic and services). Instability triggered by bed degradation has the potential to adversely affect land and infrastructure, such as bridge abutments and piers, private properties, and utilities/services, in or in proximity to the river.

This appendix summarises the risk to bank stability and the resultant bank stability hazard, as a result of the projected bed degradation. The principal conditions controlling bank stability are considered (soil/rock type, slope height and angle, vegetation cover, river morphology and past instability), with each attribute being weighted and summed to identify the relative risk. The projected bed degradation profiles for 100 and 50 years (Smart, 2003) have been factored and multiplied by the bed degradation induced slope instability weightings to provide a slope instability hazard classification resented in the bank slope hazard map in this appendix.

2 Conditions that Affect Bank Stability

The underlying causes of slope instability are fairly well known from case studies of specific failures. The causes can often be directly related to the rock and soil composition, which are relatively constant, or may be transient (e.g. seismic vibration or storm events) or imposed by new events (e.g. construction activities and bed degradation).

In a given area the more constant factors can be recognised and their effects rated. Some can be mapped and correlated with each other and with past slope movements. An understanding of the mechanisms of slope failure and why failures occur when and where they do, allows prediction of susceptibility by extending local information to larger areas.

A general description of soil and rock masses outcropping in the vicinity of the Waikato River between Ngaruawahia and Karapiro is given in Section 2.1. A simple classification of the types of slope movement observed is given in Section 2.2 and the main conditions that promote instability are identified in Section 3. Their relative contribution is estimated in Section 4 and the relative effects of the amount of bed degradation predicted are incorporated in Section 5. In this way a summary of the potential hazard has been built up which depends on the number of failure inducing factors present, their severity and their interaction.

2.1 Soil and Rock Types

2.1.1 Geological Setting

The Waikato River runs through the Hamilton Basin, a depression formed by faulting and uplift of the surrounding ranges in Pliocene times. The soil and rock types in the Mid-Waikato (between Lake Karapiro and Ngaruawahia) are largely the result of sedimentary filling of this Basin in the Quaternary (though volcanism has also played a part).

The geology (as mapped) in the vicinity of the river is described below in Table D1 (in top-down stratigraphic order):

Table D1: Surface Geology of the Mid-Waikato

Unit Name	Description*	Age (years BP)
Alluvium	Alluvial sand, silt and gravel	0 to 10,000
Peat	Peat and peaty silt	
Taupo Pumice Alluvium	Alluvial pumice with charcoal, c.130 AD	
Hinuera Formation	Mainly rhyolitic, current-bedded sand and gravel, interbedded with peat and pumiceous silt and sand	10,000 to 1.6 million
Walton Subgroup, Karapiro Formation	Fluviatile/ lacustrine sand and gravel with silt interbeds (less pumiceous than Puketoka Fmn and more weathered than Hinuera Fmn)	
Walton Subgroup, Puketoka Formation	Very stiff to hard (weakly cemented) sensitive silt, very weak to very soft pumiceous cemented silt/ignimbrite, well sorted light grey-white pumiceous clay, sand and breccia	
?	Siltstone, sandstone and conglomerate with interbedded airfall and redeposited pumice tuff	
?	Fluviatile silt, sand, gravel and interbedded pumiceous tuff	
Manaia Hill Group	Banded siltstone, rare sandstone and conglomerate	144 to 208 million
	Indurated sandstone and siltstone, with tuffaceous beds	208 to 245 million
*Descriptions assembled from Selby and Lowe (1992) as well as published geologic maps: Kear (1960); Healy, Schofield and Thompson (1964); and records of investigations in the area.		

The filling of the Hamilton Basin comprised two stages of alluvial fan building:

- Walton Subgroup alluvium deposited by pre-Waikato rivers and subsequently incised by river meanders to leave upstanding hills; and
- Hinuera Formation deposited by the ancestral Waikato River when it changed course from the Hauraki Plains to its present path.

The Waikato River ceased its depositional phase and took a meandering form some 15,000 years ago, and has downcut into the Hinuera Formation and Walton Subgroup by up to 70 m.

Sediment from the 130 AD Taupo Eruption was carried by the Waikato River, and filled the river channel and tributary stream gullies with Taupo Pumice Alluvium. The River has largely cut through this material, although a thickness of up to 30 m of Taupo Pumice Alluvium remains on Hinuera terraces at about 6 m above river level.

Today the river cuts through an unknown thickness of alluvium, confined by ranges of greywacke at Karapiro and Ngaruawahia. The greywacke is understood to occur in the riverbed:

- At Karapiro for a distance of a few hundred metres or so, dipping to the north; and
- Toward Ngaruawahia, possibly at much greater depth due to down-faulting.

The depth to greywacke between these points is expected to be significant, and it is considered unlikely that there is an erosion-resistant stratum to be reached in the foreseeable future to which the river may degrade and reach a stable profile.

2.1.2 Soils and Rocks in the River Bed and Banks

For the most part, the Waikato River cuts through readily erodible alluvium, with occasional pockets of slightly more resistant 'cemented' alluvium and/or ignimbrite, and possibly greywacke. The inherent variability of Mid-Waikato geology means that bed degradation is likely to occur at a variable rate, with varying effect on bank stability along the course of the River. The geological units have been grouped according to their expected geotechnical behaviour.

Direct observations during the River reconnaissance trip indicated that there are broadly two extremes in geotechnical behaviour within the alluvial deposits, as expressed through the bank geomorphology. At one extreme is a gorge-like morphology where the geology is more resistant to erosion, and is competent enough to stand almost vertically. This is inferred to be due to cementation of the alluvium and/or corresponds with ignimbrite flow deposits. These banks fail by spalling or slabbing of blocks along discontinuities. At the other extreme are loose silty to sandy banks where the materials sit in a state of limit-equilibrium (at their angle of repose). These banks are particularly susceptible to erosion where vegetation has been lost/removed. A combination of these extremes is also observed, typically with slide failure occurring in the weaker alluvial materials on a lower permeability interface with the more resistant stratum, which extends below river level.

2.2 Slope Height and Angle

The steepness and height of a bank in relation to the properties of the soil and rock slopes may be critical to bank stability. While most natural slopes are irregular, comprising sections of different steepness, average slope angles and heights have been used for this assessment. Bed degradation essentially increases slope height.

2.3 Active Movement

Evidence of past instability indicates a potential for failure of geologically similar slopes of similar slope grade in the same area, thereby providing an important guide to the likely future behaviour of slopes in the locality.

3 Hazard Contributions

3.1 Geomorphic Type (soil type + slope angle)

Because the soil/rock units exposed along the length of the Waikato River include a range of soil types of unknown distribution, the geomorphic expression of these soil and rock differences has been used instead as an input to the hazard assessment. The geomorphic type is a summation of the soil/rock properties, groundwater and slope angle. The riverbanks can be grouped into four geomorphic types as described in Table D2. The table also shows a sub-category, B1, which has been identified from aerial photographs as areas of historical deeper-seated instability.

Table D2: Geomorphic Types

Class	Description
A	Wide platforms gently sloping to river
B	Moderately steep banks (evidence of shallow slips, slumps and slides)
B1	As for B, with evidence of larger scale historical slope movements
C	Steep to very steep banks exhibiting spalling and slabbing type failures
D	Slopes comprising a lower portion as per C and an upper portion as per B, that has failed

Back-Analysis

With the exception of type B1, each bank geomorphic type was modelled using the computer program SLOPE/W to assess the effects of bed degradation on bank stability. Typical cross-sections were identified from a combination of bed cross-section data and range-finder profiles created during river reconnaissance trips as part of this investigation.

Soil properties were broadly grouped as alluvium and “cemented” alluvium, and parameters applied derived from available geotechnical data and back-analysis of existing slopes (assuming existing slopes have a factor of safety of around 1.0 to 1.1). The properties modelled are given in Table D3.

Table D3: Geotechnical Properties

Material	Unit Weight γ(kN/m³)	Cohesion c' (kPa)	Friction angle ϕ’ (°)
Alluvium	17	3	28
Cemented alluvium	19	20/50/100	34

Class A

Failure by sliding or creep on a moderately shallow circular failure surface.

Class B

Failure by sliding along a circular failure surface and passing through the toe of the slope. Of the four geomorphic types modelled, Class B is most at risk from bed degradation.

Class C

Failure by individual rock falls spalling or slabbing vertically. Where these extend to depth, the failure surface may change to a curved profile extending to the slope toe.

Bed degradation has only a small influence on the margin of stability, provided similarly cemented materials exist to depth. Should weaker soils become exposed on bed degradation, then the influence will be significant and slope movement is likely to extend back into the riverbank. The likely distance back from the bank crest affected is expected to be equivalent to the height of the slope at the friction angle of the weaker soils.

Class C is considered to have a low risk of bed degradation induced failure, provided the same cemented materials extend to depth. This will need to be confirmed by site specific subsurface investigation in critical areas.

Class D

Failure by sliding along a circular failure surface on the water-lubricated interface with the underlying cemented alluvium.

As for type C, the effect of degradation is small, as the geotechnical properties of the lower cemented alluvium layer control stability. However, should these materials be of limited vertical extent and weaker materials become exposed by bed degradation, the effect on bank stability will be significant.

Typical Profiles

Once the profiles and parameters were established, the effect of bed degradation (i.e. lengthening of the slopes) by 1.5 m and 3.0 m was modelled. The results of these analyses are shown in Table D4.

Table D4: Effect of Bed Degradation on Existing Slope Stability

Class	Materials	Slope Height (m)	Slope Angle (°)	2005 FoS	FoS 2055	FoS 2105
A	Alluvium	4	7°	1.5	1.2	1.1
B	Alluvium	12	30°	1.0	0.9	0.8
C	Cemented Alluvium	50	70°	1.1	0.9	0.8
D	Alluvium/Cemented alluvium	20	30° on 85°	1.1	1.05	0.8

3.2 Slope Height

Slopes are generally higher at the Karapiro end of the Waikato River section studied (average height of 35 m) and lower at the Ngaruawahia end of the river (average height of 4 m). The heights of banks have been grouped as shown in Table D5. The mapped height groupings have been developed from on-river range-finder measurements, correlated with DTM heights.

Table D5: Slope Height Classes

Class	Description	Bank Height Range (m)
A	Low	0 – 5
B	Low to Moderate	5 – 15
C	Moderate to High	15 – 30
D	High	30 +

3.3 Active Slope Movement

Inferred areas of past instability extending back from the immediate area of the riverbank have been identified from examination of stereopairs of aerial photographs. These areas have been allocated Class B1 within the geomorphic type series (see Table D2).

3.4 Vegetation

The presence of willows was observed to have a noticeable influence on the position of the toe of the riverbank and the maintenance or loss of a "beach" fronting the riverbank. Maintenance of a beach or terrace in front of the bank significantly reduces the risk of bank movement in response to bed degradation. Native and other species provide more limited protection to banks. Classes have been assigned according to the presence and type of vegetation as described in Table D6.

Table D6: Vegetation Classes

Class	Description
A	Willows
B	Other tree and bush species
C	Grass

3.5 River Morphology

The bank inside a river meander will be protected against scour and to some extent against bed degradation, whereas the bank on the outer side of a river meander will be exposed to maximum scour and bed degradation. Inside, straight, outside and sharp outside bends have therefore been identified for weighting in the hazard assessment as described in Table D7.

Table D7: River Morphology Classes

Class	Description
A	Inside meander
B	Straight river
C	Outside meander
D	Sharp outside meander

3.6 Projected Bed Degradation

The expected depth of bed degradation has been grouped as described in Table D8. Projected (100 years) bed degradation figures between Narrows and Pukete boat ramp have been interpolated from figures in Smart (2003); projections beyond this reach (north of Pukete boat ramp and south of Narrows) are less well constrained.

Table D8: Projected Bed Degradation

Class	Description	Degradation Range (m) (50 yrs)	Degradation Range (m) (100 yrs)
A	Nil – low	0 – 0.2	0 – 0.5
B	Low	0.2 – 0.5	0.5 – 1.0
C	Moderate	0.5 – 1.0	1.0 – 2.0
D	High	> 1.0	> 2.0

4 Hazard Assessment

Regional scale assessment of bank stability hazard due to bed degradation has been carried out by allocating weighted scores to each of the key attributes contributing to bank movement and presenting these on a series of maps at a scale of 1:75,000. The scores for each attribute have been summed using Geographic Information Systems technology to produce a regional bank stability hazard map.

4.1 Geomorphic Type and Past Instability

The distribution of geomorphic types (types A – D) and past instability (type B1) have class scores as summarised in Table D9.

Table D9: Geomorphic Type

Class	Score
A	2
B	4
B1	5
C	1
D	2

4.2 Bank Height

The variation of slope height (Classes A – D) class scores are summarised in Table D10.

Table D10: Bank Height

Class	Score
A	1
B	2
C	3
D	3

4.3 Vegetation

The variation of vegetation (Classes A – C) class scores are summarised in Table 11.

Table D11: Vegetation

Class	Vegetation Score
A	0
B	1
C	2

4.4 River morphology

The distribution of inner, outer and straight sections of river (Classes A – C) class scores are summarised in Table D12.

Table D12: River Morphology

Class	Description	Score
A	Inside bend	0
B	Straight	0.5
C	Outer bend	1.5
D	Sharp outer bend	2

4.5 Projected Bed Degradation

The variation in projected bed degradation (classes A – D) class scores are summarised in Table D13.

Table D13: Projected Bed Degradation

Class	Score (50yr)	Score (100 yr)
A	0.5	0.5
B	0.5	0.65
C	0.65	0.85
D	0.85	1.0

4.6 Hazard Scores

The scores from Tables D8 to D12 have been combined using GIS and presented on the attached Map "Bank Slope Hazard Map" as Hazard Assessment Scores for 50 and 100 year projected degradation. The total scores are interpreted in terms of bank stability hazard in Table D14.

Table D14: Hazard Assessment

Total Score	Class	Hazard Risk
0 – 4	A	Low bank instability hazard
>4 - 7	B	Moderate bank instability hazard: stability will be dependent on local factors such as depth of weathering and degree of saturation
>7 - 9	C	High bank instability hazard: slopes unstable; ongoing movement anticipated
>9 - 12	D	Severe bank instability hazard

5 Set-back Distances

The contributors to slope instability described in the sections above have been used in conjunction with the projected bed degradation to develop a "set-back" beyond which there is judged (from regional data) to be an unacceptably high risk that movement could occur over the period in which 1.5 m of bed degradation occurs in Hamilton City (Smart, 2003). A "set-back" is identified with the aim of assisting decision makers in planning future land use and identifying where development should not take place without specific investigation of bank slope stability and the potential for slope movement due to its present marginal state, accelerated by bed degradation. The proposed "set-back" is shown approximately on Map 2 attached. In producing Map 2, the toe of the bank has been assumed to be the interface of the river with the shore.

Because this is a regional scale study, set-backs have been assessed conservatively to provide stable bank angles of 7° (reworked weak silty materials) and 14° (sandy materials). These stable angles are derived by taking the present (marginally stable) slope angle of the existing river bank grouped broadly into these two types of materials, and allowing for the winter conditions when these banks become saturated. Then, assuming a saturated slope, a margin is added to yield the stable slope angle recommended.

For example a sandy bank could stand marginally stable at around 40° when dry, but can be expected to fail to 20° when saturated, and so for a safe location a set-back angle of 14° is assumed. Similarly, banks in a weak silt soil may be marginally stable at 20° when dry, and 10° when saturated, and so a set-back angle of 7° is assumed.

These approximate regional set-backs can be refined by specific geotechnical investigation and design. The approximate, and coarse, two categories assumed for discussing set-backs would not cover for example, some of the stronger more cemented banks. For this example, a 14° residual slope angle has been assumed because it is not known whether the more cemented materials extend to depth (i.e. significantly below the projected bed degradation depth). These set-backs could be (and should be) refined by specific geotechnical investigation and stability analyses.

Projected riverbed degradation (Smart, (2003) 50-year case) was grouped into four degradation categories (Table D15) to allow the average projected increase in bank height at any location to be identified.

Table 15: Degradation Classes

Degradation Class	Degradation Range (m)	Average Depth of Degradation (m)
D1	0 – 0.2	0.15
D2	0.2 – 0.5	0.4
D3	0.5 – 1.0	0.8
D4	> 1.0	1.5

These average degradation "heights" were added to existing bank height data along the length of the river and classified as shown in Table D16, using the "typical" height for trigonometric calculations.

Table 16: Projected Bank Heights

Bank Height Class	Bank Height Range (m)	Typical Height (m)
A	0 – 5	5
B	5 – 15	13
C	15 – 30	25
D	> 30	33

The set-back angle for outside meanders was determined by trigonometry, using the projected bank height measured from the "bottom of the bank" (bank/river interface) and the residual bank angle for the soil type exposed. For straight sections of river, bank retreat will be lesser and is graded from the minimum estimated by the above method according to height. The shortest set-back calculated by the trigonometric method is allocated to banks on inside meanders.

The resulting set-back estimates were rounded to 25 m, 50 m, 100 m, and 130 m as shown in Table D17 and on Map 2.

Table D17: Proposed Set-Back

Bank Height + Degradation	Material Type	River Morphology Class	Set-Back (m)
A	Silt	A	50
A	Silt	B	25
A	Sand	A	25
A	Sand	B	25
A	Silt or Sand	C and D	25
B	Silt	A	100
B	Silt	B	50
B	Sand	A	50
B	Sand	B	25
B	Silt or Sand	C and D	25

Bank Height + Degradation	Material Type	River Morphology Class	Set-Back (m)
C	Silt	A	Does not occur
C	Silt	B	50
C	Sand	A	100
C	Sand	B	50
C	Silt or Sand	C and D	25
D	Silt	A	Does not occur
D	Silt	B	50
D	Sand	A	130
D	Sand	B	50
D	Silt or Sand	C and D	25

The set-back identified for areas designated 'steep' (dotted on Map 2) may be reduced if site-specific investigation proves that the stronger materials exposed in the river bank at these locations extend to depth below the river bed.

6 References

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Bank Slope Hazard Classification

- Severe
- High
- Medium
- Low

(Refer Table D14)

Chainage 95,000 m at Ngaruawahia to 149,600 m at Karapiro Dam

Scale 1 : 75,000 at A1

Imagery sourced from Terralink International Limited.
Information dispayed on this map is indicative only.

Map D1
Mid Waikato Bed Degradation
Bank Slope Hazard Classification

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Legend

Set Back Distances
(Set back distance from bank/river interface.)

- 25 m
- 50 m
- 100 m
- 130 m
- Steep Bank - Setback may be reduced with site specific investigation.
- Chainage (m)

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A

Scale 1 : 35,000 at A1

Map D2a
Mid Waikato Bed Degradation
Development Set Back

Legend

Set Back Distances
(Set back distance from bank/river interface.)

- 25 m
- 50 m
- 100 m
- 130 m
- Steep Bank - Setback may be reduced with site specific investigation.
- Chainage (m)

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This map has been compiled at a regional scale.
It is not suitable as a site investigation database and should not replace any requirement for detailed site specific geological or geotechnical investigations.

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A

Environment Waikato REGIONAL COUNCIL

Scale 1 : 35,000 at A1

Map D2b
Mid Waikato Bed Degradation
Development Set Back

▪ Appendix E

Stakeholder Preferred Outcomes (interviews)

KEY STAKEHOLDER PREFERRED OUTCOMES FROM STAGES I, II, III & IV

Mid-Waikato Bed Degradation Investigations Stages III & IV - EW Contract No. AM20004/05-30

STAKEHOLDER ORGANIZATION	INTERVIEW DATE	REPRESENTATIVE	DEPARTMENT	PREFERRED OUTCOMES
Environment Waikato	27 May 2005	Murray Mulholland Senior Rivers Engineer Project Manager	Asset Management	*Natural river environment is maintained and enhanced. *Environmental stewardship. A zoned hazard map for bank stability including effects of predicted bed degradation over 100 years in alignment with EW regional responsibilites for natural hazard management. *Risk assessment based on hazard mapping and identified property and assets. *Management strategy for the use of the resource (waterway). *Definition of Capital Works options for including cost estimates for the LTCCP. *Cost benefit assessment of options, and peferred options to feed in to both the management strategy and the LTCCP.
Mighty River Power	27 May 2005	Mark Henry Environmental Advisor		*Maintenance of existing operational flexibility from Karapiro. *Understanding of others' perceptions about contribution from ramping. *Develop common understanding of the impact that structures built 50 years ago have had on sediment entrapment. *Decisions are based on agreed/appropriate science.
Hamilton City Council	02 June 2005	Leroy Leach Manager	Water & Waste Services	* Ensure that the bed degradation is fully understood and predicted over the next 100 years and that best management strategies are put in place to protect the banks, tributaries, public infrastructure, public access, public and private property *Establish agreement on future equitable cost sharing for capital works, bank protection and management of the waterways. *Establish suitable riverbank and tributary set backs for future community developments *Resolution of the MRP consent appeal by HCC and MRP
		Bill Featherstone Manager	Parks & Gardens	*Being able to comply with the RMA and Reserves Act and meet community aspirations for future development and protection of the reserves adjacent to the river as expressed through community consultation. *Ultimate goal is to hand over the reserves to the next generation in the same or better shape than exists at present. This includes maintaining continuous and safe access to waterways, protecting cultural sites, protecting infrastructure, maintaining existing natural environment especially through plant diversity (no Rome or London concrete lined waterways) and successfully limiting/reducing liability for HCC through protection and maintenance of the riverside reserves.
Waikato District Council	02 June 2005	Allan Turner Environmental Planner		* Define slope bank stability limit that accounts for bed degradation as predicted over the next 100 years. *Understand downstream impacts from potential upstream in-river works *Gain agreement on future equitable cost sharing for capital works, bank protection and management of the waterways. *Understand vulnerability of 'no-grow' zone that is present within the range of fluctuating river level changes *Establish suitable riverbank set backs for future community developments as framework for sub-divisions or building consent applications, preferably with clear parameters for site specific investigations.
Waipa District Council	06 July 2005	Tim Harty Water Services Manager	Utility Services	* Bed degradation and slope stability risk are understood over the 100 years timeframe so that a common ground is established for making priority and systematic decisions under the umbrella of Environment Waikato. * Have supporting documentation to deliver a common approach to respective councils that describe the proposed management strategies to protect the near-bank infrastructure. * Develop a consistent approach by each affected organization to manage the details of specific bank areas that require attention. *Understand the impact of future consent applications and reapplications such as for storm water discharge to the River.
Tainui	10 August 2005	Tim Manukau Environmental Manager	Environmental Unit Waikato Raupatu Trustee Company	* Improve and enhance the health and well-being of the river, physically, culturally and spiritually * Improve and enhance the natural environment of the river channel as much as possible. Use wood for construction over concrete/steel where appropriate. * Encourage responsible sustainable development, all solutions need to be considered in this context. *Access to the waterway is compulsary, especially at the Marae. Involve manawhenua on local matters of importance. *Tainui view with importance the need to protect, enhance and restore all waterways.

- Appendix F

River Section Priority Ranking

River Section Priority Ranking

	Distance from river mouth (km)				50 years	
Ref no.	From	To	Bank	Location	Bank Hazard (0 - 1.5m degradation)	Infrastructure
136	119.75	120.4	R	Hamilton East Cemetery	Severe	Walkway, park/rural, cemetery, timber landing.
125	118.41	118.48	L	Cobham Bridge	High	Bridge
64	108.72	108.92	L	Braithwaite Park, Pukete Sewer Bridge	High	Water, bridge, sewer pipe, parkland.
4	95.7	95.98	R	Regent Street, Turangawaewae Marae	High	Marae, residential property.
29	101.5	101.8	L	Affco Horotiu Meatworks	High	Meatworks & associated water treatment.
53	107.92	108.02	L		High	Water, stormwater outfalls, residential property.
48	107.2	107.37	L	Opposite Featherstone Park	High	Residential/rural property, stormwater, water, stormwater outfalls
49	107.37	107.55	L	Opposite Featherstone Park	High	Rural/park
61	108.68	108.72	L	Braithwaite Park	High	Parkland
87	111.85	112	L	St Andrews Terrace	High	Stormwater outfall, walkway?, residential property
107	115.8	116	L		High	Commercial property, stormwater outfall.
110	116.37	116.6	R	Hamilton East Shopping Centre	High	Stormwater outfalls, water, walkway, commercial property
129	118.64	118.85	R	Rogers Rose Gardens	High	Park, stormwater outfalls.
145	121	121.42	R	Hammond Park	High	Parkland, stormwater outfalls.
82	111.4	111.6	R	Donny Park - Perindale Road	High	Water, stormwater, residential property.
97	113.64	114.08	L	Fairfield Esplanade	High	Stormwater outfalls, water, residential property, timber landing, Waitawhiriwhiri Stream outfall.
134	119.3	119.75	R	Hamilton Gardens	High	Walkway, park, Waikato Institute of Technology Gardens Campus
11	97.7	98.14	L	Waikato Esplanade, Ngaruawahia (south)	High	Residential property, walkway/park
89	112.06	112.1	L	Matakanohi Reserve (Beerescourt)	High	Water, stormwater outfall, residential property.
92	112.54	112.55	R	Waikato Diocesan School for Girls	High	Residential
183	128.88	128.97	R		High	Rural/residential
35	103.26	103.27	R		High	Residential, rural.
57	108.45	108.6	R	Braithwaite Park	High	Rural/residential property.
68	109.12	109.17	R	Pukete	High	Residential property
146	121.03	121.11	L		High	Rural
158	124.08	124.16	L		High	Rural
21	99.3	99.33	R		High	Rural
26	100.93	101.08	L	Affco Horotiu Meatworks	High	Meatworks, water intake.
37	104.2	104.24	L	Hutchinson Road	High	Rural
119	117.57	117.71	L	Graham Park	High	Park, Hospital Drain outfall.
124	118.27	118.41	L	Yendall Park	High	Parkland
152	123.1	123.6	R	Newell Road	High	Rural
156	123.65	123.77	R		High	Rural
3	95.67	95.7	R	NIMT Railway Bridge 267 and SH1 Road Bridge, Ngaruawahia	Medium	Bridges
104	115.3	115.8	L	ECMT Railway Bridge 6 and Claudelands Bridge - Ferrybank	Medium	Stormwater outfalls, bridge, water, commercial property.
106	115.7	116.37	R	New Memorial Park - Victoria Bridge (Bridge Street)	Medium	Bridge, stormwater outfall, parkland, bridge, walkways
1	95.3	95.96	L	Waipa Confluence, Lower Waikato Esplanade, SH1 Bridge, Ngaruawahia.	Medium	Water, bridge, walkway.
2	95.3	95.67	R	Waipa Confluence, Rail Bridge	Medium	Residential property, water, bridges
28	101.49	102.63	R	Horotiu Road Bridge	Medium	Quarry, bridge, rural.
63	108.71	109.12	R	Pukete Sewer Bridge	Medium	Residential property, sewer, outfall structure
69	109.17	110.42	R	Pukete Road Bridge, Te Hikuwai Reserve (Flagstaff)	Medium	Bridge, reserve, stormwater outfalls, water.
70	109.59	109.6	L	Pukete Road Bridge	Medium	Bridge
94	112.79	114.12	R	Fairfield	Medium	Water, stormwater, stormwater outfalls, residential property, Fairfield Bridge, timber jetty.
96	113.29	113.64	L	Milne Park, Fairfield Bridge	Medium	Bridge, stormwater, residential property.
98	114.08	115.3	L	Boundary Road Bridge (Whitiora)	Medium	Bridge, stormwater outfalls, water, residential property
105	115.33	115.7	R	ECMT Railway Bridge 6 and Claudelands Bridge - Ferrybank, Jesmond Park	Medium	Bridge, stormwater outfalls, water, parkland, walkways.
109	116.2	116.86	L	Victoria Bridge (Bridge Street), Swimming Pool	Medium	Bridge, stormwater outfalls, water, commercial property.
127	118.5	118.64	R	Cobham Bridge - Rogers Rose Gardens	Medium	Bridge, park, stormwater outfall.
214	140.43	142.15	R	Grey Street	Medium	Bridge, residential, stormwater, stormwater outfalls, water, pipe bridge
6	95.98	96.15	R	Turangawaewae Marae, Ahurei Drive	Medium	Marae, residential property, stormwater outfall
101	114.5	115.03	R	Miropiko Reserve	Medium	Stormwater outfalls, residential property, water, timber landing
169	126.22	126.26	R		Medium	Rural
116	117.26	117.9	R	Hayes Paddock	Medium	Reserve, walkways.
181	127.51	130.3	L	Mystery Creek National Field Days Site	Medium	Golf course, rural/buildings, water intake
24	100.17	100.87	R	Perry's Quarry/Landfil	Medium	Quarry/landfill
22	99.33	99.43	R	Perry's Quarry/Landfil	Medium	Rural/quarry/landfill
27	101.08	101.5	L	Affco Horotiu Meatworks	Medium	Meatworks & associated water treatment.
30	101.8	102	L	Affco Horotiu Meatworks	Medium	Meatworks & associated water treatment.
32	102.6	104.2	L	Quarry	Medium	Quarry
45	106.3	106.38	L	Pukete Boat Ramp	Medium	Boat ramp - jetty and retaining walls, stormwater outlet
114	117.01	117.27	L		Medium	Water, stormwater outfalls, commercial property.
132	118.98	119.32	L	Mangakotukutuku Stream confluence, Sandford Park	Medium	Rural, water mains on pipe bridge
217	142.6	142.97	R	Fergusson Bridge	Medium	Bridge, water, golf course.
14	98.25	98.3	L		Medium	Rural, walkway/park.
52	107.55	107.92	L	Pukete	Medium	Park/walkway
60	108.62	108.68	L	Braithwaite Park	Medium	Parkland
62	108.69	108.71	R	Pukete	Medium	Walkway/parkland
79	110.42	110.9	R	Opposite St Andrews Golf Course	Medium	Residential property, stormwater outfalls, water, private boat landing
85	111.65	111.85	L	St Andrews Terrace	Medium	Water, stormwater outfalls, residential property.
88	112	112.06	L	St Andrews Terrace	Medium	Water, stormwater outfalls, residential property, footbridge.
93	112.55	112.79	R	Waikato Diocesan School for Girls	Medium	Residential, stormwater outfall, boat ramp.
95	113	113.29	L	Milne Park	Medium	Parkland, stormwater outfalls, water.
108	116	116.2	L	Rowing Club	Medium	Commercial property, stormwater outfall.
111	116.6	116.89	R	New Memorial Park	Medium	Stormwater, water, parkland, walkways.
112	116.86	117.01	L	Roose Commerce Park	Medium	Stormwater outfalls, water, walkways.
115	117.14	117.26	R		Medium	Stormwater outfall, walkways.
117	117.27	117.47	L	Hamilton Skills Centre (old pumping station)	Medium	Skills centre, stormwater outfall.
121	117.9	117.95	R	Dillicar Park/Graham Island	Medium	Park, walkways.
131	118.85	119.12	R	Hamilton Gardens	Medium	Walkway, park.
8	96.2	97.7	L	Waikato Esplanade, Martin Street - Thomas Street	Medium	Walkway/park, residential, water, stormwater outfall, wastewater
13	98.14	98.25	L	Waikato Esplanade	Medium	Walkway/park, residential property.
54	108.02	108.23	L		Medium	Stormwater outfall.
58	108.6	108.62	L	Braithwaite Park	Medium	Parkland
72	109.7	109.72	L		Medium	Walkway, residential.
76	109.99	110.06	L		Medium	Walkway, residential, stormwater outfalls.
78	110.12	111.22	L	St Andrews Golf Course	Medium	Residential, golf course, walkway, outfall structure
80	110.9	111.4	R	Queenwood, Wymer Road	Medium	Stormwater, water, residential property, Swarbicks Landing
84	111.6	111.65	R	Days Park (Chartwell)	Medium	Parkland
90	112.1	113	L	Matakanohi Reserve (Beerescourt)	Medium	Residential property, walkway?
118	117.47	117.57	L	Graham Park	Medium	Park, stormwater.
120	117.71	118.27	L	Graham Park	Medium	Park, stormwater.
122	117.95	118.1	R	Dillicar Park	Medium	Park, walkways.
133	119.12	119.3	R	Hamilton Gardens	Medium	Walkway, park, Hamilton Gardens building at ch1193
140	120.4	120.99	R		Medium	Walkway, stormwater.
221	143.3	143.5	L	Leamington	Medium	Residential property, stormwater outfall, water
66	108.99	109	L	Braithwaite Park	Medium	Residential property, water, stormwater outfall
99	114.12	114.2	R		Medium	Water, stormwater, residential property.
159	124.15	124.55	R	Redwood Grove	Medium	Rural/residential
167	125.92	126	L		Medium	Residential/rural, buildings
176	126.85	126.92	L		Medium	Rural/residential.
182	128.8	128.88	R		Medium	Rural/residential
185	129.4	129.55	R		Medium	Rural/residential
220	143.13	143.3	L		Medium	Residential
7	96.15	96.28	R	Porotaka Place	Medium	Rural/residential property.
20	99.3	100.93	L	Ngaruawahia Golf Course - Anzac Street East	Medium	Golf course, residential property, rural.
34	103.18	103.26	R		Medium	Residential, rural.
36	103.27	104.9	R		Medium	Residential, rural.
55	108.18	108.45	R	Pukete	Medium	Rural/residential property.
65	108.92	108.99	L	Braithwaite Park	Medium	Residential property, water.
91	112.15	112.54	R	Days Park (Chartwell) - Braithwaite Street	Medium	Residential property, stormwater, water, stormwater outfalls
149	121.6	122.55	R		Medium	Rural/residential.
168	126	126.33	L		Medium	Residential/rural, buildings
175	126.55	126.85	L		Medium	Rural/residential, buildings, floating pontoon with access walkway
177	126.92	127.31	L		Medium	Rural/residential.
184	128.97	129.4	R	Blue Heron Place	Medium	Rural/residential
186	129.55	129.6	R		Medium	Rural/residential
219	143	143.13	L		Medium	Residential
148	121.42	121.6	R		Medium	Stormwater, rural/industrial.
38	104.24	105.25	L	Te Rapa Dairy Factory	Medium	Factory, rural, water intake.
46	106.38	107.2	L	Pukete Farm Park Equestrian Centre, Water Pollution Control Plant	Medium	Equestrian Centre, rural/industrial, wastewater outlet

River Section Priority Ranking

Ref no.	Distance from river mouth (km) From	To	Bank	Location	50 years Bank Hazard (0 - 1.5m degradation)	Infrastructure
213	140.31	142.3	L	Marlowe & Fletcher Streets.	Medium	Rural/industrial, stormwater.
40	105.25	105.43	L		Medium	Rural
126	118.48	118.6	L	Yendell Park	Medium	Parkland
130	118.7	118.98	L	Sandford Park	Medium	Park
135	119.32	119.8	L	Sandford Park to Peacockes Rd Esplanade	Medium	Rural
138	120.15	120.4	L		Medium	Rural
141	120.58	120.67	L	Peacockes Rd Esplanade	Medium	Rural
143	120.99	121	R		Medium	Parkland
144	121	121.03	L		Medium	Rural
160	124.16	124.4	L		Medium	Rural
163	124.72	124.8	L		Medium	Rural
165	124.81	125.53	R		Medium	Rural
171	126.33	126.37	L		Medium	Rural
187	129.6	130.3	R	Opposite the Mystery Creek National Field Days Site	Medium	Rural
188	130.3	130.54	L		Medium	Rural
193	131.76	132.45	R	Hooker Road	Medium	Rural
197	133.35	133.48	R	Duncan Road	Medium	Rural
199	134.17	134.62	L		Medium	Rural
201	135.55	135.6	L		Medium	Rural
203	136.25	136.3	R		Medium	Rural
10	97.12	97.8	R		Medium	Rural
15	98.3	98.47	L		Medium	Rural
17	98.6	99.3	R		Medium	Rural
18	98.75	98.81	L		Medium	Rural
41	105.43	105.9	L		Medium	Rural
42	105.72	106.65	R	Horsham Downs Golf Club	Medium	Golf course, rural.
44	106.19	106.3	L		Medium	Rural
59	108.6	108.69	R	Pukete	Medium	Stormwater outfall, rural
113	116.89	117.14	R	New Memorial Park	Medium	Water, stormwater, parkland.
128	118.6	118.7	L	Yendell Park	Medium	Parkland
137	119.8	120.15	L	Peacockes Rd Esplanade	Medium	Rural
139	120.4	120.58	L		Medium	Rural
147	121.11	123.46	L		Medium	Rural
151	122.62	123.1	R	Riverglade Drive	Medium	Rural
154	123.56	124.08	L		Medium	Rural
155	123.6	123.65	R		Medium	Rural
157	123.77	124.15	R		Medium	Rural
161	124.4	124.72	L		Medium	Rural
162	124.55	124.81	R		Medium	Rural
164	124.8	125.92	L		Medium	Rural
166	125.53	126.22	R		Medium	Rural
170	126.26	126.38	R		Medium	Rural
174	126.51	127.2	R		Medium	Rural, golf course.
179	127.3	128.8	R		Medium	Golf course
190	130.54	131.04	L		Medium	Rural
192	131.45	131.99	L	Kaipaki	Medium	Rural
195	132.45	133.35	R		Medium	Rural
196	133	134.17	L		Medium	Rural
198	133.48	136.25	R	Pukeroro	Medium	Rural
200	134.62	135.55	L		Medium	Rural
202	135.6	137.53	L		Medium	Rural, water intake.
204	136.3	138.2	R		Medium	Rural
207	138.6	138.78	R		Medium	Rural
223	147.24	147.75	L		Medium	Rural
225	148.73	148.76	L		Medium	Rural
227	149.31	149.38	L		Medium	Rural
100	114.2	114.5	R	Boundary Road Bridge (Whitiora)	Low	Bridge, residential property, water, stormwater.
31	102	102.6	L	Horotiu Road Bridge	Low	Bridge, rural.
67	109	109.59	L	Pukete Road Bridge	Low	Bridge, water, stormwater outfall, residential property
172	126.37	126.55	L	The Narrows	Low	Bridge, rural.
205	137.53	139.11	L	Pukerimu	Low	Electricity (high power), rural/industrial, water intake
208	138.78	140.43	R		Low	Rural, electricity (high power)
218	142.97	149.6	R	Cambridge Golf Course	Low	Electricity (high power), golf course, rural, stormwater outfalls, wastewater, water
224	147.75	148.73	L		Low	Rural, electricity (high power)
23	99.43	100.17	R	Perry's Quarry/Landfill	Low	Quarry/landfill
212	140.2	140.31	L		Low	Rural, water, wastewater.
216	142.3	143	L	Fergusson Bridge	Low	Bridge, water, stormwater, wastewater, residential.
74	109.76	109.81	L		Low	Walkway, residential.
211	140	140.2	L	Cambridge Wastewater Treatment Plant	Low	Treatment plant, water, wastewater,
5	95.96	96.2	L	Market Street	Low	Residential, water, stormwater outfall.
56	108.23	108.6	L	Braithwaite Park	Low	Parkland
71	109.6	109.7	L		Low	Water, stormwater outfall, walkway.
73	109.72	109.76	L		Low	Walkway, residential.
75	109.81	109.99	L		Low	Walkway, residential.
77	110.06	110.12	L		Low	Walkway, residential.
86	111.65	112.15	R	Days Park (Chartwell)	Low	Parkland
123	118.1	118.5	R	Dillicar Park	Low	Residential property, stormwater outfall, walkways
215	142.15	142.6	R	Victoria Bridge (Cambridge)	Low	Walkways, water
102	115.03	115.18	R		Low	Residential property
103	115.18	115.33	R	North of Claudelands Bridge	Low	Residential property, stormwater outfall, water
180	127.31	127.51	L		Low	Rural/residential.
209	139.11	139.24	L	Cambridge Wastewater Treatment Plant	Low	Wastewater treatment plant, rural.
210	139.24	140	L	Cambridge Wastewater Treatment Plant	Low	Wastewater treatment plant, rural.
50	107.38	107.42	R		Low	Rural
83	111.5	111.65	L	St Andrews Golf Course	Low	Golf course, stormwater outfall.
142	120.67	121	L		Low	Rural
189	130.3	131.76	R	Pencarrow Road	Low	Rural
9	96.28	97.12	R		Low	Rural
12	97.8	98.6	R		Low	Rural
16	98.47	98.75	L		Low	Rural
19	98.81	99.3	L	Ngaruawahia Golf Course	Low	Rural, golf course.
25	100.87	101.49	R		Low	Rural
33	102.63	103.18	R		Low	Rural
39	104.9	105.72	R	Horsham Downs Golf Club	Low	Golf course
43	105.9	106.19	L		Low	Rural
47	106.65	107.38	R	Featherstone Park	Low	Rural
51	107.42	108.18	R	Featherstone Park	Low	Rural, stormwater outfall at ch1072.
81	111.22	111.5	L	St Andrews Golf Course, Swarbricks Landing	Low	Golf course, stormwater outfall.
150	122.55	122.62	R		Low	Rural
153	123.46	123.56	L	Nukuhau Pa	Low	Rural
173	126.38	126.51	R		Low	Rural, golf course.
178	127.2	127.3	R		Low	Golf course
191	131.04	131.45	L		Low	Rural
194	131.99	133	L		Low	Rural
206	138.2	138.6	R		Low	Rural
222	143.5	147.24	L	Opposite Cambridge Golf Course	Low	Rural
226	148.76	149.31	L		Low	Rural
228	149.38	149.6	L	Karapiro Dam	Low	Rural, dam.

▪ Appendix G

Options to Manage Bed Degradation

G1 – Directly Control or Slow Bed Degradation

1 Degradation projections and mechanisms

The bed degradation in the mid-Waikato reach is assessed by Graeme Smart in *Degradation of the Waikato River, Karapiro to Ngaruawahia, Review of existing knowledge and recommendations for future work,* prepared for Environment Waikato, August 2003. He projects degradation in the bed through Hamilton as a tilting plane with an imaginary hinge in the vicinity of Karapiro Dam. His projections are given in Table G1-1.

Table G1-1

Future mean bed levels predicted by extrapolating present trends

Location	River distance	Rate of fall in mean bed	Fall below present by 2050
Bed plane below Narrows	km 126.0	17.3 mm/yr	0.8 m
Victoria Bridge mean bed level	km 116.3	28.2 mm/yr	1.3 m
Bed plane below Hamilton (XS 140)	km 106.3	32.3 mm/yr	1.5 m

Source: Smart, August 2003.

Smart discusses the mechanisms which could contribute to the degradation in *Analysis of Degradation. Waikato River Karapiro to Ngaruawahia*, prepared for Environment Waikato, August 2005.

Smart assesses that the present degradation is primarily due to upstream hydro dams:

> *"The hydro dams upstream of Cambridge currently trap bed material that would have been transported past Karapiro prior to construction of the dams. The trapped volume is estimated to be over 100,000 m³/yr, which is similar to the average annual volume of degradation between Karapiro and Ngaruawahia. This indicates that the river is degrading downstream of Karapiro in order to recover the deficit of bed material created by the upstream hydro lakes (Hicks, 2003)."*

Smart reports that Stage II investigations indicate that, at the sites measured, the entrainment process is episodic, only taking place during and following flood surges. Very rapid ramping moved but did not break a protective surface layer of gravel on the bed. Without the protective gravel, ramping waves could move enormous volumes of sand. Ramping therefore has the potential to significantly affect degradation rates, depending on the composition of the river bed surface.

Smart assessed the effect of other degradation mechanisms as minor. His summary is given in Table G1-2.

Table G1-2

Relative importance of factors causing the present degradation in the middle Waikato River

Process	Lower estimate	Upper estimate
Upstream hydro dams	85%	100%
Ramping of flows	2%	20%
Sand mining	0%	10%
Tongariro diversions	2%	5%
Land use changes	0%	10%
River management	0%	5%
Geomorphologic processes	-10%	0%

Notes:

1. As all lower (or upper) estimates in the table will not coincide, the columns do not add up to 100%.
2. Source: Smart, August 2005.

2 Global options

Possible remedial measures to address the bed degradation over the length of the Hamilton reach are listed below. These are only global options – local options to protect particular structures are considered in Appendix G2.

a. Restore sediment supply:

1. Decommission / remove dams
2. Release sediment past the dams
3. Sacrificial bank erosion

b. Reduce sediment mobilisation through operating rules:

4. Operate dams to reduce flood surges
5. Operate dams to reduce ramping surges

c. Reduce sediment mobilisation through engineering works:

6. Submerged rock sills
7. Control weirs
8. Erosion protection

These options have not been studied, but a preliminary assessment of each is discussed below.

Economic costs are taken as the construction cost plus other costs such as lost power generation and lost land, but do not include the benefit from controlling bed degradation.

2.1 Decommission / remove dams

Decommissioning and/or removal of the dams would ultimately restore the sediment supply to the middle Waikato reach. However, this would be at very high economic and environmental cost, due to loss of hydro generation and decades of river instability.

Mighty River Power prepared a report *Taupo Waikato Resource Consents Application: "No Consents" Baseline,* May 2002. This considers a regime in which all structures would remain on the bed of the river channel, but they would not be used to generate electricity or control flow.

Under this regime, fine sediments trapped behind the dams would be mobilised and flushed downstream. The system would be highly unstable for many decades. The river below the Karapiro dam would be highly impacted by sediment remobilisation and significantly reduced water clarity for decades.

Removal of the dams is expected to have similar unacceptable environmental effects.

Summary:

Technical effectiveness	High
Construction cost	Moderate
Economic cost	High
Social impact	High
Environmental impact	High
Cultural impact	High
Warrants further study?	No

2.2 Release sediment past the dams

Another way to restore the sediment supply downstream of Karapiro would be to release sediment past the dam.

Lake Karapiro is some 25 km long, and most of any sediment in the Waikato River would deposit at the upstream end, so it is not practicable to release the sediment by flushing from the dam. In practice there will be little sediment passing down the river into Lake Karapiro, due to the chain of dams on the river (most constructed since Karapiro Dam).

Any attempt to pass sediment through Lake Karapiro would require dredging from the head of the lake and from the mouth of the main tributary streams. The costs of this dredging operation would be high, and the quantity of sediment available would be insufficient to meet the sediment deficit in the river downstream, therefore the operation is unlikely to be worthwhile.

Summary:

Technical effectiveness	Low
Construction cost	High
Economic cost	High
Social impact	Low
Environmental impact	Moderate
Cultural impact	Low

Warrants further study?	No

2.3 Sacrificial bank erosion

Smart (2003) quotes a technique used successfully in Europe. Removing bank vegetation at appropriate locations can encourage erosion at these sites. A resulting increase in bed load will then help reduce degradation of the bed.

The deficit in sediment supply downstream of Karapiro is some 100,000 m^3/year (Smart, 2003), which would need to be replaced by bank erosion, in order to control bed degradation.

For this technique to address the bed degradation in the Hamilton reach of the Waikato River, a suitable bank erosion site would be required between the Narrows and Hamilton (upstream of the narrows the river banks tend to be steeper and less likely to erode). Assuming erosion from 5 km of 20m high bank in this reach would require an annual loss of 1 m of bank to meet the sediment deficit: this is unlikely to be acceptable.

Summary:

Technical effectiveness	High
Construction cost	Moderate
Economic cost	Moderate
Social impact	High
Environmental impact	High
Cultural impact	Moderate/high
Warrants further study?	No

2.4 Operate dams to reduce flood surges

Stage II investigations indicate that degradation is primarily taking place during and following flood surges. One approach to controlling degradation is therefore to reduce the flood surges downstream of Karapiro dam.

This would require lower normal operating levels in Lake Taupo and the hydro lakes, so as to provide increased flood detention storage. The effect of this would be reduced generation, due to lower head at the power stations and to reduced storage for low inflow periods.

Restrictions on the permitted lake operating ranges may mean that the floods that cause most bed degradation cannot be attenuated significantly.

We recommend preliminary investigation of the likely feasibility of this option. Detailed study would be required to optimise the dam flood control operating rules with respect to bed degradation.

Summary:

Technical effectiveness	Moderate
Construction cost	Low
Economic cost	High
Social impact	Low
Environmental impact	Moderate/high (due to increased lake level range)
Cultural impact	Low

Warrants further study?	Yes

2.5 Operate dams to reduce ramping surges

Ramping has the potential to significantly affect degradation rates, depending on the composition of the river bed surface. Smart (2005) suggests that ramping may be responsible for between 2% and 20% of bed degradation.

Elimination of ramping would convert the Waikato hydro system to meeting only base load, and not the twice daily peak electricity demand. The effect would be to cause electricity prices to rise significantly.

More realistically, operation rules could be developed to reduce the ramping rate downstream of Karapiro dam, in order to reduce the effect of ramping on bed degradation.

We understand that ramping operation rules have been studied in detail for the re-consenting of the hydro schemes, but these studies would not have taken account of the Stage II degradation studies. We recommend preliminary investigation of the implications of the Stage II studies for the ramping regime.

Summary:

Technical effectiveness	Low
Construction cost	Low
Economic cost	High
Social impact	Low
Environmental impact	Positive
Cultural impact	Low
Warrants further study?	Yes

2.6 Submerged rock sills

Sills have been used successfully to control degradation at bridges in degrading cobble and gravel bed rivers. They are less suitable in the Waikato River reach under consideration, because of the flat river gradient, and because the bed is predominantly fine material under a gravel armour layer.

The rock sills are envisaged as a layer of rock over the bed and banks of the river, to control the bed profile at intervals down the river. The sills would not be high enough to have a significant effect on the hydraulic profile of the river. The sills would therefore not prevent flood flows from breaching the gravel armour layer and re-suspending the finer material, which would be carried over the sills. Under normal ramping, unless the sills were placed flush with the armour layer, the sills would restrict the downriver movement of the armour gravel: this would result in the armour layer being breached immediately downstream of each sill, where increased degradation would result.

We consider it unlikely that submerged rock sills would be effective as a global solution to bed degradation. They could be considered for local bed control, however, to protect a specific structure (eg bridge or submerged pipe crossing), with suitable arrangements to control downstream degradation.

Summary:

Technical effectiveness	Low
Construction cost	Moderate
Economic cost	Moderate
Social impact	Low
Environmental impact	Low
Cultural impact	Low
Warrants further study?	No

2.7 Control weirs

Control weirs could be used to raise the flood water level so that the sediment transport capacity of the river is reduced. Depending on the selected arrangement and operation, the weirs may also raise normal water levels and thereby control bed degradation due to ramping.

A control weir would be most useful just downstream of Hamilton, to control bed degradation through the city, and avoid the impacts of that degradation on the Hamilton infrastructure.

The effect of a weir at Hamilton would be reduced bedload downstream of the weir, with consequently increased bed degradation in the downstream reach. To avoid this, a second weir would be required just downstream of the bridges at Ngaruawahia, at the confluence with the Waipa River. (A single weir at Ngaruawahia would not raise levels at Hamilton sufficiently to control bed degradation there without causing flooding near Ngaruawahia.)

A third weir to raise water levels upstream of the Narrows is unlikely to be justifiable, because the upstream reach has less bed degradation, and less infrastructure at risk.

The weirs at Hamilton and Ngaruawahia would reduce the sediment load in the river downstream. Detailed study would be required to assess the effects of this on downstream bed levels. The sediment load from the Waipa River would to some extent offset the impact downstream.

Appropriate arrangements and levels for the weirs would be the subject of detailed study, considering implications on existing infrastructure, flood levels and sediment transport. We envisage that the weirs would raise water levels by about two metres. There are three sub-options for the control weir arrangement:

a. Gated or inflatable weir

This structure would be on the bed of the river and would not affect normal water levels. Under normal conditions boat and fish passage would not be affected. The gates would only be raised or the weir inflated in advance of flood flows.

b. Fixed weir with boat lock and fish passage

A fixed weir would create a permanent rise in water level upstream of the weir, would eliminate any degradation due to ramping, and in time sedimentation could reverse some of the historic bed degradation. Negative effects are interference with river traffic and fish migration: these would be addressed by providing a boat lock and a fish passage.

c. Fixed weir with power station, boat lock and fish passage

This is functionally the same as sub-option b above, but generation from a low-head hydroelectric power station would offset some or all of the weir cost.

Summary:

	a) Gated or inflatable weirs	b) Fixed weirs	c) Fixed weirs with small hydro
Technical effectiveness	High	High	High
Construction cost	High	High	High
Economic cost	High	High	Low
Social impact	Low	Moderate	Moderate
Environmental impact	Low	High	High
Cultural impact	High	High	High
Warrants further study?	Yes	Yes	Yes

2.8 Erosion protection

Local bed degradation control can be provided by bed and bank armouring, eg using rock or articulated concrete block mattress. This could be extended to become a global option.

As with the control weirs option, the effect of bed armouring is to reduce the bed mobilisation, and therefore the sediment load passing downstream, and thus to increase bed degradation downstream. Therefore if bed armouring were planned for the Hamilton reach, it should be continued down to the Waipa confluence at Ngaruawahia, and detailed study would be required to assess the effects on downstream bed levels.

The river length from upstream of Hamilton to Ngaruawahia is some 24 km. Assuming 100 m mean lined perimeter and 600 mm rock armour layer thickness, that represents 1.44 million cubic metres (2.6 million tonnes) of rock.

The rock would need to be placed under water, after trimming the bed profile using pontoon-mounted plant. Suitable rock is not available locally, so the costs would be very high.

Alternatively one could use 2.4 million square metres of mattress. The mattress would be lowered in strips from a pontoon, but divers would probably be required to join adjacent strips. This alternative would also be high cost.

Total lining of 24 km of river would have a high environmental impact.

Summary:

Technical effectiveness	High
Construction cost	High
Economic cost	High
Social impact	Low
Environmental impact	High
Cultural impact	Moderate
Warrants further study?	No

3 Summary and recommendations

The options are summarised in Table G1-3.

None of the Options 1-3 to restore the sediment supply to the river is seen as practicable.

We recommend further study of Options 4 and 5, concerning the operating regime for the existing dams. This has presumably been subject to earlier studies taking account of flooding and bank erosion, but perhaps not of the impact on bed degradation. We therefore recommend preliminary studies to consider the implications of the Stage II degradation studies, and further optimisation studies if appropriate. Neither of these options is likely to arrest the bed degradation, but they could reduce the rate of bed degradation.

Option 7, control weirs, is the only global option with high technical effectiveness that warrants further study. Option 7a (gated or inflatable control weirs) has the lowest social, environmental and cultural impacts, while Option 7c (including small hydroelectric power stations) has the lowest economic cost. Subject to political acceptability, we recommend further study of all three sub-options (7a, 7b and 7c).

Table G1-3 Global options preliminary assessment

	Option	Technical effectiveness	Construction cost	Economic cost	Social impact	Environmental impact	Cultural impact	Warrants further study?
a. Restore sediment supply								
1	Decommission / remove dams	High	Moderate	High	High	High	High	No
2	Release sediment past the dams	Low	High	High	Low	Moderate	Low	No
3	Sacrificial bank erosion	High	Moderate	Moderate	High	High	Moderate/high	No
b. Reduce sediment mobilisation through operating rules								
4	Operate dams to reduce flood surges	Medium	Low	High	Low	Moderate	Low	Yes
5	Operate dams to reduce ramping surges	Low	Low	High	Low	Positive	Low	Yes
c. Reduce sediment mobilisation through engineering works								
6	Submerged rock sills	Low	Moderate	Moderate	Low	Low	Low	No
7a	Gated or inflatable control weirs	High	High	High	Low	Low	High	Yes
7b	Fixed control weirs with boat locks and fish passages	High	High	High	Moderate	High	High	Yes
7c	Fixed control weirs with power stations, boat locks and fish passages	High	High	Low	Moderate	High	High	Yes
8	Erosion protection	High	High	High	Low	High	Moderate	No

G2 – Manage the Effects of Bed Degradation

1 Introduction

The bed degradation in the mid-Waikato reach is assessed by Graeme Smart in *Degradation of the Waikato River, Karapiro to Ngaruawahia, Review of existing knowledge and recommendations for future work,* prepared for Environment Waikato, August 2003. Projected mean bed degradation in the Hamilton reach over the next 100-years is of the order of 3 metres. The projected drop in low flow water levels is less, about one metre, due to narrowing of the riverbed and to local high sills. These changes will have a significant impact on existing infrastructure.

The local bed degradation may be substantially more than the 3 metres mean bed degradation, due to varying bed materials, changing river cross-section, and the effect of bends in the river.

Smart (2005) concludes there is evidence of local widening at a number of locations but overall the river is narrowing (as measured at average annual flood level). The river morphology is highly dynamic and cyclic with previously widening reaches now narrowing and vice-versa. Degradation is greatest at narrow sections of the river. Continued bed degradation must eventually lead to bank collapse in many reaches.

The types of infrastructure at risk are given in the table below, with the nature of the risk:

Table G2-1

Risks to infrastructure

Infrastructure at risk	Risk factor		
	Bed degradation	**Bank failure**	**Water level lowering**
Bridge piers in river	Loss of lateral restraint, and possible undermining of piles		
Bridge piers on bank		Foundation failure	
Bridge abutments		Foundation failure Loss of embankment fill	
River bank walkways		Collapse into river	
Landings and boat ramps		Collapse into river	Insufficient water depth. Water further from bank.
Stormwater outfalls		Collapse into river	Scour channel to river
Water intakes		Collapse into river	Insufficient water depth. Water further from bank.
Buried pipe crossing	Scour/ exposure to damage	Collapse into river	

Identified infrastructure is on the photographs and spreadsheet, and river distances are marked on the GIS (see Appendices A, B and J). River distances are nominally from the river mouth: they have been set to match the km 126.4 used by Smart at Narrows Bridge: there are minor differences in river distance upstream and downstream of this point.

Global options to address the degradations have been discussed Appendix G1. This Appendix G2 considers local options that may be required if a global option is not pursued.

The local options include:

- Install or extend bank protection (rock armour, sheet pile walls, timber pile walls, gabions, stone masonry, sprayed concrete)
- Underpin bridges
- Bed armouring at bridge piers and the buried pipe crossing (but see Sections 3.1 and 3.6)
- Replace bridges
- Relocate infrastructure beyond zone of risk (if not water-linked), and allow banks to collapse.
- Relocate infrastructure so that access to water is maintained (landings, stormwater outfalls, water intakes).

2 Bank protection options

It is to be expected that bed degradation will lead to bank failure along significant portions of the river: particularly at the outside of bends, but also along straight reaches. Lengths where bank protection has previously been installed are likely to require additional protection.

Where land is available, the cheapest solution will be to allow the banks to collapse as the river degrades. Within urban areas, however, some form of protection is likely to be required. Options for this protection are given in Table G2-2. In most situations, the recommended option is to use rock armour, because of its flexibility, and the possibility of adding additional rock to top up the protection as required by ongoing bed degradation. In specific cases, other methods will be appropriate, but rigid linings will not be acceptable over extended length of bank, because they restrict the habitat for plant and fish life.

Table G2-2

Bank protection options

Bank protection	Type	Comments
Vegetation	Flexible lining	Low cost; only protects above normal water level.
Rock armour	Flexible lining	Easily extended. Recommended where space available and direct access to river not required.
Rubble armour	Flexible lining	Easily extended. Visually undesirable.
Gabions	Flexible lining	20-year life. Difficult to construct below water level.
Sprayed concrete lining	Rigid lining	Liable to toe failure. Cannot be applied below low water level.
Steel sheet piling	Rigid wall	High cost. Could be retrofitted in front of existing walls, or where ready access to the river is required (e.g. boat ramps).
Timber piled retaining wall	Rigid wall	Liable to toe failure. Possibility of adding extra wall later to protect toe.
Concrete block wall	Rigid wall	Liable to toe failure. Difficult to construct below water level.
Stone masonry wall	Rigid wall	Liable to toe failure. Difficult to construct below water level.

3 Local options to address bed degradation

3.1 Bridges

There are 15 bridges over the Waikato River in the reach under consideration, and also two bridges over tributaries at their confluence. Most have piers in the river. These will be exposed to increased scour risk due to bed degradation. The loss of lateral support may be an issue for some bridges. Those with abutments or piers close to the riverbanks may be vulnerable to bank instability caused by bed degradation.

Recommendations:

- Monitor riverbed cross-section at each bridge every 5-10 years.
- Review record drawings and bridge design for the impact of bed degradation on foundation stability.
- Underpin bridge piers or replace bridge if necessary.

Bed armouring at piers has not been recommended, because the projected extent of bed degradation would be likely to lead to break up of any armouring layer.

Submerged rock sills are discussed in Appendix G. They are not recommended, because of the potential degradation downstream of the sill.

3.2 River bank walkways

Walkways extend along both banks of the river through most of Hamilton City over a total riverbank length of some 29 km: from approximately km 106, near Pukete Boat Ramp, to Sandford Park (km 119.5 left bank) and Mangaonua Stream (km 121.6 right bank). These banks are presently protected by a mixture of natural vegetation, flexible revetments (rock or rubble armour, and gabions) and rigid protection (steel sheet piling, timber-piled retaining walls, stone masonry walls, and sprayed concrete lining).

The walkways will be vulnerable to bank collapse triggered by bed degradation. Bank instability can be addressed by the methods described in the Section 2. At some locations it may be possible to relocate the footpath to avoid bank collapses, or to put the footpath onto an elevated timber walkway.

3.3 Landings and boat ramps

Landings and boat ramps are at risk from bank collapse triggered by bed degradation, as well as from the water level lowering leaving the structures in inadequate water depth.

Bank instability can be addressed by the methods described in the Section 2.

Inadequate water depth at landings will normally require the landing to be relocated in deeper water, by adding an extra flight of timber steps. In some cases it may be appropriate to excavate the bank at the landing to provide sufficient water depth

Inadequate water depth at boat ramps will normally require the ramp to be extended into deeper water. Sometimes it may be preferable to reconstruct the ramp at a lower level.

3.4 Stormwater outfalls

Stormwater outfalls are at risk from bank collapse triggered by bed degradation, as well as from the water level lowering leaving the structures vulnerable to erosion and more visible.

Bank instability can be addressed by the methods described in the Section 2.

Outfalls will need new or extended toe erosion protection to deal with falling river levels. Rock armour, gabions or steel sheet piling are suitable methods: the selection will depend on any existing protection at the structure, or adjacent bank protection. Alternatively outfalls may be lowered and extended.

3.5 Water intakes

Water intakes are at risk from bank collapse triggered by bed degradation, as well as from the water level lowering affecting the operation of the intake.

Bank instability can be addressed by the methods described in the Section 2.2.

Irrigation intakes are typically mounted on floating pontoons, which may need to be moved into deeper water, but will otherwise be unaffected by bed degradation.

There may be a need to relocate fixed intakes at lower level, further out. Intakes for Hamilton water supply, the dairy factory and the meat works are all fixed structures. It will be necessary to review the record drawings for these structures to assess the impact of falling water levels: e.g. ability to capture water and pump suction head.

3.6 Buried pipe crossing

A buried pipe crossing close to the Hamilton Water Treatment Station may be vulnerable to bed degradation. We are not aware of other buried pipes or cables crossing the river.

Recommendations:

- Monitor riverbed at the site every 5-10 years
- Review record drawings for the impact of bed degradation
- Use a submerged rock sill if necessary. This is likely to be cheaper than reconstructing a deeper crossing, but there are river morphology issues, see Section 2.6 of Appendix G. Ongoing monitoring would be required.

G3 – Six Engineered Options for High Priority Sites at Risk from Predicted Future Bed Degradation

1 Priority Areas and Actions

Priority areas have been identified that should be addressed in the short term (1-3 years) at the same time the acceptability of bed degradation is being assessed. Stage III of the study investigated the areas of bank instability hazard and matched this with the priority rankings formulated by the Bed Degradation project group. The result is a priority table of sites (Appendix F). The highest priority sites are those where the combined risk of bank stability hazard and where assets/infrastructure and/or public safety is at risk (ranked as highest priority by Bed Degradation Project Team). The following section outlines possible site-specific engineered options for the top six priority sites if passive or soft-engineered options are not deemed appropriate.

Cost Estimates

The estimates presented in this report have been provided to indicate a very rough order of cost, and have been based on visual observations only. It must be appreciated that the final installed costs could vary significantly from these estimates once more investigation and design solutions are explored. The estimates presented should not be used for any purpose other than to indicate a probable cost guide.

Initial enquiries suggest that any work carried out which requires barge access is subject to very limited availability. All estimates that include such costs will be subject to significant variation should either local availability or size prove restrictive or unavailable. It is likely that segmental barges may have to be transported from external sources to suit this purpose with an unknown cost at present, which is not covered within the estimate values given below.

1. Hamilton East Cemetery (km 119.7 – km 120.4, RB)

Existing Situation/Problem

This 700-metre length is on the outside of a bend below a moderately steep and high slope, vegetated with tree and bush species. There is evidence of large-scale historical slope movement.

Behind the riverbank are a riverside walkway, parkland and Hamilton East Cemetery.

Resolution

To stabilise this slope, construction of a rock-armoured fill toe to the slope is recommended. The top of the fill would be a 3-m wide berm at RL 13.0 m, which is the top of the ramping range. A 5-m wide rock blanket extending beyond the toe of the slope (at existing bed level RL 6.5 m) would drop down providing protection as the bed degrades.

Cost Estimate $6 - $8m

2. Cobham Bridge (km 118.5)

Existing Situation/Problem

Cobham Bridge takes SH1 over the Waikato River, and is the major crossing on the south side of Hamilton.

Two of the bridge piers are in the river, with pile caps just above water level. The piers are exposed to increased scour risk due to bed degradation. The loss of lateral support may be an issue.

Failure of the bridge due to bed degradation would lead to severe traffic disruption.

Resolution

The susceptibility of the bridge to bed degradation is not known. We recommend:

- Monitor the riverbed cross-section at the bridge every 5-10 years.
- Review the record drawings and bridge design for the impact of bed degradation on foundation stability.
- Underpin the bridge piers or replace the bridge if necessary.

Cost Estimate $5,000

3. Braithwaite Park, Pukete Sewer Bridge (km 108.7 – km 108.9, LB)

Existing Situation/Problem

a. Bridge

The Pukete Sewer Bridge is a significant part of the Hamilton infrastructure.

Two of the bridge piers are in the river. The piers are exposed to increased scour risk due to bed degradation. The loss of lateral support may be an issue.

Failure of the bridge due to bed degradation could have severe environmental effects.

b. Revetments

Gabion revetments have been used to protect the riverbank walkway and access to timber steps adjacent to Braithwaite Park. Between portions of gabion revetment, the bank is protected by trees and bush. The gabions do not extend below low water level, and show evidence of undermining at the toe.

c. Landing

Water level lowering as the result of bed degradation will mean that the water depth at the landing will be too shallow in future.

Resolution

a. Bridge

The susceptibility of the bridge to bed degradation is not known. We recommend:

- Monitor the riverbed cross-section at the bridge every 5-10 years.
- Review the record drawings and bridge design for the impact of bed degradation on foundation stability.

- Underpin the bridge piers or replace the bridge if necessary.

b. Revetments

The existing gabions that are not already undermined can be stabilised by armouring the slope below the gabions with rock. Where the existing gabions are already undermined, we recommend that they be removed and replaced by rock armouring.

We recommend continuous rock armouring of this reach, including below the areas of existing trees and bush, which should be left in place.

A 5-m wide rock blanket extending beyond the toe of the slope (at existing bed level RL 7.0 m) will drop down providing protection as the bed degrades.

c. Landing

The landing will need to be extended into deeper water in future.

Cost Estimate $750K - 1.0m (revetment only)

4. Turangawaewae Marae (km 95.6 – km 96.0, RB)

Existing Situation/Problem

This 400-m reach is at the outside of the bend upstream of the Ngaruawahia bridges (NIMT rail bridge and SH1 road bridge). The 200 metres below Regent Street, immediately upstream of the bridges, are vegetated with trees and bush. Further upstream, below the marae, the bank is primarily grass-covered.

Bank erosion due to bed degradation at this site could affect the bridge abutments and piers at the bank (with serious consequences for transport links), Regent Street and the marae.

Resolution

To stabilise this slope, we propose rock-armouring the slope. Some fill would be required to extend the armour to the top of the ramping range. A 5-m wide rock blanket extending beyond the toe of the slope (at existing bed level RL 6.5 m) will drop down providing protection as the bed degrades.

Cost Estimate $2.5 - $3m

5. Affco Horotiu Meat works (km 101.5 – km 101.8, LB)

Existing Situation/Problem

This site is on a straight section of river, below a treatment pond associated with the meat works.

The 5 hectare treatment pond is set back some 60 m from the edge of the river. The 300 m by 60 m area between the pond and the river is at a shallow slope and primarily grassed, but includes a 140 m by 40 m block of trees.

There would be severe environmental effects if the side of the treatment pond were breached by river bank erosion.

Resolution

There is low risk of river bank erosion extending to the treatment pond, therefore we do not consider rock armouring of the bank to be justified at this stage.

We recommend planting trees in the area between the treatment pond and the river, to lower the risk of bank erosion at this site. Rock armour could be added later if monitoring indicated that the treatment pond was at risk.

Cost Estimate $100K - $150K (Depends on maturity and tree spacing)

6. NIMT Railway Bridge 267 and SH1 Road Bridge, Ngaruawahia

Existing Situation/Problem

These two bridges are important as part of the national transport infrastructure.

Their northern (right bank) abutments are at the downstream end of an outside bend, so could be vulnerable to bank instability caused by bed degradation.

Both bridges also have piers located at the bank, which could be vulnerable to bank instability.

Both bridges have two piers in the main river channel. The piers are exposed to increased scour risk due to bed degradation. The loss of lateral support may be an issue.

Resolution

Bank instability can be addressed by rock lining, included above under Turangawaewae Marae.

The susceptibility of the bridge piers to bed degradation is not known. We recommend:

- Monitor the riverbed cross-section at the bridges every 5-10 years.
- Review the record drawings and bridge designs for the impact of bed degradation on foundation stability.
- Underpin the bridge piers or replace the bridges if necessary.

Cost Estimate $10,000

▪ Appendix H

Statutory Responsibilities Related to Bed Degradation

Appendix H – Statutory Responsibilities Related to Bed Degradation

1 Statutory Context

As a strategic document, the purpose of the Bed Degradation Management Strategy is to provide direction to both the Territorial Authorities and the Regional Council when managing the bed degradation hazard. It is a non-statutory document prepared to highlight management approaches of bed degradation in the river, to minimise risks of hazards to public health and safety, community wellbeing, infrastructure and private properties. Although a non-statutory document, the Statutory Context of the strategy is important in highlighting the drivers behind the work. It is also important to recognise the influence that national, regional and district strategic and policy documents and past community consultation provide to the Bed Degradation Management Strategy.

1.1 Local Government Act 2002

The purpose of the local Government Act 2002 (LGA) is to provide a framework for local authorities to decide which activities they undertake and the manner in which they will undertake them; promote the accountability of local authorities to their communities; and provide for local authorities to play a broad role in promoting the social, economic, environmental, and cultural well-being of their communities, taking a sustainable development approach. One stated purpose of Local government is *to promote the social, economic, environmental, and cultural well-being of communities, in the present and for the future (section 10(b))*. The LGA sections that relate to the strategy are discussed in more detail in the technical appendices accompanying this report.

Section 93 of the Local Government Act 2002 states that a local authority must have, at all times, a long-term council community plan (LTCCP). LTCCPs must state community outcomes, which are a desired future position or state (similar to a vision). The community outcomes currently identified in the Regional Council and Territorial Authorities LTCCP development processes are discussed briefly below:

Environment Waikato LTCCP

The Environment Waikato LTCCP identifies the main community outcomes that relate to hazards as

- Risks to people and property from natural hazards and accidents are minimised.
- Communities are more aware of Regional hazards and their risks and they are better prepared to respond appropriately.
- The public amenity values associated with rivers and streams will be secured and enhanced.

Waipa District LTCCP

Community Outcomes identified from the Waipa District Council LTCCP are: 1) Sustainable Waipa, 2) Healthy community, 3) Economic security, 4) Liveable Waipa (quality services and infrastructure) and 5) Vibrant and strong community.

Hamilton City LTCCP

The community's overall vision for Hamilton as outlined in Hamilton's Strategic Plan 2002–2012 is that:

"*Hamilton will continue to develop in a sustainable way, using fewer resources to achieve more social, economic, and environmental benefits for everyone in the city*".

There are six community outcomes identified: 1) Sustaining Hamilton's Environment, 2) Growing Hamilton, 3) Promoting Hamilton, 4) Experiencing Arts, Culture and Heritage in Hamilton, 5) Living in Hamilton and 6) Enjoying Hamilton.

Waikato District LTCCP

The Waikato District Council has identified nine community outcomes following two rounds of consultation. They are:

1) Accessible Waikato - a district where the community's access to infrastructure, transport and technology meets its needs;

2) Active Waikato - a district that provides a variety of recreation and leisure options for the community;

3) Educated Waikato - a district where education options are varied, and allow our community to be skilled for work and life;

4) Green Waikato - a district where our natural resources are protected, developed and enhanced for future generations;

5) Sustainable Waikato - a district where growth is effectively managed;

6) Thriving Waikato - a district where business and industry are encouraged and supported and employment contributes to a successful local economy;

7) Vibrant Waikato - a district where our heritage and culture are recognised, protected and celebrated;

8) Well Waikato - a district where people can access quality community health and care services; and,

9) Safe Waikato - a district where people feel safe and supported within their communities, and where crime is under control.

1.2 Resource Management Act 1991

The Resource Management Act 1991 (RMA) provides a framework for the integrated and sustainable management of natural and physical resources. Avoidance or mitigation of hazards must be undertaken in a manner that achieves the purpose and principles of the RMA, and must be consistent with the provisions of the relevant statutory documents which derive from it. Explicit provisions relating to the management of river and lake beds are found within s13 of the RMA.

Part IV of the RMA relates to functions, powers and duties of central and local government. Section 30 states that Regional Councils must "*control of the use of land for the purpose of the avoidance or mitigation of natural hazards*." Section 31 sets out the functions of territorial authorities which includes the "*control of any actual or potential effects of the use, development, or protection of land, including for the purpose of the avoidance or mitigation of natural hazards….*" Under Sections 62, 65, 68, 75 and 76 of the RMA, regional policy statements, regional plans and district plans shall include policies, methods and rules to manage the effects of natural hazards, and the effects of land use on natural hazards where this is considered a "*significant resource management issue*".

Waikato Regional Policy Statement

The Waikato Regional Policy Statement (RPS) summarises the significant resource management issues relating to natural hazards as follows:

1. The roles and responsibilities of local authorities and other agencies for the management of natural hazards in the Waikato Region have not been agreed or clearly identified. Until this is done, inefficiencies and/or a duplication of functions may occur.

2. A lack of public awareness of the causes and potential effects of natural hazard events increases the likelihood of adverse effects when these events occur.

A number of implementation methods are proposed that outline EWs role managing hazards in the beds of rivers through the Regional Plan, identifying and prioritising hazards in the region and developing and undertaking mitigation plans and actions in conjunction with territorial authorities

Specifically relating to bed degradation management, the RPS sets the objective of "*a net reduction in the adverse effects of the destabilisation of river and lake beds*." An implementation method proposed to achieve this objective is to advocate to territorial local authorities that surface water activities are managed in a manner that avoids the destabilisation of the beds and banks of lakes and rivers. There is no specific policy that addresses bed degradation caused by activities other than surface water activities.

Waikato Regional Plan

The Waikato Regional Plan (WRP) outlines the important relationship Tangata whenua have with river and lake beds and specifically mentions the relationship of Waikato Tainui with the Waikato River who derive their identity, their health and their strength from the Waikato River (Section 2.2.3 of the WRP).

Section 4 of the WRP is the River and Lake module. In this section the WRP notes that "*destabilisation may cause changes in the course of rivers and streams, resulting in loss of land, damage to property and damage to infrastructural assets such as roads, bridges, flood protection and drainage works*".

The WRP has policies that seek to manage the effects structures may have on bed stability. The WRP states that Environment Waikato will also use environmental education programmes to inform the community and resource users of methods that protect the beds and banks of rivers and lakes from destabilisation.

It is noted that rule 4.2.15.1 of the WRP permits erosion protection measures in the River. Conditions around the structures look to control construction materials (i.e. not corrodible objects and no steel visible in final construction) and ensure that the cross sectional area of the river is not reduced as a result of the structure location and lengths. The permitted activity rule highlights the fact that structures for the purpose of erosion control are deemed necessary in some situations and, if designed to minimise effects, are considered appropriate within the context of the river environment.

District Plans

a. Waipa District Plan

Of relevance to this strategy, the Waipa District Plan has a Policy (AD3) that requires state of the environment monitoring and activities in the District for the purposes of avoiding or mitigating natural hazards and to take necessary action as may be required.

The Waipa District plan does not have a natural hazards section. However Rule 1.7.1 requires land to be suitable for the proposed building or use. When deciding what land is suitable, hazard areas on planning maps and areas liable to flooding, erosion or landslip are specifically mentioned.

b. Hamilton City Proposed District Plan

The Hamilton City Proposed District Plan (HCDP) has an Environmental Protection Overlay (EPO) that identifies restrictions on development in areas that are adjacent to the Waikato River. The EPO closely coincides with and has been adjusted to incorporate identified potential natural hazard areas, particularly in terms of flooding and land instability (accelerated erosion).

Objective 3.2.1 of the HCDP aims to identify and mitigate the impacts from natural hazards on people, property, and the environment. The associated policies relate to avoiding or limiting intensification of development in hazard prone areas and ensuring stormwater disposal does not contribute to flooding, erosion and land instability. The HCDP implements these objectives and policies through the Environmental Protection Overlay, Reserves contributions (making provision for esplanade reserve to be acquired in hazard prone areas) and through subdivision and development rules that provide extra controls in hazard prone areas.

The Riverside Reserve Management Plan also contains objectives and policies to maintain the stability of the riverbanks. There is also a "Maori Landmarks on Riverside Reserves Management Plan (Nga Tapuwae O Hotumauea) " that has been developed for riverside reserves within Hamilton city and that is consistent with the Riverside Reserves Management Plan. This Management Plan also discusses European heritage sites in the Hamilton area. The 17 sites identified are not specifically recognised in the HCDP.

c. Proposed Waikato District Plan

Waikato District Council have an operative District Plan (WDP) and have prepared a new Proposed Waikato District Plan (PWDP) which was notified in September 2004. Section 41 of the WDP has objectives and Policies that relate to natural hazards avoidance. Subdivision and development in hazard-prone areas are discouraged to protect health, safety and property from unnecessary risks.

The PWDP planning maps for the study area indicate flood hazard areas where development is discouraged. However these areas are not exhaustive. Extensive areas of the district are subject to some flood, erosion or subsidence hazards, but these areas are not shown on the Planning Maps. The Council has little site-specific knowledge of these.

1.3 Civil Defence Emergency Management Act 2002

The Civil Defence Emergency Management Act 2002 (CDEM) updates and redefines the duties, functions and powers of central government, local government, emergency services, lifeline utilities and the general public. The purpose of the CDEM is to improve and promote the reduction of risks, reduce community disruption from avoidable hazards and risks, reduce fiscal risks from the costs of disruption and promote more effective and efficient emergency readiness, response and recovery through the integrated activities of responsible agencies. The CDEM requires Environment Waikato and District and City councils in the Waikato Region to form a Waikato Civil Defence and Emergency Management Group (CDEM Group). Section 17 of the CDEM states the functions of a Civil Defence Emergency Management Group in relation to relevant hazards and risks is to identify, assess, and manage those hazards and risks, consult and communicate on risks and identify and implement cost-effective risk reduction.

▪ Appendix I

Valuations

1 Scope

The scope of the exercise was to assess the value attributed to assets within 100m of the banks of the mid-Waikato River. Assets include land, buildings, improvements, and infrastructure (bridges, roading, water reticulation, power reticulation).

2 Purpose

The purpose of the valuation is to provide an indication as to the dollar value of assets that may be affected by bed degradation of the river.

3 Methodology

3.1 Property Valuations

The Rating Valuations were used as a base. These are divided into rating units, which are the individual properties. These valuations are as at 2002 and 2003 depending on the local authority. They are made up of Land Value and Capital Value. By definition the Value of Improvements (buildings and site development) is the Capital Value less the Land Value.

The values were adjusted to 2005 values through analysis of current sales information by property type (category) and by local authority.

GIS was used to determine whether rating units were in or out of the 50 m and 100 m band distances from river. The area of each property within these bands was also determined using GIS.

The distance along the river was also calculated using GIS to enable grouping into hazard zones.

The property values reported are the capital values. The values are for property which is in the relative 50m or 100m band. Where a property is not wholly in the bands, the values were split on a pro-rata basis, using the area in the band compared to the total area of the valued parcel of property.

This assumes that the value in the improvements and the land is spread evenly over the parcel of property. To get a more accurate estimate would require the sighting of every individual property which is outside the scope of this project.

3.2 Infrastructure Valuations

The length of road within each band was assessed using GIS. The road width varies depending on the category and type. Area calculations of each section of road affected were determined and a unit rate was applied to assess replacement costs. Unit rates were varied depending on the type of road construction. The types identified include rural, urban, state highway and bridges.

Road widths were assumed to be between 6m and 8m depending on the type of road. Rural was split into either sealed or metalled road. Urban roads were assessed as having a footpath associated with them and this replacement cost was calculated using the length of the road within the buffer areas.

The replacement costs of other infrastructure was based on the assumption that major waste water, storm water, water supply and electrical reticulation use roadways as their conduits.

The lengths of the roads were used as a basis for the lengths of the reticulated infrastructure. Unit rates were assessed on average costs for each type of infrastructure and applied to assess a replacement cost estimate for each buffer zone.

Rural roads and state highways were assessed as having open drains for storm water and no water or waste water reticulation.

Karapiro dam and the associated generation station were not included in this assessment due to the complexity of the structures and the view that the dam would need to be treated as a separate exercise given the scope of this project.

3.3 Values Reported in the Table

The table lists the distance from/to of each hazard zone identified from the mouth of the river, which side of the river the assets are on, the general name of the location (where known), the hazard rating, the assets at risk, and the values of assets within the 50m and 100m buffer areas.

The attached table totals the following:

Pro-rata capital value in each hazard zone and distance from river band for the properties affected, based on the area in each band compared to the total area of each rating unit.

The infrastructure for each hazard zone was summed and added to the property valuations to form a total value for each hazard zone by 50m and 100m buffer areas.

4 Assumptions

No assessment was made of the environmental or structural soundness of any building or infrastructure and it has been assumed that the construction conforms to current building, fire, occupational health & safety etc regulations & codes.

Where information has been supplied by another party, this information has been taken to be reliable.

5 Limitations

This assessment encompasses only those assets identified in the scope.

The assessments and schedules have been compiled on the basis stated for the purpose stated herein.

The assessment information shall not be used for any other purpose. Any party that relies upon it for an alternative purpose without reference to Beca does so at their own risk.

Neither the entire nor any individual part of this report may be referred to or included in any published document, circular or statement without our written approval of the form and context in which it may appear.

Beca responsibility for this assignment is limited to Environment Waikato and to Environment Waikato only. Beca disclaim all responsibility and will accept no liability to any other party.

Beca reserve the right, but not the obligation, to review all calculations included or referred to in this report and, if considered necessary, to revise its opinion in the light of any information existing at the date of valuation which becomes known to Beca after the date of this report.

This was a desktop exercise only; no site surveys were carried out to reconcile the schedules and no responsibility can be accepted for errors, omissions or inclusion of assets no longer in existence. Furthermore, this report does not constitute an environmental audit.

Unless otherwise stated, no account has been taken of the effect on value due to contamination or pollution or of the possible effect on value of possible increases in standards for noise, emissions or waste disposal.

The values reported are assessed on a summary level and were completed as a desktop exercise. To this extent, they cannot be deemed reliable for use in determining reinstatement costs following a partial or full loss of the assets.

Distance From (m)	Distance To (m)	River Side	Location	Hazard	Types of Assets At Risk	Values of Assets within 50m (NZ$)	Values of Assets within 100m (NZ$)
95200	95950	Left	Lower Waikato Esplanade	Medium	Water, bridge	1,441,882	2,976,014
95200	95700	Right	Waipa confluence - North of SH1 bridge, Ngaruawahia	Medium	Residential property, water, bridge	4,491,302	8,169,086
95700	95900	Right	Regent Street	High	Residential property, water	208,833	2,069,561
95900	96050	Right	Turangawaewae Marae	Severe	Marae	134,201	1,144,817
96050	96150	Right	Ahurei Drive	High	Residential property, stormwater outfall	725,486	10,047,887
96150	96300	Right	Porotaka Place	Medium	Rural/residential property	35,257	744,794
96200	96500	Left	Martin Street	Medium	Residential, water, stormwater outfall	1,185,800	1,358,280
96300	97150	Right		Low	Rural	556,819	5,584,881
96500	97000	Left	Jordan Street - Ellery Street East (Waikato Esplanade)	High	Residential property, wastewater, water	306,425	1,617,636
97000	97300	Left	Belt Street - North Street	Medium	Residential property, wastewater, water	806,029	2,868,164
97300	97600	Left	North Street	Low	Residential property, wastewater, water	27,515	818,807
97350	97650	Right		High	Rural	223,986	445,765
97600	98150	Left	Ngaruawahia (south).	High	Residential property	904,314	4,393,943
97650	97750	Right	Driver Rd West	Medium	Rural property, some buildings	38,501	95,317
97750	98100	Right		Low	Rural	147,525	328,955
98100	99200	Right		Medium	Rural property, some buildings	1,314,708	3,682,320
98150	99000	Left	North of Ngaruawahia Golf Course	Medium	Rural/residential	383,448	1,051,488
99200	99350	Right	Opposite Ngaruawahia Golf Course	High	Rural property, some buildings	287,199	578,277
99350	100950	Right	Perry's Quarry/Landfill	Medium	Quarry/landfill, rural	397,679	831,488
99600	100850	Left	Ngaruawahia Golf Course	Medium	Golf Course	1,274,440	3,154,192
100850	100950	Left	Horotiu Meatworks	High	Meatworks	164,707	164,937
100950	101100	Left	Horotiu Meatworks	Severe	Meatworks	1,611,127	3,454,563
101100	101700	Right		Medium	Rural/quarry	21,701	42,452
101700	102050	Right		High	Rural/quarry	139,349	276,652
102050	102500	Right	Sullivan Road	Medium	Rural	-	-
102300	105500	Left	Horotiu Bridge	Medium	Bridge, quarry	1,775,557	2,190,918
102500	103200	Right	Horotiu Bridge	Low	Bridge, rural	1,569,510	2,098,219
103200	105300	Right	River Downs	Medium	Residential/rural property	5,165,580	13,554,246
104250	0	Left	Hutchinson Road	High	Rural	8,570,870	17,242,940
105500	106100	Left		Low	Rural	207,743	449,133
105500	105750	Right	Horsham Downs Golf Club	Medium	Golf Course	196,882	418,687
105800	106700	Right		Medium	Rural/residential property, water	4,627,133	9,360,891
106700	106950	Left	Water Pollution Control Plant	High	Stormwater, rural/industrial	315,188	853,091
106700	108050	Right	Featherstone Park	Low	Rural/residential property, water, stormwater outfalls	4,111,341	10,285,214
106950	107200	Left		Medium	Residential	403,200	588,800
107200	107550	Left	Opposite Featherstone Park	Severe	Residential property, stormwater, water Stormwater outfalls at ch1072 and ch1079	649,926	5,596,887
107550	107900	Left	Pukete	High	Residential	79,072	5,646,193
107900	108050	Left		Severe	Water, stormwater outfalls, residential property	1,317,008	8,383,053
108050	108700	Left	Braithwaite Park	Medium	Park	1,212,685	10,645,000
108050	108350	Right		Medium	Stormwater outfall	347,462	787,244
108350	108550	Right	Pukete	High	Stormwater outfall, water, residential property	560,310	2,881,619
108550	110450	Right	Pukete Road Bridge	Medium	Bridge, residential property, water, stormwater, stormwater outfalls	2,334,906	7,502,396
108700	109000	Left	Braithwaite Park	High	Water, Pukete Sewer Bridge	3,844,405	7,035,115
108700	0	Right		High	Residential property	3,059,368	12,931,113
109000	110350	Left		Medium	Water, stormwater outfalls, residential property	22,296,465	48,719,796
109100	0	Right	Pukete/ Flagstaff	High	Residential property	6,944,485	13,718,267
109650	0	Right	Te Hikuwai Reserve (Flagstaff)	High	Reserve	9,536,770	19,869,703
110350	110950	Left	St Andrews Golf Course	High	Golf course, stormwater outfall	958,944	2,057,282
110450	110950	Right	Opposite St Andrews Golf Course	High	Residential property, stormwater outfalls, water, private boat landing	8,354,492	16,309,975
110950	111200	Right	Queenwood	Medium	Stormwater, water, residential property	2,445,657	5,787,613
111200	111400	Right	Wymer Road	High	Water, stormwater, stormwater outfall, residential property, Swarbricks Landing	699,483	3,382,896
111400	111500	Right	Donny Park - Perindale Road	Severe	Water, stormwater, residential property	564,265	2,868,515
111500	111850	Left	St Andrews Terrace	Medium	Water, stormwater outfalls, residential property	2,082,985	7,464,832
111500	111650	Right		High	Residential property, stormwater, water	1,230,559	5,162,495
111650	112100	Right	Days Park (Chartwell)	Low	Park	582,342	1,026,275
111850	112250	Left		High	Water, stormwater outfalls, residential property, footbridge	6,025,335	15,959,768
112100	112500	Right	Days Park (Chartwell) - Braithwaite Street	Medium	Residential property, stormwater, water, stormwater outfalls	115,074	1,384,574
112250	113700	Left	Matakanohi Reserve (Beerescourt)	Medium	Water, stormwater outfalls, residential property, bridge, wastewater pumpstation and outfall	18,515,010	38,215,775
112250	0	Right	Days Park (Chartwell)	High	Park/residential property	3,540,598	7,372,759
112500	112800	Right	Waikato Diocesan School for Girls	High	Stormwater outfalls, residential property, boat ramp	6,847,381	12,838,654
112800	114150	Right	Fairfield	Medium	Water, stormwater, stormwater outfalls, residential property, Fairfield Bridge, timber jetty	27,291,661	47,657,394
113300	0	Left	North fo Milne Park	High	Stormwater, residential property	3,682,343	12,210,673
113700	114050	Left	Fairfield Esplanade	High	Stormwater outfalls, water, residential property, timber landing	8,848,959	19,318,678
114050	115000	Left	Boundary Road (Whitiora) Bridge	Medium	Bridge, stormwater outfalls, water	10,732,944	31,643,863
114150	114500	Right	Boundary Road (Whitiora) Bridge	Low	Bridge, residential property, water, stormwater	4,638,899	10,569,618
114500	115000	Right	Miropiko Reserve	Medium	Stormwater outfalls, residential property, water, timber landing	8,026,931	20,986,659
115000	115200	Left	Liverpool Street	Low	Stormwater outfall	2,198,180	8,265,271
115000	115200	Right		Low	Residential property	2,791,580	6,420,066
115200	115300	Left	Hamilton Street	Medium	Commercial property, stormwater	1,294,224	11,009,264
115200	115350	Right	North of Claudelands Bridge	Medium	Residential property, stormwater outfall, water	2,421,775	5,139,312
115300	115800	Left	Claudelands Bridge - Ferrybank.	High	Bridge, stormwater outfalls, water, commercial property	30,300,026	111,442,667

Distance From (m)	Distance To (m)	River Side	Location	Hazard	Types of Assets At Risk	Values of Assets within 50m (NZ$)	Values of Assets within 100m (NZ$)
115350	116500	Right	Jesmond Park to New Memorial Park	High	Residential property/park, stormwater, stormwater outfalls, water, Victoria (Bridge St) Bridge	5,622,671	11,343,109
115650	0	Right	North of Parana Park	Medium	Water	9,847,019	20,992,296
115800	115900	Left		Severe	Commercial property, stormwater outfall	2,999,523	9,687,251
115900	116200	Left		High	Commercial property, stormwater outfalls, water	5,758,909	33,776,601
116200	116900	Left		Medium	Stormwater outfalls, water, commercial property	4,554,066	18,376,945
116500	116600	Right	Hamilton East Shopping Centre	Severe	Commercial property, water, stormwater outfalls	591,473	3,523,580
116600	117000	Right	New Memorial Park	High	Park, water, stormwater outfalls, boat ramp	5,995,850	29,651,419
116900	117000	Left	Roose Commerce Park	High	Stormwater outfalls, water	907,877	2,592,543
117000	117300	Left		Medium	Water, stormwater outfalls, commercial property	3,020,607	8,441,810
117000	117800	Right	Hayes Paddock	Medium	Reserve	185,358	3,455,224
117200	0	Right		High	Stormwater outfall	2,675,975	7,667,497
117300	117700	Left		High	Park, Hamilton Skills Centre (old Pumping Station) Stormwater outfalls, Hospital drain outfall	982,003	1,714,629
117700	118250	Left	Graham Park	Medium	Park, stormwater	1,165,121	1,929,720
117800	118100	Right	Dillicar Park	High	Park, residential property	354,070	1,240,272
117900	0	Right	Graham Island	Severe	Park, residential property	1,096,538	3,614,288
118100	118600	Right		Medium	Residential	3,472,085	9,749,814
118250	118600	Left		High	Park	-	1,455,876
118500	0	Left	Cobham Bridge	Severe	Bridge	3,959,540	4,313,149
118600	118850	Left	Yendell Park	Medium	Park	-	48,825
118600	118950	Right	Rogers Rose Gardens	High	Gardens, stormwater outfall	247,536	699,553
118850	119150	Left	Sandford Park	High	Park, stormwater outfall, Mangakotukutuku Stream confluence, crossed by twin 450 dia water mains on pipe bridge	61,378	271,102
119150	119350	Left		Medium	Rural, water treatment plant intake	1,643,216	4,996,229
119350	120000	Left	Sandford Park - Peacockes Rd Esplanade	High	Park/rural	521,789	1,367,463
119350	120450	Right	Hamilton East Cemetery	Severe	Gardens (building at ch1193), cemetery, residential property Walking track adjacent to river, timber landing	2,984,585	9,339,903
120000	120700	Left	Peacockes Rd Esplanade	Medium	Rural	163,745	540,726
120450	120550	Right		Medium	Residential/reserve	627,479	3,037,133
120550	120800	Right		Low	Water, stormwater, residential property	564,476	3,865,836
120700	121000	Left	Weston Lea Drive	Low	Rural	374,043	753,000
120800	121000	Right		Medium	Stormwater	850,776	5,361,992
121000	121600	Right	Hammond Park	High	Residential/industrial, stormwater outfalls, park	4,479,892	15,389,626
121550	122400	Left	Peacockes Rd	High	Rural	466,747	909,768
121600	123050	Right		Medium	Industrial/residential property, stormwater	5,127,565	12,961,444
122400	124050	Left	Nukuhau Pa	Medium	Rural	434,985	875,001
122650	0	Right	Riverglade Drive	Low	Residential property	563,919	1,799,022
123050	123800	Right	Newell Road	High	Rural/residential property	762,695	1,555,391
123700	0	Right		Severe	Rural/residential property	190,259	404,848
124050	124300	Left		High	Rural	-	50,244
124200	125550	Right	Redwood Grove	High	Rural/residential	2,104,451	4,045,443
124300	125400	Left		Medium	Rural	689,639	1,571,669
124700	0	Left		High	Rural	89,343	266,699
125550	126000	Right		Medium	Rural	291,300	560,318
126000	126250	Right	North of Narrow's Bridge	High	Residential/rural, buildings	1,641,372	4,328,270
126250	126400	Right		Medium	Golf course	110,839	234,489
126400	126550	Left	The Narrows	Low	Bridge	789,663	904,619
126500	127200	Right		Medium	Golf course	351,122	776,556
126550	126900	Left	South of Narrow's Bridge	High	Rural/residential, buildings, floating pontoon with access walkway	1,130,072	1,668,546
126900	127300	Left		Medium	Rural	712,550	1,533,795
127300	127650	Left		Low	Rural/residential	282,977	576,230
127300	127800	Right		Medium	Golf course	8,907	8,907
127650	127800	Left		High	Rural	114,333	221,769
127800	128250	Left		Medium	Rural	173,690	346,950
127800	128800	Right		High	Rural/residential?	1,953,640	4,887,335
128250	128800	Left	Mystery Creek (Golf Course)	High	Rural/golf course	183,325	485,778
128800	128950	Right		Severe	Rural/residential?	957,340	2,355,350
128950	129100	Right	Blue Heron Place	High	Rural/residential	150,224	400,753
129100	129500	Left		High	Rural/golf course, water intake	294,322	601,407
129100	129450	Right		Medium	Rural/residential	1,212,574	2,928,293
129450	129700	Right		Severe	Rural/residential	630,117	1,404,472
129700	0	Left		High	Rural/golf course	594,974	1,226,954
129700	130450	Right	Opposite Mystery Creek National Field Days Site	High	Rural/residential	341,405	666,224
130200	130950	Left		High	Rural/buildings	241,413	574,886
130850	130950	Right		High	Rural	253,226	489,601
130950	131450	Left		Medium	Rural	82,246	185,270
131200	131350	Right	Pencarrow Road	High	Rural	99,498	196,931
131350	131750	Right		Medium	Rural	194,769	360,832
131450	131900	Left	Kaipaki	High	Rural	156,890	319,783
131750	132250	Right	Hooker Road	High	Rural	290,926	665,821
132000	132400	Left		Low	Rural	111,354	217,632
132250	132400	Right		Severe	Rural	271,117	731,909
132400	133000	Left		Medium	Rural	6,635	16,712
132400	133350	Right	Duncan Road	High	Rural	694,342	1,369,191
133000	133350	Left		High	Rural	81,297	156,484
133350	133650	Right		Severe	Rural	119,008	296,599
133800	134200	Left		High	Rural	120,646	248,030
133950	134450	Right		High	Rural	234,038	454,471
134200	134650	Left		Severe	Rural	476,501	862,334
134450	135600	Right		Medium	Rural	117,749	229,878

Distance From (m)	Distance To (m)	River Side	Location	Hazard	Types of Assets At Risk	Values of Assets within 50m (NZ$)	Values of Assets within 100m (NZ$)
134650	135000	Left		High	Rural	170,821	359,856
135550	0	Left		High	Rural	373,260	725,526
135600	135900	Right		High	Rural	312,669	618,533
136100	137900	Right		High	Rural	77,621	155,377
136500	137500	Left	North of Cambridge Wastewater Treatment Plant	High	Rural/industrial, water intake	370,233	755,666
137500	138250	Left	Pukerimu	Medium	Rural/residential, water intake	153,805	580,508
137850	0	Left		Low	Rural/residential	100,981	280,968
138000	138200	Right		High	Rural	289,081	539,935
138050	0	Left		Low	Rural/residential	214,994	632,474
138500	139100	Left	Cambridge Wastewater Treatment Plant	Medium	Rural, wastewater treatment plant	305,741	654,849
138600	138750	Right		High	Rural	21,205	39,827
138750	140450	Right		Medium	Rural	430,480	836,777
139300	140300	Left	Cambridge Wastewater Treatment Plant	Medium	Rural/industrial/residential, wastewater, water, stormwater outfall, pipe bridges, Victoria Bridge	215,664	1,893,242
140300	141250	Left		High	Rural	2,367,742	7,964,117
140900	141250	Right		High	Residential, stormwater, stormwater outfall, wastewater, water	1,900,680	6,213,858
141250	142000	Left	Marlowe, Fletcher Streets	Severe	Rural/industrial/residential, wastewater, water, stormwater outfall, pipe bridges, Victoria Bridge	1,080,121	6,884,919
141250	141500	Right		Medium	Residential, wastewater, stormwater	1,150,372	2,888,297
141500	141700	Right		High	Residential, stormwater outfall	12,884	3,169,103
141700	142550	Right	Victoria Bridge	Medium	Residential, stormwater, wastewater, water, bridge	3,366,173	7,838,886
142000	143100	Left	Fergusson Bridge	Medium	Bridge, water, stormwater, wastewater, residential	1,157,862	7,179,165
142550	0	Right		Low	Residential, water, wastewater	167,628	820,641
142700	143000	Right	Fergusson Bridge	High	Bridge, water	1,563,937	2,372,680
143100	143400	Left	Leamington	Severe	Residential property, stormwater outfall	2,300,726	7,747,675
143400	145700	Left	Opposite Cambridge Golf course	Medium	Rural	175,567	1,043,060
143400	149600	Right	Cambridge Golf Course - Karapiro Dam	Medium	Golf course/rural	499,373	1,243,154
145000	0	Left		Low	Rural	374,272	758,800
145700	146050	Left		High	Rural	171,406	353,401
146100	0	Right		High	Golf course/rural	50,602,109	80,309,189
147650	148000	Left		Severe	Rural, electricity (high power)	121,169	235,661
148000	148700	Left		Medium	Rural	249,491	497,837
148950	149450	Left		High	Rural	95,106	277,940
149450	149600	Left	Karapiro Dam	Medium	Rural, dam	22,206	52,383
					Totals	412,172,733	1,084,208,302

- Appendix J

GIS

Metadata for Waikato Degradation Shape File

Metadata Type		Description
Description		Predicted degradation along Waikato River
Purpose		For use in determining requirement for more detailed investigation on degradation along Waikato River and gaining an understanding of the potential for degradation along the Waikato River
Projection		New Zealand Transverse Mercator (NZGD2000)
Accuracy		Data has been captured using a number of datasets with varying degrees of spatial accuracy. Information used to define the location of particular instances was obtained from sources including photo interpretation, field inspections and hard copy reports. The data captured is not an accurate representation of the riverbank and is more closely related to the parcel boundaries. Data is designed to be viewed at 1:75,000 and should not be used at scales beyond which it was prepared for. The spatial accuracy of the data is estimated to be no better than +/- 50 m for located features.
Object Type		Polyline
Attributes	UniqueID	Unique ID of the record
	IsectID	ID used in working
	Class100y	100-year classification. Used to derive the 100-year rating. Valid values are 0-0.5,0.5-1, 1-2 and >2
	Rating100y	100-year rating. Used in calculation of values for the hazard score incorporating bias for degradation. Valid values are 0.50, 0.65,0.85 and 1.00,
	HzScoreDeg	Hazard score incorporating bias for degradation. Range: 1.50 to 11
	Hzscore	Hazard score not incorporating bias for degradation. Used as basis for calculating the Hazard Score incorporating bias for degradation for 100year, 50 year and 10 year scenarios. Calculated from values recorded for vegetation classification, vertical classification, river classification and bends classification. Range: 2.50 – 12.00