River Clyde Flood Mapping Study

Central Highlands Council

18 May 2023

→ **The Power of Commitment**

Project name	River Clyde Flood Mapping Study
Document title	River Clyde Flood Mapping Study | Study
Project number	12571871
File name	12571871-GHD-XX-XX-REP-HW-0001 River Clyde Flood Study Report.docx

Status Code	**Revision**	**Author**	**Reviewer**		**Approved for issue**		
			Name	**Signature**	**Name**	**Signature**	**Date**
S4	0	K Kiseleva D Cundall	F Haynes K Williams C Ormes		E Gruber		

GHD Pty Ltd | ABN 39 008 488 373

2 Salamanca Square,

Hobart, Tasmania 7000, Australia

T +61 3 6210 0600 | **F** +61 3 8732 7046 | **E** hbamail@ghd.com | **ghd.com**

The Power of Commitment

Executive Summary

The primary objective of the project was to provide informed recommendations to better manage floodwaters which will aid in preparing the community, service providers, and emergency management responses in the event of flooding. The project aligns with the objectives of the National Disaster Risk Reduction Framework and aims to reduce the risk and increase the long-term resilience of the community against disruption or disaster arising from flood.

The flood study, modelling, and mapping included landowner and community consultation to inform the community of flood risk and gain knowledge from the community on key social and physical infrastructure that should be protected or improved in the event of flooding. This will aid in better understanding floods, preparing and responding to them. The study will also assist the council to make informed decisions regarding capital works expenditure, land use planning, and future-proofing rural communities. It will empower the community and reduce the sense of isolation and vulnerability that can be caused during floods or while waiting for flood damage to be repaired.

The project involved partnerships across the three levels of government, private landowners, and the private sector to align with the procedures of the State Emergency Services, council emergency management policies and procedures. Overall, this project will assist to build a more resilient community, build confidence and trust in the council, encourage further investment in the Bothwell township and surrounding areas, and help in better managing floodwaters.

To achieve these objectives, the project team conducted a technical investigation of flood behaviour in the Bothwell township and River Clyde catchments, analysing local flood history and available collected flood data, developing hydrologic and hydraulic models, calibrating, and verifying the models against historic flood events/gauges, and estimating the full range of flood behaviour in the study area.

The study area was focused on the Bothwell township and nearby community at Nant Lane. Potential mitigation measures have been identified for further investigation, which may assist to reduce flood risk in the study area.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.2 and the assumptions and qualifications contained throughout the Report.

Contents

Table index

Figure index

Appendices

1. Introduction

Central Highlands Regional Council (Council) has received the financial support from the Australian Government program of Department of Industry, Science, Energy and Resources (the department), to identify flood behaviour through rigorous data collection and modelling to inform investment decisions, infrastructure upgrades, industry development and community education to reduce the financial and social impacts of future flooding.

The grant application objective is to map the River Clyde flood plain in the township of Bothwell and surrounding area. The study shall provide a series of informed recommendations to better manage flood waters. This will better prepare the community, service providers and emergency management responses in the event of flooding.

1.1 Purpose of this report

The purpose of this report is to outline the works undertaken as part of the River Clyde Flood Mapping Study (the Project) including information gathered, land use planning analysis, community consultation, hydrologic analysis and natural values assessment. The assessment of flood management and mitigation options is described.

1.2 Scope and limitations

The scope of the Project included the following:

- Data Collection
- Site Investigation
- Land Use Planning Analysis
- Community Consultation
- Hydrologic & Hydraulic Analysis; and
- Natural Values Analysis.

The following limitations apply to the River Clyde Flood Mapping Project:

- The study is limited to the Bothwell township and River Clyde catchments and may not provide relevant information for other areas.
- The study is based on the available information and data, which may not be complete or accurate.
- The study is limited by the accuracy of the models used and the assumptions made during their development.
- The results of the study should be interpreted in the context of the limitations of the data and models used.
- The study may not reflect the full range of flood behaviour and potential impacts in the study area, particularly in rare and extreme flood events.
- The study includes limited implementation of flood mitigation measures, which may be necessary to reduce flood risk in the study area.

This report has been prepared by GHD for Central Highlands Council and may only be used and relied on by Central Highlands Council for the purpose agreed between GHD and Central Highlands Council as set out in section 1.1 of this report.

GHD otherwise disclaims responsibility to any person other than Central Highlands 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 subsequent to 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 7 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared the River Clyde Model ("Model") for, and for the benefit and sole use of, Central Highlands Council to support flood risk assessment 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 Central Highlands 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 Central Highlands 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.

1.3 Assumptions

Assumptions for the hydrological study of the River Clyde Flood Mapping Project are as follows:

– The flow of the River Clyde is free from significant blockages in the study area.
– The historical flood events and data collected accurately represent the flood behaviour in the study area.
– The flood mapping project assumes that historical flood events and gauges data is an accurate representation of the current flood behaviour in the study area.
– The flood mapping project assumes that no significant changes occur in the study area's physical characteristics during the study period, such as changes in land topography, land use, urbanisation, or deforestation.
– The study assumes that the data collected for the analysis is reliable and sufficient to produce accurate results.

2. Overview

2.1 Flood Study

The study was overseen and guided by Council. Other agencies were also consulted as described in the *Consultation and Engagement Summary Report* (GHD, 2023). For the full *River Clyde Flood Mapping Study Consultation and Engagement Summary* please refer to Appendix F of this report.

This project involved conducting a flood study, which is a comprehensive technical investigation of flood behaviour that provides the main technical foundation for the development of a floodplain risk assessment. It aims to provide an understanding of the full range of flood behaviour and flood hazard in the study area. It involved consideration of the local flood history, available collected flood data, and the development of hydrologic and hydraulic models. The model was verified against historic flood events and gauge data and then extended to estimate the full range of flood behaviour.

The overall project seeks to provide an understanding of, and information on, flood behaviour and associated risk to inform:

– relevant government information systems,
– government and strategic decision makers on flood risk,
– flood risk management and planning for existing and future development, and
– other key stakeholders (including utility providers and the insurance industry) on flood risk.

The outputs of the study will be able to assist by providing a better understanding of the variation in flood behaviour, flood function, flood hazard and flood risk in the study area. This will facilitate information sharing on flood risk across government and with the community.

The study focuses on the River Clyde catchment and the town of Bothwell, with a particular emphasis on the impact of development in the area and the risk of flooding. The study includes consideration of the current land uses in the catchment, the population density, and the plans for future development in the area.

2.2 Study Area

Bothwell is a town located in the Central Highlands of Tasmania. It is situated approximately 105 kilometres south-south-west of Launceston and 63 kilometres north-west of Hobart. The town is situated on the banks of the River Clyde, which is the main source of water for the town and the surrounding areas.

The major hydrological features in the River Clyde catchment area include two significant storages, Lake Sorell and Lake Crescent, River Clyde tributaries, and the various dams and irrigation infrastructure in the area.

The study area is located in the central part of the River Clyde catchment area, in the vicinity of Bothwell. The extent of the study area can be seen in Figure 1 below.

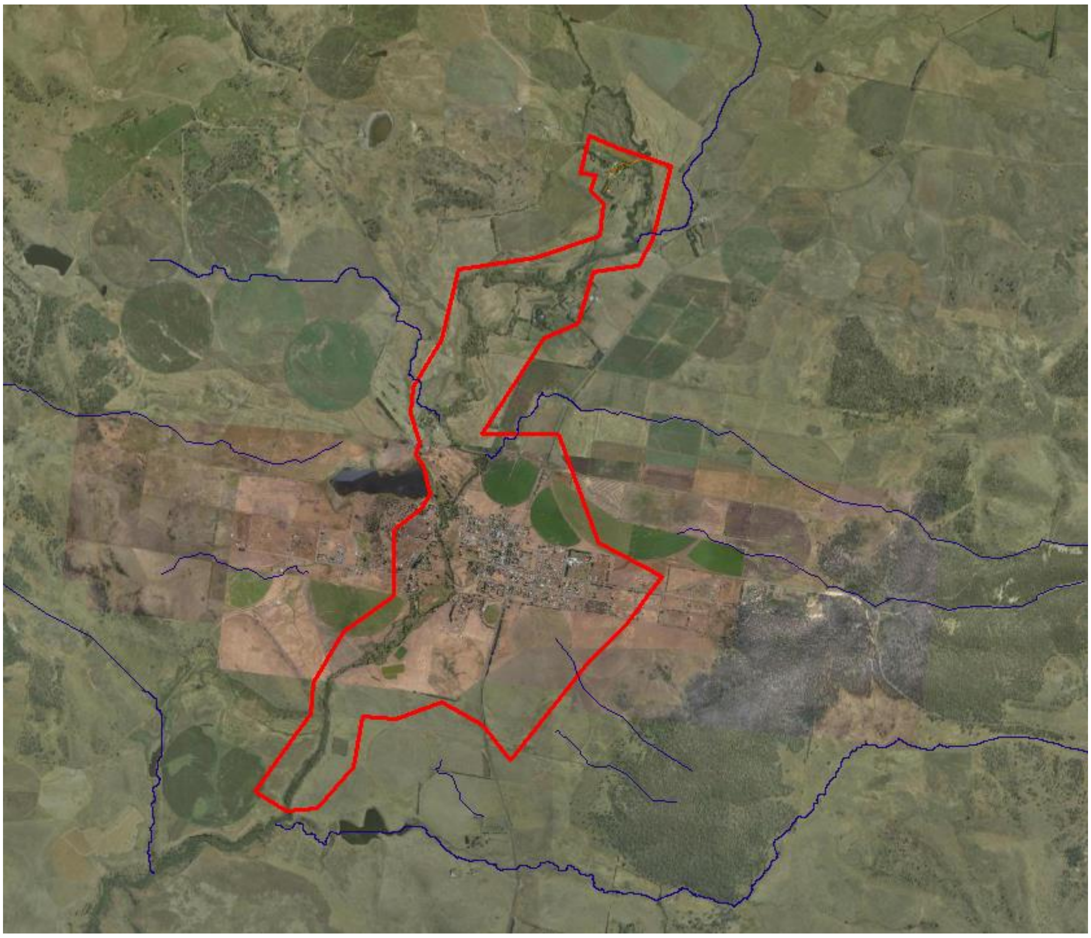


Figure 1 Flood Modelling Area

Flooding has been a major issue in the River Clyde catchment area in the past. Floods in the River Clyde catchment have had significant impacts on local communities, causing damage to infrastructure, homes, and businesses. Some of the most notable flood events in the River Clyde area include:

– 2011 floods: In January 2011, following heavy rainfall the River Clyde catchment experienced severe flooding. The floods caused widespread damage to roads, bridges, and homes, and disrupted essential services such as power and water supplies.
– 1960 floods: The 1960 floods in the River Clyde catchment were caused by heavy rainfall. The floods caused significant damage to homes and infrastructure and disrupted essential services such as power and water supplies.
– 1929 floods: The 1929 floods in the River Clyde catchment were some of the worst in Tasmanian history. The floods caused widespread damage, with the town of Bothwell being particularly affected. Homes, businesses, and bridges were destroyed, and many people were left homeless.
– 1905 flood: Between 30th and 31st of May, floods were recorded at Bothwell, River Clyde;
– 1903 flood: Between 8th and 9th of June, there is heavy flooding in the Clyde and Lachlan rivers. Much of the country around Bothwell, Ratho, and Hamilton is inundated.
– 1901 flood: On 28th of October, the River Clyde floods at Bothwell.
– 1880 flood: between 2nd and 4th of August, flooding about southern Tasmania. At Bothwell, the River Clyde was reported to be at its highest level for some years.
– 1869 flood: January 25th, streets flooded in Bothwell.

The River Clyde catchment area is approximately 1,200 square km in size. The catchment includes the River Clyde, its tributaries, and several lakes and dams. The topography of the headwaters of River Clyde flow from unglaciated dolerite plateau through the rolling hills and gentle valleys of the midlands. The soils in the area are predominantly deep and fertile, making them ideal for agriculture and other forms of land use.

There are several features that influence flooding in the River Clyde catchment area. These include the high rainfall in the area, the steep terrain, and the narrow valleys that can cause rapid runoff and flash flooding. Additionally, the flat floodplain areas are vulnerable to overflow during periods of heavy rainfall.

Development in the River Clyde catchment area is relatively sparse, with most of the land being used for agriculture or other forms of rural land use. However, there is some development pressure in the area, particularly in the town of Bothwell, where land has been zoned for residential and business purposes. This development pressure is significant as it could impact the natural hydrological systems in the area and increase the risk of damage or harm from flooding.

There are also several flood-dependent ecosystems in the River Clyde catchment area, including wetlands, which play an important role in reducing the impact of flooding by providing areas for water to accumulate and be slowly released. The preservation of these ecosystems is crucial for reducing the risk of flooding in the catchment area.

The River Clyde catchment area and the town of Bothwell are managed by the Central Highlands Council. The catchment is also under the jurisdiction of the River Clyde Trust, which was formed following an Act of Parliament initially passed in 1857. The River Clyde Trust works closely with the local council and other stakeholders to ensure that the area is managed in a sustainable manner.

The population of the River Clyde catchment area is relatively small, with the majority of residents living in the town of Bothwell.

The land uses in the River Clyde catchment area are primarily agricultural, with the majority of the land being used for farming and grazing. There are also some areas of forest and conservation land in the catchment. In the town of Bothwell, there is a mix of residential and commercial land use, with some areas designated for industrial use.

The flood behaviour in the River Clyde catchment area and the town of Bothwell is primarily riverine in nature. The catchment responds rapidly to rainfall, with flash flooding often occurring in the steep upper sections and narrow valleys. The flooding duration can range from a few hours to several days, depending on the severity of the event.

There are several flooding hot spots in the study area, particularly in the town of Bothwell and in low-lying areas near the River Clyde. These areas are subject to riverine flooding during periods of heavy rainfall.

Exacerbating factors for flooding in the study area include blockages in the River Clyde and its tributaries, antecedent conditions, and natural or constructed hydraulic controls, including dams and bridges. Tributary flooding can also coincide with riverine flooding, leading to increased water levels and flood risk in the catchment.

Frequently inundated areas in the catchment include low-lying farmland near the River Clyde, and areas in the town of Bothwell close to the river and its tributaries.

3. Data Collection

Data and information available from previous studies/flood events has been collated and examined. A search for any additional relevant data was performed. A summary of the sources of available data and relevance to the project is included below.

3.1 Sources of Data

The River Clyde catchment area has some history of hydrological data collection, with a variety of data sources available for modelling purposes. Some of the available data includes:

– Hydrological data: This includes daily rainfall data, streamflow data collected by the Bureau of Meteorology and the Department of Primary Industries, Parks, Water, and Environment.
– Geographical data: This includes topographical data, such as digital elevation models, land use maps, and soil type maps. These data are used to support the development of hydrological models and to understand the impact of land use on the catchment.
– Climate data: Climate data, such as daily temperature and rainfall data, are used to understand the climatic patterns in the catchment and to support the development of climate models.
– Management strategies: There is a Draft Amended River Clyde Water Management Plan 2017 (Altering the River Clyde Water Management Plan 2005) available for the River Clyde catchment. This strategy provides a policy relating to preserving water in extreme climatic conditions for environmental, economic and social needs and catchment management strategies.
– Flood history: There is some historical data available on flooding in the River Clyde catchment, including information on flood events, flood damage, and flood management strategies.
– Previous studies: This data is used to support the development of hydraulic models.

The available and compiled data is summarised below, along with organisations and relevant contacts.

Table 1 Summary of previous studies

Study name	Description (one paragraph summary)	Author	Year	Accessible
Stormwater Infrastructure Survey and Assessment of The Bothwell Township for Central Highlands Council	The Central Highlands Council required a Stormwater System Management Plan for the Town of Bothwell. There were no records of existing stormwater infrastructure in Bothwell. The project consultant was required to carry out works in two stages. In Stage A, PDA Surveyors located and surveyed existing stormwater infrastructure, prepared a GIS map of the urban area, reviewed flood studies and mapped stormwater catchments. In Stage B, PDA Surveyors liaised with Council staff, analysed infrastructure in critical areas, and prepared a concept design and construction estimates for proposed upgrading.	PDA Surveyors	2019	Electronic copy of the DRAINS model and report provided by Council
Tasmanian Strategic Flood Map Hydrology Methods Tasmanian Strategic Flood Map Hydrodynamic Methods	The Tasmanian Strategic Flood Mapping Project aimed to help flood-affected communities recover from the 2016 floods by improving the understanding of flood behaviour and increasing the resilience of Tasmanian communities to future floods. The project had targeted outcomes of ensuring that post-flood recovery is informed by updated flood risk information, allocating ownership of flood risk appropriately, enabling flood risk to be included in investment decisions, and allocating responsibility for flood mitigation costs appropriately. The state-wide Strategic Flood Maps are being developed to support flood risk assessment and post-event analysis using	WMA Water	2021	https://d2kpbjo3hey01t.cloudfront.net/uploads/2022/02/Tasmanian-Flood-Map-Project-Hydrology-Methods-Report.pdf https://d2kpbjo3hey01t.cloudfront.net/uploads/2022/03/Hydrodynamic-methods-report-Aug-21.pdf

Study name	Description (one paragraph summary)	Author	Year	Accessible
	the Innovyze ICM software platform, with hydrologic modelling methods developed in two platforms – WMA water's in-house RAFTS modelling framework and ICM. An established, automated approach using the external hydrologic model enabled the efficient calibration of the state-wide hydrologic models. Historical rainfall data were used to calibrate the hydrologic model, and catchment average initial and continuing loss values were calibrated at gauged sites.			
Derwent Catchment Review	Several organisations and agencies initiated the Derwent Catchment Technical Review project to manage water quality and quantity in the Derwent catchment. Previous reviews of water quality issues were integrated with contemporary datasets from the entire catchment to develop conceptual models. The project focused on reviewing existing water quality and stream-flow datasets to identify stressors, data gaps, and requirements for additional monitoring. Conceptual models were developed for waterways impacted by regulation and those with no modification to flow regime. The major outcomes were to assess the adequacy of existing monitoring, identify emergent water quality issues and provide recommendations for an integrated monitoring program for stakeholders.	TasWater Consulting Pty	2011	https://www.derwentestuary.org.au/assets/Derwent_Catchment_Review_2011_Part1.pdf

Table 2 Available and compiled existing data

Data type	Description	Source/agency	Year	Accessible
Historic flood information	TasMap 1:13,542	Thelist.tas.gov.au TASMAP	NA	https://maps.thelist.tas.gov.au/listmap/app/list/map
Hydrologic data Stream water level gauge	Station number: 54.1 Latitude: -42.38 Longitude: 147.00 Number of years: 44.10	TAS - Department of Primary Industries, Parks, Water and Environment		http://www.bom.gov.au/waterdata/
Survey data (Imagery/topographic DEMs)	Aerometrex was commissioned by Department of Primary Industries, Parks, Water and Environment DPIPWE to provide LiDAR coverage over Central Highlands. This project was flown in conjunction with other projects in the region. UDM was commissioned by Council to capture an imagery of high flow of River Clyde.	Derwent Valley 2019_DEM_1m_GDA2020_55 Imagery was obtained on 31 October 2022	2019 2022	https://elevation.fsdf.org.au/
GIS layers	The list databases, including building polygons, road polygons, land use etc.	TheList.tas.gov.com.au		https://maps.thelist.tas.gov.au/listmap/app/list/map

Table 3 Organisations with relevant existing data

Agency/office	Relevant contacts – name, email, phone	Comments
Bureau of Meteorology	Ann Conroy, ann.conroy@bom.gov.au	Rainfall data
SES Tasmania	Lynley Hocking, Lynley.Hocking@ses.tas.gov.au	SES Manning's data

3.2 Digital Elevation Model (DEM) Data

The Digital Elevation Model (DEM) with a 1m resolution was a crucial component of the project area to determine the elevation and bathymetry data. The data was obtained through a cloud-based system called Elvis Elevation and Depth, which provided quick and easy access to the DEM. The DEM was represented as a continuous surface of elevation values using a regular array of z-values, which were referenced to the GDA 2020 Zone 55 datum. The representation was in the form of a grid or raster data set, which made it possible to visualize the topographic surface.

However, the DEM only represented the ground surface and excluded features such as vegetation, trees, shrubs, and human-constructed features like sheds and houses. A high-level review of the original 1m DEM was carried out to ensure that the data quality was sufficient for the flood modelling process. The review was done to identify areas that could cause issues in the modelling process, but the data was found to be of sufficient quality to support the project's objectives.

3.3 Manning's n Data

The State Emergency Service (SES) has provided a statewide Manning's 'n' layer. The data was supplied in a raster format and is based on the methodology outlined in the *Statewide Manning's Layer DocumentationV2.docx*. This documentation outlines the process used to determine the suggested Manning's 'n' values, which were ultimately adopted for the project. The results of this process are presented in Table 4. The data was reviewed and found appropriate for use from both technical and consistency aspects. Adoption of this data has also allowed the modelling team to spend additional time in other aspects of the model without loss of accuracy.

Table 4 Surface-type classes with suggested Manning's-n values

ID	Group	n_2	DESCRIPTION
1	Rural&Forested	0.020	mown or well grazed 0.05 stubble and low undulations
2	Rural&Forested	0.030	mixed areas of slashed/grazed grassland with some shrubs and/or taller grass clumps
3	Rural&Forested	0.040	tall stiff grass with significant areas of clumped shrubs
5	Rural&Forested	0.050	moderate density little underbrush typically easy to walk thru off track
7	Rural&Forested	0.100	High density substantial underbrush and fallen limbs typically cannot walk thru off track
8	Rural&Forested	0.050	Low density mod height shrubs foliage from ground some gaps between
11	Roads	0.020	roads/parking areas - mostly free of parked vehicles
12	Roads	0.035	roads/parking areas - significant number of parked vehicles present
13	Roads	0.035	roads/parking areas - roads with side veg swales - few parked vehicles
16	Residential	0.050	low density typically large blocks with small dwelling footprint significant grassed yard and open fences
17	Residential	0.100	average density some solid fences

ID	Group	n_2	DESCRIPTION
18	Residential	0.200	typically, smaller blocks with large dwelling footprint small yards and frequent solid fences
19	Residential	0.150	where dwelling is modelled as a solid - mostly solid fences perpendicular to flow
23	Commercial	0.100	small building footprint significant paving mostly permeable fences
26	Commercial	0.150	where building is modelled as solid - Stored matl/cars and mostly solid fences perp to flow
27	Commercial	0.040	where building is modelled as solid - mostly free of solid fences and stored matl/cars
28	Industrial	0.050	low density small building footprint significant paving and permeable fences
29	Industrial	0.100	average density 30% footprint some solid fences
34	Waterways	0.011	concrete lined channel
35	Waterways	0.013	flat variable grade sandy bed low undulations no instream vegetation - typically estuary and/or lake
37	Waterways	0.035	uniform bed grade and section little instream vegetation
47	Miscellaneous	1.000	nom 1% permeability modelled as n =100*0.100

3.4 Structures Data

The infrastructure data set was obtained from the PDA Surveyors DRAINS model which was conducted in 2019. The DRAINS data included information about the pipes, pits, manholes, and culvert inlets/outlets in the Bothwell township. The extracted data was then transferred into a GIS data set and imported into InfoWorks ICM.

After a thorough evaluation, the data was found to be of sufficient quality to support the desired analysis and modelling needs.

This data set provided the invert level and pipe diameters of the various pipes and other infrastructure components. Additionally, the data also included important information such as the location, type, and material of the pipes, pits, manholes, and culvert inlets/outlets. This data set is crucial in providing a comprehensive understanding of the drainage infrastructure in the Bothwell township. The invert level and pipe diameter information were used in determining the flow capacity and hydraulic performance of the drainage system.

3.5 Initial and Continuing Losses

In hydrology, initial losses (IL) and continuing losses (CL) are two important parameters used in the rainfall-runoff modelling process. Initial losses represent the amount of rainfall that is lost to infiltration and evaporation before any runoff is generated, while continuing losses represent the amount of water that is lost due to evapotranspiration after runoff has begun. In this study, the initial and continuing losses were extracted from the ARR 2019 data hub and adopted for the modelling process. Table 5**Error! Reference source not found.** provides the values of initial and continuing losses for each sub-catchment in the study area. These values were used in the RAFTS runoff-routing model to simulate the runoff generation process and estimate the flow volumes and peak flows for different rainfall events.

Table 5 Initial and Continuing Losses

Land Use	IL (mm)	CL (mm/h)
Impervious	0.0	0.0
Low Density Residential	8.9	3.9
Environmental Management	8.9	3.9
Significant Agricultural	8.9	3.9
Rural Resources	19.9	4.9

Land Use	IL (mm)	CL (mm/h)
Rural Living	0.0	0.0
Community Purpose	8.9	3.9
Village	8.9	3.9
Open Space	19.9	4.9
Recreation	19.9	4.9
Utilities	0.0	0.0

3.6 Building Footprints

In the development of the hydraulic model for this project, the buildings within the study area were not raised on the DEM. This is because the focus was on identifying the areas that are most at risk of flooding and developing appropriate mitigation strategies rather than on accurately modelling every building within the study area rather than introducing a solid obstruction to the flow of water and therefore significantly alter the velocity and direction of the water.

However, it is important to note that the increased height of the buildings can have an impact on flood behaviour. Specifically, the increased height of the buildings can cause an increase in the floodplain extent, meaning that more areas will be affected by floodwaters. Additionally, the increased height of the buildings may also lead to changes in the water depth at specific locations, which can impact the severity of the flood in those areas. Therefore, while the buildings were not raised on the DEM for the purposes of the hydraulic model development, it is important to consider the potential impact of the buildings on flood behaviour and to incorporate this information into any flood mitigation strategies developed as a result of this project.

3.7 Site Visits

During the initial stages of any project, it was critical to gain a comprehensive understanding of the study area. The project team undertook a field inspection of the study area to gain an understanding of the catchment and floodplain features that may influence flood behaviour. This included topography, land use, vegetation cover, and watercourses. The aim of this familiarisation exercise was to identify potential sources of flooding, such as low-lying areas, drainage systems, and infrastructure that could exacerbate flood risk.

In addition, the project team liaised with the local council and landowners to gain a better understanding of flood behaviour, existing flood mitigation controls, and how they operate. This included a visit to Thorpe Farm, where the team liaised with the landowner to understand the current flood mitigation measures in place. This included levees, flood walls, drainage systems, and other infrastructure that is designed to manage flood risk.

The findings from the field inspection and familiarisation exercise informed the development of the hydrologic and hydraulic model. This model enabled the project team to simulate flood behaviour under different scenarios and identify potential interventions that could mitigate flood risk. By incorporating data on existing flood mitigation measures into the model, the team was able to determine the effectiveness of these measures and identify areas for improvement.

Overall, undertaking a field inspection and familiarisation exercise was crucial in the initial stages of a flood management project. It enabled the project team to gain a comprehensive understanding of the study area and identify potential sources of flooding. Incorporating data on existing flood mitigation measures into the hydrologic model enabled the team to determine the effectiveness of these measures and identify opportunities for improvement.

4. Flood Model

4.1 Model Setup

4.1.1 InfoWorks ICM

The hydraulic model was set up using the InfoWorks ICM 2023.1.

InfoWorks ICM is a powerful hydraulic modelling software tool that is widely used in the water industry. It is reasonably user-friendly, and its features enable users to create accurate hydraulic models of complex stormwater systems. The latest version, InfoWorks ICM 2023.1, has several enhancements, including improved modelling of urban network, better visualization of model results, and a more user-friendly interface.

Setting up the hydraulic model using InfoWorks ICM 2023.1 involved creating a digital representation of the stormwater system, defining the hydraulic characteristics of the system components, and running simulations to analyse system behaviour under different scenarios. This included analysing the impact of rainfall events on flood risk.

One of the key advantages of using InfoWorks ICM is its ability to integrate with other software tools, enabling users to import and export data from other sources, including GIS software, AutoCAD and other hydraulic modelling software. This integration makes it easier for users to incorporate different data sources into the model and ensures that the model reflects the most up-to-date information about the stormwater system.

4.1.2 RAFTS Hydrology

The RAFTS model is an ideal choice for the rainfall-runoff modelling required for this project. This non-linear runoff-routing model has been extensively used throughout Australia and has been found to be suitable for both rural and urban catchments. The model works by dividing each sub-catchment into pervious and impervious portions, each of which is treated as a cascading non-linear storage unit with a specific relationship. The sub-catchment parameters for the RAFTS model are inputted by specifying different land use types and their associated surface runoff types. This allows for the model to account for the varying levels of infiltration and runoff depending on the type of land use within the catchment. By using this model, we can accurately simulate the movement of rainfall through the catchment, and how it is transformed into surface runoff, groundwater recharge, and evaporation. The results of this modelling will be critical in assessing the flood risk within the study area and developing appropriate mitigation measures.

4.1.2.1 Catchment Delineation

Catchment delineation is a key step in hydrological modelling as it involves identifying the boundaries of the catchment areas that drain water to a specific point. In this case, the digital elevation model (DEM) data was used to perform catchment delineation using ArcMap software's Hydrology toolset. This toolset is a mathematical algorithm that uses ground elevations and slopes to estimate flow path lengths, directions, and sub-catchment boundaries.

The results of the catchment delineation are presented in Table 6, which shows the catchment areas and slope for each catchment. The sub-catchment boundaries resulting from the application of the ArcMap Hydrology toolset are shown in Figure 2. However, the additional manual checks and reviews of the catchment boundaries were carried out during hydraulic model development to verify ArcMap's delineation and to identify any connections to additional sub-catchments through cross-drainage structures.

Hydraulic modelling involves simulating water movement in a catchment area, and accurate catchment delineation is crucial in developing a reliable hydraulic model. The verification of the catchment boundaries through manual checks and reviews helps to ensure that the hydraulic model accurately represents the catchment's actual characteristics. This further enhances the reliability and accuracy of the model, and ultimately the flood risk assessment or management plan that is based on it.

Table 6 Catchment area and slope

Catchment ID	Area (ha)	Slope (m/m)
1	555	0.044
213	4136	0.117
211	1077	0.117
3	6052	0.426
4	2257	0.117
5	8017	0.088
6	5101	0.290
7	28	0.012
8	87	0.068
9	218	0.056
10	314	0.038
212	617	0.041
12	99	0.043
214	492	0.006
215	855	0.006
216	5525	0.076
16	6552	0.111
17	3873	0.140
18	2488	0.033
19	7385	0.192
20	4507	0.231
21	9477	0.176

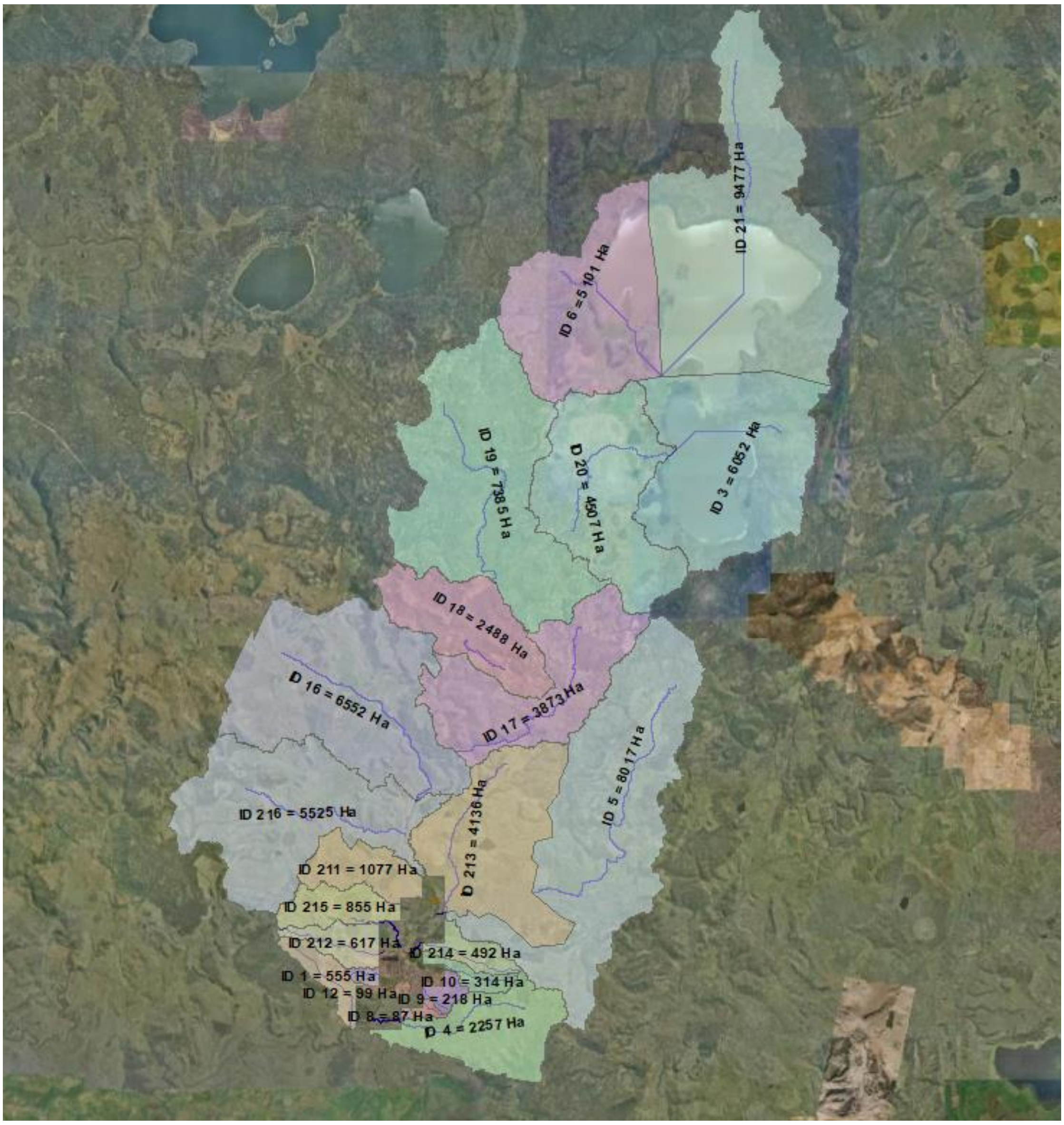


Figure 2 Sub-catchment delineation map

The outflows from the Hydrology model flow directly into the Hydaulic model (refer section 4.1.3 below).

4.1.3 Hydraulic Model

4.1.3.1 Topography

In order to develop an accurate hydraulic model, it is essential to have an accurate representation of the topography of the study area. A Digital Elevation Model (DEM) is a widely used tool for creating a detailed representation of the terrain. In this case, a 1m DEM was adopted to develop the baseline topography for the InfoWorks ICM model.

The review of Elvis's DEM has highlighted no issues within the study area, indicating that the data is of high quality and suitable for use in developing the hydraulic model. This is crucial because any errors or inaccuracies in the topography data could have a significant impact on the model's accuracy and reliability.

The topography within the agreed project area is represented as a 2D element mesh model. The mesh is a set of interconnected elements that represent the terrain's surface in a digital format. Water flows according to the hydraulic properties of the land surface, as defined by the 2D topography and roughness. The roughness values are assigned to the mesh elements to represent the land surface's resistance to flow, which affects the velocity and direction of water movement.

By adopting a high-quality DEM data and creating an accurate 2D topography model, the hydraulic model can accurately simulate the water movement in the study area. This enables the development of effective flood management strategies and decision-making processes based on reliable data.

4.1.3.2 Mesh Size

To accurately simulate the behaviour of water in the study area, the project team has decided to apply the rain on grid model to the 2D mesh within the agreed project area. The 2D mesh of elements provides a more detailed overland flow analysis and is generated using the Shewchuk Triangle meshing functionality. Heights at the vertices of the generated mesh elements are calculated by interpolation from the ground model by Elvis DEM. This approach applies rainfall directly to each cell of the 2D mesh model, and after losses are accounted for, the excess rainfall becomes runoff and is routed over 2D surfaces per 2D zone settings.

The 2D surface runoff can flow out of 2D zone boundaries or be captured by 1D elements to enter 1D networks. The InfoWorks ICM software allows for a varying mesh size, and the project team has incorporated mesh sizes ranging from 100 m^2 to 50 m^2 for the model base, and 25 m^2 to 5 m^2 for Township Bothwell and Nant Lane. The proposed mesh cell size is considered suitable to properly represent all the key topographic and land use features of the study area, without significantly impacting the expected simulation run times.

The use of the rain on grid model in the 2D mesh allows for a more accurate representation of how rainfall and runoff behave in the study area, taking into account the land surface's hydraulic properties and roughness values. By applying rainfall directly to each cell of the 2D mesh model, the model can account for spatial variability in rainfall and simulate the movement of runoff over the terrain's surface. The incorporation of varying mesh size ensures that key features are captured within the model, providing a more accurate representation of the study area's behaviour.

Figure 3 ***Example of various mesh elements within the project area***

4.1.3.3 Linear Infrastructure

Linear Infrastructure (pits, pipes, and channels) have been modelled as 1D elements coupled to the 2D hydraulic model. This approach allows flow interchanges between the 1D open channels and underground pipelines and the 2D surface. The hydraulic model elements are shown in Figure 4 - Figure 7.

The 1D conduit network model is used to simulate the hydraulic processes in the stormwater network. The network has been developed to a high level of detail and includes the stormwater drainage conduits, pipes, manholes and pits in the project area that could be identified from the PDA Surveyors DRAINS model provided by Council.

Figure 4 ***Bothwell Township***

Figure 5 ***Bothwell Bridge***

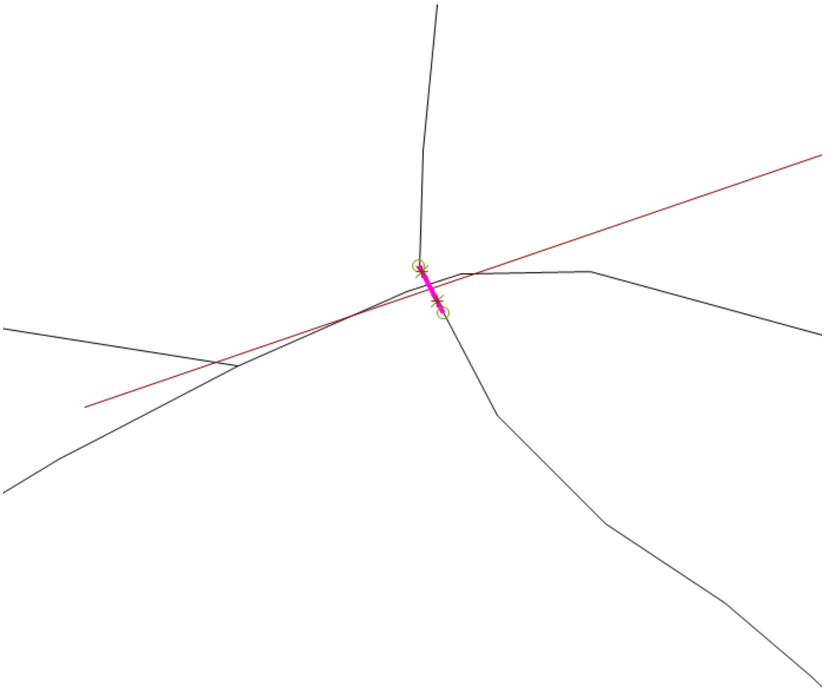


Figure 6 Nant Lane Bridge

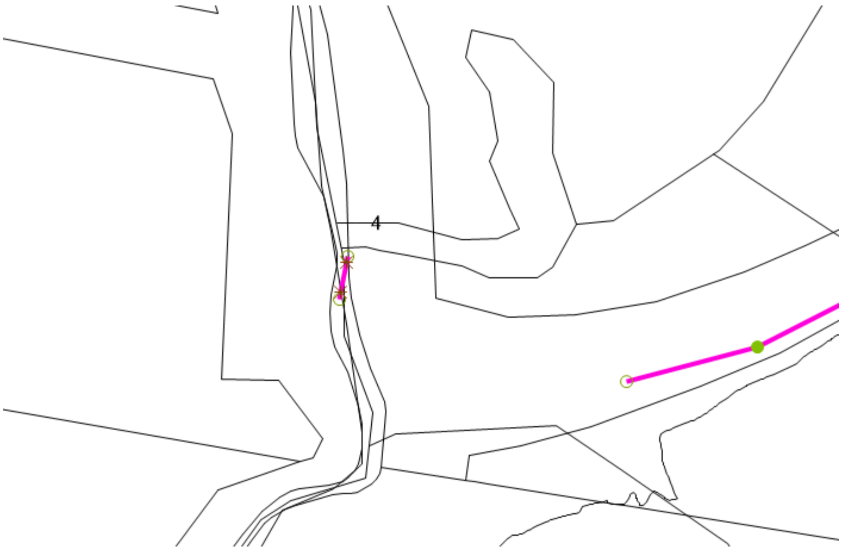


Figure 7 Arthur Crescent Bridge

4.1.4 Model Domain Linkages

The River Clyde hydraulic model is a complex system used to simulate the flow of water in the urban and rural domain of River Clyde catchments. It consists of three different model domains, each with their own unique characteristics and properties. The first domain is the 1D conduit network, which includes a network of pipes and conduits that carry water through the system. The second domain is the 1D sub-catchment network, that collect water from the surrounding area and feed it into the 1D conduit network and 2D surface of the model. The third domain is the 2D surface, which represents the surface of the river and the surrounding area.

In this model, flow is transferred between all three domains in all directions, allowing for a comprehensive understanding of how water moves through the system. To model the connections between the conduit network and the open channel, an approach called 'Outlet 2D' is used, which specifies the conduit diameter as the width and height. This method allows the model to convey water between a conduit invert and open channel bed level while remaining stable.

When the conduit network discharges directly into the upstream end of a 1D channel network, a 2D node is used to connect the downstream end of the conduit link to the upstream end of the open channel. In this case, flow across 'Outfall 2D' nodes are calculated using a vortex control with a nominal head discharge relationship.

Finally, when a node is located beneath a road, the nodes 'Flood Type' is set to 'Sealed', preventing the exchange of flow between the 2D model and the 1D pipe network. This allows the model to accurately simulate the effects of road infrastructure on water flow and to predict potential flooding in these areas.

4.2 Design Event Simulations

As per the agreed scope of work, we simulated 1% and 5% AEP events in the hydraulic analysis. The study primarily focused on the overland flow paths, and therefore, the design event analysis was initially focused on durations ranging from 15 minutes to 36 hours. In accordance with the ARR 2019 guidelines, we ran ten temporal patterns per each duration in the hydraulic model. This approach allowed us to account for the variability in rainfall distribution that may occur during a storm event and ensure that the temporal patterns used in the analysis were appropriate for the specific catchments being studied.

Based on the results of this analysis, the critical duration for the area was determined to be a 6-hour storm, with the 6^{th} and 2^{nd} temporal patterns identified as the critical temporal patterns. This information is necessary in developing an effective flood mitigation strategy for the area, as it enables to design infrastructure that can handle the maximum amount of runoff that may occur during a 6-hour storm event. By following the guidelines set out in the ARR 2019 and using a range of temporal patterns in the hydraulic model, we were able to develop an accurate analysis of the catchment's response to rainfall.

The flood inundation extents and depths for 1% and 5% AEP is shown in Appendix A (at the time of peak flood level).

4.3 Sensitivity Tests

The sensitivity tests aimed at estimating the effects of the model parameters on the computed flood levels was performed on the single probability (5% AEP) design event only.

The sensitivity tests on model parameters were performed on one (1) selected critical duration and one (1) selected temporal pattern. The selected critical duration and temporal pattern was 5% AEP 6 hour 2.

As per our proposal, we carried out sensitivity tests on the following model parameters:

– Manning's roughness coefficients: an increase/decrease of ± 20% in the Manning's 'n' roughness coefficients of the hydraulic model.

The initial (IL) and continuing (CL) losses adopted for this study and provided in Table 5**Error! Reference source not found.**.

Table 7 ± 20% in the Manning's 'n' roughness coefficients

(ID) Land-use category	Roughness coefficients	Manning's 'n' roughness +20%	Manning's 'n' roughness -20%
1 Rural&Forested	0.020	0.024	0.016
2 Rural&Forested	0.030	0.036	0.024
3 Rural&Forested	0.040	0.048	0.032
5 Rural&Forested	0.050	0.060	0.040
7 Rural&Forested	0.100	0.120	0.080
8 Rural&Forested	0.050	0.060	0.040

(ID) Land-use category	Roughness coefficients	Manning’s ‘n’ roughness +20%	Manning’s ‘n’ roughness -20%
11 Roads	0.020	0.024	0.016
12 Roads	0.035	0.042	0.028
13 Roads	0.020	0.024	0.016
16 Residential	0.030	0.036	0.024
17 Residential	0.040	0.048	0.032
18 Residential	0.050	0.060	0.040
19 Residential	0.100	0.120	0.080
23 Commercial	0.050	0.060	0.040
26 Commercial	0.020	0.024	0.016
27 Commercial	0.035	0.042	0.028
28 Industrial	0.035	0.042	0.028
29 Industrial	0.050	0.060	0.040
34 Waterways	0.100	0.120	0.080
35 Waterways	0.200	0.240	0.160
37 Waterways	0.150	0.180	0.120
47 Miscellaneous	0.100	0.120	0.080

The sensitivity of flood levels to changes in surface Manning's n appeared to be insignificant. The primary reason the flood levels are not significantly different despite the increase/decrease in Manning's n by 20% is due to the rural nature of the model area.

The flood inundation extents and depths for 5% AEP Sensitivity tests are shown in Appendix B (at the time of peak flood level).

4.4 Climate Change

Over the past few decades, global warming has been observed and linked to alterations in the large-scale hydrological cycle, such as changes in atmospheric water vapor content, precipitation patterns, intensity, and extremes, variations in soil moisture and runoff, and an increase in melting snow and ice (Bates et al., 2008). It is increasingly apparent that climate change induced by humans is impacting precipitation extremes and has caused a rise in extreme flooding on a global scale during the 20th century (Trenberth, 2011). The IPCC (2007) and Bates et al. (2008) have reported that these changes in the hydrological cycle will result in more variability in precipitation and increased occurrence of flood events in many areas. The effects of climate change on flooding will influence the intensity, duration, timing, spatial extent, and frequency of extreme weather and climate events, possibly leading to unprecedented events (IPCC, 2012).

In order to assess the impact of climate change on flooding within River Clyde catchments, a simulation was performed using a specific climate change scenario. The scenario involved increasing rainfall intensities due to one selected projection horizon and one gas emission scenario. Specifically, the simulation was carried out with the following parameters: a projection horizon of the year 2090, a gas emission scenario of Representative Concentration Pathway (RCP) of 8.5 (which represents a 16.3% increase), and the application of an increase in rainfall intensity induced by climate change to the 1% AEP scenario. To obtain the necessary climate change factors for the simulation, data was downloaded from the ARR 2019 data hub. These types of simulations are necessary in order to fully understand the potential impact of climate change on flooding, including changes in rainfall intensity, frequency, and duration.

The flood inundation extents and depths for 1% AEP Climate Change is shown in Appendix C (at the time of peak flood level).

4.5 Model Validation

The hydraulic model used for the River Clyde system was validated against historical flood events for which records exist, such as flood extents and impacted properties. This validation process involved adjusting key model parameters, such as Manning's 'n' roughness coefficient and loss rates, within acceptable limits to achieve a level of agreement between the modelled and observed behaviour. To ensure the robustness of the model, a sensitivity analysis on key model parameters was also undertaken by GHD. This analysis allows for a better understanding of the model's sensitivity to variations in the parameters and their impact on the results.

The design event calculated from hydrologic models was compared to the peak flows calculated by stream gauging for the Clyde using a Flood Frequency Analysis. This analysis helps to verify the accuracy of the model by comparing the calculated design event with the recorded peak flows. By comparing the results of the model with the actual historical flood events and the recorded stream gauging data, the hydraulic model's accuracy was evaluated and improved as necessary. Overall, these validation processes ensure that the hydraulic model used for the River Clyde system is robust, accurate, and reliable for predicting potential flooding events and developing effective flood mitigation strategies.

In addition, UDM was engaged to undertake a drone footage of the floodplain after the flooding that occurred on 27 October 2022. The purpose of this survey was to compare the results of the frequent flood event, which happens approximately once every year, with the modelled flood extent generated by the hydraulic model. The results of this comparison showed a high degree of accuracy between the calculated flood extent and the actual footage of the flooded area along the River Clyde. The modelled flood map 63% AEP and the drone aerial picture are shown in Appendix D.

This indicates that the hydraulic model used for the River Clyde system is reliable and can be used to predict the potential flooding extent effectively. The use of drone technology for surveying also highlights the importance of innovative methods for data collection and analysis in modern flood management practices.

4.6 Post-processing of Modelling Results

As per the modelling scope, the direct rainfall hydraulic modelling results were filtered using the ArcGIS software. During the filtering process, depths lower than 0.05 meters were excluded from the map. The purpose of this exclusion was to remove any insignificant information and focus on the areas that had a higher impact from direct rainfall. By removing low-depth areas from the map, the focus was placed on areas where the direct rainfall had a more significant impact. This exclusion of depths lower than 0.05 meters also helped to simplify the map, making it easier to interpret and understand the impact of direct rainfall.

4.7 Flood Hazard

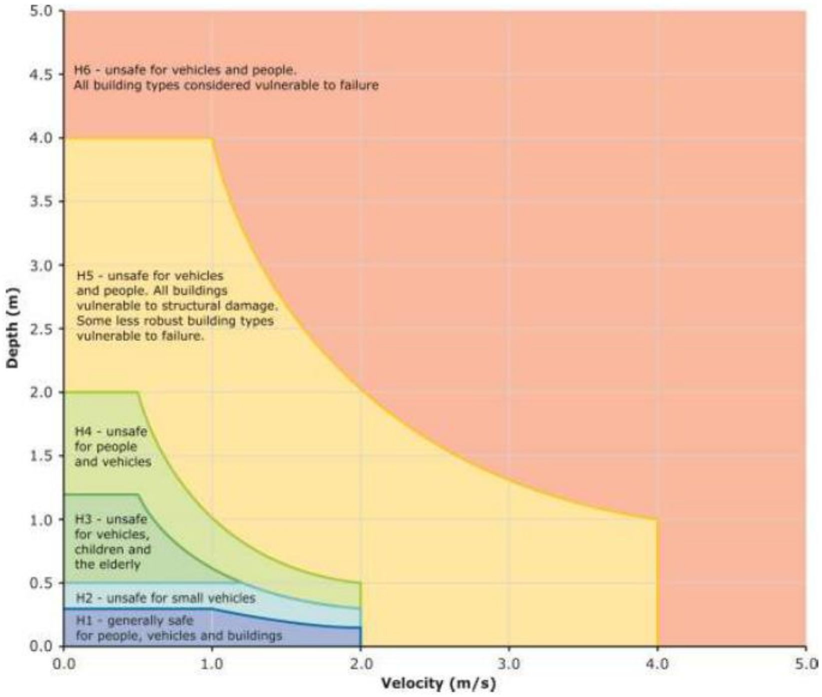
The severity of flooding varies depending on its behaviour, such as extent, depth, velocity, isolation, rate of rise of floodwaters, and duration. To manage flood risk, it is important to understand the potential flood behaviour and identify the relative degree of flood hazard on a floodplain. This section defines flood hazard as the potential loss of life, injury, and economic loss caused by future flood events. It also outlines methods to quantify flood hazard, which can help identify specific flood parameters and benchmark them against thresholds to better understand the danger of flooding to people, buildings, and infrastructure in the community.

The quantification and classification of flood hazard involve considering flood depth and velocity in combination. Understanding the relative degree of hazard and underlying flood behaviour is crucial as different management approaches may be required.

The combined flood hazard curves presented in Figure 8 set hazard thresholds that relate to the vulnerability of the community when interacting with floodwaters. The combined curves are divided into hazard classifications that relate to specific vulnerability thresholds as described in Table 8. Table 9 provides the limits for the classifications provided in Table 8.

A flood hazard map classified against these vulnerability thresholds for the River Clyde floodplain presented in Appendix E.

For full details and additional information on the flood hazard classification, please refer to the *Australian Disaster Resilience Guideline 7-3: Technical flood risk management guideline: Flood hazard, 2014, Australian Institute for Disaster Resilience.*



Source: Australian Disaster Resilience Guideline 7-3:Technical flood risk management guideline: Flood hazard, 2014, Australian Institute for Disaster Resilience.

Figure 8 ***General flood hazard vulnerability curves***

Table 8 ***Combined hazard curves – vulnerability thresholds***

Hazard Vulnerability Classification	Description
H1	Generally safe for vehicles, people and buildings.
H2	Unsafe for small vehicles.
H3	Unsafe for vehicles, children and the elderly.
H4	Unsafe for vehicles and people.
H5	Unsafe for vehicles and people. All building types 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.

Table 9 ***Combined hazard curves – vulnerability thresholds classification limits***

Hazard Vulnerability Classification	Classification limit (D (depth)and V (velocity) in combination) m2/s	Limiting still water depth (D) m	Limiting velocity (V) m/s
H1	D*V ≤ 0.3	0.3	2.0
H2	D*V ≤ 0.6	0.5	2.0
H3	D*V ≤ 0.6	1.2	2.0

Hazard Vulnerability Classification	Classification limit (D (depth)and V (velocity) in combination) m2/s	Limiting still water depth (D) m	Limiting velocity (V) m/s
H4	D*V ≤ 1.0	2.0	2.0
H5	D*V ≤ 4.0	4.0	4.0
H6	D*V > 4.0	-	-

4.8 Flood Model Results

The River Clyde model was run for a number of design rainfall events (discussed in Section 6.2). The flood inundation extents and depths for 1% and 5% AEP are summarised in Table 10, and shown graphically in Appendix A (at the time of peak flood level).

Table 10 Flood modelling summary and results

Rainfall event (AEP)	Design rainfall temporal pattern	Location of the results line	Flow (megalitres/ per day)	Flow (m3/sec)	Time of peak flood level	Peak flood elevation above ground level (m)	Peak flood inundation area (ha) (%) out of total 2D zone area (1286.2 ha)
63.2%	6 hours, ensemble 8	Below Clyde Bridge	2,842.6	32.9	8 hours	1.97	217.2 (16%)
5%	6 hours, ensemble 2	Below Clyde Bridge	19,897.9	230.3	7 hours	2.10	289.5 (22%)
1%	6 hours, ensemble 6	Below Clyde Bridge	28,874.8	334.2	6 hours	2.401871	295.3 (23%)

The overall flooding regime within Bothwell consists of an initial inundation due to rainfall and subsequent catchment inflows from northeast and south side of the residential area. As a result, low-lying areas in the middle section of the residential area gradually experience flooding. The high level of the river also restricts the flow from reaching the discharge locations, further exacerbating the flooding problem.

Based on the model results, it can be concluded that Bothwell township is at a high risk of both river and overland flooding. The police station and fire station area are particularly vulnerable, as the surrounding areas are likely to be inundated in the event of a flood, which could impede emergency response efforts.

Additionally, some water pooling is expected to be in close proximity to the emergency assembly point and ambulance centre, posing a potential threat to emergency services in the area. The model also predicts severe flooding along High Street and Willian Street, as well as full inundation of Arthur Crescent and Nant Lane. The north side of the school grounds is also expected to be at risk of inundation. Private properties along the overland flow path are also deemed to be high-risk flood zones. These properties are located in low-lying areas and are at a high risk of experiencing significant flood damage.

5. Land Use Planning analysis

This section of the report will provide the land use planning analysis for the study area in relation to flooding, flood mitigation and flood mapping.

5.1 Land Use

The study area is defined by two (2) distinct areas. The built township of Bothwell and the farming land that surrounds the township.

Land use is mostly agricultural use outside the township of Bothwell and mixed residential, commercial and community use within the township.

The agricultural use of the land is mixed-use farming for mostly cropping and grazing livestock, which is supported by a residential use.

There is, uniquely, land at 2122 Highland Lakes Road, Bothwell (CT164109/1) which is used for both agriculture and a 9 hole golf course with club house, food services and accommodation. This is unique in that the golf course is located in an intensive agricultural environment and is considered to be the oldest golf course in the southern hemisphere.

Also, in the agricultural area, is a whisky distillery and visitor centre at 254 Nant Lane, Bothwell (CT 151816/1). Within the township of Bothwell, the land is primarily used for residential development, which is comprised of mostly single dwelling housing located on a grid pattern town layout. The residents of the town and surrounding area are supported by community and commercial services such as post office, council chambers, fuel services, food services, open space, school and small industry.

Bothwell is known as an historic township owing to the many colonial buildings, the history of the area and pattern of development. Many of these buildings are still in use and have been maintained and restored over the past 200 years. The town is also part of the "Heartlands" tourism route and is a frequent destination for tourist and visitors.

5.2 Land Development

The study area is, overall, sparsely developed. The agricultural area is defined by expansive cropping, improved pastures and standing vegetation around the River Clyde. There are outbuildings, typically around a dwelling, fencing, dams and other farm infrastructure such as irrigation pipes, irrigators and access tracks. The agricultural area contains public roads including the Lake Highway, Nant Lane, Dennistoun Road, Hollow Tree Road and Meadsfield Road. The Lake Highway is a Category 5 Road under the State Road Hierarchy used primarily as an access road, but also low frequency freight and forestry activities.

The built township of Bothwell is defined by lower density housing on large residential lots on a grid pattern of paved, gravel and unmade roads. There are large sheds and open backyards and small paddocks throughout the town. There are many undeveloped titles which are mostly flat grassed areas. The central business and community area is around Patrick Street, Alexander Street, Market Place and Dalrymple Street. This part of the town is defined by larger buildings. This includes a large sandstone pub, sandstone church, visitor centre, community halls and what is currently the Elders business on the corner of Patrick Street and Queen Street. The roads are wide with grassed nature strips, trees and swale or open drains which is typical for historic colonial towns.

5.3 Zoning

The study area is over 2000ha of land around the township of Bothwell. This land is under the *Tasmanian Planning Scheme – Central Highlands* (the Planning Scheme).

The zoning for the land is shown in Figure 9 and is described as follows:

– The agricultural land, which is most of the study area, is in the Agriculture Zone.

- The Highland Lakes Road, Patrick Street, River Clyde pump station (CT 151816/2), and the TasWater treatment ponds (167794/1) are in the Utilities Zone
- The River Clyde is in the Environmental Management Zone
- The larger rural living lots are either in the Rural Zone or Rural Living Zone
- The small areas of low density living around Barrack Hill are in the Low Density Residential Zone
- The higher density residential, commercial and community areas in the centre of the township of Bothwell are in the Village Zone
- The top of Barrack Hill is in the Open Space Zone
- The Bothwell Recreation Ground is in the Recreation Zone
- The Bothwell District School is in Community Purpose Zone

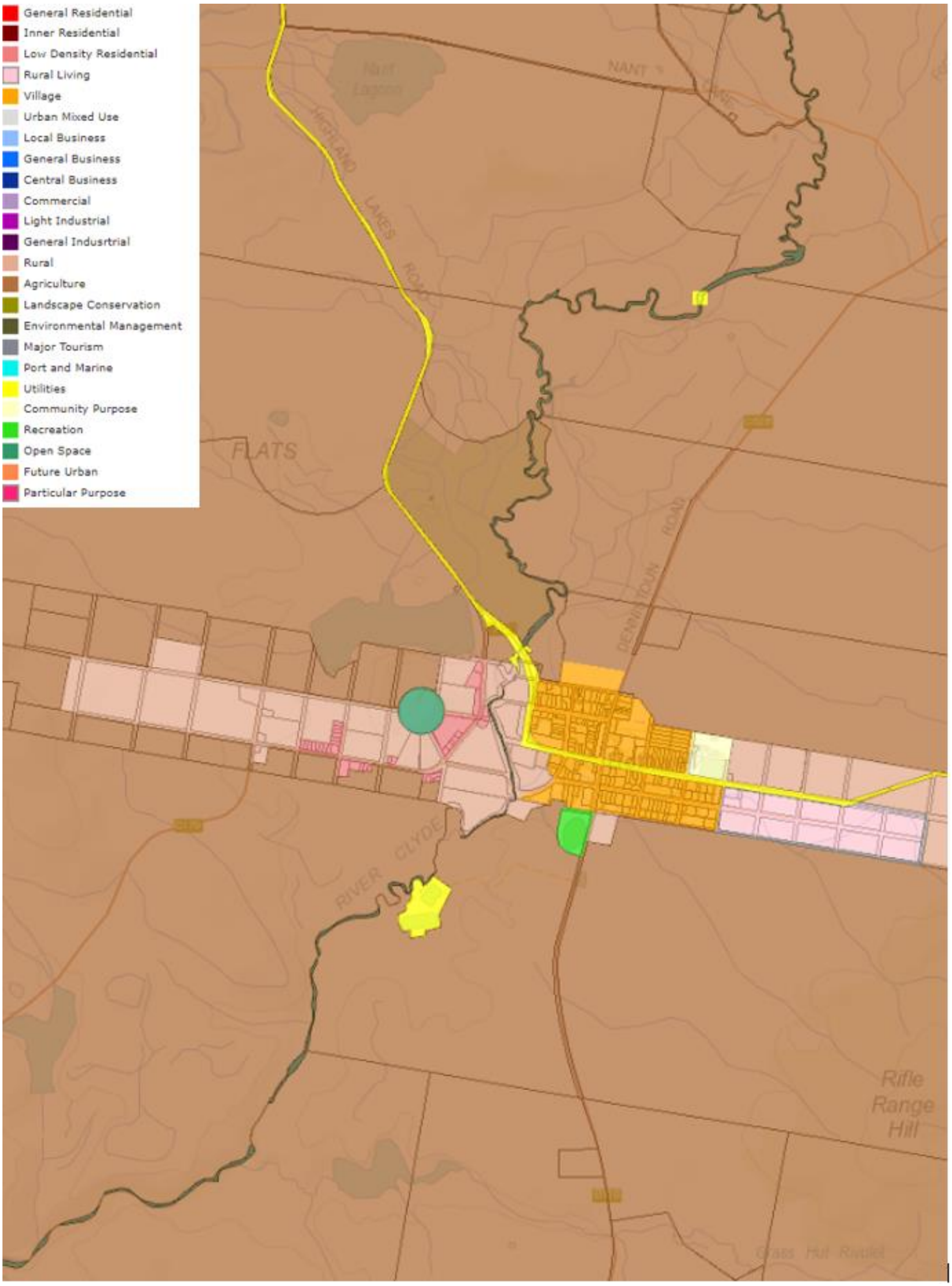


Figure 9 Study Area Zoning Map – Tasmanian Planning Scheme – Central Highlands

Source: LISTMap © State of Tasmania

5.4 Codes and Overlays

The following codes have been mapped as an overlay in the Planning Scheme:

- C4.0 Electricity Transmission Infrastructure Protection Code (Figure 10)

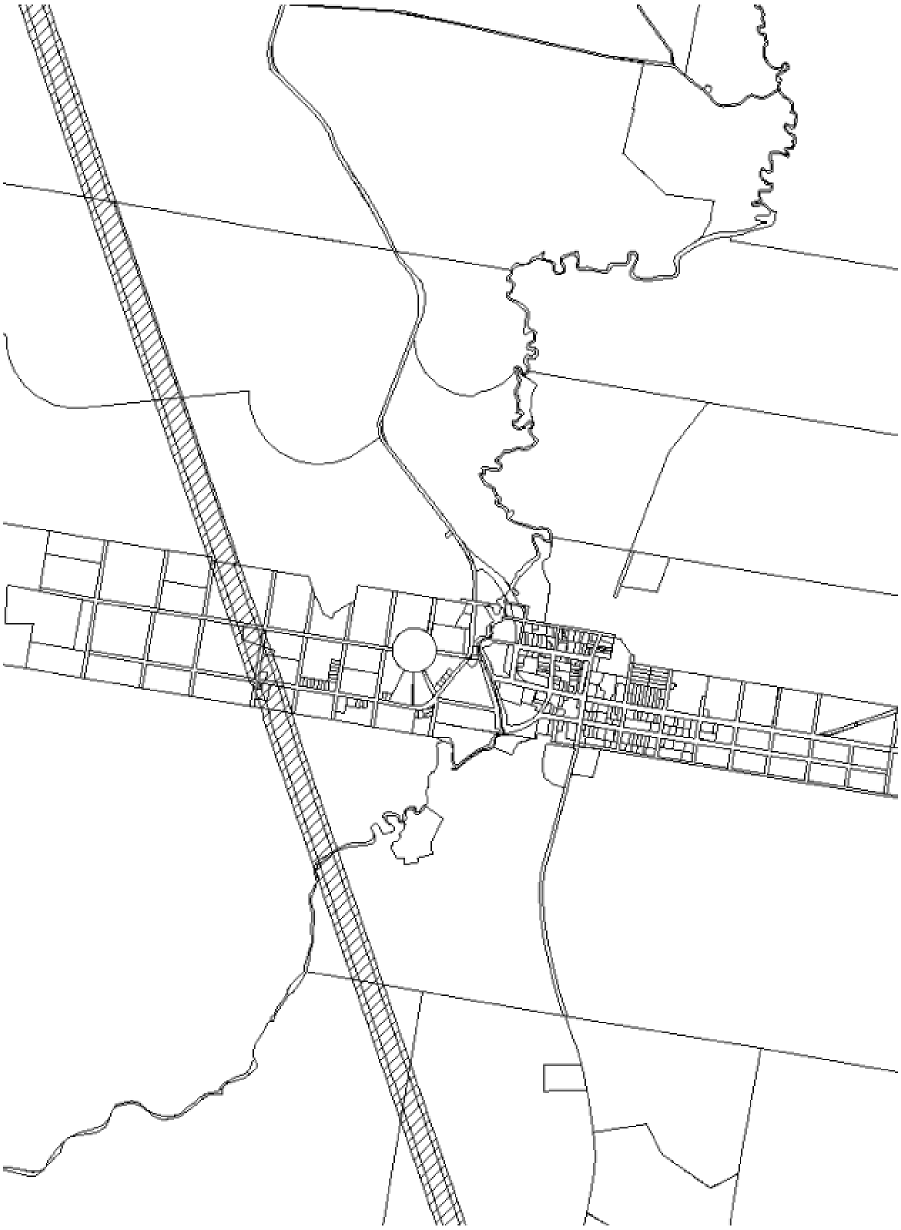


Figure 10 C4.0 Electricity Transmission Infrastructure Protection Code

Source: LISTMap © State of Tasmania

- C6.0 Local Historic Heritage Code (Figure 11)

Figure 11 C6.0 Local Historic Heritage Code

Source: LISTMap © State of Tasmania

- C7.0 Natural Assets Code:
  - Priority Vegetation Overlay (Figure 12

Figure 12 Priority Vegetation Overlay

Source: LISTMap © State of Tasmania

- Waterway and Coastal Protection Area Overlay (Figure 13)

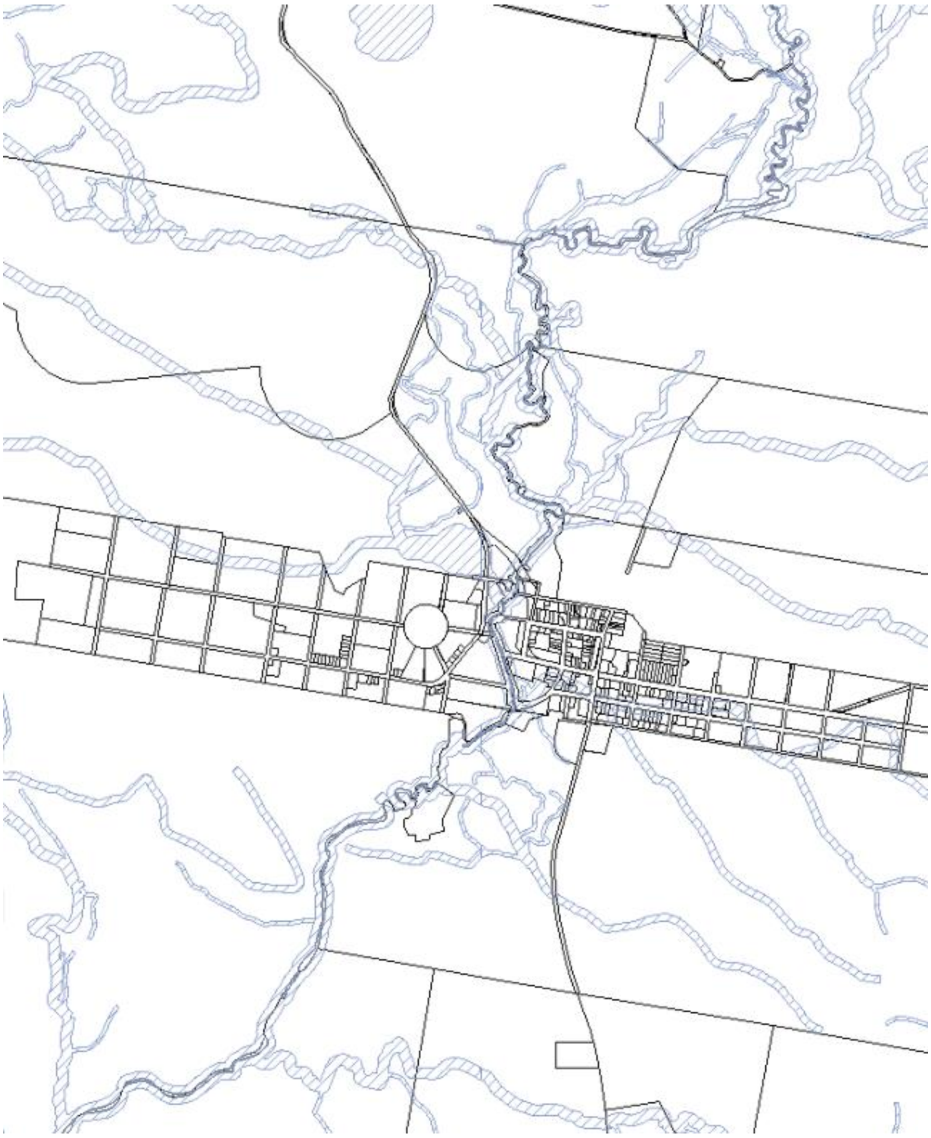


Figure 13 Waterway and Coastal Protection Area Overlay

Source: LISTMap © State of Tasmania

- C13.0 Bushfire-Prone Areas Code (Figure 14)

Figure 14 C13.0 Bushfire-Prone Areas Code

Source: LISTMap © State of Tasmania

- C15.0 Landslip Hazard Code (Figure 15)

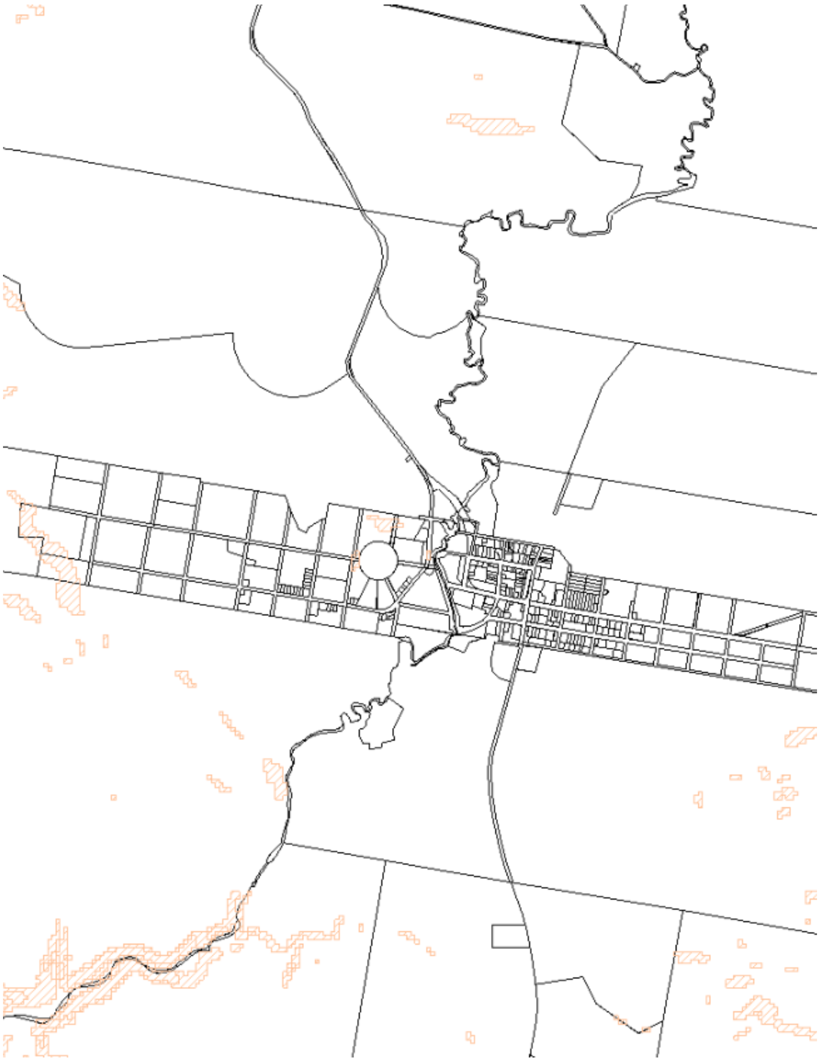


Figure 15 C15.0 Landslip Hazard Code

Source: LISTMap © State of Tasmania

The following codes also apply to use and development of the land, in the study area, but are not mapped as an overlay:

- C1.0 Signs Code
- C2.0 Parking and Sustainable Transport Code
- C3.0 Road and Railway Assets Code
- C5.0 Telecommunications Code
- C9.0 Attenuation Code
- C12.0 Flood-Prone Areas Hazard Code
- C14.0 Potentially Contaminated Land Code (likely but not confirmed)

5.5 Analysis of Codes and Zones

5.5.1 Background

The current zoning of the land reflects both current and intended future use and development of the land based on the available data, characteristics and strategic plans of the Council at the time of preparing and implementing these zones through the *Land Use Planning and Approvals Act 1993* (the Act).

Most of the current zoning in the Central Highlands Local Government Area (LGA) was converted from the previous zoning under the *Central Highlands Interim Planning Scheme 2015*, which, was also a conversion of zoning under the former *Central Highlands Planning Scheme 1998*. This is relevant to the flood mapping as the zoning that has been applied to the land within the study area, under the current Planning Scheme, has evolved from zoning that has been in place for 25 years. This zoning has, to some extent, had regard to the flooding constraints of the area. This is evident particularly around the River Clyde in the Bothwell township as shown in Figure 16 Figure 9below. Where there is a distinct town boundary between the Rural Zone and the Village and Low Density Residential Zone in the vicinity of the River Clyde flood path. Previous planning schemes have avoided application of higher density development zones such as the residential or commercial zones along the banks of the River Clyde. This has carried through to the current Planning Scheme.

In preparing the current Planning Scheme, through the LPS process, Council did not include a flood-prone area overlay in the mapping. This is simply because Council did not yet have in its possession flood mapping and data that is compliant with the requirements for mapping flood prone areas per the *Guideline No.1 Local Provisions Schedule (LPS): Zone and Code Application,* Tasmanian Planning Commission, June 2018 (Guideline No.1).

Council, per the recommendations of this report will likely initiate an amendment to the LPS to introduce a flood-prone area overlay map to apply the Flood-Prone Areas Code. Council will use the flood modelling from this project to create the map and use the data (including this report) to support the planning scheme amendment process. This is explained in Section 5.7 of this report.

Figure 16 Zoning in vicinity of River Clyde in the Bothwell Township

Source: LISTMap © State of Tasmania

The GHD flood model, created by the flood study, shows that the majority of land within the flood path is within the Rural or Agriculture Zone. The exceptions are:

– The lower lying land in the vicinity of Arthur Crescent, Dalrymple Street and Highland Lakes Road within the Bothwell township which is partly in the Village Zone; and
– Low lying land accessed from Wentworth Street is in the Low Density Residential Zone
– The TasWater treatment ponds and a pump station on the River Clyde (189 Dennistoun Road, CT 106748/1) is in the Utilities Zone.
– The River Clyde reserve is in the Environmental Management Zone.

The Rural and Agriculture Zones are more suitable zones for flood prone areas as compared to those zones listed above. The purpose of the Agriculture Zone is to provide and protect land for agricultural use and development where land is relied upon for livestock, cropping, harvesting and related agricultural use and development. Such land is typically on larger lots and around waterways. It follows that floods and flood paths around waterways are a normal and natural occurrence and land is typically developed to manage and avoid these flood paths where they are known from flood history. The Rural Zone has similar purposes, which is to allow for agricultural land use and development that does not conflict with agricultural land use. Both of these zones are typically applied to land outside of settlements and townships in Tasmania.

The Agriculture Zone and the Rural Zones are very different to residential, community or commercial zones. They do not encourage a high density of development or activities at risk of harm from flooding. Land within these zones is rarely serviced for sewer and does not ordinarily have other infrastructure such as footpaths, sports grounds, local or community businesses and services which may put the public at greater risk of harm from flooding. Much of the land in these zones is open spaces such as pasture or bushland.

The Village Zone, and Low Density Residential Zone encourages higher density of development and are serviced for sewer and water. These zones are allocated to the township of Bothwell with the intention of facilitating residential, commercial and community development and to facilitate growth of the town.

The Utilities Zone is applied to assets and infrastructure or sites intended for future public assets and infrastructure.

The Environmental Management Zone is applied to mostly public reserves to protect and managed conservation values and to allow for compatible use and development that is consistent with the management of such values.

These zones and codes were recently reviewed by Council in preparing and implementing the current *Tasmanian Planning Scheme – Central Highlands*. This came into effect in February 2023. This new scheme replaced the former *Central Highlands Interim Planning Scheme 2015* (Interim Planning Scheme). The new planning scheme is a product of the state legislated roll-out of the *Tasmanian Planning Scheme* which is intended to be a single, state-wide Planning Scheme that will replace all 30 planning schemes in Tasmania.

In implementing this new Planning Scheme, the Central Highlands Council prepared a Local Provisions Schedule (LPS) which provides the maps (zones and overlays) together with a written ordinance that provides the written provisions for the LGA. The local provisions are particular to each LGA and include matters such as provisions for specific area plans, local heritage places and precincts, particular purpose zones and code lists for major roads etc. Councils are able to also include flood prone area overlays in their LPS.

Council now has the opportunity, as a result of the GHD flood study, to review zoning around the River Clyde and to apply the flood prone area overlay map to the LPS. This review will also assist with future strategic plans for Bothwell such as land use and development strategies, master plans and structure plans for the town.

5.5.2 Flood-Prone Areas Hazard Code

The Tasmanian Planning Scheme-Central Highlands includes the Flood-Prone Areas Hazard Code (Code C12.0 of the State Planning Provisions). The purpose of this code, per C 12.1, is:

- To ensure that use or development subject to risk from flood is appropriately located and managed, so that:
  - a) people, property and infrastructure are not exposed to an unacceptable level of risk;
  - b) future costs associated with options for adaptation, protection, retreat or abandonment of property and infrastructure are minimised; and
  - c) it does not increase the risk from flood to other land or public infrastructure.
- To preclude development on land that will unreasonably affect flood flow or be affected by permanent or periodic flood.

Per C12.2, the code applies to development of land within a flood-prone hazard area and for use of land if for a change of use to a new habitable room or building. The identification of a flood-prone hazard area is reliant upon the Planning Authority having in its possession information that demonstrates the land is susceptible to flooding, a report provided by a suitably qualified person or where the land is identified as a flood-prone hazard area in the LPS map overlays. The overlay in the LPS would appear as hatched blue line area on the map as shown in the example given in Figure 17.

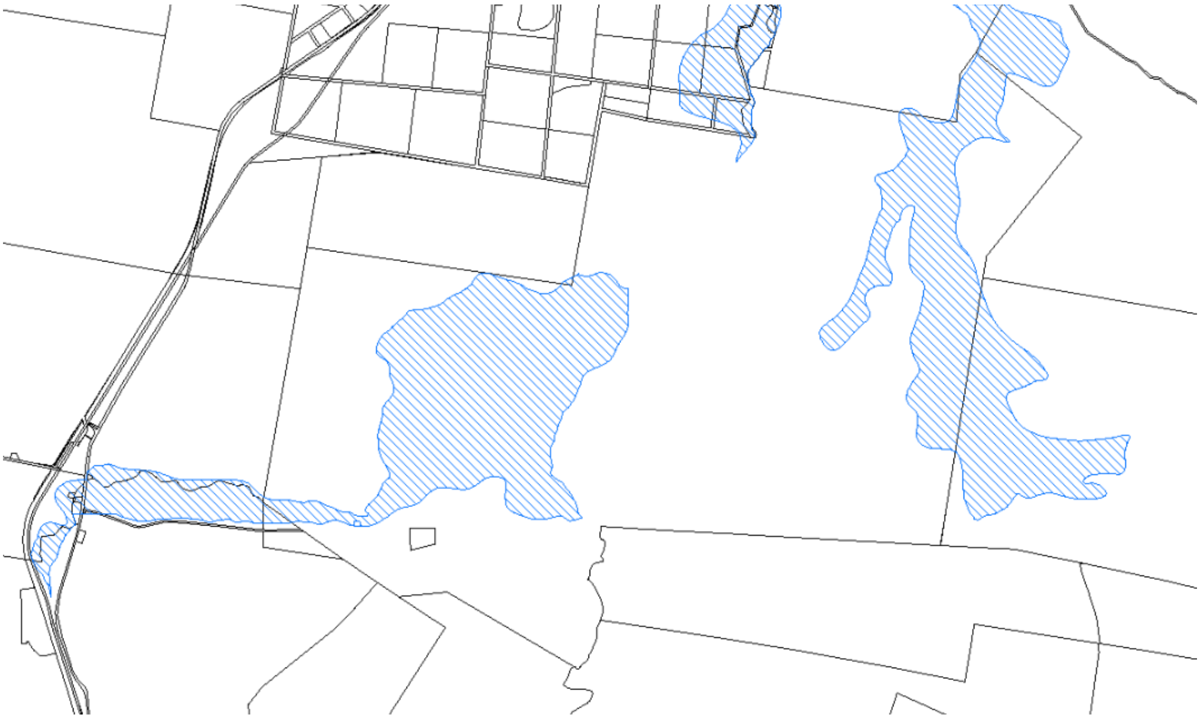


Figure 17 ***Example of Flood-Prone Area Hazard Overlay Mapping in adjacent Local Government Area***

Source: LISTMap © State of Tasmania

The code can be applied to all zones. However, there are a number of exemptions from the code for the following uses or development as provided in C12.4 of the Code:

a) alterations or extensions to an existing building if:

   (i) the site coverage is not increased by more than 20m² from that existing at the effective date; and

   (ii) not for a critical, hazardous, or vulnerable use;

b) use or development of land for:

   (i) Natural and Cultural Values Management;

   (ii) Passive Recreation;

   (iii) Port and Shipping in a proclaimed wharf area;

   (iv) Resource Development, excluding a habitable building;

   (v) minor utilities;

(vi) infrastructure for the generation of hydro-electricity; and

(vii) outbuildings;

c) planting or disturbance of vegetation on existing pasture or crop production land; and

d) consolidation of lots.

The code is used in the assessment of use and development that is not exempt from it per C12.4 and where the use or development is within a flood-prone area per C12.2. The code provides standards for both use and development of land within the flood-prone area. These standards are designed to achieve the purpose statements of the code per C12.1. The standards either require avoidance of the flood-prone area hazard or management of the flood hazard which is supported by expert reporting and recommendations by a suitably qualified engineer.

The full extent of the 1% AEP flood model created by GHD ought to be converted to a flood-prone area hazard overlay in the LPS. This will then achieve clarity and certainty as to where the C12.0 Flood-Prone Areas Hazard Code applies. As currently there is ambiguity and uncertainty as to the extent of flooding in the study area. The Council Planning Authority, landowners and developers ought to be able to establish the extent of flooding through the Planning Scheme overlay mapping.

5.6 Planning Options for Flood Mapping

The GHD flood study provides mapping and data that can be used for assessing and guiding land use and development through the planning system.

The options for Council in applying the Flood Prone-Areas Hazard Code to the study area are provided as follows:

A. Council upload and maintain a copy of the flood mapping report and maps on Council's website where the information is readily accessible at all times to the public. This can then be used for land use and development planning. Council and community can rely upon these maps for the purposes of assessment against the standards of the C12.0 Flood Prone Areas Hazard Code; and/or

B. Council can create their own interactive flood maps online that can be accessed by the public at all times. Council, landowners and developers (and general public) can use this map and software to search property and areas. There are many Councils across Tasmania that have interactive maps such as these, including Glenorchy City Council, Clarence City Council and Kingborough Council; and/or

C. Council create a GIS layer in their current GIS mapping software that can be accessed by Council and copies of specific maps and areas can be provided to the public upon request.

D. In addition to the above Council can, of its own motion, per Section 40D of the *Land Use Planning and Approvals Act 1993* prepare a draft amendment of the LPS to map the flood-prone hazard area overlay. If the amendment is successful through the legislated amendment process then the LPS will be amended to include a flood-prone areas hazard overlay.

All of these options are a means of providing a readily available copy of the flood mapping and data for Council and public in the preparation and assessment of Development Applications. The mapping, per part C12.2 of the Flood-Prone Areas Hazard Code does not need to be applied as an overlay in the LPS in order for the code to apply. Simply by the maps and data being information in the possession of the Council, allows the Planning Authority to make a request for a report, prepared by a suitably qualified person, to determine that a proposed use or development is subject to risk from flood or has the potential to cause increased risk from flood.

There is however significant logic in ensuring the mapping and data is readily available to the public in the preparation of Development Applications, land purchase, land use decisions and strategies. It also aligns with the objectives of the RMPS to encourage public involvement in the planning system.

There are pros and cons to the options for mapping the overlay in the LPS:

– Once the map is applied as an overlay in the LPS then any changes to the flood model or flood extent and behaviour due changes in topography, flood and stormwater mitigation measures and other development, for example, should then require an amendment to the LPS to modify the flood prone areas overlay. This can be problematic for landowners, developers and Council where the code technically applies to the land per the overlay and development applications must then be assessed against the standards of the Code regardless of the existence of flood waters.
– The overlay can also unnecessarily constrain a site for development or dissuade acquisition and purchase of land for future use and development. The issue can ordinarily be resolved through reporting by a suitably qualified person and Council taking a pragmatic approach, however, the requirements of the code can be burdensome for development and landowners where the risk from flood is nil or negligible.

The recommended option is to provide both the mapping and reports to the public through Council's website without delay and to create a GIS layer in their current GIS mapping software. Then initiate an amendment to the LPS through the planning scheme amendment process to map the flood prone areas of the study area.

5.7 Planning Scheme Amendment Process

As described in Section 5.6 above. Council may choose to both provide copies of the flood mapping and reports on Council's website and include a GIS layer on their GIS mapping software. Council may then commence the planning scheme amendment process.

The amendment process can be in the form of the creation of the flood-prone area overlay for the study area only or Council may delay creating the layer pending further flood studies in the Central Highlands and initiate an amendment to multiple areas a single suite of amendments. It is however recommended that Council initiate the amendment with minimal delay as the flood-prone area overlay under the Planning Scheme is typically the data and maps that the public would rely upon in land development, land purchase or land use.

Pending Council acceptance of the mapping and reports by GHD (this project) then Council can initiate the planning scheme amendment process as follows:

1. **Create a Flood-Prone Hazard Areas Code Overlay**
   Council prepare a flood-prone hazard area overlay map that complies with *Guideline No.1*. This Guideline is legislated under Section 8A of the *Land Use Planning and Approvals Act 1993* (the Act) and was intended to be a reference guide for the application for all zones and codes for the preparation of the LPS. An example of the map is provided in Figure 17. The Guideline provides the following requirements in relation to flood prone hazard areas:

Table 11 Exerpt from Guideline No.1

Code	Code Purpose	Code Application Guidelines
C12.0 Flood-Prone Hazard Areas Code Flood-prone areas	The purpose of the Flood-Prone Hazard Areas Code is: C12.1.1 To ensure that use or development subject to risk from flood is appropriately located and managed, so that:	Overview The Flood-Prone Hazard Areas Code is applied by reference to a flood-prone hazard area overlay. There is currently no statewide mapping of land potentially susceptible to flooding risks to

Code	Code Purpose	Code Application Guidelines
Red 103, Green 169, Blue 207	people, property and infrastructure are not exposed to an unacceptable level of risk; future costs associated with options for adaptation, protection, retreat or abandonment of property and infrastructure are minimised; and it does not increase the risk from flood to other land or public infrastructure. C12.1.2 To preclude development on land that will unreasonably affect flood flow or be affected by permanent or periodic flood.	guide the application of the overlay. Guidelines for applying the Flood-Prone Hazard Area overlay FPHAZ 1 The flood-prone hazard area overlay should be applied to areas known to be prone to flooding, particularly areas known to be within the 1 per cent annual exceedance probability (AEP) level. FPHAZ 2 In determining the extent of the flood-prone hazard area overlay, planning authorities may utilise their own data, including any equivalent overlay contained in an interim planning scheme or section 29 planning scheme for that municipal area, or data from other sources.

Council will need to refine the data set to create this overlay map and should engage the services of a suitably qualified engineer and GIS consultant to generate the final overlay map.

Council will also need to create the amendment instrument (diagram).

2. **Report to Council**
   Council's Planner or Strategic Planner will need to prepare a report to Council per Section 40F of the Act to demonstrate the proposed amendment meets the LPS Criteria. This report will present and support the amendment. Council will need to demonstrate the amendment instrument complies with the Guideline No.1.

3. **Public Exhibition and Certification**
   Council, if satisfied the amendment meets the LPS Criteria, must certify the amendment as meeting the requirements of the Act. Council must then provide to the Tasmanian Planning Commission (TPC) a copy of the certified amendment. Council will then notify the relevant agencies, State Service Agencies and Authorities that the Planning Authority considers may have an interest. The amendment is placed on exhibition for a period of 28 days in accordance with Section 40G and 40H of the Act.

4. **Representations and Report**
   Council, per Section 40K of the Act will need to consider any representations received in a report to the TPC prepared by Council's Planner or Strategic Planner. The report is to contain:
   a) a copy of each representation made under section 40J in relation to the draft amendment before the end of the exhibition period in relation to the draft amendment, or, if no such representations were made before the end of the exhibition period, a statement to that effect; and
   b) a copy of each representation, made under section 40J in relation to the draft amendment after the end of the exhibition period in relation to the draft amendment, that the planning authority, in its discretion, includes in the report; and
   c) a statement of the planning authority's opinion as to the merit of each representation included under paragraph (a) or (b) in the report, including, in particular, as to –

(i) whether the planning authority is of the opinion that the draft amendment ought to be modified to take into account the representation; and
(ii) the effect on the draft amendment, and the LPS to which it relates, as a whole, of implementing the recommendation; and

d) a statement as to whether it is satisfied that the draft amendment of an LPS meets the LPS criteria; and
e) any recommendations in relation to the draft amendment that the planning authority thinks fit.

The report is to be provided to the TPC within 35 days after the end of the public exhibition (or further period as allowed by the TPC).

5. Hearings

As soon as practicable after receiving the report under Section 40K, the TPC may hold hearings under Section 40L in relation to the amendment and the representations received.

The TPC, per Section 40M, is to consider:

a) the report and the draft amendment of an LPS to which it relates; and
b) the information obtained at the hearings; and
c) whether it is satisfied that the draft amendment of an LPS meets the LPS criteria; and
d) whether modifications ought to be made to the draft amendment of an LPS

6. Action and decision by the TPC

The TPC may direct the Planning Authority to modify the amendment, reject or substantially modify the amendment and commence the exhibition and Council assessment process.

If the TPC is otherwise satisfied the amendment meets the LPS Criteria together with those matters listed under Section 40M then the TPC can approve the amendment.

The amendment will come into effect on a specified date after the approval is given.

Once the amendment has come into effect then the “Flood Prone-Area Hazard Overlay” map will be included in the Planning Scheme maps and will be relied upon per C12.2.

The process of preparing an amendment, the Council decision, public exhibition, hearings and the final decision by the TPC can take 6-12 months.

5.7.1 Further Strategic Planning

The GHD flood modelling, together with this report, will provide valuable data that Council can use in the preparation of further strategic plans for the Bothwell township and the surrounding area. Council may rely upon these plans for precinct planning the township of Bothwell and for the allocation of new zones within the township. This will be useful for placemaking, planning open space and for any future residential or commercial areas. In any future structure planning for Bothwell, Council will have regard to the flood model before making recommendations for further growth or development.

This will be particularly relevant for the land around assets such as the Fire Station, Police Station and Council works depot. Stakeholders and Council can make a more informed decision on future development of these sites based on the flood modelling.

Similarly Council, in considering the flood mitigation options, will need to prepare specific outcome focussed objectives that factor the social and physical infrastructure of the town. For example, works to alleviate flooding around the Council Works depot would potentially allow further growth of this site or encourage other compatible services into this area of town.

6. Community Consultation

A Stakeholder and Community Engagement Plan was developed identifying key stakeholders, outlining key messages, activities, project timing and feedback opportunities to support the project objectives. Stakeholder engagement content was prepared to provide information around why the Flood Mapping Study was being undertaken and how it will enable the council to prepare a Stormwater System Management Plan. Content was prepared to inform the community about the Study and invite them to contribute information about flooding.

Two community drop-in sessions were held, coinciding with community events – the Bothwell Bicentennial and Bushfest. Project information was shared and the public were encouraged to share stories and, photographs and to fill out an online survey.

The surveys collected information around flood awareness, emergency planning and impacts. A total of eight survey responses were collected.

Surveys and pop-up sessions were promoted via traditional media, social media, the council website, the Bothwell District High School newsletter, the Highlands Digest, a postcard mailout to every Bothwell post office box holder and posters around the township.

Two stakeholder workshops were held to share project details and gather information from industry, government departments, landowners, residents and business owners. The workshops discussed past flood levels and impacts, and involved a risks, priorities and opportunities analysis. Resulting community feedback from both online and face to face consultation was collated and analysed providing additional data for the Study.

Feedback received from the community consultation identified the following:

- Flood awareness is greater amongst those with lived experience of flooding in the area.
- Landowners who attended the drop-in sessions showed that they had high awareness of flooding and have emergency management plans in place for when flooding occurs.
- Landowners would like to see more willow management in the area with the addition of flood levees to reduce the severity of flooding.
- Although flooding is of concern to the community, it is a lower priority when compared to other extreme weather events such as drought.
- Broadly speaking, the community awareness if flooding is high, though understanding of how they can be better prepared and mitigate the impact of flooding is relatively low. The community may be more inclined to take action to be better prepared with further education and engagement.

A follow up community drop-in session will be held at the completion of the Study to share key findings and recommendations.

For the full *River Clyde Flood Mapping Study Consultation and Engagement Summary* please refer to Appendix F of this report.

7. Consequences of Flooding on the Community

Flooding in the River Clyde catchments, particularly in Bothwell, has significant consequences on people, economy, environment, public administration, and social setting. The following assessment provides insights into these consequences, including historical and anecdotal information, modelling outputs, and flood emergency response planning classifications.

7.1 People

Floods can pose significant risks to people's safety, causing fatalities and injuries. Floodwaters can also cause significant disruptions to people's daily lives, such as evacuations, loss of property, and interruption of basic services like power, water, and communication. Flood warnings and effective emergency response planning can help reduce these risks and protect people's safety.

In terms of the impact of flooding on people, there are specific areas in Bothwell that are of particular concern. One such area is Arthur Crescent, which is vulnerable to flooding due to the existing ground levels. During periods of heavy rain or flooding, the area of Arthur Crescent up to the High Street intersection can become inundated with water, which poses a significant risk to the safety of people if they enter flood waters.

Currently, we understand Council erect signage to limit access to flooded portions of Arthur Crescent. Further measures to reduce the risk of people entering floodwaters in Arthur Crescent such as a permanent boom gate could be considered to prevent people from entering the area and potentially putting themselves in danger.

Another area that is at risk of flooding is Highland Lake Road, which is also located in close proximity to the River Clyde. The flooding of the road verge and the area around Highland Lake Road could lead to difficulties for emergency services to reach people in need, which could be especially dangerous in case of a medical emergency.

7.2 Economy

Floods can have significant economic consequences on the town of Bothwell and its surrounding areas. Floodwaters can damage buildings, roads, bridges, and other infrastructure, leading to costly repairs and reconstruction efforts. In addition, flooding can disrupt business operations, causing loss of income for local businesses and their employees.

During community consultation, landowners indicated that flooding of the River Clyde poses a significant risk to livestock and land infrastructure such as fencing. Loss of livestock and damage to private infrastructure can cause both loss of income and additional financial outlay for repair and replacement to the landowners effected.

Furthermore, flood-related power outages can cause additional economic losses by disrupting production in businesses. The financial burden of flood recovery can be overwhelming for communities, and the long-term economic impact can be felt for years.

7.3 Environment

Flooding can have severe environmental consequences, including the destruction of ecosystems, water pollution, and loss of biodiversity. Floods can also damage agriculture and farming lands, affecting food supply and food security. The assessment of flood risk should take into account the environmental impact of flooding and consider ways to reduce this impact.

Communication with farmers about safe and compliant storage of harmful pesticides and chemicals is essential to prevent contamination of water sources during flood events. To prevent contamination, it is important to educate farmers on the risks of having hazardous materials or substances near flood zones. They should be made aware of the potential consequences of not storing these materials properly and the impact it can have on the environment and human health. This includes ensuring that these materials are stored in a designated area that is located away from flood zones and is well-ventilated with proper lighting to prevent accidents and spills. Appropriate storage containers, such as chemical storage cabinets, should also be used to prevent leaks and spills. Proper labelling of all containers with clear and accurate information about the contents and associated hazards is also important. Regular inspections of the storage area and containers should be conducted to ensure that they are in good condition and that there are no signs of leaks or damage. The farmers should have an emergency response plan in place in case of a spill or release of hazardous materials. This plan should include clear procedures for containing and cleaning up the spill, as well as contacting emergency services if necessary. By taking proactive measures to store and handle these materials properly, farmers can help to protect the environment and ensure the safety of the surrounding community.

7.4 Public Administration

Effective flood risk management requires coordinated efforts between government agencies, emergency services, and other stakeholders. It is essential to have clear and efficient communication systems and well-established emergency response plans to minimize the effects of flooding on public administration.

In addition to issuing timely and appropriate warnings, clear advice on emergency evacuation centres must be provided. The regional emergency evacuation centre is an essential resource for people forced to evacuate their homes due to flooding. Clear direction and guidance must be provided on the location of the evacuation centre, the services it provides, and how to access it safely.

To ensure a coordinated approach to flood warnings, appropriate communication, direction, and leadership are necessary. This involves collaboration between Council, SES, and other agencies responsible for managing flood risk. Clear lines of communication must be established, and roles and responsibilities must be clearly defined to ensure an effective response to flood events. Effective leadership and direction are essential to ensure that warning systems are fit for purpose, that adequate resources are in place, and that emergency response plans are regularly reviewed and updated. Finally, community education and engagement could be helpful in raising awareness about flood risk and encouraging people to take steps to protect themselves and their property. Flood risk awareness campaigns can help people understand the risks and prepare for floods by taking preventive measures. Community engagement activities, such as workshops, seminars, and training sessions, can help residents learn about the best practices for flood preparedness, such as moving valuables to higher ground and creating evacuation plans. By raising awareness and promoting preparedness, the community can become more resilient to the impact of floods.

7.5 Social Setting

Flooding can have significant impacts on the social fabric of communities. One of the most significant impacts is the displacement of people. When floods occur, homes and communities can be destroyed, leaving people without shelter and forcing them to relocate to safer areas. This displacement can have long-lasting effects on individuals and families, causing emotional and psychological trauma, as well as economic hardship.

In addition to displacement, flooding can also result in the loss of cultural heritage. Communities often have unique cultural and historical sites, such as buildings, monuments, and artifacts, that can be damaged or destroyed during floods. This loss can be devastating to the community's identity and sense of place.

Flooding can also cause damage to community infrastructure, including roads, bridges, and buildings. This damage can disrupt daily life, making it difficult for people to access essential services, such as healthcare and education. It can also be costly to repair, diverting resources away from other community needs.

Another social impact of flooding is the strain it can place on social services, such as emergency response, healthcare, and mental health services. During and after floods, these services can become overwhelmed by the demand for assistance, leading to delays in response times and inadequate support for those in need.

Flooding can also have significant impacts on the social fabric of communities, including the displacement of people, loss of cultural heritage, and damage to community infrastructure. Effective flood risk management requires a community-based approach that takes into account the social and cultural context of the affected area.

To summarise, the following actions Council may need to consider for flood risk management in Bothwell include:

- Implement flood mitigation measures for high-risk areas, such as Arthur Crescent and Highland Lake Road.
- Consider the installation of a boom gate to prevent people from entering flood-prone areas.
- Develop and implement early warning systems and evacuation plans.
- Ensure timely and clear communication of flood warnings through various channels, including radio, television, social media, and mobile devices.
- Encourage residents to take responsibility for their own flood preparedness.
- Assess priority for sandbag distribution and develop a register of vulnerable properties for prompt notification and response.
- Prioritise the distribution of sandbags to high-risk properties to protect the most vulnerable properties first.
- Develop a plan to support local businesses affected by floods by providing financial assistance and resources to help them recover and resume operations.
- Develop a plan to support local farmers and the agricultural sector by offering financial support for crop and livestock losses.
- Educate Bothwell residents and businesses about the importance of reviewing insurance policies to ensure adequate coverage for flood damage.
- Encourage property owners to take responsibility for managing the flood-inundated areas around their properties to reduce the impact of flooding on infrastructure.
- Develop a debris management plan to minimise damage to infrastructure and the effects of flooding caused by debris.
- Educate farmers on safe and compliant storage of hazardous materials and substances to prevent contamination of water sources during floods.
- Coordinating efforts between government agencies, emergency services, and stakeholders to establish clear communication systems and emergency response plans.
- Providing timely and clear warnings and guidance on emergency evacuation centres.
- Establishing clear communication and leadership roles between council, SES, and other agencies responsible for flood risk management.
- Raising community awareness of flood risks and promoting preparedness through education and engagement activities.

8. Mitigation Options

GHD has investigated a range of mitigation options that could be implemented to reduce the impact of flooding in flood-prone areas. As part of this investigation, GHD has considered various infrastructure upgrades that could be implemented to enhance flood protection. The options assessed by GHD consider the available space, existing underground services, and the condition and historical value of the existing infrastructure. Attention has been paid to the options that incorporate the principles of best practice flood management, which recognizes that flooding is a natural process that needs to be integrated into the rural landscape. This approach ensures that flood mitigation measures are sustainable and effective in the long term.

GHD has also conducted a natural values assessment and a land use planning assessment to inform the options and highlight any risks associated with them.

8.1.1 Willow Removal

Willow removal is a flood mitigation option that involves the removal of invasive willow trees from flood-prone areas. Willow trees are known for their ability to grow quickly and form dense stands, which can reduce water flow and increase the risk of flooding. By removing these trees, it is possible to restore natural water flow and increase the capacity of waterways to handle floodwaters. Willow removal is an effective and sustainable solution to reduce the risk of flooding, especially in areas prone to frequent floods. This mitigation option has been widely adopted in many parts of the world, and its benefits have been observed in improved flood protection, increased biodiversity, and enhanced recreational opportunities. This section of the report will explore the benefits of willow removal as a flood mitigation option and its role in improving the resilience of communities to floods.

Willow removal as a flood mitigation option offers several benefits. Firstly, willow removal can help to increase the capacity of rivers and streams to carry water, which can reduce the risk of flooding. By removing willows, the flow of water can be increased, allowing water to move more quickly through the river system. Secondly, willow removal can improve the ecological health of river systems by increasing the amount of sunlight that reaches the riverbed. This can encourage the growth of native plant species, which in turn can provide habitat for a range of aquatic and terrestrial species. Thirdly, removing willows can reduce the amount of sediment that accumulates in rivers and streams, which can improve water quality. Finally, willow removal can help to reduce the risk of damage to infrastructure such as bridges and roads, which can be costly to repair or replace in the event of a flood. Overall, willow removal as a flood mitigation option offers a range of benefits that can help to reduce the impact of flooding and improve the ecological health of river systems.

Furthermore, willow removal can play an important role in improving the resilience of communities to floods. By increasing the capacity of rivers and streams to carry water, willow removal can reduce the risk of flooding in some areas, which can help to protect homes, businesses, and critical infrastructure from damage. This can have a positive impact on the social and economic well-being of communities, as it can reduce the costs associated with flood damage, such as repairs and clean-up efforts. Additionally, by improving the ecological health of river systems, willow removal can help to support the natural services and functions that are important for the well-being of communities. For example, healthy river systems can support fish populations, provide recreational opportunities, and contribute to the overall aesthetic value of an area. By reducing the impact of floods and supporting the ecological health of river systems, willow removal can improve the resilience of communities to the impacts of flooding and help to ensure the long-term sustainability of communities in flood-prone areas.

Careful planning is crucial when it comes to projects for willow control and stream rehabilitation, as it ensures that funds are used efficiently and that long-term outcomes are achieved. This is especially important when undertaking willow control in a single operation, as there may not be sufficient funds available for repeat visits by a works crew and large machinery. A well-planned project should include periodic follow-up to ensure the eradication of willows and prevent re-infestation, as well as the regeneration of native species. A multi-year project that involves gradual willow removal and replacement with native species may be more costly, but it is more likely to succeed in the long term. Prioritising and planning willow removal requires a systematic approach that involves identifying areas of high priority, assessing the scope and complexity of the project, developing a detailed plan and budget, and ensuring that appropriate resources are available to carry out the work. By following a careful planning process, it is possible to achieve successful outcomes in willow control and stream rehabilitation projects, and to ensure the long-term sustainability of river systems and the communities that depend on them.

The following steps required in prioritising and planning willow removal:

- Scoping the problem: Conduct a thorough survey to identify the distribution and extent of willow trees along the River Clyde and assess the potential threats to natural assets such as native plant species, wildlife habitats, and water quality.
- Determining priorities: Determine the priority areas for willow removal based on the severity of the problem, the level of threat to assets, and the potential benefits of removal.
- Working with the community: Involve the local community in the planning and implementation of the project, including identifying stakeholders, communicating project objectives, and engaging the community in the decision-making process.
- Planning for short-term consequences: Plan for short-term consequences of willow removal such as soil erosion, water flow changes, and potential impacts on recreational activities.
- Willow control/removal: Use appropriate methods for willow control and removal, such as cutting, herbicide application, or a combination of both, while minimising the impact on the environment and ensuring worker safety.
- Revegetation and follow-up: Develop a plan for restoring native plant species and revegetating the area following willow removal to prevent future infestations. Establish a follow-up plan to ensure the success of the restoration efforts.
- Monitoring and evaluation: Establish a monitoring and evaluation plan to assess the effectiveness of the project in achieving its objectives, measure the impact on natural assets, and engage the community in the process.

By involving the local community throughout the entire process, from planning to monitoring and evaluation, the project will benefit from better ownership and success. The project objectives will ensure that the willow removal is done in a responsible and effective manner, minimizing negative consequences and maximizing benefits for the local environment and community.

In addition to scoping the problem Council will need to consider and allow for statutory approval and landowner consent to inform the scope of works, timeframe and budget. A standalone project plan for the willow weed management should be created as part of the initial planning phase. The *Environmental Best Practice Guidelines 1. Legislative and Policy Requirements for Protecting Waterways and Wetlands when Undertaking Works*, prepared by the Department of Natural Resources Environment Tasmania should be considered as part of the project planning. There are a significant number of legislative requirements that must complied with prior to commencing works within a wetland or watercourse. The *Wetlands and Waterways Works Manual*, developed by the Department of Natural Resources Environment Tasmania and available at **https://nre.tas.gov.au/conservation/flora-of-tasmania/tasmanias-wetlands/wetlands-waterways-works-manual** should be used as a guide through-out the process. An Aboriginal Heritage desktop survey should also be undertaken during the scoping phase of the planning.

The works will however likely be exempt from requiring a permit under *the Land Use Planning and Approvals Act 1993* per Part 4.0 of the Planning Scheme. This is provided in Table 4.4 of the Scheme per clause 4.4.2 and 4.4.3 listed below:

- *4.4.2 landscaping and vegetation management*

Landscaping and vegetation management within a private garden, public garden or park, or within State-reserved land or a council reserve, if:

a. the vegetation is not protected by legislation, a permit condition, an agreement made under section 71 of the Act, or a covenant; or

b. the vegetation is not specifically listed and described as part of a Local Heritage Place or a significant tree in the relevant Local Provisions Schedule,

unless the management is incidental to the general maintenance.

AND

- *4.4.3 vegetation rehabilitation works*

The planting, clearing or modification of vegetation for:

c. soil conservation or rehabilitation works including Landcare activities and the like, provided that ground cover is maintained and erosion is managed;

d. the removal or destruction of declared weeds or environmental weeds listed under a strategy or management plan approved by a council;

e. water quality protection or stream bank stabilisation works approved by the relevant State authority or a council;

f. the implementation of a vegetation management agreement or a natural resource, catchment, coastal, reserve or property management plan or the like, provided the agreement or plan has been endorsed or approved by the relevant State authority or a council; or

g. the implementation of a mining and rehabilitation plan approved under the terms of a permit, an Environment Protection Notice, or rehabilitation works approved under the Mineral Resources Development Act 1995.

High level modelling of a reduction in willow density indicated that willow removal/control would likely reduce the extent of flooding to the River Clyde floodplain during frequent flood events and shown graphically in Appendix G (at the time of peak flood level).

8.1.2 Debris Management

Debris management can also be a major issue following a flood event, particularly if catchment management is lacking. Large amounts of debris can be washed into rivers, including trees and other vegetation from private properties. This can cause significant damage to infrastructure and exacerbate the effects of flooding. It is important to communicate these issues to property owners and encourage them to take responsibility for managing the flood-inundated areas around their properties. This can help to reduce the overall impact of flooding on the local economy and community.

8.1.3 Insurance Policy

In addition, individuals who are unaware of whether they have flood insurance coverage may be faced with unexpected expenses and financial difficulties, adding to the trauma they have already experienced from the flood.

The conflict between flood and storm cover in insurance policies can also contribute to confusion and uncertainty. Storm cover typically refers to damage caused by high winds, hail, and other severe weather conditions, while flood cover is designed to protect against damage caused by rising water levels. However, there may be overlap between these two types of coverage, and policy language can be complex and difficult to understand. To address these issues, it is important for Bothwell residents and businesses to review their insurance policies carefully and ensure that they have adequate coverage for flood damage. Council can provide some education efforts to help raise awareness of the risks of flooding and the importance of being prepared. By taking proactive steps to mitigate the impact of floods, individuals and businesses can help protect themselves and the local economy from the financial and emotional toll of these disasters.

8.1.4 Infrastructure Upgrade

GHD investigated options for an infrastructure upgrade to minimize flooding in the town of Bothwell. The proposed option was designed to take into consideration the constructability of any new infrastructure required, the available space, existing underground services, historical value, and alignment of the existing infrastructure. The focus was on incorporating best practice flood management principles, recognising that flooding is a natural process that needs to be integrated into the rural landscape rather than ignored or eliminated through feats of engineering. GHD conducted a thorough options assessment that included a natural values assessment and a land use planning assessment to highlight any potential risks and inform the options.

The reduction of release volumes from Lake Crescent was an option that was considered as a potential flood risk management measure. However, this option was ultimately dismissed due to community consultation feedback and concerns about drought conditions. The community expressed their opposition to the idea, and there were concerns that reducing the release volumes could impact irrigation in the area. Additionally, there was a realisation that this measure might not have a significant impact on the overall flood behaviour in the wider River Clyde catchment.

Another potential option that was considered for flood risk management was the construction of in-stream detention basins. However, this option was also dismissed due to several factors. The main concern was the high cost of building and maintaining these basins, which made them economically unfeasible. Additionally, there were potential safety concerns associated with the construction and operation of the basins, such as the risk of erosion and flooding.

This section will explore the option proposed by GHD, its advantages, and its suitability in mitigating flooding in Bothwell.

8.1.4.1 Option 1 - Stormwater Infrastructure Upgrade

It has been determined that Option 1, as proposed by PDA Surveyors, is a viable option for mitigating the flooding issue. This option involves laying a new stormwater pipework along the local overland flow path through the back of the hotel and through No 8 Patrick St and No 4 Patrick St. While this option is expected to effectively convey flow in frequent floods, it is important to note that during high river flows, the proposed option may be ineffective.

During high river flows, it is likely that the downstream levels of the River Clyde will not allow the water to be discharged freely, which could result in backflow and further exacerbate the flooding problem. As such, it is important to consider measures to address this potential issue, such as implementing a valve or other backflow prevention devices at the outlet location. This will ensure that the proposed option remains effective in mitigating flooding during frequent floods, while also addressing the potential issue of backflow during high river flows. Overall, a comprehensive approach to flood management that considers both frequent and extreme flood events, as well as downstream conditions, will be necessary to ensure the long-term effectiveness of any proposed solutions.

The flood inundation extents and depths for 5% AEP is shown graphically in Appendix G (at the time of peak flood level).

8.1.4.2 Option 2 - Open Drainage Channel

Option 2 proposes the construction of an open channel that will convey water from the northeast to the south side of the residential area along Franklin Street and discharging water into the River Clyde. However, it presents some challenges, such as the need for additional measures like culverts and underground infrastructure to ensure safe and efficient conveyance of water. Additionally, the downstream piped section is necessary to accommodate private driveway crossings, which can add complexity to the construction process. Excavation is also a significant undertaking, as the channel will need to be deep enough to handle a significant amount of water. Moreover, constructing the channel against the existing natural ground slope in the upper reaches will require careful planning and execution to ensure that the channel banks are stable. Despite these challenges, Option 2 remains a viable solution for managing water flow in the residential area of Bothwell township.

Additionally, it can be designed to integrate with the existing landscape and infrastructure, ensuring minimal disruption to the surrounding environment. The open channel could also serve as a natural habitat for wildlife, depending on its design and construction.

Two additional upgrades have been considered for the Arthur Crescent and Nant Lane areas. The first option was to upgrade the bridge/crossing, but due to the significant cost compared to the benefits, this option does not appear viable in the short term. As an alternative, the Council should consider implementing safety measures at the crossing to exclude movements during flooding. The second option was to undertake levee works adjacent to the properties, but it is not considered viable due to the significant inundation of the wider area and inflow from the east side of the area.

The flood inundation extents and depths for 5% AEP are shown graphically in Appendix G (at the time of peak flood level).

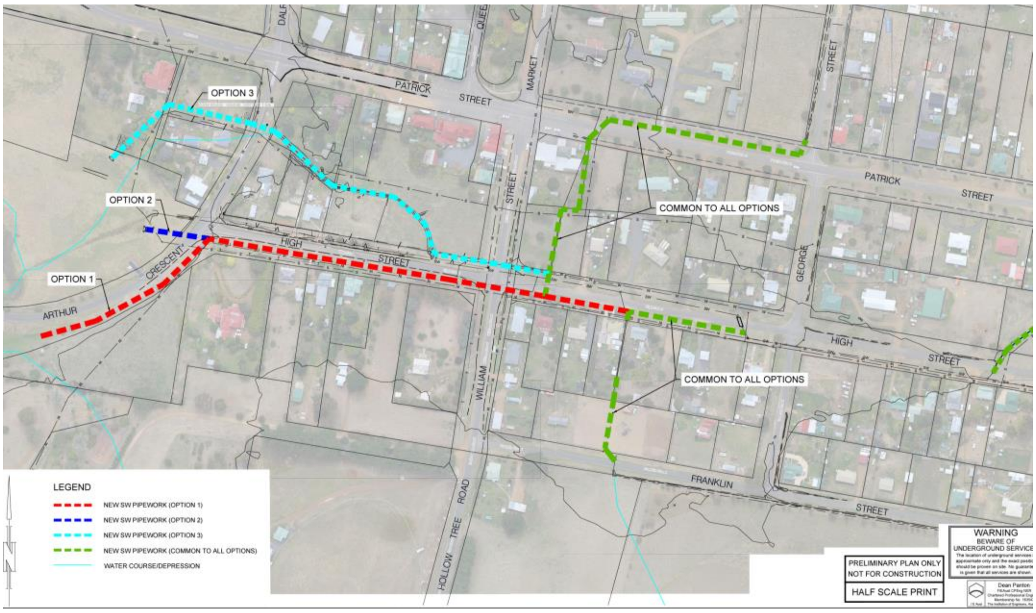


Figure 18 PDA Surveyors Mitigation Options

8.1.5 Land Use Planning Considerations for Infrastructure Options

In considering the infrastructure options for flood and stormwater management, Council will need to factor requirements under the Planning Scheme. This should be undertaken early in the project planning phase as part of a project plan.

The following planning considerations are provided for the options shown in Figure 18:

– Stormwater works such as pipes, open drains/swales, detention or retention basin dam are defined as mostly “Minor Utilities”, however a large detention or retention basin/dam could mean the works are “Utilities” and may require a permit.

- There are six (6) heritage listed places under the *Historic Cultural Heritage Act 1995*. These are 6 High Street, 16-18 High Street, ‘Castle Hotel’ 14 Patrick Street, 10 Patrick Street, 8 Patrick Street and 4 Patrick Street. Works could be managed through design solutions or avoidance of property or extent of heritage values.
- Works are in the Bothwell Heritage Precinct under the Local Historic Heritage Code.
- There is a small area of Priority Vegetation Overlay under the Natural Assets Code at 2 Franklin Street.
- The area is mixed zones. The use status of works for each zone is provided as follows:
  - Village Zone – likely exempt from requiring a permit as stormwater infrastructure per 4.2.2 of the Planning Scheme
  - Agriculture Zone – likely exempt as stormwater infrastructure per 4.2.2 of Scheme.
  - Rural Living Zone - likely exempt as stormwater infrastructure per 4.2.2 of Scheme
  - Recreation Zone - likely exempt as stormwater infrastructure per 4.2.2 of Scheme
- GHD recommend an Aboriginal Heritage desktop assessment be undertaken during the planning and design phase of the project – particularly closer to the River Clyde.
- Works should and ought to be undertaken within the road reserve where possible.

The infrastructure options are likely exempt from requiring a permit under the Planning Scheme. However further considerations will be required early in the project planning phase.

9. Natural Values Assessment

GHD conducted a desktop based natural values assessment to examine and assess the existing environment within a defined survey area and identify the extent of any environmental values that may constrain the suitability and implementation of any proposed mitigation options (specifically Option 2 as per section 8.1.4.2) for the River Clyde mapping study and flood mitigation strategies.

Environmental constraints assessed include the potential presence of conservation significant vegetation communities, flora species, fauna species and habitat. The desktop assessment collates data from verified publicly available databases, although does not contain any field assessment or site investigation conducted in association with the works. As such, small scale variations in vegetation, flora composition, fauna habitat and general condition of the site are unlikely to be represented in the assessment.

Key recommendations of the desktop assessment include:

- A total of 11 state and/or Commonwealth listed flora species have the potential to or are likely to be located within the survey area.
- A total of seven state and/or Commonwealth listed fauna species (two birds, four mammals & one reptile) are potentially present within the survey area based on previous records, their known habitat preferences and the habitat identified during the desktop assessment.
  - The survey was not considered to provide suitable nesting or denning habitat for the Tasmanian devil, spotted tailed-quoll, Tasmanian wedge-tailed eagle, and Tasmanian masked owl given the lack of representative suitable habitat.
  - Suitable nesting/denning habitat for the eastern quoll, eastern barred bandicoot and the tussock skink may be present within the survey area.
- The survey area intersects with a small area listed as 'Priority Vegetation' under the Natural Assets Code of the Central Highlands Local Provisions Schedule and Tasmanian Planning Scheme.
  - According to aerial imagery, the vegetation in this area looks to comprise roadside planted shrubs and trees, however, this will require confirmation.
- Based on the above, prior to the commencement of any construction a natural values survey conducted by a suitably qualified ecologist is recommended to map and record the baseline ecological values within the survey area.
  - It is noted that the majority of the survey area is mapped as modified vegetation in the form of agricultural/pastoral land, house and transport infrastructure and urban areas. However, some threatened flora and/or fauna species are known to inhabit such communities which may provide refugia in a heavily cleared landscape.
  - The survey should aim to target those species (flora and/or fauna) whose suitable habitat was identified as potentially present.
  - Field survey methods should be developed in accordance with the NRE Guidelines for Natural Values Surveys - Terrestrial Development Proposals
  - Flora surveys should ideally be conducted during the spring/early summer flowering period for most Tasmanian flora species as this will increase the likelihood of positive identifications.
    - Where baseline flora surveys identify the likely presence of potential threatened flora species, or some flora species are unable to be identified in the field, additional targeted flora surveys may be required.
- Once the preferred flood mitigation option has been selected, the final project footprint should be determined.
  - This will assist the assessment of the potential impacts of any proposed development and inform the methods and the extent of the proposed survey activities.
- Eleven declared weeds under the Tasmania *Weed Management Act 1999* have been recorded within 500m and 5km of the survey area respectively. Several of which are also known to be Weeds of National Significance (WoNS).

  - As such, the proponent should develop and implement a Weed & Hygiene Management Plan (WHMP) to reduce the risk of introduction and spread of invasive flora species as a result of any development.
  - The WHMP may be included as part of any Construction Environmental Management Plan (CEMP) developed for the project.
- Once the final project footprint is confirmed, impacts to listed flora, fauna and vegetation communities should be confirmed to inform the need for any relevant permits and approvals.
  - This will be informed by the results of the recommended field survey.

The full desktop assessment can be found in Appendix H of this report

10. Conclusion

This study has investigated the flood levels along River Clyde, resulting from flood inundation caused by the 1% and 5% AEP design flood events and the 1% AEP design flood event with climate change. The study investigated flooding between Nant Lane and the River Clyde Falls, focused on Bothwell township. A hydrological study was conducted using a RAFTS hydrology. A variety of available and collected data was utilised for modelling purposes. This includes hydrological, geographical, climate, management, flood history, and previous study data. The availability of this data has supported the development of hydrological and hydraulic models for the River Clyde catchment area. The compiled data and relevant contacts for organisations have been summarised in this report, providing a useful resource for future research and planning in the area.

The results of the hydrological study show that the critical duration for the catchment was 6 hours for both the current study as well as the climate change scenario. The climate change scenarios analysed project increases in the magnitudes of the 1% AEP flood by 16.3% by the end of the century.

InfoWorks ICM modelling results indicate that the residential area in Bothwell, Arthur Crescent, Williams Street and Nant Lane are likely to flood during frequent and rare rainfall events.

InfoWorks ICM modelling results also indicate that the flood capacity of the stormwater infrastructure within Bothwell is restricted due to the high River Clyde levels.

It is important to note that the results of the study should be interpreted in the context of the limitations of the data and models used. Moreover, the study may not reflect the full range of flood behaviour and potential impacts in the study area, particularly in rare and extreme flood events. A high-level review of potential flood mitigation measures was undertaken with several option identified for potential future investigation and implementation, including:

- Willow removal and management
- Debris management
- Insurance policy review
- Infrastructure upgrades
- Administrative controls (flood risk communication and response planning)

Further details of these mitigation measures are outlined in Sections 7.5 and 8 of this report.

11. References

Babister, M., Trim, A., Testoni, I. and Retallick, M. 2016. The Australian Rainfall and Runoff Datahub, 37th Hydrology and Water Resources Symposium Queenstown NZ

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) *Australian Rainfall and Runoff: A Guide to Flood Estimation*, © Commonwealth of Australia (Geoscience Australia), 2019.

Bates, B., Evans, J., Green, J., Griesser, A., Jakob, D., Lau, R., Lehmann, E., Leonard, M., Phatak, A., Rafter, T., Seed, A., Westra, S. and Zheng, F. (2015), Development of Intensity-Frequency-Duration Information across Australia - Climate Change Research Plan Project. Report for Institution of Engineers Australia, Australian Rainfall and Runoff Guideline: Project 1. 61p.

CSIRO and Bureau of Meteorology (2015), Climate Change in Australia, Projections for Australia's NRM Regions. Technical Report, CSIRO and Bureau of Meteorology, Australia. Retrieved from www.climatechangeinaustralia.gov.au/en [http://www.climatechangeinaustralia.gov.au/en].

Engineers Australia (2012), Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engineering. The National Committee on Coastal and Ocean Engineering, 3rd edition, revised 2013.

IPCC (Intergovernmental Panel on Climate Change) (2013), Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. [Stocker, T.F., and others (Eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA.

Wasko, C. and Sharma, A. (2015), Steeper temporal distribution of rain intensity at higher temperatures within Australian storms, Nature Geoscience, 8(7), 527-529.

Zheng, F., Westra, S. and Leonard, M. (2015), Opposing local precipitation extremes. Nature Climate Change, 5(5), 389-390, doi: 10.10. 38/nclimate2579, Available at: http://dx.doi.org/10.1038/nclimate2579.

Australian Disaster Resilience Guideline 7-3:Technical flood risk management guideline: Flood hazard, 2014, Australian Institute for Disaster Resilience CC BY-NC

Appendices