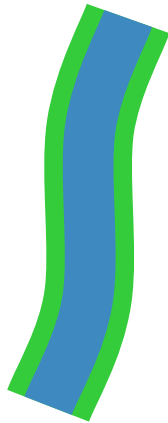


**Benmore Crescent
Proposed Industrial Park
Flood Assessment**



Report prepared for Rosco Industrial
by

River Edge Consulting Limited

June 2022

Version: Final v2

Prepared for Rosco Industrial

Report prepared by: Philip Wallace

Date: 13 June 2022

Table of Contents

1	Introduction.....	1
2	Hutt River flood hazard	3
3	Existing site environment	5
3.1	Culvert 1	5
3.2	Culvert 2	7
3.4	Culvert 3	7
3.5	Culvert 4	7
4	Benmore Crescent site model	9
5	Flow Scenario	10
6	Development Scenarios Modelled	11
6.1	Scenario 1: Existing situation.....	11
6.2	Scenario 2: T+T platform earthworks and new culverts	11
6.2.1	Earthworks platform and stream corridor	11
6.2.2	Culvert upgrades	15
7	Results and discussion	18

Appendix A Initial Flood Assessment

1 Introduction

River Edge Consulting has been engaged to carry out a flood assessment of a site at 30 Benmore Crescent, Manor Park (Lower Hutt) and of the impacts of a proposed industrial park development on the site.

The site lies on the right bank of the Hutt River, between the river and SH2 (Figure 1-1). The site is elevated above the river, and the railway also lies between the river and the site. A small stream, Dry Creek¹, runs through the site and discharges to the Hutt River. The catchment of Dry Creek is around 350 ha and drains the hills behind the Dry Creek entrance to Belmont Regional Park.

An initial report on the flood assessment was presented in the form of a letter to the client in late 2021. That letter is reproduced in Appendix A.

Since that time, a multi-disciplinary team² has been working on a revised site layout proposal, in order that applications for a Private District Plan Change and for resource consents can be lodged in mid-2022. As a result of that work, Tonkin and Taylor (T+T) has prepared a fill platform design, with a wider stream corridor running through it. The flood assessment has now incorporated this design, along with designs for replacement culverts to give access across the stream, and the findings are presented in this current report.

¹ Referred to as Benmore Stream in the earlier letter, based on other sources which suggested that Dry Creek was a smaller stream to the north. However, it is understood that the stream through the site is indeed Dry Creek.

² Compromising of specialists from Tonkin and Taylor, Harris Architects, Boffa Miskell, Stantec, Vecta and River Edge Consulting



Figure 1-1 Site location

2 Hutt River flood hazard

On-line flood maps³ show the site as being subject to a 0.23% AEP⁴ (440-year ARI) Hutt River flood. However, those maps are based on an old model (c2000) of the Hutt River. Subsequent Hutt River modelling work by River Edge Consulting and DHI Water and Environment (DHI) (c2018) indicated that the site would not be subject to flooding from the Hutt River in such an event (Figure 2-1), (also as reported in the letter of 21 November). More recent work by Tonkin and Taylor carried out for GWRC confirms this (Figure 2-2), with results for the two models being very similar in the area of interest. (Note that flood depths within the Hutt River main channel are not shown, throughout this report.)



Figure 2-1 Predicted flood depths, Hutt River 0.23% AEP scenario (440-year return period, 2300 m3/s) from previous modelling

³ <https://data-gwrc.opendata.arcgis.com/datasets/gwrc-flood-hazards-areas-for-the-wellington-region/explore>

⁴ Annual Exceedance Probability. The AEP is the inverse of the return period or average recurrence interval (ARI), so 0.23% AEP has the same meaning as a 440-year event, and a 1% AEP is also referred to as a 100-year event.

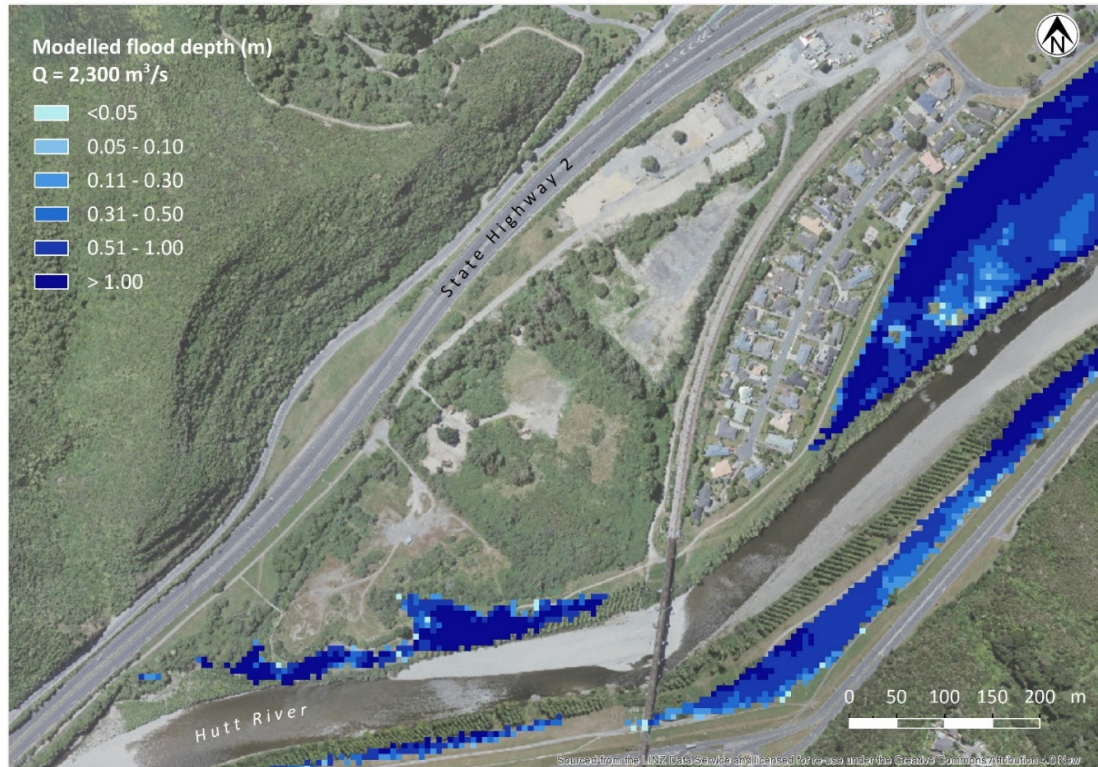


Figure 2-2 Predicted flood depths, Hutt River 0.23% AEP scenario (440-year return period, 2300 m³/s) from recent modelling for GWRC by T+T

3 Existing site environment

Dry Creek is an ill-defined stream for much of its path through the site, from Benmore Crescent to the lower footbridge on the Hutt River Trail. Willows and overgrown vegetation dominate the riparian margins, as well as part of the stream bed. At time of a site visit in July 2021, relatively fresh gravel deposits were present, from the Benmore Crescent culvert ("culvert 1") at least as far downstream as culvert 2 (Figure 3-1).

In the lower reaches of the stream, it becomes incised within steep banks before it reaches the Hutt River.

Currently, there are four sets of culverts in the Dry Creek channel within the site boundaries, at locations 1 to 4 in Figure 3-1. Details of each are given below.

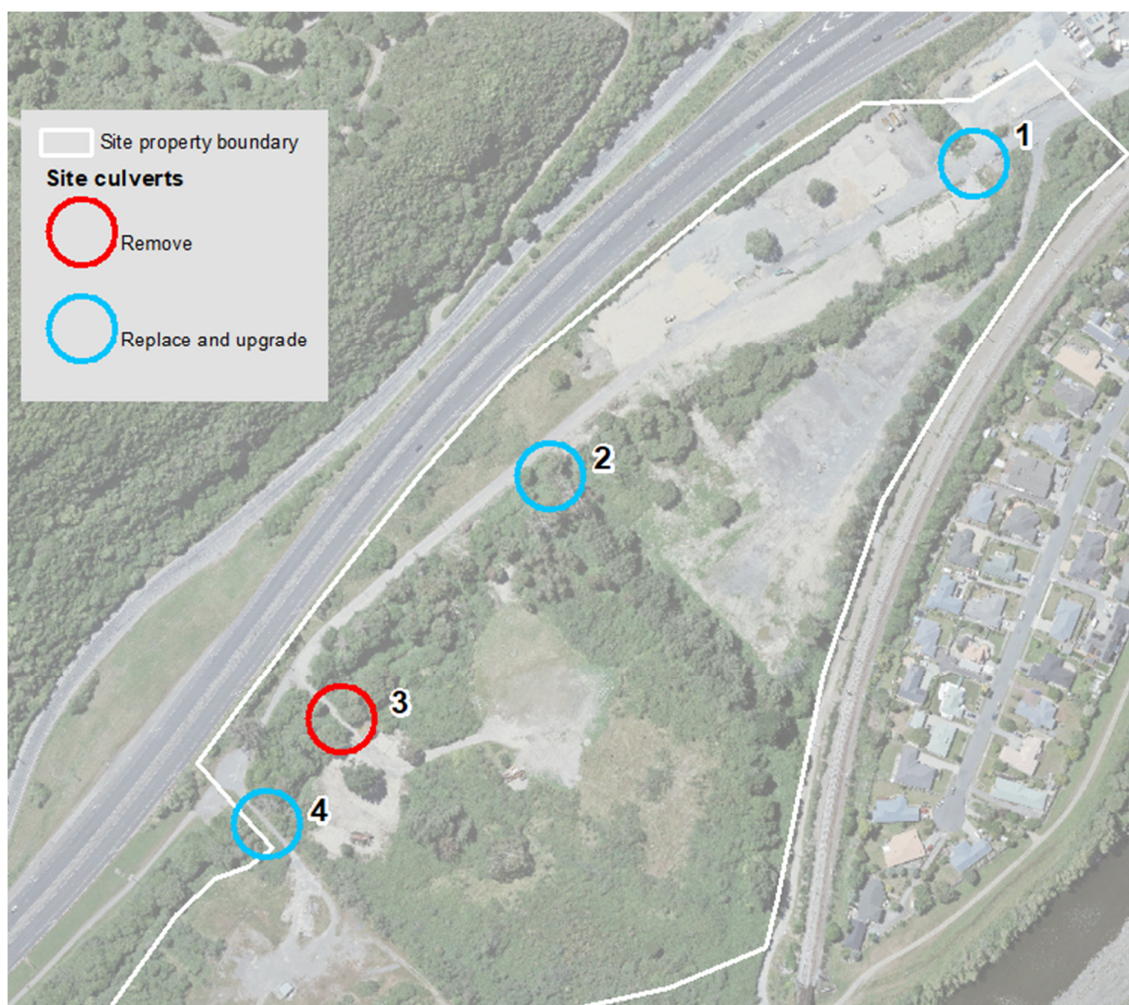


Figure 3-1 Culvert locations (existing and proposed)

3.1 Culvert 1

Culvert 1, under Benmore Crescent at the northern part of the site, is a concrete box culvert, 2.8 m wide. The inlet opening has been significantly reduced by gravel build-up (Figure 3-2) and as of November 2021, the opening was approximately 0.6 m high. For comparison, the downstream

opening at the time was between 1.1 m and 1.6 m high (Figure 3-3). The capacity of the culvert is therefore limited.

The culvert is 14 m long, which suggests that it will be difficult to mechanically clear the entire length of the culvert of excess gravel. A more appropriate strategy would be to regularly (and after flood events) remove gravel from the upstream entrance.

The culvert will be replaced during the site development, in order to reduce the flow constriction it causes.



Figure 3-2 Inlet to culvert 1



Figure 3-3 Outlet of culvert 1

3.2 Culvert 2

Culvert 2 is 1.8 m in diameter and 2.5 m in length. It will be replaced during the site development.

3.4 Culvert 3

Culvert 3 is 1.35 m in diameter and approximately 5 m long. Figure 3-4 show the culvert inlet. The culvert will be removed during the site development and is thus only included in the model of the existing situation.



Figure 3-4 Culvert 3 inlet

3.5 Culvert 4

Twin culverts currently exist at location 4, each of around 1.8 m in diameter and approximately 15 m long. Flow exiting the culverts appears sluggish (Figure 3-5), presumably due to upstream obstructions. They will be replaced during the site development.



Figure 3-5 Culvert 4 outlet

4 Benmore Crescent site model

The initial model, using MIKE FLOOD software, for the Benmore Crescent site flood assessment has been developed from the DHI model, cropped and refined as outlined in the letter of 21 November. The final model adopted is a variation on this, with the Dry Creek channel and floodplain now both represented in 2D within the model.

The final model also makes use of recently published LiDAR data, obtained from an aerial survey in 2021.

5 Flow Scenario

For the site flood assessment, the flood risk from Dry Creek and from the Hutt River have been combined into a single scenario. Hydrological assumptions were outlined in the letter of 21 November 2021, but in summary the flow scenario assumed is a 1% AEP flow in the Dry Creek, with a climate change allowance, with a concurrent 0.23% AEP (440-year ARI) Hutt River flood.

The design flow for the 1% AEP Dry Creek flood event has been assessed at 30 m³/s, as discussed in the previous letter. However, results indicate that only a portion of this passes under SH2 and enters the development site (as illustrated in the figures in section 7 of this report).

6 Development Scenarios Modelled

6.1 Scenario 1: Existing situation

The existing situation model is based on data obtained from

- Spencer Holmes surveys of the site, stream and culverts, carried out in October-November 2021
- 2021 LiDAR of Hutt City.

6.2 Scenario 2: T+T platform earthworks and new culverts

6.2.1 Earthworks platform and stream corridor

A draft concept plan for the site was prepared by Harris Architects, as shown in Figure 6-1. Based on this plan, preliminary results from the flood assessment modelling and feedback from other members of the multi-disciplinary team, T+T provided a conceptual earthworks platform, involving cut and fill over the site. A schematic of the platform is shown in Figure 6-2. All elevations are given in Wellington 1953 Vertical Datum.

A stream corridor of approximately 24 m top width, with 2:1 batters⁵, has been incorporated within the conceptual earthworks platform. The base of the stream corridor is 10 m wide. The existing low flow channel, as surveyed by Spencer Holmes in October 2021, is typically only around 2 – 4 m wide however (Figure 6-3). The low flow channel of the final proposal would be expected to meander within that 10 m bottom width of the stream corridor.

For modelling purposes, bed levels within base of the proposed stream corridor have generally been left as for the existing case, other than to remove high banks within the corridor and minor regrading at new culverts. Figure 6-4 shows the extent of the assumed cuts within the corridor (along with the cut and fill over the development platform in the northern half of the site). These cuts are outside the low flow channel, while in the lower half of the site, no cuts within the corridor are assumed.

⁵ Batter slopes expressed as horizontal:vertical ratio

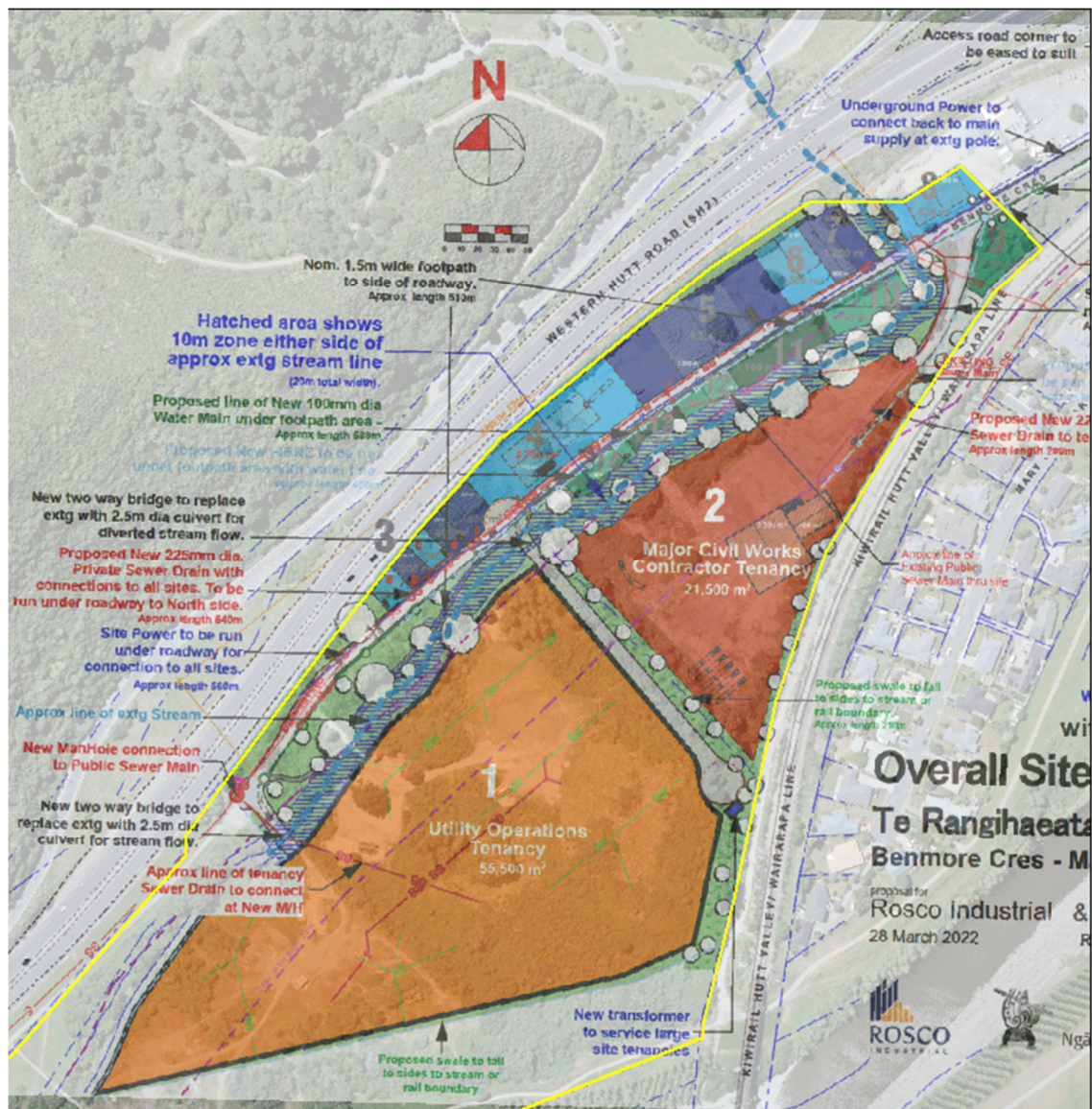


Figure 6-1 Concept plan of site development

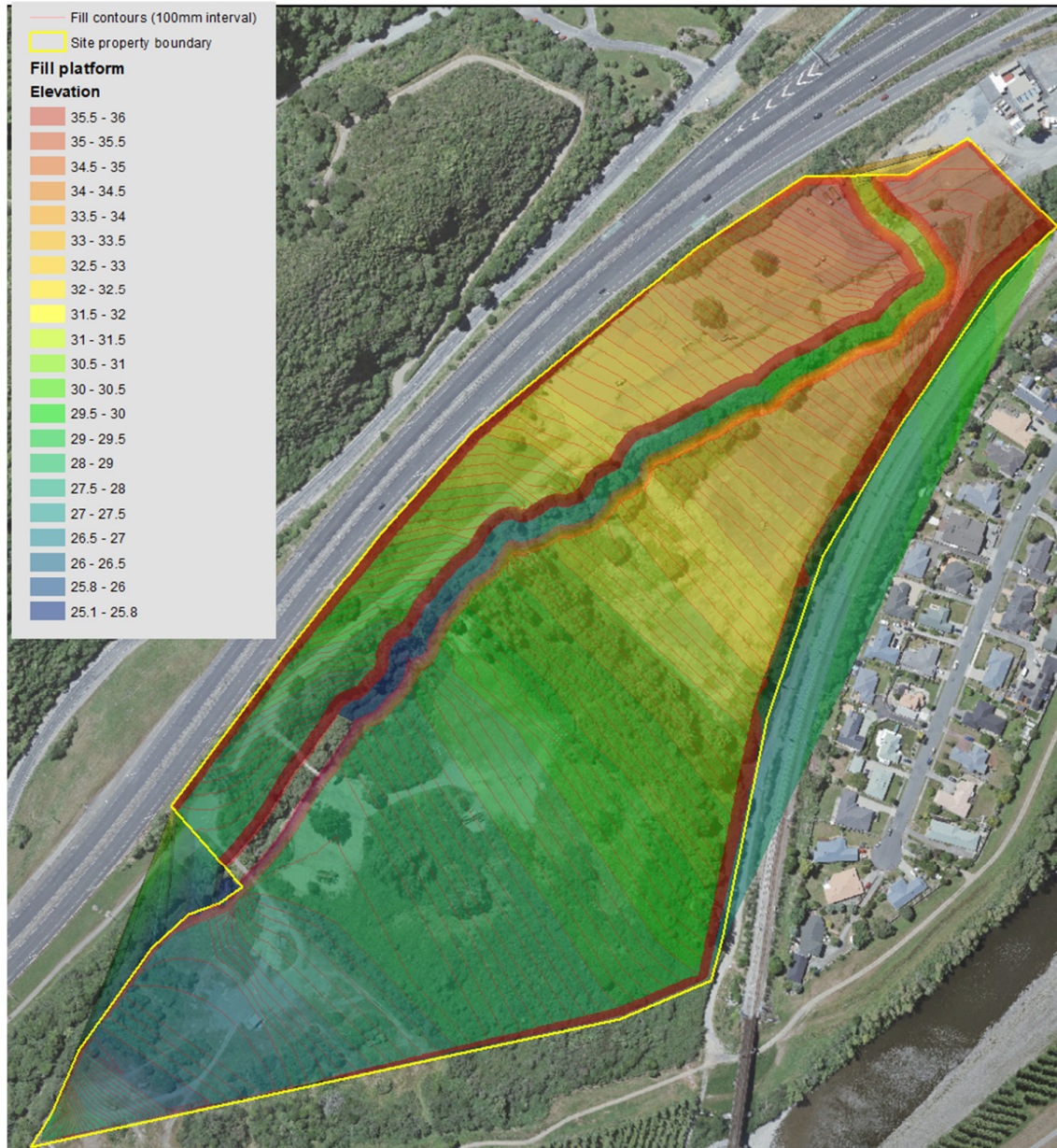


Figure 6-2 Schematic of proposed platform, as supplied by T+T

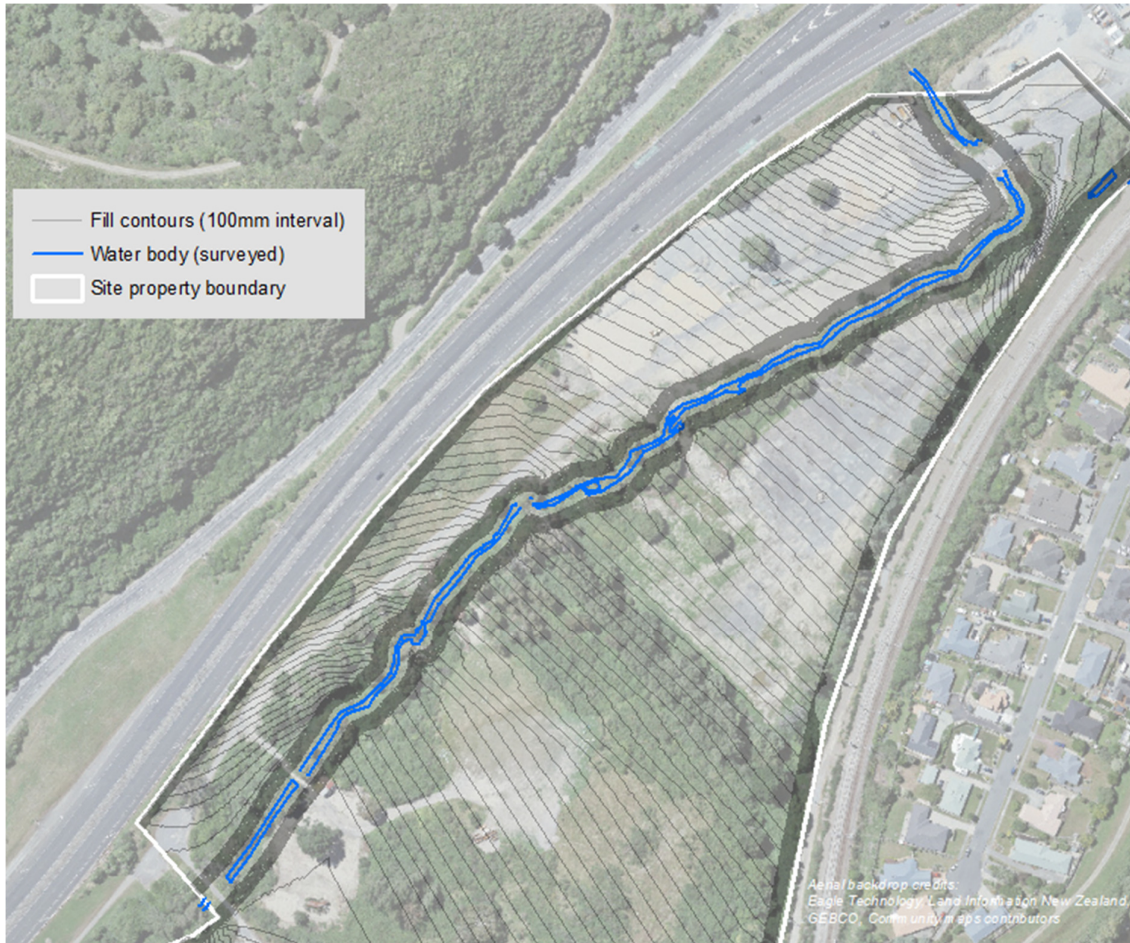


Figure 6-3 Fill platform contours, proposed stream corridor and existing low flow channel

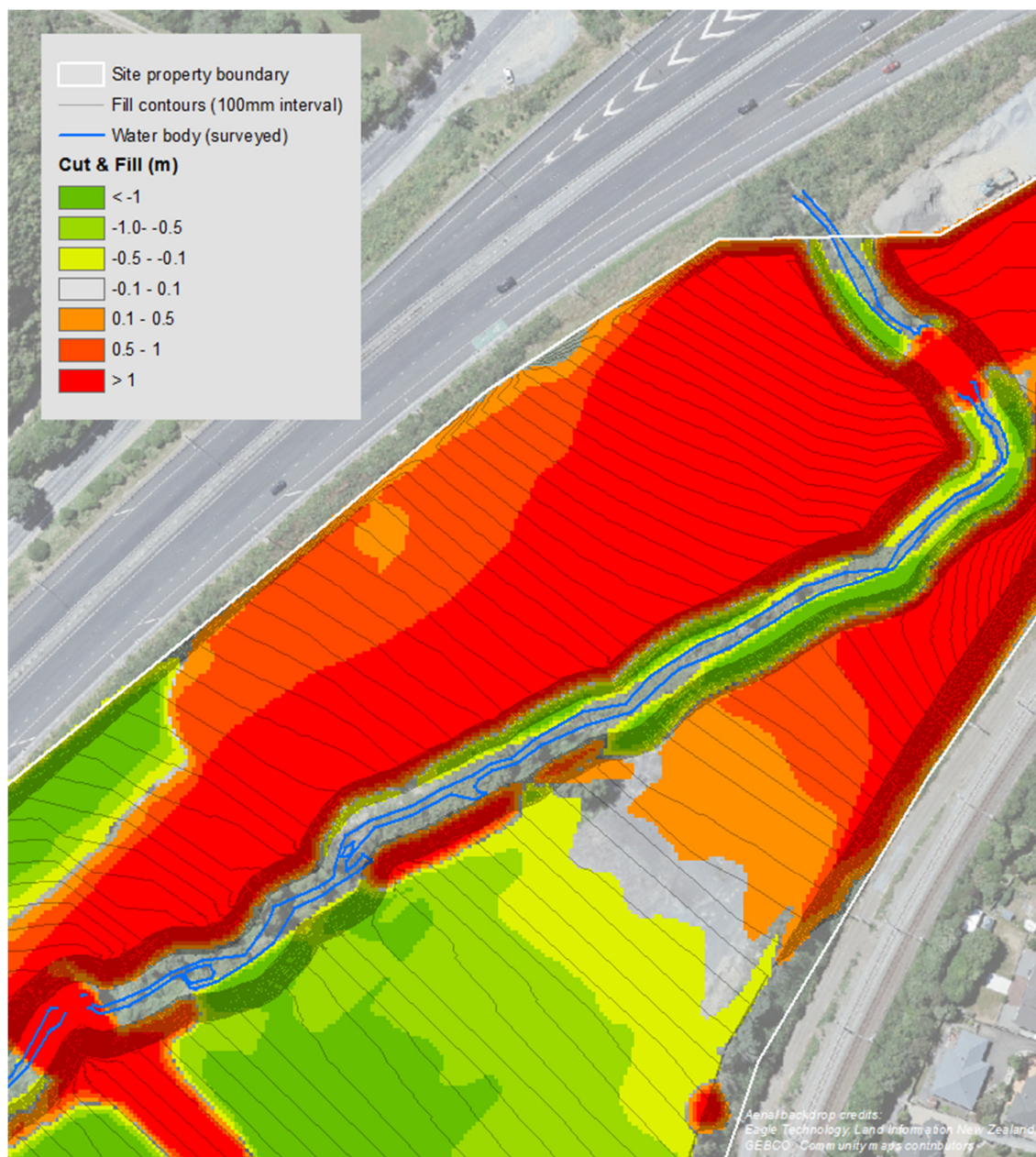


Figure 6-4 Cut (green) and fill (red) of development platform and within stream corridor

6.2.2 Culvert upgrades

Replacement culverts are proposed for this development scenario, at locations 1, 2 and 4, while culvert 3 would be removed. Several iterations of culvert sizes have been assessed, as flood levels within the constrained corridor proposed have proven to be strongly affected by the culvert crossings. Box culverts are assumed for all replacements, rather than circular culverts, providing additional flow area for the same soffit level.

Initial simulations assumed that the Benmore Crescent culvert (culvert 1) could be retained. However, the combination of the constrained stream corridor and the restricted existing opening of the culvert required higher fill platform levels and led to off-site impacts that would need to be

mitigated. Even if a larger entrance opening could be made for the existing culvert, that would likely be only short-lived, given the general gradient of the stream bed in the location.

Fish pass guidelines⁶ recommend that new culverts should be either open bottom or embedded by 25-50% of the culvert height. The final model simulations have assumed either 2 m or 2.5 m high box culverts, embedded by 0.5 m. In addition, the guidelines recommend that the width of new culverts be 1.3 x bankfull width. Twin 2.5m width culverts have been assumed for the final simulation; given that the surveyed width of the stream is typically 2-4 m, this latter criterion would generally be met.

Roading standards will likely require a crossing top width (parallel to the flow direction) of around 10 m, with an additional 1 m either side to accommodate barriers, plus upstream and downstream batters of 3:1. The crossing will also need to be more or less level with the adjacent platform so as to allow easy heavy vehicle access.

Table 6-1 provides detailed assumptions for each of the culverts for this development scenario. All levels are given in Wellington 1953 Vertical Datum. The culvert invert levels indicated have been designed to fit in with the general gradient of the stream bed (see Figure 7-6).

Note that the current design is based on LiDAR data for the stream channel downstream of culvert 4, with survey data only extending to immediately downstream of the existing culvert 4. The proposed invert levels, and possibly the box culvert size, of the replacement culvert 4 could be refined with additional survey data downstream.

Note also that the access crest level assumes 0.5 m freeboard above the design flood level and is lower than the conceptual fill platform (refer section 7 of this report). The cover and length are derived from the access crest level.

Culvert	Status	Length	Modelled/representative size (width x height)	Invert level		Access crest level	Cover (approx.)	Upstream flood level (design event)
				upstream	downstream			
1	replace/upgrade	19.5	twin 2.5 x 1.5m	30.9	30.4	33.6	1.05	33.1
2	replace/upgrade	19.5	twin 2.5 x 1.5m	27.1	26.6	29.8	1.05	29.3
3	remove							
4	replace/upgrade	24.6	twin 2.5 x 2m	24.55	24.4	28.1	1.4	27.6

Table 6-1 Culvert upgrades

Figure 6-5 shows the indicative size and location of the replacement culverts 1, 2 and 4, as well as the location of culvert 3 to be removed. Note that the batters of the stream corridor at location 2 may need some local refinement to provide a better alignment for the upgraded culvert. Some minor bed regrading either side of the replacement culverts will likely be required, as well as removal of the crossing at culvert 3.

Replacement culverts will reduce the current problem of blockage by gravel build-up, particularly at culvert 1. Nonetheless, regular inspection of the culverts is recommended.

⁶ NIWA (2018); New Zealand Fish Passage Guidelines. NIWA Client Report 2018019HN

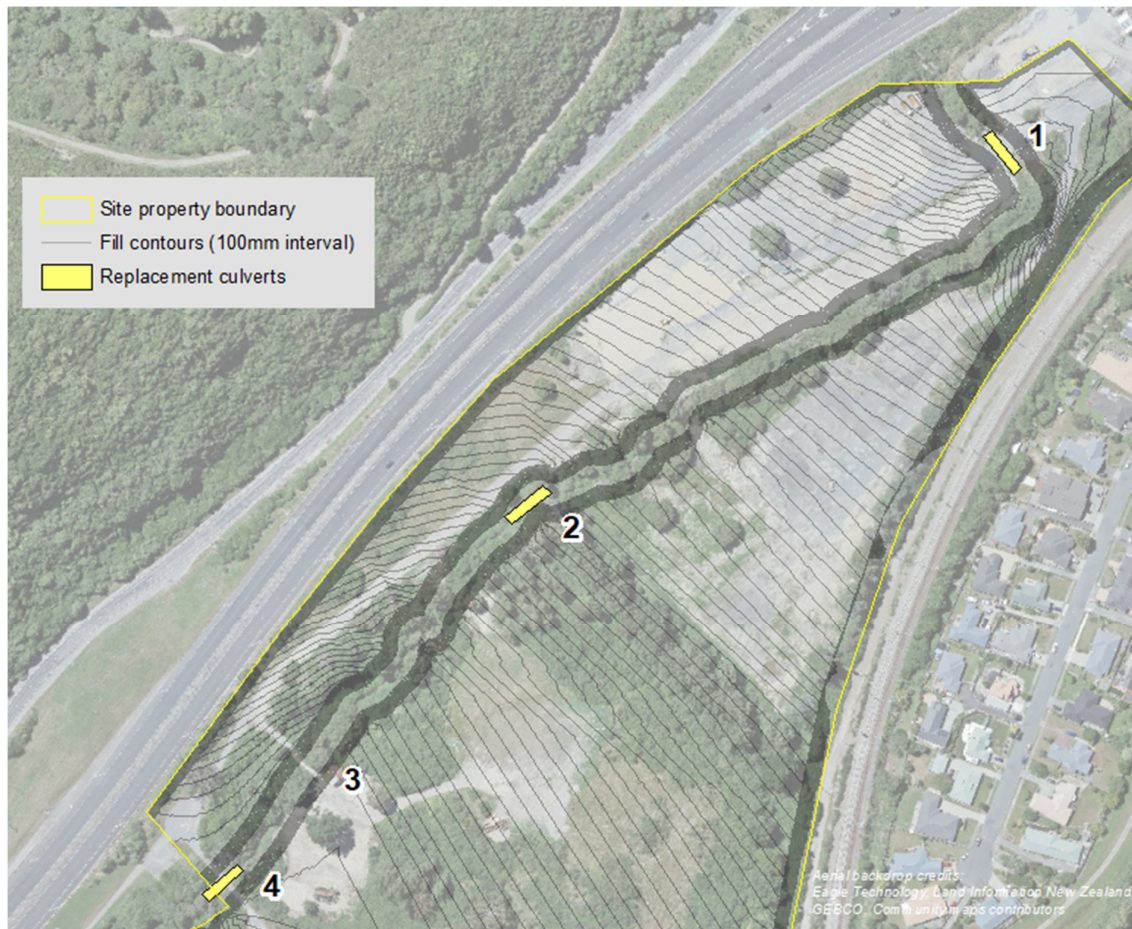


Figure 6-5 Culvert replacement and upgrades

7 Results and discussion

Key results are presented below. These include flood depth maps for the design flow scenario, and maps of the impact of the development on peak flood levels.

Figure 7-1 shows the flood depths for the existing situation. Of the design inflow at the upstream end of the model (30 m³/s), only around half of this passes under SH2, with the remainder travelling down along Hebden Crescent and out of the area of interest. This is also the case with the development scenarios modelled.

Flood depths for the development scenario are shown in Figure 7-2. Floodwaters are contained within the wider stream corridor within the site.

Figure 7-3 shows the impact of the proposed development platform on flood levels. With the exception of increases (of less than 300 mm) in the incised stream channel downstream of culvert 4 (Figure 7-4) which would pose no additional risk to people or assets, all increases in depth are contained within the site. Floodwaters are cut off along the KiwiRail access track alongside the railway, hence a small decrease in depth along the track is shown in Figure 7-3.

Results for the design scenario have then had freeboard added. NZS 4404 specifies a minimum freeboard of 0.3 m for commercial or industrial buildings, but higher levels are suggested here, to provide greater protection for any high value assets. GWRC uses 0.9 m freeboard for Hutt River design levels, so that has been added to the Hutt River levels in this current study. A lesser amount, 0.5 m, has been applied to the Dry Creek flood levels, in recognition that this is a much smaller stream.

With freeboard added, the platform as modelled would be subject to some minor overflows from the stream channel downstream of culvert 4 (Figure 7-5). However, this result is subject to a likely conservative assumed stream bed downstream, being based on LiDAR (limited due to vegetation cover) in the absence of survey data. In any case, the overflow could be readily addressed by a slight increase of 200 – 300 mm in the platform level along the platform edge (or a small bund).

Further upstream, results show that the conceptual fill platform referred to in 6.2.1 need not be as high as initially proposed, after increasing the replacement culvert sizes. Figure 7-6 and Table 7-1 present a longitudinal profile of flood levels and the original platform levels down the stream corridor. (Figure 7-7 shows the longitudinal distances; zero chainage is at the upstream end of the Hebden Crescent culvert.) As can be seen, the platform levels could be reduced by over a metre over much of the site whilst still providing the desired freeboard (notwithstanding other considerations in setting the platform levels).

Final design results will be provided to T+T in shape file format, so that the development platform can be revised.

During subsequent detailed design stages, some additional survey downstream of culvert 4 is recommended. Current design takes levels in that area from LiDAR data and the actual stream bed may not be well-represented.

At detailed design stages, the economics of bridge options spanning the stream rather than culverts, allowing greater waterway areas at the crossings and hence lower flood levels (and, potentially lowered platform levels) could also be considered.

However, with the proposed stream corridor and the culvert replacements outlined in this study, it is shown that the design flood can be accommodated, protecting future development over the site whilst causing no adverse effects off-site.

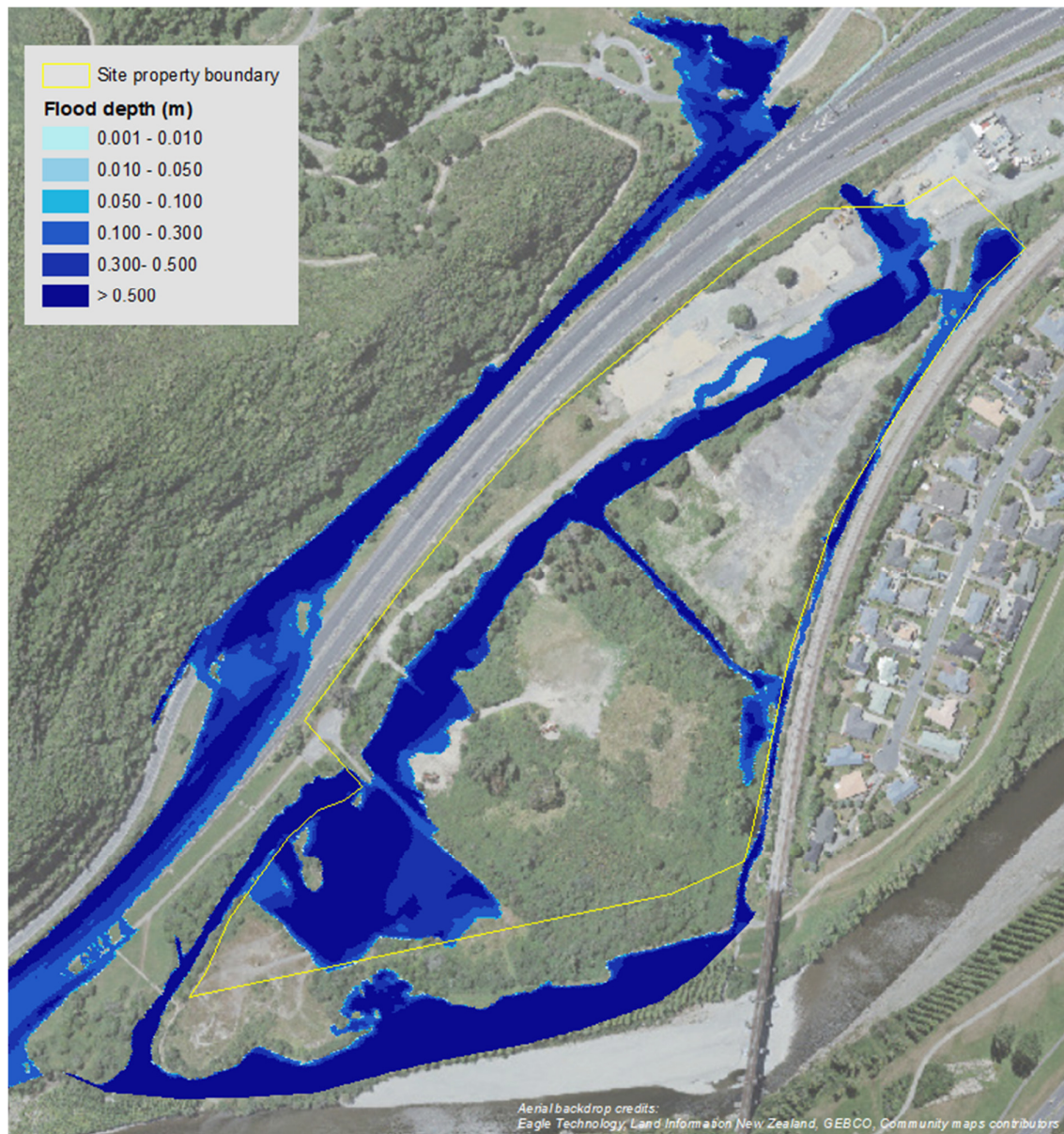


Figure 7-1 Predicted flood depths, existing situation (scenario 1)

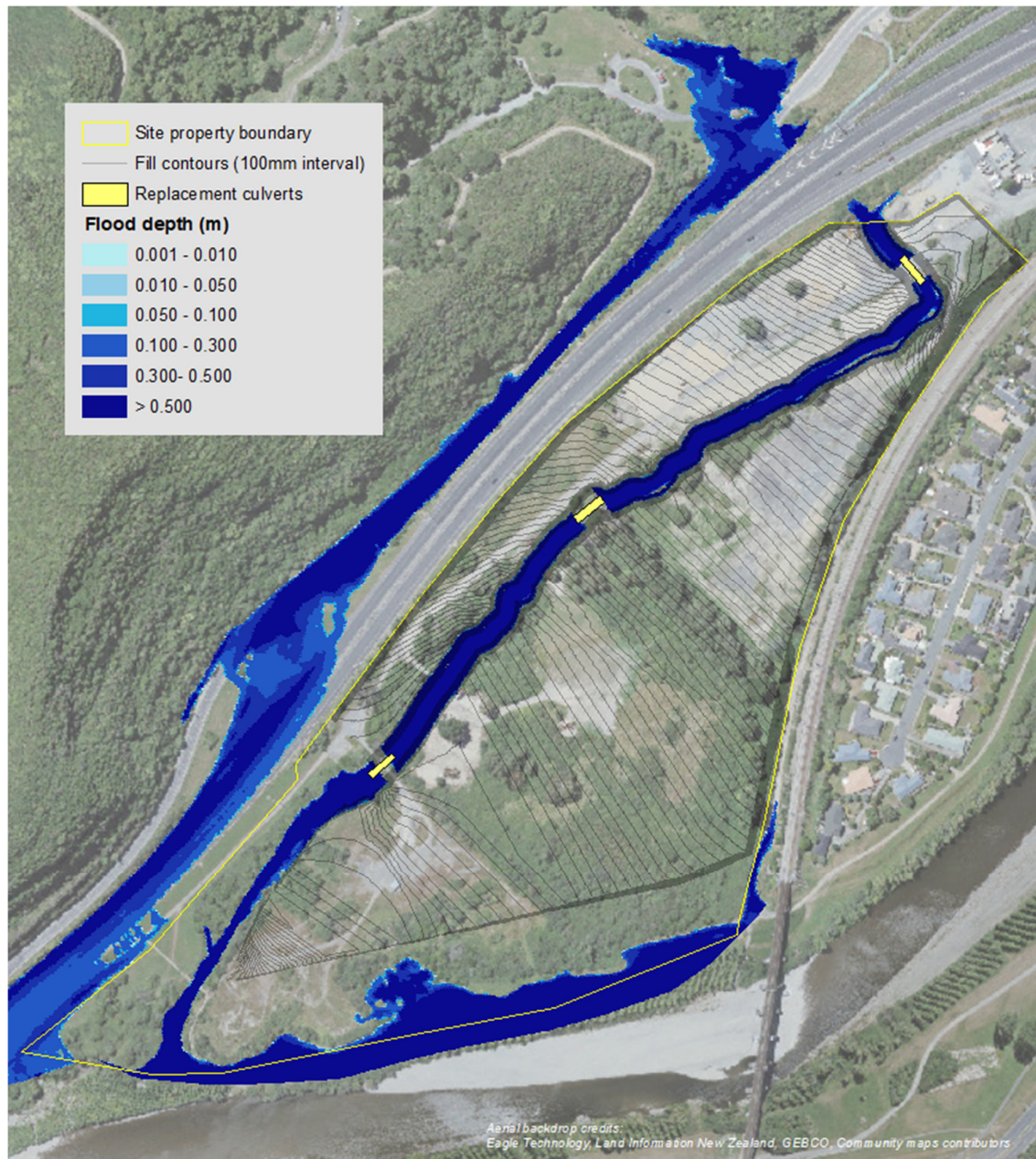


Figure 7-2 Predicted flood depths, developed situation

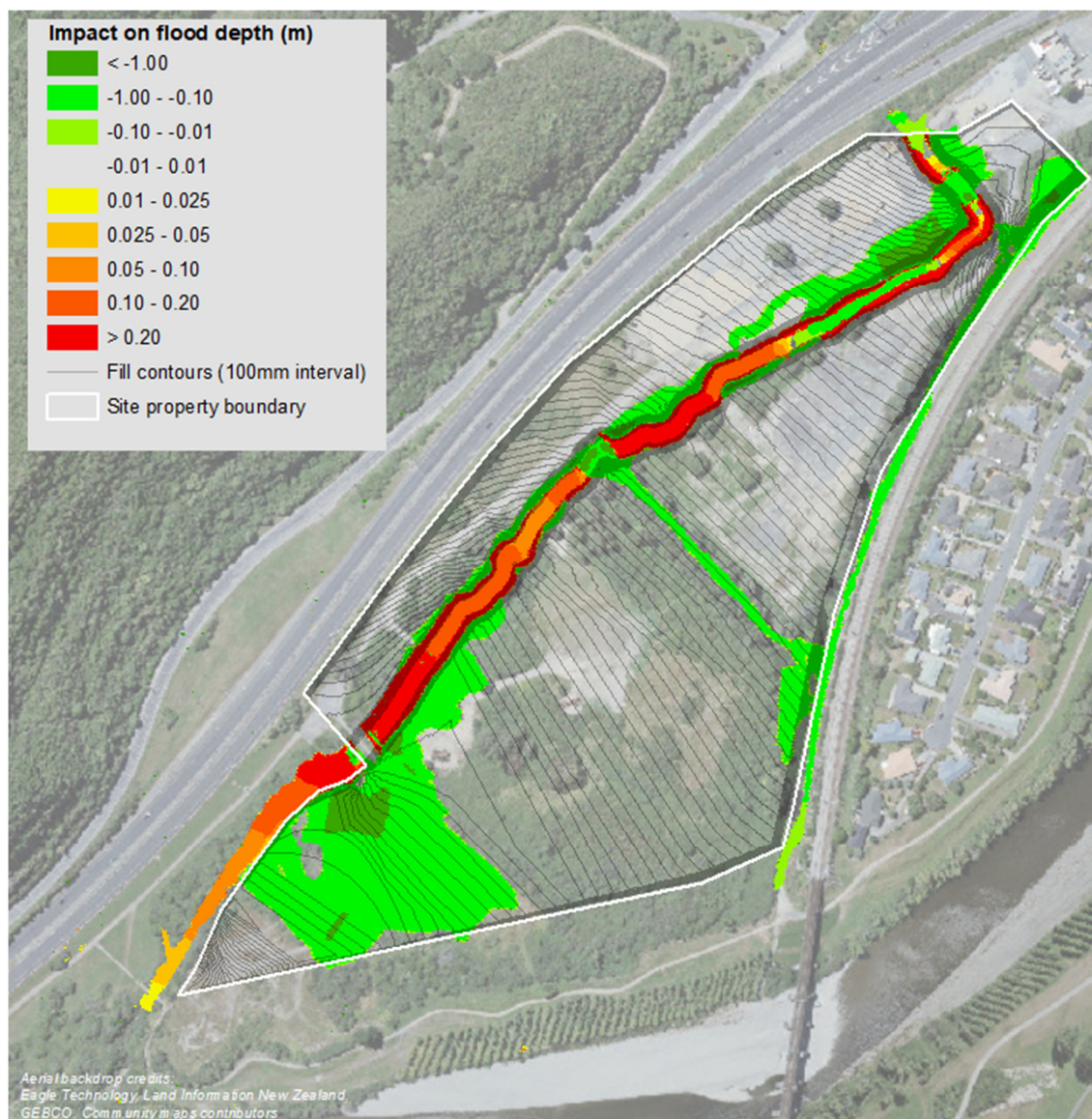


Figure 7-3 Impact of proposed development on peak flood depths

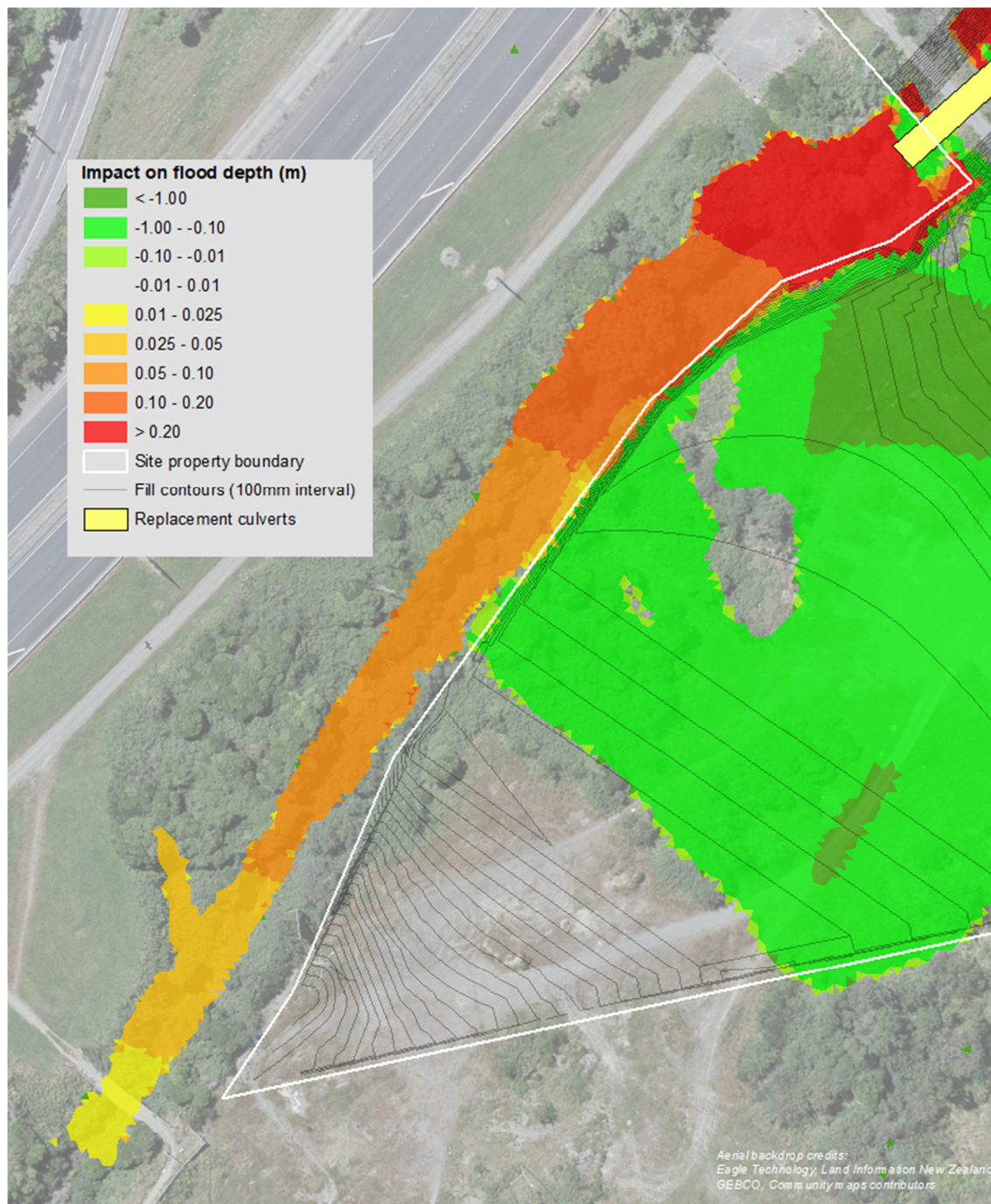


Figure 7-4 Impact of proposed development on peak flood depths downstream of culvert 4

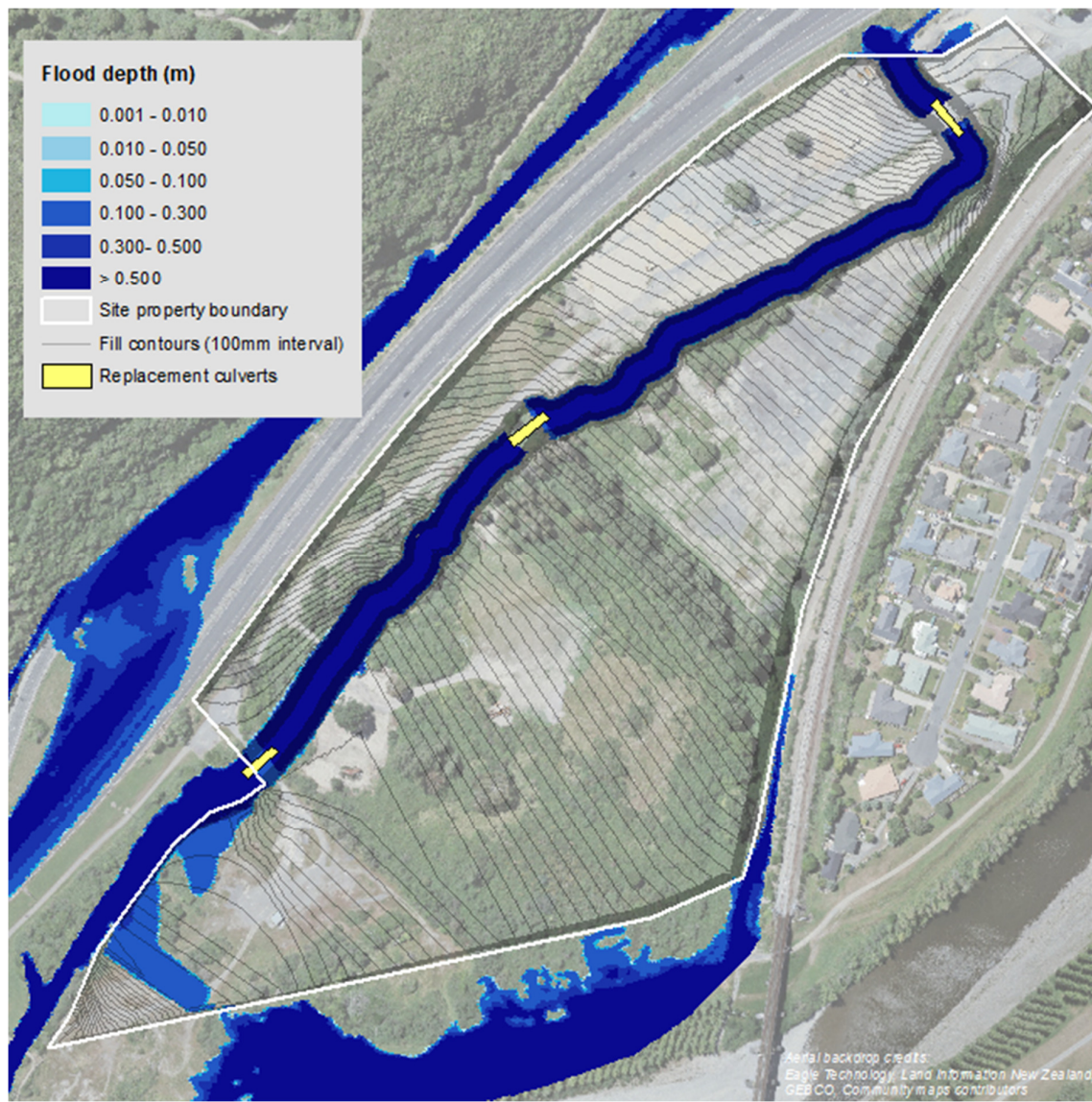


Figure 7-5 Predicted flood depths, developed situation with freeboard allowance

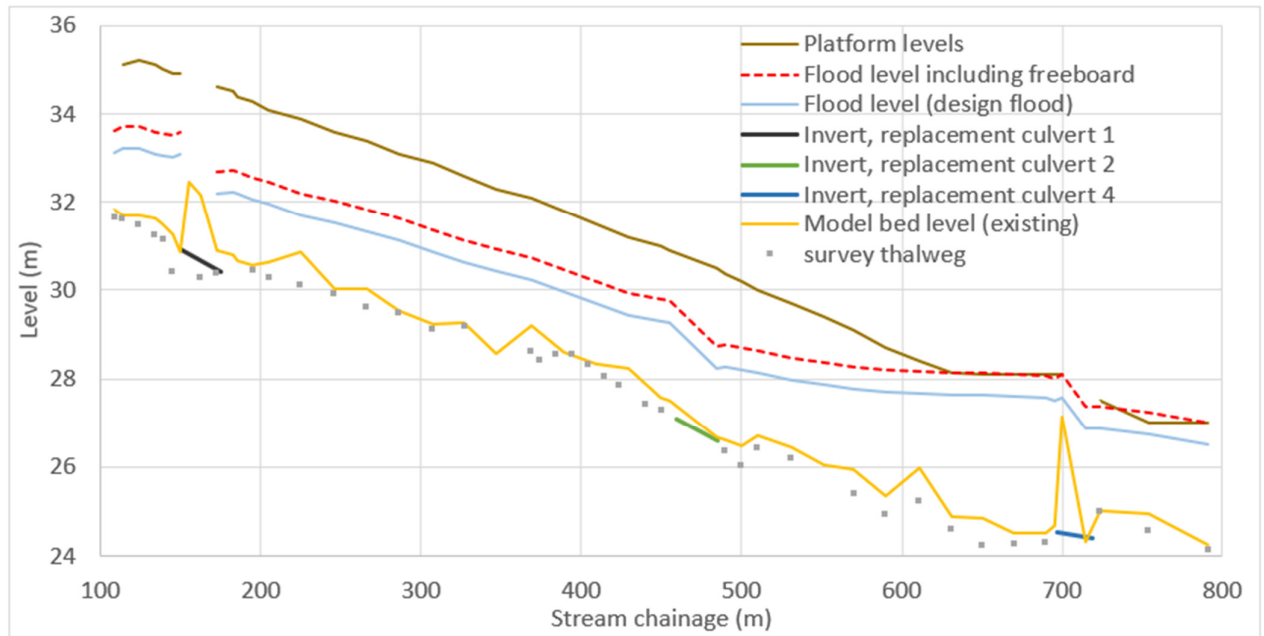


Figure 7-6 Longitudinal profiles along stream of bed levels, culvert invert levels, flood levels, conceptual fill platform levels (proposed case)



Figure 7-7 Stream chainage (refer Figure 7-6)

Table 7-1 Bed levels, culvert invert levels, flood levels, conceptual fill platform levels (proposed case) along stream

Stream chainage	Thalweg (surveyed)	Model bed level (existing)	Replacement culvert invert	Flood level		Platform level	
				model prediction	incl. freeboard	left bank	right bank
114	31.61	31.704		33.21	33.71		35.1
124	31.48	31.701		33.23	33.73		35.2
134	31.26	31.628		33.10	33.60	35.1	35.1
139	31.13	31.505		33.05	33.55	35	35
145	30.41	31.263		33.02	33.52	34.9	34.9
150		30.848	30.9	33.09	33.59	34.85	34.9
155		32.463					
162.5	30.29	32.150	culvert 1				
172.5	30.37	30.886		32.19	32.69	34.6	34.6
175.5			30.4				
182.5		30.800		32.21	32.71	34.51	34.5
185		30.656		32.18	32.68	34.4	
195	30.46	30.551		32.06	32.56	34.3	34.22
205	30.28	30.638		31.97	32.47	34.1	34.1
225	30.12	30.855		31.70	32.20	33.9	33.9
246	29.91	30.024		31.53	32.03	33.6	33.6
266	29.62	30.040		31.32	31.82	33.34	33.38
286	29.49	29.531		31.13	31.63	33.1	33.1
307	29.11	29.252		30.87	31.37	32.85	32.9
327	29.19	29.256		30.63	31.13	32.6	32.6
347		28.563		30.42	30.92	32.3	32.3
369	28.61	29.213		30.22	30.72	32.1	32.1
389		28.613		29.95	30.45	31.8	31.8
409		28.336		29.69	30.19	31.5	31.5
429		28.250		29.43	29.93	31.2	31.1
450	27.28	27.591		29.31	29.81	31	30.9
455		27.522		29.28	29.78	30.9	30.9
459			27.1				
484		26.691	culvert 2	28.24	28.74	30.4	30.5
485			26.6				
490	26.35	26.627		28.28	28.78	30.36	30.31
500	26.04	26.483		28.21	28.71	30.2	30.2
510	26.42	26.696		28.13	28.63	30	30
531	26.2	26.434		27.98	28.48	29.7	29.7
551		26.061		27.86	28.36	29.3	29.4
570	25.41	25.947		27.78	28.28	29	29.1
590	24.95	25.343		27.72	28.22	28.7	28.7
611	25.23	25.973		27.67	28.17	28.41	28.41
631	24.59	24.899		27.64	28.14	28.15	28.15
650	24.23	24.865		27.63	28.13	28.1	28.1
670	24.28	24.530		27.60	28.10	28.1	28.1
690	24.3	24.518		27.57	28.07	28.1	28.1
695		24.673		27.51	28.01	28.1	28.1
697	24.26		24.55				
700		27.132		27.59	28.09	28.1	28.1
715		24.323	culvert 4	26.88	27.38		
719			24.4				
724	24.999	25.013		26.88	27.38	27.5	
754	24.583	24.935		26.76	27.26	27	
791	24.14	24.243		26.52	27.02	27	

Notes: Thalweg for chainages 724 and downstream from LiDAR. Platform levels from T+T conceptual platform dated 20 May 2022

Appendix A

Initial Flood Assessment: Letter from River Edge Consulting to Richard Burrell



River Edge Consulting Limited
PO Box 6321
Marion Square
Wellington 6141
021 238 7515

21 November 2021

Richard Burrell
Rosco Ice Cream Ltd.
richard@buildingsolutions.co.nz

Dear Richard,

30 Benmore Crescent, Lower Hutt – Flood Impact Assessment

1. Introduction

The site at 30 Benmore Crescent, Manor Park (Lower Hutt) lies on the right bank of the Hutt River, between the river and SH2. The site is elevated above the river, and the railway also lies between the river and the site. The site is also bordered by the Benmore Stream, a small stream that discharges to the Hutt River. The catchment of Benmore Stream is around 350 ha and drains the hills behind the Dry Creek entrance to Belmont Regional Park (Figures 1 and 2, attached).

Although on-line flood maps¹ show the site as being subject to a 0.23% AEP² (440-year ARI) Hutt River flood, more recent modelling (c2018) that I have carried out indicates that the site is clear of river flooding in such an event (Figure 3). At a meeting with Greater Wellington Regional Council (GWRC) staff on 26 July 2021, this point was acknowledged by GWRC and indeed GWRC also has preliminary results from further modelling that come to the same conclusion.

However, the Benmore Stream poses a potential flood risk to the site and I have carried out a flood assessment to assist in the site layout design and resource consent process.

2. Site Description

Benmore Stream is an ill-defined stream much of its path through the site, from Benmore Crescent to the lower footbridge on the Hutt River Trail. Willows and overgrown vegetation dominate the riparian margins, as well as part of the stream bed. At time of a site visit in July 2021, relatively fresh gravel deposits were present, downstream of Benmore Crescent.

The culvert under Benmore Crescent has a build-up of gravel at its entrance, while flow through twin culverts under an access track about 300 m upstream of the Hutt River appeared very sluggish. The Hutt River Trail footbridge, about 200 m upstream of the Hutt River, is sufficiently high not to affect the stream flow.

¹ <https://data-gwrc.opendata.arcgis.com/datasets/gwrc-flood-hazards-areas-for-the-wellington-region/explore>

² Annual Exceedance Probability. The AEP is the inverse of the return period or average recurrence interval (ARI), so 0.23% AEP has the same meaning as a 440-year event, and a 1% AEP is also referred to as a 100-year event.

The bulk of the site itself, between the stream and the railway, is generally rough; consisting of areas of rough vegetation, remains of foundations of previous structures and abandoned cleared and raised platforms.

3. Model Software

The software program MIKE FLOOD has been used to build a hydraulic model of the site area and adjacent watercourses.

The MIKE FLOOD program simulates both channel flow and overland flow, dynamically linking them during a simulation. This program is used extensively within New Zealand and worldwide for flood hazard investigations.

4. Model Configuration

A section of the Hutt River, from the Pomare Rail bridge to around 200 m downstream of the Benmore Stream confluence, has been extracted from the recent Hutt River model. Flow and water level results have been extracted from that model at those locations, for use as boundary conditions in the model here.

Benmore Stream, from the Belmont Regional Park entrance on Hebden Crescent to the Hutt River, has been represented as a 1-dimensional (1D) channel in the model. Cross-sections have been obtained from a Spencer Holmes survey and from aerial LiDAR³ data.

The stream passes through several culverts in this reach and these have been represented in the model.

Floodplain topography for the existing situation has been obtained from various sources (where these sources overlap, the most recent data set has been used):

- Spencer Holmes survey, October-November 2021
- 2019 LiDAR of Hutt River and adjacent berms/floodplain
- 2013-14 LiDAR

Note that the reconfigured SH2-SH58 interchange is not shown in the model topography (built after the 2013-14 LiDAR but not captured in the 2019 LiDAR). However this does not impact on the Benmore Stream flows or floodwaters in the area of interest here.

The variation of the model has also been run with a raised flood-free area, shown in a preliminary earthworks cut/fill plan, prepared by Spencer Holmes and dated 6 July 2021 (drawing S20-0380-EW10 Rev A). This represents a “post-development” scenario.

5. Flow Scenario

The flow scenario assumed is 1% AEP flow in the Benmore Stream, with a climate change allowance.

There is no flow recorder in the Benmore Stream catchment and design flow estimates have been derived from rainfall-runoff modelling.

Current GWRC design advice is to use climate change scenario RCP 6 with a 100-year time horizon⁴. Rainfall data for the catchment have been taken from NIWA’s on-line HIRDS v4. However, as the on-line tables do

³ Light Detection and Ranging. Obtained from aerial laser survey in this case.

not extend out to 2120, the results for RCP 8.5 to 2080-2100 have been assumed. This is likely to be slightly conservative.

Wellington Water hydrology guidelines⁵ recommend using a nested storm with rainfall peaking later in the storm and also recommend use of a SCS hydrological approach.

With these assumptions, HEC-HMS software has then been used to generate a design storm inflow hydrograph for the Benmore Stream. A peak flow at Hebden Crescent of 30 m³/s has resulted.

In stormwater design work for the SH2/SH58 Interchange, Aurecon estimated the Benmore Stream peak design flow to be 17 m³/s (using the Modified Rational Method) but also carried out a sensitivity test on a design flow of 22 m³/s, derived from the 1989 *Flood Frequency in New Zealand* approach.

For this current study, a sensitivity test with a peak flow of 22 m³/s has been carried out.

A concurrent 0.23% AEP (440-year ARI) Hutt River flood is assumed.

6. Results and conclusions

Figure 4 shows the peak flood depths for the design scenario, i.e. 1% AEP (30 m³/s) Benmore Stream flow plus 0.23% AEP (2300 m³/s) Hutt River flow, for the existing situation. (The depth legend is not applied to flow within the stream channel, but the channel is shown in green.) The Hebden Crescent and SH2 culverts restrict flow, and some flow is therefore diverted south along the western side of SH2. Within the 30 Benmore Crescent site, flooding is largely restricted to an area on the true right bank of the stream just downstream of Benmore Crescent and to part of the southern portion of the site.

Figure 5 shows peak flood levels (to Wellington Vertical Datum 1953) for this scenario.

A sensitivity test, with the Benmore Stream flow peaking at 22 m³/s, gives peak flood depths shown in Figure 6. Results within the site are not significantly different from the base (30 m³/s) case, due to the capacity limitations of the Hebden Crescent, SH2 and Benmore Crescent culverts. Levels are generally around 10 cm lower and more typically less than 5-6 cm lower.

Although high Manning's n values have been applied in the model (0.100 to 0.150 for most of the length of the stream through the site), a sensitivity test has also been carried out with the stream resistance values increased by 20%. Figure 7 shows the resulting peak flood depths. Depths are generally less than 6 cm higher.

The final simulation has been with a raised flood-free platform⁶ (taking from Spencer Holmes drawing S20-0380-EW10 Rev A). Peak flood depths from that case are shown in Figure 8. The effect of that flood-free area (i.e. the difference from the results shown in Figure 1) is shown in Figure 9. Other than a small increase on the northern boundary of the site and along the access track alongside the railway, the impacts are

⁴ https://www.gw.govt.nz/assets/council-reports/Meeting_Documents/7720_Agenda_Climate%20Committee%2019%20October%202021,%20Order%20Paper.pdf RCP = Representative Concentration Pathway, scenario for greenhouse gas emission projections

⁵ *Reference Guide for Design Storm Hydrology*, Wellington Water 2019

⁶ A raised platform is one means of protecting the site from stream flooding; an alternative would be to construct a bund or stopbank parallel to the stream.)

contained within the site. Results also indicate no impact on levels upstream of SH2 or on downstream river levels.

Spencer Holmes extracted cross-sections from its topographical model along three alignments (A, B, C) shown in Figure 10. Table 1 presents the peak levels within the stream channel along these alignments, and along an additional alignment for the lower reach, from each of the four model simulations. For the “post-development” case, these levels would represent the necessary height of the flood-free platform or stopbank (excluding freeboard).

It needs to be noted that the model of the Benmore Stream is uncalibrated, and freeboard should be applied as a hedge against uncertainties. Depending on the ultimate use of the site and the assets to be protected, a freeboard of up to 500 mm could be appropriate.

Please contact me should you require clarification of any of the above or any further information.

Yours sincerely,



Philip Wallace
Director
RIVER EDGE CONSULTING LIMITED

Encls: *Figures 1 – 9, Table 1*



Figure 1 Site location and catchment



Figure 2 Site location

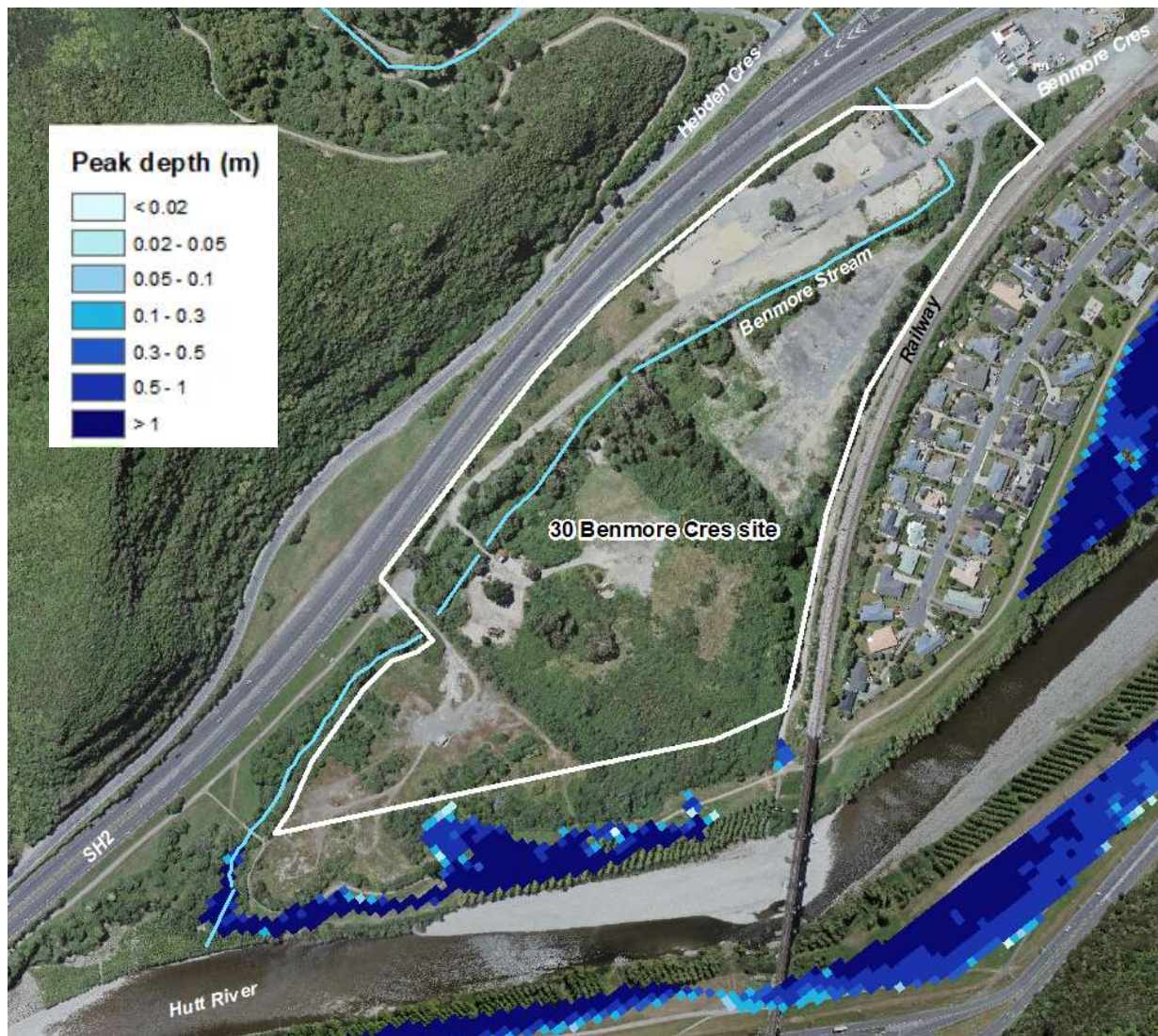


Figure 3 Predicted flood depths, Hutt River 0.23% AEP scenario (440-year return period, 2300 m³/s) from recent modelling (Note – flood depths within the Hutt River channel not shown)

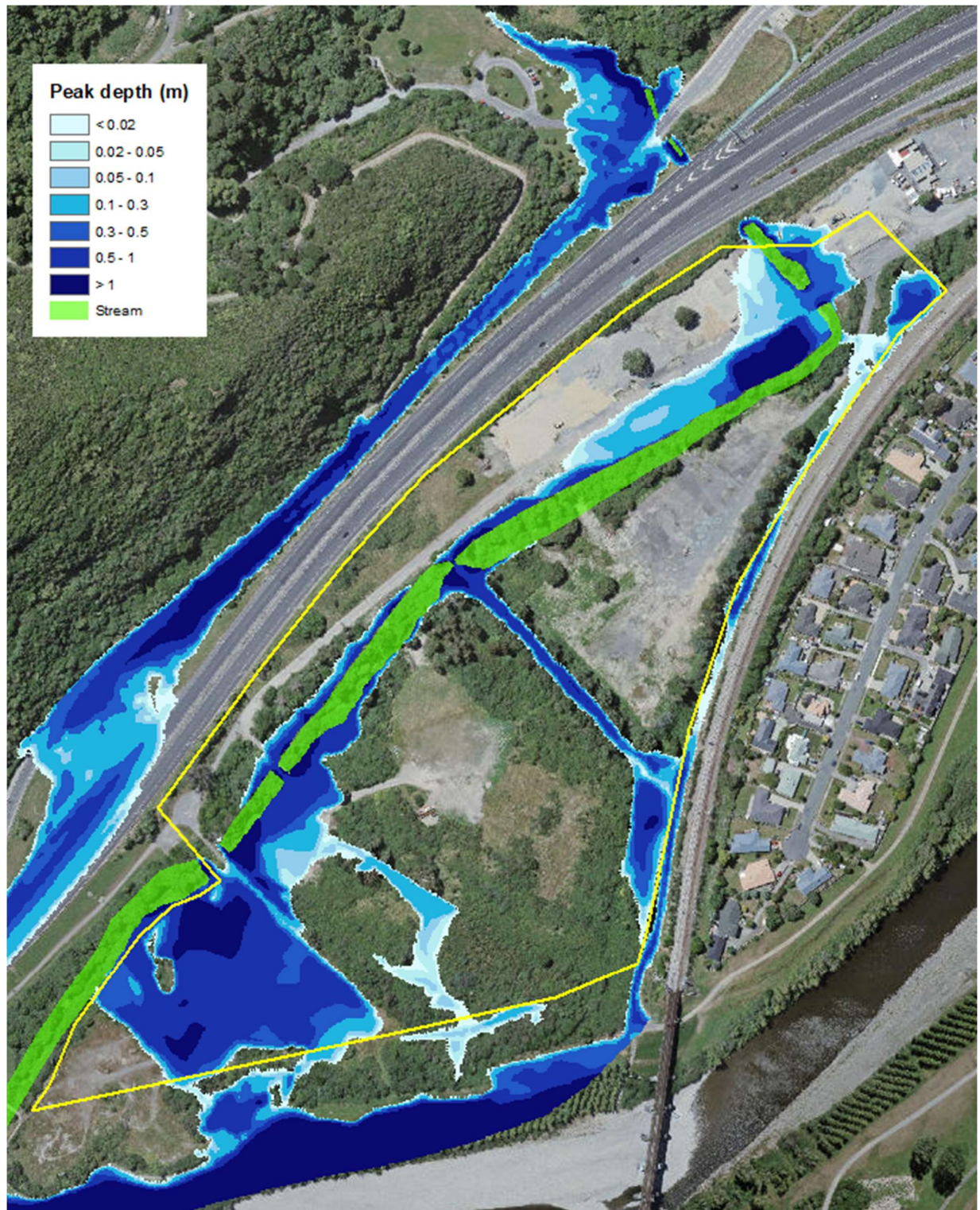


Figure 4 Predicted flood depths, 1% AEP scenario, with climate change

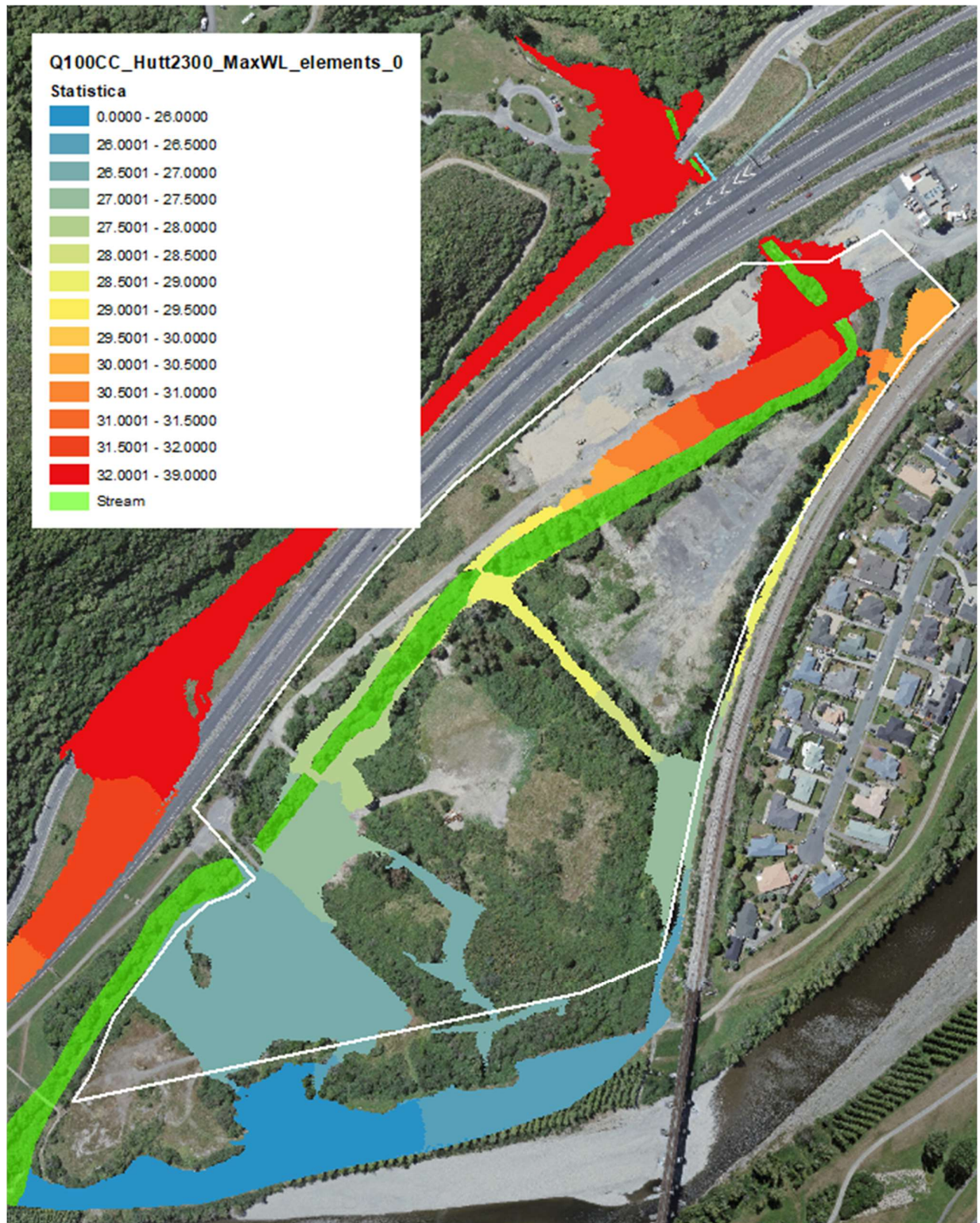


Figure 5 Predicted flood levels, 1% AEP scenario, with climate change excluding freeboard

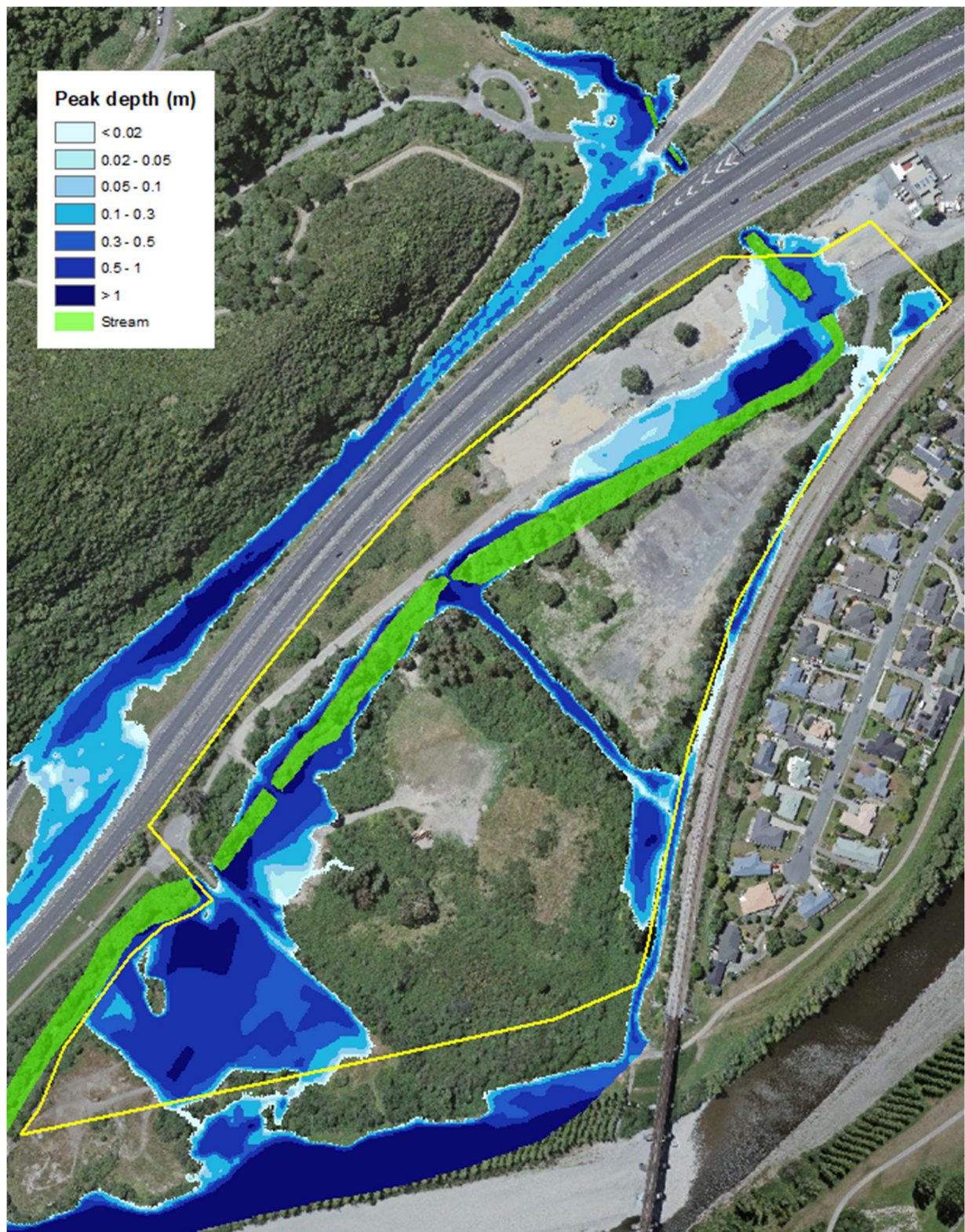


Figure 6 Sensitivity test : predicted flood depths, 22 m/s peak Benmore Stream flow

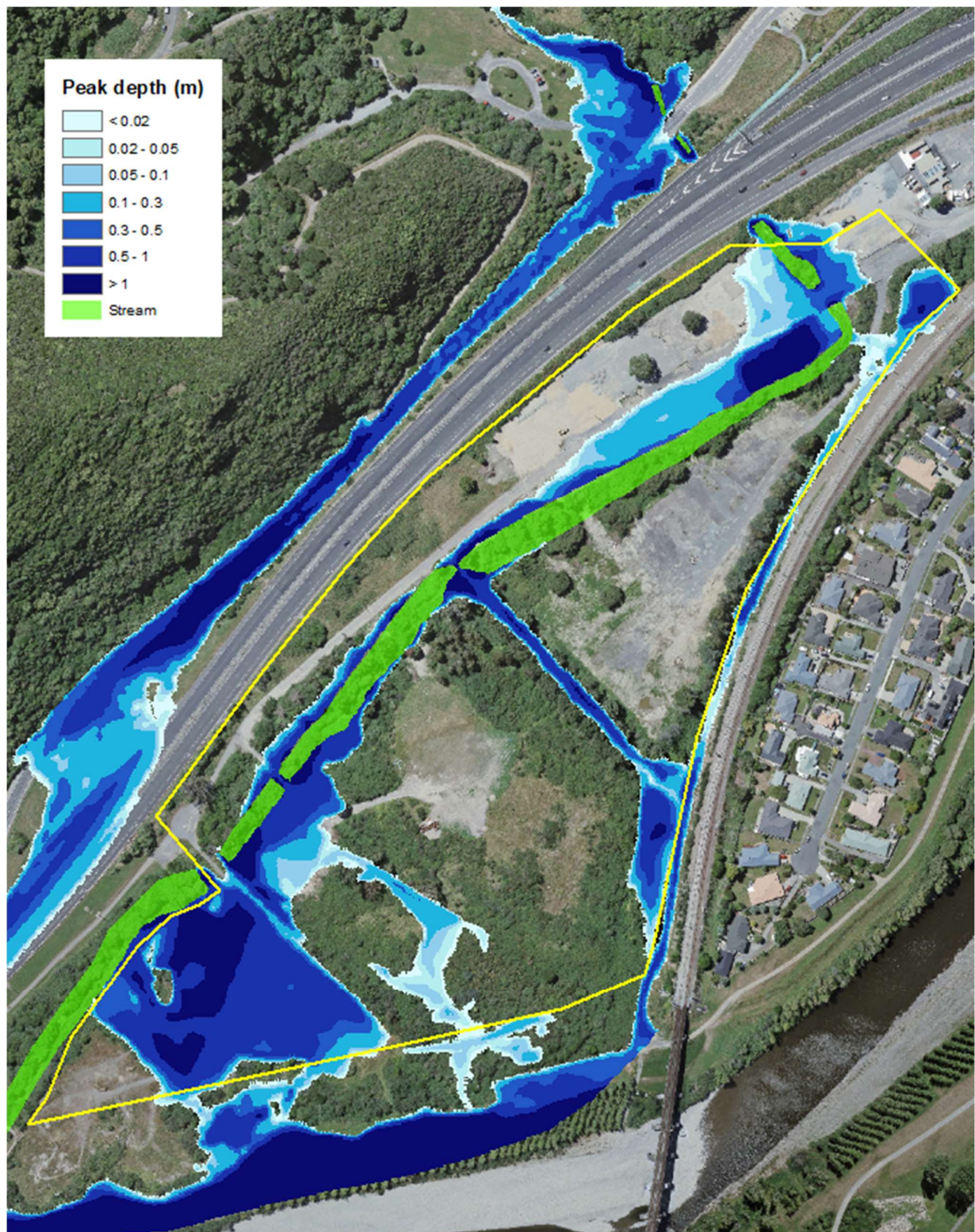


Figure 7 Sensitivity test : predicted flood depths, stream resistance increased by 20% (30 m³/s peak stream flow)

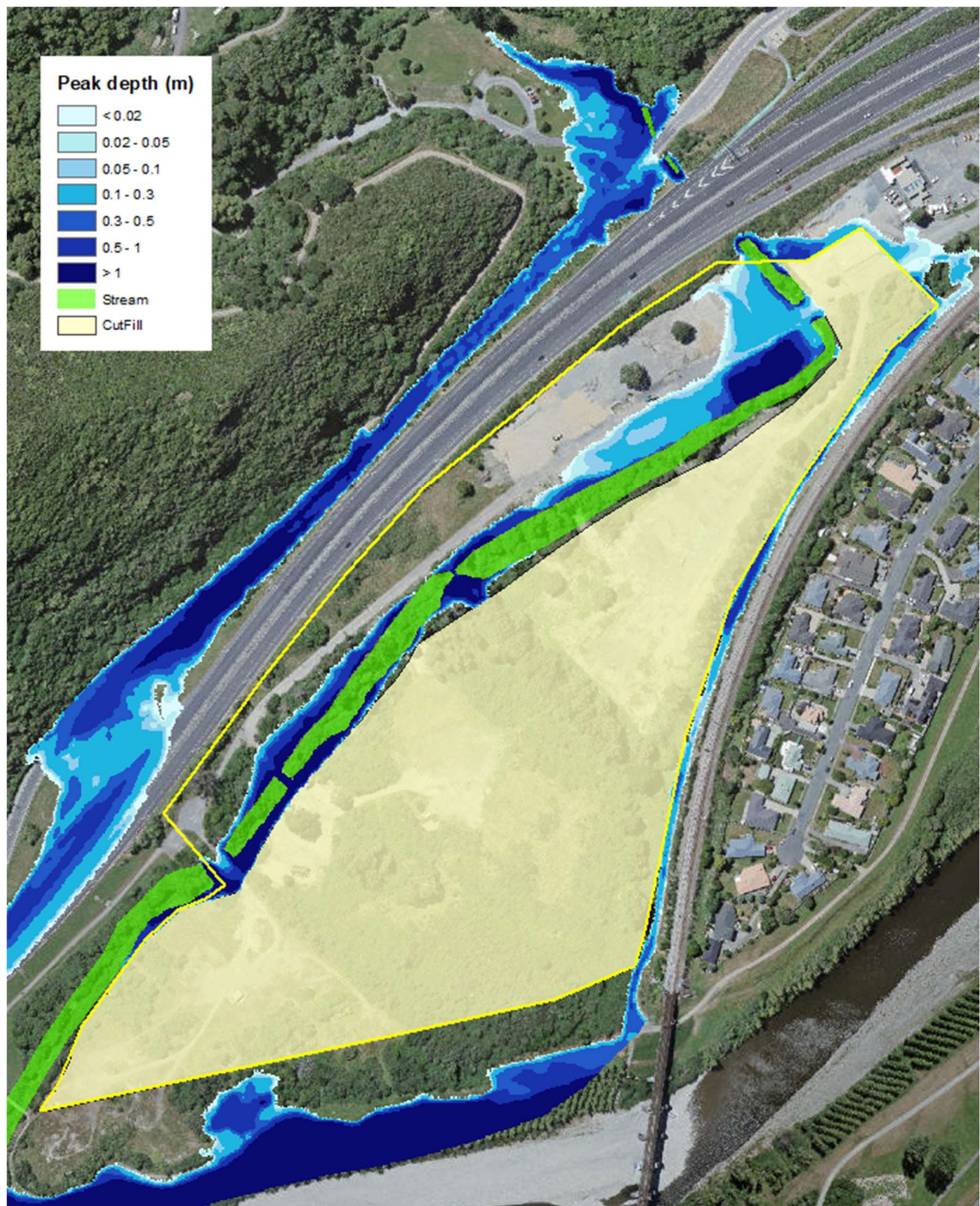


Figure 8 Predicted flood depths, 1% AEP scenario, with climate change, raised platform ("post-development")

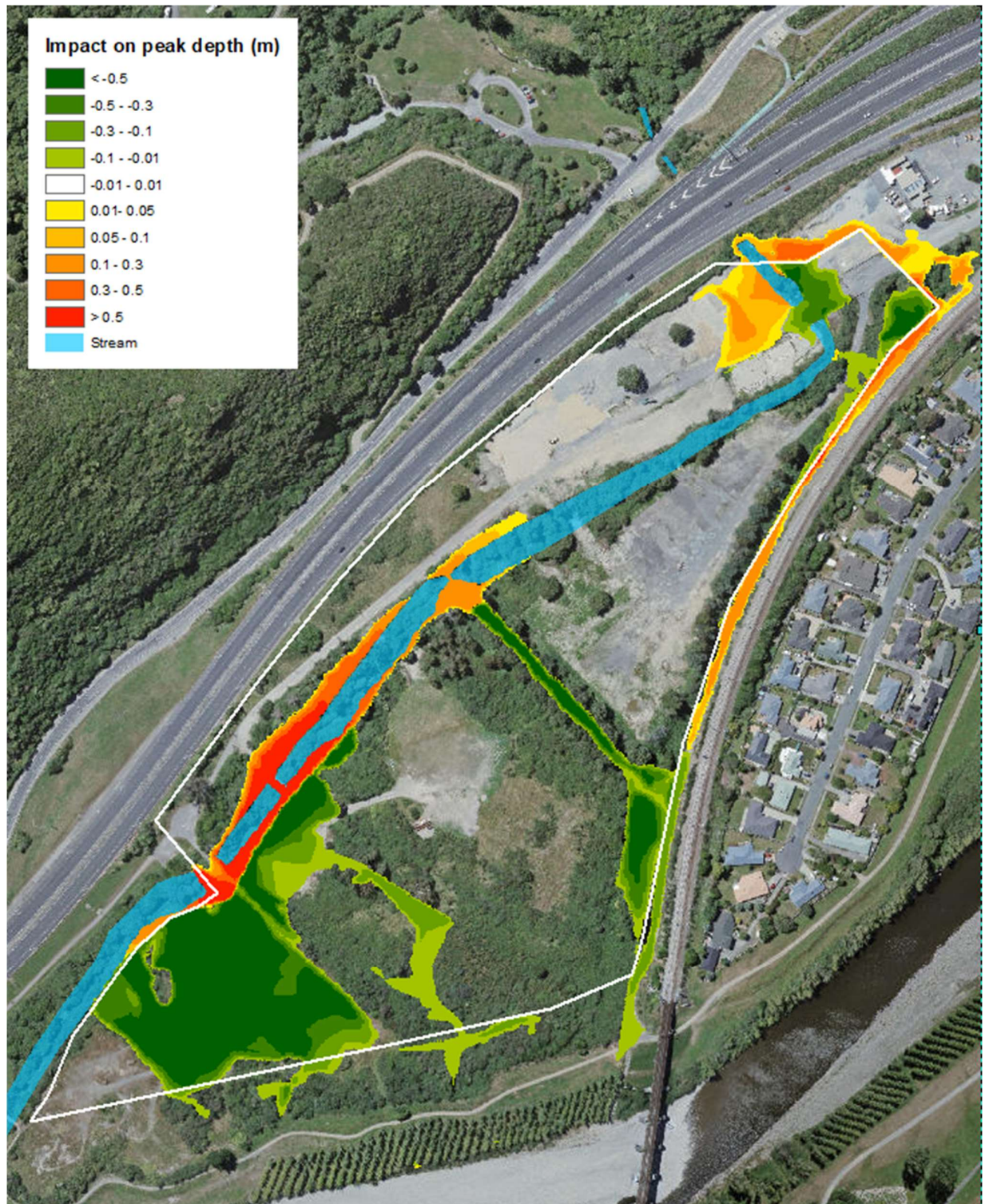


Figure 8 Impact of raised platform ("post-development") on flood depths

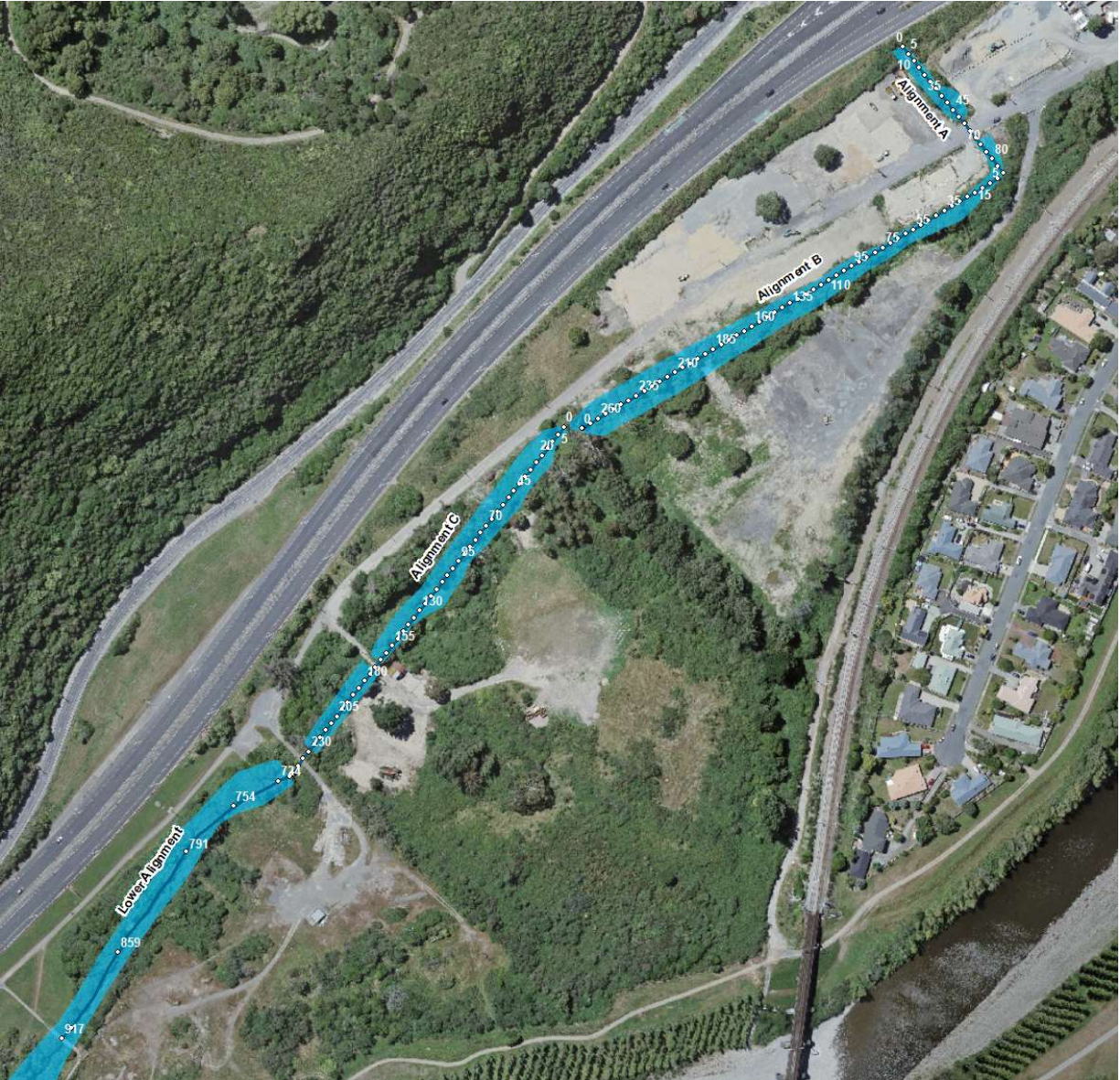


Figure 9 Stream channel cross-section locations

	X-Section	model chainage	Peak stream levels (m, Wellington Datum)			
			existing	Sensitivity tests		Post-development
				22 m ³ /s peak	+20% resistance	
Alignment A	0					
	5	99	33.55	33.55	33.49	33.62
	10	104	33.47	33.47	33.42	33.53
	15	109	33.44	33.44	33.39	33.48
	20	114	33.36	33.36	33.31	33.39
	25	119	33.27	33.27	33.23	33.29
	30	124	33.24	33.24	33.20	33.25
	35	129	33.23	33.23	33.19	33.23
	40	134	33.22	33.22	33.18	33.21
	45	139	33.20	33.20	33.17	33.19
	50	145	33.20	33.20	33.16	33.18
						36.87
	70	162.5	32.25	32.25	32.23	32.29
	75	167.5	32.20	32.20	32.19	32.24
	80	172.5	32.16	32.16	32.14	32.19
Alignment B	0					
	5	190	32.03	32.03	31.99	32.05
	10	195	32.00	32.00	31.97	32.03
	15	200	31.99	31.99	31.94	32.02
	20	205	31.98	31.98	31.93	32.01
	30	215	31.96	31.96	31.91	31.99
	40	225	31.94	31.94	31.90	31.98
	50	235	31.93	31.93	31.88	31.96
	60	246	31.90	31.90	31.85	31.93
	70	256	31.83	31.83	31.79	31.88
	80	266	31.72	31.72	31.68	31.77
	90	276	31.57	31.57	31.53	31.62
	100	286	31.43	31.43	31.39	31.48
	110	297	31.25	31.25	31.21	31.31
	120	307	31.12	31.12	31.07	31.17
	130	317	30.97	30.97	30.92	31.02
	140	327	30.82	30.82	30.77	30.87
	150	338	30.65	30.65	30.60	30.71
	165	353	30.42	30.42	30.37	30.48
	180	369	30.19	30.19	30.13	30.25
	185	374	30.11	30.11	30.06	30.18
	195	384	29.96	29.96	29.91	30.03
	205	394	29.72	29.72	29.67	29.80
	215	404	29.49	29.49	29.43	29.56
	225	414	29.31	29.31	29.25	29.38
	235	424	29.15	29.15	29.08	29.22
	250	440	28.98	28.98	28.89	29.04
	260	450	28.93	28.93	28.84	28.98

Table 1 Peak flood levels in stream channel

	X-Section	model chainage	Peak stream levels (m, Wellington Datum)			
			existing	Sensitivity tests		Post-development
				22 m ³ /s peak	+20% resistance	
Alignment C	0	470	28.66	28.66	28.58	28.75
	10	480	28.56	28.56	28.48	28.66
	20	490	28.41	28.41	28.33	28.52
	30	500	28.33	28.33	28.25	28.42
	40	510	28.25	28.25	28.18	28.34
	50	521	28.19	28.19	28.12	28.28
	60	531	28.13	28.13	28.06	28.21
	70	541	28.06	28.06	27.99	28.13
	75	546	28.02	28.02	27.95	28.09
	90	560	27.94	27.94	27.87	27.99
	100	570	27.89	27.89	27.82	27.93
	110	580	27.83	27.83	27.77	27.86
	120	590	27.80	27.80	27.74	27.82
	130	600	27.76	27.76	27.70	27.77
	140	611	27.72	27.72	27.66	27.73
	150	621	27.70	27.70	27.64	27.70
	160	631	27.68	27.68	27.63	27.68
	180	650	27.46	27.46	27.42	27.47
	190	660	27.45	27.45	27.41	27.46
	200	670	27.44	27.44	27.40	27.45
	210	680	27.42	27.42	27.37	27.42
	220	690	27.39	27.39	27.35	27.39
Lower	724	724	26.75	26.75	26.70	26.81
	754	754	26.66	26.66	26.59	26.74
	791	791	26.43	26.43	26.34	26.55
	859	859	25.41	25.41	25.34	25.55
	909	909	24.91	24.91	24.90	24.95
	917 (footbridge)	917				

Table 1 (cont.) Peak flood levels in stream channel

Memorandum



To: Alex Gifford, Tonkin + Taylor

From: Philip Wallace, River Edge Consulting

Date: 27 July 2022

Re: Benmore Crescent – Alternative culvert option

1. Introduction

Subsequent to my flood assessment report of June 2022, in which I reported on the flood hazard on the site at 30 Benmore Crescent for the existing situation and the proposed development, a proposal for an alternative culvert arrangement has been prepared. I have now carried out a flood assessment of this alternative.

2. Alternative culvert option

The earlier proposal assessed in my June report involved removal of one culvert in Dry Creek within the site and replacement and upgrades of three further culverts, including that under Benmore Crescent at the northern end of the site ("culvert 1"). Details of the upgrades were provided in the June report and in my memo to you dated 15 June 2022.

The alternative now under consideration involves removal of all of the Dry Creek culverts within the site and replacement of only culvert 1. Figure 1 shows the location of the culverts.

Culvert 1 is also now proposed to be 35 m long (Figure 2). This compares to a length of around 20 m in the earlier proposal and is to accommodate a revised site layout for a yard on the true right bank of Dry Creek and access to that yard.

Note that the fill contours shown in Figure 2 are based on the earlier fill platform prepared by Tonkin + Taylor (in turn, to accommodate flood predictions from a preliminary model simulation with the existing culvert). These fill contours will need to be updated to pass over and tie into the new culvert. They could also be lowered, in light of current flood model results. However, in modelling this alternative culvert option, the fill platform has been left as it was in the earlier proposal (other than the minor adjustments made in the freeboard modelling, as noted in section 3.1 below). Assumptions of minor cutting of high banks within the stream corridor (i.e. Figure 6-4 of the June report) are also adopted in this current modelling.

As with the previous proposal, the modelled culvert 1 consists of twin 2.5 m wide x 2 m high box concrete culverts. These would be embedded by around 500 mm, to provide a natural gravel bed and meet fish passage guidelines. Thus the effective height of the twin culverts would be 1.5 m.

The new culvert is proposed to be laid a gradient (2.3%) reflecting the general gradient of the stream bed in the vicinity, although it is expected that stream gradient will adjust itself in light of the much

larger culvert opening proposed (compared to the existing culvert opening). Having an initial embedment of 500 mm will provide some leeway for the bed to adjust itself. Figure 3 shows the existing stream bed gradient and the culvert invert levels. The dotted red line shows the level at which the culvert invert would be laid while the solid red line, 500 mm higher, shows the bed level assumed through the culvert.

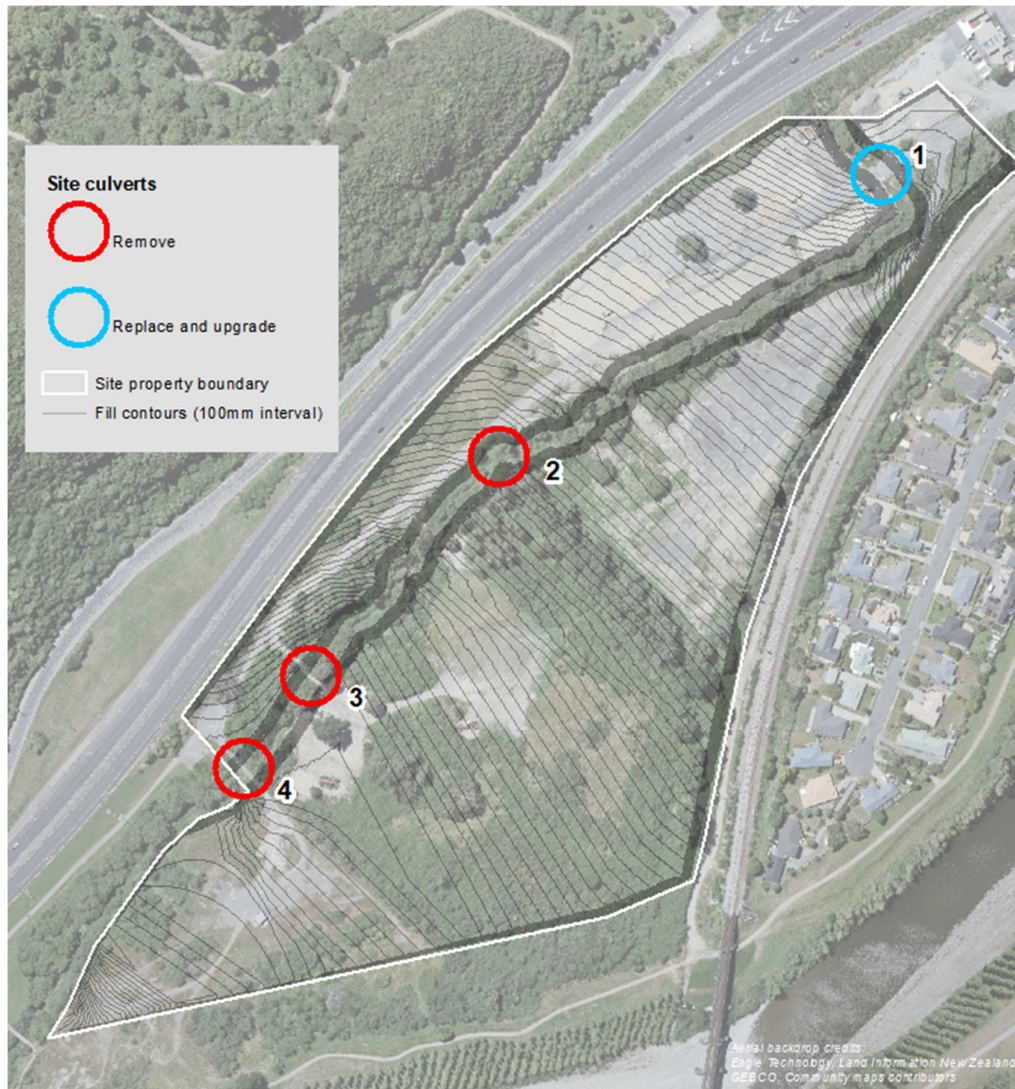


Figure 1 Alternative culvert option, July 2022: removal and replacement

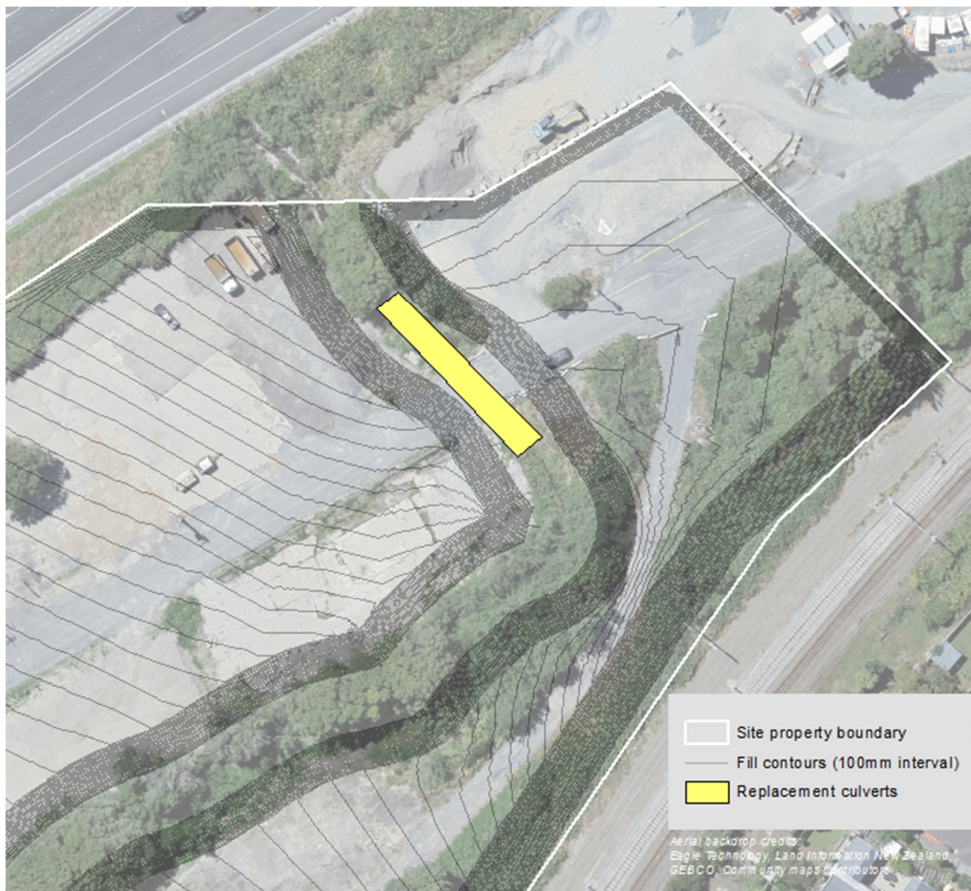


Figure 2 Alternative culvert option, July 2022: culvert 1 replacement

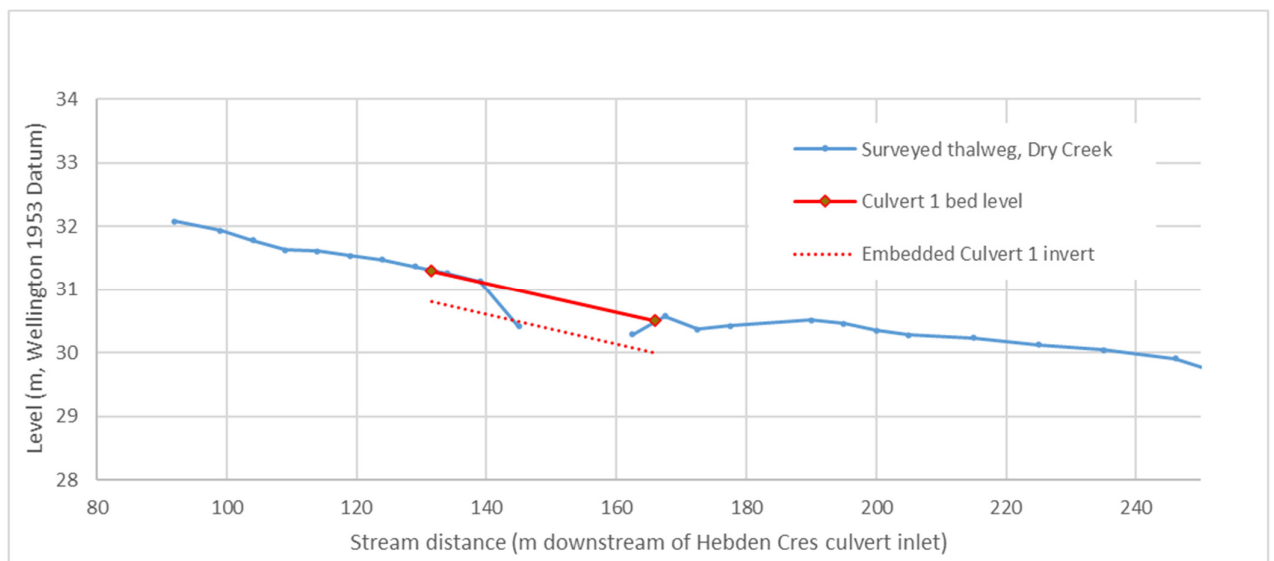


Figure 3 Alternative culvert option, July 2022: culvert 1 bed and invert levels

2. Model results

Flood depths for the development scenario are shown in Figure 4. Floodwaters are contained within the wider stream corridor within the site.

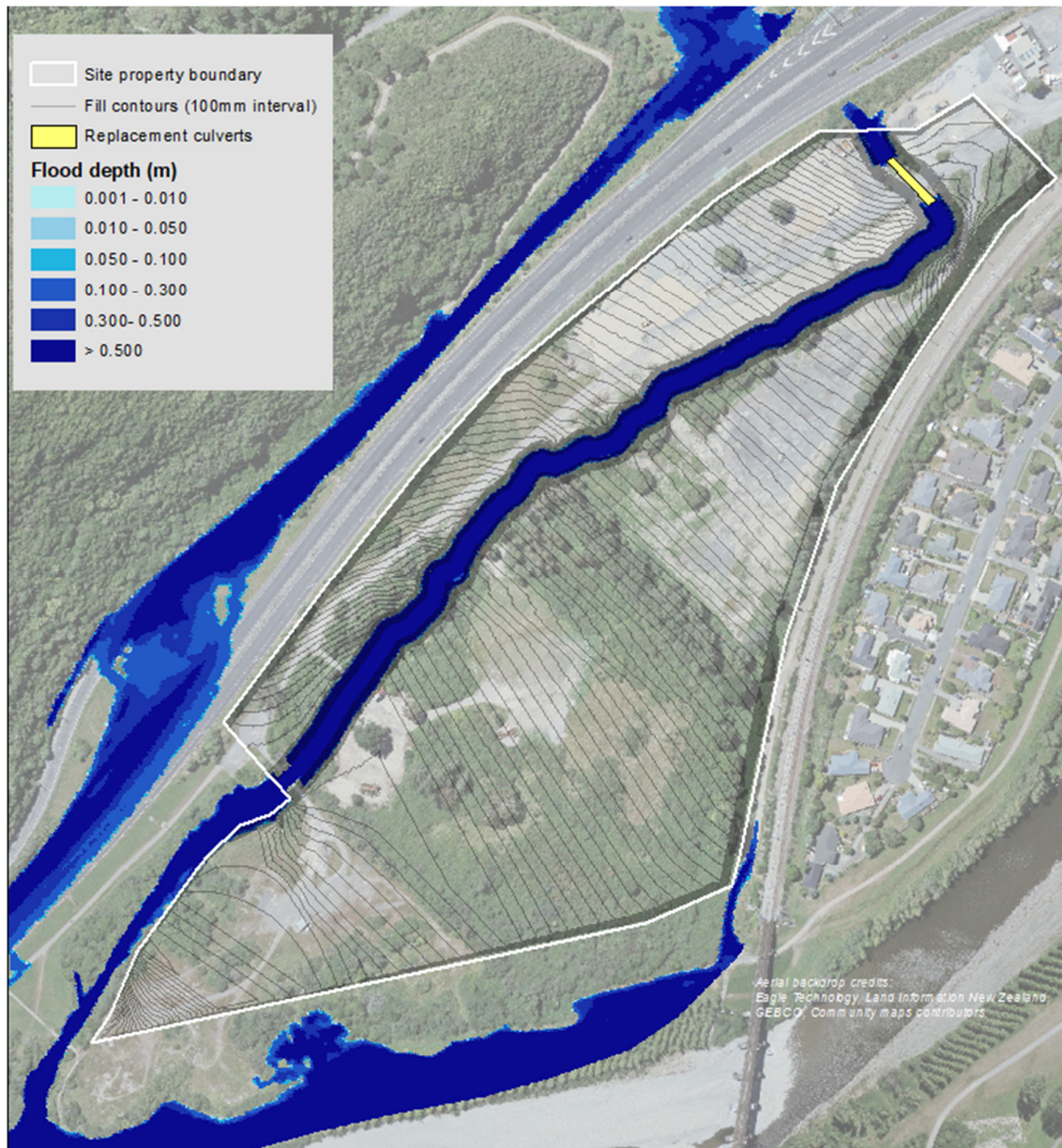


Figure 4 Predicted flood depths, developed situation

Model results predict that the peak flow through culvert 1 would be 14.4 m³/s, with a velocity of 1.92 m/s. The upstream water level would be approximately 33.1 m RL.

Figure 5 shows the impact of the proposed development platform on flood levels. Increases of less than 300 mm are predicted in the incised stream channel downstream of where the existing culvert 4 is, which would pose no additional risk to people or assets. There is also a trivial amount of

additional flooding on the edge of the yard between the upstream end of the site and SH2, currently used to stockpile roading gravel (Figure 6).

Otherwise, all increases in depth are contained within the site. Floodwaters are cut off along the KiwiRail access track alongside the railway, hence a small decrease in depth along the track is shown in Figure 5

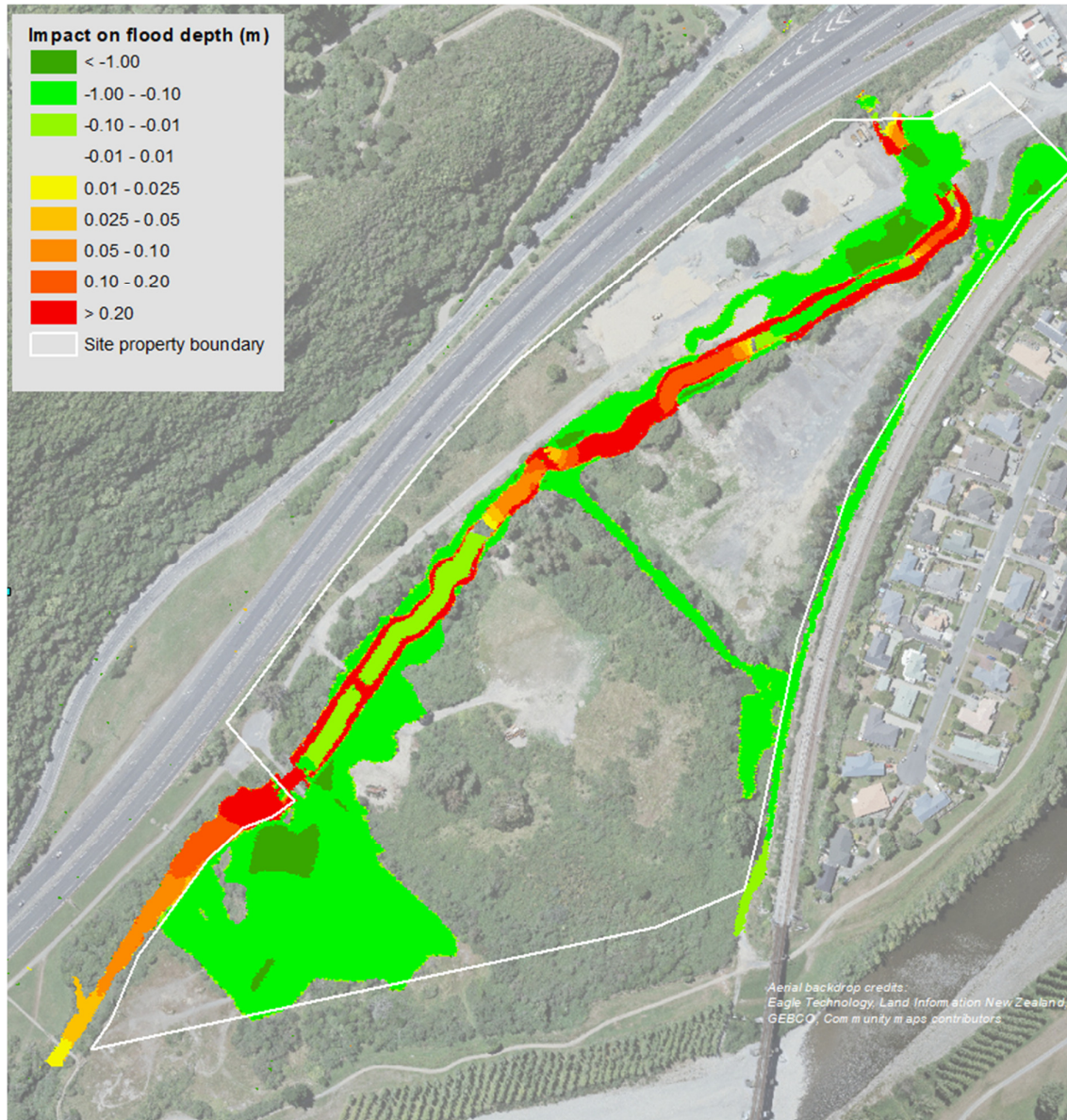


Figure 5 Impact of proposed development on peak flood depths

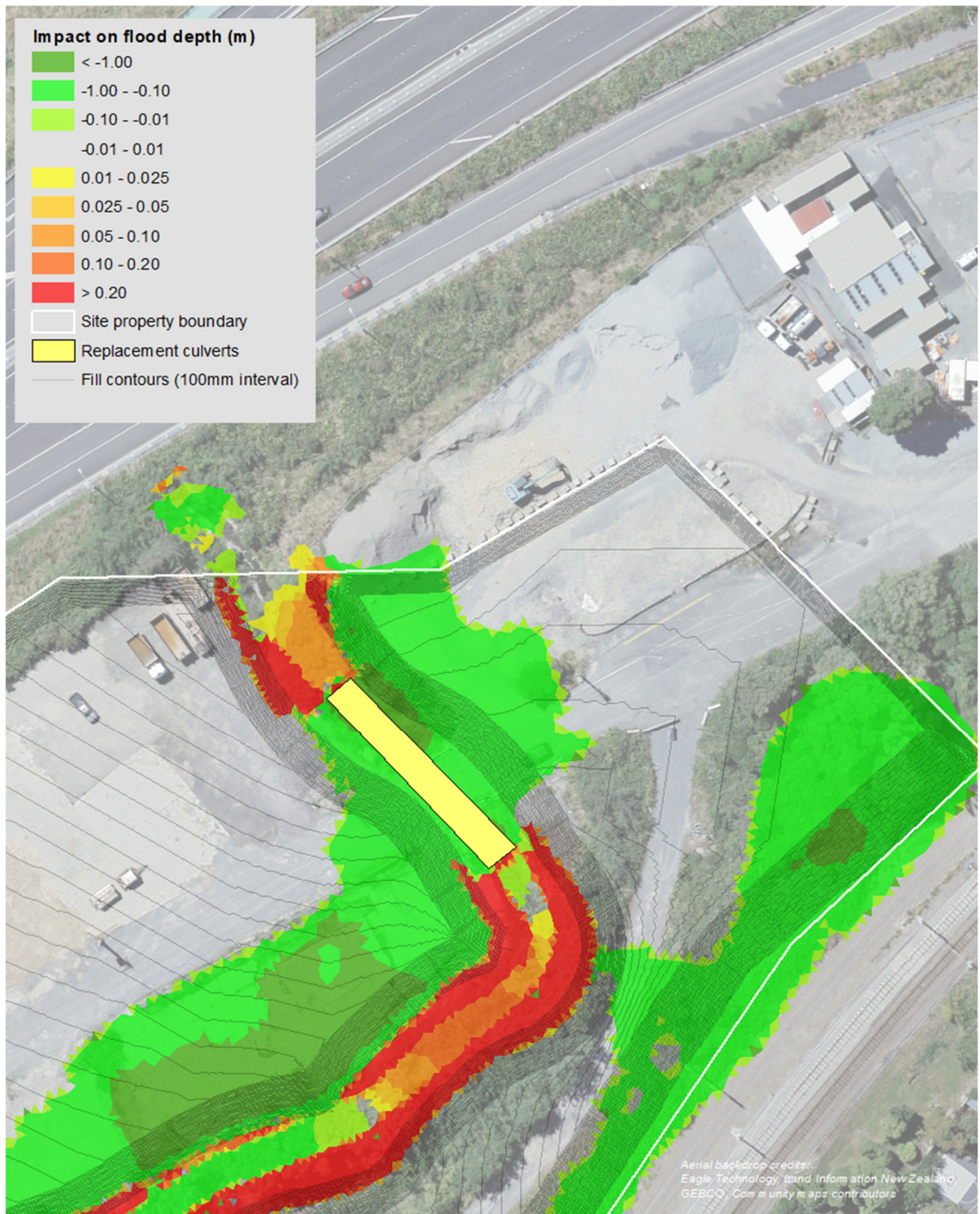


Figure 6 Impact of proposed development on peak flood depths, close-up at northern end of site

3.1 Freeboard

Results for the design scenario have then had freeboard added. NZS 4404 specifies a minimum freeboard of 0.3 m for commercial or industrial buildings, but higher levels are suggested here, to provide greater protection for any high value assets. GWRC uses 0.9 m freeboard for Hutt River design levels, so that has been added to the Hutt River levels in this current study. A lesser amount, 0.5 m, has been applied to the Dry Creek flood levels, in recognition that this is a much smaller stream.

With freeboard added, the platform as originally provided would be subject to some minor overflows from the stream channel downstream of the existing culvert 4 location, similar to that shown in Figure 7-5 of the June report. Although this result is possibly due a to likely conservative assumptions regarding the stream bed downstream, the platform has been amended with a slight increase of up to 500 mm in level (but typically less than 200 mm) along the platform edge in that location (see Figure 7 for revised contour levels). The model has been rerun with the freeboard applied. The resulting depths are as shown in Figure 8.



Figure 7 Amendment of fill platform

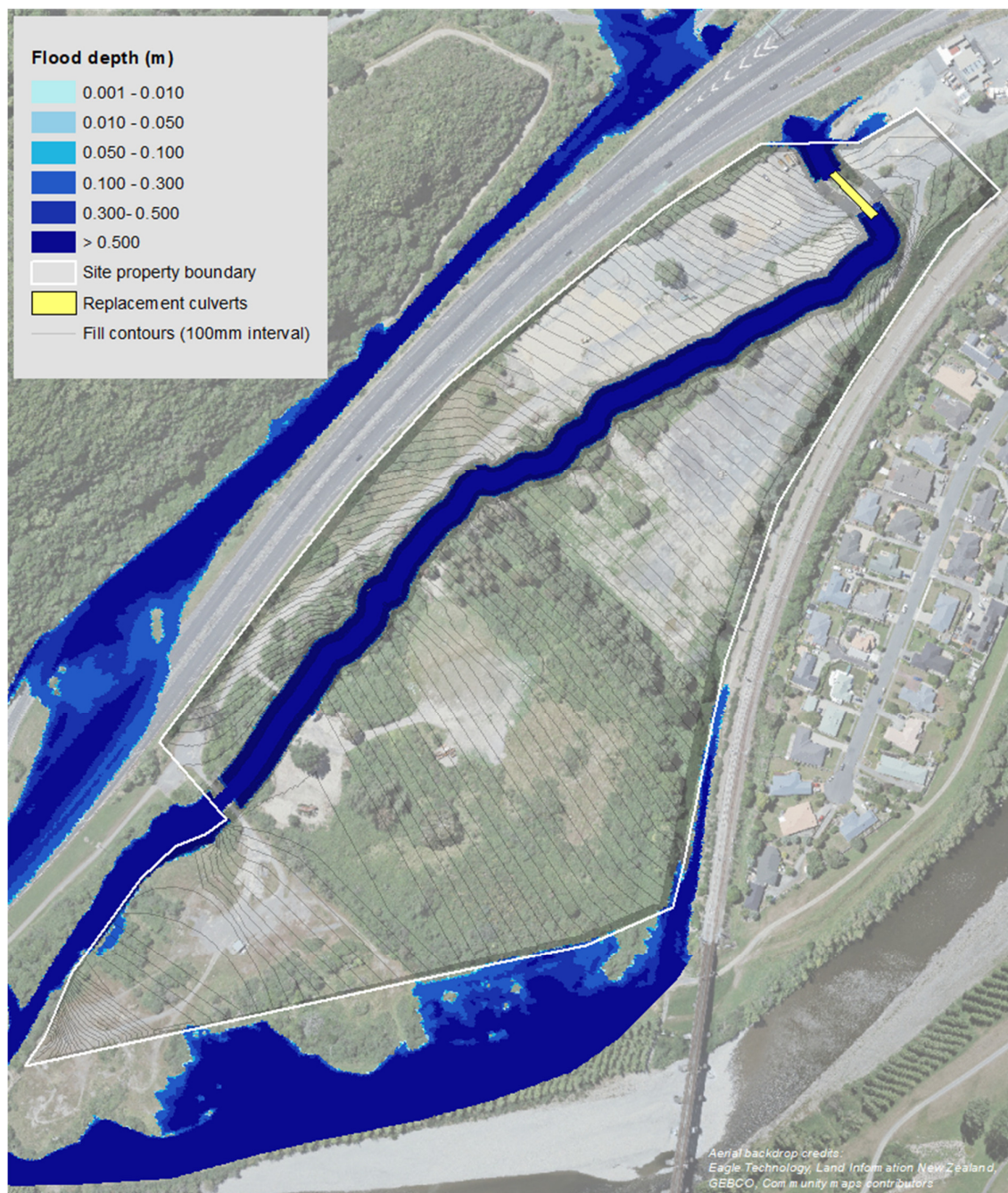


Figure 8 Predicted flood depths, developed situation with freeboard allowance

As with the previous results, results with the alternative culvert proposal show that the conceptual fill platform need not be as high as proposed (other than along the section of platform edge referred to above). Figure 7 and Table 1 present a longitudinal profile of flood levels and the original platform levels down the stream corridor; these are updates of Figure 7-6 and Table 7-1 in the original report, for the alternative culvert option.

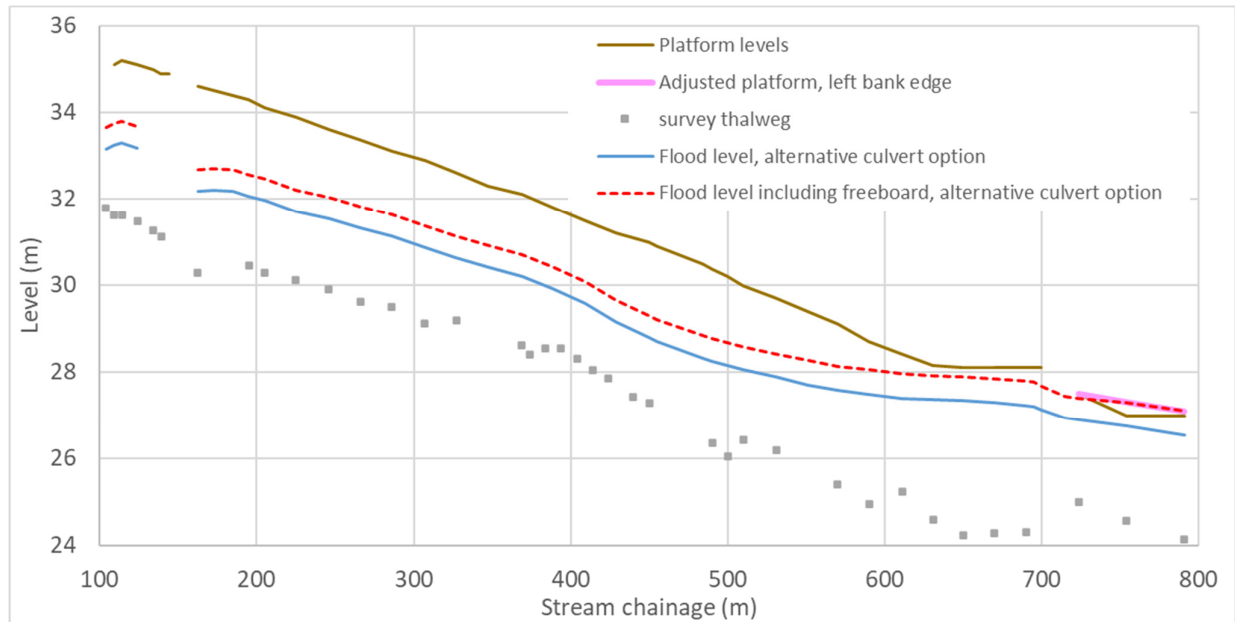


Figure 9 Longitudinal profiles along stream of bed levels, culvert invert levels, flood levels, conceptual fill platform levels (proposed case)

Table 1 Bed levels, culvert invert levels, flood levels, conceptual fill platform levels (proposed case) along stream

Stream chainage	Thalweg (surveyed)	Replacement culvert invert	Flood level		Platform level	
			model prediction	incl. freeboard	left bank	right bank
109	31.63		33.26	33.76		35.10
114	31.61		33.29	33.79		35.20
124	31.48		33.18	33.68	35.10	35.10
131		31.3				
134	31.26				35.00	35.00
139	31.13				34.90	34.90
144					34.85	34.90
149						
159		culvert 1				
162.5	30.29		32.18	32.68	34.60	34.60
166		30.5				
172.5			32.21	32.71	34.51	34.50
185			32.18	32.68	34.40	
195	30.46		32.06	32.56	34.30	34.22
205	30.28		31.97	32.47	34.10	34.10
225	30.12		31.70	32.20	33.90	33.90
246	29.91		31.53	32.03	33.60	33.60
266	29.62		31.32	31.82	33.34	33.38
286	29.49		31.13	31.63	33.10	33.10
307	29.11		30.86	31.36	32.85	32.90
327	29.19		30.63	31.13	32.60	32.60
347			30.42	30.92	32.30	32.30
369	28.61		30.21	30.71	32.10	32.10
389			29.91	30.41	31.80	31.80
409			29.58	30.08	31.50	31.50
429			29.14	29.64	31.20	31.10
450	27.28		28.79	29.29	31.00	30.90
455			28.71	29.21	30.90	30.90
459						
484			28.33	28.85	30.40	30.50
485						
490	26.35		28.26	28.78	30.36	30.31
500	26.04		28.16	28.69	30.20	30.20
510	26.42		28.07	28.59	30.00	30.00
531	26.2		27.89	28.42	29.70	29.70
551			27.71	28.27	29.30	29.40
570	25.41		27.58	28.14	29.00	29.10
590	24.95		27.49	28.05	28.70	28.70
611	25.23		27.40	27.97	28.41	28.41
631	24.59		27.36	27.92	28.15	28.15
650	24.23		27.33	27.89	28.10	28.10
670	24.28		27.29	27.85	28.10	28.10
690	24.3		27.23	27.79	28.10	28.10
695			27.21	27.77	28.10	28.10
697	24.26					
700			27.13	27.67	28.10	28.10
715			26.94	27.44		
719						
724	24.999		26.90	27.40	27.50	
754	24.583		26.76	27.29	27.00	
791	24.14		26.53	27.10	27.00	

Notes: Thalweg for chainages 724 and downstream from LiDAR. Platform levels from T+T conceptual platform dated 20 May 2022