Goorambat Solar Facility

Flood Risk Assessment

27th February 2020

Level 17, 141 Walker St
North Sydney NSW 2060
Australia

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Revision 1

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Project: GOORAMBAT SOLAR FACILITY
FLOOD RISK ASSESSMENT

Rev	Description	Author	Review	Advisian Approval	Date
A	Draft Report (*Issued for Internal Review*)	DB D Bird	WJH W Honour		19-02-2020
1	Draft Issued for Client Review	DB D Bird	WJH W Honour		27-02-2020

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1 Introduction

Advisian has been engaged by Neoen Australia to prepare a Flood Risk Assessment (*FRA*) for the proposed Goorambat Solar Photovoltaic (*PV*) Project. The project is located in close proximity to the township of Goorambat in northern Victoria. Goorambat is located 18 km north of Benalla within the Benalla Rural City Local Government Area (*LGA*) (*refer* **Figure 1**).

The proposed site layout plan has not been finalised at the time of writing. However, it is understood that the works will include installation of solar panel arrays, internal access roads, platforms for onsite switchgear enclosures, inverter pads, a substation and a compound area. The solar farm will comprise two sites; an eastern and western site (*refer* **Figure 1**).

The Broken River runs east-to-west to the south of the two sites. Broken Creek runs approximately north-south between the two sites. Given the proximity to these watercourses, there is potential for mainstream flooding to affect the sites. There is also potential for local overland runoff to affect the sites, especially the eastern site.

Accordingly, a WBNM hydrologic model and a TUFLOW rainfall-on-the-grid hydrodynamic model have been developed and employed to model the expected rainfall and flood behaviour for the 100 year Average Recurrence Interval (*ARI*) event. The results from these flood models have been used to evaluate the flood risk at the site due to mainstream flooding from the Broken River and Broken Creek. Overland flows through the site from local drainage catchments have also been captured in the modelling.

This report documents the findings of the flood modelling and serves as the flood risk assessment for the proposed Goorambat solar facility.

2 Existing Site Conditions

2.1 Topography and Drainage

The two solar farm sites are situated adjacent to the Goorambat township with the two sites separated by Broken Creek (*refer* **Figure 1**). Broken River is located to the south of the two sites. Broken Creek splits from the Broken River approximately 3 kilometres to the south of the eastern solar site. At the closest points, the eastern site is located 2 km north of the Broken River and 1 km west of Broken Creek, while the western site is located 4.2 km north of the Broken River and 3.3 km west of Broken Creek, with Major Creek passing the north-eastern most corner of this site (*refer* **Figure 1**).

Three sets of terrain data were obtained for the study area (*refer* **Figure 2**). Survey data was initially collected by Land Surveys in 2019 covering the two sites and a limited extent beyond them. Terrain data for areas further afield was provided by VicMaps, which contains data from a variety of sources including LiDAR and surface contours from older topographic sources. It is not clearly defined the extent sourced from LiDAR compared to the extent that is sourced from contours.

The VicMaps data was most detailed in areas that were less than 500 to 1,500 m from either the Broken River or Broken Creek. This suggests that the data along the creeks was either sourced from LiDAR or detailed survey. In other areas the terrain contained in the VicMaps data set is made up of what appear to be smooth, undulating hills. This indicates that the basis of the terrain data in these areas is likely contours with intervals of 10 or 20 m, which is not sufficiently detailed for our final modelling. For initial broadscale flood modelling the VicMaps data was used as the basis for the terrain for the entire model.

The extent of detailed terrain data from VicMaps was considered in conjunction with the results of the broadscale flood modelling to identify the gaps where additional detailed survey was required (*refer yellow hatched area in* **Figure 2**). Land Surveys collected this additional data in early 2020 via aerial LiDAR techniques.

The topography of the two sites and the surrounding countryside is generally very flat, with typical grades of 0.5% increasing to a maximum of 4% (*refer* **Figure 3**). The local runoff catchment at the eastern site is expected to drain to the west toward Broken Creek. There is potential for floodwaters spilling from the Broken River and Broken Creek to pass along the western boundary of the eastern site. The western site is potentially affected by floodwaters spilling from Broken River and Broken Creek flowing in a north-west direction.

2.2 Soils and Vegetation

A geotechnical report was prepared for the Goorambat Solar Farm by AECOM following a site investigation and sample testing undertaken in May 2019 (AECOM, 2019).

The investigations found that over the two sites the topsoil was generally comprised of clay which extended to the termination depth of the boreholes. According to the Geotechnical Interpretive Report (AECOM, 2019) the upper 5 m of the ground profile is assumed to be very stiff and hard clay. The report states that groundwater was in general not encountered at the site, with some exceptions where groundwater was identified at depths of 3 to 4 m below the existing ground surface.

According to aerial imagery provided by Land Surveys, both sites are situated on land which has mostly been cleared of large trees and shrubs. The majority of the land and surrounding area is currently used for agricultural purposes, the sites themselves appearing to be predominantly covered by low grasses. A small number of trees are spread across each of the sites, particularly along the sides of roads or watercourses.

3 Existing Flood Conditions

The existing flood characteristics in the vicinity of the site have been investigated and are presented in the following, accounting for mainstream flooding due to the proximity of the site to the Broken River and Broken Creek, and the potential for overland flows to pass through the site from the local drainage catchment.

3.1 Previous Flood Mapping

The site is located within the northern portion of the Benalla Rural City local government area. Flood levels and extents are mapped by the Goulburn Broken Catchment Management Authority (CMA) as part of the 1% Flood Level Contour Atlas (*Goulburn Broken CMA, 2008*). The 1% Annual Exceedance Probability (AEP) is equivalent to the 100 year Average Recurrence Interval (ARI) flood.

The CMA flood mapping in the vicinity of the two sites has been reviewed to provide an indication of the flood levels and extents that are expected in terms of mainstream flooding from the Broken River. The eastern site is located within the area depicted in Drawing 39 (*refer* **Appendix A**). The extent of floodwaters depicted at this site come up to the western boundary of the site at levels around 155 to 156 mAHD.

The western site is covered by Drawings 34, 38, and 39. The extent of flooding crosses the north-eastern corner of the site with floodwaters from Major Creek breaking out over a small area of the site with a 1% AEP level of level of 147 mAHD (*refer* **Appendix A**).

The exact source of the CMA 1% Flood level contours in not known. Notes that accompany the mapping indicate that it is based on *available historical flood level and flow information, hydrologic and hydraulic modelling*.

Detailed flood modelling for the Broken River catchment is considered necessary to reliably define the flood characteristics in the vicinity of the Goorambat Solar Farm sites. Accordingly, hydrologic and hydraulic models were developed.

3.2 Hydrologic Modelling

The conversion of rainfall to runoff over the upstream Broken River catchment was modelled using the WBNM hydrologic modelling software. WBNM is able to incorporate such parameters as the size of subcatchments, initial and continuing rainfall losses, impervious fraction and the interactions between subcatchments to calculate flows at each node in the model. Modelling has been completed for the 100 year ARI event. Techniques and rainfall data prescribed by Australian Rainfall and runoff 2016 (ARR16) have been employed.

3.2.1 Catchment Delineation

The Broken River catchment upstream of the Goorambat Solar Site covers an area of approximately 2,100 km^2 in size, extending over 90 km to the south of the site (*refer* **Figure 4**). Two separate WBNM models were developed. The first model focused on assessing peak flows of the 100 year ARI mainstream flooding along the Broken River, and the second focused on localised overland flows from the east of the eastern site (*refer inset* **Figure 4**).

The Broken River catchment was delineated into 23 subcatchments using available terrain data from VicMaps for the wider catchment area.

The separate WBNM model used to assess overland flows at the eastern site covers an area of approximately 23 km^2. This area was further delineated into five subcatchments using survey data for the site and terrain data sourced from VicMaps (*refer* **Figure 4**).

3.2.2 Critical Storm Duration Analysis

The WBNM model was used to determine the critical storm duration for both mainstream flooding along the Broken River and overland flows at the eastern site. The critical storm duration represents the duration of storm that leads to the greatest flow for a defined catchment and ARI. The critical storm durations for the 100 year ARI event are summarised in **Table 1** below.

Table 1 – Critical Storm Duration Summary

Location	WBNM Subcatchment (refer **Figure 4**)	Critical Storm Duration
Broken River Catchment	1.7	24 hours
Eastern Portion of Eastern Site (Overland Flow Model)	2	6 hours
Downstream Limit of Eastern Site (Overland Flow Model)	5	6 hours

Storm durations of both 6 and 24 hours have been adopted for the hydraulic modelling described in the following section.

3.3 Hydraulic Modelling

Flood behaviour for the 100 year ARI event was simulated using a two-dimensional TUFLOW hydraulic model incorporating a combination of inflow hydrographs from WBNM for upstream reaches of the Broken River and direct rainfall (*i.e., rainfall-on-the-grid*) over the TUFLOW model domain.

Hydraulic modelling was undertaken in two stages. Firstly, a broadscale model was developed using only the VicMaps terrain data. This model was used to obtain a general understanding of flood behaviour and extent in the catchment.

The model extent was then refined to allow for modelling on a smaller scale and greater fine-tuning, particularly to terrain. As described in **Section 2.1**, additional LiDAR survey was collected for areas surrounding the two sites and some manual adjustments were made as required. This included the channels that run under road bridges on the Midland Highway, and also enforcing the crest of the railway line embankment through the eastern site. This model allowed for greater detail and understanding of how flooding will affect the site and surrounding areas.

The extent of the refined TUFLOW model is shown in **Figure 2**. A grid size of 7 metres was adopted.

3.3.1 Bridges and Culverts

There was no survey of culverts or bridges undertaken for the purpose of the flood modelling. Culverts were included under the railway line that runs through the eastern site and the township of Goorambat. The location and sizing of these culverts was based on the aerial photos provided by Land Surveys, with invert levels to match the surrounding terrain and an assumed depth of cover of about 500mm.

Manual modifications were also made to the terrain data in an effort to represent the flows that may occur under the Midland Highway in the 100 year ARI flood.

3.3.2 TUFLOW Boundary Conditions

The inflows from the WBNM model were incorporated into the Broken River channel and a point further south, as shown in **Figure 5**. Rainfall-on-the-grid was applied over the entire TUFLOW model domain.

Downstream boundary conditions have been incorporated in to the TUFLOW model according to a head verses flow relationship assuming normal depth flows. These have been included where flows exit the model both within defined watercourses (*i.e., the Broken River, Broken Creek and Major Creek*) and as overland flows (*refer* **Figure 5**).

3.3.3 TUFLOW Model Results

Peak flood levels, depths and velocities were extracted from the hydraulic model results for the 100 year ARI event and are presented in the following figures:

- **Figure 6, 7 and 8**: Peak flood levels;
- **Figure 9, 10 and 11**: Peak flood depths;
- **Figure 12, 13 and 14**: Peak flow velocities.

The flood mapping has been filtered to remove areas of inundation with depths less than 50 mm, which is a common approach adopted for rainfall-on-the-grid results.

3.3.4 Discussion of Flood Model Results

Discussion of the TUFLOW model results is presented in the following:

- The eastern site is more susceptible to overland flows than mainstream flooding. The critical storm duration for the eastern site is 6 hours. Peak food levels for the 6 hour event are included in **Figure 7**.
- The western site, like much of the surrounding area, is impacted by mainstream flooding from the Broken River and Broken Creek more than local overland flows. The critical storm duration for this site is 24 hours. See **Figure 8** for peak flood levels at the western site.
- Depths in the 100 year ARI storm at the eastern site are generally shallow with large areas having only sheet flow with depths less than 0.15 m (*refer* **Figure 10**). There are some more defined

overland flowpaths within the site where depths are generally up to 0.2 m in the western half of the site or 0.5 m in the eastern half of the site. Flow velocities are highest along these flowpaths (*refer* **Figure 13**). There is expected to be a backing-up of floodwaters against the railway that runs through the middle of the site and against Benalla-Tocumwal Road that runs along the western boundary. Outside of farm dams the depths on the western boundary typically do not exceed 0.7 m, other than in the north-western corner where depths are up to 0.9 m. Depths where backing up occurs against the railway line typically do not exceed 0.7 m.

- The greatest depths at the western site are along an ephemeral watercourse that runs through the south western portion of the site (*refer* **Figure 11**). This flowpath appears to feed into several farm dams that are dotted across the site. The depth in the 100 year ARI event is up to 1.3 m in this area, excluding the localised depressions and farm dams. There is an approximately 160 m stretch of this flowpath with depths between 2.0 and 2.2 m. There area several areas where floodwaters spread-out in the southern portion of the site at depths of up to 0.6 m. In the northern portion of the site floodwaters are more spread-out in the 100 year ARI event with depths generally not exceeding 0.2 m. Flow velocities are typically low aside from along the defined flowpath through the southern portion of the site (*refer* **Figure 14**).

In comparison to the CMA flood mapping, at the north-west corner of the eastern site the TUFLOW results matched reasonably well to the CMA flood level contours (*within 300 to 400 mm*). This is also the case for most of the western boundary of the eastern site. Near the south-west corner of the eastern site the TUFLOW food levels are up to 0.5 m lower than the CMA flood contours. The source of the CMA flood level or the method used to derive them is not clear. It is likely that any flood modelling previously completed employed a simplified 1-dimensional modelling approach, whereas the 2-dimensional TUFLOW modelling would better account for the complex flow patterns across this relatively flat floodplain.

At the western site there was a reasonable match between the TUFLOW results and the CMA flood level contours, typically within 200 to 300mm.

4 Conclusions

A WBNM hydrologic model and a two-dimensional TUFLOW hydraulic model have been developed and used to simulate existing flood conditions at the Goorambat Solar Facility sites to determine the existing flood risk.

The model results show that for the 100 year ARI event the eastern site will be predominantly impacted by overland flows while the western site is more susceptible to mainstream flooding. The eastern site is largely impacted by floodwaters that are less than 0.15 m in depth, however, with some increased depths of up to 0.7 m where backing-up occurs against the railway and road embankments.

At the western site where mainstream flooding from the Broken River and Broken Creek has a greater influence on flooding there is a defined flowpath through the southern part of the site with depths typically up to 1.3 m (*aside from localised depressions and farm dams*), with depths of up to 2.2 m at one 160 m long stretch. Otherwise depths across the western site are typically less than 0.2m in the north and 0.6 m in the south.

It is understood that Neoen will use the prepared 100 year ARI flood mapping in the design of the proposed solar panel arrays and other electrical infrastructure on the site, with a view to minimising the potential flood damages and avoiding any impact on flood conditions at adjacent properties.

5 References

- AECOM (2019), *Geotechnical Factual Report - Neoen Solar Farm.*
- AECOM (2019), *Geotechnical Interpretive Report - Neoen Solar Farm.*
- Benalla Rural City Council (2018), *Benalla Planning Scheme.*
- Goulburn Broken Catchment Management Authority (2008), *1% Flood Level Contour Atlas.*

FIGURE 1

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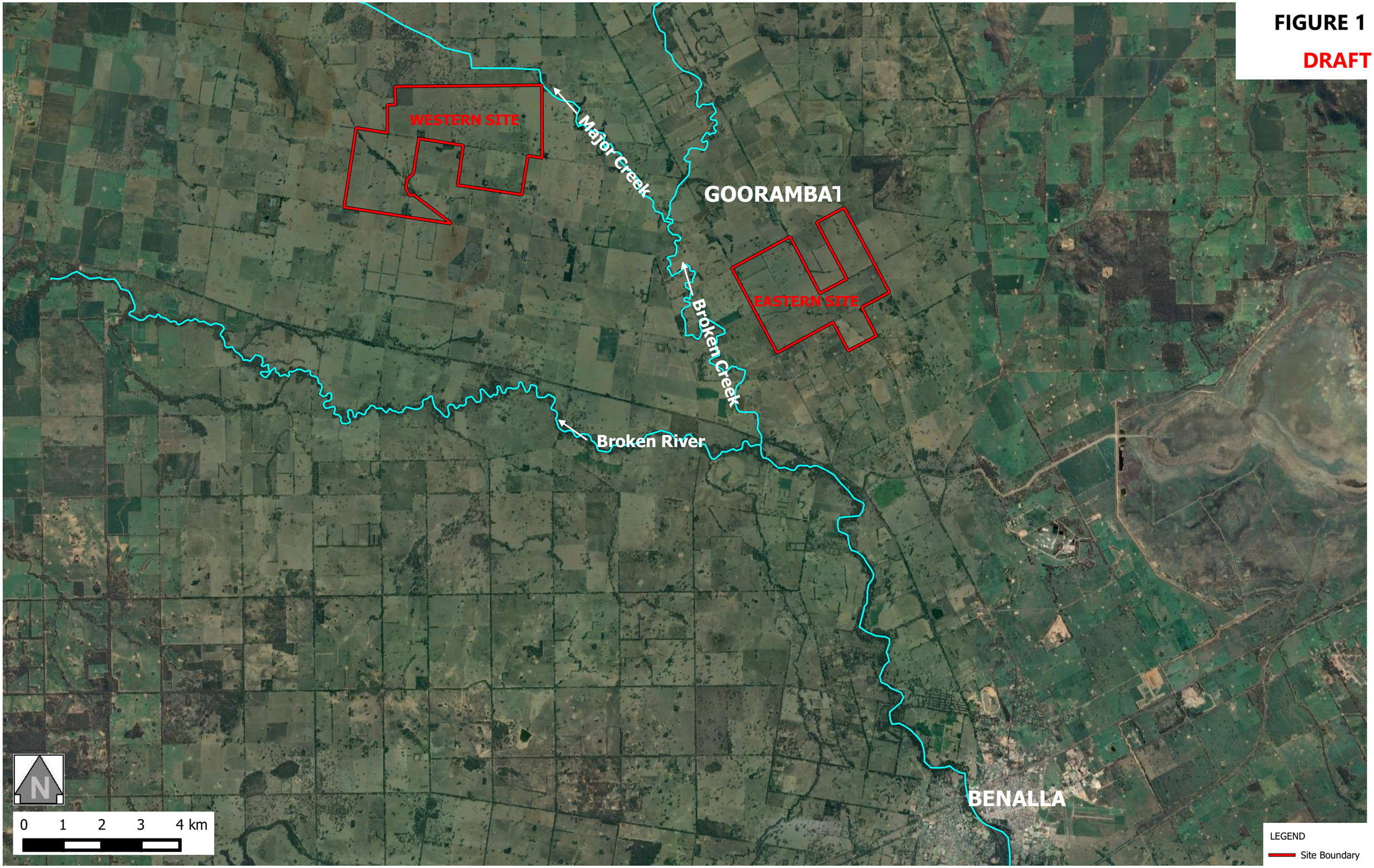

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GOORAMBAT SOLAR FARM SITE LOCATIONS

FIGURE 1 Site Location
Goorambat -TUFLOW.qgz

FIGURE 2

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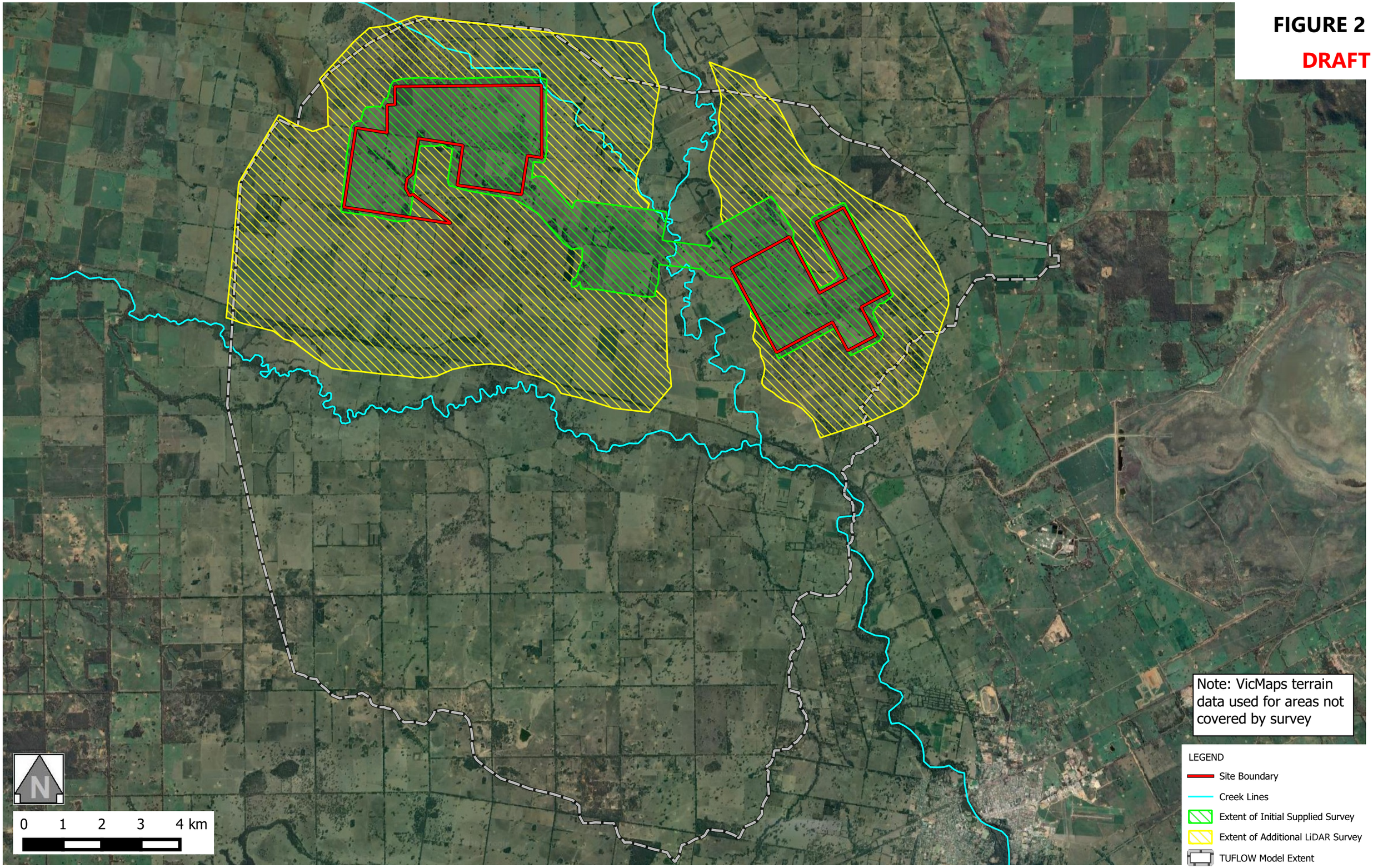

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SOURCES OF TERRAIN DATA USED IN HYDRAULIC MODELLING

Figure 2 - Drone Survey Requirements
Goorambat -TUFLOW.qgz

FIGURE 3

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Major Creek

Broken Creek

Broken River

LEGEND

- Site Boundary
- TUFLOW Model Extent
- Creek Lines

Elevation [mAHD]

- <= 142
- 142 - 144
- 144 - 146
- 146 - 148
- 148 - 150
- 150 - 152
- 152 - 154
- 154 - 156
- 156 - 158
- 158 - 160
- 160 - 162
- 162 - 164
- 164 - 166
- 166 - 168
- 168 - 170
- 170 - 172
- 172 - 174
- 174 - 176
- 176 - 178
- 178 - 180
- 180 - 182
- 182 - 184
- 184 - 186
- 186 - 188
- > 188

N

0 1 2 3 4 km

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GOORAMBAT SOLAR FARM SITE TERRAIN

FIGURE 3
Goorambat -TUFLOW.qgz

FIGURE 4

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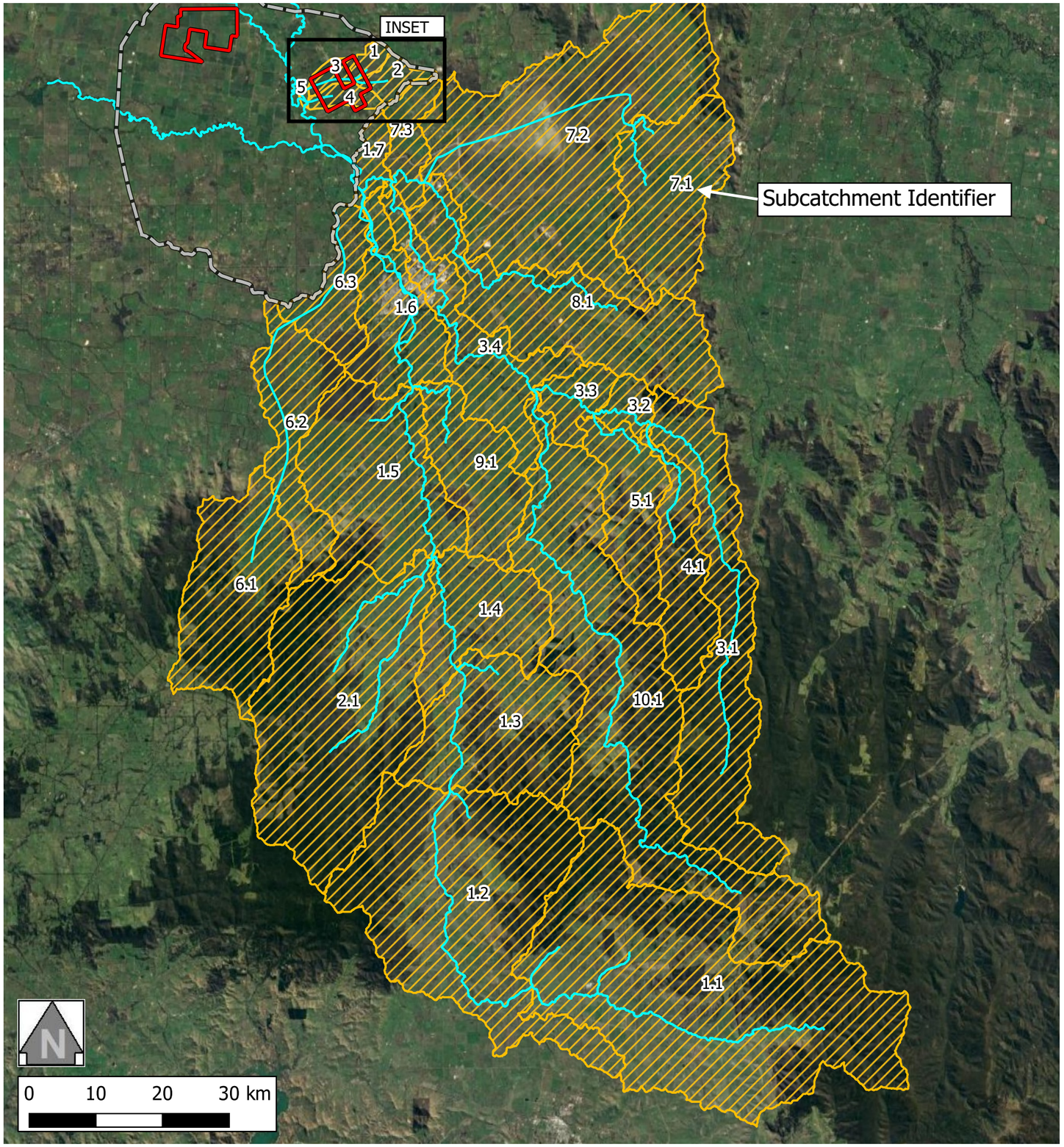

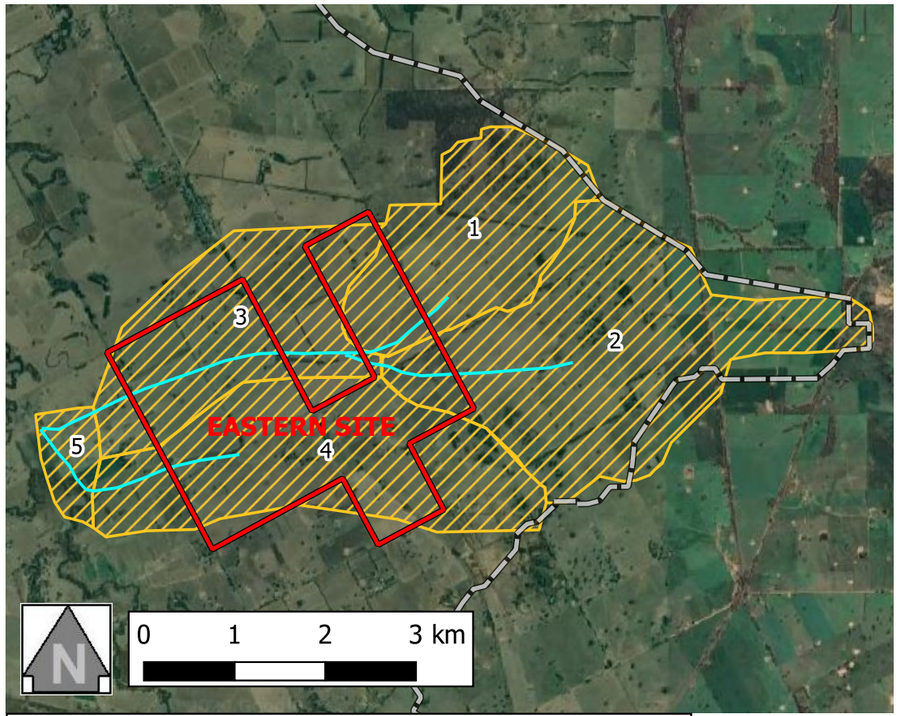

INSET: Local Drainage Catchment to Eastern Site

LEGEND

- Site Boundary
- TUFLOW Model Extent (Rainfall on grid)
- WBNM Catchments
- Watercourses / Flowpaths

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FIGURE 4 WBNM Catchments
Goorambat -TUFLOW.qgz

WBNM HYDROLOGIC MODEL SUBCATCHMENT LAYOUT

FIGURE 5

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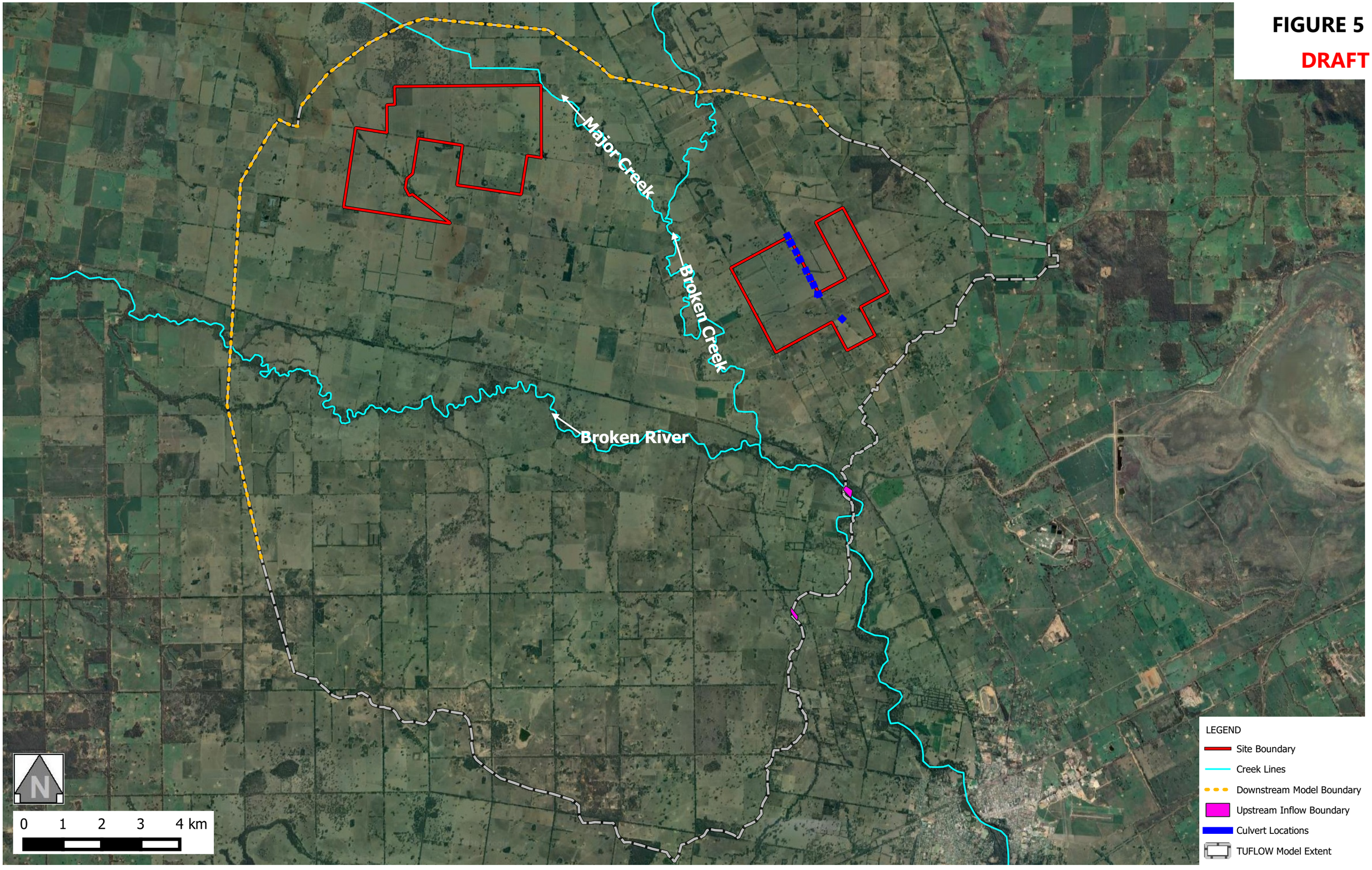

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TUFLOW MODEL LAYOUT

Figure 2 - Drone Survey Requirements
Goorambat -TUFLOW.qgz

FIGURE 6

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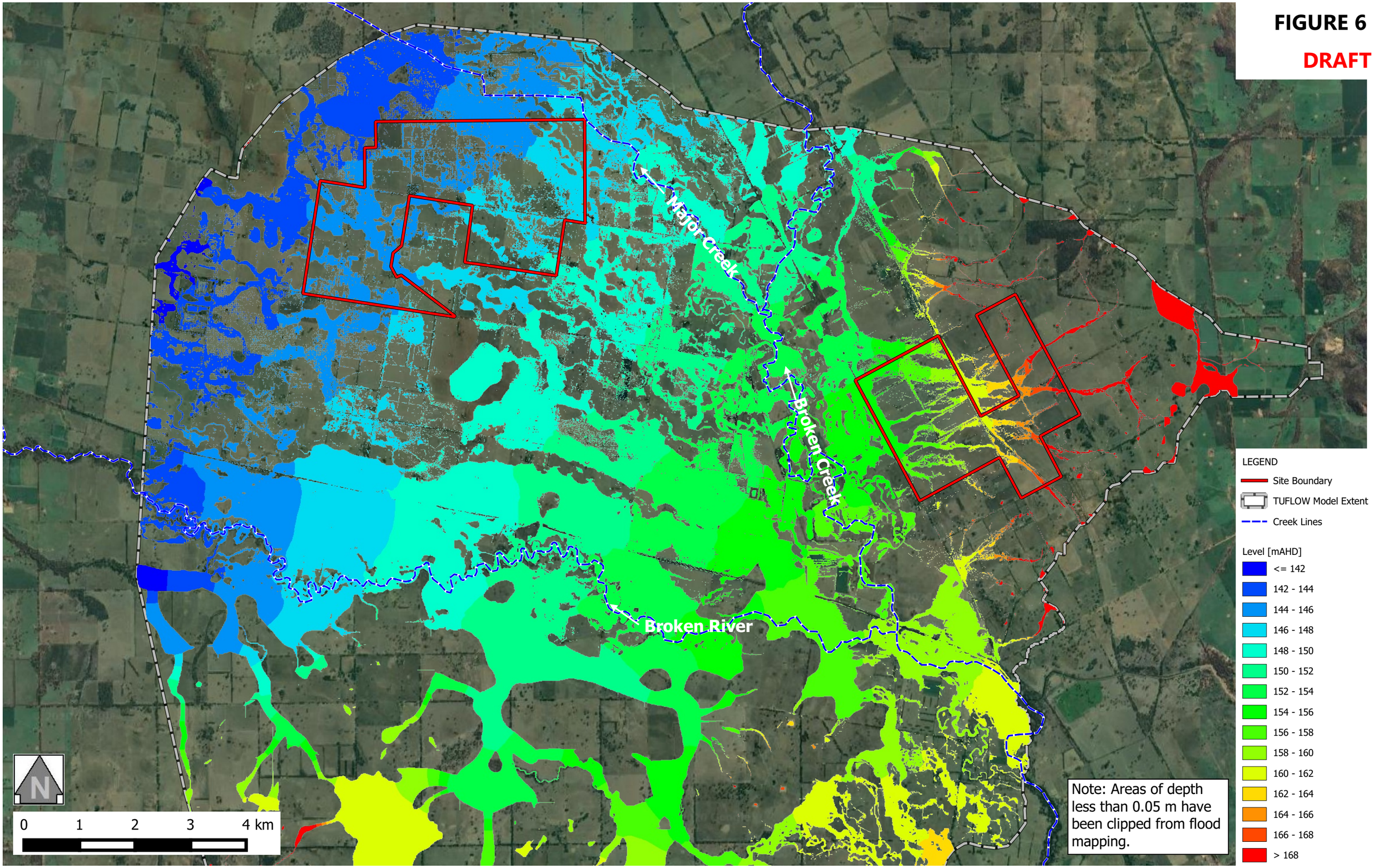

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Figure 6 - Level all
Goorambat -TUFLOW.qgz

PEAK 100 YEAR ARI FLOOD LEVELS [24 HOUR STORM DURATION]

FIGURE 7

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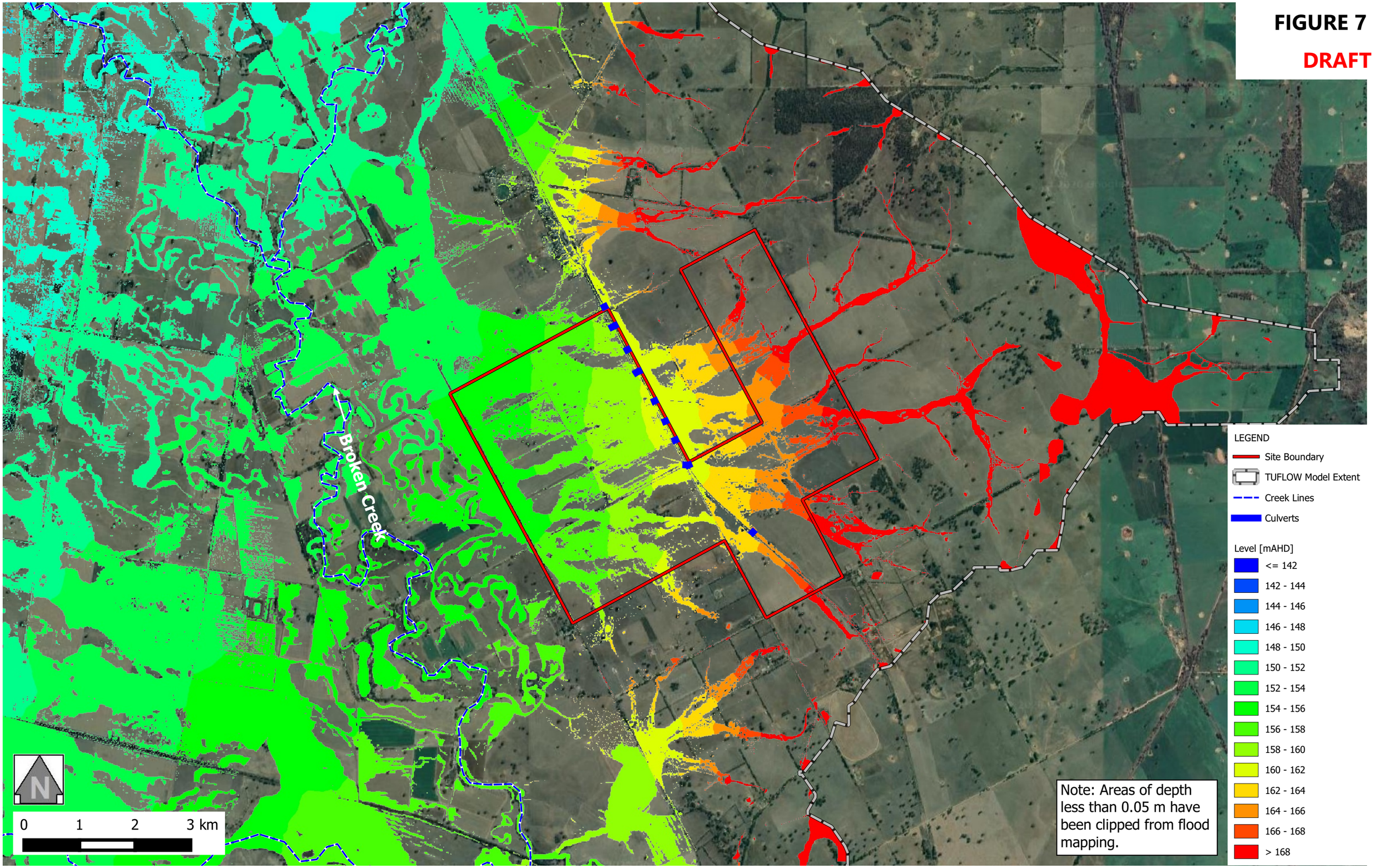

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Figure 7 - Level EAST
Goorambat -TUFLOW.qgz

PEAK 100 YEAR ARI FLOOD LEVEL
EASTERN SITE
[6 HOUR STORM DURATION]

FIGURE 8

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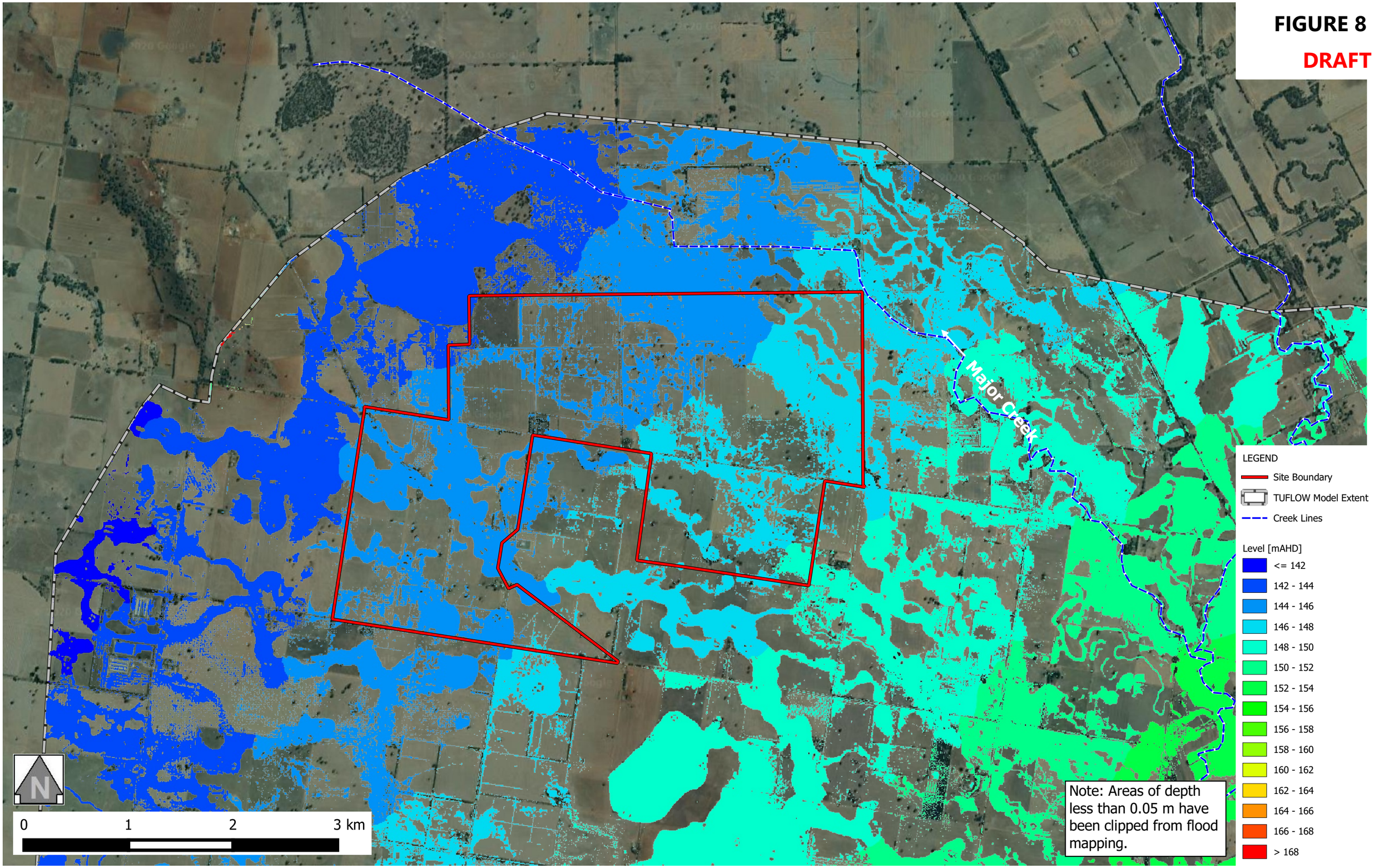

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Figure 8 - Level WEST
Goorambat -TUFLOW.qgz

PEAK 100 YEAR ARI FLOOD LEVELS
WESTERN SITE
[24 HOUR STORM DURATION]

FIGURE 9

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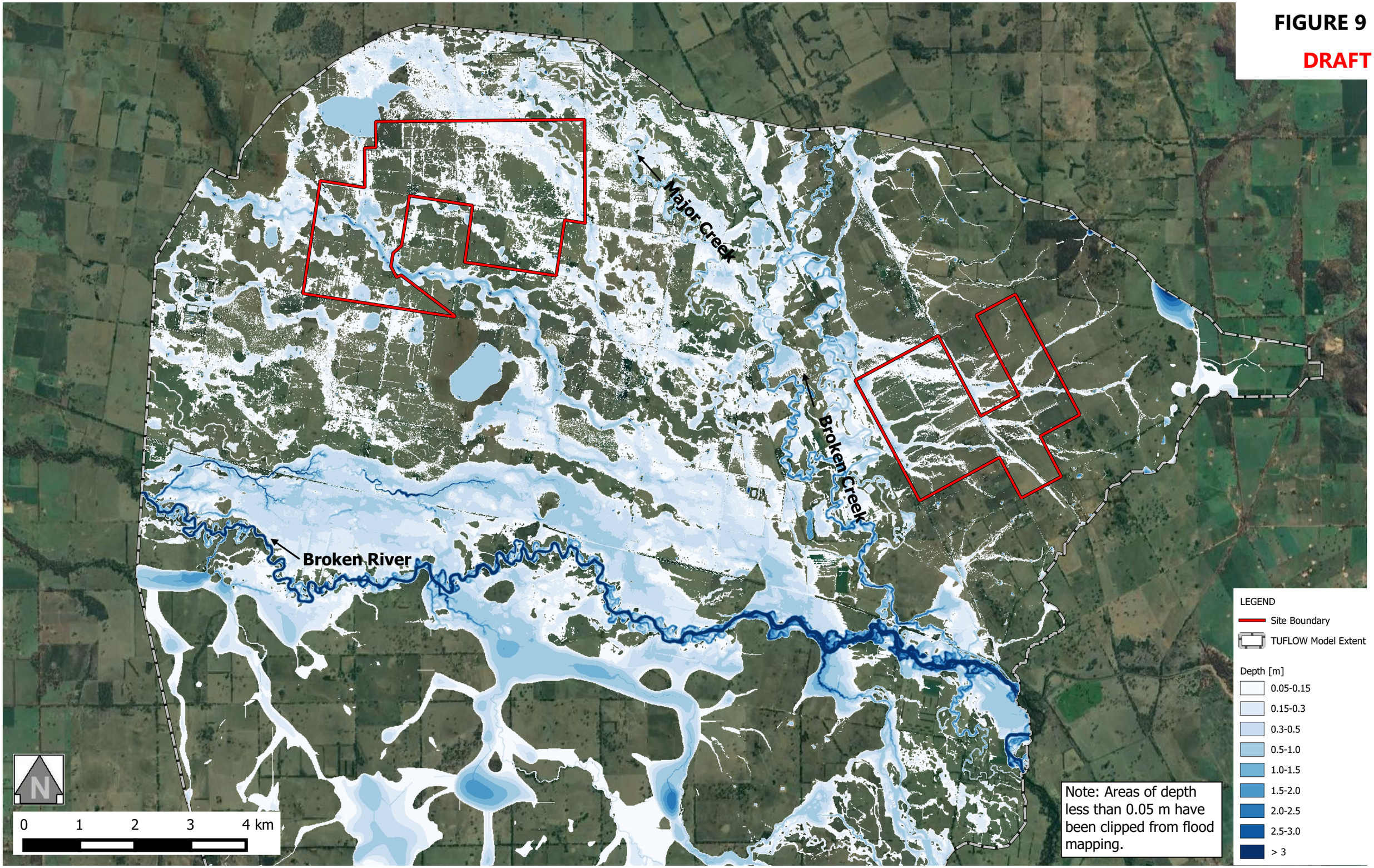

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Figure 9 - Depth all
Goorambat -TUFLOW.qgz

PEAK 100 YEAR ARI FLOOD DEPTHS [24 HOUR STORM DURATION]

FIGURE 10

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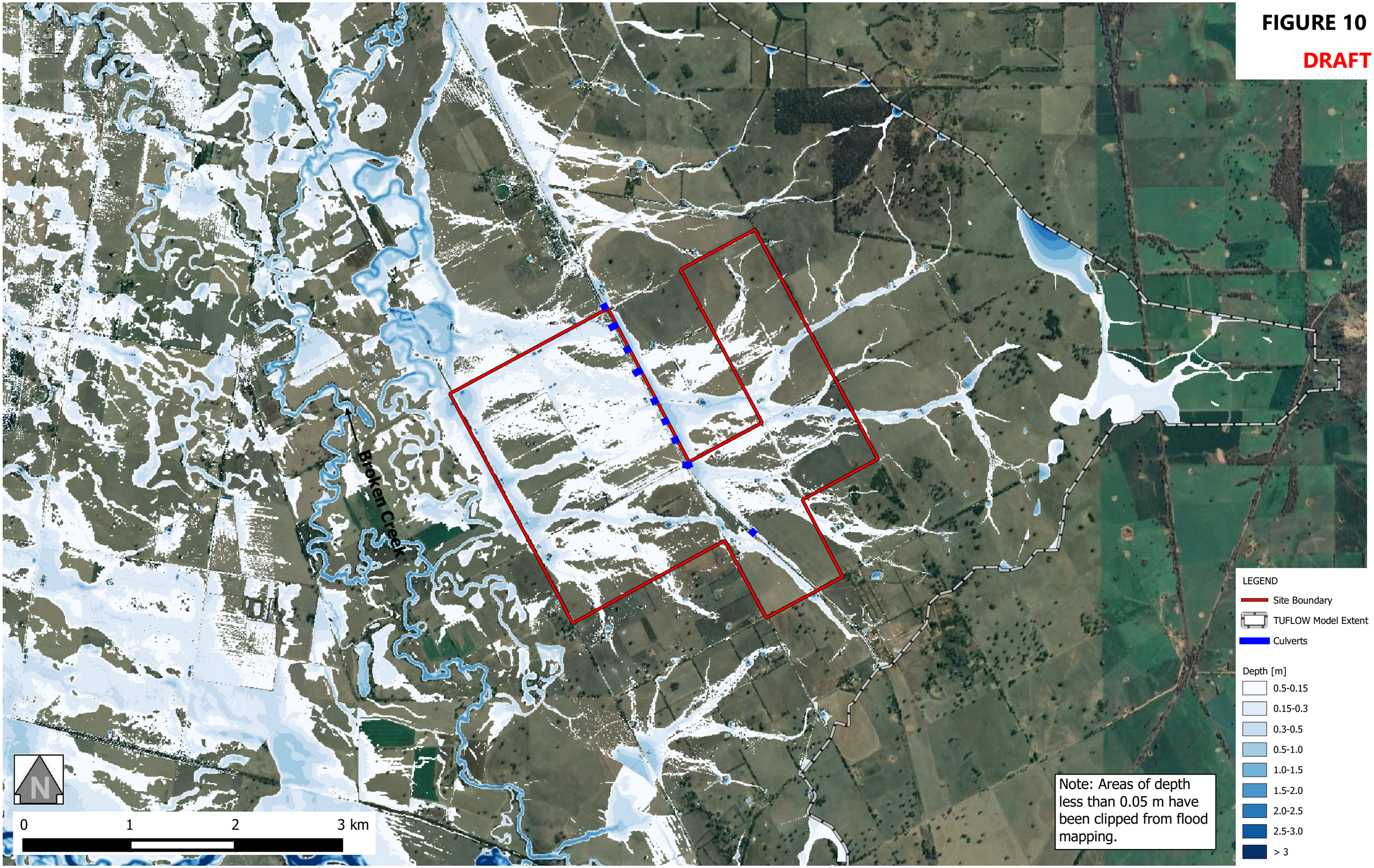

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Figure 10 - Depth EAST
Goorambat -TUFLOW.qgz

PEAK 100 YEAR ARI FLOOD DEPTHS
EASTERN SITE
[6 HOUR STORM DURATION]

FIGURE 11

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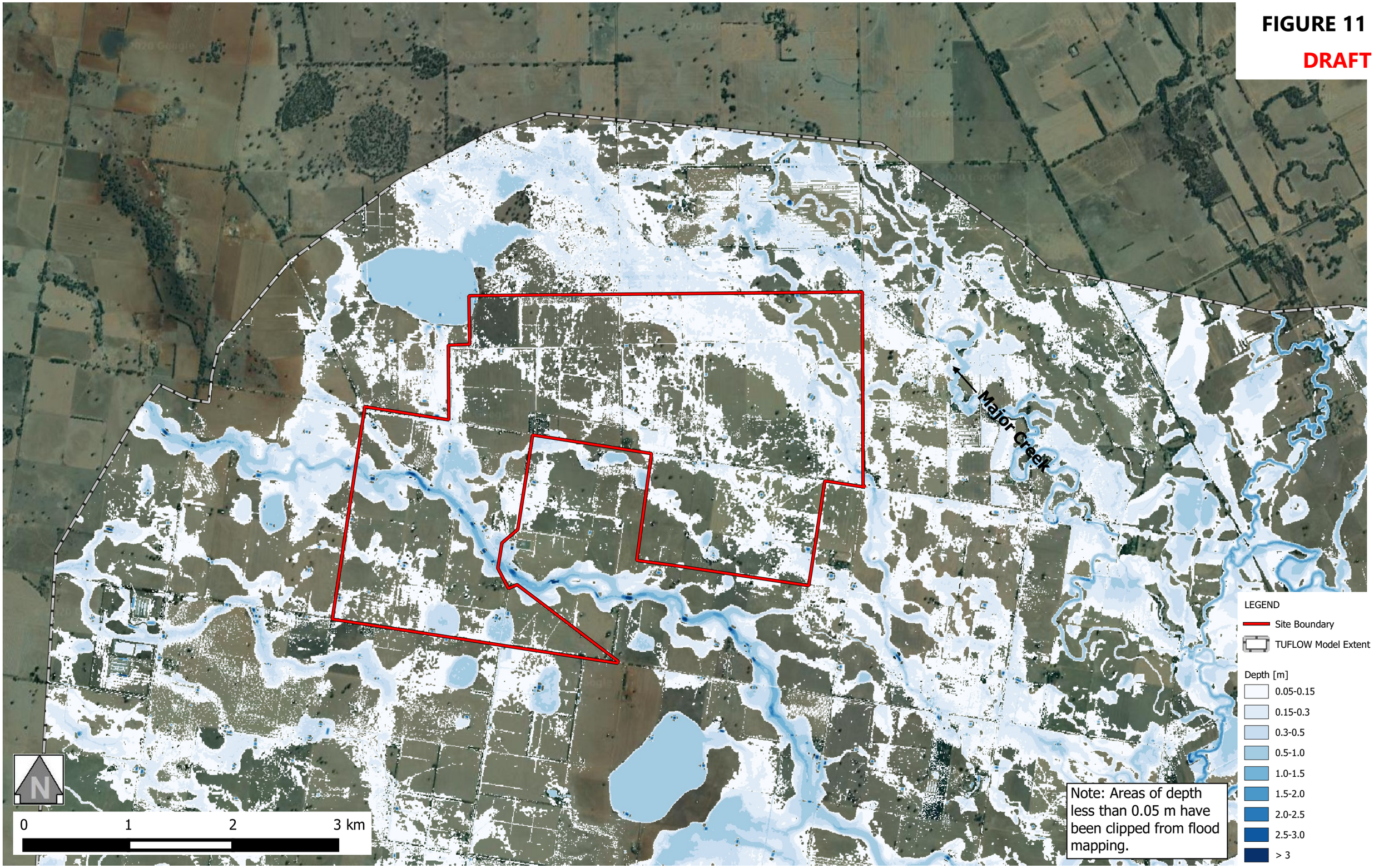

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Figure 11 - Depth WEST
Goorambat -TUFLOW.qgz

PEAK 100 YEAR ARI FLOOD DEPTHS
WESTERN SITE
[24 HOUR STORM DURATION]

FIGURE 12

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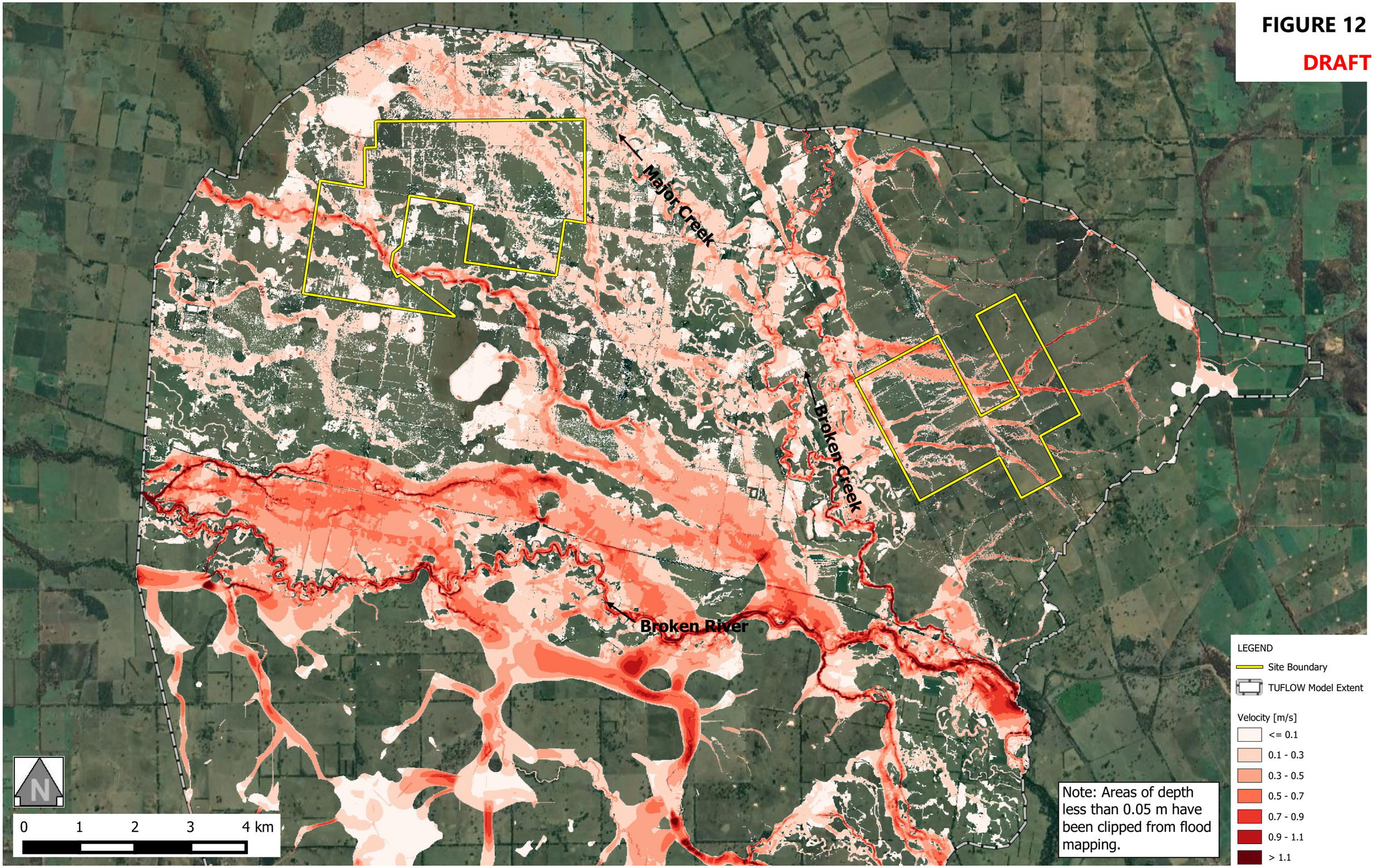

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Figure 12 - Velocity all
Goorambat -TUFLOW.qgz

PEAK 100 YEAR FLOW VELOCITIES [24 HOUR STORM DURATION]

FIGURE 13

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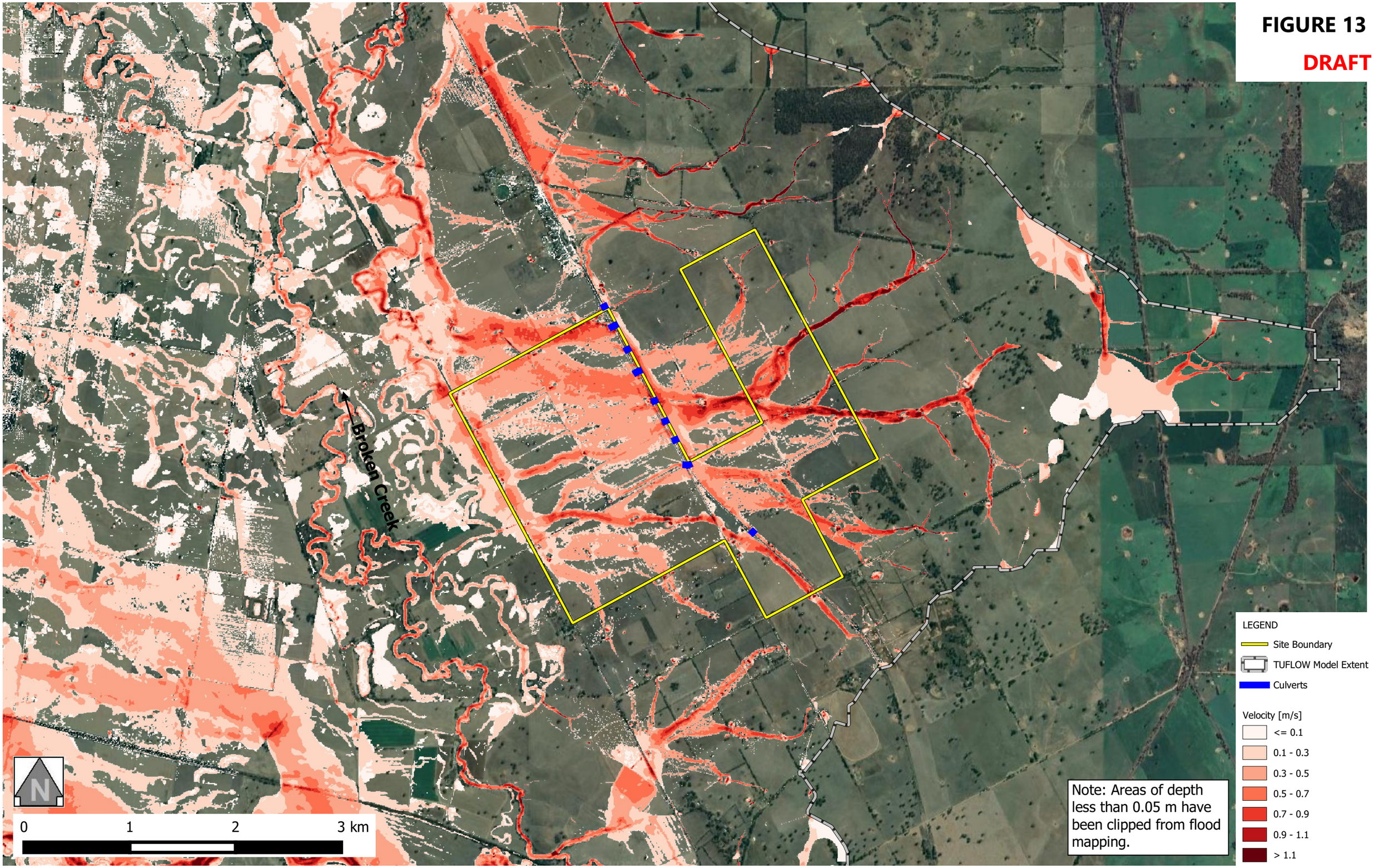

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Figure 13 - Velocity EAST
Goorambat -TUFLOW.qgz

PEAK 100 YEAR FLOW VELOCITIES
EASTERN SITE
[6 HOUR STORM DURATION]

FIGURE 14

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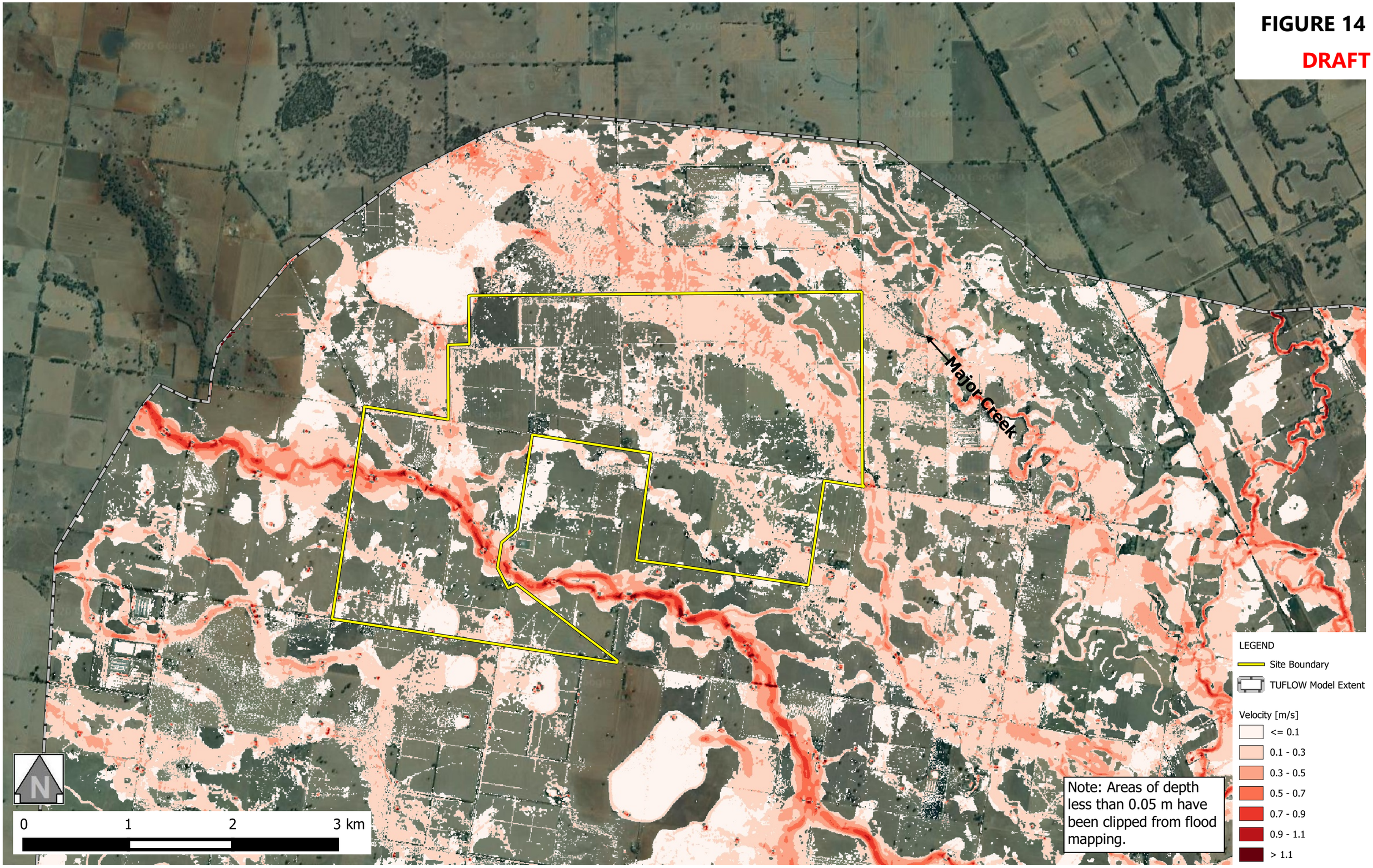

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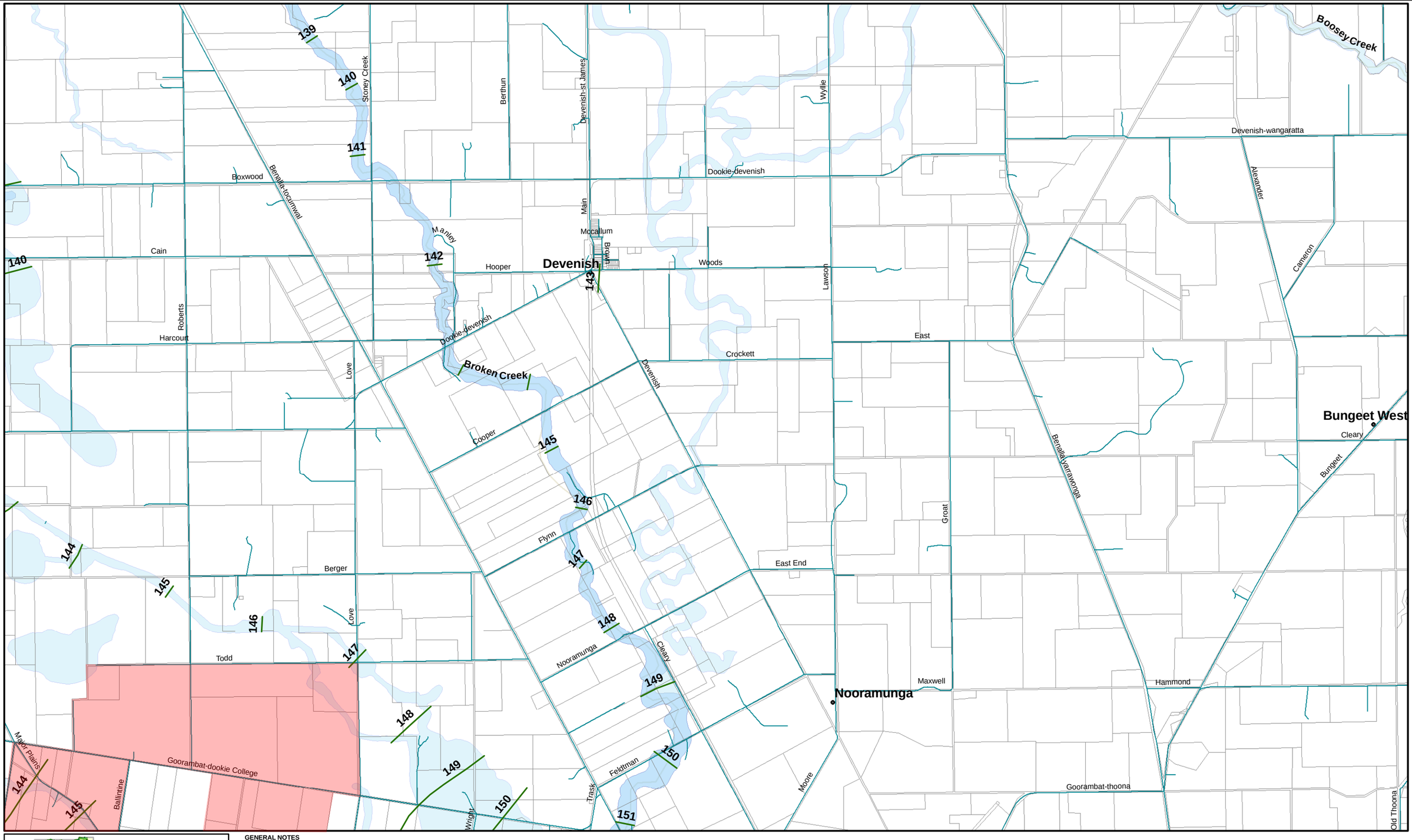
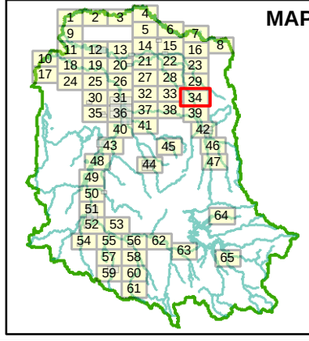
Figure 14 - Velocity WEST
Goorambat -TUFLOW.qgz

PEAK 100 YEAR FLOW VELOCITIES
WESTERN SITE
[24 HOUR STORM DURATION]

Appendix A: Goulburn Broken CMA Flood Mapping



MAP KEY



GENERAL NOTES

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Cadastral information is supplied by Department of Sustainability and Environment.

This map has been prepared using the best available data and mapping techniques. The accuracy of this map however, is not absolute and reflects only the accuracy of the data and techniques used. This information is subject to change where new information is found or determined from future studies.

NOTES ON DECLARATION AND BEST ESTIMATED FLOOD LEVELS

The flood level lines shown on this plan define the surface level of the "1% probability flood". Where flood level declarations have occurred, this is the flood prescribed by Section 204 of the *Water Act 1989*, for floodplain management purposes and has a 1 in 100 chance of being equalled or exceeded in any one year. Other flood level contours represent the best estimate of the 1% probability flood.

The derivation of these 1% flood level lines has been based on available historical flood level and flow information, hydrologic and hydraulic modelling.

Areas outside the 1% probability flood limit may be inundated by rarer flood events.

For the purpose of determining flood levels for locations between flood level lines, it can be assumed that the flood surface levels change at a uniform rate between flood level lines.

The flood level lines shown on this plan can be used to assist in the determination of designated levels in accordance with Clause 6.2 of the *Building Regulations 1994*.

Although there may be buildings within the area covered by the flood level lines, it should not be assumed that the floor of any individual building is below flood level. Buildings should be surveyed to determine whether their floors are above or below the 1% flood level.

FLOOD OVERLAY INFORMATION

This map showing Urban Floodway Zone (UFZ), Floodway Overlay (FO or RFO) and Land Subject to Inundation Overlay (LSIO) are indicative only and not to be used as a substitute over the planning scheme maps.

0 0.25 0.5 1 1.5 2 Kilometres

Scale 1:50,000 at A3

Legend

- Declared/Designated Flood Contours (metres AHD)
- Best Estimated Flood Contours (metres AHD)
- Land Subject to Inundation Overlay
- Floodway or Rural Floodway Overlay
- Urban Floodway Zone
- Known Levees
- Irrigation Channels
- Waterways
- Roads
- GBCMA Waterway Boundary

AUSTRALIA
DEPARTMENT OF FINANCE AND ADMINISTRATION

GOULBURN BROKEN CATCHMENT MANAGEMENT AUTHORITY

GOULBURN BROKEN CATCHMENT MANAGEMENT AUTHORITY

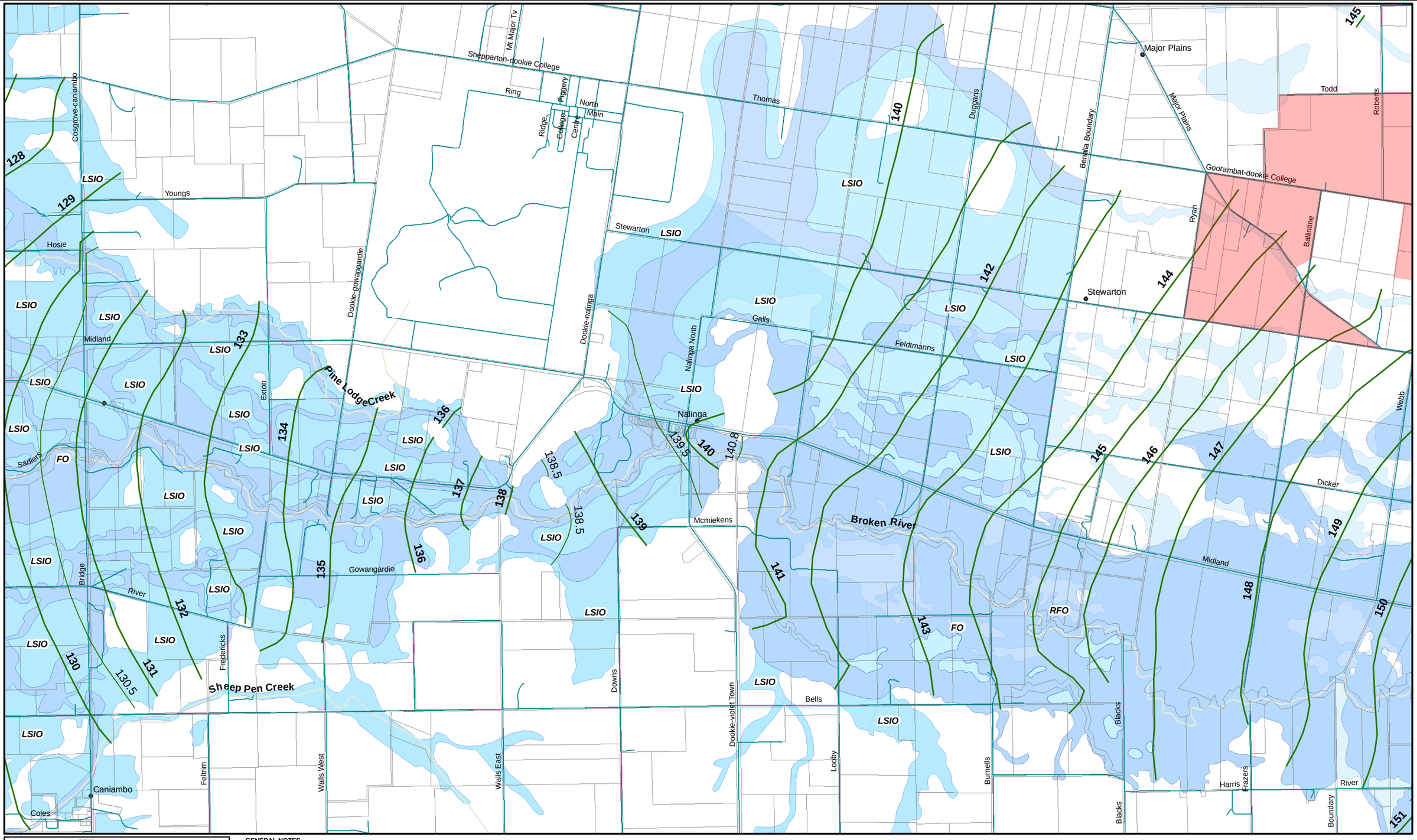
1% FLOOD LEVEL CONTOUR ATLAS

Date: 30 June 2008

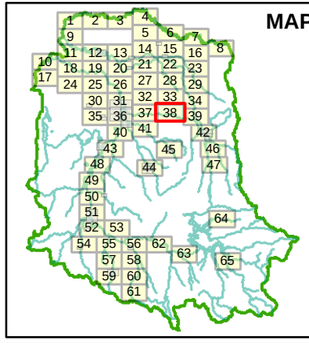
SHEET NUMBER: **34** of **104**

DRAWING NUMBER: **540335**

REVISION:



MAP KEY



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The Goulburn Broken Catchment Management Authority does not warrant that this document is definitive nor free of error and does not accept liability for any loss caused or arising from reliance upon information provided herein.

Cadastral information is supplied by Department of Sustainability and Environment.

This map has been prepared using the best available data and mapping techniques. The accuracy of this map however, is not absolute and reflects only the accuracy of the data and techniques used. This information is subject to change where new information is found or determined from future studies.

NOTES ON DECLARATION AND BEST ESTIMATED FLOOD LEVELS

The flood level lines shown on this plan define the surface level of the "1% probability flood". Where flood level declarations have occurred, this is the flood prescribed by Section 204 of the *Water Act 1989*, for floodplain management purposes and has a 1 in 100 chance of being equalled or exceeded in any one year. Other flood level contours represent the best estimate of the 1% probability flood.

The derivation of these 1% flood level lines has been based on available historical flood level and flow information, hydrologic and hydraulic modelling.

Areas outside the 1% probability flood limit may be inundated by rarer flood events.

For the purpose of determining flood levels for locations between flood level lines, it can be assumed that the flood surface levels change at a uniform rate between flood level lines.

The flood level lines shown on this plan can be used to assist in the determination of designated levels in accordance with Clause 6.2 of the *Building Regulations 1994*.

Although there may be buildings within the area covered by the flood level lines, it should not be assumed that the floor of any individual building is below flood level. Buildings should be surveyed to determine whether their floors are above or below the 1% flood level.

FLOOD OVERLAY INFORMATION

This map showing Urban Floodway Zone (UFZ), Floodway Overlay (FO or RFO) and Land Subject to Inundation Overlay (LSIO) are indicative only and not to be used as a substitute over the planning scheme maps.

0 0.25 0.5 1 1.5 2 Kilometres

Scale 1:50,000 at A3

Legend

- Declared/Designated Flood Contours (metres AHD)
- Best Estimated Flood Contours (metres AHD)
- Land Subject to Inundation Overlay
- Floodway or Rural Floodway Overlay
- Urban Floodway Zone
- Known Levees
- Irrigation Channels
- Waterways
- Roads
- GBCMA Waterway Boundary

AUSTRALIA
DEPARTMENT OF FINANCE AND ADMINISTRATION

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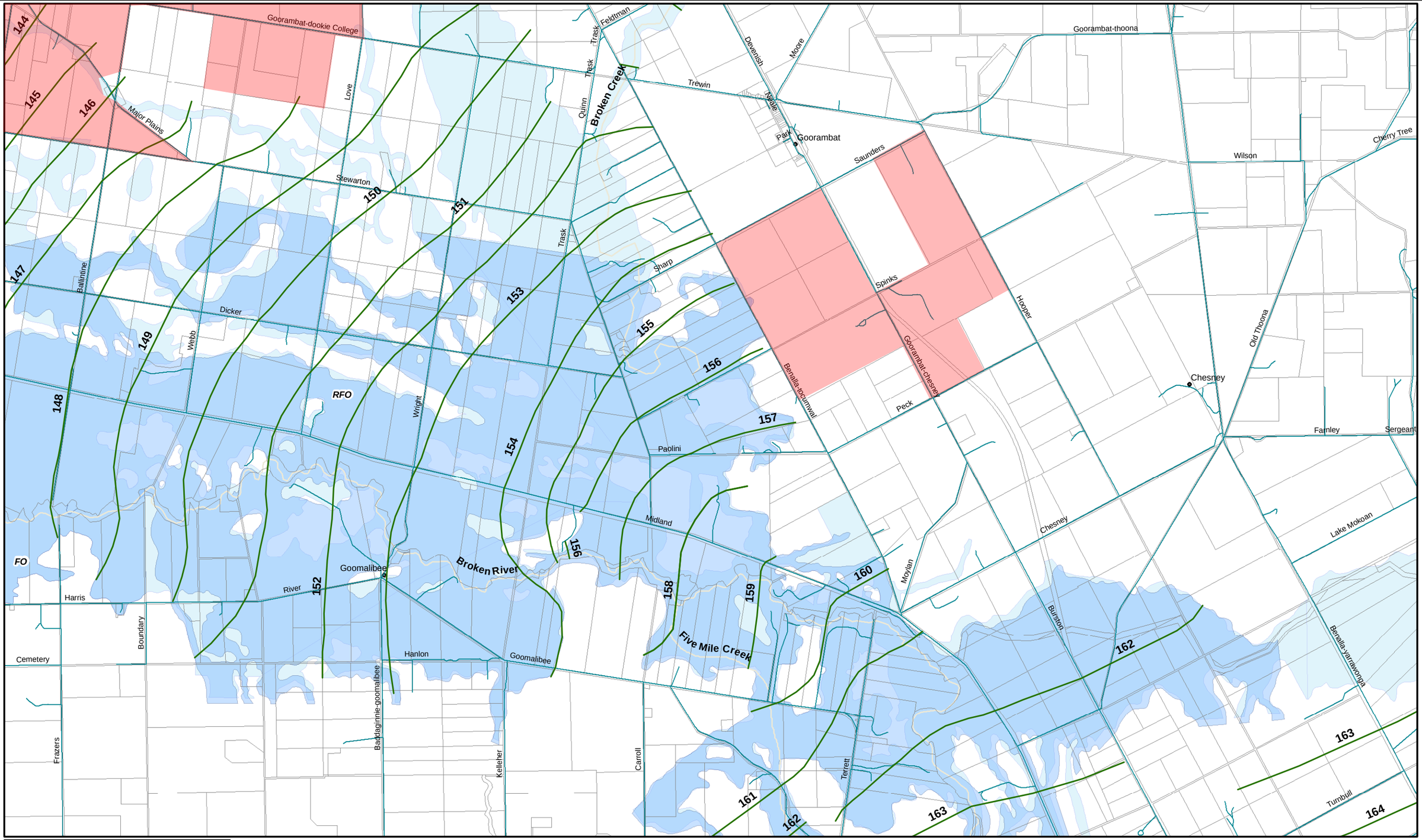

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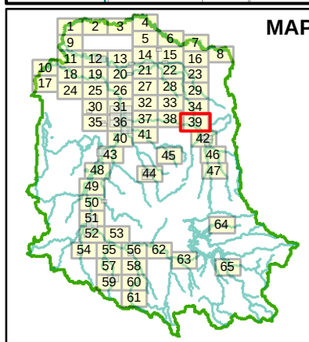

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