CH2M Beca

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Report

Te Otamanui Fatal Flaw Assessment

Prepared for Hamilton City Council

Prepared by CH2M Beca Ltd

3 May 2017

Revision History

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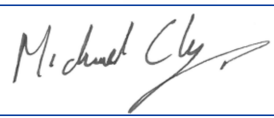
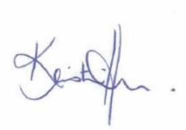
1	**Angela Pratt**	Draft for client review	3/5/17

Document Acceptance

Action	Name	Signed	Date
Prepared by	**Angela Pratt**		3/5/17
Reviewed by	**Michael Law**		3/5/17
Approved by	**Kristina Hermens**		3/5/17
on behalf of	**CH2M Beca Ltd**		

Executive Summary

CH2M Beca Ltd has been engaged by Hamilton City Council (HCC) to carry out a fatal flaw assessment to confirm whether flow could be diverted from the Mangaheka Stream catchment into the Te Otamanui Lagoon catchment. The following tasks have been carried out as part of this work:

- Site Visit (high level walkover)
- Consideration of tasks required to assess feasibility
- Survey of the upper reaches of the Te Otamanui Stream catchment
- Analysis of survey data to determine if water can discharge into the Te Otamanui Stream already
- Desktop study to determine if there are any issues with discharging water in to the Lagoon catchment including tasks such as:
  - Aerial photo inspections
  - Consent searches
  - High level catchment area, runoff generation and channel capacity calculations
  - Contact Waikato Regional Council (WRC) to determine if there are any existing flooding issues in the catchment that may be exacerbated by discharging water from the Mangaheka and the effects on both catchments will occur at a later stage (Task 8b).

Table 8 below provides a summary of the findings of this investigation. The final column has been coloured green, where there is a potential benefit seen in supplementing Te Otamanui Flows with flows from the Mangaheka Catchment. Items coloured yellow need further investigation.

Summary of Findings

	Comments	Fatal flaw or not?
Te Otamanui Stream Obstructions	There are a number of obstructions including buildings within 5m of the stream and culverts which may cause issues if flood levels were increased. These obstructions would need to be viewed during a site visit to confirm if this would be an issue or not.	Unclear until a further site visit is carried out.
Consented Activities	A number of consented activities in the catchment may cause issues if additional flows were discharged. These works would need to be viewed during a site visit to confirm if this would be an issue or not. Groundwater and surface water takes in the Mangaheka catchment may also be impacted.	Unclear until a further site visit and investigations (GW and SW takes) are carried out.
Flooding records	Flooding records indicate that diversions from the Te Otamanui catchment have occurred in the past. Since then, development may have occurred within the previous floodplain that may now be impacted if additional water was diverted from the Mangaheka catchment.	Unclear until a further site visit is carried out.
Existing Stream Capacity and Existing Flows	Our basic rational method calculations have identified that there is approximately 250L/s of capacity in the upper Te Otamanui catchment. This provides an opportunity to discharge flows from the Mangaheka Catchment	No
Device 6 size	Our basic calculations have shown that whilst discharging 250L/s is not likely to have an impact on the device 6 size, if more (1m^3/s) can be	No

	Comments	Fatal flaw or not?
	discharged by appropriately timing the discharge, there is likely to be a significant reduction in pond volume required.	

Based on our above investigations and the above summary table, it is concluded that no fatal flaws have been found relating to supplementing flows in the Te Otamanui Catchment. There is however additional work that needs to be carried out to better confirm feasibility. It is recommended that the following tasks occur as the next stages:

Detailed Assessment

Task a: Site Walkover to confirm:

- Have any farmers/landowners constructed structures over stream that may be flooded?
- Are there any small culverts that may be under capacity if flows increased?

Task b: Flow Analysis

- What flows would we take (low flows/mid flows/high flows? When and how much?
- Comparison of flows with stream capacity (refer section 8).

Task c: Modelling

- Updating the Mangaheka 1D model to determine the effect of the diversion on the Mangaheka catchment. This would involve a simple discharge arrangement for the diverted flows and would not include an assessment of effects on the Te Otamanui Lagoon catchment.

In addition to the above, based on our work carried out, we have also identified that the following investigations will also need to occur to further confirm feasibility.

- A site visit should also confirm:
  - If any of the buildings that are close to the Te Otamanui stream are habitable or if significant effects are likely if these are flooded due to increased flows
  - Any additional obstructions that were not seen on the aerial photos
- Effects of reduction in base flows in the Mangaheka catchment
- Will discharging flood flows from the Mangaheka catchment have any impact on base flows in the Te Otamanui catchment and the lagoon water levels? If so, there may be little benefit to the Te Otamanui catchment in discharging additional flows
- The cultural effects of mixing of waters from two different catchments needs to be investigated.
- Discharging low flows may have ecological effects on the Mangaheka catchment.
- Erosion assessment of the stream and its capacity to take the additional flows (this may require soils/geotech information).
- Assessment of effects on any existing groundwater and surface water takes in the Mangaheka catchment.

Contents

Appendices

1 Introduction

CH2M Beca Ltd has been engaged by Hamilton City Council (HCC) to carry out a fatal flaw assessment to confirm whether flow could be diverted from the Mangaheka Stream catchment into the Te Otamanui Lagoon catchment.

The Te Otamanui Lagoon catchment lies alongside the larger Mangaheka Stream catchment on the north-west side of Hamilton. The Te Otamanui Lagoon is located in the downstream part of the catchment, just upstream of the discharge point to the Waipa River. This lagoon has appeared to be drying out in recent times and supplementing flows is seen as something that may improve this situation.

This report does not seek to confirm why the lagoon appears to be drying out, rather whether flows could be supplemented from the nearby Mangaheka Stream catchment and hence whether it would be feasible to carry out further investigations to do this.

Figure 1 shows the location of the Te Otamanui Stream catchment, the Mangaheka Stream catchment and Hamilton City.

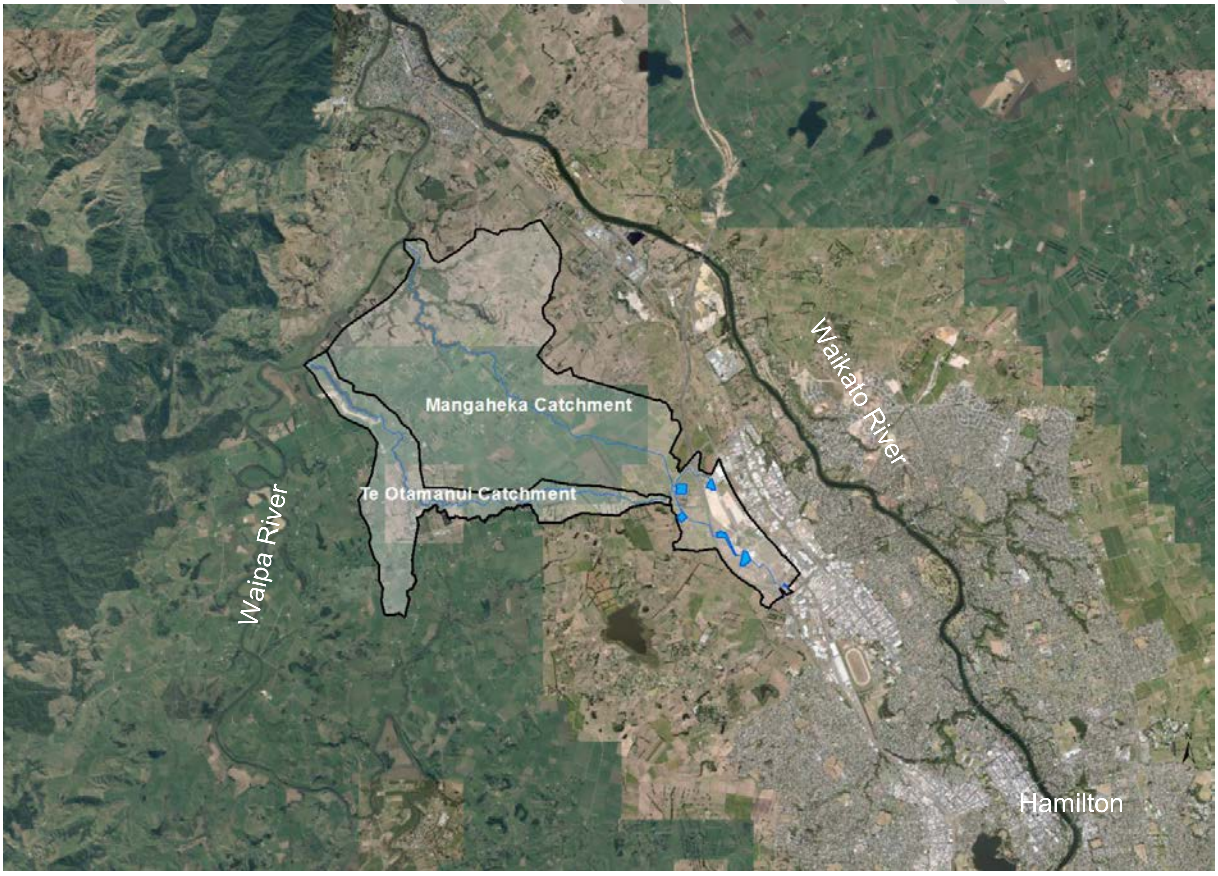


Figure 1 Te Otamanui Catchment Location

2 Background

The Te Otamanui catchment lies alongside the Mangaheka Stream catchment to the north-west of Hamilton City. The Te Otamanui Stream catchment is approximately 9.5km long and 500 hectares in area with an approximate grade of 1 in 550. The stream flows through farmland and a rural town (Te Kowhai) before discharging into the Waipa River.

The current Te Otamanui Lagoon catchment starts near the Koura Drive roundabout with Te Kowhai Road. The upper part of this catchment (upstream of Koura Drive) appears to have been disconnected at some stage in the past, and now drains towards the Mangaheka Stream. If this connection were re-established in some form, this could help the Te Otamanui Lagoon (depending on the hydrology of the lagoon and whether baseflows or storm flows are used to supplement it) but also potentially reduce the mitigation requirements for development in the Mangaheka catchment, which forms part of the Mangaheka Integrated Catchment Management Plan.

Figure 2 below shows a plan of the current upper catchment.

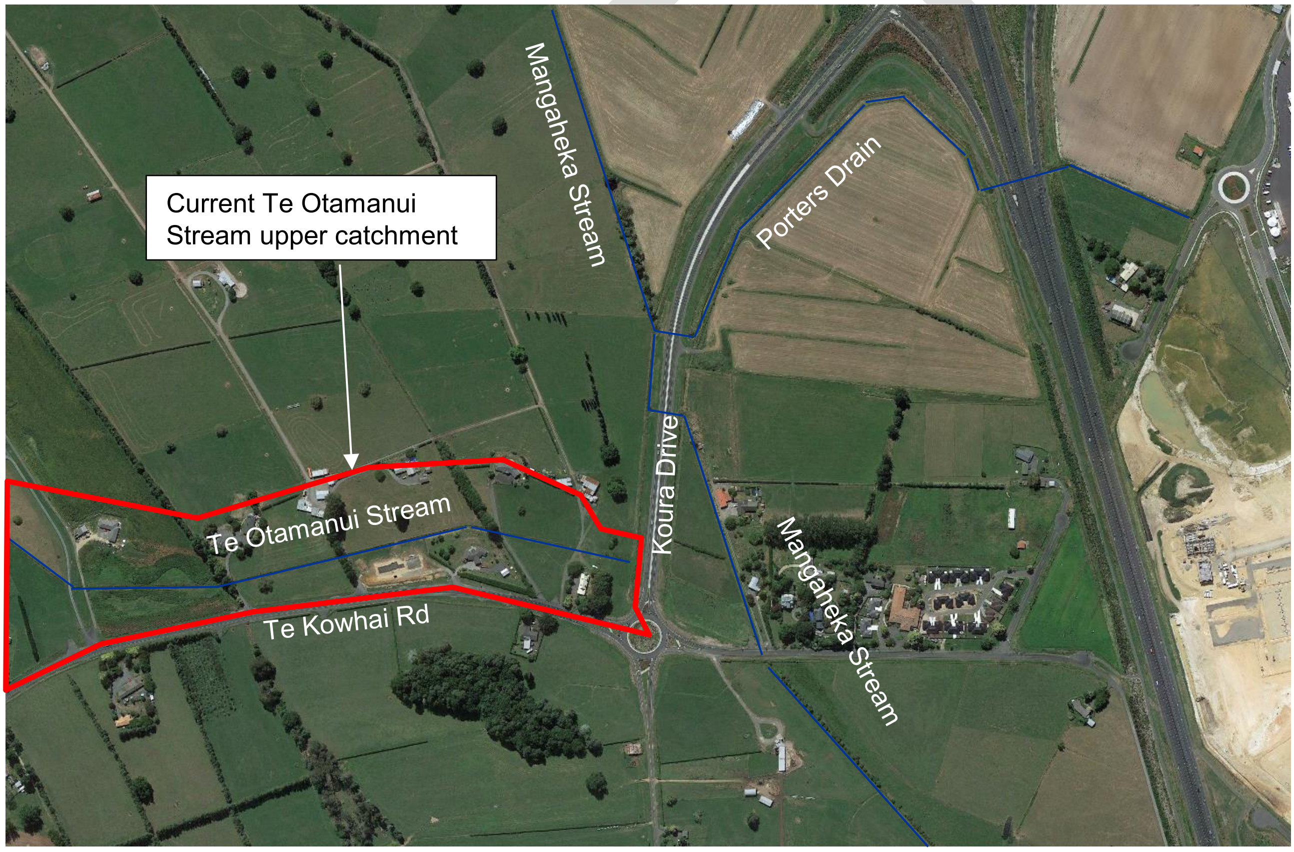


Figure 2 Upper Te Otamanui Catchment

3 Scope

The overall objective of this report is to assess the feasibility of discharging flows into the Te Otamanui Stream from the Mangaheka Stream.

A multiple stage approach has been proposed and this report covers the results of the Stage 1 and 2 tasks set out below.

Stage 1: Survey and Site Visit

- Site Visit
- Consideration of tasks required to assess feasibility
- Survey of the upper reaches of the Te Otamanui Stream catchment

The above tasks have already been undertaken.

Stage 2: Desktop Study

This report covers the following tasks:

- Analysis of survey data to determine if water can discharge into the Te Otamanui Stream already
- Determine if there are any issues with discharging water in to the Lagoon catchment, based on:
  - Aerial photo inspections
  - Consent searches
  - High level catchment area, runoff generation and channel capacity calculations
  - Contacting Waikato Regional Council (WRC) to determine if there are any existing flooding issues in the catchment that may be exacerbated by discharging water from the Mangaheka and the effects on both catchments will occur at a later stage).

During the scoping of this project it was identified that further stages would likely be needed if no fatal flaws were identified during the desktop study. These are further described in Section 12 – Recommendations.

4 Existing Stream Constraints

There are numerous restrictions along the channel in the Te Otamanui catchment, including several culverts, footbridges and two buildings within 5 m of the channel.

Appendix A shows a list of the obstructions which were clear in aerial photography as well as a map showing the location of each obstruction.

If more water is put into the catchment, there could be potential flooding effects as a result of increased water levels. Even if the stream channel has the capacity to convey flood flows, more flow may result in increased flooding upstream of culverts which currently restrict flows, and could cause overtopping of driveways causing access issues. There is also risk of flooding of structures located close to the stream. These buildings seen in aerial photographs appear to be sheds, so additional flooding (frequency and depth) may not be as much of an issue as if they were habitable dwellings. It is however unknown at this stage what the current flood levels are and hence what the exact effect on flood levels will be if more water is flowing in the channel than does currently.

To be able to determine if any of these obstructions are likely to cause issues if additional flows are discharged to the catchment, a further detailed site visit to gather details on these obstructions, as well as further modelling would likely be required. This is discussed further in section 12 .

5 Consented Activities

There are a number of resource consents granted (or in process) by the Waikato Regional Council for activities in the catchment which may have an impact on the Te Otamanui stream and its hydrology especially if additional water is discharged. The locations of these are shown in Appendix A.

Table 1 Resource Consents

ID	Type	WRD ID	Description
R1	Bed disturbance	Auth 126346.01.01	Culvert extension
R2	Bed disturbance	Auth 126346.01.01	Culvert extension
R3	Bed disturbance	Auth 126346.01.01	Culvert extension
R5	Land -Disturbance	Auth 135666.02.01	Discharging clean fill to land – sand mining operation and walkway construction
R6	Bed- disturbance	Auth 131348.02.01	Rechannelising and stream restoration

Note: There are other consents shown in Appendix C. However only the ones that could potentially have an impact on stream hydrology are shown here.

Consents R1, R2 and R3 appear to relate to culvert widening for the purposes of constructing driveways. Such consents have the potential to impact on the stream if the design of the extensions caused changes to the hydraulics and hence flood water levels in the area of the culvert.

In regard to resource consent R5 and 56, sand mining operations, walkway construction and stream rechannelising also have potential to have hydraulic implications and hence might influence water levels during high flows.

In addition, there may also be groundwater and surface water takes in the Mangaheka catchment that may be impacted if a discharge to the Te Otamanui stream proceeds. Further investigations as to the types of abstraction will need to be done at a later stage to confirm if these will be impacted.

A site visit to each consent location will likely be required to be able to confirm whether the works carried out will have implications if additional water is discharged from the Mangaheka stream.

6 Existing Flooding Records

6.1 Overview

Existing flooding records can be a good way to see how a catchment reacts to high flows and hence can help to gauge the effects that additional flows may have on the catchment. We have carried out a general internet search for flooding records in the Te Otamanui Catchment and contacted WRC and WDC staff. The following limited records have been found.

6.2 Internet Search Results

- WRC, 2011 notes that: "Much of the catchment's water had been diverted leading to the lagoon drying out. Restrictions at the culvert. Flooding frequency is close to 1 in 10 years, where it would normally have been around 1 in 2 years." Unfortunately this report does not go into detail as to what this means or where the culvert is, but it is possible that there is out of bank flows in a 10-year ARI[1] event.
- NIWA's Historic Weather Events Catalogue refers to a flooding event in the Te Kowhai area in July 1953, where the Te Kowhai to Whatawhata and Te Kowhai to Ngaruawahia roads were under some feet of water in multiple places. Exact locations were not given

Aside from this, little record could be found of any other flooding events in this area.

6.3 Conversations with WRC

During conversations with Graham McBride, a previous Waipa Zone Liaison Committee Chairman, Graham could not recall any specific flooding events but he did mention that there is no connectivity from the Mangaheka Catchment to the Te Otamanui Catchment at Koura Drive. He also noted that in the past there was a diversion at Ken Commons' property at 714 Te Kowhai Road in Te Kowhai. It was proposed build a hay barn over a drain at 714 Te Kowhai Road but at the time there was no record of the drain and therefore HCC granted the consent. Having granted consent, they then had to allow a drain diversion to occur. Instead of going underneath Horotiu Road to the Te Otamanui catchment, the drain was apparently diverted into the Mangaheka Catchment. Mr McBride also suggested that Te Otamanui is an old path of the Waipa River. It is possible that this diversion has impacted on the water levels in the Te Otamanui catchment and lagoon.

Figure 3 shows the approximate location of the diversion and hay shed. Note that the location and presence of a diversion has not has been verified by either Graham McBride or Beca.

[1] ARI: Average Recurrence Interval

Figure 3: 714 Te Kowhai Road property

6.4 Discussion

The above information gathered does not provide any particularly strong insights into whether the catchment would handle the additional flows, other than to say that if diversions from the catchment have occurred, the catchment would likely have had to manage higher flows in the past. Since the diversions have occurred, development in the catchment (new culverts, dwellings, buildings) may have encroached on areas that may have once been floodplain. If the catchment did convey higher flows, additional flooding effects may be seen.

7 Can Flows Already Enter?

7.1 Overview

When undertaking our site visit on the 8th of June 2016, it appeared that it may have been possible for water to enter the Te Otamanui catchment from the Mangaheka Stream, either via what appeared to be a culvert or by overflow from the swale alongside Koura Drive. The potential point of discharge is shown in Figure 4 and Figure 5 below.

To be able to confirm whether water can enter the Te Otamanui catchment, we have carried out surveying of the area to determine levels and presence (or not) of a culvert.

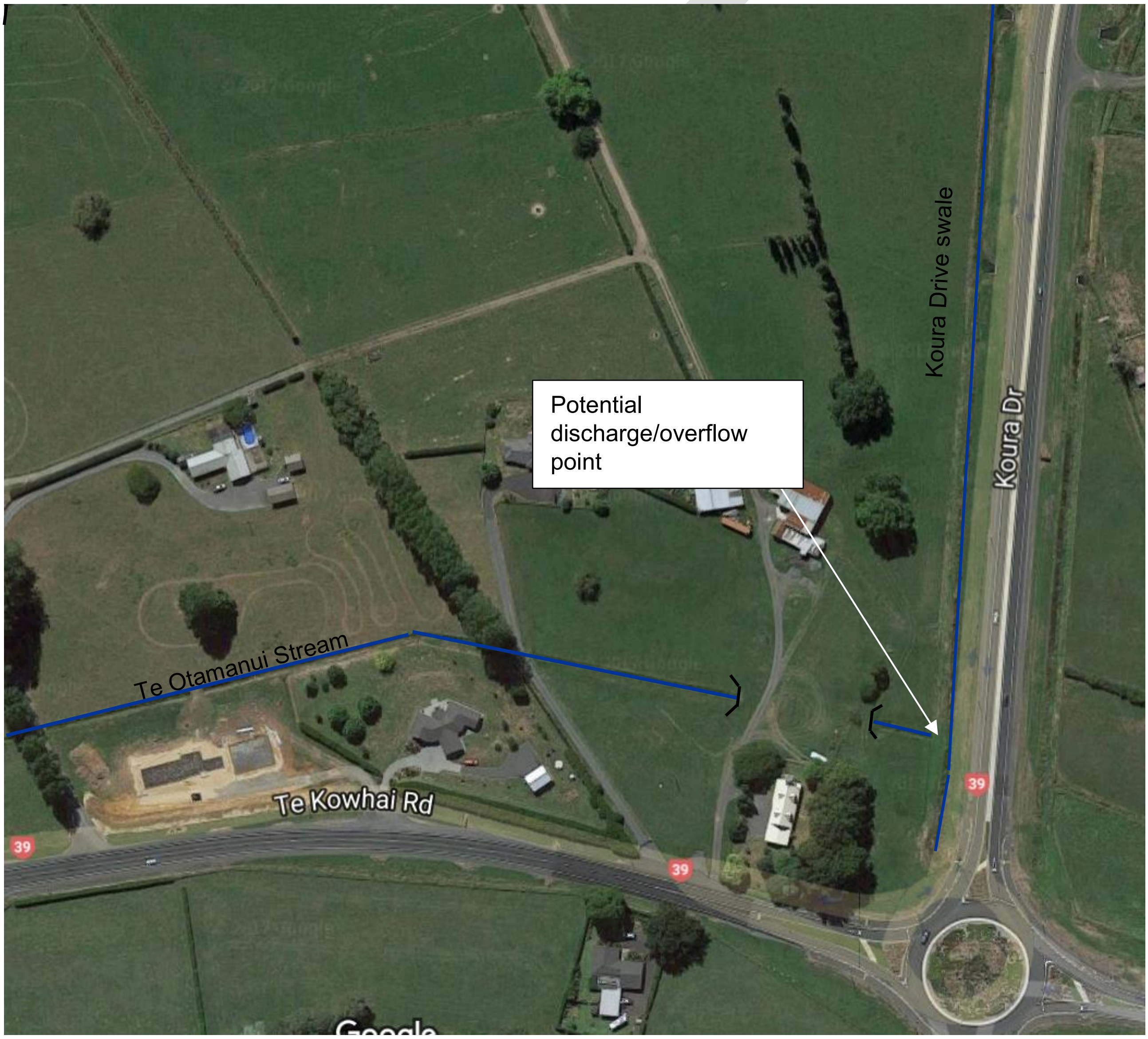


Figure 4 Upper Te Otamanui Stream

Figure 5 Photo Te Otamanui Stream upper reach looking from the Koura Drive swale

7.1.1 Surveying

Based on the survey, there is no direct culvert connection to the upper Te Otamanui catchment from the swale alongside Koura Drive. Table 2 below shows the ground and invert levels in the Koura Drive swale, the upper Te Otamanui catchment. This shows that there is almost 1 m of level difference between the swale and the Te Otamanui Stream. This means that it may be feasible to discharge flows via some sort of connection in this location.

Table 2 Ground and Invert Levels

Description	Level (mRL)
Invert level in swale alongside Koura Drive	29.37
Invert level in most upper part of Te Otamanui Stream	28.29

7.1.2 Existing Discharges

As mentioned above, there is no direct connection from the Mangaheka catchment into the Te Otamanui catchment via a culvert. Although there is no direct connection, it is possible that overland flows could discharge during flooding events. Whether and how often flows already discharge from the Mangaheka catchment to Te Otamanui, relates to how high water levels get in the Mangaheka Catchment and the frequency of these high flows. Table 3 shows the 10-year and 100-year ARI flood levels in two locations (6 and 8 on Appendix C) in Mangaheka stream catchment, which are close to the upper reaches of the Te Otamanui catchment i.e. locations where flow could be diverted from. These flood levels have been taken from Beca, 2016.

Table 3 Flood Levels

Description	Level (mRL)
100-year water level at Koura Dr culverts (Location 8)	29.38
100-year water level just downstream of Device 6 (Location 6)	30.49
10-year water level (Location 8)	29.23
10-year water level (Location 6)	30.10

Table 3 above shows that water levels at location 8 are only slightly higher than the invert of the Te Otamanui Stream upper reaches in a 100 year event (refer Table 2), but at Location 6, water levels are higher in both a 10 year and a 100 year event. This means that, if a channel or pipe from the location 6 to the Te Otamanui was constructed, water could potentially be diverted to the Te Otamanui stream from this location, much more easily than from location 8.

8 Catchment Flows and Capacity

8.1 Overview

To be able to discharge flows from the Mangaheka Catchment into the Te Otamanui Catchment, the Te Otamanui catchment needs to be able to have additional capacity in the channel compared to the runoff that is generated by the contributing catchment. To be able to confirm if there is additional capacity, peak flows have been calculated and compared to calculated channel capacity. Note that this part of the assessment has only been based on the upper Te Otamanui catchment, where surveying was carried out. Whilst this cannot be relied on as an indicator that the whole catchment can handle additional flows, if the upper catchment cannot accept additional flows, this is likely to be a fatal flaw. If the catchment can take extra flows based on this simplistic approach, a more detailed capacity check of the whole catchment would be justified.

8.2 Existing Flows – Upper Catchment

Peak flows for the 10 and 100-year storm events, with and without climate change, have been calculated for the current Te Otamanui upper catchment, using the catchment shown in Figure 6, below. Note that whilst the survey locations have numerical location references, they are not the same as the locations described in Beca, 2011, which are described earlier in the report.

Table 4 shows the catchment parameters used to determine flows, which are shown in Table 5, together with the associated rainfall intensity for each storm event.

The rational method was used to calculate peak flows using the catchment parameters shown in

Table 4. With the area assumed to be 5% impervious, the catchment was considered to have a weighted average SCS Curve Number of 70.5 which is equivalent to a 55% runoff coefficient. Time of concentration was calculated as 25 minutes using the method described in Auckland Council's TP108 document. Peak flow calculations for each storm event were then based on rainfall intensities referred to in the HCC Standard Stormwater Modelling Methodology, for a 25 minute storm duration.

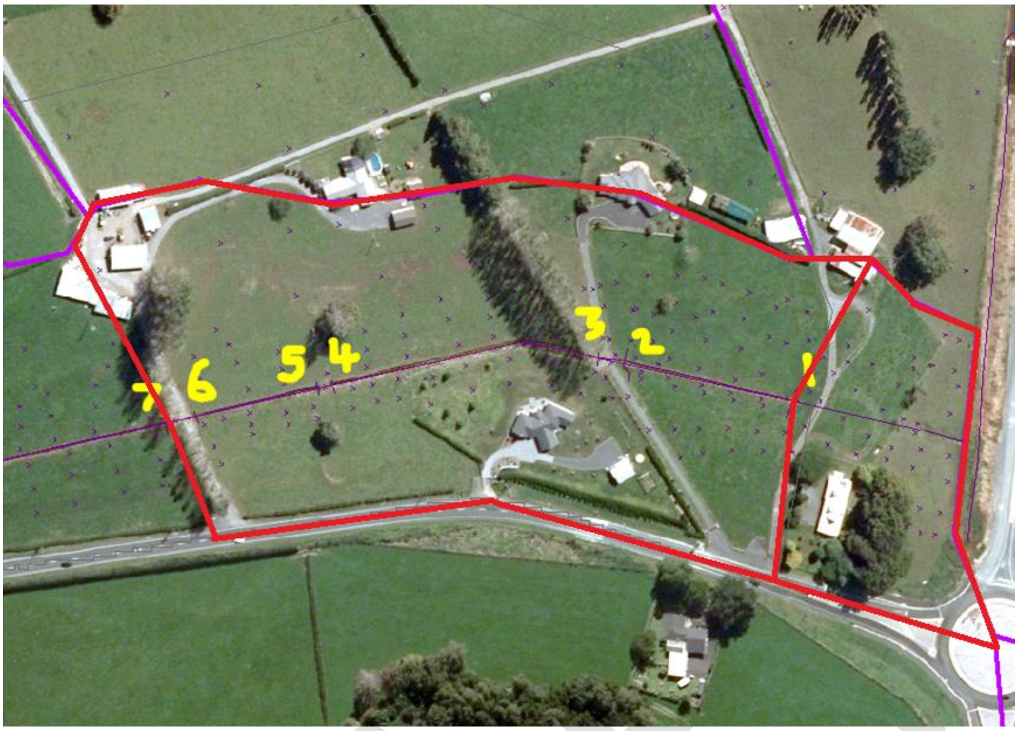


Figure 6: Catchment area (outlined in red) and location of surveyed cross-sections for Te Otamanui upper catchment

Table 4: Catchment parameters for Te Otamanui upper catchment

Catchment Parameter	Value
Catchment area (ha)	5.68
Catchment length (km)	0.44
Gradient (%)	0.66
Channelisation coefficient	0.8
Percentage impervious (%)	5
Weighted SCS Curve Number	70.5
Runoff coefficient (%)	55
Time of concentration (min)	25

Table 5: Peak flows for Te Otamanui upper catchment

Storm Event	Rainfall Intensity (mm/hr)	Peak Flow (m^3/s)
10 yr	63.5	0.55
10 + CC	73.7	0.64
100 yr	93.2	0.81
100 yr + CC	108.8	0.94

8.3 Existing Channel Capacity

To be able to discharge flows into the Te Otamanui stream, the stream channel needs to have sufficient capacity to accept additional flows above that generated currently. We have therefore determined the capacity of the channel using Manning's Equation. This has been done using the cross-section data from our survey of the upper reaches of the catchment.

Based on surveyed cross-section data, the channel capacity at each cross-section is shown in Table 6 below. This is based on a Mannings 'n' roughness value of 0.035 and an average channel slope of 0.16%.

Table 6: Te Otamanui Stream upper catchment capacity

Cross-section	Capacity (m^3/s)
1	1.93
2	0.83*
3	1.63
4	2.75
5	3.76
6	1.14
7	1.18

*Cross-section 2 appears to have a lower capacity that the other cross-sections. The reason for this has not been investigated, and the cross-section has been ignored for the purposes of the overall capacity assessment as all other cross-sections have higher capacity, and it may be an anomaly.

Based on Table 6 above, it appears that the upper catchment can convey upwards of $1.1m^3/s$. Comparing this to the peak flow that the upper catchment produces ($0.93m^3/s$) it is likely that there is additional capacity in the upstream part of the catchment in the order of 250L/s. This extra capacity could potentially be utilised by inputting flows from the Mangaheka catchment into the upper Te Otamanui catchment.

9 Diversion Scenarios

9.1 Scenarios

There are a number of possible ways of supplementing flows in the Te Otamanui catchment using flows from the Mangaheka catchment. Discharges of either flood flows, mid-flows or low flows could occur and there are a number of possible discharge locations.

Options include:

- Divert flood flows from Mangaheka directly from Device 6; a proposed attenuation pond for mitigating runoff from development of the Upper Mangaheka catchment. This device is located at a higher level than the upper reaches of the Te Otamanui Stream. Therefore, a diversion from Device 6 could occur under gravity. Such a diversion could provide positive effects on the Te Otamanui stream but could also reduce the size of Device 6. Device 6 is shown in Appendix C.
- Divert flood flows from Mangaheka Stream via the swale along west side of Koura Drive. As noted in Table 3, there is only 100mm difference between the 100 year flood level in Mangaheka Stream (Location 8) and the Te Otamanui Stream. This means that the duration and quantity of diverted flows would be dependent on the timing of flood hydrographs in the two catchments. More detailed modelling would be required to confirm feasibility.
- Divert flood flows from Mangaheka Stream around location 6, within the Mangaheka Stream. Diversion from this location, rather than a device may be able to have benefits in terms of reducing the size of other devices other than just device 6.
- Divert low flows from Mangaheka Stream. This would likely need to occur under gravity and not from a device as these will not be discharging flows when it is not raining. Other effects of a low-flow discharge would also need to be investigated further including minimum flow requirements for environmental purposes.

For this stage of the project, all of the above scenarios have not been investigated further. We have only investigated a diversion from Device 6. Only this scenario has been investigated as it was possible using a simplistic approach (refer section 15), whereas other scenarios will require more detailed modelling. However if benefits are seen via a diversion from Device 6, other types of diversions would likely also have benefits. The other scenarios could be investigated at a later stage.

10 Diversion from Device 6

To assess the reduction in storage volume required in Device 6 as a result of discharging flow to the Te Otamanui catchment via a weir, we have undertaken a basic flood routing calculation (spreadsheet based) using the following outputs from our 1D HEC-RAS model:

- Inflows to Device 6 from the contributing catchment
- Outflows through the simple culvert outlet structure located in the base of the pond. This was used to approximate a linear relationship between pond stage and outflow rate.
- The pond stage vs volume curve generated as an input to our model.

The spreadsheet developed was used to determine what flows would discharge over a simple weir structure) based on weir height and weir length. The spreadsheet then determined the reduction in required stored volume in the Device 6 pond based on changing the weir parameters.

Initially our spreadsheet model was used to determine the reduction on Device 6 volume using a target 250L/s weir discharge, as this was the additional capacity of the catchment, however this flowrate had little impact on the pond volume i.e this discharge would be of little benefit to Device 6. Instead a flowrate of 1m³/s was used. Whilst 1m³/s is higher than the additional capacity that the Te Otamanui catchment has, if the timing of the discharge was controlled, such that the discharge occurred after the peak of the Te Otamanui catchment, it is possible that the water levels in the wider catchment are not increased. This timing will need to be further investigated at a later stage, however we have determined that the time of concentration of the Te Otamanui catchment is roughly 4 hours.

Table 7 shows the pond size reduction based on discharging 1m³/s. To do this, the weir width was determined based on passing this flow over a weir of a nominated elevation. The weir width was varied to ensure a maximum of 1m³/s was discharged.

Table 7: Pond storage in relation to proposed weir parameters (1m³/s discharge)

Weir Elevation	Weir width (m)	Max pond depth (m RL)	Max pond volume (m³)	Reduction in volume (m³)	Reduction in volume (%)
No weir (current HEC-RASmodel)	(none)	31.20	35,800	N/A	N/A
31.0	42.1	31.11	34,409	1,391	4%
30.5	3.9	31.05	33,407	2,393	7%
30.0	1.6	31.02	32,852	2,948	9%
29.5	0.9	30.99	32,379	3,421	10%
29.0	0.6	30.92	31,390	4,410	12%
28.5	0.5	30.80	29,496	6,304	18%
28.0	0.5	30.58	26,115	9,685	27%

Table 6 shows that by discharging 1 m³/s of flow, a reasonable reduction in pond size could be achieved. It should be noted that the invert of Device 6 is at 28.0m. Therefore, the final line in Table 6 is for a discharge occurring throughout the storm. This arrangement (and some of the other lower weir elevations) may restrict the opportunities to delay a discharge until after the peak of the Te Otamanui catchment. By increasing the height of the weir, this means that the discharge would not start occurring until later in a storm event. This does however need further investigation, and more detailed modelling.

11 Conclusions

Table 8 below provides a summary of the findings of this investigation. The final column has been coloured green, where there is a potential benefit seen in supplementing Te Otamanui Flows with flows from the Mangaheka Catchment. Items coloured yellow need further investigation.

Table 8 Summary

	Comments	Fatal flaw or not?
Te Otamanui Stream Obstructions	There are a number of obstructions including buildings within 5m of the stream and culverts which may cause issues if flood levels were increased. These obstructions would need to be viewed during a site visit to confirm if this would be an issue or not.	Unclear until a further site visit is carried out.
Consented Activities	A number of consented activities in the catchment may cause issues if additional flows were discharged. These works would need to be viewed during a site visit to confirm if this would be an issue or not. Groundwater and surface water takes in the Mangaheka catchment may also be impacted.	Unclear until a further site visit and investigations (GW and SW takes) are carried out.
Flooding records	Flooding records indicate that diversions from the Te Otamanui catchment have occurred in the past. Since then, development may have occurred within the previous floodplain that may now be impacted if additional water was diverted from the Mangaheka catchment.	Unclear until a further site visit is carried out.
Existing Stream Capacity and Existing Flows	Our basic rational method calculations have identified that there is approximately 250L/s of capacity in the upper Te Otamanui catchment. This provides an opportunity to discharge flows from the Mangaheka Catchment	No
Device 6 size	Our basic calculations have shown that whilst discharging 250L/s is not likely to have an impact on the device 6 size, if more (1m^3/s) can be discharged by appropriately timing the discharge, there is likely to be a significant reduction in pond volume required.	No

Based on our above investigations and the above summary table, it is concluded that no fatal flaws have been found relating to supplementing flows in the Te Otamanui Catchment. There is however additional work that needs to be carried out to better confirm feasibility.

12 Recommendations

When preparing a scope of works for this project, we identified that a range of further tasks would likely need to be carried out if no fatal flaws were identified during the desktop study. The following were identified as the next set of tasks that should be undertaken:

Detailed Assessment

Task a: Site Walkover to confirm:

- Have any farmers/landowners constructed structures over stream that may be flooded?
- Are there any small culverts that may be under capacity if flows increased?
- Scope survey for additional modelling (see Task c)

Task b: Flow Analysis

- What flows could be diverted (low flows/mid flows/high flows? When and how much?
- Comparison of flows with stream capacity (refer section 8).

Task c: Modelling

- Updating the Mangaheka 1D model to determine the effect of the diversion on the Mangaheka catchment. This would involve a simple discharge arrangement for the diverted flows and would not include an assessment of effects on the Te Otamanui Lagoon catchment.
- Hydraulic/flood model of the Te Otamanui stream

A further assessment of effects on the Te Otamanui Lagoon/catchment will also likely be required. Refer to our 2016 VO for further details (Item's 9 and 10).

In addition to the above, based on our work carried out, we have also identified that the following investigations will also need to occur to further confirm feasibility.

- A site visit should also confirm:
  - if any of the buildings that are close to the Te Otamanui stream are habitable or if significant effects are likely if these are flooded due to increased flows
  - Any additional obstructions that were not seen on the aerial photos
- Effects of reduction in base flows in the Mangaheka catchment
- Will discharging flood flows from the Mangaheka catchment have any impact on base flows in the Te Otamanui catchment and the lagoon water levels? If so, there may be little benefit to the Te Otamanui catchment in discharging additional flows
- The cultural effects of mixing of waters from two different catchments needs to be investigated.
- Discharging low flows may have ecological effects on the Mangaheka catchment.
- Erosion assessment of the stream and its capacity to take the additional flows (this may require soils/geotech information).
- Assessment of effects on any existing groundwater and surface water takes in the Mangaheka catchment.

13 References

Beca, 2016, *Mangaheka 1D Modelling Report*, CH2M Beca Ltd, 8th December 2016.

WRC, 2011, *Significant Natural Areas of the Waikato Region – Lake Ecosystems*, Waikato Regional Council Technical report 2011/05, prepared by Wildland Consultants, April 2011.

Appendix A

Te Otamanui Stream Obstructions

Click here and
then click
‘insert picture’

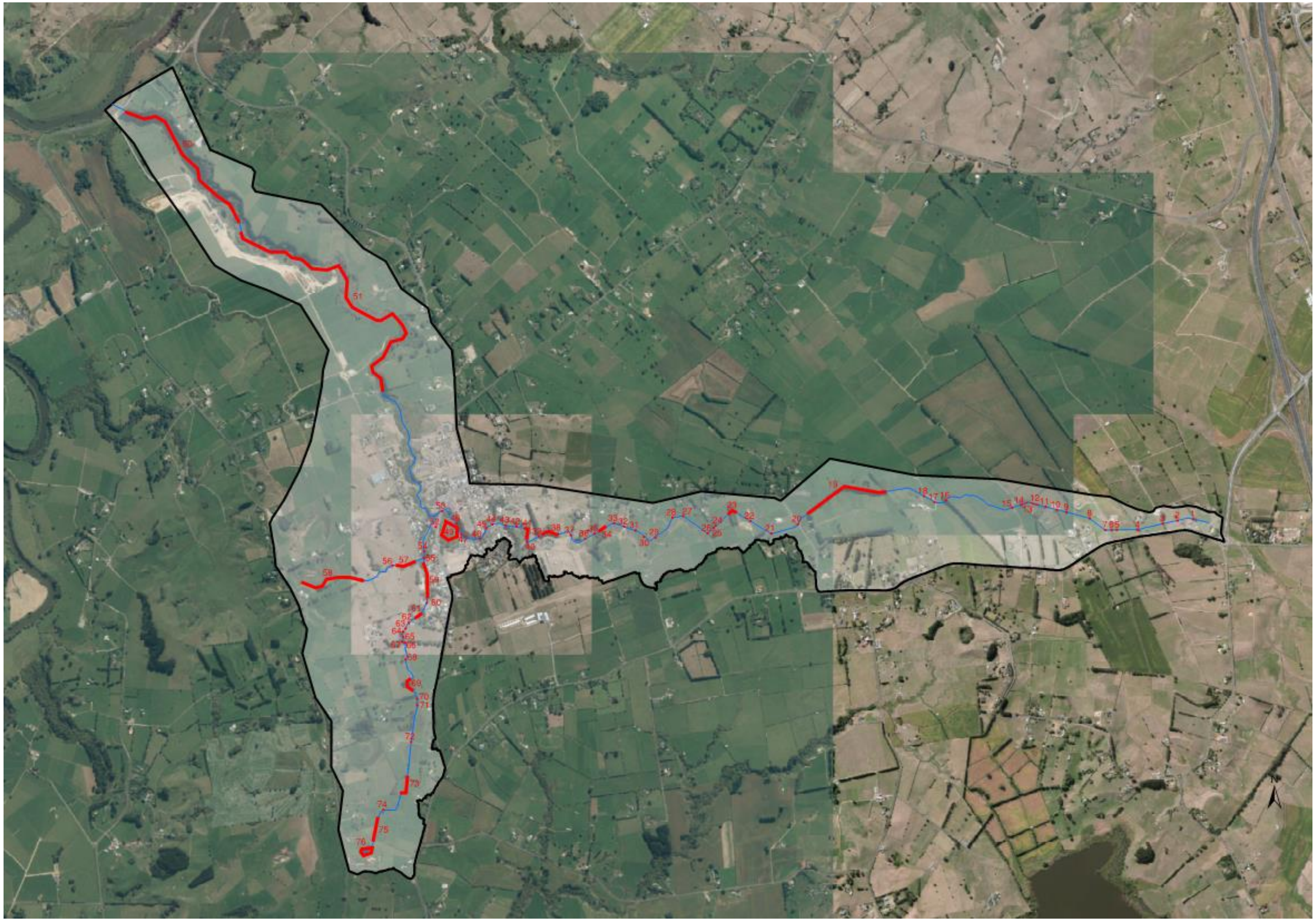
Te Otamanui Fatal Flaw exercise
Obstructions, culverts, buildings etc

ID	Obstruction T	Description	Comments
1	A	Gravel/seal driveway - bridge/culvert	
2	B	Grass covered bridge /culvert	
3	A	Gravel/seal driveway - bridge/culvert	
4	A	Gravel/seal driveway - bridge/culvert	
5	D	Pipe across stream	
6	A	Gravel/seal driveway - bridge/culvert	
7	A	Gravel/seal driveway - bridge/culvert	
8	D	Pipe across stream	unclear
9	A	Gravel/seal driveway - bridge/culvert	
10	E	Trees - unclear if stream blocked from aerial	
11	B	Grass covered bridge /culvert	
12	E	Trees - unclear if stream blocked from aerial	
13	F	Debris (e.g. logs) over stream	logs
14	B	Grass covered bridge /culvert	
15	A	Gravel/seal driveway - bridge/culvert	
16	E	Trees - unclear if stream blocked from aerial	
17	A	Gravel/seal driveway - bridge/culvert	
18	A	Gravel/seal driveway - bridge/culvert	
19	E	Trees - unclear if stream blocked from aerial	
20	G	Major road culvert/bridge	Te Kowhai Rd
21	A	Gravel/seal driveway - bridge/culvert	
22	B	Grass covered bridge /culvert	
23	E	Trees - unclear if stream blocked from aerial	
24	E	Trees - unclear if stream blocked from aerial	
25	B	Grass covered bridge /culvert	
26	E	Trees - unclear if stream blocked from aerial	
27	H	Fence across stream	unclear
28	I	Building within 5m of stream	shed
29	A	Gravel/seal driveway - bridge/culvert	
30	F	Debris (e.g. logs) over stream	unclear
31	H	Fence across stream	unclear
32	A	Gravel/seal driveway - bridge/culvert	32 + 33 one culvert combined
33	A	Gravel/seal driveway - bridge/culvert	32 + 33 one culvert combined
34	J	Stream opens out into pond	
35	C	Other bridge/culvert	unclear
36	B	Grass covered bridge /culvert	small grass bridge
37	B	Grass covered bridge /culvert	
38	E	Trees - unclear if stream blocked from aerial	
39	A	Gravel/seal driveway - bridge/culvert	
40	J	Stream opens out into pond	
41	K	Wetland area with vegetation	also trees - unclear if stream blocked
42	C	Other bridge/culvert	stream emerges from culvert
43	F	Debris (e.g. logs) over stream	logs?
44	C	Other bridge/culvert	small bridge
45	E	Trees - unclear if stream blocked from aerial	
46	C	Other bridge/culvert	small bridge
47	E	Trees - unclear if stream blocked from aeria	one bridge, rest of area unclear

Legend

Obstruction T	Description	Number of obstructions Colu
A	Gravel/seal driveway - bridge/culvert	21
B	Grass covered bridge /culvert	9
C	Other bridge/culvert	6
D	Pipe across stream	2
E	Trees - unclear if stream blocked from aeria	18
F	Debris (e.g. logs) over stream	3
G	Major road culvert/bridge	3
H	Fence across stream	2
I	Building within 5m of stream	2
J	Stream opens out into pond	6
K	Wetland area with vegetation	4

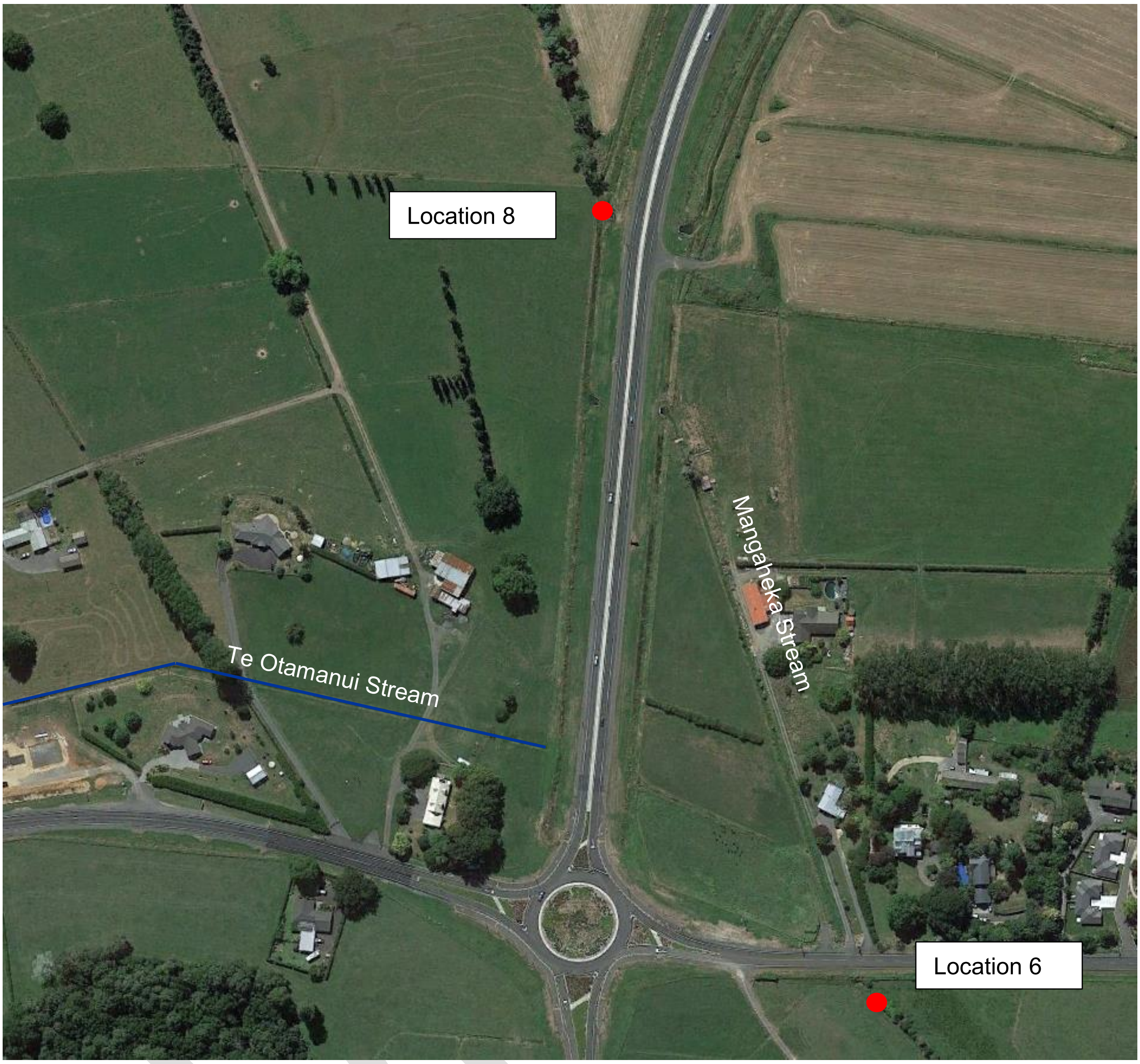
48	J	Stream opens out into pond	
49	K	Wetland area with vegetation	
50	J	Stream opens out into pond	
51	K	Wetland area with vegetation	unclear if stream blocked
52	G	Major road culvert/bridge	Bedford Rd
53	G	Major road culvert/bridge	Horotiu Rd
54	I	Building within 5m of stream	shed + water tank. Tank may have been removed
55	E	Trees - unclear if stream blocked from aerial	
56	A	Gravel/seal driveway - bridge/culvert	
57	E	Trees - unclear if stream blocked from aerial	
58	E	Trees - unclear if stream blocked from aerial	
59	E	Trees - unclear if stream blocked from aerial	
60	A	Gravel/seal driveway - bridge/culvert	
61	J	Stream opens out into pond	
62	A	Gravel/seal driveway - bridge/culvert	
63	E	Trees - unclear if stream blocked from aerial	
64	C	Other bridge/culvert	small bridge
65	A	Gravel/seal driveway - bridge/culvert	
66	A	Gravel/seal driveway - bridge/culvert	
67	E	Trees - unclear if stream blocked from aerial	
68	B	Grass covered bridge /culvert	
69	E	Trees - unclear if stream blocked from aerial	
70	A	Gravel/seal driveway - bridge/culvert	
71	C	Other bridge/culvert	unclear
72	A	Gravel/seal driveway - bridge/culvert	
73	E	Trees - unclear if stream blocked from aerial	
74	B	Grass covered bridge /culvert	
75	K	Wetland area with vegetation	unclear if any blockages
76	J	Stream opens out into pond	



Appendix B

1D Modelling Reporting Locations

Click here and then click 'insert picture'


Location 8
Te Otamanui Stream
Mangaheka Stream
Location 6

Appendix C

Device 6 Location

Click here and then click 'insert picture'

Beca

MANGAHEKA MAXIMUM PROBABLE DEVELOPMENT CATCHMENT BOUNDARIES CLOSE UP

FOR INFORMATION ONLY

A3

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