DEPARTMENT OF PLANNING, INDUSTRY AND ENVIRONMENT

JUNE 2021

TECHNICAL STUDY REPORT

ENGINEERING – FLOODING AND WATER QUALITY

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GLOSSARY

AUSRIVAS	The Australian River Assessment Scheme (AUSRIVAS) is a rapid bioassessment method which utilises macroinvertebrates as sensitive indicators of in-stream health.
Catchment	The area drainage by a stream or body of water or the area of land from which water is collected.
Flood prone land	Land susceptible to flooding by the probable maximum flood. Note that the flood prone land is also known as flood liable land.
Floodplain	Area of land which is inundated by floods up to and including the probable maximum flood event (i.e. flood prone land).
Freeboard	A factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. It is usually expressed as the difference in height between the adopted flood planning level and the peak height of the flood used to determine the flood planning level. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the floodplain, such as wave action, localised hydraulic behaviour and impacts that are specific event related, such as levee and embankment settlement, and other effects such as "greenhouse" and climate change. Freeboard is included in the Flood Planning Level.
Hydraulics	term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
Hydrology	Term given to the study of the rainfall and runoff process, including surface and groundwater interaction; with particular focus on the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Investigation Area	The investigation area for the Snowy Mountains SAP, encompassing an area of 72,211 ha including Jindabyne and the Alpine Resorts of Kosciuszko National Park.
megalitres	1,000,000 litres which is equivalent to 1000 cubic metres (m^3)
Monero Ngarigo	Aboriginal linguistic group who traditionally occupied the eastern side of the Kosciuszko plateau and further north towards the Murrumbidgee River. The traditional custodians of the Snowy Mountains are the Monero Ngarigo people.
PMF	Probable maximum flood. The flood that occurs as a result of the probable maximum precipitation on a study catchment. The probable maximum flood is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The probable maximum flood defines the extent of flood prone land (i.e. the floodplain).
Pollutant	Any measured concentration of solid or liquid matter that is not naturally present in the environment.
Runoff	The amount of rainfall that ends up as streamflow, also known as rainfall excess.
Snowy Mountains	The highest mountain range on the continent of mainland Australia, located in southern New South Wales and part of the larger Australian Alps and Great Dividing Range. The mountain range experiences large natural snowfalls every winter.
Special Activation Precinct	A Special Activation Precinct is a dedicated area in a regional location identified by the NSW Government to become a thriving business hub to create jobs, attract business and investors, support local industries and fuel economic development.
Waterway	Any flowing stream of water, whether natural or artificially regulated (not necessarily permanent).

ABBREVIATIONS

AEP	Annual Exceedance Probability. The probability that a design event (rainfall or flood) has of occurring in any 1 year period.
AHD	Australian height datum
ARR	Australian Rainfall and Runoff
AIDR	Australian Institute for Disaster Resilience
ASRIS	Australian Soil Resource Information System
AUSRIVAS	Australian River Assessment System
BoM	Bureau of Meteorology
CBD	Central Business District
DPIE	Department of Planning, Industry and Environment
DRNSW	Department of Regional New South Wales
EbD	Enquiry by Design
EC	Electrical Conductivity
EES	Environment, Energy and Science (NSW)
EPA	Environment Protection Authority
HNSW	Heritage New South Wales
KNP	Kosciuszko National Park
KNP POM	Kosciuszko National Park Plan of Management
LEP	Local Environmental Plan
LGA	Local government area
NARCliM	NSW and ACT Regional Climate Modelling
NPWS	National Parks and Wildlife Service
NSW	New South Wales
PMF	Probable Maximum Flood
RAP	Registered Aboriginal Party
RGDC	Regional Growth NSW Development Corporation
SAP	Special Activation Precinct
SEPP	State Environmental Planning Policy
SES	State Emergency Service
SMRC	Snowy Monaro Regional Council
STP	Sewage Treatment Plant
TfNSW	Transport for NSW
TN	Total Nitrogen
TP	Total Phosphorus

EXECUTIVE SUMMARY

The Snowy Mountains region is one of Australia's most iconic natural environments and is located at the top of the Great Dividing Range dividing the Snowy River catchment to the east from the Murrumbidgee River and Murray Darling Basin to the west. In addition to hosting to some of Australia's premier alpine destinations, the Snowy Mountains is home to over 35,000 people and Australia's highest peak, Mount Kosciuszko.

The region's unique natural environment allows locals and visitors to participate in a diverse array of recreational activities year-round, with many visitors still experiencing the region through the peak winter season.

The Snowy Mountains Special Activation Project (SAP) is intended to develop a regional plan that considers the needs of Jindabyne, the ski resorts, and surrounding areas in a way that supports the growth of a shared destination, rather than isolated tourist facilities. The aspirations of the Snowy Mountains SAP project relevant to this technical study include:

- Adventure and Ecotourism – Lake Jindabyne
- Sustainability and wellness – through green infrastructure
- Design and culture – Lake Jindabyne and its waterfront
- Infrastructure and connections – accessibility through roads.

This Technical Study forms part of the Engineering Package for the Snowy Mountains Special Activation Precinct and provides an understanding of flood behaviour and water quality across the study area. The study area includes the Snowy River catchment which includes subcatchment areas of Perisher Creek and its tributaries, Thredbo River and its tributaries, Lake Jindabyne and its tributaries of Lees Creek, Wollondibby Creek, Rushes Creek, Widows Creek and Mowamba River.

Snowy Hydro Limited operate Lake Jindabyne as a storage to supply water to their hydro power stations as part of the Snowy Hydro Scheme. Lake levels are controlled by Snowy Hydro Limited and are subject to inflows from the Snowy River, Eucumbene River, Thredbo River and many minor tributaries.

To understand flood behaviour across the Snowy Mountains SAP study area, detailed flood models were built using the latest topographic information and aerial photography. The flood models focused on the ski resort area of Perisher and Thredbo, Bullocks Flat and Jindabyne, East Jindabyne, and the land to the south west of Jindabyne.

The hydraulic model results show that the flood behaviour within the Snowy Mountains SAP area is primarily confined to existing defined watercourses and rivers, with very little areas exhibiting widespread surface flooding. Even in the extreme events such as the Probable Maximum Flood event, no major overbank areas were inundated, with floodplains confined to the banks or immediate overbank areas of the existing watercourses.

Water quality and biological health monitoring of the rivers and streams in the Kosciuszko National Park has been undertaken since 2004. The data is summarised in Kosciuszko National Park, Resorts Water Quality and River Health Monitoring Sites reports with a focus on the Perisher and Thredbo Valleys. The data has indicated total nitrogen levels to be above national guidelines levels particularly in the Perisher Valley. The quality of water in Lake Jindabyne has not been assessed recently for stormwater pollutants but is regularly tested at inlets to water treatment plants with a monitoring event in August 2020 indicating high turbidity levels.

Activities that affect water quality, particularly in the streams of the Kosciuszko National Park, include the application of salt to reduce the build-up of ice on roads during the winter season. Salinity (measured as Electrical Conductivity) monitoring results for both Perisher and Thredbo Valleys indicated a few elevated readings in both spring and autumn but no consistent trend. Cloud seeding by Snowy Hydro is monitored annually for impacts by the Natural Resources Commission and has been found to have minimal impacts on water quality.

The Snowy Mountains SAP Strategic Master Plan developed by Jenson Plus, representing the Proposed Growth Areas to align with inputs of the stakeholders, identifies a number of growth areas around Jindabyne, East Jindabyne and the ski resorts. The growth areas have been considered against the existing flood behaviour and known water quality conditions to develop recommended performance criteria to minimise the impact of growth on the surface water environment across the Snowy Mountains SAP.

For flood risk management, the following performance criteria are recommended:

- adopting a flood planning level of 1% Annual exceedance probability plus 0.5 m freeboard
- specifying flood compatible building material for buildings in the floodplain
- development must be sited, designed and located to avoid or mitigate the flood risk to people, property and infrastructure
- development should mitigate the impacts of local overland flooding through the provision of adequate site drainage systems
- development must consider and plan for emergency evacuation situations to ensure the safety of all areas within the Probably Maximum Flood extent

For water quality, the following performance criteria are recommended:

- promoting integrated water cycle management
- capturing and reusing stormwater from roofs at the source
- implement stormwater quality treatment at the source
- water quality discharge should aim to meet the targets of:
  - Total Suspended Solids: 85% reduction
  - Total Phosphorus: 60% reduction
  - Total Nitrogen: 45% reduction
  - electrical conductivity levels to be maintained below the 30 µS/cm ANZG 2018 Guideline Value for upland rivers of south-east Australia.
- consider future climate change projections for rainfall in planning growth areas
- erosion and sediment control should be managed during construction to ensure impacts to waterways are minimized.

1 INTRODUCTION

Special Activation Precincts (SAPs) are dedicated areas in regional NSW identified by the NSW Government to become thriving hubs. The SAP program facilitates job creation and economic development in these areas through infrastructure investment, streamlining planning approvals and investor attraction.

The SAP program adopts a collaborative and integrated whole-of-government approach, bringing together the local Council and a range of other relevant State and local agencies.

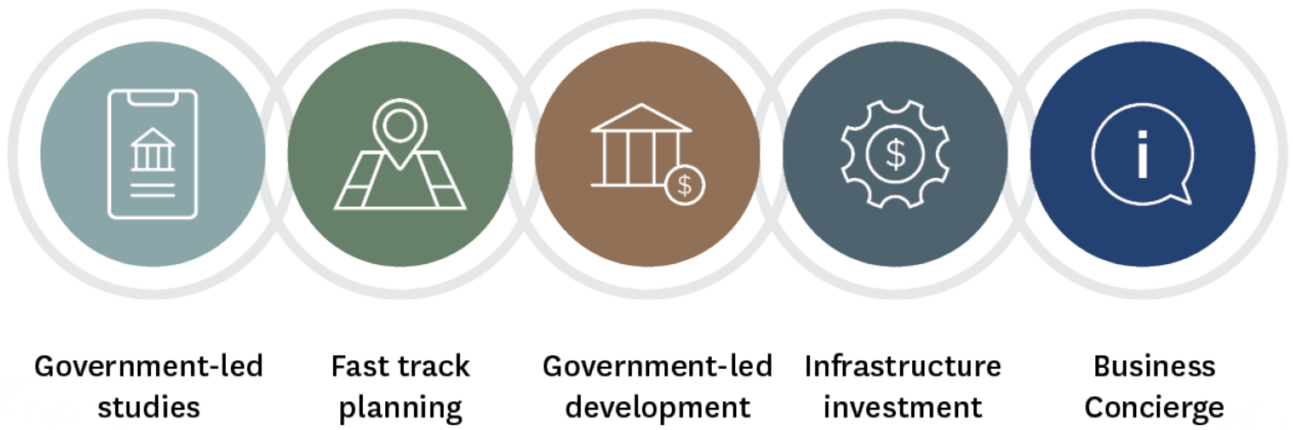
SAPs are unique to regional NSW. By focusing on planning and investment, their goal is to stimulate economic development and create jobs in line with the competitive advantages and economic strengths of a region.

On 15 November 2019, the NSW Government announced its commitment to investigating the Snowy Mountains SAP, to revitalise the Snowy Mountains into a year-round destination and Australia's Alpine Capital, with Jindabyne at its heart. The Snowy Mountains SAP is being delivered through the $4.2-billion Snowy Hydro Legacy Fund.

Different components of each SAP are led by different teams within the NSW Government:

- The **Department of Regional NSW** assesses potential locations for inclusion in the program and considers government investment for essential infrastructure to service the SAPs.
- The **NSW Department of Planning, Industry and Environment** (the Department) is responsible for the planning of SAPs. The Department leads the master planning process, including community and stakeholder engagement, the technical studies required to inform the preparation of a master plan and development of the simplified planning framework for each Precinct.
- The **Regional Growth NSW Development Corporation** (Regional Growth NSW) is responsible for delivering and implementing Special Activation Precincts. This includes attracting investment, providing support to businesses, developing enabling infrastructure, and creating strategic partnerships to foster education, training and collaboration opportunities.

The five core pillars of the Special Activation Precincts are:



The planning framework for each Special Activation Precinct includes three key parts:

State Environmental Planning Policy (Activation Precincts) 2020	**Special Activation Precinct Master Plans**	**Special Activation Precinct Delivery Plans**

— Identifies each Special Activation Precinct.
— Requires that an Activation Precinct Certificate be sought prior to a development application or complying development certificate being issued, to ensure the development is consistent with the Master Plan and Delivery Plan.
— Provides zoning and land use controls for each Precinct.
— Identifies Exempt and Complying Development pathways for certain development.
	— Made by the NSW Department of Planning, Industry and Environment and approved by the Minister.
	— Identifies the Vision, Aspirations and Principles for the Precinct.
	— Provides more detailed land use controls where required.
	— Identifies Performance Criteria at a Precinct-scale for amenity, environmental performance and infrastructure provision.
	— Identifies the matters to be addressed as part of the Delivery Plan.
		— Prepared by Regional Growth NSW and approved by the Planning Secretary.
		— Identifies site-level development controls.
		— Provides detailed strategies and plans for:
		   — Aboriginal cultural heritage
		   — environmental protection and management
		   — protection of amenity
		   — infrastructure and services
		   — staging
		   — provides procedures for ongoing monitoring and reporting.

1.1 MASTER PLANNING

The master planning process for the SAPs adopts an evidenced based approach to determining the best outcome for the precincts. It is designed to ultimately provide a clear pathway for the right types of future development, in the right locations.

The process involves the engagement of a range of technical experts to investigate the study area and prepare technical studies (such as this report) to demonstrate their findings. Each of the technical studies are specifically designed and scoped for each SAP and tailored to the needs of the study area.

Importantly, the master planning process for the Snowy Mountains SAP will build on work already undertaken for portions of the study area as part of the Go Jindabyne master plan.

To achieve integrated and balanced planning outcomes, technical experts and other stakeholders work together at a series of enquiry by design workshops throughout the master planning process. At these workshops, opportunities and constraints are discussed and assessed to inform how the precinct should be shaped. This includes the evaluation of matters such as environmental impacts and benefits, transport opportunities, infrastructure capabilities, stormwater, economic viability and many others. These workshops are designed to give technical experts and decision makers a chance to ensure the identified vision, aspirations and principals for the precinct are guiding the outcomes.

The technical reports will ultimately inform the development of planning controls for the Snowy Mountains SAP to guide the precincts development. These controls will be contained in the master plan, Special Activation Precincts SEPP and delivery plan and will relate to important matters such as amenity, environmental performance and infrastructure provision.

Throughout the planning process, community, stakeholder and industry consultation takes place. Ongoing consultation provides an opportunity for community members and landowners to contribute and help shape the vision for the project.

1.2 SNOWY MOUNTAINS SAP

The Snowy Mountains region is one of Australia's most iconic natural environments. In addition to hosting some of Australia's premier alpine destinations, the Snowy Mountains is home to over 35,000 people and Australia's highest peak, Mount Kosciuszko. The traditional custodians of the Snowy Mountains are the Monero Ngarigo people, in connection with the Walgalu, Ngunnawal and Bidhawal people.

The Snowy Mountains are located in the south east of NSW. This region forms the northern part of the Australian Alps which extends south into Victoria. Predominantly the region is accessed from Canberra which is located approximately 150 kilometres to the north. To the south and west of this region is the sparsely populated high country. The township of Jindabyne situated on Lake Jindabyne provides a hub for the region, with opportunities for tourism and facilities supporting the regional catchment.

Jindabyne is located 175 km south of Canberra and 60 km south-west of Cooma. Jindabyne has evolved into the gateway to the Snowy Mountains and currently services 1.4 million visitors each year who travel to the region to enjoy its unique tourism and recreational offerings (Destination NSW, June 2020 report). There are approximately 35,500 residents of the Snowy Mountains, of which 3,500 residents live in Jindabyne (including Kalkite, East Jindabyne and Tyrolean Village).

Portions of the Snowy Mountains are within Kosciuszko National Park. Kosciuszko National Park is the central segment of the Australian Alps Bioregion containing the highest mountains in Australia and is the largest national park in NSW (NSW National Parks and Wildlife Service, 2006). The park possesses exceptional diversity of alpine plant communities, containing threatened ecological communities (TECs) and providing habitat for a number of rare and threatened species (National Parks and Wildlife Service, 2006). The park contains most of the alpine endemic species found on the Australian mainland (National Parks and Wildlife Service, 2006).

The Snowy Mountains region is home to the Monero Ngarigo people, the tribal homeland stretches from the western slopes of the coastal ranges to the eastern side of the Kosciuszko plateau and further north. Included in the Ngarigo land is the peak of Mount Kosciuszko and the Snowy Ranges. European settlers accessed the region in 1823, and between the late 1830s to 1957 the Monaro highland region was grazing by cattle and sheep. The original town of Jindabyne was settled in the 1840s on the banks of the Snowy River where the main river crossing took place. A bridge was constructed over the river in 1893, contributing to the success of the town. In 1949 the Snowy Mountains Scheme was introduced which consisted of plans to dam and divert water from the Snowy River. By 1964 the dam had created Lake Jindabyne and the township relocated to where it is today. The old town disappeared under Lake Jindabyne in 1967. Although losing much of its built heritage, Jindabyne, as we know it today, was rebuilt and has continued to steadily grow leveraging its tourist and agricultural offerings (Ozark Environment and Heritage, 2020).

Today, the Snowy Mountains region plays a crucial role within the regional and state economy, with its local population swelling with an additional 1.4 million international and domestic visitors each year (Destination NSW, June 2020 report). The region's unique natural environment allows locals and visitors to participate in a diverse array of recreational activities year-round, with many visitors still experiencing the region through the peak winter season.

Priorities for the Snowy Mountains SAP are to capitalise on the unique cultural and environmental attributes which attract 1.4 million visitors annually to the region, revitalise the Snowy Mountains into a year-round destination, and reaffirm Australia's Alpine Capital (Destination NSW, June 2020 report). The revitalisation is to focus on year-round adventure and eco-tourism, improving regional transport connectivity, shifting towards a carbon neutral region, increasing the lifestyle and wellbeing activities on offer, and supporting Jindabyne's growth as Australia's national winter sports training base.

1.3 STUDY AREA

The Snowy Mountains SAP Investigation Area encompasses 72,211 hectare (ha) of land and within this study area are several key areas called "development opportunity areas":

- Jindabyne growth opportunity areas: parcels of land located primarily to the south and west of the existing Jindabyne township, but also at East Jindabyne
- Jindabyne centre opportunity areas: areas within the existing town of Jindabyne
- Tourism opportunity areas: areas both near the town of Jindabyne and in the Kosciuszko National Park.

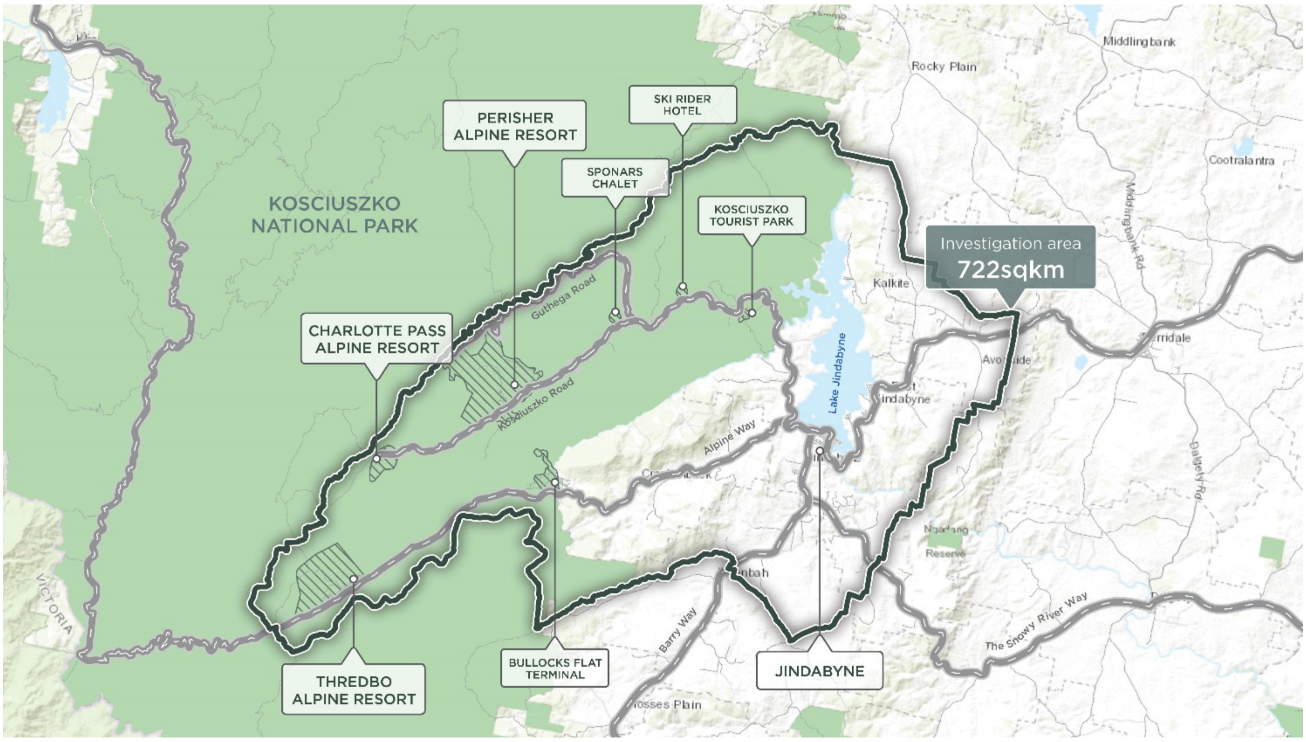


Figure 1.1 Study area

1.3.1 FLOODING TECHNICAL REPORT STUDY AREA

The study area for this technical study extends beyond the Snowy Mountains SAP area to cover the contributing hydrologic catchments which are presented in Figure 1.2. The hydrologic catchments contribute runoff to the Snowy Mountains SAP investigation area and inform the flooding and water quality technical assessments.

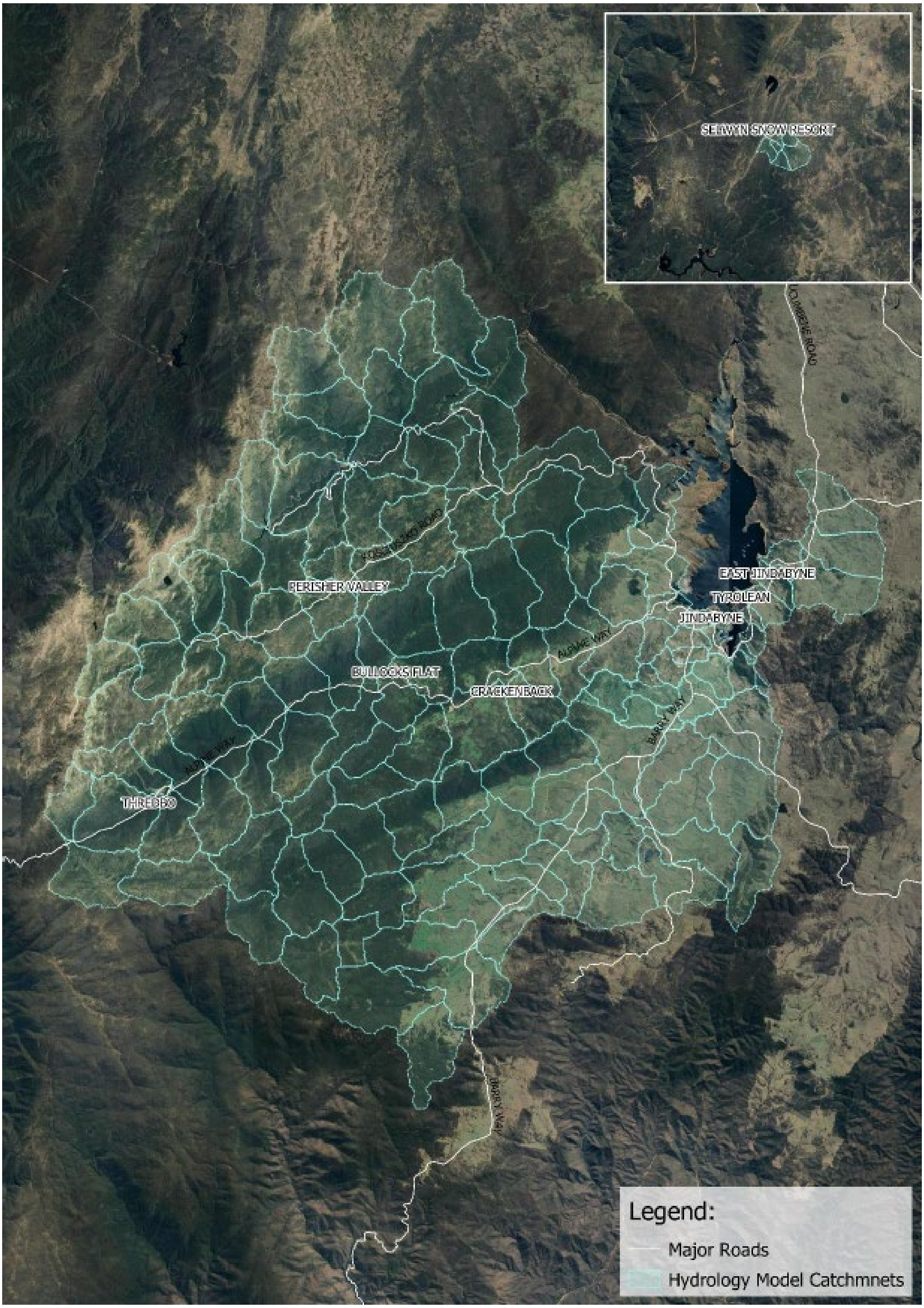


Figure 1.2 Study area hydrologic catchments

1.4 PURPOSE

This Technical Study will form part of the Engineering Package for the Snowy Mountains Special Activation Precinct (SAP). This report builds on the context analysis reporting to provide a holistic view of the issues, opportunities and constraints within the Snowy Mountains SAP study area. It explores stakeholder issues and current and future constraints to investigate strategic projects for the Snowy Mountains area. This Technical Study has been prepared through collaboration with the NSW Government, Snowy Monaro Regional Council, Snowy Hydro Limited and other stakeholders including representatives from the Alpine Resorts.

The recommendations from this report will combine with other technical studies in the disciplines of engineering, planning, environment, economics and legislation to inform the Master Planning for the Snowy Mountains SAP.

1.5 BACKGROUND

The following background information has been reviewed to inform this technical study:

EXISTING STUDIES
Determination of the effects of Perisher car park on the water quality & biological integrity of Perisher Creek, Cooperative Research Centre for Freshwater Ecology (no date)
Ski Resorts in the Upper Snowy Catchment Stormwater Management Plan 2000 (2000), Storm Consulting
Snowy Precipitation Enhancement Project, Draft Environmental Impact Statement (May 1993), Snowy Mountains Hydro-Electric Authority
Definition of the Physical, Chemical & Biological Condition of the Thredbo River to August 1993 (July 1994), Cooperative Research Centre for Freshwater Ecology
Flood Level Study of Perisher Creek – Copy 1 (April 1997), SMEC
Flood Level Study of Thredbo River – Copy 1 (February 1988), SMEC
Perisher Creek Flood Study – Update for 500 year flood (Nov 1999), SMEC
Thredbo Alpine Village Stormwater Management Plan 2000, Storm Consulting
Flood Study of Pipers and Rock Creeks, Perisher Valley (Sept 2001), SMEC
A Biophysical Profile of the Snowy Catchment, NSW (Jan 2002), J Catford, K Minto, K Mitchell
Perisher Creek Floodplain Management Plan – Copy 1 (July 2002), Storm Consulting
Perisher Roads – Water Sensitive Urban Design (2003), Storm Consulting
Ski Resorts in the Upper Snowy Catchment – Stormwater Management Plan (May 2000), Storm Consulting
Climate Change Impacts in the NSW Alpine Region, Projected changes in snowmaking conditions (2019), NSW Environment, Energy and Science Group
Lake Jindabyne ad Water Quality Project for Snowy Hydro Electric Authority (1990), Boreham and Bowling
Caring for our Australian Alps Catchments (2011), Worboys et al, 2011
Climate Change Impacts in the NSW Alpine Region Projected Climate in the NSW Alpine Region (2018), NSW Environment, Energy and Science Group

1.6 THIS REPORT

The report includes the following sections:

- Section 2 – Relevant Legislation, Policies and Guideline
- Section 3 – SAP Environment – a description of the existing climate and surface water environment
- Section 4 – Case Studies – A summary of the key features of similar locations to inform the Snowy Mountains SAP
- Section 5 – Flood Assessment – details of the flood assessment to inform the Snowy Mountains SAP
- Section 6 – Water Quality Assessment – details of the water quality assessment to inform the Snowy Mountains SAP
- Section 7 – Opportunities and Constraints
- Section 8 – Summary.

2 RELEVANT LEGISLATION, POLICIES AND GUIDELINES

2.1 AUSTRALIAN RAINFALL AND RUNOFF (2019)

Australian Rainfall and Runoff (ARR 2019) is a national guideline document, data and software suite and is used for the estimation of design flood characteristics in Australia. The guideline provides recommended nationally consistent practices for the following:

- estimation of rainfall and runoff for storm events of varying magnitude/severity
- guidance on flood estimation under changing climatic conditions
- provides a methodology for calibration and verification of flood flow estimates
- provides a source for location specific hydrological and hydraulic modelling parameters.

The ARR 2019 document is used as the basis of best practices for flood estimation and modelling, where NSW specific advice has not otherwise been provided by NSW Environment, Energy and Science Group.

It is noted the project brief required ARR 2016 to be adopted as the guide for the technical study. ARR 2016 was a draft version of the guideline which has since been updated following industry review and finalised in 2019.

2.2 FLOODPLAIN RISK MANAGEMENT GUIDELINES (OEH)

The NSW Environment, Energy and Science Group (OEH) provides a number of documents designed to inform and support preparation and implementation of floodplain risk management plans. These guidelines aim to complement and clarify items within the Floodplain Development Manual (NSW 2005) (refer to section 2.4). Key documents within these guidelines include:

- Floodway Definition (OEH 2007)
- Rainwater Tanks – limitations as flood risk management devices (OEH 2007)
- Consideration of ARR 2016 in Studies (OEH 2019).

In particular, these guidelines set out a number of recommendations for alternate methodologies to be adopted within NSW as appropriate regional modification of the national ARR 2019 guidelines. This study addresses and adopts these NSW specific recommendations where appropriate.

2.3 AUSTRALIAN INSTITUTE OF DISASTER RESILIENCE (AIDR) HANDBOOK 7

The AIDR handbook provides advice on management of flooding within the floodplains and catchments of waterways due to flooding from prolonged or intense rainfall. The handbook outlines best practices for managing the flood risk to communities inhabiting floodplains in Australia. The key document within these guidelines is as follows:

- AIDR Handbook 7 Series Guideline 7-3 Flood Hazard.

2.4 FLOODPLAIN DEVELOPMENT MANUAL – THE MANAGEMENT OF FLOOD LIABLE LAND (NSW 2005)

The Floodplain Development Manual (2005) provides guidance for development and implementation of detailed local floodplain risk management plans to produce robust and effective floodplain risk management outcomes. The manual provides the basis for best practice in flood risk management, however some specific methodologies are outdated in favour of more recent approaches documented in guidelines including ARR 2019, Floodplain Risk Management Guidelines (OEH) and the Australian Institute of Disaster Resilience (AIDR) Handbook 7.

2.5 SNOWY RIVER LOCAL ENVIRONMENT PLAN 2013

Specific clauses of the Snowy River Local Environment Plan 2013 relevant to the flood and water quality aspects of the project are described below.

Part 7 Clause 7.1, Flood planning

This clause relates to managing the flood risk to allow land to be developed, to minimise changes to flood behaviour and to manage the long term risk of flooding. It stipulates the flood planning level to be the 1% Annual Exceedance Probability Event (AEP) plus 0.5 metres freeboard. Flood modelling has been used to identify and define risks within flood prone land and define flood compatible development requirements.

Part 7 Clause 7.3 Riparian land and watercourses

This clause relates to the protection of riparian land and watercourses to ensure their sustainability and environmental habitat. The riparian land is defined as “all land that is within 40 metres of the top of the bank of each watercourse on land identified as ‘Watercourse’ on that map”. The watercourses identified on the map include: Cobbin Creek, Lees Creek, Widows Creek, Wollondibby Creek, Thredbo River and Snowy River.

Part 7 Clause 7.4 Wetlands

This clause relates to the protection of wetlands. There are number of wetland areas identified across the study area, with areas mapped along Wollondibby and Mowamba Creeks, and across the ridge lines between the Thredbo and Snowy Rivers.

2.6 SNOWY RIVER DEVELOPMENT CONTROL PLAN 2013

Chapter C General Planning Considerations 2.0 Flood Prone Land identifies the floodplain level to be the 1% AEP flood level plus 0.5 m freeboard. The section identifies suitable development types for flood hazard categories and outlines minimum flood information requirements for new development.

2.7 KOSCIUSZKO PLAN OF MANAGEMENT 2014

The plan outlines how the Kosciuszko National Park will be managed and identifies specific policies and actions set out in the following sections.

2.7.1 FLOODING ASPECTS

The scope of the plan of management with reference to flooding, as outlined in Section 3.6 of the plan, includes the following:

- the maintenance of natural processes
- the preservation of catchment values
- the protection and management of wild rivers.

The plan describes the current climate (refer to section 3.2 of this report) and future predicted changes (refer to the latest climate change information in section 3.2.1 of this report) and identified issues and opportunities and management objectives. Climate change is identified as the greatest potential threat to the Park.

2.7.2 WATER QUALITY POLICIES AND ACTIONS

1. Apply the best available and practicable technology to protect water quality. Provide particular attention to reducing nutrient levels, biological oxygen demand and non-filterable residues in the treatment of wastewater where effluent is to be released into watercourses. In the event that desired water quality standards cannot be attained by using best practicable technology, aim to reduce the sources of pollution.
2. Periodically review developments in wastewater treatment technologies, especially in areas of similar climate and high conservation value, nationally and internationally.
3. Formulate water quality objectives and targets for catchments in the park. Aim to ensure that the standards for effluent discharged into watercourses do not impair water quality above the levels prescribed.
4. Expand water quality monitoring programs to include all watercourses and waterbodies in the park potentially at risk from pollution. Continue to utilise the AUSRIVAS (Australian River Assessment System) model and other appropriate bacteriological indicators.
5. As part of this monitoring regime, annually assess the water quality of the five glacial lakes and streams and rivers adjacent to popular campsites on the Main Range.
6. Utilise water quality monitoring results to inform management decision-making concerning recreational activities, infrastructure development and other uses.
7. Monitor the impacts of using road de-icing agents on water quality.

2.8 STATE ENVIRONMENTAL PLANNING POLICY (KOSCIUSZKO NATIONAL PARK—ALPINE RESORTS) 2007

Part 5 Division 1 Clause 24 Flood Prone Land describes the provisions applicable prevention of development of flood prone land. The intent of the clause is to prevent development of land subject to flooding and to prevent development of land subject to inundation up to the 1 in 100 year flood level (also referred to as the 1% AEP), where the works are likely to have adverse impact to flood behaviour.

2.9 NATIONAL WATER QUALITY MANAGEMENT STRATEGY

The National Water Quality Management Strategy (NWQMS) aims to protect the nation's water resources by improving water quality while supporting the businesses, industry, environment and communities that depend on water for their continued development. The main policy objective of the NWQMS is to achieve sustainable use of water resources, by protecting and enhancing their quality, while maintaining economic and social development

The NWQMS includes water quality guidelines that define desirable ranges and maximum levels for certain parameters that can be allowed (based on scientific evidence and judgement) for specific uses of waters or for protection of specific values. They are generally set at a low level of contamination to offer long-term protection of environmental values. The NWQMS water quality guidelines include the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018) and the Australian Drinking Water Guidelines (NHMRC 2011).

2.9.1 AUSTRALIAN AND NEW ZEALAND GUIDELINES FOR FRESH AND MARINE WATER QUALITY (ANZECC 2000)

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018) have been prepared as part of the NWQMS. The guideline provides a process for developing water quality objectives (WQOs) required to sustain current or likely future environmental values for natural and semi-natural water resources. These guidelines are an updated version of the previous guidelines referred to as the ANZECC 2000 guidelines.

Where water quality objectives are required for waterways in the Snowy catchment, Environment, Energy and Science (EES) recommends that aquatic ecosystems protection, raw drinking water (for treatment), primary and secondary recreation be applied as default environmental values, with numerical criteria derived consistent with the processes and methodology outlined in ANZG (2018) and ANZECC (2000)). Irrigation, livestock and homestead water use are recommended as additional environmental values outside the Kosciuszko National Park.

In NSW the guiding principles are that:

- where the environmental values are being achieved in a waterway, they should be protected, and
- where the environmental values are not being achieved in a waterway, all activities should work towards their achievement over time.

Table 2.1 shows the default guideline values for physical and chemical stressors for South-East Australia. The 2004 Perisher Water Quality Monitoring report noted that ANZECC/ARMCANZ (2000) water quality trigger concentrations are those below which adverse biological effects in an ecosystem are unlikely to occur. Trigger concentrations for Victorian alpine stream ecosystems (ANZECC/ARMCANZ (2000)) were used in the 2004 study as the ecosystem type compares most closely to the sites in the study area. Trigger levels for NSW upland ecosystems were used when a Victorian alpine ecosystem trigger level was not given in the ANZECC/ARMCANZ (2000) guidelines. ANZECC/ARMCANZ (2000) define upland streams as those above 150 mAHD, while alpine streams are those at altitudes above 1500 mAHD. The default guidelines values for toxicants are as provided on the ANZG Water website.

ANZG (2018) acknowledge that different levels of protection may be appropriate for different water bodies. The policy in NSW is that the level of protection applied to most waterways is the one suggested for “slightly to moderately disturbed” ecosystems. However, waterways that mainly flow through relatively undisturbed national parks, World Heritage areas or wetlands of outstanding ecological significance are designated as being of “high conservation value”. For waterways afforded a high conservation value level of protection there should be no reduction in existing water quality.

Table 2.1 ANZG 2018 guideline water quality trigger values for physical and chemical stressors for slightly disturbed ecosystems in upland rivers and freshwater lakes and reservoirs in south-east NSW

PARAMETER	VALUE	
	Upland Rivers	Freshwater lakes and reservoirs
Chlorophyll-a (mg/L)	n/a	0.005
Total Phosphorus (TP) (mg/L)	0.01 (Victorian alpine streams)	0.01
Filterable Reactive Phosphorus (FRP) (mg/L)	0.005 (Victorian alpine streams)	0.005
Total Nitrogen (TN) (mg/L)	0.1 (Victorian alpine streams)	0.35
Oxides of nitrogen (NO_x) (mg/L)	0.015	0.01
Ammonia (NH_4) (mg/L)	0.013	0.01
Dissolved Oxygen (DO)	90%–110%	90–110%
Turbidity (NTU)	2–25	1–20
pH	6.5–8	6.5–8.5
Salinity (µS/cm)	30–350	20–30
Oils, petroleum and hydrocarbons	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour.	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour.

2.10 MANAGING URBAN STORMWATER – SOILS AND CONSTRUCTION

The Managing Urban Stormwater – Soils and Construction series of handbooks are an element of the NSW Government's urban stormwater program specifically applicable to the construction phase of developments. These are aimed at providing guidance for managing soils in a manner that protects the health, ecology and amenity of urban streams, rivers estuaries and beaches through better management of stormwater quality.

The handbooks were produced to provide guidelines, principles, and recommended minimum design standards for good management practice in erosion and sediment control during the construction of projects.

2.11 FRAMEWORK FOR CONSIDERING WATERWAY HEALTH OUTCOMES IN STRATEGIC LAND-USE PLANNING DECISIONS

The NSW Environment, Energy and Science Group and the NSW Environmental Protection Authority have prepared a Risk based framework for waterway health (NSW OEH and EPA, 2017). This document outlines a framework for decision-makers, such as councils and environmental regulators, to develop management measures that meet waterway values. The Framework links the National Water Quality Management Strategy and other planning instruments to environmental values, land use activities and management measures.

The purpose of the Framework is to:

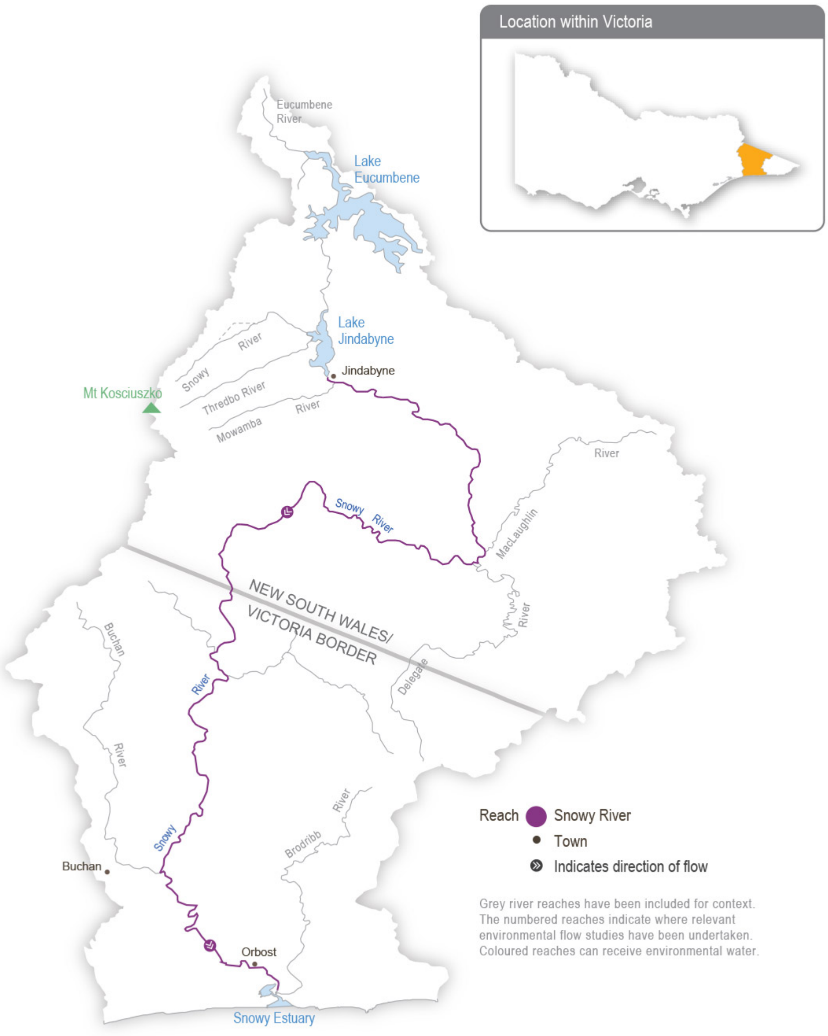
- ensure the community's environmental values and uses for our waterways are integrated into strategic land-use planning decisions
- identify relevant objectives for the waterways that support the community's environmental values and uses, and can be used to set benchmarks for design and best practice
- identify areas or zones in waterways that require protection
- identify areas in the catchment where management responses cost-effectively reduce the impacts of land-use activities on our waterways
- support management of land-use developments to achieve reasonable environmental performance levels that are sustainable, practical, and socially and economically viable.

3 SAP SURFACE WATER ENVIRONMENT

The surface water environment is described here to provide context for the flooding and water quality assessments in later chapters. It is based on the available existing information, topographic information and historic studies and data.

3.1 CATCHMENTS

The Snowy Mountains SAP Study area lies at the top of the Snowy River catchment. The Snowy River is described as one of the largest snowmelt rivers in Australia (NSW Planning, Industry and Environment, 2020). It flows east off the slopes of Mount Kosciuszko and then into Victoria and into Bass Strait. There are four major dams and multiple diversion weirs in the upper Snowy River Catchment that divert water to the Murrumbidgee and River Murray valleys. (Victorian Environmental Water Holder, 2020). Lake Eucumbene is a major dam upstream of the Snowy Mountains SAP study area and Lake Jindabyne is the major dam in the Snowy Mountains SAP Study area. Figure 3.1 shows the Snowy River catchment both upstream and downstream of Lake Jindabyne and several of its tributaries for the study area.



Source:[*https://www.vewh.vic.gov.au/rivers-and-wetlands/gippsland-region/snowy-river*](https://www.vewh.vic.gov.au/rivers-and-wetlands/gippsland-region/snowy-river)

Figure 3.1 Snowy River catchment

3.1.1 DAMS AND DIVERSIONS

Lake Jindabyne and Lake Eucumbene are two of the major storages that form part of the Snowy Hydro Scheme. Eucumbene Dam is an earthfill dam constructed in 1958 with a capacity of 4,798,400 Megalitres which makes it the largest storage in the Snowy Scheme.

Jindabyne Dam is a rockfill dam constructed in 1967 with a capacity of 689,900 Megalitres and is the 4th largest storage in the scheme. The dam incorporates a concrete spillway and hydro-power scheme. The spillway is required to pass design floods in accordance with the NSW Dam Safety Committee guidelines and the dam is also required to release environmental flows to the Snowy River. Similarly the Eucumbene Dam spillway, upstream of the Snowy Mountains SAP Study Area would be required to pass design floods in accordance with the NSW Dam Safety Committee guidelines. It is noted that during high flow events, water is transferred from Eucumbene to lower storages, Khancoban, Geehi or Talbingo but once these storages are full they flow downstream (Snowy Hydro, 2020).

Water is diverted from both Lake Jindabyne and Eucumbene to power stations via tunnels through the mountains. These tunnels transfer the flows from the Snowy River catchment to the Murrumbidgee and Murray Catchment to support agriculture in NSW, Victoria and South Australia and electricity generation is a core by-product of the transfers (Snowy Hydro, 2020). The diversion of the flows from Lake Jindabyne and Eucumbene has reduced the natural flow in the Snowy River at Jindabyne significantly and has changed the structure and function of the river all the way to its mouth at Bass Strait. Snowy Hydro however maintain the water level in the lakes to facilitate recreational use of the lakes.

The Snowy Hydro water operations require water releases from Jindabyne Dam into the Snowy River for environmental purposes. NSW Department of Planning, Industry and Environment – Water require environmental water releases to occur every day of the year and larger flow releases occur in spring to better reflect the hydrology of the mixed rainfall/snowmelt rivers of the Snowy Mountains. During a high flow event (flood event), flows approximating the natural flood flow rates are released to ensure no exacerbation of flooding downstream (Snowy Hydro, 2020).

Guthega Dam is a smaller dam with a concrete gravity wall with a capacity of 1,550 megalitres and constructed in 1959. The Snowy River is the main feeding catchment for the dam with smaller tributaries of Farm Creek and Blue Cow Creek originating near the Perisher Valley Resort. The streams draining the resort areas of Perisher and Smiggin Holes have been diverted via the Perisher Range Aqueduct into Guthega Dam. Flows in excess of the capacity of the aqueduct off take structure bypass the structure and continue downstream in their respective watercourses. The Guthega Dam storage is then used to power the Guthega hydro power station.

Mowamba River is diverted by a weir which is located 4.25 km upstream of the confluence with the Snowy River. Flows up to 523 ML per day to the weir are diverted to Jindabyne Dam via the Mowamba Aqueduct (NSW Office of Water, 2010).

3.1.2 TRIBUTARIES

While the Snowy River is the largest catchment draining through the Snowy Mountains SAP Study area, there are several tributaries that contribute flows to the Snowy River both upstream and downstream of Lake Jindabyne. The creeks and rivers running through the Study Area and into Jindabyne Dam include:

- Eucumbene River (on which the Eucumbene Dam, also part of the Snowy Mountains Scheme, is located, noting that Eucumbene Dam is located outside of the Snowy Mountains SAP Study Area)
- Snowy River
- Perisher Creek
- Rock Creek
- Pipers Creek
- Mowamba River
- Spencers Creek
- Diggers Creek
- Sawpit Creek

- Thredbo River (also known as Crackenback River)
- Friday Flat
- Wollondibby Creek
- Rushes Creek
- Widows Creek; and
- Lees Creek.

A 1990 study (Boreham and Bowling 1990) estimated the contributions to Lake Jindabyne from the tributaries. Table 3.1 below show the breakdown.

Table 3.1 Lake Jindabyne Inflow estimates

WATERCOURSE	PERCENTAGE TOTAL ANNUAL AVERAGE INFLOW
Thredbo River	69%
Mowamba River	15%
Eucumbene River (below dam)	6%
Wollondibby Creek	2.5%
Others combined	7.5%

Source: Boreham and Bowling, 1990

The Snowy River is described as an alpine stream with a steep rock channel upstream of Guthega Dam with its tributaries also having steep rock slopes. (Storm Consulting, 2000). Streams in the Kosciuszko-Perisher region of the Kosciuszko National Park are primarily of two types, either fast flowing and turbulent with stony beds, or highland plateau streams having pools that accumulate fine sediments and organic matter. Both of these stream types are ground water fed and are perennial. They also respond quickly to surface runoff from the catchment and are supported by snowmelt. (CRC for Freshwater Ecology 2004).

Perisher and Rock Creeks have gentle grades through the Perisher Village. The Perisher Creek floodplain is described as being wide and resort developments have encroached into the Rock/Perisher Creek floodplains (Storm Consulting, 2000).

Downstream of Jindabyne Dam, the Study Area also includes other significant creek and river systems that are tributaries of the Snowy River, including Cobbin Creek and Mowamba River (but flows in the Mowamba River are diverted to Lake Jindabyne except during high flow events).

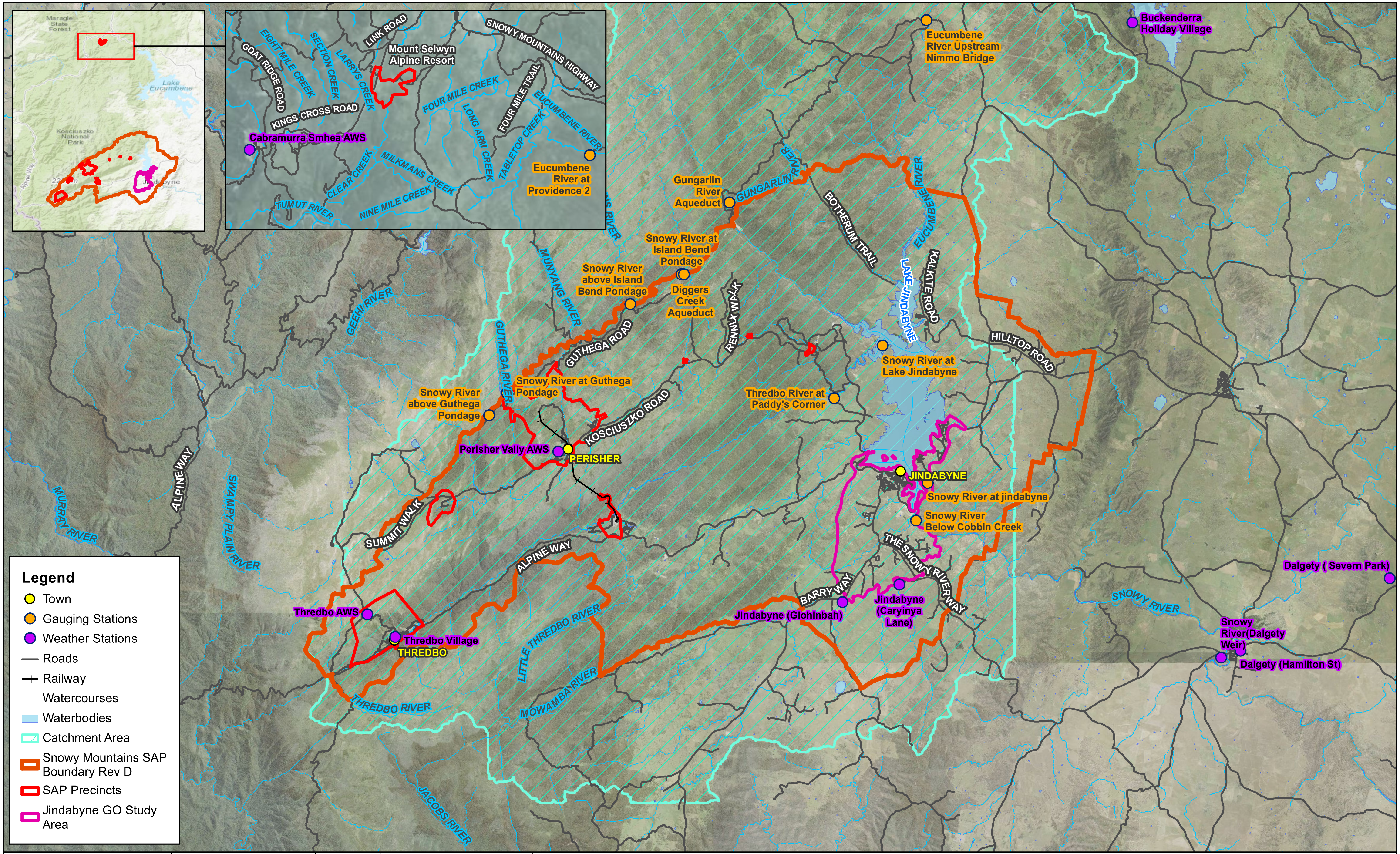
The creek and river systems are generally located within steeply incised valleys that are typical of mountain systems and would have confined floodplains that do not inundate extensive areas of land. Wollondibby Creek, Cobbin Creek and Mowamba River are located within the foothills of the ranges and would have wider and more extensive floodplains.

3.1.3 STREAM FLOW DATA

Stream flow data was sourced from the Australian Bureau of Meteorology, Water Data Online portal and the Water NSW Real Time Data portal. The historic gauge record is summarised in Table 3.2 below and presented with the weather station gauge data on Figure 3.1. It is noted that many of the gauges are owned and monitored by Snowy Hydro Pty Ltd to inform operation of the Snowy Hydro Electric scheme.

Table 3.2 Stream flow stations

STATION NAME	STATION NUMBER	YEARS OF RECORD	PARAMETERS RECORDED
Thredbo River at Paddy's Corner	222541	34	Flow/Stage
Snowy River at Lake Jindabyne	222540	45	Storage level/Storage Volume
Snowy River at Jindabyne	222501	5 (CLOSED)	Water Temperature
Snowy River below Cobbin Creek	222020	13	Flow/Stage
Snowy River at Guthega Pondage	222537	23	Storage level/Storage Volume
Snowy River above Guthega Pondage	222527	54	Flow/Stage
Snowy River above Island Bend Pondage	222532	4	Flow/Stage
Snowy River at Island Bend Pondage	222539	23	Storage level/Storage Volume
Diggers Creek Aqueduct	600168	53	Flow/Stage
Bar Ridge Aqueduct (Tolbar Creek)	600167	36	Flow/Stage
Gungarlin River Aqueduct	600166	54	Flow/Stage
Eucumbene River at Providence 2	222522	63	Flow/Stage
Eucumbene River at Lake Eucumbene	222538	27	Flow/Stage
Eucumbene River upstream Nimmo Bridge	222028	10	Electrical Conductivity at 25C/Water Course Level (Stage)/Water Temperature



Map: PS120074_GIS_017_A2	Author: David.Naiken		0 1,750 3,500 m 1:200,000
Date: 17.06.2021	Approved by: Karen.Brakell		

Coordinate System: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

Snowy Mountains SAP

Figure 3.2
Weather Stations and Stream Flow Gauging Stations

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3.2 CLIMATE

The climate for the Snowy Mountains SAP Study area varies with altitude. Thredbo, Perisher, and Smiggin Holes are higher and therefore colder all year around, compared to Jindabyne and the areas at lake level. Snow cover is generally from June to September. Snow depths of up to two metres occur in the higher regions, but snow depths can vary considerably depending on exposure to the prevailing westerly weather system. The summers are mild and generally dry, although intense thunderstorms can occur. The driest period of the year is December to April. A brief summary of the available historic data in included below.

3.2.1 RAINFALL

Rainfall data is collected at the following locations near the Study area.

Table 3.3 Bureau of Meteorology automatic weather stations, sub daily Rainfall Records

STATION NUMBER	STATION NAME	DATE OPENED	LAST RECORD	YEARS OF DATA
71075	Perisher Valley Aws	2010 May	Still open	10.1
71032	Thredbo Aws	2010 Dec	Still open	9.6
70217	Cooma Airport Aws	2008 Sep	Still open	11.8
72162	Khancoban Aws	2011 Oct	Still open	8.8

There are a further 40 stations that record daily rainfall totals, with the Jindabyne (Glochinbah) Site number 071021, at an elevation of 990 mAHD recording data since 1906. The historic annual average rainfall is 627 mm per year at this station and Figure 3.3 below shows the annual rainfall totals for the period of record.

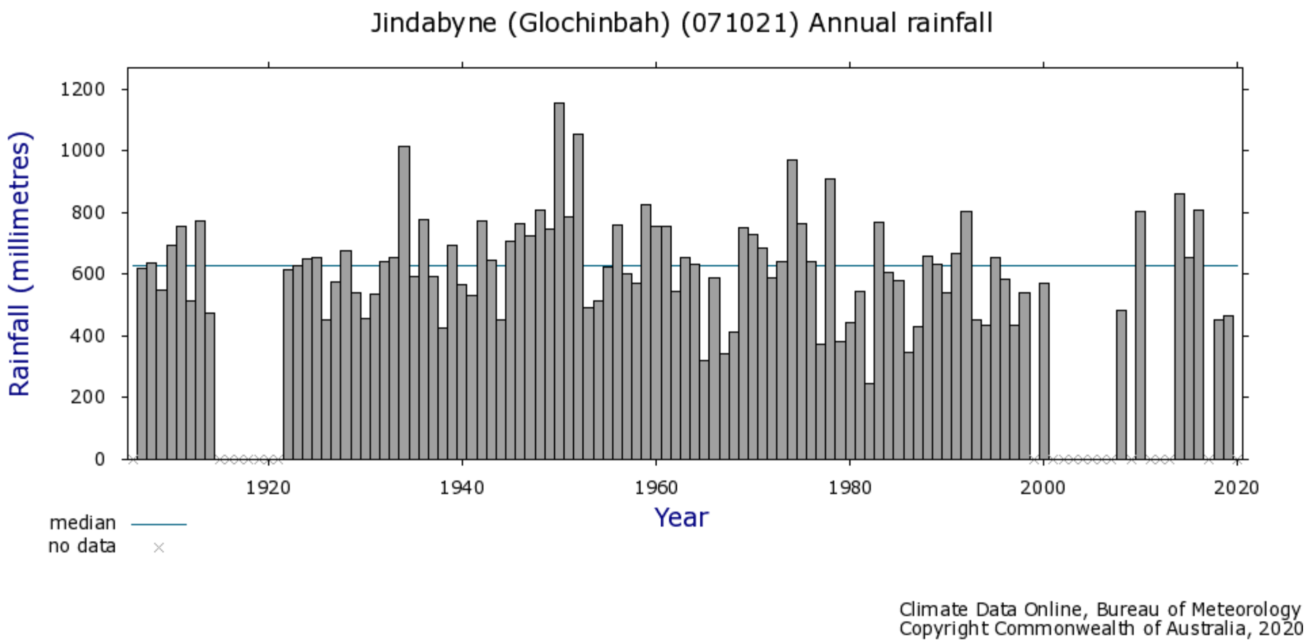


Figure 3.3 Jindabyne at Glochinbah (station 071021) Annual Rainfall (mm)

The Perisher Valley, Ski Centre Site 071072 is at an elevation of 1735 mAHD and was opened in 1976 and closed in 2010. This site has an annual average rainfall of 1785 mm per year. The Perisher Automatic Weather Station (AWS) Site 071075 was opened in 2010 to replace the Ski centre site and has an average annual rainfall of 2155 mm per year. The historic monthly data as presented in Figure 3.4 indicates a dominant spring rainfall season and dry summer. Figure 3.5 shows the annual rainfall totals for the two Perisher Valley stations.

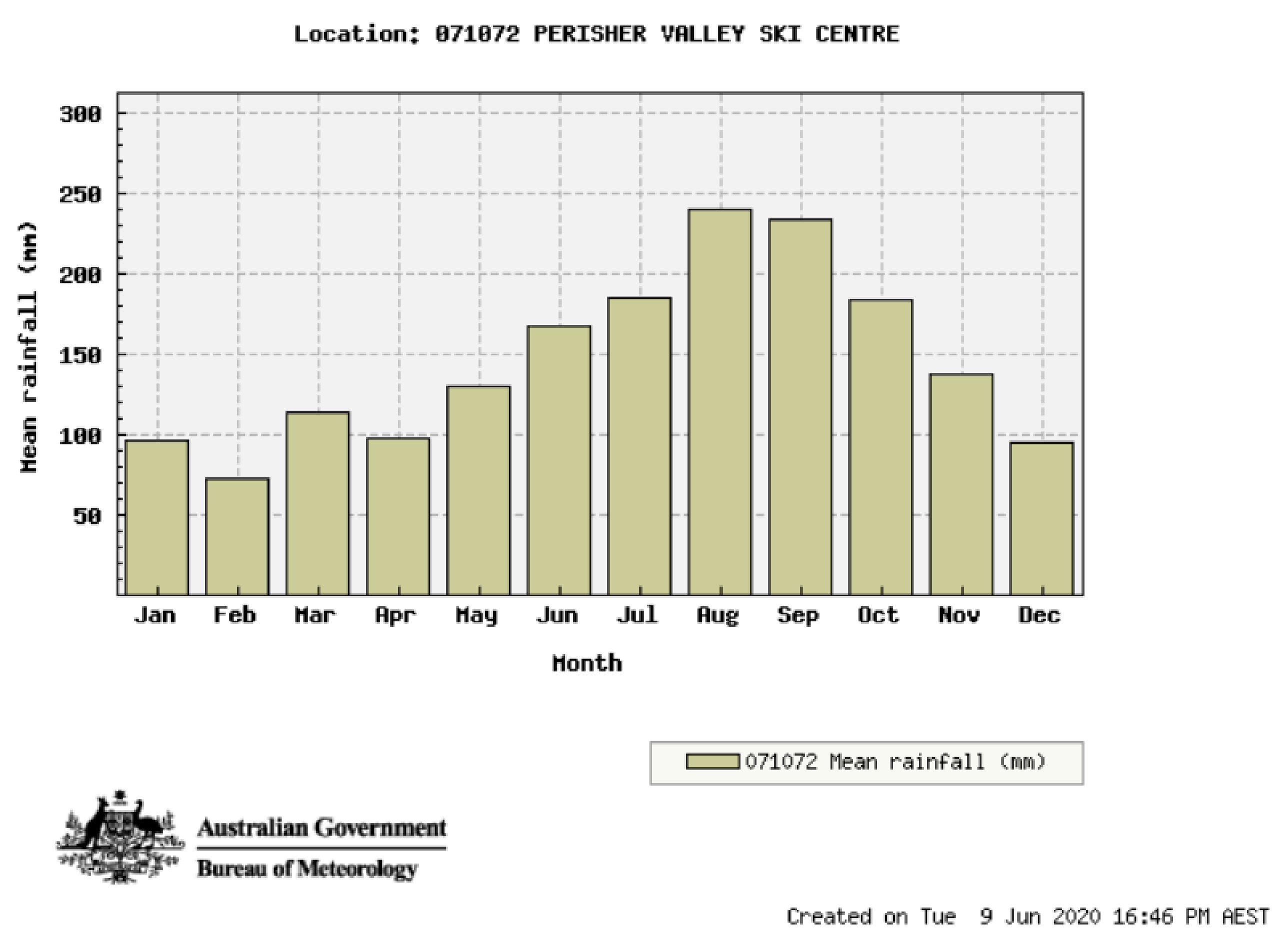


Figure 3.4 Perisher Valley Ski Centre, Station number 071072 monthly mean rainfall totals (mm)

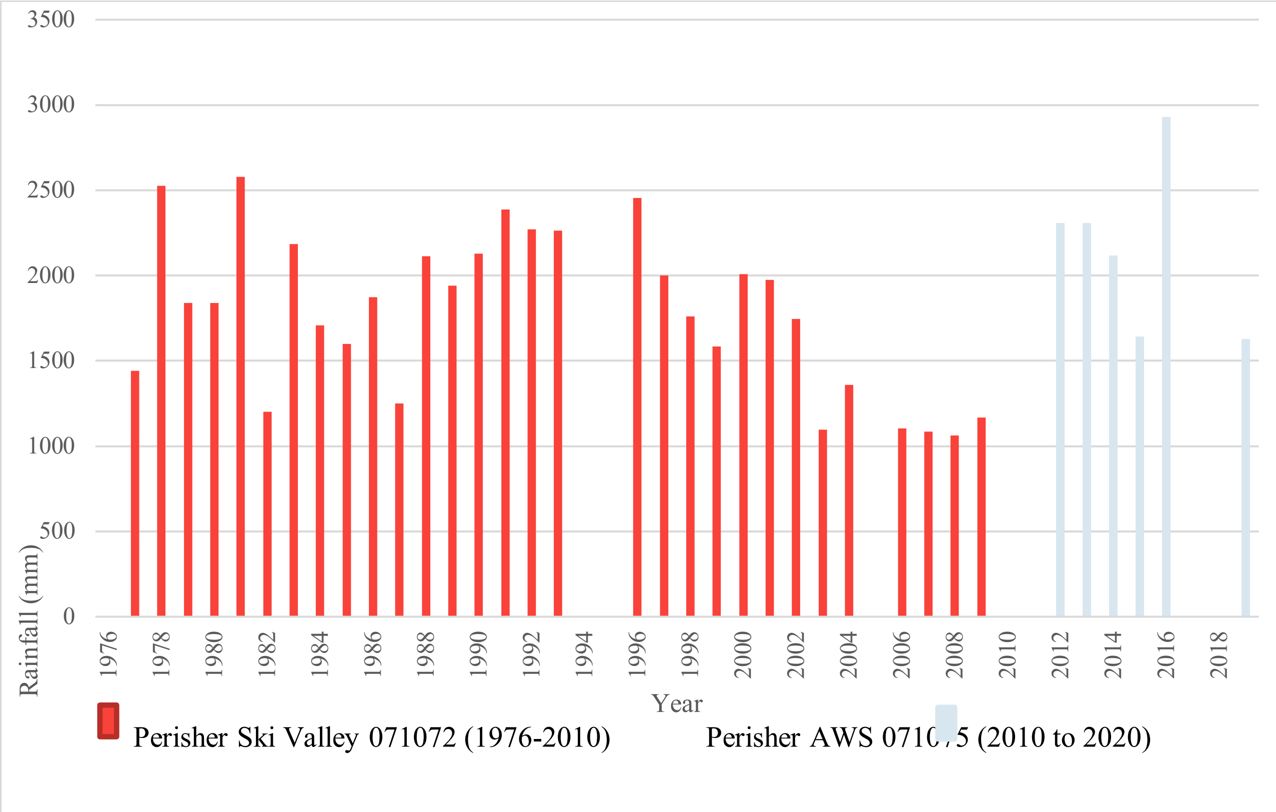


Figure 3.5 Annual rainfall totals Perisher rainfall stations

Thredbo village, station number 071041 is at an elevation of 1380 mAHD and recorded mean annual rainfall of 1771 mm for the period 1969 to June 2020. This would include a significant portion of snow. The Thredbo Automatic Weather station number 071032 at an elevation of 1957 mAHD has an annual average rainfall total of 1406 mm. Figure 3.6 shows the annual data for the period of record, noting that the station is missing many years of data.

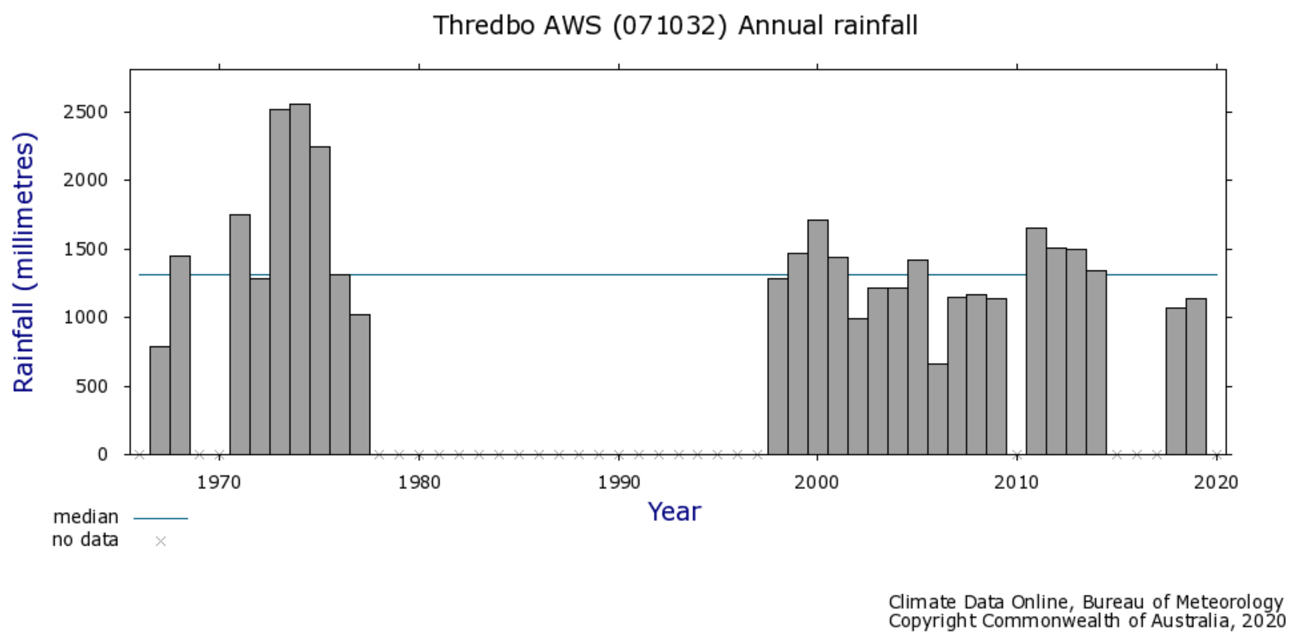
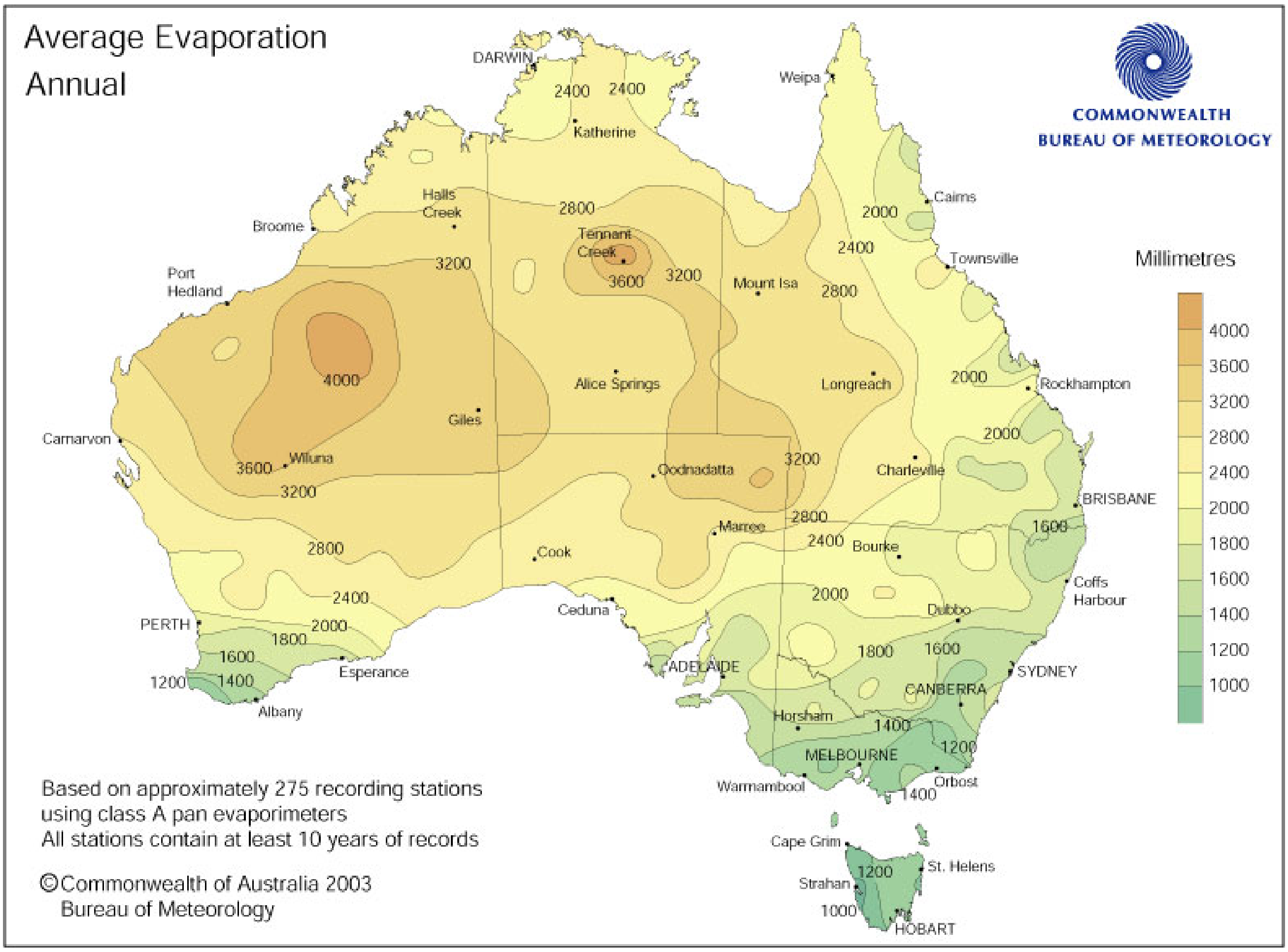


Figure 3.6 Thredbo Automatic Weather Station 071032, mean annual rainfall (mm)

The historic rainfall totals indicate that elevation has a significant impact on rainfall which correlates to snowfall. Higher elevations receive more snowfall and have higher annual rainfall totals.

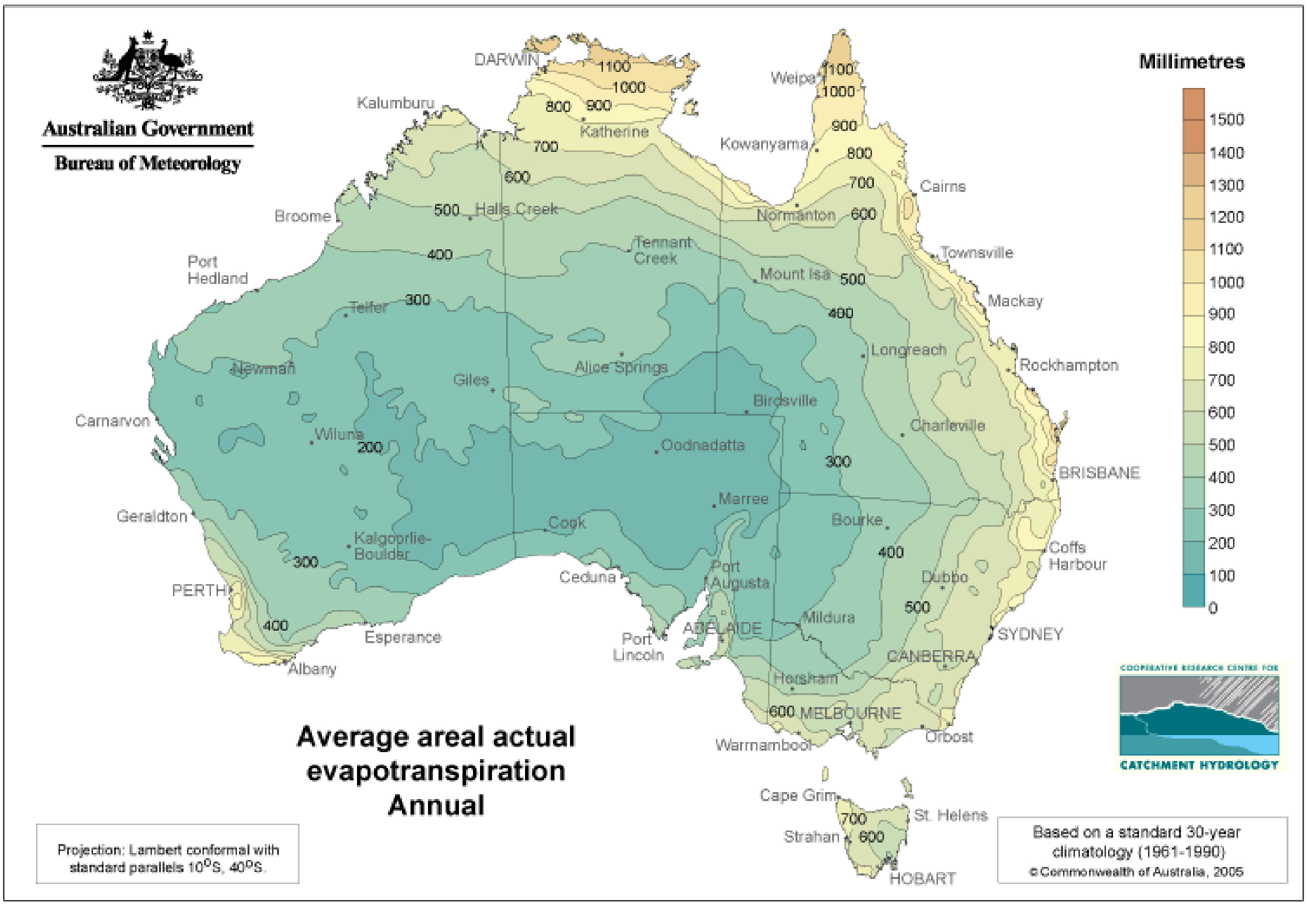
3.2.2 EVAPORATION AND EVAPOTRANSPIRATION

According to the BOM the annual average evaporation (refer Figure 3.7 below is at least 1200 mm per year, and annual average areal actual evapotranspiration is around 600 mm per year, refer to Figure 3.8.



Source: Bureau of Meteorology, 2003

Figure 3.7 Annual average evaporation



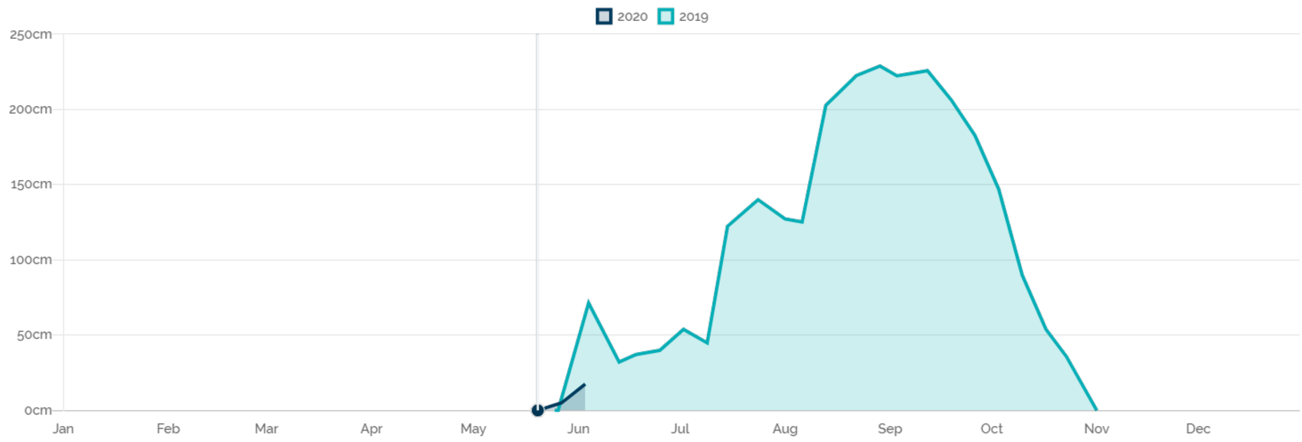
Source: Bureau of Meteorology, 2005

Figure 3.8 Annual average areal actual evapotranspiration

3.2.3 SNOW AND ICE

Some areas of the study area can experience up to 2 metres of snow seasonally. Snow tends to be wind-driven and does not accumulate across the study area evenly. (Storm Consulting, 2000). The 1993 Snow Precipitation Enhancement Project (Snowy Mountains Hydro-Electric Authority, 1991) found that the natural snow precipitation in the Snowy Mountains is very variable in the maximum depth, the timing of the maximum snow depth and the duration of the snow cover.

Snow depth data is measured by Snowy Hydro and the Ski resorts. Snowy Hydro undertakes snow depth readings at three locations across the Snowy Mountains which is used to inform the operation of the dams and the Snowy Scheme during the snow season. Snow depth measurements for 2019 at Spencers Creek, a tributary of the Snowy River is presented in Figure 3.9 with the available 2020 snow depths included for comparison.



Source: *https://www.snowyhydro.com.au/generation/live-data/snow-depths/ Accessed 12/06/2020 1:58 PM*

Figure 3.9 Spencers Creek snow depths 2019 and 2020

3.2.4 CLIMATE CHANGE

The Snowy 2.0 Study Report (Snowy Hydro 2017) included the climate projections from the NSW and ACT Regional Climate Modelling (NARCliM) Project which uses the "business-as-usual" high emission scenarios to which emissions are currently most closely tracking.

NARCliM modelling suggests that mean annual precipitation in the Snowy Mountains region may decline by up to -9% by 2060–2079 with the results dominated by winter–spring decline (-15% to -20%) (DPIE, 2020). The modelling also suggests that the warmer season (autumn–summer) rainfall is likely to remain unchanged or increase for the region.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) Climate Futures tool (CSIRO 2020) indicates for the spring to winter period (September to November) for the high emission scenario of Representative Concentration Pathway (RCP) 8.5 and the projection year of 2090 the rainfall is likely to be lower by up to 15% with a hotter climate. The predictions for annual rainfall are not conclusive with a similar number of climate models predicting no changes to a reduction of up to 15%. The NARCliM modelling projection and CSIRO projections are therefore similar with likely reduced spring winter flows.

The ratio of precipitation falling as snow or rain will change in a warming climate with less precipitation falling as snow. With continued warming, there is very high confidence that snowfall, snow depth and the snow covered area will further decrease, particularly at low elevation areas.

The generally dryer climate, with less rainfall expected will have impacts on the overall water availability but rainfall intensity is not commonly included in these projections. Rainfall intensity impacts flood behaviour more than total rainfall depths over extended periods.

Snow making conditions for the future climate projections indicate a decrease in suitable conditions for the far future 2060–2079 period. (DPIE, 2020)

ARR 2019 provides a procedure for estimating the increase in rainfall intensity as a result of climate change projections. The procedure is based on the CSIRO Natural Resource Management (NRM) "clusters" for which the Snowy Mountains SAP study area is located on the boundary of the Murray Basin and the Southern Slopes Mainland Cluster. The CSIRO information indicates that a majority of the Global Climate Models (GCMs) are predicting a temperature increase of more than 3 degrees by 2090 for RCP 8.5. Considering a design horizon of 2090 the procedure estimates rainfall intensities will increase by 16.3% or a factor of 1.163. Refer to section 5.9 for further information relating to this assessment.

3.2.5 CLOUD SEEDING

Cloud seeding is a process used to improve the capacity of clouds to yield precipitation as snow. To achieve this, chemical particles are introduced, or seeded, into these clouds. (NSW Environmental Protection Authority June 2020). Snowy Hydro Limited under the Snowy Mountains Cloud Seeding Act 2004 are permitted to conduct permanent cloud seeding operations across a defined area of the Snowy Mountains. The operations must be in accordance with the Environmental Management Plan agreed with the NSW Ministers for Environment and Planning.

The cloud seeding areas cover the Perisher and Thredbo valley within the Snowy Mountains SAP Study area. Cloud seeding does not commence, or is suspended, if the freezing level measured over the catchment is higher than 1600 metres. This is to ensure precipitation falls as snow to at least 1400 metres. Additional controls are implemented if the freezing level is between 1550 and 1600 metres, including monitoring live camera feeds and verifying conditions with personnel within the target area (Snowy Hydro September 2020).

A summary of conditions since 2013 for each year is provided below:

- 2013 – 106 hours of cloud seeding occurred between July and August
- 2014 – 68 hours of cloud seeding occurred between June and July
- 2015 – 35.5 hours of cloud seeding occurred in July
- 2016 – 76 hours of cloud seeding between July and August
- 2017 – 95 hours of cloud seeding between July to September
- 2018 – 118 hours of cloud seeding between May to August
- 2019 – 147 hours of cloud seeding between May to September.

The results do not indicate a pattern and are solely dependent on the prevailing climate conditions, which show that most cloud seeding was undertaken in 2019 based on the records from 2013.

3.3 TOPOGRAPHY

The topography of the Snowy Mountains SAP area varies but generally consists of steep rocky slopes due to its location on the Great Dividing Range and being in close proximity to Australia's highest peak Mount Kosciuszko. Thredbo Village is approximately 7 km to the east and downhill of Mount Kosciuszko near the base of the Thredbo River valley with steep valley walls of up to 10% slope. The developed area of the village closer to the river tends to have flatter slopes in the 3–4% range.

Around Charlotte Pass, approximately 7 km east north east of Mount Kosciuszko the alpine resort sits in a flatter area adjacent to Spenser Creek but beyond the resort the land rises steeply. Catchment slopes are around 10% beyond the resort development.

The Perisher Ski Resort sits at the junction of Perisher Creek and Rock Creek with flatter slopes of less than 3% through the developed areas and a width of less than 0.5 km across the flatter area. At the outer areas of the ski resort the land rises sharply with slopes of up to 9% where the ski runs are located.

The Ski Rider and Sponars Chalet are located on the edge of narrow creek valleys with hill slopes similar to the Perisher area.

Kosciuszko tourist park is located in a flatter area on the edge of Sawpit Creek with slopes of about 4%.

Bullocks Flat as the name suggests is located in a flat area at the junction of the Little Thredbo River and the Thredbo River with slopes less than 2% across the Snowy Mountains SAP precinct.

Mount Selwyn lies at the top of a catchment on the ridgeline with slopes of about 8% away from the resort.

3.4 EXISTING LAND USE

This section focuses on the land use types that influence rainfall runoff processes within the subject catchments. The available data indicates that the higher elevations of the catchments tend to be covered by alpine shrubs and snow grass, with eucalypts (snow gums) further down the slopes. The developed areas include hard surfaces, roads and roofs with grassed areas.

The Mowamba River includes a large portion of pasture in comparison to the other more forested catchments.

The town of Jindabyne includes more dense urban development with a mixture of residential, commercial, educational and tourism land uses. East Jindabyne has areas of less dense urban development.

At Thredbo, the developed areas tend to be confined to small areas beside the Thredbo River. At Perisher the residential lots are more spread out with patches of vegetation between the chalets and a large car park accommodating visitors to the site. The other smaller ski resorts tend to have smaller hardstand areas which include car parks, access tracks and buildings and significant stands of vegetation.

A number of the watercourses support riparian corridor land that acts as core habitat for a range of native flora and fauna. (National Parks and Wildlife Service, 2006) According to the Kosciuszko Alpine Reports Riparian Corridor Lands Study, riparian land has been lost along Perisher and Smiggin Creeks in the vicinity of Perisher Village as development has encroached, such as the Skitube development, on the watercourses and this has subsequently changed the immediate land surfaces in these catchments.

3.5 SOILS

The Australian Soil Resource Information System (ASRIS) mapping indicated that four soil types, not including water bodies and not assessed areas, are present in the site investigation area and Mount Selwyn area.

Table 3.4 Summary of soil types identified within the site investigation area and Mount Selwyn

REFERENCE	NAME	DESCRIPTION
AH	Alpine Humus Soils	Shallow, very friable loams. The most extensive soil type found in the subalpine and alpine zones, occurring on relatively sheltered, gentle, well-drained slopes. The surface soil is highly organic with strong plant root development. Highly porous and friable.
ACP	Acid Peats	Found in basins and depressions where water collects all year around. They are highly organic and contain undecomposed and partially decomposed plant remains.
BRE	Brown Earths	Lower Montane: loams gradually merging into clay with depth. Upper Montane: deep friable loams. Highly porous and friable, these soils are found on the steep slopes of the montane zone.
L	Lithosols	Very shallow loams found in pockets on high exposed ridges and elevated stony slopes. They have a lower organic content than alpine humus loams and are highly porous.

3.6 WATER QUALITY

Water quality varies across the study area and is dependent on the contributing surface water catchment. For the watercourses immediately downstream of urban development, including roads and carparks, the water quality tends to be poor due to the presence of urban pollutants.

A water quality study of Lake Jindabyne between 1980 and 1986 revealed an apparent high phosphorus loading and retention rate in lake sediments and low dissolved oxygen concentrations within lake waters. (Boreham and Bowling, 1990). There are no water quality treatment devices currently operational in the Snowy Monaro Shire Council area (email: G. Shakespeare, Manager Infrastructure, Snowy Monaro Shire Council, 6/7/2020). While no long term monitoring is undertaken for Lake Jindabyne, water is extracted from Lake Jindabyne for potable supplies to Jindabyne and the surrounding urban areas to the south west and this water is routinely tested. In August 2020, wet weather caused an increase in turbidity of the water near the intake which rendered the water unsafe for consumption (Snowy Monaro, August 2020).

The stormwater management plans prepared for the alpine villages of Thredbo and Perisher indicate that stormwater quality has been poor and management of stormwater runoff is crucial to maintaining the pristine nature of the downstream waterways. A study by the Cooperative Research Centre for Freshwater Ecology identified potential sources of stormwater pollution from the Perisher Resort Carpark to be:

- salt from de-icing activities – particularly in winter
- sediment runoff from dirt roads – suspended solids and overflows of silt traps
- oil, trace metals from parking areas – trace metals are greatest in winter
- rubbish (gross pollutants).

Cloud seeding as discussed in Section 3.2.5 requires chemicals used as the seeding agent and tracer which are silver iodide and indium trioxide. The NSW Natural Resources Commission has assessed the impact of the program and has concluded "There is no evidence that the chemicals used have accumulated in sampled soils, sediments, water or moss in the areas being tested. There is also no evidence of impacts on snow habitats, or of difference in the concentrations of ammonia and nitrogen oxides in seeded and unseeded snow".

Water quality and biological health monitoring of the rivers and streams in the Kosciuszko National Park has been undertaken since 2004. The data is summarised in Kosciuszko National Park, Resorts Water Quality and River Health Monitoring Sites reports (some annual and some quarterly), with a focus on the Perisher and Thredbo areas. No water quality monitoring occurs at Selwyn Ski Resort as there are no Sewage Treatment Plants (STP) on site, with all wastewater managed through a septic system and adsorption trench system, and no permanently flowing streams with sufficient volume to enable monitoring within or immediately adjacent to the resort area.

The water quality monitoring results show that the electrical conductivity (EC) in alpine streams is generally very low, and low salt concentration are a typical characteristic of Kosciuszko National Park's fresh flowing waters. High EC may inhibit plant and animal growth and prolonged exposure to elevated salts can lead to decline or changes in macroinvertebrates. More recent research (unpublished papers) has indicated that elevated electrical conductivity immediately downstream of the roads and carparks where salt is being applied is having an impact. Salt use is described below in Section 3.6.3 and the Salt Impact Management Plan (WSP 2020) Section 5.1.1 identified impacts to aquatic systems as follows:

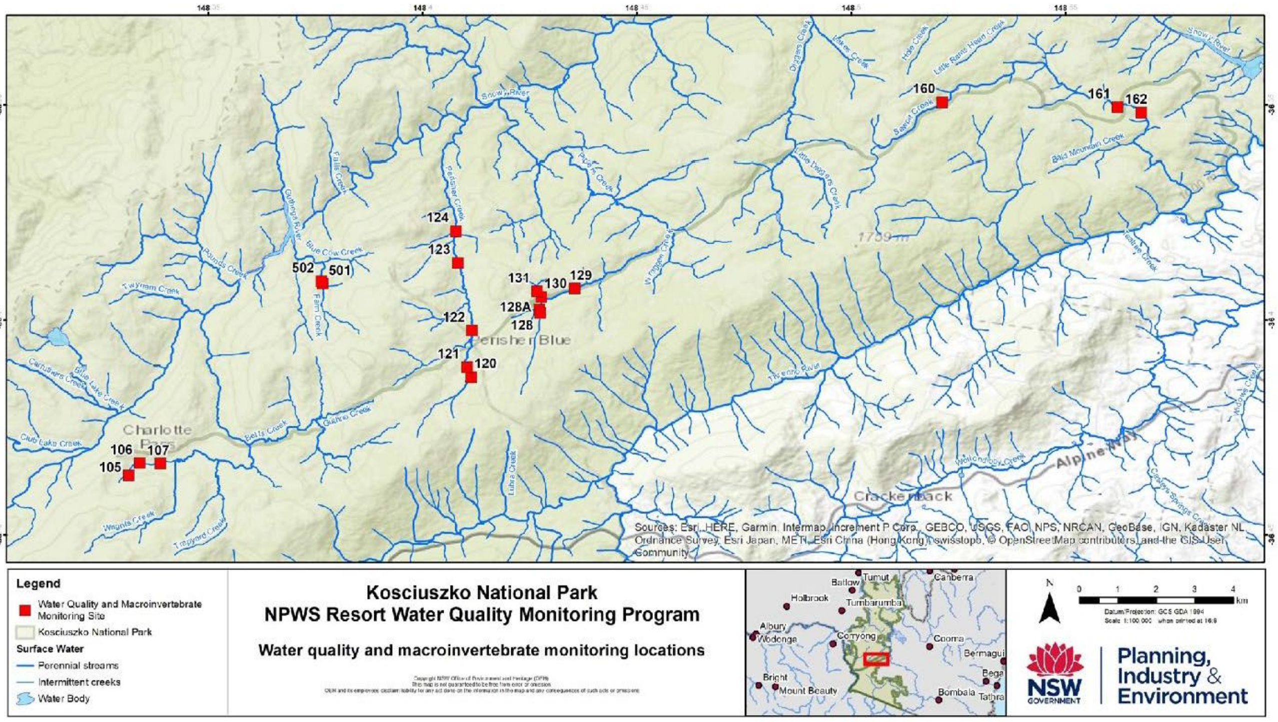
- Watercourses that receive salt-impacted runoff from a dense network of roads and highways have been found to have the greatest impacts.
- Studies conducted on Kosciuszko Road from 1995–1998 (Allen, N.D.) on the efficacy of road salting techniques found potential issues with wetland areas were noted (though monitoring was not allowed in the Perisher car park).

The Kosciuszko Management Plan (KMP) notes that effluent from sewage treatment plants associated with the alpine resorts and other high use sites is discharged to water courses in the park. The results of the water quality monitoring suggest that the sewage treatment plants discharging into these watercourses create constant but generally mild pollution. The long-term impacts of these effluent discharges on the park's rivers and streams are unknown. In addition to threats identified by the Cooperative Research Centre for Freshwater Ecology the KMP notes the following other threats to water quality:

- Nutrient enrichment from feral animals. Ongoing disturbances associated with catchment modifications from past grazing and mining activities. Increased sediment loads from road and walking track erosion after fire events.

3.6.1 PERISHER AND CHARLOTTE PASS

Bi-annual monitoring occurs at a total of 18 sites within the Perisher Valley along the Spencers, Rock, Perisher, Pipers, Smiggin, Sawpit and Farm creeks. These monitoring locations are shown in Figure 3.10. Additional fortnightly sampling is carried out during winter and spring at a further nine sites along Perisher, Pipers, Diggers and Sawpit creeks to test standard water quality parameters. It is noted that there are three STPs within the Perisher area, Charlotte Pass STP upstream of site number 107, Perisher STP upstream of site number 123 and Ski Rider between sites 160 and 161 on Figure 3.10.



Source: Kosciuszko National Park, Report Card for Resort Water Quality and River Health Monitoring Program 2018

Figure 3.10 Water quality monitoring locations for Snowy River Ski Resorts

A summary of the results and trends of the water quality monitoring from 2016–2019 is provided below. Overall, the results indicate persistent elevated levels of nutrients, i.e. Total Nitrogen (TN) and Total Phosphorus (TP), and poor ratings for macroinvertebrates (an indicator of ecological health)across all the watercourses in the Perisher Valley. Elevated EC was isolated to Sawpit, Smiggin and Pipers Creeks and occurred both in Autumn and Spring.

3.6.1.1 SPENCERS CREEK

The 2017 autumn monitoring showed TN levels were within guidelines, whereas the 2017 spring monitoring showed elevated TN across all sites. The 2018 monitoring results showed elevated TN and nitrogen oxides in the autumn sampling events, with all levels recovering in the spring monitoring. The spring 2018 sampling indicates that nutrient concentrations in Spencers Creek which may have been elevated during spring 2017 to autumn 2018 by discharge from the Charlotte Pass STP had returned to baseline and control site conditions. A trend of slightly elevated nutrients downstream of the STP discharge remains, but in most cases, except for total nitrogen, the nutrient concentration were within guidelines.

The autumn 2017 sampling events recorded elevated levels of TP and turbidity at all sites, however these values returned within guidelines in the spring monitoring event. With one exception at site 124, the 2018 TP monitoring values were all within the guidelines.

EC remained below guideline levels for the 2016 to 2018 monitoring period.

3.6.1.2 PERISHER CREEK

The sites located along Perisher Creek downstream of both the Perisher car park and the STP consistently showed exceedances in TN, nitrous oxides and ammonia, particularly in the autumn monitoring events. The autumn 2017 monitoring showed exceedances for TN and TP in all locations. The spring 2017 monitoring showed the TP levels returned to within the guidelines, however TN remained elevated. The sources of these levels may be natural, however would require further investigation.

EC remained below guideline levels for the 2016 to 2018 monitoring period.

3.6.1.3 FARM CREEK (GUTHEGA)

The monitoring results showed TN and TP as slightly above ANZECC trigger levels. TN has shown some variability since 2010 but there does not appear to be a strong seasonal or temporal trend. Both the 2017 and 2018 monitoring showed exceedances in TN in autumn but again returned below guideline levels in spring monitoring.

The autumn 2017 monitoring showed a spike in TP at sites located both above and below the water supply weir in autumn, with both sites exceeding guidelines by more than twice the trigger value, however the concentration returned to within guideline levels during subsequent monitoring. This was a similar pattern to the 2016 results at both sites, suggesting there may be some seasonality to TP concentrations in Farm Creek, however all 2018 monitoring for TP were within guidelines. All other parameters were mostly equal to or better than reference conditions with very minor variations.

EC remained below guideline levels for the 2016 to 2018 monitoring period.

3.6.1.4 ROCK CREEK

At Rock Creek the sites showed elevated levels of TN in spring 2017 and autumn 2018. All sites also recorded elevated levels of TP in autumn 2017, however these levels were back within the guidelines by the spring 2017 monitoring event. All other parameters were generally within the guidelines. EC remained below guideline levels for 2016 to 2018 monitoring period.

3.6.1.5 PIPERS AND SMIGGIN CREEKS

The sites, both above and below the water supply weir (on Pipers Creek) and above and below the resort area (on Smiggin Tributary) displayed elevated nutrient levels.

TN levels were elevated for the Autumn sampling event in 2016, all sampling events in 2017, all sampling events on Smiggin Tributary in 2018 and all autumn sampling events at Pipers Creek in 2018.

TP was elevated at all sites for the 2017 autumn monitoring event, but showed improvements at most sites in 2018, with all but two sites (Site 128A below the water supply weir on Pipers Creek and Site 130 Smiggin Tributary below Kosciuszko Road) recording levels within guidelines.

Spikes in salinity, nitrogen oxides and ammonia have been noted in Smiggin and Pipers Creeks. Potential contributing factors include snow clearing and salt application on Kosciuszko Road, loose surfacing on aging car parks, absence of stormwater management and pollutant traps; bare earth areas, old sewer pipes and litter.

EC levels were consistently elevated above guidelines for both the spring and autumn monitoring during the 2016 to 2018 period.

3.6.1.6 SAWPIT CREEK

Sawpit Creek displayed consistently elevated levels of TP, TN and EC across all three sites, up and downstream of Ski Rider Motel and downstream of the STP, for all sampling events in 2017.

TN levels exceeded guideline values at all sites in both 2017 and 2018, particularly during the spring 2017 monitoring.

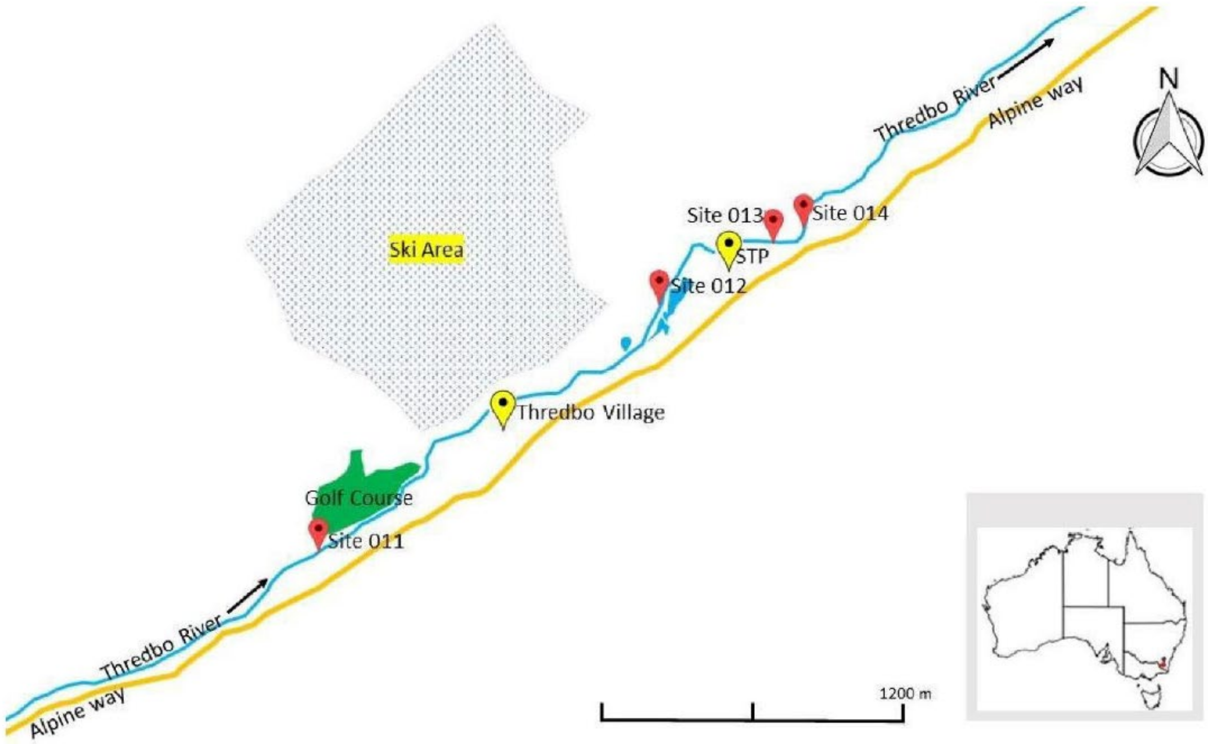
TP levels were elevated at all sites in 2017, and all spring monitoring events in 2018.

Turbidity levels were also elevated across all sites for all sampling events in 2017 and all but one in 2018.

The continued impairment of all these sites requires further investigation, however the nutrients, EC and turbidity results suggest inputs into Sawpit Creek may not be related to the Ski Rider, campground or STP, but that other catchment characteristics may be responsible. High salt levels in Sawpit Creek may be related to use of salt for de-icing roads and may be temporally and spatially cumulative through the catchment as salt, that has been applied to roads in previous years and washed off with surface runoff, may be accumulating and slowly leaching through the landscape over time.

3.6.2 THREDBO MONITORING RESULTS

Monitoring at the Thredbo resort is carried out at four locations on the Thredbo River as shown on Figure 3.11. Site 011 is upstream of the Thredbo village and golf course. Site 012 is downstream of the golf course and village but upstream of the existing STP while sites 013 and 014 are downstream of all these urban elements.



Source: Kosciuszko National Park, Report Card for Resort Water Quality and River Health Monitoring Program 2018

Figure 3.11 Water quality monitoring locations for Thredbo Ski Resort

Thredbo sites are monitored four times a year. While the results are highly variable over seasons and years, the following trends are noted:

- The sampling sites downstream of the village and the STP showed consistently elevated levels (outside guideline levels) of TN, nitrates and nitrites during most sampling events, with the exception of November. While the sites upstream and immediately below the village also showed elevated levels of nitrates and nitrites in the May and August sampling periods.
- Nutrients (specifically TP and nitrates) fluctuate over the reporting period at the three sites downstream of the village likely due to their proximity to the village and location of the lower 2 sites downstream of the STP.
- EC was generally below guidelines levels except in 2017 where it was above guideline levels in both February and August downstream of the STP. In 2018 all sites both above the village and below recorded EC values above guideline levels.
- pH and turbidity varied throughout the report periods, with fluctuations over all four monitoring sites occurring.
- Macroinvertebrate levels are an indicator for ecological health of the waterway and they tended to be significantly impacted downstream of the village but were not considered impacted upstream of the village.

Overall, the results indicate persistent elevated levels of nutrients, particularly TN and TP across all the watercourses in the Thredbo Valley.

3.6.3 ROAD SALT USE AND MANAGEMENT

Transport for NSW (TfNSW) is responsible for winter maintenance (snow and ice management) on the main highways including in the Kosciuszko National Park, with the ski resorts managing snow and ice within resort areas. Typically, the winter season lasts from the June long weekend to the October long weekend. The following average amounts of road salt are used per season:

- Snowy Mountain and Monaro Highways: 30 tonnes
- All other Roads: 250 tonnes
- Alpine Way: 120 tonnes.

Salt is only applied on the areas that required de-icing. While the road salt application rate is varied to address road and weather conditions, the average rate is estimated to be 20 g/m^2 overall with the following breakdown:

- 10–20 g/m^2 for Snowy Mountain and Monaro Highways
- 20–30 g/m^2 for Kosciuszko Road and Alpine Way.

Road salt is commonly used in alpine and snowy areas for de-icing of roads. The type of salt used is commonly sodium chloride (NaCl) with added ferrocyanide as an anti-caking agent. There are a number of water quality and environmental impacts that may result from the use of road salt which include:

- **Changes in density gradients (ponds and small lakes):** High density salt-laden water accumulates in lake bottoms and inhibits the lake's seasonal mixing (meromixis), so that the normal distribution of oxygen and nutrients within the lake is interrupted, resulting in decreased oxygenation, nutrients, and temperature in the bottom water and a general disruption of the lake ecosystem. Meromixis has been observed in lakes with concentrations of 600 mg/L of sodium and 105 mg/L of chlorides (Environment Canada, 2004).
- **Contaminant mobility**: Heavy metals including Hg, Cd, Zn, Cu can be released from bottom and suspended sediments into more biologically available forms when changes in lake density gradient occur.
- **Toxicity:** Chloride concentrations that cause acute and chronic effects range greatly for different species. Based on research and US state values, an acute value of between 600 and 850 mg/L and chronic value of between 200 and 500 mg/L depending on hardness (lower for soft water) seem to be a general level for effects to be evident on sensitive aquatic species. Research has shown that chloride concentrations exceeding 100 mg/L can have negative, non-lethal, impacts to certain organisms during sensitive life stages (Findlay and Kelly, 2011).
- **Soil pH:** Increased pH and soil salinity.
- **Mobilization of Metals:** Sodium (Na) replaces calcium (Ca), potassium (K), and magnesium (Mg) and heavy metals and/or increases heavy metals bioavailability.
- Watercourses that receive salt-impacted runoff from a dense network of roads and highways have been found to have the greatest impacts.

3.7 STORMWATER MANAGEMENT

Stormwater is the runoff that is generated from rainfall on surfaces. In urban areas, rain that falls on house roofs, paved areas like driveways, roads and footpaths, or flows from saturated gardens and grass fields, is carried away through stormwater pipes and canals to the nearest creek, river or lake. For the urban areas of Jindabyne the stormwater system comprises of road kerbs and gutters, pits and pipes that convey the stormwater flows (including pollutants) to Lake Jindabyne. Figure 3.12 to Figure 3.14 show the stormwater network for the urban areas, Jindabyne, East Jindabyne and Kalkite.

Figure 3.12 Stormwater network in Jindabyne

Figure 3.13 Stormwater network in East Jindabyne

Figure 3.14 Stormwater network in Kalkite

Beyond the urban areas, many of the roads do not include kerbs and gutters and stormwater runoff simply flows off the edge of the road, into the nearest overland flow path and creek. See Photo 3.1 below which shows Barry Drive at Cobbin Creek.

Photo 3.1 Barry Drive out of Jindabyne at Cobbin Creek – Stormwater runoff to shoulder then into creek (WSP)

Stormwater management varies for the ski resorts such that some roads have kerb and gutters to collect stormwater runoff. For Thredbo, the main roads and river crossings include kerbs and pits such as the Thredbo River crossing at Friday Drive as presented in Photo 3.2 below. Photo 3.3 shows several roads in Thredbo without kerb and gutters.

Photo 3.2 Friday Drive crossing at the Thredbo River. Note the roll kerb and drainage pit on the left (WSP)

Source: Google Street view February 2010, viewed 3/09/2020 1:32 PM

Photo 3.3 Corner of Mountain Drive and Riverview Terrace, no kerb and gutters

Photo 3.4 shows the rolled kerb at the corner of Kosciuszko Road and Wheatly Road Perisher. Photo 3.5 shows Kosciuszko Road with no kerbs and Photo 3.6 shows the carpark. Photo 3.7 shows pollutant traps at the outlet to culverts under Kosciuszko Road for an unnamed creek that connects to Perisher Creek downstream of the car park.

Source: Google StreetView June 2014, Accessed 3/09/2020 2:11 PM

Photo 3.4 Intersection of Kosciuszko Road and Wheatly Road

Photo 3.5 Kosciuszko Road with no kerb and gutter at Perisher (WSP)

Photo 3.6 Car park on the side of Kosciuszko Road and unnamed creek in Perisher (WSP)

Photo 3.7 Unnamed creek under Kosciuszko Road near Perisher car park (WSP)

In addition to the pollutant traps it is understood that a buried stormwater retention device, a "Stormceptor" unit, has been installed in the corner of the Perisher car park. This device has a capacity of 26,000 litres, catching runoff from the car park and allows for suspended solids to be filtered before water enters the creek. Monitoring of turbidity was tested above and below the Stormceptor during 2014 and 2015. Initial monitoring indicates a reduction in turbidity during low flow. (OEH 2017). Figure 3.15 shows the buried Stormceptor at the edge of the car park.

Source: Aerometrex 2020

Figure 3.15 Stormceptor at Perisher car park

4 CASE STUDIES

Stormwater and floodplain management practices implemented in other comparable alpine tourist towns that have similar characteristics to Jindabyne and the Snowy Mountains have been researched for this assessment. The themes of the selected towns included:

- seasonal towns, where the population grows significantly and most of the economic activity happens in parts of the year and tied to seasonal activities
- settlement and development in sensitive environments
- waterfront towns and cities, drawing lessons about connecting town centres to the waterfront and ideas for temporary and permanent activation in flood prone areas
- core elements of success for year-round alpine tourism towns and regions, and how they address international competitiveness, seasonal economies, liveability for residents and amenity for visitors.

Best practices for stormwater management that have been implemented in these areas are documented in this section.

4.1 QUEENSTOWN

Queenstown is located on the south island of New Zealand on the edge of Lake Wakatipu. Lake Wakatipu is a glacial lake and drained through the Frankton Arm and into the Kawarau River to the east of the town of Queenstown.

The town is subject to flooding from the Lake when significant rainfall falls over the upper catchment areas. It is also understood that stormwater network overflows through town can also result in flooding.

Flooding is managed through a risk-based approach (Centre for Advanced Engineering, 2005) through the application of a protocol. The protocol has a number of elements listed below:

- Element 1: Natural river and catchment processes as non-negotiable constraints on river modifications
- Element 2: Interaction of natural and social systems as the basis of floodplain management
- Element 3: Context-based decision-making
- Element 4: Continuing community engagement
- Element 5: Appropriate forms and levels of protection
- Element 6: Residual risk
- Element 7: Adaptive management.

Stormwater management is through a network of pits and pipes with no formal stormwater quality treatment before discharge to the lake. It is understood that stormwater pollution has historically been a result of sewerage system leaks into the stormwater system. Otago Regional Council (ORC, 2020) promotes proper stormwater management through identifying the consequences of poor stormwater management. These aspects include:

- an end to fishing trips and seafood dinners. Shellfish, watercress, eels and other fish can die or become contaminated by toxins washed in via stormwater
- the fun we have in and on the water becomes hazardous to our health. High levels of bacteria and poisons in our lakes and harbours due to polluted stormwater runoff could make swimming, surfing and other water sports a thing of the past
- our waterways look like rubbish dumps. Streams and beaches can become blocked or littered with rubbish carried down by stormwater. This is not just unsightly but also a breeding ground for disease and bacteria
- our drinking water makes us sick. Council water supply sources can become contaminated by waterways draining polluted stormwater. This makes our drinking water costly and difficult to treat to safe levels.

The Council then promote good stormwater management where “we only drain rain it will mean:

- we can eat healthy fish, free of contaminants
- we can swim in our lakes, rivers and oceans without the fear of getting sick
- our waterways look clean and smell fresh
- we can trust our drinking water”.

4.1.1 QUEENSTOWN LEARNINGS FOR THE SNOWY MOUNTAINS SAP

Management of flooding and stormwater quality by Otago Regional Council has similar themes to Australian practices and guidelines. Specifically, the following aspects could be used to inform the Snowy Mountains SAP:

- Floodplain management – Natural river and catchment processes as non-negotiable constraints on river modifications. The application of this element means ensuring the natural river and creek processes are considered when developing the catchment upstream and adjacent to the waterways. Ensuring flood extents are understood so that future development does not impact flood behaviour and is not impacted by flood events.

- Stormwater management – at source management is just as important as end of pipe solutions and community education is important for preserving the environment. This means stormwater management needs to include community education to ensure the community understands what type of water and runoff should be disposed of to the stormwater network and the impacts to the lake foreshore and lake use if incorrect substances are disposed of via the stormwater network.

4.2 LAKE TAUPO

Lake Taupo is located near New Zealand’s largest ski fields and has several towns situated on the Lake’s edge. The lake itself was dammed so that it could be used to generate hydroelectric power. The lake level is understood to vary due to hydroelectric power uses and local rainfall runoff and catchment runoff. Water quality and foreshore erosion have been identified as key environmental issues for the Lake. The Waikato Regional Council (2020) indicate the erosion around Lake Taupo is a natural process that is influenced by:

- “soft” geological material unique to Lake Taupo around the shoreline
- vegetation removal
- the effect of structures, such as dams and groynes, on the way sediment moves around in the lake
- developments near the shoreline
- seiching (water slopping)
- wind and waves
- the level of the lake under the consented lake management regime.

Waikato Regional Council and Taupo District Councils have prepared a Lake Taupo Erosion and Flood Strategy (December 2009) to manage future erosion and flood hazard around the lake.

4.2.1 LAKE TAUPO LEARNINGS FOR THE SNOWY MOUNTAINS SAP

The Lake Taupo Erosion and Flood Strategy (2009) has a number of strategies that are relevant for the Snowy Mountains SAP. These include:

- when physical works are necessary and when to favour soft structural options over hard structures
- flood awareness and appropriate planning conditions for new development and infrastructure
- for erosion, prevention of accelerated erosion rather than mitigation
- consider future changes to climate.

Specifically, the actions for erosion management include looking at how lake levels are managed, better managing structures that prevent sediment getting to the Lake or inhibit its movement once there, settlement patterns and land use practices.

4.3 JACKSON HOLE

Jackson Hole is located in the Snake River Valley with the main towns of Teton Village or Jackson. The available information indicates that stormwater quality runoff into creeks in the Snake River Valley is an issue (Teton County, 2019). Teton County have proposed a number of stormwater works to prevent uncontrolled and untreated discharge of potentially polluted runoff into Flat Creek (a tributary of Snake River) (Teton County, 2019). A water quality monitoring report from 2016 summarized that total iron levels exceeded the Wyoming Chronic Life Criterion for total recoverable iron (Yoder et al, 2016).

Flood extent information for the Snake River is available for selected locations along the river but it is noted that the 1% Chance Flood event is the only flood presented on these maps (Teton County, 2020). The floodplain management resolution (2015) outlines criteria for developing on and near flood affected land.

The review of information for Jackson Hole has not yielded any information to inform the management of flood liable land and stormwater quality for the Snowy Mountains SAP.

4.4 LAKE PLACID

Lake Placid is described as 802 ha lake located in Essex County in the Town of North Elba in New York State. The contributing catchment area is mainly forest with less than 2 km of roads within its catchment. A 2014 study (Adirondack Watershed Institute, 2015) collected water quality data from Lake Placid and compared it against other Adirondack Lakes. The sample results did not indicate water quality was an issue for the Lake.

The review of information for Lake Placid has not yielded any information to inform the management of flood liable land and stormwater quality for the Snowy Mountains SAP.

4.5 WHISTLER

Whistler is a town north of Vancouver, British Columbia, that is home to Whistler Blackcomb, one of the largest ski resorts in North America and sits within the Alta Creek valley. The town itself does not appear to be affected by mainstream flooding but is subject to localised flooding and stormwater runoff within the Crabapple and Gonzales creeks which drain to Alta Creek downstream of Alta Lake.

A 2010 study summarised water quality data for the region include Crabapple and Gonzales creeks, which indicated that total suspected solids and nitrogen were not above local guidelines levels but iron was recorded to be above guidelines. Overall the water quality was described as typical of low to moderately urbanised coastal British Colombia stream (Kerr Wood Leidal, 2010).

The 2010 study also found that there was high specific conductivity due to road salting during winter snowfall events. The concentrations for chloride (where sodium chloride is a salting agent) were below federal guidelines but the study recommended more analysis of the long term effects of chloride in aquatic environments (Kerr Wood Leidal 2010).

The study proposed stormwater management strategies and water quality treatment levels similar to measures considered in Australia, including:

- on building sites where the existing imperviousness is greater than 50%, the technical requirement is to reduce the rate and quantity of stormwater runoff by 25%
- on building sites where the existing imperviousness is less than 50%, the requirement is that post development discharge and quantity shall not exceed pre-development rate and quantity
- treatment removal rates of 80% for total suspended solids (TSS) and 40% for phosphorus relative to existing or unmitigated flows.

Although there was very little discussion on flooding, the study recommended that flood conveyance should be considered as part of the stormwater management strategy with the following design criteria:

- 10 year event – minor storm system, storm sewers an inlets
- 100 year event – major storm system, overland flood routes
- 200 year event – peak instantaneous flow – for culverts, bridges or other structures crossing a creek.

4.5.1 WHISTLER LEARNINGS FOR THE SNOWY MOUNTAINS SAP

From the information reviewed, the following considerations for future development in the Snowy Mountains SAP are relevant:

- Stormwater management
  - for development sites, post development stormwater quantity and rate should not exceed pre development quantity and rate.
- Floodplain Management
  - 10 year event (referred to as the 10% AEP) capacity to be allowed for in the minor storm system, storm sewers and inlets
  - 100 year event (referred to as the 1% AEP) capacity to be allowed for in the major storm system and overland flood routes.

4.6 BANFF

The town of Banff is located with the Rockies National Park which is listed as a UNESCO site. In and around the town of Banff, hydrological features include mineral springs, lakes, falls, and rivers with the main river being the Bow River.

The Town of Banff Green Site and Building Guidelines, Version 1.1, May 2004 provides a guide for development in the town. The guideline describes the Bow Valley as the most biologically diverse ecological unit in the Banff National Park and managing development is crucial for the habits of the Park. Some key points from the guideline include:

- reducing the width of roads can reduce the overall site imperviousness by 5–20%. This reduces runoff quantities, as well as land consumption. Roadside planting in the newly available space combined with drainage detention swales improves stormwater quality by capturing sediment, nutrients, hydrocarbons, and metals
- buffer strips are vegetated areas placed around paved areas or adjacent to receiving water bodies. Providing heavy planting around paved areas, especially parking lots, can help to alter stormwater runoff and to moderate urban heat island effects and air emissions
- specify erosion control measures that minimise construction disturbances to receiving water bodies.

A key objective is to develop effective drainage systems that balance drainage efficiency with minimised negative impacts on the environment.

Recommended practices include:

- incorporate green roofs
- specific permeable surfaces
- protect riparian Corridors
- incorporate rain barrels and cisterns
- develop code of practice for site preparation and building construction
- incorporate vegetated strips
- incorporate grassed swales
- reduce road widths and surface parking
- disconnect rainwater leaders (downpipes from roofs)
- allow for retention or detention
- minimise changes to existing topography/vegetation
- minimise lawns.

4.6.1 BANFF LEARNINGS FOR THE SNOWY MOUNTAINS SAP

The recommendations for managing stormwater flows and quality are similar to current best practice stormwater management measures adopted in Australia. A point of difference in the guideline is the consideration to reduce road widths which results in less impervious surfaces and potentially less runoff quantities. Reduced road widths in conjunction with edge buffer strips could be considered for the national park regions of the Snowy Mountains SAP area ensuring all other road design criteria are satisfied.

4.7 ZERMATT

Zermatt is located in Valais, Switzerland and is located in a valley with the Triftbach Stream flowing through the centre of town. The Triftbach Stream is confined to a concrete channel through the town and in 2019 some parts of the town were flooded when it is understood a glacier melted creating a large flow of water in the channel (SDA-Keystone, 2019).

Development of the town is confined to a narrow valley. Little information regarding flooding and stormwater could be found but images of the town indicate that flooding is confined to the concrete channel through town which is also likely to receive stormwater runoff and snow melt from the town.

The review of information for Zermatt has not yielded any information to inform the management of flood liable land and stormwater quality for the Snowy Mountains SAP.

5 FLOODING ASSESSMENT

5.1 METHODOLOGY

The adopted methodology for the flood assessment is summarised below. The methodology follows relevant National and State guidelines as identified in Section 2, and includes:

- review of available historic flood data and previous studies
- Flood Frequency Analysis using recorded stream data to understand local flood occurrences
- development of project specific hydrologic and hydraulic flood models to understand existing flood behaviour across the Snowy Mountains SAP
- consideration of future climate conditions and impacts on flood behaviour
- review of proposed strategic planning options against existing flood behaviour.

5.2 PREVIOUS FLOODING ASSESSMENTS

5.2.1 FLOOD LEVEL STUDY OF THREDBO RIVER, SMEC, FEBRUARY 1999

The Thredbo river has a catchment area of 34 km^2 upstream of the village and 52 km^2 downstream of the village near the sewage treatment works. The catchment varies in elevation from 2190 mAHD to 1335 mAHD at the village. The main tributaries are Merritts Creek and Friday Flat Creek.

The study used a regional flood frequency approach due to lack of site specific information. The hydraulic assessment was completed with a 1-dimensional HEC-RAS model which estimated peak flood levels along the main creek channels. The study considered snow encroachment into the channels with a reduced cross-sectional area adopted.

The study concluded that some access roads were susceptible to inundation in regular events and additional culverts would be required to minimise the effects of flooding. Additional site specific flow and water level data should be collected to provide an improved understanding of flood behaviour in the Thredbo River catchment.

The 20 year and 100 year Average Recurrence Interval (ARI) or 5 and 1% Annual Exceedance Probability (AEP) flood extents are presented in the figures below. The flood extent mapping in Figure 5.1 and Figure 5.2 shows that the 5 and 1% AEP flood extents are similar through the main Thredbo village area indicating an incised channel. For the Woodridge area only the 1% AEP flood extent has been provided, refer to Figure 5.3.

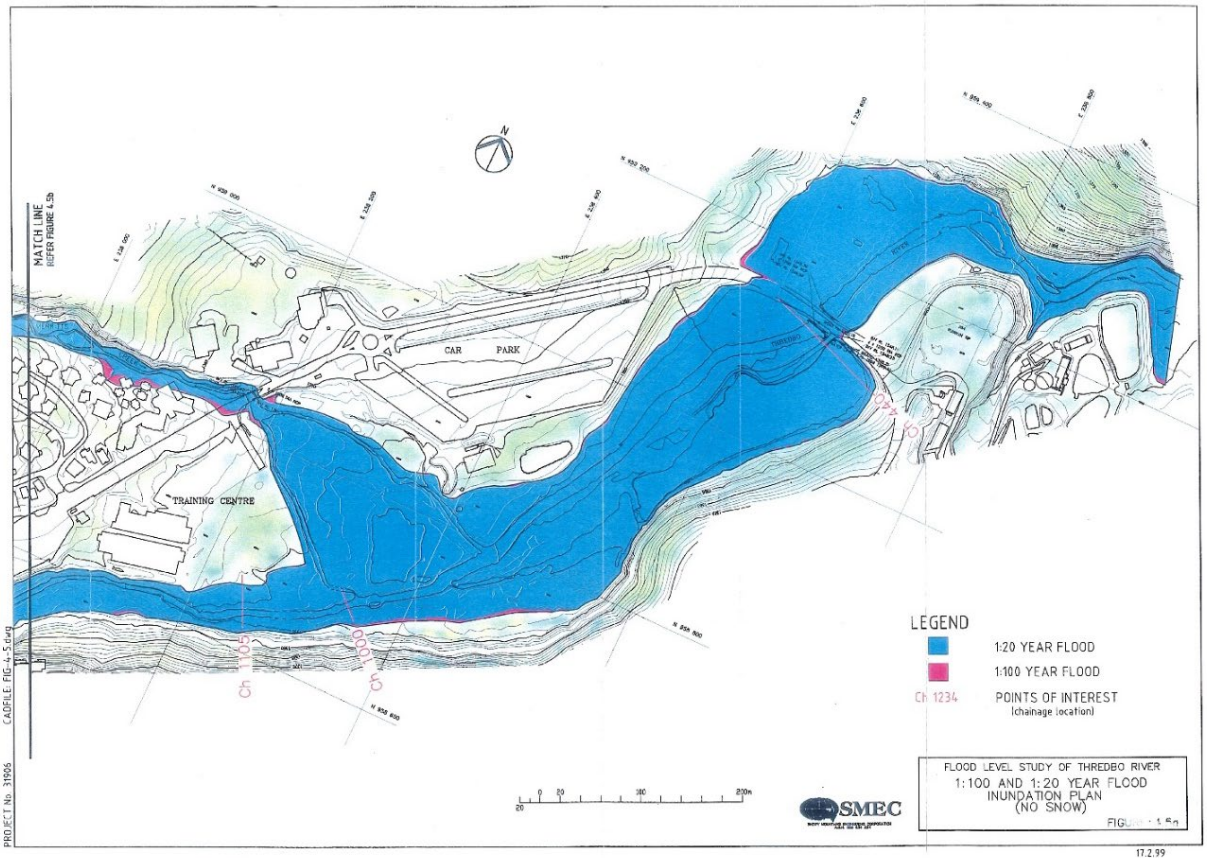


Figure 5.1 Thredbo River flood extents at car park, 5 and 1% AEP events

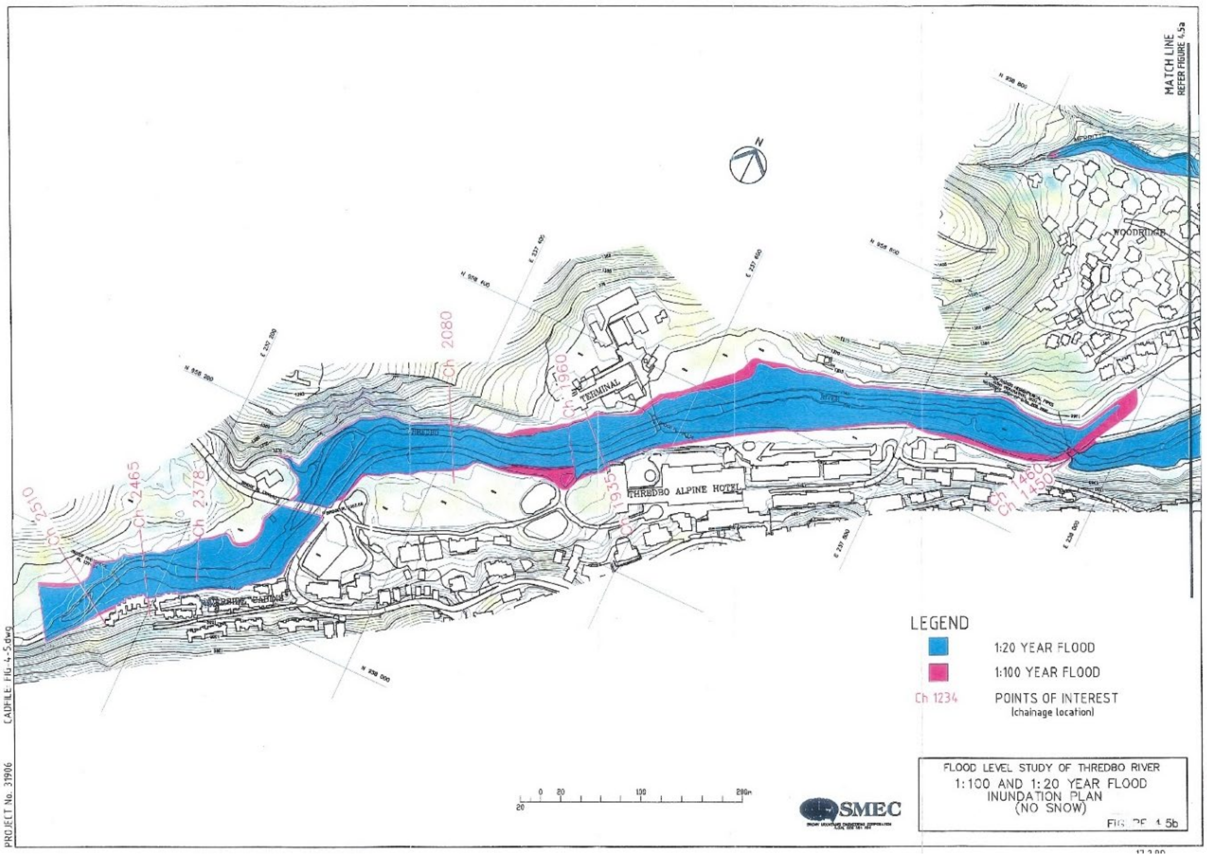


Figure 5.2 Thredbo River flood extents at the Thredbo Alpine Hotel, 5 and 1% AEP event

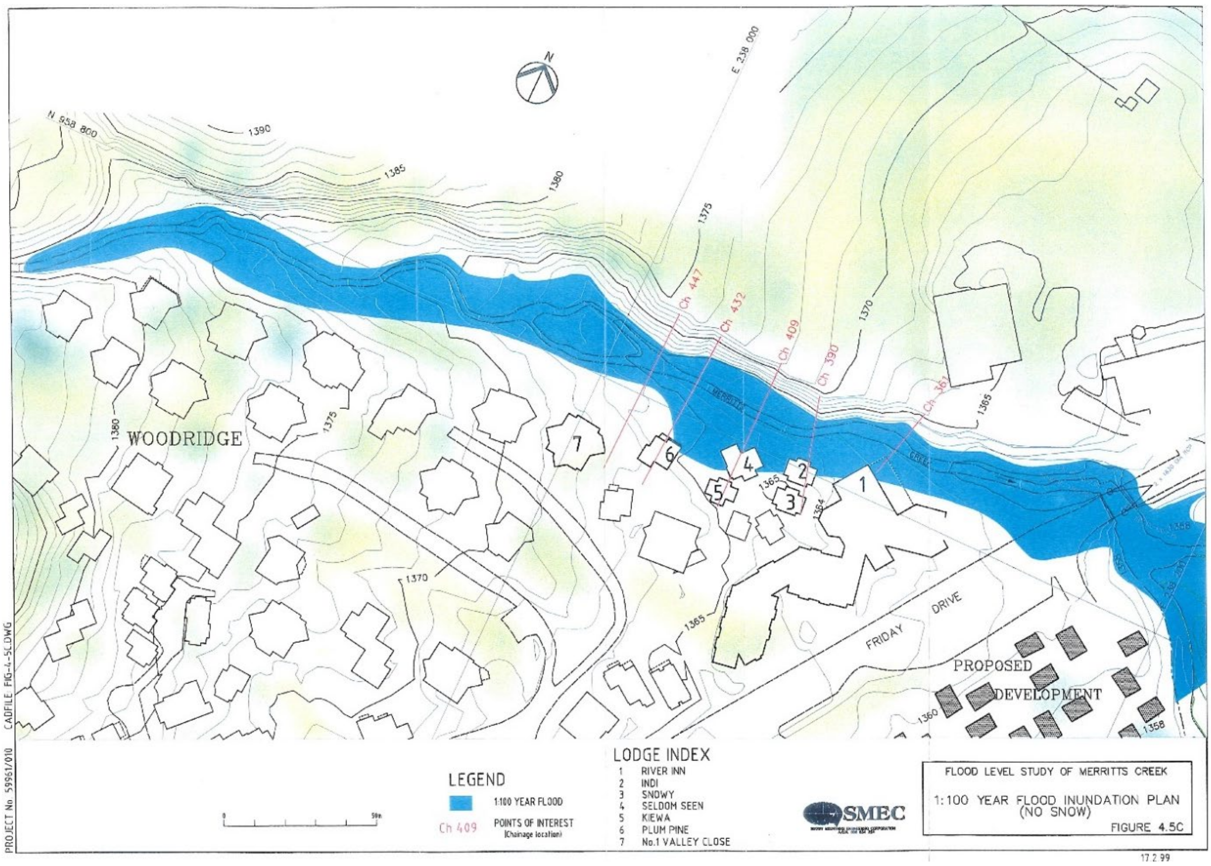


Figure 5.3 Merritts Creek 1% AEP flood extent

5.2.2 FLOOD LEVEL STUDY OF PERISHER CREEK, SMEC, APRIL 1997

The study used a regional flood frequency approach and the rational method to estimate peak flows for the Perisher Creek catchment. Peak flood level data was available for the 1995 and 1996 event. The hydraulic assessment was completed with a 1-dimensional HEC-RAS model which estimated peak flood levels along Perisher and Rock creeks. The model included surveyed cross-sections of the creek and bridge and culvert dimensions at each road crossing. The study considered snow encroachment into the channels with a reduced cross-sectional area adopted.

The study concluded that the Sewage Pumping Station No. 2 may be inundated in a 1% AEP event and several of the oversnow bridges would be overtopped for all events modelled. Additional site specific flow and water level data should be collected to provide an improved understanding of flood behaviour in the Perisher Creek catchment.

The 20 year, 50 year and 100 year ARI (5%, 2% and 1% AEP) flood extents were mapped but not included with the report.

5.3 FLOOD FREQUENCY ANALYSIS

The available historic stream flow data, as identified in Section 3.1.3 was sorted into annual maximum values to enable a flood frequency analysis to be completed. Flood Frequency Analysis (FFA) refers to procedures that use recorded and related flood data to identify the magnitude and probability of flood peaks, at a particular location in the catchment. The information from an FFA can identify the probability of historic flood events and select the range for input parameters input into hydrologic and hydraulic models.

Suitable stream flow data sites for the region were identified for the FFA analysis. The Guthega Pondage Gauge 222527 which is upstream of the pond and the Thredbo River at Paddy's Corner 222541 were selected. The Guthega Pondage gauge is located on the Snowy River which is a major inflow to Lake Jindabyne, it is all upstream of the storage and the ski resorts in the Perisher Valley so it is unaffected by the storage and stormwater networks in the ski resorts. The Thredbo River at Paddy's Corner was selected because it has a large catchment that contributes flows to Lake Jindabyne. The Guthega Pondage 222527 Gauge has data available for the period of 1965 to 2018. The Thredbo River at Paddy's Corner 222541 Gauge has data for the period of 1985 to 2019.

The TUFLOW FLIKE software package was used to analyse the annual maximum values from the two gauges and the data available includes instantaneous maximum recorded values for each calendar year of record and is presented in the tables below.

Table 5.1 Snowy River above Guthega Pondage Gauge 222527 annual maximum flow

YEAR	MAX DISCHARGE (m^3/s)	YEAR	MAX DISCHARGE (m^3/s)
1965	132.5	1992	104.3
1966	152.1	1993	223.1
1967	92.2	1994	60.9
1968	135.8	1995	232.2
1969	242.2	1996	162.9
1970	188.3	1997	69.1
1971	103.8	1998	240.2
1972	33.2	1999	136.1
1973	256.7	2000	83.9
1974	160.1	2001	163.4
1975	173.2	2002	114.7
1976	152.1	2003	192.9
1977	109.9	2004	86.2
1978	146.5	2005	200.3
1979	117.9	2006	103.9
1980	103.4	2007	53.5
1981	153.8	2008	189.9
1982	79.8	2009	77.2
1983	191.4	2010	252.2

YEAR	MAX DISCHARGE (m^3/s)	YEAR	MAX DISCHARGE (m^3/s)
1984	85.7	2011	301.3
1985	71.5	2012	320.4
1986	97.8	2013	209.0
1987	92.0	2014	96.1
1988	161.0	2015	64.4

Table 5.2 Thredbo River Gauge 222541 annual maximum flow data

YEAR	MAX DISCHARGE (m^3/s)	YEAR	MAX DISCHARGE (m^3/s)
1985	29.7	2003	83.1
1986	74.1	2004	59.7
1987	41.0	2005	123.9
1988	82.5	2006	56.3
1989	60.1	2007	29.1
1990	135.6	2008	140.4
1991	67.2	2009	51.6
1992	134.7	2010	134.4
1993	87.8	2011	115.9
1994	28.8	2012	245.7
1995	115.8	2013	78.8
1996	97.3	2014	76.7
1997	54.8	2015	35.8
1998	134.8	2016	201.4
1999	71.4	2017	92.2
2000	71.6	2018	27.1
2001	70.5	2019	48.9
2002	66.2		

The results of the flood frequency analysis are presented below and the best fit probability function for both gauges was determined to be the Bayesian Log Pearson III fit method. This is determined from the gauge data sitting within the 90% confidence limits and aligned to the expected probability line on the graph.

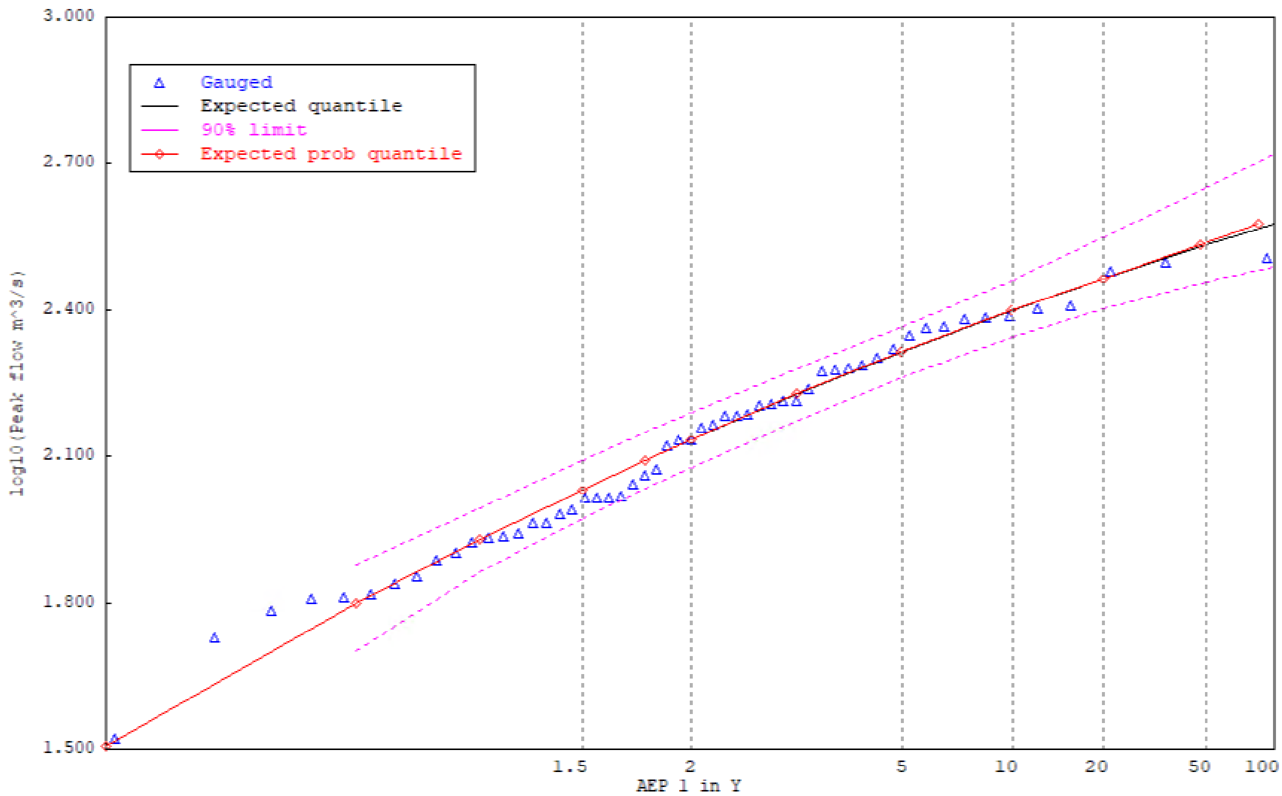


Figure 5.4 Snowy River at Guthega Pondage FFA probability curve

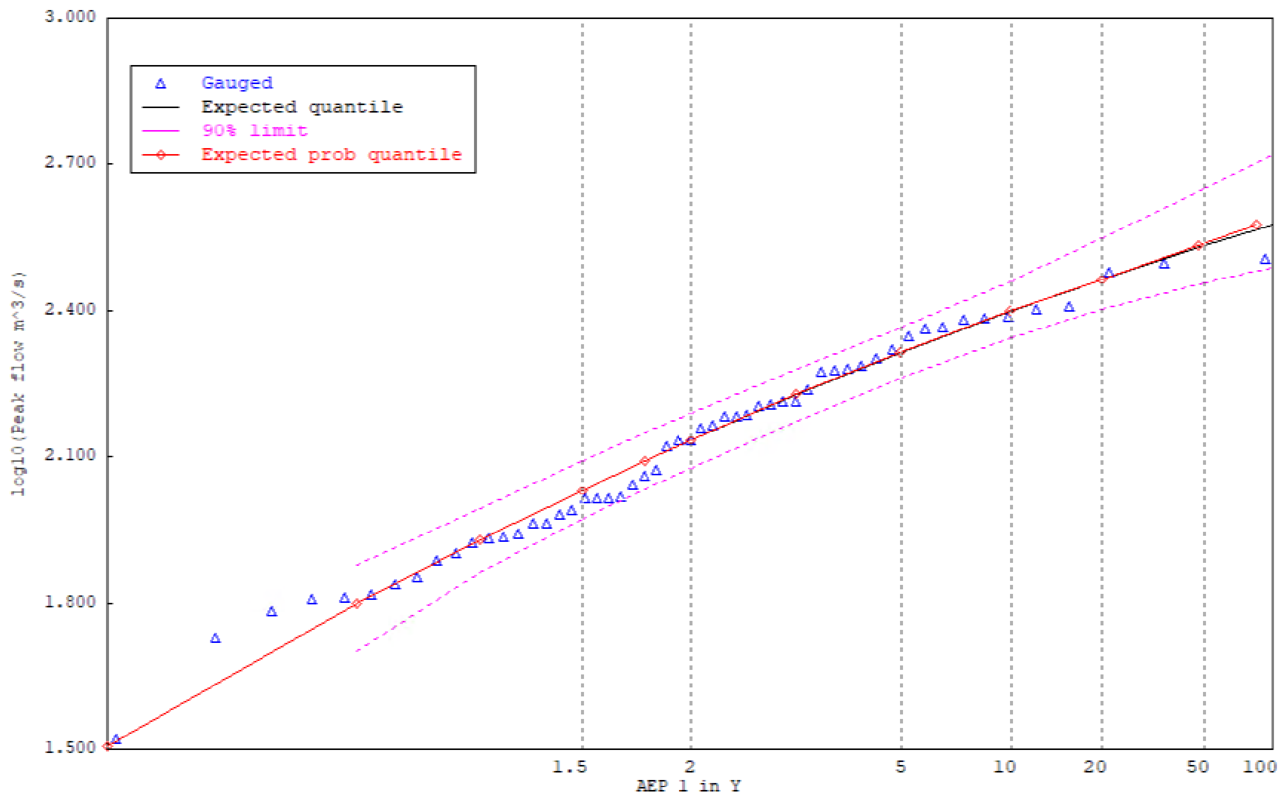


Figure 5.5 Thredbo River at Paddy's Corner FFA curve

The FFA estimated the peak flows for a range of flood events and are presented in Table 5.3. The full set of results are included in Appendix B.

Table 5.3 FFA results – Expected quartile results

AEP (%)	SNOWY RIVER UPSTREAM OF GUTHEGA PONDAGE (222527) (m^3/s)	THREDBO RIVER AT PADDYS CORNER (222541) (m^3/s)
50	135	75
20	205	122
10	250	157
5	291	193
2	341	244
1	377	286

5.3.1 REGIONAL FLOOD FREQUENCY ESTIMATION

Regional Flood Frequency Estimation (RFFE) is a technique that uses readily available flow data from all nearby gauges to develop flood flow estimates for a location of interest. The technique can be used to check or verify flow estimates from other estimation techniques such as FFA or hydrological modelling. As noted previously, the available data for the Snowy River at Guthega Pondage gauge was for a period of 53 years and the Thredbo River gauge has 34 years of data. An RFFE analysis was therefore undertaken to check the FFA estimates against a wider range of flow data from regional datasets.

The ARR Regional Flood Frequency Estimation Model for the 4th edition of Australian Rainfall and Runoff was utilised to provide estimated flood quartiles, and used gauges up to 150 km away. The catchments of Snowy River upstream of the Guthega Pondage and Thredbo River at Paddy's Corner were considered to enable comparison against the FFA results at these locations. Table 5.4 provides the estimated flows for a range of flood events for each catchment and the FFA results from Table 5.3 above.

Table 5.4 RFFE and FFA data – Expected quartiles

AEP (%)	SNOWY RIVER RFFE (m^3/s)	SNOWY RIVER FFA (m^3/s)	THREDBO RIVER RFFE (m^3/s)	THREDBO RIVER FFA (m^3/s)
50	21.3	135.9	49.7	75
20	41.9	205.7	100	122
10	60.2	250.3	145	157
5	81.4	291.2	198	193
2	115	341.6	283	244
1	145	377.5	359	286

The results for Thredbo River at Paddys Corner are within the RFFE 95% confidence limits (refer to Appendix B for the full set of results.) and within the +/-10% confidence limits for the FFA. However, there is significant lack of agreement between the RFFE and FFA for the Snowy River upstream of the Guthega Pondage. The RFFE is based on a number of gauges with different catchment areas and are largely at lower elevations to Guthega Pondage on the Snowy River, which is at over 1600 mAHD. It is noted that significant difference in historic rainfall data has been observed and the topography of the Snowy River at the top of the Great Dividing Range is likely to influence both the rainfall and resulting stream flows. Subsequently, since the FFA data is based on actual data from the site it is deemed more representative than the RFFE for the Snowy River upstream of the Guthega Pondage.

5.4 HYDROLOGICAL AND HYDRAULIC MODELS

5.4.1 TOPOGRAPHIC DATA AND DIGITAL ELEVATION MODEL

Topographic data is a fundamental input to the flood model and is used to:

- delineate sub-catchments for the hydrological model; and
- define the terrain data within the hydraulic model grid.

The Snowy Mountains SAP flood models were based on the following topographic datasets:

- 2017 and 2018 point cloud data covering SAP area. The point cloud data is a set of irregularly spaced points derived from LiDAR survey, each with an X, Y, Z value. This data was sourced from the Australian Government's Elevation and Depth Foundation Spatial Data service (ELVIS), which was provided the data by NSW Spatial Services.
- 2017 and 2018 digital elevation model (DEM) data covering the Snowy Mountains SAP area. The DEM consists of 2x2 metre grid data generated from the ELVIS point cloud data.
- 2010 Shuttle Radar Topography Mission (SRTM) data at 30 m resolution. This is a coarse dataset only used to delineate catchments outside areas covered by the more detailed data. This data was sourced from ELVIS.
- 2020 Photogrammetry, Aerometrex. This data has been used to confirm bridge and culvert crossings information.

The DEM used as the basis for the Snowy Mountains SAP flood models is a combination of the above datasets.

5.5 HYDROLOGICAL MODELLING METHODOLOGY

5.5.1 OVERVIEW

Hydrological models have been used to simulate rainfall processes and flow routing through the catchments upstream of the area of interest. The hydrological modelling has provided critical runoff hydrographs for input into the hydraulic models of local catchments covering the Snowy Mountains SAP areas.

For the technical study, a series of new hydrology models were developed using the XP-RAFTS 2018.1 (XP-RAFTS) software. The following process was completed in development of these models:

- develop a surface elevation model (refer to Section 5.4 above) and identify broad hydrological catchment divides
- delineate the sub-catchments to an appropriate level of detail for hydrological estimation and hydraulic design
- use the catchment delineations and aerial photos to define the hydrological sub-catchment nodes in a hydrological model
- build and calibrate the hydrological model to available historical rainfall and flow gauge data
- use the calibrated hydrological model parameters to inform estimate design flows for a range of events at the gauge and compare these to FFA and RFFE method flow estimates for available streamflow gauges to confirm that the model produces credible design peak flow estimates; and
- run design rainfall events in the calibrated hydrological model to develop design flows at each cross-drainage location.

The XP-RAFTS software has been utilised for the development of the hydrology for the project. XP-RAFTS uses the Laurenson non-linear runoff routing procedure to develop a stormwater runoff hydrograph from either historic rainfall data or design rainfall data. The 2018.1 version of the software utilises the latest ARR Data Hub design rainfall information.

5.5.2 *CATCHMENT AND CLIMATE PARAMETERS AND CHARACTERISTICS*

5.5.2.1 CATCHMENT DELINEATION AND LAND USE DATA

The processed topographic data as described in Section 5.4 was used to determine catchment boundaries for the hydrologic catchments both upstream and downstream of the Snowy Mountains SAP area.

Publicly available aerial photography was utilised to estimate land uses to inform hydrologic catchment parameters for input to the model.

5.5.2.2 RAINFALL DEPTHS AND TEMPORAL PATTERNS

The design rainfall was specified as per the ARR2019 design guidelines (Chapter 3, Book 2, ARR 2019). Rainfall depths for the range of design storms were generated from the Bureau of Meteorology 2019 Intensity-Frequency-Duration (IFD) dataset and applied to temporal patterns sourced from the ARR2019 datahub.

The IFD data was analysed against elevation because the annual rainfall depths (refer to Section 3.2) differed between precinct locations based on elevations. Analysis of the data has indicated that the higher elevations have higher rainfall depths for individual storm events. Table 5.5 below presents the IFD data for selected SAP precinct catchments for the 6 hour storm event. A similar trend in rainfall totals was observed across the range of storm events and this correlates with the findings from a review of historic data, refer to Section 3.2. The data also indicates rainfall changes significantly across the Snowy Mountains SAP area with the western facing Perisher Creek catchment experiencing lower rainfall totals to the eastern Thredbo River and Lees Creek catchment flowing towards Jindabyne.

It is noted that the Flood Level Study for Perisher Creek (SMEC) completed in 1997 identified that the prevailing weather comes from the westerly direction and ridgelines cause a sheltering effect. The study indicated that ridgelines resulted in different lower rainfall and snow depths in Perisher Creek compared to Spencers Creek to the south-west.

Table 5.5 Examples of variation in design IFD data

SAP PRECINCT CATCHMENT	POINT DATA ELEVATION (mAHD)	6 HOUR 1% AEP RAINFALL TOTAL (mm)
Thredbo upstream of village	1908	110
Perisher west of village	1842	44.6
Perisher	1734	41.6
Thredbo downstream of village	1359	88
Jindabyne (Lees Creek)	963	77

No pre-burst rainfall depth was applied to the hydrological models as the models were run with losses calibrated to the gauges for historical events.

Temporal patterns have been sourced from the ARR Data Hub. The Snowy Mountains SAP area lies within the Southern Slopes region and these storm temporal patterns have been adopted for the design storm event modelling. Refer to Appendix A for a copy of ARR data Hub information.

The 0.5% AEP and 0.2% AEP storm events were undertaken using the same general methodology as for the 1% AEP and 10% AEP storm events. Refer to Section 5.5.6 for a description of the methodology to derive the PMF flows.

5.5.2.3 CATCHMENT LOSS

The model catchment initial and continuing losses were calibrated and verified to historical gauge data. Refer to Section 5.5.3 for details about the model calibration.

During the model build phase, initial catchment rainfall losses were generated from the ARR2019 datahub website for the sections of the Snowy Mountains SAP precinct areas and were compared to calibrated losses for previous studies in the area. These provided a starting estimate but were later refined following calibration and verification of the hydrologic model to historical data and flood frequency analysis.

5.5.2.4 AREAL REDUCTION FACTORS

An Areal Reduction Factor (ARF) is a reduction factor applied to rainfall depth in larger catchments to allow for the fact that larger catchments are less likely to experience the high intensity rainfall depth estimated at a point location simultaneously across the entire area as per ARR2019 design guidelines (Chapter 4, Book 2, ARR2019).

The ARR2019 guideline estimates the ARF factor to the point of interest (e.g. to an individual development area) with the factor varying based on AEP, storm duration and catchment area. ARR2019 also states that "*There has been limited research on ARF applicable to catchments that are less than 10 km^2. The recommended procedure is to adopt an ARF of unity for catchments that are less than 1 km^2, with an interpolation to the empirically derived equations for catchments that are between 1 and 10 km^2*".

The XP-RAFTS ARR Storm Generator reads the project specific data from the ARR Data Hub, including the Text File, ARR Temporal Patterns Increments File, and BOM Design Rainfall. The generator then produces an XPX file with all the rainfall event of selected AEP and all of the durations for the given location. The software allows for an ARF to be applied if required. For the project, the catchments that have an area greater than 10 km^2 had an ARF applied. The ARF was calculated by the Storm Generator based on the catchment area and duration in accordance with Equation 2.4.1 (Chapter 4, Book 2, ARR2019) for durations less than 12 hour and Equation 2.4.2 (Chapter 4, Book 2, ARR2019) for durations between 12 and 24 hours.

5.5.3 MODEL CALIBRATION AND VALIDATION

Model calibration and validation are intended to identify suitable input model parameters that ensure the hydrologic model response to rainfall is representative of actual SAP area conditions. Calibration uses recorded rainfall data as an input and recorded stream flow data for comparison against the model output. The manipulated model parameters include initial and continuing losses, catchment storage and surface roughness values. Validation then applies the same model parameter set to additional historic events to determine if the calibration model parameter set produces reasonable correlation to other events.

Sub catchment slopes were calculated using the equal area slope method. The reach was defined for each sub catchment and the elevation vs chainage for each reach was plotted and the equal area slope estimated.

The Kinematic Wave Equation was used to estimate the lag time for each reach routing. This was adopted because no detailed survey of the channels was available to allow XP-RAFTS to route the flow hydrographs from one catchment to the next. The Lag is proportional to the length of the channel reach and can be estimated using kinematic wave speed which is approximated as 1.67 times the average flow velocity through the routing reach.

5.5.3.1 CALIBRATION SITES

Two sites were selected for calibration of the hydrologic models. Snowy River above Guthega Pondage (gauge 222527) and Thredbo River at Paddys Corner (gauge 222541) were selected because they both have long years of recorded stream flow data (refer to Section 3.1.1) and are unaffected by the Snowy Hydro scheme, such that there are no artificial diversions or extraction of water above these gauge locations. Refer to Figure 3.1 for the location of the stream gauges.

For the Snowy River above Guthega pondage gauge 222527 the calibration event selected was the 19 February 2011 event which is estimated to have a magnitude of approximately 5% AEP. The 1 March 2012 event was then selected for validation of the model and is estimated to have a magnitude of between 5% and 2% AEP.

For the Thredbo River at Paddys Corner gauge 222541 the selected calibration event was 1 March 2012 event which is estimated to have a magnitude of between 5% and 2% AEP and the selected validation event was 22 July 2016 which is estimated to have a magnitude of between 10% and 5% AEP.

5.5.3.2 RAINFALL DATA

The rainfall data was sourced from the Bureau for five (5) of the nearest gauges with suitable data. Table 5.6 presents the available rainfall and automatic weather station data that was available for the model calibration and validation.

Table 5.6 Rainfall data used for calibration and validation

STATION NAME	STATION CODE	FIRST	LAST	LENGTH (YEARS)	DATA TYPE AVAILABLE
Guthega Power station	071034	1969 Jul	1974 Sep	5.3	Pluviograph
Guthega Dam	071063	1957 Dec	1969 Jun	11.6	Pluviograph
Moobah (Riverview)	071035	1969 Aug	1970 Mar	0.7	Pluviograph
Perisher Valley AWS	071075	2010 May	2020 Jul	10.2	Rainfall total minutes
Thredbo AWS	071032	2010 Dec	2020 Jul	9.7	Rainfall total Minutes

5.5.3.3 CALIBRATION RESULTS

For the Snowy River upstream of Guthega Pondage (gauge 222527) the calibration event of February 2011 result is presented in Figure 5.6 below. The modelled (XP-RAFTS) result shows a good match to the gauged data for both the timing to peak and duration of the flow event. The adopted model parameters were an initial loss of 10 mm and a continuing loss of 2.5 mm/hr, catchment storage coefficient BX 0.6 and catchment roughness of 0.05–0.09.

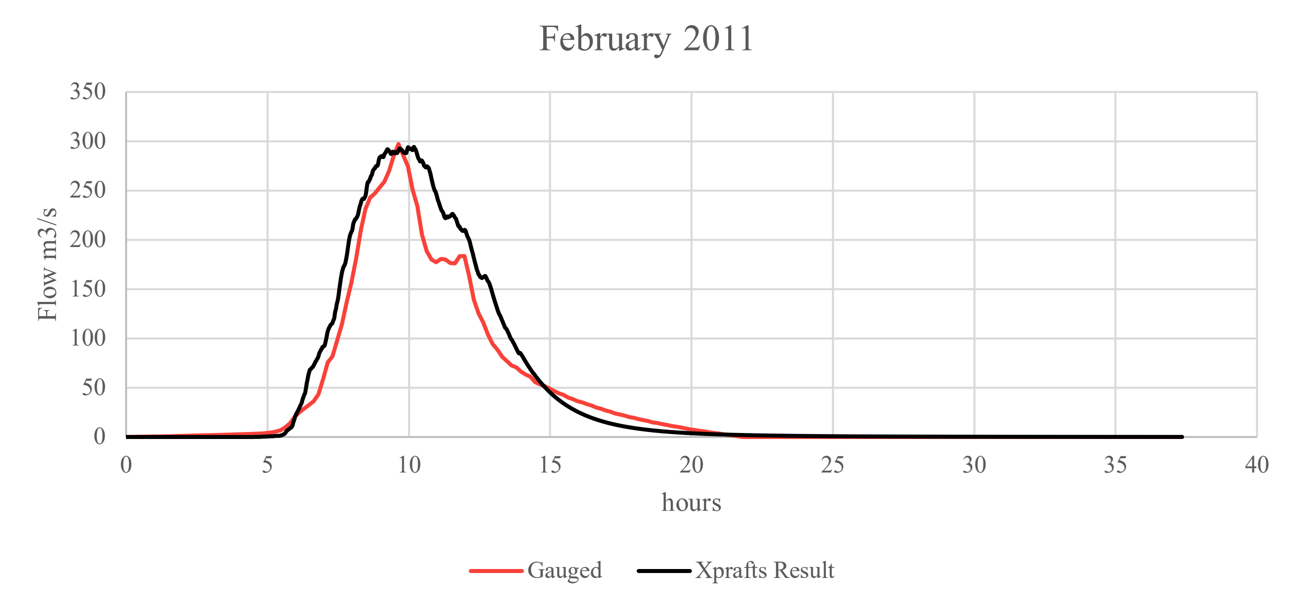


Figure 5.6 Model calibration at Snowy River upstream of Guthega Pondage for February 2011 event

For the validation event, the 1 March 2012 event included two peak flows which started on the 29 February 2012. The model was able to replicate the first peak flow, timing and duration well but the peak flow for the second peak underestimated the gauge value. The timing and duration of the second peak however were close but there was a significant underestimation of the second peak flow.

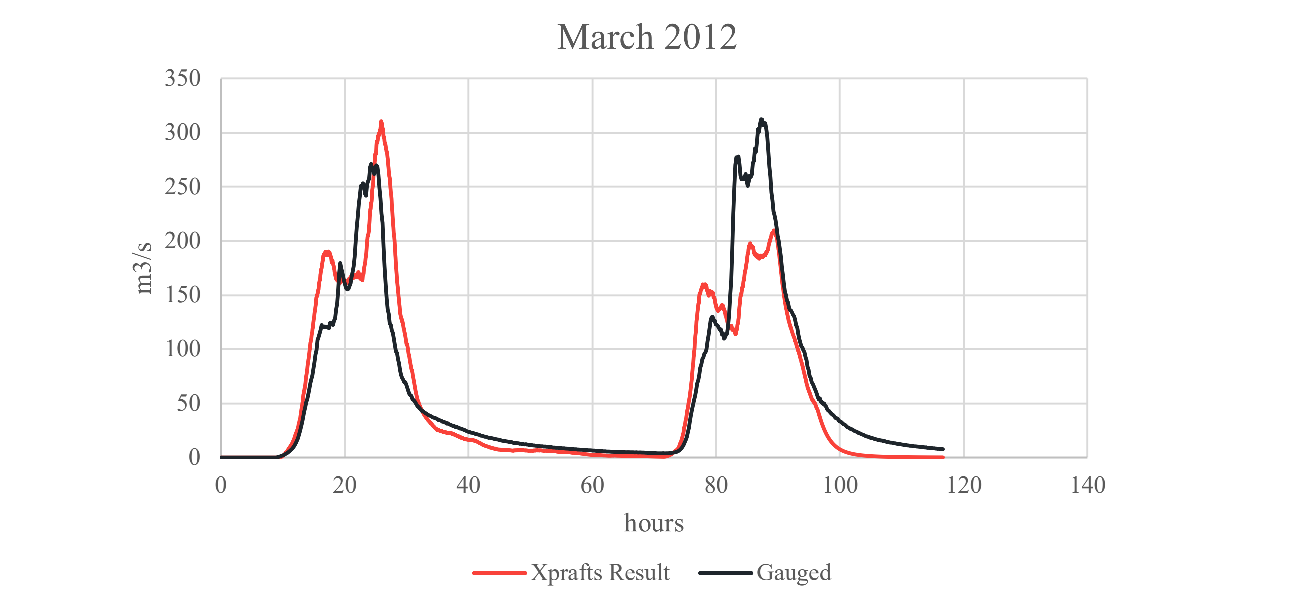


Figure 5.7 Model validation at Snowy River upstream of Guthega Pondage for March 2012 event

The FFA and RFFE analysis showed that the rainfall across the Snowy Mountains SAP area is variable so it was considered appropriate to undertake a second model calibration for the catchment to the Thredbo River at Paddy's Corner gauge. The 1 March 2012 event results were used for calibration and presented below in Figure 5.8.

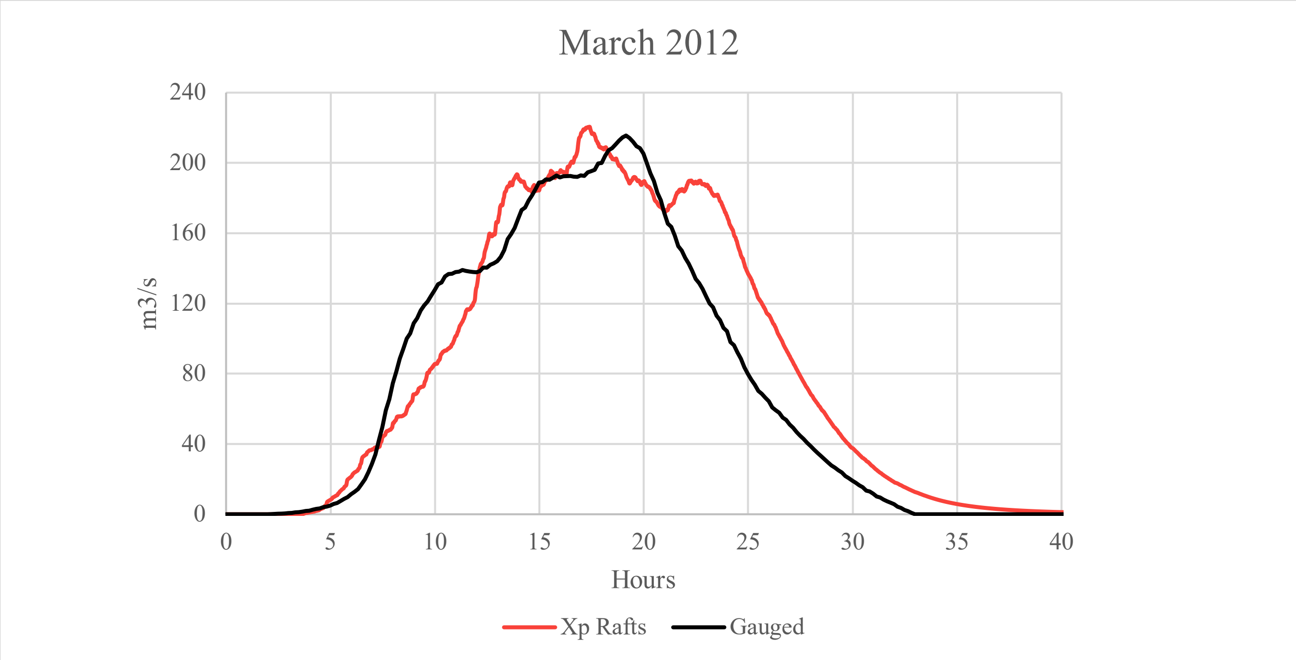


Figure 5.8 Model calibration at Thredbo River at Paddy's Corner for March 2012 event

The results show the peak flow is similar for the modelled (XP-RAFTS) and gauged results. The duration of the hydrograph is similar and the recession slope is similar but the rise at the beginning of the hydrograph does not quite match. Several iterations of the model parameters were tested to attempt to replicate the gauged hydrograph and the best result is presented in Figure 5.8. The adopted model parameters were and initial loss of 15 mm, continuing loss of 9 mm/hr, coefficient BX 0.5 and catchment roughness of 0.05–0.09.

The results from the 22 July 2016 validation model simulation are presented in Figure 5.9 below. The results show that the timing of the peak flow is similar but the magnitude of the modelled flow is more than double the gauged value. The volume of the hydrograph is also overestimated by the model which would indicate the continuing loss may be under estimated.

The July 2016 storm event occurred at a period of time during the year where the Thredbo catchment had a large amount of snow on the ground and during a time where snowfall was recorded. The peak height of the annual snowpack for the Thredbo area is generally around July to September period, with Thredbo Top Station recording a significant depth of snow during this period and that a significant snowfall occurred in the days following this storm event.

The hydrological model does not model the effects of snowpack, snowfall or sub-zero temperatures on the runoff for the catchment. An overestimation of the XP-RAFTS flow compared to the gauged flow can likely be attributed to the presence of a deep snowpack prior to the storm event and sub-zero temperatures included recorded snow fall in the following days.

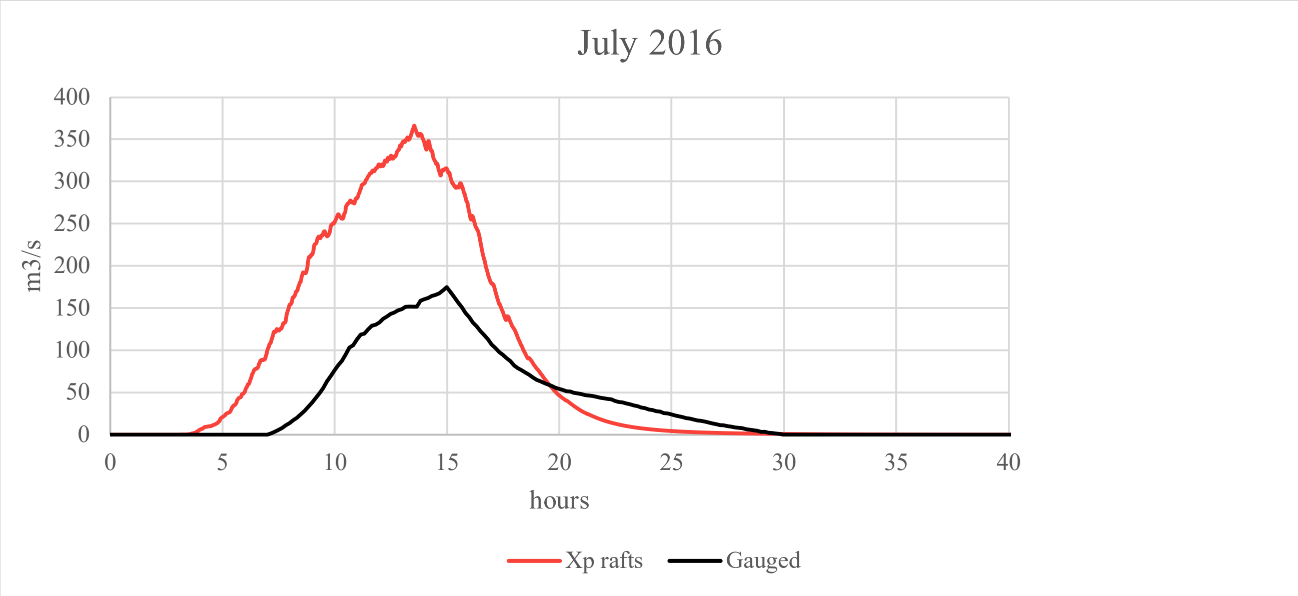


Figure 5.9 Model validation at Thredbo River at Paddy's Corner for July 2016 event

The model calibration and validation were good for the Snowy River and the initial and continuing losses of 10 mm and 2.5 mm/hour respectively have been used to inform the initial hydrologic model runs for design conditions. The Thredbo River model calibration was reasonable, however, the model significantly overestimated flows for the validation event, which was likely due to the effects of snowpack and snowfall for that event. As overestimation of the design flows in the validation model for Thredbo River can be attributed to the presence of snowpack, the calibration model initial and continuing losses of 15 mm and 9 mm/hr respectively have been used to inform the initial hydrologic model runs for design conditions.

5.5.4 IMPACT OF SNOWFALL AND SNOWPACK ON FLOOD RESULTS

The July 2016 verification model indicates that the presence of snowpack and snow fall during a storm event reduces the downstream flood flows in the catchment. As the presence of snow is expected to reduce the catchment runoff, the simulation of snowpack and snow fall has been excluded from the flood modelling analysis to ensure that the models produce conservative estimates of catchment runoff and flow in watercourses and overland flow paths.

5.5.5 DESIGN EVENTS

The design events simulated in the XP-RAFTS model are listed in Table 5.7 below.

Table 5.7 Design events simulated in XP-RAFTS model

EVENT	PURPOSE
10% AEP	For validation against FFA and required by brief
1% AEP	For validation against FFA and required by brief
0.5% AEP	Required by brief
0.2% AEP	Required by brief
Probable Maximum Flood (PMF)	Required by brief

The design event modelling was undertaken using the ensemble method of flow estimation, as detailed within Chapter 3, Book 4 of ARR 2019 and shown in overview in Figure 5.10. Each flood event (AEP) was run for a range of standard durations and for an ensemble of 10 temporal patterns within each duration. The median flow of the ensemble is then selected as the design flow for each event.

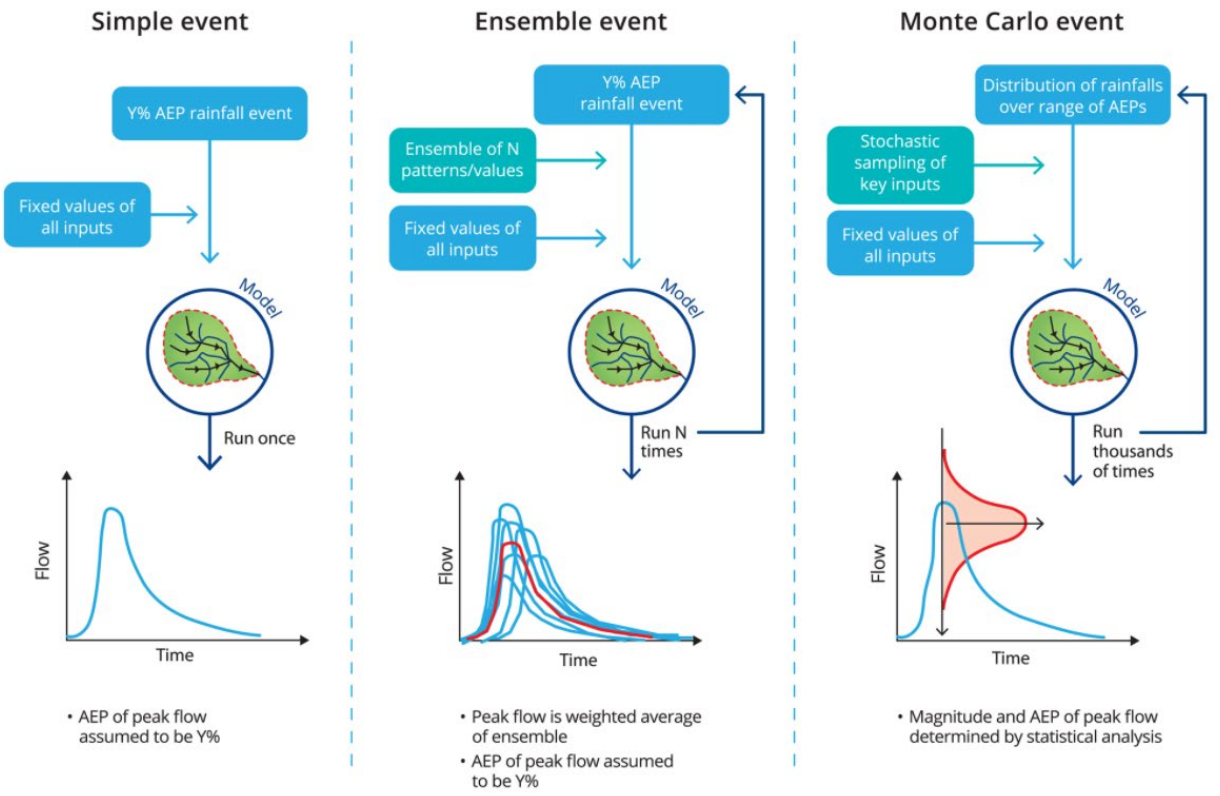


Figure 5.10 ARR2019 approaches to estimation of peak flow (from ARR2016 Chapter 3, Book 4)

For the Snowy Mountains SAP XP-RAFTS model, the critical storm duration was found to vary between 1 and 12 hours, depending on sub-catchment size and AEP. The critical storm producing highest median flows to the downstream boundary of the Snowy Mountains SAP was the 12 hour storm.

5.5.6 METHODOLOGIES FOR DEFINING EXTREME FLOWS

The probable maximum flood (PMF) is the theoretical upper limit of flooding within a given catchment, used to inform flood risk management for communities. It provides a basis of the maximum extent of the floodplain and upper scale for the flood risks faced by communities. The PMF flood is particularly important for emergency management considerations.

Estimation of the PMF involves both flow estimation and routing of flows through a hydraulic model to determine a flood extent. In NSW, the *Floodplain Risk Management Guideline: Incorporating 2016 Australian Rainfall and Runoff in Studies (OEH 2018, Updated in 2019)* sets out the preferred method for calculation of the PMF flood. The document notes that this methodology is preferable to the method documented in Book 8 of ARR2016 (recently updated to ARR2019). As such, the following methodology has been undertaken to determine the PMF flood event:

1 determination of PMP depths and temporal patterns from using the GSDM methodology for short duration events and GSAM for long duration events
2 provide an envelope of the GSDM and GSAM PMP depths, and extrapolated data points for the intermediate storm durations
3 run hydrological model with an initial loss of 0 mm and a continuing loss of 1 mm/h to generate PMF flows
4 run PMF hydrological flows through hydraulic model with all storages modelled as full.

5.5.7 VERIFICATION OF DESIGN FLOWS TO THE FFA FLOWS

The 10% AEP and 1% AEP event flows were verified against historical data using the FFA process detailed in Section 5.3. Table 5.8 and Table 5.9 show a comparison of the design hydrological model flow to the FFA expected flows. Both gauges show a good fit for the 1% AEP storm event and a slight underestimation of flows for the 10% AEP storm event. No FFA verification was able to be undertaken for the 0.5% AEP, 0.2% AEP or PMF flood events due to a limit in historical flow data available for the site.

Table 5.8 Snowy River upstream of Guthega Pondage Gauge 222527

AEP (%)	FFA EXPECTED QUANTILE (m3/s)	LOWER CONFIDENCE LIMIT 10% (m^3/s)	UPPER CONFIDENCE LIMIT (90%) (m^3/s)	DESIGN MODEL FLOW (m3/s)
10	250.28	220.67	289.2	207.799
1	377.51	306.7	526.0	352.054

Table 5.9 Thredbo River at Paddys Corner Gauge 222541

AEP (%)	FFA EXPECTED QUANTILE (m3/s)	LOWER CONFIDENCE LIMIT 10% (m^3/s)	UPPER CONFIDENCE LIMIT (90%) (m^3/s)	DESIGN MODEL FLOW (m3/s)
10	157.23	128.0	203.5	124.32
1	286.43	201.67	511.6	278.35

As the design requirement for land use planning is generally the 1% AEP storm event, the 1% AEP hydrological model results are a good fit for use in planning purposes. Some caution should be exercised when land use planning to the 10% AEP event as it is expected to slightly underestimate the flood flow, however it is noted that the area has generally highly defined waterbody geometry with little to no open floodplain areas. As such it is expected that at minor storm events such as the 10% AEP event, flooding extent would not be very sensitive to minor increases in flood levels.

5.6 HYDRAULIC MODEL METHODOLOGY

5.6.1 MODEL OVERVIEW

The Snowy Mountains SAP area is to be broken up into a number of hydraulic models. To inform the initial planning stage for the Snowy Mountains SAP project, the following existing conditions hydraulics models were built:

1. Go Jindabyne Precinct
2. Thredbo Village to Bullocks Flat
3. Perisher Village.

Hydraulic modelling is undertaken to simulate complex flow conditions for urban areas and creeks particularly where the urban environment has encroached on the creek or waterway, where flow paths are not well defined due to flat surfaces or where new development is proposed near a waterway. No hydraulic model was built for precinct areas that would not exhibit regional flooding or have any significant waterways other than local catchment overland flows.

5.6.1.1 GO JINDABYNE PRECINCT MODEL

The extent of the hydraulic model area for the Go Jindabyne Precinct is shown below in Figure 5.11. The TUFLOW model extends to encompass all major flow paths in the vicinity of the area surrounding Jindabyne including local catchment flows such as Lees Creek, Widows Creek and Cobbin Creek, as well as inflows from and sections of the Mowamba River, Wollondibby Creek, Rushes Creek and the Snowy River in addition to the water level within the Jindabyne Reservoir. The outflow from the Jindabyne Reservoir has been estimated from earlier Jindabyne dam break assessments undertaken prior to this project, as no dam break assessment was considered as part of the hydraulic model for this study.

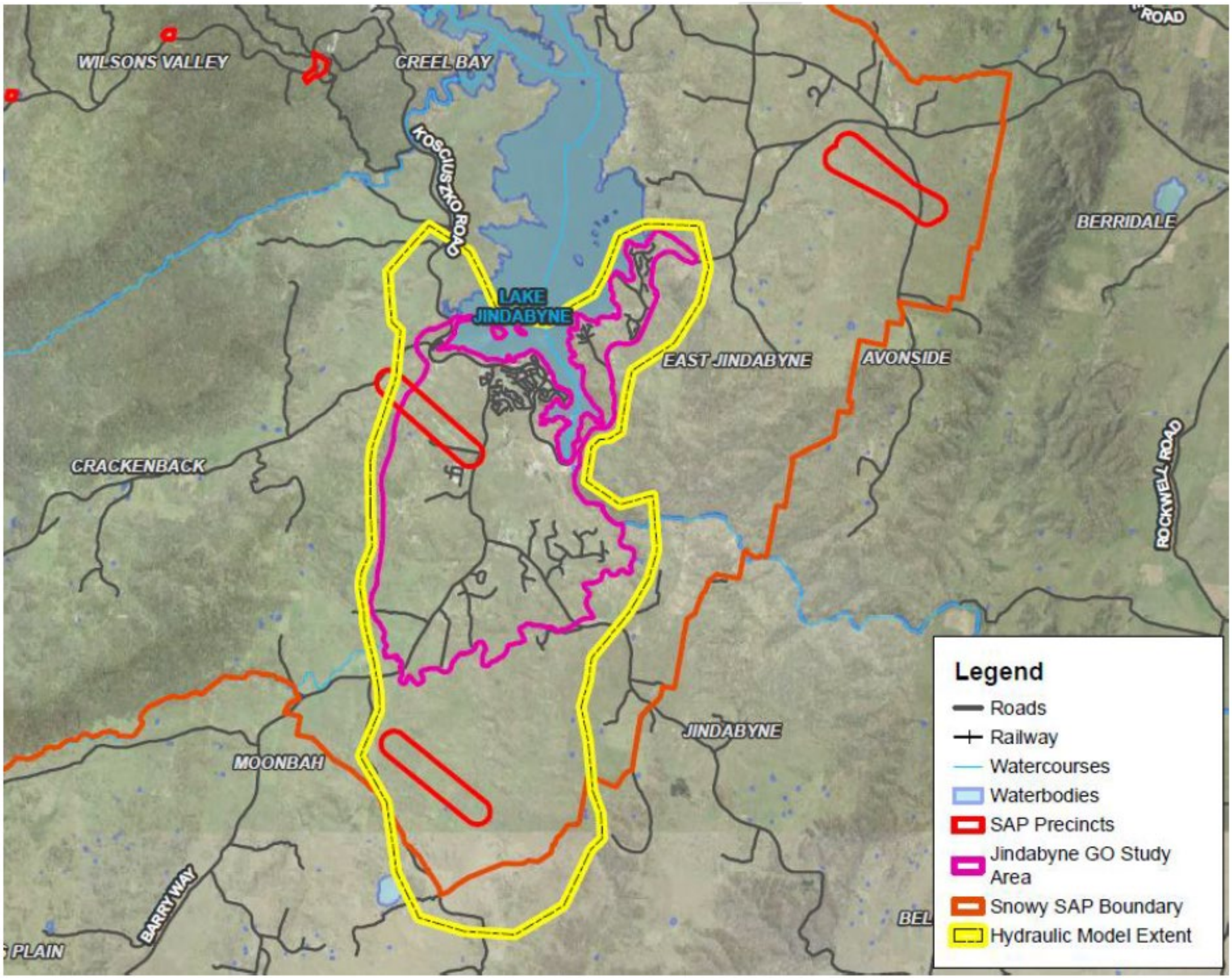


Figure 5.11 Extent of the Go Jindabyne precinct hydraulic model

5.6.2 THREDBO VILLAGE TO BULLOCKS FLAT MODEL

The extent of the hydraulic model area for the Thredbo Village to Bullocks Flat model is shown below in Figure 5.12. The TUFLOW model extends to encompass all major flow paths in the vicinity of the area surrounding Thredbo village including the inflows from the Thredbo River, Merritts Creek and Friday Flat Creek and extending down Thredbo River to encompass the Bullocks Flat area and surrounds with inflows from all upstream catchments in the vicinity of the hydraulic model.

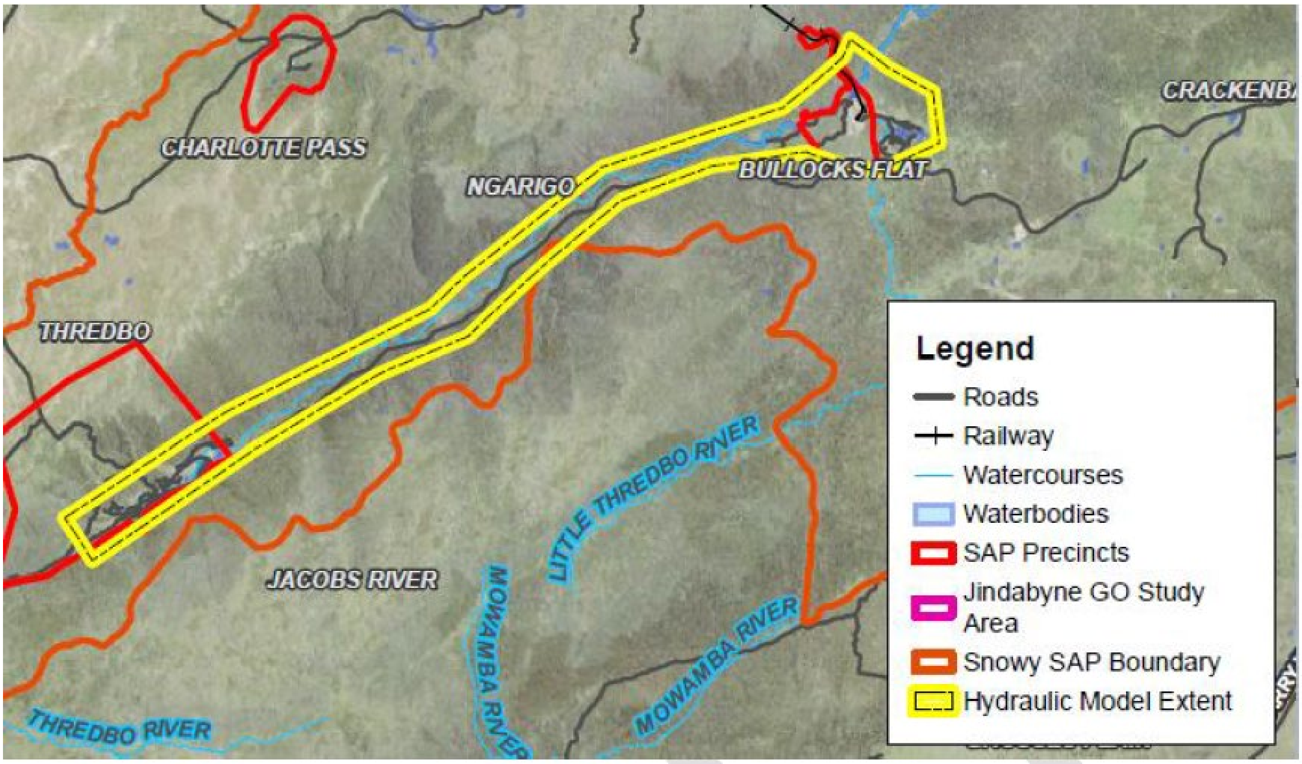


Figure 5.12 Extent of the Thredbo Village to Bullocks Flat hydraulic model

5.6.3 PERISHER VALLEY MODEL

The extent of the hydraulic model area for Perisher Valley is shown below in Figure 5.13. The TUFLOW model extends to encompass all major flow paths in the vicinity of the area surrounding Perisher Valley including all upstream inflows in the vicinity of the hydraulic model.

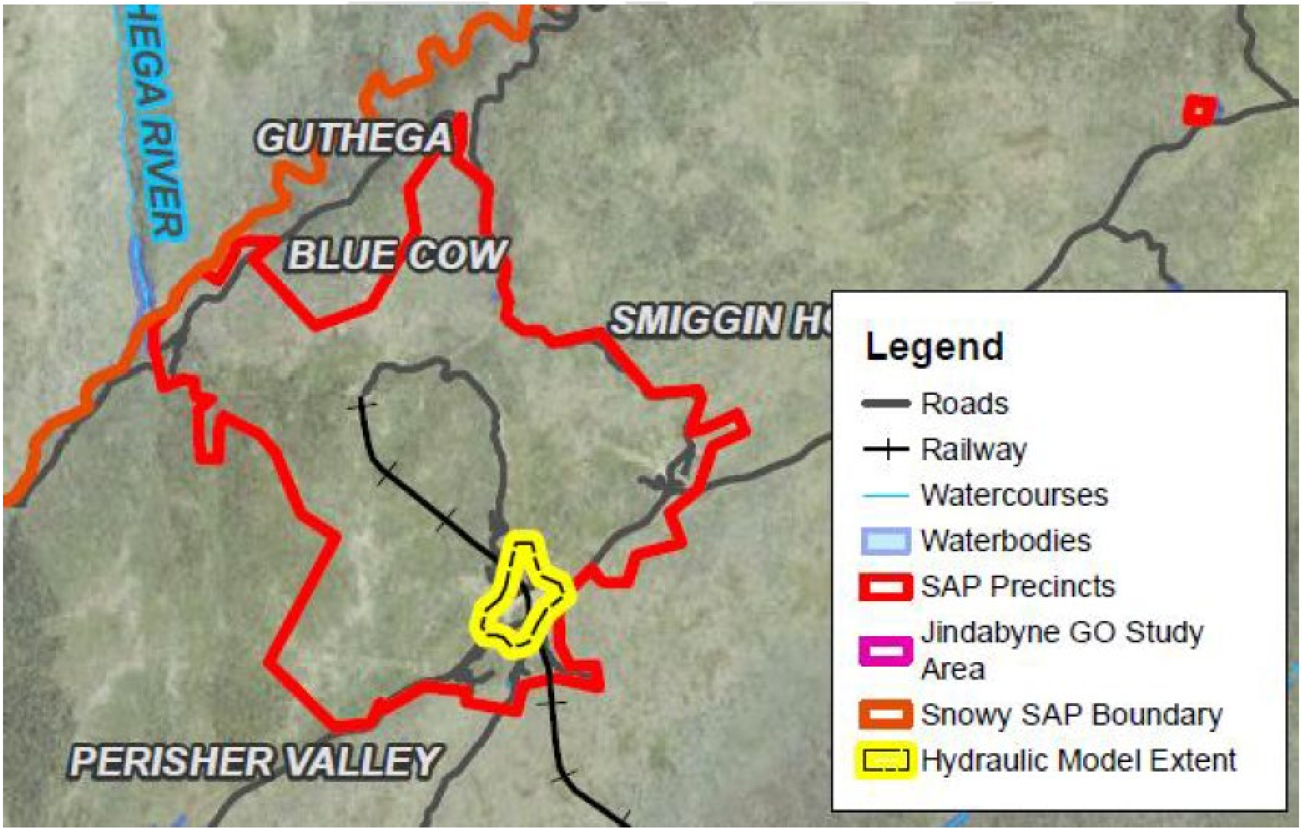


Figure 5.13 Extent of the Perisher Valley hydraulic model

5.6.4 HYDRAULIC MODEL REPRESENTATION

5.6.4.1 MODELLING SOFTWARE

The hydraulic models were constructed in the TUFLOW HPC software program using a two-dimensional (2D) fixed grid for modelling the terrain and the one-dimensional (1D) solver used for flow control structures such as culverts under roads.

5.6.4.2 REPRESENTATION OF FLOW CONTROL STRUCTURES

Key structures that affect the conveyance or storage of flood flow within a floodplain system include raised embankments (e.g. levees, road/rail embankments), dams and bridges/culverts under embankments. The embankments and dams are represented in the 2D terrain model within TUFLOW and the flow behaviour through and around bridges and culverts is modelled using the 1D solver approach.

The Jindabyne Dam spillway was artificially blocked off in the hydraulic model using a "glass wall" approach as the outflow from the Jindabyne Dam was modelled separately to the water level in Jindabyne Reservoir. The dam outflow flood extent was estimated from earlier Jindabyne dam break assessments undertaken prior to this project, as no dam break assessment was considered as part of the hydraulic modelling for this study, and as the dam is a controlled structure where outflow depends on storage capacity and active hydraulic control structures, no downstream flow could be assigned directly to any given storm event.

5.6.4.3 BOUNDARY CONDITIONS (HYDROLOGICAL INFLOWS)

Inflow hydrographs were applied on a sub-catchment scale using local catchment flows and a flow versus time boundary for concentrated upstream overland flow in rivers and creeks. Local catchment and concentrated upstream overland flow inflow hydrographs were generated in the XP-RAFTS hydrological models for the area and imported for use as a TUFLOW inflow boundary condition.

The XP-RAFTS model generates peak flows using the ensemble method of flow estimation from the ARR2019 design guidelines. The mean critical duration storm design flow for each AEP event was selected for each individual sub-catchment and for the concentrated upstream overland flow in creeks and rivers. This selected flow hydrograph was run in the hydraulic model to generate a peak flood surface for the modelling area.

5.6.4.4 BOUNDARY CONDITIONS JINDABYNE RESERVOIR

The Jindabyne Reservoir has been modelled as a separate water body to the dam wall and separate from flows in the Snowy River downstream of the dam wall. Jindabyne Dam is a Snowy Hydro controlled structure, with activatable flow controls and multiple spillway options and was not modelled as part of this study. Instead, Jindabyne dam levels have been modelled using the following scenarios (SHD is +1.117 m above AHD):

- 10% AEP Storm Event – Water level of 910.23 mAHD (911.35 m SHD)
- 1% AEP Storm Event – Water level of 910.63 mAHD (911.75 m SHD)
- 0.5% and 0.2% AEP Storm Events – Water level of 912.38 mAHD (913.5 m SHD)
- PMF Storm Event – Water level of 918.03 mAHD (919.15 m SHD).

It is noted that a full supply level for Jindabyne Dam is at 910.35 mAHD, slightly above the 10% AEP Storm Event water level. The 10% AEP Storm Event probability was determined from a median peak water level in the dam along with probabilities of flood scenarios, however it is noted that the dam can reach above the 10% AEP level as part of normal operating conditions if the dam is operating at full supply level.

These levels were adopted as fixed levels to account for impact of these levels on the local watercourse entering the Jindabyne Reservoir within the Snowy Mountains SAP study area. The levels have been extracted from information provided by Snowy Hydro Limited. It should be noted that the reservoir flood level scenarios simulated for this study are solely intended to define boundary conditions for the watercourses draining into the reservoir. Flood planning levels for development around the foreshore area of the reservoir are defined by Eucumbene Dam flood conditions set by Snowy Hydro and Snowy Monaro Regional Council.

5.6.4.5 BOUNDARY CONDITIONS SNOWY RIVER OUTFLOW DOWNSTREAM OF JINDABYNE DAM

The following capacity of the Jindabyne Dam spillway has been noted in the *Snowy Water Licence (May 2002, amended Oct 2011)*, refer to Figure 5.14. A 3000 m^3/s dam outflow has been adopted for the 1% AEP flood event in line with the spillway capacity for the dam.

Assumed outflows for the flood events 10%, 0.5%, 0.2% AEP and PMF are based on information extracted from Snowy Hydro reports.

JINDABYNE DAM	**Spillway:** Gated Capacity - 3 000 m^3/s Crest length - 41.8 m Crest level - RL 905.26 m **River Outlet Works:** 0.91 m diameter pipe siphon under spillway to provide discharge up to 0.6 m^3/s in the river below the dam.

Figure 5.14 Extracts showing the operating levels and spillway capacity for Jindabyne Dam sourced from the Snowy Water Licence (May 2002, amended Oct 2011)

5.6.4.6 FLOODPLAIN REPRESENTATION

Floodplain roughness (specified as the Manning's "n" value for different land use types) is a key hydraulic model parameter that affects the routing of overland flow as it is conveyed over land. The Manning's "n" values adopted for use in floodplain areas are consistent with ARR2019 guidance and were estimated from land use mapping and aerial photography. The values are identified below in Table 5.10.

Table 5.10 TUFLOW model roughness values adopted in floodplain areas

LAND USE	MANNING'S "N" VALUE
Pasture	0.05
Roads/Rail	0.02
Buildings	3.00
Ponds and other water	0.03
Urbanised areas	0.10
Industrial areas	0.10
Low density urbanised areas	0.08
Heavily vegetated creek	0.08
Maintained grass	0.04
Sparse to Moderate Vegetation	0.05
Moderate to Heavy Vegetation	0.07

5.6.4.7 GRID SIZE AND TIMESTEP

A 5 m grid size was adopted for the TUFLOW model. The grid size was selected following initial testing of several model grid resolutions (5 m, 10 m and 20 m) to determine the optimum balance between accuracy of representation of floodplain and flow control features and model run time.

The TUFLOW HPC modelling solution uses an adaptive time step solution that allows the solution to vary the timestep and repeat timesteps as required to maintain stability of the numerical analysis.

5.7 RESULT OUTPUTS

Results from the TUFLOW modelling have been presented in Appendix D for the following hydraulic models:

1. Go Jindabyne Precinct
2. Perisher Village
3. Thredbo Village to Bullocks Flat.

The Thredbo Village to Bullocks Flat model has been presented as two separate sheets, one for Thredbo Village and one for Bullocks Flat.

The hydraulic models were run for the following design storm events during this stage the project:

1. 10% AEP
2. 1% AEP
3. 1% AEP Climate Change 2090
4. 0.5% AEP
5. 0.2% AEP
6. Probable Maximum Flood (PMF).

For each storm event, a design flood level was chosen as the peak mean critical flood height at the location of interest. For the Thredbo Village to Bullocks Flat model, two sets of critical results were chosen for the model. The results presented at each location (Thredbo Village and Bullocks Flat respectively) are the critical results for that given location.

The hydraulic models were output for the following map types:

1. Peak Flood Depth
2. Peak Flood Hazard.

Flood maps have been generated for all the above options and have been included in Appendix D.

5.7.1 ASSESSMENT OF CLIMATE CHANGE EFFECTS

The 1% AEP flood event is typically used as the benchmark event for setting flood planning levels and assessing risks to development. Assessments of climate change effects typically involve application of increase factors to the 1% AEP rainfall or flow. For this study, a climate scenario of RCP 8.5 for the year 2090 was chosen to represent a 1% AEP climate change scenario. The rainfall intensity for all hydrological catchments was increased by 16.3% to model this scenario in line with the climate change factors from the site specific ARR 2019 datahub data in Appendix A.

Flood maps have been generated for the climate change scenarios for each site and have been included in Appendix D.

5.7.2 FLOOD HAZARD

The TUFLOW model is used to assess flood hazard for the Snowy Mountains SAP and surrounding area. Flood hazard is the product of flood depth and flood velocity and is used to define safe uses of land. Flood hazard has been assessed in accordance with the recommendations of ARR 2019 Book 6, Chapter 7. The hazard categories are shown below in Figure 5.15 reflect the flood hazard categories on the mapping included in Appendix D.

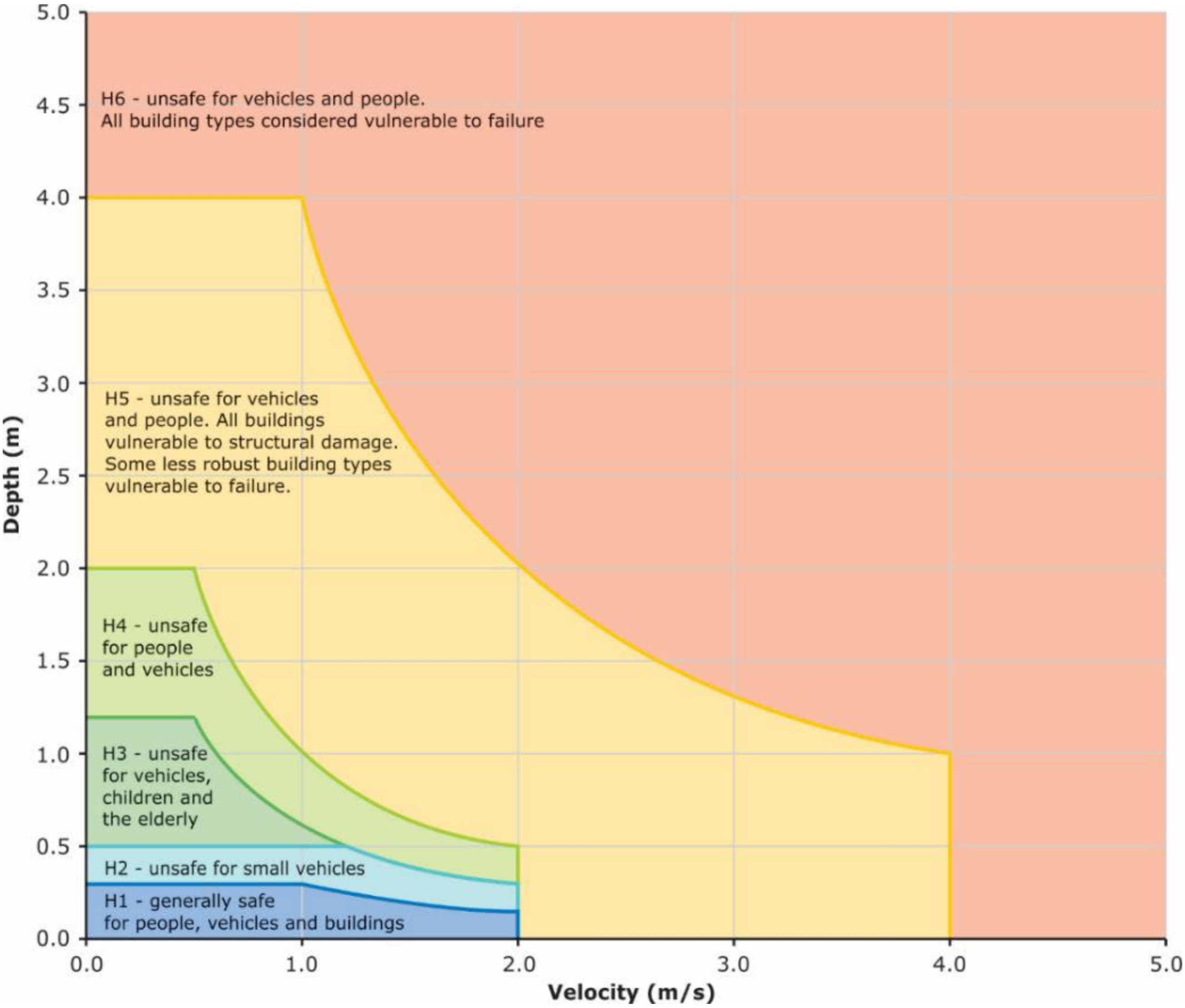


Figure 5.15 Combined flood hazard curves (from ARR 2019 Book 6, Chapter 7)

5.8 EXISTING CONDITIONS RESULTS

The hydraulic model results show that the flood behaviour within the extended Snowy Mountains SAP area is primarily confined to existing defined watercourses and rivers, with very little area exhibiting widespread surface flooding. Even in the extreme events such as the PMF flood event, no major overbank areas were inundated and only a relatively minor increase in flood extent was exhibited beyond the existing watercourses.

5.8.1 THREDBO VILLAGE AND BULLOCK FLAT

Thredbo Village, Bullocks Flat and the Jindabyne GO area were primarily flooded by rising waters in river systems overtopping the existing banks of the river and flooding the immediate surrounds, with some minor impacts from local catchments draining through the site. The Jindabyne GO area was also impacted by rising water levels in the Jindabyne Reservoir, where extreme flood events such as the PMF causes a significant rise in water level, however the vast majority of the proposed land use planning areas was beyond the extent of even the PMF flood event.

The majority of Thredbo Village remained relatively immune to flooding up to the PMF level event, however some public open space areas along Friday Drive and both buildings and carparks along Chimneys Way were flooded to some extent in the 10% AEP flood and above. It is noted that the areas along Chimneys Way were primarily flooded due to low depth local overland flow. No local pit and pipe system for drainage in the area has been modelled as part of this study, further analysis is required to confirm if this overland flow is adequately serviced by the local drainage system to mitigate any impacts in this area. Friday Drive at the Thredbo River bridge north east of the car parking areas appears to be flood immune in the 10% AEP storm events, but not in the 1% AEP or beyond. It is noted that the earlier study undertaken by SMEC identified this road as flood affected in the 5% AEP storm event. In addition, Friday Drive may also have a low immunity at the unnamed creek crossing near Thredboland, and at the bridge across the Thredbo River north of the Thredbo Landslide Site Memorial.

The majority of the Snowy Mountains SAP precinct for Bullocks Flat remains unflooded in up to the 0.5% AEP storm event, with a minor area surrounding the Ski Tube track flooding in all events modelled. No alignment levels for the Ski Tube rail were available for the model to confirm flood immunity of the service. Widespread flooding throughout this area was present for the PMF flood event in particular in the north and the east areas of the Snowy Mountains SAP Precinct near Bullocks Flat Terminal.

5.8.2 JINDABYNE GO AREA

The wider Jindabyne GO area exhibits minimal impacts from flooding in all flood events, with only minor floodplain extends beyond the main channel up to the PMF. The undeveloped area to the south of Lee Avenue along Barry Way exhibited some minor flooding as well as the area near the junction between Barry Way and the Mowamba River. Increases in water levels in the Jindabyne Reservoir up to the 1% AEP level had only a very minor impact on the Snowy Mountains SAP Precinct areas. Kosciuszko Road was immune at the Wollondibby Creek and Lees Creek crossings in the 1% AEP flood event; however it is noted that the increased level in Jindabyne Reservoir flooded both Kosciuszko Road and Barry Way at their intersection to the west of Jindabyne.

5.8.3 PERISHER VALLEY

Perisher Valley has a smaller upstream catchment then the other sites and the creeks running through the village appeared to overtop at an earlier stage then the other locations within the Snowy Mountains SAP. It is expected that the site will exhibit flooding events that are shorter and faster to peak then in other locations. In particular it was noted that Kosciuszko Road was immune to flooding in up to the 0.5% AEP flood event and that most major buildings and carparking infrastructure was relatively flood free up to the 1% AEP Climate Change 2090 condition.

The following flood maps showing model predictions of flood extents, depths and flood hazard under existing conditions are provided in Appendix D.

Table 5.11 Existing condition results flood maps in Appendix D

MAP FIGURE REF	TYPE OF MAP	LOCATION	FLOOD EVENT
001	General Site Overview	All Locations	N/A
002	Peak Flood Depth	Jindabyne	10% AEP
003	Peak Flood Depth	Thredbo Valley	10% AEP
004	Peak Flood Depth	Perisher Valley	10% AEP
005	Peak Flood Depth	Bullocks Flat	10% AEP
006	Peak Flood Depth	Jindabyne	1% AEP
007	Peak Flood Depth	Thredbo Valley	1% AEP
008	Peak Flood Depth	Perisher Valley	1% AEP
009	Peak Flood Depth	Bullocks Flat	1% AEP
010	Peak Flood Depth	Jindabyne	1% AEP Climate Change 2090
011	Peak Flood Depth	Thredbo Valley	1% AEP Climate Change 2090
012	Peak Flood Depth	Perisher Valley	1% AEP Climate Change 2090
013	Peak Flood Depth	Bullocks Flat	1% AEP Climate Change 2090
014	Peak Flood Depth	Jindabyne	0.5% AEP
015	Peak Flood Depth	Thredbo Valley	0.5% AEP
016	Peak Flood Depth	Perisher Valley	0.5% AEP
017	Peak Flood Depth	Bullocks Flat	0.5% AEP
018	Peak Flood Depth	Jindabyne	0.2% AEP
019	Peak Flood Depth	Thredbo Valley	0.2% AEP
020	Peak Flood Depth	Perisher Valley	0.2% AEP
021	Peak Flood Depth	Bullocks Flat	0.2% AEP
022	Peak Flood Depth	Jindabyne	PMF
023	Peak Flood Depth	Thredbo Valley	PMF
024	Peak Flood Depth	Perisher Valley	PMF
025	Peak Flood Depth	Bullocks Flat	PMF
026	Peak Flood Hazard	Jindabyne	10% AEP
027	Peak Flood Hazard	Thredbo Valley	10% AEP
028	Peak Flood Hazard	Perisher Valley	10% AEP
029	Peak Flood Hazard	Bullocks Flat	10% AEP
030	Peak Flood Hazard	Jindabyne	1% AEP
031	Peak Flood Hazard	Thredbo Valley	1% AEP
032	Peak Flood Hazard	Perisher Valley	1% AEP

MAP FIGURE REF	TYPE OF MAP	LOCATION	FLOOD EVENT
1033	Peak Flood Hazard	Bullocks Flat	1% AEP
034	Peak Flood Hazard	Jindabyne	1% AEP Climate Change 2090
035	Peak Flood Hazard	Thredbo Valley	1% AEP Climate Change 2090
036	Peak Flood Hazard	Perisher Valley	1% AEP Climate Change 2090
037	Peak Flood Hazard	Bullocks Flat	1% AEP Climate Change 2090
038	Peak Flood Hazard	Jindabyne	0.5% AEP
039	Peak Flood Hazard	Thredbo Valley	0.5% AEP
040	Peak Flood Hazard	Perisher Valley	0.5% AEP
041	Peak Flood Hazard	Bullocks Flat	0.5% AEP
042	Peak Flood Hazard	Jindabyne	0.2% AEP
043	Peak Flood Hazard	Thredbo Valley	0.2% AEP
044	Peak Flood Hazard	Perisher Valley	0.2% AEP
045	Peak Flood Hazard	Bullocks Flat	0.2% AEP
046	Peak Flood Hazard	Jindabyne	PMF
047	Peak Flood Hazard	Thredbo Valley	PMF
048	Peak Flood Hazard	Perisher Valley	PMF
049	Peak Flood Hazard	Bullocks Flat	PMF

5.8.4 DAM FAILURE FLOOD RISK

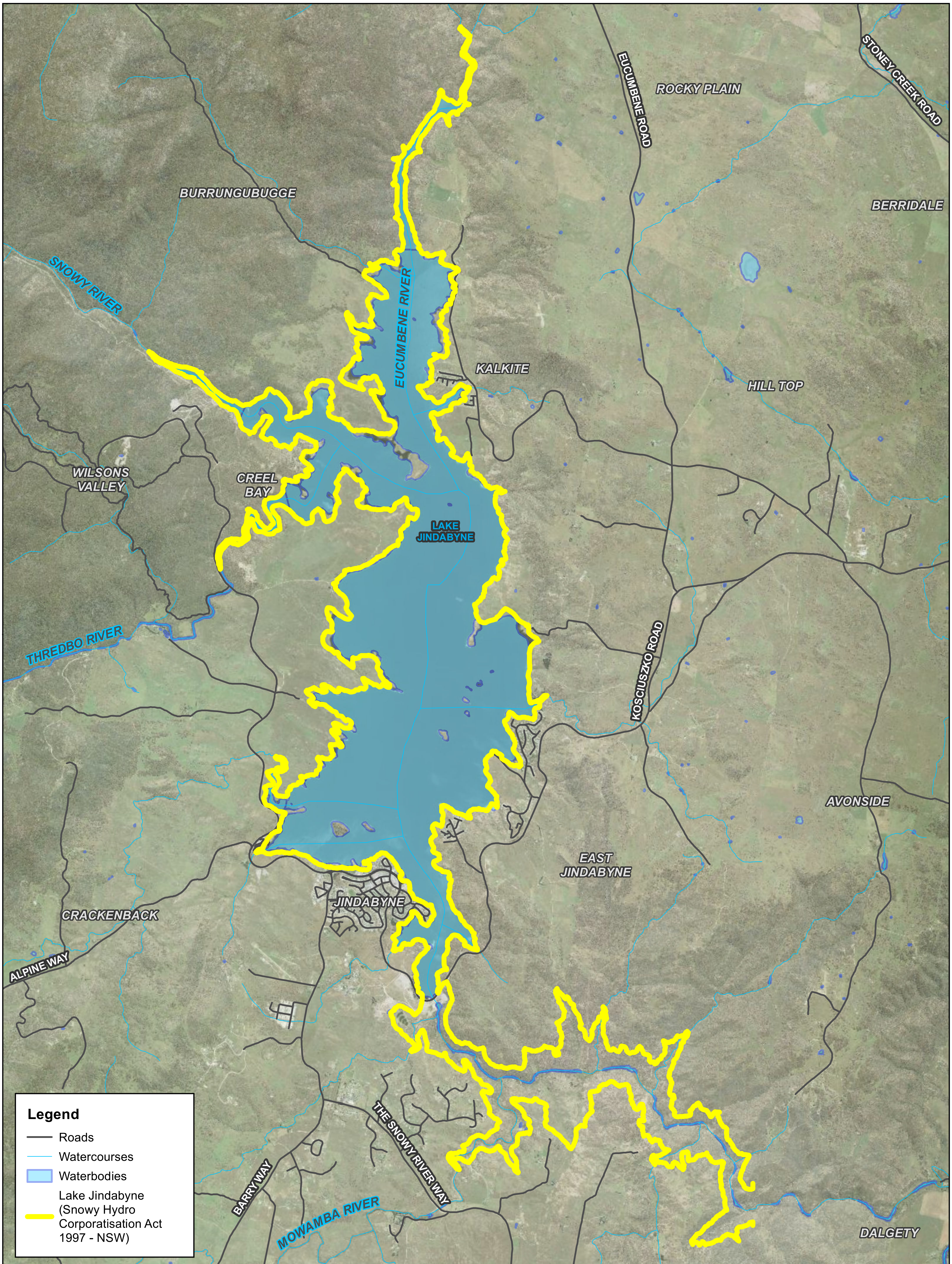
Dam failure is a key consideration for major storage structures to understand the risk of failure and develop and implement maintenance strategies to ensure the integrity of the dam. Snowy Hydro Pty Ltd as the owner of Eucumbene, Jindabyne and Guthega Dams, are responsible for assessing the consequences of failure of these dams. As far as dam-failure planning is concerned the NSW State Emergency Service (SES) is the combat agency for dam failures and are required to prepare a series of plans to guide evacuation operations downstream of dams.

The information pertaining to the failure of Eucumbene, Jindabyne and Guthega Dams is held by Snowy Hydro and has been made available for this technical study. The information includes structure, geotechnical, hydrologic and hydraulic investigations to understand the range of risks for each dam wall and embankment. Dam failure consequence assessments summarise the technical information to provide a risk rating for each dam and inform maintenance and operating procedures. The consequence assessments are not intended to be used to inform land use planning decisions and therefore the information in the reports is not included in this technical study.

5.8.5 DAM OPERATIONS

Snowy Hydro Ltd operate each dam within the range of minimum operating level (MOL) and full supply level (FSL). These levels are outlined in the Snowy Water Licence 2011 which is issued under the Snowy Hydro Corporatisation Act 1997 (NSW). For Jindabyne Dam the minimum operating level is 896.11 m SHD and the full supply level is 911.35 m SHD. The extent of the full supply level is approximately between the 10% and the 1% AEP reservoir levels shown for the reservoir within Appendix D.

Figure 5.16 shows the extent of the full supply level.



Map: PS120074_GIS_081_A1	Author: David.Naiken	
Date: 08.10.2020	Approved by: K.Brakell	

Data source: © Department of Customer Service 2020
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri

0 500 1,000 m
1:62,000

Coordinate system: GDA 1994 MGA Zone 55

Scale ratio correct when printed at A3

Snowy Mountains SAP

Figure 5.16: Lake Jindabyne

5.9 PROPOSED STRATEGIC PLANNING CONDITIONS

Jensen Plus has prepared a strategic framework for growth across the Snowy Mountains SAP precincts which considers future population projections and existing environmental constraints. The Snowy Mountains SAP aspirations as outlined in Section 1.4 identify infrastructure and connections which for flooding means ensuring all new or upgraded infrastructure is free from regular flooding and has a minimum flood immunity to ensure continuity of service during a significant rainfall event.

As such the proposed planning considerations with respect to the flood assessment are largely qualitative due to the lack of detail on the future developments at this stage of planning. The below items provide a general overview of high level proposed strategic planning conditions that should be applied to future development within the Snowy Mountains SAP precinct, providing a set of recommendations that future developments can be assessed against.

5.9.1 FLOOD PLANNING LEVEL

The flood planning level is defined as a level that includes a specified flood event level and freeboard, where freeboard accounts for uncertainty in the flood level or factor of safety. In general, land uses such as public open space, minor roads and sports fields can be assigned a flood planning level with a lower level of flood immunity as the impact and risks of more regular flood inundation are low in these land uses, as opposed to sites such as commercial buildings, residential buildings and major roads which would have increased risks and impacts associated with flood inundation. At the other extreme, emergency service buildings, hospitals and key evacuation routes and congregation facilities should be assigned a flood planning level appropriate for facilities that require little to no disruption during flood events. Key emergency infrastructure is usually located outside the PMF flood extent where possible, thus placing these facilities beyond the extent of the theoretical upper limit of flooding within a given catchment, providing complete immunity to flooding for sensitive infrastructure and land uses. The appropriateness of development within a floodplain is dependent on the suitability of the proposed use compared to the site flood risks and hazards for a given area.

The current Snowy Mountains River Development Control Plan 2013, Chapter C General Planning Considerations, indicates that the flood planning level is the 1% AEP flood level plus 0.5 m freeboard. It is recommended that the 1% AEP plus 0.5 m freeboard be maintained as the flood planning level for urban development to ensure consistency across the Snowy Mountains SAP but variations could be considered for other types of development.

5.9.2 FLOOD COMPATIBLE DEVELOPMENT CONDITIONS

The following considerations should be applied within the flood extent:

1. All structures to have flood compatible building components below 1% AEP flood level plus 500 mm freeboard.
2. All emergency and evacuation infrastructure to have flood compatible building components below PMF flood level plus 500 mm freeboard.
3. All structures are to be designed to withstand the forces of floodwater, debris and buoyancy up to 1% AEP flood plus 500 mm freeboard.
4. All emergency and evacuation infrastructure structures are to be designed to withstand forces of floodwater, debris and buoyancy up to PMF flood plus 500 mm freeboard.

5.9.3 PRECINCT CONSIDERATIONS

As outlined in Section 1.4, areas of growth have been identified across the Snowy Mountains SAP study area. The exact details of future developments were not available to include in the model due to the early stage of the planning process, however the existing flood models have been interrogated to understand what impact flooding will have on each area.

JINDABYNE AND LAKE JINDABYNE

The precinct areas generally are not significantly affected by widespread flooding as most flooding is confined to the general vicinity of the existing watercourses up to the 1% AEP event, including key precinct areas such as the Western Lake Jindabyne Area, Eastern Lake Jindabyne Area and the Alpine Way area.

Any proposed development should be outside the extent of the mainstream 1% AEP flood, with consideration given to changes in the extent and hazard of flooding due to climate change for the proposed design life of the development. Local overland flooding will have to be assessed and mitigated for each development through the provision of adequate site drainage systems. Adequate planning for emergency evacuation should be undertaken to ensure the safety of all areas within the PMF flood extent.

ALPINE RESORTS – THREDBO

The hydraulic modelling identified a few key access routes that had a low immunity, namely Friday Drive within Thredbo Village which may not have adequate immunity in a 1% AEP storm event and the junction between Barry Way and Kosciuszko Road west of Jindabyne. In addition, a number of minor roads particularly in Thredbo Village have been identified with low flood immunity.

It is recommended that the low immunity access locations be reviewed in more detail and that additional infrastructure be constructed to ensure that the right level of immunity is reached. It is expected that a bypass surrounding Jindabyne will provide an alternate route to mitigate the low flood immunity between Barry Way and Kosciuszko Road, however the Friday Drive bridge should be assessed further to determine whether it requires upgrading to provide a higher level of immunity.

SOUTHERN BYPASS

The proposed southern bypass road around Jindabyne should be provided with flood immunity up to the 1% AEP event plus 500 mm freeboard with consideration given to changes in the extent, height and hazard of flooding due to climate change for the proposed design life of the road. For the minor roads, upgrading drainage infrastructure or locally raising the road to meet a higher flood immunity should be considered to mitigate any impact of flooding in these areas.

6 WATER QUALITY ASSESSMENT

6.1 OVERVIEW

The water quality assessment has focused on understanding stormwater pollutant runoff generation for the ski resorts and Jindabyne and identifying potential water sensitive urban design measures to minimise the impacts of development on the downstream watercourses and Lake Jindabyne.

6.2 EXISTING CONDITIONS WATER QUALITY MODELLING

A water quality model using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) software program was prepared to assess the existing stormwater flow and pollutant generation from the Snowy Mountains SAP area. The MUSIC software program was deemed suitable for this assessment because it can estimate volumes and pollutant loads for stormwater based on historic continuous rainfall data. Stormwater management typically deals with regular rainfall events so use of a continuous rainfall provides an understanding of how the system behaves over a longer term reference period, e.g. over numerous years. This informs an assessment of the pollutant load generation over a range of climatic conditions and long term stormwater flow and pollutant fluctuations. The model set up referenced the NSW MUSIC Modelling Guidelines (BMT WBM, 2015).

6.2.1 RAINFALL AND EVAPOTRANSPIRATION DATA

A climatic data template for MUSIC was not available for the study area and therefore climatic data from the closest station at Ingebyra (Grosses Plains) (071042) was requested from the BOM. The Ingebyra station is set at an elevation of 1215 mAHD and is located approximately 25 km south west of Jindabyne and on the eastern side of the Great Dividing Range which would create similar climatic conditions to Jindabyne and the wider SAP study area. The climatic data period was from 2007–2016 and the mean annual rainfall at the station as 805 mm. Potential evapotranspiration values were taken from the Canberra Areal PET default MUSIC file which has a mean annual evapotranspiration value of 1111 mm. It is noted that this will be updated should data more representative of the Snowy Mountains SAP area be available.

6.2.2 PERVIOUS AREA PARAMETERS

Soil reports from the NSW Soil and Land Information System identified the dominant top soil profiles in the area are colluvial soils (OEH, 1992). This was estimated as sandy loam and Table 6.1 shows the pervious area parameters provided by the NSW MUSIC Modelling Guidelines for this soil type. These parameters were adopted for all source nodes.

Table 6.1 Pervious area parameters

PERVIOUS AREA PARAMETER	VALUE
Pervious Area Soil Storage Capacity (mm)	98
Pervious Area Soil Initial Storage (% of Capacity)	25
Field Capacity (mm)	70
Pervious Area Infiltration Capacity coefficient – a	250
Pervious Area Infiltration Capacity exponent – b	1.3
Groundwater Initial Depth (mm)	10
Groundwater Daily Recharge Rate (%)	60
Groundwater Daily Baseflow Rate (%)	45
Groundwater Daily Deep Seepage Rate (%)	0

6.2.3 IMPERVIOUS AREA PARAMETERS

The impervious area rainfall threshold (mm/day) was set at 1.5 mm for sealed and unsealed roads and 1 mm for all other land uses as per Table 5-4 in the NSW MUSIC Modelling Guidelines for large areas of interest. The impervious area percentages for each node are shown in Table 6.4 and were set based on the values in Table 5-3 of the NSW MUSIC Modelling Guidelines.

6.2.4 POLLUTANT CONCENTRATION PARAMETERS

Table 6.2 shows the baseflow and stormflow pollutant concentration parameters for the source nodes. These values were taken from Table 5-6 of the NSW MUSIC Modelling Guidelines. The stochastic estimation method was selected for all pollutant types with the exception of phosphorus in agricultural nodes. The NSW 2015 guidelines note that phosphorus stormflow concentrations within MUSIC are correlated to suspended solids concentrations when the stochastic estimation method is selected. As such a sensitivity test was run to test both stochastic estimation and mean estimation methods in agricultural nodes.

It is noted that MUSIC is not able to model electrical conductivity. There is insufficient research on the generation of salt based on land use to be able to develop a reliable method for estimating salt generation and subsequent electrical conductivity values in receiving waters. With reference to Section 3.6, the existing water quality monitoring indicates TN to be an issue for the ski resort areas and receiving waters.

Table 6.2 Source node pollutant concentrations

SOURCE NODE	FLOW	TSS (MG/L)		TP (MG/L)		TN (MG/L)	
		Mean log	SD log	Mean log	SD log	Mean log	SD log
Agricultural	Baseflow	1.3	0.13	-1.05	0.13	0.04	0.13
	Stormflow	2.15	0.31	-0.22	0.3	0.48	0.26
Forested	Baseflow	0.78	0.13	-1.22	0.13	-0.52	0.13
	Stormflow	1.60	0.20	-1.10	0.22	-0.05	0.24
Vegetated	Baseflow	1.15	0.17	-1.22	0.19	-0.05	0.12
	Stormflow	1.95	0.32	-0.66	0.25	0.3	0.19
Sealed road	Baseflow	1.20	0.17	-0.85	0.19	0.11	0.12
	Stormflow	2.43	0.32	-0.30	0.25	0.34	0.19
Unsealed road	Baseflow	1.20	0.17	-0.85	0.19	0.11	0.12
	Stormflow	3.00	0.32	-0.30	0.25	0.34	0.19
Roof	Baseflow	n/a	n/a	n/a	n/a	n/a	n/a
	Stormflow	1.30	0.32	-0.89	0.25	0.30	0.19
Low Density Residential	Baseflow	1.15	0.17	-1.22	0.19	-0.05	0.12
	Stormflow	1.95	0.32	-0.66	0.25	0.3	0.19
Town	Baseflow	1.20	0.17	-0.85	0.19	0.11	0.12
	Stormflow	2.15	0.32	-0.60	0.25	0.3	0.19
Footpath	Baseflow	1.20	0.17	-0.85	0.19	0.11	0.12
	Stormflow	2.15	0.32	-0.60	0.25	0.3	0.19

SOURCE NODE	FLOW	TSS (MG/L)		TP (MG/L)		TN (MG/L)	
		Mean log	SD log	Mean log	SD log	Mean log	SD log
Recreational	Baseflow	1.15	0.17	-1.22	0.19	-0.05	0.12
	Stormflow	1.95	0.32	-0.66	0.25	0.3	0.19
Industrial	Baseflow	1.20	0.17	-0.85	0.19	0.11	0.12
	Stormflow	2.15	0.32	-0.60	0.25	0.30	0.19

6.3 LAND USES

The existing land uses and infrastructure present in the Snowy Mountains SAP area are discussed in Section 3.4. Different approaches were used to assess the land use values in different precincts depending on the level of detail available.

6.3.1 ROADS

For all precincts road data was provided by the DPIE (2020) which provided a road classification such as primary, secondary, residential etc. for all roads in the Snowy Mountains SAP area. Roads were then classified as sealed or unsealed roads based on their road type and aerial imagery, with resulting classifications given in Table 6.3. To estimate road areas, widths of 12 m were used for secondary roads, 9.2 m for tertiary, 8.7 m for residential, 5 m for track and 6 m for all other types. These widths were based on AustRoads standards where applicable and aerial imagery estimates where not applicable.

Table 6.3 Road type classifications

MUSIC NODE	NSW ROAD CLASSIFICATION
Sealed Road	Secondary, tertiary, residential, pedestrian, unclassified
Unsealed Road	Track, path, service, residential, unclassified
Residential	Footway, cycleway, steps

6.3.2 OTHER LAND USES

Land use areas were identified for the precincts by identifying the areas likely to have impervious surfaces in them. These areas were identified in each precinct as follows:

- for the Jindabyne precinct, land use classification data was taken from the 2017 NSW Land Use Data set (DPIE)
- for Perisher, Thredbo and Selwyn, land uses areas were estimated and digitised based on aerial imagery
- for all other precincts which are of smaller size, land uses were able to be identified and digitised specifically into roof areas, road areas, cleared areas etc based on aerial imagery.

The impervious and pervious percentages for each land use were then set to average values based on the 2015 NSW MUSIC Modelling Guidelines where applicable or estimated based on aerial imagery where not directly applicable. These values are shown in Table 6.4.

Remaining land in each precinct was classified as vegetated, agricultural or forested land. Varying percentages for agricultural or forested land were used in each precinct and these percentages were estimated based on aerial imagery as shown in Table 6.5.

Table 6.4 Impervious area percentages for source nodes

LAND USE	MUSIC SOURCE NODE TYPE	% IMPERVIOUS	% PERVIOUS
Agricultural	Agricultural	0	100
Forested	Forest	0	100
Vegetated	Revegetated Land	0	100
Sealed road	Sealed Road	100	0
Unsealed road	Unsealed Road	50	50
Roof	Roof	100	0
Low Density Residential	Rural residential	5	95
Footpath	Residential	100	0
Town	Residential	60	40
Recreational	Rural residential	20	80
Industrial	Industrial	85	15
Park	Revegetated	0	100

Table 6.5 Percentage of agricultural, forested or vegetated land assigned to each precinct

NODE TYPE	AGRICULTURAL	FORESTED	VEGETATED
Jindabyne	85%	10%	5%
Perisher	0	90%	10%
Thredbo	0	90%	10%
Selwyn	0	80%	20%
Charlotte Pass	0	90%	10%
Sponars Chalet	0	90%	10%
Bullocks Flat	0	90%	10%
Ski Rider Hotel	0	90%	10%
Kosciuszko Tourist Park	0	90%	10%

6.3.3 LAND USES IN EACH PRECINCT

Table 6.6 to Table 6.14 show the areas of each land use in the existing condition Snowy Mountains SAP precinct models and Appendix C presents the information in Figures.

Table 6.6 Jindabyne land use types and areas

	AREA (ha)
Agricultural	2214.83
Forested	260.57
Vegetated	138.34
Sealed road	72.39
Unsealed road	37.81
Low Density Residential	540.44
Town	205.43
Recreational/Cleared	56.60
Park	8.06
Industrial	36.52
Total area	3571

Table 6.7 Perisher land use types and areas

	AREA (ha)
Forested	1385.87
Vegetated	153.99
Sealed road	14.19
Unsealed road	22.52
Roof	1.17
Low Density Residential	33.37
Town	1.27
Footpath	0.03
Industrial	0.82
Total area	1613

Table 6.8 Thredbo land use types and areas

	AREA (ha)
Forested	813.10
Vegetated	90.34
Sealed road	9.75
Unsealed road	16.11
Low Density Residential	5.66
Town	27.04
Recreational	0.39
Industrial	1.53
Total area	965.85

Table 6.9 Selwyn land use types and areas

	AREA (ha)
Forested	162.16
Vegetated	40.54
Sealed road	2.06
Unsealed road	0.19
Roof	0.07
Low Density Residential	11.34
Total area	216

Table 6.10 Charlotte Pass land use types and areas

	AREA (ha)
Forested	144.82
Vegetated	16.09
Sealed road	1.95
Unsealed road	2.75
Roof	0.90
Total area	166

Table 6.11 Sponars Chalet land use types and areas

	AREA (ha)
Forested	3.04
Vegetated	0.34
Sealed road	0.07
Unsealed road	0.18
Roof	0.15
Total area	3.77

Table 6.12 Bullocks Flat land use types and areas

	AREA (ha)
Forested	112.11
Vegetated	12.46
Sealed road	12.36
Unsealed road	3.87
Roof	0.60
Industrial	5.22
Total area	147

Table 6.13 Ski Rider Hotel land use types and areas

	AREA (ha)
Forested	3.04
Vegetated	0.34
Sealed road	0.87
Roof	0.68
Total area	4.82*

*A 0.15 ha reservoir area was removed from total the Ski Rider Hotel precinct area as the reservoir is not considered to generate significant pollutant loads.

Table 6.14 Kosciuszko Tourist Park land use types and areas

	AREA (ha)
Forested	10.23
Vegetated	1.14
Low Density Residential	1.06
Roof	0.02
Park	0.95
Unsealed road	1.22
Footpath	0.19
Total area	14.81

6.4 EXISTING WATER QUALITY RESULTS

Table 6.15 shows the existing flow and pollutant concentrations predicted by the MUSIC models from the precincts of the Snowy Mountains SAP area. A sensitivity test was run for the TP pollutant for mean versus stochastic generation in agricultural nodes which only affected the Jindabyne precinct. The use of the mean generation method over the stochastic method showed an increase of 50 kg/yr in TP to give a total of 1580 kg/yr in the Jindabyne precinct.

Table 6.15 Existing condition – Flow and pollutant load to catchment receiving nodes

	JINDABYNE	PERISHER	THREDBO	SELWYN	CHARLOTTE PASS	SPONARS CHALET	BULLOCKS FLAT	SKI RIDER HOTEL
Flow (ML/yr)	5870	2270	1510	288	242	7	285	14
TSS (kg/yr)	727000	245000	200000	13200	31000	1640	0	2130
TP (kg/yr)	1530	291	235	32	34	1	69	4
TN (kg/yr)	10800	2640	1980	332	293	10	445	26
GP (kg/yr)	59900	8360	11700	561	1190	84	3950	310

6.5 LIMITATIONS AND ASSUMPTIONS OF THE MUSIC MODEL ASSESSMENT

The following outlines some limitations of the MUSIC model:

- Runoff from each precinct was divided into land use types as outlined in Section 6.2.3 and these were directed to a single outlet point to understand the combined existing discharges into the downstream environment. This was considered to be sufficient to assess the existing conditions.
- The NSW MUSIC Modelling Guidelines (BMT WBM, 2015) notes that the hydrology of highly pervious rural catchments is typically more complex than highly impervious urban catchments. The guidelines recommend that model results of highly pervious catchments in MUSIC should be checked against gauged flows and/or typical water balance estimates for sites in similar catchments.
- For proposed treatment measures recommended as part of the Snowy Mountains SAP strategy, the NSW MUSIC Modelling Guidelines (BMT WBM, 2015) note that the treatment performance of measures modelled in MUSIC has not been rigorously tested in rural catchments. Whilst it is expected that similar performance characteristics may be observed, care should be taken to consider the species of constituents (i.e. soluble or particulate) coming from the catchment and the measure's ability to effectively treat them.

Key assumptions to note in the approach are as follows:

- Average values were taken to represent road widths based on AustRoads guidelines. In the Jindabyne precinct the road line shapefiles were removed where possible from the other land use areas. In some locations where this has not occurred there may be minor double counting of impervious areas. It is considered that this is relatively minor and offset by the assumption that all areas not within a defined land use area are 100% pervious land.
- Average impervious and pervious fractions were applied to large land use areas based on the 2015 MUSIC modelling guidelines and aerial imagery.

6.6 PROPOSED STRATEGIC PLANNING CONSIDERATIONS FOR WATER QUALITY

Jensen Plus has prepared a strategic framework for growth across the Snowy Mountains SAP precincts which considers future population projections and existing environmental constraints. The Snowy Mountains SAP aspirations as outlined in Section 1.5 highlight the need to ensure stormwater runoff is managed to minimise impacts to the natural environment of the KNP and to ensure Lake Jindabyne continues to be suitable for recreational uses and water supply for the urban areas.

Water quality monitoring has been undertaken quarterly since 2004 for the Perisher Valley and Thredbo River areas (refer to Section 3.6) and it indicates that Total Nitrogen and Total Phosphorus levels in the waterways are often elevated above ANZG guideline levels. Electrical Conductivity levels indicate the presence of excessive salt, which has been detected on a few occasions during the monitoring period as outlined in Section 3.6.

Future climate projections indicate a reduction in mean annual rainfall across the Snowy Mountains SAP study area. Snow precipitation is also predicted to decrease due to future climate changes (refer to Section 3.2.1) which will impact cloud seeding. Overall, a reduction in rainfall leads to a reduction in stormwater runoff.

As outlined in Section 1.5, future growth areas have been identified. It is assumed these growth areas will result in increased impervious surfaces across the Snowy Mountains SAP study area and are likely to result in an increase in pollutant sources, concentrations and loads. With reference to Table 6.15, flow decreases at the outlet of the area due to capture in rainwater tanks, but all other values increase with increases in development and population.

While the future precinct developments were not be modelled due to the early stages of planning, the models were amended to understand what treatment measures could be required to meet reductions targets and reduce the future impact of growth across the Snowy Mountains SAP. The following sections include recommended stormwater quality treatment reduction targets and treatment measures to assist with understanding how water quality will need to be considered as part of the growth strategy.

6.6.1 PROPOSED STORMWATER QUALITY MANAGEMENT

6.6.1.1 STORMWATER QUALITY MANAGEMENT DESIGN CRITERIA

For developed areas in NSW, consent authorities typically require stormwater quality management measures be designed to achieve pollutant load reductions in the following typical ranges:

- Total Suspended Solids: 80 to 85% reduction
- Total Phosphorus: 30 to 60% reduction
- Total Nitrogen: 30 to 45% reduction.

Snowy Monaro Regional Council do not currently specify pollutant load reduction criteria but the Snowy River Local Environment Plan 2013 requires existing riparian lands and wetlands to be protected. The Kosciuszko Plan of Management 2014 requires nutrient levels to be managed and for ongoing monitoring to be carried out but it does not provide pollutant reduction criteria.

Given that no specific stormwater quality management criteria have been established for the Snowy Mountains SAP, the following initial criteria have been assumed and are recommended to assess the required mitigation measures for future development and population growth:

- reduce loads of Total Suspended Solids, Total Phosphorus and Total Nitrogen discharged to the receiving catchments to meet targets of:
  - Total Suspended Solids: 85% reduction
  - Total Phosphorus: 60% reduction
  - Total Nitrogen: 45% reduction
- electrical conductivity levels to be maintained below the 30 µS/cm ANZG 2018 Guideline Value for upland rivers of south-east Australia.

6.6.1.2 WATER QUALITY TREATMENT AND MITIGATION MEASURES

Water quality treatment should consider treatment as a train of treatment measures that allows for the removal of pollutants based on their typical size, i.e. design to remove largest particles first, then fines and lastly treat dissolved pollutants. The most efficient trains also start at the source of the pollution, such as the edge of the carpark, or edge of road. The proposed water quality treatment measures have considered this train of treatment and the following stormwater quality treatment measures were investigated for the Snowy Mountains SAP:

- rainwater tanks for capture and re-use of stormwater from roof areas within the Snowy Mountains SAP
- gross pollutant traps for capture of litter and large sized particles
- jellyfish units for treatment of TSS and nutrients
- bioretention basins for treatment of nutrients and dissolved pollutants.

Details of how these measures were assessed in the MUSIC model are provided in the following sections.

RAINWATER TANKS

Rainwater tanks provide for the storage of rainwater off roof areas which would otherwise drain to the nearby stormwater network and into the nearest waterway. Rainwater on rooves can be considered a water resource that should be captured and used for non-potable uses and therefore reduce demand on potable water supplies.

Rainwater tanks are unlikely to be suitable for the ski resort areas of the Snowy Mountains SAP due to winter temperatures falling below freezing. Unless the tank can be installed below ground with all inflow and outflow pipes insulated from the freezing temperatures it is not recommended that rainwater tanks be considered for the ski resort areas.

For areas around Lake Jindabyne and for the new school and sport and recreational precinct, rainwater tanks should be considered to reduce potable water demand. They have not been modelled or sized because the proposed strategic planning information does not identify exact increases in buildings to be able to estimate volume of rainfall for capture but they are recommended to be considered for the new school and sport and recreational developments.

GROSS POLLUTANT TRAPS

Gross pollutant traps (GPTs) are typically provided to remove litter, organic debris and coarse sediment that may otherwise overload measures provided to manage fine particulates and nutrients. (BMT WBM, 2005). They are best modelled at the sub catchment scale because their capacity is limited due to the nature of the pollutants they capture. As such they are recommended to be installed at the end of stormwater networks, such as those discharging into Lake Jindabyne and at the edge of carparks, similar to the Stormceptor (refer to Section 3.7) at the Perisher car park.

GPTs have not been included in the MUSIC model because they required more detailed sub precinct planning information to be able to identify local stormwater catchments.

JELLYFISH UNITS

Jellyfish stormwater treatment units are a proprietary stormwater treatment device that allows for efficient stormwater quality treatment in an underground unit. The device includes membrane filters that provide a very large surface area to effectively remove fine sand and silt-sized particles, and a high percentage of particulate-bound pollutants such as nitrogen, phosphorus, metals, and hydrocarbons (Contech, 2020). The unit can be installed at the end of a piped stormwater network similarly to the Stormceptor located at the outlet of the Perisher Carpark (refer to Section 3.7). The Jellyfish unit has been adopted as a typical treatment measure to understand the impact of including underground units for treatment of stormwater runoff.

The advantage of this type of unit is the minimal land required but it does require maintenance and changing of filters as they become blocked. The disadvantage is that the unit is placed below ground and therefore does not provide a visual reminder about the need to protect the local waterways from stormwater runoff.

Properties for the jellyfish filtration units were obtained from the manufacturer and are shown in Table 6.16. The high flow bypass rate was taken from manufacturers specifications.

Table 6.16 Jellyfish filtration unit typical details

PARAMETER	INPUT VALUE	
Low flow bypass (L/s)	0	
High flow bypass (L/s)	12.50, 55.0 and 0152.5	
Transfer function properties		
	Input	**Output**
TSS (mg/L)[1]	0	0
	200.0000	14.0000
TP (mg/L)[2]	0.00	0.00
	0.4000	0.1720
TN (mg/L)[3]	0.0	0.0
	7.0000	3.5000
Gross pollutants (kg/ML)	0	0
	100.0000	1.0000

BIORETENTION BASINS

Bioretention basins are typically large basins provided in large open space areas to manage stormwater quality at the sub-catchment scale.(BMT WBM 2005). For the purposes of understanding the level of treatment required to meet the reduced load targets basins have been modelled. It is noted that bioretention swales could be considered as an alternative when further details of development are available. The bioretention basins allow for the removal of nutrients and dissolved pollutants and provide an aesthetically appealing treatment option.

The following parameters were used for the bioretention basins. Areas of bioretention proposed are shown in Table 6.17.

Table 6.17 Bioretention basin parameters

PARAMETER	INPUT VALUE
Low flow bypass (m^3/s)	0
High flow bypass (m^3/s)	100
Extended detention depth (m)	0.3
Filter area (m^2)	Half of surface area
Unlined Filter Media Perimeter (m)	0.01
Evaporative loss as % of PET	0.75
Saturated hydraulic conductivity (mm/hr)	120
Filter depth (m)	0.5
TN content of filter media (mg/kg)	400
Orthophosphate content of filter media (mg/kg)	40
Low flow pipe diameter (mm)	100
Exfiltration rate (mm/hr)	0
Vegetated with effective nutrient removal plants?	Yes
Base lined?	Yes
Underdrain present?	Yes

6.6.1.3 WATER QUALITY DEVICE MODELLING

The water quality devices described above were simulated in the strategic planning scenario MUSIC model. The model was based on existing land use conditions due to the limited specific strategic planning definition of the growth scenarios. Given the size of some of the precincts, each precinct was then divided into a smaller areas to assess the approximate areas that could be treated by the above water quality devices. The number of areas used for each precinct is shown in Table 6.18. The number and size of the treatment devices was iteratively increased to estimate the required treatment of existing conditions to meet the proposed reduction targets. The results of the modelling can then be used to understand the impact of increasing pollutant generating land uses across the precincts.

Forested and vegetated areas were not included in the treated scenarios. The town and resort areas are typically clustered within the precinct. Runoff from these areas would be more likely to be captured in the same outlets than runoff from the vegetated pervious area. Additionally these areas are more likely to be priority areas for installation of water quality treatment measures.

No jellyfish units were modelled in the Sponars Chalet, Ski Rider Hotel or Kosciuszko Tourist Park areas as these precincts could be sufficiently treated with bioretention only.

6.6.1.4 FINAL RESULTS WITH MITIGATION MEASURES

The mitigation measures described above were simulated in the strategic planning scenario MUSIC model and the resulting flow and pollutant loads were compared to the results of the existing conditions model to determine the effectiveness of the measures. The results are provided below in Table 6.18. The combination of the jellyfish (JF) and bioretention basin for each precinct area were sized to meet the reduction targets as outlined in Section 6.6.1.1 above.

Table 6.18 Master Plan scenario MUSIC model results with mitigation measures

<table>
<tr><th></th><th>JINDABYNE</th><th>PERISHER</th><th>THREDBO</th><th>BULLOCKS FLAT</th><th>CHARLOTTE PASS</th><th>SKI RIDER HOTEL</th><th>SPONARS CHALET</th><th colspan="2">KTP</th><th>SELWYN</th></tr>
<tr><td>No. areas</td><td>15</td><td colspan="2">5</td><td>5</td><td>3</td><td>1</td><td>1</td><td>1</td><td>2</td><td>2</td></tr>
<tr><td>JF capacity (L/S)</td><td>152.5</td><td colspan="2">55</td><td>55</td><td>55</td><td>55</td><td>n/a</td><td>n/a</td><td>n/a</td><td>55</td></tr>
<tr><td>Bioretention area (m^2)</td><td>700</td><td colspan="2">400</td><td>500</td><td>150</td><td>200</td><td>120</td><td>30</td><td>50</td><td>100</td></tr>
</table>

The MUSIC model for the low density residential line showed that a jellyfish unit with a high flow bypass of 152.5 L/s and a bioretention basin of 1000 m^2 would be required to treat 8 hectares of low density residential areas of 95% pervious land to meet the pollutant reduction targets.

The results indicate that it is possible to provide sufficient treatment to meet the reduction targets.

6.6.1.5 PRECINCT CONSIDERATIONS

The water quality modelling has shown what is required to meet the reduction targets proposed in Section 6.6.1.1. The following sets out how the proposed stormwater quality management measures could be adopted for each precinct.

JINDABYNE AREA – SOUTHERN BYPASS

The proposed southern bypass will pass through land that is currently relatively free from development and therefore the road will change stormwater runoff by increasing the quantity of runoff as well and increasing the pollutant loads. Linear treatment measures beyond the road shoulder such as bioretention basins and bioretention swales (refer to Section 6.6.1.2) should be implemented to prevent additional sediment loads entering Lake Jindabyne via Lees and Widows Creek.

WESTERN LAKE JINDABYNE AREA

Development of the western Lake areas should adopt integrated water cycle management strategies to manage future growth. Integrated water cycle management could consider stormwater as a resource, rainwater tanks and natural treatment opportunities to minimise potable water supply demands and water quality impacts to the Lake.

EASTERN LAKE JINDABYNE AREA

Similarly to the western Lake area, adopt integrated water cycle management strategies to manage future growth. Integrated water cycle management could consider stormwater as a resource, rainwater tanks and natural treatment opportunities to minimise potable water supply demands and water quality impacts to the Lake.

ALPINE WAY AREA

Consider vegetated road shoulders, subject to bushfire hazard conditions to treat stormwater runoff at the point of generation.

ALPINE RESORTS

As best as possible minimise increased in impervious, hardstand areas within the resorts. Provide point source water treatment measures at the outlets to carparks and install kerb and gutters on the edges of carparks to enable control of stormwater runoff and therefore improve capture of stormwater pollutants including salt used for de-icing. Include vegetated (bioretention) areas along the edges of the road and parking areas or consider nitrogen offsetting to minimise vegetation near the resort and therefore minimise fuel available for bushfires. Install rainwater tanks and reuse stormwater across the resorts as much as possible to reduce potable water demands.

7 OPPORTUNITIES AND CONSTRAINTS

The flood modelling and water quality modelling has been completed for the existing conditions and has considered the proposed strategic planning growth area recommendations and outlined in Section 1.4. Specific Snowy Mountains SAP precinct and sub precinct opportunities and constraints are identified in sections 5 and 6. Opportunities with respect to floodplain management and water quality are identified below to inform planning conditions for the Snowy Mountains SAP and sub precinct areas. General Snowy Mountains SAP constraints identified below and should be considered when detailed growth land use development scenarios have been developed.

7.1 OPPORTUNITIES

7.1.1 FLOODING

The flood modelling indicates the waterways are largely incised and flooding is generally confined to narrow floodplains, which means, the narrow floodplain widths are unlikely to pose any constraints on future development.

Climate change projections have less rainfall/snow annually but potential increases in summer/autumn rainfall and increases in rainfall intensity. The understanding of projected changes in rainfall can be used to inform future infrastructure planning across the Snowy Mountains SAP precincts and subsequently build resilience to future flooding events.

7.1.2 WATER QUALITY

The 16 years of water quality data has provided a good understanding of the existing water quality conditions downstream of Thredbo Village and the Perisher Valley Ski resorts and the monitoring should continue to be able to identify impacts of future development in the KNP. The monitoring data could be used to adjust KNP Management practices in the future to further reduce the impact to the KNP.

Water is a key feature of many aspects of the Snowy Mountains SAP. Water is used for recreation (as snow for snow sports, as water for lake uses) and power generation across the Snowy Mountains SAP precincts and therefore its quality should be considered equal to the quantity. Future planning should consider the complete water cycle and promote stormwater quality management, such as in Queenstown where Otago Regional Council promote good stormwater management, articulated as follows:

"If we only drain rain it will mean:

- *We can eat healthy fish, free of contaminants*
- *We can swim in our lakes, rivers and oceans without the fear of getting sick*
- *Our waterways look clean and smell fresh*
- *We can trust our drinking water*",

The following additional measures could also be considered as opportunities for sustainable management of stormwater quality:

- Constructed floating wetlands. Floating wetlands consist of rafts of vegetation that float on the surface of the water and the roots grow into the water and absorb nutrients and other dissolved substances thus removing them from the water. These could be considered as a treatment solution at stormwater outlets from the urban areas around Lake Jindabyne with the advantage that they can rise and fall as the Lake changes levels and potentially move horizontally to account for the change in the Lake edge.

- Nutrient offsetting. Nutrient offsetting is where stormwater treatment to remove nutrients is placed downstream from the pollutant source (but preferably within the same catchment) to provide water quality treatment for the removal of nutrients. The offsetting means the overall catchment nutrient removal levels are achieved but the site specific nutrient removal levels are not achieved. This could be considered for the ski resort areas where natural vegetated water quality treatment measures adjacent to the ski resort developments may increase bushfire risk. Therefore by considering downstream treatments/plantings away from the ski resorts ensures the overall nutrient removal levels are achieved without compromising land for development and or increasing bushfire risks.

7.2 CONSTRAINTS

Constraints for the Snowy Mountains SAP are identified above in sections 5.9 and 6.4 where existing conditions are described but some general constraints include:

- the existing water quality stresses on the environment are nutrients, predominantly total nitrogen and salinity
- changing Lake Jindabyne levels limit stormwater management options on the edge
- Future climate conditions are predicted to reduce snow and winter rainfall which could increase pollutant concentrations in the stormwater runoff from carparks and roads in the KNP.

8 RECOMMENDATIONS FOR PLANNING CONSIDERATIONS

The KNP Plan of Management and the Snowy Monaro Planning documents already include planning conditions for maintaining water quality and managing development on flood liable land. It is recommended that the Snowy Mountains SAP precinct planning documents incorporate additional requirements to meet the aspirations of the Snowy Mountains SAP. These requirements include:

- integrated water cycle management – collection of stormwater, treatment of stormwater and more natural flow release, capture of rainwater and reuse, stormwater is a resource
- rainwater tanks – but ensure piping and pumps are protected from freezing, provide information on tips to manage rainwater tanks during freezing temperature periods
- point source pollution control – as best as possible manage stormwater runoff at the source, such as along the edges of road and carparks, within new developments use the green spaces to treat stormwater runoff
- climate change projected rainfall – reusing stormwater through capture and reuse on site will reduce the dependence on potable water supplies which in turn could ensure more water is available in Lake Jindabyne for hydro power and Snowy River environmental flow releases
- stipulate flood compatible building design – including types of materials, fencing types around overland flow paths
- maintain flood planning conditions as per the Snowy River LEP Clauses 7.1, 7.2 and 7.3
- define and maintain riparian zones around all waterways.

Recommended performance criteria have then be developed based on utilising the existing planning directions and incorporation of additional best practice conditions. The recommended performance criteria include:

For flood risk management:

- adopting a flood planning level of 1% Annual exceedance probability plus 0.5 m freeboard
- all structures to have flood compatible building components below 1% AEP flood level plus 500 mm freeboard.
- all emergency and evacuation infrastructure to have flood compatible building components below PMF flood level plus 500 mm freeboard.
- all structures are to be designed to withstand the forces of floodwater, debris and buoyancy up to 1% AEP flood plus 500 mm freeboard.
- all emergency and evacuation infrastructure structures are to be designed to withstand forces of floodwater, debris and buoyancy up to PMF flood plus 500 mm freeboard
- the proposed southern bypass road around Jindabyne should be provided with flood immunity up to the 1% AEP event plus 500 mm freeboard with consideration given to changes in the extent, height and hazard of flooding due to climate change for the proposed design life of the road
- development must be sited, designed and located to avoid or mitigate the flood risk to people, property and infrastructure
- development should mitigate the impacts of local overland flooding through the provision of adequate site drainage systems
- development must consider and plan for emergency evacuation situations to ensure the safety of all areas within the Probably Maximum Flood extent

For water quality:

- promoting integrated water cycle management
- capturing and reusing stormwater from roofs at the source
- implement stormwater quality treatment at the source

- water quality discharge should aim to meet the targets of:
  - Total Suspended Solids: 85% reduction
  - Total Phosphorus: 60% reduction
  - Total Nitrogen: 45% reduction
  - electrical conductivity levels to be maintained below the 30 µS/cm ANZG 2018 Guideline Value for upland rivers of south-east Australia.
- consider future climate change projections for rainfall in planning growth areas
- erosion and sediment control should be managed during construction to ensure impacts to waterways are minimized.

9 LIMITATIONS

This Report is provided by WSP Australia Pty Limited (*WSP*) for Planning NSW(*Client*) in response to specific instructions from the Client and in accordance with WSP's proposal dated 18 March 2020 and agreement with the Client dated 19 May 2020 (*Agreement*).

9.1 PERMITTED PURPOSE

This Report is provided by WSP for the purpose described in the Agreement and no responsibility is accepted by WSP for the use of the Report in whole or in part, for any other purpose (*Permitted Purpose*).

9.2 QUALIFICATIONS AND ASSUMPTIONS

The services undertaken by WSP in preparing this Report were limited to those specifically detailed in the Report and are subject to the scope, qualifications, assumptions and limitations set out in the Report or otherwise communicated to the Client.

Except as otherwise stated in the Report and to the extent that statements, opinions, facts, conclusion and/or recommendations in the Report (*Conclusions*) are based in whole or in part on information provided by the Client and other parties identified in the report (*Information)*, those Conclusions are based on assumptions by WSP of the reliability, adequacy, accuracy and completeness of the Information and have not been verified. WSP accepts no responsibility for the Information.

WSP has prepared the Report without regard to any special interest of any person other than the Client when undertaking the services described in the Agreement or in preparing the Report.

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APPENDIX A

ARR DATA HUB DATA

```
Results - ARR Data Hub
[STARTTXT]

Input Data Information
[INPUTDATA]
Latitude,-36.469000
Longitude,148.367000
[END_INPUTDATA]

River Region
[RIVREG]
Division,South East Coast (Victoria)
River Number,2
River Name,Snowy River
[RIVREG_META]
Time Accessed,03 July 2020 03:47PM
Version,2016_v1
[END_RIVREG]

ARF Parameters
[LONGARF]
Zone,Southern Temperate
a,0.158
b,0.276
c,0.372
d,0.315
e,0.000141
f,0.41
g,0.15
h,0.01
i,-0.0027
[LONGARF_META]
Time Accessed,03 July 2020 03:47PM
Version,2016_v1
[END_LONGARF]

Storm Losses
[LOSSES]
ID,9989.0
Storm Initial Losses (mm),29.0
Storm Continuing Losses (mm/h),6.1
[LOSSES_META]
Time Accessed,03 July 2020 03:47PM
Version,2016_v1
[END_LOSSES]

Temporal Patterns
[TP]
code,SSmainland
Label,Southern Slopes (Vic/NSW)
[TP_META]
Time Accessed,03 July 2020 03:47PM
Version,2016_v2
[END_TP]

Areal Temporal Patterns
[ATP]
code,SSmainland
arealabel,Southern Slopes (Vic/NSW)
[ATP_META]
Time Accessed,03 July 2020 03:47PM
Version,2016_v2
[END_ATP]

Median Preburst Depths and Ratios
[PREBURST]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),0.3 (0.018),0.2 (0.007),0.1 (0.003),0.0 (0.000),0.0 (0.000),0.0 (0.000)
90 (1.5),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.4 (0.010),0.8 (0.015)
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120 (2.0),2.6 (0.110),1.8 (0.058),1.3 (0.035),0.8 (0.019),0.4 (0.008),0.1 (0.001)
180 (3.0),4.7 (0.167),3.4 (0.089),2.4 (0.055),1.6 (0.031),0.8 (0.014),0.3 (0.005)
360 (6.0),5.5 (0.134),8.4 (0.155),10.3 (0.164),12.2 (0.171),10.9 (0.133),10.0 (0.111)
720 (12.0),4.0 (0.066),8.3 (0.105),11.1 (0.122),13.9 (0.135),17.9 (0.150),20.9 (0.159)
1080 (18.0),1.6 (0.022),6.7 (0.069),10.1 (0.090),13.3 (0.105),17.2 (0.117),20.2 (0.123)
1440 (24.0),1.5 (0.018),4.5 (0.041),6.6 (0.051),8.5 (0.058),9.8 (0.057),10.8 (0.057)
2160 (36.0),0.0 (0.000),0.4 (0.003),0.7 (0.005),1.0 (0.006),2.1 (0.010),2.9 (0.013)
2880 (48.0),0.0 (0.000),0.0 (0.000),0.1 (0.000),0.1 (0.001),0.0 (0.000),0.0 (0.000)
4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
[PREBURST_META]
Time Accessed,03 July 2020 03:47PM
Version,2018_v1
Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.
[END_PREBURST]

10% Preburst Depths
[PREBURST10]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
90 (1.5),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
120 (2.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
180 (3.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
360 (6.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
720 (12.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
1080 (18.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
1440 (24.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
2160 (36.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
2880 (48.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
[PREBURST10_META]
Time Accessed,03 July 2020 03:47PM
Version,2018_v1
Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.
[END_PREBURST10]

25% Preburst Depths
[PREBURST25]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
90 (1.5),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
120 (2.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
180 (3.0),0.2 (0.006),0.1 (0.002),0.0 (0.001),0.0 (0.000),0.0 (0.000),0.0 (0.000)
360 (6.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
720 (12.0),0.0 (0.000),0.2 (0.002),0.3 (0.003),0.4 (0.004),0.5 (0.004),0.5 (0.004)
1080 (18.0),0.0 (0.000),0.7 (0.007),1.1 (0.010),1.5 (0.012),1.3 (0.009),1.2 (0.007)
1440 (24.0),0.0 (0.000),0.2 (0.002),0.3 (0.002),0.4 (0.003),0.3 (0.002),0.2 (0.001)
2160 (36.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
2880 (48.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
[PREBURST25_META]
Time Accessed,03 July 2020 03:47PM
Version,2018_v1
Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.
[END_PREBURST25]

75% Preburst Depths
[PREBURST75]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),9.5 (0.555),7.7 (0.330),6.5 (0.234),5.4 (0.166),9.3 (0.238),12.2 (0.276)
90 (1.5),12.1 (0.596),13.0 (0.470),13.5 (0.414),14.1 (0.372),13.9 (0.312),13.9 (0.276)
120 (2.0),15.5 (0.666),16.3 (0.522),16.9 (0.459),17.4 (0.412),14.7 (0.296),12.7 (0.229)
180 (3.0),19.7 (0.694),17.2 (0.456),15.6 (0.352),14.0 (0.277),15.7 (0.267),17.0 (0.261)
360 (6.0),16.9 (0.408),24.6 (0.455),29.8 (0.474),34.7 (0.488),32.5 (0.396),30.9
```

```
(0.341)
720 (12.0),19.1 (0.317),29.3 (0.373),36.1 (0.397),42.6 (0.414),51.0 (0.428),57.3 (0.435)
1080 (18.0),10.6 (0.143),21.9 (0.226),29.3 (0.262),36.5 (0.288),43.6 (0.295),49.0 (0.298)
1440 (24.0),11.7 (0.139),18.8 (0.169),23.4 (0.183),27.9 (0.192),30.4 (0.178),32.3 (0.170)
2160 (36.0),6.8 (0.068),9.3 (0.071),11.0 (0.073),12.6 (0.073),16.9 (0.083),20.2 (0.088)
2880 (48.0),2.8 (0.025),4.8 (0.033),6.2 (0.037),7.5 (0.039),8.0 (0.035),8.4 (0.033)
4320 (72.0),0.0 (0.000),0.0 (0.000),0.1 (0.000),0.1 (0.000),0.3 (0.001),0.5 (0.002)
[PREBURST75_META]
Time Accessed,03 July 2020 03:47PM
Version,2018_v1
Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.
[END_PREBURST75]

90% Preburst Depths
[PREBURST90]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),19.4 (1.136),19.2 (0.820),19.0 (0.681),18.9 (0.579),20.7 (0.532),22.1 (0.501)
90 (1.5),19.4 (0.955),24.7 (0.895),28.1 (0.861),31.4 (0.832),30.7 (0.688),30.2 (0.603)
120 (2.0),26.1 (1.122),33.8 (1.081),38.9 (1.057),43.8 (1.034),50.1 (1.008),54.8 (0.989)
180 (3.0),35.2 (1.236),35.7 (0.944),36.1 (0.816),36.5 (0.722),40.3 (0.685),43.1 (0.662)
360 (6.0),28.4 (0.688),49.1 (0.906),62.8 (1.000),75.9 (1.068),73.6 (0.897),71.9 (0.795)
720 (12.0),41.4 (0.686),55.1 (0.700),64.2 (0.705),72.9 (0.709),89.3 (0.749),101.5 (0.771)
1080 (18.0),34.1 (0.460),49.3 (0.510),59.4 (0.531),69.1 (0.546),79.6 (0.539),87.5 (0.533)
1440 (24.0),25.9 (0.306),41.0 (0.370),51.0 (0.398),60.6 (0.417),66.1 (0.388),70.3 (0.370)
2160 (36.0),32.2 (0.324),33.6 (0.257),34.4 (0.227),35.3 (0.205),42.5 (0.209),47.9 (0.210)
2880 (48.0),18.8 (0.171),24.1 (0.167),27.6 (0.164),31.0 (0.162),34.6 (0.153),37.4 (0.146)
4320 (72.0),15.9 (0.130),13.8 (0.085),12.3 (0.065),11.0 (0.051),21.8 (0.085),29.8 (0.103)
[PREBURST90_META]
Time Accessed,03 July 2020 03:47PM
Version,2018_v1
Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.
[END_PREBURST90]

Interim Climate Change Factors
[CCF]
,RCP 4.5,RCP6,RCP 8.5
2030,0.648 (3.2%),0.687 (3.4%),0.811 (4.0%)
2040,0.878 (4.4%),0.827 (4.1%),1.084 (5.4%)
2050,1.081 (5.4%),1.013 (5.1%),1.446 (7.3%)
2060,1.251 (6.3%),1.229 (6.2%),1.862 (9.5%)
2070,1.381 (7.0%),1.460 (7.4%),2.298 (11.9%)
2080,1.465 (7.4%),1.691 (8.6%),2.719 (14.2%)
2090,1.496 (7.6%),1.906 (9.7%),3.090 (16.3%)

[CCF_META]
Time Accessed,03 July 2020 03:47PM
Version,2019_v1
Note,ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.
[END_CCF]

Probability Neutral Burst Initial Loss
[BURSTIL]
min (h)\AEP(%),50,20,10,5,2,1
```

```
60 (1.0),17.1,13.4,12.2,12.6,12.5,11.8
90 (1.5),20.4,13.1,11.6,11.3,10.9,9.6
120 (2.0),20.4,11.9,10.5,10.5,9.6,8.6
180 (3.0),18.9,12.1,11.1,11.8,10.9,8.5
360 (6.0),18.6,12.0,10.3,9.4,8.5,5.9
720 (12.0),18.4,12.5,11.7,9.9,8.2,3.8
1080 (18.0),21.4,14.4,13.4,11.9,11.0,4.6
1440 (24.0),22.8,16.6,16.0,14.2,14.8,6.2
2160 (36.0),24.2,19.6,21.1,20.9,19.6,10.3
2880 (48.0),26.7,22.2,22.9,24.7,22.9,12.8
4320 (72.0),27.9,24.9,25.8,30.4,25.6,15.9
[BURSTIL_META]
Time Accessed,03 July 2020 03:47PM
Version,2018_v1
Note,As this point is in NSW the advice provided on losses and pre-burst on the <a href="./nsw_specific">NSW Specific Tab of the ARR Data Hub</a> is to be considered.  In NSW losses are derived considering a hierarchy of approaches depending on the available loss information.  Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.
[END_BURSTIL]Transformational Pre-burst Rainfall
[PREBURST_TRANS]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),11.8,15.5,16.7,16.3,16.4,17.1
90 (1.5),8.5,15.8,17.3,17.6,18.0,19.3
120 (2.0),8.5,17.0,18.4,18.4,19.3,20.3
180 (3.0),10.0,16.8,17.8,17.1,18.0,20.4
360 (6.0),10.3,16.9,18.6,19.5,20.4,23.0
720 (12.0),10.5,16.4,17.2,19.0,20.7,25.1
1080 (18.0),7.5,14.5,15.5,17.0,17.9,24.3
1440 (24.0),6.1,12.3,12.9,14.7,14.1,22.7
2160 (36.0),4.7,9.3,7.8,8.0,9.3,18.6
2880 (48.0),2.2,6.7,6.0,4.2,6.0,16.1
4320 (72.0),1.0,4.0,3.1,0.0,3.3,13.0
[PREBURST_TRANS_META]
The tranformational pre-burst is intended for software suppliers in the NSW area and is simply the Initial Loss - Burst Initial Loss. It is not appropriate to use these values if considering a calibrated initial loss.
[END_PREBURST_TRANS]

[ENDTXT]
```

```
Results - ARR Data Hub
[STARTTXT]

Input Data Information
[INPUTDATA]
Latitude,-36.400000
Longitude,148.340000
[END_INPUTDATA]

River Region
[RIVREG]
Division,South East Coast (Victoria)
River Number,2
River Name,Snowy River
[RIVREG_META]
Time Accessed,06 July 2020 02:39PM
Version,2016_v1
[END_RIVREG]

ARF Parameters
[LONGARF]
Zone,Southern Temperate
a,0.158
b,0.276
c,0.372
d,0.315
e,0.000141
f,0.41
g,0.15
h,0.01
i,-0.0027
[LONGARF_META]
Time Accessed,06 July 2020 02:39PM
Version,2016_v1
[END_LONGARF]

Storm Losses
[LOSSES]
ID,25368.0
Storm Initial Losses (mm),26.0
Storm Continuing Losses (mm/h),4.6
[LOSSES_META]
Time Accessed,06 July 2020 02:39PM
Version,2016_v1
[END_LOSSES]

Temporal Patterns
[TP]
code,SSmainland
Label,Southern Slopes (Vic/NSW)
[TP_META]
Time Accessed,06 July 2020 02:39PM
Version,2016_v2
[END_TP]

Areal Temporal Patterns
[ATP]
code,SSmainland
arealabel,Southern Slopes (Vic/NSW)
[ATP_META]
Time Accessed,06 July 2020 02:39PM
Version,2016_v2
[END_ATP]

Median Preburst Depths and Ratios
[PREBURST]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),0.4 (0.024),0.3 (0.010),0.1 (0.005),0.0 (0.001),0.2 (0.006),0.4 (0.008)
90 (1.5),1.0 (0.045),0.8 (0.027),0.7 (0.019),0.5 (0.013),0.6 (0.012),0.6 (0.011)
```

```
120 (2.0),2.4 (0.095),2.2 (0.064),2.0 (0.050),1.8 (0.040),0.8 (0.016),0.1 (0.001)
180 (3.0),4.1 (0.130),3.0 (0.071),2.2 (0.046),1.5 (0.027),1.2 (0.018),0.9 (0.013)
360 (6.0),5.0 (0.105),6.6 (0.106),7.6 (0.107),8.6 (0.107),9.5 (0.103),10.2 (0.100)
720 (12.0),4.0 (0.057),8.4 (0.092),11.2 (0.107),14.0 (0.118),17.0 (0.124),19.2 (0.127)
1080 (18.0),2.0 (0.023),5.9 (0.052),8.5 (0.065),10.9 (0.074),13.5 (0.079),15.5 (0.081)
1440 (24.0),0.9 (0.009),3.3 (0.025),4.9 (0.033),6.4 (0.038),7.8 (0.039),8.9 (0.040)
2160 (36.0),0.0 (0.000),0.6 (0.004),0.9 (0.005),1.3 (0.006),1.9 (0.008),2.4 (0.009)
2880 (48.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
[PREBURST_META]
Time Accessed,06 July 2020 02:39PM
Version,2018_v1
Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.
[END_PREBURST]

10% Preburst Depths
[PREBURST10]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
90 (1.5),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
120 (2.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
180 (3.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
360 (6.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
720 (12.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
1080 (18.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
1440 (24.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
2160 (36.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
2880 (48.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
[PREBURST10_META]
Time Accessed,06 July 2020 02:39PM
Version,2018_v1
Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.
[END_PREBURST10]

25% Preburst Depths
[PREBURST25]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
90 (1.5),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
120 (2.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
180 (3.0),0.1 (0.002),0.0 (0.001),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
360 (6.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
720 (12.0),0.0 (0.000),0.2 (0.002),0.4 (0.003),0.5 (0.004),0.3 (0.002),0.2 (0.002)
1080 (18.0),0.0 (0.000),0.5 (0.004),0.8 (0.006),1.0 (0.007),0.8 (0.005),0.6 (0.003)
1440 (24.0),0.0 (0.000),0.0 (0.000),0.1 (0.001),0.1 (0.001),0.1 (0.000),0.1 (0.000)
2160 (36.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
2880 (48.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
[PREBURST25_META]
Time Accessed,06 July 2020 02:39PM
Version,2018_v1
Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.
[END_PREBURST25]

75% Preburst Depths
[PREBURST75]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),10.8 (0.587),10.2 (0.406),9.8 (0.327),9.4 (0.269),12.5 (0.301),14.9 (0.316)
90 (1.5),12.8 (0.574),14.6 (0.489),15.9 (0.449),17.1 (0.418),15.8 (0.328),14.8 (0.275)
120 (2.0),15.6 (0.609),17.0 (0.495),17.8 (0.444),18.7 (0.405),15.9 (0.294),13.8 (0.229)
180 (3.0),20.2 (0.634),20.3 (0.482),20.3 (0.415),20.4 (0.365),20.0 (0.309),19.7 (0.276)
360 (6.0),22.7 (0.480),28.1 (0.455),31.6 (0.444),35.0 (0.436),36.3 (0.392),37.3 (0.366)
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720 (12.0),19.0 (0.270),29.2 (0.319),35.9 (0.341),42.4 (0.357),50.5 (0.368),56.7 (0.374)
1080 (18.0),10.5 (0.122),21.0 (0.186),28.0 (0.214),34.7 (0.235),38.6 (0.225),41.6 (0.218)
1440 (24.0),8.9 (0.090),16.7 (0.129),21.8 (0.145),26.7 (0.157),29.2 (0.147),31.1 (0.140)
2160 (36.0),3.1 (0.027),7.9 (0.052),11.1 (0.062),14.1 (0.070),17.7 (0.074),20.4 (0.076)
2880 (48.0),1.4 (0.011),3.2 (0.019),4.3 (0.022),5.4 (0.024),6.9 (0.026),8.0 (0.027)
4320 (72.0),0.0 (0.000),0.1 (0.001),0.2 (0.001),0.3 (0.001),0.2 (0.001),0.1 (0.000)
[PREBURST75_META]
Time Accessed,06 July 2020 02:39PM
Version,2018_v1
Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.
[END_PREBURST75]

90% Preburst Depths
[PREBURST90]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),22.9 (1.243),23.0 (0.917),23.1 (0.771),23.1 (0.664),23.9 (0.573),24.4 (0.518)
90 (1.5),25.7 (1.155),30.1 (1.008),33.1 (0.937),35.9 (0.880),33.6 (0.698),31.9 (0.590)
120 (2.0),31.3 (1.218),35.6 (1.040),38.5 (0.958),41.3 (0.894),45.9 (0.849),49.3 (0.819)
180 (3.0),40.8 (1.280),43.8 (1.041),45.7 (0.933),47.6 (0.853),46.7 (0.722),46.1 (0.644)
360 (6.0),51.2 (1.082),61.3 (0.994),68.0 (0.954),74.4 (0.924),80.6 (0.869),85.2 (0.836)
720 (12.0),37.4 (0.533),54.8 (0.600),66.2 (0.629),77.2 (0.650),92.3 (0.672),103.6 (0.683)
1080 (18.0),35.7 (0.412),49.6 (0.439),58.8 (0.451),67.6 (0.459),77.1 (0.448),84.2 (0.441)
1440 (24.0),30.2 (0.305),44.1 (0.341),53.4 (0.356),62.2 (0.366),67.9 (0.341),72.1 (0.325)
2160 (36.0),23.6 (0.203),33.8 (0.221),40.6 (0.228),47.1 (0.233),47.5 (0.199),47.8 (0.179)
2880 (48.0),12.0 (0.094),20.1 (0.119),25.5 (0.130),30.7 (0.137),39.7 (0.149),46.5 (0.155)
4320 (72.0),8.8 (0.062),15.0 (0.080),19.2 (0.087),23.1 (0.092),21.9 (0.073),20.9 (0.062)
[PREBURST90_META]
Time Accessed,06 July 2020 02:39PM
Version,2018_v1
Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.
[END_PREBURST90]

Interim Climate Change Factors
[CCF]
,RCP 4.5,RCP6,RCP 8.5
2030,0.648 (3.2%),0.687 (3.4%),0.811 (4.0%)
2040,0.878 (4.4%),0.827 (4.1%),1.084 (5.4%)
2050,1.081 (5.4%),1.013 (5.1%),1.446 (7.3%)
2060,1.251 (6.3%),1.229 (6.2%),1.862 (9.5%)
2070,1.381 (7.0%),1.460 (7.4%),2.298 (11.9%)
2080,1.465 (7.4%),1.691 (8.6%),2.719 (14.2%)
2090,1.496 (7.6%),1.906 (9.7%),3.090 (16.3%)

[CCF_META]
Time Accessed,06 July 2020 02:39PM
Version,2019_v1
Note,ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.
[END_CCF]

Probability Neutral Burst Initial Loss
[BURSTIL]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),19.0,11.6,10.8,11.5,11.0,9.8
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90 (1.5),19.0,11.1,10.1,10.4,9.8,8.2
120 (2.0),17.8,11.1,9.9,10.1,9.0,8.1
180 (3.0),16.1,10.8,10.1,10.5,9.7,7.1
360 (6.0),14.4,10.4,10.3,9.4,8.1,4.5
720 (12.0),17.0,11.6,10.7,10.0,8.5,3.5
1080 (18.0),19.5,14.0,13.5,12.5,12.4,4.2
1440 (24.0),21.3,15.9,15.7,14.9,15.1,6.3
2160 (36.0),23.3,19.3,19.3,19.8,16.4,10.4
2880 (48.0),25.9,21.9,22.5,24.5,18.9,14.1
4320 (72.0),26.9,23.3,23.9,26.2,23.5,16.6
[BURSTIL_META]
Time Accessed,06 July 2020 02:39PM
Version,2018_v1
Note,As this point is in NSW the advice provided on losses and pre-burst on the <a href="./nsw_specific">NSW Specific Tab of the ARR Data Hub</a> is to be considered.  In NSW losses are derived considering a hierarchy of approaches depending on the available loss information.  Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.
[END_BURSTIL]Transformational Pre-burst Rainfall
[PREBURST_TRANS]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),7.4,14.8,15.6,14.9,15.4,16.6
90 (1.5),7.4,15.3,16.3,16.0,16.6,18.2
120 (2.0),8.6,15.3,16.5,16.3,17.4,18.3
180 (3.0),10.3,15.6,16.3,15.9,16.7,19.3
360 (6.0),12.0,16.0,16.1,17.0,18.3,21.9
720 (12.0),9.4,14.8,15.7,16.4,17.9,22.9
1080 (18.0),6.9,12.4,12.9,13.9,14.0,22.2
1440 (24.0),5.1,10.5,10.7,11.5,11.3,20.1
2160 (36.0),3.1,7.1,7.1,6.6,10.0,16.0
2880 (48.0),0.5,4.5,3.9,1.9,7.5,12.3
4320 (72.0),0.0,3.1,2.5,0.2,2.9,9.8
[PREBURST_TRANS_META]
The tranformational pre-burst is intended for software suppliers in the NSW area and is simply the Initial Loss - Burst Initial Loss. It is not appropriate to use these values if considering a calibrated initial loss.
[END_PREBURST_TRANS]

Baseflow Factors
[BASEFLOW]
Downstream,10987
Area (km2),785.663808
Catchment Number,10960
Volume Factor,0.328779
Peak Factor,0.081421
[BASEFLOW_META]
Time Accessed,06 July 2020 02:39PM
Version,2016_v1
[END_BASEFLOW]

[ENDTXT]
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Results - ARR Data Hub
[STARTTXT]

Input Data Information
[INPUTDATA]
Latitude,-36.505000
Longitude,148.306000
[END_INPUTDATA]

River Region
[RIVREG]
Division,South East Coast (Victoria)
River Number,2
River Name,Snowy River
[RIVREG_META]
Time Accessed,03 July 2020 11:55AM
Version,2016_v1
[END_RIVREG]

ARF Parameters
[LONGARF]
Zone,Southern Temperate
a,0.158
b,0.276
c,0.372
d,0.315
e,0.000141
f,0.41
g,0.15
h,0.01
i,-0.0027
[LONGARF_META]
Time Accessed,03 July 2020 11:55AM
Version,2016_v1
[END_LONGARF]

Storm Losses
[LOSSES]
ID,9982.0
Storm Initial Losses (mm),29.0
Storm Continuing Losses (mm/h),5.4
[LOSSES_META]
Time Accessed,03 July 2020 11:55AM
Version,2016_v1
[END_LOSSES]

Temporal Patterns
[TP]
code,SSmainland
Label,Southern Slopes (Vic/NSW)
[TP_META]
Time Accessed,03 July 2020 11:55AM
Version,2016_v2
[END_TP]

Areal Temporal Patterns
[ATP]
code,SSmainland
arealabel,Southern Slopes (Vic/NSW)
[ATP_META]
Time Accessed,03 July 2020 11:55AM
Version,2016_v2
[END_ATP]

Median Preburst Depths and Ratios
[PREBURST]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.2 (0.005),0.3 (0.007)
90 (1.5),0.8 (0.038),0.6 (0.022),0.5 (0.016),0.4 (0.011),0.6 (0.012),0.7 (0.013)
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120 (2.0),3.0 (0.123),2.6 (0.079),2.3 (0.060),2.0 (0.046),0.9 (0.017),0.0 (0.001)
180 (3.0),3.8 (0.125),2.4 (0.061),1.5 (0.033),0.7 (0.013),0.7 (0.011),0.7 (0.010)
360 (6.0),4.2 (0.095),8.1 (0.137),10.6 (0.156),13.1 (0.169),12.4 (0.140),12.0 (0.122)
720 (12.0),3.1 (0.046),8.6 (0.099),12.3 (0.122),15.9 (0.139),18.5 (0.141),20.6 (0.142)
1080 (18.0),1.7 (0.020),6.4 (0.059),9.4 (0.076),12.4 (0.088),16.1 (0.098),18.9 (0.104)
1440 (24.0),0.8 (0.009),4.6 (0.037),7.1 (0.050),9.5 (0.059),10.4 (0.055),11.0 (0.052)
2160 (36.0),0.0 (0.000),0.8 (0.005),1.3 (0.008),1.8 (0.009),2.2 (0.010),2.6 (0.010)
2880 (48.0),0.0 (0.000),0.0 (0.000),0.1 (0.000),0.1 (0.001),0.0 (0.000),0.0 (0.000)
4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
[PREBURST_META]
Time Accessed,03 July 2020 11:55AM
Version,2018_v1
Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.
[END_PREBURST]

10% Preburst Depths
[PREBURST10]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
90 (1.5),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
120 (2.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
180 (3.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
360 (6.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
720 (12.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
1080 (18.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
1440 (24.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
2160 (36.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
2880 (48.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
[PREBURST10_META]
Time Accessed,03 July 2020 11:55AM
Version,2018_v1
Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.
[END_PREBURST10]

25% Preburst Depths
[PREBURST25]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
90 (1.5),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
120 (2.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
180 (3.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
360 (6.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
720 (12.0),0.0 (0.000),0.3 (0.004),0.5 (0.005),0.8 (0.007),0.6 (0.004),0.5 (0.003)
1080 (18.0),0.0 (0.000),0.6 (0.006),1.1 (0.008),1.5 (0.010),0.9 (0.005),0.5 (0.003)
1440 (24.0),0.0 (0.000),0.2 (0.002),0.3 (0.002),0.5 (0.003),0.3 (0.002),0.2 (0.001)
2160 (36.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
2880 (48.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
[PREBURST25_META]
Time Accessed,03 July 2020 11:55AM
Version,2018_v1
Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.
[END_PREBURST25]

75% Preburst Depths
[PREBURST75]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),10.3 (0.589),8.6 (0.360),7.5 (0.262),6.4 (0.193),10.6 (0.264),13.7 (0.302)
90 (1.5),15.0 (0.713),15.7 (0.550),16.1 (0.477),16.5 (0.423),14.8 (0.320),13.5 (0.260)
120 (2.0),15.4 (0.633),17.6 (0.541),19.1 (0.499),20.6 (0.466),15.5 (0.300),11.8 (0.204)
180 (3.0),17.2 (0.571),17.0 (0.424),16.8 (0.360),16.7 (0.312),18.3 (0.295),19.6 (0.285)
360 (6.0),17.7 (0.395),27.3 (0.465),33.7 (0.495),39.8 (0.516),35.5 (0.400),32.3 (0.330)
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720 (12.0),15.8 (0.237),28.9 (0.331),37.5 (0.373),45.8 (0.403),56.3 (0.427),64.1 (0.441)
1080 (18.0),9.0 (0.109),20.9 (0.195),28.9 (0.232),36.4 (0.259),41.8 (0.255),45.8 (0.252)
1440 (24.0),10.2 (0.109),18.2 (0.148),23.5 (0.165),28.6 (0.177),29.5 (0.156),30.1 (0.143)
2160 (36.0),6.2 (0.056),10.0 (0.069),12.5 (0.075),14.9 (0.078),18.1 (0.080),20.5 (0.081)
2880 (48.0),1.1 (0.009),3.5 (0.022),5.2 (0.028),6.8 (0.032),7.2 (0.029),7.5 (0.027)
4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.1 (0.001),0.2 (0.001)
[PREBURST75_META]
Time Accessed,03 July 2020 11:55AM
Version,2018_v1
Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.
[END_PREBURST75]

90% Preburst Depths
[PREBURST90]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),20.4 (1.166),21.7 (0.906),22.5 (0.788),23.3 (0.700),22.8 (0.572),22.5 (0.497)
90 (1.5),25.7 (1.223),28.4 (0.998),30.2 (0.896),31.9 (0.819),31.2 (0.675),30.6 (0.590)
120 (2.0),32.2 (1.326),36.4 (1.117),39.2 (1.021),41.8 (0.948),43.5 (0.841),44.8 (0.777)
180 (3.0),32.0 (1.063),34.0 (0.850),35.3 (0.756),36.6 (0.686),44.0 (0.709),49.5 (0.720)
360 (6.0),39.8 (0.888),56.6 (0.962),67.7 (0.994),78.4 (1.017),77.0 (0.867),76.1 (0.777)
720 (12.0),32.6 (0.489),49.7 (0.571),61.0 (0.606),71.9 (0.632),97.7 (0.743),117.1 (0.806)
1080 (18.0),28.5 (0.346),48.2 (0.448),61.2 (0.492),73.7 (0.523),82.1 (0.501),88.5 (0.486)
1440 (24.0),26.6 (0.283),45.5 (0.370),58.0 (0.407),70.0 (0.433),70.6 (0.373),71.1 (0.337)
2160 (36.0),35.7 (0.325),36.1 (0.250),36.3 (0.216),36.5 (0.191),42.3 (0.188),46.7 (0.185)
2880 (48.0),8.5 (0.071),18.5 (0.117),25.1 (0.136),31.4 (0.150),35.0 (0.141),37.7 (0.135)
4320 (72.0),10.1 (0.076),9.9 (0.056),9.8 (0.048),9.6 (0.041),21.2 (0.076),29.9 (0.095)
[PREBURST90_META]
Time Accessed,03 July 2020 11:55AM
Version,2018_v1
Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.
[END_PREBURST90]

Interim Climate Change Factors
[CCF]
,RCP 4.5,RCP6,RCP 8.5
2030,0.648 (3.2%),0.687 (3.4%),0.811 (4.0%)
2040,0.878 (4.4%),0.827 (4.1%),1.084 (5.4%)
2050,1.081 (5.4%),1.013 (5.1%),1.446 (7.3%)
2060,1.251 (6.3%),1.229 (6.2%),1.862 (9.5%)
2070,1.381 (7.0%),1.460 (7.4%),2.298 (11.9%)
2080,1.465 (7.4%),1.691 (8.6%),2.719 (14.2%)
2090,1.496 (7.6%),1.906 (9.7%),3.090 (16.3%)

[CCF_META]
Time Accessed,03 July 2020 11:55AM
Version,2019_v1
Note,ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.
[END_CCF]

Probability Neutral Burst Initial Loss
[BURSTIL]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),17.4,13.0,11.6,12.0,11.7,11.2
90 (1.5),20.8,11.6,10.5,10.9,10.9,9.6
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120 (2.0),19.5,11.1,9.9,10.0,9.7,8.8
180 (3.0),19.3,12.4,11.2,11.8,10.4,8.5
360 (6.0),17.4,11.2,9.9,8.9,7.6,5.4
720 (12.0),19.2,12.5,11.4,9.7,7.5,3.6
1080 (18.0),21.9,14.6,13.5,11.9,11.3,5.0
1440 (24.0),22.7,16.2,15.0,14.2,14.6,6.6
2160 (36.0),23.5,19.0,20.4,20.1,18.9,10.3
2880 (48.0),28.4,22.7,23.0,24.6,22.9,12.7
4320 (72.0),28.7,25.1,27.1,30.7,25.5,16.2
[BURSTIL_META]
Time Accessed,03 July 2020 11:55AM
Version,2018_v1
Note,As this point is in NSW the advice provided on losses and pre-burst on the <a href="./nsw_specific">NSW Specific Tab of the ARR Data Hub</a> is to be considered.  In NSW losses are derived considering a hierarchy of approaches depending on the available loss information.  Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.
[END_BURSTIL]Transformational Pre-burst Rainfall
[PREBURST_TRANS]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),11.2,15.6,17.0,16.6,16.9,17.4
90 (1.5),7.8,17.0,18.1,17.7,17.7,19.0
120 (2.0),9.1,17.5,18.7,18.6,18.9,19.8
180 (3.0),9.3,16.2,17.4,16.8,18.2,20.1
360 (6.0),11.2,17.4,18.7,19.7,21.0,23.2
720 (12.0),9.4,16.1,17.2,18.9,21.1,25.0
1080 (18.0),6.7,14.0,15.1,16.7,17.3,23.6
1440 (24.0),5.9,12.4,13.6,14.4,14.0,22.0
2160 (36.0),5.1,9.6,8.2,8.5,9.7,18.3
2880 (48.0),0.2,5.9,5.6,4.0,5.7,15.9
4320 (72.0),0.0,3.5,1.5,0.0,3.1,12.4
[PREBURST_TRANS_META]
The tranformational pre-burst is intended for software suppliers in the NSW area and is simply the Initial Loss - Burst Initial Loss. It is not appropriate to use these values if considering a calibrated initial loss.
[END_PREBURST_TRANS]

[ENDTXT]
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Results - ARR Data Hub
[STARTTXT]

Input Data Information
[INPUTDATA]
Latitude,-36.430000
Longitude,148.610000
[END_INPUTDATA]

River Region
[RIVREG]
Division,South East Coast (Victoria)
River Number,2
River Name,Snowy River
[RIVREG_META]
Time Accessed,14 July 2020 11:50AM
Version,2016_v1
[END_RIVREG]

ARF Parameters
[LONGARF]
Zone,SE Coast
a,0.06
b,0.361
c,0.0
d,0.317
e,8.11e-05
f,0.651
g,0.0
h,0.0
i,0.0
[LONGARF_META]
Time Accessed,14 July 2020 11:50AM
Version,2016_v1
[END_LONGARF]

Storm Losses
[LOSSES]
ID,13868.0
Storm Initial Losses (mm),28.0
Storm Continuing Losses (mm/h),5.6
[LOSSES_META]
Time Accessed,14 July 2020 11:50AM
Version,2016_v1
[END_LOSSES]

Temporal Patterns
[TP]
code,SSmainland
Label,Southern Slopes (Vic/NSW)
[TP_META]
Time Accessed,14 July 2020 11:50AM
Version,2016_v2
[END_TP]

Areal Temporal Patterns
[ATP]
code,SSmainland
arealabel,Southern Slopes (Vic/NSW)
[ATP_META]
Time Accessed,14 July 2020 11:50AM
Version,2016_v2
[END_ATP]

Median Preburst Depths and Ratios
[PREBURST]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),0.0 (0.000),0.0 (0.001),0.0 (0.001),0.0 (0.001),0.5 (0.012),0.9 (0.019)
90 (1.5),0.0 (0.000),0.3 (0.011),0.5 (0.015),0.7 (0.018),0.5 (0.010),0.3 (0.006)
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120 (2.0),0.0 (0.000),0.1 (0.004),0.2 (0.005),0.3 (0.006),0.2 (0.004),0.1 (0.002)
180 (3.0),1.8 (0.075),1.9 (0.056),2.0 (0.048),2.0 (0.043),1.0 (0.018),0.2 (0.004)
360 (6.0),0.7 (0.023),0.9 (0.021),1.0 (0.020),1.1 (0.019),2.7 (0.039),3.8 (0.050)
720 (12.0),0.2 (0.005),1.7 (0.030),2.7 (0.040),3.6 (0.047),5.3 (0.060),6.6 (0.067)
1080 (18.0),0.0 (0.000),0.6 (0.009),1.0 (0.013),1.4 (0.016),3.1 (0.030),4.4 (0.038)
1440 (24.0),0.0 (0.000),0.3 (0.003),0.4 (0.005),0.6 (0.006),1.0 (0.008),1.2 (0.009)
2160 (36.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.2 (0.001),0.3 (0.002)
2880 (48.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
[PREBURST_META]
Time Accessed,14 July 2020 11:50AM
Version,2018_v1
Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.
[END_PREBURST]

10% Preburst Depths
[PREBURST10]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
90 (1.5),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
120 (2.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
180 (3.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
360 (6.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
720 (12.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
1080 (18.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
1440 (24.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
2160 (36.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
2880 (48.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
[PREBURST10_META]
Time Accessed,14 July 2020 11:50AM
Version,2018_v1
Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.
[END_PREBURST10]

25% Preburst Depths
[PREBURST25]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
90 (1.5),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
120 (2.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
180 (3.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
360 (6.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
720 (12.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
1080 (18.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
1440 (24.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
2160 (36.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
2880 (48.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
[PREBURST25_META]
Time Accessed,14 July 2020 11:50AM
Version,2018_v1
Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.
[END_PREBURST25]

75% Preburst Depths
[PREBURST75]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),6.4 (0.375),8.8 (0.362),10.4 (0.352),11.9 (0.342),13.8 (0.326),15.1 (0.315)
90 (1.5),6.7 (0.349),10.6 (0.388),13.2 (0.399),15.7 (0.404),14.3 (0.307),13.3 (0.251)
120 (2.0),8.5 (0.401),12.3 (0.409),14.8 (0.409),17.1 (0.407),14.2 (0.284),12.1 (0.214)
180 (3.0),9.2 (0.377),12.0 (0.351),13.8 (0.339),15.6 (0.329),14.6 (0.261),13.9 (0.222)
360 (6.0),10.3 (0.322),12.4 (0.286),13.9 (0.270),15.3 (0.258),19.1 (0.275),21.9 (0.284)
720 (12.0),5.7 (0.134),11.1 (0.195),14.7 (0.220),18.1 (0.238),19.8 (0.221),21.0 (0.211)
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1080 (18.0),4.1 (0.082),7.3 (0.110),9.4 (0.121),11.5 (0.129),12.9 (0.124),14.1 (0.120)
1440 (24.0),0.5 (0.009),4.2 (0.057),6.7 (0.077),9.0 (0.091),9.8 (0.084),10.4 (0.079)
2160 (36.0),0.0 (0.000),1.1 (0.013),1.8 (0.018),2.5 (0.022),5.7 (0.042),8.1 (0.053)
2880 (48.0),0.0 (0.000),0.9 (0.009),1.4 (0.013),2.0 (0.016),4.2 (0.028),5.9 (0.035)
4320 (72.0),0.0 (0.000),0.5 (0.005),0.8 (0.007),1.2 (0.008),0.9 (0.005),0.7 (0.004)
[PREBURST75_META]
Time Accessed,14 July 2020 11:50AM
Version,2018_v1
Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.
[END_PREBURST75]

90% Preburst Depths
[PREBURST90]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),16.9 (0.999),21.2 (0.874),24.0 (0.814),26.7 (0.766),25.2 (0.597),24.1 (0.501)
90 (1.5),16.5 (0.853),25.4 (0.926),31.3 (0.944),36.9 (0.950),32.3 (0.693),28.9 (0.547)
120 (2.0),21.6 (1.013),29.8 (0.992),35.2 (0.976),40.4 (0.959),48.9 (0.975),55.3 (0.979)
180 (3.0),23.3 (0.952),28.5 (0.833),31.8 (0.781),35.1 (0.742),34.4 (0.615),33.9 (0.542)
360 (6.0),23.1 (0.726),31.5 (0.723),37.1 (0.720),42.4 (0.717),46.9 (0.675),50.2 (0.650)
720 (12.0),15.0 (0.356),25.3 (0.445),32.1 (0.482),38.7 (0.508),38.8 (0.434),38.8 (0.390)
1080 (18.0),16.5 (0.332),20.3 (0.304),22.8 (0.292),25.2 (0.283),27.3 (0.261),28.9 (0.247)
1440 (24.0),13.0 (0.235),17.0 (0.228),19.6 (0.226),22.1 (0.223),24.7 (0.211),26.8 (0.204)
2160 (36.0),2.9 (0.046),7.9 (0.092),11.2 (0.112),14.4 (0.126),23.9 (0.176),31.1 (0.203)
2880 (48.0),0.7 (0.009),6.8 (0.073),10.9 (0.099),14.8 (0.118),22.4 (0.149),28.0 (0.166)
4320 (72.0),2.0 (0.026),10.3 (0.098),15.7 (0.128),20.9 (0.149),18.3 (0.109),16.3 (0.086)
[PREBURST90_META]
Time Accessed,14 July 2020 11:50AM
Version,2018_v1
Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.
[END_PREBURST90]

Interim Climate Change Factors
[CCF]
,RCP 4.5,RCP6,RCP 8.5
2030,0.648 (3.2%),0.687 (3.4%),0.811 (4.0%)
2040,0.878 (4.4%),0.827 (4.1%),1.084 (5.4%)
2050,1.081 (5.4%),1.013 (5.1%),1.446 (7.3%)
2060,1.251 (6.3%),1.229 (6.2%),1.862 (9.5%)
2070,1.381 (7.0%),1.460 (7.4%),2.298 (11.9%)
2080,1.465 (7.4%),1.691 (8.6%),2.719 (14.2%)
2090,1.496 (7.6%),1.906 (9.7%),3.090 (16.3%)

[CCF_META]
Time Accessed,14 July 2020 11:50AM
Version,2019_v1
Note,ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.
[END_CCF]

Probability Neutral Burst Initial Loss
[BURSTIL]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),17.0,13.8,12.5,12.2,11.4,10.7
90 (1.5),19.3,14.0,12.2,11.6,11.2,10.4
120 (2.0),21.2,13.4,11.8,11.2,10.2,8.8
180 (3.0),20.6,13.5,12.2,12.1,11.0,9.4
360 (6.0),20.9,14.8,12.9,12.6,10.2,7.1
720 (12.0),23.1,16.9,14.7,14.1,12.1,8.0
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1080 (18.0),23.7,18.4,17.5,17.5,16.0,10.7
1440 (24.0),25.4,20.2,19.6,19.6,18.4,12.2
2160 (36.0),27.7,23.1,22.9,23.0,21.8,13.3
2880 (48.0),28.6,23.5,23.3,23.9,22.7,15.0
4320 (72.0),28.4,23.4,23.0,24.3,24.4,18.8
[BURSTIL_META]
Time Accessed,14 July 2020 11:50AM
Version,2018_v1
Note,As this point is in NSW the advice provided on losses and pre-burst on the <a href="./nsw_specific">NSW Specific Tab of the ARR Data Hub</a> is to be considered.  In NSW losses are derived considering a hierarchy of approaches depending on the available loss information.  Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.
[END_BURSTIL]Transformational Pre-burst Rainfall
[PREBURST_TRANS]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),10.6,13.8,15.1,15.4,16.2,16.9
90 (1.5),8.3,13.6,15.4,16.0,16.4,17.2
120 (2.0),6.4,14.2,15.8,16.4,17.4,18.8
180 (3.0),7.0,14.1,15.4,15.5,16.6,18.2
360 (6.0),6.7,12.8,14.7,15.0,17.4,20.5
720 (12.0),4.5,10.7,12.9,13.5,15.5,19.6
1080 (18.0),3.9,9.2,10.1,10.1,11.6,16.9
1440 (24.0),2.2,7.4,8.0,8.0,9.2,15.4
2160 (36.0),0.0,4.5,4.7,4.6,5.8,14.3
2880 (48.0),0.0,4.1,4.3,3.7,4.9,12.6
4320 (72.0),0.0,4.2,4.6,3.3,3.2,8.8
[PREBURST_TRANS_META]
The tranformational pre-burst is intended for software suppliers in the NSW area and is simply the Initial Loss - Burst Initial Loss. It is not appropriate to use these values if considering a calibrated initial loss.
[END_PREBURST_TRANS]

[ENDTXT]
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APPENDIX B

FFA AND RFFE DATA

B1 FLOOD FREQUENCY DATA

Snowy River upstream of Guthega Pondage Gauge 222527

AEP (%)	FFA EXPECTED QUANTILE (m3/s)	LOWER CONFIDENCE LIMIT 10% (m^3/s)	UPPER CONFIDENCE LIMIT (90%) (m^3/s)
50	135.87	119.41	154.2
20	205.73	182.40	232.4
10	250.28	220.67	289.2
5	291.21	252.73	353.4
2	341.56	286.75	446.5
1	377.51	306.7	526.0

Thredbo River at Paddys Corner Gauge 222541

AEP (%)	FFA EXPECTED QUANTILE (m3/s)	LOWER CONFIDENCE LIMIT 10% (m^3/s)	UPPER CONFIDENCE LIMIT (90%) (m^3/s)
50	75.1	62.98	89.4
20	122.05	101.77	149.9
10	157.23	128.0	203.5
5	193.74	152.78	271.6
2	224.99	181.72	394.6
1	286.43	201.67	511.6

B2 REGIONAL FLOOD FREQUENCY DATA

Snowy River upstream of Guthega Pondage Gauge 222527

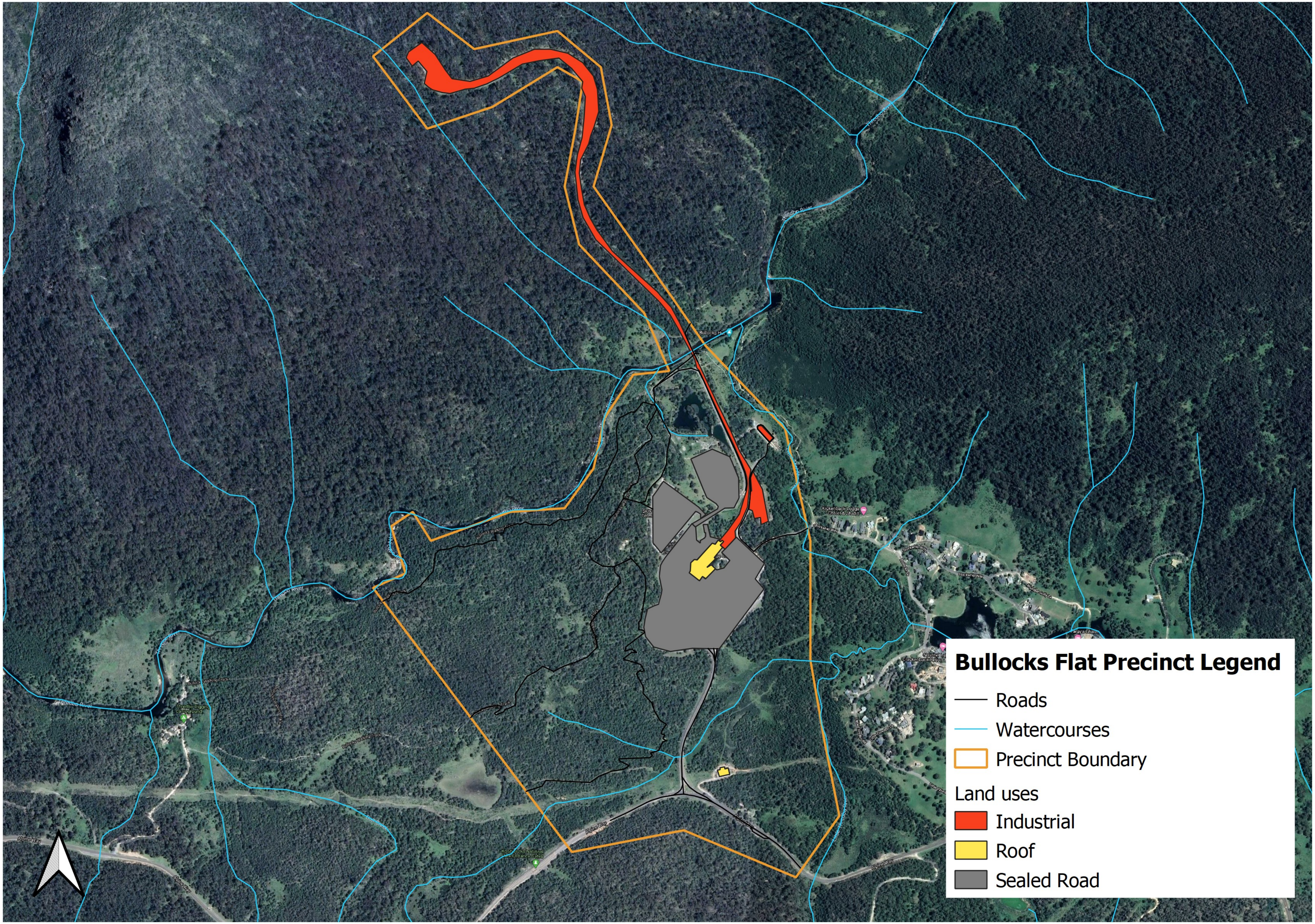
AEP (%)	RFFE EXPECTED QUANTILE (m3/s)	LOWER CONFIDENCE LIMIT (5%) (m^3/s)	UPPER CONFIDENCE LIMIT (95%) (m^3/s)
50	21.3	9.13	53.2
20	41.9	18.6	101
10	60.2	25.3	152
5	81.4	32	217
2	115	40.8	336
1	145	47.6	456

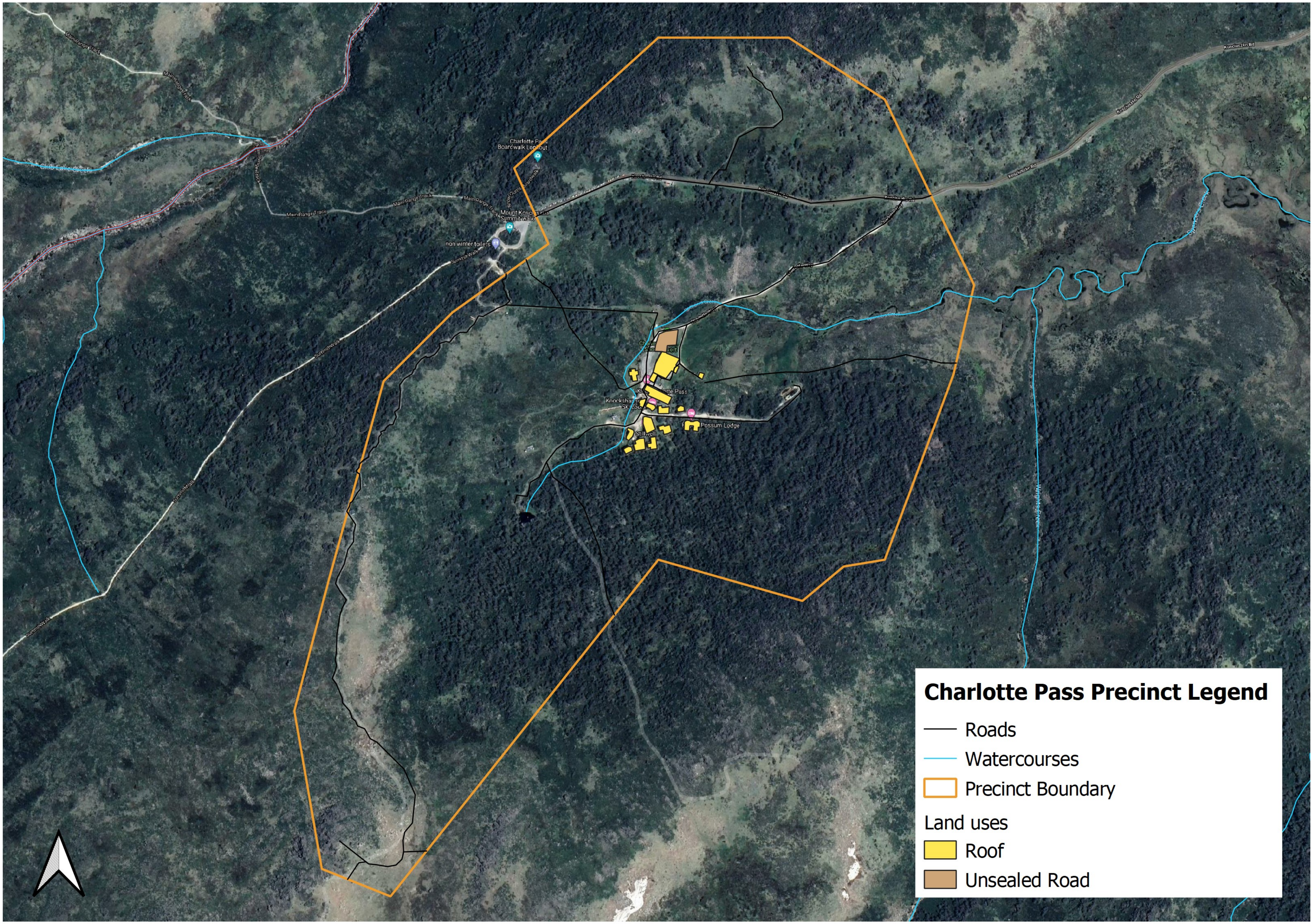
Thredbo River at Paddys Corner Gauge 222541

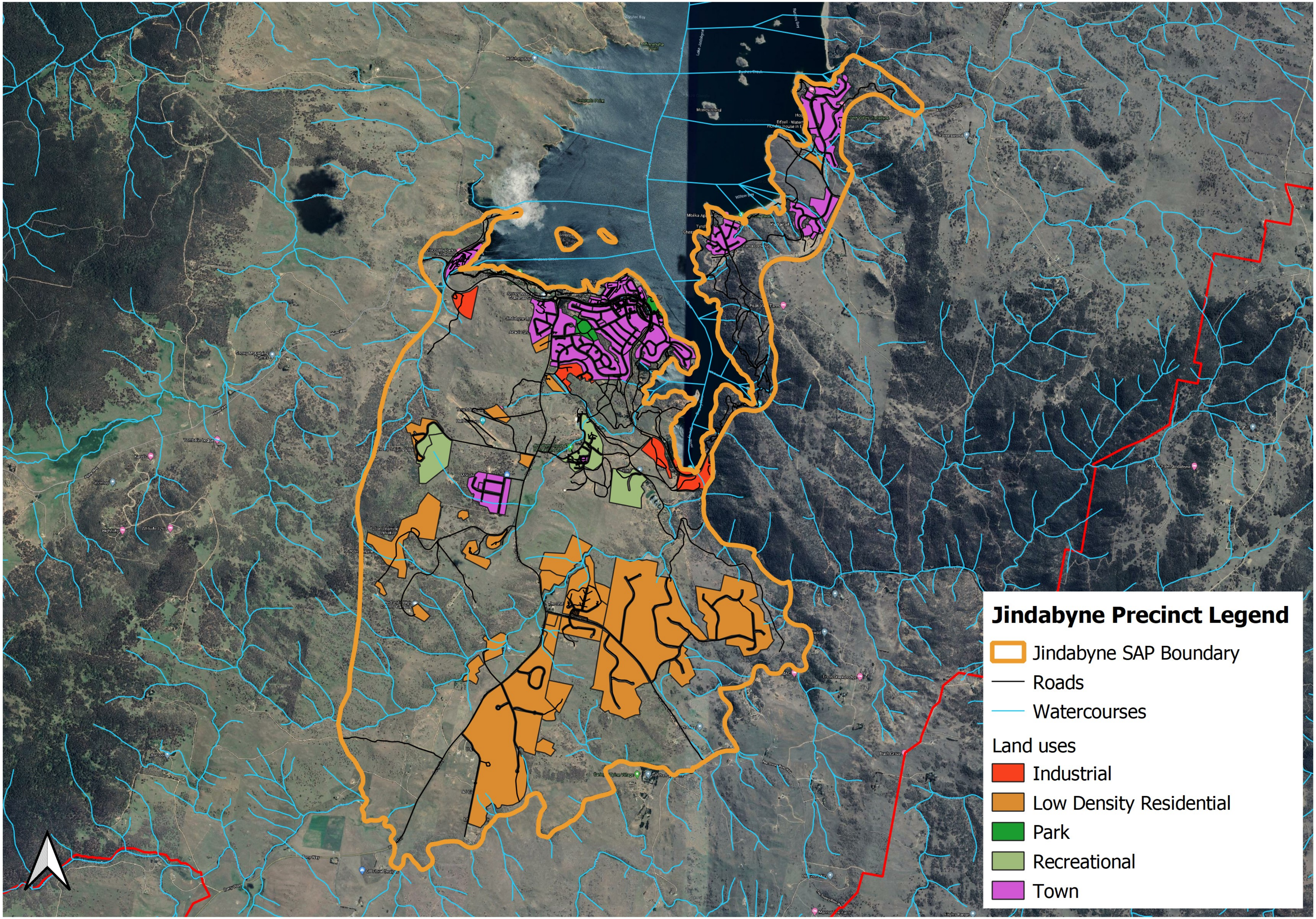
AEP (%)	RFFE EXPECTED QUANTILE (m3/s)	LOWER CONFIDENCE LIMIT (5%) (m^3/s)	UPPER CONFIDENCE LIMIT (95%) (m^3/s)
50	49.7	19.1	135
20	100	40.0	262
10	145	56.1	390
5	198	73	557
2	283	96.5	853
1	359	116	1150

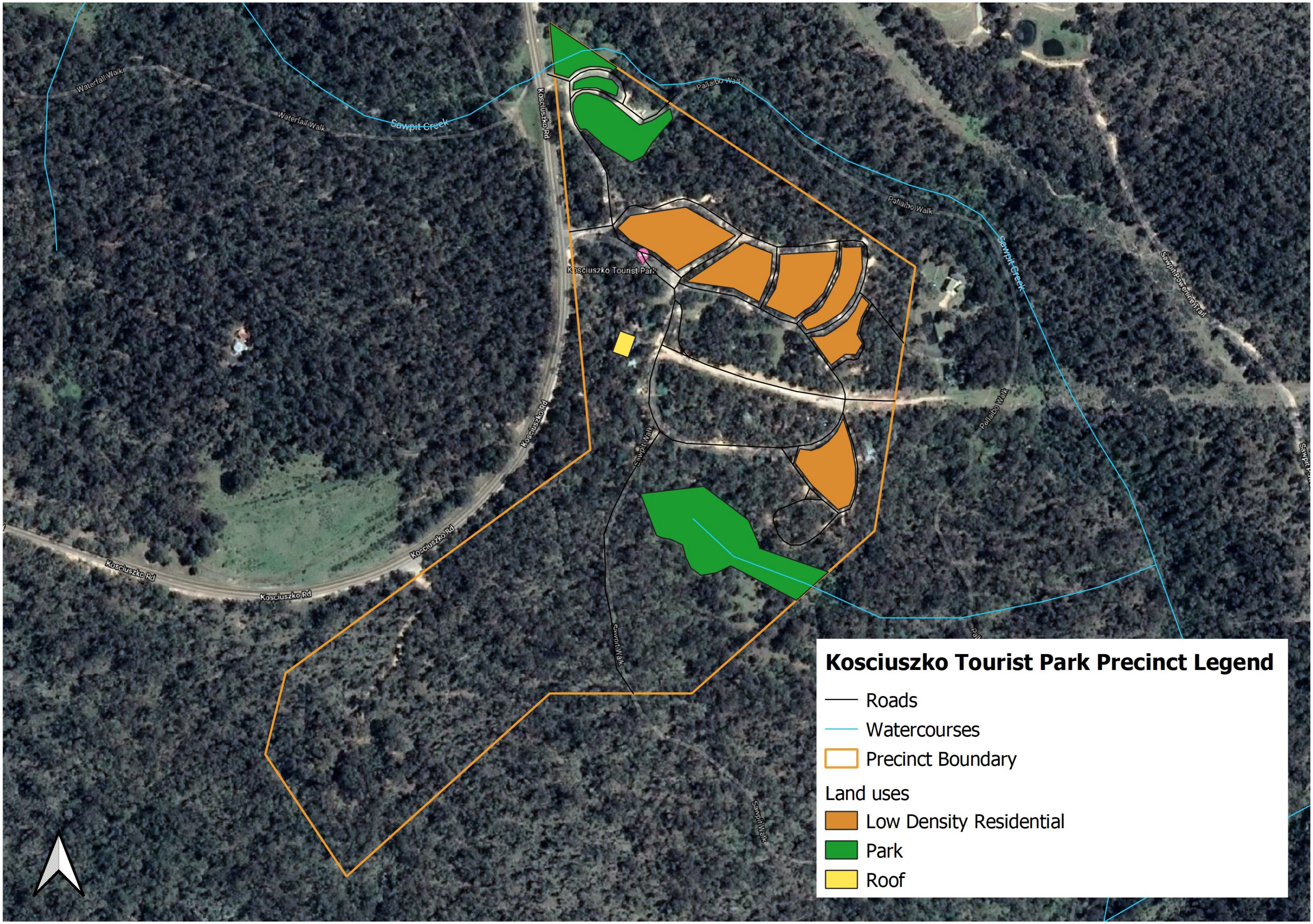
APPENDIX C

LAND USE MAPS BY PRECINCT

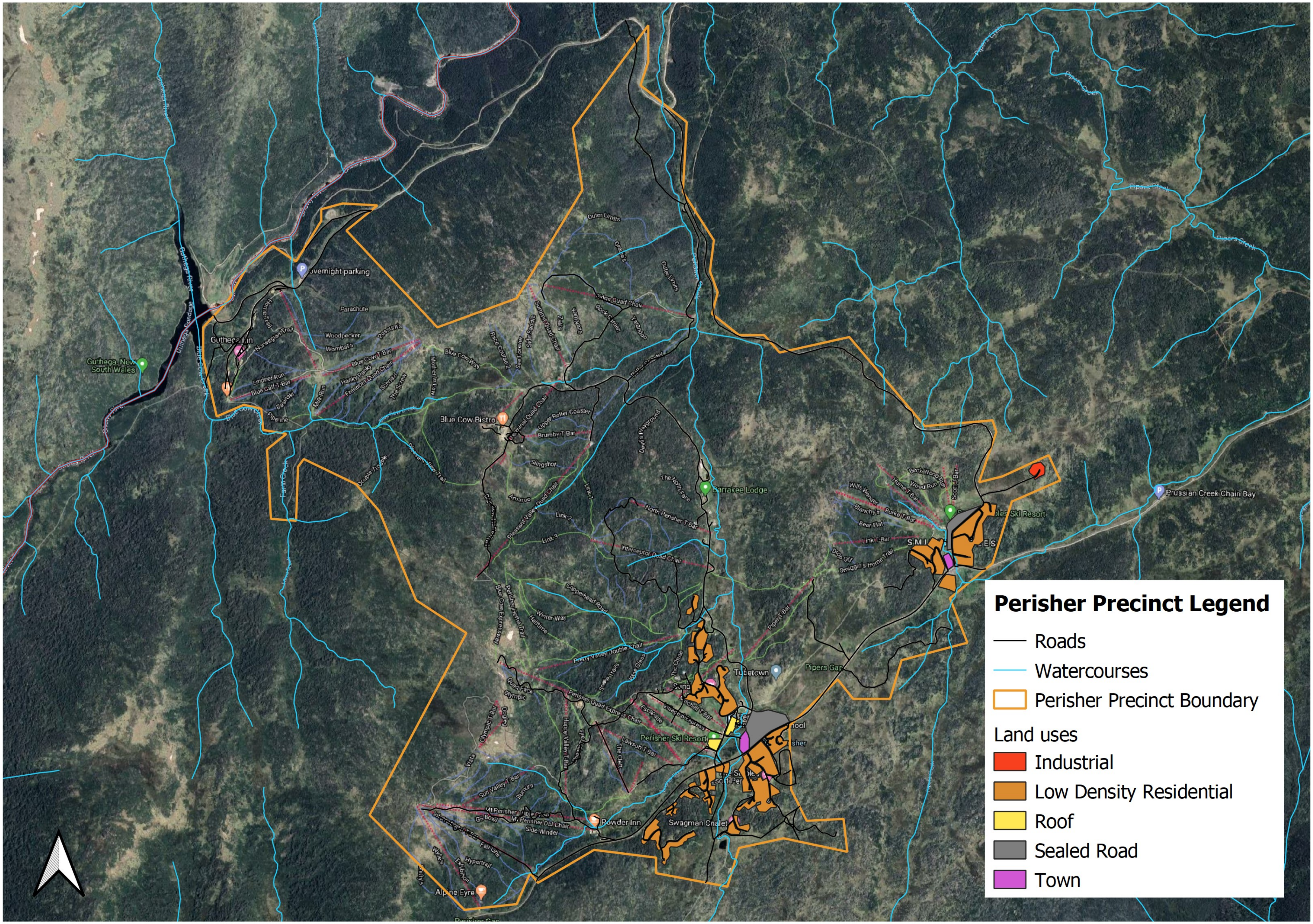

Bullocks Flat Precinct Legend
Roads
Watercourses
Precinct Boundary
Land uses
Industrial
Roof
Sealed Road

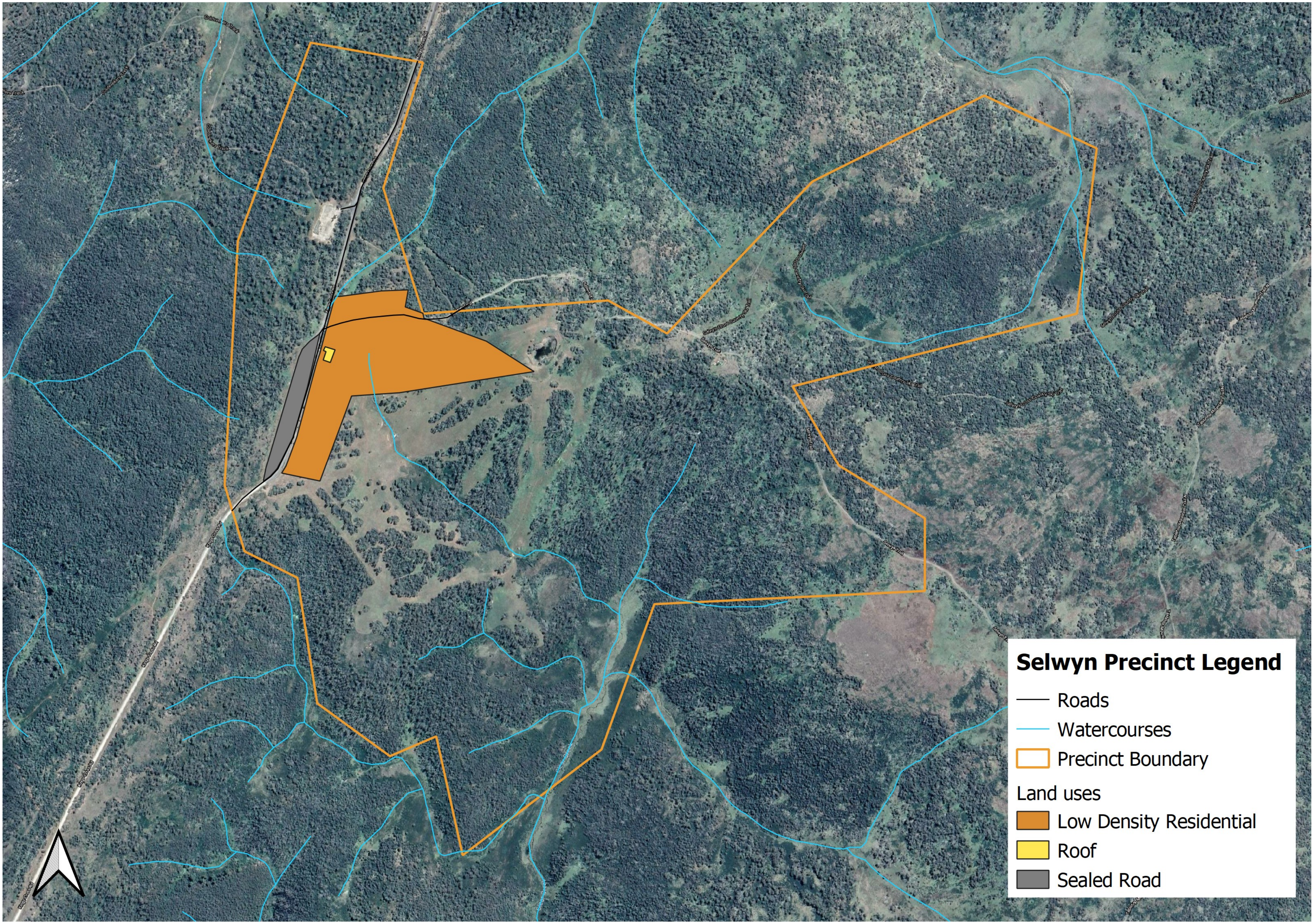

Charlotte Pass Precinct Legend
Roads
Watercourses
Precinct Boundary
Land uses
Roof
Unsealed Road
Possum Lodge

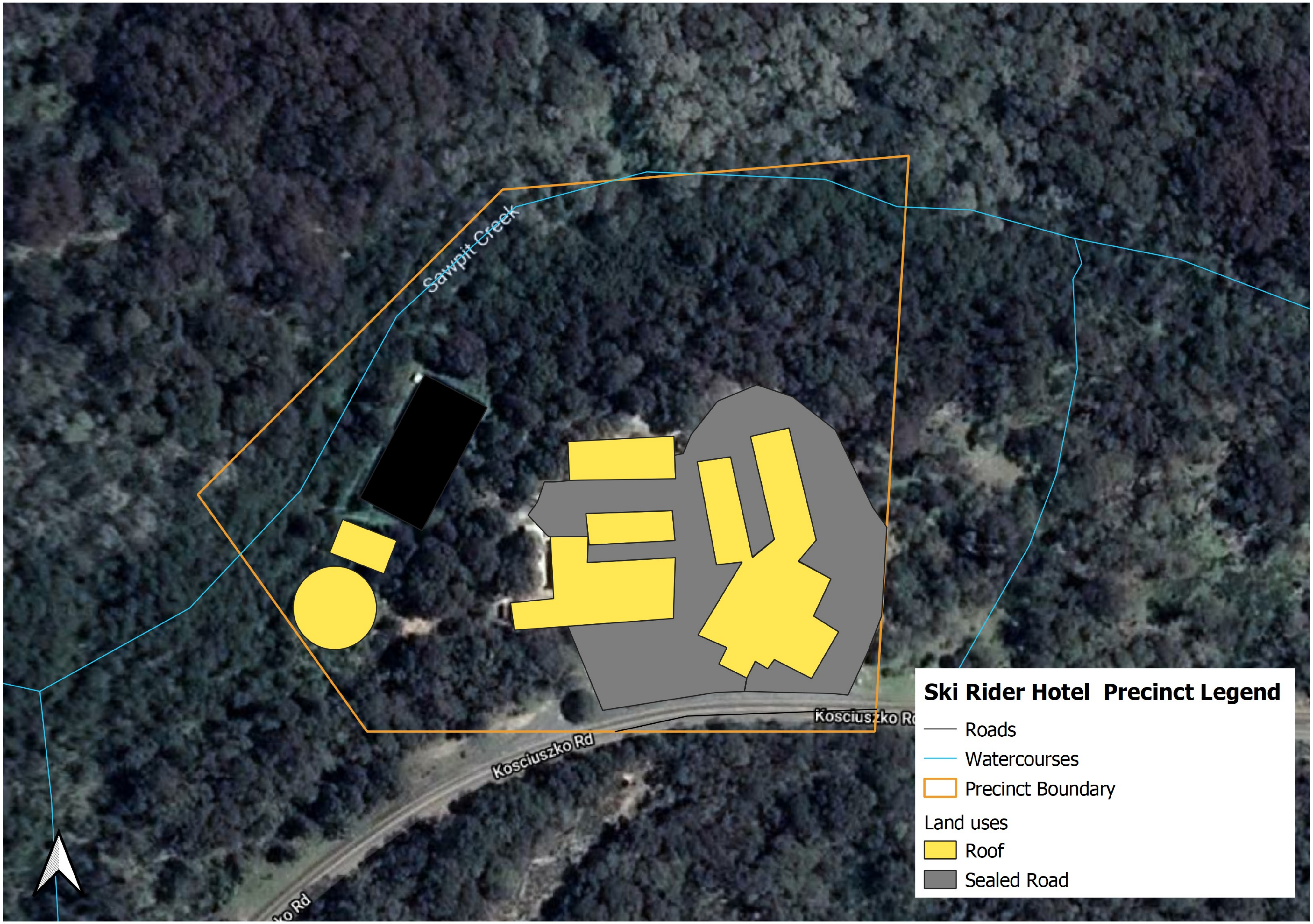

Jindabyne Precinct Legend
Jindabyne SAP Boundary
Roads
Watercourses
Land uses
Industrial
Low Density Residential
Park
Recreational
Town



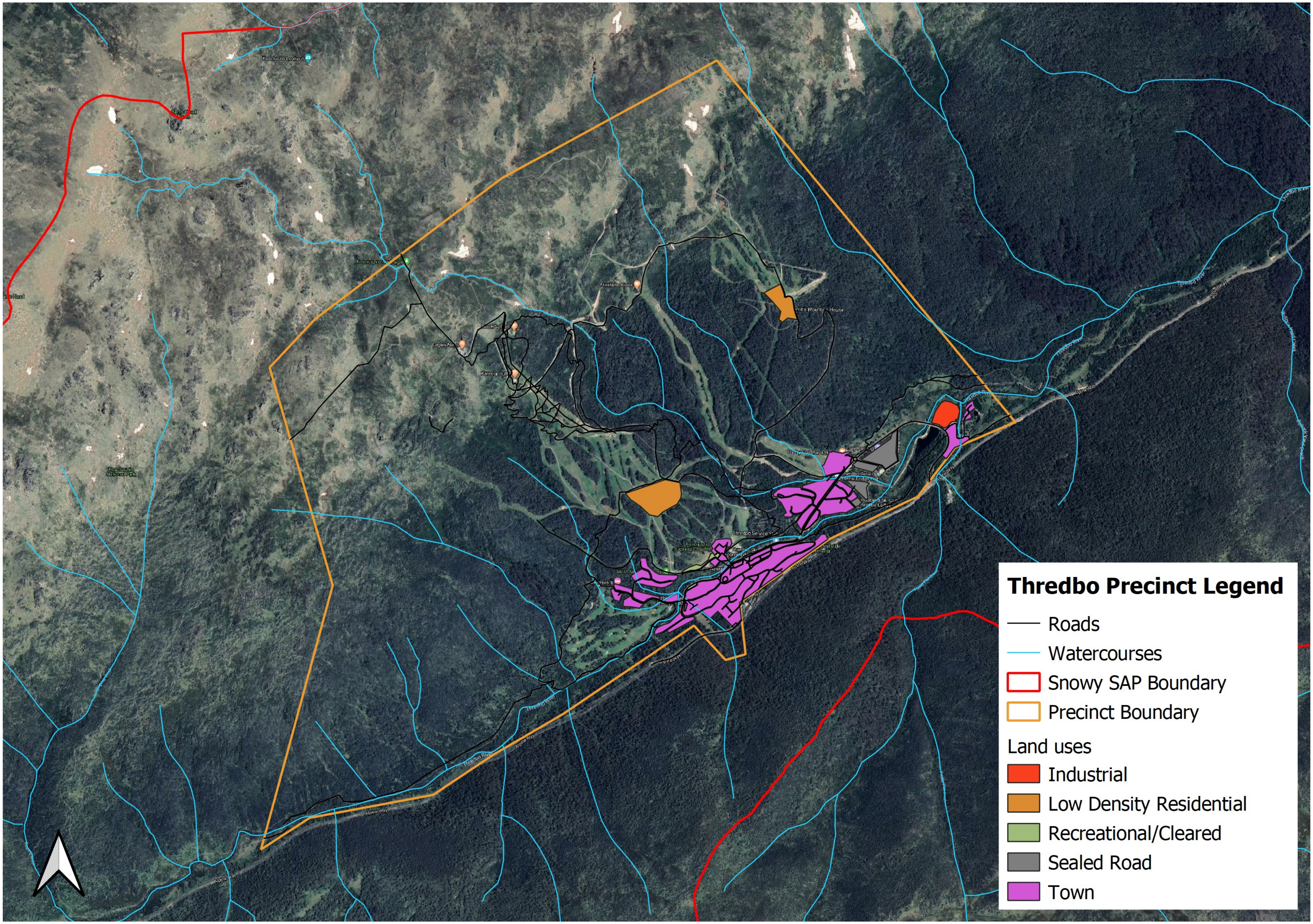
Kosciuszko Tourist Park Precinct Legend
Roads
Watercourses
Precinct Boundary
Land uses
Low Density Residential
Park
Roof
Kosciuszko Tourist Park
Kosciuszko Rd
Waterfall Walk
Sawpit Creek
Pallaibo Walk
Sawpit Walk


Perisher Precinct Legend
Roads
Watercourses
Perisher Precinct Boundary
Land uses
Industrial
Low Density Residential
Roof
Sealed Road
Town
Guthega Inn
Blue Cow Bistro
Perisher Ski Resort
Tubetown
Pipers Gap
Barrakee Lodge
Powder Inn
Swagman Chalet
Alpine Eyre
Prussian Creek Chain Bay
Overnight parking
Guthega, New South Wales


Selwyn Precinct Legend
Roads
Watercourses
Precinct Boundary
Land uses
Low Density Residential
Roof
Sealed Road

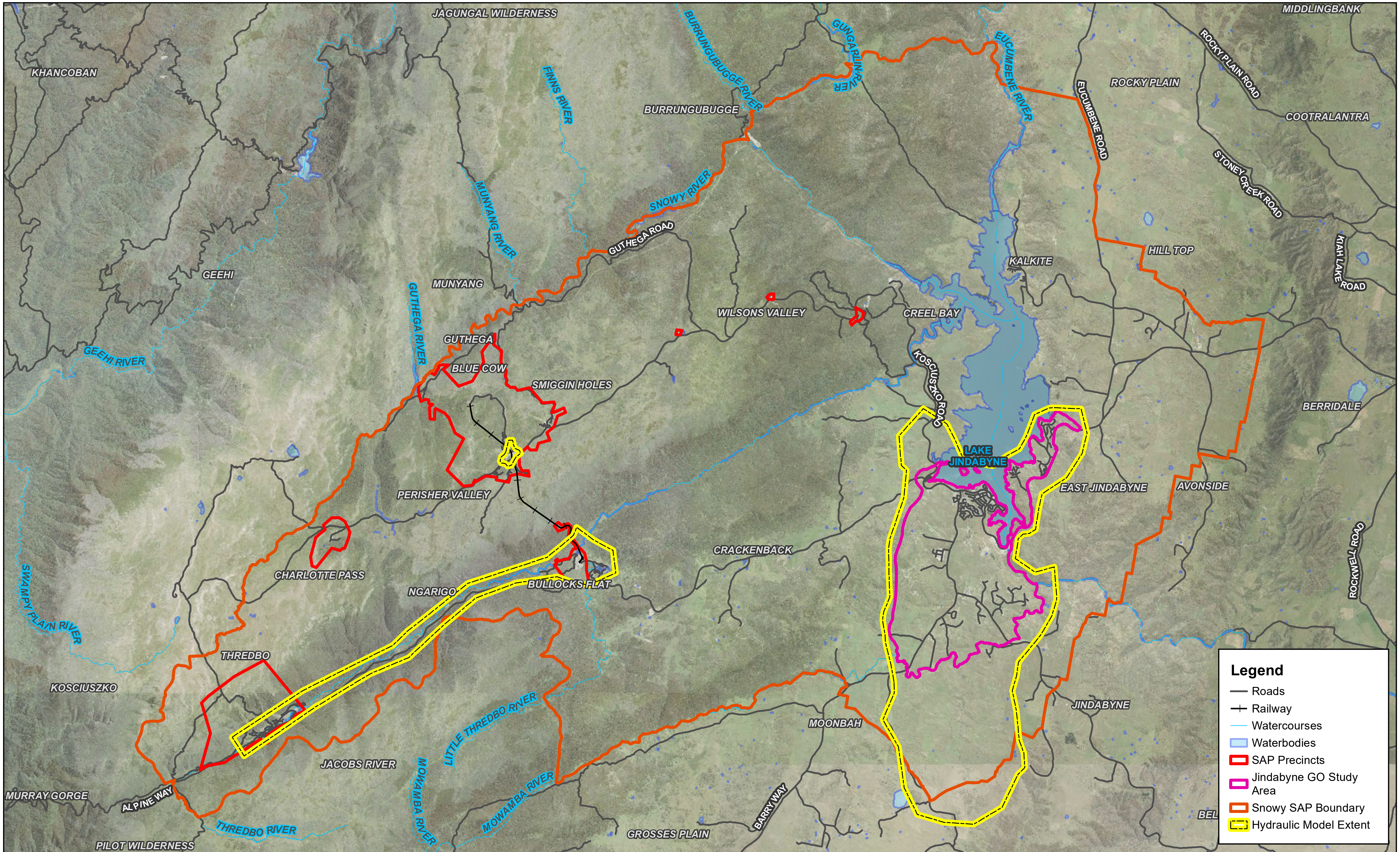

Sawpit Creek
Kosciuszko Rd
Kosciuszko Rd
ko Rd
Ski Rider Hotel Precinct Legend
Roads
Watercourses
Precinct Boundary
Land uses
Roof
Sealed Road

Diggers Creek
Sponars water jet
Diggers Creek
Sponars Chalet
Kosciuszko Rd
Sponar Chalet Precinct Legend
Roads
Watercourses
Precinct Boundary
Land uses
Roof
Sealed Road


Thredbo Precinct Legend
Roads
Watercourses
Snowy SAP Boundary
Precinct Boundary
Land uses
Industrial
Low Density Residential
Recreational/Cleared
Sealed Road
Town

APPENDIX D

FLOOD MAPPING



Map: PS120074_GIS_031_A2	Author: David.Naiken		0 1,100 2,200 m 1:140,000
Date: 15.06.2021	Approved by: Joel.Sercombe		

Imagery © Department of Customer Service 2020
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

Coordinate System: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

Snowy SAP - Flood Mapping

Figure 1: Snowy SAP Study Area

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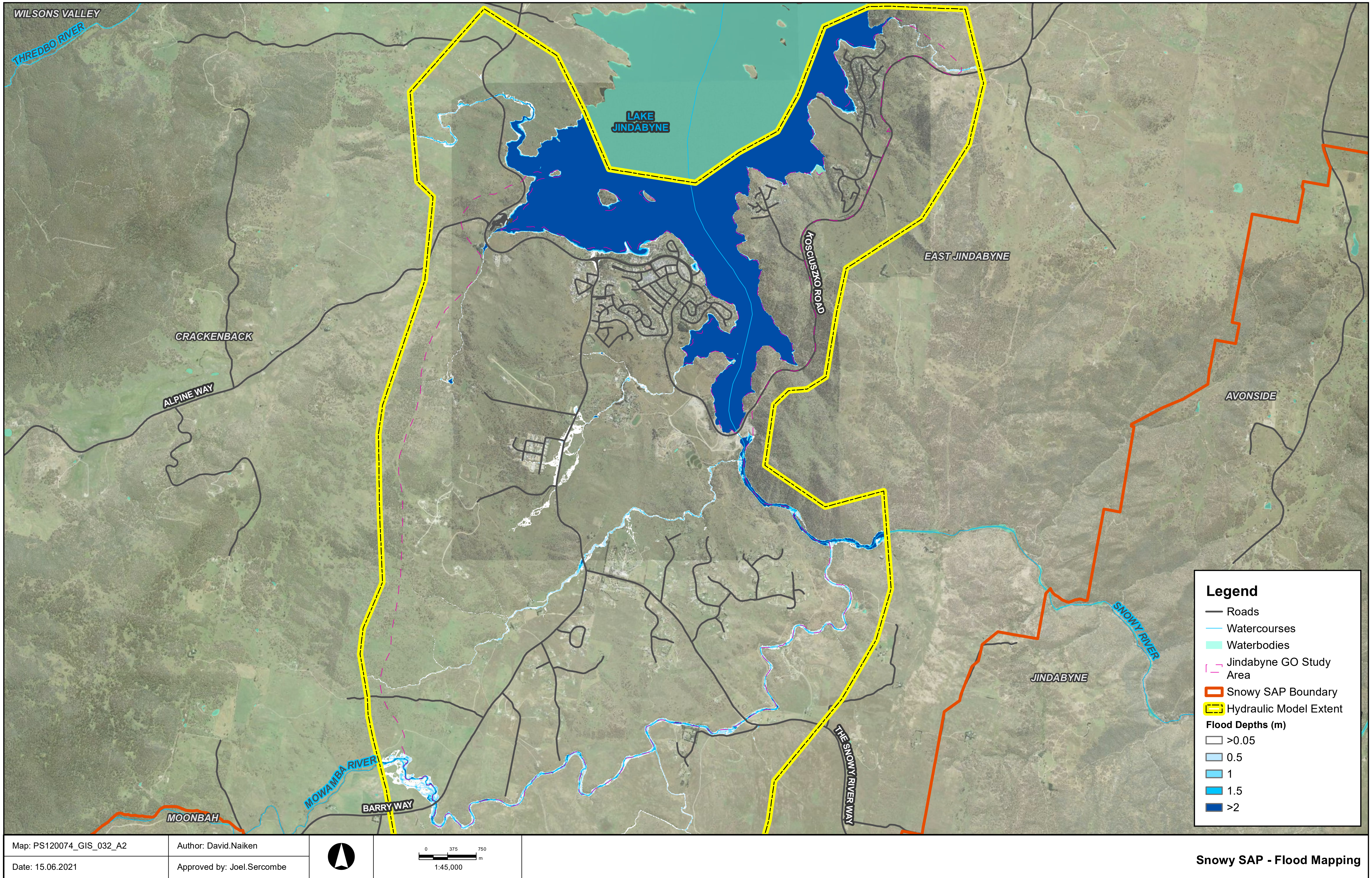

Map: PS120074_GIS_032_A2	Author: David.Naiken
Date: 15.06.2021	Approved by: Joel.Sercombe

Imagery © Department of Customer Service 2020
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

Coordinate System: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

Snowy SAP - Flood Mapping

Figure 2: 10% AEP Flood - Peak Flood Depth - Jindabyne

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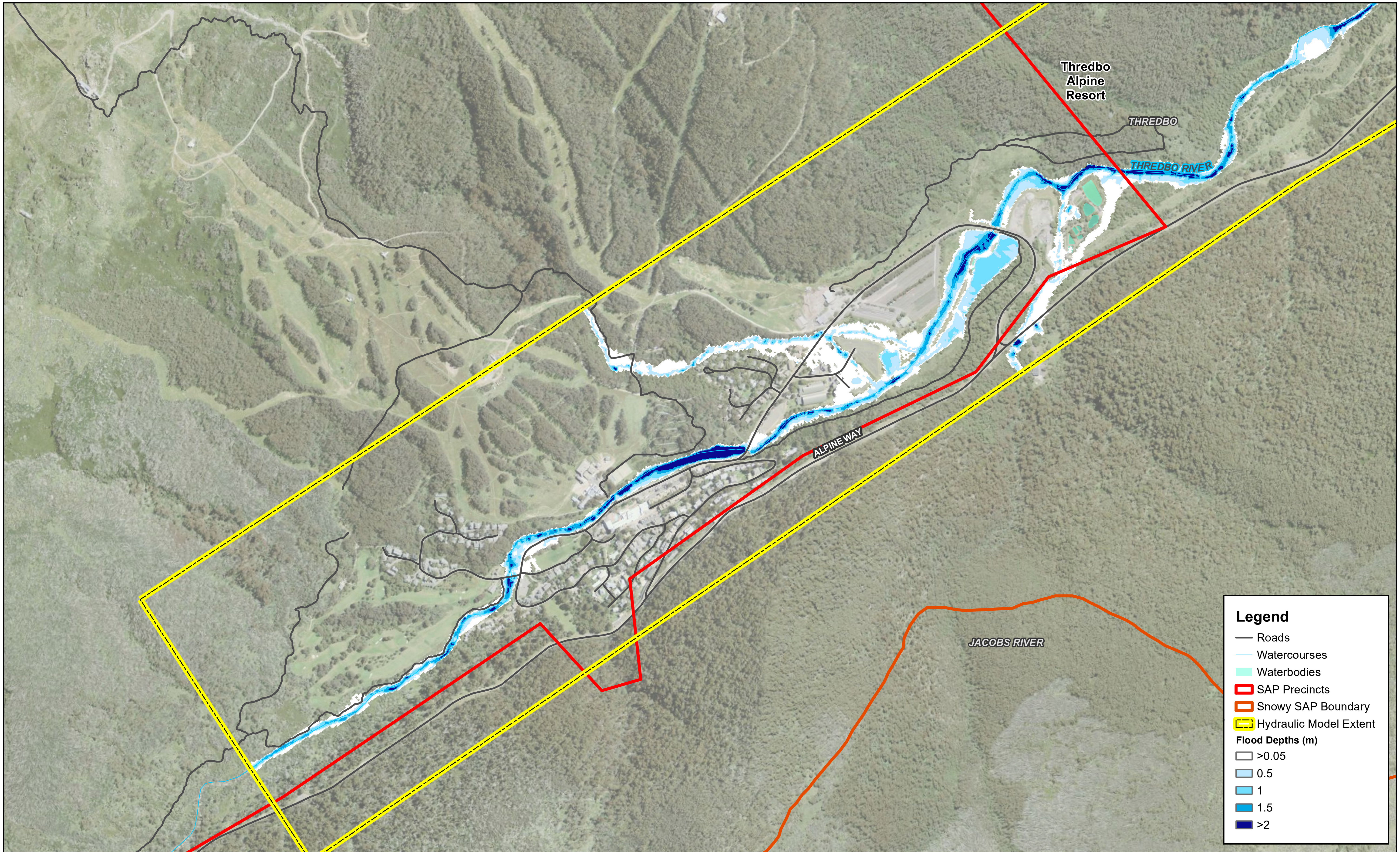

Map: PS120074_GIS_033_A1	Author: David.Naiken
Date: 06.10.2020	Approved by: Joel.Sercombe

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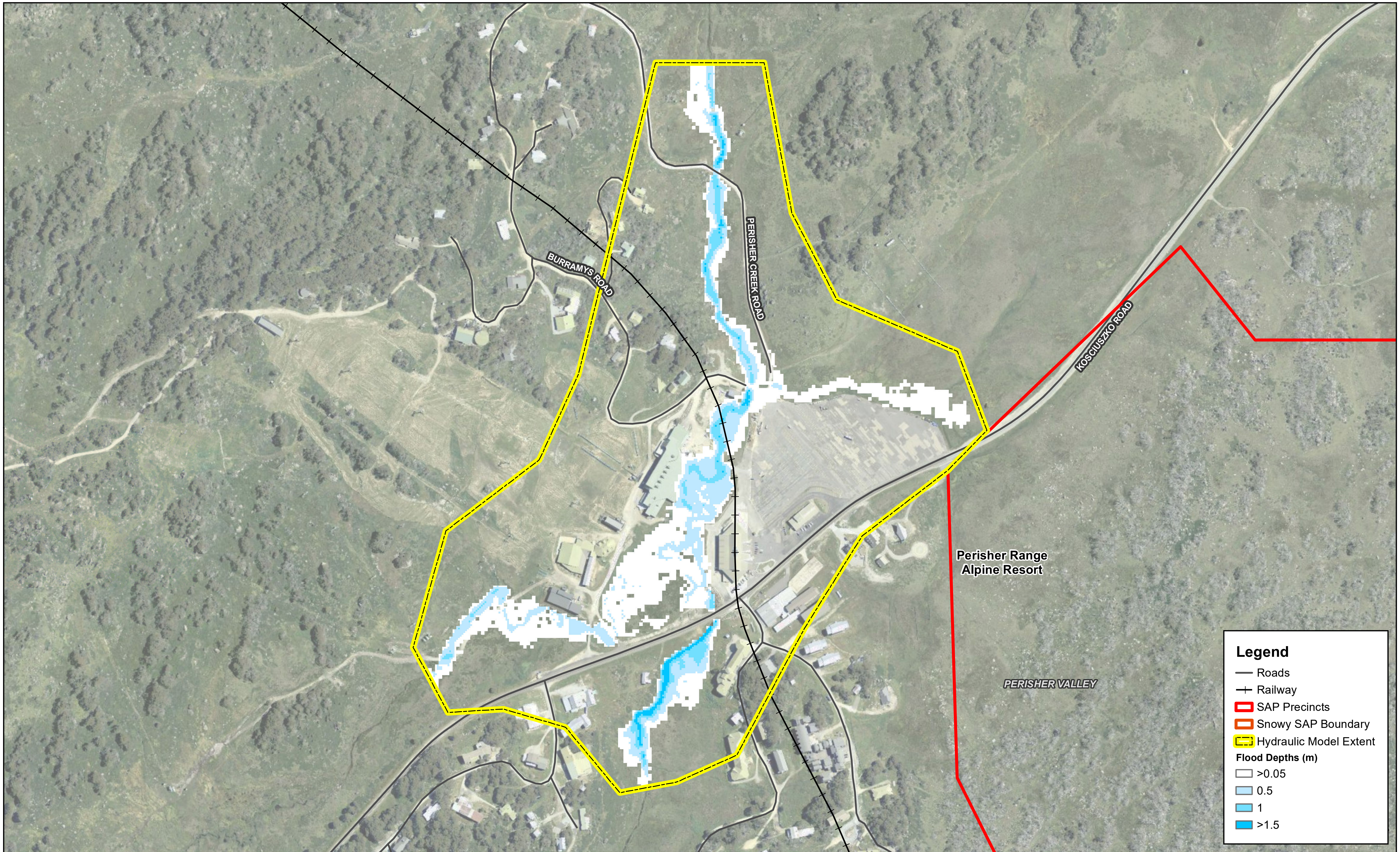
1:10,000

Coordinate System: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

Imagery © Department of Customer Service 2020
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

Snowy SAP - Flood Mapping

Figure 3: 10% AEP Flood - Peak Flood Depth - Thredbo Valley



Map: PS120074_GIS_034_A1
Author: David.Naiken
Date: 06.10.2020
Approved by: Joel.Sercombe

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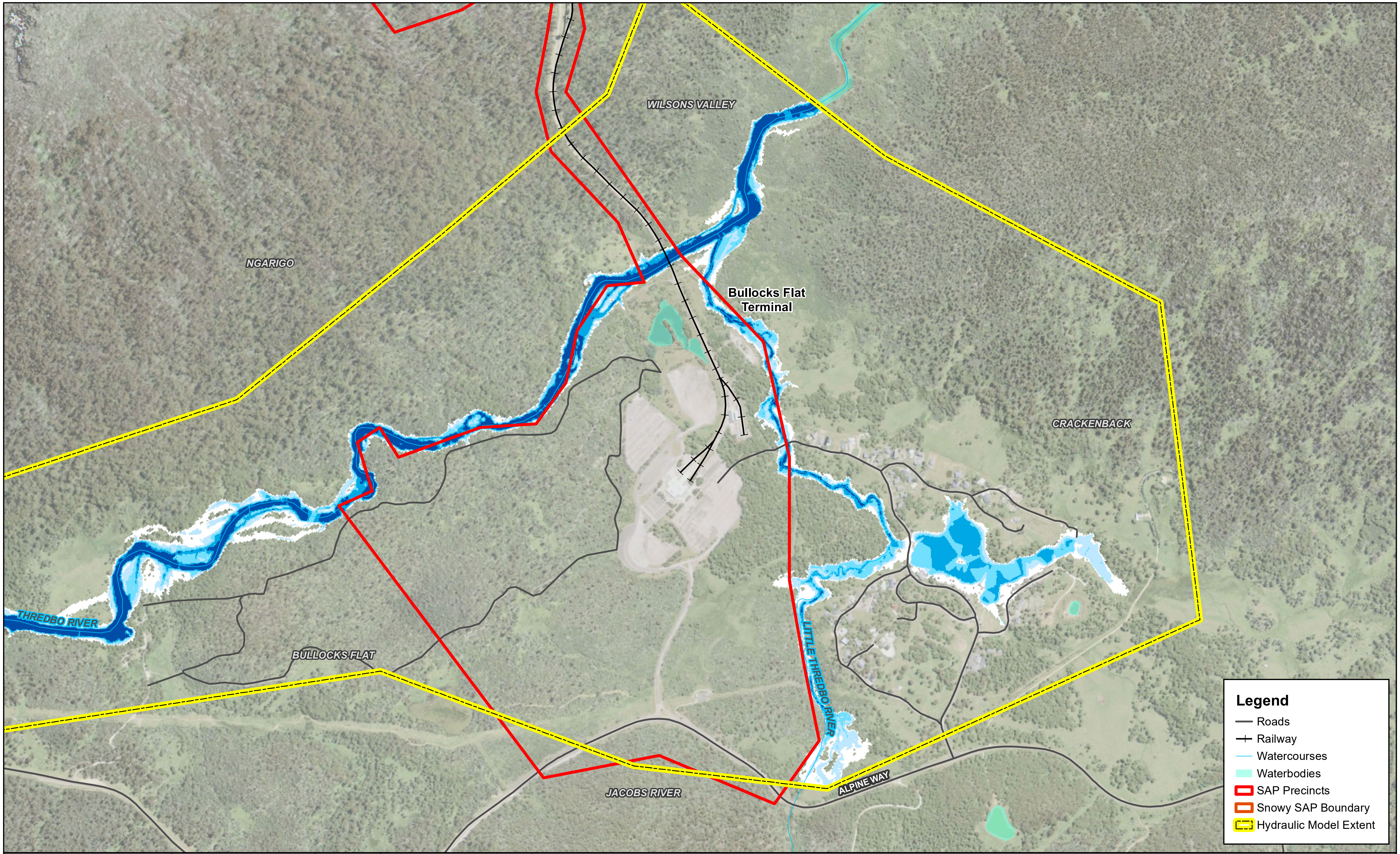
1:5,000

Imagery © Department of Customer Service 2020
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

Coordinate System: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

Snowy SAP - Flood Mapping

Figure 4: 10% AEP Flood - Peak Flood Depth - Perisher Valley



Map: PS120074_GIS_035_A1	Author: David.Naiken	
Date: 06.10.2020	Approved by: Joel.Sercombe	

0 70 140 m
1:10,000

Imagery © Department of Customer Service 2020
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

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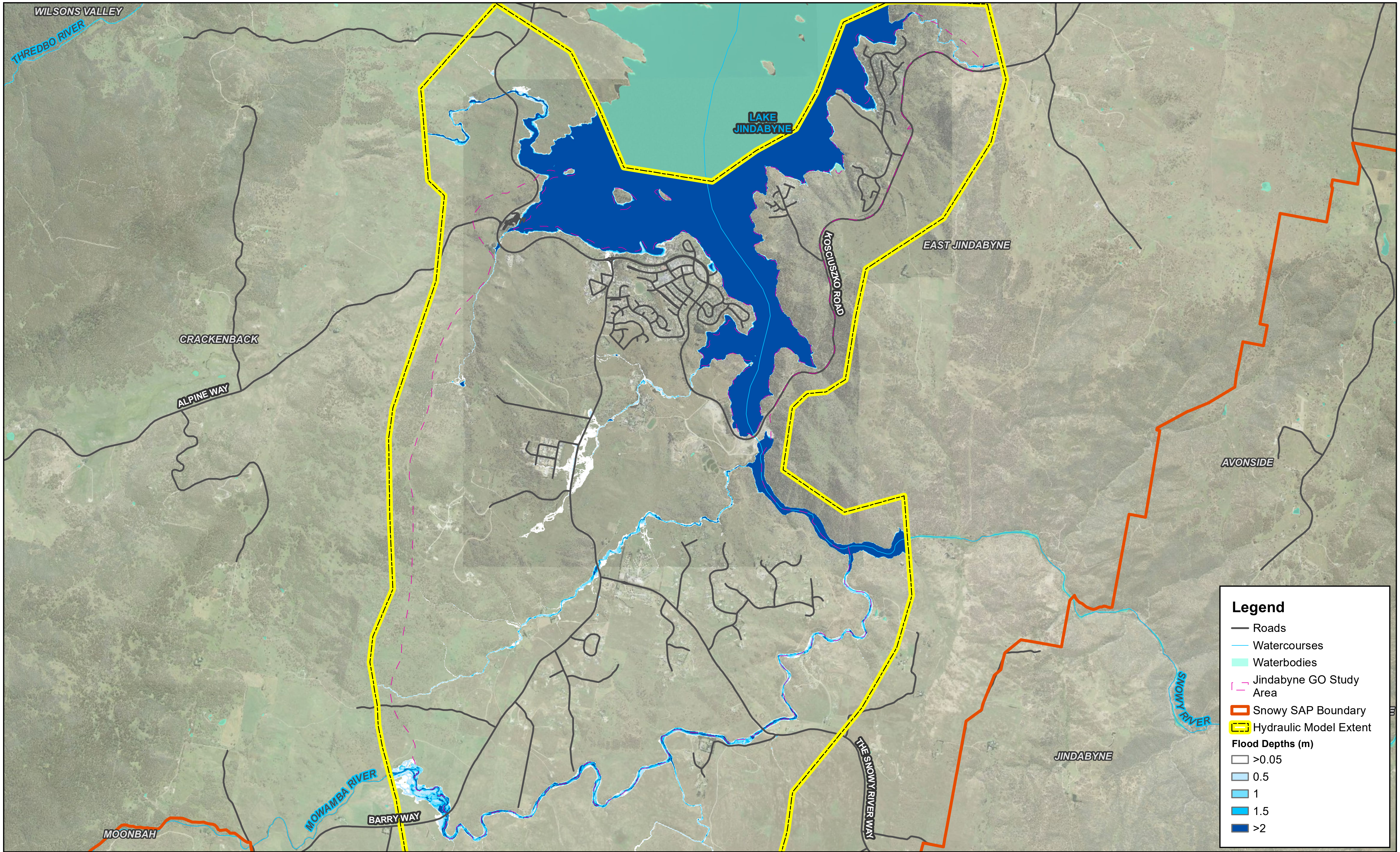
Snowy SAP - Flood Mapping

Figure 5: 10% AEP Flood - Peak Flood Depth - Bullocks Flat



Map: PS120074_GIS_036_A2	Author: David.Naiken
Date: 15.06.2021	Approved by: Joel.Sercombe

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1:45,000

Coordinate System: GDA 1994 MGA Zone 55
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Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

Snowy SAP - Flood Mapping

Figure 6: 1% AEP Flood - Peak Flood Depth - Jindabyne

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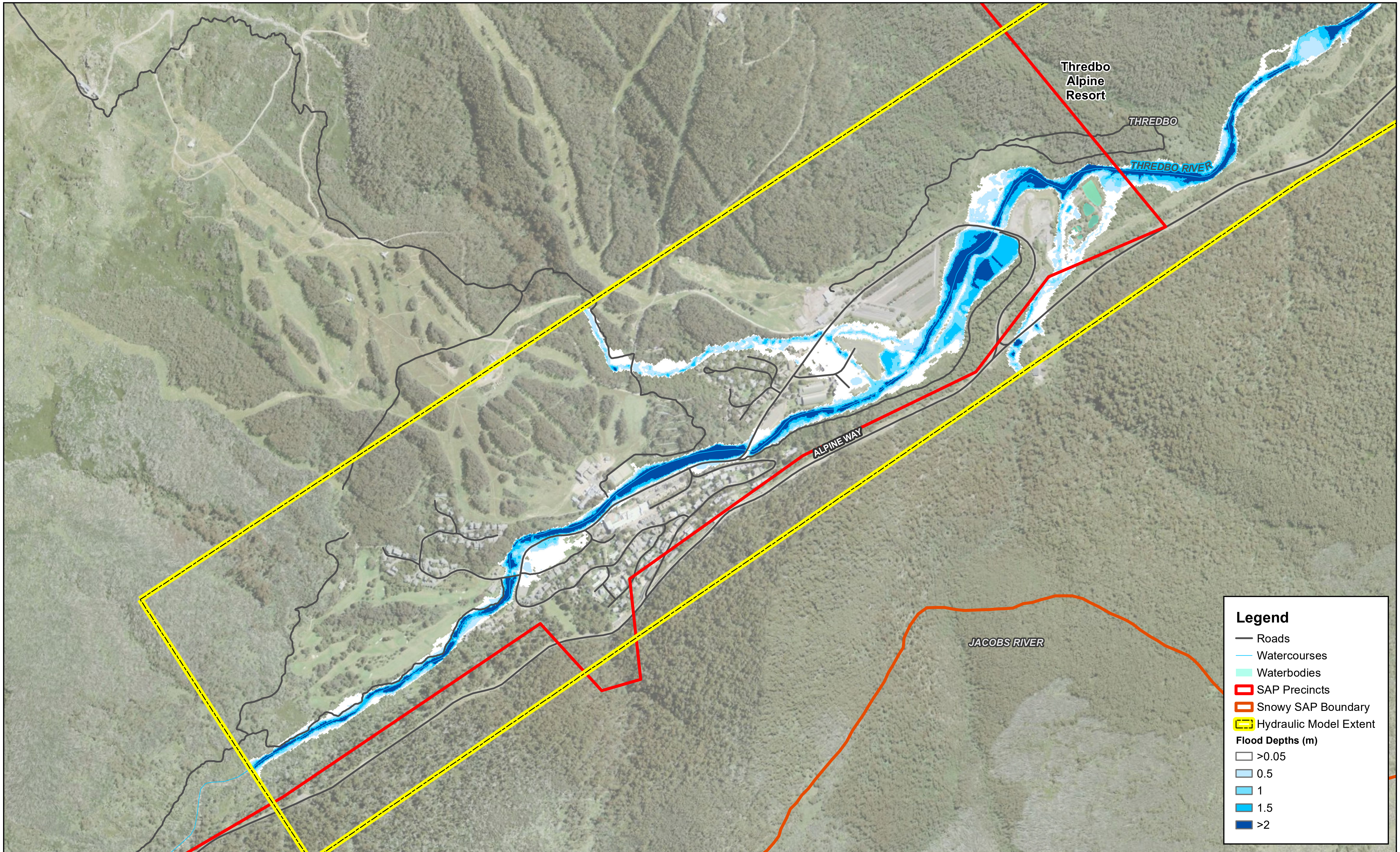

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Date: 06.10.2020	Approved by: Joel.Sercombe

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Coordinate System: GDA 1994 MGA Zone 55
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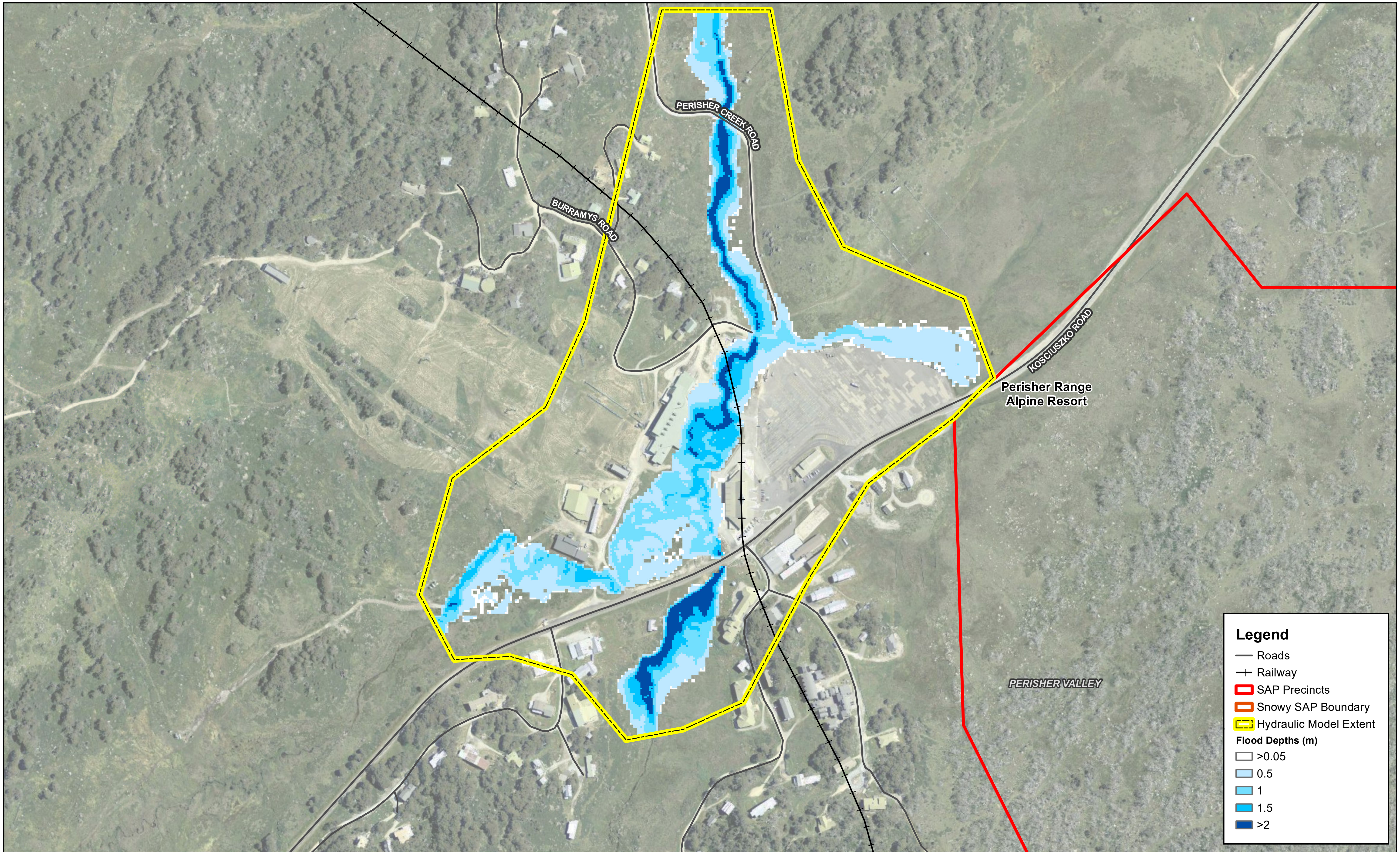
Snowy SAP - Flood Mapping

Figure 7: 1% AEP Flood - Peak Flood Depth - Thredbo Valley



Map: PS120074_GIS_038_A1	Author: David.Naiken
Date: 06.10.2020	Approved by: Joel.Sercombe

Coordinate System: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

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Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

Snowy SAP - Flood Mapping

Figure 8: 1% AEP Flood - Peak Flood Depth - Perisher Valley

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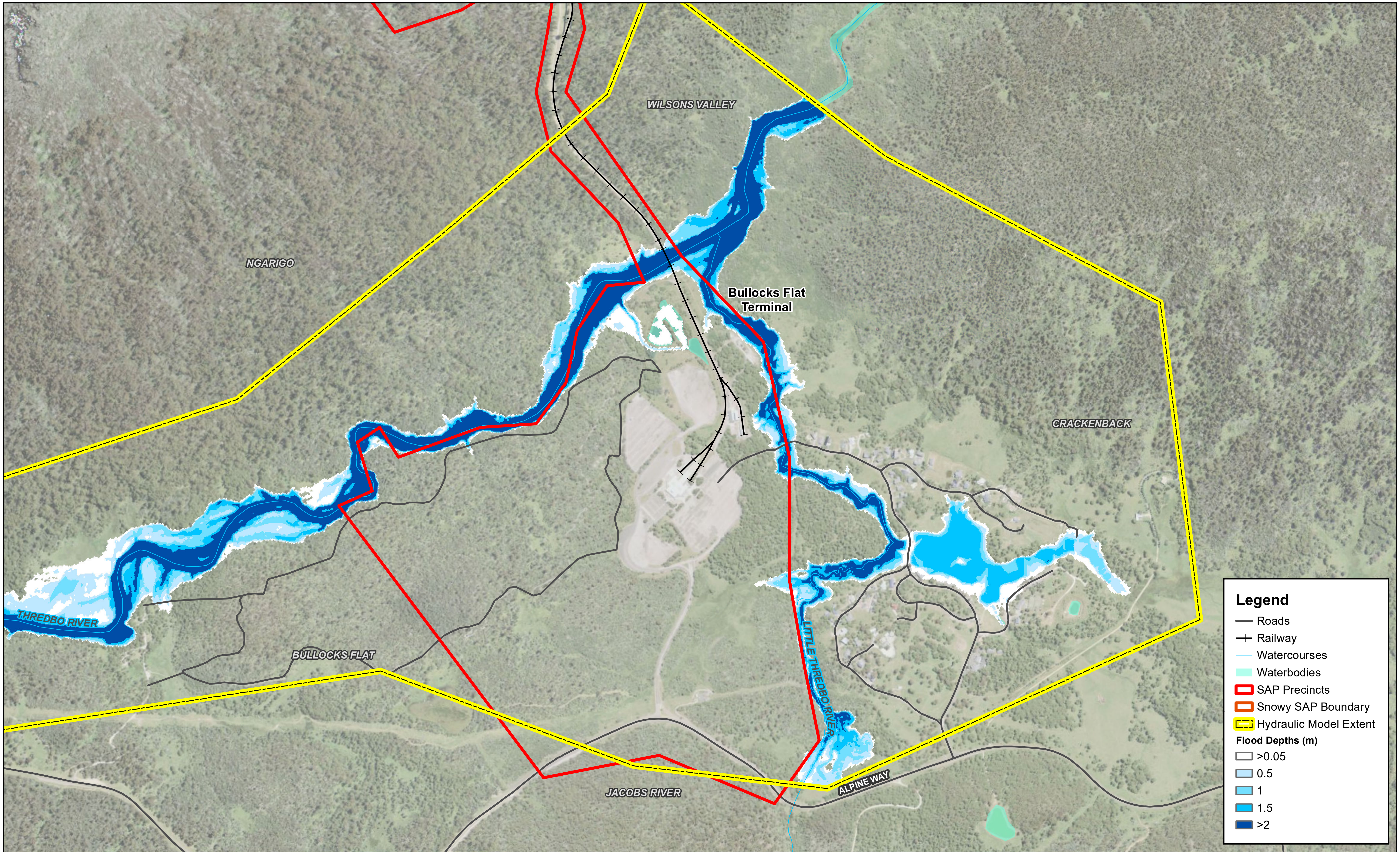

Map: PS120074_GIS_039_A1	Author: David.Naiken
Date: 06.10.2020	Approved by: Joel.Sercombe

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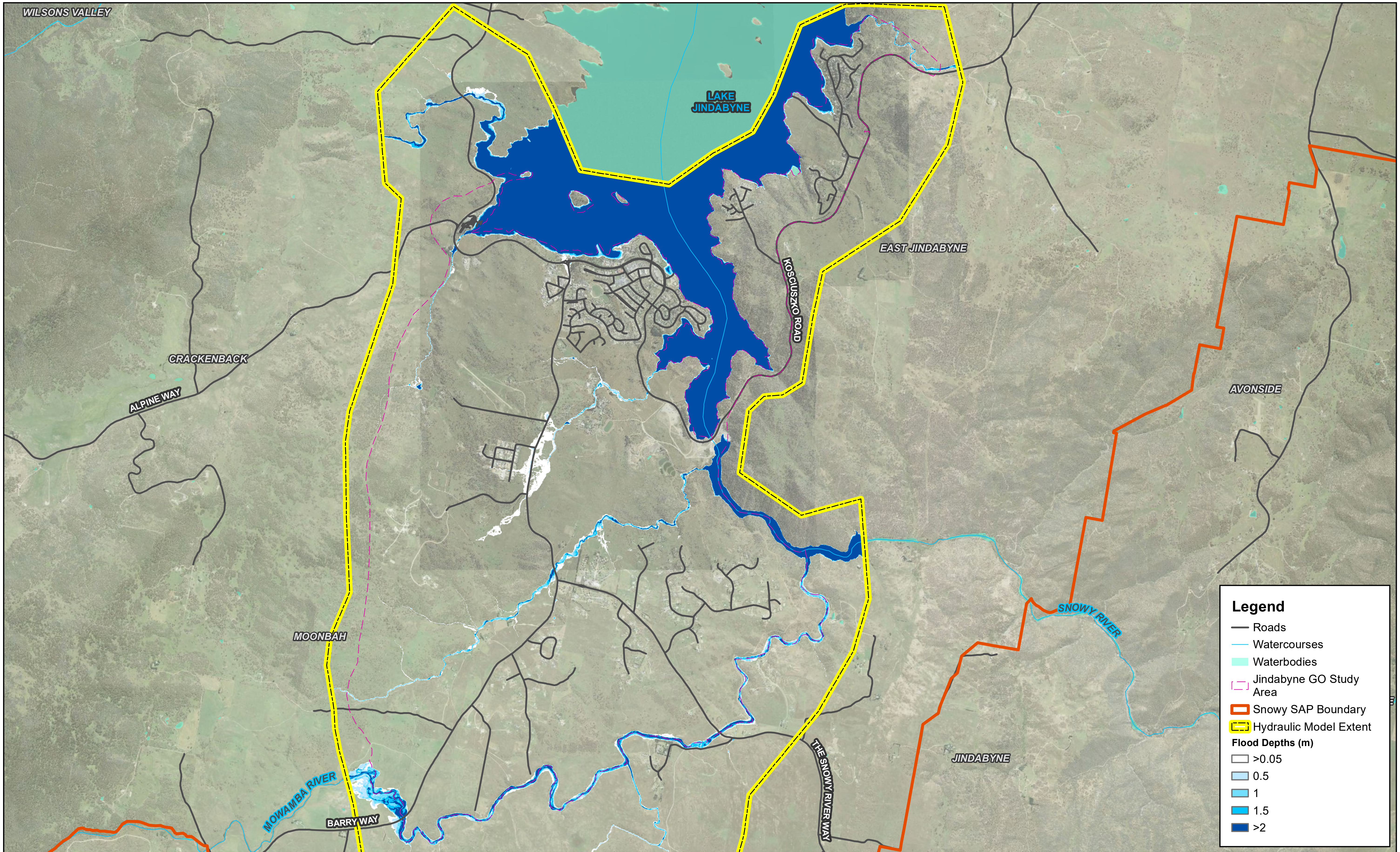
1:10,000

Imagery © Department of Customer Service 2020
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

Coordinate System: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

Snowy SAP - Flood Mapping

Figure 9: 1% AEP Flood - Peak Flood Depth - Bullocks Flat



Map: PS120074_GIS_040_A2	Author: David.Naiken
Date: 15.06.2021	Approved by: Joel.Sercombe

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1:45,000

Coordinate System: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

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Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

Snowy SAP - Flood Mapping

Figure 10: 1% AEP Climate Change 2090 Flood - Peak Flood Depth - Jindabyne

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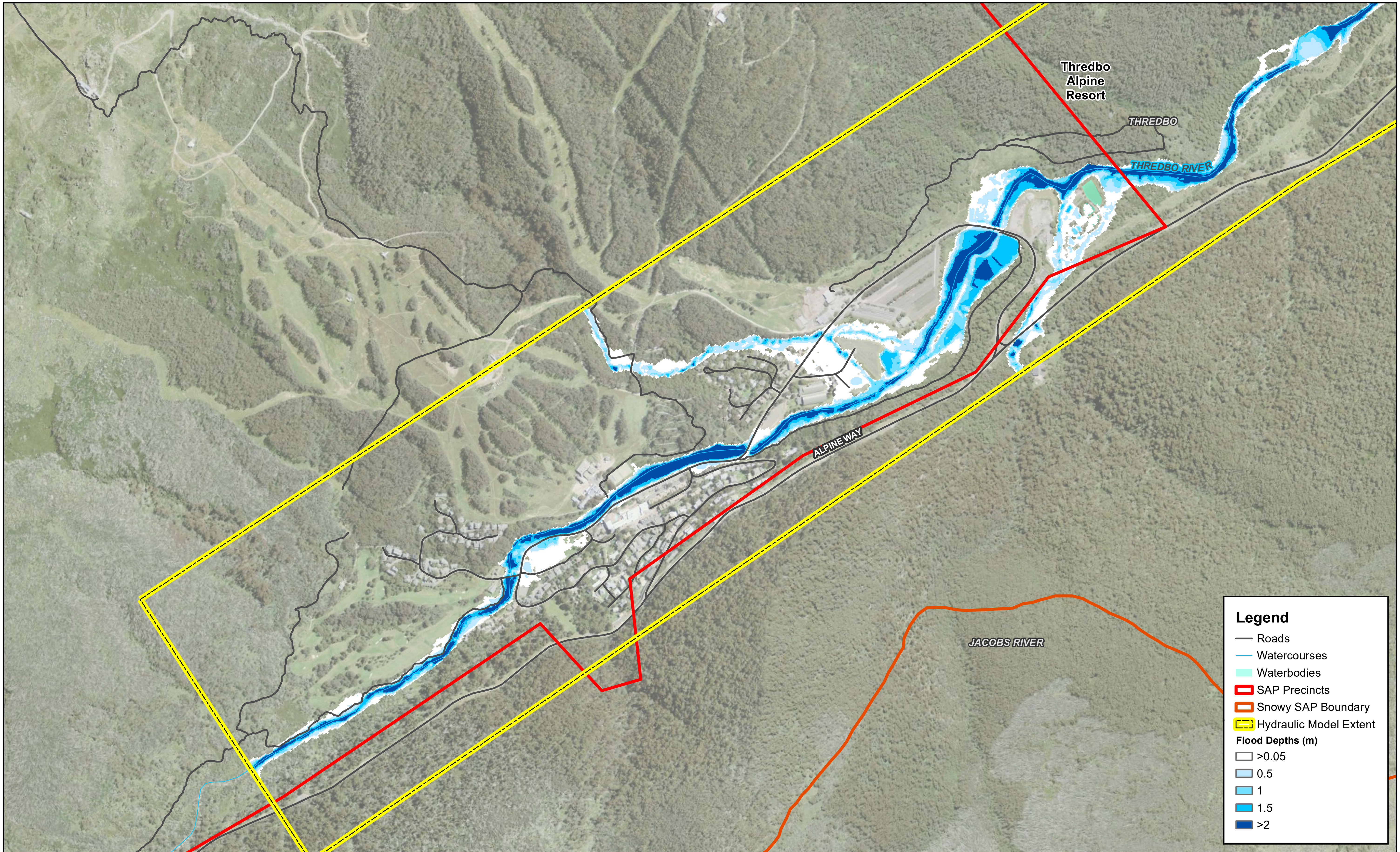

Map: PS120074_GIS_041_A1	Author: David.Naiken
Date: 06.10.2020	Approved by: Joel.Sercombe

0 70 140 m
1:10,000

Imagery © Department of Customer Service 2020
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

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Snowy SAP - Flood Mapping

Figure 11: 1% AEP Climate Change 2090 Flood - Peak Flood Depth - Thredbo Valley

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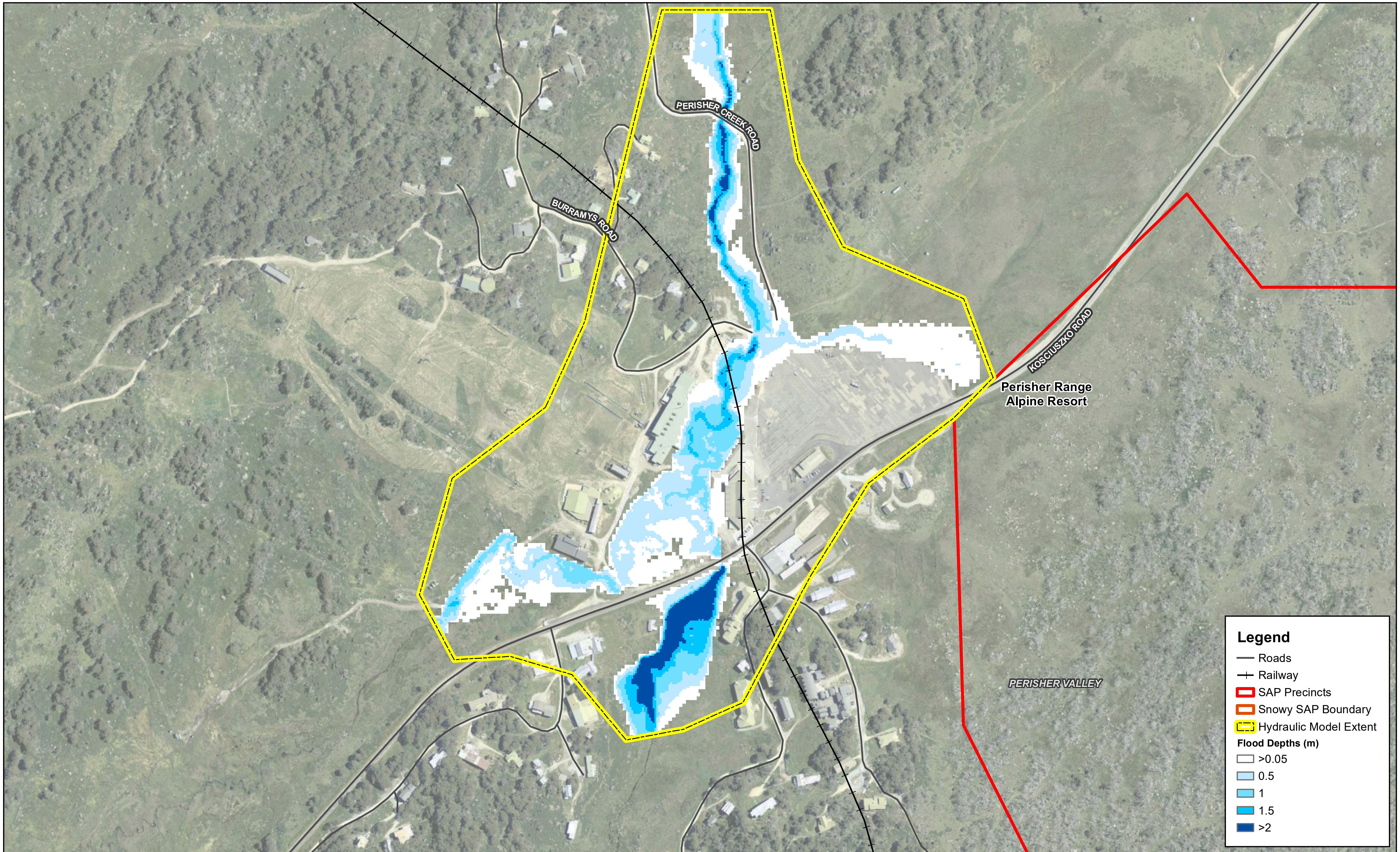
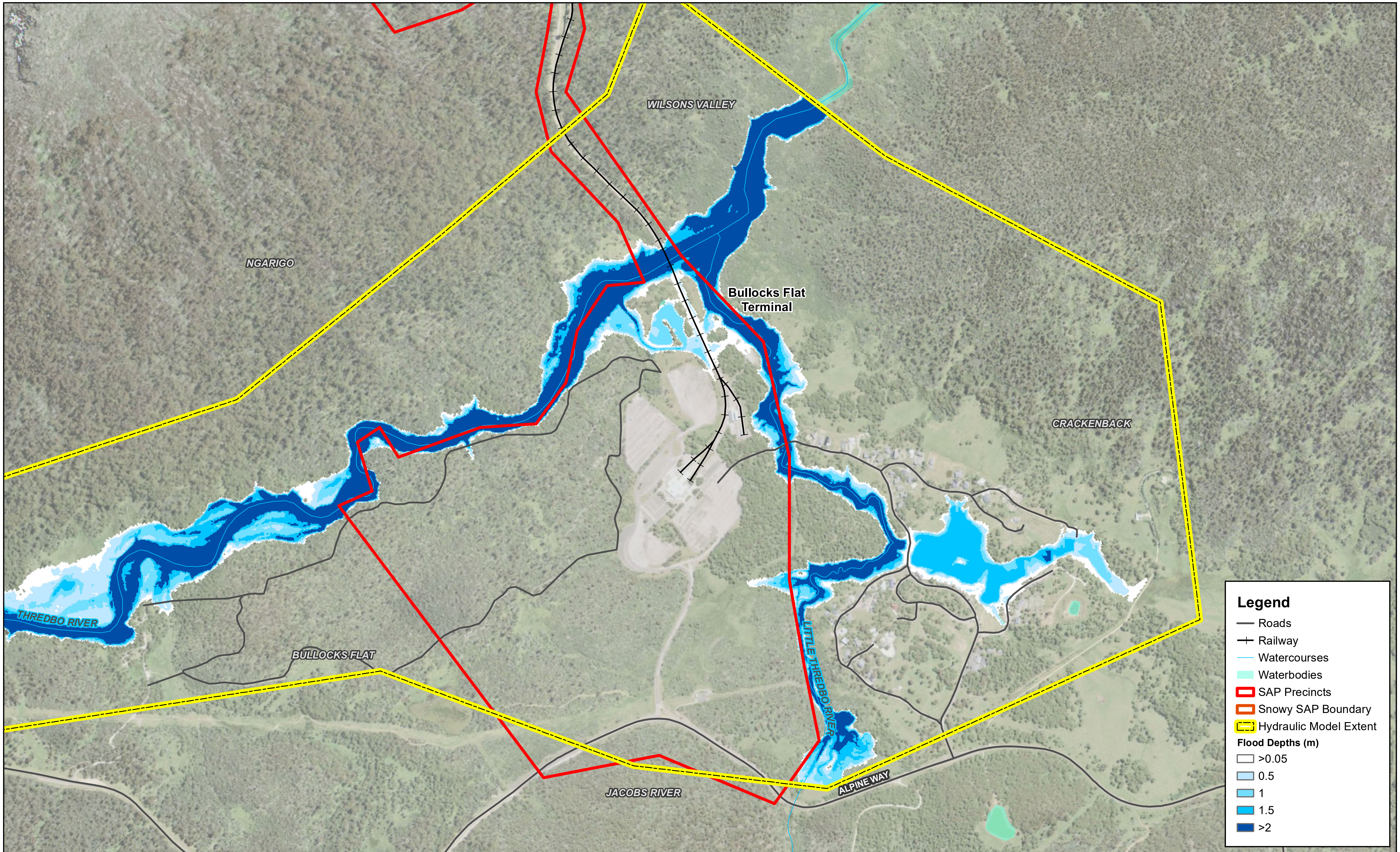


Map: PS120074_GIS_042_A1	Author: David.Naiken		0 30 60 m 1:5,000	Snowy SAP - Flood Mapping
Date: 07.10.2020	Approved by: Joel.Sercombe			Figure 12: 1% AEP Climate Change 2090 Flood - Peak Flood Depth - Perisher Valley

Imagery © Department of Customer Service 2020
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

Coordinate System: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3



Map: PS120074_GIS_043_A1	Author: David.Naiken
Date: 07.10.2020	Approved by: Joel.Sercombe

0 70 140 m
1:10,000

Imagery © Department of Customer Service 2020
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

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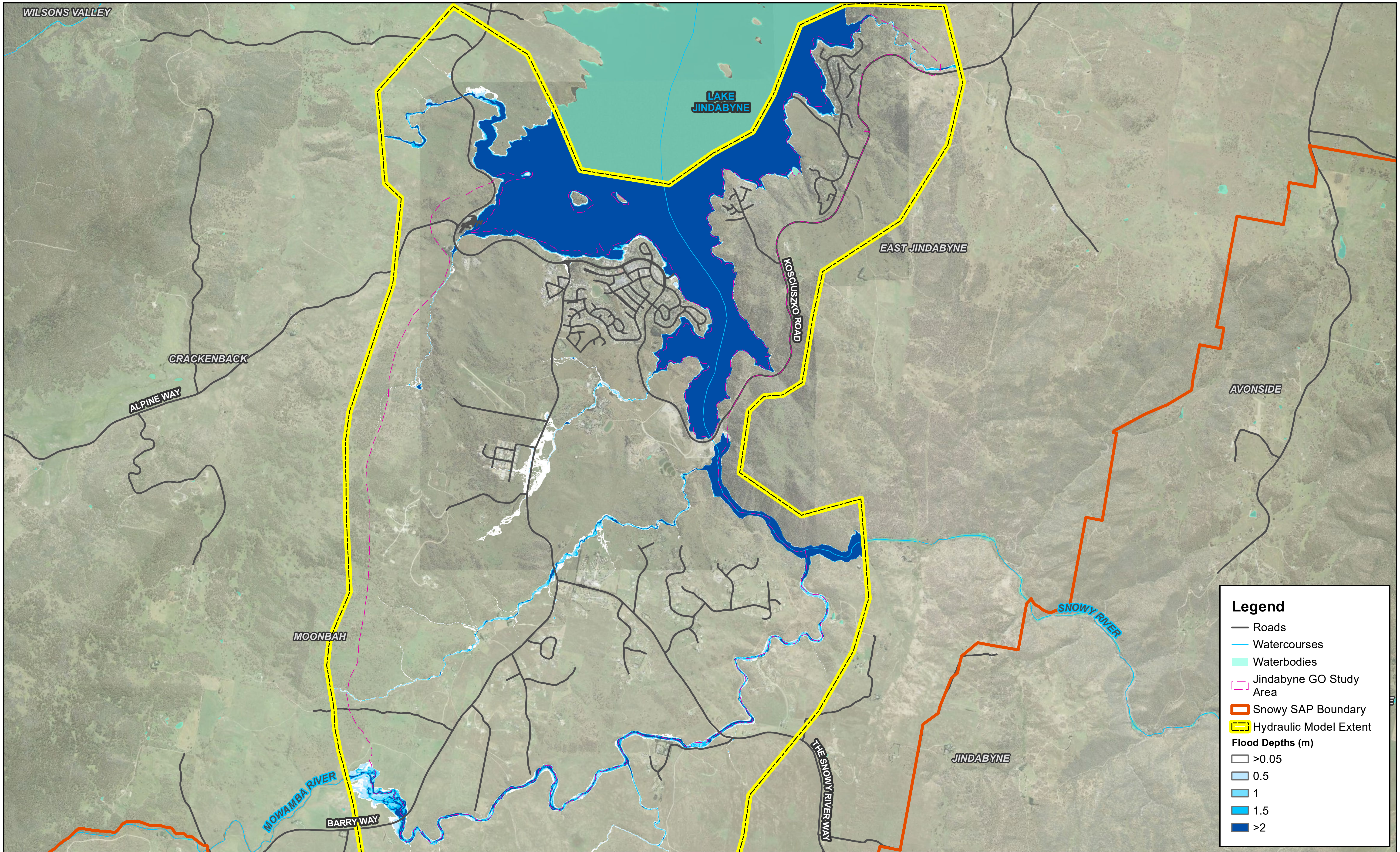
Scale ratio correct when printed at A3

Snowy SAP - Flood Mapping

Figure 13: 1% AEP Climate Change 2090 Flood - Peak Flood Depth - Bullocks Flat



Map: PS120074_GIS_045_A2	Author: David.Naiken
Date: 15.06.2021	Approved by: Joel.Sercombe

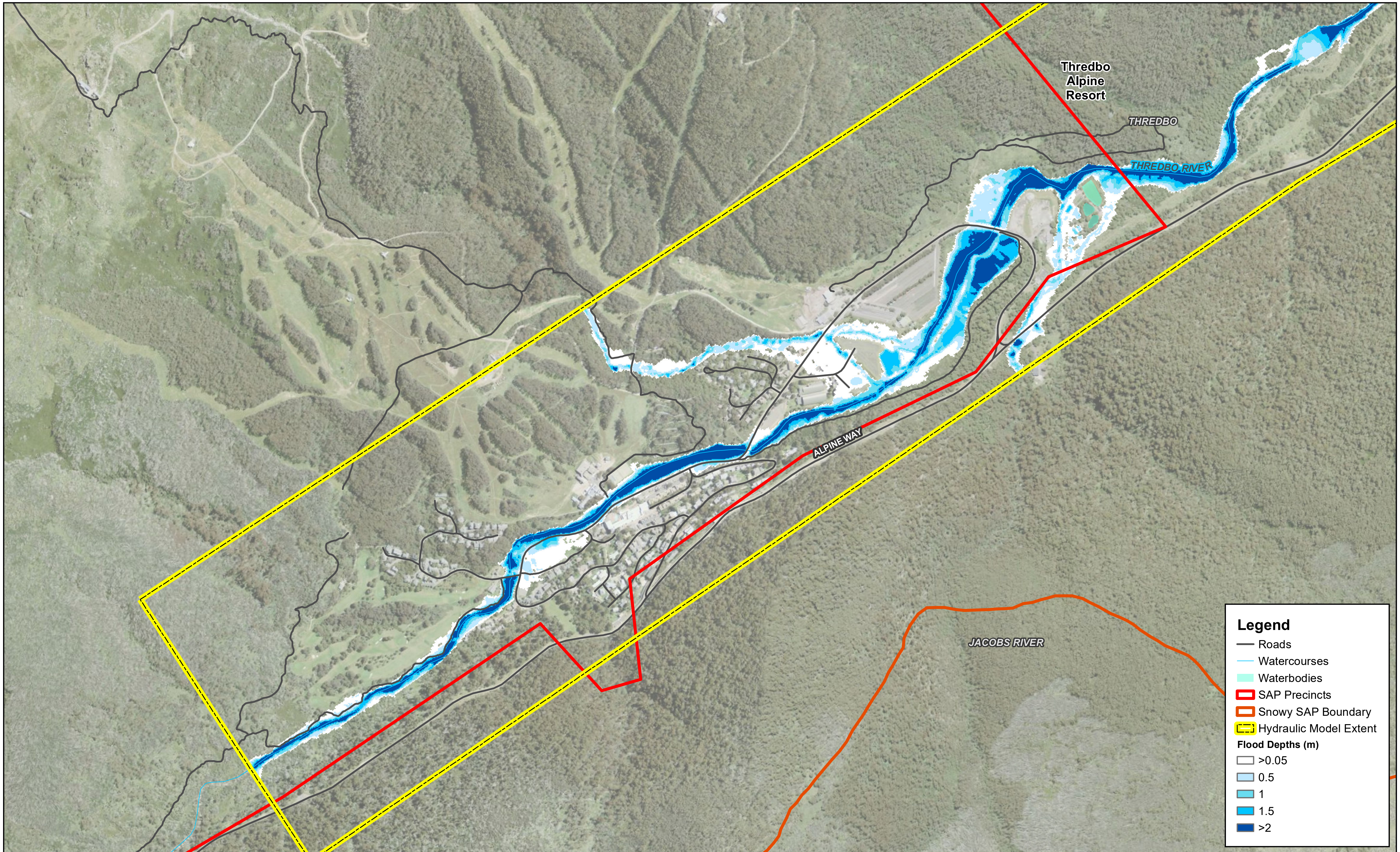
0 330 660 m
1:45,000

Imagery © Department of Customer Service 2020
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

Coordinate System: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

Snowy SAP - Flood Mapping

Figure 14: 0.5% AEP Flood - Peak Flood Depth - Jindabyne



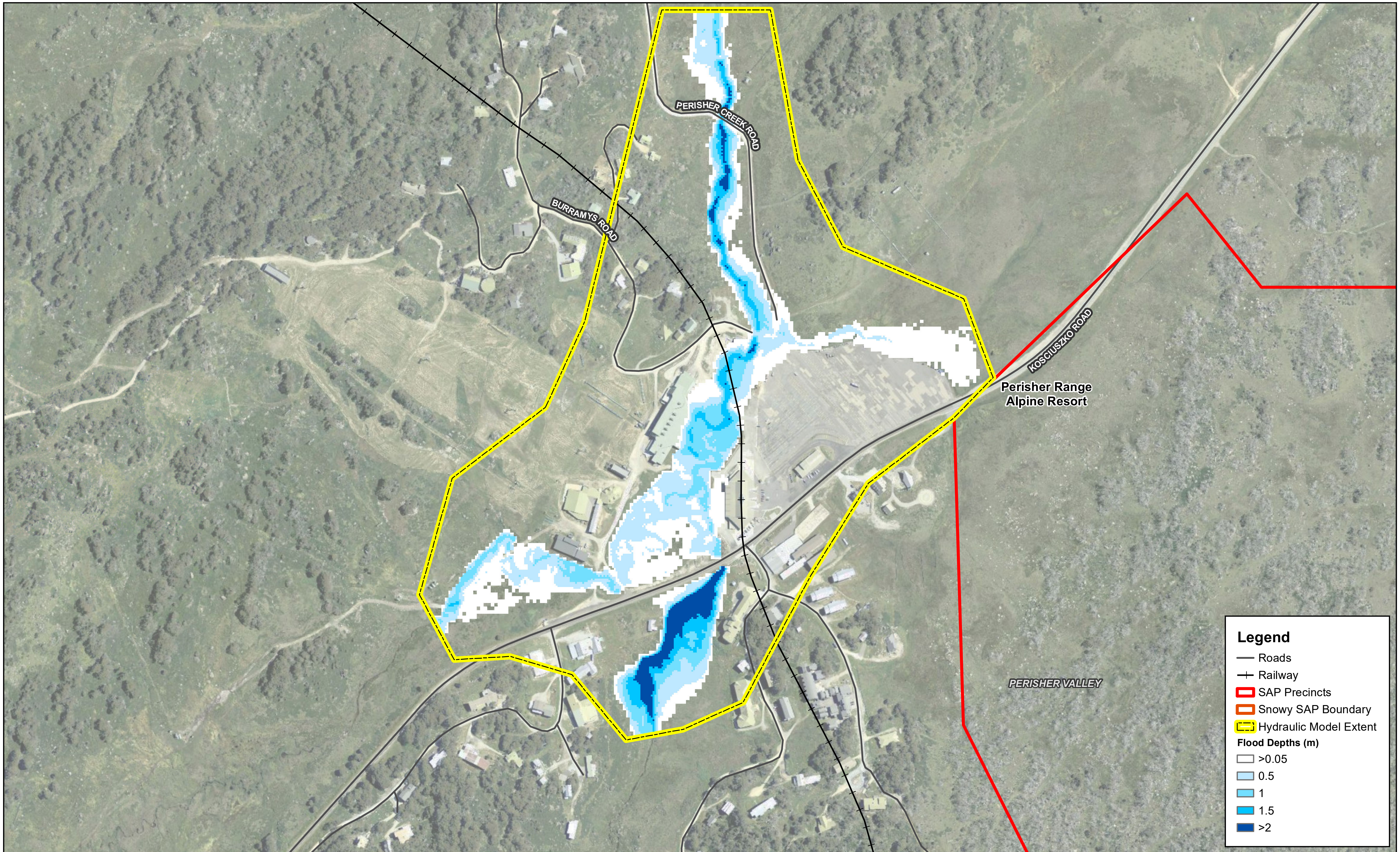
Map: PS120074_GIS_046_A1	Author: David.Naiken
Date: 07.10.2020	Approved by: Joel.Sercombe

0 75 150 m
1:10,000

Coordinate System: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

Snowy SAP - Flood Mapping

Figure 15: 0.5% AEP Flood - Peak Flood Depth - Thredbo Valley



Map: PS120074_GIS_047_A1	Author: David.Naiken	
Date: 07.10.2020	Approved by: Joel.Sercombe	

0 30 60 m
1:5,000

Imagery © Department of Customer Service 2020
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

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Snowy SAP - Flood Mapping

Figure 16: 0.5% AEP Flood - Peak Flood Depth - Perisher Valley

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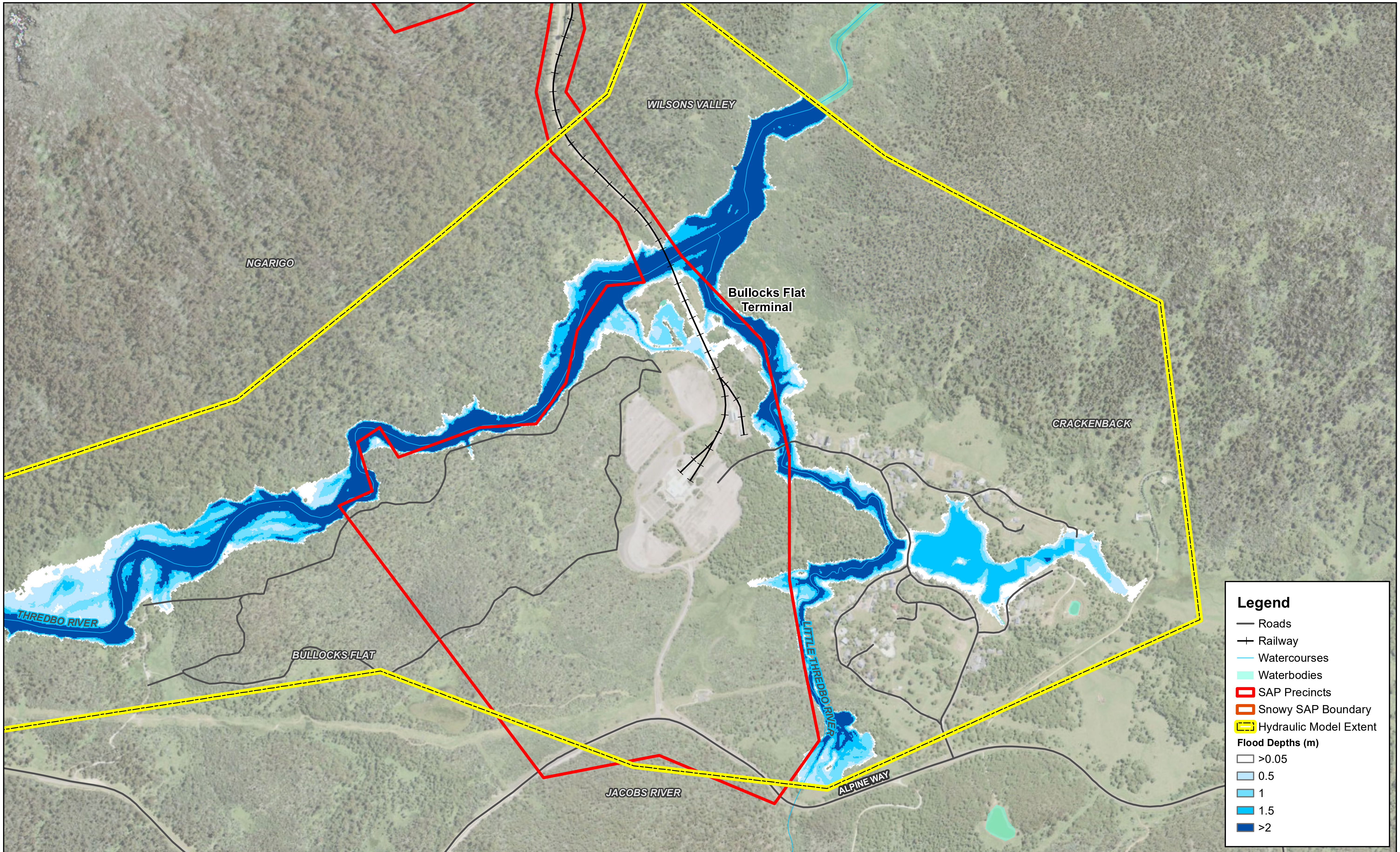
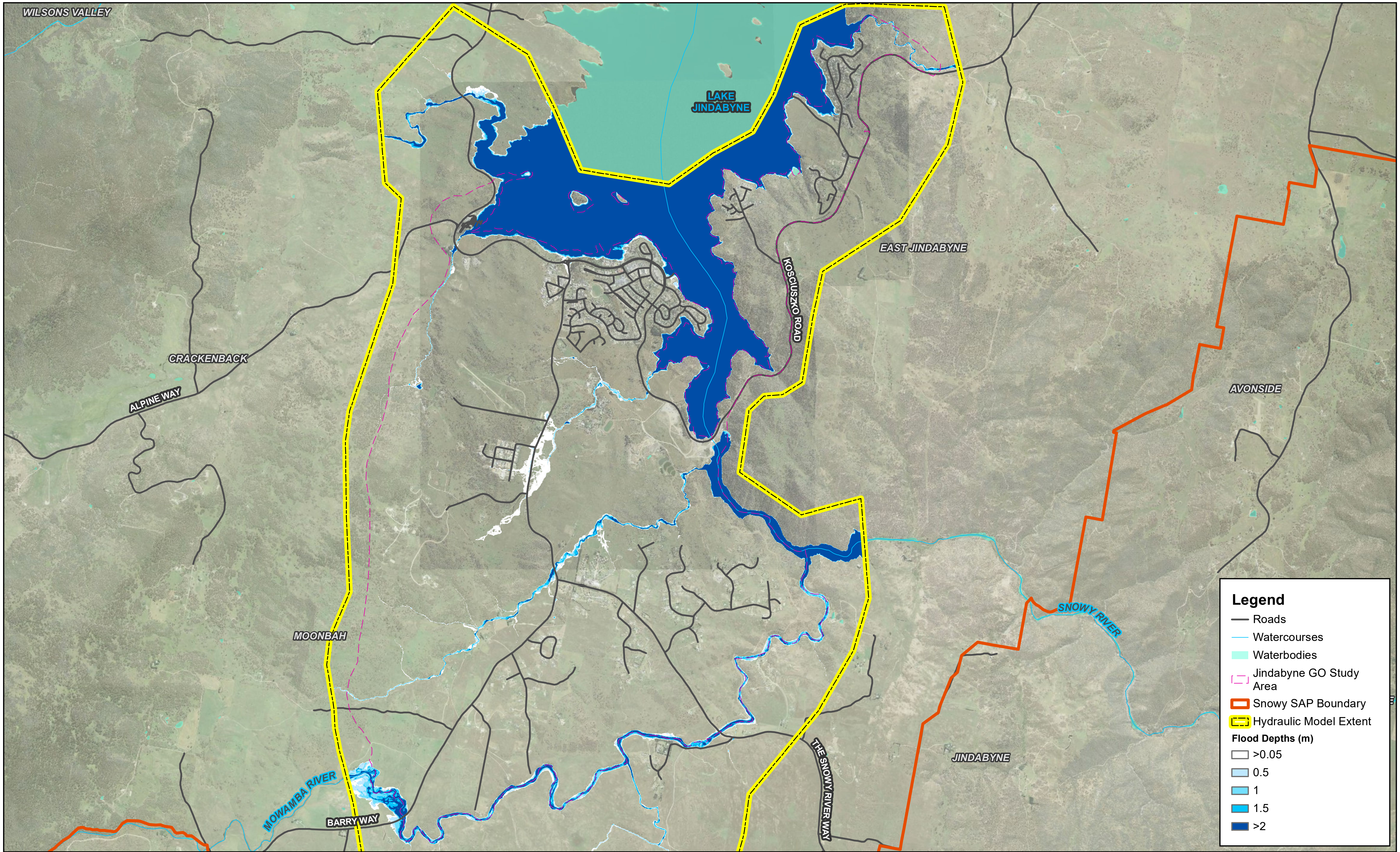


Map: PS120074_GIS_048_A1	Author: David.Naiken	
Date: 07.10.2020	Approved by: Joel.Sercombe	

Coordinate System: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

Snowy SAP - Flood Mapping

Figure 17: 0.5% AEP Flood - Peak Flood Depth - Bullocks Flat

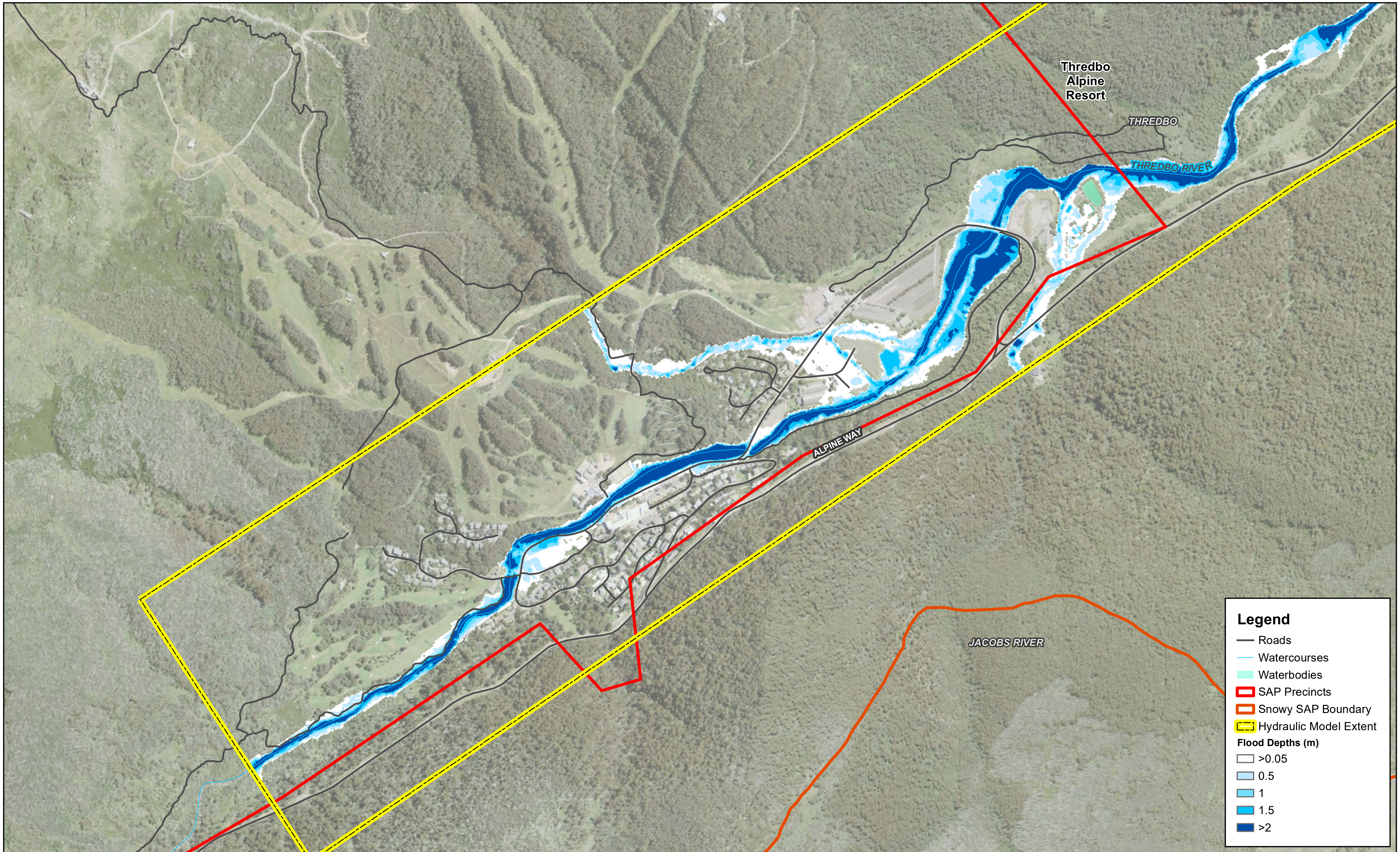


Map: PS120074_GIS_049_A2	Author: David.Naiken
Date: 15.06.2021	Approved by: Joel.Sercombe

Coordinate System: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

Snowy SAP - Flood Mapping

Figure 18: 0.2% AEP Flood - Peak Flood Depth - Jindabyne



Map: PS120074_GIS_050_A1	Author: David.Naiken
Date: 07.10.2020	Approved by: Joel.Sercombe

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1:10,000

Coordinate System: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

Imagery © Department of Customer Service 2020
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

Snowy SAP - Flood Mapping

Figure 19: 0.2% AEP Flood - Peak Flood Depth - Thredbo Valley

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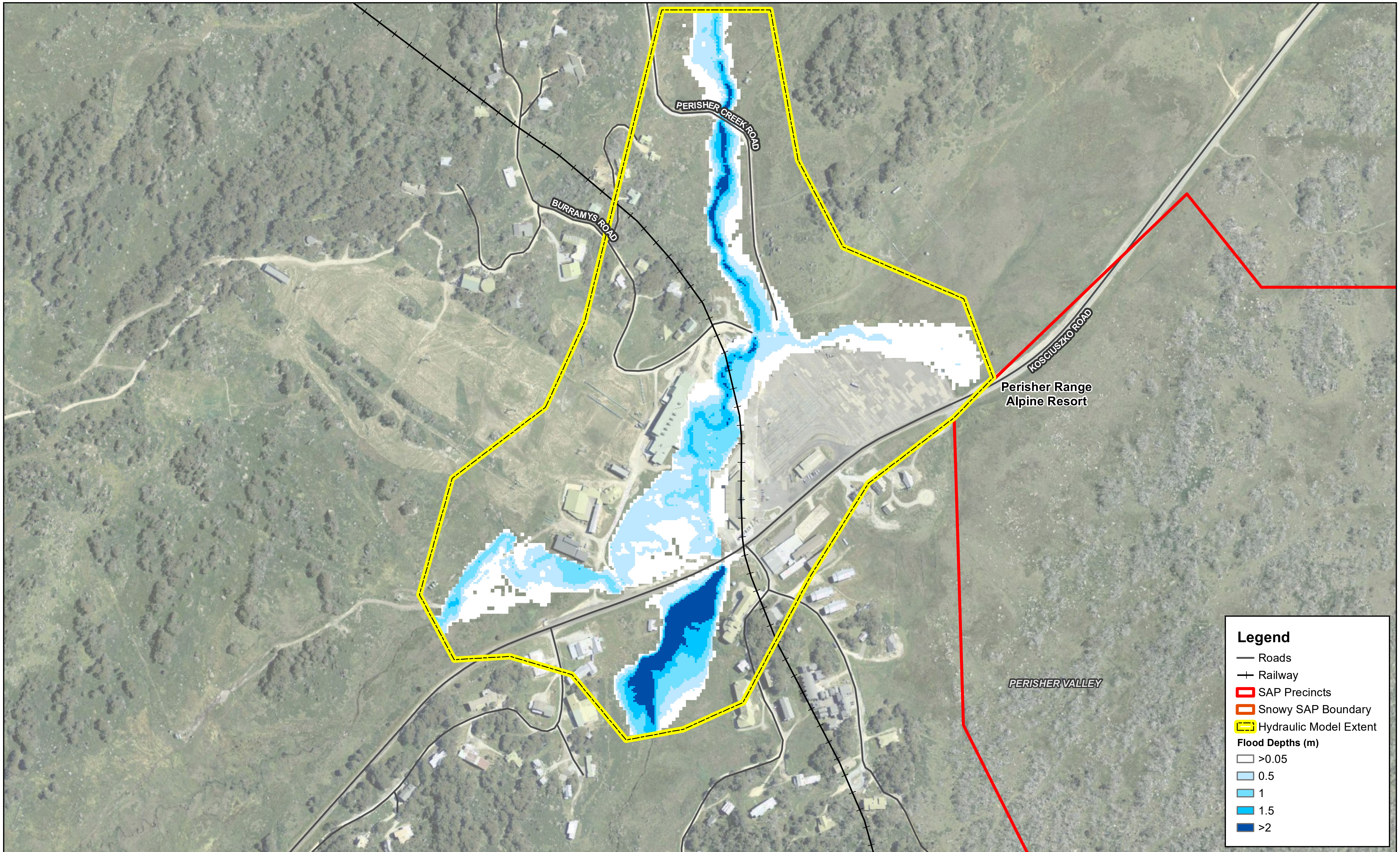

Map: PS120074_GIS_051_A1	Author: David.Naiken
Date: 07.10.2020	Approved by: Joel.Sercombe

0 30 60 m
1:5,000

Coordinate System: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

Imagery © Department of Customer Service 2020
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

Snowy SAP - Flood Mapping

Figure 20: 0.2% AEP Flood - Peak Flood Depth - Perisher Valley

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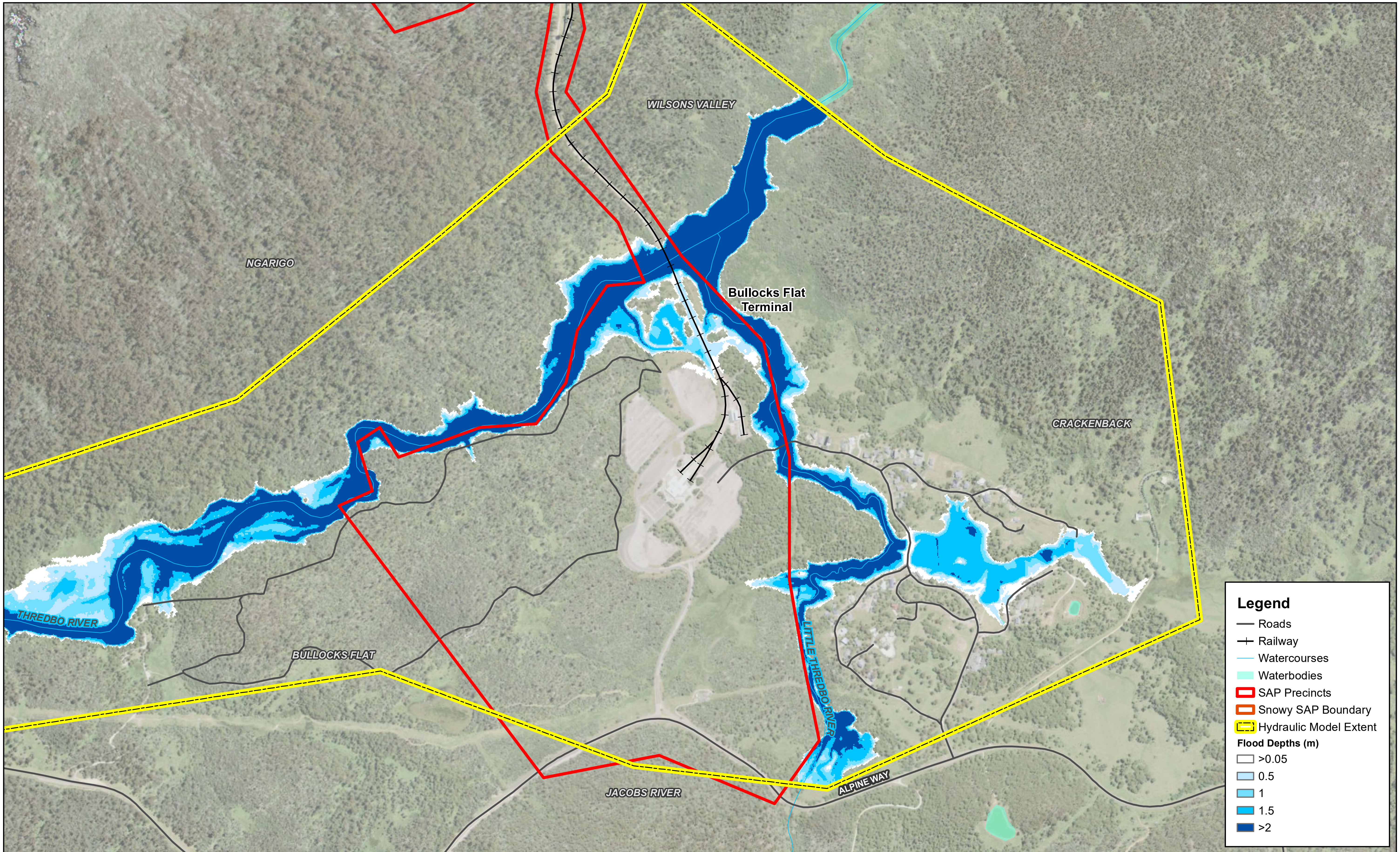

Map: PS120074_GIS_052_A1	Author: David.Naiken
Date: 07.10.2020	Approved by: Joel.Sercombe

0 70 140 m
1:10,000

Imagery © Department of Customer Service 2020
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

Coordinate System: GDA 1994 MGA Zone 55
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Snowy SAP - Flood Mapping

Figure 21: 0.2% AEP Flood - Peak Flood Depth - Bullocks Flat

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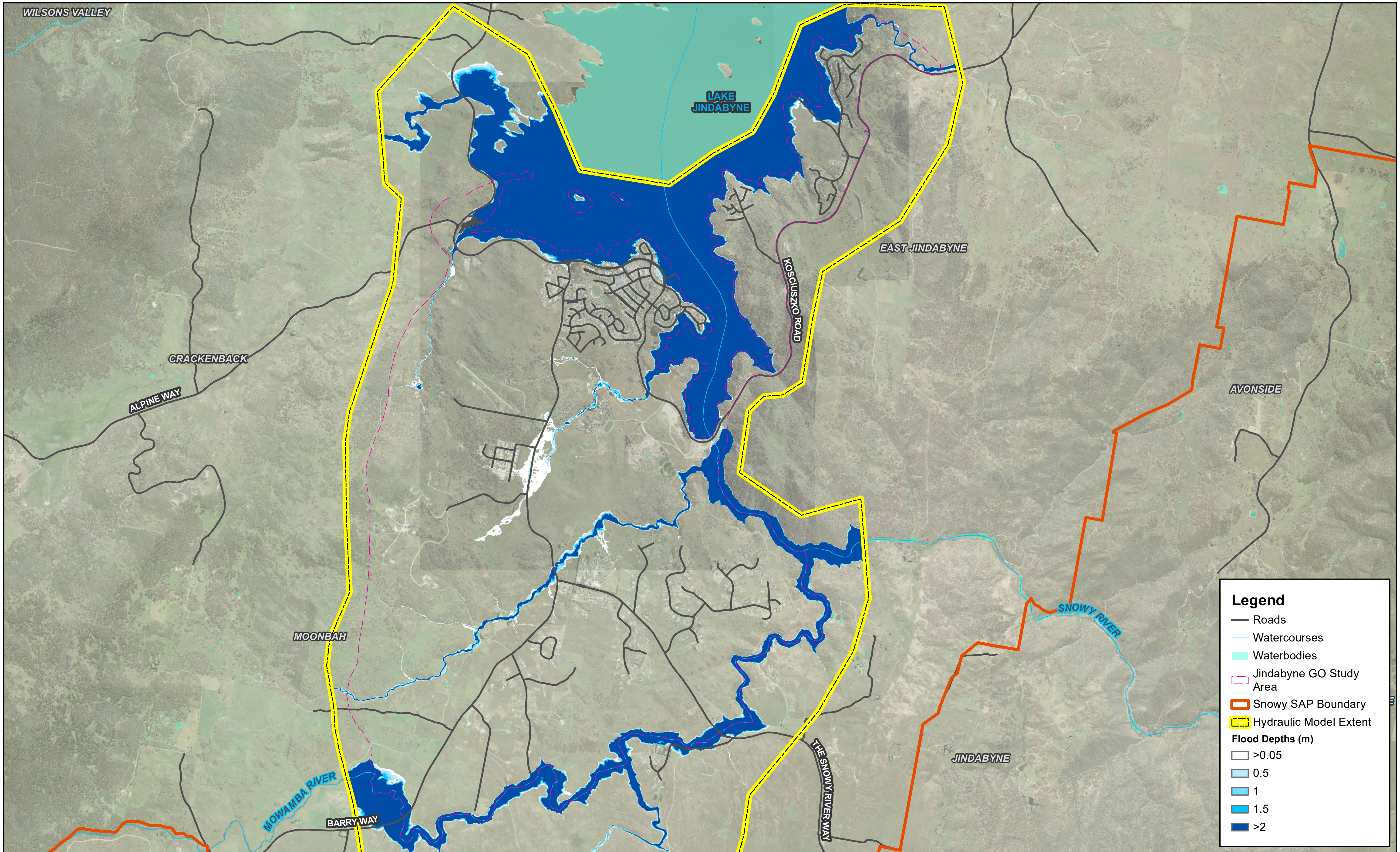

Map: PS120074_GIS_053_A2	Author: David.Naiken
Date: 15.06.2021	Approved by: Joel.Sercombe

0 340 680 m
1:45,000

Imagery © Department of Customer Service 2020
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

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Snowy SAP - Flood Mapping

Figure 22: PMF Flood - Peak Flood Depth - Jindabyne

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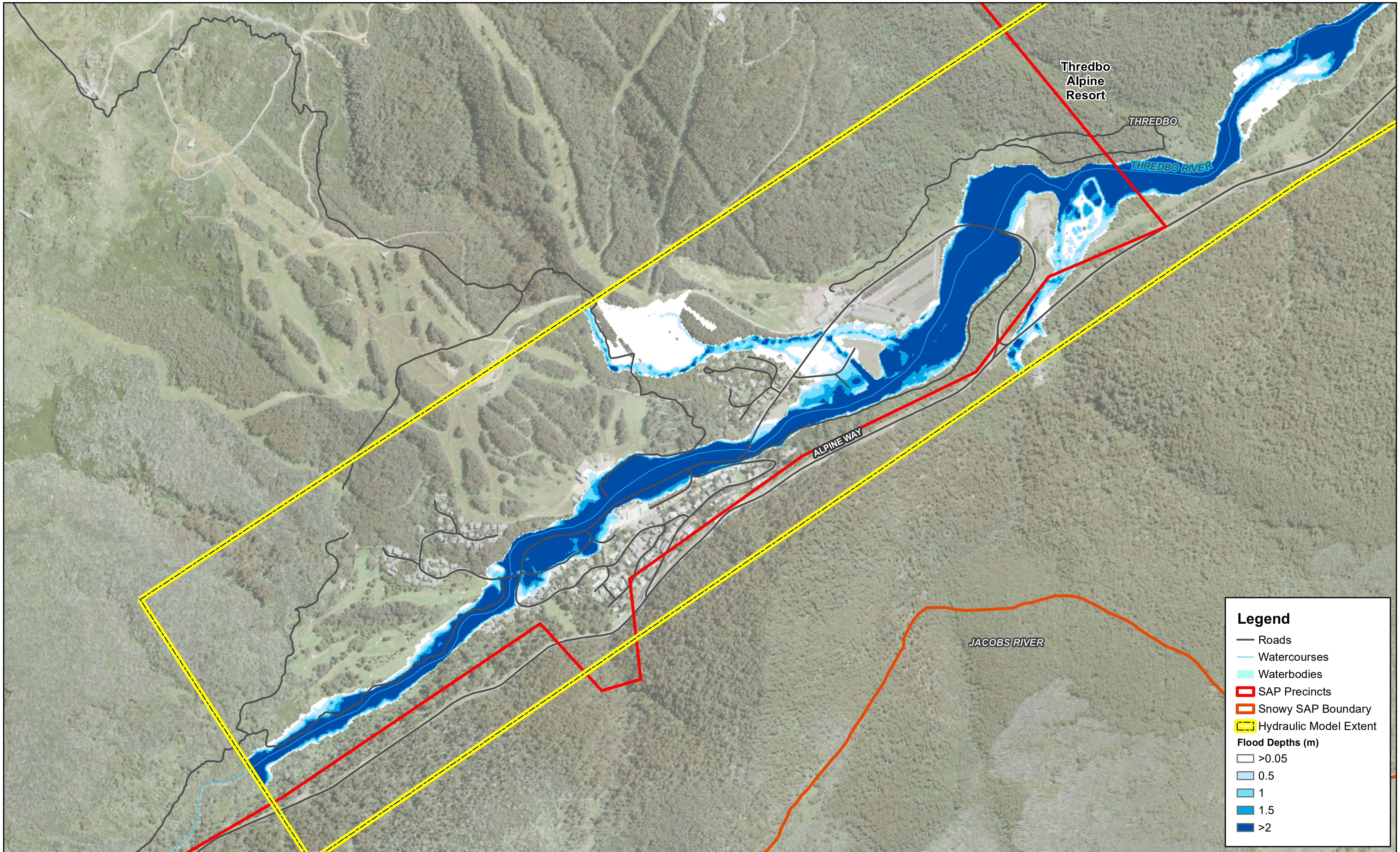

Map: PS120074_GIS_054_A1	Author: David.Naiken
Date: 08.10.2020	Approved by: Joel.Sercombe

0 70 140 m
1:10,000

Coordinate System: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

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Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

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Figure 23: PMF Flood - Peak Flood Depth - Thredbo Valley

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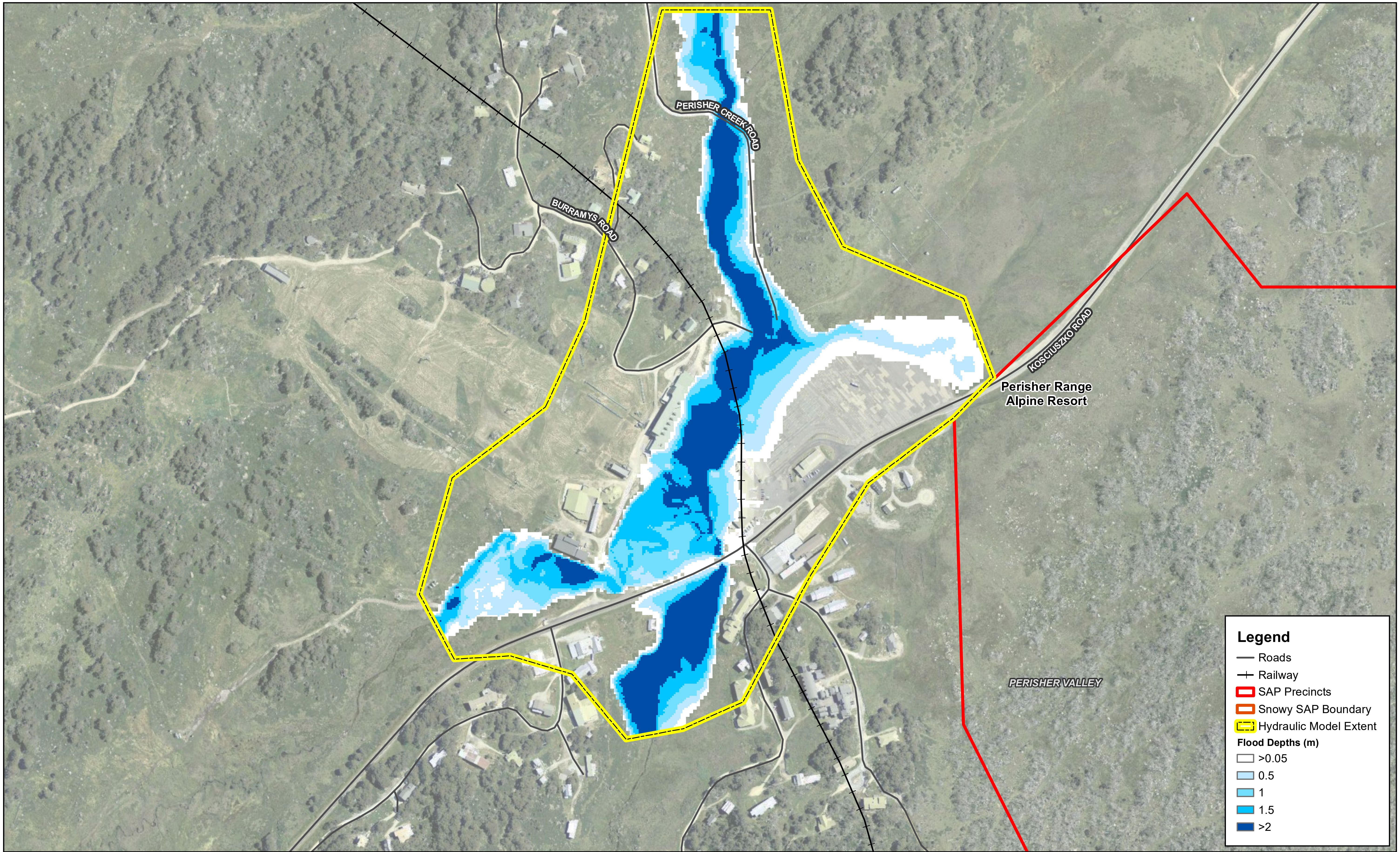

Map: PS120074_GIS_055_A1	Author: David.Naiken	
Date: 08.10.2020	Approved by: Joel.Sercombe	

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1:5,000

Coordinate System: GDA 1994 MGA Zone 55
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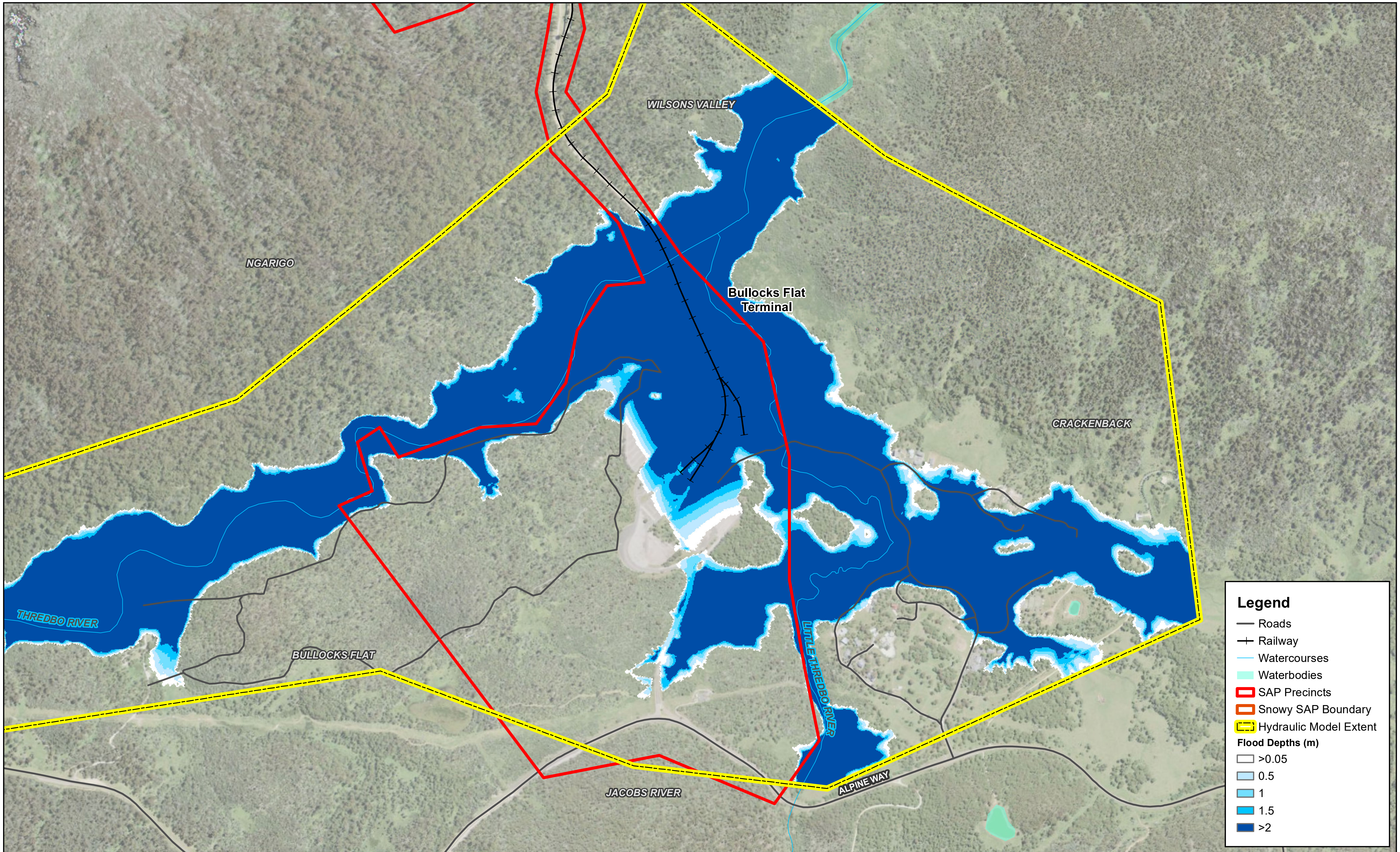
Snowy SAP - Flood Mapping

Figure 24: PMF Flood - Peak Flood Depth - Perisher Valley



Map: PS120074_GIS_056_A1	Author: David.Naiken
Date: 08.10.2020	Approved by: Joel.Sercombe

0 70 140 m
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Coordinate System: GDA 1994 MGA Zone 55
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Figure 25: PMF Flood - Peak Flood Depth - Bullocks Flat

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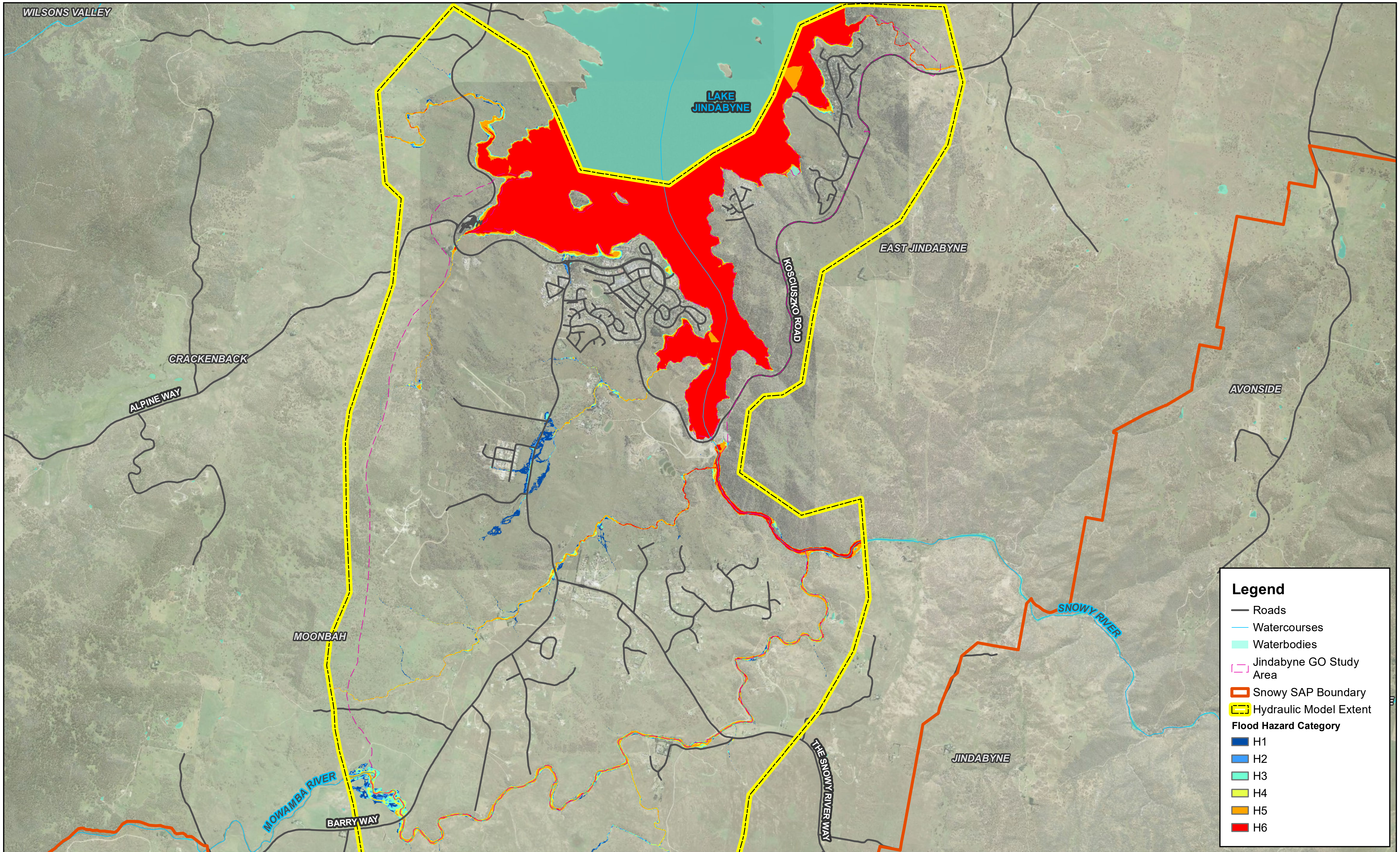

Map: PS120074_GIS_057_A2	Author: David.Naiken
Date: 15.06.2021	Approved by: Joel.Sercombe

Coordinate System: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

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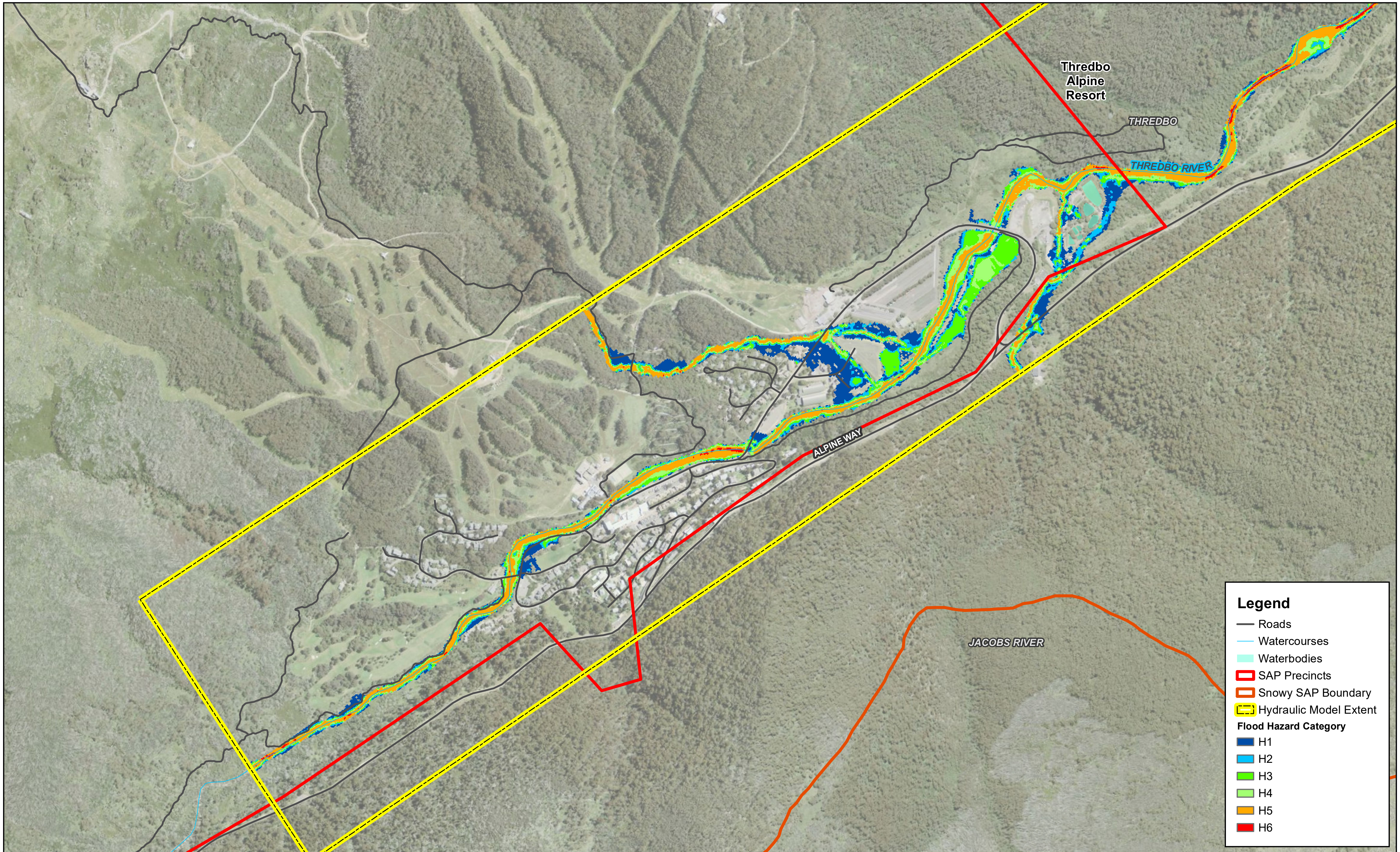
Figure 26: 10% AEP Flood - Peak Flood Hazard - Jindabyne



Map: PS120074_GIS_058_A1	Author: David.Naiken
Date: 07.10.2020	Approved by: Joel.Sercombe

0 70 140 m
1:10,000

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Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

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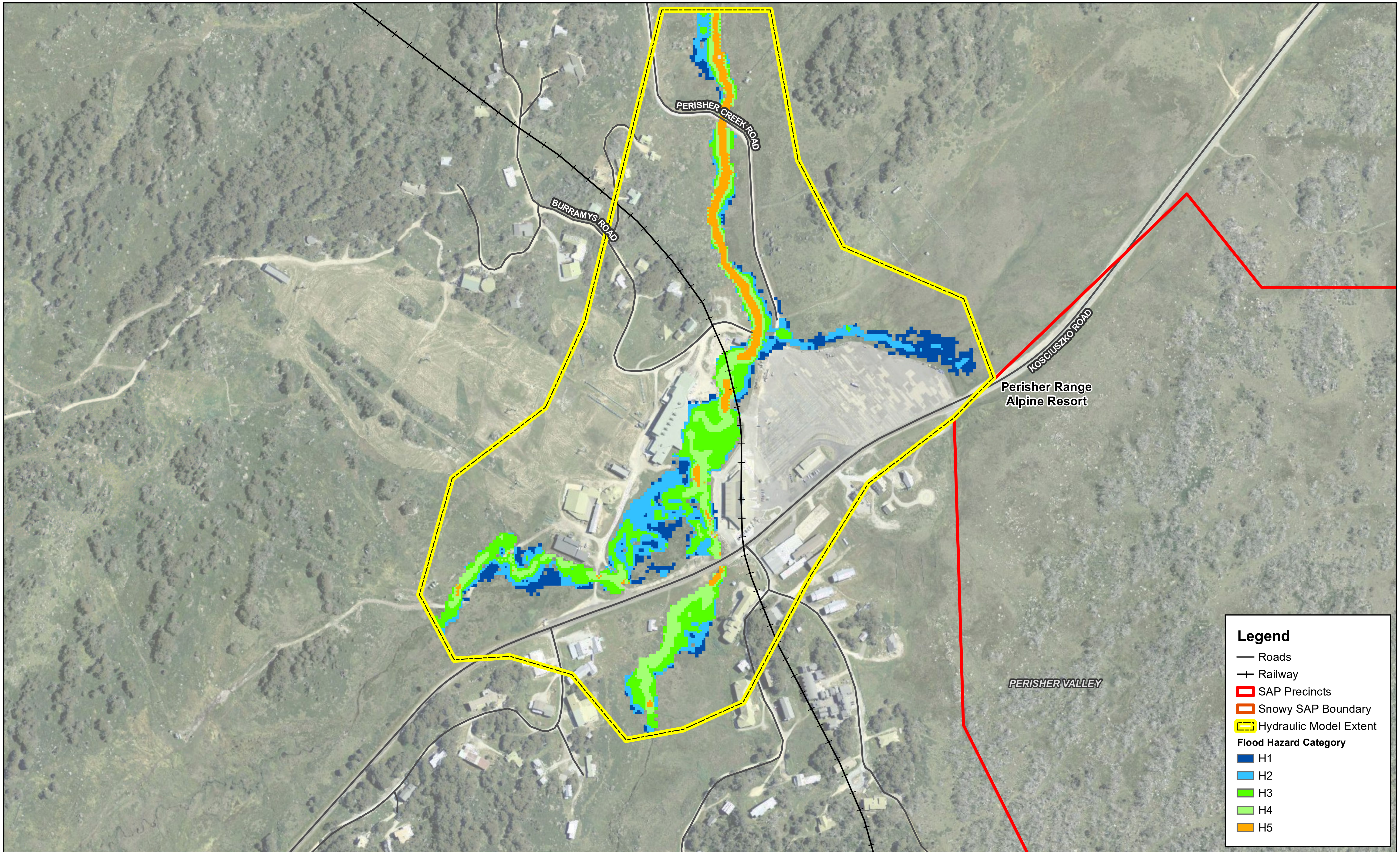
Figure 27: 10% AEP Flood - Peak Flood Hazard - Thredbo Valley



Map: PS120074_GIS_059_A1	Author: David.Naiken
Date: 07.10.2020	Approved by: Joel.Sercombe

0 30 60 m
1:5,000

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Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

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Figure 28: 10% AEP Flood - Peak Flood Hazard - Perisher Valley

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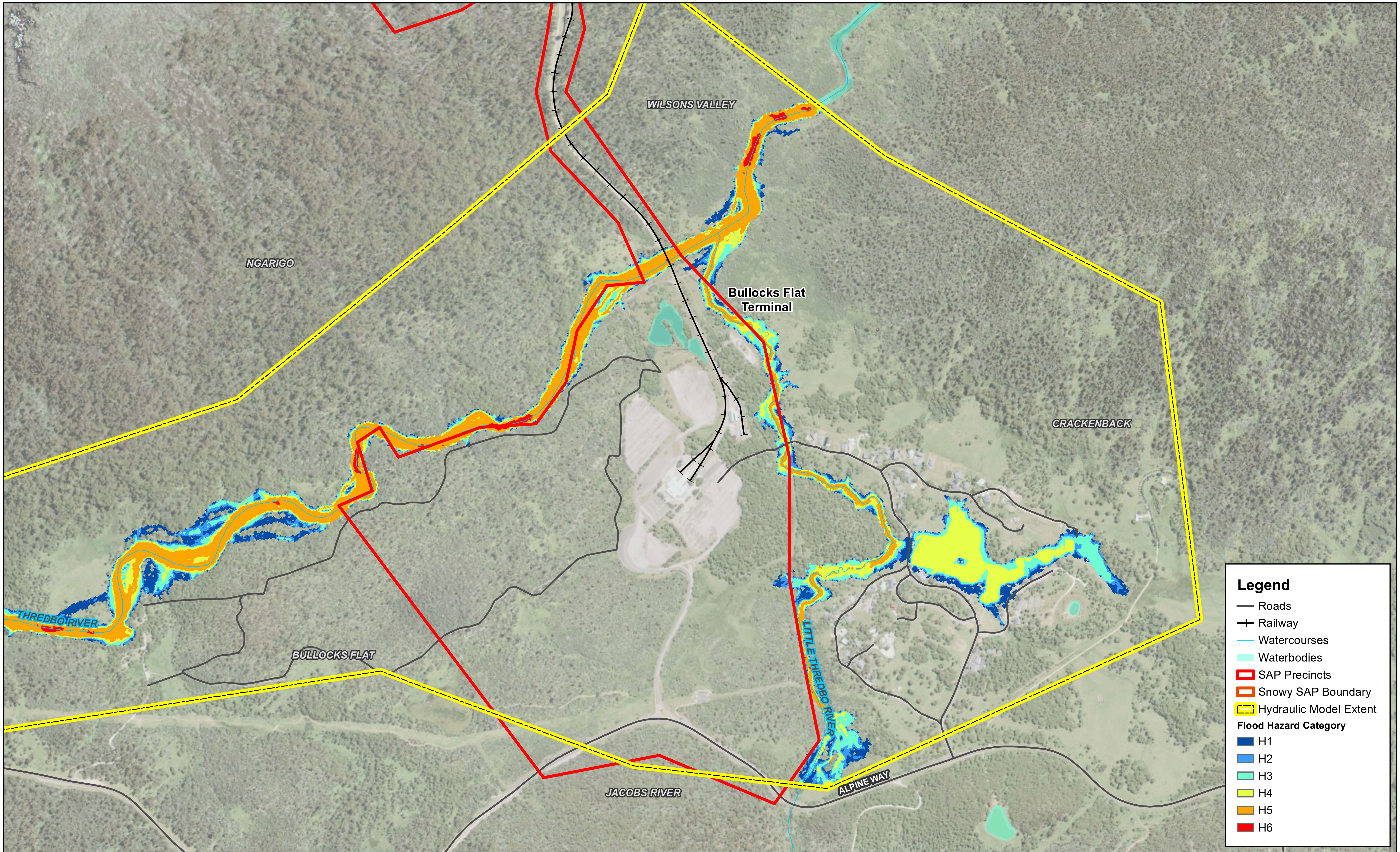

Map: PS120074_GIS_060_A1	Author: David.Naiken		Coordinate System: GDA 1994 MGA Zone 55
Date: 07.10.2020	Approved by: Joel.Sercombe		Scale ratio correct when printed at A3

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Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

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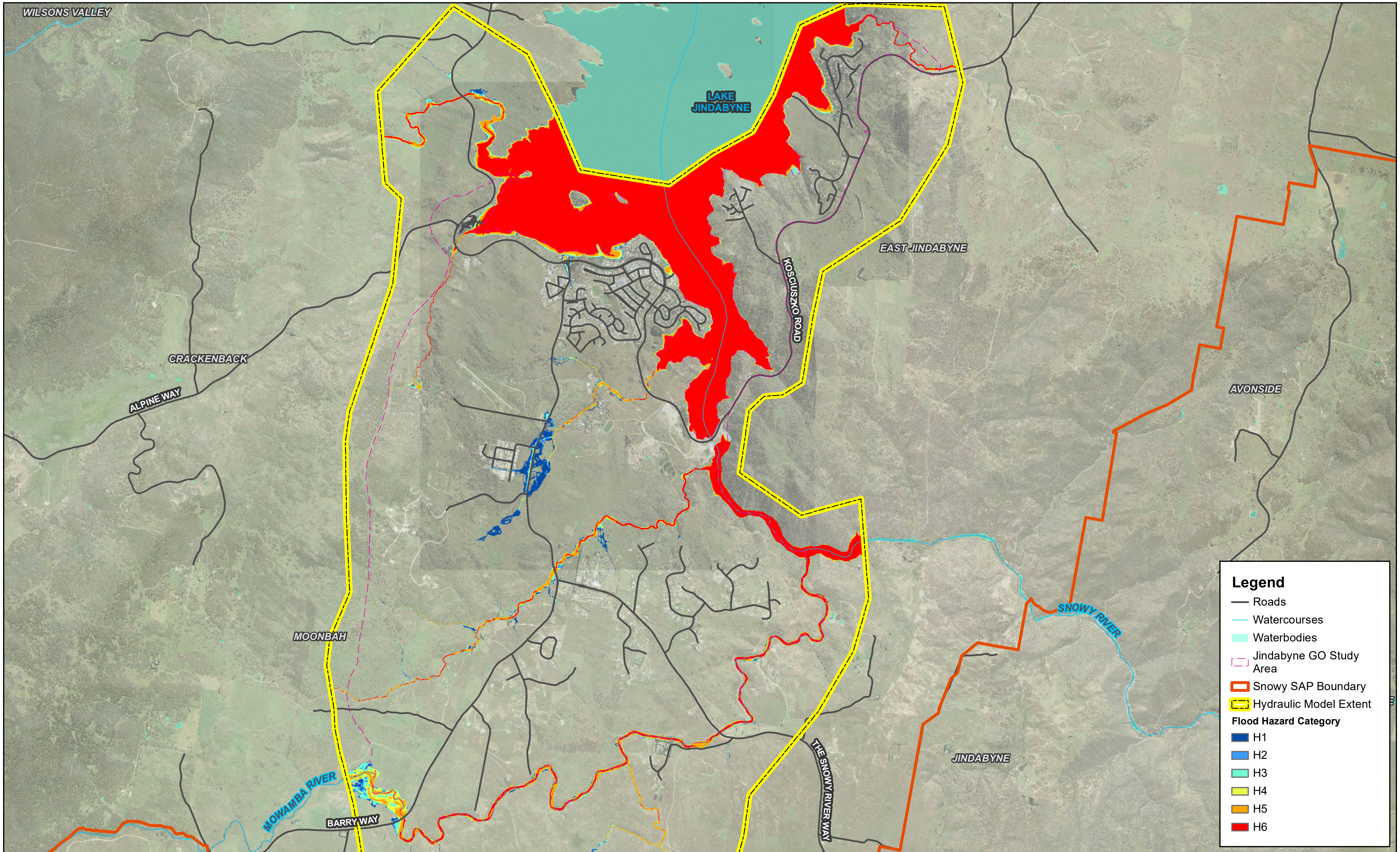
Figure 29: 10% AEP Flood - Peak Flood Hazard - Bullocks Flat



Map: PS120074_GIS_061_A2	Author: David.Naiken		0 340 680 m 1:45,000
Date: 15.06.2021	Approved by: Joel.Sercombe		

Imagery © Department of Customer Service 2020
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

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Figure 30: 1% AEP Flood - Peak Flood Hazard - Jindabyne

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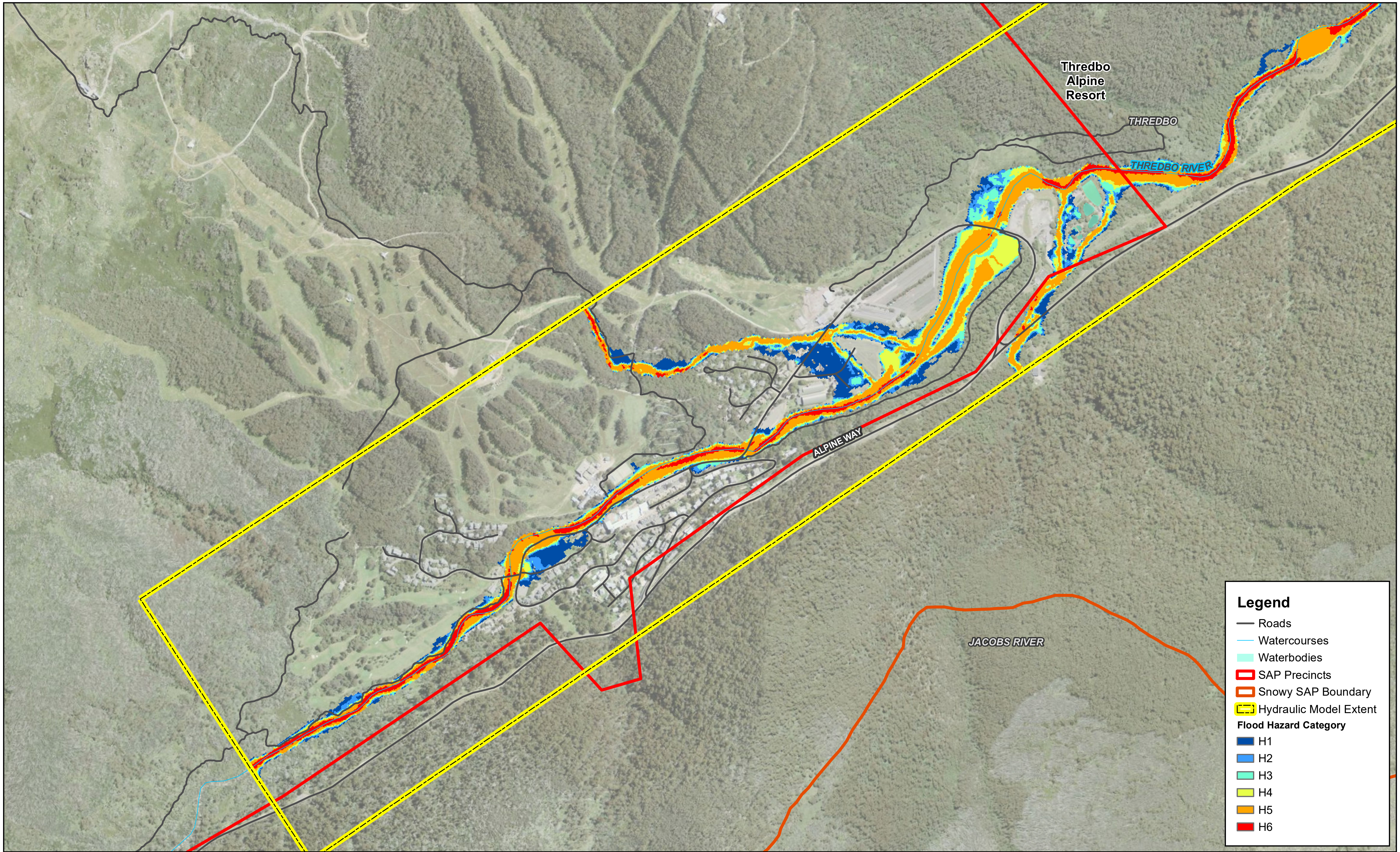

Map: PS120074_GIS_062_A1	Author: David.Naiken
Date: 07.10.2020	Approved by: Joel.Sercombe

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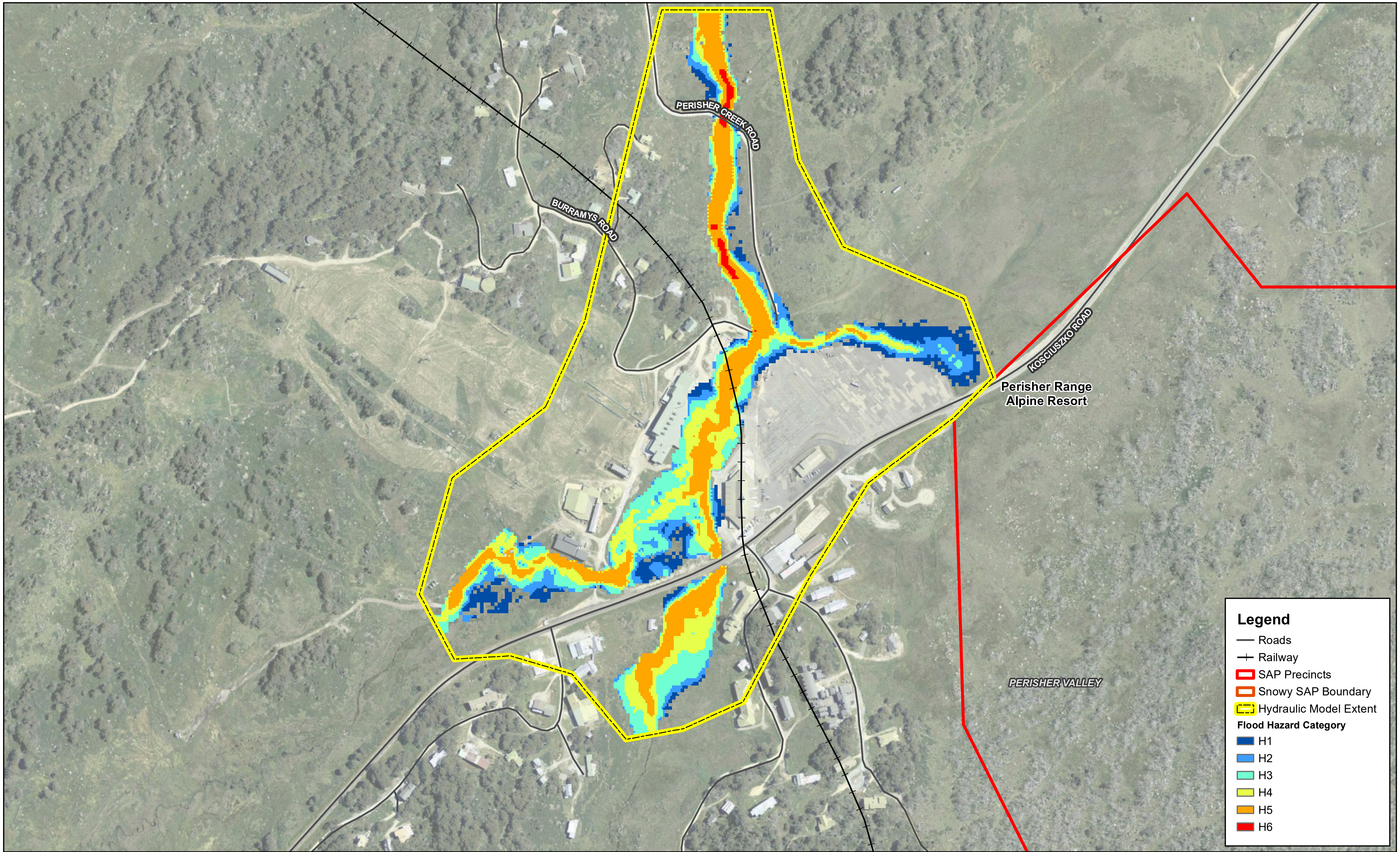
Figure 31: 1% AEP Flood - Peak Flood Hazard - Thredbo Valley



Map: PS120074_GIS_063_A1	Author: David.Naiken
Date: 07.10.2020	Approved by: Joel.Sercombe

0 30 60 m
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Figure 32: 1% AEP Flood - Peak Flood Hazard - Perisher Valley

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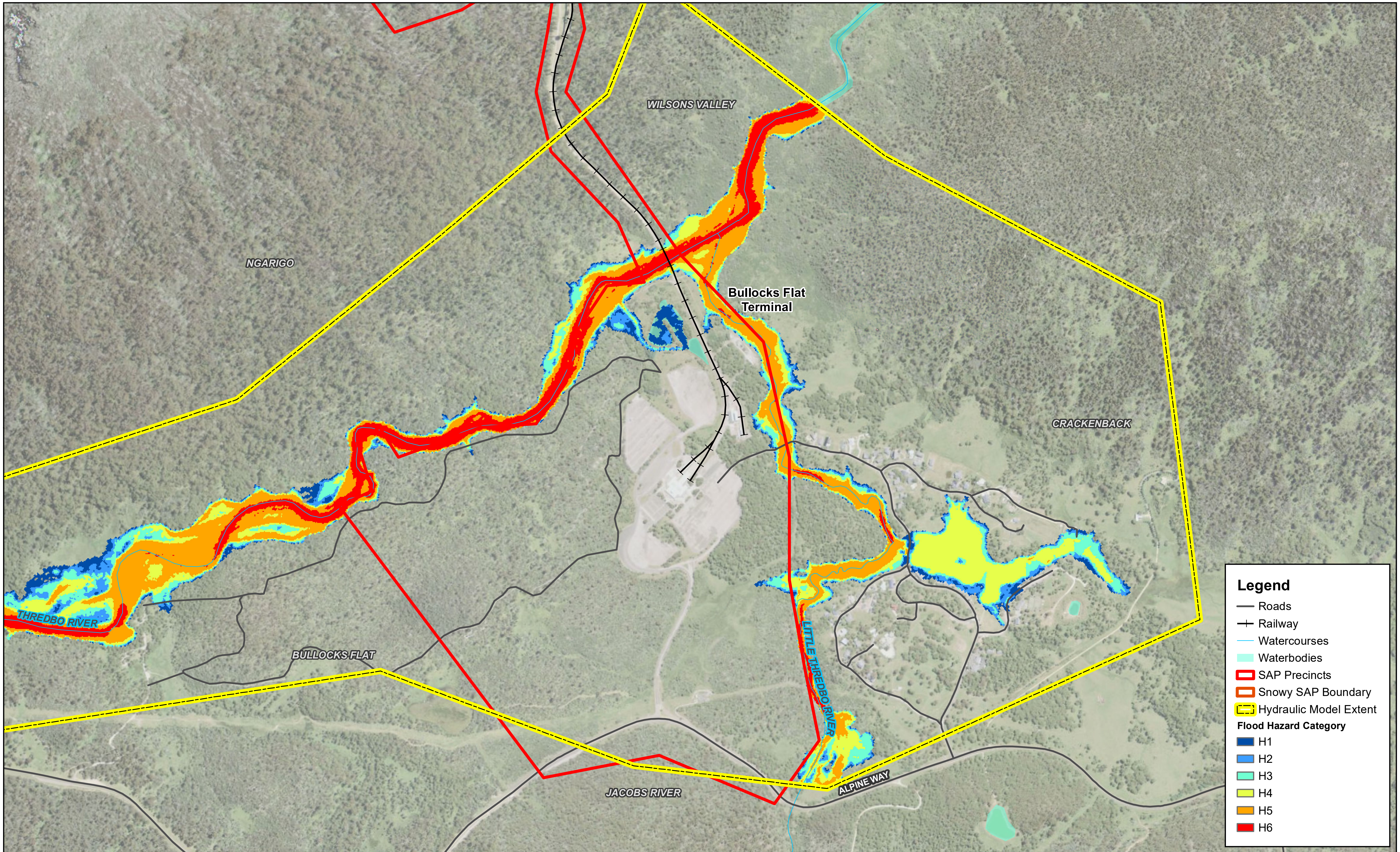

Map: PS120074_GIS_064_A1	Author: David.Naiken
Date: 07.10.2020	Approved by: Joel.Sercombe

0 70 140 m
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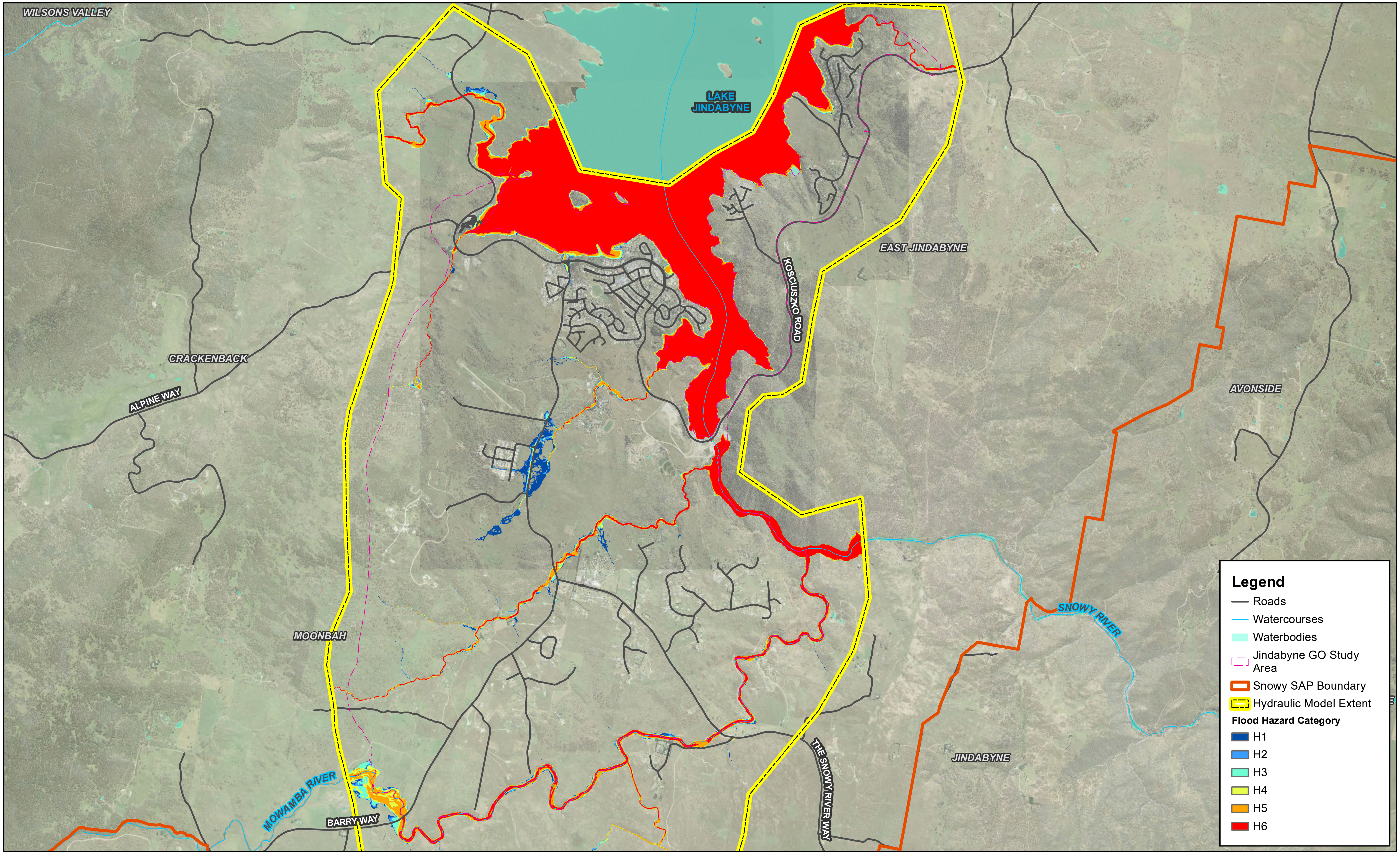
Figure 33: 1% AEP Flood - Peak Flood Hazard - Bullocks Flat



Map: PS120074_GIS_065_A2	Author: David.Naiken	
Date: 15.06.2021	Approved by: Joel.Sercombe	

Coordinate System: GDA 1994 MGA Zone 55
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Figure 34: 1% AEP Climate Change 2090 Flood - Peak Flood Hazard - Jindabyne

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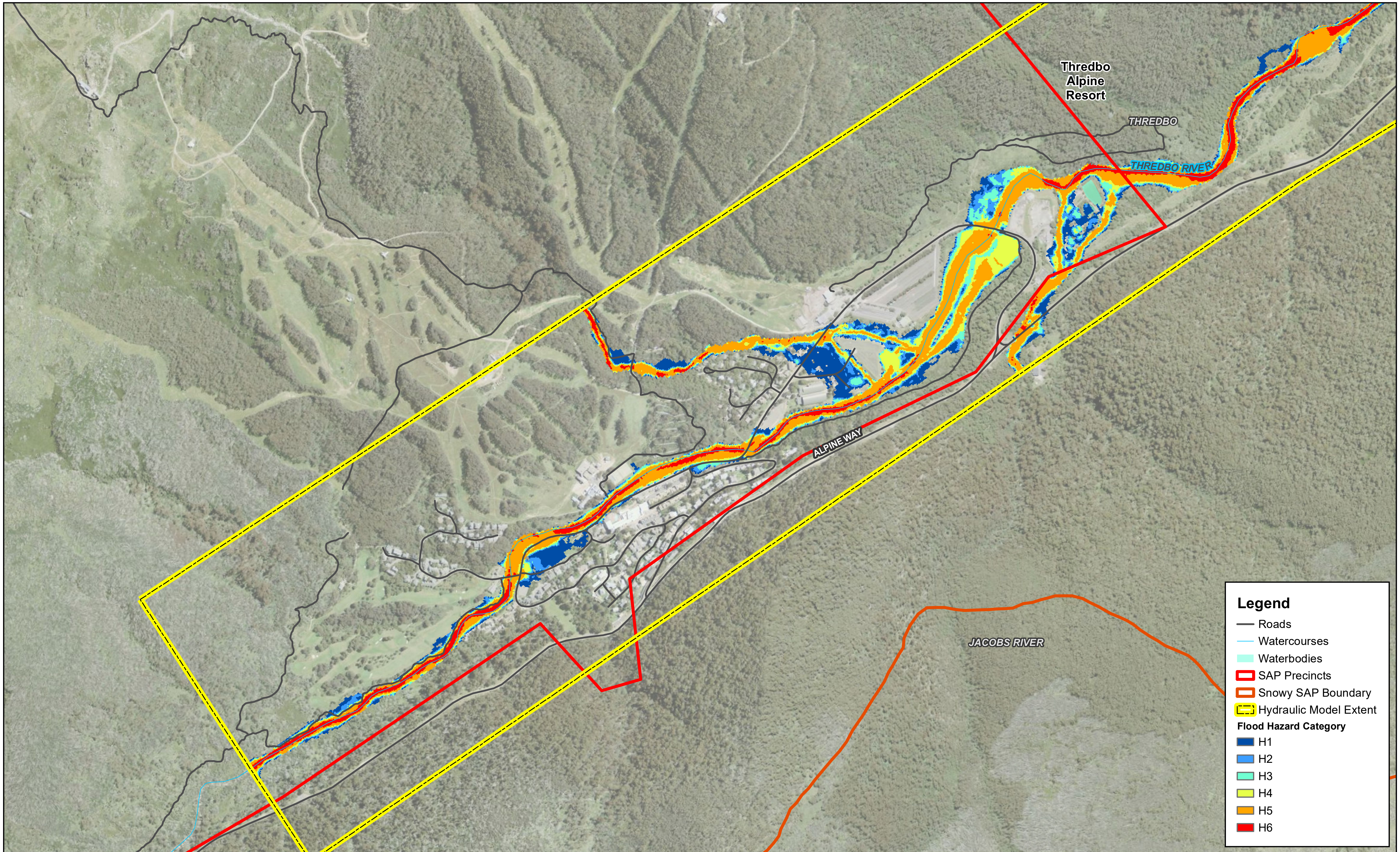

Map: PS120074_GIS_066_A1	Author: David.Naiken
Date: 08.10.2020	Approved by: Joel.Sercombe

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Coordinate System: GDA 1994 MGA Zone 55
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Figure 35: 1% AEP Climate Change 2090 Flood - Peak Flood Hazard - Thredbo Valley

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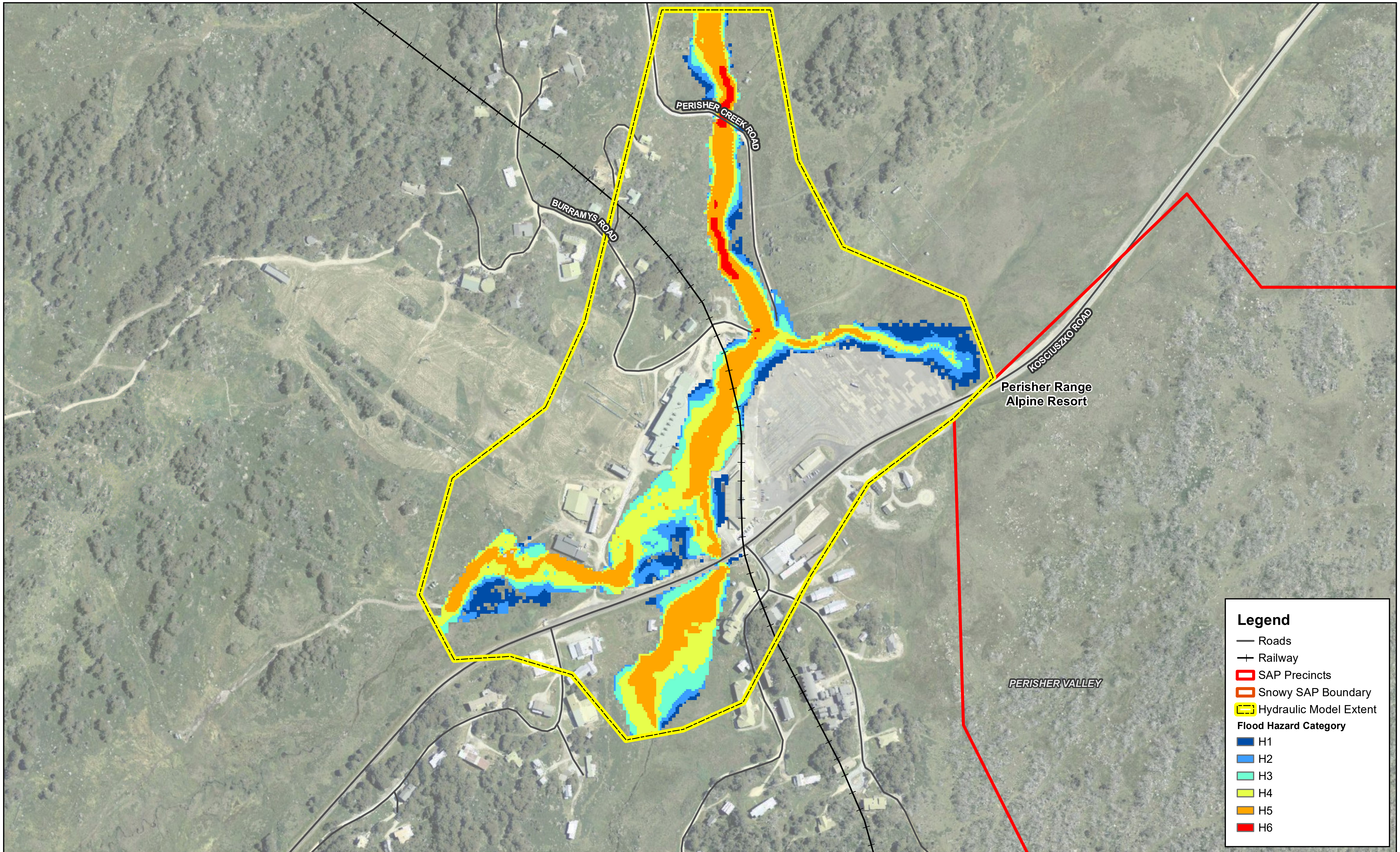

Map: PS120074_GIS_067_A1	Author: David.Naiken
Date: 08.10.2020	Approved by: Joel.Sercombe

0 30 60 m
1:5,000

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Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

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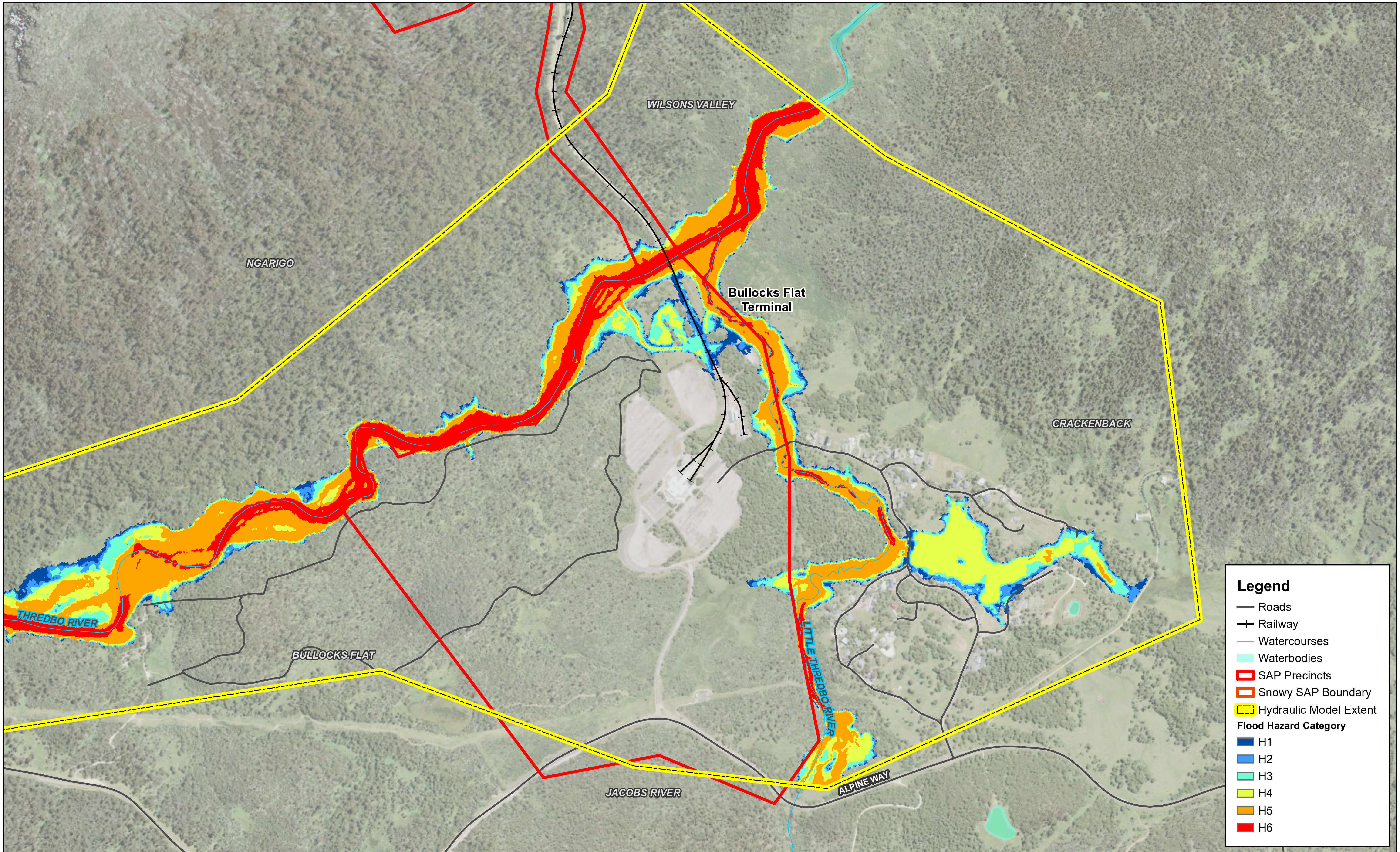
Figure 36: 1% AEP Climate Change 2090 Flood - Peak Flood Hazard - Perisher Valley



Map: PS120074_GIS_068_A1	Author: David.Naiken
Date: 08.10.2020	Approved by: Joel.Sercombe

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Coordinate System: GDA 1994 MGA Zone 55
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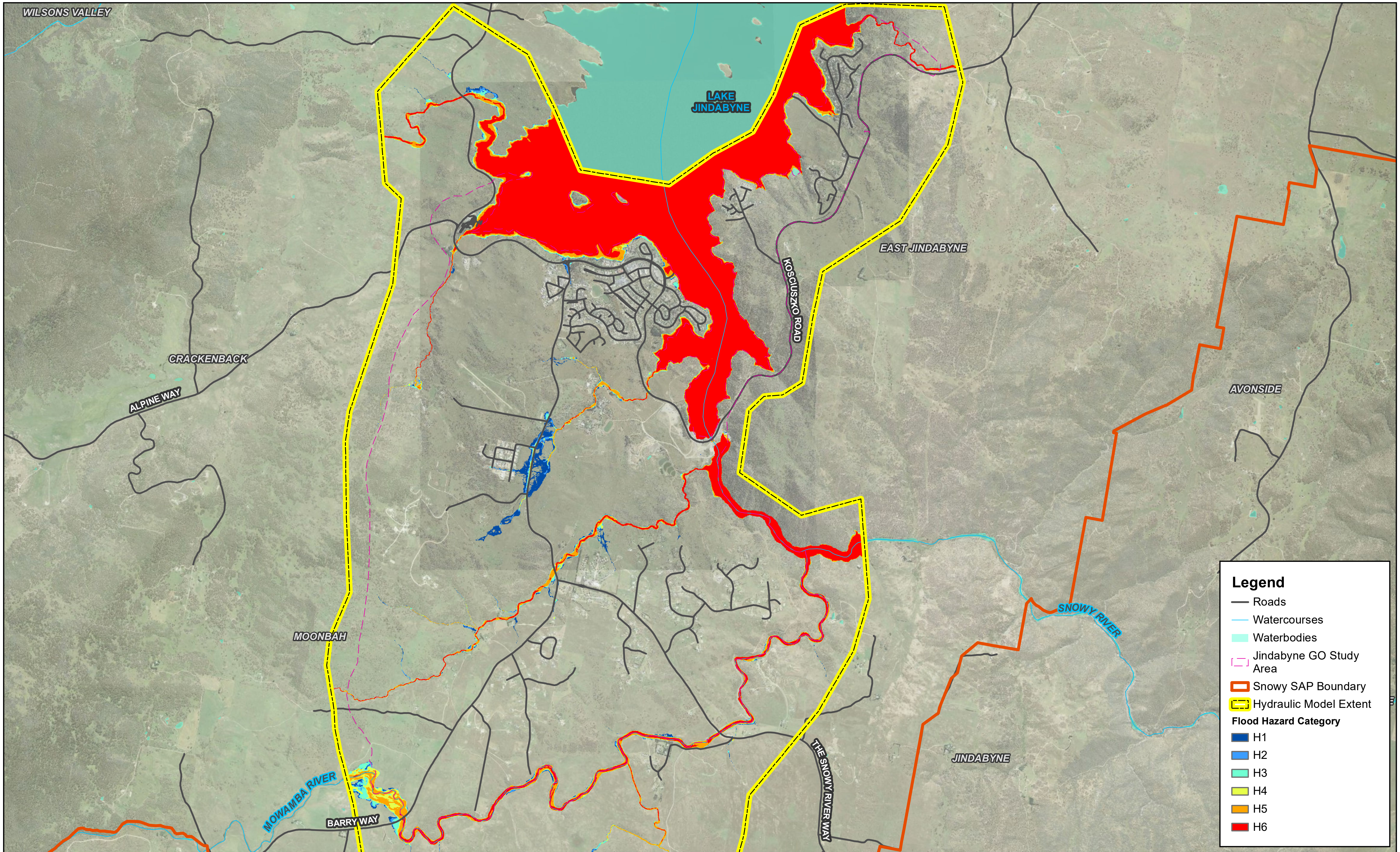
Figure 37: 1% AEP Climate Change 2090 Flood - Peak Flood Hazard - Bullocks Flat



Map: PS120074_GIS_069_A2	Author: David.Naiken
Date: 15.06.2021	Approved by: Joel.Sercombe

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Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

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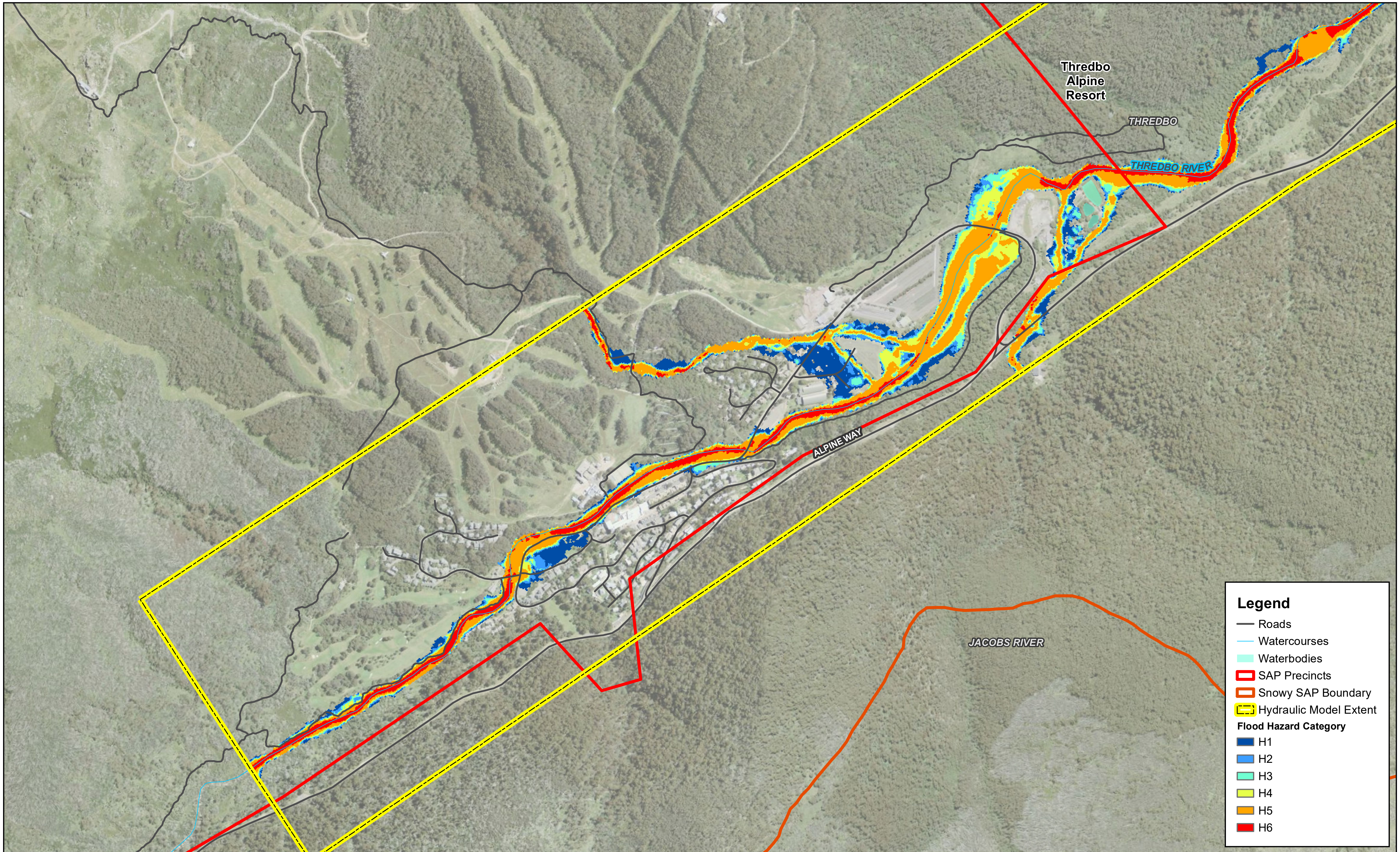
Figure 38: 0.5% AEP Flood - Peak Flood Hazard - Jindabyne



Map: PS120074_GIS_070_A1	Author: David.Naiken
Date: 08.10.2020	Approved by: Joel.Sercombe

0 70 140 m
1:10,000

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Figure 39: 0.5% AEP Flood - Peak Flood Hazard - Thredbo Valley

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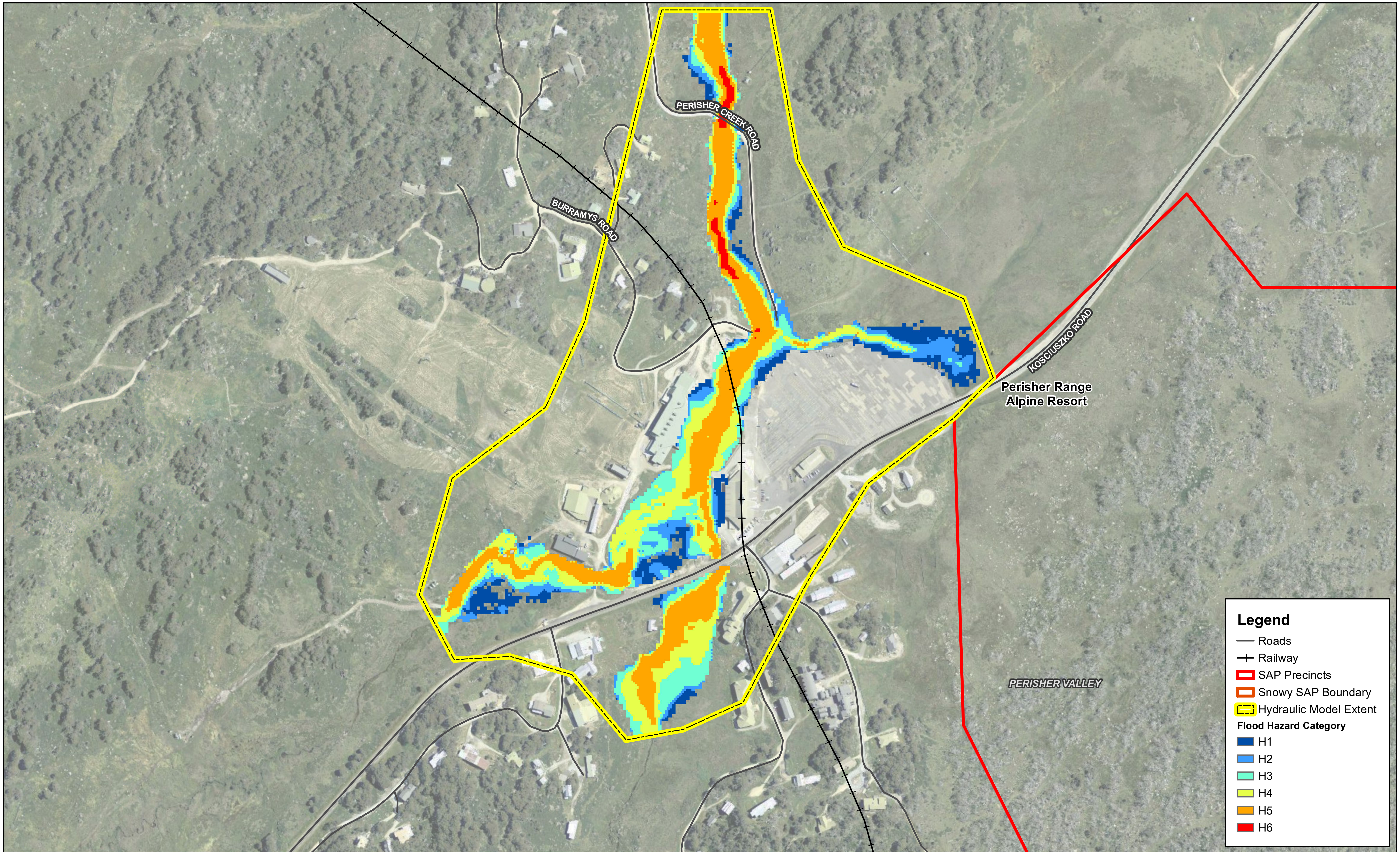

Map: PS120074_GIS_071_A1	Author: David.Naiken
Date: 08.10.2020	Approved by: Joel.Sercombe

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Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

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Figure 40: 0.5% AEP Flood - Peak Flood Hazard - Perisher Valley

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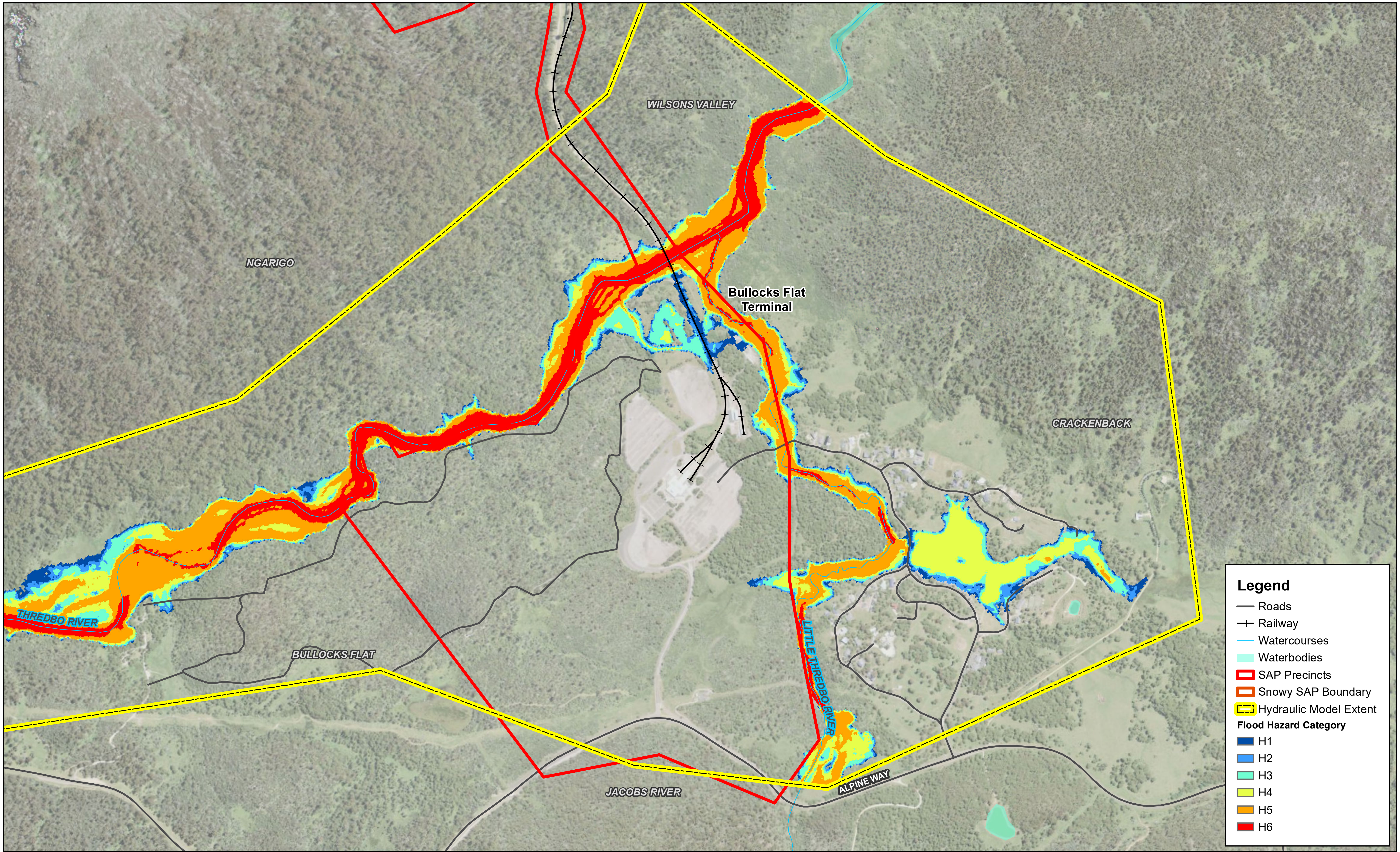

Map: PS120074_GIS_072_A1	Author: David.Naiken
Date: 08.10.2020	Approved by: Joel.Sercombe

0 70 140 m
1:10,000

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Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

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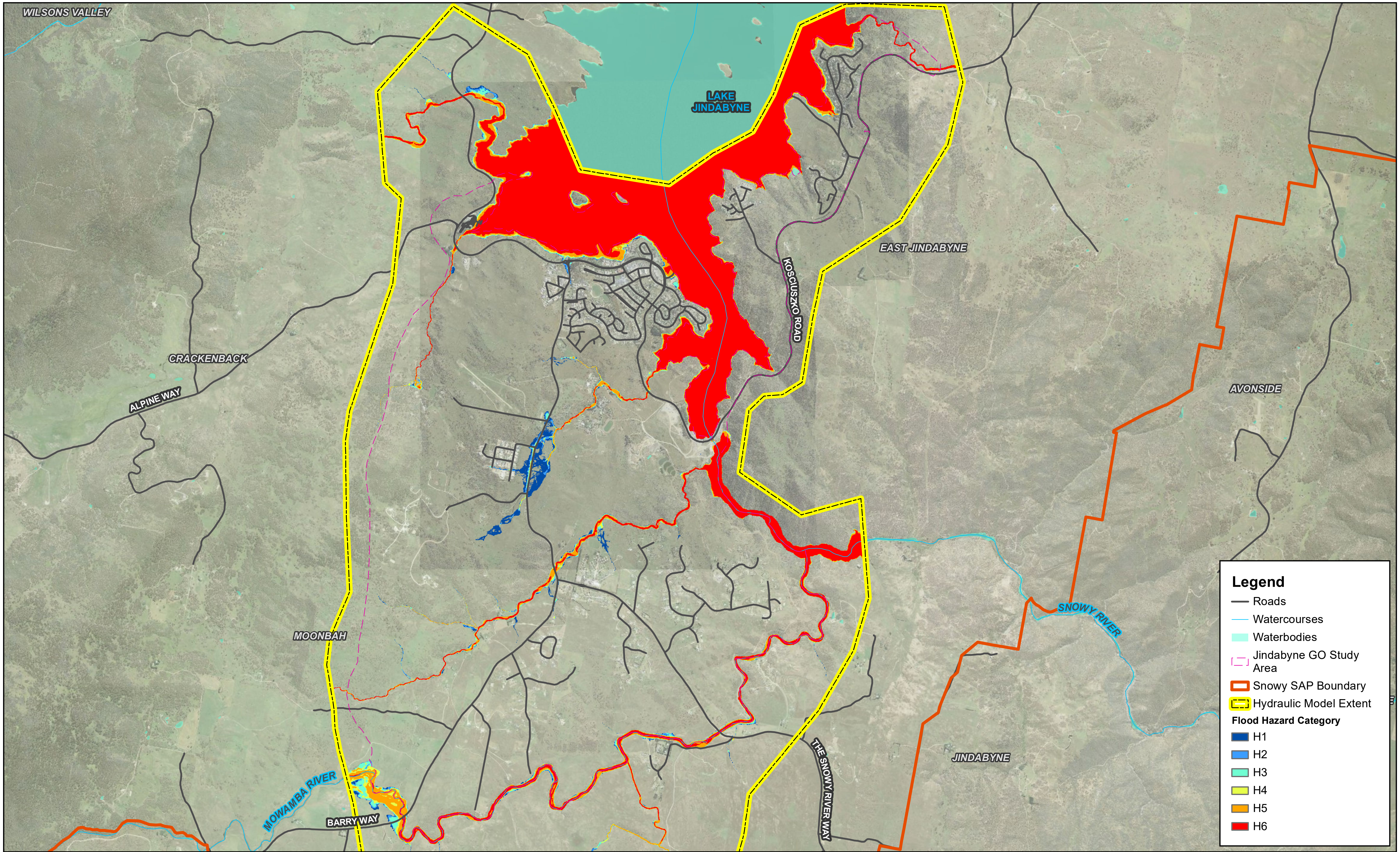
Figure 41: 0.5% AEP Flood - Peak Flood Hazard - Bullocks Flat



Map: PS120074_GIS_073_A2	Author: David.Naiken
Date: 15.06.2021	Approved by: Joel.Sercombe

0 340 680 m
1:45,000

Imagery © Department of Customer Service 2020
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

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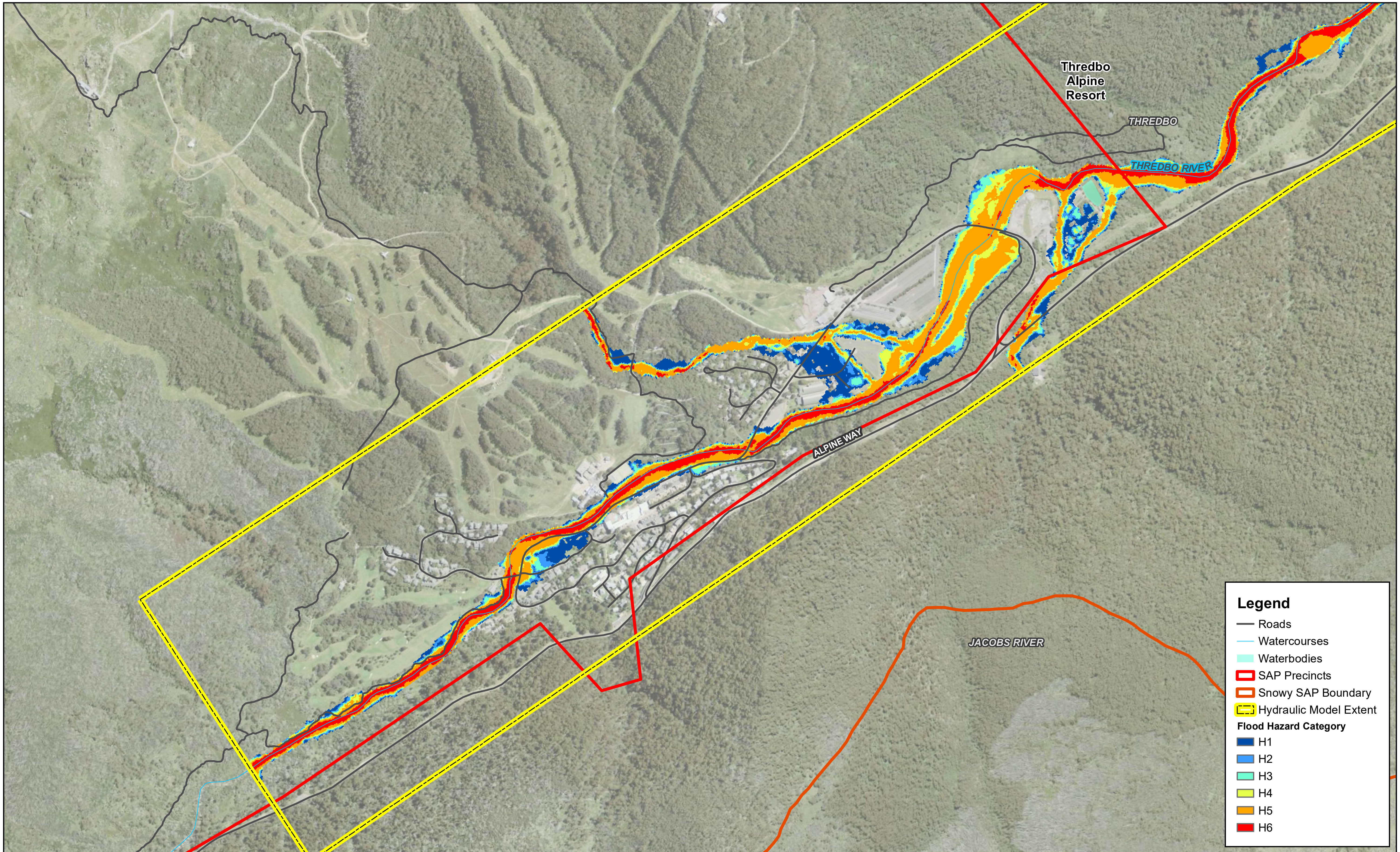
Snowy SAP - Flood Mapping

Figure 42: 0.2% AEP Flood - Peak Flood Hazard - Jindabyne



Map: PS120074_GIS_074_A1	Author: David.Naiken
Date: 08.10.2020	Approved by: Joel.Sercombe

0 70 140 m
1:10,000

Coordinate System: GDA 1994 MGA Zone 55
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Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

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Figure 43: 0.2% AEP Flood - Peak Flood Hazard - Thredbo Valley

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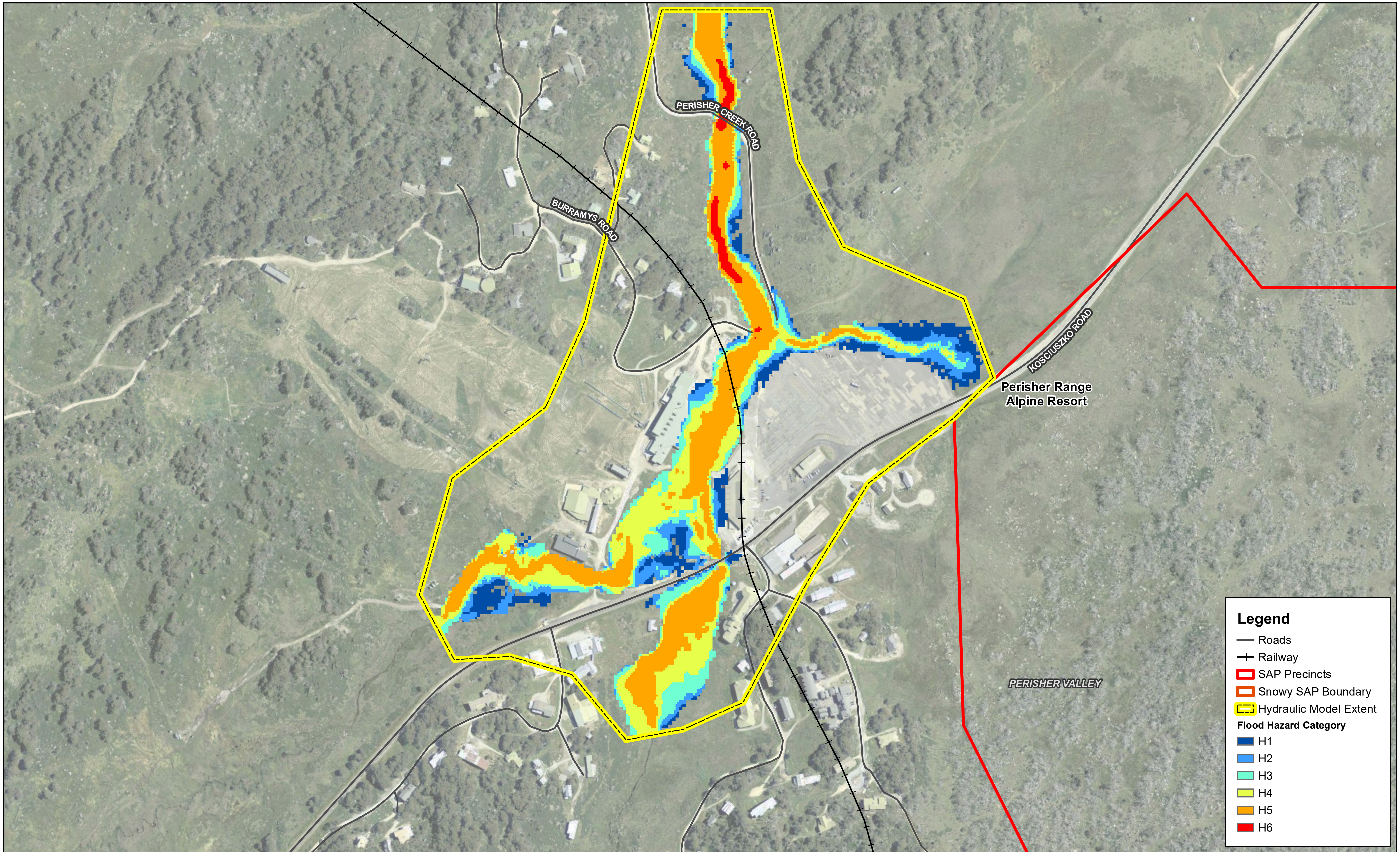

Map: PS120074_GIS_075_A1	Author: David.Naiken
Date: 08.10.2020	Approved by: Joel.Sercombe

0 30 60 m
1:5,000

Coordinate System: GDA 1994 MGA Zone 55
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Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

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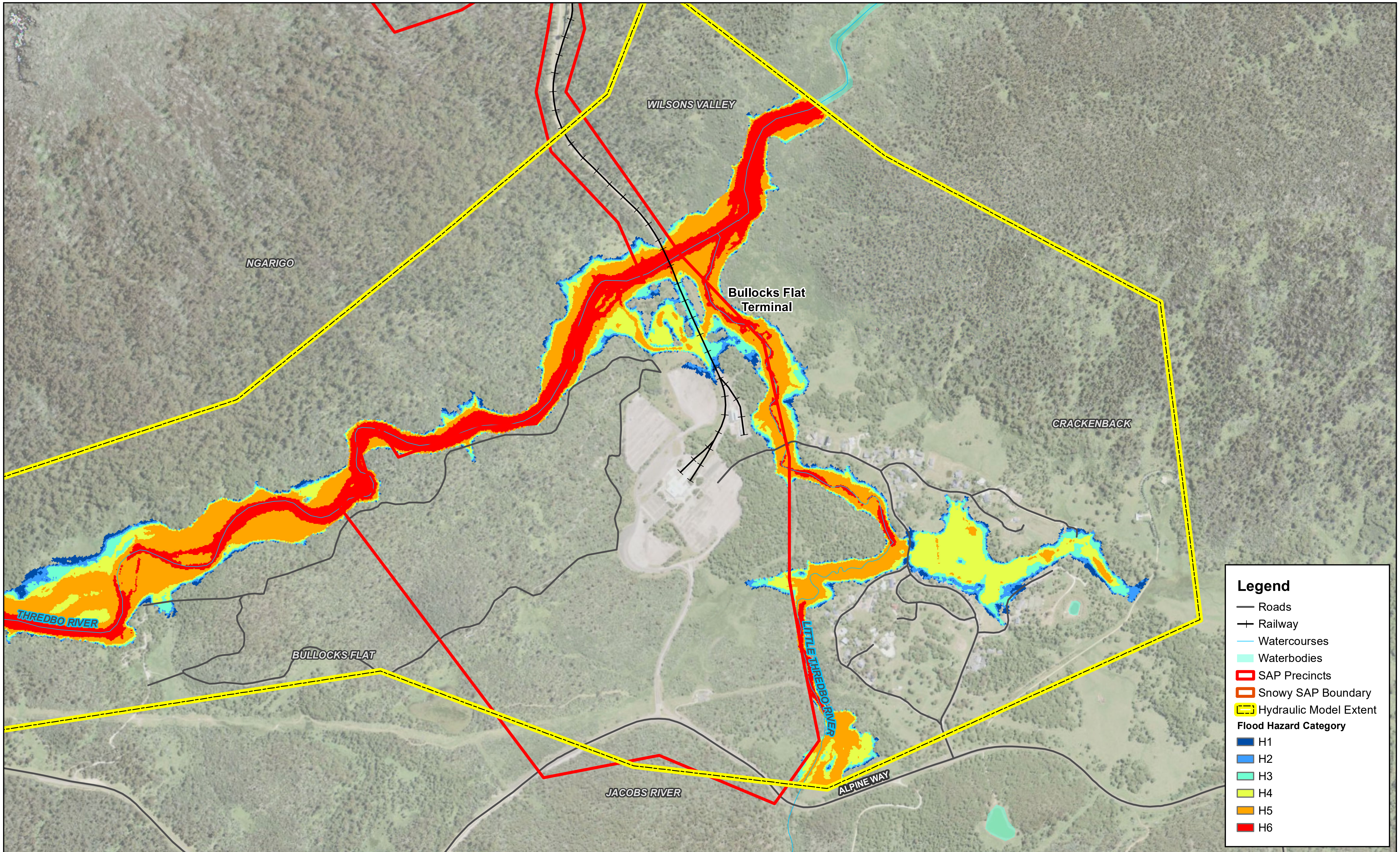
Figure 44: 0.2% AEP Flood - Peak Flood Hazard - Perisher Valley



Map: PS120074_GIS_076_A1	Author: David.Naiken
Date: 08.10.2020	Approved by: Joel.Sercombe

Coordinate System: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

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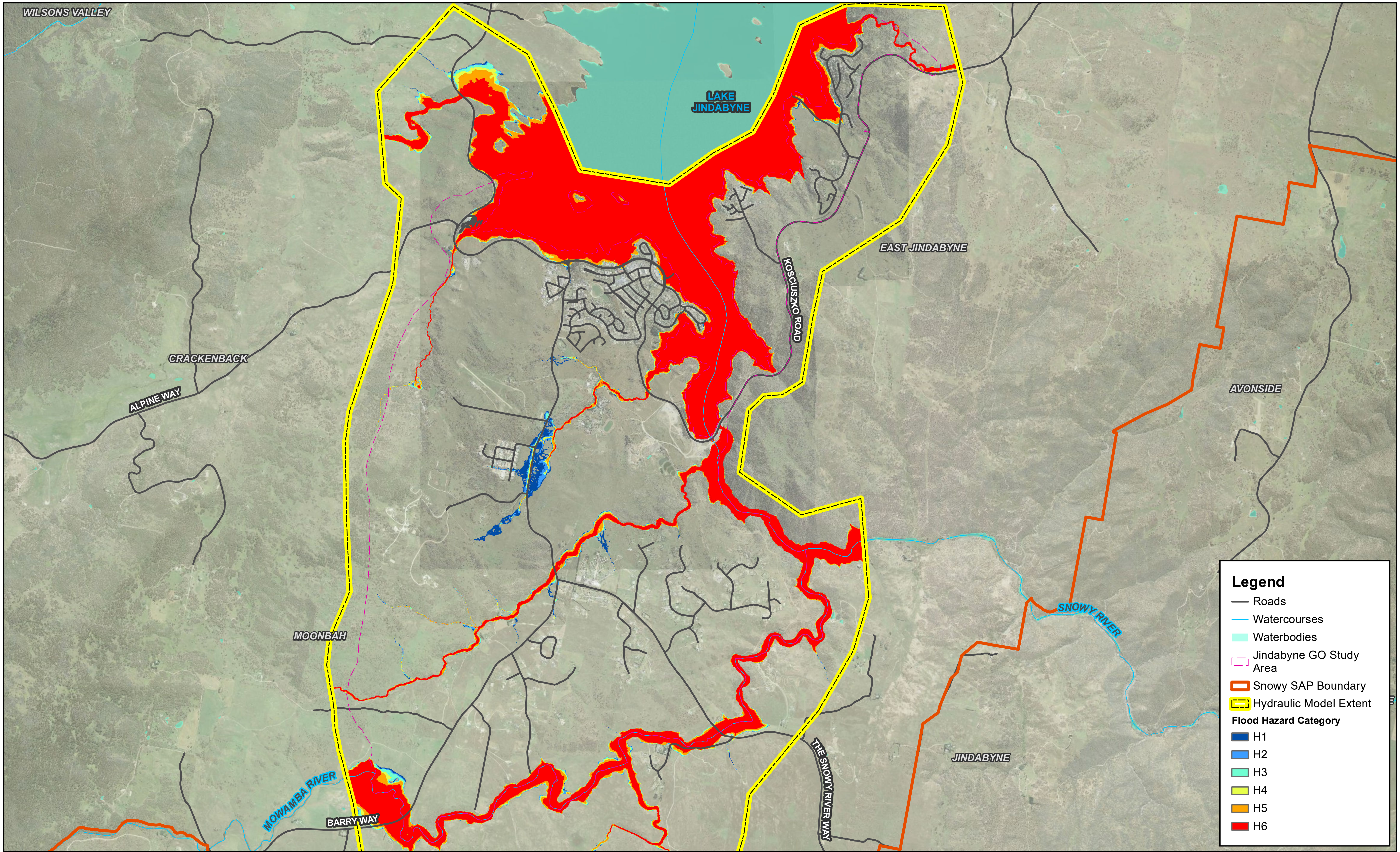
Figure 45: 0.2% AEP Flood - Peak Flood Hazard - Bullocks Flat



Map: PS120074_GIS_077_A2	Author: David.Naiken
Date: 15.06.2021	Approved by: Joel.Sercombe

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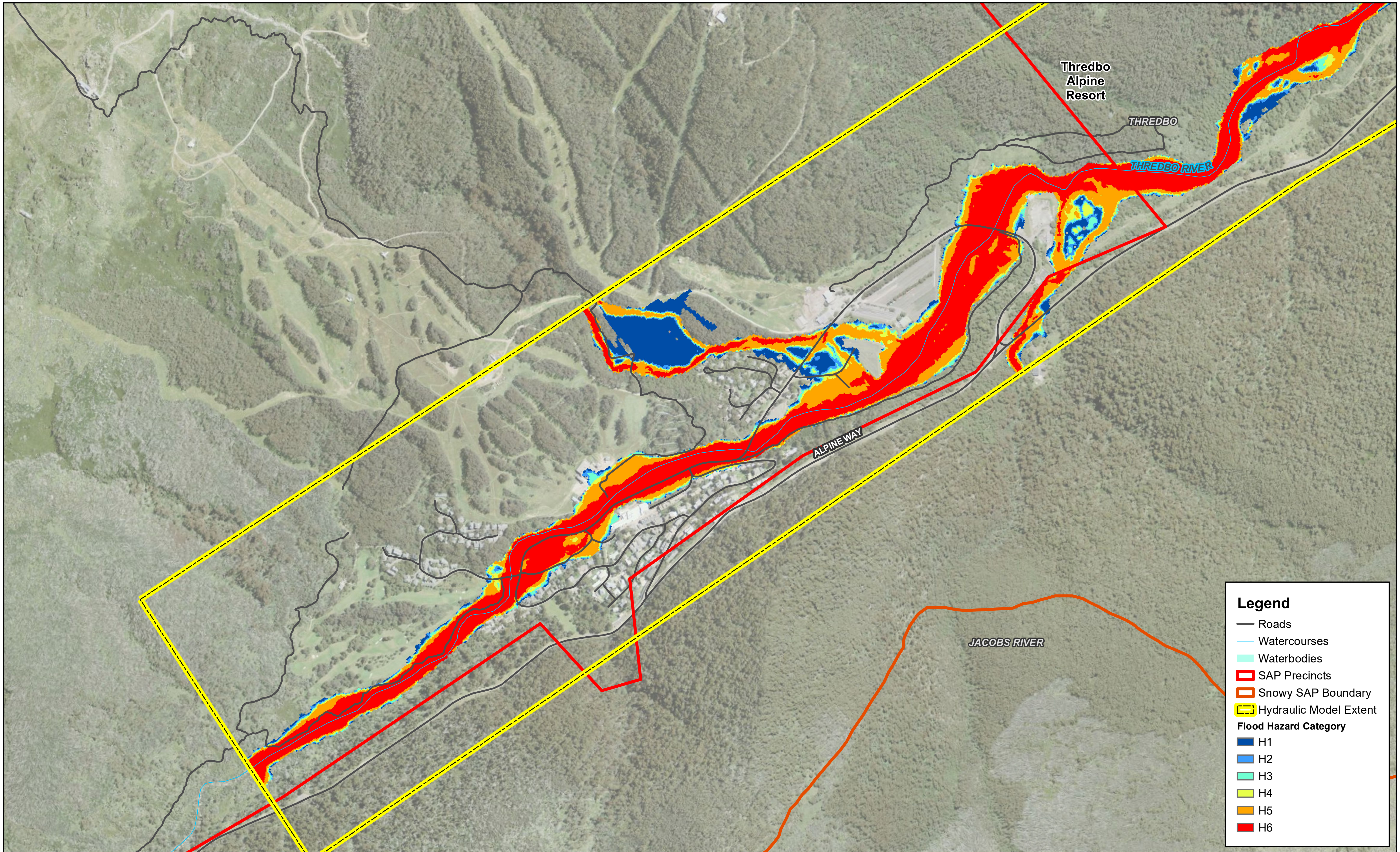
Snowy SAP - Flood Mapping

Figure 46: PMF Flood - Peak Flood Hazard - Jindabyne



Map: PS120074_GIS_078_A1	Author: David.Naiken
Date: 08.10.2020	Approved by: Joel.Sercombe

Coordinate System: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

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Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

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Figure 47: PMF Flood - Peak Flood Hazard - Thredbo Valley

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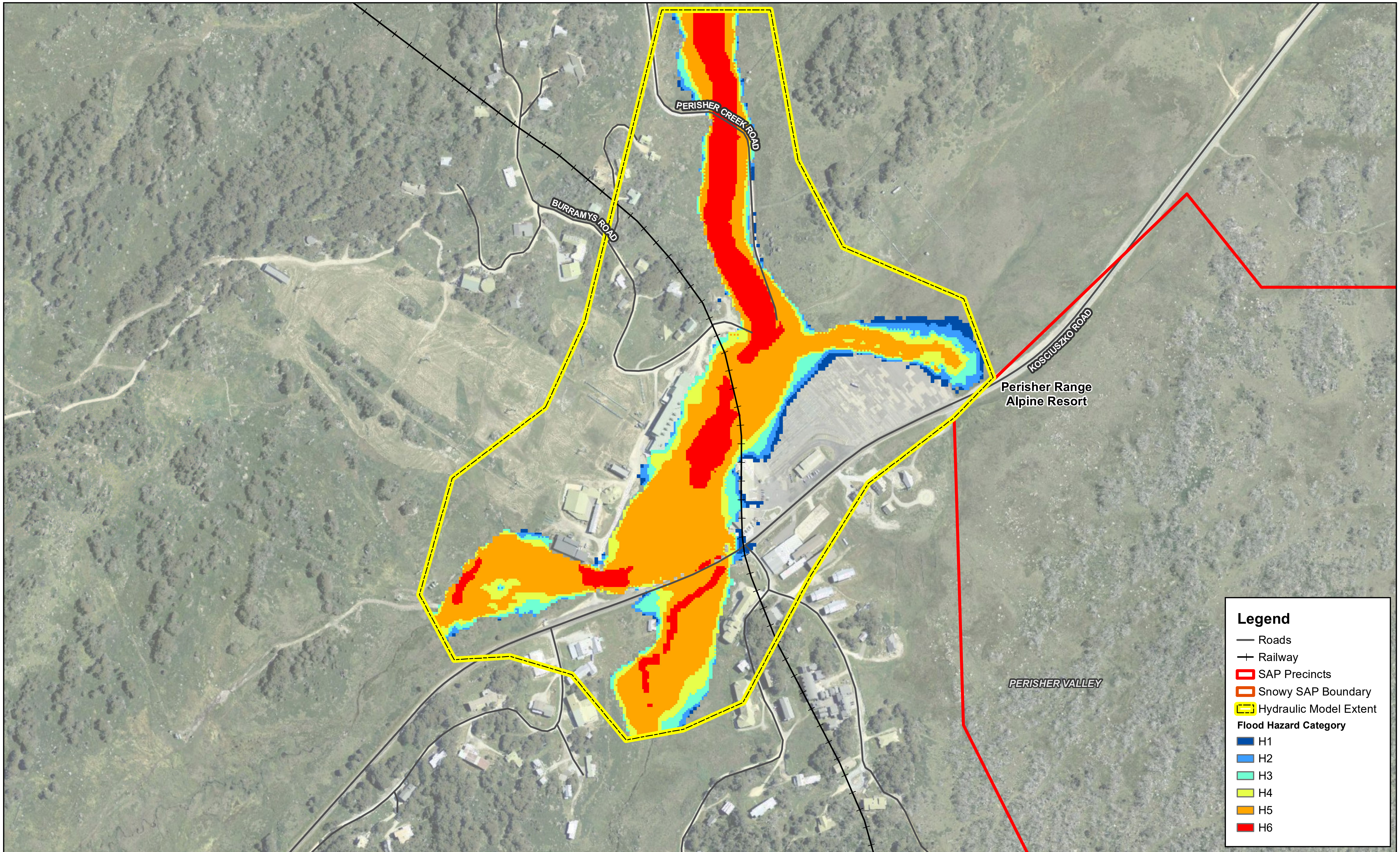

Map: PS120074_GIS_079_A1	Author: David.Naiken
Date: 08.10.2020	Approved by: Joel.Sercombe

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Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

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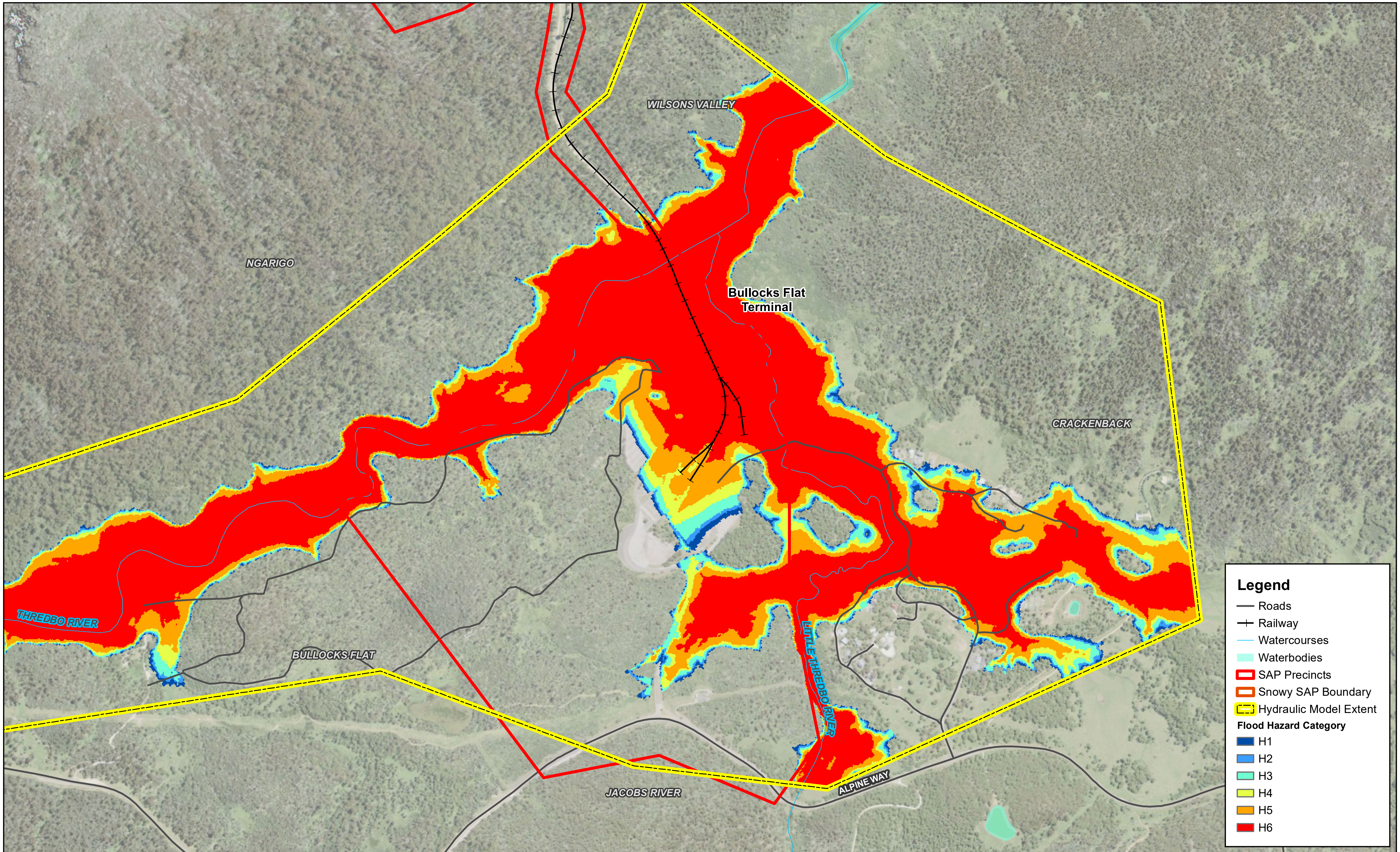
Figure 48: PMF Flood - Peak Flood Hazard - Perisher Valley



Map: PS120074_GIS_080_A1

Author: David.Naiken

Date: 08.10.2020

Approved by: Joel.Sercombe

Coordinate System: GDA 1994 MGA Zone 55
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Figure 49: PMF Flood - Peak Flood Hazard - Bullocks Flat

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