Before the Independent Hearings Panel
at Waimakariri District Council

under: the Resource Management Act 1991

in the matter of: Proposed private plan change RCP31 to the Operative Waimakariri District Plan

and: **Rolleston Industrial Developments Limited**
Applicant

Evidence of Ben Throssell

Dated: 6 July 2023

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EVIDENCE OF BEN THROSSELL

1 My full name is Benjamin Graham Throssell. I am a Senior Engineer with Pattle Delamore Partners Limited (*PDP*), an environmental consulting firm specialising in water matters.

2 I hold a Bachelor of Engineering (Hons) (Natural Resources Engineering) from the University of Canterbury. I have 12 years of experience specialising in water resources engineering, with particular expertise in assessing flood hazard and constructing 2D hydraulic models. I have prepared and presented expert evidence at Council hearings on flood hazard matters around the Waimakariri District and the wider Canterbury region.

CODE OF CONDUCT

3 Although this is not an Environment Court hearing, I note that in preparing my evidence I have reviewed the Code of Conduct for Expert Witnesses contained in Part 9 of the Environment Court Practice Note 2023. I have complied with it in preparing my evidence. I confirm that the issues addressed in this statement of evidence are within my area of expertise, except where relying on the opinion or evidence of other witnesses. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

SCOPE OF EVIDENCE

4 My evidence is presented on behalf of Rolleston Industrial Developments Limited, the Applicant in these proceedings.

5 I have been involved with the project since November 2021. My role has been to provide advice on the flood hazard and effects on flooding which may result from the proposed development. I prepared the report detailing my assessment of the likely effects of the proposed development on flooding dated June 2022 which was attached to the application for this plan change.

6 My evidence will cover:

6.1 A summary of my assessment methodology and further model updates;

6.2 Commentary on the flooding effects section of the Waimakariri District Council's (*WDC*) s 42A report;

6.3 Any relevant points in the submissions made on the application; and

6.4 The conclusions of my flooding assessment.

SUMMARY

7 I oversaw the construction of a flood model which has been employed to determine the effects of flooding from the proposed development for the 200-year flood event (the *PDP Model*).

8 I consider that enabling the conveyance of floodwaters through the site without diverting them to other locations will ensure off site effects are minimised. One way to achieve this is minimising development in areas where the existing conveyance of floodwaters is significant.

9 To assess the difference in flood elevations, I have taken all building footprints, not just habitable dwellings, and extracted the average water level over each footprint for both the post-developed and pre-developed water levels. I take the difference between these two water levels to be the effects on the building footprint.

10 The updated PDP Model has demonstrated that there is a viable subdivision layout which ensures the effects of the proposed subdivision on flood levels will not exceed 20 mm for any habitable dwelling. I consider this effect is less than minor.

11 I accept Mr Bacon's recommendation at his paragraph 19 on freeboard requirements for the proposed development. I understand the applicant has agreed to adopt this recommendation.

12 I conclude that Ōhoka is prone to low hazard flood events, similar to those experienced in June 2014 and July 2022. I note the magnitude of these events at Ōhoka was probably between a 10-year and 20-year event. The stormwater solution within the site will provide mitigation of any additional stormwater generated by the site for events of these magnitudes.

13 For more significant events, modelling of the 200-year event shows the flood hazard is still low for areas south of Mill Road/downstream of Whites Road and moderate for areas north of Mill Road. I note the PDP Model predicts limited increases greater than 10 mm for areas north of Mill Road and no increase greater than 20 mm for habitable dwellings elsewhere within the PDP Model.

METHODOLOGY AND MODELLING

14 I oversaw the development of a 2D hydraulic model prepared by PDP using Tuflow modelling software. The purpose of the PDP Model was to determine the effects of flooding as a result of any filling required to meet the minimum floor levels set for this site.

15 At its simplest, a hydraulic model consists of three components:

15.1 A digital terrain model, which represents the elevation surface of the land;

15.2 Boundary conditions, which control how water enters and exits the model domain; and

15.3 A roughness value which is used to represent the energy losses incurred by the free water surface. Energy losses can be thought of as the resistance incurred by the water surface, where higher resistance equates with greater energy losses and a higher roughness value. The roughness value is related to the surface type. For example, the free water surface will incur greater losses when flowing through dense vegetation compared to an asphalt surface.

16 The digital terrain model has been derived from LIDAR data. Since our June 2022 report, PDP has updated the PDP Model with the latest dataset available, the Canterbury LiDAR 1m DEM. This was captured between 1 May 2020 and 12 Nov 2020 and made available on 22 Nov 2022.

17 Upstream boundary conditions for the PDP Model were provided by WDC, extracted from the District Wide Model.

18 Roughness values have been set via inspection of aerial photographs, geospatial files and a site visit to determine surface type.

19 To determine the effects of the proposed development on flooding, the PDP Model was run with the existing environment (i.e. as it is currently). This scenario provides the baseline for which development effects could be compared against.

20 I ran additional post-development models with the proposed buildings and topographic modifications. The differences in flood elevations and velocities between this model and the pre-development scenario represents the effects of development on flooding.

21 Since my 2022 report, we have made further refinements to the subdivision layout and model build which are detailed in the following section.

FLOOD MODEL UPDATES

22 The key changes to the PDP Model since our June 2022 report are:

23 Changes to the subdivision layout, which demonstrate that further mitigation of flood effects can be achieved. PDP modified the subdivision layout to optimise the conveyance of existing

floodwater. **Attachment 1** shows the main hydraulic improvements that have been made to the PDP Model. Key features are:

23.1 Post-development conveyance through the Ōhoka Stream matching pre-development conveyance. This ensures that water is not transported through the proposed development at a quicker rate;

23.2 A building set-back of 15 m from the northern corner of the subdivision. This ensures that existing overland flow/conveyance is maintained;

23.3 Along Whites Rd, a building set-back of at least 15 m is required to help balance conveyance in a flood event;

23.4 Minimise development adjacent to the Ōhoka Stream, particularly at the upstream boundary adjacent to Bradleys Rd; and

23.5 Stormwater attenuation areas have also been included in the PDP Model. These have been blocked out of the PDP Model to ensure attenuation volumes are available for stormwater generated by the proposed development and not filled by external floodwater entering the site via Ōhoka Stream or similar.

24 Employment of an updated LIDAR surface that was not available at the time of our original modelling exercise.

25 Rainfall has been added to the internal PDP Model area, the previous PDP Model only considered external flow into the area of interest and the effects of floodplain displacement due to filling to meet minimum floor level requirements. The updated PDP Model now incorporates both the effects of floodplain displacement and the effects of increased run-off due to an increase in impervious cover.

26 An infiltration component was also added to the PDP Model. For impervious areas, an infiltration rate of zero has been applied.

27 I note there is always uncertainty associated with selecting an appropriate infiltration rate for pervious areas and therefore we have run two models in parallel, one with a low infiltration rate and one with a high infiltration rate. This provides an envelope of effects and determines the sensitivity of the PDP Model to this assumption.

28 I note that a lower infiltration rate will produce more run-off and vice versa. When considering effects on flooding due to development, the infiltration rate for pervious areas determines the difference in run-off produced. A higher infiltration rate will produce

a greater difference in flow pre and post development and I consider a higher rate is likely to provide a conservative estimate of effects.

29 I have selected a lower infiltration rate which matches the ultimate rate specified in the District Wide Model which. For Ōhoka, this is DRAINAGE 1 class (DHI, 2020)[1], 1.67 mm/hr.

30 To determine an upper infiltration rate, I present **Attachment 2** and **Attachment 3** which, for the Cust River catchment, show the proportion of rainfall which became runoff for the July 2022 and June 2014 flood events (discussed in further detail below). These attachments show that for both these flood events, rainfall intensities did not exceed 8 mm/hr and the percentage of rainfall than became runoff is between 45 and 49%.

31 If infiltration rates were 8 mm/hr, then no runoff for either the 2014 or 2022 events would have been observed. An infiltration rate of 4 mm/hr assumes that, for a rainfall intensity of 8 mm/hr, 50% of the rainfall will become runoff.

32 Therefore, I select an infiltration rate of 5 mm/hr and I consider this is a conservatively high rate for the following reasons:

32.1 Observed data for the Cust River tells us the runoff ratio is higher than 0.375 (5/8 = 0.375) and therefore infiltration rates are lower;

32.2 The ECan soils layer[2] shows that soils within the Cust River catchment are better drained (have higher infiltration rates) when compared to the proposed subdivision area which is classed as poorly drained. This indicates that infiltration rates for the proposed subdivision are likely to be lower when compared to the Cust River catchment; and

32.3 Rainfall intensities in 2014 and 2022 are generally less than 8 mm/hr, therefore comparing infiltration rates to this intensity is conservative.

WDC DISTRICT WIDE MODEL

33 The WDC District Wide Model (the *District Wide Model*) is a separate flood model constructed by DHI on behalf of WDC. It was most recently updated in 2021. This flood model aims to provide flood

[1] DHI. (2020). Flood Hazard Models Update District and Urban and MIKE FLOOD models. Waimakariri District Council

[2] https://gis.ecan.govt.nz/arcgis/rest/services/Public/Landcare_SMap_Layers/MapServer

hazard predictions for the entire Waimakariri District for the 100-year, 200-year and 500-year flood events.

34 PDP have adopted the hydrological assumptions made in the District Wide Model and applied them to the PDP Model. Boundary conditions for the PDP Model are required upstream of Bradleys Road. These boundary conditions specify how much flow enters the PDP Model. These flows have been provided by WDC who have extracted the flows from the District Wide Model.

35 It is worth considering the accuracy and/or conservatism of these hydrological parameters which have been imported from the District Wide Model.

36 The District Wide Model employs a rain on grid approach which is influenced by rainfall depth, infiltration, roughness and terrain assumptions.

37 Regarding rainfall assumptions in the District Wide Model, DHI (2020)[3] reports:

> "*The district flood hazard models all employ a 24 hour nested storm event. The nested storm approach is used in the flood hazard models due to the long model run times and the need to manage the number of simulation runs. The nested storm is created using the 'Alternating Block Method' and is constructed using rainfall depths from the 1, 3, 6, 9, 12, 18 and 24 hour storm events. The profile features 24 equally distributed time steps. The 24 hour storm was selected as this is approximately the critical time of concentration for the coastal parts of the district from rainfall originating in the foothills behind Oxford and Okuku*."

38 On climate change, DHI (2020) reports:

> "*For stormwater and flood modelling WDC uses the RCP8.5 emissions scenario for the period 2081 – 2100 (80 year projection). This is consistent with MfE guidance around long life infrastructure assets. The rainfall projections for RCP8.5 are included in the HIRDS4 output.*"

39 Therefore, by adopting the District Wide Model hydrology, I conclude our modelled scenarios include climate change, specifically RCP (Representative Concentration Pathway) 8.5 2081-2100.

[3] https://openmaps.waimakariri.govt.nz/HazardsReports/DistrictFloodMappingDHI.pdf

40 Turning to the validation of the District Wide Model, DHI (2020) report there is limited opportunity for validation or calibration of this District Wide Model. DHI report:

> *"The MIKE 21 model results for a 1 in 100 year event give a peak flow of 910m³/s at the Fox Creek Okuku gauge, Figure 3-6. This is around double the flow estimated using frequency analysis, indicating that the infiltration rates may be too conservative in the hillside areas. However, given the uncertainties involved in the flood frequency analysis, it is difficult to determine by how much"*
>
> Further:
>
> *"Despite the potential overestimation of flow, it is believed that the model is still performing better in this area than in the earlier modelling".*

41 Whilst the hill catchments are not of particular relevance to our area of interest (Ōhoka), this validation shows that District Wide Model appears to be conservative in its uncertainty. That is, runoff is likely overestimated rather than underestimated for hill catchments.

42 As no model validation information specific to Ōhoka is presented for the District Wide Model, I have compared the flow predictions made by the District Wide Model with design flood estimates provided by Tonkin and Taylor (2017)[4].

43 The Tonkin and Taylor study was commissioned by ECan to provide flood estimates for 42 sites on selected Canterbury Rivers including the Ōhoka Stream. This report provides the most up to date and comprehensive review of available historical flood studies including McKerchar and Pearson[5] (1989), NIWA[6] (2011), Tomlinson[7] (1980) and HIRDS V3[8].

44 I understand[9] that ECan is currently in the process of updating many of the sites presented in this Tonkin and Taylor study although the

[4] Tonkin and Taylor (2017). Flood frequency analysis for Canterbury Rivers. Environment Canterbury, Christchurch.

[5] McKerchar, A.I. and Pearson, C.P., (1989). Flood Frequency in New Zealand. Publication No, 20 of the Hydrology Centre, Christchurch.

[6] NIWA (2011). Review of flood frequency in the Canterbury region. Report R11/50, August 2011.t

[7] Tomlinson, A.I. (1980). The frequency of high intensity rainfall. Part 1. Soil Water Rach Publ No. 19. Ministry of Works and Development Christchurch

[8] Thompson C (2011). HIRDS. V3: High Intensity Rainfall Design System – The method underpinning the development of regional frequency analysis of extreme rainfalls for New Zealand

[9] Email correspondence between Michelle Wild (ECan) and Ben Throssell (PDP) on 16 June 2023

Ōhoka Stream will not be included in this update. At the time of preparing my evidence, the updated ECan report was still under review. Therefore, I consider the Tonkin and Taylor (2017) report provides the best available estimates on design flows.

45 For the Ōhoka Stream at Cust Main Drain confluence, Tonkin and Taylor (2017) adopt the following flows (with no allowance for climate change) of:

45.1 60 m^3/s for the 100-year event;

45.2 70 m^3/s for the 200-year event;

45.3 80 m^3/s for the 500-year event;

46 For comparison, at the same location, the District Wide Model predicts flows of:

46.1 100 m^3/s for the 100-year event;

46.2 160 m^3/s for the 200-year event;

46.3 240 m^3/s for the 500-year event;

47 I note the Tonkin and Taylor (2017) estimates do not include climate change. The increase in the 24-hour rainfall depth, out to 2081-2100 for RCP 8.5, is 22% (NIWA, 2023)[10]. For the 6 hour event, which is more relevant to the Ōhoka Stream as the time of concentration is likely to be closer to six hours, the increase in rainfall for the same period is 30%. I note that flow response to rainfall is non-linear, that is, a 10% increase in rainfall will not necessarily result in a 10% increase in flow. Further, the flow response typically exceeds the rainfall response.

48 The District Wide Model gives us an indication as to how flow increases will respond to rainfall increases. When comparing the 100-year, 200-year and 500-year events supplied by the District Wide Model, every percentage increase in rainfall results in a 2.2% increase in flow. Therefore, a 30% increase in rainfall depth will likely generate a 66% increase in flow. Applying this adjustment factor to the Tonkin and Taylor (2017) flow estimates gives:

48.1 100 m^3/s for the 100-year event;

48.2 116 m^3/s for the 200-year event;

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[10] NIWA. (2023). High Intensity Rainfall Design System v4. Retrieved June 13, 2023, from NIWA: https://hirds.niwa.co.nz/

48.3 133 m³/s for the 500-year event;

49 Therefore, I conclude the hydrological inputs which have been derived from the District Wide Model (as per paragraph 32) are likely conservative for the 200-year and 500-year events.

SECTON 42A REPORT

50 The S 42A report summarises Mr Bacon's evidence as follows:

> *"Mr Bacon considers that the increase in flood depth needs to be further assessed to demonstrate there are no adverse off-site effects, and all effects of the development in the 0.5% AEP event can be fully mitigated, and any remaining effects demonstrated to be less than minor to ensure existing dwellings are not adversely impacted by the development. He considers that there is a risk there is no practical mitigation able to be identified at resource consent stage which can be implemented to protect the affected properties and that it would be helpful to understand the types of mitigation measure the Applicant could put forward to manage increased flood effects on offsite dwellings"*

51 Mr Bacon states in his evidence concludes:

> *"Overall the modelling work done by PDP is reasonable, but the results do raise some concerns and anecdotal evidence from submitters should be assessed by the Applicant."*

52 Mr Bacon also states in his evidence:

> *"Turning to the model results first, the modelling shows some existing dwellings have an increase in flood depth in the 0.5% event of 45mm. The report does not state whether or not this effect is reasonable or less than minor; at this stage it has simply identified the problem. The existing 200-year (0.5%) flood hazard applicable to each of these affected properties needs to be confirmed (i.e. low or medium), as this will dictate the freeboard those properties should retain post-development. For example, if a property is in a medium hazard area, unless the existing FFL of that dwellings is already more than 545mm above the 0.5% event this will not be acceptable, as it needs a freeboard of 500mm above the 0.5% flood level to protect residents and property."*

53 I note this requirement and address it when presenting the updated PDP Model results below.

54 I accept Mr Bacon's statement at his paragraph 17 that further modelling will be required at the subdivision consent application

stage to determine floor levels and road levels and ensure that all weather access can be maintained to the residential dwellings in a 2% AEP event.

55 I accept Mr Bacon's recommendation at his paragraph 19 on freeboard requirements for the proposed development. I understand the applicant has agreed to adopt this recommendation.

56 Turning to Mr Bacon's final recommendation at his paragraph 20 on additional mitigation of flooding and demonstrating effects to offsite dwellings are less than minor. I address the effects in the section below and I have described one option for additional mitigation that can be implemented. Specifically, minimising development in areas of significant floodwater conveyance.

SUBMITTERS

57 Floodings is recognised as an area of concern for submitters. I identified approximately 195 submissions that express concern about flooding. Of these, I found that 46 submitters stated their property had flooded recently, generally because of either the June 2014 or July 2022 flood events which I discuss below. Of these 46, I identified five submitters[11] who noted flooding within a garage, shed or building on either their property or a neighbours' property.

58 Some submitters[12] state that climate change effects are not accounted for in the PDP Model. We have adopted the District Wide Model flows in the latest model updated (the result of which are set out below) which include an allowance for climate change out to 2081 to 2100 using the RCP 8.5 model.

59 Some submitters[13] asked what the effects or displacement effects are downstream of Whites Road. This is the purpose of our flood hazard investigation and the updated effects are presented in my evidence below.

60 Submitters[14] mention the limitations of the PDP Model. To clarify some of our limitations, the PDP Model relies on flows generated by the District Wide Model. I address the assumptions and limitation of this model above. Overall, I conclude that the flows and flood levels presented in the District Wide Model are likely to be conservative (higher than expected) for the 200-year event and I make the same conclusion for the PDP Model and my own assessment.

[11] Simmonds A (103.1), Leggett M. T. (223.26), Low E. (377.1), Lake P. (381.1), Low R (452.1), and Killner N. (634.1)

[12] Wilsons Rd Residents, Myall D., Wood N.

[13] J W Docherty, Morton B.

[14] J W Docherty, Docherty C.

61 A number of submitters[15] note that tidal effects are not accounted for in this hydraulic model or raised the impacts of the tidal influence on streams that feed into the Kaiapoi River. Tidal effects have no impact on water levels at the modelled location, it is too far upstream. The land elevation at the proposed development location is between 22 m and 24 m above mean sea level. The downstream boundary of the PDP Model (Jacksons Road) is around 12 m above mean sea level. SeaRise[16] provides the most up to date information regarding sea level rise and vertical land movement. For 2120, RCP 8.5, SeaRise predicts an increase in sea level of 1.42 m. Even for this sea level rise scenario, backwater effects from an increased downstream boundary condition will not impact the results presented in the PDP Model.

62 Submitters[17] correctly note that the PDP Model is uncalibrated. However, the purpose of the PDP Model is to investigate the effects of flooding rather than determine an absolute water level. This distinction is critical. When looking at what the effects are, only one parameter is changed, in this instance, the proposed subdivision. All other parameters remain the same. Therefore, for the purposes for which it has been employed, determining effects on flooding, I consider the PDP Model is appropriate and is used as such for plan changes like this one all around the country.

63 A number of submitters[18] point out the need to consider a range of events, not just the 200-year event. I agree this should be addressed and can be addressed at the consenting stage, which is typical.

64 Submitters[19] note the impact that high groundwater and springs have on flooding at this location. I note the resolution of the PDP Model is 2 m, this means that the PDP Model employs one elevation for every four square meters of area. Therefore, small drains and streams are effectively modelled as blocked due to the model resolution. This modelling approach is comparable to modelling high groundwater and/or springs occupying the conveyance capacity of these drains. Further, I note the sum of flows south of Mill Rd total 53 m^3/s for the 200-year event whilst the sum of flows between Mill Rd and Cust Main Drain (which is north of the plan change site) are in excess of 100 m^3/s. Therefore, I expect these flows to be significantly greater than any groundwater or spring flows that may be experienced and flood levels in a 200-year event will be

[15] Wilsons Rd Residents, Docherty C.

[16] https://www.searise.nz/

[17] Myall D.

[18] Nikloff A., ECan.

[19] ECan.

dominated by these surface flow effects rather than groundwater and spring effects.

65 Many submitters[20] provided photos of the June 2014 event and July 2022 events, some of the larger recent events in the area. Submitters[21] have also queried the return period of the 2014 and 2022 flood events which resulted in flooding around Ōhoka. The return periods of these events provide an indication of when flooding may be expected to occur. I address this in the following sections.

July 2022 Flood Event

66 NIWA, in their monthly climate summary, reported[22]:

> *"On 11-12 July an atmospheric river of moisture brought heavy rain and strong winds large parts of the North Island and northern and eastern parts of the South Island."*

67 NIWA also reported in the same monthly climate summary that Christchurch in July 2022:

> *"was the wettest month (of any month) on record. The 310 mm of rain recorded there was the first time that more than 300 mm of rain was observed in one month since records began in 1863. This represents around half of the rain that Christchurch typically receives over the course of one year."*

68 Closer to Ōhoka, rainfall depths for the 12 July event were remarkably consistent across the district, around 70 to 80 mm of total rainfall for recorders across the Waimakariri District. A summary of rainfall and flow recorded in the nearby Cust River is presented in **Attachment 2**. This attachment shows the Cust River recorder a peak flow of just over 100 m^3/s, a total rainfall depth of 70 mm and maximum intensity of 7.5 mm/hr.

69 Analysis of the Ōhoka Rainfall recorder which has sub-daily rainfall data shows a maximum depth of:

69.1 34.8 mm was recorded over a six-hour duration, about a 5-year event (36.6 mm) according to HIRDS V4;

[20] J W Docherty, Hurley L. & Stephen C., Marsden A., Mr PG and MRS M Driver, Foy R. Wilsons Rd Residents, Myall D., Wood N.

[21] J W Docherty.

[22] https://niwa.co.nz/sites/niwa.co.nz/files/Climate_Summary_July_2022_Final-v3.pdf

69.2 a maximum depth of 61.8 mm was recorded over a 12-hour duration, about a 10-year event (62 mm) according to HIRDS V4, and,

69.3 a maximum depth of 76.4 mm was recorded over a 24-hour hour duration, between a 5-year (69.5 mm) to 10-year (83.5 mm) event according to HIRDS V4.

70 Therefore, I conclude that the 12 July 2022 rainfall event had a return period of between five and ten years although at this stage I note that this does not necessarily mean the flood event and water levels at Ōhoka also had a return period of between five and ten years. As noted above, rainfall and flow response are non-linear.

71 ECan maintain a rated flow recorder at the nearby Cust Main Drain (Threlkelds Road). Rated flow and gauging data provided by Tony Gray (Ecan)[23] shows that:

71.1 The recorder has 37 full years of data, from 1981 to 1986 and 1992 to the present day. There is a gap in the data from 1986 to 1992; and,

71.2 The largest rated flow is 117.009 m^3/s on 6 August 1995, very similar to the recorded peak for the 10 June 2014 event (115.634 m^3/s) and the 12 July 2022 event (103.501 m^3/s).

72 I have conducted a standard flood frequency analysis by fitting a Gumbel distribution to the annual maxima recorded for the Cust River. This allows me to estimate the return period of historical flood events. For context, my assessment predicts a 10-year flow of 84 m^3/s and 20-year flow of 102 m^3/s. Ecan report[24] a 10-year flow of 90 m^3/s for the same recorder. The flow recorded in Cust River for the July 2022 event peaked at 103.501 m^3/s. My flood frequency analysis shows that this flow has a return period of 20 years (102 m^3/s).

73 Ultimately, we are interested in the return period of flood elevations which are a function of both rainfall and the antecedent conditions. I note this event occurred in winter and there was rainfall in the preceding days. Over the preceding four days, the Ōhoka recorder shows 13.5 mm, Threlkelds Rd shows 13.5 mm and Poyntzs Rd shows 30.5 mm. Therefore, I consider the return period of this flood event, for Ōhoka, was likely between 10 and 20 years.

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[23] Email from Tony Gray (ECan) to Ben Throssell (PDP) on 23 May 2023

[24] https://www.ecan.govt.nz/data/riverflow/

June 2014 Flood Event

74 The NIWA weather catalogue[25] reports that the 9-10 June 2014 event was due to a slow-moving high which pushed cold air onto the south island. This column air clashed with a warmer north-easterly over North Canterbury resulting in heavy rain. The NIWA weather catalogue reports that:

> *"23 elderly dementia patients were evacuated from their rest home after it was flooded. Rangiora High School was closed due to flooding"*

75 A summary of rainfall and flow recorded in the nearby Cust River is presented in **Attachment 3**. This attachment shows the Cust River recorded a peak flow of almost 120 m³/s and a total rainfall depth of 144 mm and maximum intensity of 7.5 mm/hr.

76 The Ōhoka rainfall recorder was not operative at this time and therefore, I have relied on the Cust recorder[26] (at Thelkelds Rd) to determine sub-hourly rainfall data:

76.1 40.0 mm was recorded over a six-hour duration, between a 5-year (36.6 mm) and 10-year (44.6 mm) event according to HIRDS V4;

76.2 a maximum depth of 72.0 mm was recorded over a 12-hour duration, about a 20-year event (73.4 mm) according to HIRDS V4, and,

76.3 a maximum depth of 114.0 mm was recorded over a 24-hour duration, exactly a 40-year (114 mm) event according to HIRDS V4.

77 The flow recorded in Cust River peaked at 115.634 m³/s. My flood frequency analysis shows that this flow has a return period of somewhere between 20 years (102 m³/s) and 50 years (125 m³/s).

78 Therefore, I consider the return period of this flood event for Ōhoka was likely around 20 years.

79 I consider that both the June 2014 and July 2022 flood events had return periods of around ten to twenty years, certainly less than a 50-year event. The stormwater solution (see evidence by **Mr. Eoghan O'Neill**) for the plan change site provides stormwater mitigation for up to, the 50-year event with the appropriate allowance for climate change. Therefore, I consider that the type of

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[25] https://hwe.niwa.co.nz/event/June_2014_New_Zealand_Storm

[26] Supplied by Tony Gray (ECan) to Ben Throssell (PDP) on 15 June 2023

flooding experienced by residents in June 2014 and July 2022 will be mitigated as described by **Mr. O'Neill**.

MODEL RESULTS

80 In this section, I will cover the effects from flooding on freeboard for off-site dwellings and the effects on flood levels for off-site dwellings.

81 I want to distinguish between the various categories of flooding. I accept that high groundwater conditions, springs and heavy soils means that the proposed site and the surrounding Ōhoka area is subject to what I would categorise as low-hazard flooding from smaller events such as those experienced in 2014 and 2022. That is, flooding that is unlikely to cause significant damage to infrastructure or result in loss of life.

82 Whilst the WDC hazard classifications are useful, I consider a more extensive categorisation of flooding is provided by the Australian Rainfall and Runoff Guidelines[27]. I note that these flood hazard curves are often employed in New Zealand and the hazard curves are recommended by the Greater Wellington Flood Hazard Modelling Standard (May 2021)[28].

83 **Attachment 4** shows the flood hazard classification for the 200-year pre-development event. This figure shows that:

83.1 For the area south of Mill Rd (where the plan change site is), the hazard in the vast majority of the area for this event is classified as low (H1) outside of the channels meaning that it is generally safe for people and buildings;

83.2 North of Mill Road, the hazard classification outside of the Ōhoka Stream ranges from H2 (unsafe for small vehicles) to H4 (unsafe for people and vehicles);

83.3 Therefore, I conclude that the area north of Mill Road is more vulnerable to high-risk flooding when compared to the area south of Mill Road.

84 I consider that whilst Ōhoka may be subject to more frequent flooding when compared to other areas in Canterbury, this flooding is low hazard. For significant events, such as the 200-year event, the flood hazard is still low for areas south of Mill Road and moderate for areas north of Mill Road.

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[27] Australian Rainfall and Runoff – Book 6 Flood Hydraulics (2016), after Smith et al., 2014

[28] Greater Wellington Regional Council - Flood Hazard Modelling Standard (2021)

85 Primarily the PDP Model is aiming to solve a conveyance issue. In other words, how can the post-developed site be configured to best match the flood waters discharged in the pre-development state? This is demonstrated in **Attachments 5A, 5B and 5C** which show the predicted flow discharged from the site in the pre-development and post-development models.

86 Summarising the PDP Model results with the lower and higher infiltration rates, I find the total flood water leaving the subdivision (over Mill Road and White Road) is:

86.1 0.9 m^3/s for the lower infiltration rate model (1.67 mm/hr). 60.7 m^3/s pre-development and 61.8 m^3/s post-development; and,

86.2 1.7 m^3/s for the higher infiltration rate model (5.00 mm/hr). 58.3 m^3/s pre-development and 60.0 m^3/s post-development.

87 Therefore, I conclude that adding rainfall and impervious areas to the PDP Model has slightly increased flows, but the predominant issue is still a conveyance issue rather than an attenuation issue.

88 I conclude that the use of 5 mm/hr as an infiltration rate will provide a more conservative assessment of the effects on flooding and I have employed this model in my further analysis of the results below.

89 **Attachment 5A** shows the total flow leaving the subdivision over the combined length of Mill Road and Whites Road. This attachment shows that the difference between pre-developed and post-developed flows is largely indistinguishable (58.3 m^3/s vs 60.0 m^3/s, or around 1,700 L/s or a 2.9% increase in flow).

90 **Attachment 5A** also shows the total flow if rainfall is excluded from the PDP Model. There are two key differences:

90.1 An earlier peak is observed when rainfall is included. Whilst this looks significant, water levels will be determined by the peak flow and therefore, this will have little effect on the PDP Model. This peak is due to the employment of a nested storm profile as specified by the District Wide Model; and,

90.2 The peak flow without rainfall is around 2.6 m^3/s lower, or around 96% of the flow with rainfall. This demonstrates that flood hydraulics are dominated by the catchment upstream of the proposed subdivision and whilst the inclusion of rainfall will improve the accuracy of the PDP Model, it is unlikely to have a significant impact on conclusions.

91 **Attachment 5B** shows the flow over each of Mill Road and Whites Road. The flow over these roads capture all of the flood water leaving the subdivision. Mill Rd is located on the northern boundary of the subdivision and Whites Rd is located on the eastern boundary. For Mill Rd, the peak flow is slightly reduced (15.3 m^3/s to 15.6 m^3/s) whilst for Whites Rd, the peak flow has increased slightly (42.3 m^3/s to 42.6 m^3/s). I note that further modelling could be completed to better balance the conveyance of these flows and provide a very close match to pre-developed flows.

92 **Attachment 5C** shows the flow over various locations along Whites Rd. This shows that as we increase the granularity of the PDP model interrogation, there is a greater discrepancy between the pre-development and post-development flows. In general though, peak flows are generally within 0.5 m^3/s (500 L/s) with the exception of the south and Mid South Channel for which the post-developed flow is up to 1.0 m^3/s (1,000 L/s) more than the pre-developed flow.

93 I conclude from these three attachments (**5A**, **5B** and **5C**) that conveyance of floodwaters through the site is the main issue that needs to be solved from a flood effects lens. Therefore, I consider the most effective mitigation is to ensure development is minimised in areas where the existing conveyance of floodwaters is significant. Alternatively, channel re-shaping and site contouring may also achieve a similar outcome which can be explored at the subdivision consenting stage.

EFFECTS ON FREEBOARD

94 To determine the effects on freeboard off-site, three inputs are required:

94.1 The finished floor levels, or as-built levels, of existing dwellings;

94.2 The pre-development flood level; and

94.3 The post-development flood level.

95 To obtain accurate finished floor levels would require a detailed survey of the Ōhoka township which is beyond the scope of this analysis and should be completed, if required, at the resource consenting stage. As a preliminary screening exercise, I have estimated finished floor levels using the following approach:

95.1 Estimate the ground level for each dwelling using LIDAR. When the LIDAR is post-processed and converted to a Digital Terrain Model (*DTM*), structures are removed from the dataset. Therefore, the area beneath the footprint is an interpolated surface made up of the capture points around the perimeter of the structure. Dwellings are typically built from the highest elevation contained within the building footprint. I have assumed that the average elevation contained within the building footprint is representative of the ground level.

95.2 Whilst the District Plan requires a freeboard over the 200-year model event of 400 or 500 mm depending on the hazard classification, I note that the majority of these dwellings would have been constructed prior to this requirement. Therefore, to be conservative I have assumed that finished floor levels will be 300 mm above the ground elevation.

96 Water levels for the pre-development and post-development events for each habitable dwelling have been obtained by extracting the average flood level over the building footprint.

97 Building footprints have been obtained from LINZ although I have excluded footprints which are within the proposed subdivision.

98 I note there are 1,007 building footprints remaining within the modelled area. Of these, manual inspection against aerial photography and Google street view shows that 437 of these footprints could be habitable dwellings. For the purposes of this assessment, I do not consider garages or utility sheds habitable dwellings.

99 With these assumptions, I obtain the following results:

99.1 335 of the dwellings are within a low or no hazard area (as defined by WDC) and therefore the applicable freeboard is 400 mm.

99.2 The remaining 59 dwellings are within a medium or high hazard area and therefore the applicable freeboard is 500 mm.

99.3 Applying the recommended freeboards for each dwelling and comparing the recommended minimum floor level to the 200-year pre-development flood level, I find:

(a) 3 dwellings meet the recommended freeboard requirements:

(b) 391 dwellings do not meet the recommended freeboard requirements.

99.4 Completing the same assessment but with the post-development flood level, I find:

(a) 3 dwellings meet the recommended freeboard requirements:

(b) 391 dwellings do not meet the recommended freeboard requirements.

100 Therefore, I conclude there is no change or impact on compliance with recommended freeboard requirements for existing dwellings as a result of the proposed development.

EFFECTS ON FLOOD LEVELS

101 The effects on post-development flood levels are presented in **Attachment 6**. This attachment shows that outside of the subdivision:

101.1 Effects north of Mill Rd are generally less than 10 mm;

101.2 South of Mill Rd and east of Whites Rd, the effects are greatest at the subdivision boundary and dissipate as the floodwater moves east. There are generally only small pockets of flood increases which exceed 10 mm.

102 I understand[29] the freeboard test referenced in Mr Bacon's evidence at his paragraph 14 is required to further quantify effects if the flood differences are not less than minor.

103 To assess the difference in flood elevations, I have taken all building footprints, not just habitable dwellings, and extracted the average water level over the footprint for both the post-developed and pre-developed water levels. I take the difference between these two water levels to be the effects on the building footprint.

104 Summarising the effects of development for the 200-year event on all building footprints, my analysis shows:

104.1 A decrease in flood elevations of more than 20 mm for one building footprint;

104.2 A change in flood elevations of between -20 and 10 mm for 995 building footprints;

104.3 An increase in flood elevations of between 10 and 20 mm for nine building footprints; and,

[29] Phone conversation between Ben Throssell and Chris Bacon on Monday 26 June 2023

104.4 An increase in flood elevations of greater than 20 mm for two building footprints (24 mm and 28 mm).

105 Inspection of aerial imagery and google street view shows that both building footprints with an increase of greater than 20 mm are sheds. The locations of these sheds are shown in **Attachment 7.**

106 Given that for all other building footprints, and therefore all habitable dwellings, there are no predicted increases in the flood elevation of greater than 20 mm, I conclude that my assessment demonstrates the effects of flooding on these dwellings are less than minor. When considering effects, I note there is limited guidance available. Therefore, I take the following items into consideration:

106.1 The size of the development – I consider a 50 mm effect on two habitable dwellings from a proposed one lot development is less acceptable than the same effect from a hundred lot development;

106.2 The sensitivity of the effected dwellings to flooding – A 50 mm effect on a habitable dwelling with 1000 mm of freeboard is more acceptable than the same effect on a habitable dwelling that has no freeboard; and

106.3 The magnitude of the effect – A 100 mm effect is less acceptable than a 50 mm effect.

107 I also conclude that the subdivision layout presented is a viable configuration that results in less than minor effects of flood hazard.

108 I note further modelling will be required at the detailed design and consenting stage to ensure that a less than minor effect (no more than 20 mm) is achieved with the final subdivision surface. Given most of the existing dwellings within the modelled area of interest do not satisfy the WDC freeboard requirements, I conclude that WDC will be unlikely to accept effects which reduce the available freeboard for existing dwellings.

CONCLUSION

109 I consider that conveyance of floodwaters through the site is the main issue that needs to be solved from a flood effects lens. Therefore, I consider the most effective mitigation will be to ensure development is minimised in areas where the existing conveyance of floodwaters is significant.

110 The updated PDP Model has demonstrated that there is a viable subdivision layout which minimises development in areas of existing flood conveyance. This layout ensures the effects of the proposed

subdivision on flood levels will not exceed 20 mm for any habitable dwelling.

111 For habitable dwellings, I conclude that an average increase in flood elevation of less than 20 mm for the 200-year event is a less than minor effect.

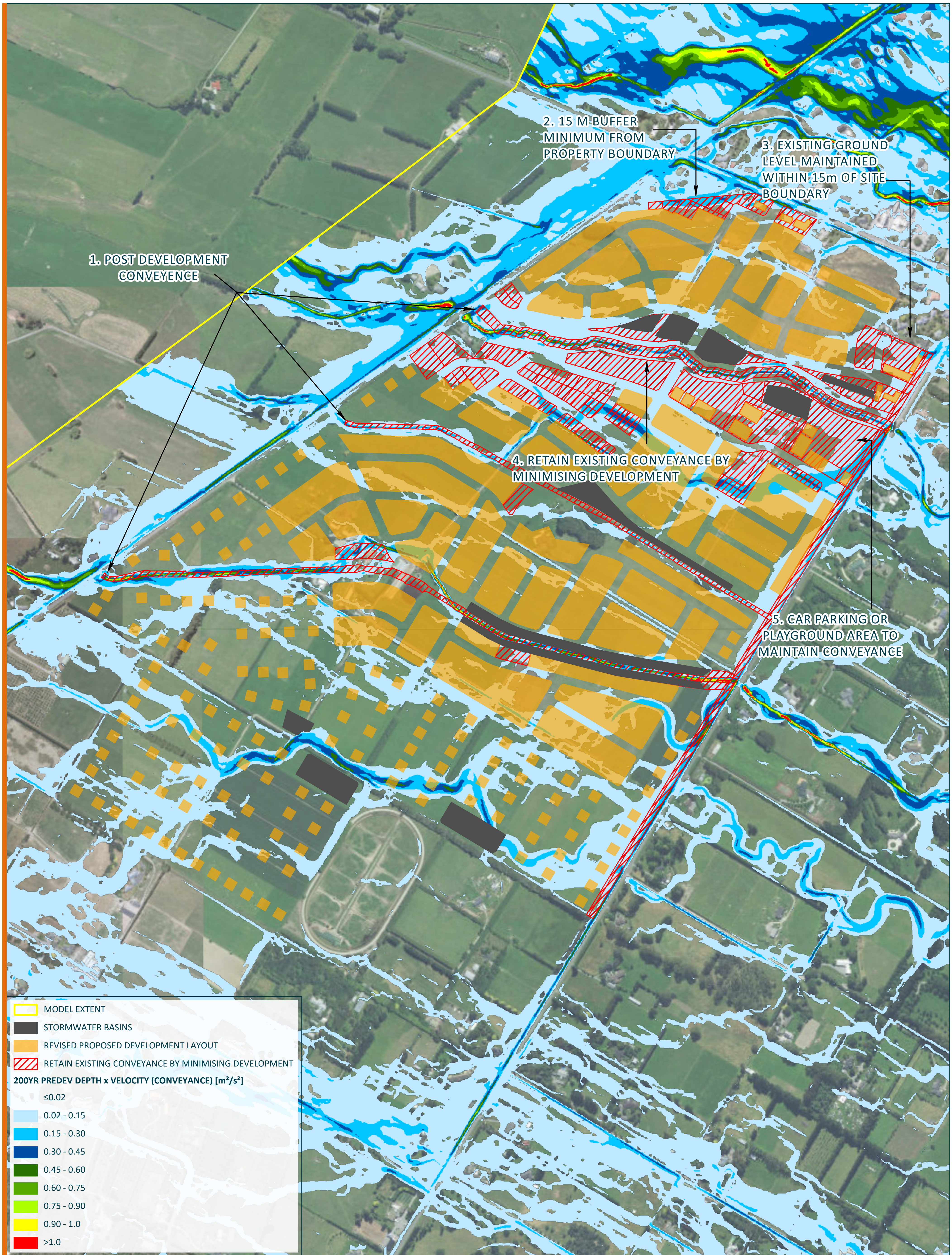
112 I accept Mr Bacon's recommendation at his paragraph 19 on freeboard requirements for the proposed development. I understand the applicant has agreed to adopt this recommendation.

113 I conclude that Ōhoka is prone to low hazard flood events, similar to those experienced in June 2014 and July 2022. I note the magnitude of these events at Ōhoka was probably between a 10-year and 20-year event. The stormwater solution within the site will provide mitigation of any additional stormwater generated by the site for events of these magnitudes.

114 For more significant events, modelling of the 200-year event shows the flood hazard is still low for areas south of Mill Road/downstream of Whites Road and moderate for areas north of Mill Road. I note the PDP Model predicts generally limited effect greater than 10 mm for areas north of Mill Road and no increase greater than 20 mm for habitable dwellings elsewhere within the PDP Model.

Dated: 6 August 2023

Ben Throssell



pdp

ATTACHMENT 1: MODELLED SUBDIVISION LAYOUT

OHOKA PLAN CHANGE

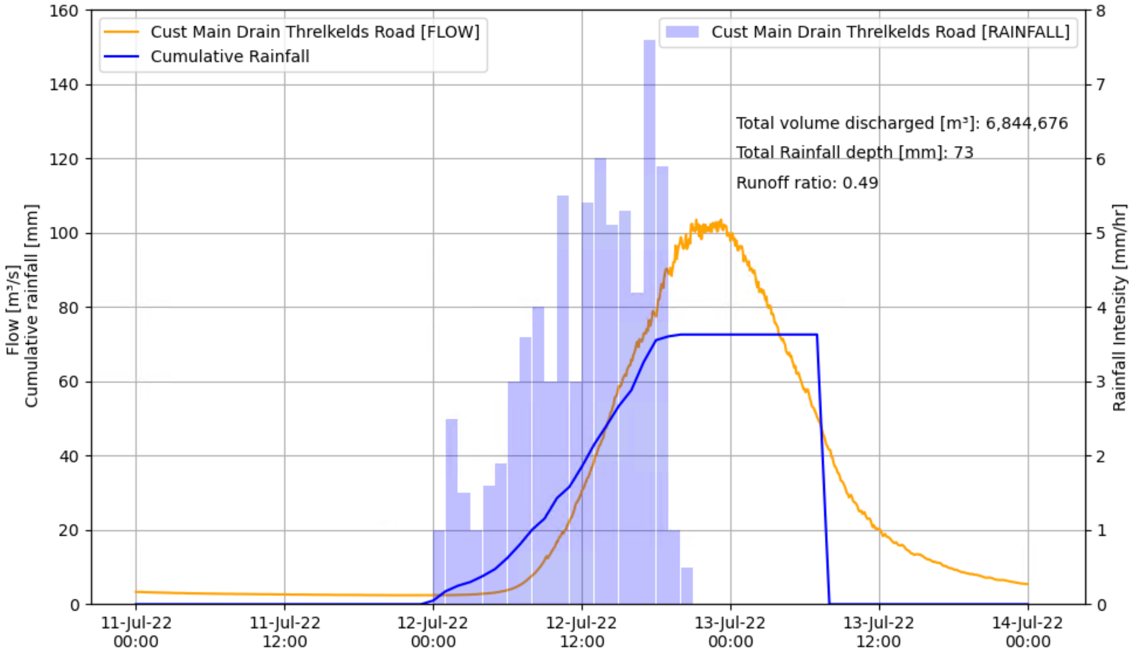
SOURCE:
1. AERIAL IMAGERY: EAGLE TECHNOLOGY, LAND INFORMATION NEW ZEALAND, GEBCO, COMMUNITY MAPS CONTRIBUTORS.

SCALE : 1:7,000 (A3)

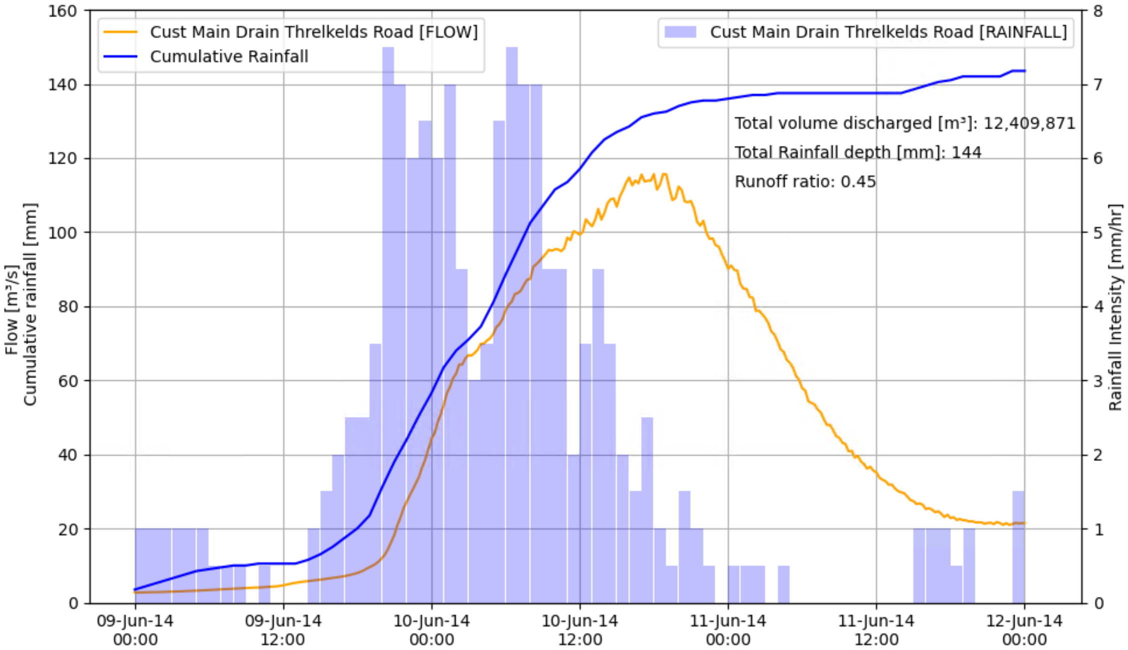
REVISION: 01 | DATE: JUN 23 | BY: JR

CLIENT: ROLLESTON INDUSTRIAL DEVELOPMENTS LIMITED

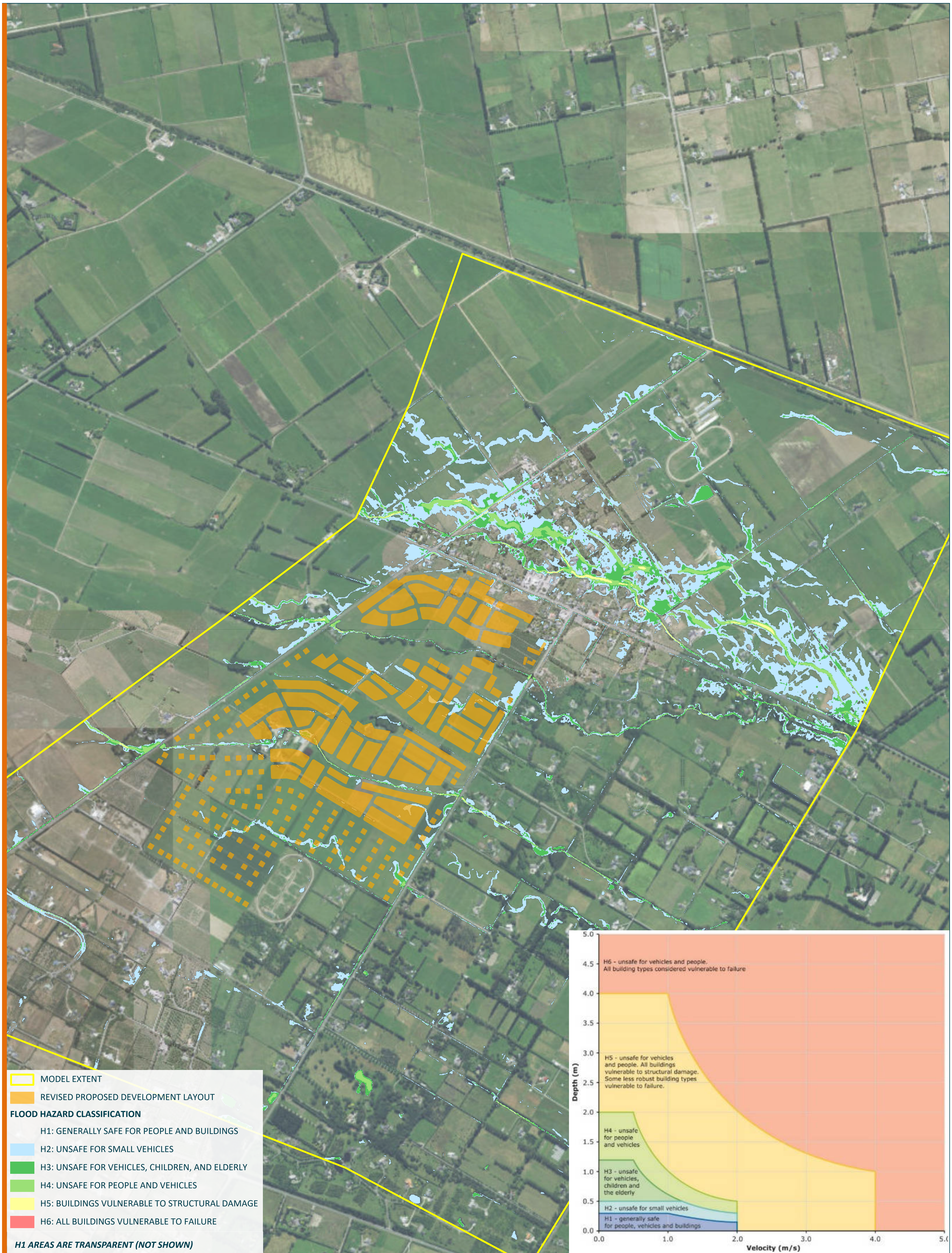
C04518300_GIS001



Attachment 2: Recorded flows and depths for Cust River at Threlkelds Road for 11 July to 14 July 2022



Attachment 3: Recorded flows and depths for Cust River at Threlkelds Road for 9 June to 12 June 2014



pdp

ATTACHMENT 4: FLOOD HAZARD CLASSIFICATION FOR THE 200YR PRE DEVELOPMENT EVENT

OHOKA PLAN CHANGE

SOURCE:
1. AERIAL IMAGERY: EAGLE TECHNOLOGY, LAND INFORMATION NEW ZEALAND, GEBCO, COMMUNITY MAPS CONTRIBUTORS.

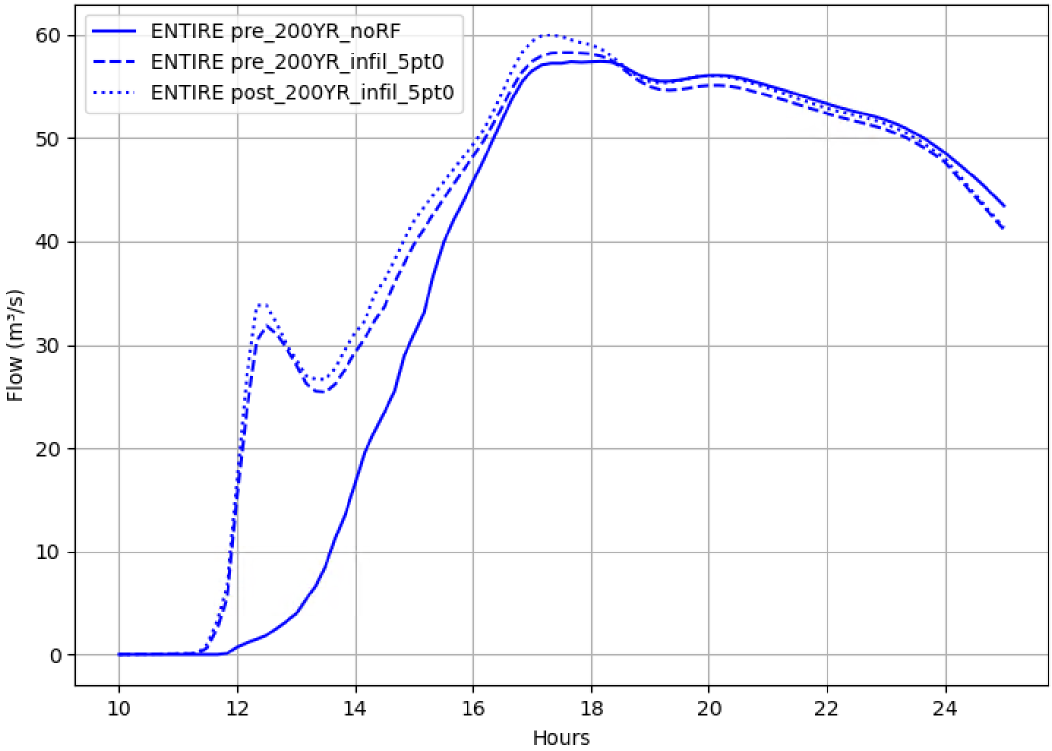
0 250 500
Meters
SCALE : 1:15,000 (A3)

N

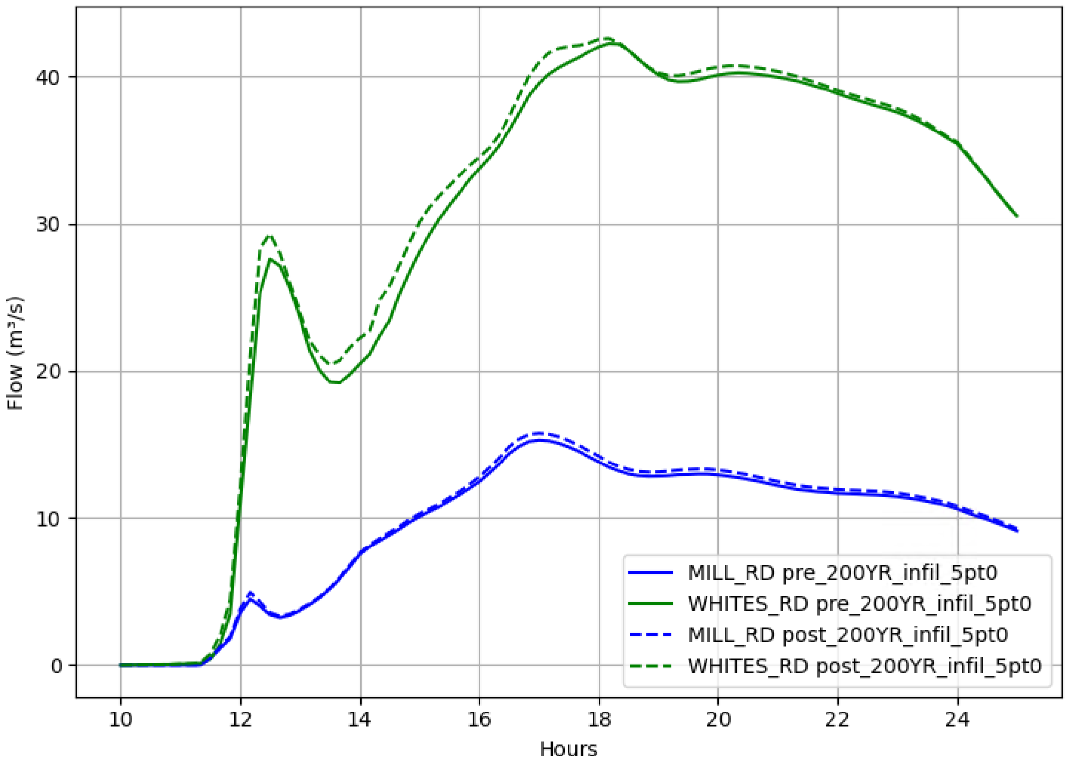
REVISION: 01 | DATE: JUN 23 | BY: JR

CLIENT: ROLLESTON INDUSTRIAL DEVELOPMENTS LIMITED

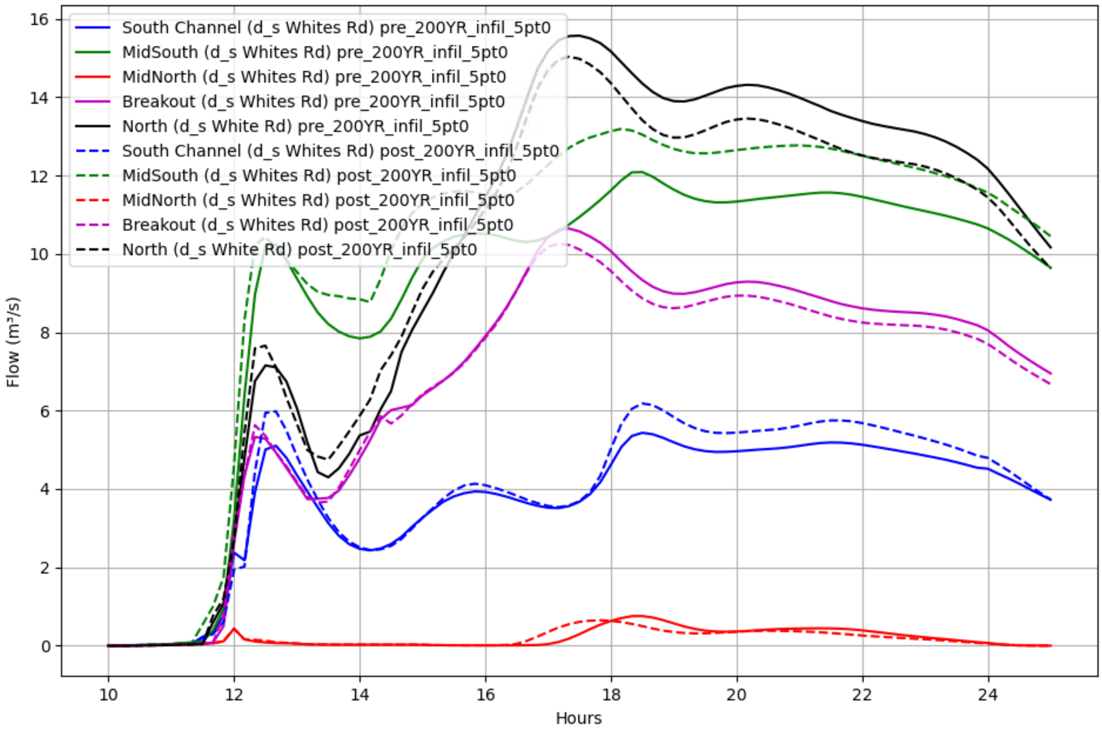
C04518300_GIS002



Attachment 5A: Predicted total flow leaving the subdivision (over Mill Rd and Whites Rd combined) for the 200-year flood event. Showing the pre-development scenario and post-development scenario, both with rainfall and the post-development scenario without rainfall.



Attachment 5B: Predicted total flows over Mill Rd and Whites Rd for the 200-year flood event. Showing the pre-development scenario and post-development scenario, both with rainfall.



Attachment 5C: Predicted flows leaving the subdivision (at various locations over Whites Rd) for the 200-year flood event. Showing the pre-development scenario and post-development scenario, both with rainfall. Locations of the flow extraction points are presented in Figure A4, Appendix A of our June 2022 report and reproduced below (Attachment 8).

pdp

ATTACHMENT 6: DIFFERENCES IN FLOOD ELEVATION FOR THE 200YR EVENT

OHOKA PLAN CHANGE

SOURCE:
1. AERIAL IMAGERY: EAGLE TECHNOLOGY, LAND INFORMATION NEW ZEALAND, GEBCO, COMMUNITY MAPS CONTRIBUTORS.
2. ROAD INFORMATION DERIVED FROM LINZ.

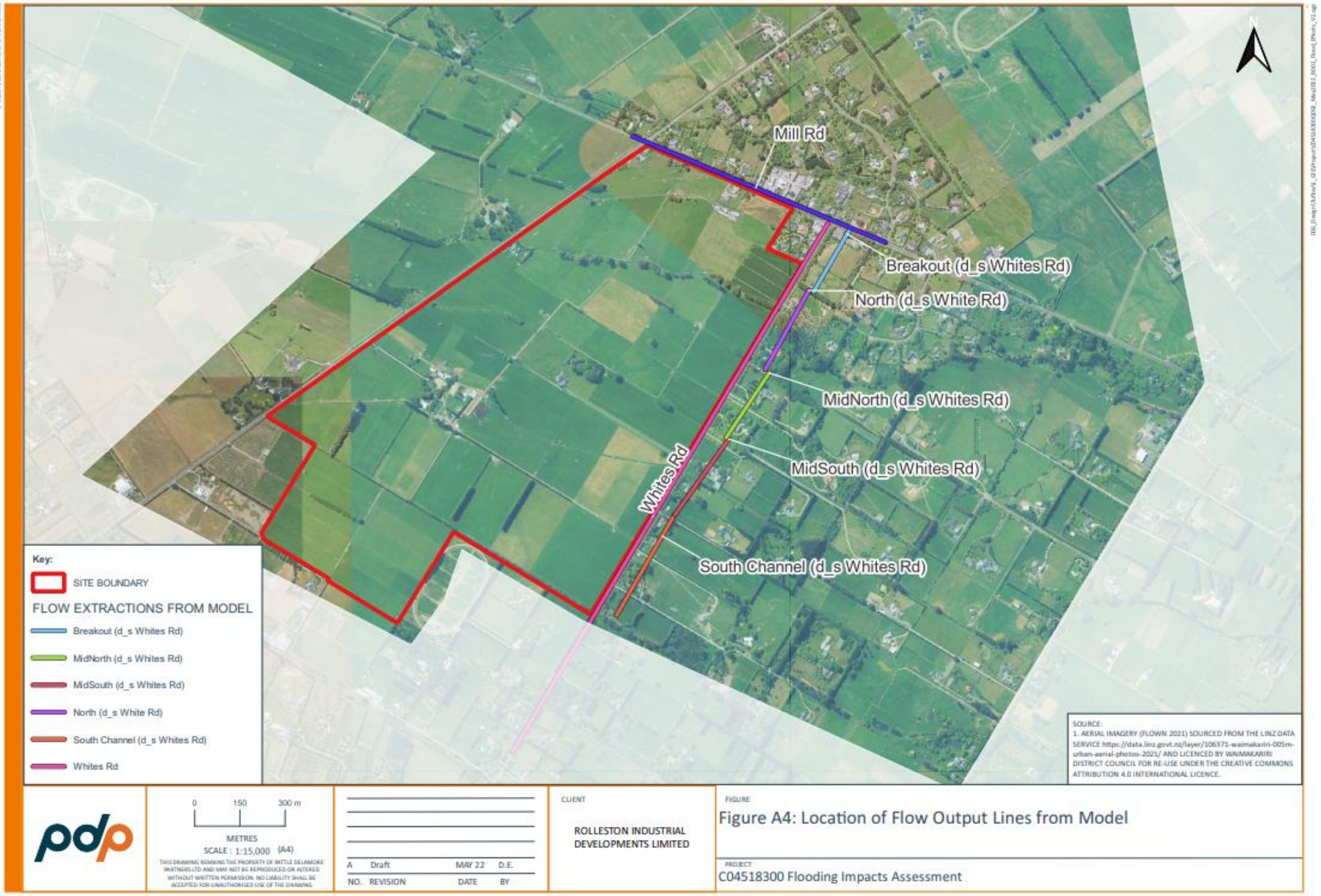
0 250 500
Meters
SCALE : 1:10,000 (A3)

N

REVISION: 01 | DATE: JUN 23 | BY: JR
CLIENT: ROLLESTON INDUSTRIAL DEVELOPMENTS LIMITED

C04518300_GIS004

Attachment 7: Location of two building footprints where the average water level increase across the footprint exceeds 20 mm (290 and 296 Whites Road)



Attachment 8: Showing locations where flows have been extracted from the model. Figure reproduced from the PDP June 2022 report