IRC Flood Model & Hazard Mapping 2023

Moranbah

Isaac Regional Council

13 October 2023

→ **The Power of Commitment**

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The Power of Commitment

Contents

1. Introduction 1

1.1 Overview 1

1.2 Purpose of this report 1

1.3 Scope and limitations 1

1.4 Clarifications 2

1.5 Assumption 2

2. Site information 4

2.1 The study area 4

2.2 Review of catchments 4

2.3 Land use assessment 4

2.4 Available information 4

2.4.1 Previous studies 4

2.4.2 Design rainfall data 8

2.4.3 Topographic data 8

2.4.4 Other data 8

3. Hydrologic analysis 10

3.1 Data collection 10

3.2 Hydrologic model 10

3.3 Isaac River 10

3.3.1 Model selection 10

3.3.2 Flood frequency analysis (FFA) 11

3.3.2.1 Analysis methodology 11

3.3.2.2 Annual maxima series 12

3.3.2.3 Results and Flow Scaling 12

3.4 Grosvenor Creek 15

3.4.1 Model selection 15

3.4.2 Model development 16

3.4.3 Model parameters 16

3.4.3.1 Catchment delineation 16

3.4.3.2 Catchment slope 18

3.4.3.3 Land use/catchment roughness 18

3.4.3.4 Rainfall losses 18

3.4.3.5 Design storm 19

3.4.3.6 Probable Maximum Flood (PMF) 19

3.4.3.7 Areal reduction factors 22

3.4.3.8 Climate change 22

3.4.4 Model results and validation 23

3.5 Local Moranbah area 24

3.5.1 Model development 24

3.5.2 Model parameters 24

3.5.2.1 Catchment delineation 24

3.5.2.2 Catchment slope 26

3.5.2.3 Land use/roughness 26

3.5.2.4 Rainfall losses 26

3.5.2.5 Design storm 26

3.5.2.6 Probable Maximum Flood (PMF) 26

3.5.2.7 Areal reduction factor 27

Document Set ID: 5266977

Version: 1, Version Date: 29/08/2024

3.5.2.8 Climate change 27
3.5.3 Critical event selection 28

4. Hydraulic analysis 29

4.1 Data collection 29
4.2 Hydraulic model setup 31
4.2.1 Model selection 31
4.2.2 Model development 31
4.2.3 Software version 31
4.2.4 Cell size convergence 31
4.2.5 Model parameters 32
4.2.5.1 Topography 32
4.2.5.2 Design event modelling 32
4.2.5.3 Inflow boundaries 32
4.2.5.4 Outflow boundaries 33
4.2.5.5 Hydraulic roughness 33
4.2.5.6 1D hydraulic infrastructure 33
4.3 Model results 39
4.3.1 Flood inundation mapping 39
4.3.1.1 Post-processing approach 39
4.3.2 Discussion of flood behaviour 40
4.4 Model validation 44
4.5 Sensitivity assessment 44

5. Summary 46

References 50

Table index

Table 1 Design event peak flow comparison (Isaac River) from FFA 15
Table 2 Adopted hydrologic PERN ‘n’ roughness (WP Software, 1994) 18
Table 3 Loss Parameters (18 hour storm duration) 18
Table 4 Design storm durations 19
Table 5 PMP- parameters 19
Table 6 Areal-reduction factor coefficients (short duration) 22
Table 7 Climate Change variables 23
Table 8 Grosvenor Creek RAFTS model peak flow validation 23
Table 9 Adopted hydrologic PERN ‘n’ roughness (WP Software, 1994) 26
Table 10 PMP- parameters 26
Table 11 Critical events (Moranbah town area) 28
Table 12 Grid cells convergence assessment summary 32
Table 13 Manning’s ‘n’ roughness values 33
Table 14 Discussion of flood behaviour observations from the hydraulic model results 40
Table 15 Discussion of flood behaviour observations from the hydraulic model results 46
Table A.1 AMS for the Deverill gauge (Isaac River) 53
Table B.1 BoM Design Rainfall IFDs (Frequent and Infrequent) – Moranbah 56
Table C.1 Grosvenor Creek model sub-catchments characteristics 58
Table C.2 Moranbah model sub catchments characteristics 60
Table D.1 Culvert structures (details) 63

Table D.2 Bridge structures (details) 63

Figure index

Figure 1 Moranbah locality map 5
Figure 2 Moranbah Catchment Map 6
Figure 3 Moranbah Catchment Map (Local Area) 7
Figure 4 Isaac Regional Planning Scheme Zoning (IRC, 2021) 9
Figure 5 Methods of hydrologic analysis 11
Figure 6 Flood frequency curve at Deverill gauge – FLIKE output 12
Figure 7 Area scaling catchment map 14
Figure 8 Grosvenor Creek Catchment 17
Figure 9 Depth-Duration-Area Curves of Short Duration Rainfall 21
Figure 10 Rainfall Depths for the PMP event (Grosvenor Creek) 22
Figure 11 Local Moranbah Catchment 25
Figure 12 Rainfall depths for the PMP Event (Local Moranbah area) 27
Figure 13 Hydraulic model extent (Whole Area) 30
Figure 14 TUFLOW hydraulic roughness (Whole extent) 34
Figure 15 TUFLOW hydraulic roughness (Local Area) 35
Figure 16 Existing Drainage Infrastructure 38
Figure 17 Post-processing filtering conditions (AIDR, 2017) 39
Figure 18 Post-processing flood results example (cyan – raw results, purple – post-processed results) (1% AEP event) 40
Figure 19 Water level difference histogram considering adopted Manning’s n and 10% increased Manning’s n 45
Figure 20 Water level difference histogram considering adopted Manning’s n and 10% decreased Manning’s n 45

Appendices

Appendix A Annual maximum series (AMS)
Appendix B BoM design rainfall IFDs (Frequent, Infrequent and Rare)
Appendix C Catchment characteristics
Appendix D Hydraulic structures
Appendix E Flood mapping

1. Introduction

1.1 Overview

GHD Pty Ltd (GHD) was engaged by Isaac Regional Council (IRC) to update the flood models for the towns of Clermont, Moranbah, and Nebo within the Isaac Regional Council Local Government Area (LGA). The intention of the project is to update the flood models to be in line with the latest Australian Rainfall and Runoff guidelines (2019), including the development of flood hazard mapping. The updated flood models are level 3 flood models for each study area, seen as suitable for urban zones within these points of interest and as defined by the Guide for Flood Studies and Mapping in Queensland (BMT WBM, 2017) This report focusses on the Moranbah study area as part of the overall project.

1.2 Purpose of this report

This study aims to provide IRC with a better understanding of flood behaviour in Moranbah. It is envisaged that the outcomes presented in this report may assist Council in:

– Incorporation into the IRC Planning Scheme and disaster management purposes
– Improve the flood resilience of residents and infrastructures located in the study areas by understanding locational risk profiles for a range of flood events.

1.3 Scope and limitations

This report: has been prepared by GHD for Isaac Regional Council and may only be used and relied on by Isaac Regional Council for the purpose agreed between GHD and Isaac Regional Council as set out in this report.

GHD otherwise disclaims responsibility to any person other than Isaac Regional Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring after the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer Section 1.5 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared the RAFTS and TUFLOW models ("Model") for, and for the benefit and sole use of Isaac Regional Council to support the design and documentation of the works and must not be used for any other purpose or by any other person.

The model is a representation only and does not reflect reality in every aspect. The model contains simplified assumptions to derive a modelled outcome. The actual variables will inevitably be different to those used to prepare the model. Accordingly, the outputs of the model cannot be relied upon to represent actual conditions without due consideration of the inherent and expected inaccuracies. Such considerations are beyond GHD's scope.

The information, data and assumptions ("Inputs") used as inputs into the Model are from publicly available sources or provided by or on behalf of the Isaac Regional Council, (including possibly through stakeholder engagements). GHD has not independently verified or checked Inputs beyond its agreed scope of work. GHD's scope of work does not include review or update of the Model as further Inputs becomes available.

The Model is limited by the mathematical rules and assumptions that are set out in the Report or included in the Model and by the software environment in which the Model is developed.

The Model is a customised model and not intended to be amended in any form or extracted to other software for amending. Any change made to the Model, other than by GHD, is undertaken on the express understanding that GHD is not responsible, and has no liability, for the changed Model including any outputs.

GHD has prepared this report on the basis of information provided by Isaac Regional Council and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

Accessibility of documents

If this report is required to be accessible in any other format, this can be provided by GHD upon request and at an additional cost if necessary.

1.4 Clarifications

The following outlines clarifications associated with this report.

The corresponding Annual Exceedance Probability (AEP) notation for the following events is as follows:

- 1 in 2 AEP, or 50% AEP
- 1 in 5 AEP, or 20% AEP
- 1 in 20 AEP, or 5% AEP
- 1 in 50 AEP, or 2% AEP
- 1 in 100 AEP, or 1% AEP
- 1 in 100 AEP, or 1% AEP plus climate change
- 1 in 500 AEP, or 0.2% AEP
- PMF

1.5 Assumption

The following identifies further assumptions made throughout the hydrological and hydraulic assessment:

– All data supplied is correct and/or suitable to IRC for use in this assessment (i.e., no data has been verified at this stage of the study, we recommend verification of data upon receipt of community feedback)

– Fraction impervious and Manning's 'n' values were selected based on a combination of the existing land use through review of aerial photography, zoning data and cadastral data

  – The accuracy of the modelling was based on the quality of LiDAR data provided. A key limitation of LiDAR is that in areas of dense vegetation the LiDAR may not accurately pick up significant flow paths

  – It is advised LiDAR may not account for any new developments since the LiDAR data was captured. Until then, all data provided is assumed accurate and up to date, with any development/changes since the data capture excluded from the modelling (i.e., the modelling was undertaken using the LiDAR data supplied as nothing newer was available), except as noted in this report.

  – The model assumed fully functioning stormwater infrastructure; however, IRC acknowledge that an incomplete dataset was provided. As such, assumptions were made regarding invert levels, cover, and grades of the 1D network. Should these assumptions not be sufficient to cover IRC's risk profile, it is recommended that a detailed survey of all the stormwater infrastructure is undertaken and remodelled in the hydraulic simulations.

  – Lag times between each sub-catchment were derived by applying velocities from the hydraulic model over each catchment's longest watercourse (or streamflow path where appropriate) initially and then verified through hydraulic modelling of the waterways informing the velocity assumption. Lag times were then updated accordingly to reflect hydraulically modelled velocity and hydrology model results exported.

2. Site information

2.1 The study area

This study is focused on the Moranbah town area, which is located on a ridge line between Grosvenor Creek and the Isaac River. The area consists of the town and includes urban areas with stormwater collected within a piped system. This study has been developed considering the current township flood study and other previous studies. Level 3 hazard mapping has been produced for this study. The locality map of the study area is presented in Figure 1.

2.2 Review of catchments

Upon initial review of the study catchments and major flow paths, it was observed that the study area predominantly includes a mix of urban, rural, pastoral, industrial land (including mining), and state forest, which formed the different land uses. The current development and planning scheme has been considered for this study and any future development has not been accounted for.

The town of Moranbah is sited between Grosvenor Creek and the Isaac River. As the Isaac River flows downstream in a south-easterly direction, Grosvenor Creek flows in an easterly direction, reaching a confluence point with the Isaac River, immediately upstream of the Peak Downs Highway crossing of the Isaac River. Grosvenor Creek has a catchment area of 760 km^2 to the confluence with the Isaac River. Isaac River has a catchment area of 1,913 km^2 to the confluence point with Grosvenor Creek (excluding the Grosvenor Creek catchment area). Figure 2 and Figure 3 show the catchments considered in this study both as a whole and the local town catchment map, respectively.

2.3 Land use assessment

A review of the latest IRC Planning Scheme 2021 documentation (IRC, 2021) also produced the IRC nominated land used zones, which are proposed to form the basis of land use allocations for the hydraulic modelling. Within the study area, the zoning including industrial, community facilities, township, open space and recreation and special purpose along with residential lots. This has been assessed as per the Isaac Regional Planning Scheme 2021 (Zoning) ZM 1.7 mapping, see Figure 4.

2.4 Available information

2.4.1 Previous studies

IRC provided GHD with the following previous studies that include the study area for this study:

1. Moranbah Flood Study (2018)

This study generated a TUFLOW flood model for the town of Moranbah (Cardno, 2018) and included the Cherwell and Grosvenor Creek systems along with the Isaac River. It modelled scenarios for 0.1%, 0.5%, 1%, 2%, 5%, 10% and 20% AEP design flood events. It was calibrated to the 1991 and 2015 flood events. The output was focussed on the impact of flooding on infrastructure and evacuation routes to prepare an emergency management plan.

2. Isaac River Flood Study (July 2021)

This study generated a TUFLOW flood model for the Isaac River catchment (KBR, 2021), across the entire catchment to its confluence with the Mackenzie River. It modelled scenarios for the 5%, 2%, 1%, 0.5%, 0.1% AEP and Probable Maximum Flood (PMF) events. It was calibrated with the 2017 Cyclone Debbie flood event within the catchment. The study also produced hazard mapping.

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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Flood Model and Hazard Mapping
Moranbah Study Area

Moranbah Locality Map

Project No. **12593557**
Revision No. **A**
Date **13 Oct 2023**

Figure 1

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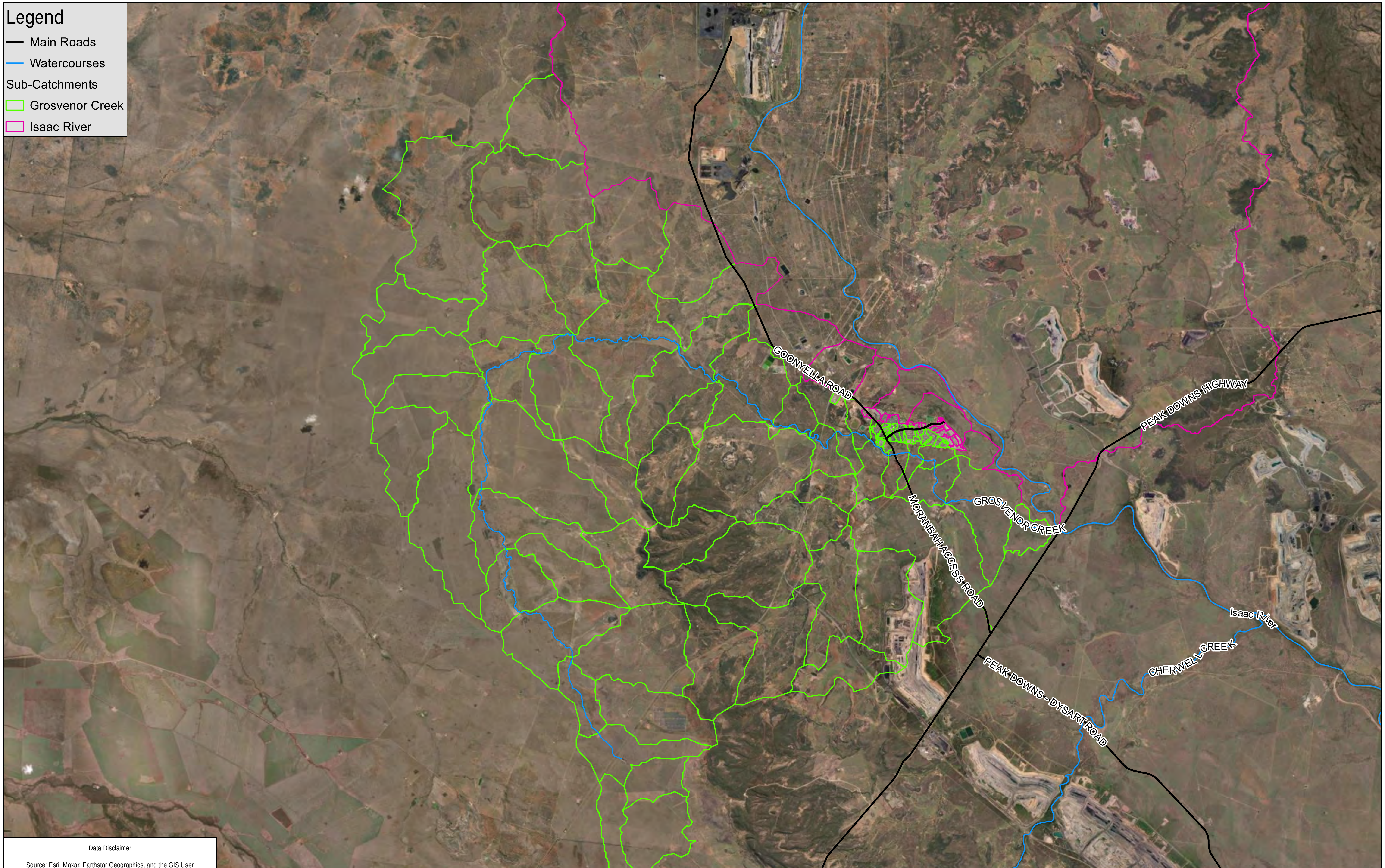

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Paper Size ISO A3
0 310 620 930 1,240
Kilometers

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Grid: GDA 1994 MGA Zone 55

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Moranbah Study Area

Moranbah Catchment Map

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Figure 2

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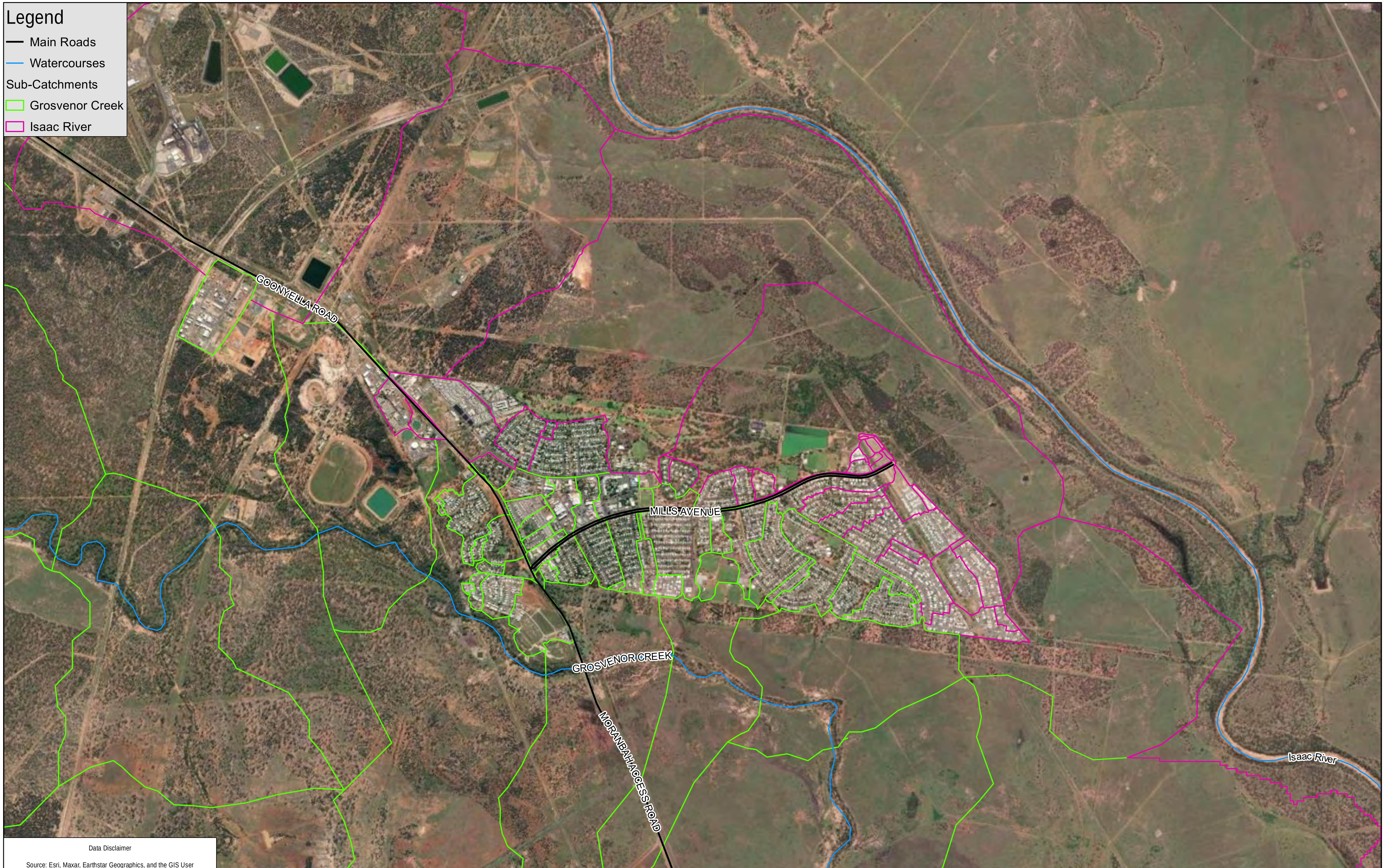

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3
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Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Flood Model and Hazard Mapping
Moranbah Study Area

Moranbah Catchment Map
Local Area

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Date 05 Oct 2023

Figure 3

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2.4.2 Design rainfall data

Design Australian Rainfall and Runoff 2019 (ARR; 2019) rainfall Intensity Frequency Duration (IFD) data for the study area was obtained from the Bureau of Meteorology (BoM) on 8th December 2022. The IFD data is presented in Appendix B for frequent, infrequent and rare design rainfalls, for the Moranbah town area. Rainfall data for the Probable Maximum Flood (PMF) event was calculated using the Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method (GSDM) guidebook. Please note the Revised Generalised Tropical Storm Method (GTSMR) was considered for this assessment but as the storm durations critical to the study area were less than the GTSMR guidebook duration limits for Moranbah, GTSMR was not used further.

2.4.3 Topographic data

Detailed LiDAR topographic data was sourced from the ELVIS spatial data portal with a grid cell size of one metre for the Moranbah Town area captured in 2011 and further data was sourced from the following sources:

- One metre LiDAR derived elevation data – provided by Queensland Department of Transport and Main Roads (TMR) – for the Peak Downs Highway. This data was confined to the road corridor and roughly 1.1km wide (550 m each side of the road).
- Design TIN model for the Utah Drive Stage 6 and 7 development - obtained from GHD's design commissions and verified by As-built survey taken at the completion of the development.
- Design TIN model from As-built survey for the Bushlark Drive Stage 2 and 3 development.
- One second Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) for areas across the study area where detailed topographic data was not available.

2.4.4 Other data

The following details other data used to inform the study:

- Stream gauge data (from stream gauge number 130410A Isaac River at Deverill) – obtained from the Queensland Government's - Water Monitoring Information Portal (WMIP).

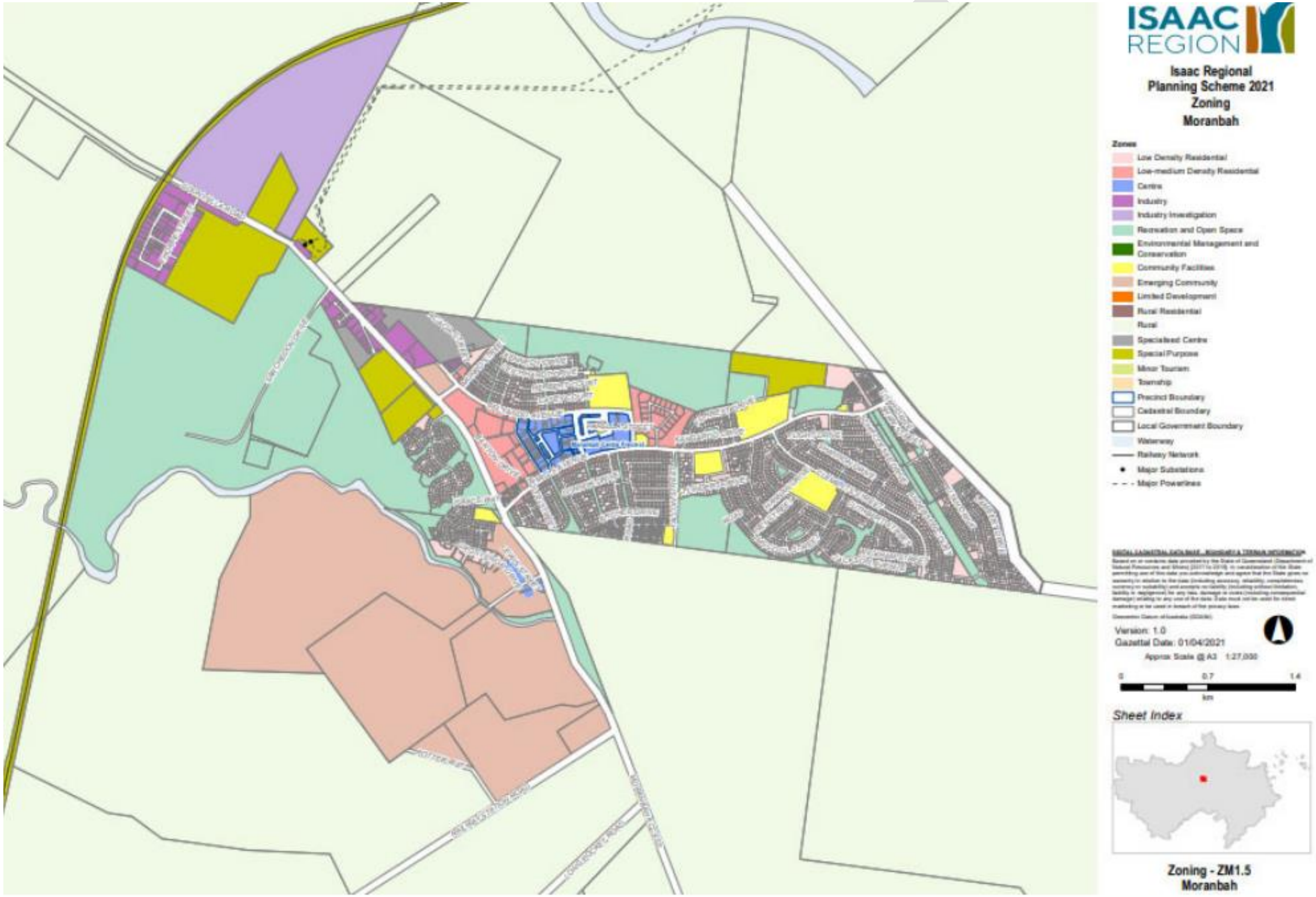

Figure 4 Isaac Regional Planning Scheme Zoning (IRC, 2021)

3. Hydrologic analysis

This section summarises the hydrologic investigations undertaken on the catchment. The scope of work included:

– Data collection and review of available hydrological information.

– Hydrologic model setup and validation of model outputs.

– Estimation of design event flow rates and hydrographs.

3.1 Data collection

The following data was used to undertake this assessment:

- One metre LiDAR derived elevation data – provided by Queensland Department of Transport and Main Roads (TMR) – for Peak Downs Highway Road corridor and roughly 1.1 km wide (550 m each side of the road).
- One second Shuttle Radar Topographic Mission (SRTM) derived LiDAR elevation data obtained from the ELVIS Spatial data portal for part of the study area.
- IFD Rainfall Data – obtained from Bureau of Meteorology (BoM), ARR (2019) Data System.
- Other design inputs (e.g., temporal patterns, losses, pre-bursts) – ARR (2019) Data Hub.
- Stream gauge data (from stream gauge number 130410A Isaac River at Deverill) – obtained from the Queensland Government's - Water Monitoring Information Portal (WMIP).

3.2 Hydrologic model

Sections 3.3, 3.4 and 3.5 present the approach to the hydrologic modelling for the different waterway areas that potentially influence flooding of the Moranbah town area. These have been presented as they were analysed, including a separate section for:

– Isaac River – which involved undertaking a Flood Frequency Analysis (FFA) based on the stream gauge data recorded at the Deverill gauge (130410A).

– Grosvenor Creek.

– Moranbah Town area.

3.3 Isaac River

3.3.1 Model selection

There are several methods that can be used to undertake hydrologic analysis, Figure 5 identifies the common methods for hydrologic analysis and their level of accuracy. GHD were provided with a report for the Isaac River by KBR (KBR, 2021) that covered the entire catchment extent to it's confluence with the Mackenzie River. The KBR study did not include a detailed rainfall-runoff hydrologic model for the catchment and instead included TUFLOW rainfall on grid modelling to complete the assessment. Results from the KBR TUFLOW model have been compared to the results of this study.

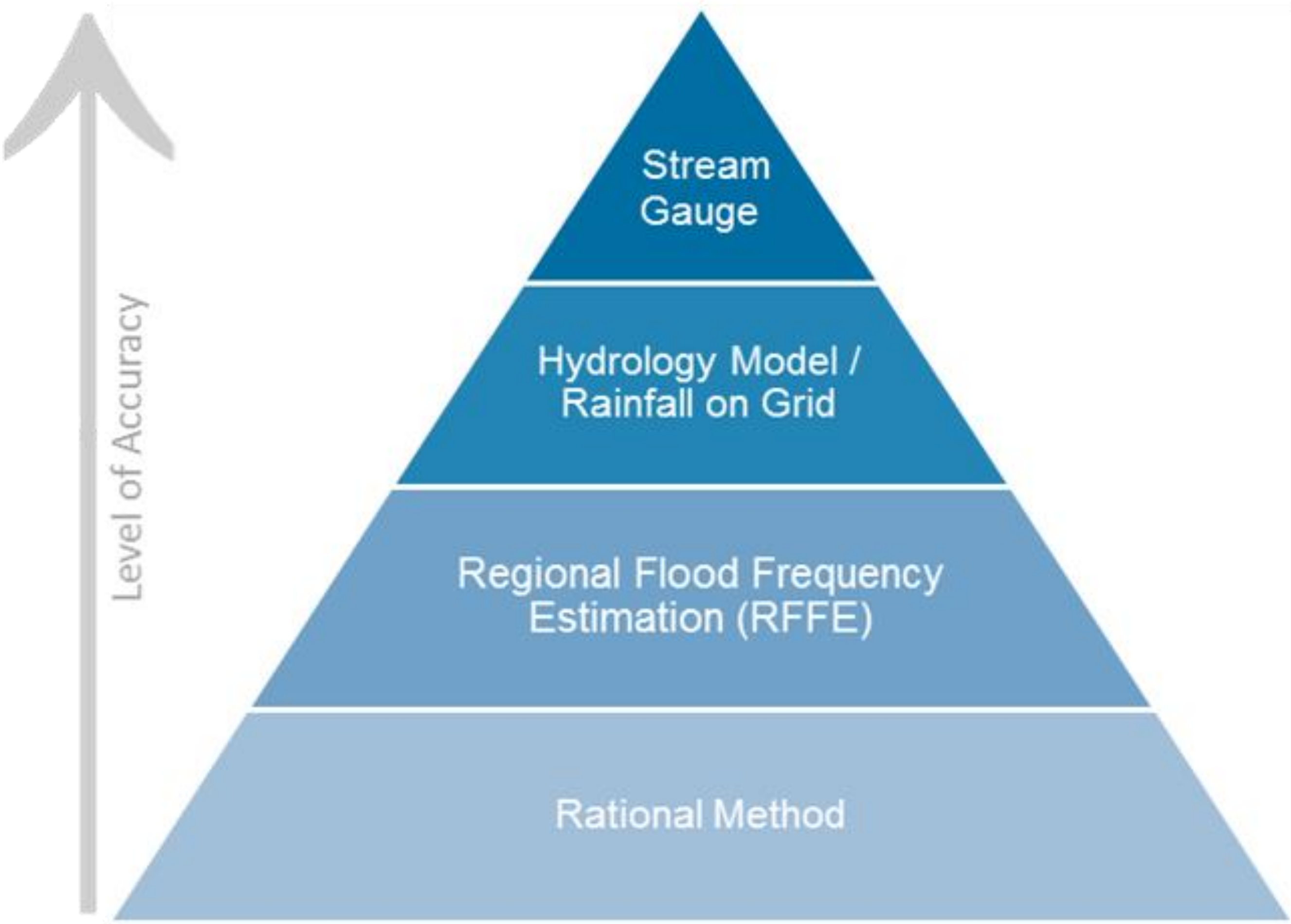

Figure 5 ***Methods of hydrologic analysis***

Stream gauges are the preferred method of choice as they collect real time data from stream flow events. Hydrologic models can be calibrated with the stream gauge data to represent the site's historic stream flow events. Stream gauges are often located in larger catchments, and, in this case, there is a stream gauge for the Isaac River catchment within our study area. The gauge is located at Deverill (130410A), approximately 40 kilometres downstream from Moranbah along the Isaac River. This gauge is operated by the Queensland Government and has more than 60 years of stream gauging data. From this data, a FFA was undertaken for flood flows in the Isaac River to develop inflows into the hydraulic model. As the intention of this assessment was not to complete detailed rainfall-runoff modelling for the Isaac River (this was completed by KBR for the Isaac River Flood Study (KBR, 2021)), the approach for quantify flows in the Isaac River for this study was to use the FFA derived design event flows in the hydraulic model, scaled by catchment area. Section 3.3.2.3 provides further detail on the process undertaken and the flows applied.

3.3.2 Flood frequency analysis (FFA)

As discussed in Section 3.3.1, a FFA was undertaken to estimate flow rates in the Isaac River for various design events based on recorded stream flow data. This was undertaken based on recording from the Deverill gauging station (130410A). The results of the FFA are presented in Section 3.3.2.3.

3.3.2.1 Analysis methodology

An Annual Maximum Series (AMS) approach was adopted for the flood frequency analysis using a Log Pearson III distribution (LPIII) based on the peak flow rate recorded in each water year (also referred to as the annual maxima). The analysis was undertaken using the TUFLOW FLIKE program.

3.3.2.2 Annual maxima series

A time series of the annual maxima flow recordings at the Deverill gauge (130410A) was obtained from the WMIP, including 55 years from 1968 to 2022. Two outliners (from 1968 and 1992) were excluded from the analysis due to the data for 1968 not containing a complete hydrologic year for the analysis and 1992 not registering any flow from steam gauge recordings. The stream gauge data used in the analysis is presented in Appendix A with the outliers being highlighted in Table .

3.3.2.3 Results and Flow Scaling

The TUFLOW FLIKE software package was used to analyse the Isaac River annual maxima with the Log-Pearson III (LPIII) statistical distribution, as recommended by ARR 2019. The flood frequency curve depicted in Figure 6 illustrates the model outputs for the Isaac River analysis. The observed values visually fit well along the curve, which is accompanied by a set of well fitted confidence bands. GHD note that the value derived from the 1992 hydrologic year data suggests that no flow occurred in that year and was therefore excluded from the analysis.

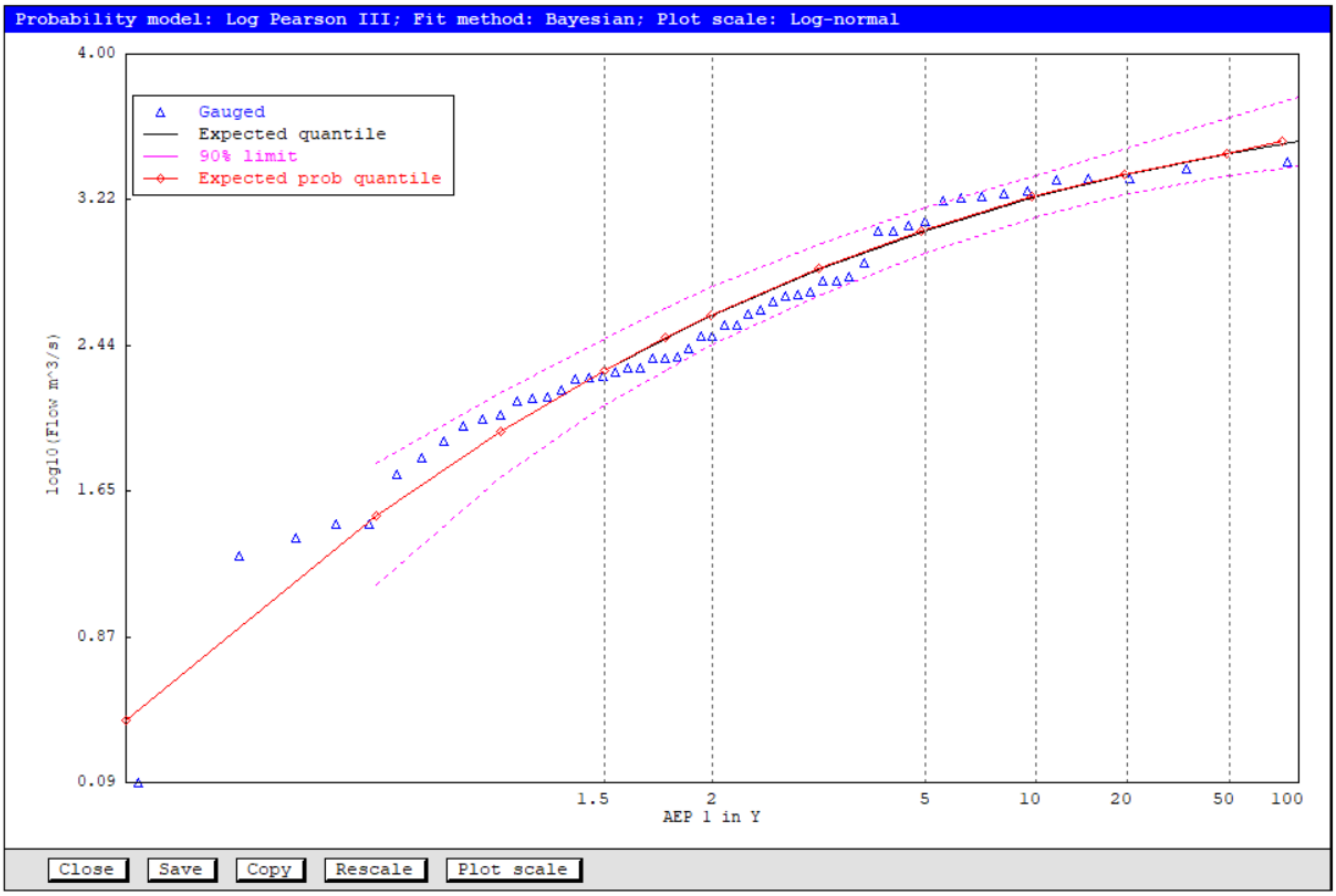

Figure 6 Flood frequency curve at Deverill gauge – FLIKE output

Scaling flows estimates was undertaken by utilising the FFA flows estimated from the Deverill gauge, which allowed us to derive the inflow into our hydraulic model, see Figure 7. The scaling of flows was undertaken using Equation 1.

Equation 1 Area scaling formula

$$Q_1 = Q_2 * \left(\frac{A_1}{A_2}\right)^{0.7}$$

Where,

Q_1 = flow at hydraulic model extent

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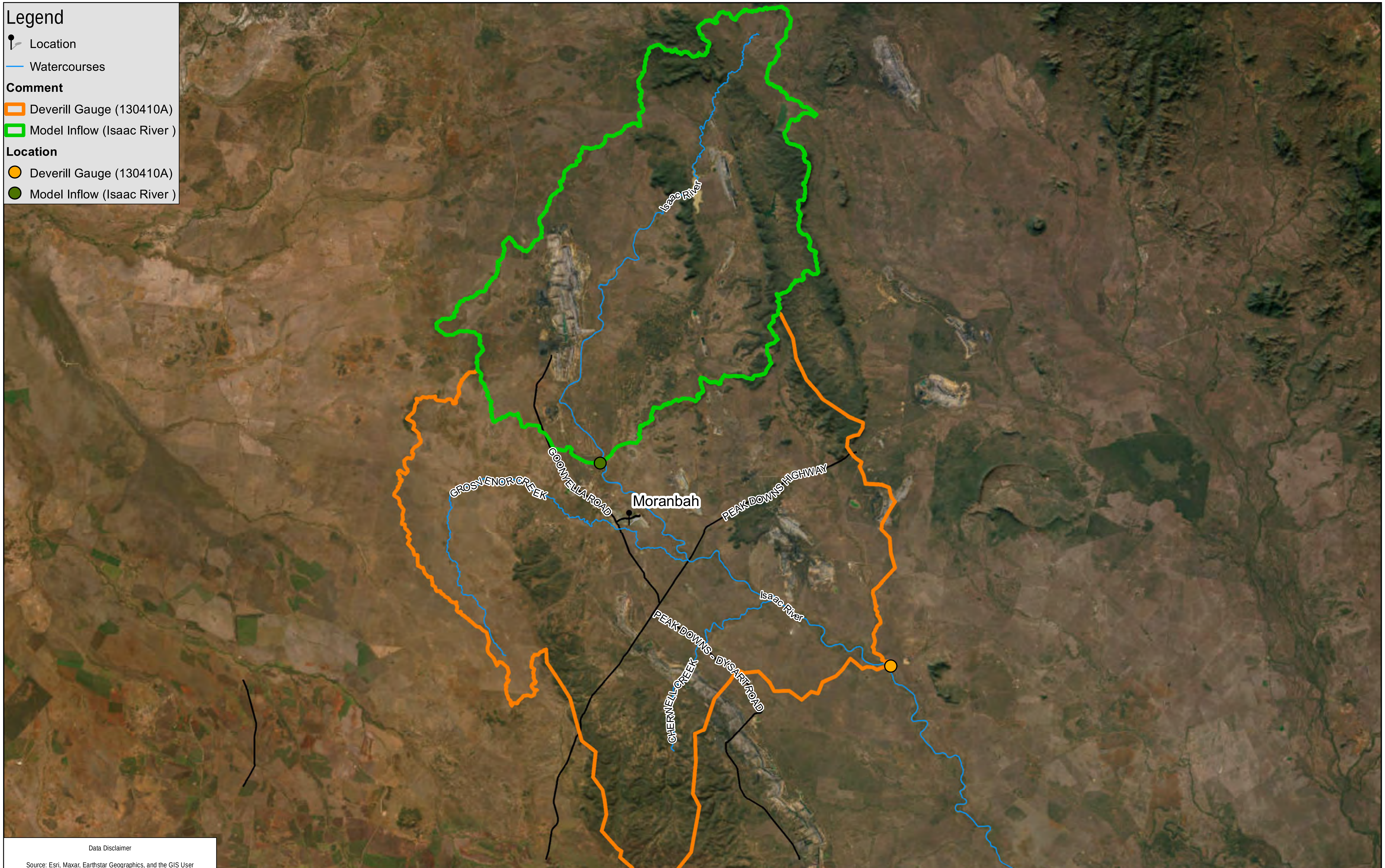
Q_2 = flow at Deverill gauge station

A_1 = catchment area at hydraulic model extent = 1389 km^2

A_2 = catchment area at Deverill gauge station = 4092 km^2



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Moranbah Study Area

Area Scaling Catchment Map

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Figure 7

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FFA estimated flows derived were as presented in Table 1.

Table 1 Design event peak flow comparison (Isaac River) from FFA

AEP Event (%)	Peak flow – Isaac River at Deverill (m^3/s)	Peak flow – Isaac River at Deverill (m^3/s) (KBR, 2021)	Scaled peak flow to hydraulic model extent (m^3/s)
50	393	-	185
20	1,129	-	530
5	2,275	2,467 (2,337)	1,068
2	2,946	2,800 (2,578)	1,383
1	3,390	2,967 (2,684)	1,591

Table 1 shows a comparison of the design event flow rates estimated from the FFA, along with the scaled flows adopted for input into the hydraulic model. The comparison of results with the regional Isaac River Flood Study (KBR, 2021) show reasonable agreement for the 5% and 2% AEP. The results for the 1% AEP vary, this is attributed to a number of factors including:

– The number of sample points (i.e. AMS values) within the analysis was 54 (1968 to 2022) for this study and for the regional study (KBR, 2021) 53 sample points (1968 to 2021) were considered in the AMS, though censoring of data meant that only 41 sample points were included in the analysis (i.e. 12 ‘outliers’ were excluded, no detail or discussion was provided in the KBR report on criteria used for the censoring).
– The analysis completed for the regional study (KBR, 2021) included sensitivity to the derivation of the FFA results based on gauge stage converted to flow versus undertaking the analysis based on gauged flow results (results in parentheses) which showed the results were sensitive to this difference in approach. The analysis undertaken for this study was undertaken based on gauged flow recordings.

3.4 Grosvenor Creek

3.4.1 Model selection

As discussed in Section 3.3.1 and shown in Figure 5, stream gauge data is the preferred method of choice for quantifying hydrologic flood flows as they collect real time data for rainfall events. For Grosvenor Creek, there are no stream gauges within the catchment. In the absence of stream gauge data, hydrologic models are the preferred option as they enable a detailed assessment of design flood hydrology. Limitations of the hydrologic models include program constraints and a heavy reliance on user input data. For this study, a RAFTS hydrologic model (rainfall-runoff model) was developed to simulate the rainfall-runoff processes for the catchment.

RAFTS hydrologic modelling software is based on the Regional Stormwater Drainage Model (RSWM) developed by the Snowy Mountains Engineering Corporation (SMEC) and is an industry standard rainfall-runoff routing analysis package. It is capable of modelling changes due to development for both rural and urban sub-catchments and is an accepted model used to quantify flood flows from catchments as specified in the ARR (2019) guidelines.

RAFTS is used in this study to estimate the runoff hydrograph from individual sub-catchments based on rainfall intensities, temporal patterns, catchment losses and the definition of parameters describing the sub-catchment characteristics. These parameters include the sub-catchment area, sub-catchment slope, sub-catchment roughness and fraction of impervious area in the sub-catchment. Sub-catchment outflow hydrographs are routed downstream through the model via links (either lag links or routing links) that connect these sub-catchments. Once the RAFTS model is configured, Storm Injector was used to simulate the model within its storm-management framework that allows for the easy application and assessment of the multitude of simulated design flood results from RAFTS.

The Regional Flood Frequency Estimation (RFFE) method was then used as a high-level assessment of peak flows to validate the adopted RAFTS storm predicted peak flow for a range of AEP event, providing an order of magnitude check. The results from a previous study within the catchment (Cardno, 2018) have been used as a further validation of hydrologic model (RAFTS) outputs.

3.4.2 Model development

The catchment area was delineated for Grosvenor Creek and the development of the RAFTS model entailed:

– Sub-dividing the catchment into a series of sub-areas to suit the catchment topography and other key features, such as the location of culverts and subterranean drainage networks.
– Determination of model parameters including design rainfall and initial/continuing loss rates based on available guidelines and model validation.
– Hydrologic model simulations using the Initial Loss-Continuing Loss approach based on the Ensemble Method, as outlined in ARR (2019).
– Review and validation of model results.

The results were validated against the RFFE results and compared to the results presented in the Flood Study and Flood Emergency Management Report - Moranbah Flood Study (Cardno, 2018) report. During this validation process adjustment of following model parameters were made to account for the uncertainty of these parameters.

- IL-CL
- Manning's 'PERN' coefficient

3.4.3 Model parameters

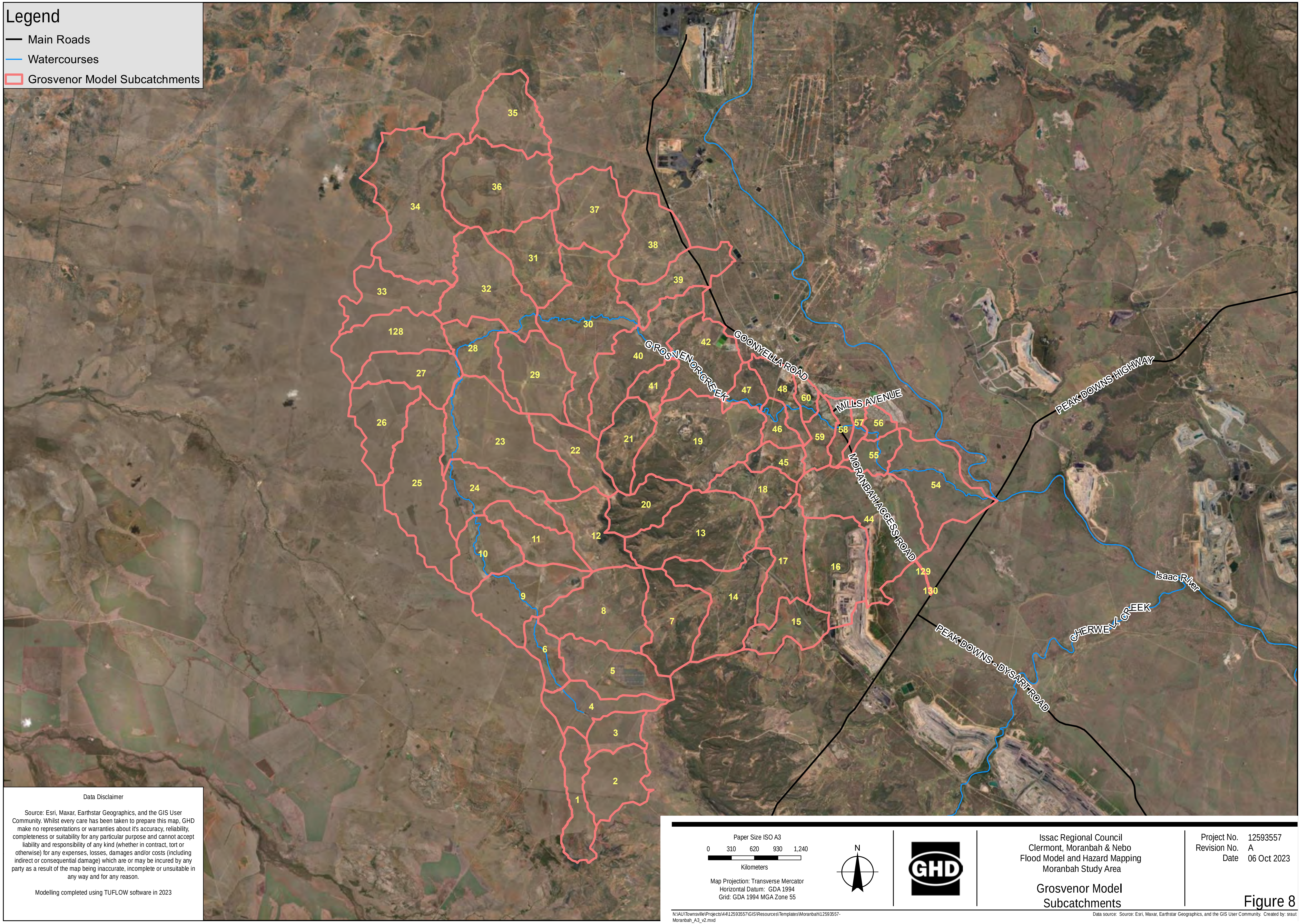
The RAFTS model required the inputs described in the following sections.

3.4.3.1 Catchment delineation

Establishment of the hydrological model required delineation of sub-catchments, which were based on:

– Identified flow paths.
– Land use types / catchment characteristics.
– Key points of interest (stream confluence points, change in direction of the stream or particular topographic features).

Delineation was undertaken using GIS software (QGIS) with a Digital Elevation Model (DEM) of the catchment in accordance with the methods detailed in Queensland Urban Drainage Manual (QUDM). Characteristics of each sub-catchment were then determined for input to the RAFTS model. A catchment map is provided in Figure 8 and a summary of each sub-catchment's parameters adopted for the study are provided in Appendix C. The catchment area to the confluence with the Isaac River is 760 km^2.



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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 310 620 930 1,240

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Issac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

Grosvenor Model
Subcatchments

Project No. 12593557
Revision No. A
Date 06 Oct 2023

Figure 8

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Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut

3.4.3.2 Catchment slope

Equal Area Slope (EAS) utilises the elevation profile of the Longest Flow Path (LFP) to determine the slope where half the points fall above and below the slope line. LFP is the distance from the furthest point of a catchment to the catchment's outlet. The length and respective EAS for each sub-catchment were determined by using the profile tool in the QGIS software to define the terrain profile along the longest flow-path line, the profile was then analysed to calculate the EAS. These results are provided for all sub-catchments in Appendix C.

3.4.3.3 Land use/catchment roughness

PERN 'n' roughness was determined for each sub-catchment based on an assessment of the existing land use as determined through a review of aerial photography, zoning data and cadastral data. Values adopted for different ground types are provided in Table 2, which vary within these classes based on density of the vegetation. For each sub catchment, the PERN 'n' value for the pervious area of the sub-catchment is provided in Appendix C.

Table 2 Adopted hydrologic PERN 'n' roughness (WP Software, 1994)

Adopted PERN 'n' Roughness	Ground Type
0.012	Impervious (i.e., roads, buildings etc.)
0.035 – 0.050	Combination of low density to medium density vegetation
0.050 – 0.070	Combination medium density to high density vegetation
0.080 – 0.120	Forested/high density vegetation

3.4.3.4 Rainfall losses

For pervious areas, initial loss of 0 mm and continuous loss of 3.1 mm/h were adopted within the hydrology model for events up to the 1% AEP event. The continuing loss value was adopted based on the ARR data hub information from the ARR 2019 guidelines and were validated by comparing the peak flows estimates from the RAFTS model against the RFFE derived peak flows for various AEP's. A zero value for initial loss and one millimetre per hour for continuing loss was adopted for the Probable Maximum Precipitation (PMP) event per ARR 2019 recommendations, interpolation of the initial and continuing loss values between the 1% AEP and PMP events was completed to derive the loss values adopted for the 0.2% AEP event. For the various AEP storms simulated, Table 3 summarises the pervious area initial and continuing loss parameters that were adopted for an 18-hour storm event in Grosvenor Creek.

Table 3 Loss Parameters (18 hour storm duration)

<table>
<tr><th>Ground type</th><th>Rainfall event</th><th>Global initial loss (mm)</th><th>Median pre-burst depth (mm)</th><th>Net initial losses (mm)</th><th>Continuing loss (mm/hr)</th></tr>
<tr><td>Impervious</td><td>All</td><td>1.00</td><td>N/A</td><td>1.0</td><td>0.0</td></tr>
<tr><td rowspan="8">Pervious</td><td>50 % AEP</td><td>50</td><td>0</td><td>0*</td><td rowspan="6">3.1</td></tr>
<tr><td>20 % AEP</td><td>50</td><td>1.6</td><td>0*</td></tr>
<tr><td>10 % AEP</td><td>50</td><td>2.6</td><td>0*</td></tr>
<tr><td>5 % AEP</td><td>50</td><td>3.6</td><td>0*</td></tr>
<tr><td>2 % AEP</td><td>50</td><td>14.2</td><td>0*</td></tr>
<tr><td>1 % AEP</td><td>50</td><td>22.1</td><td>0*</td></tr>
<tr><td>0.2% AEP</td><td>50</td><td>-**</td><td>0*</td><td>2.6***</td></tr>
<tr><td>Probable Maximum Precipitation (PMP)</td><td>-**</td><td>-**</td><td>0</td><td>1</td></tr>
</table>

* - as net initial loss is adopted as global initial loss minus median pre-burst rainfall depth the net initial loss cannot be negative, therefore a value of zero was adopted. Zero global initial loss has been adopted based on a validation of the hydrologic model results.

** - ARR 2019 data hub does not specify a median pre-burst rainfall depth for this event, therefore values shown for initial loss have been derived based on ARR 2019 guidance and applied directly.

*** - based on interpolation between the 1% AEP and the PMP event, as detailed in ARR 2019 Book 8 Chapter 4 Section 4.3.2.2.

3.4.3.5 Design storm

The design storm events that were assessed in this study included the 50%, 20%, 5%, 2%, 1%, 0.2% AEP, and the Probable Maximum Flood (PMF) events. To generate design rainfall for various durations, the RAFTS model simulated through Storm Injector used either extracted ARR (2019) Data Hub rainfall and temporal pattern data, or manually input rainfall and temporal pattern data from the Probable Maximum Precipitation guidebook. To determine discharge hydrographs for each sub-catchment, design storm events were assessed for a range of design storm durations and temporal patterns, as listed in Table 4.

Table 4 Design storm durations

Rainfall Event	Duration (min)	Source of Rainfall Data and Temporal Patterns
50% - 1%AEP	10, 15, 20, 25, 30, 45, 60, 90, 120, 180, 270, 360, 540, 720, 1080, 1440	ARR Data Hub rainfall depths extracted from the gridded rainfall point nearest to the sub-catchment centroid, Temporal Patterns applied as extracted from the ARR Data Hub.
0.2% AEP	15, 20, 25, 30, 45, 60, 90, 120, 180, 270, 360	Areal Reduction Factors (ARF) applied to ARR Data Hub rainfall depths and Generalised Short Duration Method (GSDM) Average Variability Method (AVM) temporal pattern with Jordan (Jordan et. al., 2005) temporal patterns
PMP	15, 20, 25, 30, 45, 60, 90, 120, 180, 270, 360	GSDM guidebook rainfall depths and AVM temporal pattern with Jordan (Jordan et. al., 2005) temporal patterns (GTSMR guidebook note considered due to the size of the study area for the Moranbah town area)

The design rainfall depths that were utilised are summarized in Appendix B for the frequent, infrequent and rare events.

3.4.3.6 Probable Maximum Flood (PMF)

As indicated in Table 4, PMP rainfall data were calculated based on the GSDM method. This design rainfall depth and the temporal patterns were manually imported into Storm Injector to simulate the PMF hydrographs for each sub-catchment.

The PMP rainfall depths and parameters applied to determine the PMP rainfall depth are detailed in Table 5

Table 5 PMP- parameters

Parameter	Duration (min)										
	15	30	45	60	90	120	150	180	240	300	360
Catchment area	792 km										
Elevation Adjustment	0.0 (site is below 1,500 m AHD)										
Elevation Adjustment Factor, EAF	1.0										

Parameter	Duration (min)										
	15	30	45	60	90	120	150	180	240	300	360
Moisture Adjustment Factor, MAF	0.90										
Smooth, S	0.0										
Rough, S	1.0										
Initial Depth Rough, Dr	175	256	325	392	504	582	656	708	800	878	937
PMP (mm) (Grosvenor Creek)	100	150	190	230	310	360	410	440	500	530	570

The initial rainfall depth for the ‘smooth’ (DS) and/or ‘rough’ (DR) terrain categories is taken from the Depth-Duration-Area (DDA) curves in Figure 9 for the respective catchment area and duration.

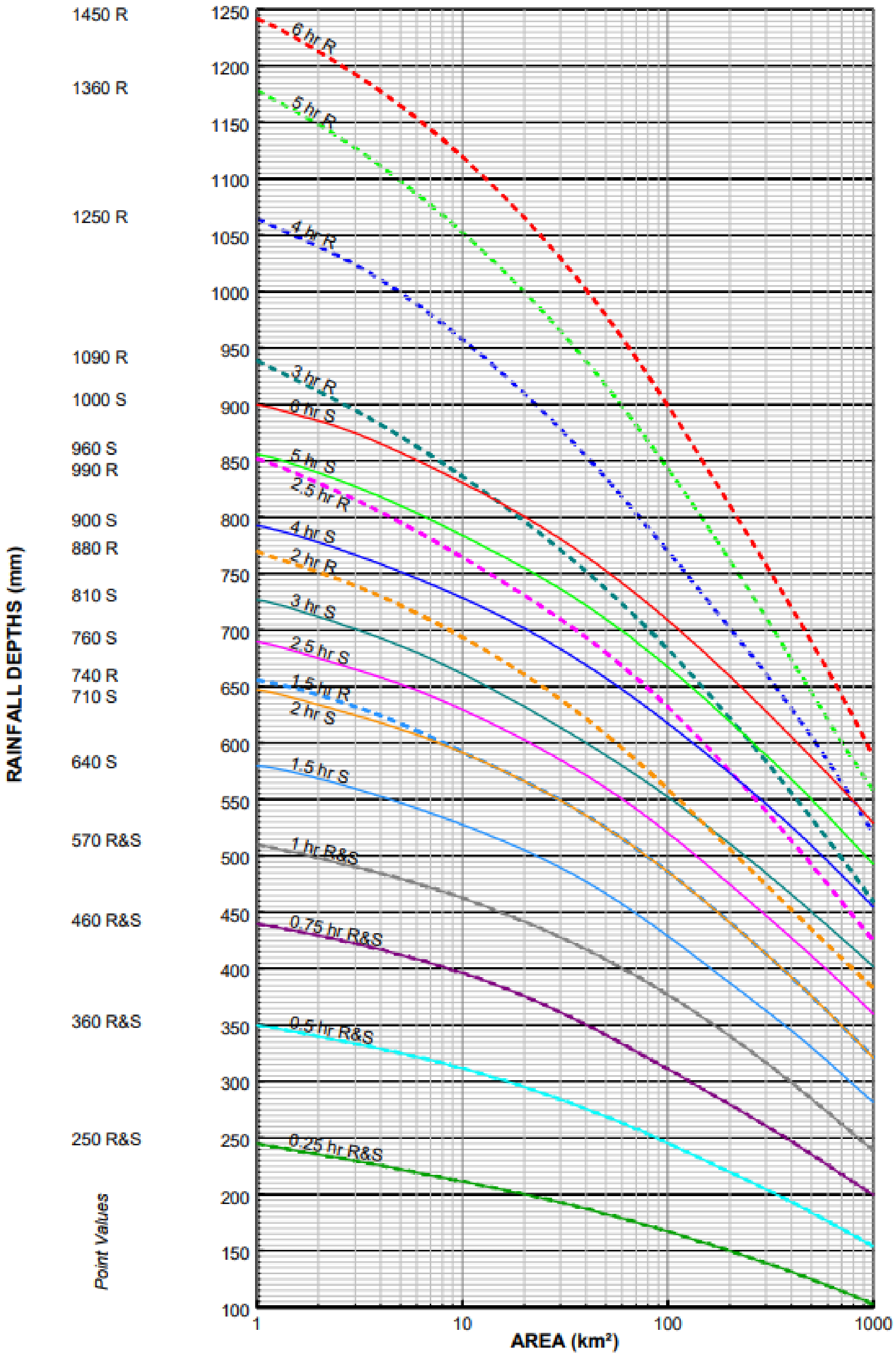


Figure 9 ***Depth-Duration-Area Curves of Short Duration Rainfall***

Note that the PMF estimate uses a different set of temporal patterns to that used in event as frequent and more frequent than the 1% AEP. For PMF simulations, 11 temporal patterns have been considered in order of assess the PMF, these being the Average Variability Method (AVM) as specified in the GSDM guidebook and the 10 Jordan Temporal Patterns (Jordan et. al., 2005).

3.4.3.7 Areal reduction factors

Areal reduction factors for the events up to the very-rare rainfall event (0.2% AEP) were applied based on the ARR 2019 areal reduction factor parameters. The coefficients informing these factors are summarised in Table 6.

Table 6 Areal-reduction factor coefficients (short duration)

Parameter	Value
Zone	Semi-arid Inland Queensland
A	0.287
B	0.265
C	0.439
D	0.36
E	0.00226
F	0.226
G	0.125
H	0.0141
I	0.213

For the PMP rainfall depths, areal reduction has been applied based on the ARR 2019 recommendations in Book 2 Chapter 4 Section 4.3.2. These areally reduced rainfall depths for the PMP event area shown in Figure 10.

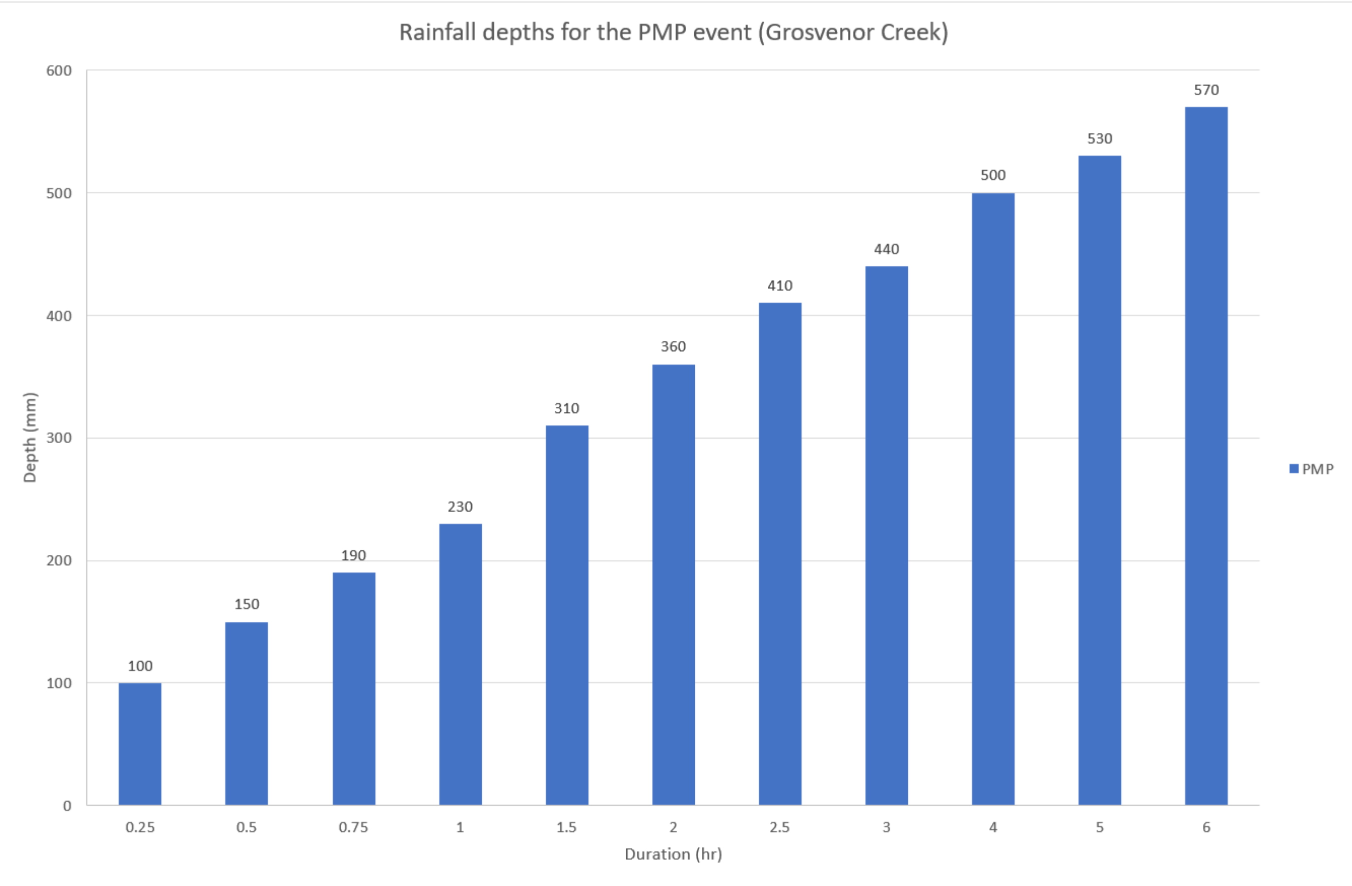


Figure 10 Rainfall Depths for the PMP event (Grosvenor Creek)

3.4.3.8 Climate change

The parameter adjusted to account for climate change impacts in this study have been limited to the rainfall intensity only. Climate change scenarios for 2050 and 2100 time horizons were modelled for the 1% AEP event

The rainfall depth percentage increase for the 2100 time horizon was extrapolated from the time horizons gathered from ARR 2019 data hub data and plotted to derive a line of best fit. The 2050 rainfall depth increase was taken from the ARR 2019 data hub values provided. The climate change scenarios considered an increase in the design rainfall as specified in Table 7, these consider the Representative Concentration Pathway (RCP) 6 climate change scenario.

Table 7 Climate Change variables

Year	Rainfall Intensity Increase (%)
2050	6.2
2100	12.7

3.4.4 Model results and validation

Due to the ARR (2019) ensemble method of determining the critical temporal pattern in combination with a range of potentially critical storm durations for each AEP, a wide range of outcomes were possible. An initial assessment of the results indicated that for the 1% AEP event, 18 hours (1080mins), 1013 (TP2) event was the critical event for Grosvenor Creek (at the confluence with the Isaac River) as this was the highest peak median value from the range of storm durations simulated.

The results from the range of AEP analysed were validated against the result from the RFFE and also compared to the Flood Study and Emergency Management Report – Moranbah Flood Study (Cardno, 2018) and are presented in Table 8.

The RFFE results produced the following observations:

– Gauges informing the RFFE area generally smaller than Grosvenor Creek (i.e. the Grosvenor Creek catchment used in this comparison is larger than most catchments that form the analysis for the RFFE).
– The 1% AEP flow estimation from the RFFE analysis for Grosvenor Creek is within the cluster of 1% AEP flow estimates from the nearby gauges analysed.
– The geographical location of the gauges informing the RFFE are a mix of coastal and inland (west of the dividing range).
– The RFFE analysis is considered a reasonable comparison of flows from the Grosvenor Creek catchment and hence justification for adjusting hydrological model parameters including the initial loss values adopted for design flow estimates.

Table 8 Grosvenor Creek RAFTS model peak flow validation

Event	RFFE peak flow estimation (m^3/s)	RFFE lower confidence limit (m^3/s)	RFFE upper confidence limit (m^3/s)	Cardno 2018 (m^3/s)	RAFTS (m^3/s)	RAFTS storm duration (hours) and temporal pattern (m^3/s)
50% AEP	391	206	780	-	219	12 hours and TP7 (928)
20% AEP	611	327	1,200	-	455	12 hours and TP7 (928)
5% AEP	944	471	1,570	-	825	18 hours and TP7 (1018)
2% AEP	1,180	555	2,660	-	1,118	18 hours and TP2 (1013)
1% AEP	1,370	614	3,240	1,406	1,352	18 hours and TP2 (1013)

3.5 Local Moranbah area

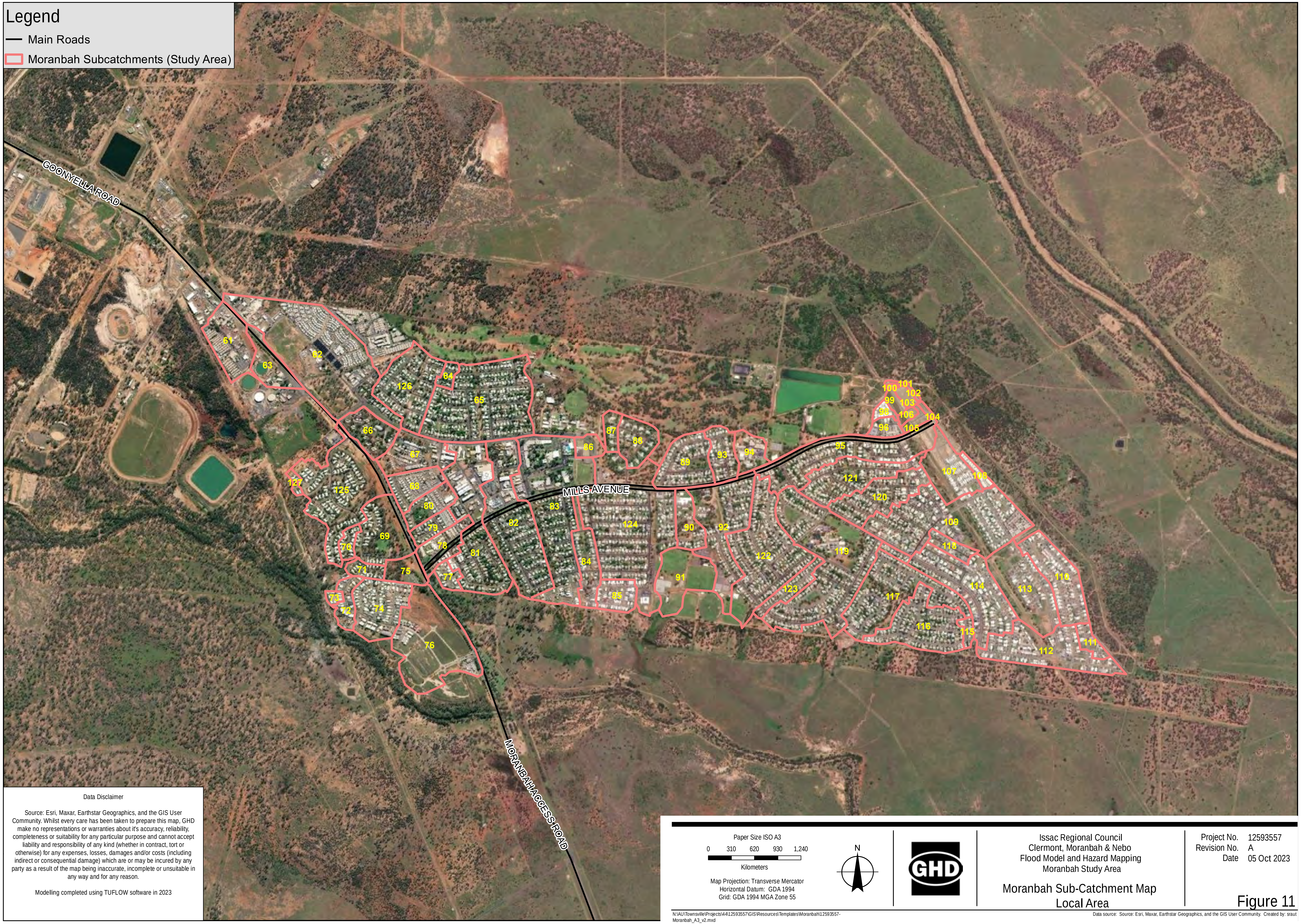
3.5.1 Model development

After validation and rationalisation of all model parameters for the Grosvenor Creek catchment, sub-catchments in the study area were updated and refined to consider local drainage features within the Moranbah town area.

3.5.2 Model parameters

3.5.2.1 Catchment delineation

As discussed in Section 3.5.1, after validation and rationalising all the parameters, sub-catchments in our study area were updated. Delineation was undertaken using GIS software (QGIS) with a DEM of the catchment in accordance with the methods detailed in QUDM. Characteristics of each sub-catchment were then determined for input to the RAFTS model. The updated catchment breakdown is shown in Figure 11 and the summary of each sub-catchment parameters adopted for the RAFTS model are provided in Appendix C.



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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 310 620 930 1,240

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Issac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

Moranbah Sub-Catchment Map
Local Area

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure 11

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3.5.2.2 Catchment slope

The process for assigning catchment slope for the Moranbah Local Area model is consistent with the process described in Section 3.4.3.2. These results are provided for all sub-catchments in Appendix C.

3.5.2.3 Land use/roughness

PERN 'n' roughness was determined and applied as described in Section 3.4.3.3 for each sub-catchment including the values referenced in Table 2. For each sub catchment, the PERN 'n' values adopted for the pervious area of the catchment are provided in Appendix C.

Table 9 Adopted hydrologic PERN 'n' roughness (WP Software, 1994)

Adopted PERN 'n' Roughness	Ground Type
0.012	Impervious (i.e., roads, buildings etc.)
0.035 – 0.050	Combination of low density to medium density vegetation
0.050 – 0.070	Combination medium density to high density vegetation
0.080 – 0.120	Forested/high density vegetation

3.5.2.4 Rainfall losses

For the Moranbah Local Area model, the same validated rainfall losses detailed in Section 3.4.3.4 have been applied to the Moranbah Local Area hydrology model for both impervious and pervious areas.

3.5.2.5 Design storm

The design storm events that were assessed in this study included the 50%, 20%, 5%, 2%, 1%, 0.2% AEP, and the Probable Maximum Flood (PMF) events.

The same approach to design storm rainfall application and temporal pattern application has been followed as detailed in Section 3.4.3.5 including the event probability and storm durations as detailed in Table 4.

The design rainfall depths that were utilised are summarized in Table 10 for the frequent, infrequent and rare events.

3.5.2.6 Probable Maximum Flood (PMF)

As indicated in Section 3.5.2.5, PMP rainfall data was calculated based on the GSDM method. This design rainfall depth and the temporal patterns were manually imported into Storm Injector to simulate the PMF hydrographs for each sub-catchment.

The PMP rainfall depths and parameters applied to determine the PMP rainfall depth are detailed in Table 10.

Table 10 PMP- parameters

Parameter	Duration (minutes)										
	15	30	45	60	90	120	150	180	240	300	360
Elevation Adjustment	0.0 (site is below 1,500 m AHD)										
Elevation Adjustment Factor (EAF)	1.0										
Moisture Adjustment Factor (MAF)	0.90										
Smooth, S	0.0										
Rough, S	1.0										
Initial Depth Rough, Dr	175	256	325	392	504	582	656	708	800	878	937

Parameter	Duration (minutes)										
	15	30	45	60	90	120	150	180	240	300	360
PMP (mm) (Local Moranbah Area)	160	230	290	350	450	520	590	640	720	790	840

The initial rainfall depth for the 'smooth' (DS) and/or 'rough' (DR) terrain categories is taken from the DDA curves in Figure 9 for the respective catchment area and duration.

Note that the PMF estimate uses a different set of temporal patterns to that used in event as frequent and more frequent than the 1% AEP. For PMF simulations, 11 temporal patterns have been considered in order of assess the PMF, these being the AVM as specified in the GSDM guidebook and the 10 Jordan Temporal Patterns (Jordan et. al., 2005).

3.5.2.7 Areal reduction factor

Areal reduction factors for the events up to the very-rare rainfall event (0.2% AEP) were applied based on the ARR 2019 areal reduction factor parameters. The coefficients informing these factors are summarised in Table 6.

For the PMP rainfall depths, areal reduction has been applied based on the ARR 2019 recommendations in Book 2 Chapter 4 Section 4.3.2. These areally reduced rainfall depths for the PMP event area shown in Figure 12.

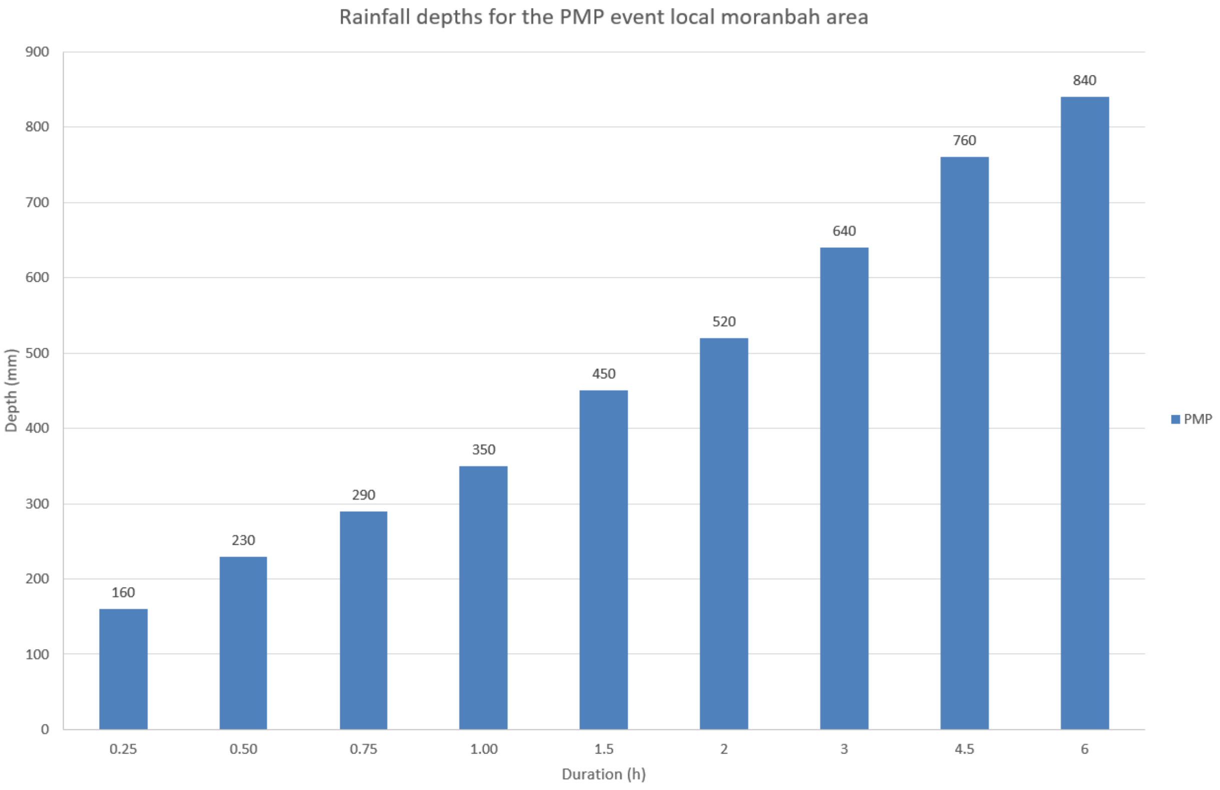


Figure 12 Rainfall depths for the PMP Event (Local Moranbah area)

3.5.2.8 Climate change

The parameter adjusted to account for climate change impacts in this study have been limited to the rainfall intensity only. Climate change scenarios for 2050 and 2100 time horizons were modelled for the 1% AEP event The rainfall depth percentage increase for the 2100 time horizon was extrapolated from the time horizons gathered from ARR 2019 data hub data and plotted to derive a line of best fit. The 2050 rainfall depth increase was taken from the ARR 2019 data hub values provided. The climate change scenarios considered an increase in the design rainfall as specified in Table 7, these consider the Representative Concentration Pathway (RCP) 6 climate change scenario.

3.5.3 Critical event selection

Due to the ARR (2019) ensemble method of determining the critical temporal pattern in combination with a range of potentially critical storm durations for each AEP, a wide range of outcomes was possible. After an assessment of the temporal patterns and durations for each AEP, a combination of different temporal patterns and durations were shown to be critical for the hydrologic model for different AEPs. Analysis of the study area (Moranbah Local Area) was undertaken in Storm Injector and a representative selection of critical duration and temporal pattern events were exported for simulation in the hydraulic model. The events selected are presented in Table 11.

Table 11 Critical events (Moranbah town area)

Storm Events	Critical Duration (minutes)	Temporal Pattern
50% AEP	30	5256 (TP8)
	60	5313 (TP4)
20% AEP	45	5271 (TP6)
	60	5313 (TP4)
5% AEP	45	5270 (TP5)
	45	5271 (TP6)
2% AEP	25	5214 (TP9)
	45	5170 (TP3)
1% AEP	30	5238 (TP8)
	45	5170 (TP3)
0.2% AEP	30	BOM 2003
	45	BR97
PMP	30	MK75
	30	DA74

4. Hydraulic analysis

This section summarises the hydraulic investigations undertaken for the study area. Hydraulic modelling was undertaken to estimate design event flood levels and velocities, and to determine flow patterns across the study area to inform flood hazard predictions. A two-dimensional (2D) flood modelling approach was adopted to simulate the complex nature of flood flows, in conjunction with a one-dimensional (1D) network of pit, pipe and cross drainage structures. Hydraulic results were utilised to identify key areas of flood risk and can be used to potentially develop flood mitigation options in the future.

The scope of work involved:

– Data collection and review of available hydraulic information.

– Hydraulic model setup (GIS and TUFLOW).

– Estimation of event-based flood inundation.

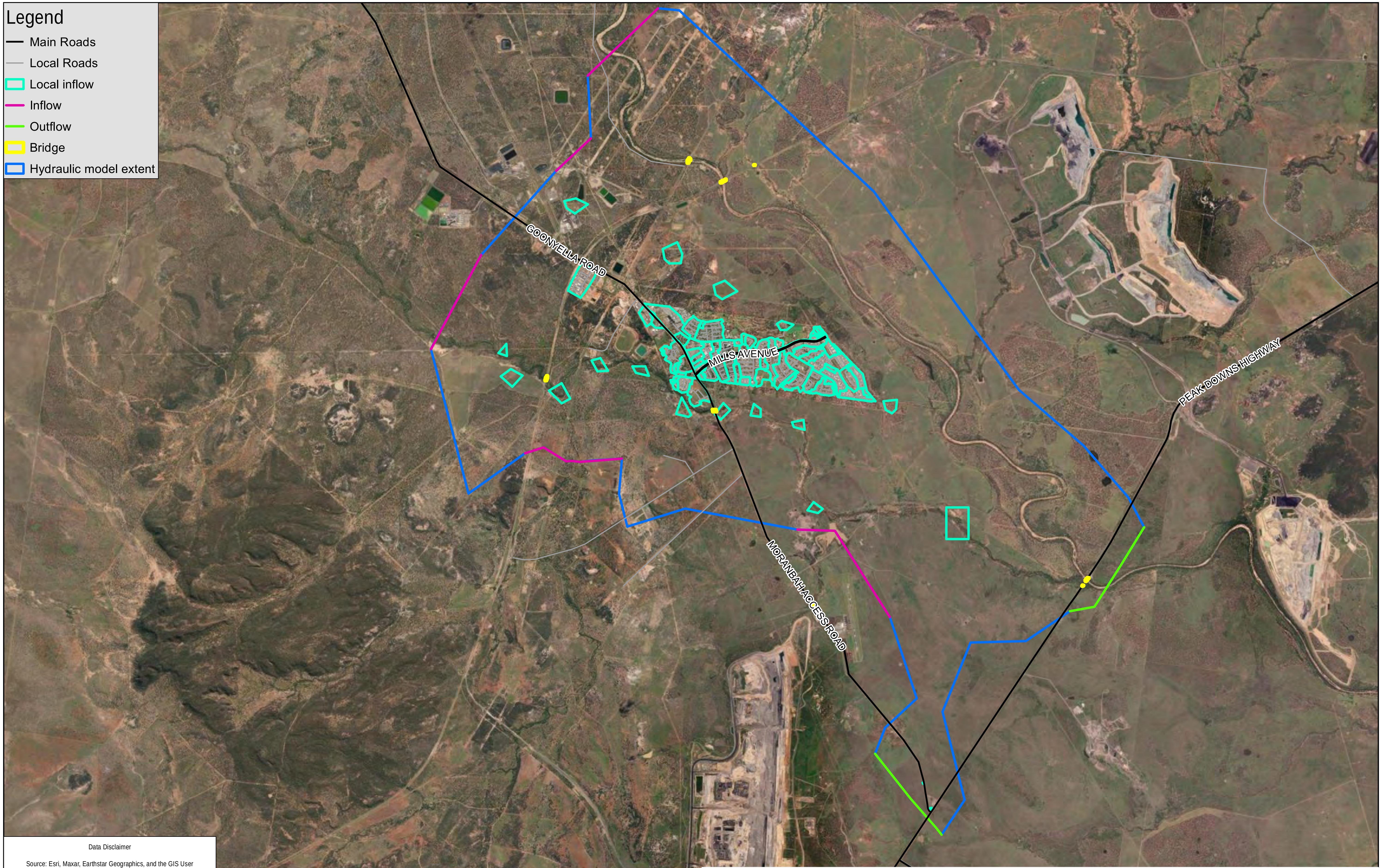
The hydraulic assessment utilised local catchment hydrographs produced in the hydrologic analysis, elevation data and other GIS layers informing the model. A plan showing the extent of the hydraulic model is provided in Figure 13 highlighting the boundary that extends significantly further than the area of interest for the study (Moranbah).

4.1 Data collection

The following data was used to undertake this assessment:

– One metre LiDAR terrain data – obtained from ELVIS Spatial data portal.
– One metre LiDAR terrain data – provided by TMR for the Peak Downs Highway.
– One metre LiDAR terrain data – obtained/derived from GHD previous design work and as-built information for Utah Drive.
– Design terrain data for Bushlark Drive – provided by IRC for Bushlark Drive.
– One second derived SRTM Terrain Data – obtained from the ELVIS Spatial data portal.
– GIS asset data for Stormwater Infrastructure – provided by IRC.
– GIS Land Use Zoning – provided by IRC.
– Hydrographs output from the RAFTS model.

Note that there was very limited asset data provided for any pits, pipes, culverts or hydraulic structures. Resulting assumptions have been identified throughout the following sections of this report.



Data Disclaimer

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Modelling completed using TUFLOW software in 2023

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Issac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

Moranbah Model Extent

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure 13

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Print date: 05 Oct 2023 - 14:59 (SMA record: 7)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut

4.2 Hydraulic model setup

4.2.1 Model selection

Hydraulic modelling has been developed using the TUFLOW hydraulic modelling software. TUFLOW is a 2D unsteady flow hydrodynamic modelling tool developed by BMT-WBM. TUFLOW is oriented towards establishing 2D flow and inundation patterns in coastal waters, rivers and floodplains, as well as urban areas (including capability to represent 1D hydraulic structures like stormwater capture pits, conveyance pipes and cross-drainage culverts). TUFLOW is recognised as an industry standard 2D hydrodynamic modelling package within Australia and is well suited to the modelling of the waterways and networks within the study area.

4.2.2 Model development

Development of the TUFLOW model entailed:

- Ingesting of terrain data.
- Implementations of hydrographs from RAFTS at identified inflow locations.
- Determination of other model parameters including boundary conditions, material properties (hydraulic roughness) and hydraulic infrastructure.
- Hydraulic model simulations.
- A critical review of model results.

The hydraulic model development for the study can be divide into two stages. In first stage the Isaac River and Grosvenor Creek flows were modelled. Flow in the Isaac River was applied as an upstream boundary condition as a constant inflow from the Isaac River (as determined by the FFA and scaled by catchment area reporting to the hydraulic model boundary). For Grosvenor Creek, inflows from the catchment area upstream of the hydraulic model boundary were introduced as a total inflow hydrograph corresponding to the routing catchment corresponding to this location from the RAFTS model. The TUFLOW model was simulated for the critical duration event in these systems.

Following the establishment of the floodplain for the Isaac River and Grosvenor Creek systems, the model was simulated considering the Moranbah town model in detail, including the pit and pipe infrastructure as well as cross-drainage, and storm events critical to the local town area. The maximum water level in the Isaac River and Grosvenor Creek from the first stage simulations were input as a static water level into the hydraulic model.

4.2.3 Software version

The model developed for this assessment has been simulated in the latest version of the TUFLOW software at the time of assessment. This included utilising some of the new functionality available in the latest version of the software. Key new functionality within the TUFLOW software (since the previous TUFLOW modelling for the study area) includes:

– Adoption of the TUFLOW Graphical Processing Unit (GPU) Heavily Parallelised Compute (HPC) solution scheme, including an explicit solver for the full 2D shallow water equation and sub-grid scale eddy viscosity
– Full release notes detailing changes from previous versions of the software are available on the TUFLOW website.

The hydraulic model was simulated using the 2023-03-AA version of the TUFLOW software.

4.2.4 Cell size convergence

To justify a balance between hydraulic model detail and performance, a grid cell size convergence assessment was undertaken to determine the effect of the model cell resolution on the following:

- Model predicted flood levels
- Simulation time

- Data volumes

In this study, the hydraulic model was simulated using a 3, 5 and 10 metre grid cell size. The results of the assessment are detailed in Table 12.

Table 12 Grid cells convergence assessment summary

Grid cell size (m)	Number of cells	Runtime (hours)[1]	Maximum grid output (MB)	Δ1% AEP in peak water level[2] (m)
3	111056704	9.34	579	0.005
5	66634023	1.48	209	-
10	33317012	0.72	133	0.005

Based on the results of the comparison detailed above, the 5-metre grid size was selected for the hydraulic model. The decision was mad based on the following key points:

– Adoption of the TUFLOW Graphical Processing Unit (GPU) Heavily Parallelised Compute (HPC) solution
– Maintains a level of model detail appropriate for the assessment.
– Provides a reasonable balance between model detail and data volumes.

4.2.5 Model parameters

The TUFLOW model required the following input parameters:

4.2.5.1 Topography

The following LiDAR terrain Data obtained was ingested into TUFLOW using a model grid cell size of 10 m.

– One metre LiDAR terrain data – obtained from ELVIS Spatial data portal.
– One metre LiDAR terrain data – provided by TMR for the Peak Downs Highway.
– One metre LiDAR terrain data – obtained/derived from GHD previous design work and as-built information for Utah Drive.
– Design terrain data for Bushlark Drive – provided by IRC for Bushlark Drive.
– One second derived SRTM Terrain Data – obtained from the ELVIS Spatial data portal.

4.2.5.2 Design event modelling

Design storm events assessed in this study were 50%, 20%, 5%, 2%, 1%, 0.2% AEP events, and the PMF. Critical storm durations were used to generate maximum flood results. Critical storm durations were determined by modelling all durations and temporal patterns in the RAFTS model and selecting a representative number of storms to be modelled in TUFLOW based on peak flow at the area of interest for the study (Moranbah).

4.2.5.3 Inflow boundaries

Hydrographs representing catchment runoff were applied as upstream boundary condition (QT or flow vs. time) throughout the hydraulic model. Inflow hydrographs were sourced from the RAFTS model result where applicable and for the inflows from the Isaac River, scaling of flows obtained from the FFA at the Deverill (130410A) gauge were input as steady inflow into the hydraulic model.

Local inflow hydrographs were applied as source-area inflow boundary conditions directly to the 2D domain where the sub-catchment is contained wholly in the hydraulic model extent. For catchments containing inflow pits, inflow is evenly distributed between the pits by dividing the inflow hydrograph by the number of pits covered by the catchment boundary. The inflow capacity of the pits is discussed in the 1D Hydraulic Infrastructure Section 4.2.5.6.2.

[1] For 1% AEP 30 minutes storm duration temporal pattern 8 selected as this event is the critical event for the 1% AEP in the vicinity of Moranbah

[2] Relative to 5 m grid cell size

4.2.5.4 Outflow boundaries

Outflow boundaries were setup as "HQ" boundaries, with slope based on the energy grade line of the waterway conveying the outflow at each location. The boundary conditions considered the Isaac River outlet from the model as well as outflow from the Moranbah Access Road portion of the model. Boundary conditions within the hydraulic model are shown in Figure 13.

4.2.5.5 Hydraulic roughness

Hydraulic roughness values across the study area was assigned in the model based on a combination of the existing land use through review of aerial photography and zoning data. The Manning's n roughness value of 0.050 was chosen as the model's global value, with the exception of the various land uses that are listed in Table 13 and a roughness map illustrating the spatial variation is presented in Figure 14 for the entire hydraulic model extent and in Figure 15 for the local town area. High roughness values were adopted for buildings to represent their obstruction to flow.

Table 13 Manning's 'n' roughness values

Adopted Manning's 'n' Roughness	Ground Type
0.016	Road
0.200	Urban Residential
0.030	Maintained Sports field
0.080	Large Urban Resident
0.040	Parkland/ Easement
0.500	Commercial/ Carpark/ Industry
0.010	Forested/ High density vegetation
0.050	Creek
0.040	Mainstream
0.010	Pond

4.2.5.6 1D hydraulic infrastructure

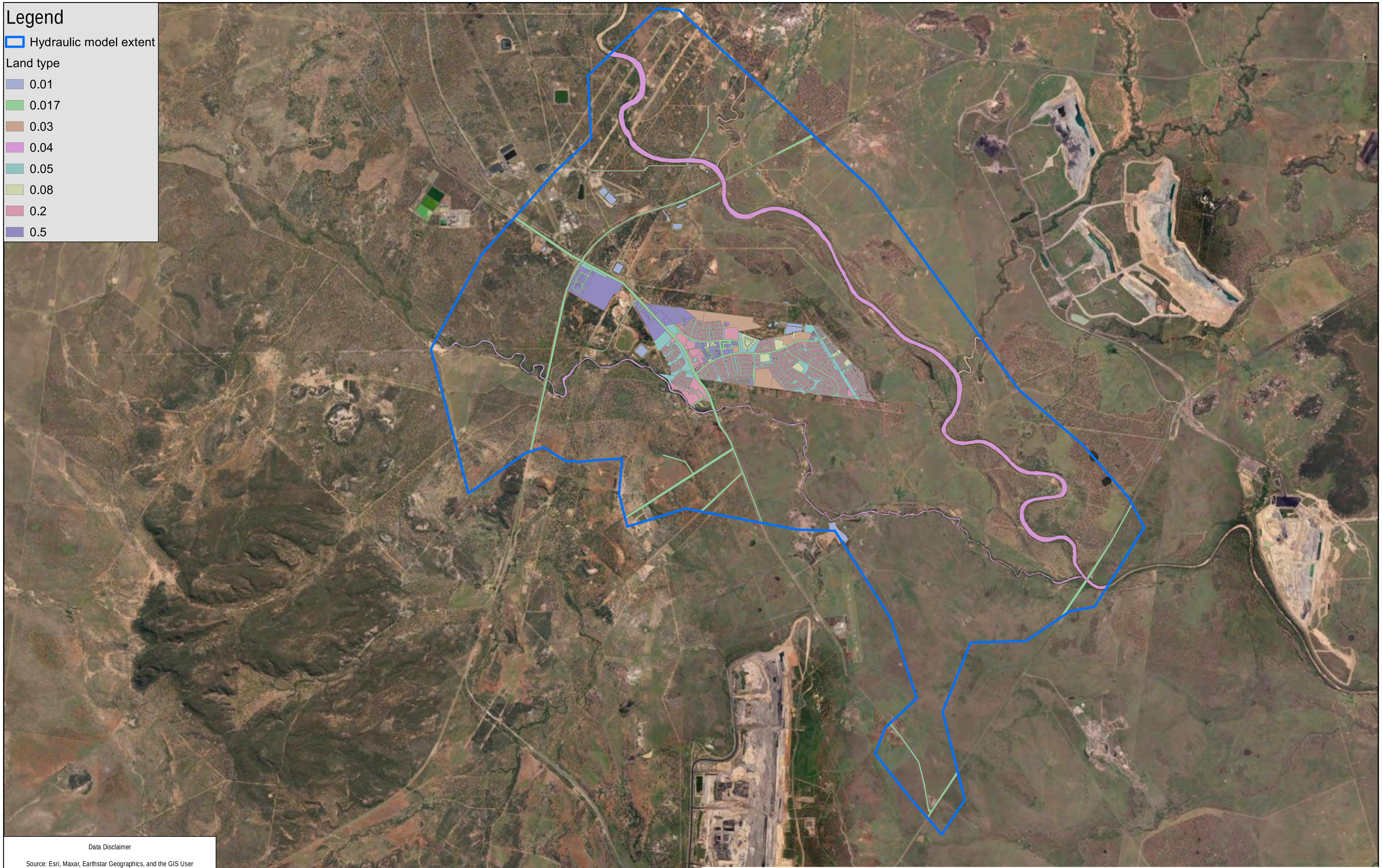
A significant number of 1D hydraulic structures were represented in the hydraulic model. The spatial location details for these structures were provided by IRC. Structures less than or equal to 300 mm diameter pipe, or equivalent box culvert were excluded from the hydraulic model simulations as these were deemed too small to influence design flood events considered in this study. Hydraulic structures were represented in the hydraulic model as 1D elements linked to the 2D terrain.

4.2.5.6.1 General

During a review of the asset details provided by IRC covering the hydraulic structures considered in this assessment, it was found that a number of details were missing from the database provided. The missing data included:

– The addition of pits that were visible in the aerial imagery but did not appear in the asset information provided.
– Some pipes appeared to be missing from the data, meaning connectivity issues in the hydraulic model.
– Some cross drainage infrastructure appeared to be missing from the data, meaning that there would be a disconnection of flow paths in the hydraulic model.
– Pit and pipe invert levels, pipe sizes and configuration.

Drainage infrastructure included in the hydraulic model are presented in Figure 16.



Data Disclaimer

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 310 620 930 1,240

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Issac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

TUFLOW Hydraulic Roughness
Whole Extent

Project No. 12593558
Revision No. A
Date 05 Oct 2023

Figure 14

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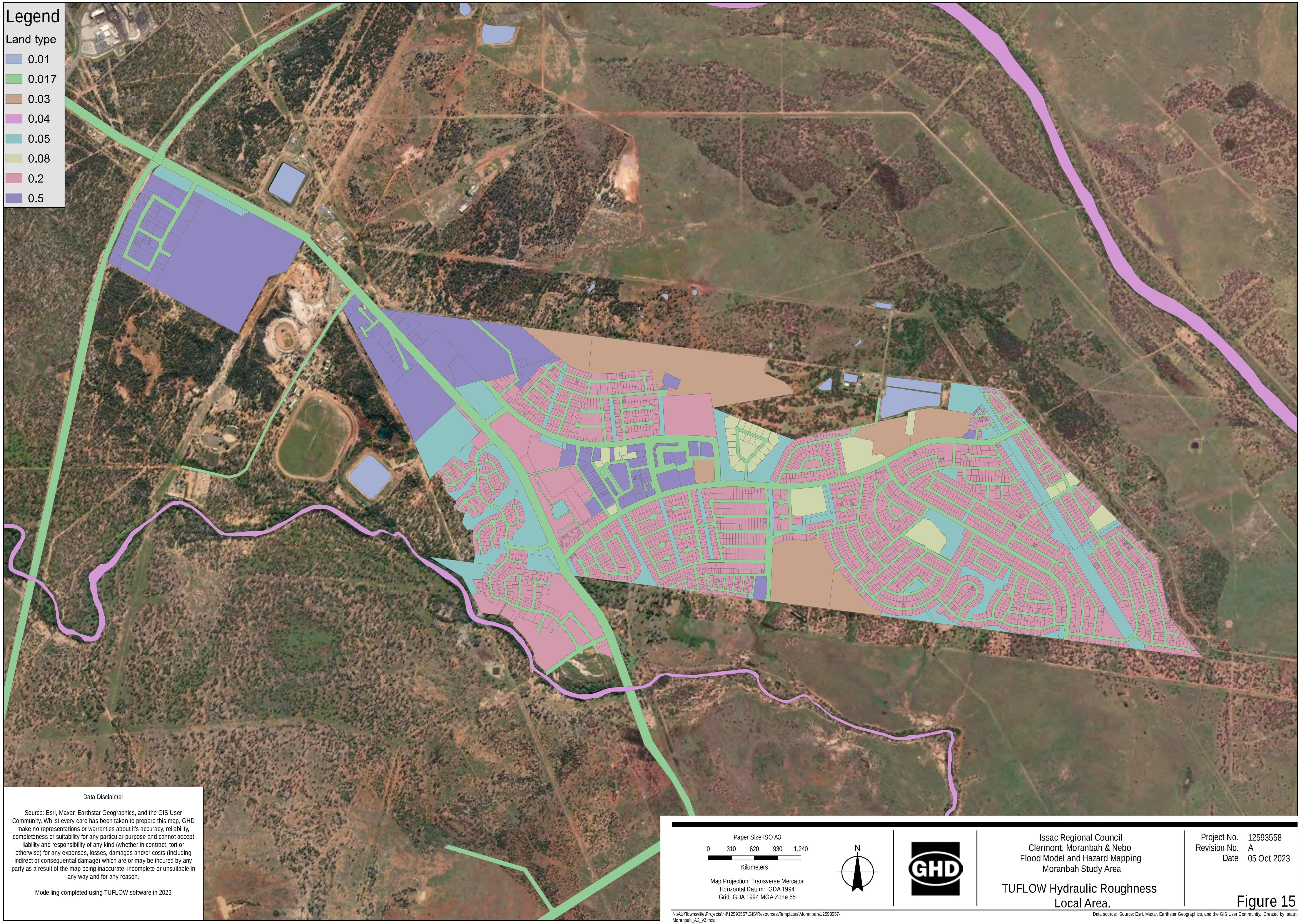
Print date: 05 Oct 2023 - 15:03 (SMA record: 9)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 310 620 930 1,240

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Issac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

TUFLOW Hydraulic Roughness Local Area.

Project No. 12593558
Revision No. A
Date 05 Oct 2023

Figure 15

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Print date: 05 Oct 2023 - 15:07 (SMA record: 11)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut

4.2.5.6.2 Pits

TUFLOW required the following information for modelling pits within the hydraulic model: pit type, size, invert levels and inlet capture capacity. The following assumptions were adopted for pit parameters.

- Council asset data were specified to be either kerb inlet including a grate (KG) or field inlet (FI) type pits. It was assumed these were 2,400 mm wide and 900 mm x 900 mm square, respectively. This sizing was adopted for simplicity, to allow for uniform depth vs. inflow curves and considering more detailed information on pit sizing was not available for the project.
- On-grade approach vs capture curves were translated into depth vs inflow curves based on the FNQROC capture curves. This included following the procedure recommended by TUFLOW (BMT Group, 2020) whereby the approach flows are used to back calculate flow depths approaching the pit. The FNQROC curves were then used to translate this depth to a capture flow for the pit.
- TUFLOW identified some pits were below the DEM level, having the undesired impact of artificially restricting inflow. This further raised concerns that if pits were above the DEM and potentially also restricting inflow. As such, all pits were adopted to have a pit top level at the DEM level (automatically generated using the TUFLOW ‘SX’ linking approach with the ‘Z’ flag option).
- Where stormwater infrastructure was misaligned to flow paths and sags (identified in the DEM), and where appropriate, stormwater infrastructure was moved spatially to align with the DEM identified flow paths and sags.

4.2.5.6.3 Pipes network

The primary inputs required for the TUFLOW pipe network include:

– Type
– Number of parallel elements
– Size
– Length
– Invert levels
– Material roughness
– Blockage percentage

IRC asset data was applied to the model where possible and practical for the model. However, much of the data (specifically with regards to invert levels) was not provided. In this case, data was populated using the following procedure:

– The system outlet elevation were determined using the DEM.
– This elevation was used to inform the downstream invert level, minimum slope as detailed in QUDM for a given pipe diameter were used to calculate the upstream invert level.
– Checks were completed to ensure that minimum cover was also achieved.
– The process was repeated to the top of the stormwater network.

1471 pipes and culvert elements were modelled in TUFLOW as 1D structures Where diameter and number of parallel elements data was missing, adjacent pipe sizes (i.e. upstream and downstream) were used to fill the data gap.

4.2.5.6.4 Culverts

Culverts were modelled in TUFLOW as 1D objects with inputs such the following required:

– Type
– Size
– Invert levels
– Number of parallel elements
– Material roughness

– Blockage

Where details for the above-mentioned attributes were missing, the following steps were undertaken to inform assumptions:

– Channel depth approaching and downstream of the structure was reviewed in the DEM and, together with minimum cover assumed, a structure height was assumed.
– Channel width approaching and downstream of the structure was reviewed in the DEM and, considering wall thickness and contraction around the culvert opening, a structure width assumed.
– Invert levels assumed based on DEM levels approaching and downstream of the structure.
– Google Streetview was reviewed where available to confirm or further inform assumptions.

Blockage for all cross-drainage structures was assessed as described in Section 4.2.5.6.5.

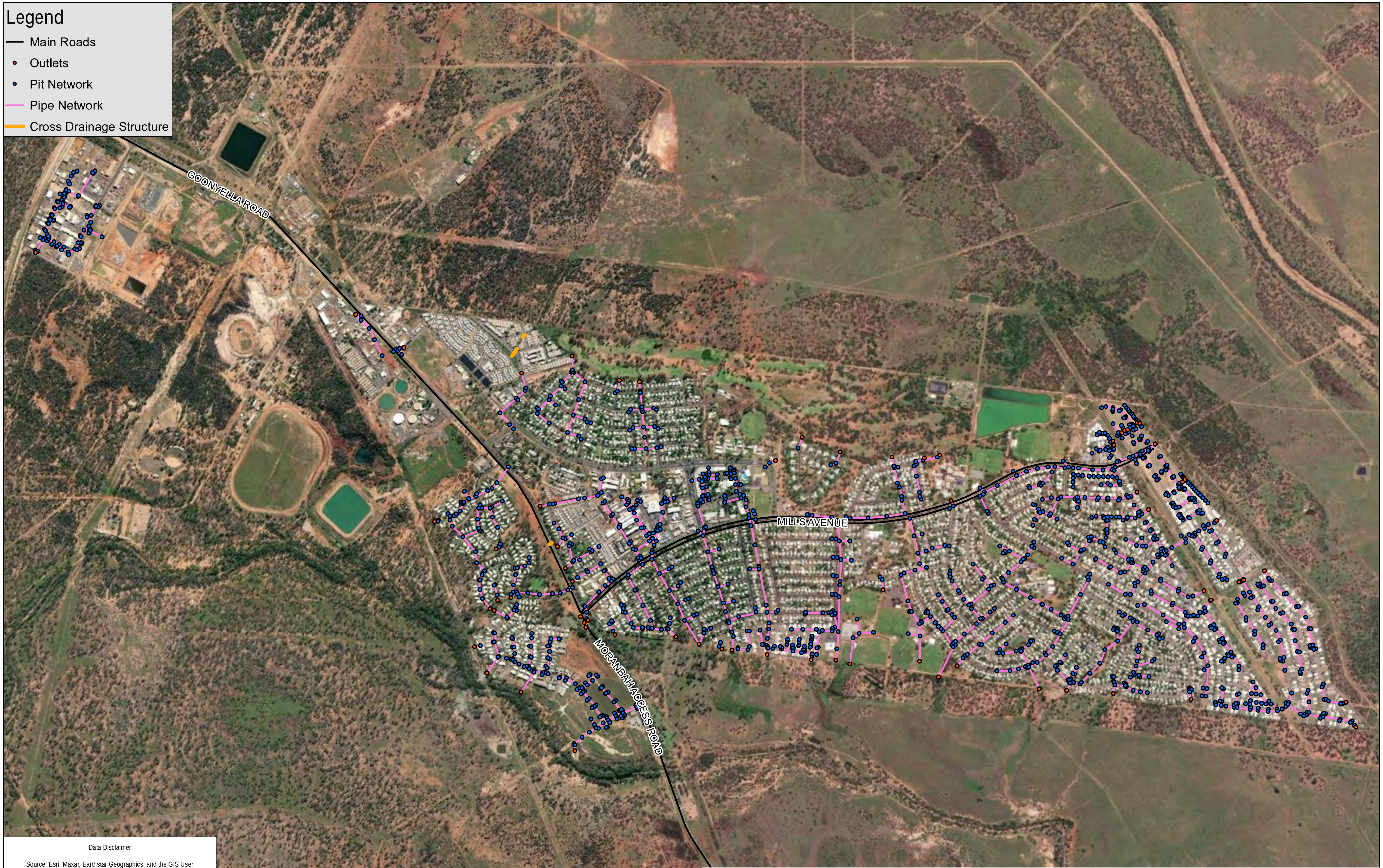
4.2.5.6.5 Blockage factors

The ARR (2019) guidelines were used to calculate the TUFLOW blockage factors for the 1D network cross drainage structures culverts. The blockage calculation described in ARR (2019) makes use of a range of criteria to assess the potential for floating and sediment-based blockage at a given site.

4.2.5.6.6 Bridge structures

Eight bridges within the model extent were identified and were represented as a 2D Layered Flow Constriction (LFC) within the TUFLOW model. Layered flow constrictions work by separating the cross section of a structure into four layers:

– **Layer 1:** Beneath the bridge deck, blockage for this first layer is assigned to account for the proportion of the cross-sectional area that is blocked by the piers and abutments, this layer also has a small form loss coefficient to account for the energy losses associated with these piers.
– **Layer 2:** The bridge deck, this layer is 100% blocked with a larger loss coefficient to account for the additional energy losses associated with the flow surcharging the deck.
– **Layer 3**: The bridge rails, this layer has conservatively been set to be 100% blocked as it is likely that events resulting in flood levels as high as the railings are also likely to have displaced a large amount of material, resulting in a blockage of the railing.
– **Layer 4:** Flow over the top of the rails – flow is assumed to be unobstructed.



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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 310 620 930 1,240

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Issac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

Existing Drainage Infrastructure

Project No. 12593558
Revision No. A
Date 05 Oct 2023

Figure 16

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Print date: 05 Oct 2023 - 15:01 (SMA record: 8)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut

4.3 Model results

4.3.1 Flood inundation mapping

As per the agreed scope for the project, 50%, 20%, 5%, 2%, 1% (including current climate, 2050 and 2100 future climate), 0.2% AEP and PMF events were simulated and the results from these simulations were mapped (see Appendix E).

Using these simulated results, the following observations were made in Section 4.3.2.

4.3.1.1 Post-processing approach

The raw simulated flood model results have been processed to remove areas of shallow, slow flowing and isolated pockets of water in urban areas that would otherwise show as flooded if the raw results were presented. This process is aligned to guidance from ARR 2019 Project 15 (Engineers Australia, 2012).

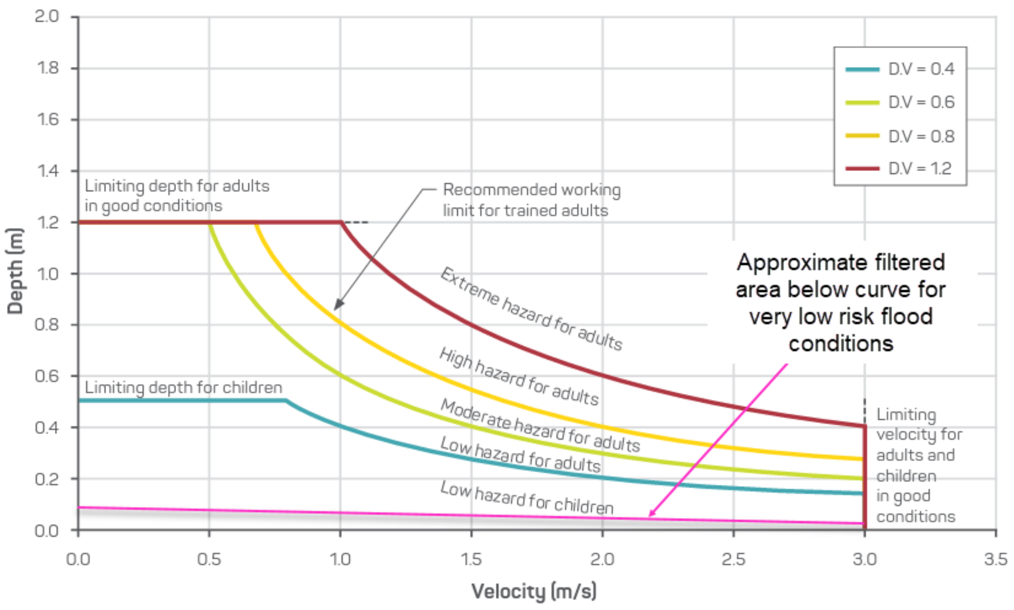
A minimum depth filter is commonly used to view results in urban areas, where areas of very shallow depth are removed from the results to leave only areas of flooding. Depth filtering alone is common practice but can underrepresent certain areas of flooding where flows are shallow with a high velocity and subsequently present a hazard to those that encounter them. For this reason, depth and velocity product can be used along with depth filtering to ensure integrity in the flood results reported.

Further to this, small depressions in the DEM where concentrated flow paths occur can lead to areas of ponding of surface water. In the majority of cases where these ponded areas are shallow, these will not be considered a flood hazard. To remove these areas where the depth of ponding may be above the filtered depth, a minimum area filter has been applied to the results.

As there are multiple conditions being applied to the processing of results, a number of different combinations were tested to represent flood conditions through the study area. The combination was aimed to sufficiently maintain flow path connectivity, while removing areas of very low risk flooding. The criteria adopted for the post-processing filters are:

– Minimum depth cut-off: 100 mm.
– Minimum velocity x depth product cut-off: 0.05 m^2/s.
– Minimum flooded area filtering: 1600 m^2.

Post-processing of results generally follows the pink highlighted line in Figure 17.



D.V = depth × velocity

Source: Modelled after Cox et al. (2010)

Figure 17 ***Post-processing filtering conditions (AIDR, 2017)***

Examples of the post-processing filtering using the chosen parameters are shown in Figure 18 These show the difference in flood extent at a particular location in the model with filtering applied (1% AEP event), and without (1% AEP event), to demonstrate what is considered 'model noise' and has, therefore, been filtered from the results presented as part of the study. For smaller events, the unfiltered flood extent will be less than what is shown on Figure 18, and as the velocity, depth and extent will decrease with event frequency, the filtered extent will likely be less than shown on Figure 18.

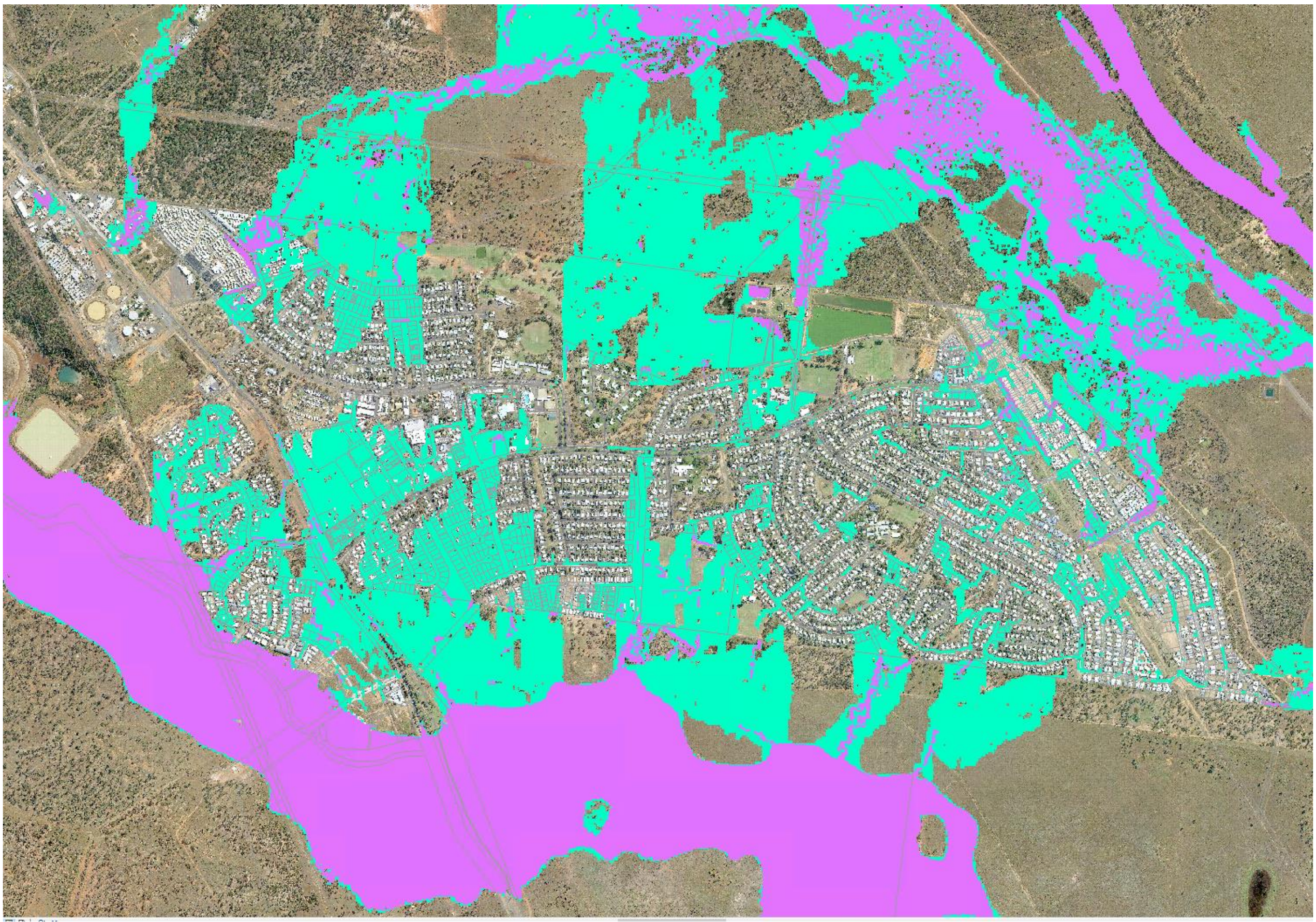


Figure 18 Post-processing flood results example (cyan – raw results, purple – post-processed results) (1% AEP event)

4.3.2 Discussion of flood behaviour

The general flood behaviour across the study area as observed from the model simulations is characterized in Table 14Table for the various AEP events assessed in this study. Peak flood depths, velocity, and hazard category maps for all the storm events are provided in Appendix E.

Table 14 Discussion of flood behaviour observations from the hydraulic model results

Flood Event (AEP)	Flood Behaviour
50%	– There is overland flow (up to 0.3 m) simulated through the Civeo Moranbah Village area (GHD notes that no stormwater drainage infrastructure details were provided for this area and therefore no underground conveyance systems have been modelled). – The industrial precinct north of Industrial Avenue off Goonyella Road is showing inundation simulated up to 0.6 m. – Sag point in Cavanagh Road in industrial precinct north-west of the town showing inundation simulated up to 0.6 m. – Ponding in a sag point between buildings at the Black Nugget Hotel, simulated up to 0.4 m.

Flood Event (AEP)	Flood Behaviour
	– Simulated flood extents around Utah Drive confined to roads and drainage corridors. – Moranbah Access Road, Grosvenor Creek crossing, inundation of the roadway simulated due to break-out flows on the southern branch of Grosvenor Creek up to 0.5 m. – At the Moranbah Access Road and Peak Downs Highway intersection, the Moranbah Access Road is not simulated to be inundated by flood water. – Velocity values simulated in any inundation extents in urban areas were generally < 0.5 m/s with some isolated locations where velocities are > 0.5 m/s.
20%	– There is overland flow (up to 0.4 m) simulated through the Civeo Moranbah Village area (GHD notes that no stormwater drainage infrastructure details were provided for this area and therefore no underground conveyance systems have been modelled). – The industrial precinct north of Industrial Avenue off Goonyella Road is showing inundation simulated up to 0.7 m. – Sag point in Cavanagh Road in industrial precinct north-west of the town showing inundation simulated up to 0.7 m. – Ponding in a sag point between buildings at the Black Nugget Hotel, simulated up to 0.4 m. – Simulated flood extents around Utah Drive confined to roads and drainage corridors, up to 0.5 m simulated depth in some sag locations. – Moranbah Access Road, Grosvenor Creek crossing, inundation of the roadway simulated due to break-out flows on the southern branch of Grosvenor Creek up to 1.4 m. – At the Moranbah Access Road and Peak Downs Highway intersection, Moranbah Access Road is not simulated to be inundated by flood water. – Velocity simulated in any inundation extents in urban areas generally < 0.5 m/s with some isolated locations where velocities are > 0.5 m/s.
5%	– There is overland flow (up to 0.4 m) simulated through the Civeo Moranbah Village area (GHD notes that no stormwater drainage infrastructure details were provided for this area and therefore no underground conveyance systems have been modelled). – The industrial precinct north of Industrial Avenue off Goonyella Road is showing inundation simulated up to 0.7 m. – Sag point in Cavanagh Road in industrial precinct north-west of the town showing inundation simulated up to 0.8 m. – Ponding in a sag point between buildings at the Black Nugget Hotel, simulated up to 0.4 m. – Simulated flood extents around Utah Drive confined to roads and drainage corridors, up to 0.5 m simulated depth in some sag locations. – Moranbah Access Road, Grosvenor Creek crossing, inundation of the roadway simulated due to break-out flows on the southern branch of Grosvenor Creek up to 1.6 m. – At the Moranbah Access Road and Peak Downs Highway intersection, Moranbah Access Road is not simulated to be inundated by flood water. – Velocity simulated in any inundation extents in urban areas generally < 0.5 m/s with increasing localised areas where velocities are > 0.5 m/s compared to the 20% AEP.
2%	– There is overland flow (up to 0.4 m) simulated through the Civeo Moranbah Village area (GHD notes that no stormwater drainage infrastructure details were provided for this area and therefore no underground conveyance systems have been modelled).

Flood Event (AEP)	Flood Behaviour
	– The industrial precinct north of Industrial Avenue off Goonyella Road is showing inundation simulated up to 0.7 m. – Sag point in Cavanagh Road in industrial precinct north-west of the town showing inundation simulated up to 0.9 m. – Ponding in a sag point between buildings at the Black Nugget Hotel, simulated up to 0.4 m. – Simulated flood extents around Utah Drive confined to roads and drainage corridors, up to 0.6 m simulated depth in some sag locations. – Moranbah Access Road, Grosvenor Creek crossing, inundation of the roadway simulated due to break-out flows on the southern branch of Grosvenor Creek up to 1.9 m. – At the Moranbah Access Road and Peak Downs Highway intersection, Moranbah Access Road is not simulated to be inundated by flood water. – Velocity simulated in any inundation extents in urban areas generally < 0.5 m/s with increasing localised areas where velocities are > 0.5 m/s compared to the 5% AEP.
1%	– There is overland flow (up to 0.4 m) simulated through the Civeo Moranbah Village area (GHD notes that no stormwater drainage infrastructure details were provided for this area and therefore no underground conveyance systems have been modelled). – The industrial precinct north of Industrial Avenue off Goonyella Road is showing inundation simulated up to 0.7 m. – Sag point in Cavanagh Road in industrial precinct north-west of the town showing inundation simulated up to 0.9 m. – Ponding in a sag point between buildings at the Black Nugget Hotel, simulated up to 0.4 m. – Simulated flood extents around Utah Drive confined to roads and drainage corridors, up to 0.6 m simulated depth in some sag locations. – Moranbah Access Road, Grosvenor Creek crossing, inundation of the roadway simulated due to break-out flows on the southern branch of Grosvenor Creek up to 1.9 m. – At the Moranbah Access Road and Peak Downs Highway intersection, Moranbah Access Road is not simulated to be inundated by flood water. – Velocity simulated in any inundation extents in urban areas generally < 0.5 m/s with increasing localised areas where velocities are > 0.5 m/s compared to the 2% AEP.
1% plus Climate Change 2050	– There is overland flow (up to 0.5 m) simulated through the Civeo Moranbah Village area (GHD notes that no stormwater drainage infrastructure details were provided for this area and therefore no underground conveyance systems have been modelled). – The industrial precinct north of Industrial Avenue off Goonyella Road is showing inundation simulated up to 0.7 m. – Sag point in Cavanagh Road in industrial precinct north-west of the town showing inundation simulated up to 0.9 m. – Ponding in a sag point between buildings at the Black Nugget Hotel, simulated up to 0.4 m. – Simulated flood extents around Utah Drive confined to roads and drainage corridors, up to 0.6 m simulated depth in some sag locations, this sag location is now spilling into the adjacent drainage reserve. – Moranbah Access Road, Grosvenor Creek crossing, inundation of the roadway simulated due to break-out flows on the southern branch of Grosvenor Creek up to 2.0 m.

Flood Event (AEP)	Flood Behaviour
	– At the Moranbah Access Road and Peak Downs Highway intersection, Moranbah Access Road is not simulated to be inundated by flood water. – Velocity simulated in any inundation extents in urban areas generally < 0.5 m/s with increasing localised areas where velocities are > 0.5 m/s compared to the 1% AEP current climate event.
1% plus Climate Change 2100	– There is overland flow (up to 0.5 m) simulated through the Civeo Moranbah Village area (GHD notes that no stormwater drainage infrastructure details were provided for this area and therefore no underground conveyance systems have been modelled). – The industrial precinct north of Industrial Avenue off Goonyella Road is showing inundation simulated up to 0.7 m. – Sag point in Cavanagh Road in industrial precinct north-west of the town showing inundation simulated up to 1.0 m. – Ponding in a sag point between buildings at the Black Nugget Hotel, simulated up to 0.4 m. – Simulated flood extents around Utah Drive confined to roads and drainage corridors, up to 0.6 m simulated depth in some sag locations, this sag location is now spilling into the adjacent drainage reserve. – Moranbah Access Road, Grosvenor Creek crossing, inundation of the roadway simulated due to break-out flows on the southern branch of Grosvenor Creek up to 2.2 m. – At the Moranbah Access Road and Peak Downs Highway intersection, Moranbah Access Road is not simulated to be inundated by flood water. – Velocity simulated in any inundation extents in urban areas generally < 0.5 m/s with increasing localised areas where velocities are > 0.5 m/s compared to the 1% AEP plus climate change 2050 event.
0.2%	– There is overland flow (up to 0.5 m) simulated through the Civeo Moranbah Village area (GHD notes that no stormwater drainage infrastructure details were provided for this area and therefore no underground conveyance systems have been modelled). – The industrial precinct north of Industrial Avenue off Goonyella Road is showing inundation simulated up to 0.7 m. – Sag point in Cavanagh Road in industrial precinct north-west of the town showing inundation simulated up to 1.0 m. – Ponding in a sag point between buildings at the Black Nugget Hotel, simulated up to 0.4 m. – Simulated flood extents around Utah Drive confined to roads and drainage corridors, up to 0.7 m simulated depth in some sag locations, this sag location is now spilling into the adjacent drainage reserve. – Moranbah Access Road, Grosvenor Creek crossing, inundation of the roadway simulated due to break-out flows on the southern branch of Grosvenor Creek up to 2.2 m. – At the Moranbah Access Road and Peak Downs Highway intersection, Moranbah Access Road is not simulated to be inundated by flood water. – Velocity simulated in any inundation extents in urban areas generally > 0.5 m/s with increasing localised areas where velocities are > 1.0 m/s compared to the 1% AEP plus climate change 2100 event.
PMF	– There is overland flow (up to 0.8 m) simulated through the Civeo Moranbah Village area (GHD notes that no stormwater drainage infrastructure details were provided for this area and therefore no underground conveyance systems have been modelled).

Flood Event (AEP)	Flood Behaviour
	– The industrial precinct north of Industrial Avenue off Goonyella Road is showing inundation simulated up to 1.2 m. – Sag point in Cavanagh Road in industrial precinct north-west of the town showing inundation simulated up to 1.2 m. – Ponding in a sag point between buildings at the Black Nugget Hotel, simulated up to 0.5 m though extent of flooding simulated to be fairly widespread. – Simulated flood extents around Utah Drive confined to roads and drainage corridors, up to 1.0 m simulated depth in some sag locations, this sag location is now spilling into the adjacent drainage reserve. – Numerous other roadways inundated through the town and flows simulated to spill beyond the roadway into private property. – Moranbah Access Road, Grosvenor Creek crossing, inundation of the roadway simulated up to 3.0 m. – At the Moranbah Access Road and Peak Downs Highway intersection, Moranbah Access Road is simulated to be inundated by flood water by more than 0.3 m. – Velocity simulated in inundation extents in urban areas generally > 1.0 m/s with increasing localised areas where velocities are > 1.5 m/s.

4.4 Model validation

The hydrology inputs for the Isaac River were developed based on the FFA completed from recorded stream flow measurements, these results were compared to the previous regional Isaac River catchment wide modelling of the area (KBR, 2021), as described in Section 3.3.2. The Grosvenor Creek catchment inputs were developed based on the RAFTS rainfall-runoff routing model. The modelled peak flows were compared to the RFFE tool peak flow estimates to provide a validation of the RAFTS model parameters. These model parameters were applied to a local catchment area RAFTS model for Moranbah. These approaches were used to inform the TUFLOW hydraulic model. As detailed calibration information was not made available for the hydraulic model, reasonableness checks were undertaken to confirm that the model was providing outputs consistent with the inputs and the surrounding hydraulic conditions.

Also, the hydraulic model results were compared to the flood mapping provided as part of the regional Isaac River catchment (KBR, 2021). The maps presented in that study (KBR, 2021) only show flood extents for the main Isaac River, and Grosvenor Creek and no detailed results are shown for the Moranbah town area. For the previous study undertaken by Cardno (Cardno, 2018) covering Grosvenor Creek, results have been compared to this study also. Where a comparison of the flood extent could be undertaken the following was noted:

– The 1% AEP event shows generally the same flood extent through Grosvenor Creek, though generally this study is lower by around 50-100 mm compared to both the previous studies. This is likely attributed to different versions of TUFLOW used for the simulation and the solver (TUFLOW Classic versus TUFLOW HPC) used for the Cardno study versus this study.
– The 1% AEP event shows generally the same flood extent through the Isaac River, different approaches to hydrologic flow estimation and application mean flood levels are different between the studies.

4.5 Sensitivity assessment

Sensitivity testing was conducted for the Manning’s ‘n’ parameter where the hydraulic roughness was adjusted by 10% (higher and lower). The +/- 10% value represents bands of Manning’s n value that fall within industry accepted-values. The results were compared against the adopted Manning’s n and a histogram chart of water level difference within the model domain is presented in Figure 19 and Figure 20. These plots show that majority of the differences in results are in the -15 and +15 mm band for both the increased and decreased Manning’s ‘n’ value scenarios. As such, it is considered that the model is generally insensitive to changes in roughness within study area. Some significant differences in flood extent were observed particularly along Grosvenor Creek and the Isaac River sections within the model, though these areas are beyond the main study area (Moranbah) covered by this report and any uncertainty in the Manning's values applied for these watercourses are not showing to have an impact on the results within the main study area (Moranbah). On this basis, the values adopted according to the industry standard range are considered appropriate for this study.

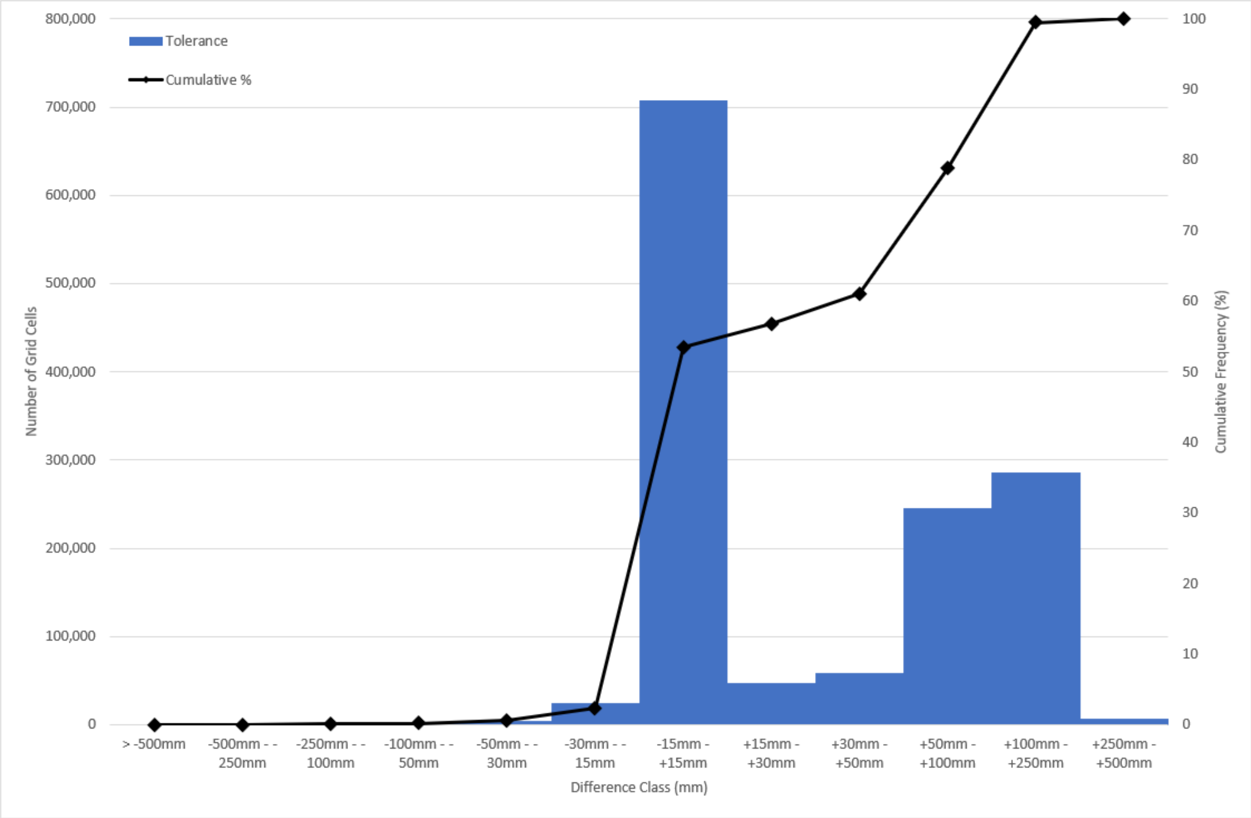


Figure 19 ***Water level difference histogram considering adopted Manning's n and 10% increased Manning's n***

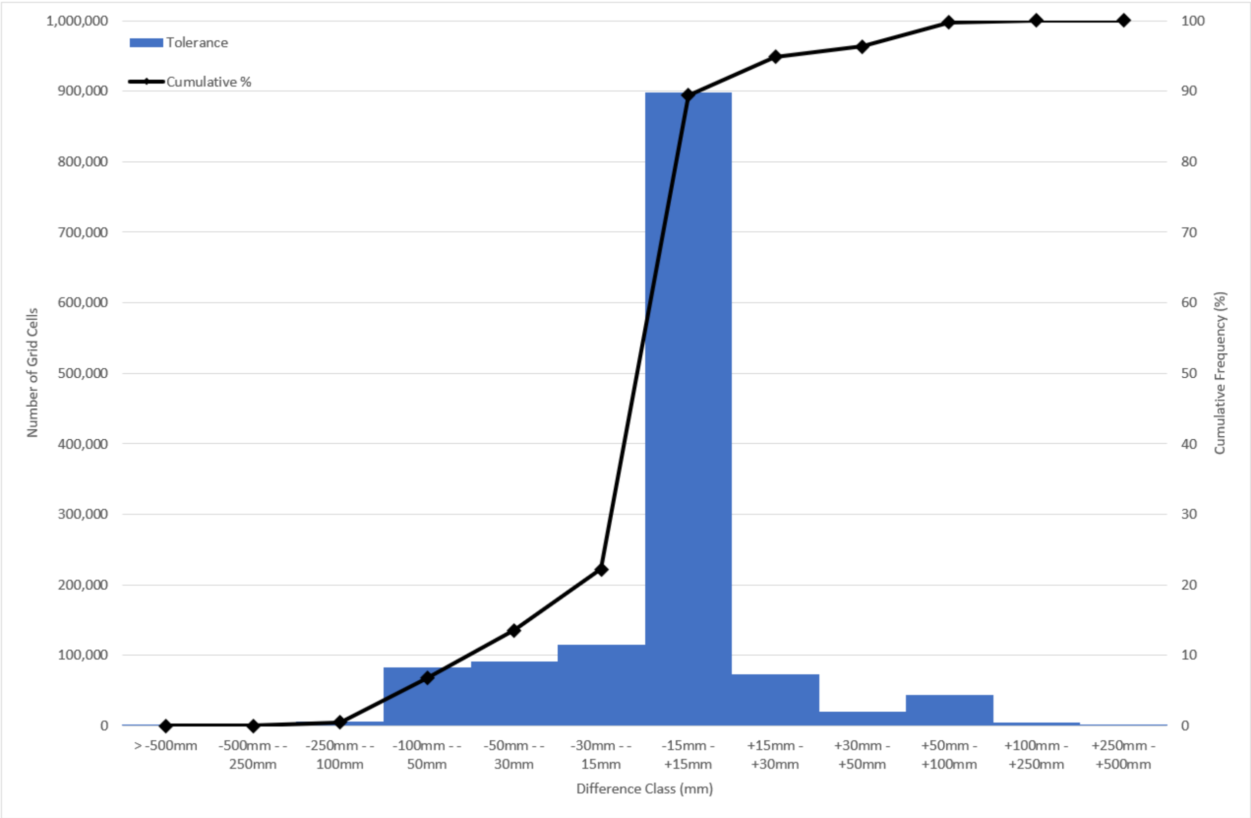


Figure 20 ***Water level difference histogram considering adopted Manning's n and 10% decreased Manning's n***

5. Summary

GHD was engaged by IRC to undertake the flood modelling and hazard mapping for the town of Moranbah and extending to the Moranbah Access Road intersection with the Peak Downs Highway. This report documents the analyses undertaken, which involved:

- Review of available data and historic flood information.
- Hydrologic and hydraulic modelling of developed flood conditions for a range of AEP events as per Council land use zones.
- Development of flood maps for each of the design events.

To develop an understanding of existing flooding and drainage issues, detailed hydrologic and hydraulic modelling and flood inundation mapping of the Moranbah catchment has been undertaken in accordance with the best practice approaches. Flood maps are provided in Appendix E.

Table 15 Discussion of flood behaviour observations from the hydraulic model results

Flood Event (AEP)	Flood Behaviour
50%	– There is overland flow (up to 0.3 m) simulated through the Civeo Moranbah Village area (GHD notes that no stormwater drainage infrastructure details were provided for this area and therefore no underground conveyance systems have been modelled). – The industrial precinct north of Industrial Avenue off Goonyella Road is showing inundation simulated up to 0.6 m. – Sag point in Cavanagh Road in industrial precinct north-west of the town showing inundation simulated up to 0.6 m. – Ponding in a sag point between buildings at the Black Nugget Hotel, simulated up to 0.4 m. – Simulated flood extents around Utah Drive confined to roads and drainage corridors. – Moranbah Access Road, Grosvenor Creek crossing, inundation of the roadway simulated due to break-out flows on the southern branch of Grosvenor Creek up to 0.5 m. – At the Moranbah Access Road and Peak Downs Highway intersection, the Moranbah Access Road is not simulated to be inundated by flood water. – Velocity values simulated in any inundation extents in urban areas were generally < 0.5 m/s with some isolated locations where velocities are > 0.5 m/s.
20%	– There is overland flow (up to 0.4 m) simulated through the Civeo Moranbah Village area (GHD notes that no stormwater drainage infrastructure details were provided for this area and therefore no underground conveyance systems have been modelled). – The industrial precinct north of Industrial Avenue off Goonyella Road is showing inundation simulated up to 0.7 m. – Sag point in Cavanagh Road in industrial precinct north-west of the town showing inundation simulated up to 0.7 m. – Ponding in a sag point between buildings at the Black Nugget Hotel, simulated up to 0.4 m. – Simulated flood extents around Utah Drive confined to roads and drainage corridors, up to 0.5 m simulated depth in some sag locations. – Moranbah Access Road, Grosvenor Creek crossing, inundation of the roadway simulated due to break-out flows on the southern branch of Grosvenor Creek up to 1.4 m. – At the Moranbah Access Road and Peak Downs Highway intersection, Moranbah Access Road is not simulated to be inundated by flood water.

Flood Event (AEP)	Flood Behaviour
	– Velocity simulated in any inundation extents in urban areas generally < 0.5 m/s with some isolated locations where velocities are > 0.5 m/s.
5%	– There is overland flow (up to 0.4 m) simulated through the Civeo Moranbah Village area (GHD notes that no stormwater drainage infrastructure details were provided for this area and therefore no underground conveyance systems have been modelled). – The industrial precinct north of Industrial Avenue off Goonyella Road is showing inundation simulated up to 0.7 m. – Sag point in Cavanagh Road in industrial precinct north-west of the town showing inundation simulated up to 0.8 m. – Ponding in a sag point between buildings at the Black Nugget Hotel, simulated up to 0.4 m. – Simulated flood extents around Utah Drive confined to roads and drainage corridors, up to 0.5 m simulated depth in some sag locations. – Moranbah Access Road, Grosvenor Creek crossing, inundation of the roadway simulated due to break-out flows on the southern branch of Grosvenor Creek up to 1.6 m. – At the Moranbah Access Road and Peak Downs Highway intersection, Moranbah Access Road is not simulated to be inundated by flood water. – Velocity simulated in any inundation extents in urban areas generally < 0.5 m/s with increasing localised areas where velocities are > 0.5 m/s compared to the 20% AEP.
2%	– There is overland flow (up to 0.4 m) simulated through the Civeo Moranbah Village area (GHD notes that no stormwater drainage infrastructure details were provided for this area and therefore no underground conveyance systems have been modelled). – The industrial precinct north of Industrial Avenue off Goonyella Road is showing inundation simulated up to 0.7 m. – Sag point in Cavanagh Road in industrial precinct north-west of the town showing inundation simulated up to 0.9 m. – Ponding in a sag point between buildings at the Black Nugget Hotel, simulated up to 0.4 m. – Simulated flood extents around Utah Drive confined to roads and drainage corridors, up to 0.6 m simulated depth in some sag locations. – Moranbah Access Road, Grosvenor Creek crossing, inundation of the roadway simulated due to break-out flows on the southern branch of Grosvenor Creek up to 1.9 m. – At the Moranbah Access Road and Peak Downs Highway intersection, Moranbah Access Road is not simulated to be inundated by flood water. – Velocity simulated in any inundation extents in urban areas generally < 0.5 m/s with increasing localised areas where velocities are > 0.5 m/s compared to the 5% AEP.
1%	– There is overland flow (up to 0.4 m) simulated through the Civeo Moranbah Village area (GHD notes that no stormwater drainage infrastructure details were provided for this area and therefore no underground conveyance systems have been modelled). – The industrial precinct north of Industrial Avenue off Goonyella Road is showing inundation simulated up to 0.7 m. – Sag point in Cavanagh Road in industrial precinct north-west of the town showing inundation simulated up to 0.9 m. – Ponding in a sag point between buildings at the Black Nugget Hotel, simulated up to 0.4 m.

Flood Event (AEP)	Flood Behaviour
	– Simulated flood extents around Utah Drive confined to roads and drainage corridors, up to 0.6 m simulated depth in some sag locations. – Moranbah Access Road, Grosvenor Creek crossing, inundation of the roadway simulated due to break-out flows on the southern branch of Grosvenor Creek up to 1.9 m. – At the Moranbah Access Road and Peak Downs Highway intersection, Moranbah Access Road is not simulated to be inundated by flood water. – Velocity simulated in any inundation extents in urban areas generally < 0.5 m/s with increasing localised areas where velocities are > 0.5 m/s compared to the 2% AEP.
1% plus Climate Change 2050	– There is overland flow (up to 0.5 m) simulated through the Civeo Moranbah Village area (GHD notes that no stormwater drainage infrastructure details were provided for this area and therefore no underground conveyance systems have been modelled). – The industrial precinct north of Industrial Avenue off Goonyella Road is showing inundation simulated up to 0.7 m. – Sag point in Cavanagh Road in industrial precinct north-west of the town showing inundation simulated up to 0.9 m. – Ponding in a sag point between buildings at the Black Nugget Hotel, simulated up to 0.4 m. – Simulated flood extents around Utah Drive confined to roads and drainage corridors, up to 0.6 m simulated depth in some sag locations, this sag location is now spilling into the adjacent drainage reserve. – Moranbah Access Road, Grosvenor Creek crossing, inundation of the roadway simulated due to break-out flows on the southern branch of Grosvenor Creek up to 2.0 m. – At the Moranbah Access Road and Peak Downs Highway intersection, Moranbah Access Road is not simulated to be inundated by flood water. – Velocity simulated in any inundation extents in urban areas generally < 0.5 m/s with increasing localised areas where velocities are > 0.5 m/s compared to the 1% AEP current climate event.
1% plus Climate Change 2100	– There is overland flow (up to 0.5 m) simulated through the Civeo Moranbah Village area (GHD notes that no stormwater drainage infrastructure details were provided for this area and therefore no underground conveyance systems have been modelled). – The industrial precinct north of Industrial Avenue off Goonyella Road is showing inundation simulated up to 0.7 m. – Sag point in Cavanagh Road in industrial precinct north-west of the town showing inundation simulated up to 1.0 m. – Ponding in a sag point between buildings at the Black Nugget Hotel, simulated up to 0.4 m. – Simulated flood extents around Utah Drive confined to roads and drainage corridors, up to 0.6 m simulated depth in some sag locations, this sag location is now spilling into the adjacent drainage reserve. – Moranbah Access Road, Grosvenor Creek crossing, inundation of the roadway simulated due to break-out flows on the southern branch of Grosvenor Creek up to 2.2 m. – At the Moranbah Access Road and Peak Downs Highway intersection, Moranbah Access Road is not simulated to be inundated by flood water. – Velocity simulated in any inundation extents in urban areas generally < 0.5 m/s with increasing localised areas where velocities are > 0.5 m/s compared to the 1% AEP plus climate change 2050 event.

Flood Event (AEP)	Flood Behaviour
0.2%	– There is overland flow (up to 0.5 m) simulated through the Civeo Moranbah Village area (GHD notes that no stormwater drainage infrastructure details were provided for this area and therefore no underground conveyance systems have been modelled). – The industrial precinct north of Industrial Avenue off Goonyella Road is showing inundation simulated up to 0.7 m. – Sag point in Cavanagh Road in industrial precinct north-west of the town showing inundation simulated up to 1.0 m. – Ponding in a sag point between buildings at the Black Nugget Hotel, simulated up to 0.4 m. – Simulated flood extents around Utah Drive confined to roads and drainage corridors, up to 0.7 m simulated depth in some sag locations, this sag location is now spilling into the adjacent drainage reserve. – Moranbah Access Road, Grosvenor Creek crossing, inundation of the roadway simulated due to break-out flows on the southern branch of Grosvenor Creek up to 2.2 m. – At the Moranbah Access Road and Peak Downs Highway intersection, Moranbah Access Road is not simulated to be inundated by flood water. – Velocity simulated in any inundation extents in urban areas generally > 0.5 m/s with increasing localised areas where velocities are > 1.0 m/s compared to the 1% AEP plus climate change 2100 event.
PMF	– There is overland flow (up to 0.8 m) simulated through the Civeo Moranbah Village area (GHD notes that no stormwater drainage infrastructure details were provided for this area and therefore no underground conveyance systems have been modelled). – The industrial precinct north of Industrial Avenue off Goonyella Road is showing inundation simulated up to 1.2 m. – Sag point in Cavanagh Road in industrial precinct north-west of the town showing inundation simulated up to 1.2 m. – Ponding in a sag point between buildings at the Black Nugget Hotel, simulated up to 0.5 m though extent of flooding simulated to be fairly widespread. – Simulated flood extents around Utah Drive confined to roads and drainage corridors, up to 1.0 m simulated depth in some sag locations, this sag location is now spilling into the adjacent drainage reserve. – Numerous other roadways inundated through the town and flows simulated to spill beyond the roadway into private property. – Moranbah Access Road, Grosvenor Creek crossing, inundation of the roadway simulated up to 3.0 m. – At the Moranbah Access Road and Peak Downs Highway intersection, Moranbah Access Road is simulated to be inundated by flood water by more than 0.3 m. – Velocity simulated in inundation extents in urban areas generally > 1.0 m/s with increasing localised areas where velocities are > 1.5 m/s.

It is a recommendation of this study that:

– The modelling be revised and if necessary updated if new LiDAR for the area is captured and/or new development is undertaken within the study area.

– A data collection and analysis process be undertaken for stormwater drainage pit and pipe systems within the Moranbah area. This data collection and analysis will allow further, more detailed stormwater and drainage analysis be undertaken to better understand the performance of these systems.

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Appendices

Appendix A

Annual maximum series (AMS)

Table A.1 AMS for the Deverill gauge (Isaac River)

Year	Peak Discharge (m^3/s)
1968	**2.7**
1969	511.3
1970	101.6
1971	187.7
1972	232.5
1973	1,260.8
1974	423.9
1975	533.2
1976	1,14.2
1977	1,702.8
1978	2,113.4
1979	178.7
1980	608.0
1981	83.4
1982	412.4
1983	1,123.9
1984	137.2
1985	142.4
1986	183.5
1987	2,638.2
1988	221.8
1989	2,137.3
1990	2,429.4
1991	110.3
1992	**0.0**
1993	752.8
1994	30.1
1995	235.8
1996	1,197.7
1997	116.0
1998	1,706.2
1999	143.9
2000	637.9
2001	67.6
2002	194.7
2003	349.7
2004	20.1
2005	307.6
2006	401.3

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Year	Peak Discharge (m^3/s)
2007	2,141.6
2008	466.0
2009	501.5
2010	1,826.9
2011	1,121.8
2012	263.0
2013	1.2
2014	205.2
2015	1,791.3
2016	1,625.0
2017	25.5
2018	30.0
2019	55.8
2020	609.6
2021	208.1
2022	353.4

Appendix B

BoM design rainfall IFDs (Frequent, Infrequent and Rare)

Table B.1 BoM Design Rainfall IFDs (Frequent and Infrequent) – Moranbah

Duration	Annual Exceedance Probability (AEP)										
	63.20%	50%	20%	10%	5%	2%	1%	1 in 100	1 in 200	1 in 500	1 in 1000	1 in 2000
1 min	2.27	2.56	3.42	4.00	4.55	5.26	5.79	5.71	6.74	8.06	9.16	10.4
2 min	3.78	4.27	5.80	6.84	7.86	9.24	10.3	9.78	11.4	13.7	15.6	17.6
3 min	5.35	6.04	8.19	9.64	11.0	12.9	14.4	13.8	16.1	19.3	22	24.8
4 min	6.85	7.72	10.4	12.2	14.0	16.3	18.1	17.5	20.6	24.6	28	31.6
5 min	8.24	9.28	12.5	14.6	16.7	19.4	21.4	20.9	24.7	29.5	33.5	37.9
10 min	13.8	15.5	20.7	24.1	27.4	31.6	34.7	34.8	41.2	49.2	55.9	63.3
15 min	17.7	19.9	26.6	30.9	35.1	40.4	44.3	44.9	53.2	63.5	72.1	81.7
20 min	20.7	23.2	31.0	36.2	41.0	47.3	52.0	52.7	62.3	74.4	84.6	95.7
25 min	23.0	25.9	34.6	40.4	45.9	53.0	58.3	58.9	69.7	83.2	94.6	107
30 min	24.9	28.0	37.6	43.9	50.0	57.8	63.7	64.1	75.8	90.5	103	116
45 min	29.1	32.7	44.2	51.8	59.3	69.0	76.4	75.9	89.5	107	122	138
1 hour	31.9	36.0	48.9	57.6	66.1	77.4	86.0	84.3	99.3	119	135	153
1.5 hour	35.8	40.5	55.5	65.8	76.0	89.7	100	96.1	113	135	154	174
2 hours	38.6	43.8	60.3	71.9	83.3	98.9	111	105	123	148	168	190
3 hours	42.6	48.4	67.4	80.8	94.2	113	127	117	139	166	188	213
4.5 hour	46.9	53.5	75.0	90.4	106	128	145	131	156	186	211	239
6 hours	50.3	57.5	81.0	97.9	115	139	159	143	170	202	230	260
9 hours	55.7	63.8	90.4	110	130	157	180	161	192	229	260	295
12 hours	60.1	68.8	97.8	119	141	171	196	177	211	252	286	324
18 hours	67.1	76.8	110	134	159	193	222	204	242	288	328	371
24 hours	72.6	83.2	119	145	172	210	241	226	267	319	362	410
30 hours	77.1	88.4	126	154	184	224	258	245	287	343	390	441
36 hours	81.0	92.9	133	162	193	236	271	262	305	364	414	469
48 hours	87.3	100	143	175	209	256	294	291	336	401	456	516
72 hours	96.2	110	159	195	232	284	327	333	382	455	515	580
96 hours	102	117	169	208	249	305	350	361	412	488	551	618
120 hours	106	123	177	218	262	320	367	379	432	508	571	639
144 hours	109	126	184	227	272	332	380	389	443	519	580	649
168 hours	111	129	189	233	280	342	390	395	449	523	582	652

Appendix C

Catchment characteristics

Table C.1 Grosvenor Creek model sub-catchments characteristics

Catchment ID	Area (ha)	Pervious Manning's value	Fraction Impervious (%)	EA Slope %
1	1004	0.04	0	0.76
2	1203	0.04	0	0.55
3	619	0.04	0	0.59
4	1017	0.04	0	0.7
5	1496	0.04	0	0.81
6	577	0.04	0	0.33
7	1592	0.04	0	0.45
8	2114	0.04	0	0.56
9	1713	0.04	0	0.21
10	1148	0.04	0	0.23
11	996	0.04	0	0.64
12	1200	0.04	0	0.77
13	2431	0.04	0	0.84
14	2009	0.04	0	0.79
15	914	0.04	5	0.71
16	1888	0.04	40	0.42
17	1419	0.04	0	0.45
18	869	0.04	0	0.35
19	2828	0.04	0	0.69
20	1006	0.04	0	1.33
21	1054	0.04	0	1.17
22	1080	0.04	0	0.7
23	2927	0.04	0	0.39
24	1467	0.04	0	0.27
25	2527	0.04	0	0.24
26	1364	0.04	0	0.29
27	1196	0.04	0	0.11
28	1010	0.04	0	0.12
29	1580	0.04	0	0.3
30	2885	0.04	0	0.3
31	1359	0.04	0	0.3
32	2054	0.04	0	0.15
33	1263	0.04	0	0.2
34	3486	0.04	0	0.23
35	1396	0.04	0	0.95
36	2720	0.04	0	0.29
37	1622	0.04	0	0.18
38	1537	0.04	0	0.27
39	1193	0.04	0	0.38
40	1986	0.04	0	0.5

Catchment ID	Area (ha)	Pervious Manning's value	Fraction Impervious (%)	EA Slope %
41	460	0.04	0	0.58
42	1537	0.04	5	0.19
44	2866	0.04	0	0.28
45	491	0.04	0	0.09
46	413	0.04	0	0.24
47	407	0.04	0	0.69
48	626	0.04	5	0.78
54	1885	0.04	0	0.38
55	515	0.04	0	0.98
56	267	0.04	50	1.15
57	227	0.04	35	0.93
58	379	0.04	40	0.58
59	533	0.04	25	0.99
60	259	0.04	10	0.89
128	1407	0.04	0	0.22

Table C.2 Moranbah model sub catchments characteristics

Catchment ID	Area (ha)	Pervious Manning's value	Fraction Impervious (%)	EA Slope %
61	9.2	65	0.04	1.33
62	36.9	50	0.04	1.6
63	5.8	50	0.04	2.04
64	1.4	65	0.04	2.55
65	27.7	65	0.04	2.35
66	6.3	45	0.04	1.08
67	8.4	50	0.04	1.17
68	5.5	90	0.04	2.02
69	11.3	30	0.04	4.26
70	1.8	65	0.04	3.7
71	2.1	65	0.04	3.3
72	3.3	65	0.04	1.72
73	0.7	65	0.04	3.99
74	10.5	65	0.04	1.73
75	3.7	5	0.04	1.95
76	21.9	5	0.04	0.94
77	2.0	65	0.04	3.03
78	5.3	70	0.04	1.88
79	3.1	70	0.04	1.7
80	4.5	60	0.04	1.75
81	21.0	65	0.04	2.17
82	22.2	65	0.04	1.74
83	29.2	60	0.04	1.85
84	6.5	60	0.04	3.19
85	4.4	60	0.04	2.37
86	2.1	45	0.04	1.69
87	2.2	50	0.04	2.11
88	5.7	50	0.04	2.11
89	9.4	55	0.04	1.71
90	4.9	25	0.04	3.3
91	9.9	20	0.04	2.17
92	17.2	45	0.04	1.59
93	5.2	65	0.04	1.37
94	4.0	65	0.04	1.88
95	18.1	65	0.04	2.37
96	2.1	70	0.04	3.15
98	1.1	65	0.04	1.35
99	1.2	5	0.04	3.61
100	0.2	50	0.04	2.67
101	0.3	0	0.04	2.24

Catchment ID	Area (ha)	Pervious Manning's value	Fraction Impervious (%)	EA Slope %
102	0.3	0	0.04	1.36
103	1.1	10	0.04	1.99
104	0.4	0	0.04	1.66
105	1.2	20	0.04	2.76
106	0.8	10	0.04	3
107	8.6	20	0.04	1.45
108	1.2	65	0.04	1.09
109	27.1	60	0.04	2.16
110	10.8	65	0.04	1.23
111	2.2	65	0.04	0.79
112	15.1	55	0.04	1.16
113	13.9	40	0.04	1.54
114	16.6	65	0.04	1.97
115	1.2	65	0.04	1.31
116	13.5	65	0.04	1.75
117	17.7	50	0.04	1.52
118	2.6	65	0.04	1.81
119	32.3	50	0.04	1.84
120	10.2	65	0.04	2.23
121	11.0	60	0.04	2.24
122	22.3	65	0.04	1.76
123	3.8	65	0.04	1.44
124	36.6	55	0.04	2.99
125	22.4	50	0.04	2.29
126	13.3	65	0.04	2.11
127	0.8	50	0.04	3.85
117	17.7	50	0.04	1.52
118	2.6	65	0.04	1.81
119	32.3	50	0.04	1.84
120	10.2	65	0.04	2.23
121	11.0	60	0.04	2.24
122	22.3	65	0.04	1.76
123	3.8	65	0.04	1.44
124	36.6	55	0.04	2.99
125	22.4	50	0.04	2.29
126	13.3	65	0.04	2.11
127	0.8	50	0.04	3.85

Appendix D

Hydraulic structures

Table D.1 Culvert structures (details)

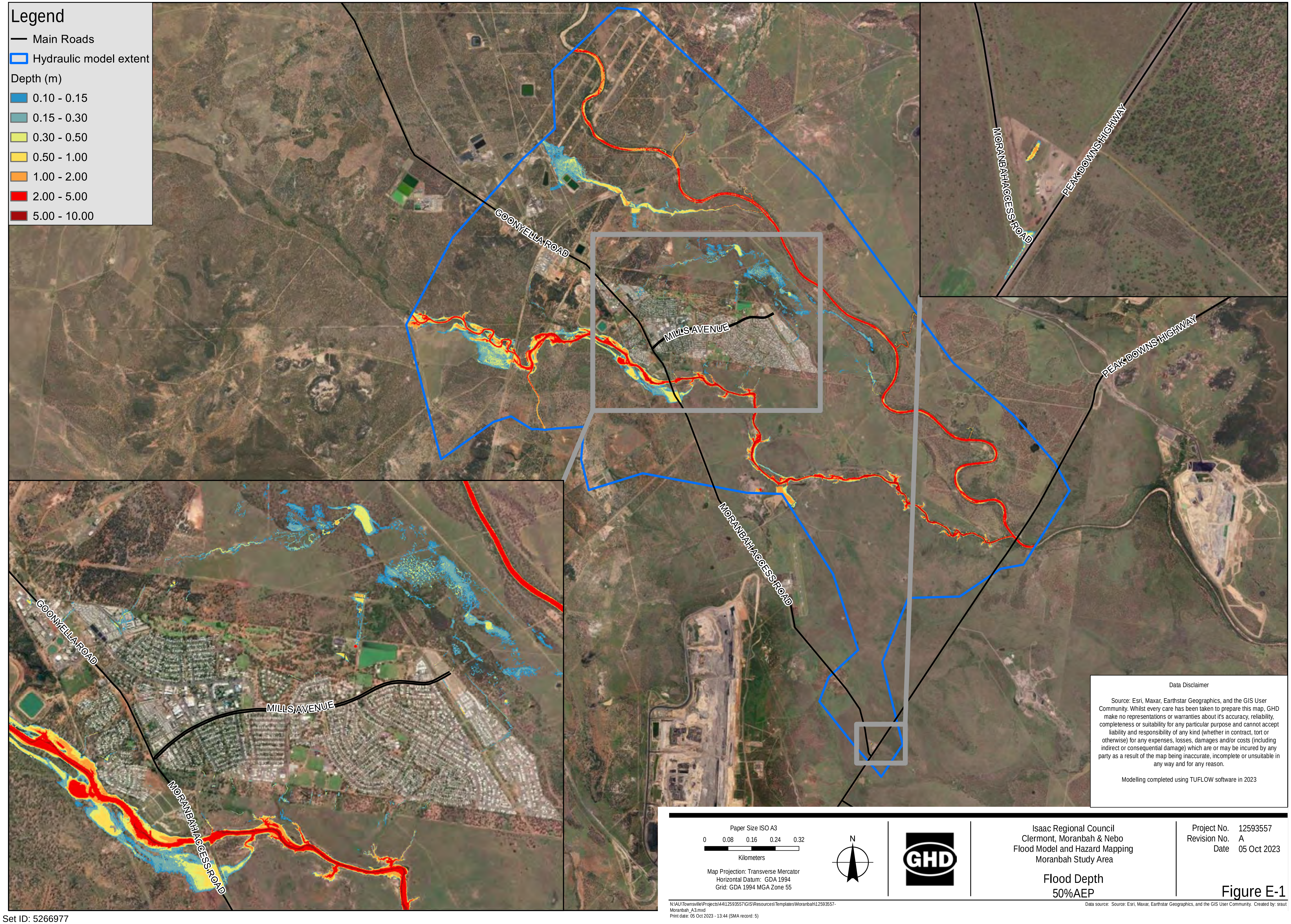
ID	Type	Length (m)	US Invert (m AHD)	DS Invert (m AHD)	Width or diameter (m)	Height (m)	Number
SP3229	RCP	22.26	250.53	250.3	0.6	0	1
ADD12	RCP	49.91	241.24	240.66	0.75	0	1
ADD13	RCBC	16.3	241.05	240.99	1.2	0.6	2
ADD14	RCBC	13.93	242.21	241.93	1.2	0.6	2
SP2421	RCP	10.85	232.5	231.92	0.75	0	1
SP2422	RCP	16.06	231.99	231.69	0.75	0	1
SP2425	RCP	12.38	230.83	230.66	0.75	0	0
SP2424	RCP	17.56	221.93	221.62	0.75	0	1
SP3367	RCP	28.4	235.54	235.21	0.95	0	1
SP1309	RCBC	26.84	223.39	221.83	1.8	0.6	2
SP3229	RCP	22.26	250.53	250.3	0.6	0	1

Table D.2 Bridge structures (details)

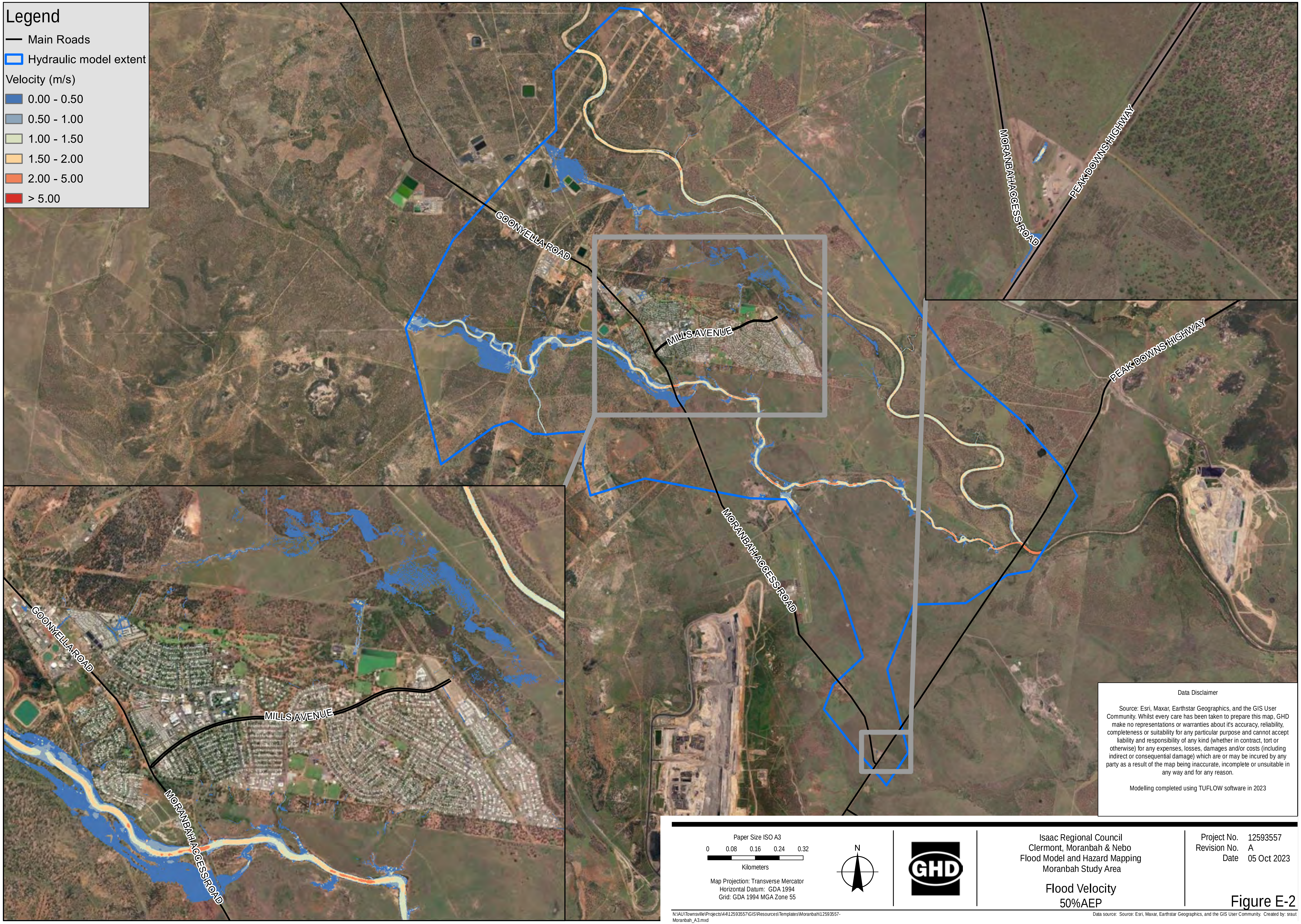
ID	Opening Width (m)	Bridge Obvert (m AHD)	Bridge Deck (m AHD)	Comment
1	18	205.6	207.1	Anabranch of the Isaac River bridge over Peak Downs Highway
2	92	218	219.5	Causeway across Isaac River
4	26	221.5	223	Rail bridge on tributary of Isaac River
5	49	224.3	225.8	Rail bridge over Grosvenor Creek
6	41	219	220.5	Bridge over Grosvenor Creek on Moranbah Access Road
7	82	223.3	224.8	Rail bridge over Isaac River
8	81	205.4	206.9	Jim Turner Bridge over Isaac River on Peak Downs Highway

Appendix E

Flood mapping



Document Set ID: 5266977
Version: 1, Version Date: 29/08/2024



Data Disclaimer

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Modelling completed using TUFLOW software in 2023

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

Flood Velocity
50%AEP

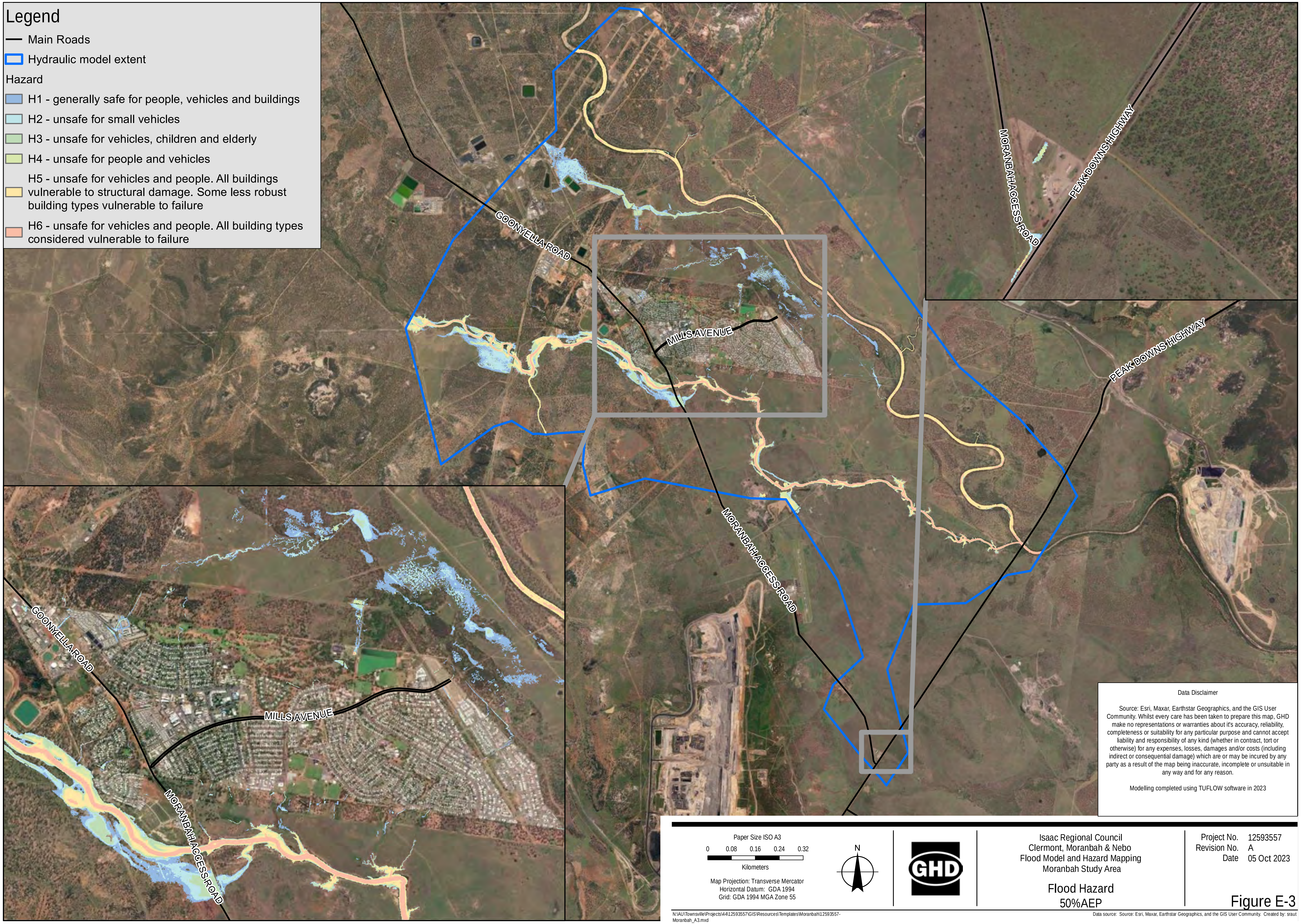
Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-2

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 14:39 (SMA record: 6)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut

Document Set ID: 5266977
Version: 1, Version Date: 29/08/2024



Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

Flood Hazard
50%AEP

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-3

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
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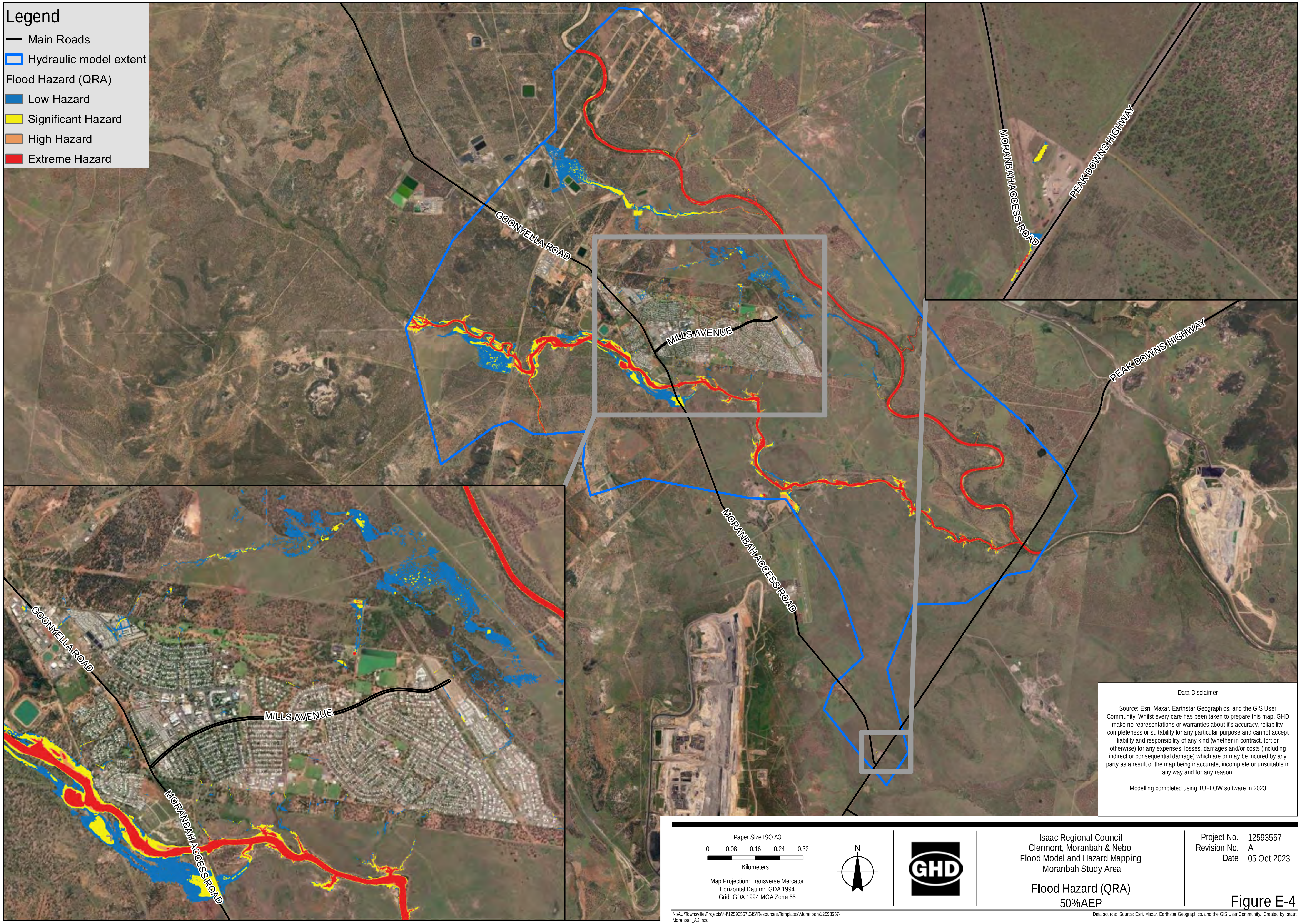
Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



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Paper Size ISO A3
0 0.08 0.16 0.24 0.32
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

Flood Hazard (QRA)
50%AEP

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-4

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
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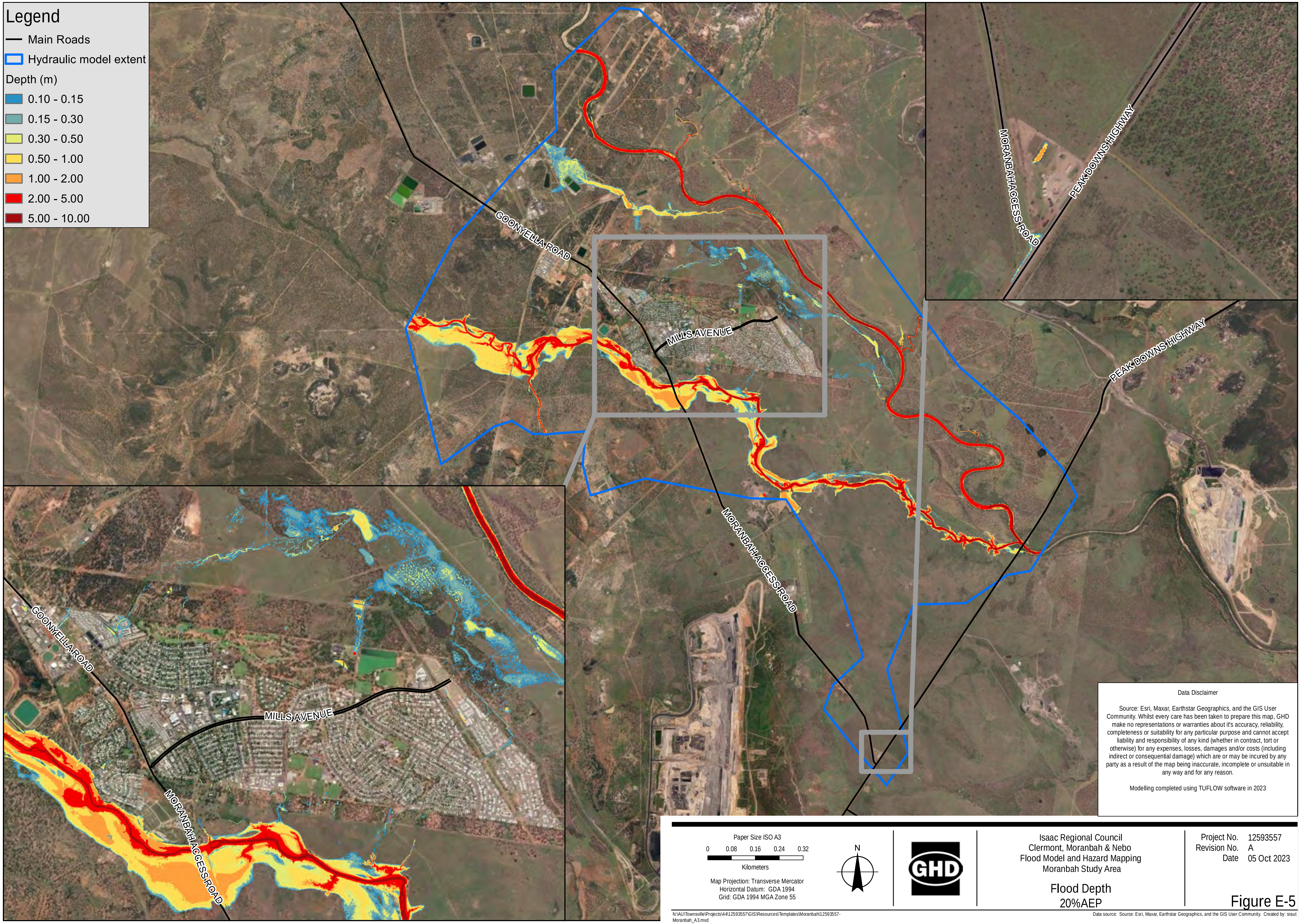
Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



Data Disclaimer

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Isaac Regional Council
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Flood Model and Hazard Mapping
Moranbah Study Area

Flood Depth
20%AEP

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Revision No. A
Date 05 Oct 2023

Figure E-5

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
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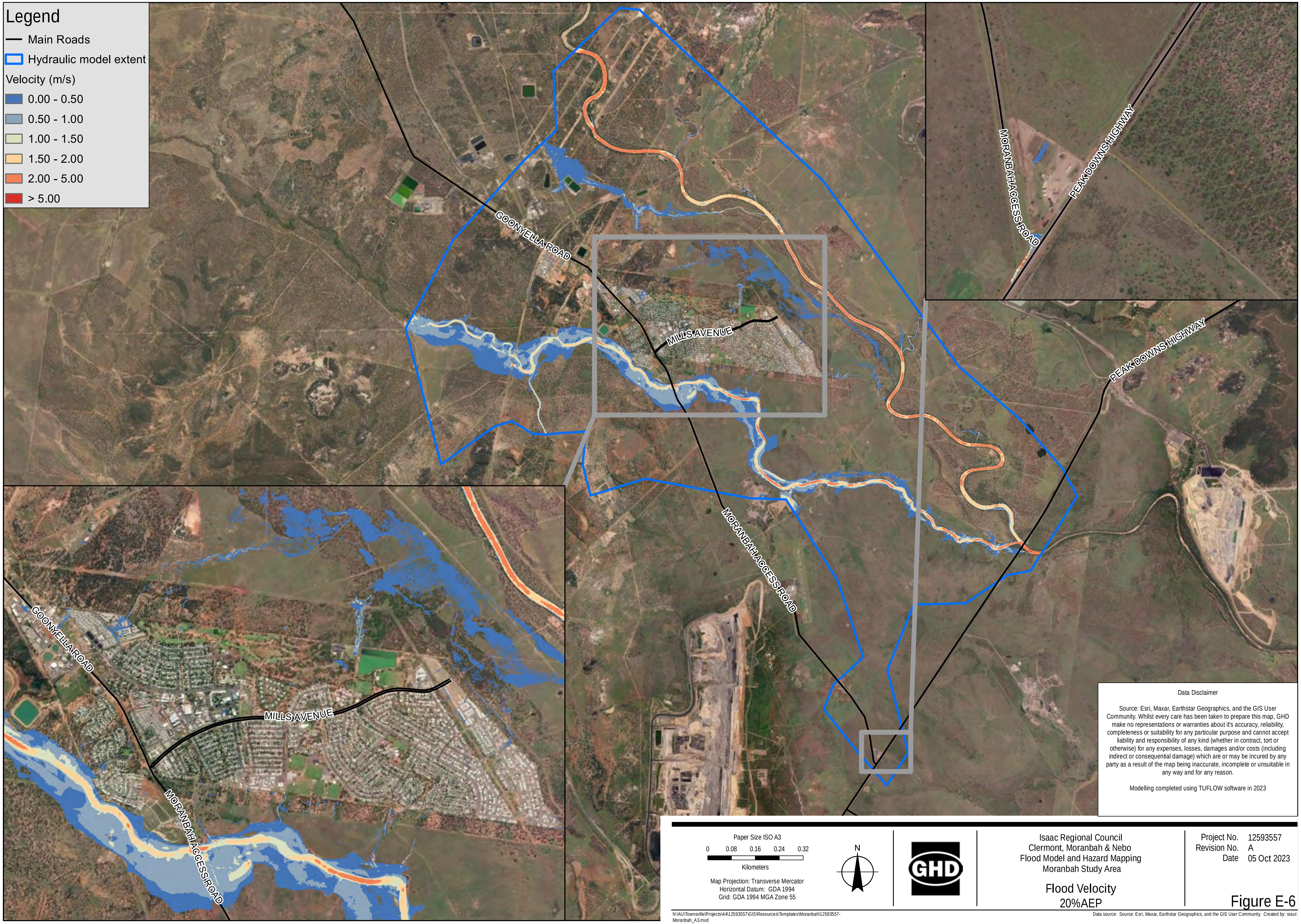

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Paper Size ISO A3
0 0.08 0.16 0.24 0.32
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

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Flood Model and Hazard Mapping
Moranbah Study Area

Flood Velocity
20%AEP

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-6

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
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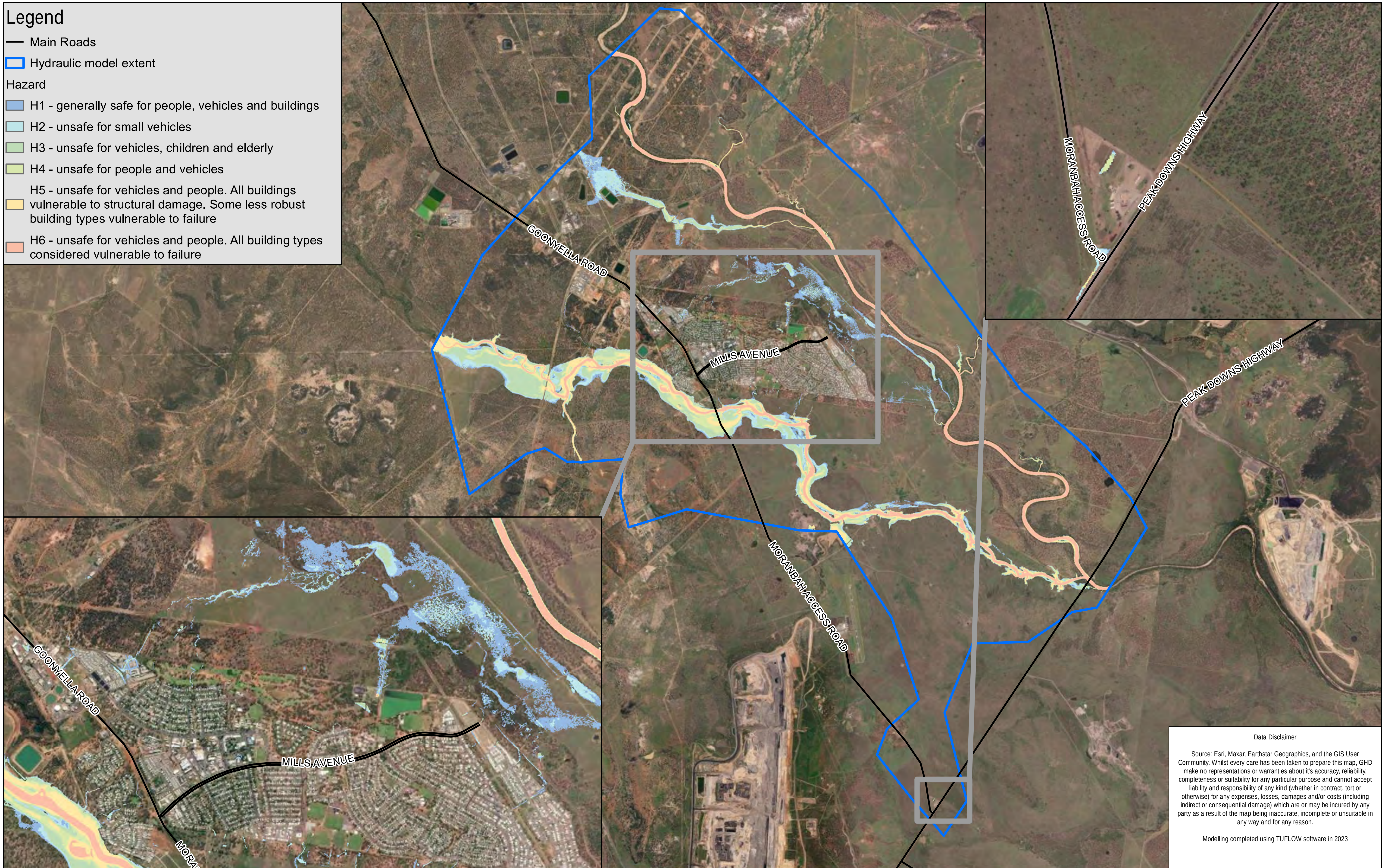
Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



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Paper Size ISO A3
0 0.08 0.16 0.24 0.32
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

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Flood Model and Hazard Mapping
Moranbah Study Area

Flood Hazard
20%AEP

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-7

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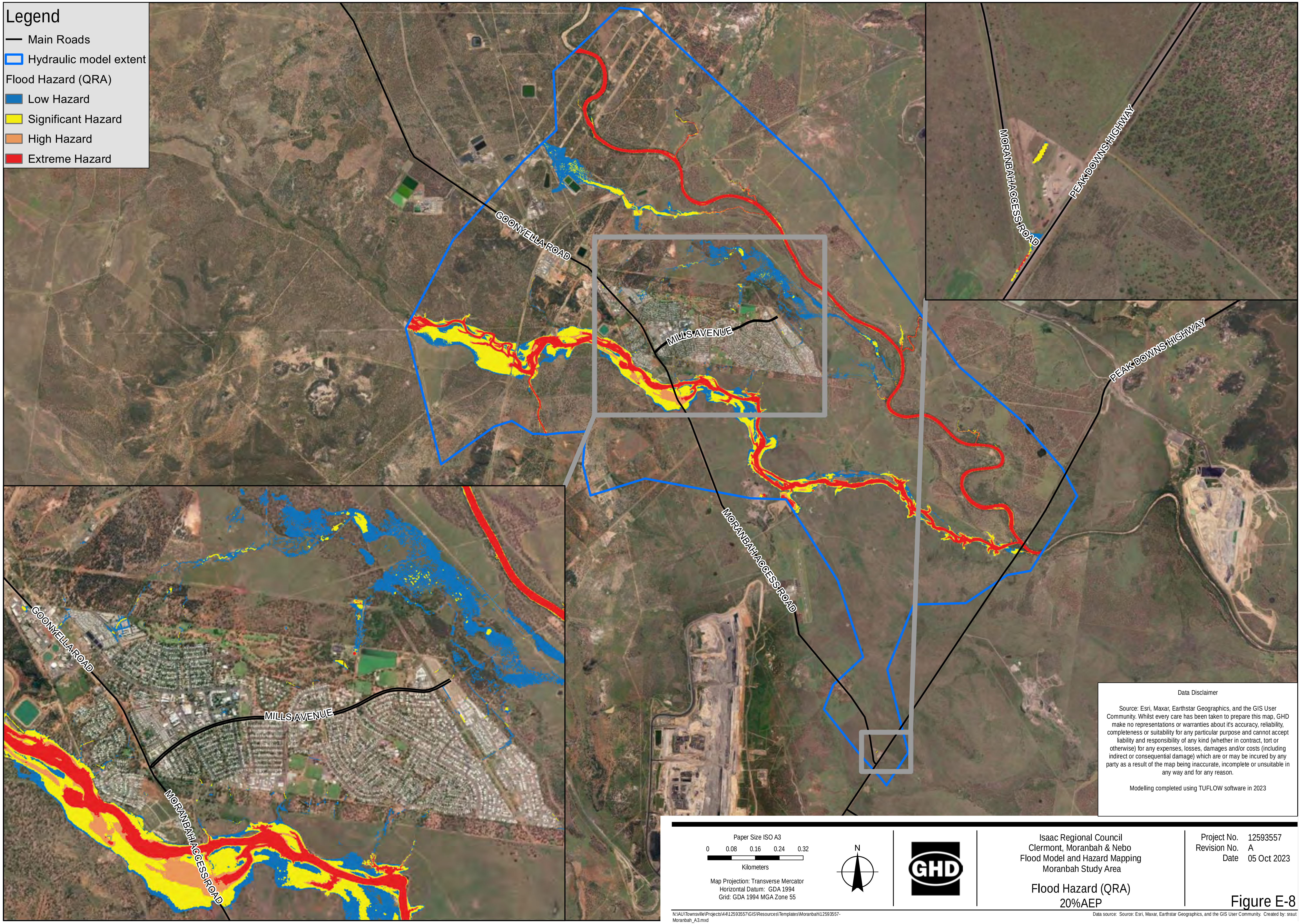

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Paper Size ISO A3

0 0.08 0.16 0.24 0.32

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

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Flood Model and Hazard Mapping
Moranbah Study Area

Flood Hazard (QRA)
20%AEP

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Revision No. A
Date 05 Oct 2023

Figure E-8

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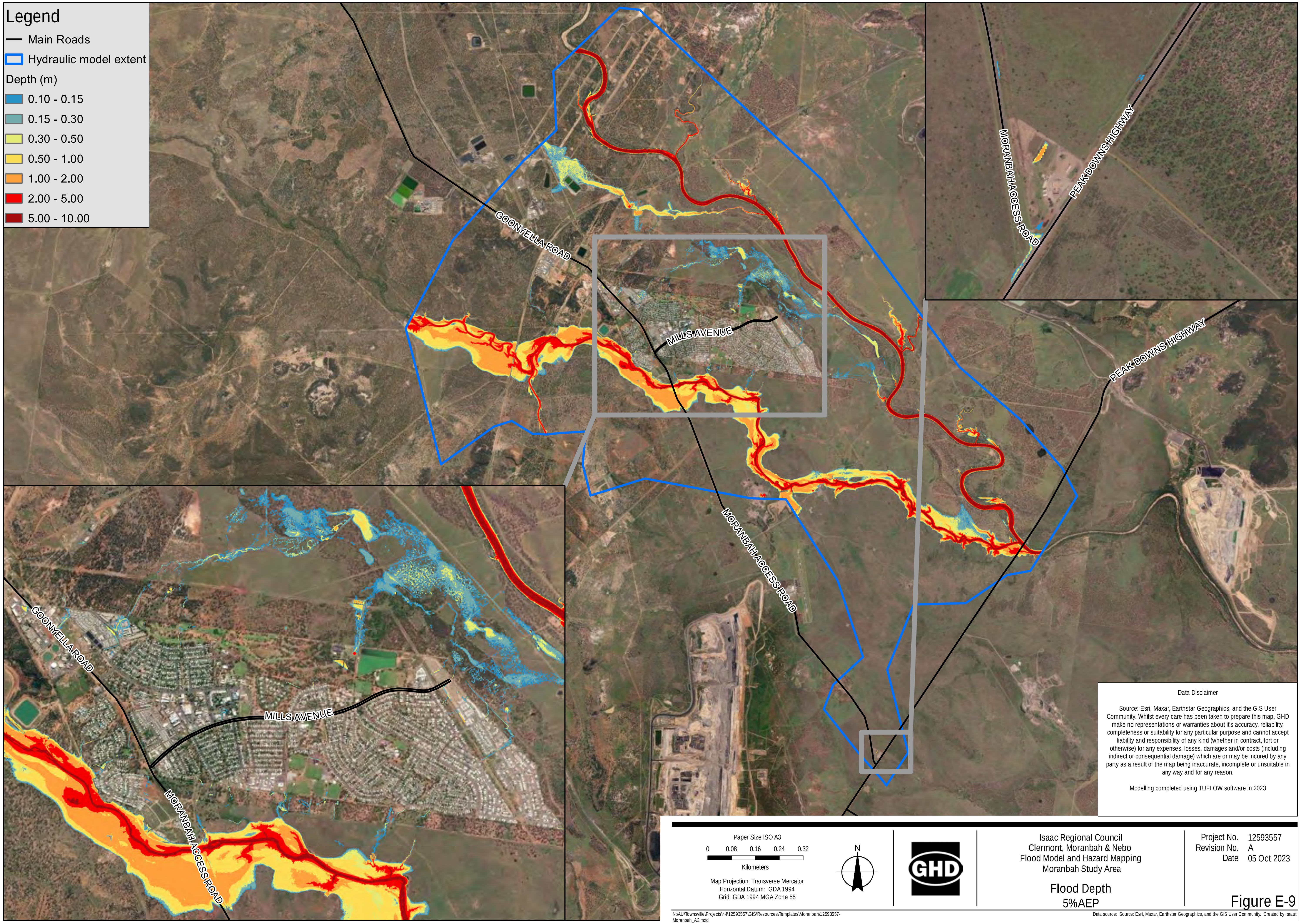

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Paper Size ISO A3
0 0.08 0.16 0.24 0.32
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Isaac Regional Council
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Flood Model and Hazard Mapping
Moranbah Study Area

Flood Depth
5%AEP

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-9

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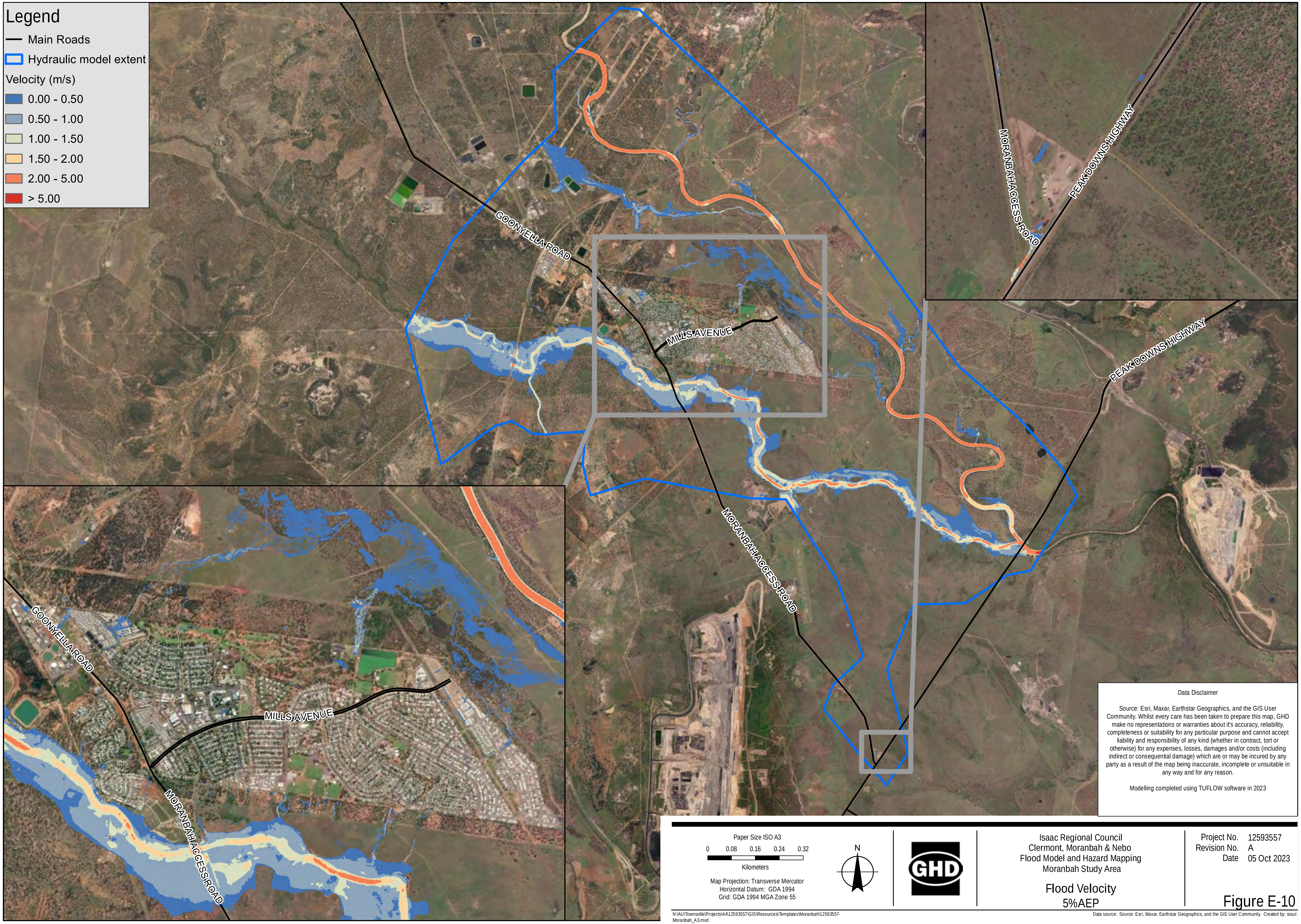

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Paper Size ISO A3
0 0.08 0.16 0.24 0.32
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

Flood Velocity
5%AEP

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-10

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
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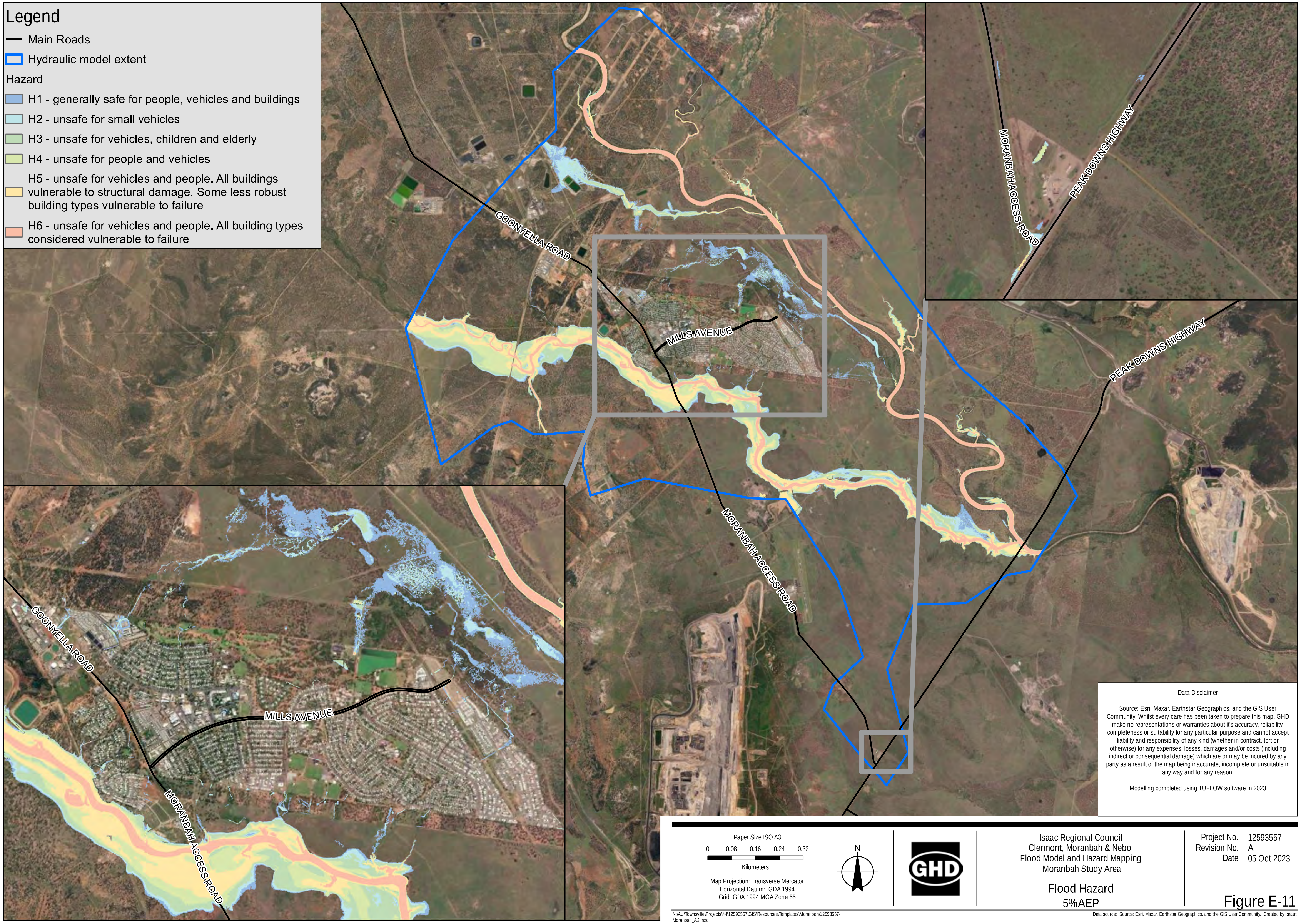

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Moranbah Study Area

Flood Hazard
5%AEP

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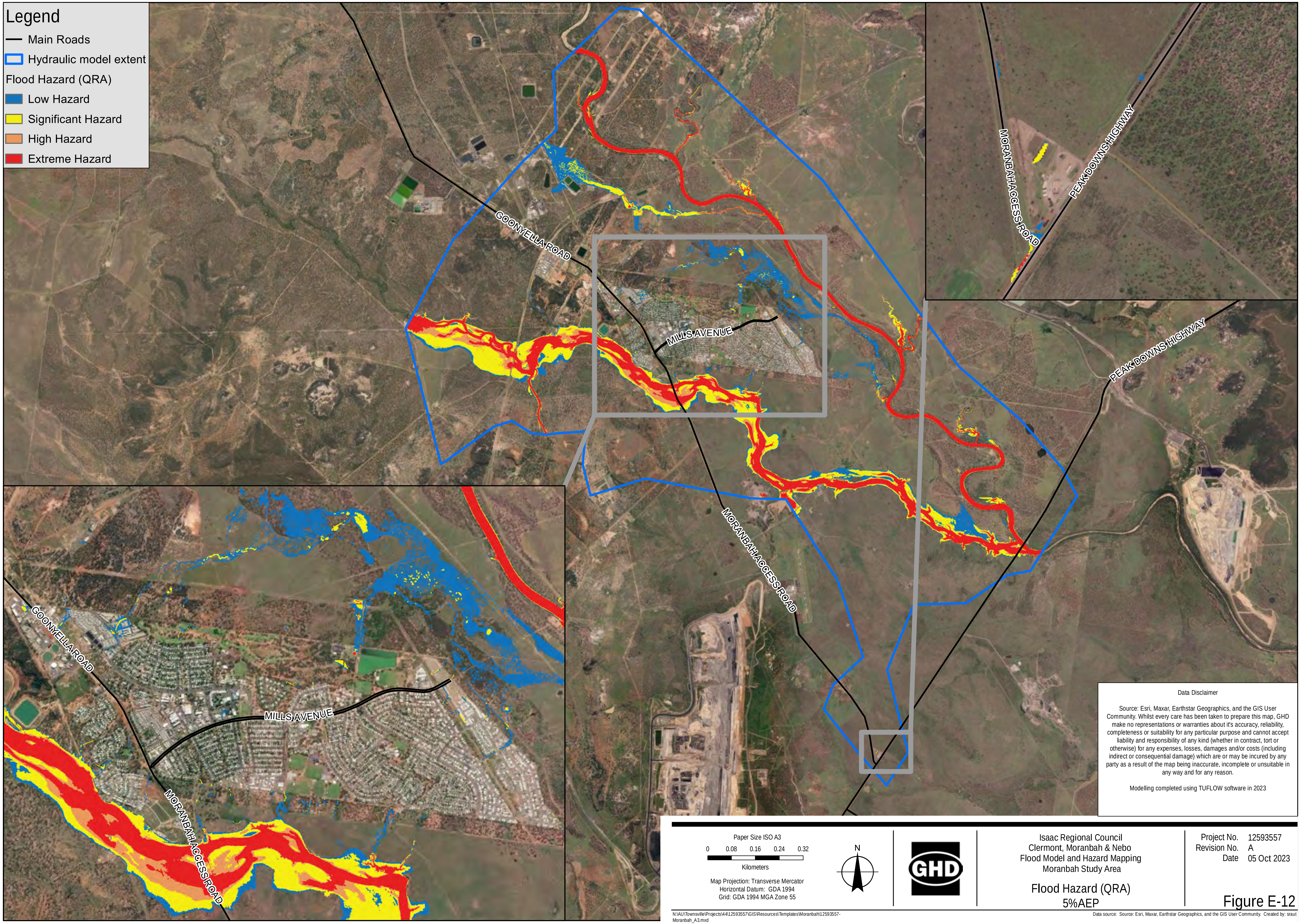
Revision No. A
Date 05 Oct 2023

Figure E-11

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 15:09 (SMA record: 15)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut

Document Set ID: 5266977
Version: 1, Version Date: 29/08/2024



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Paper Size ISO A3
0 0.08 0.16 0.24 0.32
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

Flood Hazard (QRA)
5%AEP

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-12

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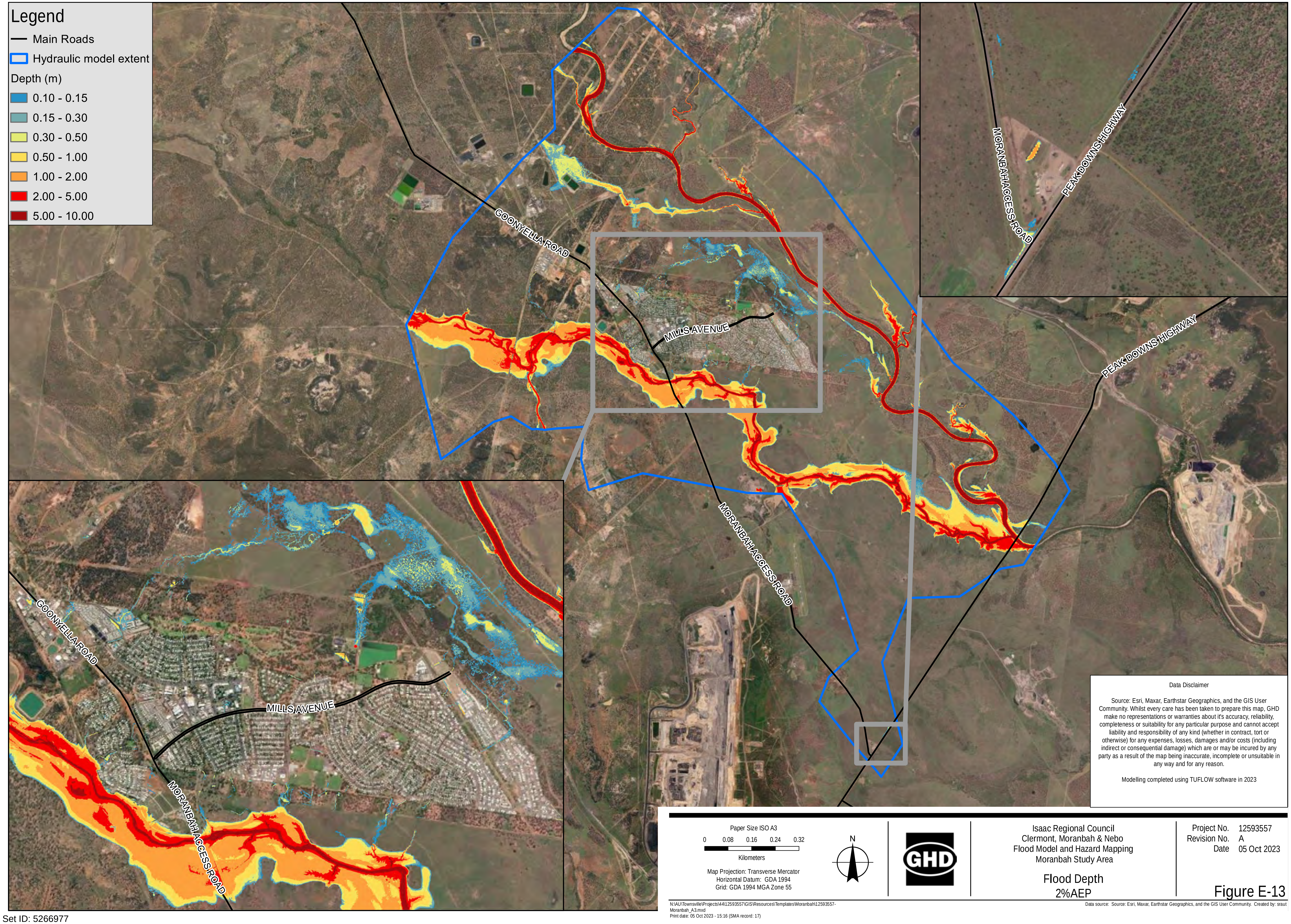
Legend
Main Roads
Hydraulic model extent
Depth (m)
0.10 - 0.15
0.15 - 0.30
0.30 - 0.50
0.50 - 1.00
1.00 - 2.00
2.00 - 5.00
5.00 - 10.00
GOONYELLA ROAD
MILLS AVENUE
MORANBAH ACCESS ROAD
PEAK DOWNS HIGHWAY
Data Disclaimer
Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about it's accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incured by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
Modelling completed using TUFLOW software in 2023
Paper Size ISO A3
0 0.08 0.16 0.24 0.32
Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55
N
GHD
Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area
Flood Depth
2%AEP
Project No. 12593557
Revision No. A
Date 05 Oct 2023
Figure E-13
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Print date: 05 Oct 2023 - 15:16 (SMA record: 17)
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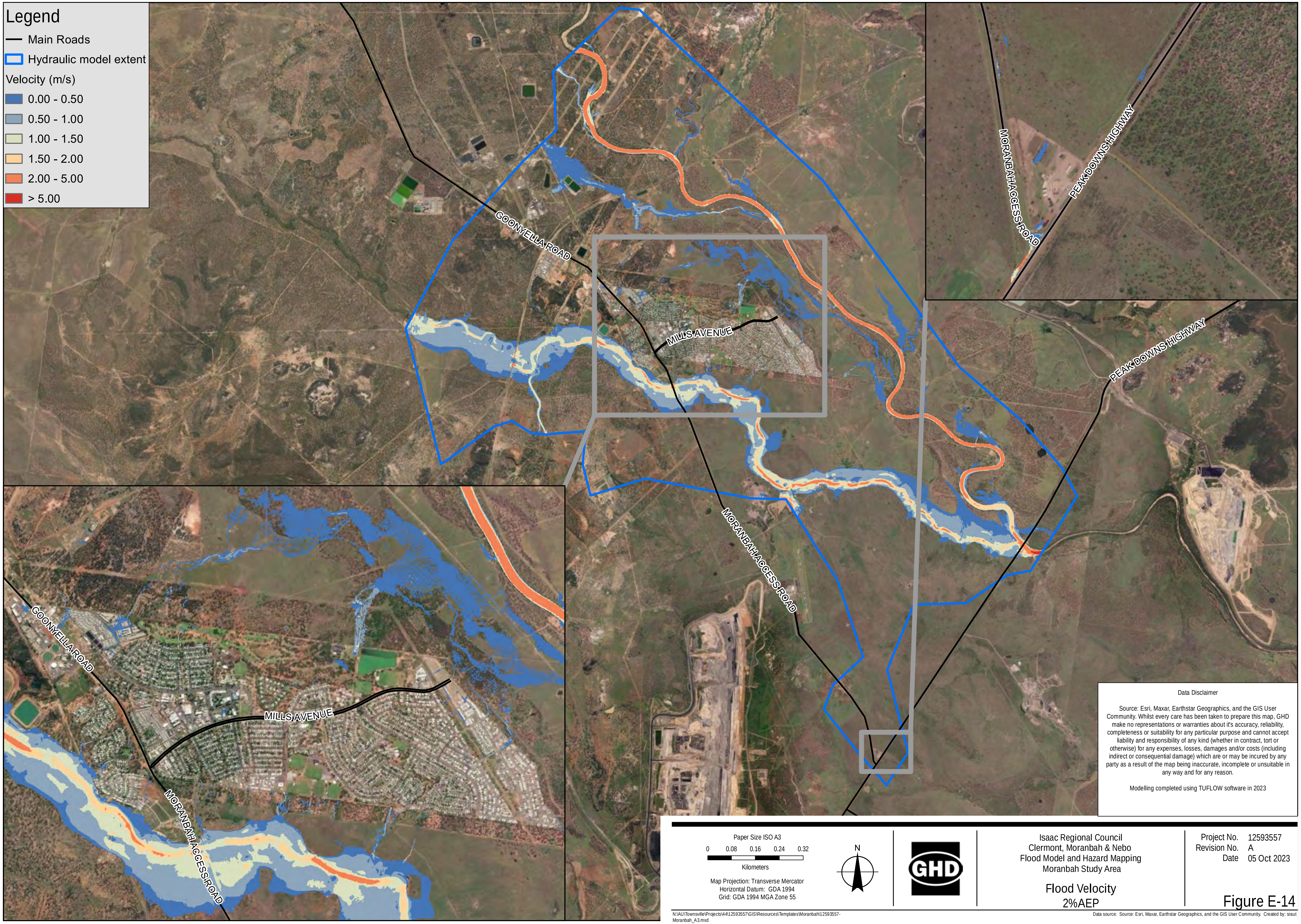

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3
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Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

Flood Velocity
2%AEP

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-14

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
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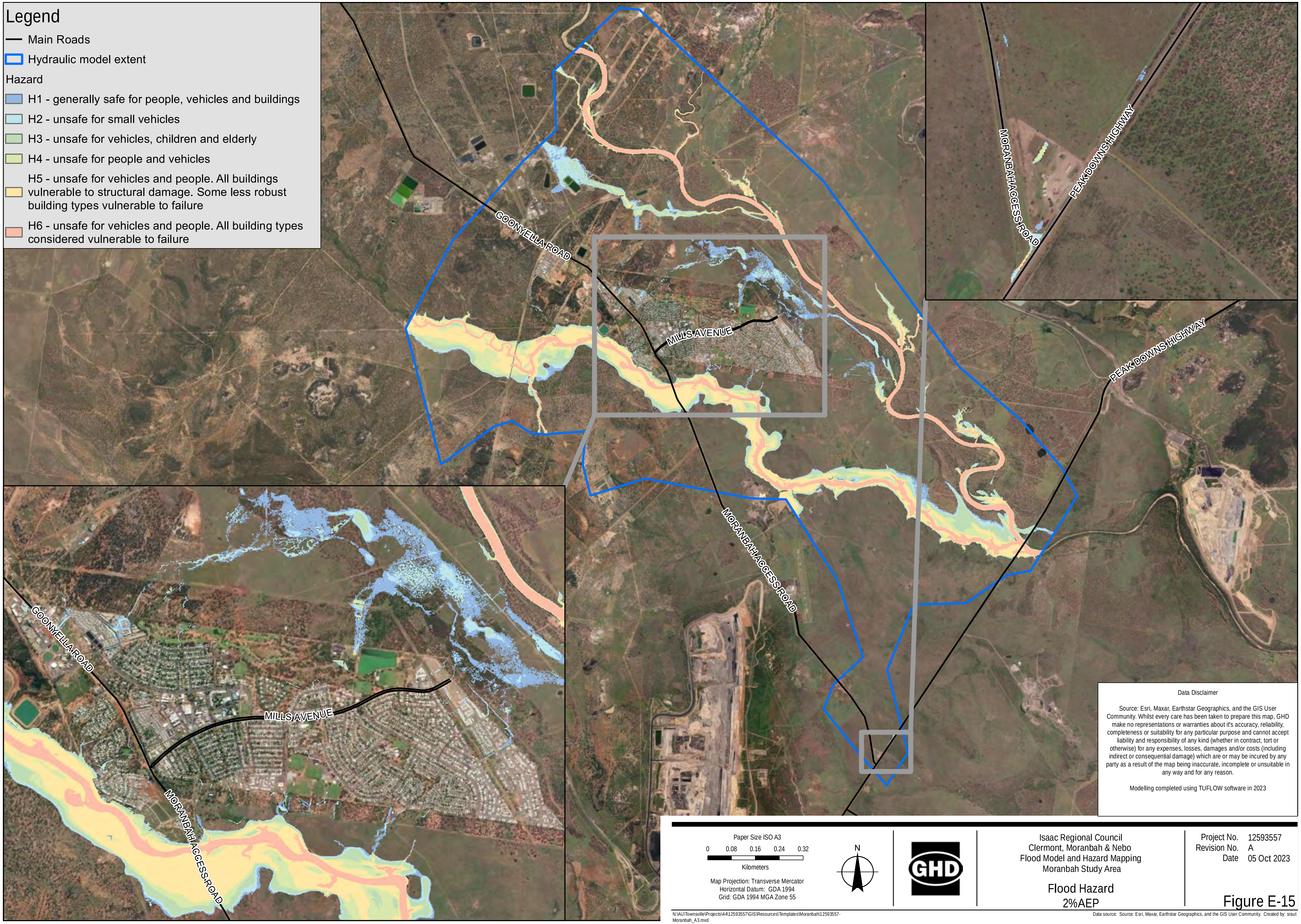
Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about it's accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incured by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.08 0.16 0.24 0.32

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

Flood Hazard
2%AEP

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-15

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
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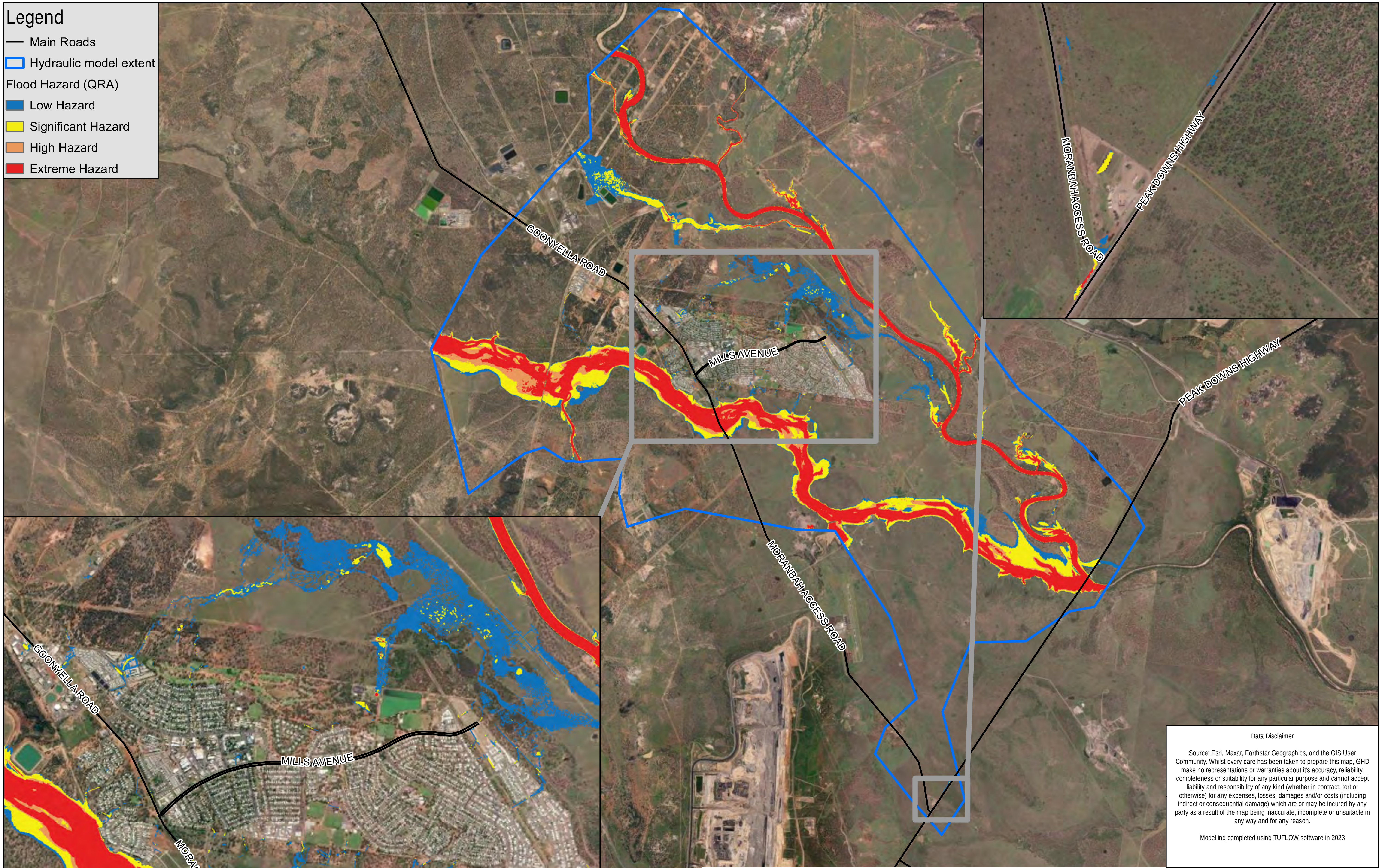
Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



Data Disclaimer

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.08 0.16 0.24 0.32

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

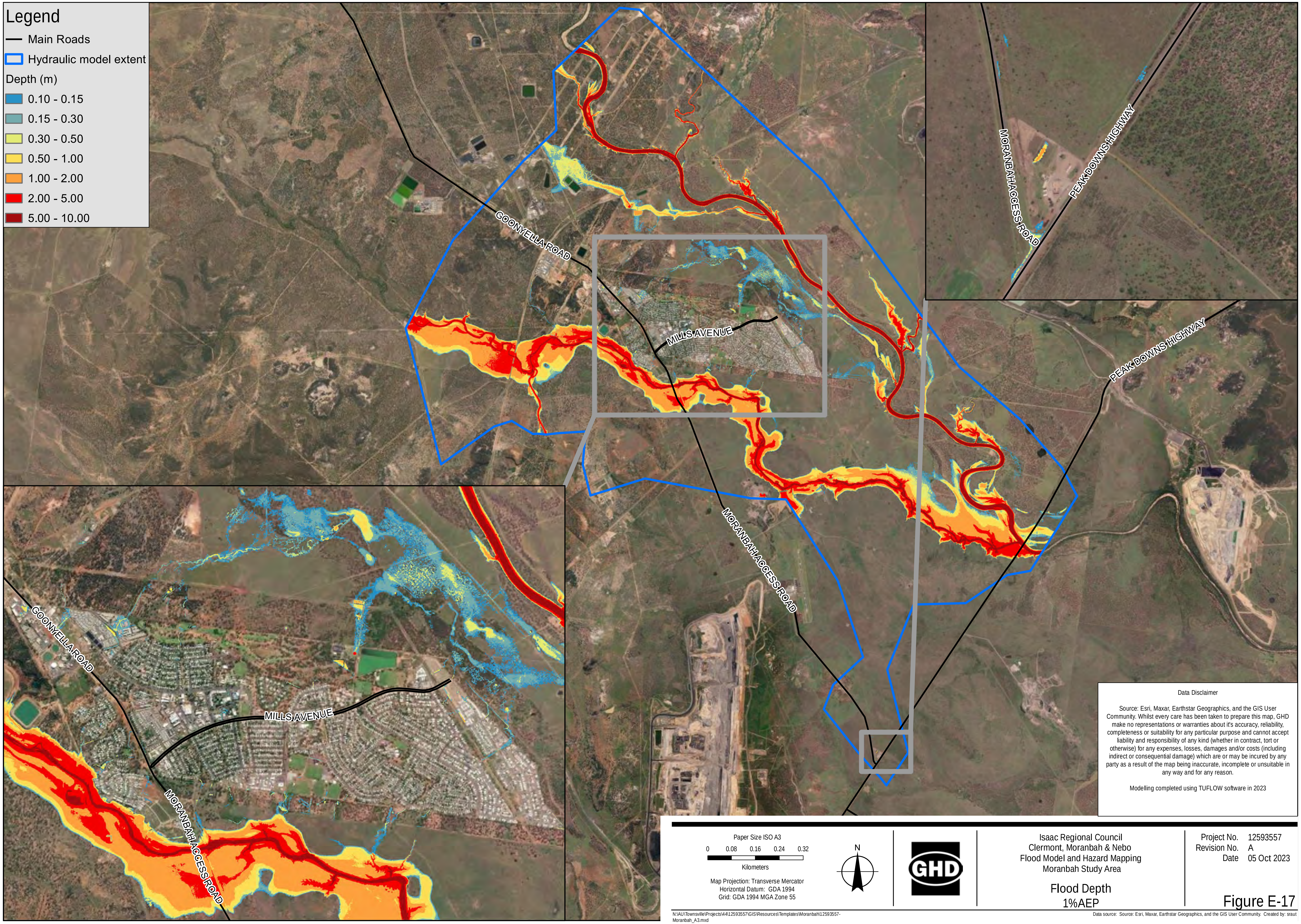
Flood Hazard (QRA)
2%AEP

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-16

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 15:27 (SMA record: 20)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



Data Disclaimer

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about it's accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incured by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Modelling completed using TUFLOW software in 2023

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

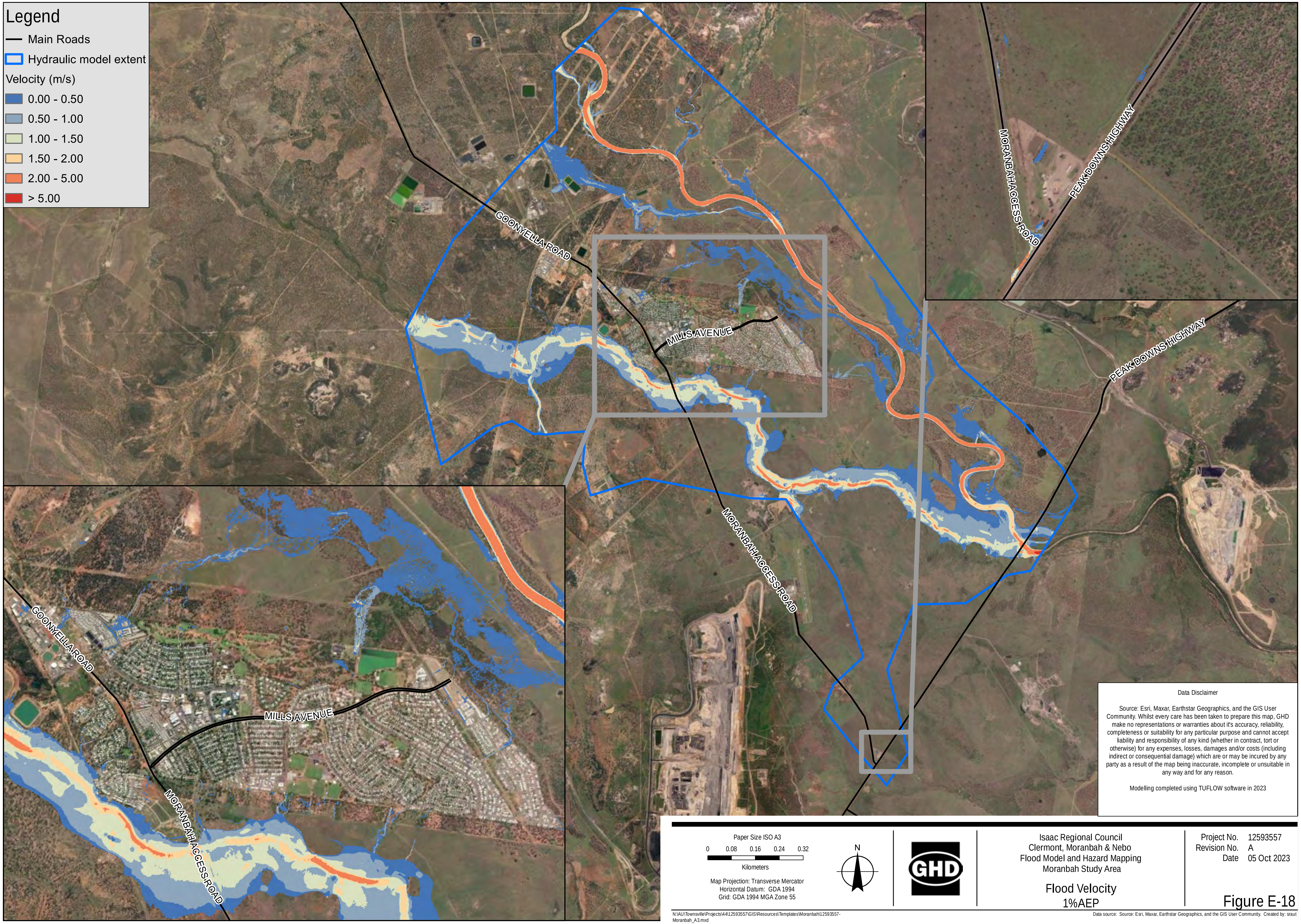
Flood Depth
1%AEP

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-17

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 15:31 (SMA record: 21)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



Data Disclaimer

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about it's accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incured by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Modelling completed using TUFLOW software in 2023

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

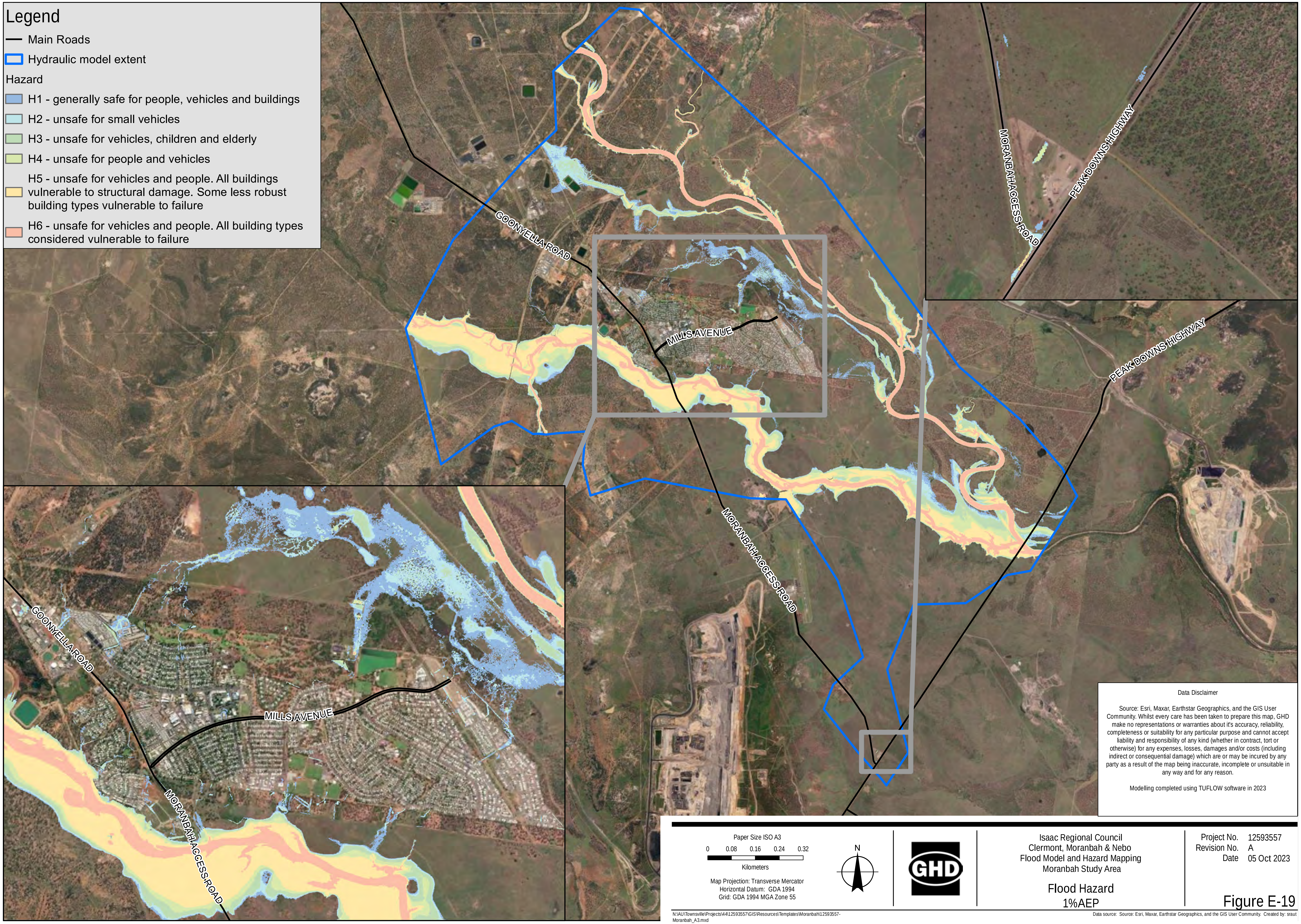
Flood Velocity
1%AEP

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-18

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 15:34 (SMA record: 22)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



Data Disclaimer

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about it's accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incured by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Modelling completed using TUFLOW software in 2023

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

GHD

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

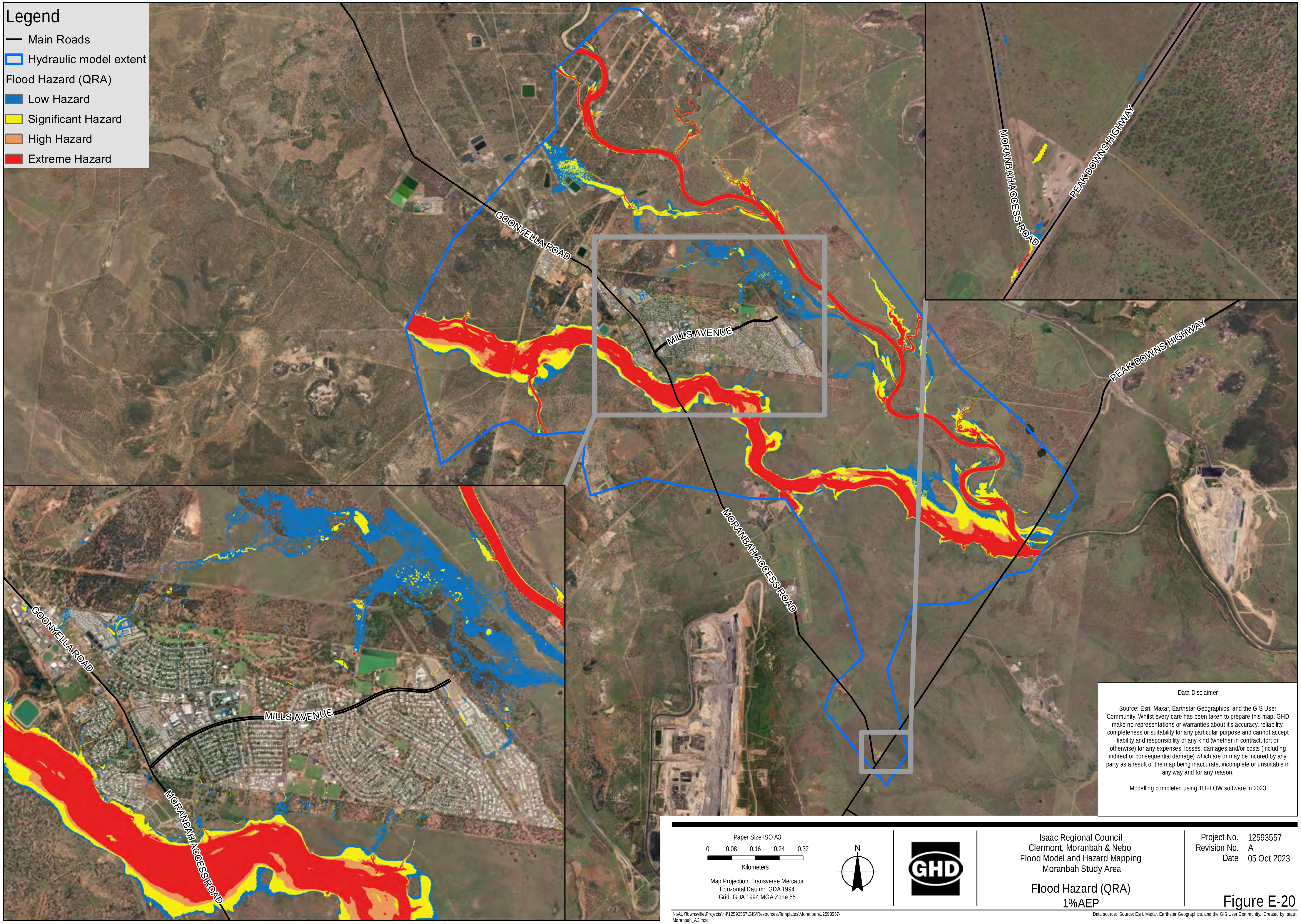
Flood Hazard
1%AEP

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-19

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 15:38 (SMA record: 23)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



Data Disclaimer

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about it's accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incured by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Modelling completed using TUFLOW software in 2023

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

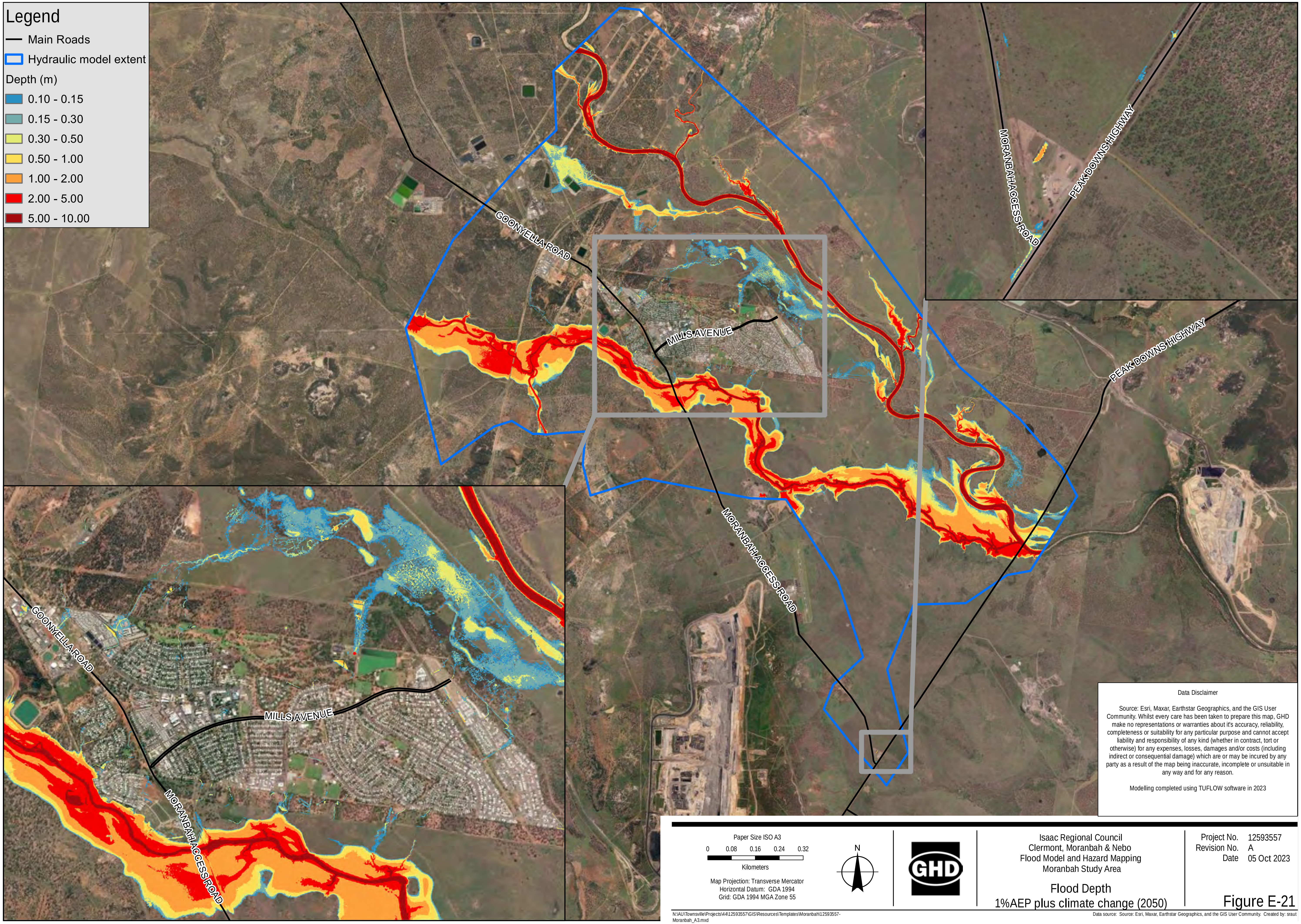
Flood Hazard (QRA)
1%AEP

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-20

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 15:42 (SMA record: 24)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



Data Disclaimer

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about it's accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incured by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Modelling completed using TUFLOW software in 2023

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

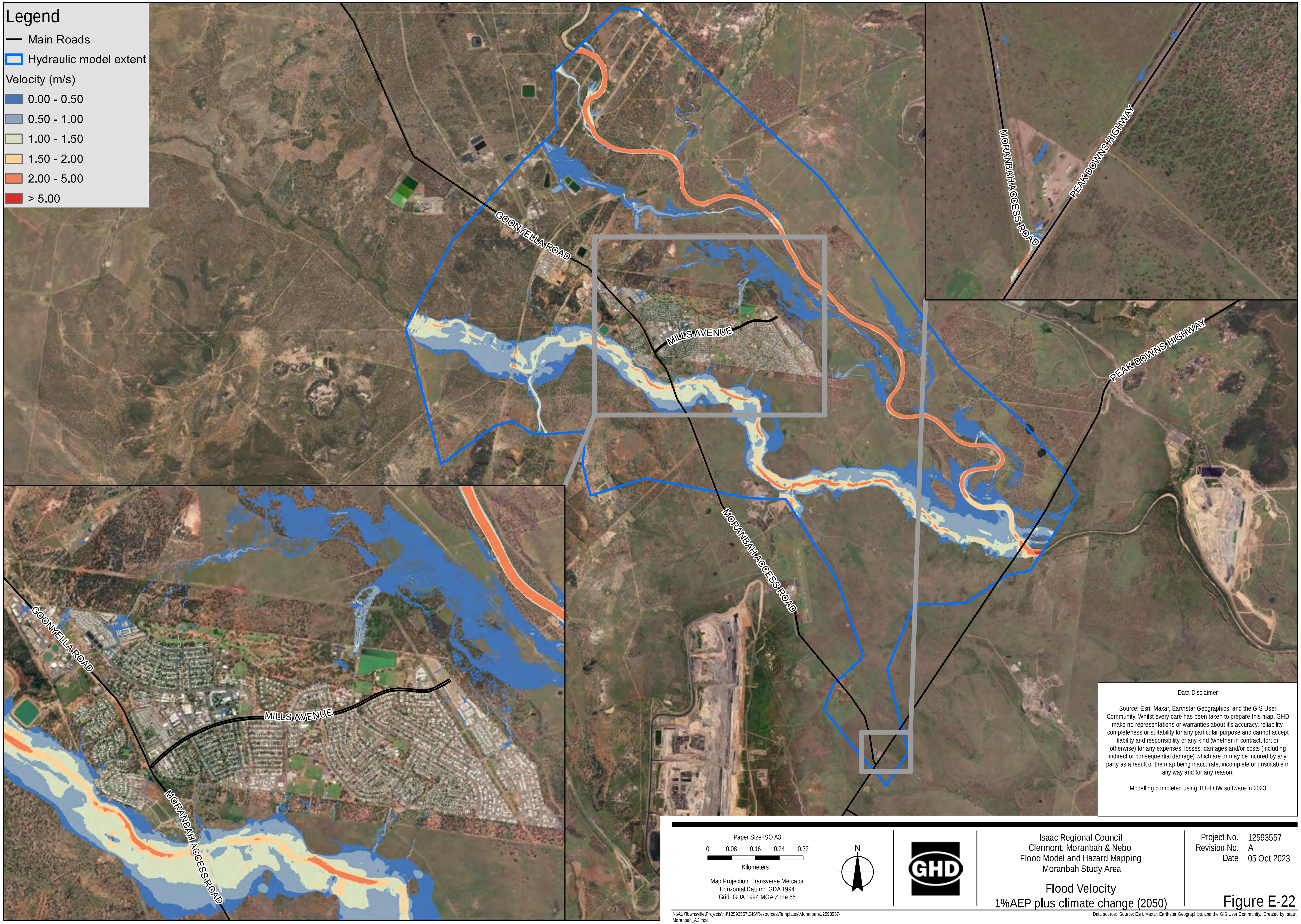
Flood Depth
1%AEP plus climate change (2050)

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-21

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 15:46 (SMA record: 25)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



Data Disclaimer

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about it's accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incured by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Modelling completed using TUFLOW software in 2023

Paper Size ISO A3
0 0.08 0.16 0.24 0.32
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

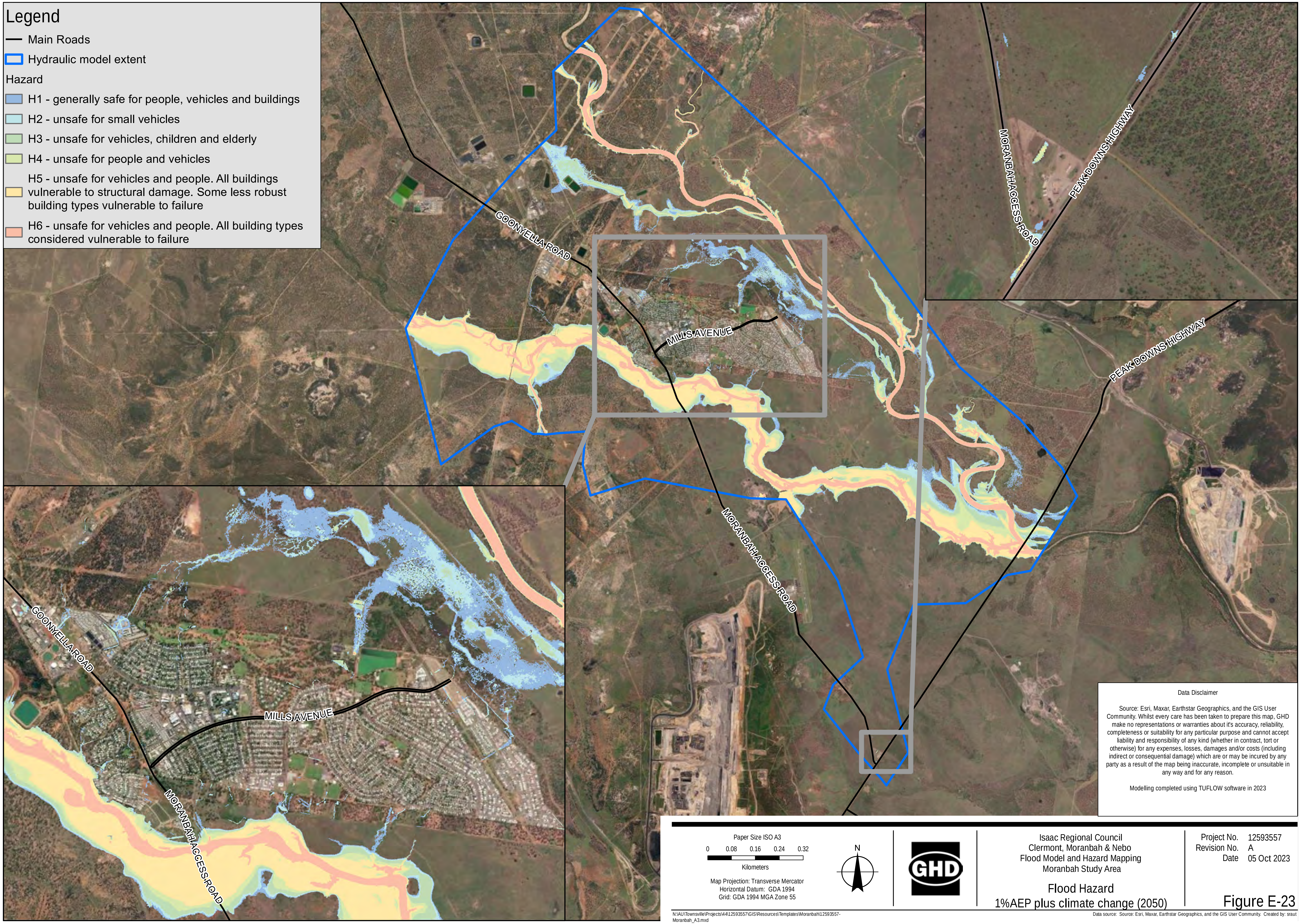
Flood Velocity
1%AEP plus climate change (2050)

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-22

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 15:50 (SMA record: 26)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



Data Disclaimer

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about it's accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incured by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.08 0.16 0.24 0.32

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

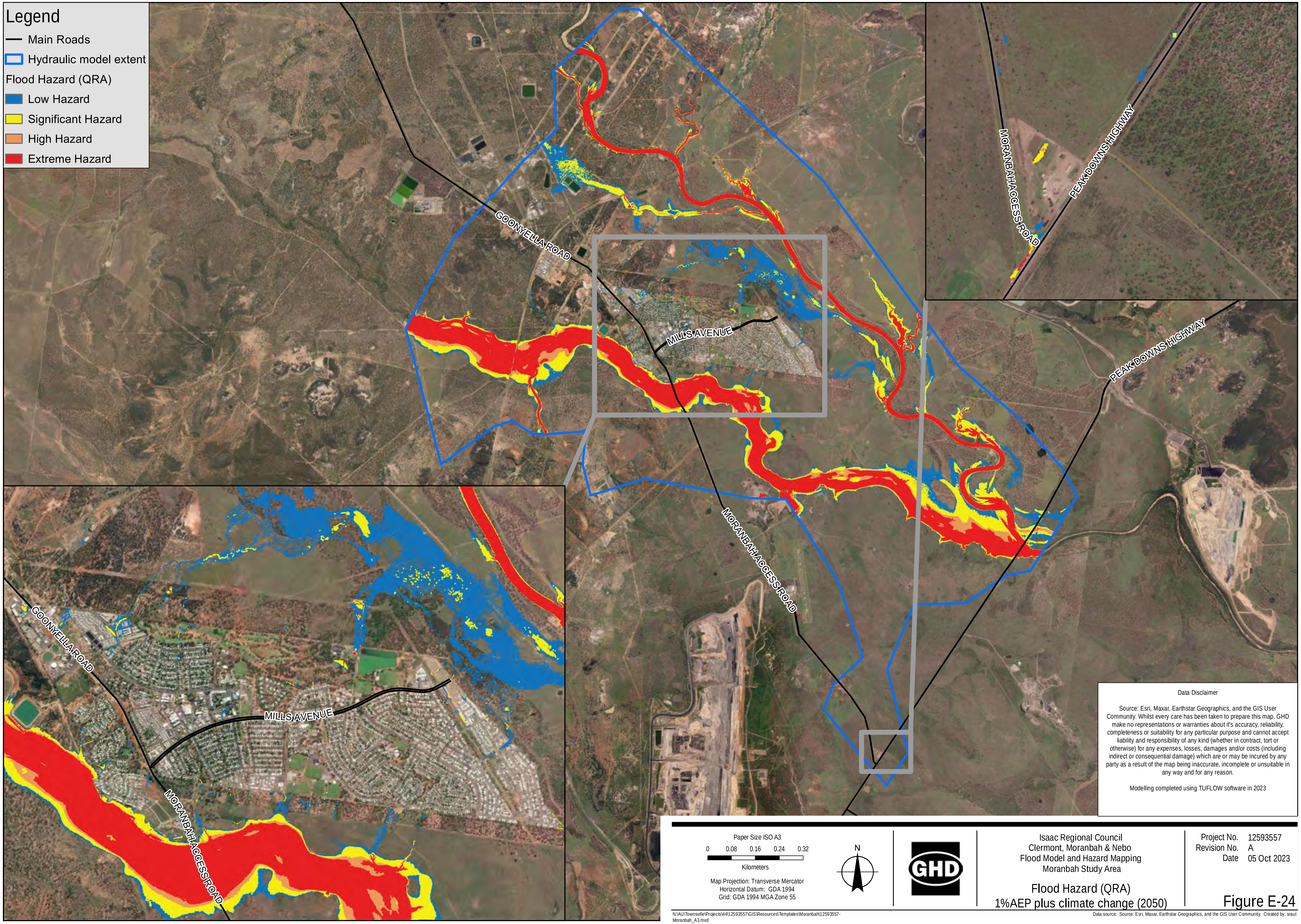
Flood Hazard
1%AEP plus climate change (2050)

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-23

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 15:53 (SMA record: 27)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



Data Disclaimer

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Modelling completed using TUFLOW software in 2023

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

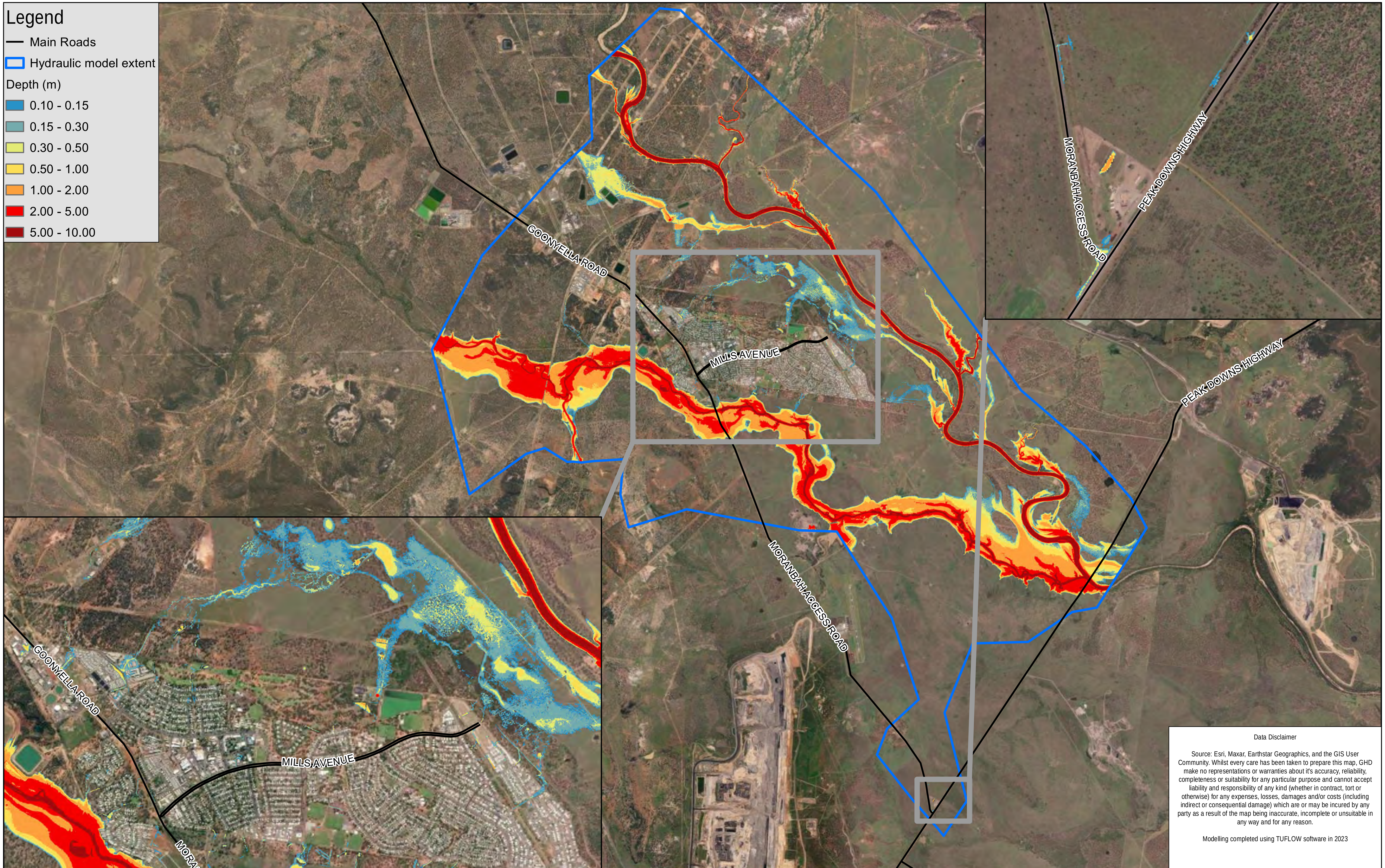
Flood Hazard (QRA)
1%AEP plus climate change (2050)

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-24

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 15:57 (SMA record: 28)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



Data Disclaimer

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about it's accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incured by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.08 0.16 0.24 0.32

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

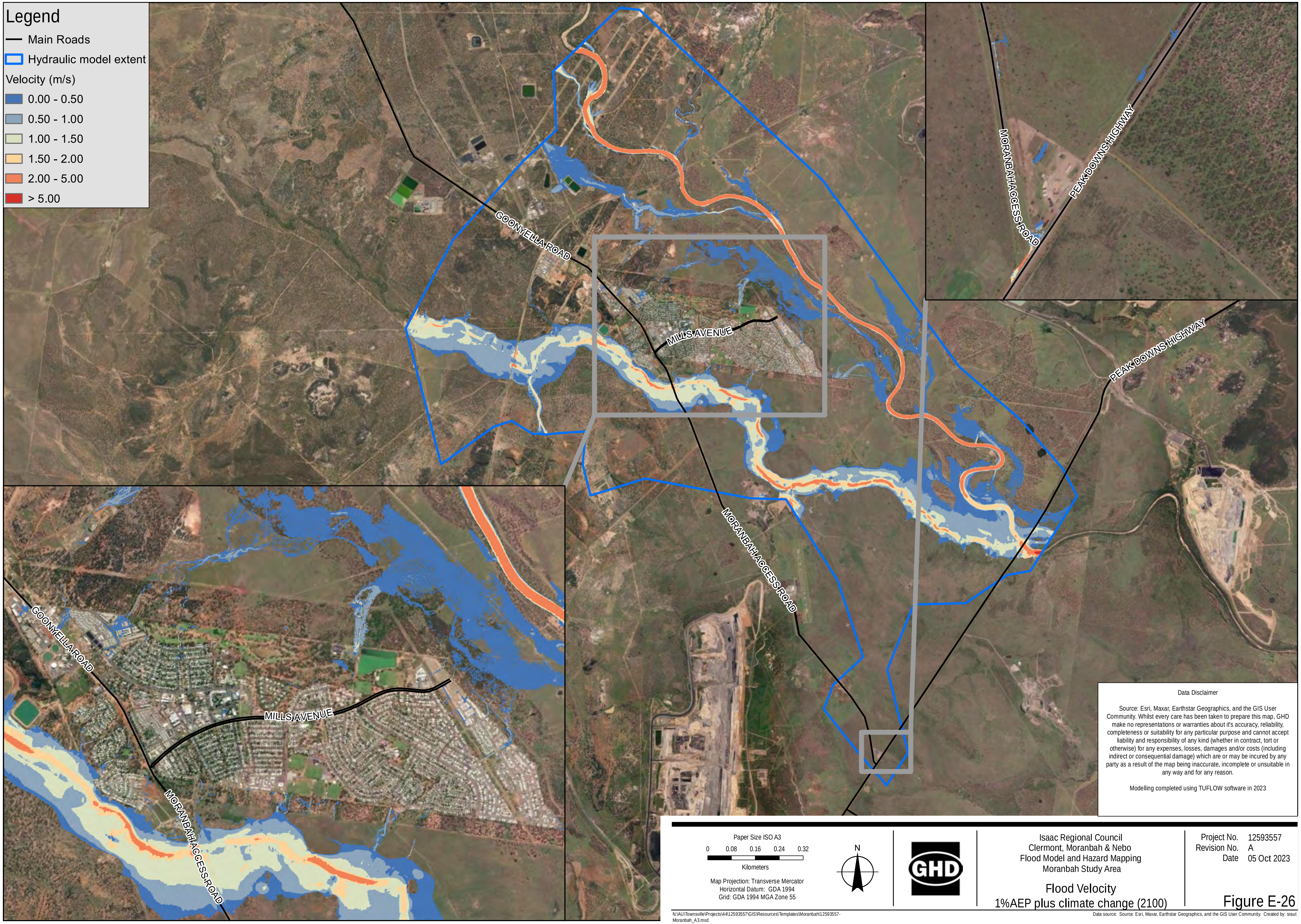
Flood Depth
1%AEP plus climate change (2100)

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-25

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 16:00 (SMA record: 29)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



Data Disclaimer

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incured by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.08 0.16 0.24 0.32

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

Flood Velocity
1%AEP plus climate change (2100)

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-26

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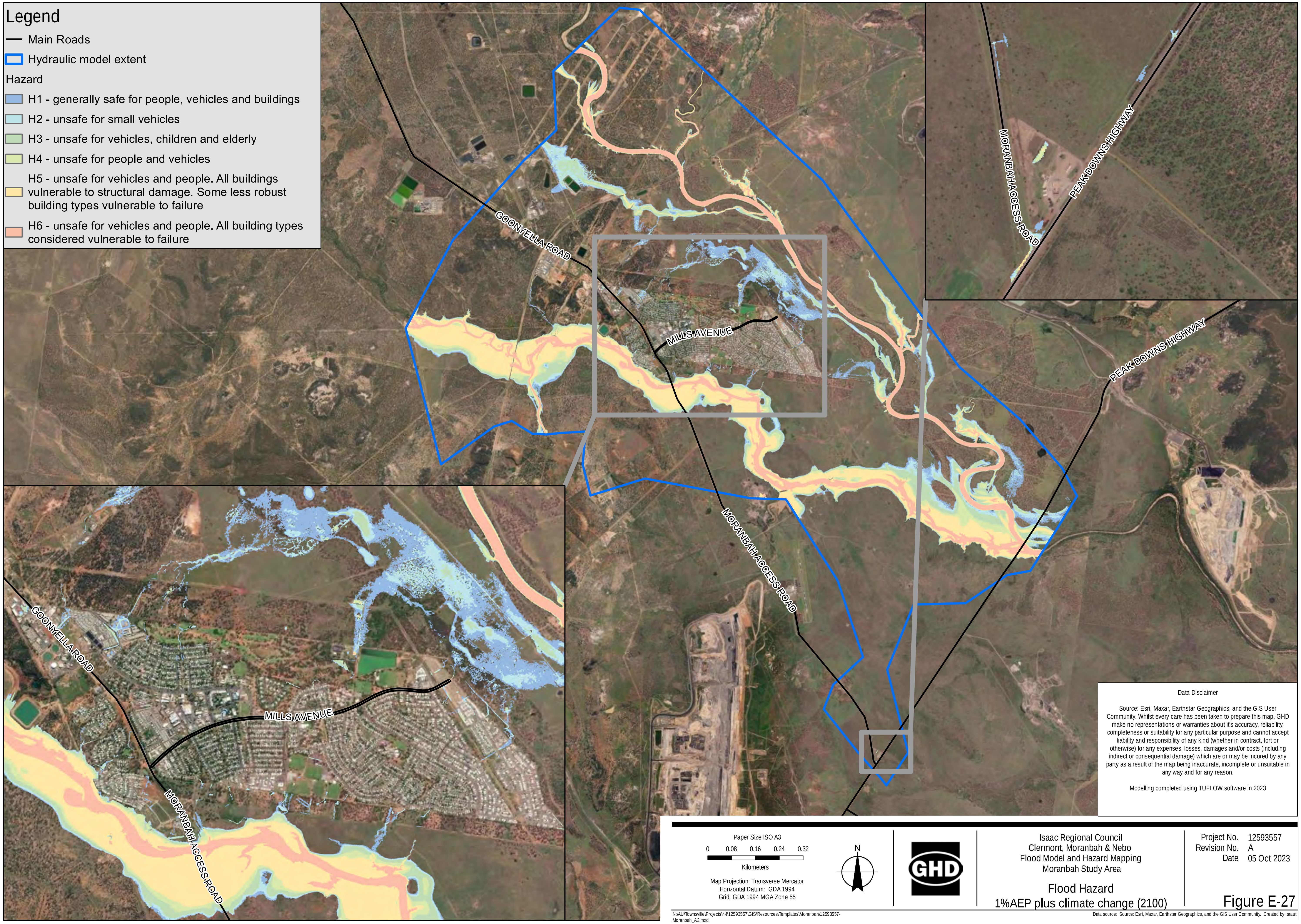
Print date: 05 Oct 2023 - 16:04 (SMA record: 30)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about it's accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incured by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Modelling completed using TUFLOW software in 2023

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

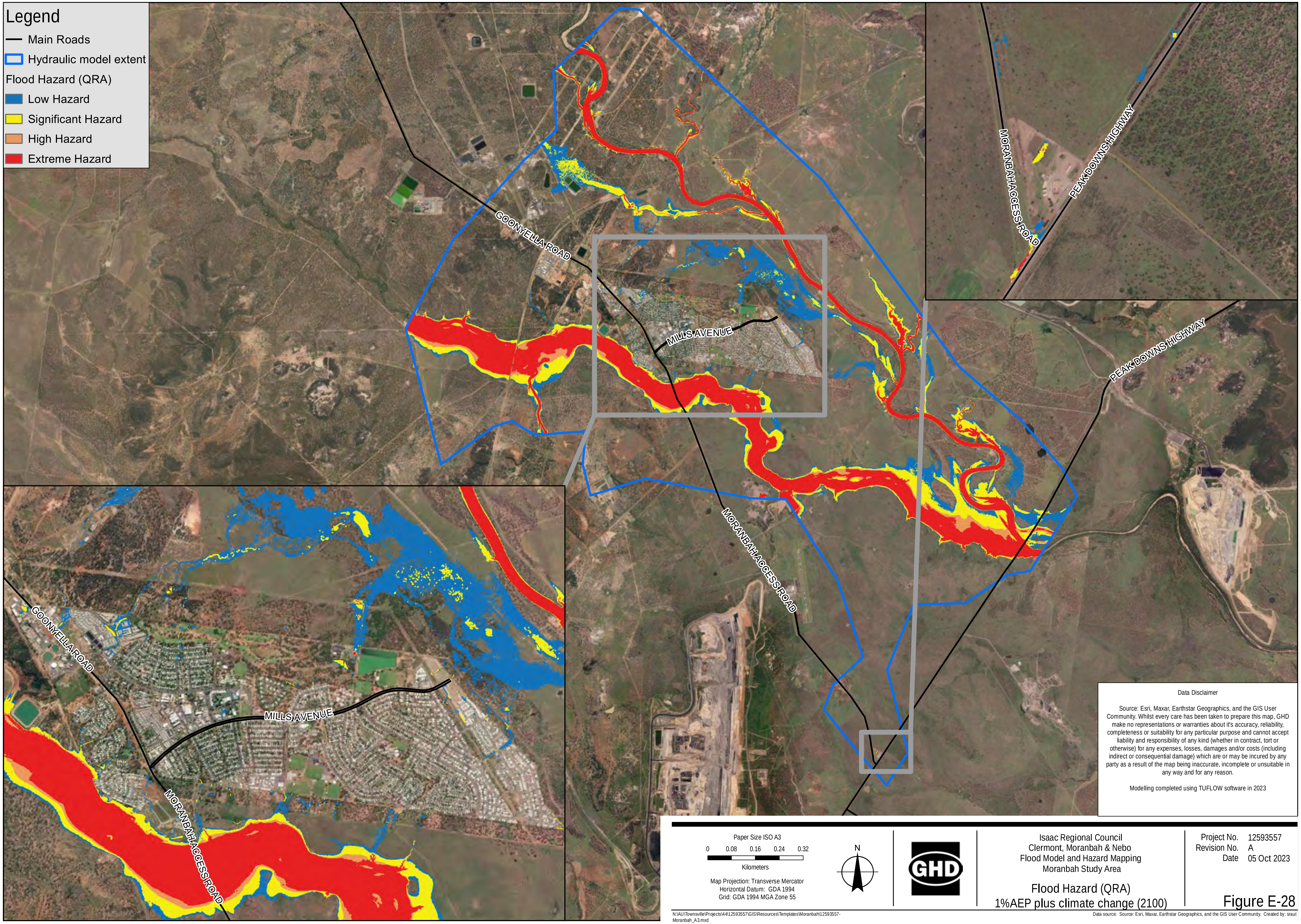
Flood Hazard
1%AEP plus climate change (2100)

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-27

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 16:08 (SMA record: 31)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



Data Disclaimer

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incured by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Modelling completed using TUFLOW software in 2023

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

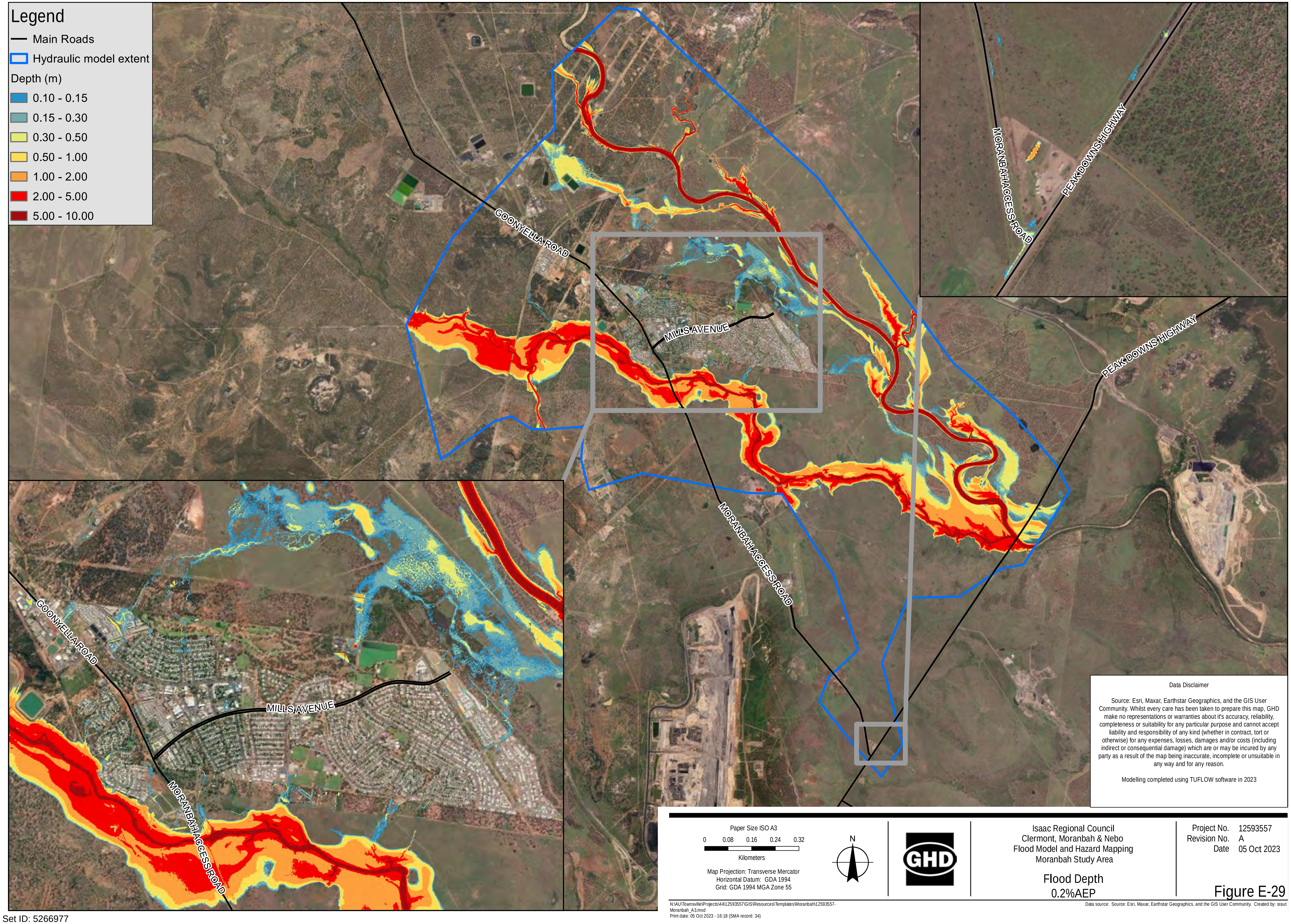
Flood Hazard (QRA)
1%AEP plus climate change (2100)

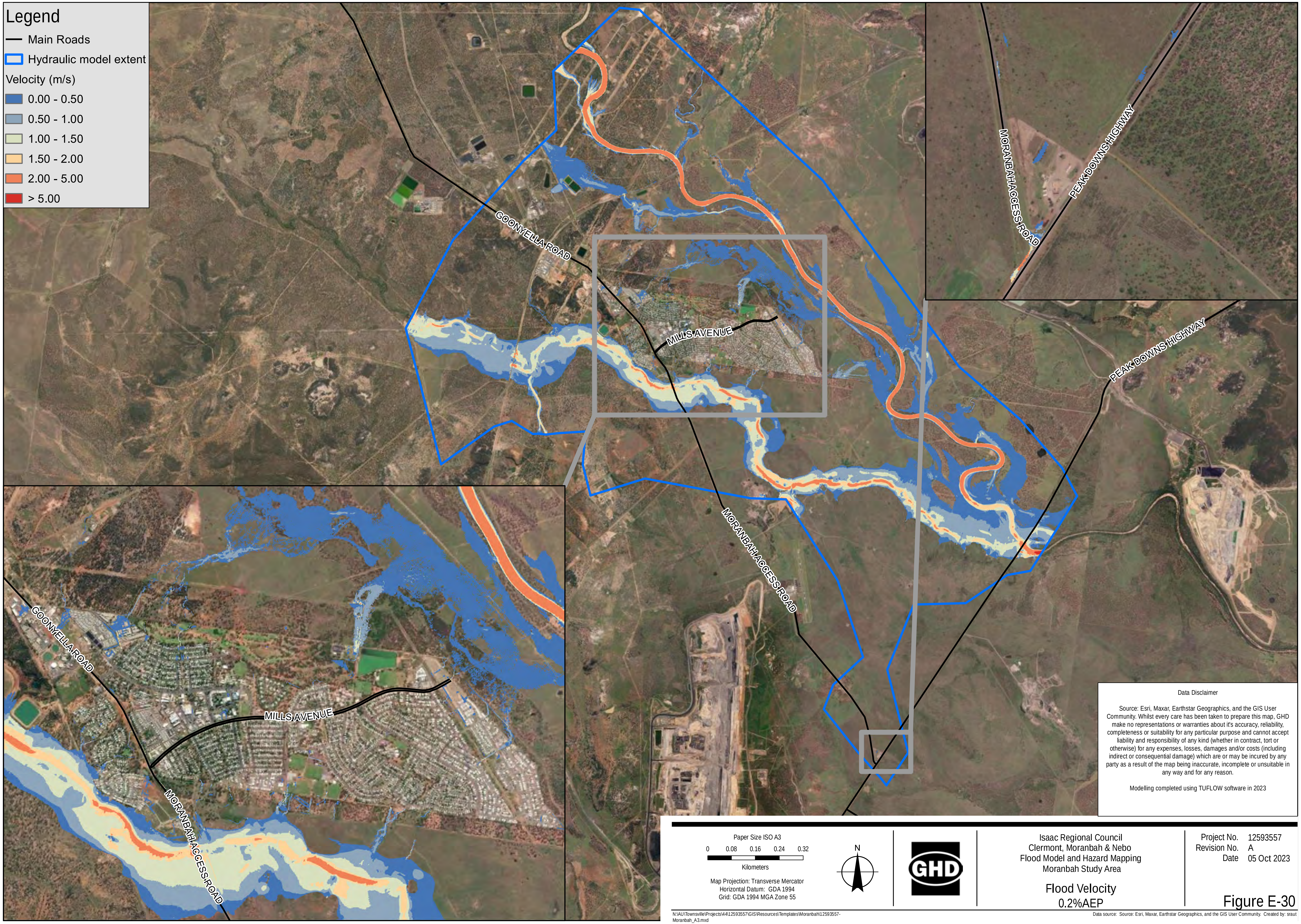
Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-28

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 16:15 (SMA record: 33)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut


Legend
Main Roads
Hydraulic model extent
Depth (m)
0.10 - 0.15
0.15 - 0.30
0.30 - 0.50
0.50 - 1.00
1.00 - 2.00
2.00 - 5.00
5.00 - 10.00
GOONYELLA ROAD
MILLS AVENUE
MORANBAH ACCESS ROAD
PEAK DOWNS HIGHWAY
Data Disclaimer
Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
Modelling completed using TUFLOW software in 2023
Paper Size ISO A3
0 0.08 0.16 0.24 0.32
Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55
N
GHD
Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area
Flood Depth
0.2%AEP
Project No. 12593557
Revision No. A
Date 05 Oct 2023
Figure E-29
N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 16:18 (SMA record: 34)
Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



Data Disclaimer

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about it's accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incured by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Modelling completed using TUFLOW software in 2023

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

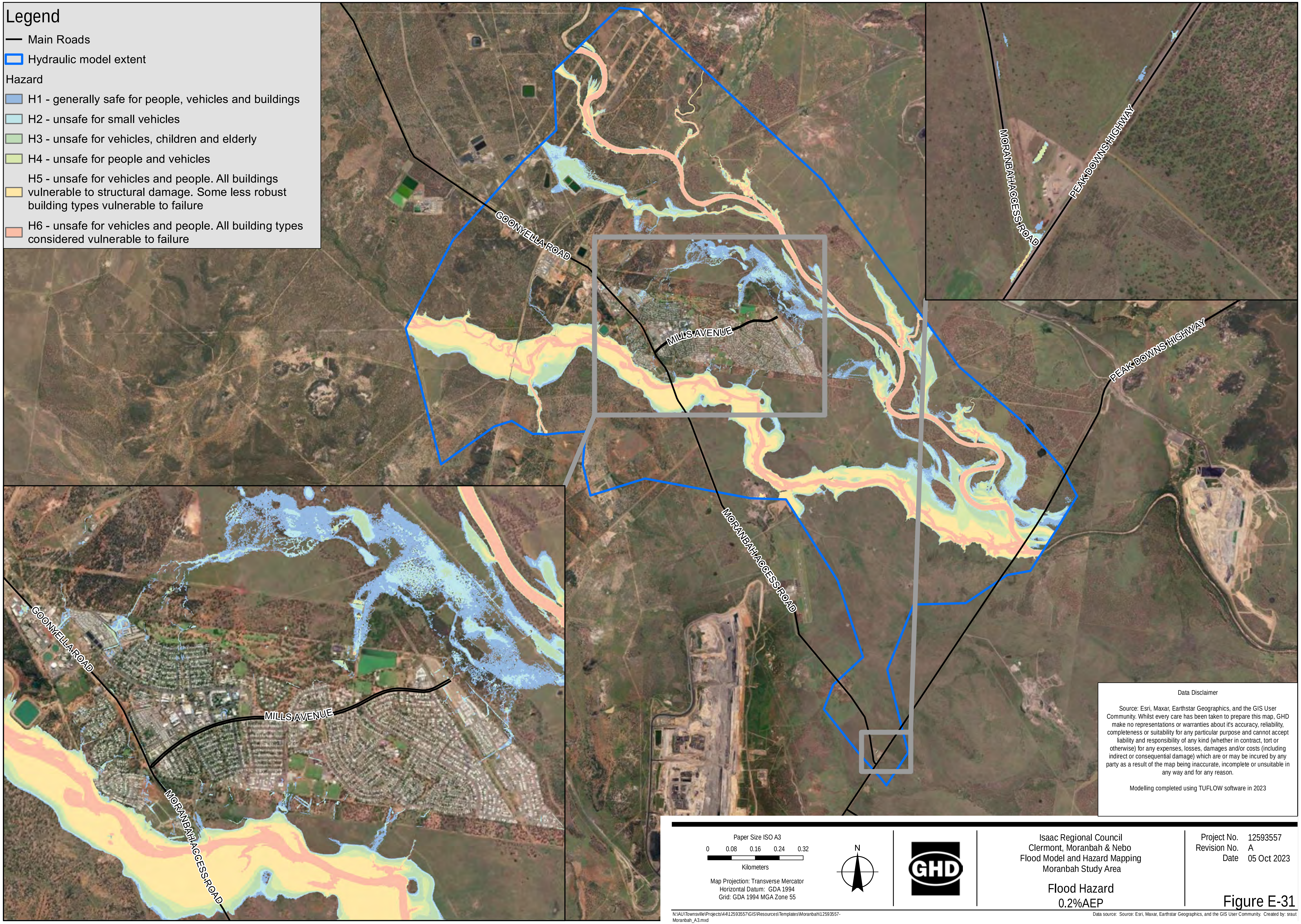
Flood Velocity
0.2%AEP

Project No. 12593557
Revision No. A
Date 05 Oct 2023

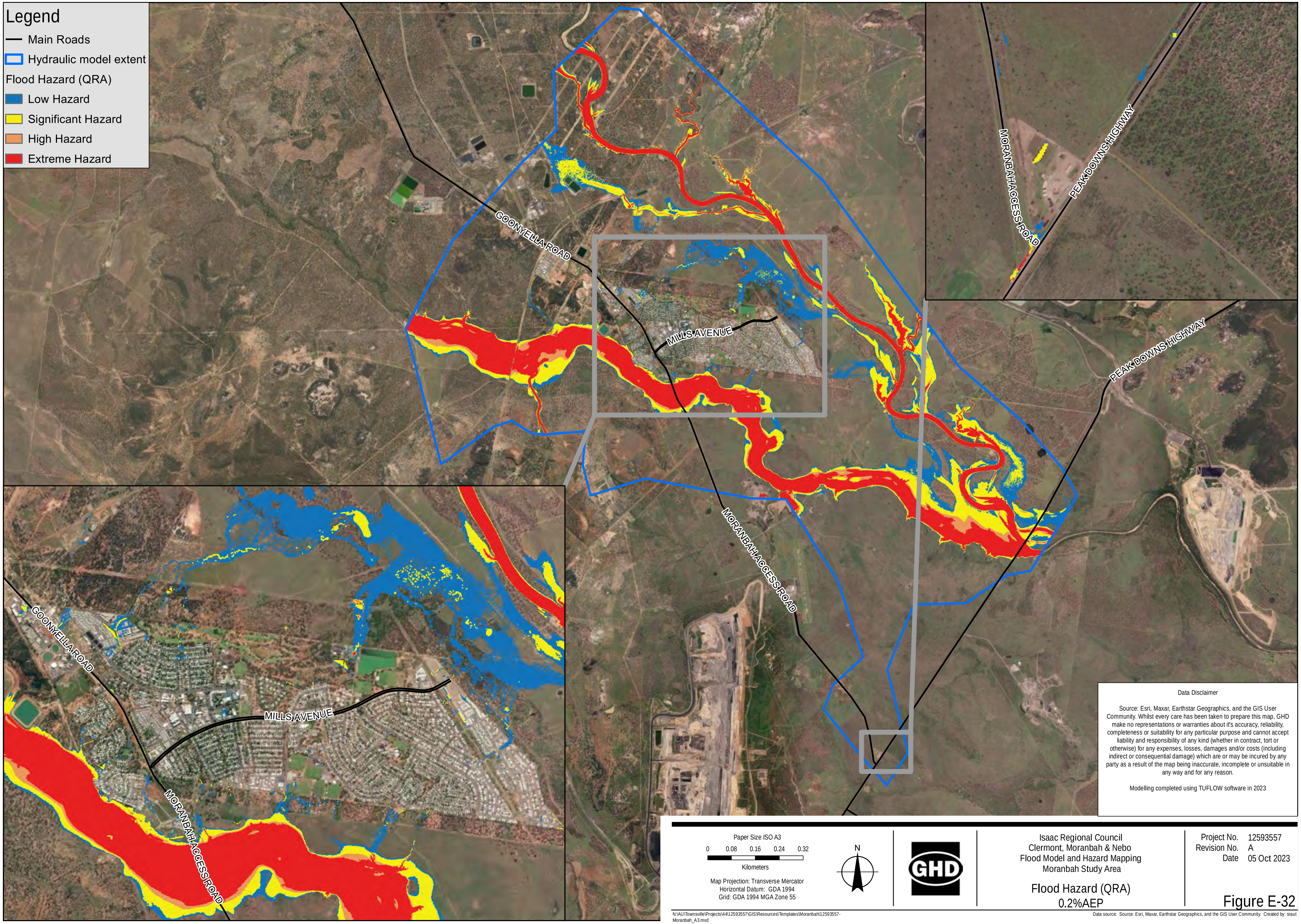
Figure E-30

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 16:22 (SMA record: 35)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



Legend
Main Roads
Hydraulic model extent
Hazard
H1 - generally safe for people, vehicles and buildings
H2 - unsafe for small vehicles
H3 - unsafe for vehicles, children and elderly
H4 - unsafe for people and vehicles
H5 - unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure
H6 - unsafe for vehicles and people. All building types considered vulnerable to failure
GOONYELLA ROAD
MILLS AVENUE
MORANBAH ACCESS ROAD
PEAK DOWNS HIGHWAY
Data Disclaimer
Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incured by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
Modelling completed using TUFLOW software in 2023
Paper Size ISO A3
0 0.08 0.16 0.24 0.32
Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55
N
Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area
Flood Hazard
0.2%AEP
Project No. 12593557
Revision No. A
Date 05 Oct 2023
Figure E-31
N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 16:26 (SMA record: 36)
Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



Data Disclaimer

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about it's accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incured by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Modelling completed using TUFLOW software in 2023

Paper Size ISO A3
0 0.08 0.16 0.24 0.32
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

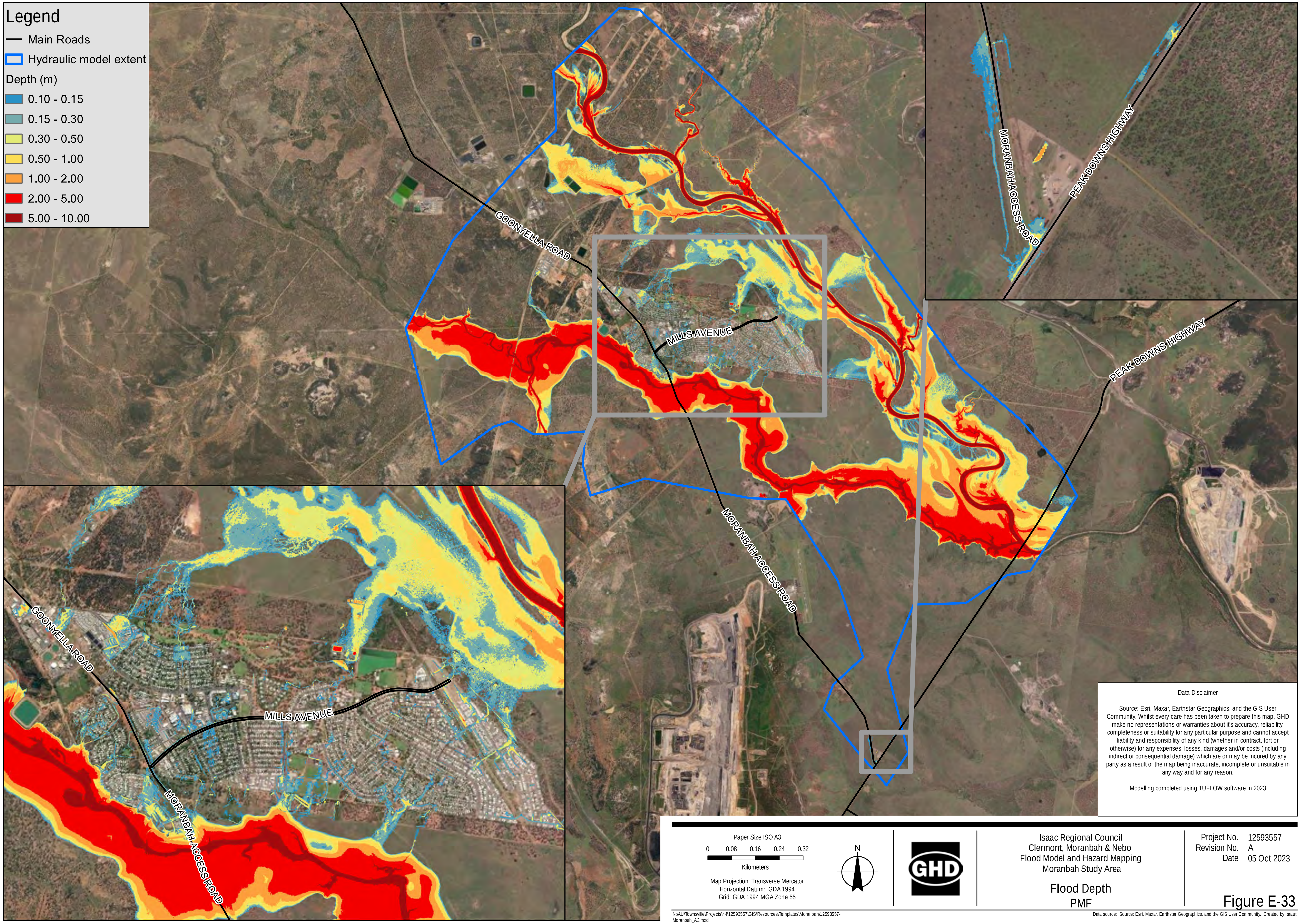
Flood Hazard (QRA)
0.2%AEP

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-32

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 16:30 (SMA record: 37)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



Data Disclaimer

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.08 0.16 0.24 0.32

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

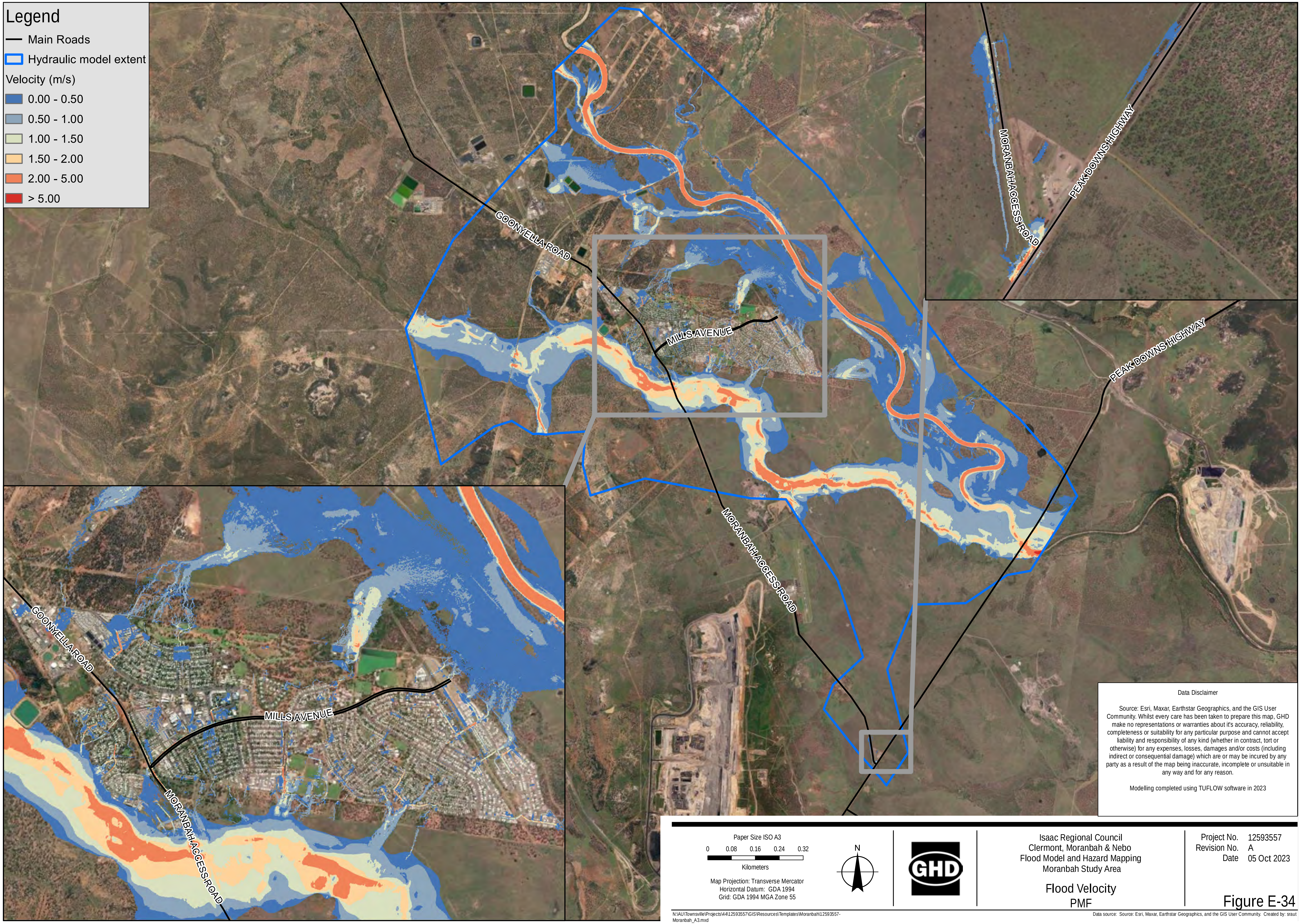
Flood Depth
PMF

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-33

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 16:33 (SMA record: 38)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



Data Disclaimer

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about it's accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incured by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Modelling completed using TUFLOW software in 2023

Paper Size ISO A3
0 0.08 0.16 0.24 0.32
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

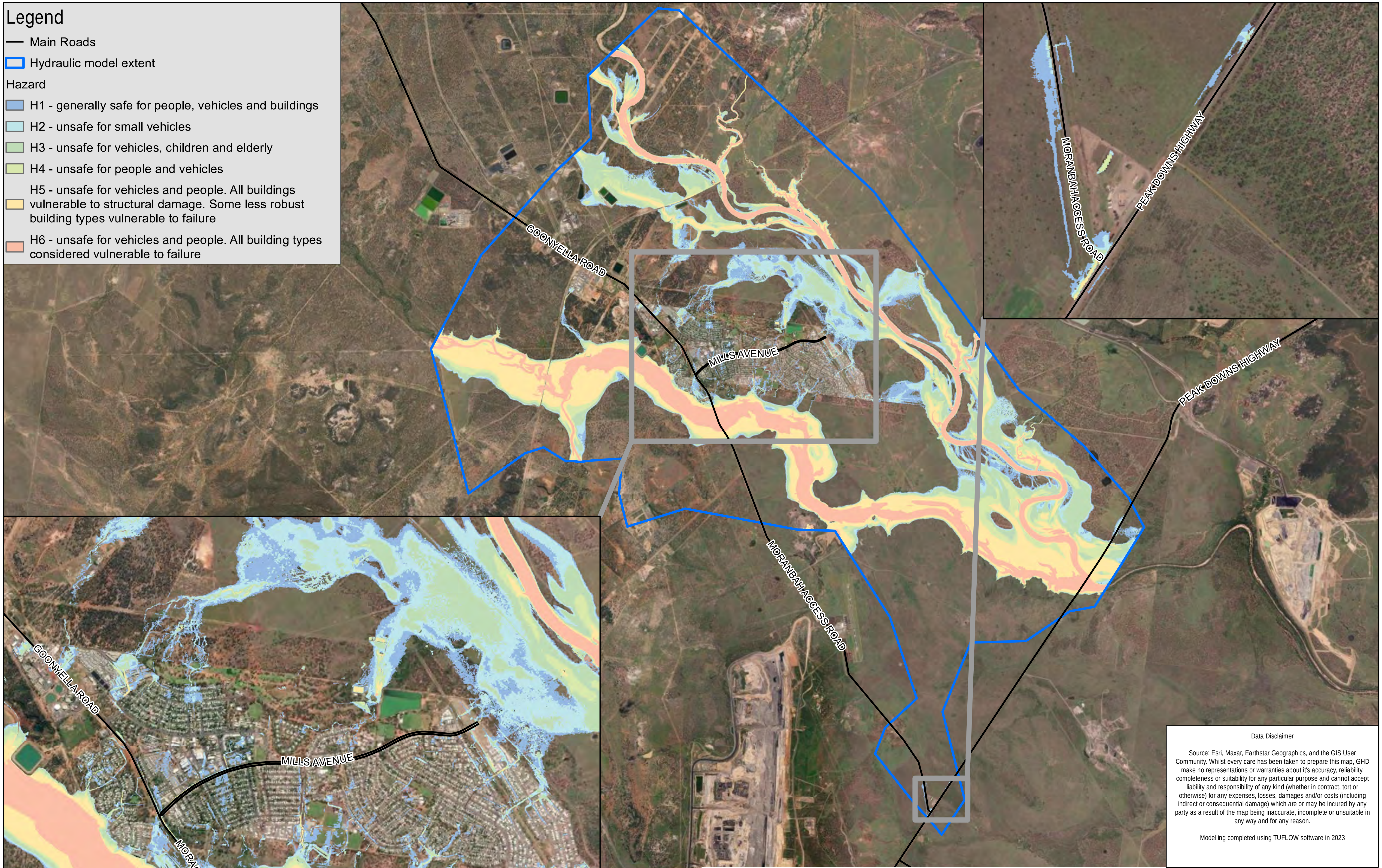
Flood Velocity
PMF

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-34

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 16:37 (SMA record: 39)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



Data Disclaimer

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Modelling completed using TUFLOW software in 2023

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

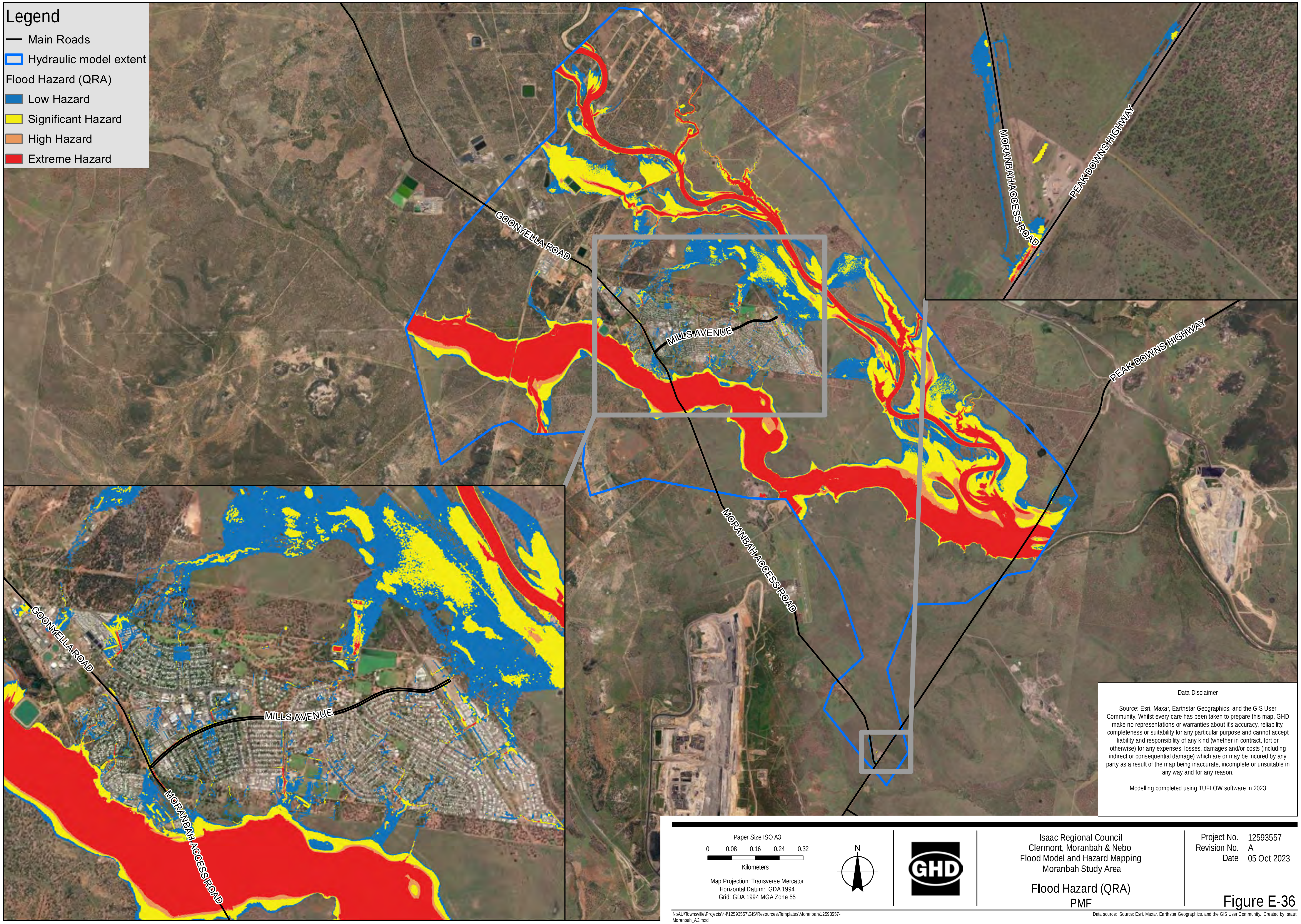
Flood Hazard
PMF

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-35

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Moranbah\12593557-Moranbah_A3.mxd
Print date: 05 Oct 2023 - 16:41 (SMA record: 40)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: sraut



Data Disclaimer

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Whilst every care has been taken to prepare this map, GHD make no representations or warranties about it's accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incured by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Modelling completed using TUFLOW software in 2023

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping
Moranbah Study Area

Flood Hazard (QRA)
PMF

Project No. 12593557
Revision No. A
Date 05 Oct 2023

Figure E-36

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Print date: 05 Oct 2023 - 16:45 (SMA record: 41)

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