JACOBS

Memorandum

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Subject	**Flood Modelling of Reid Line Floodway**	**Project Name**	Reids Line Floodway Base Model Project
Attention	Jon Bell, Manager Investigation and Design, Horizons Regional Council	**Project No.**	IZ124200
From	Mazhar Ali, Modelling Engineer, Jacobs		
Date	November 25, 2019		
Copies to	Damian Debski, Associate Engineer, Jacobs Peter Kinley, Technical Leader – Surface Water and Hydrology, Jacobs		

1. Introduction

Horizons Regional Council (HRC) engaged Jacobs New Zealand Ltd (Jacobs) to undertake the hydraulic modelling of Reid Line Floodway between the Makino Stream and the Kiwitea Stream.

To allow high flow in the Makino Stream to be diverted towards the Kiwitea Stream, a gate structure along with a stopbank are provided north-east of the town of Feilding (Figure 1). These structures are designed to provide protection to flood prone areas of Feilding to a certain extent. The main aim of the hydraulic modelling was to assess the extent and depth of flow in the floodway for flood events of 100 and 200 Year Average Recurrence Interval (ARI) derived for different flow conditions in the Makino Stream.

2. Model Extents and Boundaries

The right bank of the Makino Stream was defined as the upstream extent of the model, while its downstream boundary was setup below the confluence of Reid Line Floodway and the Kiwitea Stream (Figure 1). Right and left extents of floodway were defined as the crest of stopbank and beyond the expected flood extents for 200 Year ARI event respectively.

3. Hydraulic Model Setup

A flood model of Reid Line Floodway was built using MIKE Flood software version 2017. In this model, the floodplain was modelled in 2D using MIKE 21 FM software, while a culvert of Pharazyn Road was modelled in 1D using MIKE 11 software (Figure 1). The 2D floodplain model was coupled with 1D model in MIKE Flood software by building standard links.

A LiDAR (2016) derived Digital Elevation Model (DEM) with a grid size of 1×1m supplied by HRC was used to develop a flexible mesh. The topography of the project area was modelled in such a way that the areas along the stopbank were represented by a fine mesh having individual element size under 5 m^2 while the coarse resolution mesh was generated for the rest of the area with mesh size under 10 m^2. Besides these mesh zones, the crest of Pharazyn Road is also represented by a fine mesh with element size under 4 m^2. Overall, the average size of the mesh was 4.7 m^2.

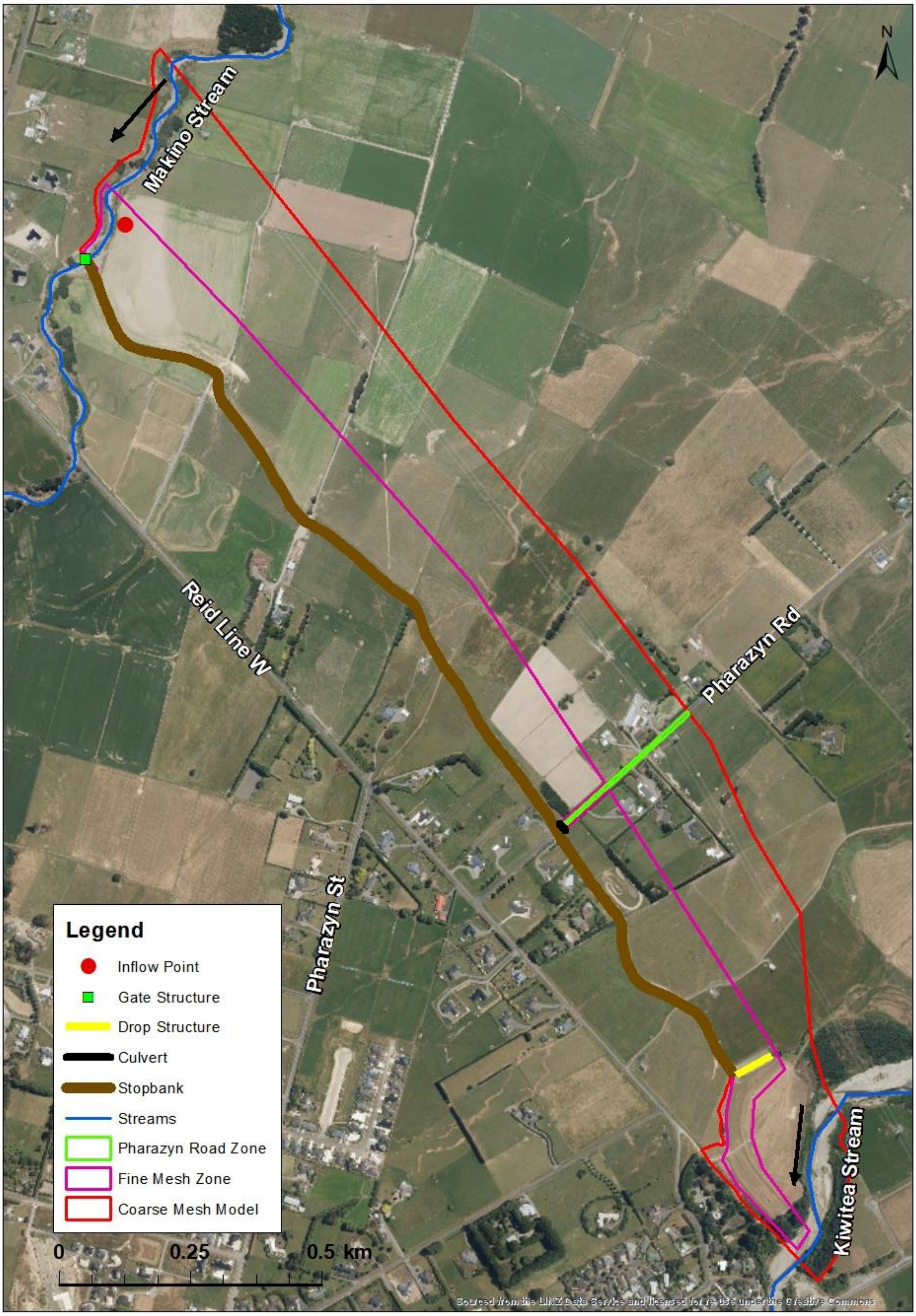

Figure 1: Mesh Zones with Location of Existing Structures

The existing structures and the methodologies adopted to model them are as follows:

- As per information provided by HRC, a single barrel rectangular culvert is provided under Pharazyn Road which is 2.5 m wide and 0.9 m deep (Figure 2). It was modelled in MIKE 11 as a part of MIKE Flood model with a single cross section upstream and downstream.

- A gabion drop structure is provided at the end of floodway (Figure 3) to drain floodwater from floodplain into a channel which drains flows further into the Kiwitea Stream. As built survey of drop structure undertaken in year 2010 was provided by HRC. In order to check the accuracy of LiDAR derived DEM, the cross-sections of drop structure derived on the basis of survey information and DEM were compared and both found similar (Figure 4).

  The crest of the structure is inclined - approximately 1.0 m deep from top left bank while it is about 1.5 m deep from its top right bank and its width is approximately 78.0 m (Figure 4). It was modelled in 2D using MIKE 21 software.

- In order to divert flood water released from the drop structure towards the Kiwitea Stream, an approximately 1.0 m deep and 35.0 m wide channel is provided (Figure 5), and it is about 300.0 m long. Similar to drop structure, it was modelled in 2D using MIKE 21 software.

- The gate structure across the Makino Stream to regulate its flows was modelled as “glass wall”, because it was assumed that it would completely divert flood water towards the Kiwitea Stream (Figure 1).

Figure 2: Photograph of Pharazyn Road Culvert Showing Upstream Side (20 March 2019)

Figure 3: Photograph of Gabion Drop Structure (20 March 2019)

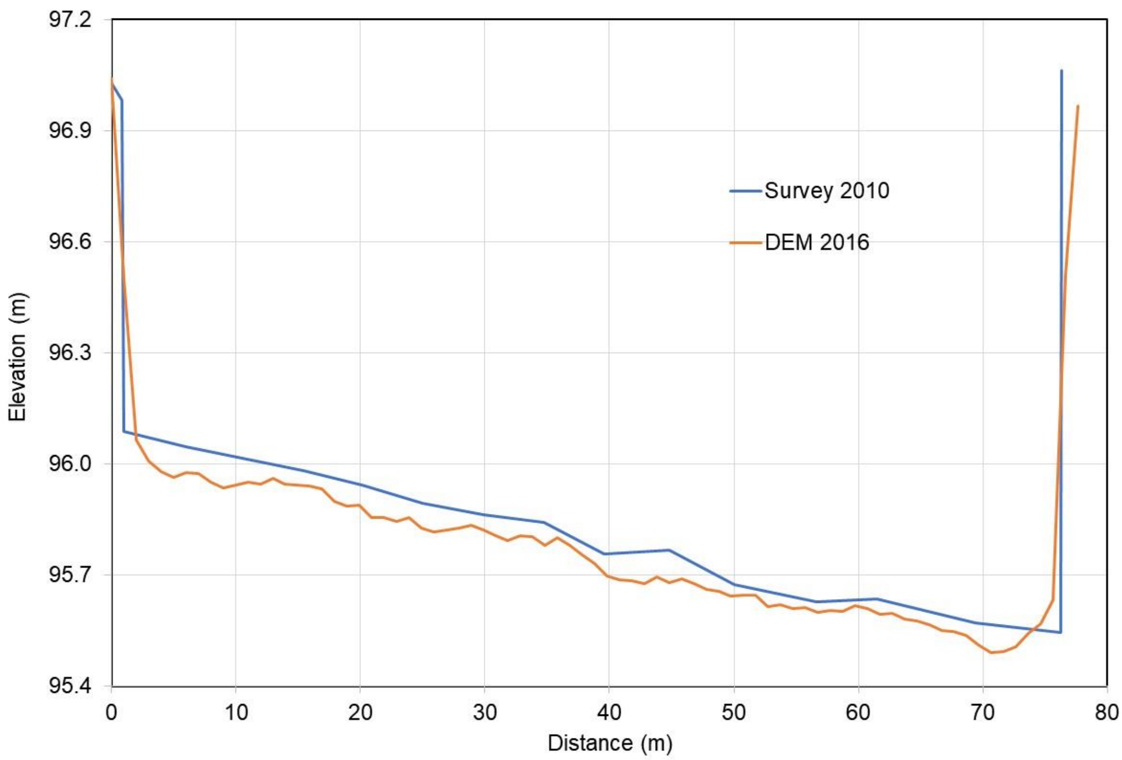

Figure 4: Graph Compares Cross-sections of Gabion Drop Structure Derived on the Basis of Survey Information and LiDAR DEM looking downstream

Figure 5: Photograph of Channel Provided Between Gabion Structure and the Kiwitea Stream (20 March 2019)

In order to define the roughness of the project area, New Zealand Land Cover Database version 4.1 (LCDBv4.1) was adopted. According to LCDBv4.1, the land cover of the project area is mainly grassland and it does not have information of local roads, hedges, trees and other hydraulic structures. Using aerial photographs, local features were included in the landcover layer (Figure 6), which was adopted to define the surface roughness in the model. The values of Manning's roughness coefficient (n) adopted for each land cover are provided below in Table 1, based on standard guidance (Auckland Council, 2011) and experience of similar systems.

Table 1: Manning's n for Different Land Covers

Land Cover Description	Manning's n
Road	0.014
Drop Structure	0.035
Grassland	0.05
Hedges	0.2
Trees	0.12

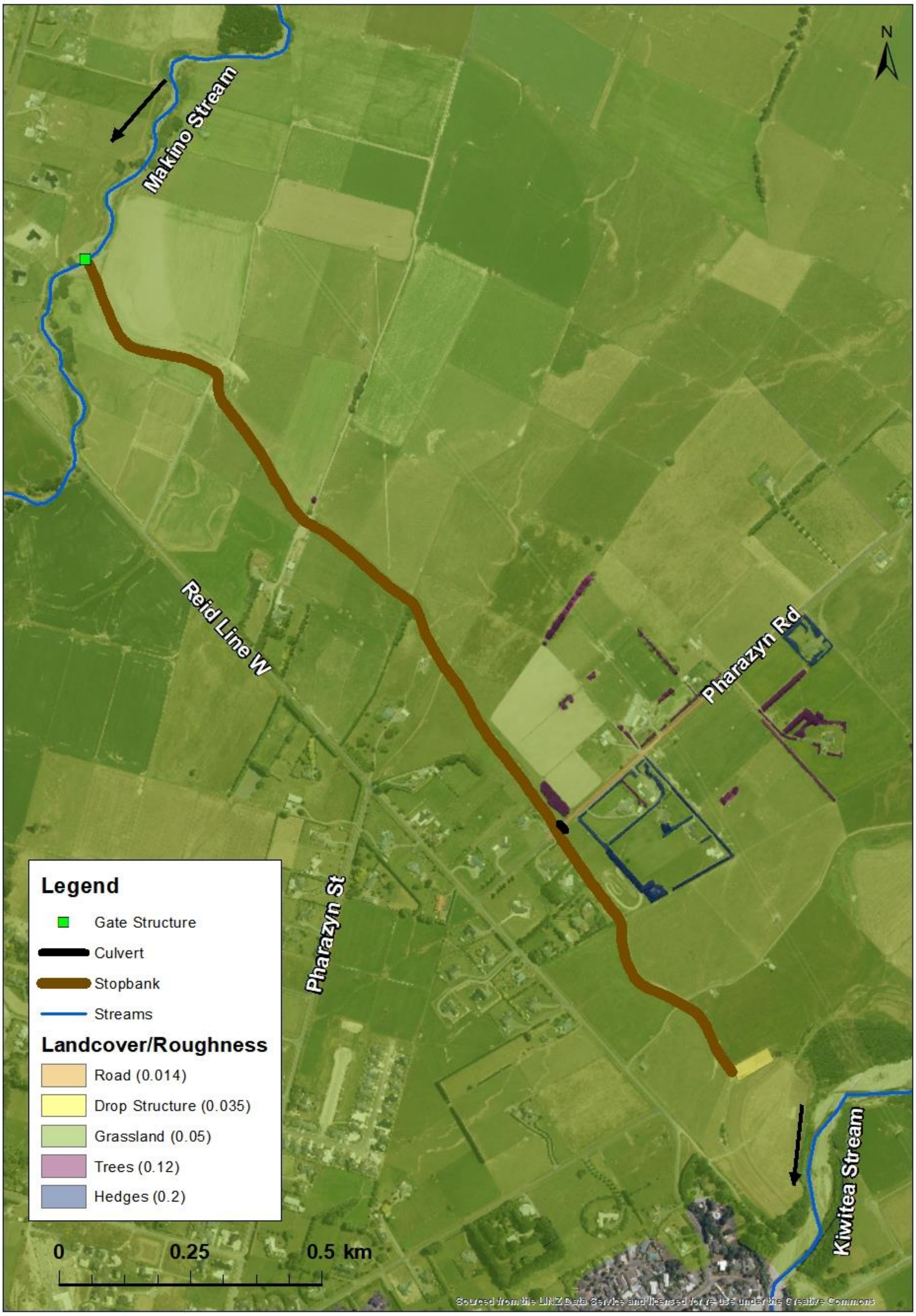

Figure 6: Updated Landcover of the Project Area

Flood hydrographs of 100 and 200 Year ARI events derived for different flow conditions were provided by HRC, which are shown below in Figure 7. The upstream boundary of the model was defined by using these hydrographs and the location where the flow is applied is shown in Figure 1. The flood hydrographs are briefly described below:

- Existing Design Flow – 100 and 200 Year ARI: The hydrographs of 100 and 200 Year ARI events derived for existing flow conditions represent the flow diverted towards the floodway from the Makino Stream with peak flows of 50 and 70 m^3/s respectively. These hydrographs are referred to in this memorandum as EDF100 and EDF200.

- Updated Design Flow – 200 Year ARI (UDF): The existing design flow hydrograph of 200 Year ARI event was updated by raising the peak flow from 70 to 120 m^3/s. It represents the flow diverted towards the floodway from the Makino Stream assuming no pass forward flow.

- Updated Design Flow with 20 m^3/s release in the Makino Stream – 200 Year ARI (UDFR): The updated design flow hydrograph of 200 Year ARI event was revised by considering 20 m^3/s release in the Makino Stream, which means 100 m^3/s flow to be diverted towards the floodway from the Makino Stream.

We understand that none of the flood hydrographs include an allowance for the effects of climate change on the flows in the Makino Stream.

A flood model representing the existing site conditions was developed and simulated using the hydrographs supplied by HRC.

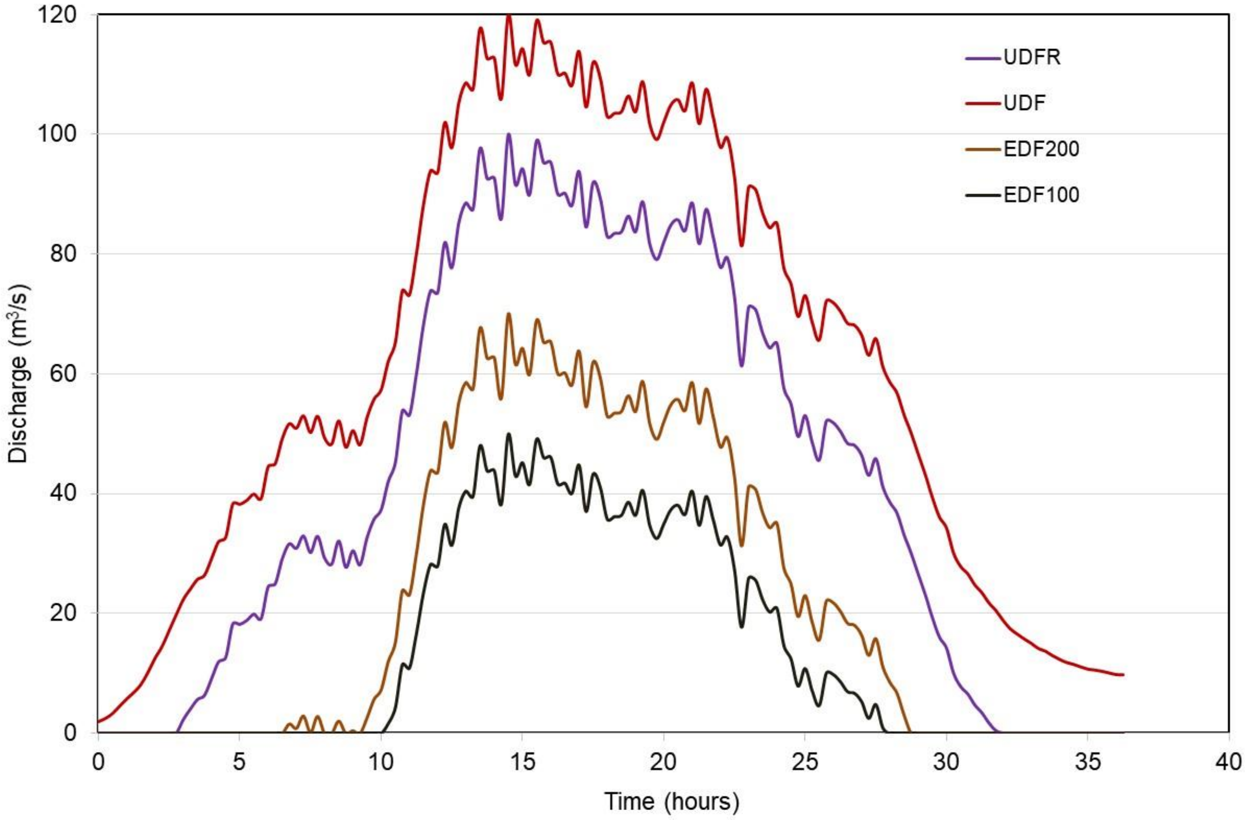

Figure 7: Hydrographs of 100 and 200 Year ARI Events Derived for Different Flow Conditions

4. Assumptions

The following assumptions were made to undertake this modelling work:

- The flows generated by minor streams between the Makino Stream and the Kiwitea Stream were not considered, since their contribution to the flood extents projected for 100 and 200 Year ARI events is likely to be small. Culverts provided under the stopbank at location of these minor streams were also not modelled, since these are closed during a flood event (see Figure 8).
- The pass-forward flow at the gate structure across Makino Stream towards the town of Feilding is not explicitly modelled.
- A normal depth tail water level condition were applied to the Kiwitea Stream.
- A “glass wall” approach was adopted to define the true right bank of Reid Line Floodway.

Figure 8: Photograph of Circular Conduit Provided across Stopbank taken from Upstream Right Side (20 March 2019)

5. Model Results

As a first step, the model results obtained for UDF (200 Year ARI event) were analysed to review the adequacy of the results to perform flood assessment along floodway because it produced worst flooding in the project area. One of the more critical locations along the floodway is gabion drop structure due to sudden drop of 5.3 m, where the flow is likely to be changed from sub-critical to super-critical. This structure will control water levels for some distance upstream. For this location, the stage – discharge curve projected by the 2D model was compared with the rating curve derived on the basis of a simple weir equation and the upstream cross-section.

Overall, the rating curves derived on the basis of model results and weir equation were found comparable (Figure 9), particularly at high flow. As a result of this comparison, it was found that the 2D representation of the drop structure is suitable to perform flood assessment along the floodway.

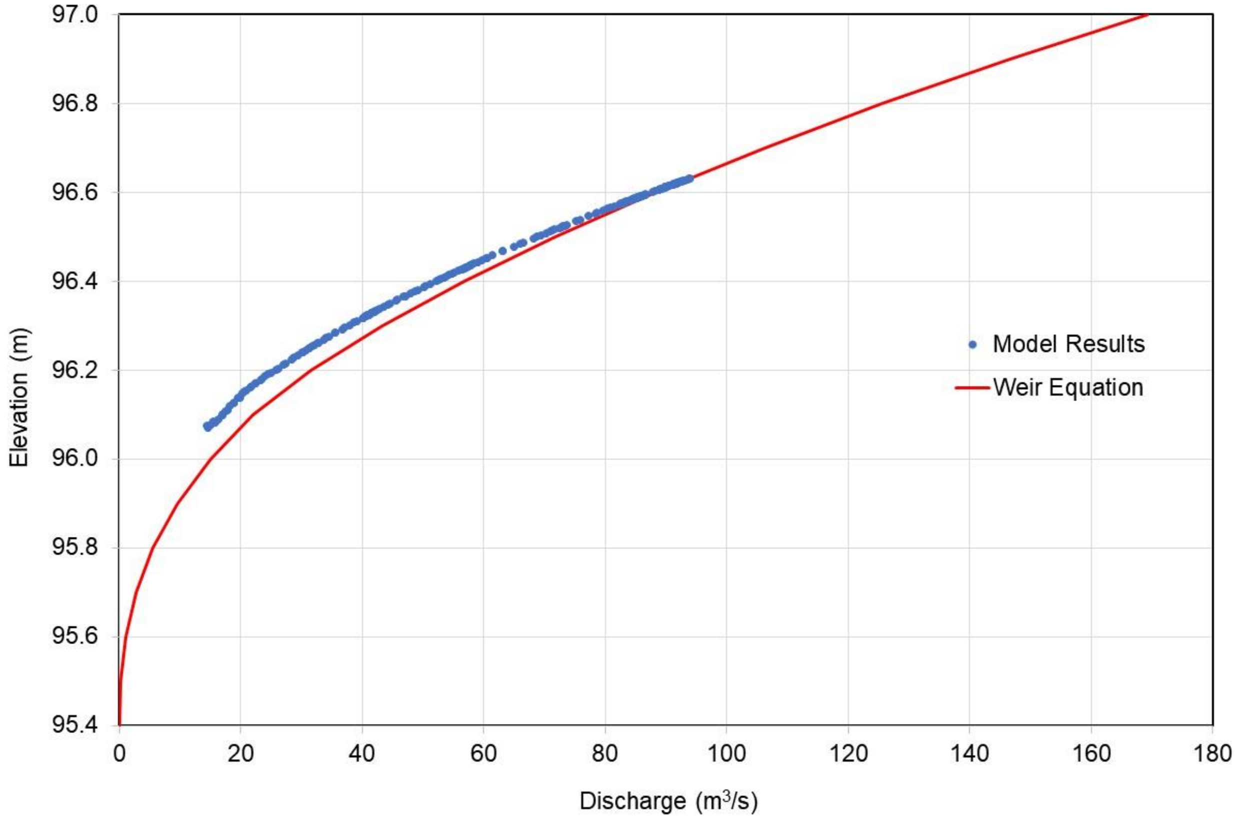

Figure 9: Comparison of Rating Curves of Drop Structure Derived by Using Weir Equation with Model Results

Likewise, a hydrograph extracted from the model results of UDF upstream of drop structure was compared with inflow hydrograph of the model (Figure 10). The results show that for a large flood event there is little attenuation of peak flow along the floodway due to the small storage volume relative to the flood flow. Water levels in the floodway are determined by the conveyance capacity.

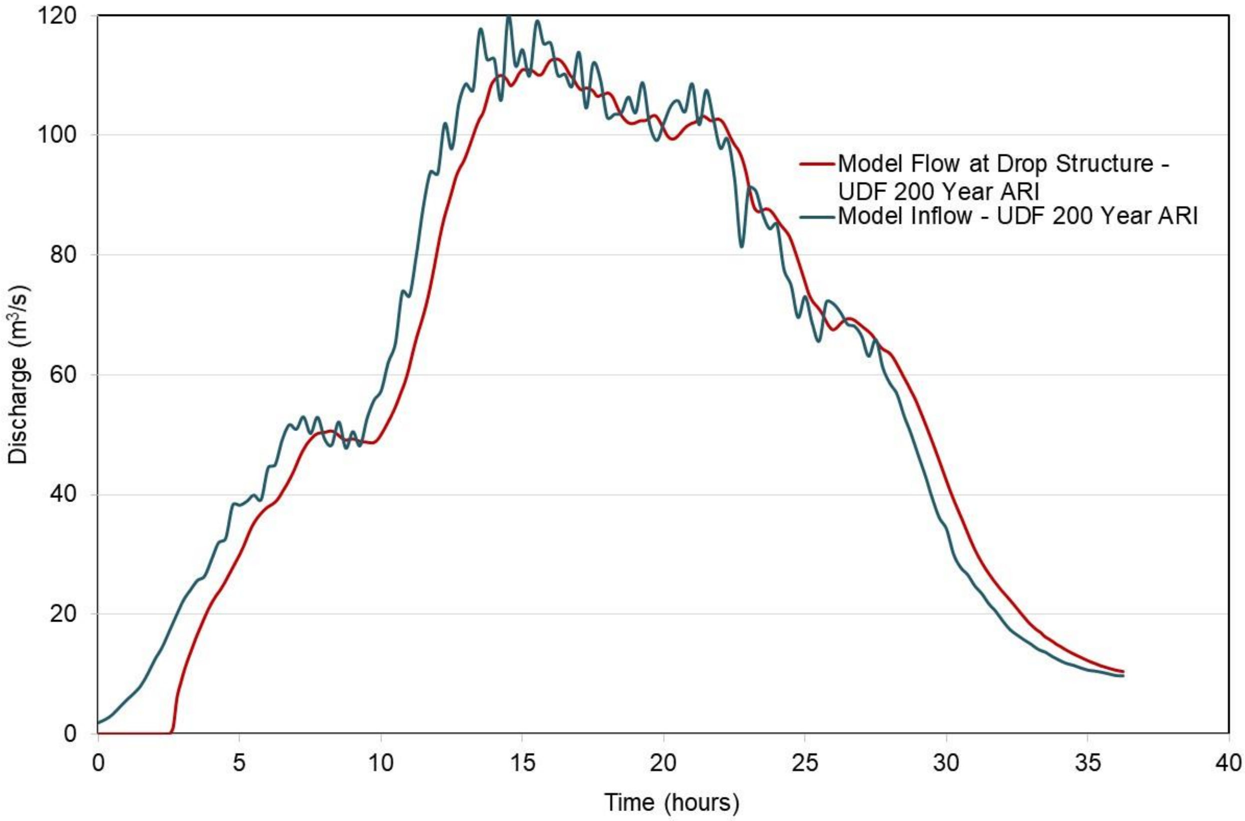

Figure 10: Comparison of UDF Hydrograph of 200 Year ARI event with Hydrograph Extracted from Model Results Upstream of Gabion Drop Structure

Since the height of the stopbank varies from 2.0 to 2.7 m, it is possible that the floodwater may overtop the stopbank in areas where the projected flow depths are above 2.0 m. In order to identify such locations, highest levels along stopbank crest were extracted from LiDAR derived DEM, which were compared with water levels estimated for UDF (Figure 11) because it projected worst flooding in the floodway. The results show that the floodwater overtop the stopbank upstream and downstream of Pharazyn Road (Figure 11). Due to uncertainty to the LiDAR data (± 200 mm is typical for such data), the results should be reviewed against ground based survey of the stopbank.

Figure 15 to Figure 18 show the flood extents of 100 and 200 Year ARI events projected for EFD100, EDF200, UDF and UDFR.

Model results show that the maximum flow through the Pharazyn Road culvert is 9.70 m^3/s, which is 8% of peak flow of 200 Year ARI event.

Downstream of drop structure, flood water inundated the area between the outlet channel and the Kiwitea Stream for EDF200, UDF and UDFR (Figure 16 to Figure 18), since the maximum flow depth attained (1.5 to 2.0 m) in this area for these scenarios was higher than left bank of the channel which is approximately 1.0 m high.

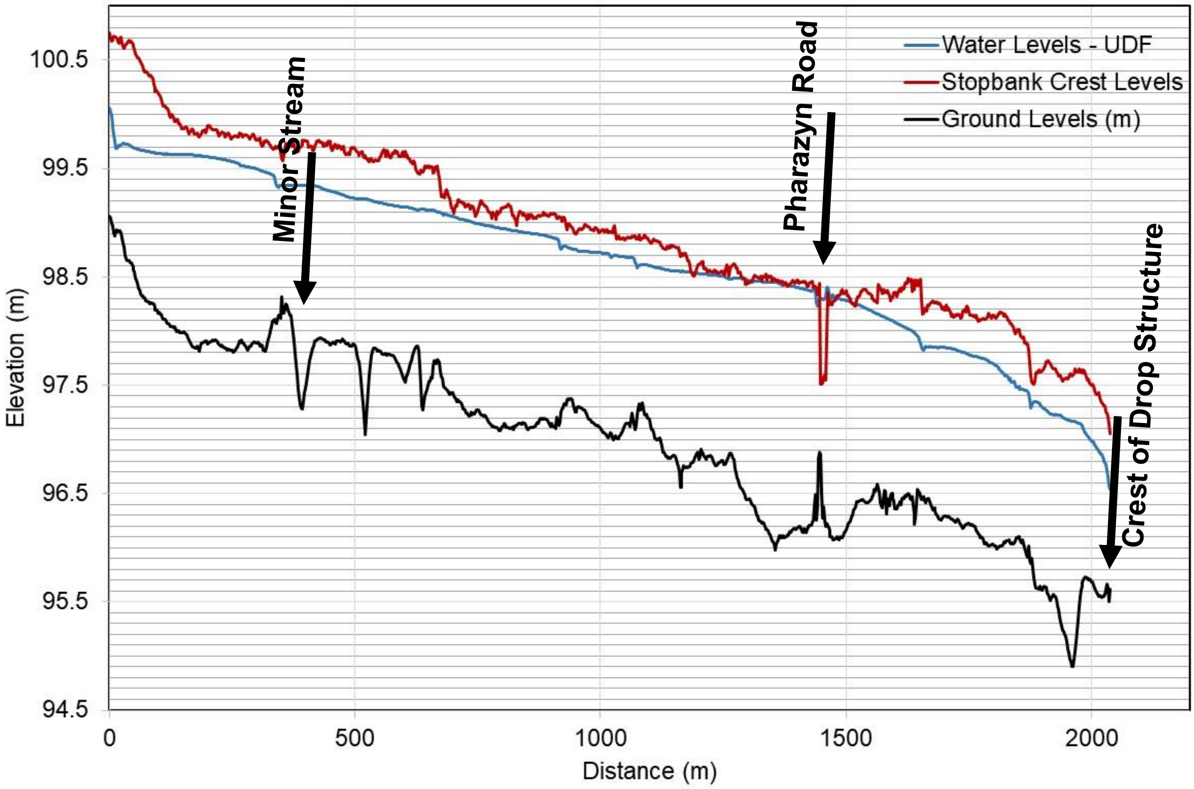

Figure 11: Comparison of Water Levels Projected for UDF in the Floodway with Stopbank Crest Levels (based on LiDAR DEM)

6. Modelling of a modified drop structure

6.1 Changes Introduced in the Model

The existing gabion drop structure in the model was replaced with a longer and less steep drop structure approximately 190m wide and 400m long (Figure 12 and Figure 13). In order to represent the modified drop structure in the model, the terrain was regraded over the length of the modified drop structure with the ground elevation gradually dropping from 97.0m to 91.3m with uniform gradient of approximately 1V:70H. Similar to modelling of the existing drop structure, the modified drop structure was also modelled in 2D using MIKE 21 software. The purpose of the modelling is to determine the effect of the modified drop structure on flood levels at Pharazyn Road and along the flood way generally.

A small area of the modified drop structure at its downstream end is outside the model extent (Figure 13), but omission of this portion from the model will not influence water levels in the flood way due to the gradient of the modified drop structure.

The surface roughness for the land where the new drop structure is proposed is the same value as adopted for the model representing existing site conditions.

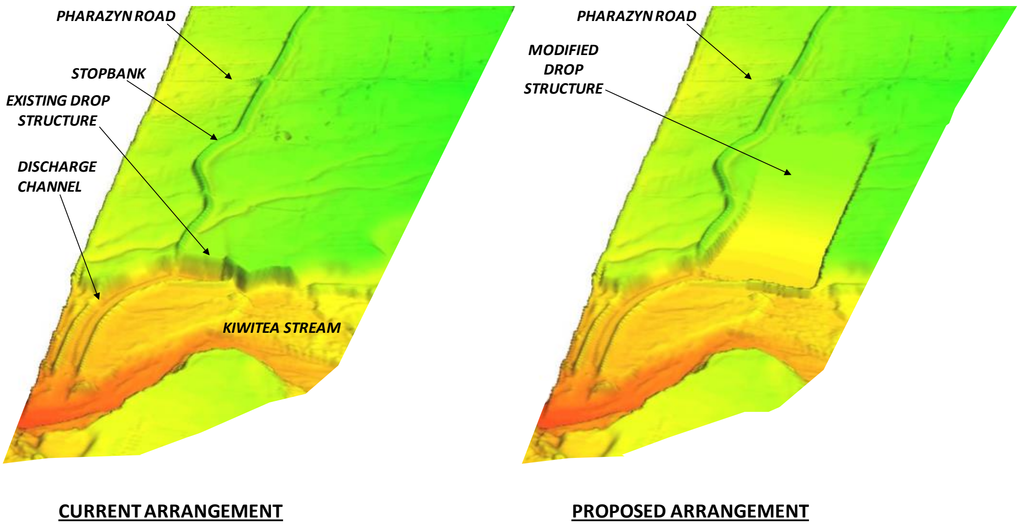

Figure 12: Existing and Modified Drop Structures

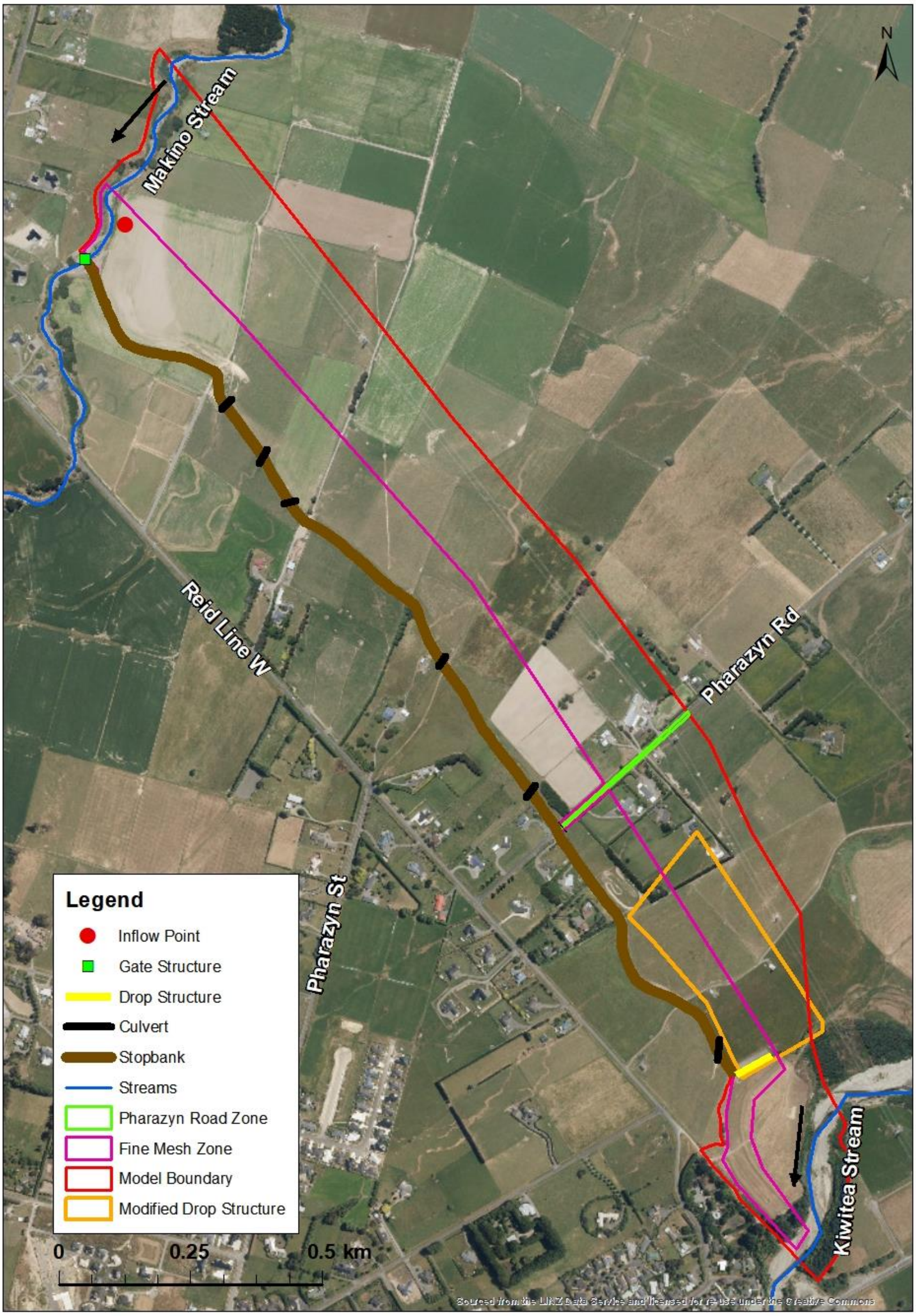

Figure 13: Location and Boundary of the Modified Drop Structure

6.2 Results

In order to assess the performance of the modified drop structure, a simulation of the 200 year Updated Design Flow (UDF) was performed with the updated model. The maximum water levels calculated for UDF in the floodway with the modified drop structure are compared with the water levels for UDF with existing drop structure (Figure 14 and Table 2). The results show that the modified drop structure decreases the water levels at Pharazyn Road, but the flood levels are well above the road crest level.

Figure 19 shows the flood extents for the UDF with the modified drop structure (i.e. the “proposed” scenario) and with the existing drop structure (i.e. the “existing” scenario). The results show that the modified drop structure would reduce flood extents by 5942 m^2 upstream of the modified drop structure. The total flood extent area is approximately 0.44 km^2.

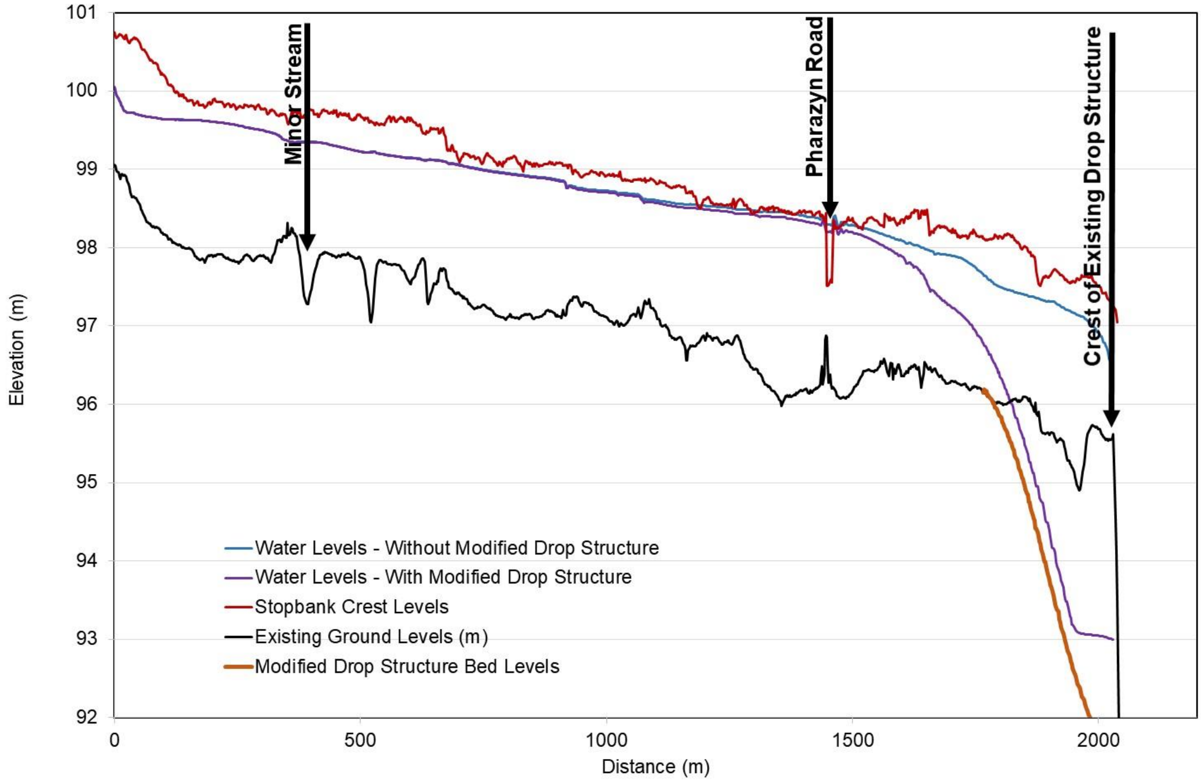

Figure 14: Comparison of Water Levels Projected for UDF in the Floodway with and without the modified drop structure

Table 2: Water Level Changes for the Modified Drop Structure

Chainage	Water Level (m RL)		Water Level Difference (m)
	Existing Scenario	Modified Drop Structure	
At 760 (where there is no effect)	98.98	98.98	0.00
1000	98.73	98.70	0.03

Chainage	Water Level (m RL)		Water Level Difference (m)
	Existing Scenario	Modified Drop Structure	
1200	98.53	98.49	0.04
1400	98.41	98.34	0.07
Pharazyn Road	98.29	98.20	0.09
1500	98.29	98.19	0.10
1600	98.09	97.89	0.20
1700	97.90	97.25	0.65
Top of the modified drop structure	97.66	96.79	0.87

7. Conclusions

In the light of results of this study, following conclusions have been made:

- The model is fit for purpose in accordance with our brief and scope.
- The current configuration of the Reids Line Floodway can convey up to the 200-year event flow as provided by Horizons Regional Council. Peak water levels for approximately 250m upstream of Pharazyn Road are at the stopbank crest level and the Pharazyn Road floodgate must be operating to prevent a spill.
- There are areas where the model can be improved to support and inform Horizons Regional Council's decision making around the future of the Reids Line Floodway. These include:
    - Considering changes to the design of the drop structure into the Kiwitea Stream. The modelling has shown, through the comparison of rating curves of drop structure (Figure 9) and flood hydrographs (Figure 10), that the modelling approach we used is suitable for performing flood assessment along the floodway.
    - Checking the impact of high tailwater levels in the Kiwitea Stream over the flood extents projected for the floodway.
    - Using a sensitivity analysis approach to study the variation in model results due to change in Manning's roughness coefficient.
    - Investigating changes to the configuration of the floodway, including allowing it to operate more frequently to reduce the flood risk to Feilding.
    - Reviewing the crest levels to identify the freeboard allowance provided by the existing stopbank crest
    - Reviewing the design event approach used to assess the performance of the floodway, including determining whether to include an allowance for the effects of climate change on the flow.
- The modelling results of the modified drop structure show that it will reduce flood levels at Pharazyn Road by approximately 0.09m in the 200-year event and will reduce the flood extent by 5942 m^2.

Figure 15: Flood Extents Projected for EDF100 of Reid Line Floodway

Figure 16: Flood Extents Projected for EDF200 of Reid Line Floodway

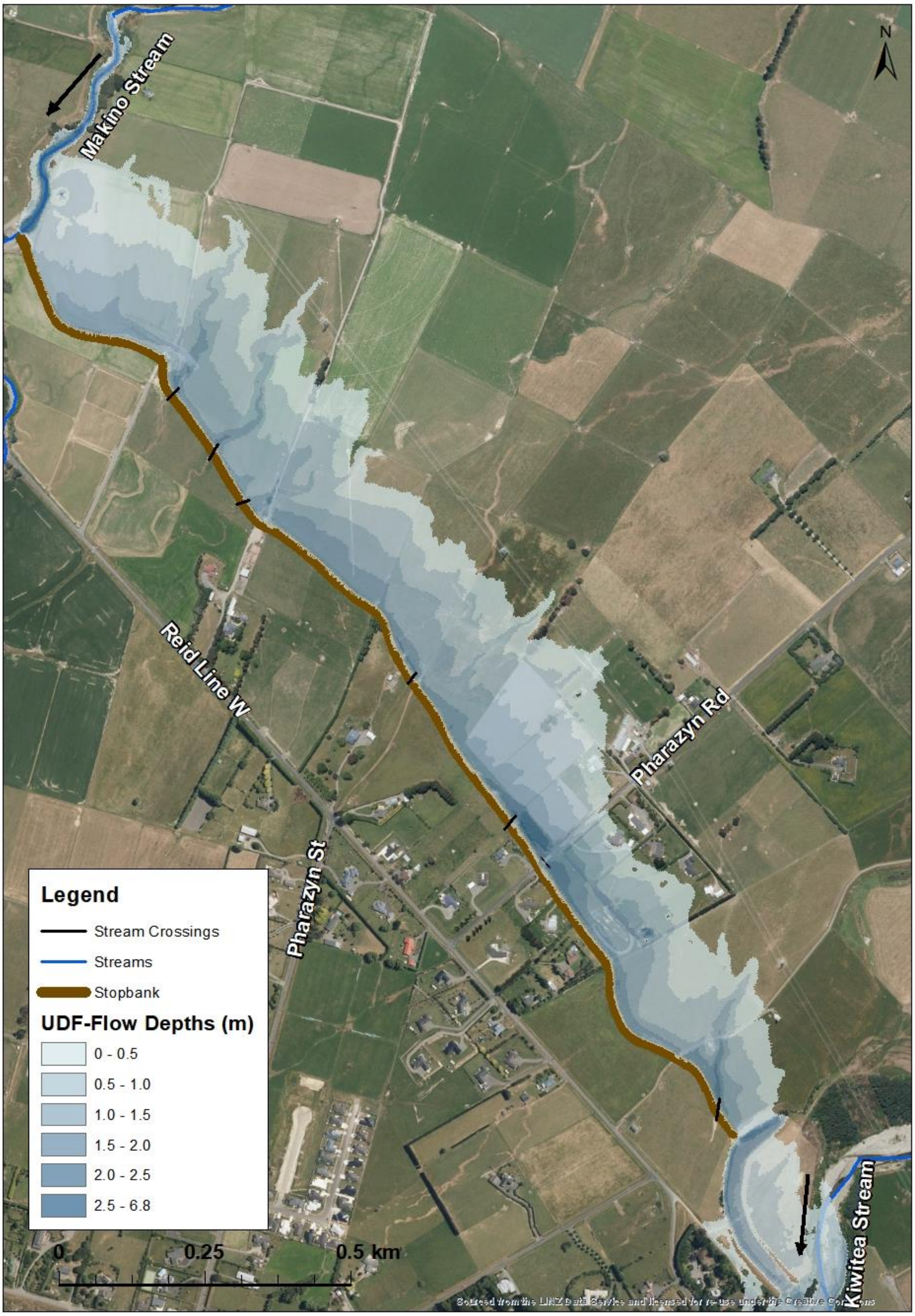

Figure 17: Flood Extents Projected for UDF of Reid Line Floodway

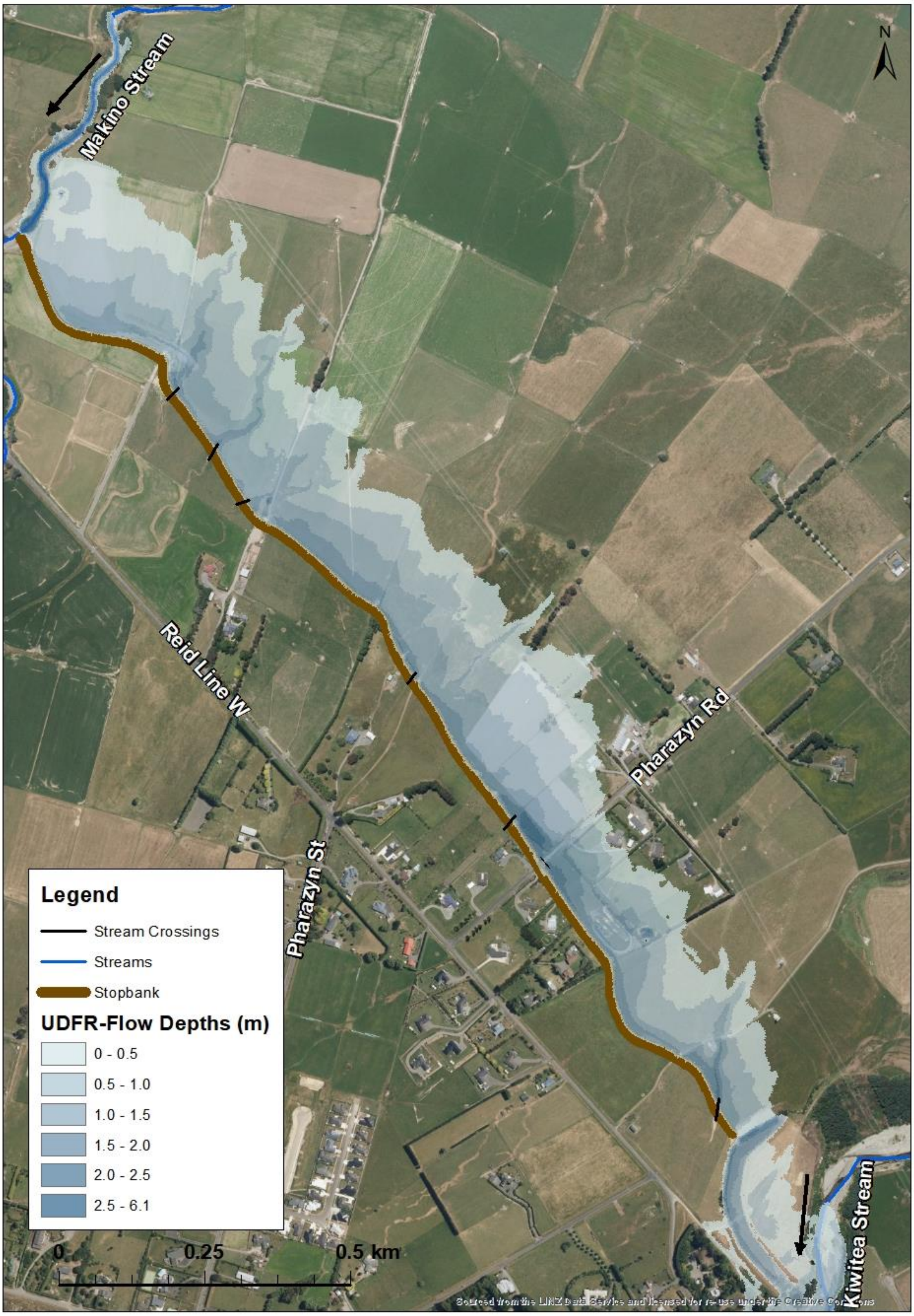

Figure 18: Flood Extents Projected for UDFR of Reid Line Floodway

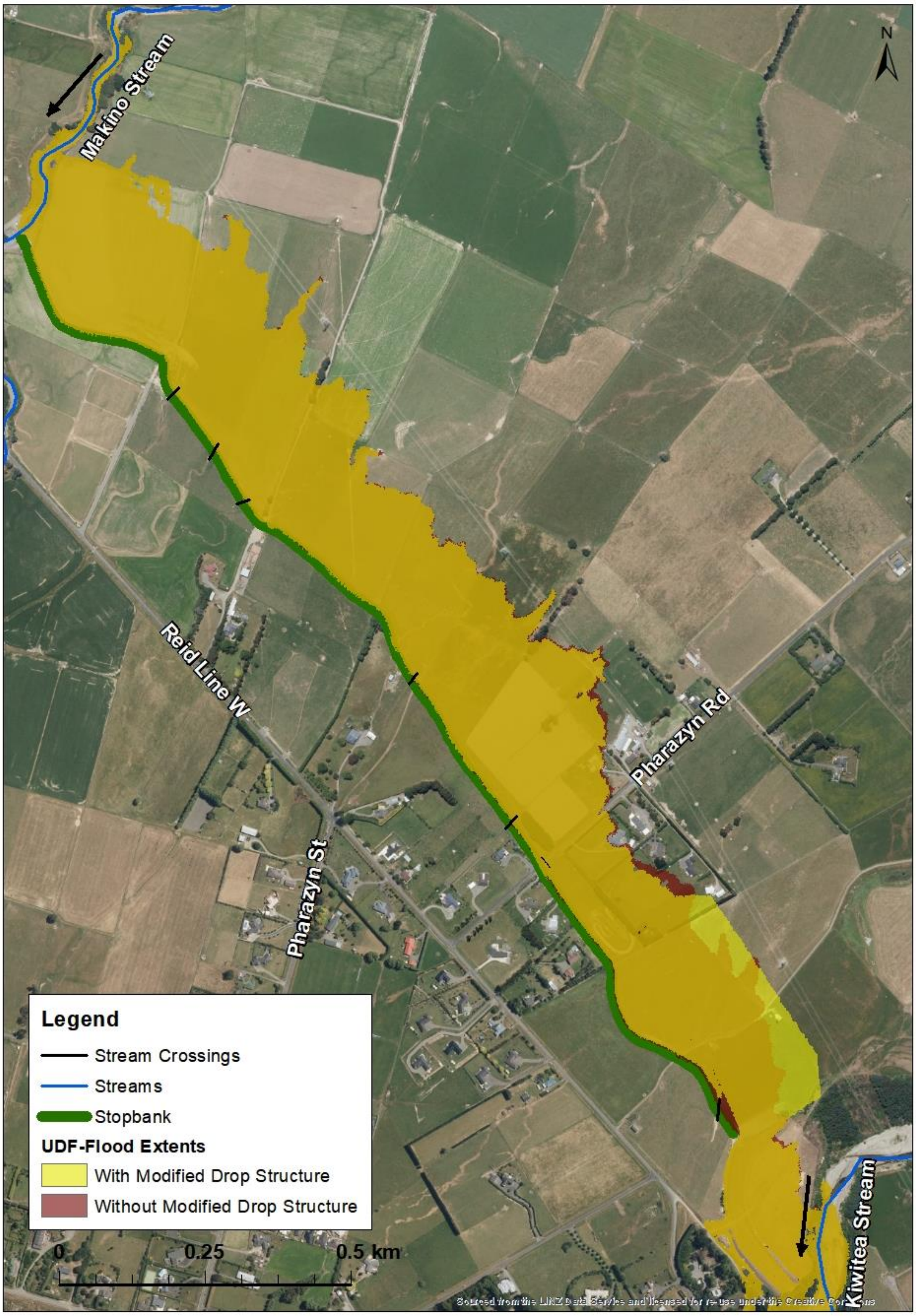

Figure 19: Comparison of Flood Extents Projected for UDF in the Floodway with and without the Modified Drop Structure

8. References

Auckland Council (2011) Stormwater Flood Modelling Specifications.

Land Cover Database v4.1 – Land Cover Database version 4.1, Mainland New Zealand. https://lris.scinfo.org.nz/layer/48423-lcdb-v41-land-cover-database-version-41-mainland-new-zealand/.