Bangalow Industrial Estate Flood Impact Assessment

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Synopsis:	**This report provides a summary of hydrologic and hydraulic modelling assessments at Bangalow Industrial Estate Lot4 DP635505**	

REVISION/CHECKING HISTORY

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1 Introduction

1.1 Project Overview

A portion of land described as Lot 4 on DP 635505 is proposed for rezoning from rural (RU1) to a land use compatible with industrial/commercial uses. The rezoning will facilitate the sub-division of this land to provide several individual allotments. The development will (in effect) extend the current Bangalow Industrial Estate to the east.

Review of flood mapping for the Byron catchment identifies the lot as flood prone, with the majority of the site inundated in a 1% AEP flood event. Council require demonstration that future development of the lot achieves flood requirements as outlined in Council's Local Environment Plan and Development Control Plans related to flooding. Generally, these guidelines set building requirements, i.e. floor levels, requirements for emergency management etc, and also require development to not give rise to offsite impacts as a result of filling and or the placement of infrastructure.

Filling of the site would be required to increase the amount of developable land.

BMT has been engaged to prepare a flood assessment for the site to determine existing design flood levels for 1%, 5% and 20% AEP for the site utilising BMT's Byron Creek catchment hydrologic and hydraulic flood models, with the application of the recent Australian Rainfall and Runoff 2019 guideline. Investigation of the potential peak flood level impacts for two scenarios of differing developed fill pad alignments is also required.

The methodology applied in this project includes:

- Inspection of study area to view site and nearby structures;
- Data collation and review;
- Model configuration (Section 2);
- Design Event Modelling (Section 3);
- Impact Assessment (Section 4); and
- Conclusion (Section 5).

1.2 Site Location

The site location is shown in Figure 1-1. The site is located immediately to the south-west of Bangalow, and lies in between the existing Bangalow Industrial Estate, Lismore Road, Maori Creek and the North Coast Railway Line. The site is located within the Byron Creek catchment, a tributary of the Wilsons River. Flooding at the site can occur from both Byron Creek and from Maori Creek.

Note that the development is proposed only on the western portion of the lot highlighted (i.e. on the western side of Maori creek). This portion of the site is approximately 1.5 ha and has approximately 200 m fronting Maori Creek.

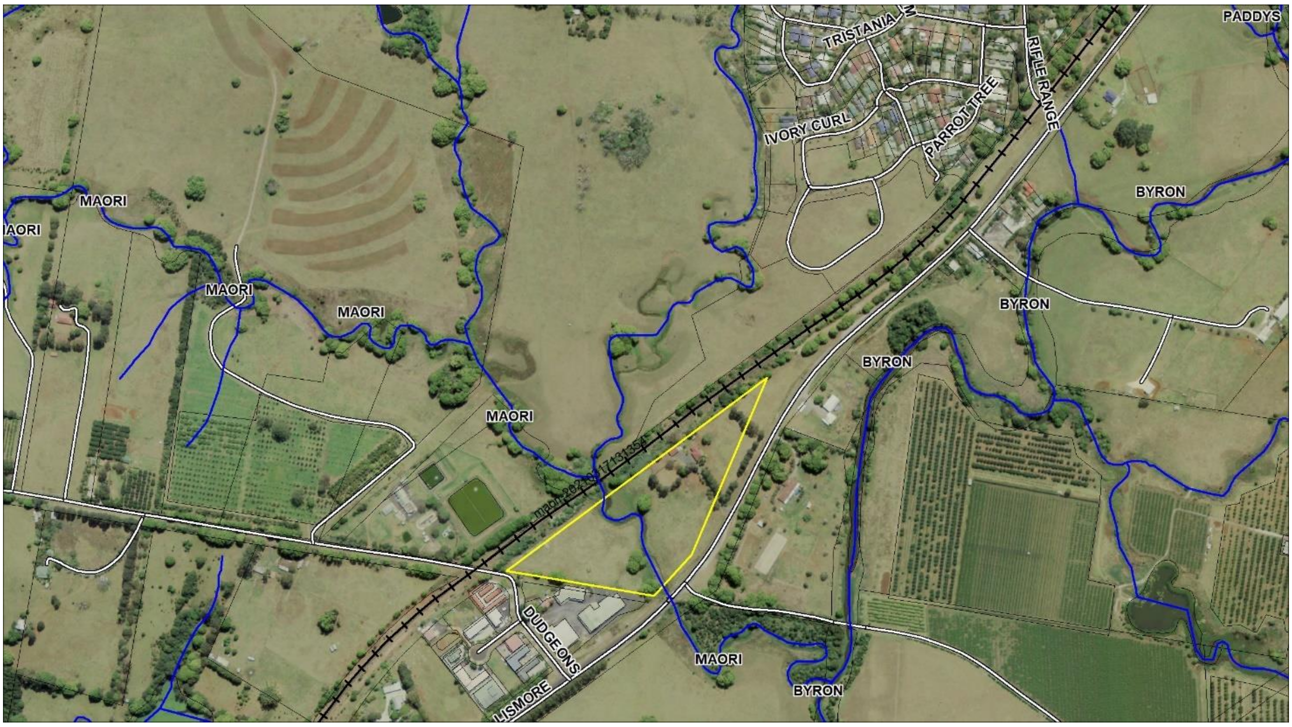


Figure 1-1 Site Locality

2 Model Configuration

A hydrologic model and hydraulic model of the Byron Creek catchment previously developed by BMT has been adopted as the basis for this assessment in agreement with the client, on the basis that Council's existing hydrologic model is based on ARR-1987 and the hydraulic model is dated (i.e. 1-dimensional model). The hydrologic model produces flow hydrographs which are applied as inputs to the hydraulic model.

A joint calibration approach of these models has been previously undertaken calibrating both the XP-RAFTS hydrologic and TUFLOW HPC hydraulic models in tandem, successfully achieving calibration to the March 2017 and February 2020 Byron Creek flood events. These models are deemed fit-for-purpose for the current flood assessment.

The available model was updated to include the following minor modifications:

- Truncation of the model (at a distance suitably downstream of the site to prevent tailwater effects);
- Addition of structures to represent the rail bridge upstream of the site and the Lismore Road culverts downstream of the site; and
- Refinement of the hydraulic roughness at the culvert structure through Lismore Road.

The following sections provide additional detail on the configuration of each of the hydrologic and hydraulic models. Key datasets used in the assessment are summarised in Table 2-1.

Table 2-1 Key Datasets Used in the Study

Item	Source	Description
Site Survey	Canty's Surveying	Survey of the site (captured in 2021). This data includes dimensions and invert levels for the cross-drainage structures upstream and downstream of the Site.
LiDAR data	Geoscience Australia	1m LiDAR data captured in 2010
Byron Creek catchment hydrologic and hydraulic models	BMT	Developed by BMT for flood impact assessments in the Byron Creek catchment
Hydrologic design event data	ARR Datahub	Design rainfall depths, losses, temporal patterns and areal reduction factors (for application to the XP-RAFTS hydrologic model)

2.1 Hydrologic Model

XP-RAFTS is a runoff routing modelling software program used to simulate the relationship between rainfall falling within the catchment and runoff generated. XP-RAFTS is extensively used throughout Australia for hydrologic analysis of conveyance systems.

XP-RAFTS contains a loss model component and a routing model component. The former determines how much of the rainfall contributes to runoff, i.e. what is not lost to infiltration or depression storage. The latter determines how the runoff is routed through the sub-catchments resulting in flow hydrographs.

Rainfall losses are represented in the model as initial and continuing losses which is standard practice.

Model sub-catchments are delineated based on local topography and the drainage network, and these are assigned a number of parameters such as slope, roughness percentage imperviousness, etc, to enable the calculation of runoff routing. The sub-catchments are joined by 'links' representing the channels.

The XP-RAFTS hydrologic model sub-catchment schematisation for the truncated model is shown in Figure 2-1. The model parameters are described below, and summarised for the sub-catchments (relevant to the hydraulic model) in Table 2-2 and Table 2-3. The configuration of the hydrologic model and its parameters was been previously confirmed to be fit-for-purpose through joint calibration with the hydraulic model.

The model schematisation was consistent for all rainfall patterns, this includes the catchment areas, slope, fraction impervious, PERN value and routing.

- Catchment slope:
    - Estimated by calculating the equal-area slope of the longest flow path within each sub-catchment;
- Fraction imperviousness:
    - The approach recommended by Catchment Simulations Solutions for split subcatchments was employed where the first subcatchment is for pervious area (0% impervious), and the second is for impervious area (100% impervious);
    - The majority of the Byron Creek subcatchment is undeveloped, and was treated as 0% impervious;
    - For subcatchments that covered areas of development, the relative 2nd subcatchment area at 100% imperviousness was calculated based on the proportional developed catchment area at 40% impervious;
- PERN values:
    - Input as a Manning's "n" representative of the average sub-catchment roughness (XP-Solutions, 2013); and
    - A PERN value of 0.06 was adopted throughout for pervious areas (1st subcatchment) and 0.025 for impervious areas (2nd subcatchment).
- Catchment links:
    - Muskingum channel routing was applied to the connections between subcatchments to calculate hydrograph attenuation and lag;
    - The K value represents the time in hours which water takes to travel from topmost section of the channel within a sub-catchment to sub-catchment outlet. The K value was calculated based on a velocity of 2 m/s divided by the subcatchment's stream length; and
    - The default X value of 0.2 was applied uniformly across all catchments.

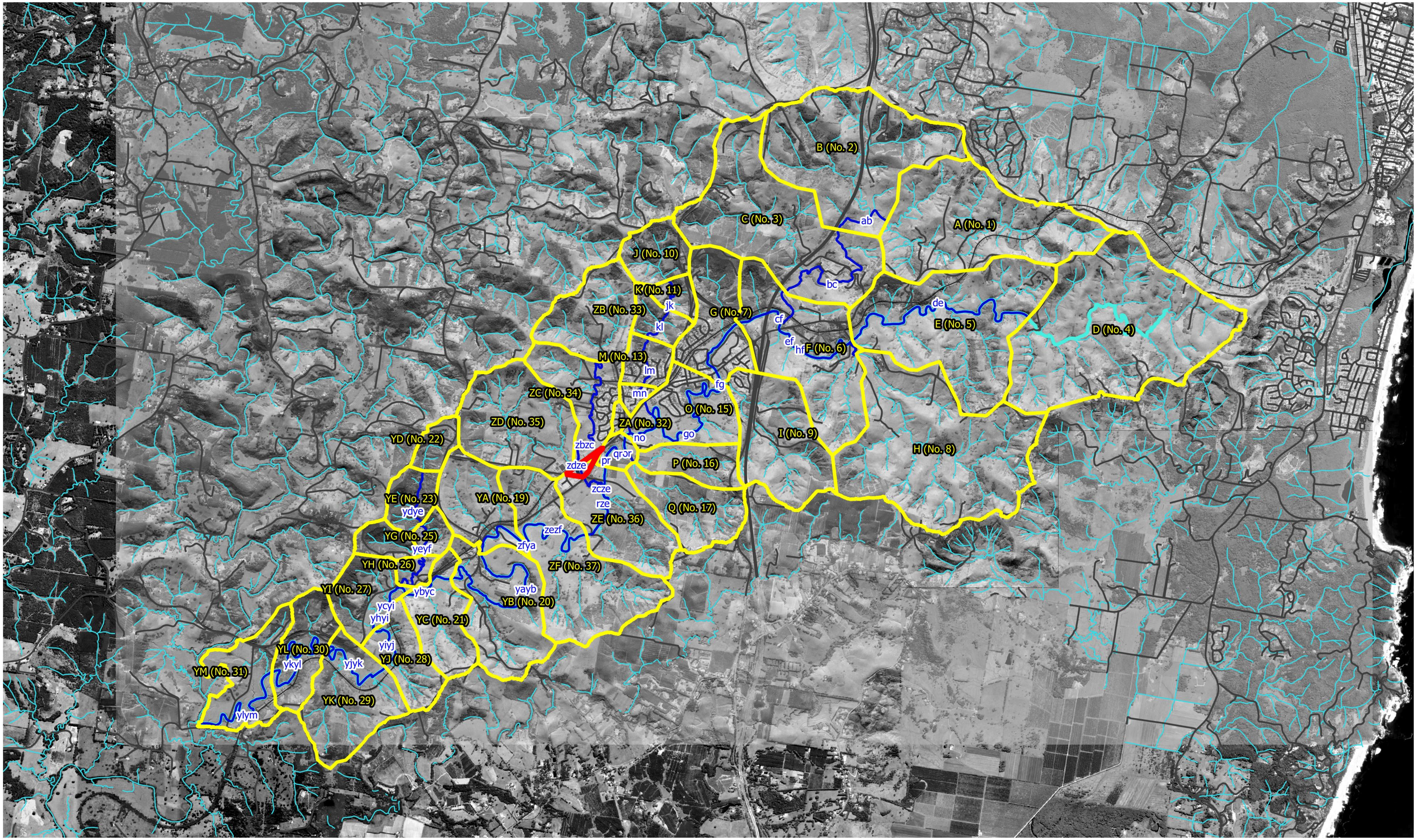
- BX factor = 1
- Event Rainfall and Losses: The application of rainfall and losses to the hydrologic model is dependent on the design event modelled and is described further in Sections 3.2.1.

Table 2-2 XP-RAFTS Link Parameters

Link Name	Length (m)	K	Link Name	Length (m)	K
AB	849	0.12	MN	248	0.03
BC	2289	0.32	NO	930	0.13
CF	1268	0.18	OR	804	0.11
DE	3505	0.49	PR	689	0.10
EF	2120	0.29	QR	689	0.10
FG	1006	0.14	Rze	1232	0.17
GO	3271	0.45	zaR	211	0.03
HF	2323	0.32	zbzc	2046	0.28
JK	483	0.07	zcze	1689	0.23
KL	605	0.08	zdze	1689	0.23
LM	707	0.10			

Table 2-3 XP-RAFTS Subcatchment Parameters

Subcatchment		Area (ha)	Slope	Subcatchment		Area (ha)	Slope
A (No. 1)	1	278.94	0.75	N (No. 14)	1	6.756	3.01
B (No. 2)	1	295.85	1.38		2	4.504	
C (No. 3)	1	297.88	1.53	O (No. 15)	1	106.21	0.05
D (No. 4)	1	421.13	0.72		2	2.52	
E (No. 5)	1	303.43	0.39	P (No. 16)	1	56.53	1.92
F (No. 6)	1	218.81	0.6	Q (No. 17)	1	94.9	1.61
G (No. 7)	1	106.18	1.52	R (No. 18)	1	17.58	0.19
	2	8.24	1.52	ZA (No. 32)	1	3.846	4.42
H (No. 8)	1	381.81	0.63		2	2.564	
I (No. 9)	1	160.37	2.23	ZB (No. 33)	1	110.89	2.32
J (No. 10)	1	56.38	6.85	ZC (No. 34)	1	92.83	1.25
K (No. 11)	1	23.67	3.16		2	3.32	
L (No. 12)	1	32.36	4.96	ZD (No. 35)	1	167.51	1.32
M (No. 13)	1	31.32	1.44				
	2	3.64	1.44				



Legend

- Site
- XP-RAFTS subcatchments
- XP-RAFTS routing links
- Roads
- Railway
- ByronCreek
- Streams

Title:

Hydrologic Model Schematisation

Drawing: **2-1**

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2.2 Hydraulic Model

2.2.1 Introduction

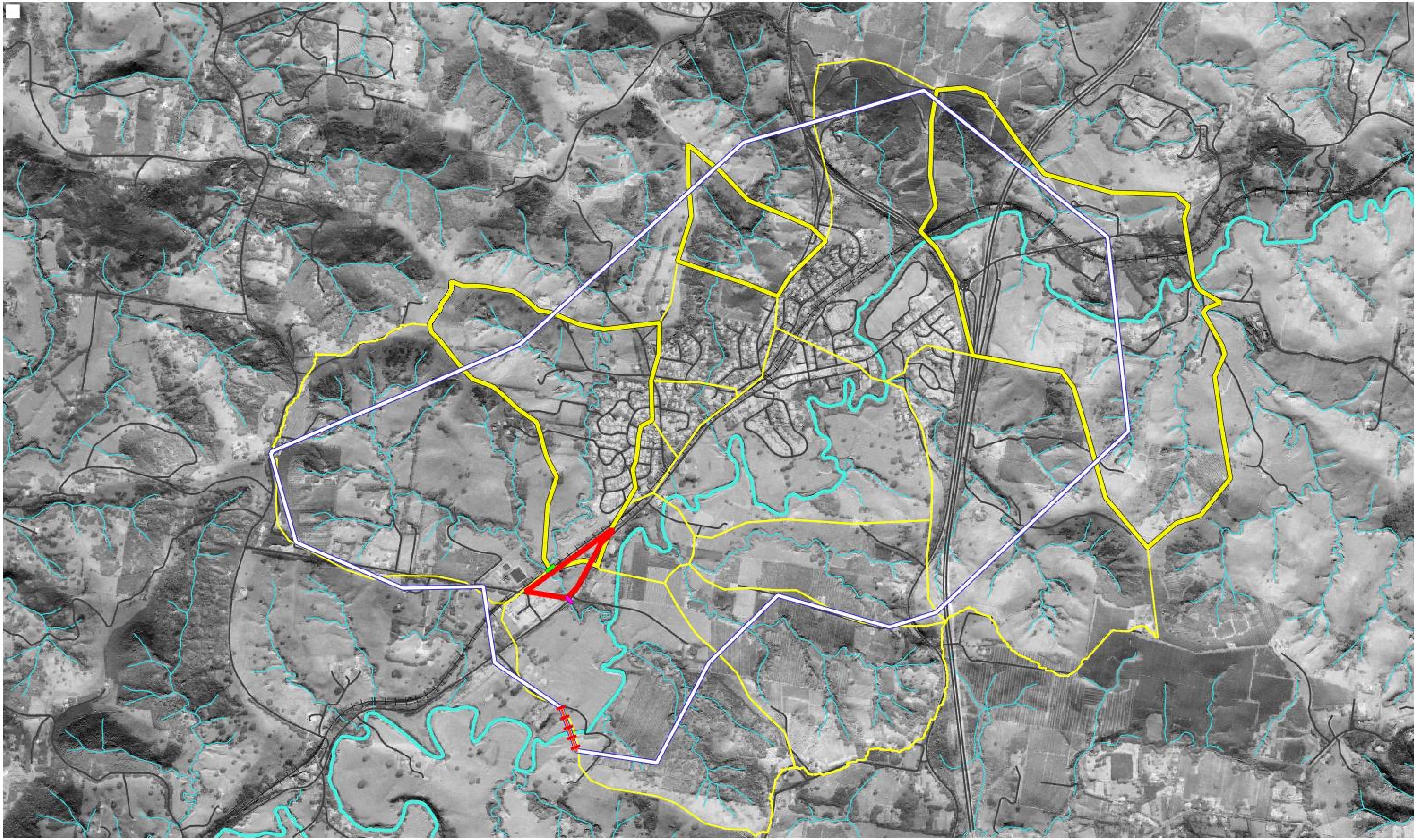
A 2D hydraulic model of the lower Byron Creek catchment has previously been developed by BMT, using TUFLOW HPC software. The truncated model used in this assessment includes approximately 6.7 km of Byron Creek extending from the Pacific Highway, upstream of Bangalow to around 1 km downstream of the site.

The TUFLOW HPC hydraulic model schematisation is shown in Figure 2-2 and is detailed in the remainder of Section 1.2.

2.2.2 Model Topography

The base topography is developed from LiDAR data captured for the Lismore and Ballina regions in 2010. This has a stated vertical accuracy of 0.3m (95% confidence interval). The LiDAR data has been compiled into a Digital Elevation Model (DEM) of 1m horizontal grid resolution covering the entire Byron Creek catchment. The LiDAR was found to be in close agreement to spot heights captured as part of site survey in March 2021 by Canty's Surveyors.

Whilst the LiDAR data captures the general topography to a high level of detail, it cannot penetrate water and so the majority of the main channel of Byron Creek is poorly represented in this dataset. The model includes topographic modifications to remove artificial bumps or ridges created by triangulation in the DEM creation process and makes for a smoother bed which helps with model stability.



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- Site
- Outflow Boundary
- Model extent

XP-RAFTS Catchments

- local flows
- total flows

- Roads
- Railway
- ByronCreek
- Streams

Title:

Hydraulic Model Schematisation

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2.3 Structures

The structures in the vicinity of the site were added to the hydraulic model, and included:

- Upstream rail bridge:
  - Details estimated from on-site inspection, and consideration of 1m topographic data:
    - Deck level: 42.9 mAHD;
    - Deck depth: 0.9m;
    - Sub-structure form loss: 0.2;
  - Included as a TUFLOW layered flow constriction element.
- Downstream Lismore Road culverts:
  - 3 x 3.5w x 2.5h (supplied site survey);
  - Upstream invert 36.7m AHD (supplied site survey);
  - Downstream invert 36.65m AHD (assumed);
  - Included as a nested 1D element, connected to the 2D model domain at the upstream and downstream ends.

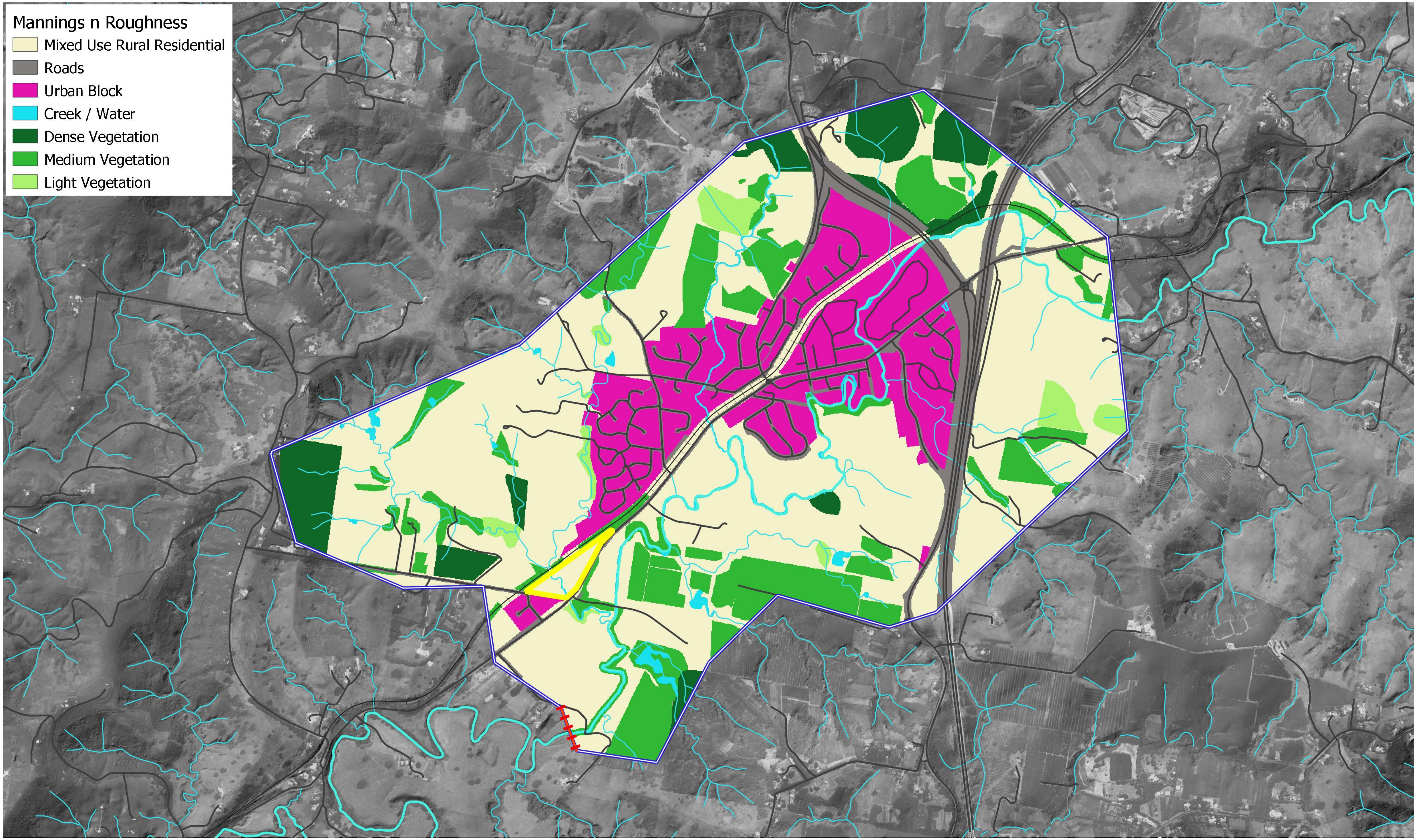
2.4 Land Use

Land use data has been delineated in order to apply appropriate hydraulic resistances spatially within the model to different land use types. Land use data has been delineated based on available aerial imagery and the mapped land uses are shown in Figure 2-3.

Each land use category was assigned a Manning's n hydraulic resistance value. These values were initially set to be within industry acceptable ranges and then refined during the model calibration process. Table 2-4 lists the land use types and associated Manning's n value applied.

Table 2-4 Adopted Manning's n values

Land Use	Adopted Manning's n Value
Creek / Water Body	0.028
Light Vegetation	0.04
Medium Density Vegetation	0.06
Dense Vegetation	0.08
Rural Mixed Use	0.045
Roads	0.025
Urban block	0.1



Legend

- Site
- Outflow Boundary
- Model extent
- Roads
- Railway
- ByronCreek
- Streams

Title:

Hydraulic Model - Land Use

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2.5 Boundaries

Hydraulic model inflows are derived from the hydrologic model and consist of 3 total inflows and 11 local inflows for the truncated model. The total inflows represent hydrographs from multiple upstream subcatchments and include the main Byron Creek inflow at the upstream limit of the model near the Pacific Highway, as well as total inflows for two of the larger tributary catchments. The local inflows apply runoff generated from within individual hydrological subcatchments and are spread across the 2D model domain.

The downstream boundary of the truncated model is located approximately 1 km downstream of the site. A normal slope boundary was applied for design events. The locations of the model boundaries are shown in Figure 2-2.

3 Design Event Modelling

3.1 Approach

Design event modelling has been undertaken in accordance with Australian Rainfall and Runoff Guidelines 2019 (ARR 2019) for the 1%, 5% and 20% AEP events.

Rainfall intensities and other hydrologic parameters were derived from ARR 2019 and applied to the calibrated hydrologic model to produce hydrographs for the required design events for a number of durations (1 hour to 24 hours). As required by ARR 2019, the temporal pattern ensemble approach was applied, where 10 temporal patterns per storm duration are simulated for each design event and a pattern that resulted in an 'average' peak flow was adopted.

An initial assessment was undertaken using the hydrologic model to determine which duration was critical for the area of interest, in terms of comparing the single peak adopted flow from the temporal pattern ensemble per duration. This was undertaken separately for each AEP for the Byron Creek catchment. For AEPs where a number of storm durations produced a similar adopted 'average' peak flows from the ensemble of temporal patterns, the critical duration was left undetermined and multiple durations were taken forward for hydraulic modelling.

The hydraulic model was then used to determine the critical duration that produced the highest peak water level at the study area.

Once the critical duration/s had been established, those durations were then used in the hydraulic model to determine the design flood levels and for the purposes of assessing flood impacts.

It is noted that hydrologic modelling and initial hydraulic modelling was also undertaken for flooding from the local Maori Creek catchment in isolation (with no elevated water levels on Byron Creek). However it was determined that at the Site, the peak flood levels in Maori Creek were significantly lower than those resulting from Byron Creek flooding (more than 0.5m lower) in all three AEP events. As such, local flooding effects of Maori Creek were not considered any further in assessing the relevant design flood levels at the site.

Sensitivity scenarios that consider a 10% and a 30% increase in rainfall intensity for the 1% AEP event have also bene undertaken, in accordance with Council's DCP 2014 and Climate Change Strategic Planning Policy (CCSPP).

3.2 Hydrologic Design Event Modelling

This section describes the process for deriving design event flows for application to the hydraulic model.

3.2.1 Parameters

Hydrologic parameters such as design rainfall depths were extracted from the ARR datahub[1] focussing on the study area. A summary of the adopted parameters is provided below:

- Rainfall depths:

[1] http://data.arr-software.org/ extracted on 11/05/2020

  - Intensity Frequency Duration data was extracted at the centroid of each hydrologic sub-catchment;
- Temporal patterns:
  - Point temporal patterns were adopted as both the regional and local catchment areas are less than 75km[2];
  - The relevant ensemble of 10 temporal patterns were considered for the rare event (1% AEP), intermediate event (5% AEP) and the frequent event (20% AEP);
- Losses:
  - The Initial Losses (IL) from the ARR datahub were selected and adjusted with a 0.4 multiplication factor and probability neutral burst initial loss values as recommended by NSW Department of Planning Industry and Environment for use in NSW;
  - A Continuing Loss (CL) of 1.0 mm/hr was adopted based on the calibration inputs.
- Areal reduction factors:
  - The impact of applying Areal Reduction Factors on the peak flows was examined and found to not make a significant difference. Areal reduction factors were not applied, to provide a slightly conservative estimate of peak flows.

3.2.2 Hydrologic Model Results and Design Event Storm Selection

Critical durations were derived for the regional Byron Creek catchment in the vicinity of the site. For each AEP/duration combination, the relevant ensemble of 10 storm patterns was simulated in the hydrologic model and the storm patterns resulting in average[2] peak flow at subcatchment 18 (Byron Creek) were assessed.

Figure 3-1 presents an example of the critical duration assessment for the regional 5% AEP event. The results are plotted in the form of a box and whisker plot and are explained as follows:

- Storm durations modelled range from 1 hour to 24 hours;
- Each duration shows an ensemble of ten peak flow results as points;
- The mean and median flow values are indicated by asterisks and horizontal lines respectively;
- The green boxes represent the interquartile range (the 25th percentile (Q1) to the 75th percentile (Q3));
- The vertical lines (whiskers) extend out to the maximum and minimum values or, if those values are considered outliers, then the lines extend out from Q1 to Q3 by a distance of 1.5 times the interquartile range with outliers shown as points beyond the lines;
- The adopted temporal pattern for each duration is taken as that which results in the 4th largest peak flow (stated in the text box along with a unique temporal pattern identifier); and

[2] The average pattern was taken as giving the 4th largest peak flow.

- The vertical yellow banding highlights the critical duration; the duration for which the adopted average flow is highest.

In Figure 3-1 the 5% AEP critical duration is shown to be 6 hours and the peak flow is around 192m^3/s generated from temporal pattern with the ID 4730. However, the adopted average peak flows for both the 9 hour and the 12 hour storms are very similar (less than 10 m^3/s difference). Durations above 12 hours and less than 6 hours show a notable drop off in adopted average flow values.

A similar finding was apparent for Byron Creek flows for all modelled AEPs with the peak flow appearing to be from either the 6 hour, 9 hour or 12 hour storm duration with only minor differences in flow between them.

Representative events from all three durations (and for each AEP), are summarised in Table 3-1 for regional Byron Creek flows. These were therefore simulated in the hydraulic model and the results mapped in terms of critical duration for peak level (see Section 3.3).

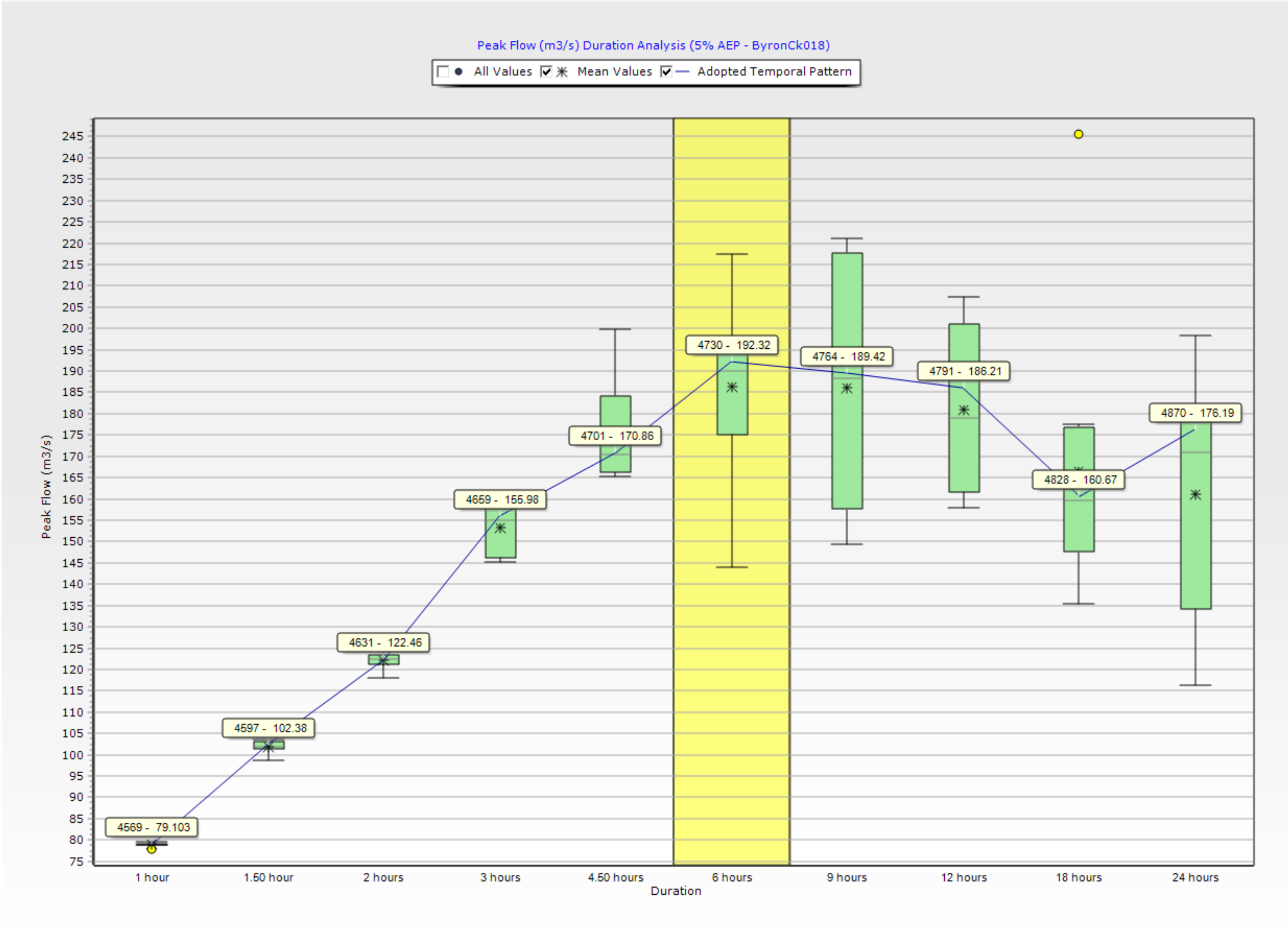


Figure 3-1 Peak Flow Duration Analysis for 5% AEP – Byron Creek Regional Subcatchment 18

Table 3-1 Hydrologic Model Design Event Peak Flow Results (m^3/s)

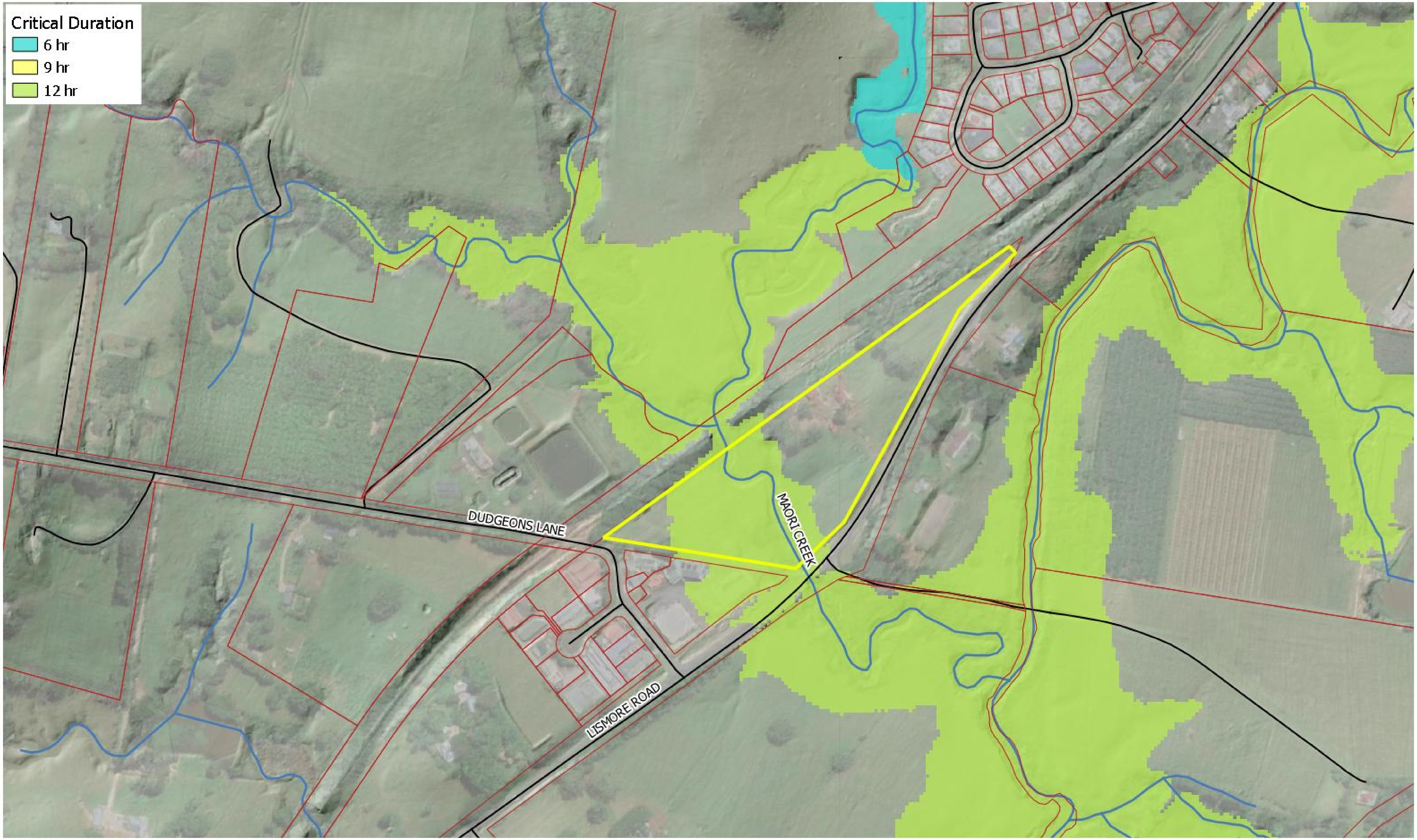
AEP	Regional (Subcatchment 18)		
	Duration (hrs)	Peak Flow (m^3/s)	Temporal Pattern ID
1%	**6**	**289.8**	**4694**
	9	277.3	4442
	12	285.9	4785
5%	**6**	**192.3**	**4730**
	9	189.4	4764
	12	186.2	4791
20%	6	117.3	4740
	9	**123.5**	**4776**
	12	119.3	4805

3.3 Hydraulic Model Critical Duration Assessment

Figure 3-2 to Figure 3-3 show the critical durations in terms of peak level across the study area for the 1%, 5% and 20% AEP events. It can be seen that for the area of interest, the following storms dominate in terms of providing the peak design flood level along Byron Creek and backing up towards the Site, and have been adopted for further design event mapping and impact assessment:

- 1% AEP: 12hr
- 5% AEP: 9hr and 12hr (enveloped)
- 20% AEP: 9 hr

It is noted that the adopted storm, based on peak flood levels in the area of interest, differ from that identified as being critical by the hydrology model in terms of flow in Byron Creek for the 5% and 1% events (refer Table 3-1).



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- Site
- Cadastre
- Roads
- Streams

Title:

1% AEP Critical Duration Map

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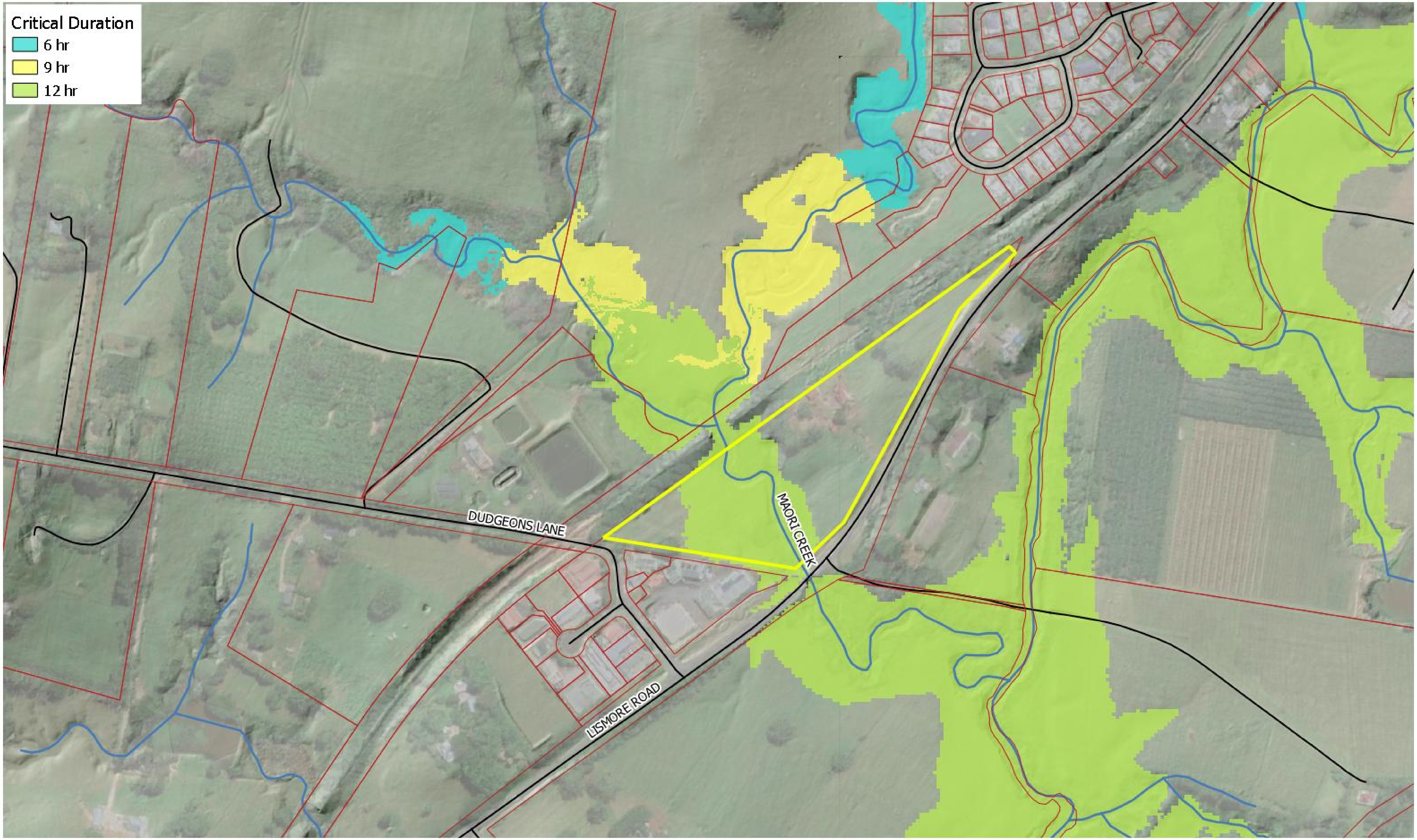

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Site

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Roads

Streams

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5% AEP Critical Duration Map

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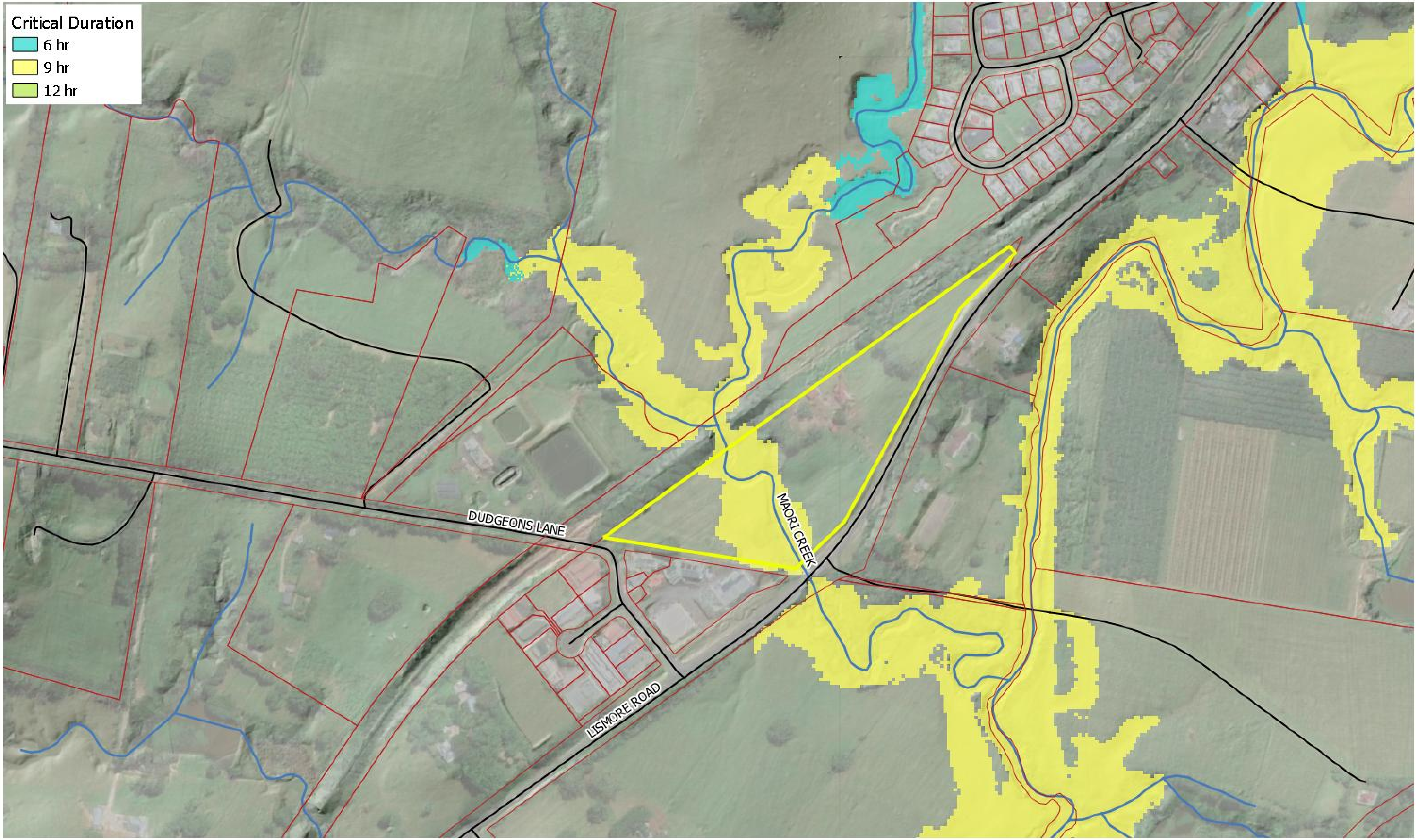

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- Site
- Cadastre
- Roads
- Streams

Title:

20% AEP Critical Duration Map

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3.4 Design Results

3.4.1 Existing Case AEP Flood Levels

Appendix A provides peak flood level maps for the 1%, 5% and 20% AEP events for the storm durations identified as being critical within the study area (see Section 3.3). Contours are shown at 0.1m intervals.

The existing peak water levels at the Site are approximately:

- 1% AEP: 40.98 m AHD
- 5% AEP: 40.46 m AHD
- 20% AEP: 39.93 m AHD

There is insignificant variation in the peak flood level across the length of the site that bounds Maori Creek, between the North Coast Railway Line and Lismore Road, as Lismore Road and the high downstream Byron Creek tailwater conditions cause a constriction.

Based on these results, the flood planning level at site is 41.48 m AHD (1% AEP level + 0.5m freeboard). While 0.5m freeboard is typically adopted for residential dwellings, and it is understood that 0.2m freeboard may be acceptable for industrial land uses.

3.4.2 Climate Change Sensitivity Scenarios

In accordance with Council's DCP 2014 and Climate Change Strategic Planning Policy (CCSPP) and assessment of climate change impacts to flooding in the 1% AEP event are required.

However, it is noted that Council's (year) 2050 and 2100 climate change scenarios primarily consider sea level rise and ocean tailwater conditions, and do not include an increase to rainfall intensity. As the site in Bangalow is well above sea level, consideration of sea level rise changes will have no impact and are not relevant, i.e. there will be no difference between the current day 1% AEP flood level and the climate change year 2050 and 2100 scenarios' flood levels at the site (FPL, 2050 FPL and 2100 FPL are all equivalent at the site). As discussed in Section 3.4.1, this level has been determined to be 41.48 m AHD (depending on the extent of freeboard allowed for).

However, the CCSPP also requires the assessment of additional climate change sensitivity scenarios, of which testing 10% and 30% increases to rainfall intensity for the 1% AEP event are relevant to the site.

The increases in rainfall intensity for the 1% AEP event were applied to the hydrologic model, providing flow hydrographs for application to the hydraulic model for the 12 hr critical duration storm (identified in Section 3.3).

Peak flood level impact maps for the climate change sensitivity scenarios, compared to the existing case conditions, are presented in Appendix D. Impacts have been mapped for any variance in peak flood level by +/- 0.01 m or more. The results show:

- For the 10% increase in rainfall intensity (Figure D-1), the 1% AEP peak flood levels increase by 0.10 m through to site, and by 0.10 m to 0.12 m directly upstream and downstream of the site;

- For the 30% increase in rainfall intensity (Figure D-2) the 1% AEP peak flood levels generally increase by between 0.2 m to 0.5 m in the vicinity of the site, with the site itself experiencing a 0.25m increase.

4 Development Impact Assessment

4.1 Introduction

As the site is flood prone, filling of the site would be required to raise ground levels above Council's flood planning level (1% AEP + freeboard) to increase the amount of developable land. Council requires that it is demonstrated that such development would achieve the relevant flood requirements as outlined in Council's Local Environment Plan and Development Control Plans related to flooding. Generally, these guidelines set building requirements, i.e. floor levels, requirements for emergency management etc and also require development to not give rise to offsite impacts as a result of filling and or the placement of infrastructure.

A flood impact assessment has been undertaken for two fill scenarios in the hydraulic model. The proposed development fill pads were represented in the TUFLOW model as a "z shape" topographic modification, with the fill level set to an arbitrary high level, well above the existing 1% AEP flood levels. No batter was accounted for, to provide a "worst case" assessment of the proposed fill extents.

The fill pad for Development Scenario 1 was aligned to be set back from Maori Creek, in the western portion of the site, and has an area of approximately 0.99 ha, Figure 4-1. The Development Scenario 2 fill pad aimed to increase the developable area by pushing the fill pad boundary back towards the creek, with an area of approximately 1.03 ha.

The impact assessment has been undertaken for the critical duration(s) resulting in the highest flood level at the site for each of the 20%, 5% and 1% AEP events, as detailed in Section 3.3 . For all three modelled AEP floods the peak levels are a result of regional flooding of Byron Creek.

Figure 4-1 Fill Pad Alignments for Development Scenarios

4.2 Results

The flood impact assessment for the proposed development scenarios compare the peak flood level results from the developed cases to the existing case site conditions. Impacts have been mapped for any variance in peak flood level by +/- 0.01 m. Peak flood level impact maps for the developed scenarios are presented in Appendix B and Appendix C. The results show that the peak flood level impact at the site does not exceed +/- 0.01 m for all events (1%, 5% and 20% AEP) for both Development Scenario 1 and 2.

The results for the culvert under Lismore Road were inspected, which show that that the culvert reached maximum capacity in all events, and there was no difference between the percentage of time that it remained full in the development scenarios. The peak flows for each event increased by less than 1 m^3/s for the development scenarios.

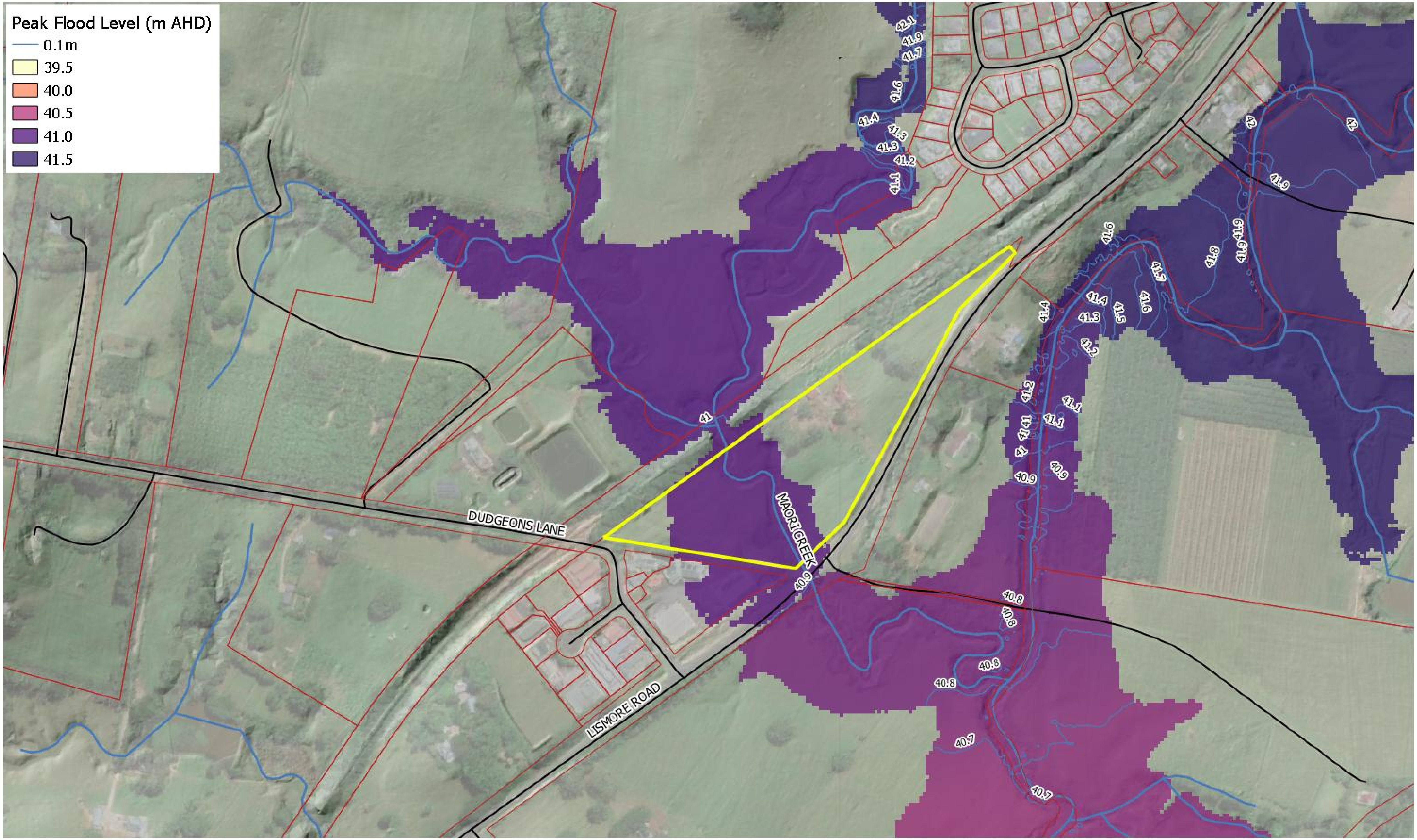
Considering the water level impacts for the proposed development do not exceed +/- 0.01m, the likelihood of any substantive risk of contribution to cumulative impact is considered unlikely.

5 Conclusions

The following points summarise the key outcomes from the assessment.

- The assessment utilised a truncated version of a previously developed and calibrated in-house hydrologic and hydraulic models of the Byron Creek catchment to inform and assess site design flood levels and potential impacts associated with filling of the site.
- Design flood levels for the 20%, 5% 1% AEP events have been established in accordance with the Australian Rainfall and Runoff 2019 guideline. The peak flood levels at the site are controlled by Byron Creek flooding.
- The current climate flood planning level (FPL) at the site has been determined as 41.48 m AHD (1% AEP peak flood level + 0.5m freeboard). The freeboard ultimately adopted for the site may vary from this assumed amount.
- The current day FPL is also equivalent to the 2050 and 2100 FPLs, as the Climate Change Strategic Planning Policy (CCSPP) identifies these climate change scenarios to only relate to increase in ocean boundary levels and sea level rises, which are not applicable at the site's topographic elevation.
- An impact assessment of climate change sensitivity scenarios indicates that a 10% and 30% increase in rainfall intensity would increase 1% AEP peak flood levels by 0.1m and 0.25m through the site, respectively.
- Two development scenarios were assessed for impacts against the existing conditions 20%, 5% 1% AEP events. Fill pads were incorporated into the hydraulic model for the proposed development extent and assumed to be raised to above the FPL. The results show that the peak flood level impact at the site does not exceed +/- 0.01 m for all events (1%, 5% and 20% AEP) for both Development Scenario 1 and 2.
- There was no significant impact evident to peak flows and the time full for the Lismore Road culverts for either of Development Scenario 1 and 2, in any of the events.

Appendix A Peak Flood Level Impact Maps



Legend

- Site
- Cadastre
- Roads
- Streams

Title:

1% AEP Peak Flood Level

Drawing: **A-1**

Rev: **A**

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0 100 200 m

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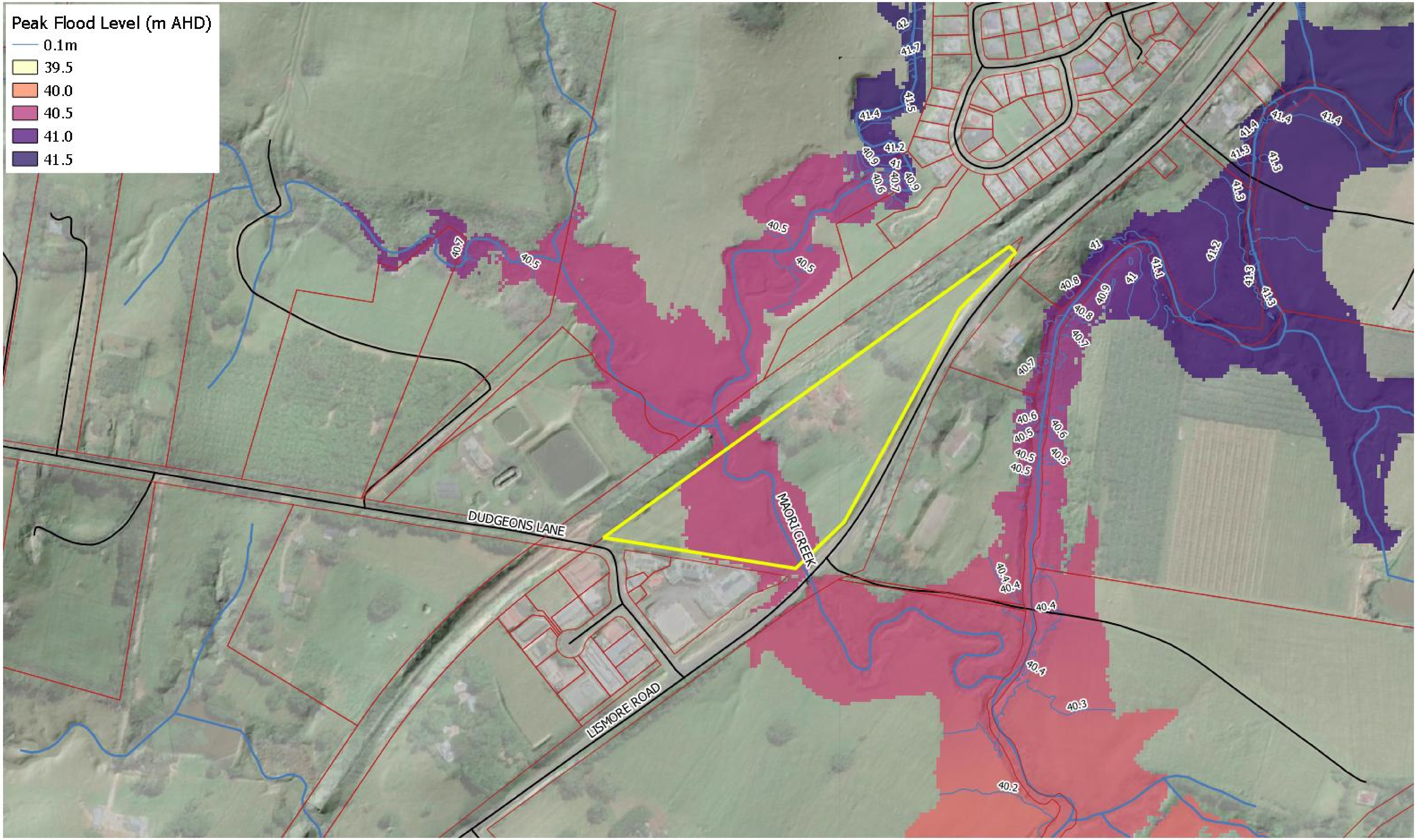

Legend

Site

Cadastre

Roads

Streams

Title:

5% AEP Peak Flood Level

Drawing: A-2

Rev: A

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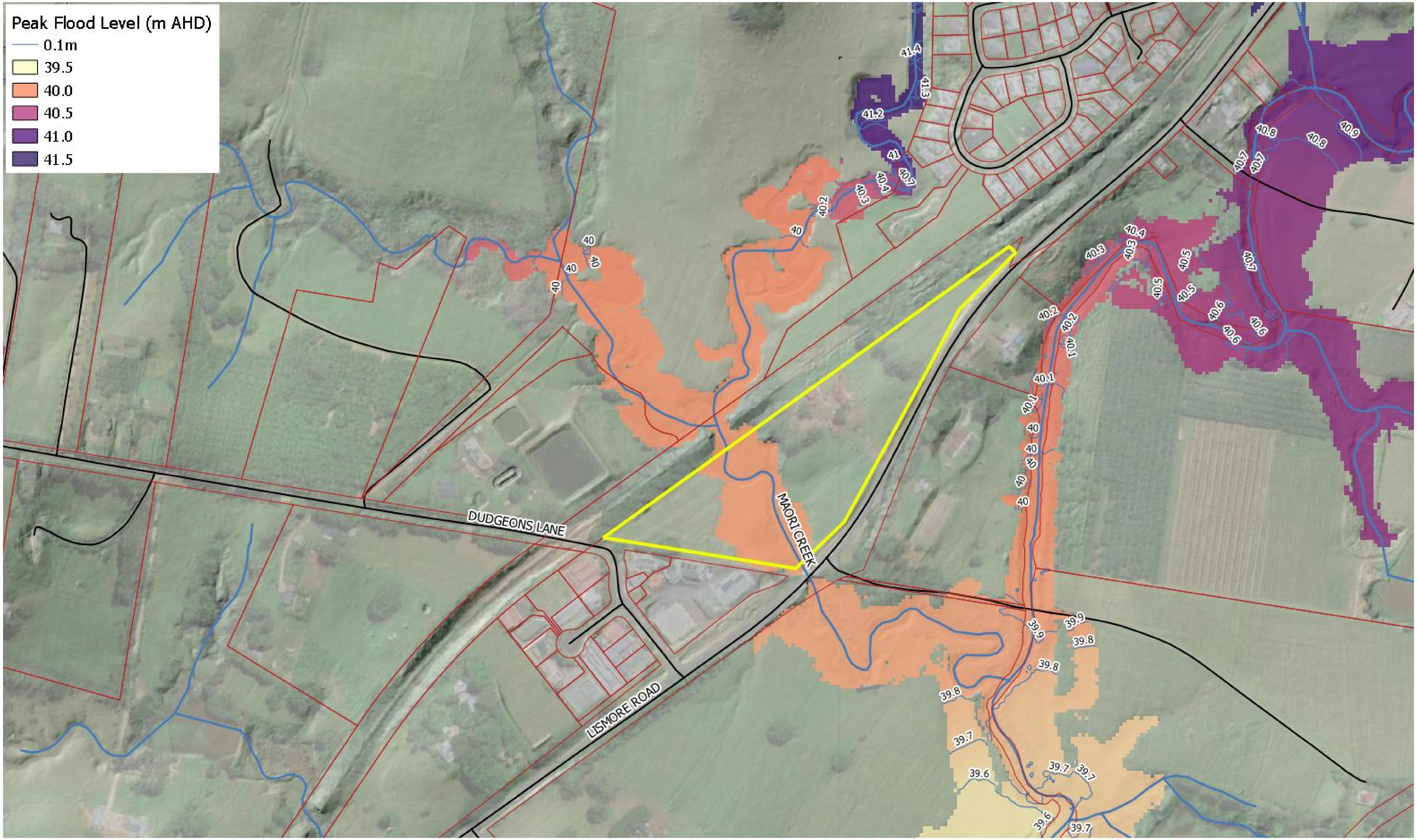

Legend

- Site
- Cadastre
- Roads
- Streams

Title:

20% AEP Peak Flood Level

Drawing: **A-3**

Rev: **A**

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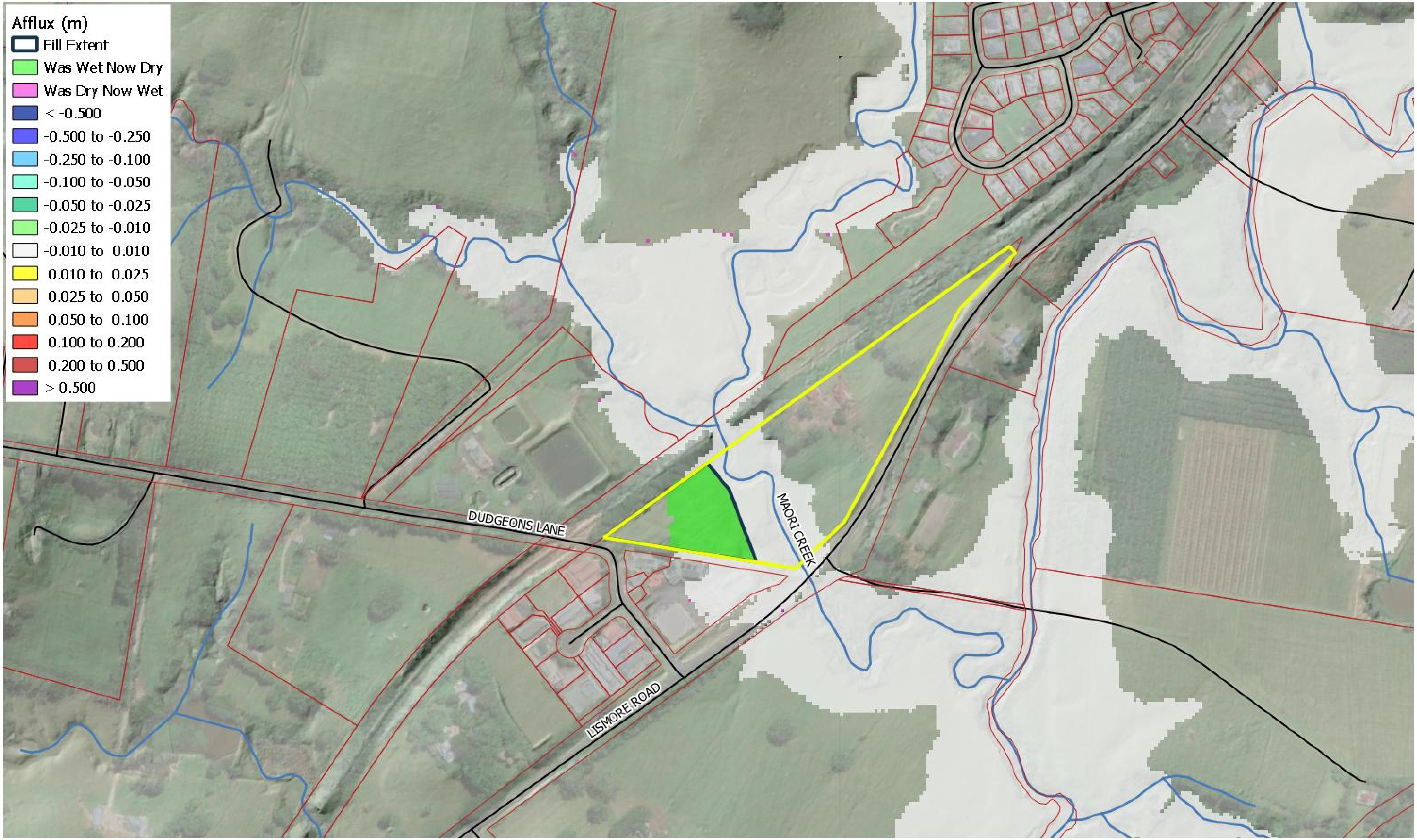
Appendix B Peak Flood Level Impact Maps – Development Scenario 1



Legend

- Site
- Cadastre
- Roads
- Streams

Title:

1% AEP Peak Flood Level Impacts - Development Scenario 1

Drawing: **B-1**

Rev: **A**

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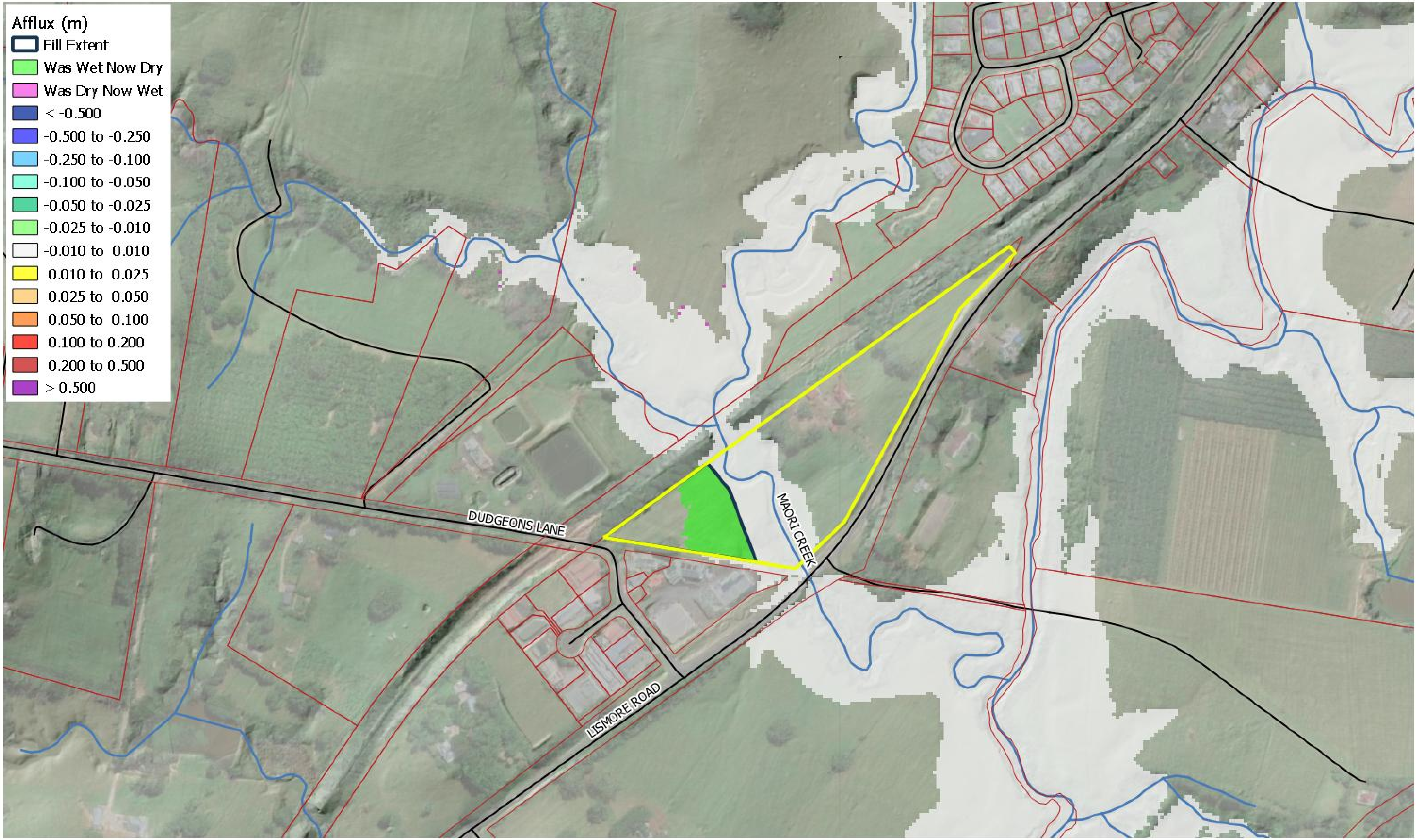

Legend

- Site
- Cadastre
- Roads
- Streams

Title:

5% AEP Peak Flood Level Impacts - Development Scenario 1

Drawing: **B-2**

Rev: **A**

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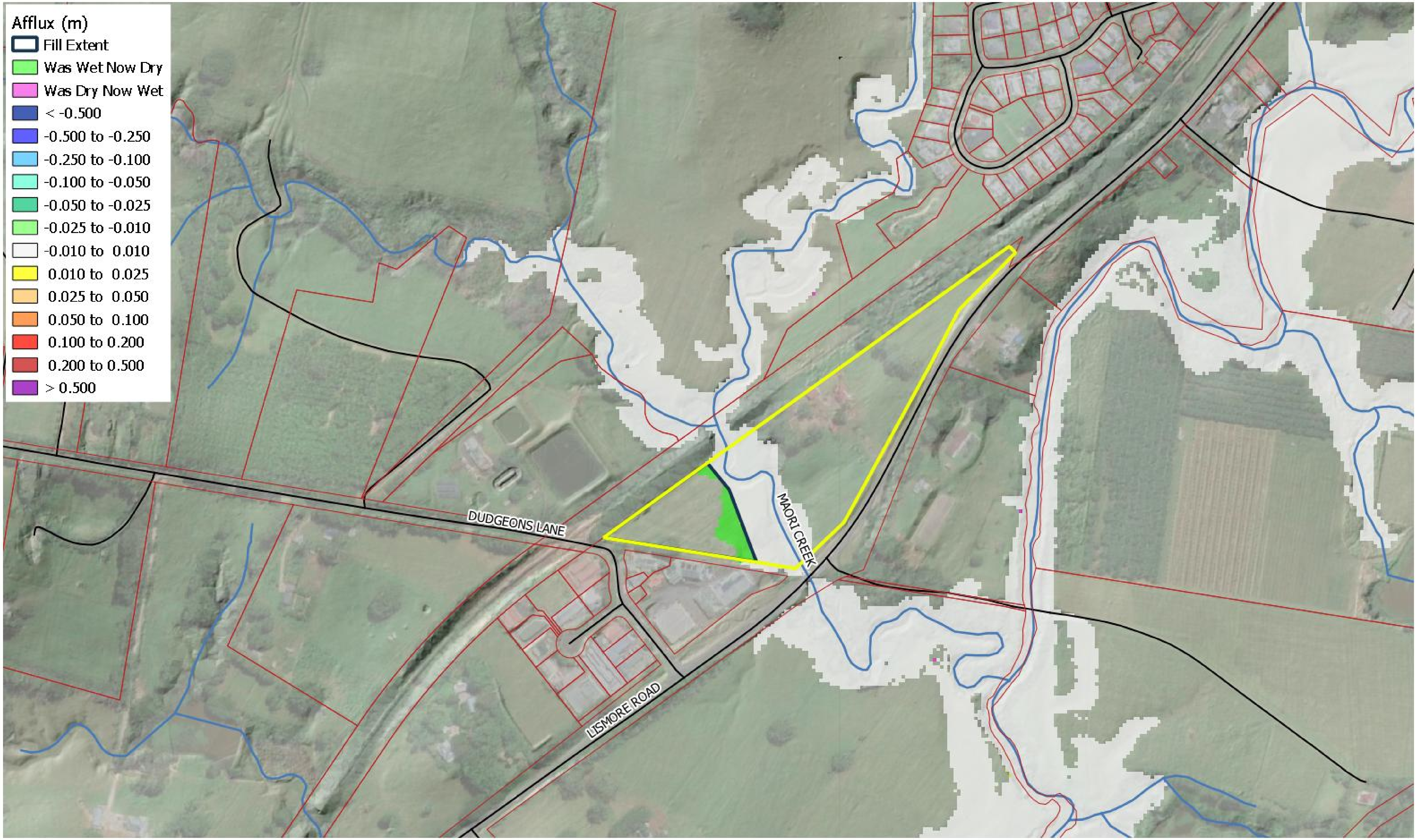

Legend

- Site
- Cadastre
- Roads
- Streams

Title:

20% AEP Peak Flood Level Impacts - Development Scenario 1

Drawing: **B-3**

Rev: **A**

0 100 200 m

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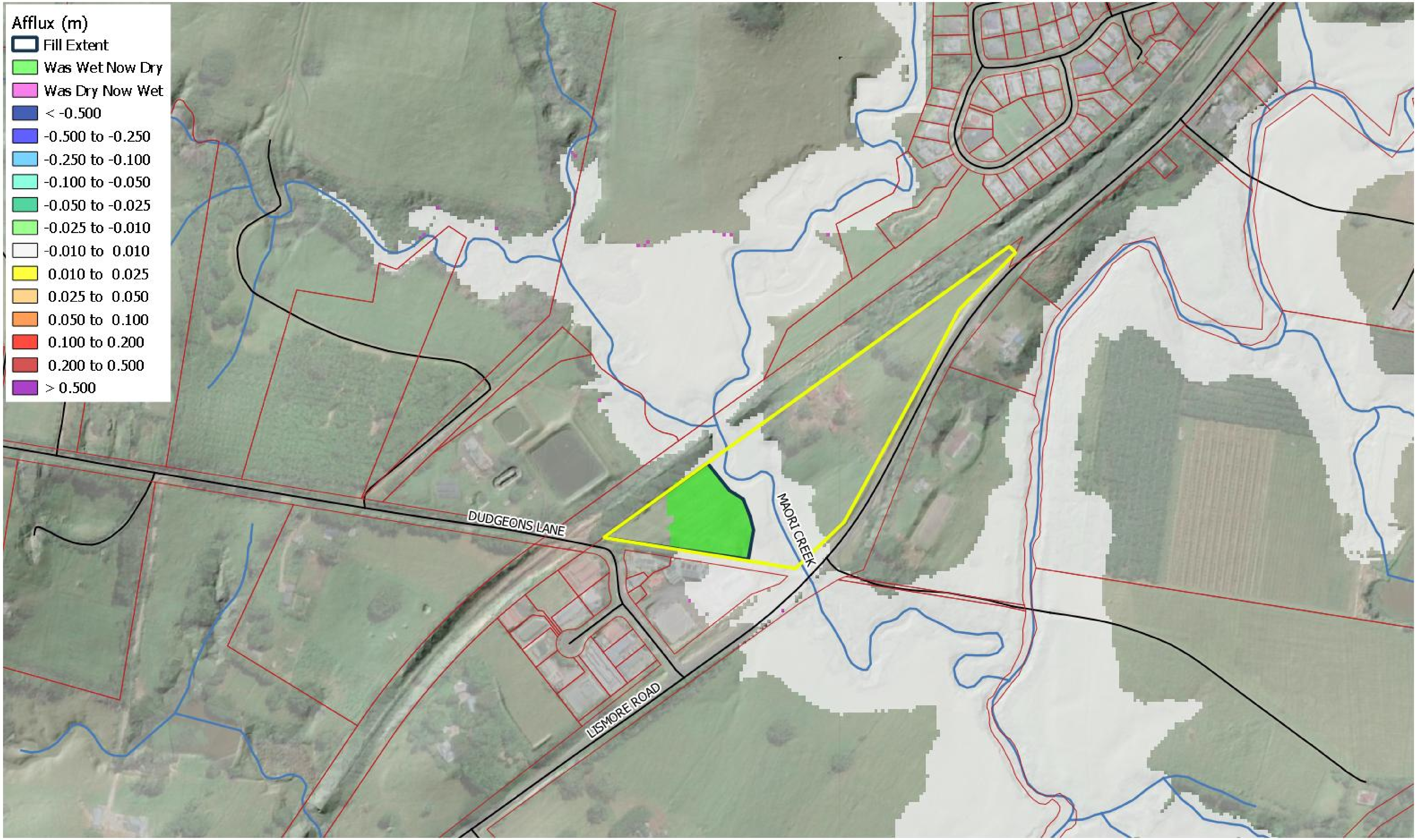
Appendix C Peak Flood Level Impact Maps – Development Scenario 2



Legend

Site

Cadastre

Roads

Streams

Title:

1% AEP Peak Flood Level Impacts - Development Scenario 2

Drawing: C-1

Rev: A

0 100 200 m

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Legend

- Site
- Cadastre
- Roads
- Streams

Title:

5% AEP Peak Flood Level Impacts - Development Scenario 2

Drawing: **C-2**

Rev: **A**

0 100 200 m

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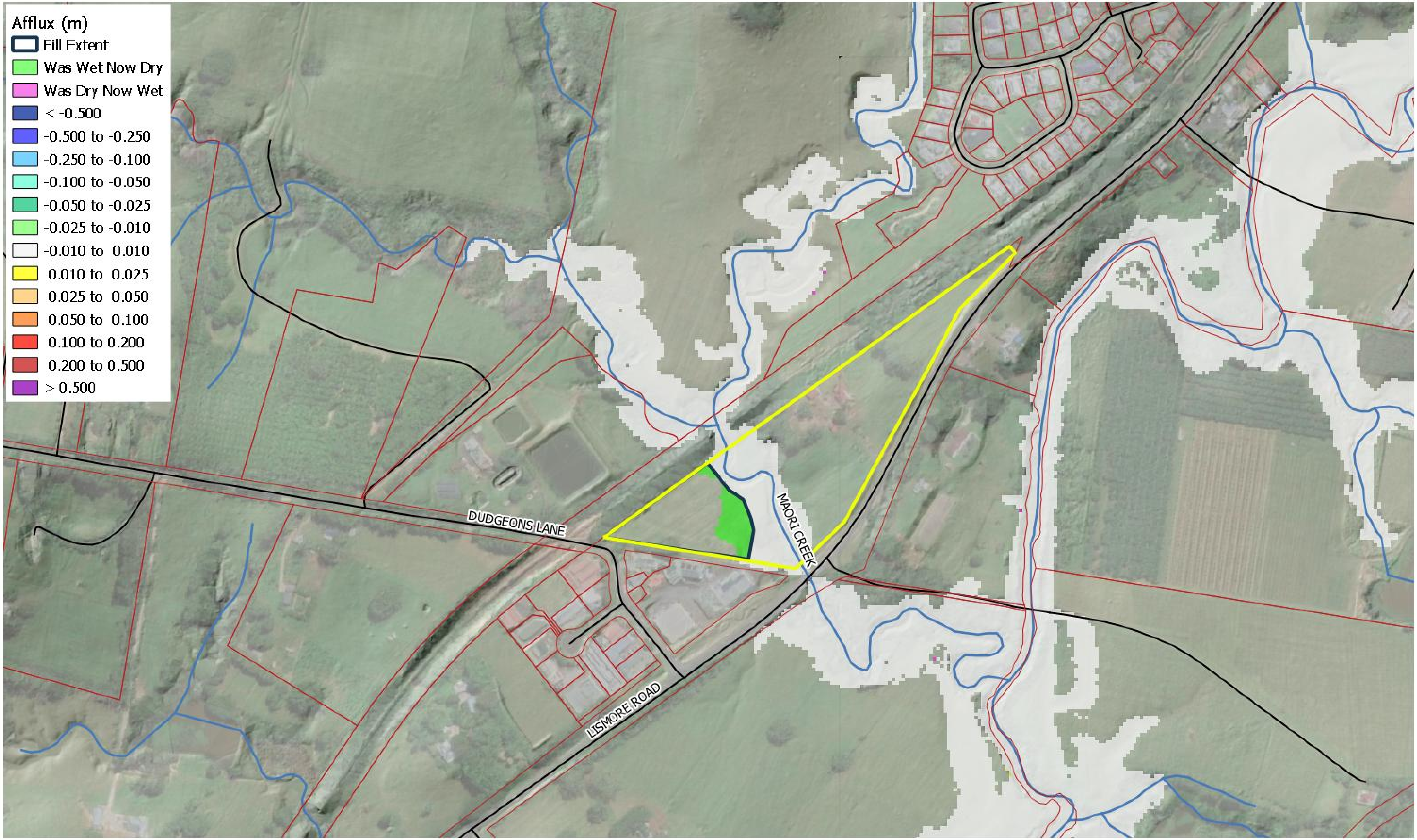

Legend

- Site
- Cadastre
- Roads
- Streams

Title:

20% AEP Peak Flood Level Impacts - Development Scenario 2

Drawing: **C-3**

Rev: **A**

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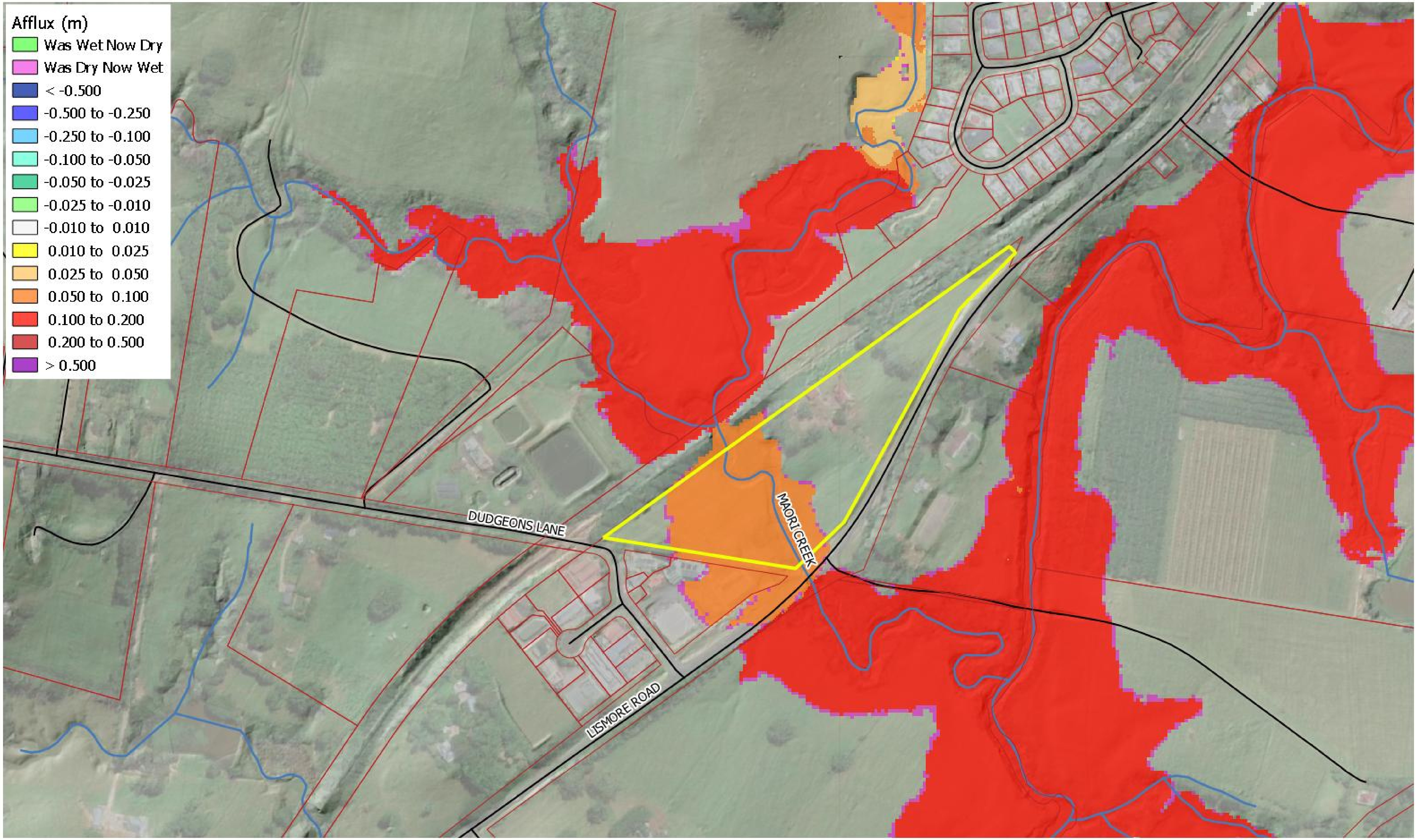
Appendix D Peak Flood Level Impact Maps – Climate Change Sensitivity Scenarios



Legend

- Site
- Cadastre
- Roads
- Streams

Title:

1% AEP Peak Flood Level Impacts - Climate Change Sensitivity (10% Rainfall Intensity Increase)

Drawing: **D-1**

Rev: **A**

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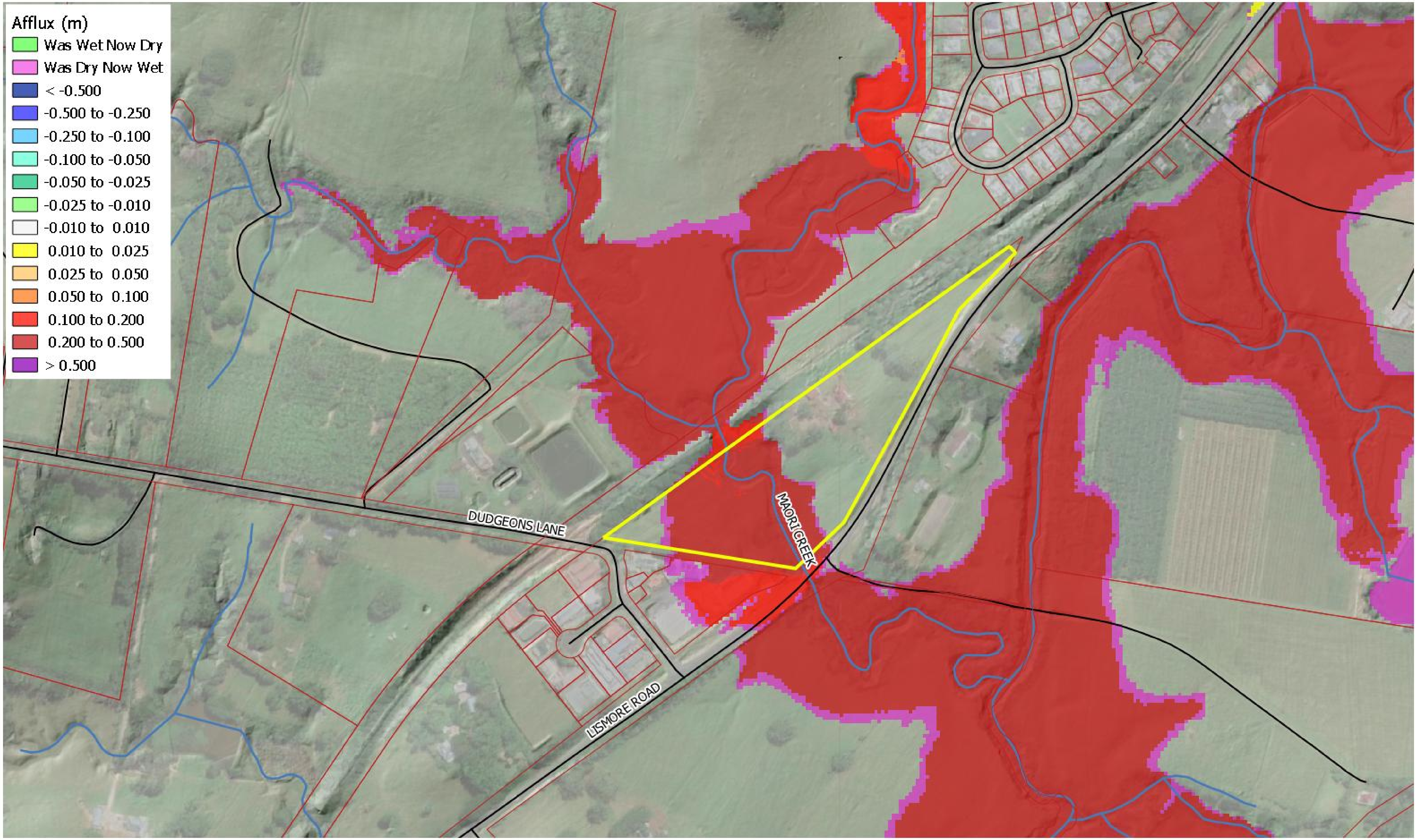

Legend

- Site
- Cadastre
- Roads
- Streams

Title:

1% AEP Peak Flood Level Impacts - Climate Change Sensitivity (30% Rainfall Intensity Increase)

Drawing: **D-2**

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