Department of Planning and Environment

Narrabri Special Activation Precinct

Flooding and Surface Water Cycle Management Report

April 2023

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Narrabri Special Activation Precinct
Flooding and Surface Water Cycle Management Report

Department of Planning and Environment

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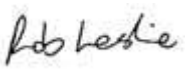
Reviewed by:	Rob Leslie	28/04/2023	
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WSP acknowledges that every project we work on takes place on First Peoples lands.
We recognise Aboriginal and Torres Strait Islander Peoples as the first scientists and engineers and pay our respects to Elders past and present.

Table of contents

CONTENTS (Continued)

List of tables

List of figures

List of appendices

Acknowledgement of Country

We acknowledge country and pay respects to the Gomeroi/Gamilaroi/Gamilaraay/Kamilaroi people as the Traditional Owners and Custodians of the land and waters on which the Narrabri Special Activation Precinct is located on.

We recognise their continued connection to Country and that this connection can be seen through stories of place and cultural practices such as art, songs, dances, storytelling and caring for the natural and cultural landscape of the area.

We also recognise the continuing living culture of Aboriginal people, and the significance of Narrabri in that living culture. We recognise the contemporary stories of displacement and the cultural significance of Narrabri in the continued journey of self-determination in Australia.

Glossary

Annual Exceedance Probability (AEP)	The probability that a design event (rainfall or flood) has of occurring in any 1 year period.
Catchment	The area drainage by a stream or body of water or the area of land from which water is collected.
Flood planning area (FPA)	Area of land at or below the flood planning level.
Flood planning level (FPL)	Combination of the 1% Annual Exceedance Probability (AEP) flood level and 0.5 m freeboard.
Flood prone land	Land susceptible to flooding by the probable maximum flood (PMF). 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.
Probable maximum flood (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.

Abbreviations

ABCB	Australian Building Code Board
AEP	Annual Exceedance Probability
AHD	Australian height datum
AIDR	Australian Institute for Disaster Resilience
ARR	Australian Rainfall and Runoff
AUSRIVAS	Australian River Assessment System
BoM	Bureau of Meteorology
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DCP	Development Control Plan
DPE	Department of Planning and Environment – Formerly Department of Planning, Industry and Environment
EbD	Enquiry by Design
EC	Electrical Conductivity
EES	Environment, Energy and Science (NSW)
EPA	Environment Protection Authority
GCM	Global Climate Model
IWCMS	Integrated Water Cycle Management Strategy
NRM	Natural Resource Management
NSW WQO	NSW Water Quality Objectives
PIC	Place-based Infrastructure Compact
PMF	Probable Maximum Flood
RCP	Representative Concentration Pathways
SAP	Special Activation Precinct
SEPP	State Environmental Planning Policy
WAL	Water access licence
WSP	Water Sharing Plan
WSUD	Water Sensitive Urban Design

Executive summary

The Narrabri Special Activation Precinct (SAP) is one of the six distinctive areas throughout regional NSW to bring together planning and investment to stimulate economic growth across a range of industries including freight and logistics, manufacturing, waste management and recycling, energy generation and agricultural and food processing activities. Narrabri SAP was declared the sixth and final SAP investigation area as its location has a strong reputation and proximity to one of Australia's highest productive grain regions and strong transport linkages to road and rail including the future Inland Rail.

The flooding and surface water technical assessment is the focus for this report and provides a key technical input for the overall Narrabri SAP Structure Plan. The Narrabri SAP Investigation area lies within the floodplains of the Namoi River at the regional level and the local floodplains of Bohena Creek and Long Gully.

Narrabri has a long history of flooding with the most serious flood occurring in February 1955, and other major floods occurring in 1971, 1974, 1976, 1984, 1998, 2000, 2004, 2012 and 2021.

Narrabri Shire Council have commissioned flood studies for the Namoi River at Narrabri and Bohena Creek to understand the severity of the historic flooding, estimate design flood information and inform future flood risk planning decisions and these models have been utilised as part of this technical assessment.

The entire SAP investigation area is inundated in the Bohena Creek and Long Gully Probable Maximum Flood (PMF) flood events but the 5% Annual Exceedance Probability (AEP) is largely contained to the creek channels of Bohena Creek and Long Gully. For the 1% AEP event the depths of flooding vary across the SAP investigation area as can be seen in Figure 3.1. The main channel of Bohena Creek has a hydraulic hazard classification of H6 and across the floodplain the rating is H4 south of Yarrie Lake Road. Between Yarrie Lake Road and the Walgett Rail line the floodplain extends both east and west with the eastern area having a H1 hazard classification up to 1.5 km east of the main channel. This area acts as a flood storage area and coincides with a sensitive vegetation area. There is a H1 hydraulic hazard classified flow path from south to north in the middle of the SAP investigation area between Bohena Creek and Long Gully and Long Gully is largely H3. The H1 hydraulic hazard classification means the land experiences low flood depths and slow moving waters is a very low flood risk.

Except for Narrabri West, the regional flood events pose the greatest risk to the urban areas of Narrabri town centre. The flood modelling indicates that many of the urban areas have a H3 to H4 hydraulic hazard classification which means they are unsafe for children and the elderly (H3), and are unsafe for all people (H4). Figure 3.3 below shows the 1% AEP flood extent as a result of the Namoi River flood event.

With respect to flood risk management there are a number of strategic guidelines that provide guidance and these include Australian Rainfall and Runoff (Ball et All 2019), Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia, Handbook 7 (AIDR, 2017) and NSW Floodplain Development Manual and Flood Prone Land Policy, DIPNR, NSW Government, 2005. NSW Government is in the process of updating the NSW Floodplain Development Manual and has issued the Flood Prone Land Package, (DPIE, 2021) to guide land use planning in the interim. In 2022, NSW experienced unprecedented flooding across a number of regions. The flooding and resulting damage were not predicted and following the events the NSW Government commissioned an independent inquiry into the 2022 flood events and a NSW Legislative Council select committee also undertook an inquiry into the 2022 flood events. The findings from these two inquiries as well as the land use planning recommendations from the Flood Prone Land Package have all been considered when informing land uses outlines for the structure plan for the Narrabri SAP.

Large areas of the SAP investigation area are currently undeveloped with an associated low rate of runoff. Bohena Creek water quality is reflective of this undeveloped area with low stormwater pollutant loads.

Method of assessment

The flooding and surface water technical assessment has adopted the following methodology:

- review and document strategic plans and policies and industry and national guidelines relevant to flood risk management and stormwater quality and quantity management
- use the Narrabri Shire Council flood model for Bohena Creek to define existing and future flood risks, flood function and flood hazard
- analyse the proposed SAP investigation area land uses against the flood risks and flood function and hazard and define flood related constraints
- identify stormwater quality and quantity management areas with consideration of the flooding, lot layouts, the existing environment, transport connections
- estimate quantities of rainwater that can be collected to support water supply opportunities
- define planning conditions for land subject to flooding
- define water sensitive urban design planning conditions.

Flooding and surface water management for the Structure Plan

The key findings from the assessment include:

Flooding

- Floodways and H5-H6 have been avoided in the development of the structure plan.
- Narrabri Town Centre and Industrial land to the north should avoid increasing density and new developments that place more people in the flood risk areas.
- Inland Port, industrial area (east) land west of Bohena Creek and the industrial land (north) are all flood prone, that is subject to inundation in the PMF event so development will be subject to specific flood risk development conditions.
- The residential area is largely above the PMF except for its northern portion and the proposed vegetation corridor to the east of centre but is already subject to the Narrabri LEP Section 5.21 as it lies within the flood planning area.
- Projected climate changes will increase the depth of flooding for the 1% AEP for all areas of the structure plan.
- The light industrial land (south) is largely flood free for the 1% AEP.
- The proposed SAP Link Road could be designed to function as a flood evacuation route and the proposed alignment minimises the loss of floodplain storage and flood fringe areas and therefore minimised impacts to flood behaviour.

Surface water

- The structure plan includes land for stormwater quality and quantity management at the Inland Port and residential areas.
- The conditions of approval will need to stipulate lot by lot water quality management measures and stormwater quantity measures for the Industrial area (south) and east and west of Bohena Creek areas.
- The proposed SAP Link Road and residential access roads will need to include attenuation and linear water quality treatment measures within the road corridor.
- Projected climate change impacts should be considered for the sizing of WSUD features with particular consideration of prolonged dry periods and increased rainfall intensity.

The Narrabri SAP structure plan is deemed to have been defined by the most up to date flood risk management advice to identify resilient and flood compatible land uses and planning conditions and incorporates the best practice approach for stormwater management.

Recommendations

Flood prone land

The following planning conditions have been developed with consideration of minimising:

- Flood Planning Level – set the flood planning level for all habitable floor levels for the precinct to the 1% AEP plus 500 mm.
- Define the flood planning area (FPA) to include the PMF flood extent and stipulate flood related planning controls to be required including:
  - no net loss of flood storage due to cut and fill or loss of flood conveyance or significant diversion of flood flows or significant changes to hydraulic flood hazard conditions that impact on private property or impact on safe access or on evacuation routes
  - fill and compensatory excavation must not change the flood function or flood hazard classification of land external to the site
  - flood compatible building design for all buildings within the FPA – including types of materials, fencing types around overland flow paths
  - property specific emergency management plans be prepared for non-residential developments within the FPA
  - hazardous industries require containment of storage establishments up the PMF plus consideration of freeboard to account for local wave action.

Stormwater management

- Define the integrated stormwater management corridors as layers in the LEP with the purpose to:
  - maintain existing overland flow paths
  - preserve areas for rainfall infiltration and potential groundwater recharge zones
  - provide opportunities for connection to country through watercourses and overland flow paths
  - provide green networks that provide for water flows
  - be part of the natural stormwater network and facilitate the more natural flow and release of stormwater flows.
- Require all new developments to include rainwater tanks – to provide some water to meet demands, but ensure piping and pumps are protected from flooding.
- Require point source pollution control – as best as possible, manage stormwater runoff at the source within new developments through Water sensitive urban design (WSUD).
- All new roads to include linear stormwater quantity and quality management measures.
- Account for the impacts of projected climate changes to stormwater through:
  - size stormwater network to account for increased intensity
  - require point source water quality treatment measures
  - include drought tolerant plants and multiple depth zones across basins
  - provide tree cover to minimise direct sunlight and reduce evaporation and maintain evapotranspiration.
- Require proposed stormwater management solutions to be tested against WaterNSW Neutral or Beneficial (NorBE) Effect on Water Quality Assessment Guideline 2022.

Indicative timing

The indicative timing of flooding and water quality infrastructure upgrades is shown in Figure ES.1. The timing is based on the nexus between the upgrade and land use generating the need for the upgrade. This timing is influenced by the rate of development and the staged release of land within the SAP and the Mt Kaputar residential area.

Figure ES.1 Overview staging of flooding and water quality infrastructure for Narrabri SAP

1 Introduction

1.1 Narrabri strategic significance/context

The New South Wales (NSW) Government, through its introduction of the Special Activation Precincts (SAPs) has identified six distinctive areas throughout regional NSW to bring together planning and investment to stimulate economic growth across a range of industries including freight and logistics, manufacturing, waste management and recycling, energy generation and agricultural and food processing activities. The planning and creation of these areas is partially facilitated and funded through the $4.2 billion Snowy Hydro Legacy Fund.

The establishment of SAPs is a joint NSW Government Agency initiative by the Department of Regional NSW, Department of Planning and Environment (DPE) and the Regional Growth NSW Development Corporation (RGDC) as part of the 20-Year Economic Vision for Regional NSW. DPE is responsible for preparing the planning framework whereas the Department of Regional NSW manages each precinct.

1.2 Scene setting (local context)

Narrabri is located in the heart of the Namoi Valley on the North West slopes and plains of New South Wales. The word Narrabri means ‘forked waters’, which describes the splintering waterways of the Namoi River, the Narrabri Creek and Horse Arm Creek. The township of Narrabri is the administrative centre of the Shire. Much of the Narrabri Shire population is centralised in the township of Narrabri, Wee Waa and Boggabri, and around the villages of Bellata, Edgeroi, Maules Creek, Baan Baa, Gwabegar and Pilliga. The Narrabri region is known for its fertile soils, abundant natural resources, strong industry and world-leading research.

In November 2020, Narrabri was declared the sixth and final SAP investigation area, enabled by its strong reputation and location within Australia’s highest productive grain region as well as its strong transportation linkages including existing road and rail connections and the future Inland Rail. To facilitate the planning within this precinct DPE has engaged WSP to prepare a series of technical studies regarding Flooding and Water Cycle Management within Narrabri SAP investigation area. An overview of the area is shown in Figure 1.2. The flood risk assessment at this stage is indicative as no details have been provided about topography changes or details of proposed structures within each land use area.

Set against the backdrop of the Nandewar Ranges and on the banks of the Namoi River, the topography of the area varies from river plains through to mountain ranges. The Namoi River meanders through these plains and acts as the lifeblood of the area supporting agriculture, industry and people. The Namoi traverses the township of Narrabri from north west to south east. A number of smaller tributaries of the Namoi are also located within Narrabri including Mulgate Creek, Horsearm Creek and Long Gully. Narrabri has historically experienced flooding from each of these sources on a regular basis.

Narrabri township is located within the Narrabri Shire local government area (LGA), approximately 530 km northwest of Sydney. As of the 2021 census, the population of Narrabri township was 6,898 persons with 16% identifying as Aboriginal and/or Torres Strait Island Peoples.

The township lies at the junction of the Newell and Kamilaroi highways and has direct rail connection to the Port of Newcastle via the Walgett branch of the Main North line. Once completed, Narrabri will also have a direct connection to the new Inland Rail route which will connect Melbourne to Brisbane via a new and upgraded freight line.

1.3 Masterplan process

The Narrabri Masterplan is the initial stage in determining the area and land uses for the Precinct and is guided and informed by DPE in partnership with the Department of Regional NSW and Narrabri Shire Council. Throughout the master planning process, community, stakeholder and industry consultation will take place, as well as a range of technical studies to help inform the preparation of a draft master plan.

Creation of the Masterplan is developed across a series of key inputs and includes a range of technical disciplines including urban design, architecture, landscape design, engineering, and environmental disciplines. The Masterplan process and its stages are summarised in Figure 1.1.

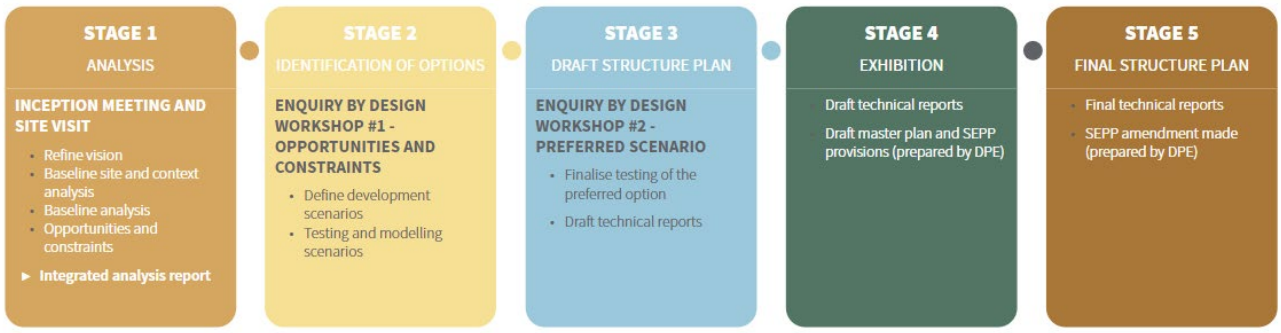


Figure 1.1 Narrabri SAP Masterplan process

The following is a summary of key inputs and activities completed to date that support the findings of this technical report:

- **Stage 1 Analysis:** This stage sets the scene for Narrabri SAP by refining the vision and providing a more detailed understanding the SAP. This stage is supported by overview findings from a site visit, baseline assessment across various technical topics, and identification of key opportunities and constraints.
- **Stage 2 Identification of Options:** Various scenarios of the Narrabri SAP were developed in conjunction with council and inputs from the technical findings from the baseline assessment. A preliminary Enquiry by Design (EbD) workshop was held on 29 and 30 March 2022 to develop a range of initial land use scenarios for further assessment.
- **Stage 3 Draft Structure Plan:** Develops more detailed structure requirements based on the preferred land use scenario based on the range of options assessed in Stage 2. The preferred land use scenario was assessed through a final EbD workshop held between 5 and 8 September 2022 to study the interdisciplinary constraints and key infrastructure requirements. This technical report assesses the land use Structure Plan from the final EbD workshop from a Flooding and Water Cycle Management perspective. Figure 1.2 is an overview of the Narrabri SAP preferred land use scenario.

Following the Stage 3 Draft Structure Plan, further community and stakeholder consultation will occur in the form of an exhibition period which includes display of technical reports from the Draft Structure Plan, Draft Master Plan, and SEPP.

1.4 Report structure

This Flooding and Water Cycle Management report has been prepared to provide key inputs for the Narrabri Structure Plan.

The remainder of this report is structured as follows:

- **Narrabri SAP overview – Structure Plan**

  Chapter 2 is an overview of the Narrabri SAP including key elements of the SAP as well as relationship with the Inland Port, Town Centre, and proposed residential areas. In addition, an indicative summary of land uses, employment, and population are summarised.

- **Local context**

  Chapter 3 provides an overview of local context from a Flooding and Water Cycle Management perspective summarising key strategic plans, policy, and planning documentation as well as existing conditions of the area.

- **Methodology**

  Chapter 4 includes a description of the process used to undertake the study, the list of stakeholders involved and information relied upon in undertaking the study.

- **Assessment and findings**

  Chapter 5 provides technical inputs and findings for the Structure Plan against the visions and aspirations of the Narrabri SAP in the context of Flooding and Water Cycle Management

- **Recommendations and conclusions**

  Chapter 6 summarises recommendations and conclusions based on findings and inputs for Flooding and Water Cycle Management within the Narrabri SAP.

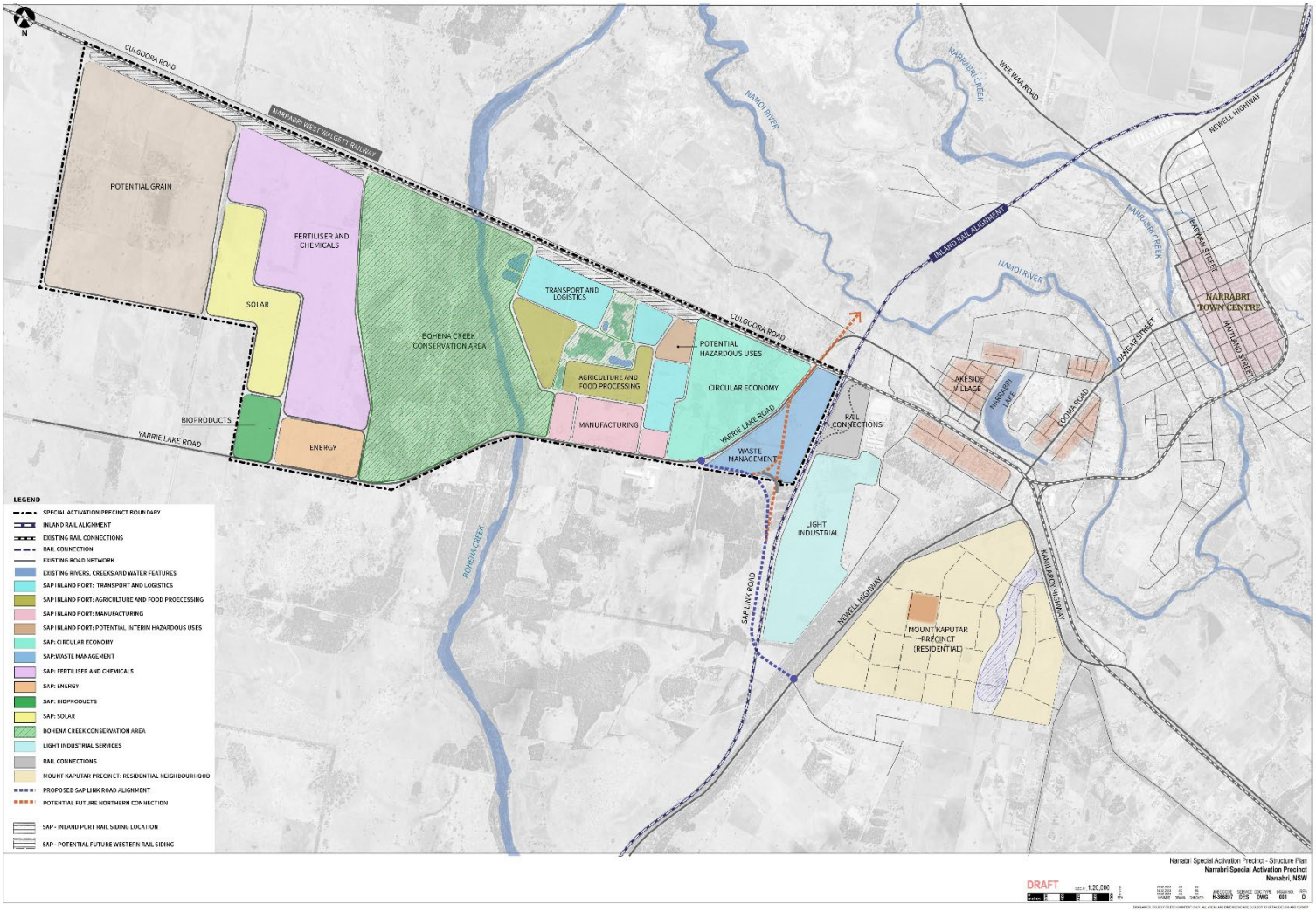


Figure 1.2 Overview of the Narrabri SAP (DPE, April 2023)

2 Narrabri SAP overview – structure plan

2.1 Overview

The investigation area for the Narrabri SAP, finalised at the Final EbD covers an area of 2,629.45 ha. It is located to the west of the existing township and incorporates two areas separated by an environmental buffer zone. This investigation area is being utilised as a basis for all technical studies, however, will not necessarily form the final SAP boundary which may change throughout the master planning process. Figure 2.1 provides an overview of key elements of the Narrabri SAP.

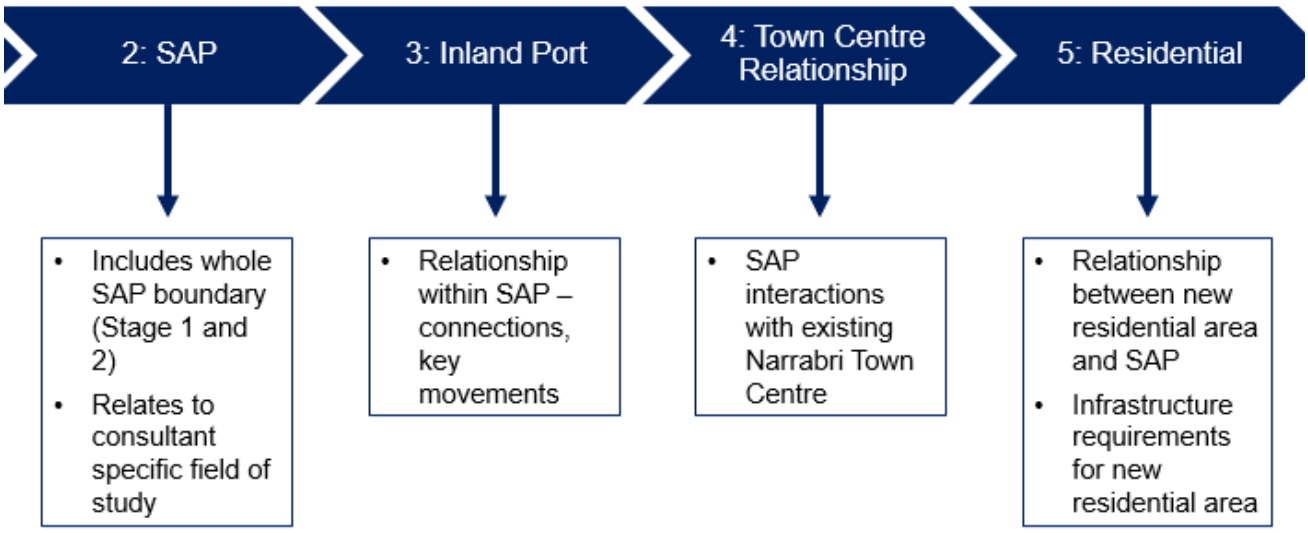


Figure 2.1 Overview of key elements of Narrabri SAP

2.1.1 Visions and aspirations

The vision and principles for the Narrabri SAP is grounded by the *7 Elements of Great Places* which is based on the United Nation's *The New Urban Agenda framework.* The Narrabri SAP Vision and Principles were developed with this framework and summarised in Table 2.1. They were refined during the preliminary EbD to respond to feedback from stakeholders and consultants. This vision will guide the design and development of the precinct and the assessment of the merits of each of the scenarios.

Strengthening our relationship with Country and Water; the Narrabri SAP will retain the Town Centre as the heart of Narrabri, unlock greater economic growth for the region, leveraging from the Inland Rail, the Northern NSW Inland Port and the Narrabri Gas Project.

Table 2.1 Narrabri SAP vision

Element	Vision
 **Equity**	Strengthen the existing community and businesses giving them the tools and the reason to stay whilst attracting economic and residential growth for Narrabri that will 'giveback' to Narrabri. Respect the cultural and lifestyle diversity by providing access to housing, health, education, social and community infrastructure to enhance the liveability and lifestyle of Narrabri.
 **Identity**	Establish a legacy at Narrabri for future generations to be proud of which reflects diversity, protects and respects the site's natural features, heritage and vegetation whilst integrating a cultural lens across the entire SAP in all actions.
 **Greenery**	Use science and local knowledge to define constraints and opportunities; enabling the protection of community and environment with a strong focus on safety, flood and bush fire risk, water security and bio values.
 **Urbanity**	Reinforce the Town Centre as the heart of Narrabri breaking down boundaries, addressing basic social deficits and embracing diversity to achieve a liveable and lovable place that is safe, connected and active.
 **Mobility**	Plan for both regional and local equitable access for future residents, visitors and workers of all ages, abilities, and economic position; aiming to improve health, convenience and social connectedness.
 **Wellness**	Prioritising the community's health, well-being and sense of belonging and setting a new environmental sustainability benchmark for energy intensive development.
 **Resilience**	Grow and retain the local small industry community whilst up-skilling and attracting new industries and enterprises setting a standard for innovation and circular economy across the board and including energy-intensive industries.

2.1.2 Staging

For the delivery of the Narrabri SAP, an indicative staging delivery plan is assumed to commence in 2024 and ongoing toward 2030 and beyond. Staging at this time is assumed across three stages:

- **Stage 1:** east of Bohena Creek with a focus on the transport and logistics land use (e.g. the inland port development), associated light industry and assumed development of 600 new residential lots.
- **Stage 2:** remaining development east of Bohena Creek and associated industry, waste management and circular economy land uses.
- **Stage 3:** west of Bohena Creek focussing on more hazardous heavy industry land development (such as energy, fertiliser and chemical production), bulk grain handling, and assumed development of a further 1,800 new residential lots.

Figure 2.2 provides an overview of the infrastructure delivery for the Narrabri SAP.

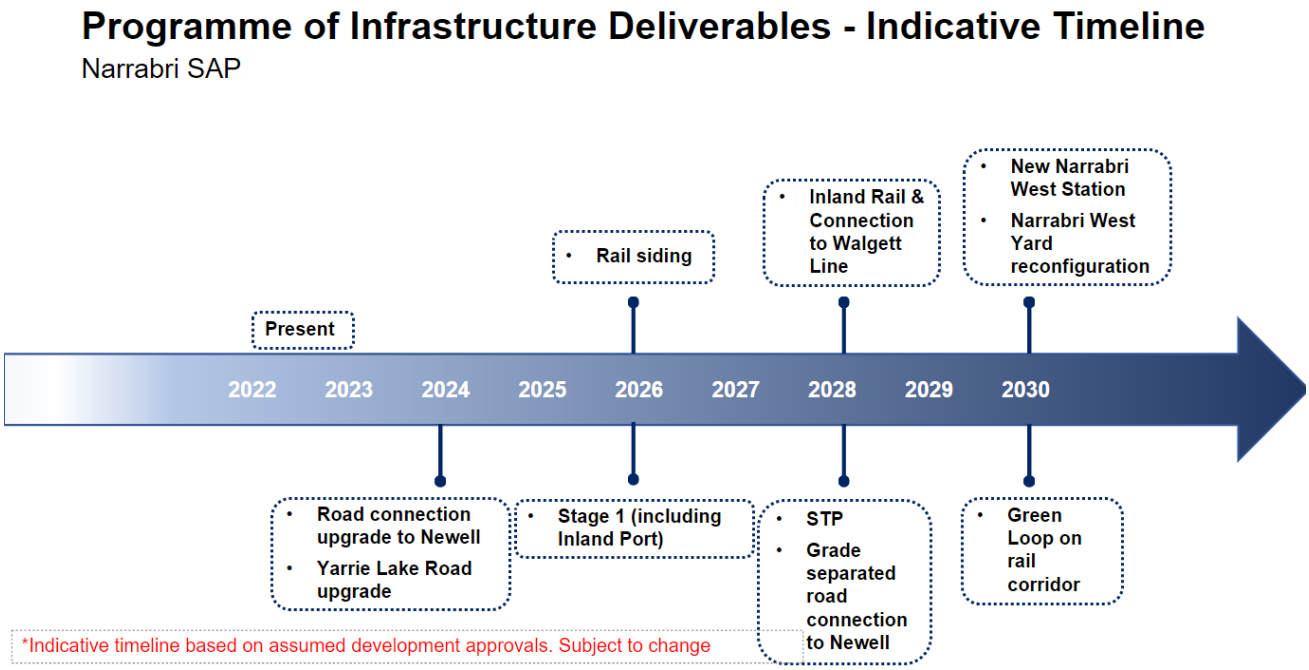


Figure 2.2 Indicative program and staging of infrastructure deliverables (subject to change)[1]

(1) Note: Reference of the 'Green loop' is considered a long-term strategic concept and is not assessed in this report.

2.2 Land uses

Land uses and size within the Narrabri SAP and external to the SAP are summarised in Table 2.2 and Figure 2.3 provides an overview of the land uses.

Table 2.2 Overview of land use and sizing within and outside the Narrabri SAP boundary

Land use within the Narrabri SAP boundary	Area (ha)	Land use outside of the Narrabri SAP boundary	Area (ha)
Fertiliser and Chemicals	366.62	Rail connection	44.92
Solar	144.14	Light Industrial (North)	106.75
Grain (Potential)	527.48	Light Industrial (South)	187.30
Western Rail Siding	37.75	Residential (2060 Target)	597.15[3]
Energy	63.31		
Bioproducts	40.79		
Inland Port (Rail siding and additional rail siding reserve)	36.07		
Transport and Logistics	108.20		
Interim Potential Hazardous Uses	19.19		
Waste Management and Recycling	94.32		
Agricultural and Food Processing	90.88		
Manufacturing	72.59		
Circular Economy[1]	181.75		
High Value Vegetation (To be retained)[2]	45.85		
Bohena Creek Conservation Area[2]	626.27		
Others (Rail, Roads, Decoupling Infrastructure)[2]	174.24		
Total	**2629.45**	**Total**	**936.12**

Source: DPE, 17 February 2023

(1) Circular Economy land use is identified land that align with circular economy goals by valuing resources, by getting as much use out of products and materials as possible, and reducing the amount of waste generated.

(2) Non-employment land uses.

(3) The net residential area (excluding flooding area and main indicative connections) = 488.18 ha.

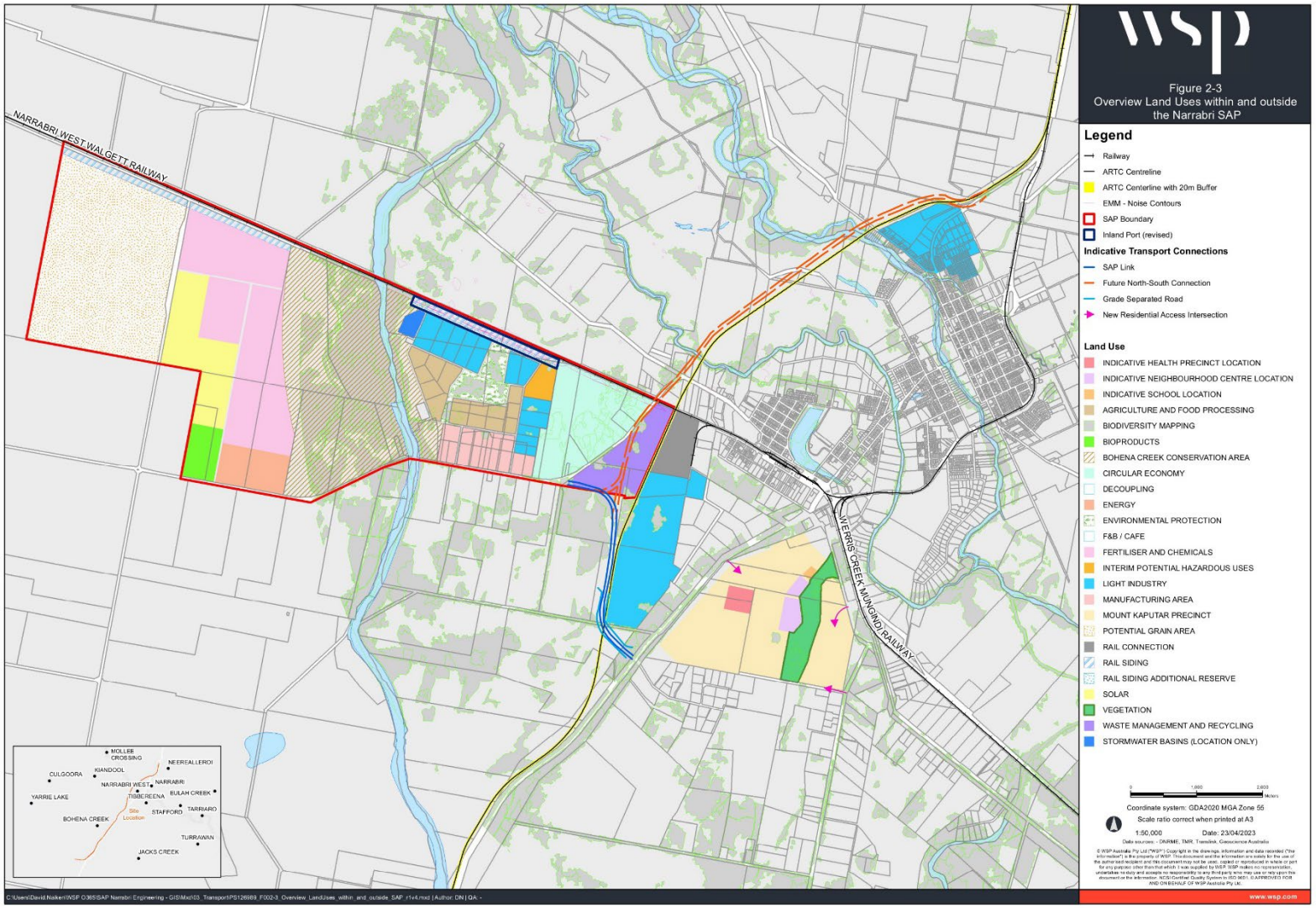


Figure 2.3 Overview land uses within and outside the Narrabri SAP (April 2023)

2.3 Employment

An estimate of the number of forecasted jobs created within the SAP is summarised in Table 2.3.

Table 2.3 Estimated employment requirements (FTEs) within the SAP based on high uptake sensitivity[1]

Industry	2027	2032	2042	2062
Fertiliser & Chemicals	260	260	260	260
Energy	10	10	10	10
Bioproducts	0	0	0	50
Transport & Logistics	70	80	90	120
Agricultural & Food Processing	40	220	220	220
Waste Management & Recycling	50	60	110	110
Total	**430**	**630**	**690**	**770**

Source: Narrabri SAP Economic Analysis Updated employment figures following September 2022 Enquiry by Design (EbD) Workshop (Aurecon, 2022-10-10)

(1) Employment numbers correspond to high uptake sensitivity with gas project

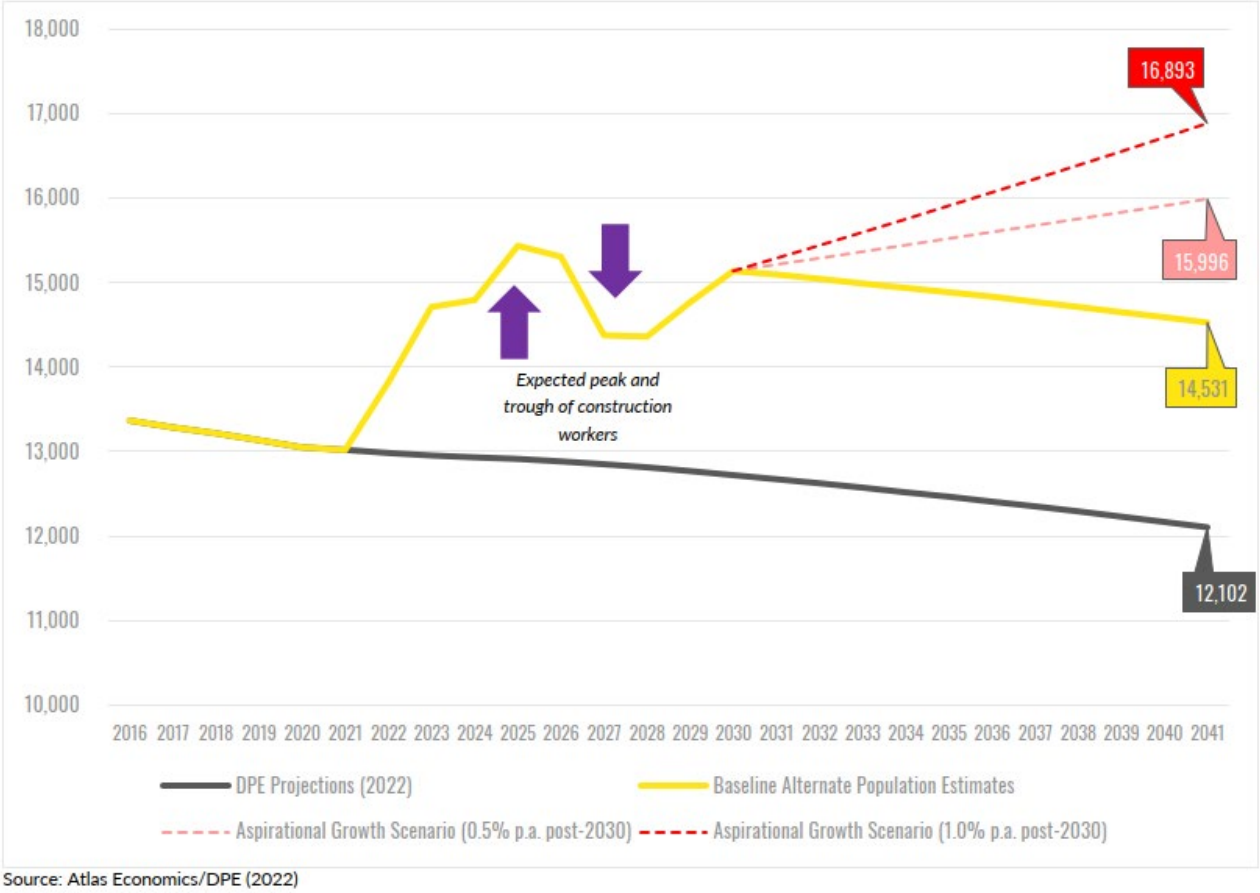
Assumptions related to these estimates include:

- It is assumed that the employment in the grain, rail siding, interim potential hazardous uses and circular economy areas would not increase substantially or is included in the estimates for other land uses.
- The employment numbers in Table 2.3 do not include a specific allowance for the land allocated for Manufacturing. DPE has advised that the total employment estimate should be considered the maximum number. For the purposes of this assessment, we have assumed that the manufacturing jobs are included within the Agricultural & Food Processing estimate (as they are adjacent to each other).
- It is assumed that the Transport & Logistics employment forecasts include those associated with the Inland Port and light industrial within the SAP.
- The numbers in Table 2.3 do not include an estimate of the number of jobs potentially created in the identified land external to the SAP (Light Industrial North and South). While the impact of this development is outside the scope of this assessment, we have included a nominal allowance for the purposes of estimating the road network performance for the SAP. Based on the relative proportions of their land areas (3.5 times), it is estimated that the number of jobs in the Light Industrial South area are 245 in 2027, 280 in 2032, 315 in 2042 and 420 in 2062.

2.4 Population

The Narrabri Shire region could reach a resident population between 14,500 and 16,900 residents by 2041 as shown in Figure 2.4. Based on these estimates the potential dwelling need for the Narrabri Shire region would be between 7,000 and 8,000 dwellings by 2041. Accordingly, the population estimate scenarios could require between 1,000 and 2,100 additional dwellings over the coming 20 years to 2041, equating to between about 50 to 110 additional dwellings per annum. These estimates identify a significant uptick in housing supply would be required to meet population growth.

Population estimates indicate that the SAP would increase the potential workforce as well as the population of Narrabri as a whole. The peak increase in workers is expected to occur in 2025/2026.



Source: Atlas Economics developed alternate population forecasts for DPE, November 2022

Figure 2.4 Narrabri Shire Population projections (2016–2041)

For the purposes of this assessment, we have assumed that the maximum increase of new residents would be contained within the new residential area, and that it would be maintained, even if there is a decline in the population in current residential areas within Narrabri Town.

3 Flooding and surface water management context

3.1 Key guidelines and plans

Table 3.1 provides an overview of the key guidelines and plans relevant to this study.

Table 3.1 Overview of plans and policy

Name	Description
Australian Rainfall and Runoff Guideline 2019 (ARR 2019) (Ball et al, 2019) is	ARR 2019 (Ball et al, 2019) is a national guideline for the estimation of design flood characteristics in Australia. The aim of the guide is to provide the best available guidance and information on design flood estimation in a manner suitable for use by Australian practitioners. This document outlines industry best practice for the flood model development.
Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia, Handbook 7 (AIDR, 2017)	The Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia, Handbook 7 (AIDR, 2017) has been developed to provide guidance on the national principles supporting disaster resilience with a specific focus on flood emergencies. This Handbook is supported by six additional guidelines that cover specific aspects of flood risk management and a practice note to assist with land use planning. Guideline 7-3 Flood Hazard, outlines methods to quantify flood hazard and the handbook provides methods for managing the hazard.
NSW Floodplain Development Manual and Flood Prone Land Policy, DIPNR, NSW Government, 2005	The manual highlights the requirements to manage flood risks in order to reduce the impact of flooding on individual owners and occupiers of flood-prone property and to reduce private and public losses resulting from floods. This includes a merit based approach to assessing development in the floodplain and the consideration of both mainstream and overland flooding.
Flood Prone Land Package, DPIE, 2021	The package includes the update of a number of materials pertaining to the management of flood-prone land within NSW. This package commenced in July 2021 and provides guidance on defining the areas to which flood-related development controls apply, with consideration of defined flood events, freeboards, extreme flooding and emergency management considerations. The Considering flooding in land use planning guideline outlines areas that warrant development controls to address risk to life considerations.
NSW Natural Hazard Package	The package supports planning authorities and councils make decisions that more effectively consider natural hazard risk and build sustainable, hazard-resilient communities.

Name	Description
Narrabri Local Environmental Plan 2012	Section 5.21 relates to flood planning for the Narrabri Local Government Area and was updated in September 2021 to address the Flood Prone Land Package. The objectives of this clause are as follows— *(a) to minimise the flood risk to life and property associated with the use of land* *(b) to allow development on land that is compatible with the flood function and behaviour on the land, taking into account projected changes as a result of climate change* *(c) to avoid adverse or cumulative impacts on flood behaviour and the environment* *(d) to enable the safe occupation and efficient evacuation of people in the event of a flood.*
Narrabri Shire Council Development Control Plan	There are a number of DCPs that include considerations for flooding and stormwater development. These include: — Drainage to buildings – Section 2.1 — Landfill development — Industrial Development Code. They all require the consideration of downstream flooding and flood hazard as part of the development design.
Narrabri Floodplain Risk Management Study and Plan (WRM 2020)	This plan has been prepared to investigate a range of flood mitigation works and measures to address the existing, future and continuing flood problems in Narrabri, in accordance with the NSW Government's Flood Prone Land Policy. The planning measures are most relevant for the Narrabri SAP investigation as they promote land use and building and development controls based on the flood hazard and vulnerability of the community.
National Water Quality Management Strategy (Australian Government 2018)	The strategy establishes objectives to achieve sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development. The *National Water Quality Management Strategy* (NWQMS) includes guidelines for protection of water resources across Australia. These guidelines have been used to determine the existing condition of rivers and water quality objectives for the proposal.
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018)	The ANZG guidelines provide a process for assessing existing water quality conditions and developing water quality objectives to sustain current or likely future community values for water resources. Default guideline values for parameters are provided for different community values as generic starting points for assessing water quality where site specific information is not available. The default guideline values are used to evaluate the existing water quality conditions against long term water quality goals.
Murray–Darling Basin Plan 2012	The overarching objective for the Basin Plan 2012 in regard to water quality and salinity is to maintain appropriate water quality, including salinity levels, for environmental, social, cultural and economic activity in the Murray-Darling Basin.

3.2 NSW flood inquiry

Prior to commencing the Narrabri SAP technical assessment, NSW experienced unprecedented flooding across a number of regions. The flooding and resulting damage were not predicted and following the events the NSW Government commissioned an independent inquiry into the 2022 flood events and a NSW Legislative Council select committee also undertook an inquiry into the events. A summary of the findings from these two inquiries is included below because they provide context for the consideration of flood risks and hazards and emergency management when planning development in floodplains.

3.2.1 NSW independent flood inquiry

The NSW Government commissioned an independent inquiry to examine and report on the causes of, planning and preparedness for, response to and recovery from the 2022 flood events. "The Inquiry makes 28 recommendations for change. The recommendations are intended to provide practical, proactive and sustained mechanisms to ensure readiness for and resilience to flood (and by extension, other disasters)" The relevant recommendations are included below and commentary of how they have been applied for the Narrabri SAP is included in Table 3.2.

Table 3.2 Independent flood inquiry recommendations and comments

Recommendation No.	Recommendation	Relevance
9. Essential Services	To minimise disruption to essential services, including outages which compromise basic communication coverage, and to ensure access to safe water supply and power during flood events.	The Narrabri SAP flood assessment has identified flood prone land. This information can be used to ensure all essential services are located out of the floodplain or the flood hazard zones and flood risks are defined to inform land use planning decisions and design criteria.
18. Risk Based approach to calculating flood planning level	Risk-based flood planning level, consideration should be given to the PMF, 1% AEP, 0.02% AEP, existing development, approved but not yet constructed developments, and existing and approved but not yet constructed evacuation routes.	The Narrabri SAP flood assessment has defined the PMF, 1% AEP and 1% plus consideration of climate change flood extents, levels and flood hazard. This information has been used to inform the land use planning for the Narrabri SAP.
19. Disaster Adaptation plans for all towns	To establish realistic expectations of safe spaces to live and deliver much needed housing quickly, Government through NSWRA working with local government. Including: — planning instruments discouraging (and in many cases forbidding) development in disaster-likely areas — hazard maps linked to Strategic Plans and LEPs — prioritise and incentivise new development in safe areas	The Narrabri SAP flood assessment has defined the PMF, 1% AEP and 1% plus consideration of climate change flood extents, levels and flood hazard. This information has been used to identify compatible (safe) areas for residential and critical infrastructure to minimise flood risks for the community. Hazard mapping has been completed to inform building development controls.

Recommendation No.	Recommendation	Relevance
20. Floodplain as assets	Such as uses that are productive and minimise risk to life during major weather events. Such uses would include sporting and recreational activities, garden plots and community gardens, agriculture and forestry, renewable energy production, biodiversity offsets, parks and outdoor education activities letting watercourses largely flow naturally rather than implementing engineering barriers.	The Narrabri SAP flood assessment has defined the PMF, 1% AEP and 1% plus consideration of climate change and 5% AEP flood extents and levels. This information has been used to identify existing overland flow paths and floodplains to be able to set boundaries for land uses. The 5% AEP flood event extent has also been used to identify compatible (safe) areas for parks and WSUD opportunities to ensure ephemeral watercourses continue to flow naturally.

3.2.2 NSW Legislative Council Select committee

In August 2022 the NSW Parliament Legislative Council Select committee provided a report documenting, "Response to major Flooding across NSW in 2022." The inquiry was set up to consider the NSW Government's preparedness, coordination and response to the flooding events of 2022. The inquiry presented 21 findings and 37 recommendations. It is noted that these are recommendations and not currently adopted as formal guidelines but have been considered here as potential emerging best practice. The relevant recommendations are included below with comments on their applicability for the Narrabri SAP project.

Table 3.3 Legislative Council Select committee flood inquiry recommendations and comments

Recommendation No.	Recommendation	Relevance
7	That the NSW Government advocate through the National Cabinet for the Bureau of Meteorology to review its rain data infrastructure and flood modelling tools, to ensure forecasting locations, rain and flood gauges and other infrastructure are appropriately placed, maintained and updated.	The SAP process could be used in conjunction with the Floodplain Risk Management Study to identify suitable locations.
13	That the NSW Government work with local governments to identify alternative routes to vulnerable roads, and that the NSW and Australian Governments fund the construction of these important routes to improve evacuation and access options in times of disaster.	Existing evacuation centres are located in the floodplain and surrounded by water in as low as the 5% AEP event. The Narrabri SAP flood assessment has defined the PMF, 1% AEP and 1% plus consideration of climate change flood extents, levels and flood hazard. It could therefore be used to identify other centres with higher flood immunity, or preferably not within the floodplain.

Recommendation No.	Recommendation	Relevance
15	That the NSW Government ensure that the current review of evacuation centres considers the role, accreditation and support of community evacuation centres, with the outcomes of this review to be made public and incorporated into the update of the state emergency plans.	Existing evacuation centres are located in the floodplain and surrounded by water in as low as the 5% AEP event. The Narrabri SAP flood assessment has defined the PMF, 1% AEP and 1% plus consideration of climate change flood extents, levels and flood hazard. It could therefore be used to identify other centres with higher flood immunity, or preferably not within the floodplain.
26	That the NSW Government consider investing in supporting relocations, land swaps and providing fair and adequate compensation for landowners who wish to relocate from severely flood-impacted areas.	The Narrabri SAP flood assessment has defined the PMF, 1% AEP and 1% plus consideration of climate change flood extents, levels and flood hazard. The Narrabri SAP investigation has been used to identify compatible land uses for land within the floodplain and identified appropriate performance measures for development of this land.
35	That the NSW Government significantly increase its investment in flood mitigation and preparation, including its support of local governments to do the same, by: — increasing ongoing, long term funding and access to technical guidance and assistance for local councils — ensuring that land-use planning and development takes a risk-based approach.	The Narrabri SAP investigation has considered the constraints and avoiding development in areas of intolerable risk (H4, H5 and H6) to reduce risk to life/public and private losses.
36	That the NSW Government work with local government, industry and sustainable planning experts, including the Government Architect, on policy initiatives in the New South Wales planning system that will help deliver more resilient and sustainable homes, buildings and places.	The Narrabri SAP investigation has been used to identify compatible land uses for land within the floodplain and identified appropriate performance measures for development of this land.
37	That the NSW Government work with relevant agencies and local landowners to find ways to improve the management of drainage channels including looking for recommendations to reduce red and green tape.	The SAP process could be used in conjunction with the Floodplain Risk Management Study to develop options to manage the drainage channels through Narrabri.

3.3 Discussion paper – Land Use Strategy Review, Lismore City Council

This discussion paper (Lismore City Council, 2022) has been produced following the devastating floods on March 2022 that affected the local government area (LGA) of Lismore. The LGA has a history of flooding similar to Narrabri and has developed strategies for managing flood risk but the discussion paper queries previous management measures and proposes updates to how future flood risk is managed. The paper presents some broad recommendations for how Lismore can build back better, summarised by the following excerpt: "discussion paper queries previous management measures and proposes updates to how future flood risk is managed This document is relevant due to the similar long flood history but also provides land use planning considerations for flood liable land that have been considered for the Narrabri SAP investigation area.

3.4 Integrated Water Cycle Management (IWCM) Strategy

Narrabri Shire Council (NSC) is currently developing an Integrated Water Cycle Management (IWCM) Strategy, which will consider long-term water supply and demand requirements for the broader NSC service area. The NSW Public Works Advisory group have prepared the Narrabri Shire Council IWCMS Issues Paper (June 2022) which is the first step in the 2019 DPE Water IWCM Strategy Check List. With respect to the flooding and surface water cycle assessment, stormwater infiltration is identified as a performance issue for the Wee Waa sewerage scheme but there is no analysis of stormwater as a resource nor was it considered as alternate supply. It is acknowledged that stormwater may play a small role in water supply and that lot scale and at source (roofs) stormwater harvesting are the most appropriate options.

3.5 Existing conditions

3.5.1 Flood information

The community within Narrabri has a high awareness of flood risk. Narrabri residents have experienced above floor flooding from the Namoi River, Mulgate Creek, Horsearm Creek and Long Gully on a regular basis. The most serious flood occurred in February 1955, with other major floods occurring in 1971, 1974, 1976, 1984, 1998, 2000, 2004 and 2012.

The available existing design flood information has been sourced from the following:

- Draft Bohena Creek Flood Study, WRM October 2019
- Narrabri Flood Study – Namoi River, Mulgate Creek and Long Gully, WRM December 2016
- Narrabri Floodplain Risk Management Study and Plan Volume I: Supplementary Flood Study -Namoi River, Mulgate Creek and Long Gully, WRM, June 2019
- Narrabri Floodplain Risk Management Study and Plan Volume II: Floodplain Risk Management Study, November 2020
- Inland Rail Narromine to Narrabri Environmental Impact Assessment, Flooding and Hydrology Assessment, Jacobs GHD, 2020.

3.5.2 Bohena Creek and Long Gully

The Bohena Creek flood model has been updated to include the Long Gully waterway to create a flood model that covers the entire SAP investigation area. The flood modelling indicates that the 1% AEP flood depths in Bohena Creek at Yarrie Lake Road are over 4 metres in depth and up to 1.3 m deep in the floodplain to the south of Yarrie Lake Road which extends up to 700 m from the main Bohena Creek channel. Refer to Figure 3.1 which shows the 1% AEP peak flood depths across the SAP investigation area. The duration of inundation in the floodplain is 42 hours. The overland flow path in the centre of the SAP investigation area experiences depths up to 0.4 m but largely the depths are less than 0.2 m for the 1% AEP flood event. Long Gully is predicted to have depths up to 1.3 m in the channel in the south east corner of the SAP investigation area and minor overbank flow up to 0.2 m in depth with a floodplain width of up to 200 m.

The 5% AEP event is contained to within the Bohena Creek channel except for a small area at Yarrie Lake Road to the immediate east of Bohena Creek. The central overland flow path has depths less than 0.15 m for most of its length with a few small areas of deeper water. Long Gully experiences depth of up to 0.4 m in the south east corner of the SAP investigation area but is largely contained within the channel.

The main channel of Bohena Creek has a hydraulic hazard classification of H6 and across the floodplain the rating is H4 south of Yarrie Lake Road. Between Yarrie Lake Road and the Walgett Rail line the floodplain extends both east and west with the eastern area having a H1 hazard classification up to 1.5 km east of the main channel. This area acts as a flood storage area and coincides with a sensitive vegetation area. There is a H1 hydraulic hazard classified flow path from south to north in the middle of the SAP investigation area between Bohena Creek and Long Gully and Long Gully is largely H3. The H1hydraulic hazard classification means the land experiences low flood depths and slow moving waters is a very low flood risk.

For the PMF event, the entire SAP investigation area is inundated except for a small area in the north east corner to the immediate west of Long Gully.

3.5.3 Namoi River flooding

The Namoi River flooding information is based on the Narrabri Flood Study (WRM December 2016), the Floodplain Risk Management Study Volume 1 (June 2019) and Volume 2 (November 2020) which included modelling of the Namoi River, Narrabri Creek, Easters Creek, Doctors Creek, O'Briens Creek, Mulgate Creek and Long Gully. The results of the flood study indicate that the 1% AEP Namoi River and Eathers Creek flood extents do not encroach into the SAP investigation area. Figure 3.2 shows the 1% AEP flood levels and depths for the Namoi River, Eathers Creek and Long Gully. Figure 3.2 shows the flood affectation of the town of Narrabri which also indicates that the SAP investigation area will be cut off from the town during large flood events.

The available flood modelling indicates the township is prone to flooding from the Namoi River and from the local creek catchments of Mulgate Creek/Horsearm Creek and Long Gully. The Floodplain Risk Management Study outlines the following flood affectation for the regional and local flood events.

For Namoi River flooding:

- 914 residential and 305 non-residential buildings would be inundated above floor level for the 1% AEP flood with most properties experiencing some inundation except for properties in Narrabri West
- flood hazard vulnerability mapping identified 351 buildings that would be unsafe for people and vehicles.

For local creek flooding:

- 139 residential and over 45 non-residential buildings would be inundated above floor level for the 1% AEP flood.

Except for Narrabri West the regional flood events pose the greatest risk to the urban areas of Narrabri but for the Narrabri North Industrial Estate both regional and local events cause flood risk in this area. The flood modelling also indicates that many of the urban areas have a H3 to H4 hydraulic hazard classification which means they are unsafe for children and the elderly (H3), and are unsafe for all people (H4). See Figure 3.3.

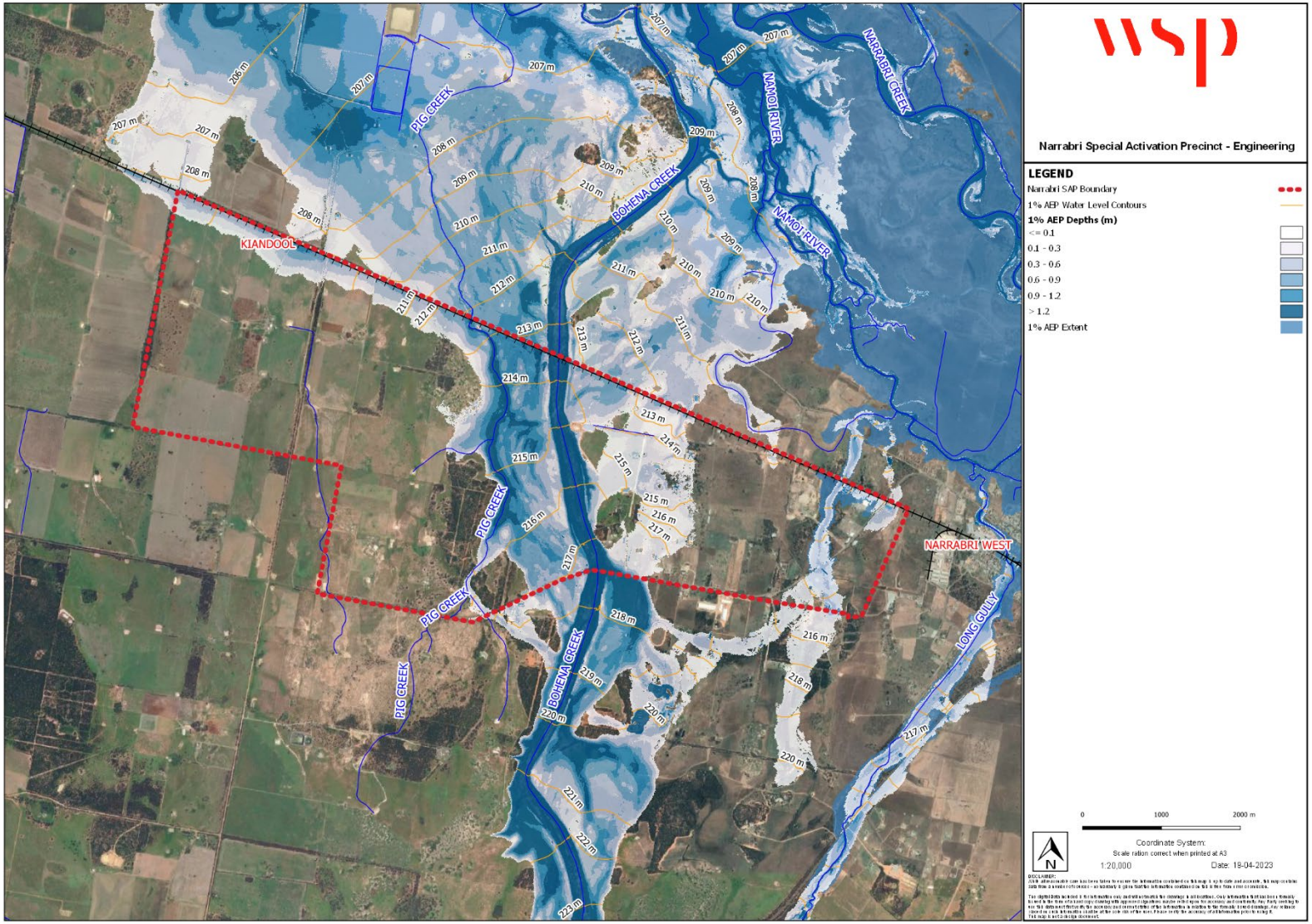


Figure 3.1 Bohena Creek 1% AEP flood peak depths and levels (April 2023)

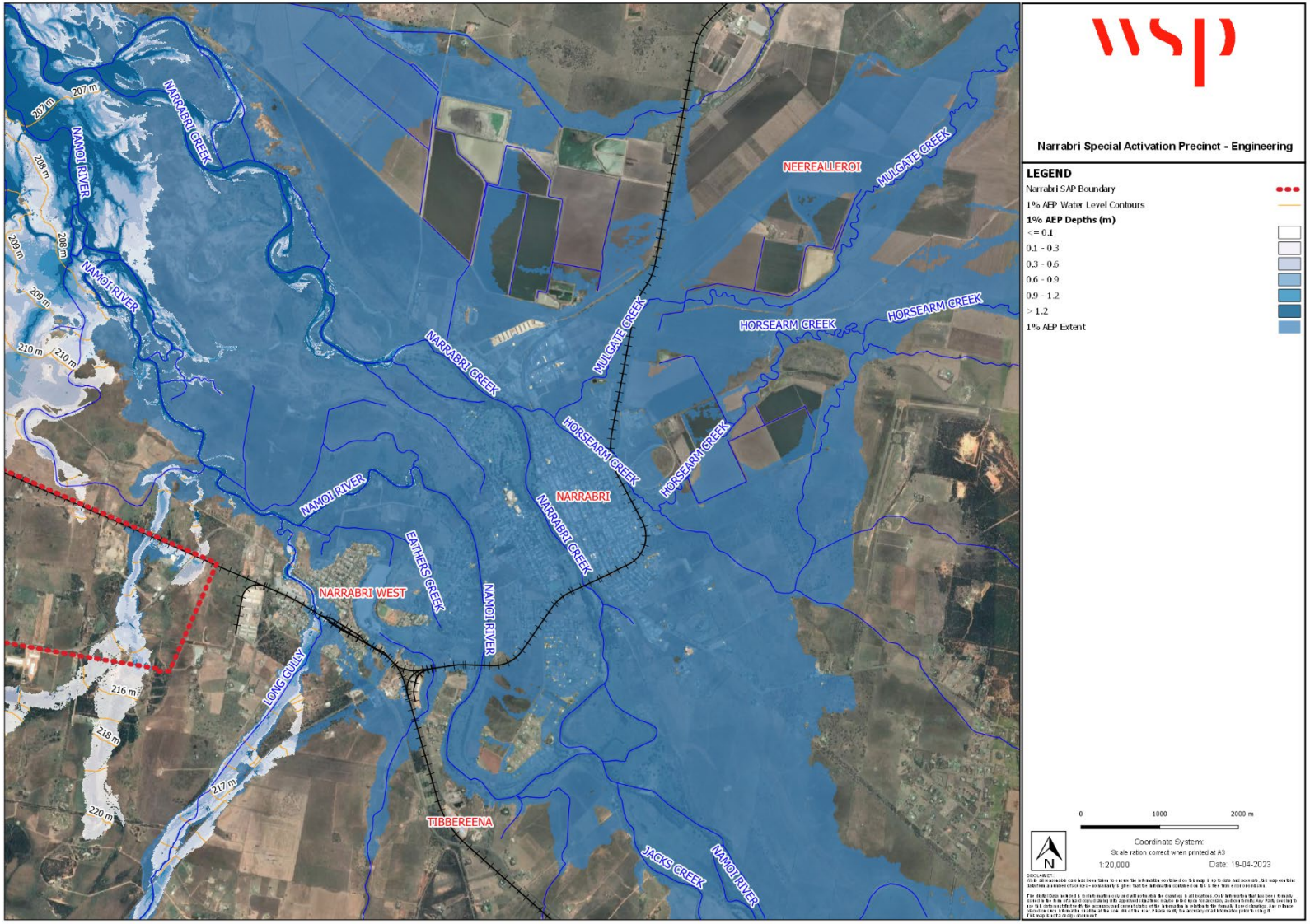


Figure 3.2 Namoi River 1% AEP flood extent and depth (April 2023)

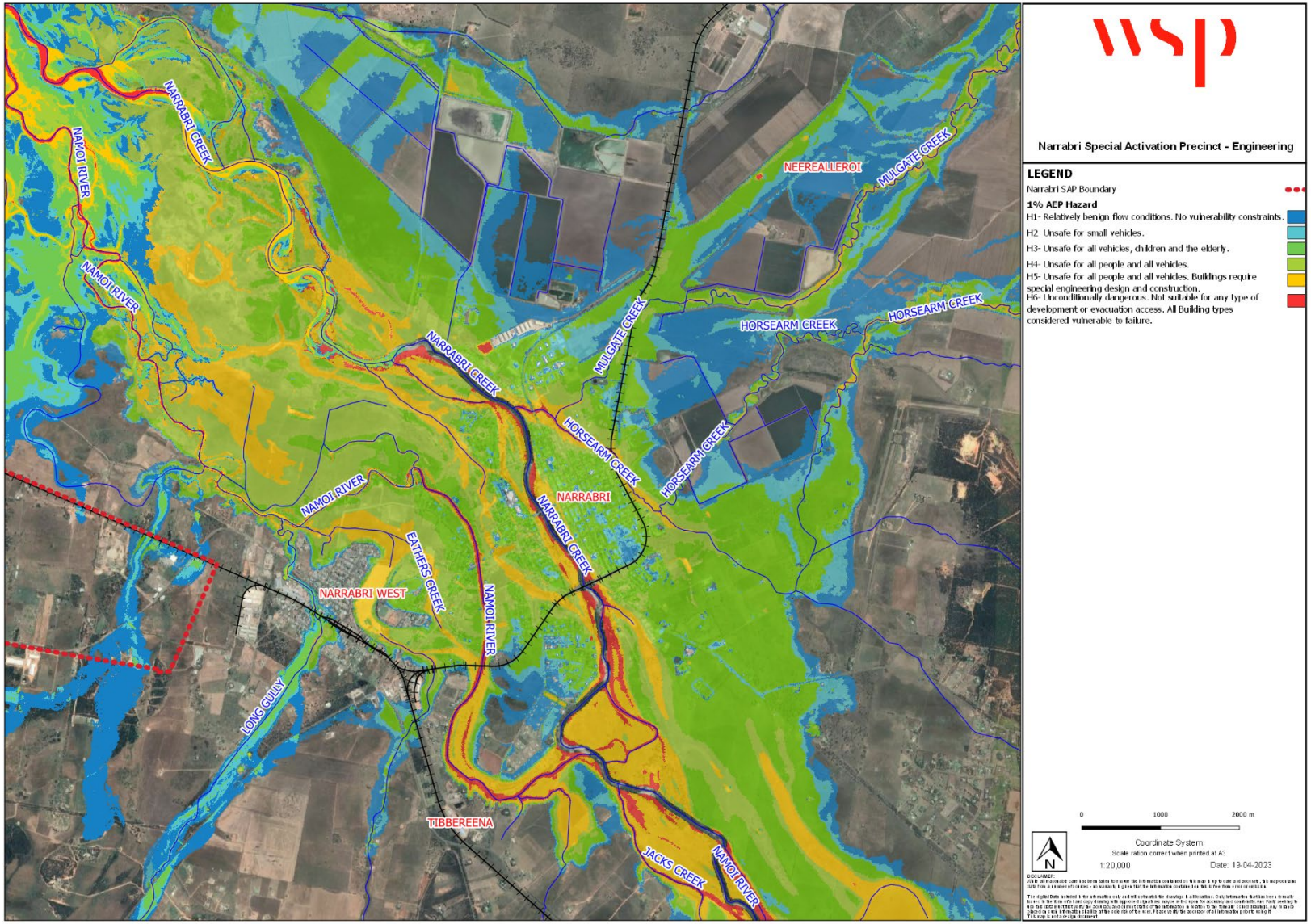


Figure 3.3 1% AEP flood hazard (April 2023)

3.5.4 Stormwater infrastructure

Stormwater infrastructure across the SAP investigation area includes culverts under existing roads and the Narrabri to Walgett Rail line but there are no underground drainage networks in the SAP investigation area and stormwater is conveyed in channels and overland flow paths.

Stormwater infrastructure through Narrabri town centre includes pit and pipe underground drainage networks but kerb and gutters on roads carry the majority of stormwater runoff from town to Narrabri and Horsearm Creeks.

3.5.5 Stormwater quality

Water quality data in the Bohena Creek catchment indicates relatively low levels of pollutants and indicates it to be a largely fresh water source (Santos, 2016). The existing low pollutant levels will set the future water quality targets to meet NSW Water Quality Objectives and minimise impacts to the downstream catchment.

3.6 Opportunities and constraints

The baseline assessment of flooding conditions, stormwater and water quality provided a good understanding of the key constraints for the Narrabri SAP Investigation area to assist with identifying opportunities for development of the Precinct.

The constraints include:

- the Narrabri SAP Investigation area includes areas of floodway
- the Narrabri SAP Investigation area includes significant areas of flood storage south of Yarra Lake Road and east of the main Bohena Creek Channel
- hazard classification of H3 to H6 occur along the eastern side of Bohena Creek and extend into the SAP Precinct south of Yarrie Lake Road and at the Narrabri to Walgett Rail line and along Long Gully
- there is an existing overland flow path through the central area of the Narrabri SAP Investigation area as defined by the H1 hazard classification
- no formal or underground stormwater networks are evident across the Precinct
- the Narrabri town centre is flood prone and infill development should be avoided to limit an increase in flood risks for the community
- the urban areas of Narrabri Town Centre have a H3 to H4 hydraulic hazard classification
- existing farm dams influence local overland flows
- existing riparian vegetation and flooding dependent vegetation is likely to be present
- Water quality is currently fresh with low pollutant levels so this would need to be maintained.

The constraints provide the context for identifying opportunities for the future development of the Narrabri SAP Investigation area. These opportunities include defining corridors and their function with respect to flood and stormwater behaviour. These corridors were defined to identify compatible land uses with the flood hazard and vulnerability classifications and therefore reflect the recommendations from the NSW Flood Inquiry (refer to Section 3.2) and updates to NSW Land use planning guidelines (refer to Table 3.1). These corridors are described as follows:

- Waterway corridors – defined as floodways across the SAP Investigation area, including areas categorised as H5 and H6.
- Flooding corridors – defined as 1% AEP flood extent (also known as the flood planning area (FPA) (where freeboard should be applied to building developments to become the flood planning level (FPL)) and areas categorised as H3 and H4 which will therefore incorporate riparian zones (and naturally flowing areas) and allow for connection to country with access along waterways.
- Integrated stormwater management corridors – which includes farm dams and minor storm overland flow paths and areas categorised as H1 and H2. These corridors can then include drainage infrastructure, including basins, wetlands, roadside swales and be used for open space and parks to maintain the natural flow of surface water.

3.6.1 Industrial area (north)

The industrial land to the north lies adjacent to the Inland Rail alignment and straddles the Newell Highway and has Wee Waa Road and Horsearm Creek to the south. The area is flood prone with several lots within this area predicted to experience increased peak flood levels due to the proposed Inland Rail project (refer to Inland Rail Narromine to Narrabri Environmental Impact Statement, Technical Paper 3, Flooding and Hydrology Assessment, Jacobs GHD, November 2020). The flooding within this site occurs at the confluence of Mulgate Creek, Horsearm Creek and Narrabri Creek, with the eastern section of the site impacted as frequently as the 20% AEP event under existing conditions. For the 1% AEP event the area is completely inundated, with depths of greater than 600 mm as shown in Figure 5.5. The hazard within the site, shown in Figure 5.4, is mostly within the H3-H4 categories with sections along the south-east having a hazard of H5.

Further development of this area is not considered appropriate and does not meet the objectives of the Narrabri Local Environment Plan (refer to Table 3.1) and would not be compatible with the flood function and behaviour of the land. This land is therefore excluded from further consideration due to the existing flood risk.

4 Methodology

4.1 Flood assessment

The Narrabri SAP investigation flood assessment has been undertaken using the following methodology:

- Review the following documents, that provide a context for establishing future planning direction for flood prone land and managing flood risk as they are based on experience from recent flood events and document best practice for flood risk management.
  - NSW Flood Inquiry (NSW Government, August 2022)
  - NSW Independent Flood Inquiry (September 2022)
  - Lismore City Council, Discussion Paper – Land Use Strategy Review (March 2022)
  - NSW Flood Risk Management Manual DRAFT, NSW Government, February 2022.
- Provide information on the flood depths, hazard and flood function categories for each existing land use area from previous flood studies and models to provide an understanding of the existing flood behaviour and expected implications of flood risk for the proposed structure plan land uses and on existing land uses/users.
- Enquiry by Design (EbD) workshops. The EbD was an iterative process that allowed for the testing of ideas, solutions and concepts by almost 30 participants across all technical streams and a range of stakeholders. For flooding and surface water cycle management, this involved specific consultation with Narrabri Shire Council, Biodiversity and Conservation Directorate (BCD) and DPE Environment & Heritage Group (EHG) Floodplain Managers to develop planning conditions for the precinct.

4.1.1 Previous flooding assessments

The community within Narrabri has a high awareness of flood risk. Narrabri residents have experienced above floor flooding from the Namoi River, Mulgate Creek, Horsearm Creek and Long Gully on a regular basis. The most serious flood occurred in February 1955, with other major floods occurring in 1971, 1974, 1976, 1984, 1998, 2000, 2004 and 2012.

The available existing design flood information has been sourced from the following:

- Draft Bohena Creek Flood Study, WRM October 2019
- Narrabri Flood Study – Namoi River, Mulgate Creek and Long Gully, WRM December 2016
- Narrabri Floodplain Risk Management Study and Plan Volume I: Supplementary Flood Study – Namoi River, Mulgate Creek and Long Gully, WRM, June 2019
- Narrabri Floodplain Risk Management Study and Plan Volume II: Floodplain Risk Management Study, November 2020
- Inland Rail Narromine to Narrabri Environmental Impact Assessment, Flooding and Hydrology Assessment, Jacobs GHD, 2020
- Inland Rail Narromine to Narrabri, Preferred Infrastructure Amendment Report, Jacobs GHD, September 2022.

4.1.2 Existing flood behaviour

The Narrabri Shire Council flood model for Bohena Creek has been updated (from the WRM October 2019 Draft Bohena Creek Flood Study) to include Long Gully and therefore provides a detailed understanding of the flood depths and levels, floodways and flood storage areas and hydraulic categories. The Bohena Creek flood study model was used to simulate the effects of this (SAP) project to generate a full set of results for the assessment.

The Namoi River flooding information is based on the Draft Narrabri Flood Study (WRM November 2020) which included modelling of the Namoi River, Narrabri Creek, Horsearm Creek, Mulgate Creek and Long Gully. The Namoi River flood model was not updated, nor was the SAP simulated in this model, but all relevant results were obtained from the previous studies to inform the assessment. The potential changes to peak flows as a result of developing the SAP were not included in the model as the development will be required to attenuate flows to predevelopment levels prior to discharge using WSUD principles and in accordance with local planning policy.

The assessment is informed through a review of the results which are presented in Table 5.1 and include the following events for Bohena Creek and the Narrabri Flood Studies:

1. 5% AEP Event
2. 1% AEP Event
3. Climate change
   a. 1% AEP plus 30% increase (to represent potential climate change projections) – Bohena Creek only
   b. 0.05% AEP (adopted to represent Climate change projections) – Namoi River only
4. PMF Event.

The flood assessment used the following parameters to define flood risks and constraints:

1. Flood depth
2. Flood Hazard – H1-H6 (refer to Section 4.1.3)
3. Flood function Categories – Floodway, Flood Fringe and Flood Storage (refer to Section 4.1.4).

4.1.3 Flood hazard

Flood hazard is a parameter that can be used to indicate the potential loss of life, injury and economic loss caused by flood events. The degree of hazard varies with the severity of flooding and is affected by flood behaviour (extent, depth, velocity, isolation, rate of rise of floodwaters, duration), topography and emergency management capability (National Flood Risk Advisory Group, 2017). The hazard categories using the combination of depth and velocity can be related to the vulnerability of the community when interacting with floodwaters. The combined velocity-depth curves are then divided into hazard classifications that relate to specific vulnerability thresholds as has been determined using the ADR Handbook 7.3. These six classifications are shown in Figure 4.1 and Table 4.1 and include the limiting depth and velocities that inform the classifications

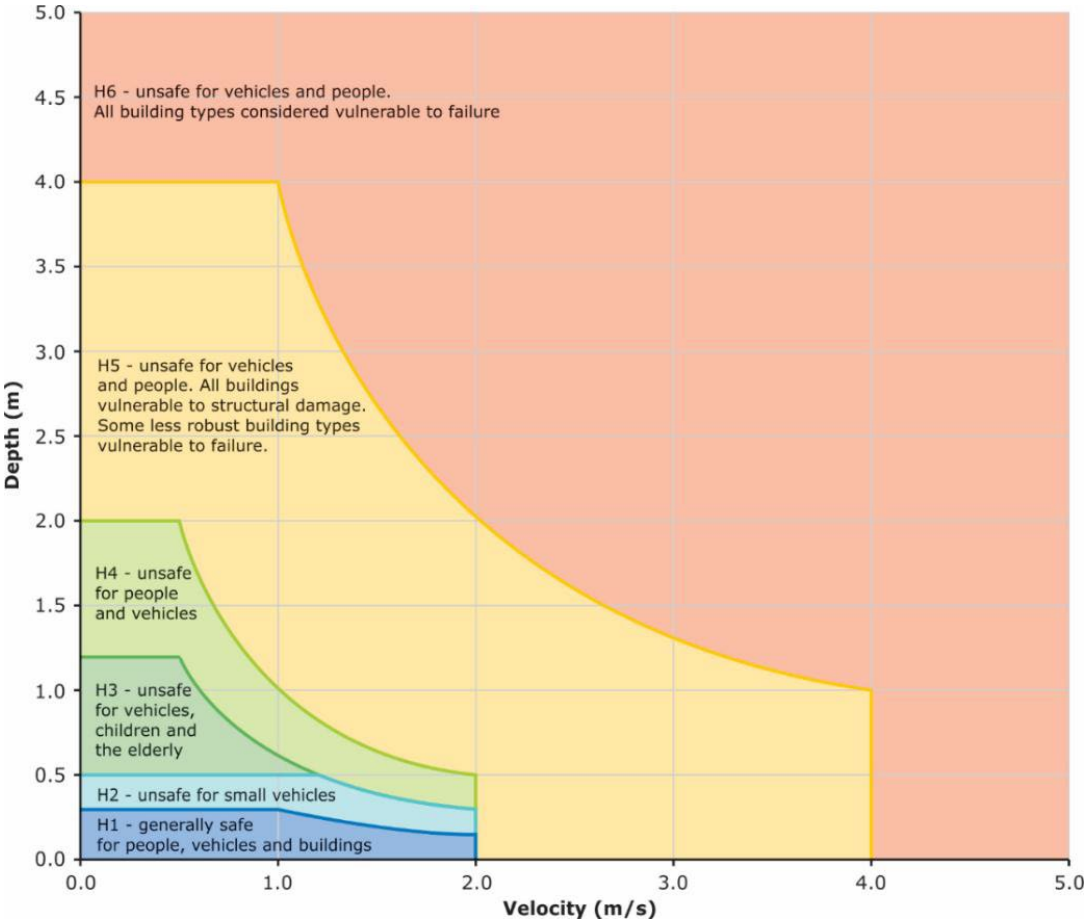


Figure 4.1 Combined flood hazard curves (from ARR 2019 Book 6, Chapter 7)

Table 4.1 Combined hazard curves – vulnerability thresholds

Hazard vulnerability classification	Description	Classification limit (D and V in combination)	Limiting still water depth (D) (m)	Limiting velocity (V) (m/s)
H1	Generally safe for vehicles, people and buildings	D*V ≤ 0.3	0.3	2.0
H2	Unsafe for small vehicles	D*V ≤ 0.6	0.5	2.0
H3	Unsafe for vehicles, children and the elderly	D*V ≤ 0.6	1.2	2.0
H4	Unsafe for vehicles and people	D*V ≤ 1.0	2.0	2.0
H5	Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure	D*V ≤ 4.0	4.0	4.0
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure	D*V > 4.0	–	–

Source – ADR Handbook 7, Table 1, Chapter 4, National Flood Risk Advisory Group, 2017.

4.1.4 Flood function categories

The flood function categories as defined in the Narrabri Flood Study (WRM 2019) have been adopted for consistency with the Narrabri Shire Council Study, and are defined as:

- Floodway – 5% AEP Flood High Hazard Extent
- Flood Storage – 1% AEP Extent outside the Floodway
- Flood Fringe – PMF Extent outside the 1% AEP Extent.

4.1.5 Flood risk assessment and mapping

The flood risk assessment methodology includes:

- identify the constraints on development based on the flood model results and identify feasible flood mitigation measures and planning conditions required to facilitate the Structure Plan
- assess the suitability and compatibility of the Structure Plan against flood hazard and flood function and recommend appropriate land uses in line with government policy (refer to section 3.1 and findings from the NSW Flood Inquiries outlined in Section 3.2)
- identify existing flood evacuation paths and areas that cannot be safely evacuated
- the assessment has then been presented in series of maps. Flood maps have included flood extents, floodways, flood storage, flood fringe, flood depths and hazard for the structure plan, refer to Section 1.4 and Section 5.1.

4.1.6 Limitations of the flood assessment

The limitations of this flood assessment include:

- topography updates and proposed new structures have not been included or modelled as landform changes and earthworks design that may be required to support development were not part of the master planning process to date. Future development of the model will need to include any proposed landform changes to assess the suitability of proposed land uses and re-confirm flood constraints and parameters for the future landform
- assessment of the proposed structure Plan against Bohena Creek flood behaviour is based on the existing condition results from the updated Bohena Creek Model from the Draft Bohena Creek Flood Study, WRM, October 2019
- assessment of the proposed structure plan against the Namoi River flood behaviour is based on the existing conditions results provided from the Narrabri Flood Study – Namoi River, Mulgate Creek and Long Gully, WRM, December 2019.

4.2 Surface water cycle assessment

- Review the proposed structure plan and estimate the area of each land use that may be assumed to be buildings. This enables the estimate of the volumes of potential rainwater that could be captured and therefore available for re-use. The estimated areas for each land use buildings are based on a review of local industrial conditions and similar land uses in other locations across NSW.
- Consider outputs from the EbD workshops. This included liaising with the land use planners (Hatch RobertsDay) to ensure stormwater overland flows and areas set aside for water quality management measures could be designated as part of the structure plan.
- Update the available stormwater model using the MUSIC-X software program for the proposed structure plan layout. The input information for the MUSIC-X model includes:
  - daily rainfall data from NSW Water gauge 419032 at Boggabri and the BOM gauge 54138 at Upper Horton
  - access potential evaporation data for the nearest station, Narrabri Airport Automatic Weather Station (54038). This is an input into the MUSIC-X model
  - update the land use input nodes to match the proposed structure plan land uses and update the estimated roof areas for each land use
  - simulate up to 10 years of daily rainfall data and extract daily and annual water quantities from roof areas.

- Qualitatively review the proposed structure plan against the proposed Integrated Stormwater Management corridors (ISMC)) and its ability to meet the desired stormwater management measures which include:
  - provision of stormwater infrastructure to drain the SAP investigation area that also incorporates storage and groundwater recharge and potential stormwater harvesting opportunities
  - water cycle management – collection of stormwater, treatment of stormwater and more natural flow release, capture of rainwater and reuse, and stormwater as a resource. Development of a treatment train approach, i.e. a sequence of stormwater treatment devices or methods throughout the catchment, for stormwater quality and quantity management with a focus on prevention before treatment
  - rainwater tanks – to provide some water to meet demands
  - point source pollution control – as best as possible manage stormwater runoff at the source.
- Document the findings for the structure plan with regards to total volume of rainwater available and quality of rainwater for re-use purposes.
- Document the potential estimated change in surface water infiltration areas as a result of the proposed structure plan and transport options.
- Make recommendations for future investigation and planning including further modelling and monitoring where required.

4.2.1 Limitations of surface water cycle assessment

The assessment has been prepared with the best available information but due to the proposed "future" nature of the structure plan it is limited by the following:

- Similar land uses are grouped together (as provided as part of the structure plan) which means estimated roof areas for each land use are also grouped together. Individual development lots will have differing roof areas and site specific rainwater collection tanks. The estimated rainwater volumes are therefore subject to change at the individual lot scale.
- Assumed roof areas are based on the following:
  - Fertiliser and Chemicals – not considered as part of the assessment due to its location west of Bohena Creek and size, such that it will need to source its own water and assess the viability of capture and reuse of rainwater at the individual lot scale.
  - Solar – not considered as part of the assessment due to its location west of Bohena Creek and not likely to include large buildings or have a demand for water.
  - Grain (potential) – not considered as part of the assessment due to its location west of Bohena Creek and size, such that it will need to source its own water and assess the viability of capture and reuse of rainwater at the individual lot scale.
  - Western Rail Siding – not considered as part of the assessment due to its location west of Bohena Creek and not likely to include large buildings or have a demand for water.
  - Energy – not considered as part of the assessment due to its location west of Bohena Creek and size, such that it will need to source its own water and assess the viability of capture and reuse of rainwater at the individual lot scale.
  - Bioproducts not considered as part of the assessment due to its location west of Bohena Creek and size, such that it will need to source its own water and assess the viability of capture and reuse of rainwater at the individual lot scale.
  - Inland Port (Rail Siding and additional Rail Side reserve) not considered as part of the assessment due to its location east of Bohena Creek and not likely to include large buildings or have a demand for water.

- Transport and Logistics – roof area based on a review of properties near the Orange Broken Hill Railway at Parkes (also located near the Inland Rail project), using a roof area of 5% of the total lot size estimate.
- Interim Potential Hazardous uses – assume 15% of area includes roof. Value adopted by Water demand strategy (Narrabri SAP, Hydrogeology and Water Demand Report, WSP, Oct 2022).
- Water Management and recycling – roof area of 700 m^2 adopted based on an average of a number of rubbish depot building in NSW.
- Agricultural and Food Processing – assume 15% of area includes roof. Value adopted by Water demand strategy (Narrabri SAP, Hydrogeology and Water Demand Report, WSP, Oct 2022).
- Manufacturing – assume 15% of area includes roof. Value adopted by Water demand strategy (Narrabri SAP, Hydrogeology and Water Demand Report, WSP, Oct 2022).
- Circular Economy – assume 15% of area includes roof. Value adopted by Water demand strategy (Narrabri SAP, Hydrogeology and Water Demand Report, WSP, Oct 2022).
- Rail Connection – not considered as part of the assessment due not likely to include large buildings or have a demand for water.
- Light Industrial South – assume 15% of area includes roof. Value adopted by Water demand strategy (Narrabri SAP, Hydrogeology and Water Demand Report, WSP, Oct 2022).
- Residential – not included because the residential buildings are subject to the Building Sustainability Index (BASIX). The Water section of BASIX aims to reduce the potable water consumption of all new residential developments by identifying alternative sources including rainwater. The proposed alternative sources are lot based and therefore are dependent on the residential dwelling and individual assessment. Since these specifics are not known at the precinct scale it was not included in the assessment. The Building Sustainability Index (BASIX) requirements apply to all residential dwelling types and are part of the development application process in NSW. (About BASIX | Planning Portal – Department of Planning and Environment (nsw.gov.au)).

4.3 Proposed road options

Included in the SAP is the proposed upgraded and new road network to integrate the proposed land uses with the existing road infrastructure. The three proposed upgrades have been separated into the SAP Link Road, new residential access routes and a potential future north-south connection. These road options are presented in Figure 4.2 and described in the following sections. Assessment of the existing road network which is not being upgraded has also been considered as part of the assessment.

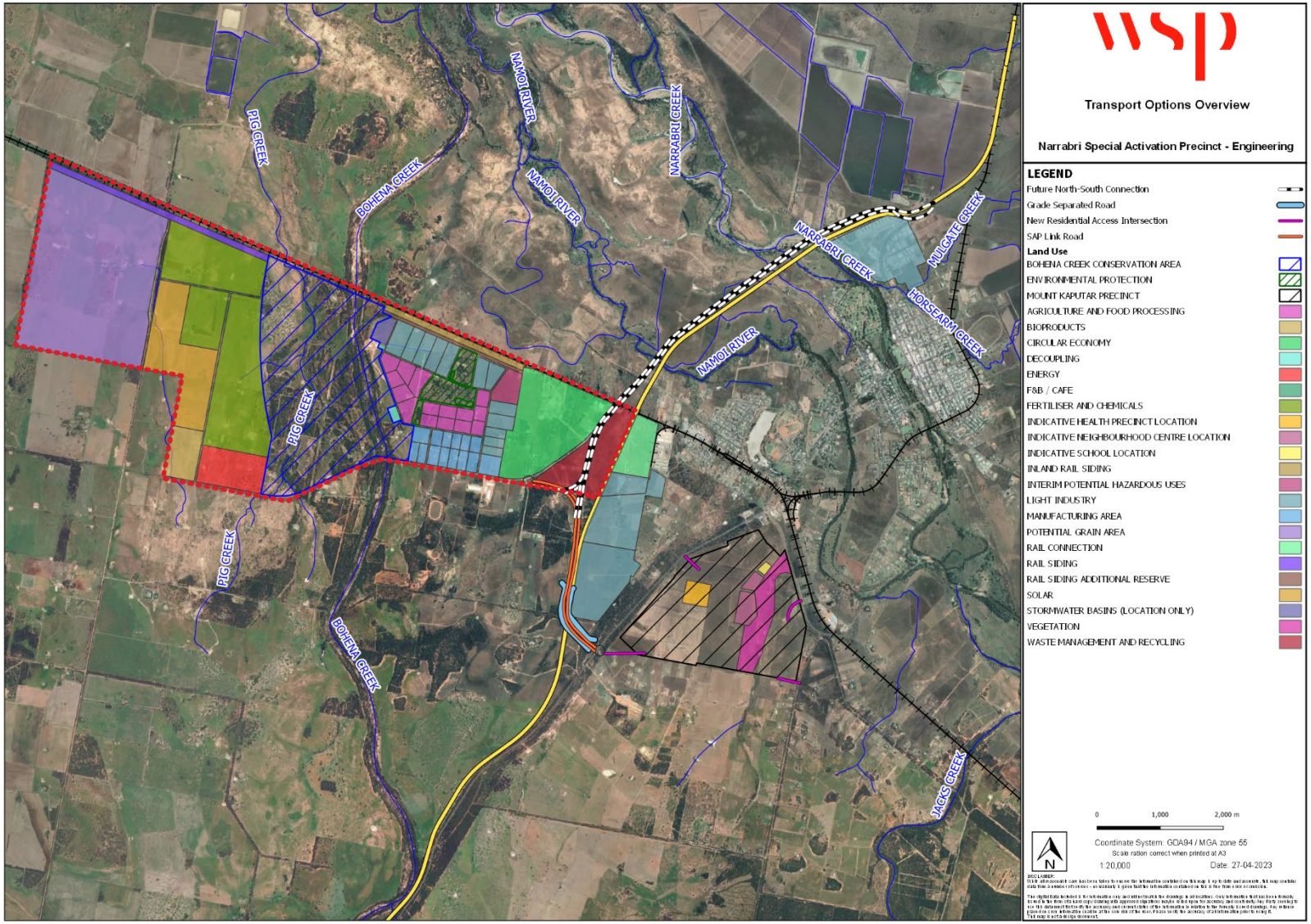


Figure 4.2 Proposed transport links (April 2023)

4.3.1 SAP road link

The proposed SAP road link provides an upgraded connection extending west from the Newell Highway, grade-separated over the Inland Rail line and Long Gully to meet with Yarrie Lake Road. The SAP Link Road also has the ability to connect with a potential future north-south connection providing a potential longer term connection for the SAP north of Narrabri.

4.3.2 New residential access

The proposed local road connections in the southern residential area provide two main entrances into the precinct, one along the west from the Newell Highway and one from the east off the Kamilaroi Highway.

4.3.3 Future north-south connection

A potential longer term connection for the SAP to the north of Narrabri would be via a north-south road connection that would run parallel to the proposed Inland Rail alignment.

4.3.4 Road options assessment

The road options and local road network have been assessed as part of the flooding and surface water cycle assessments and have considered the following:

- Flooding:
  - existing flood risk of land, including existing flood depths and extents to understand road flood immunity
  - existing flow path directions – to inform potential impacts from the future road on overland flows
  - connections to high ground, flood free transport links.
- Stormwater:
  - increase in hard surfaces and potential attenuation considerations to minimise impacts
  - potential to manage changed stormwater quality from future roads.

5 Assessment and findings

5.1 Flooding assessment

5.1.1 Precinct considerations

As outlined in Section 2, areas of growth have been identified across the SAP study area. The proposed topographic changes that may impact flooding will be required as part of the proposed structure plan. These were not available due to the early stage of the planning process, however the existing flood models have been interrogated to understand flood behaviour and flood risk for the structure plan and inform future planning criteria to minimise flood risk.

The assessment has been divided up into the different elements of the SAP investigation area, i.e. Inland Port, land west of Bohena Creek, light industrial area (south) and residential. Flood risks within each of these elements are discussed in Section 5.1.2.

5.1.1.1 Climate change

There is now widespread acceptance that human activities are contributing to observed climate change. Australian Rainfall and Runoff (ARR2019) provides guidance on understanding these changes specific to different areas across Australia based on predictions from the Climate Futures web tool developed by the Commonwealth Scientific and Industrial Research organisation (CSIRO). Information within this tool is based on the CSIRO Natural Resource Management (NRM) 'clusters' for which the Narrabri SAP investigation area is located within the NSW Central Slopes. The CSIRO information indicates that for this area the Global Climate Models (GCMs) are predicting a temperature increase of 2.9 to 4.6 degrees by 2090 for high emission scenario which is the representative concentration pathways 8.5 (RCP 8.5). Under an intermediate scenario (RCP 4.5) the projected warming is 1.3 to 2.5 degrees (CSIRO and Bureau of Meteorology, Climate Change in Australia website, accessed 5/11/21).

In relation to rainfall, the climate models predict possible overall decrease in rainfall, particularly in winter months within the cluster, with possible greater time spent in drought conditions. They also predict with high confidence an increase in rainfall intensity during extreme events. ARR 2019 provides a procedure for estimating the increase in rainfall intensity due to these climate change projections. Using this procedure, under the high emission scenario (RCP 8.5), rainfall intensities at the Narrabri SAP investigation area are predicted to increase by approximately 5.3% and 22.8% by 2030 and 2090 respectively.

For the Bohena Creek floodplain, the flood modelling indicates that for a projected 30% increase in rainfall intensity there will be up to a 0.7 m increase in flood depths across some areas of the floodplain and there will be an increase in flood extent. Across the Namoi River floodplain the flood modelling indicates varying levels of increase due to local catchment inflows, however there in an increase predicted in peak flood levels of up to 0.35 m (WRM, 2019b). The peak 1% AEP flood depths are shown in Figure 5.1 and the predicted 1% AEP flood hazard is presented in Figure 5.2.

The predicted increase in water level due to climate change is presented in Figure 5.3 which shows the relative change in peak flood levels for the 1% AEP flood event against the predicted 1% AEP with climate change included.

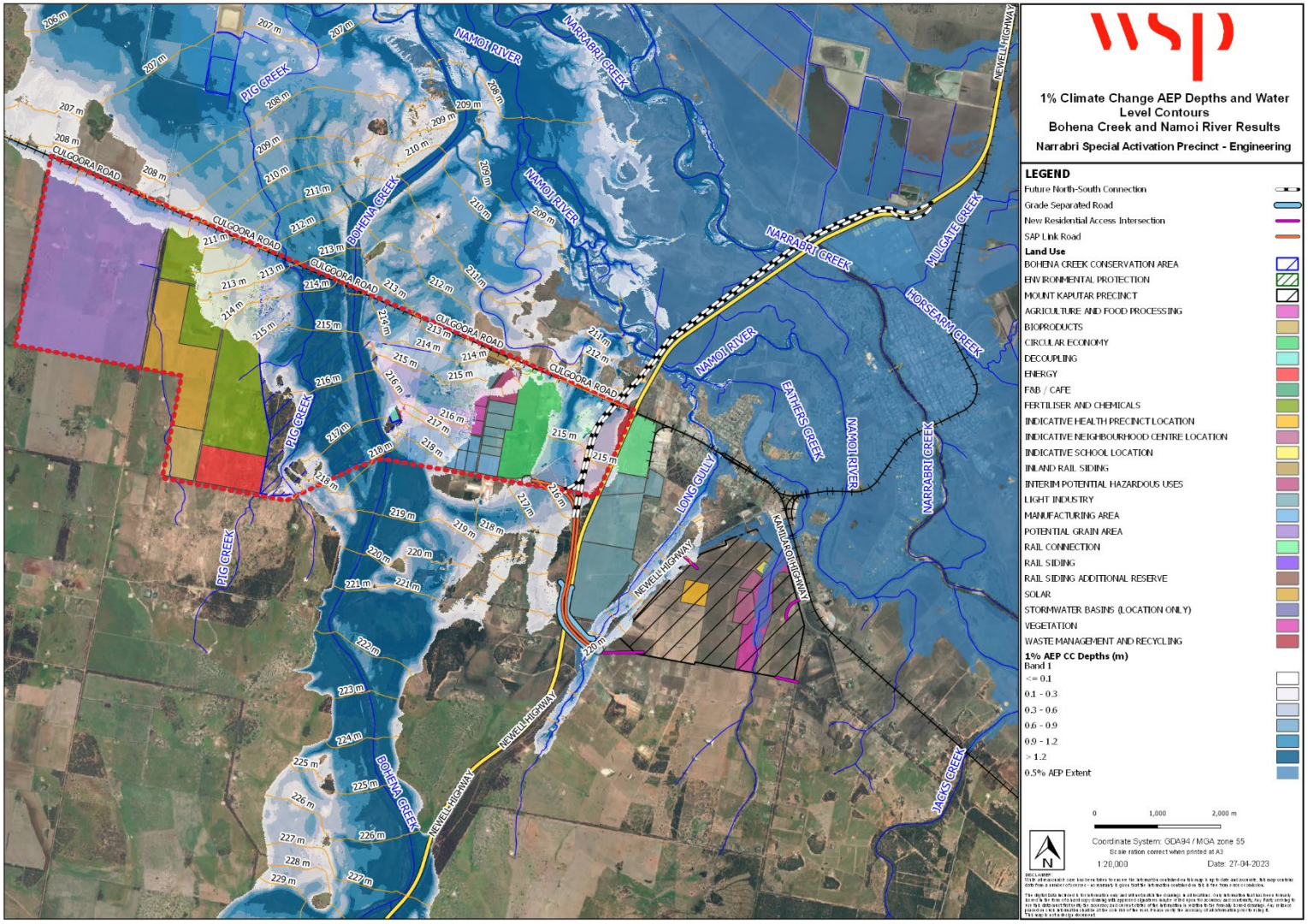


Figure 5.1 1% AEP climate change peak flood extent and depths (m) (April 2023)

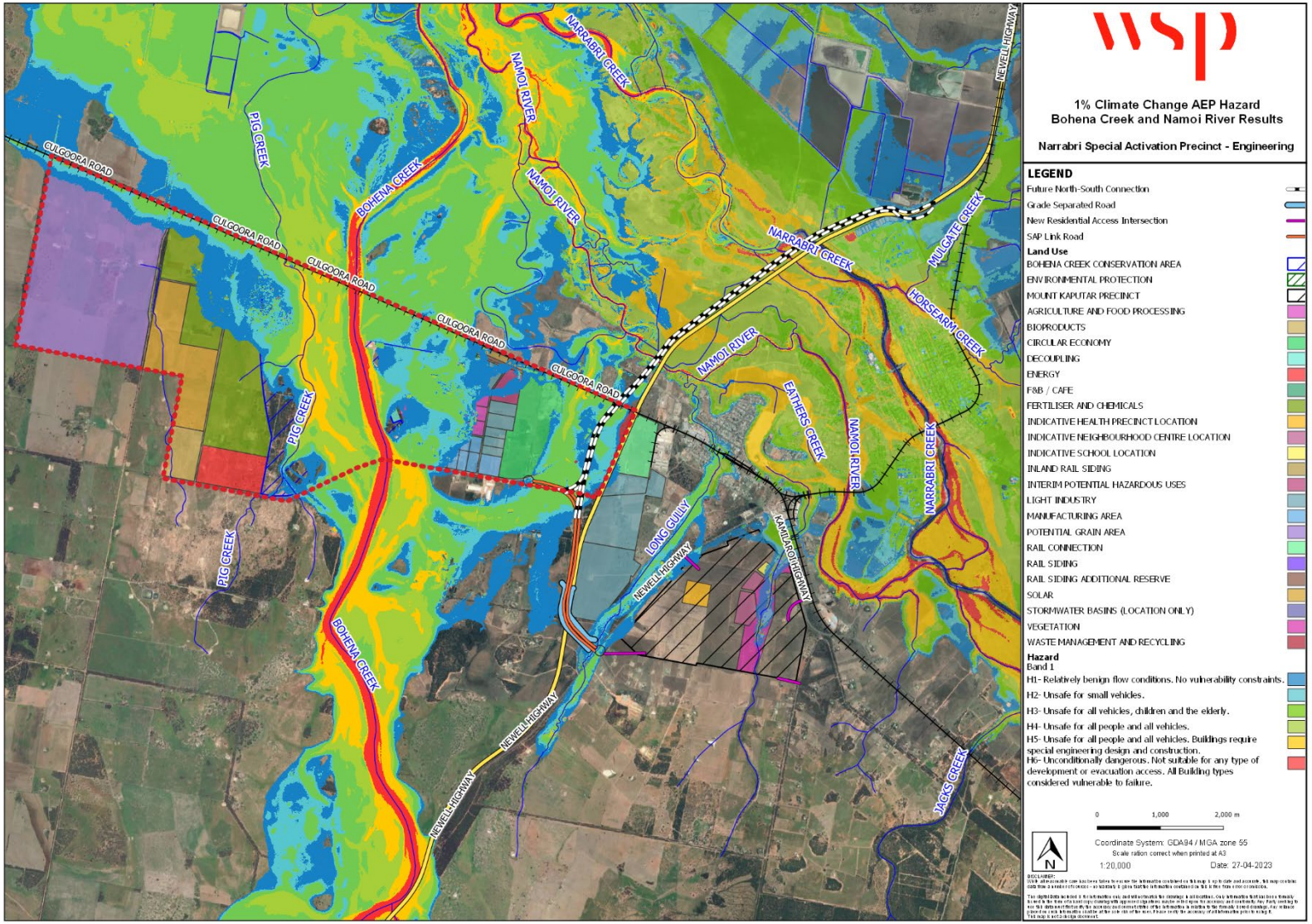


Figure 5.2 1% AEP climate change flood hazard (April 2023)

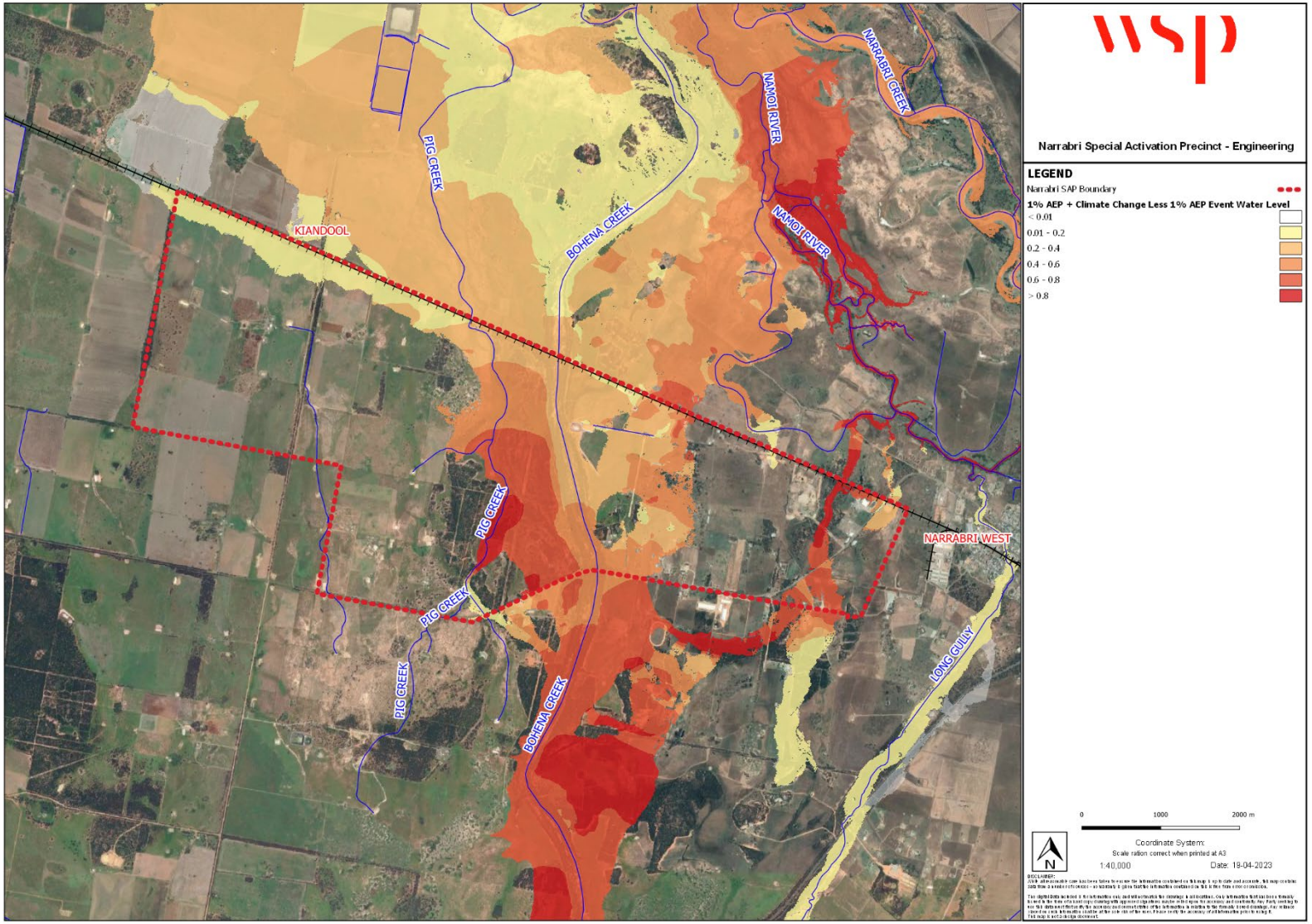


Figure 5.3 Relative change (m) in 1% AEP peak flood level with climate change considered (April 2023)

Specific areas where climate change flood levels should be adopted as the base case for flood risk management planning are as follows:

- Inland Port – depths increase across the area by up to 700 mm.
- East of Bohena Creek – circular economy and waste management and recycling zone is predicted to have an increased hazard of H3 to H5 for the 1% plus climate change scenario, as shown in Figure 5.1. The depths within the overland flow path increased to 2.4 m (from 800 mm in the 1% AEP), shown in Figure 5.3.
- West of Bohena Creek – The north east corner of the Fertiliser and Chemicals Land Use Area is affected in the 1% AEP event with climate change, with increased depths up to 700 mm, shown in Figure 5.3.
- Residential area – The 1% AEP event with climate change flood extent and depth is predicted to increase and therefore encroach into the proposed residential zoned land with depths in this northern area up to 300 mm, shown in Figure 5.3, however, the hazard rating remains at H1, shown in Figure 5.4.

5.1.2 Narrabri SAP investigation area and Inland Port and industrial area (south)

5.1.2.1 East Bohena Creek/Inland Port

The proposed land use extent east of Bohena Creek has considered avoiding the H5 and H6 flood hazard categories and is out of the floodway extent for Bohena Creek. This area is largely made up of the Inland Port Precinct, which has been identified as having high value biodiversity and sensitive vegetation through the centre of the Precinct. The preservation of this sensitive vegetation and exclusion from development occurs in an area that functions as flood storage in the 1% AEP event. Preserving this area will minimise impact to flooding as it provides for flood waters to continue to be stored. The proposed rail siding adjacent to the existing Narrabri West Walgett Railway line is located on land with H3 hazard and both flood storage and flood fringe areas. Development of the rail siding will need to consider the existing flood risk and flood function (flood storage and flood fringe) but this should not preclude use of the land as a rail siding. The existing flood risk does not preclude development of the Inland Port area but local topographic and landform changes should be kept to a minimum within flood storage areas with consideration of a cut fill balance and provide adequate drainage to minimise impact to flood behaviour both within the lots and across the high value biodiversity land.

The circular economy and waste management and recycling land has a defined flood risk centred around the overland flow path heading south to north through the site. The hazard along this overland flow path varies from H1 to H3 for the 1% AEP event, shown in Figure 5.4. The H3 hazard classification is due to the depths of up to 800 mm within the flow path, shown in Figure 5.5. There is sufficient land beyond the 1% AEP flood extent to the west of the overland flow path to develop with due consideration of local landform and overland flow path required during design. The overland flow path and H1 to H3 land is recommended to be the integrated water management corridor which should include flood management options to manage changes in local stormwater runoff. Access roads to high ground should be kept to the west of the overland flow path allowing for evacuation north to Culgoora Road or east to Yarrie Lake Road.

Overall, the Inland Port and east of Bohena Creek area lies within the Bohena Creek PMF extent and is entirely inundated in the PMF, excluding a small section of land in the south-east corner. The depths in the PMF are up to 1.9 m in the north-east, shown in Figure 5.6. Therefore, appropriate flood planning conditions and emergency management planning will be applicable to all developments in this area (refer to Section 5.2.3).

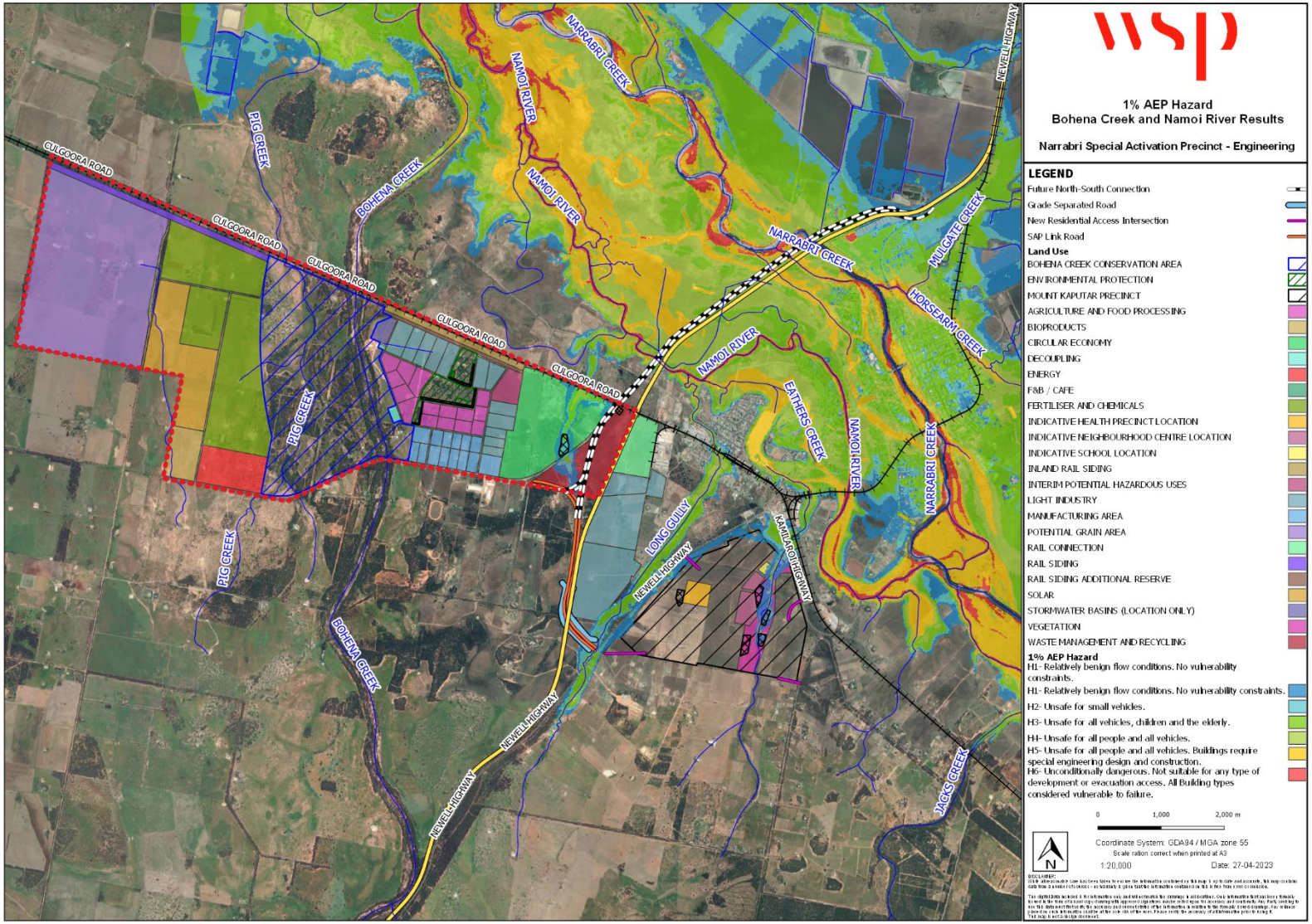


Figure 5.4 1% AEP flood hazard (April 2023)

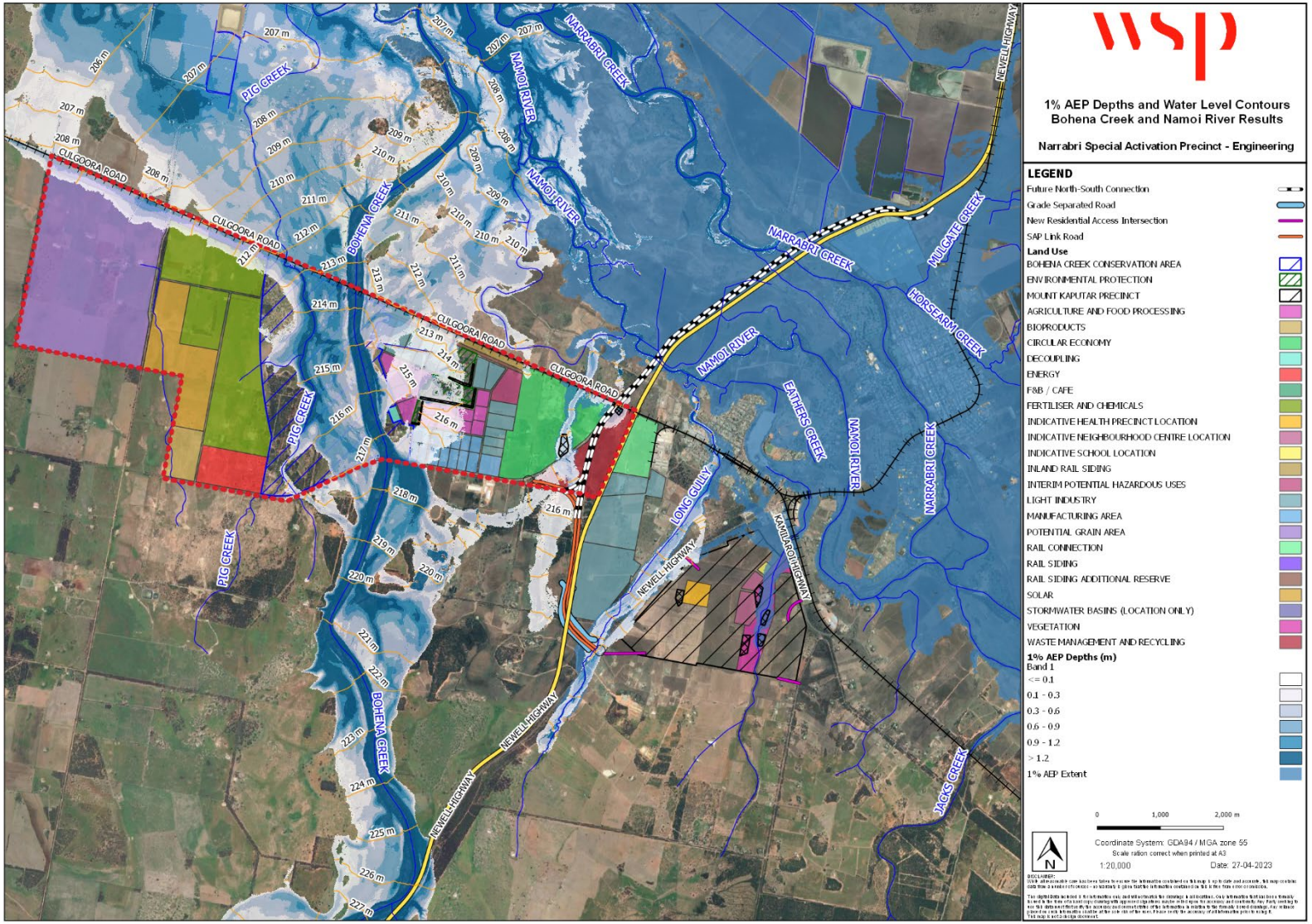


Figure 5.5 1% AEP flood event peak flood depths (m) and flood extent (April 2023)

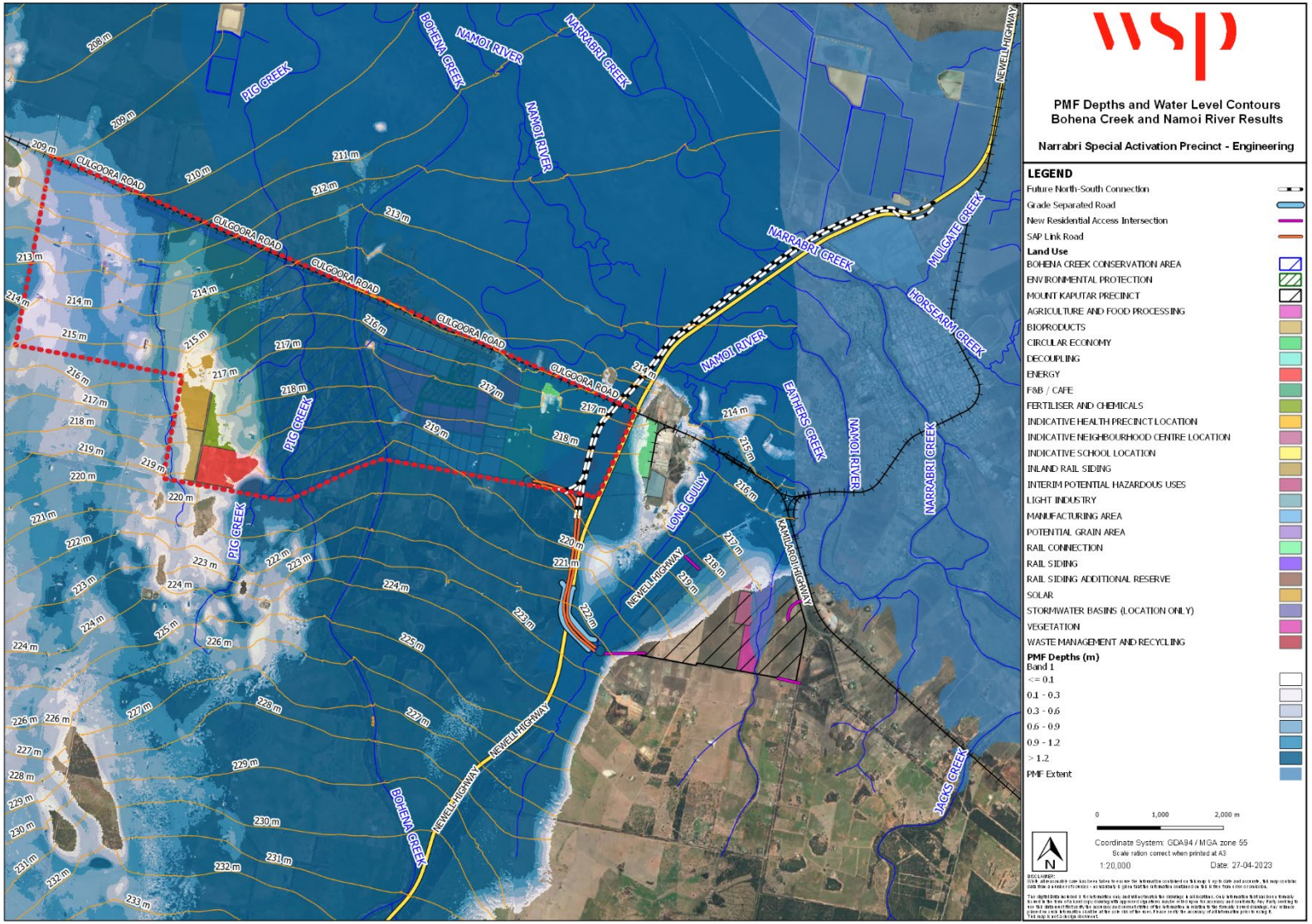


Figure 5.6 PMF depths and extent (April 2023)

5.1.2.2 Light industrial area (south)

The light industrial area (south) lies to the east of the Inland Rail alignment and outside of the existing 1% AEP flood extent but within the PMF flood extent for Bohena Creek, as presented in Figure 5.5 and Figure 5.6. The existing flood risk does not preclude development of this land but appropriate flood planning conditions will be applicable (refer to Section 5.2) to development of this land to minimise existing and future flood risks.

5.1.2.3 West of Bohena Creek

The proposed land use areas to the west of Bohena Creek include Grain, Fertiliser and Chemicals, Bio-products and Energy. The available flood model does not cover the full extent of the proposed structure plan which does not indicate that the land is not subject to inundation. Satellite data obtained for the 24th October 2022 flood event has indicated that this land is subject to overland flows (refer to Appendix A). The proposed structure plan has avoided the Bohena Creek floodway but the north east corner and western rail siding are within a flood storage area. The land within the flood storage area has a hazard H1 which does not preclude development of this land but should be considered when planning development of the lot with respect to managing the flood risk, noting the storage of hazardous substances during a flood event will need to be designed (refer to Section 5.2.3). The majority of this area is inundated by the PMF, shown in Figure 5.6, and therefore appropriate flood planning conditions will be applicable to development of this land to minimise future flood risks with the precinct and beyond the precinct. Refer to Section 5.2 for a summary and recommendations.

5.1.2.4 Residential area

The residential area lies to the east of the Newell Highway and west of the Kamilaroi Highway in a triangle shape across land that rises in elevation to the south from the intersection of the two highways. The land is largely flood free excluding an area containing a small non-perennial tributary of the Namoi River running to the east of the centre of the area. This area is however within the Flood Planning Area as defined by the Narrabri Local Environment Plan (LEP) (2012) and therefore subject to the conditions as outlined in Section 5.21 of the LEP. The proposed structure plan has considered the 1% AEP flood extent and floodway and excluded this land for development and will be zoned as a Vegetation Zone, shown in Figure 5.5. The northern portion of this area is subject to inundation in the PMF event and any land between the 1% and the PMF would be subject to flood related planning controls, but the majority of this area is not within the PMF flood extent for the Namoi River. Sensitive land uses should be avoided in the area inundated in the PMF in accordance with the latest policy updates outlined in the Flood Prone Land Package, (DPIE, 2021) (refer to Table 3.1).The 24th October 2022 satellite imagery (refer to Appendix A), however, has indicated some areas of local surface flows that have not been identified as part of the existing flood models. This means that further division of the residential parcels of land will need to consider these observed flows and ensure they are preserved and maintained to ensure minimal impact and reduce the risk of inundation across the residential areas.

The proposed Vegetation Zone and topography of this area should be used to align roads from north to south to facilitate evacuation and complement existing surface water flows. As outlined in the NSW Flood Prone Land Package, (DPIE, 2021) (see Table 3.1), the residential area can be developed but for land within the PMF extent, subdivision layouts and connections to local or regional evacuation routes need to be considered, do not permit residential accommodation in high hazard areas and dwelling densities should be low and increase beyond the PMF extent.

5.1.3 Road options flood assessment

5.1.3.1 SAP Link Road

The proposed SAP Link Road is affected by the 1% AEP flood event at the Newell Highway connection (Long Gully floodplain) and an overland flow path at the bend in Yarrie Lake Road. The remainder of the proposed alignment is outside of the 1% AEP flood extent but the entire alignment is subject to the PMF flood extent. At the connections to the Newell Highway and Yarrie Lake Road the existing flood depths are less than 200 mm and the land has a H1 hazard.

At Yarrie Lake Road the proposed connection is largely perpendicular to the south to north overland flow path. This perpendicular alignment is preferred as it will minimise the loss of floodplain storage and flood fringe areas and with sufficient waterway openings will have minimal impacts on land upstream and downstream.

With regards to access to flood free land, the proposed SAP Link Road would provide access to the south to the Newell Highway which could then be used to access high ground near the residential area to the east of the Newell. This would provide an alternative to the current arrangement where the SAP investigation area would need to evacuate along Yarrie Lake Road, Goobar and Mooloobar Street to access flood free land. An assessment of the impact the proposed road alignment will have on surrounding areas will need to be undertaken.

5.1.3.2 New residential access

The residential area access link on the west off the Newell Highway is within flood prone land, and therefore subject to inundation up to the PMF but experience depth less than 100 mm for the 1% AEP event. This link could not be used to provide access to high ground during a flood event and should not be considered as a flood evacuation route. Access to high ground is to the south within the residential area.

The residential access link on the east off the Kamilaroi Highway is beyond the PMF flood extent for the Namoi River and therefore not subject to inundation during a flood event. This access point could provide a road link to high flood free land to the south, but this would need to be considered as part of Flood Emergency Management Planning for the region.

5.1.3.3 Future north-south connection

This potential north-south road connection lies across the Namoi River floodplain and therefore its entire length is across flood prone land. Its height would be determined on the desirable immunity with consideration of potential impacts to flood behaviour. The proposed connection would be subject to similar planning conditions required for the adjacent Inland Rail. The height of the road would impact the serviceability of the road for flood evacuation. Other connections of this potential route have not been developed so its ability operate as a flood evacuation route would be subject to further investigations.

5.1.3.4 Yarrie Lake Road

Yarrie Lake Road is an existing local road that is located within the SAP investigation area and therefore its current flood affectation is important to understand due to its locality. The transport assessment identified that Yarrie Lake Road between the Inland Port and the SAP Link Road should be investigated and upgraded if required to accept long vehicles.

The part of the SAP west of Bohena Creek will be required to evacuate west along Yarrie Lake Road. The expansive width of Bohena Creek under flood conditions makes it cost prohibitive to create a flood immune route on Yarrie Lake Road to cater for heavy vehicles and other traffic. Therefore, the crossing of Bohena Creek should be upgraded to include debris blockage protection, flood hazard information and a flood depth marker. This would include replacement of culverts with an increased size to fit under the upgraded road and with improved structural integrity (of the culverts and embankment) during a flood event to help the road return to service soon after. It is recommended that proposed future roads be designed to minimise the impact on flooding.

5.2 Summary and development conditions for flood assessment

A summary of the flood assessment is presented in Table 5.1 and supported by Figure 5.7.

Table 5.1 Flood assessment summary and development conditions

Area	Flooding constraints			Development conditions	Planning conditions
	Floodway	PMF	Climate change		
Inland Port	Avoided	Up to 1.9 m	Up to 0.7 m increase in flood depths	Cut/fill balance for flood storage and flood fringe areas (refer to Section 5.2.1) Minimise fill to building footprints but provide adequate drainage Develop emergency management strategy (refer to Section 5.2.4) Structures – designed with consideration of flooding (refer to Section 5.2.1)	Set flood planning levels Building stability Evacuation strategy
Industrial area (south)	Avoided	Up to 1.9 m	Minimal impact	Cut/fill balance for flood storage and flood fringe areas (refer to Section 5.2.1) Minimise fill to building footprints but provide adequate drainage Develop emergency management strategy (refer to Section 5.2.4) Structures – designed with consideration of flooding (refer to Section 5.2.1)	Set flood planning levels
West of Bohena Creek	Avoided	Up to 3.0 m at Yarrie Lake Road	Up to 0.7 m increase in flood depths on edge of Bohena Creek	Cut/fill balance for flood storage and flood fringe areas (refer to Section 5.2.1) Hazardous Land uses to include storage and containment (refer to Section 5.2.3) Minimise fill to building footprints but provide adequate drainage Develop emergency management strategy (refer to Section 5.2.4) Structures – designed with consideration of flooding (refer to Section 5.2.1)	Set flood planning levels Building stability Evacuation strategy
Residential	Avoided	Avoided. Small parcel of land within PMF	Increase in flood extent and small increase in depth	North south alignment of roads for evacuation and surface flows Dwellings and sensitive land uses to be located beyond of PMF Buildings within PMF must have access to evacuation routes Structures – designed with consideration of flooding (refer to Section 5.2.1)	Already subject to Narrabri LEP Section 5.21 conditions

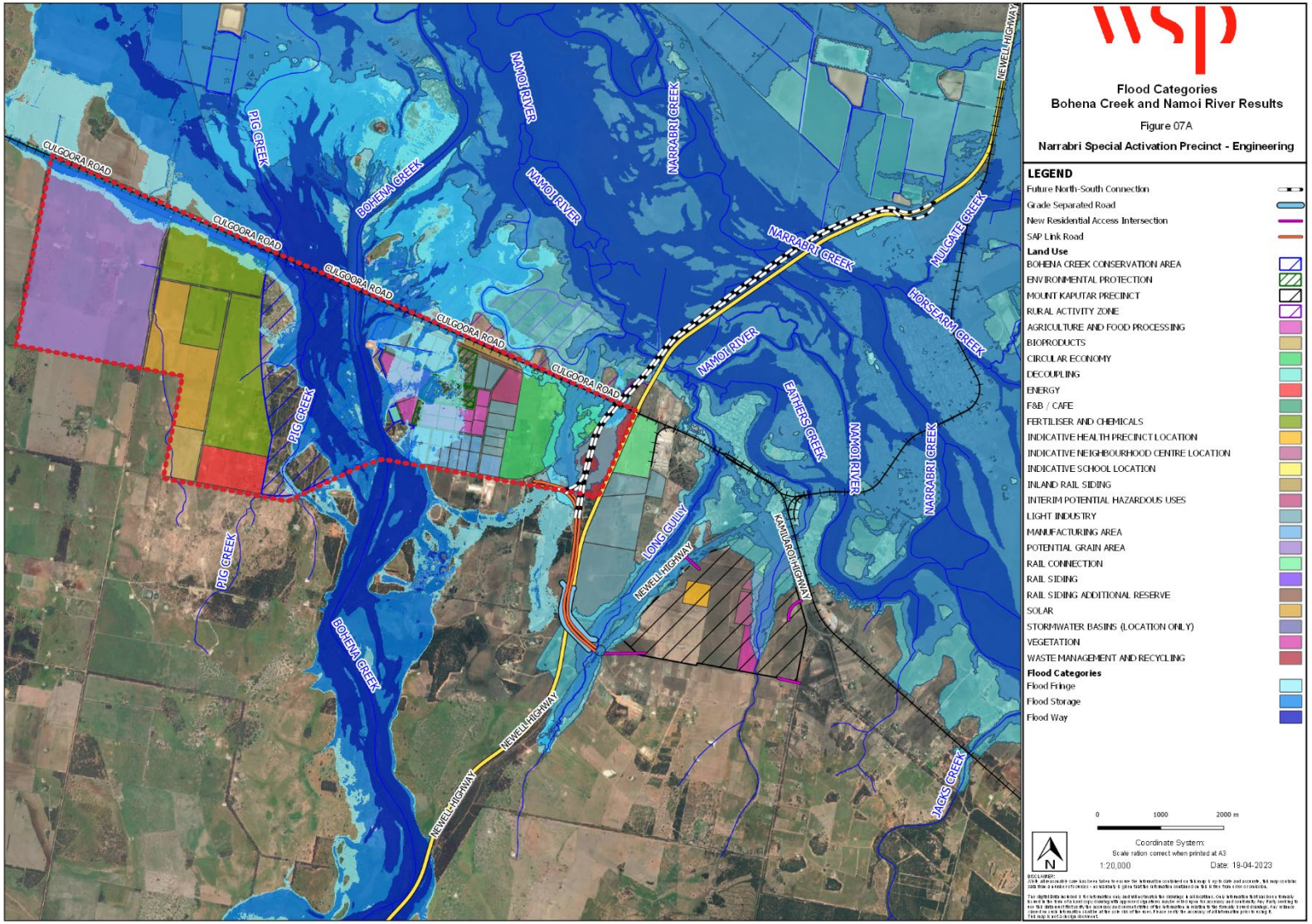


Figure 5.7 Flood function categories (April 2023)

5.2.1 Filling of flood prone land

Filling, reshaping or placing infrastructure can alter flowpaths or result in a loss of flood storage. The proposed Narrabri SAP flood investigation has identified the flood function for all proposed land within the SAP investigation area and as indicated in Table 5.1 all proposed areas avoid the floodways. Filling of flood fringe and flood storage areas for the 1% AEP flood event should be kept to building footprints and should consider the local flood function.

It is recommended that development of Narrabri SAP land can consider filling of land as long as the following criteria are met:

- filling of land so it is compatible with flood function and does not change the flood hazard classification of the land or land external to the site
- fill and compensatory excavation must not change the flood function or flood hazard classification of land external to the site.

5.2.2 Building structure information

Buildings can be vulnerable to damage and collapse under flood hazard conditions. ARR2019 provides a summary of the depth and velocity data for the structural stability of building subject to flood conditions. From this structural stability information, a set of building specific hazard curves have been developed. The hazard curves developed compliment the general hazard curves (as presented in Section Table 4.1) and are condensed into three classifications, low, moderate and high as presented in Table 5.2. It is recommended that structures that are built within the PMF flood extent should follow the minimum structural considerations as presented in Table 5.2.

Table 5.2 Structural criteria for flood hazard classification

Hazard vulnerability classification – buildings	Description of minimum structural considerations
Low Hazard H1-H4	For design of buildings within this vulnerability classification, buildings must comply with clauses 2.3 to 2.10 of the Australian Building Codes Board (ABCB) Standard: Construction of buildings in flood hazard areas, 2012.3 or NCC Volume One, BP1.4 or NCC Volume Two, P2.1.2 as appropriate.
Moderate/High Hazard H4-H5	Residential and essential services should be avoided in this classification. Possible to construct a purpose-built structure that is an appropriately engineered structure specifically designed to withstand the full range of anticipated flood forces listed below and in locations where timely evacuation is not possible, such purpose-built structures may be required for vertical evacuation (ARR, 2019). Flood forces include: — Hydrostatic forces — Buoyant forces — Hydrodynamic forces — Impulsive forces — Uplift forces — Debris Impact forces — Damming of Waterbourne Debris — Wave Actions — Erosion and Scour For design of buildings within this vulnerability classification buildings must comply with clauses 2.3 to 2.10 of the ABCB Standard: Construction of buildings in flood hazard areas, 2012.3 or NCC Volume One, BP1.4 or NCC Volume Two, P2.1.2 as appropriate.
Extreme Hazard H6	All buildings should be avoided in this classification. Buildings in areas classified with flood hazard above this threshold are considered vulnerable to collapse under these extreme flood conditions (ARR, 2019).

5.2.3 Hazardous land use considerations

In accordance with Flood Prone Land Package, (DPIE, 2021) Considering flooding in land use planning guideline (refer to Section 3.1), Special Flood Considerations apply to hazardous development in areas between the flood planning area and the PMF. These controls relate to the management of the risk of hazardous industry/hazardous storage establishments to the community and the environment in the event of a flood.

As such, hazardous industries require containment of storage establishments up the PMF plus consideration of freeboard to account for local wave action. Containment structures would then need to consider the structural considerations as outlined in Section 5.2.2 and 5.2.1. Figure 5.8 shows an example of a containment bund that could be considered.

Figure 5.8 Example of containment bunding

5.2.4 Emergency management considerations

For flood emergencies the Narrabri Shire Local Flood Plan (SES, November 2015) is the relevant flood emergency management plan for the Narrabri SAP Investigation area. The plan should be referred to for management of the flood risk for the Narrabri Town Centre and SAP Investigation area.

It is recommended that the plan be updated to consider the findings from the most recent flood investigations which includes this Narrabri SAP investigation and the following:

- Draft Bohena Creek Flood Study, WRM October 2019
- Narrabri Flood Study – Namoi River, Mulgate Creek and Long Gully, WRM December 2016
- Narrabri Floodplain Risk Management Study and Plan Volume I: Supplementary Flood Study – Namoi River, Mulgate Creek and Long Gully, WRM, June 2019
- Narrabri Floodplain Risk Management Study and Plan Volume II: Floodplain Risk Management Study, November 2020.

The Narrabri SAP Structure plan should be considered as part of the updates to the Local Flood plan with specific consideration of the following:

- establishing a flood evacuation centre beyond the PMF flood extent
- updating evacuation routes that include the new roads and rail (when built) as part of the SAP
- updating to include management and recovery for the proposed range of industries and land uses.

5.2.4.1 Property flood emergency strategies

For some of the proposed land uses it may be appropriate for property based flood emergency strategies to be developed. These strategies or plans should complement the Narrabri Local Flood Plan (SES 2015) but provide site specific details and actions to manage the flood emergency at the property. These flood emergency plans are recommended to include education, awareness, flood and weather information and preparation exercises to ensure the property and its occupants know what to do during a flood emergency, understand the risks and where to find appropriate information. The response part of the plan needs to be short and easy to follow. A recovery plan is important because it identifies the tasks needed to be completed following a flooding event.

Specifically, the plan should address the key requirements of:

- recommended flood response procedures
- warning information
- flood information and dissemination
- flood recovery.

5.3 Flood assessment findings

The key findings from the assessment include:

- floodways and H5-H6 have been avoided in development of the structure plan
- Inland Port, industrial area (east) land west of Bohena Creek and the industrial land (north) are all flood prone, that is subject to inundation in the PMF event, and therefore development will be subject to specific flood risk development conditions
- the residential area is largely above the PMF except for its northern portion and the proposed vegetation corridor to the east of centre but is already subject to the Narrabri LEP Section 5.21 as lit lies within the flood planning area
- Narrabri Town Centre and Industrial land to the north should avoid increasing density and new developments that place more people in the flood risk areas
- projected climate changes will increase the depth of flooding for the 1% AEP for all areas of the structure plan
- the light industrial land (south) is largely flood free for the 1% AEP
- the proposed SAP link could be designed to function as a flood evacuation route
- update Narrabri Shire Council LEP maps with Bohena Creek data to define the flood planning level.

5.4 Surface water cycle assessment

The surface water cycle assessment methodology is outlined in Section 4.2 and includes both a quantitative assessment and qualitative assessment as described in the following sections.

5.4.1 Structure plan stormwater infrastructure

Stormwater infrastructure across the SAP investigation area, Inland Port, residential and industrial area in the south will be determined during the detailed design for the upgraded infrastructure (road) and on a lot by lot basis. However, the proposed structure plan has been qualitatively reviewed for the key areas to assess if the proposed layout can meet the planning criteria of:

Provision of stormwater infrastructure to drain the SAP investigation area that also incorporates storage and groundwater recharge and potential stormwater harvesting opportunities.

5.4.1.1 Narrabri SAP investigation area and Inland Port and industrial area (south)

The Narrabri SAP investigation area, Inland Port and the industrial area (south) as presented in Figure 5.9 are overlaid against the integrated stormwater management corridor (ISMC) as defined in Section 4.2. The area can be further divided into east of Bohena Creek (Inland Port), west of Bohena Creek and the industrial area that lies to the east of the Inland Rail alignment. Each of these areas will be discussed separately.

East of Bohena Creek/Inland Port

The proposed land use extent east of Bohena Creek has been set to avoid the Bohena Creek floodplain which is discussed further in Section 5.1.2.1. The central area of the Inland Port precinct has been identified to contain sensitive vegetation which further justifies avoiding development of this area. The sensitive vegetation area coincides with part of the ISMC area, and therefore the area will be avoided for further development and this will help ensure the surface water supply for the vegetation is maintained. The ISMC is intended to provide multiple functions to account for more regular runoff events, maintain existing overland flow paths, provide areas for flood storage, allow for groundwater recharge and stormwater treatment (such as detention or wetlands) to minimise the impact of development across the SAP investigation area.

The proposed lot alignments through the Inland Port show proposed road connections running north-south which matches the existing slope of the land and therefore the roads could also be used as stormwater corridors which would minimise impacts to the local hydrologic cycle but could also accommodate WSUD measures (refer to Section 5.4.7.2) to treat stormwater runoff before it enters Bohena Creek.

The circular economy and waste management and recycling land uses straddle the existing Yarrie Lake Road and existing overland flow paths (ISMC). These lots are large enough to be able to avoid the ISMC but will also need to consider flood risk (as discussed in Section 5.1.2.1). Development of these lots should consider best practice WSUD principles (refer to Section 5.4.7.2) with consideration of the full range of planning criteria as listed in Section 4.2.

West of Bohena Creek

As can be seen in Figure 5.9 the western portion of the SAP area which lies west of Bohena Creek is beyond the defined ISMC. The northern portion of this area, which is proposed to be a rail siding, lies within the ISMC. This does not preclude development of the rail siding but appropriate stormwater quantity and quality management measures in accordance with the recommended planning criteria should be considered.

The 24th October 2022 satellite map (Appendix A) shows that there are overland flow paths across the proposed structure plan lots and this should be considered when detailed planning of this land is undertaken.

Industrial area (south)

The industrial area lies to the east of the Inland Rail alignment and out of the ISMC. Development of these lots should consider best practice WSUD principles (refer to Section 5.4.7.2) with consideration of the full range of planning criteria as listed in Section 4.2.

5.4.1.2 Residential area

The residential area lies to the east of the Newell Highway and west of the Kamilaroi Highway in a triangle shape across land that rises in elevation to the south from the intersection of the two highways. The land is largely flood free (as discussed in Section 5.1.2.4) and includes one main overland flow path as presented in Figure 5.10. The proposed structure plan has included the ISMC in the vegetation and biodiversity mapping area and therefore precluded it from being developed. Precluding the ISMC from being developed will ensure the criteria can be achieved, such that the corridor will provide undeveloped land for rainfall infiltration recharging groundwater and soil moisture, stormwater harvesting and stormwater treatment opportunities to minimise the impacts of the urban development.

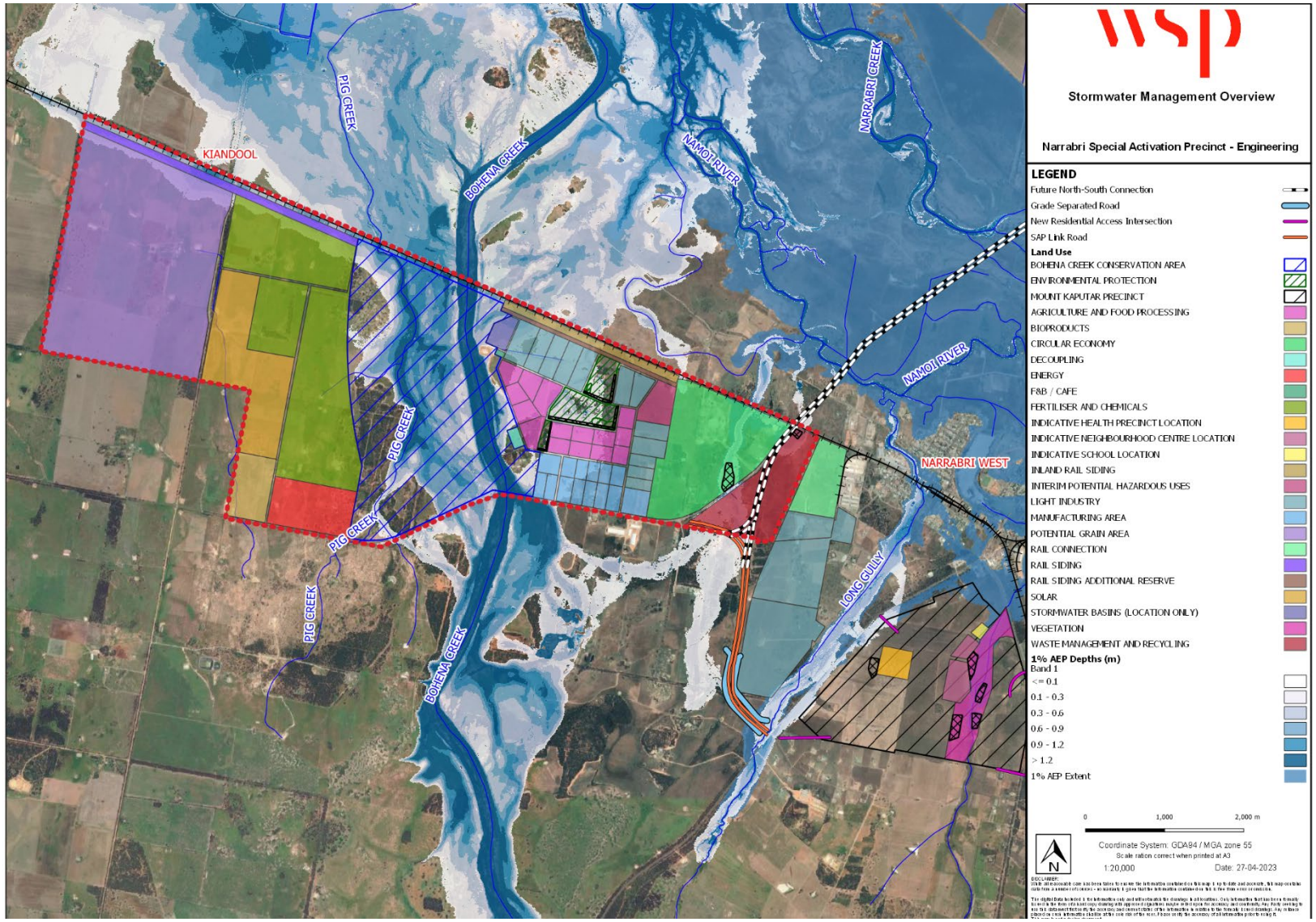


Figure 5.9 Indicative stormwater management locations, SAP investigation area and Inland Port (April 2023)

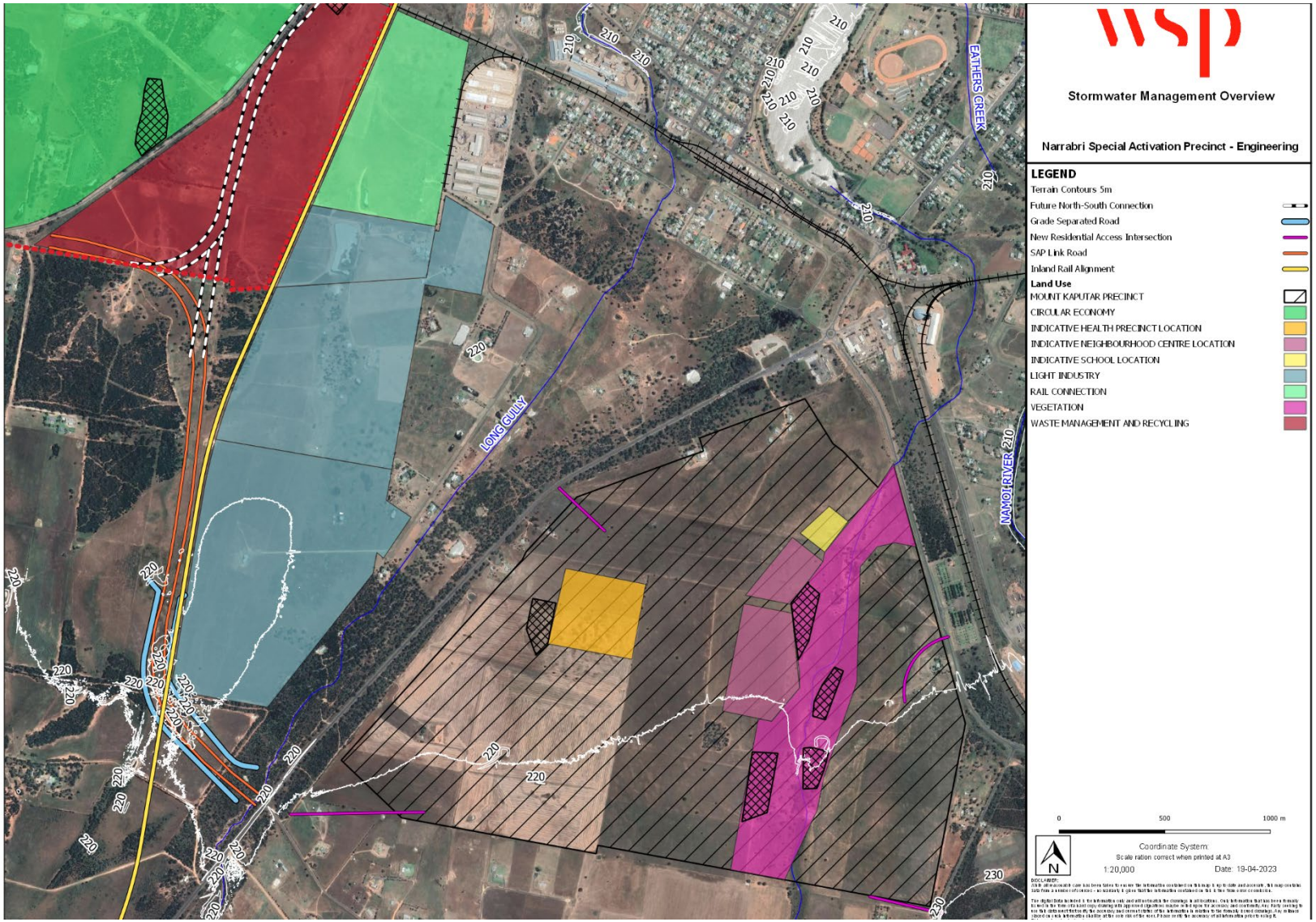


Figure 5.10 Indicative stormwater management locations, Residential area (April 2023)

5.4.2 Water cycle management

Stormwater should be viewed as a resource and therefore it is best managed at the source, which means at each individual lot. The proposed structure plan areas of the Inland Port, east of Bohena Creek, west of Bohena Creek, industrial area (south) and the residential area all provide opportunities to manage stormwater as a resource at the point of generation.

Best practice for the stormwater cycle should include collection of stormwater, treatment of stormwater and release at pre-development flow rates, capture of rainwater and reuse. (refer to Section 5.4.7.2) Development of a treatment train approach should be considered, i.e. a sequence of stormwater treatment devices or methods throughout the catchment, for stormwater quality and quantity management with a focus on prevention before treatment.

5.4.3 Rainwater harvesting

Rainwater quantities have been estimated across the SAP Investigation areas to understand the potential available volume of water that could be captured from roofs. The assumptions and methodology are outlined in Section 4.2 with a summary included in Table 5.3.

Table 5.3 Land use areas and roof area considerations

Land uses	Hectares	Area for roof (ha)
Fertiliser and Chemicals	366.62	NA#
Solar	144.14	NA#
Grain (potential)	TBC	NA#
Western Rail Siding	TBC	NA#
Energy	63.31	NA#
Bioproducts	40.79	NA#
Inland Port (rail Siding and additional Rail Side reserve)	36.07	nil
Transport and Logistics	108.2	5.41
Interim Potential Hazardous uses	19.19	2.87
Water Management and recycling	94.32	0.04
Agricultural and Food Processing	90.88	13.6
Manufacturing	72.59	10.89
Circular Economy	169.47	25.42
Rail Connection	44.92	nil
Light Industrial South	187.3	28.09
Residential	597.15	NA#
Total	**2034.95**	**86.32**

refer to Section 4.2.1

The roof areas make up just 4% of the total area of the SAP investigation area and this is based on the limitation as discussed in Section 4.2.1. The estimated rainwater quantities are presented in Table 5.4 below.

Table 5.4 Estimated rainwater quantities per land use

Land uses	Area for roof (ha)	Percentage of area (%)	Average annual rainwater quantities (megalitres/year)
Transport and Logistics	5.41	5%	39
Interim Potential Hazardous uses	2.87	15%	21
Water Management and recycling	0.04	0.04%	0.3
Agricultural and Food Processing	13.6	15%	98
Manufacturing	10.89	15%	78
Circular Economy	25.42	15%	182
Light Industrial South	28.09	15%	202
Total	**86.32**	**NA**	**620.3**

Despite the quantities being small, rainwater tanks should be considered essential as part of any new development because they can supply water that requires little to no treatment for use in buildings and across vegetated areas.

5.4.4 Stormwater quality management

The proposed structure plan does not preclude the implementation of stormwater quality management measures, and point source pollution control should be encouraged across the SAP investigation area. Appropriate stormwater quality management devices include gross pollutant traps, proprietary treatment devices, detention basins and treatment tanks, vegetated swales, wetlands and bioretention filters.

Each proposed land use should have sufficient land available to provide lot specific WSUD features. These will allow for the capture of stormwater from hard surfaces such as carparks and roof runoff (not connected to rainwater tanks) in these areas for reuse and to prevent it from entering overland flow paths and known watercourses downstream. Surface water runoff from carparks would be likely to include hydrocarbons, oil, grease and sediments and would require separators and potential filtration. At industrial sites, runoff may include heavy metals, and treatment of these heavy metals would be required prior to reuse.

Within the high value biodiversity land within the Inland Port area stormwater quality treatment should occur before it enters this area to ensure that current water quality and quantity is maintained and impacts of the surrounding development are minimised.

Given the “fresh” nature of the water quality in Bohena Creek (refer to Section 3.5.5) proposed stormwater management solutions should be tested against the neutral or beneficial effect, with consideration of the WaterNSW Neutral or Beneficial (NorBE) Effect on Water Quality Assessment Guideline 2022.

The Water quality technical report for the Namoi surface water resource plan area (SW14) (DPE, 2020) includes water quality targets for water-dependent ecosystems. The targets for water dependent ecosystems are to ensure water quality is sufficient to:

- protect and restore ecosystems
- to protect and restore ecosystem functions
- ensure ecosystems are resilient to climate change, and
- maintain the ecological character of wetlands.

The targets are as follows for the Narrabri SAP investigation area that lies within the WQ Basin zone B2.

Table 5.5 Water quality targets for Water quality Zone B2 Namoi Valley, upland zone, streams and rivers

Water quality target	Value
Turbidity (NTU)	15
Total Phosphorus (ug/L)	45
Total Nitrogen(ug/L)	490
Dissolved oxygen (mg/L ; or % saturation)	90–110
pH	7.5–8.5
Salinity (EC uS/cm)	End of valley targets (as absolute values) Median (50th%ile) – 475 (EC uS/cm) Peak (80th%ile) – 715 (EC uS/cm) Salt load Mean – 127,000 (tonne/yr)
Temperature	Between 20th and 80th percentile of natural monthly water temperature
Toxicants (must not exceed values in the 3.4.1 of the ANZECC guidelines)	The protection of 99% species

5.4.5 Road options surface water assessment

All proposed roads will increase impervious areas and therefore reduce the infiltration of rainfall and increase runoff and similar types of pollutants will be expected from all proposed roads.

The proposed lot layouts currently do not provide sufficient details to determine where attenuation could be incorporated but they do not preclude it from being included. This could be included at the road-by-road scale but it must consider the flood risk and downstream receiving environment.

5.4.5.1 SAP Link Road

This proposed road link could accommodate attenuation on land outside the 1% AEP flood extent which could also function as a water quality control treatment device. These WSUD devices could be located adjacent to the proposed link and then allow for gravity flow into the existing overland flow path that flows north under the connection to Yarrie Lake Road.

5.4.5.2 New residential access

These proposed access links are relatively minor but could incorporate roadside treatment swales to attenuate and filter stormwater runoff directly from the road.

5.4.5.3 Future north-south connection

The potential north-south connection is likely to be elevated and therefore will not be able to include water quality or attenuation features within or adjacent to the road corridor. Further consideration of treatment measures would need to occur at the next stages of planning.

5.4.6 Climate change

The projected climate changes that will influence stormwater cycle management include the increase in rainfall intensity, reduction in annual rainfall total and increased temperatures. For the proposed structure plan, maintaining existing overland flow paths and tree cover will reduce the impacts of climate change on the stormwater network, which is possible for the Inland Port, west of Bohena Creek and the residential area. Defining an overland flow path for the other areas, east of Bohena Creek and industrial land (south) will be essential to ensuring the effects of climate change are mitigated.

Table 5.6 Estimated impact to stormwater due to climate change

Projected climate change	Stormwater changes	Potential mitigation
Rainfall intensity	More intense rainfall means more water and faster flowing water in a short period of time, increases the mobilisation of pollutants and transfer through the catchment.	Size stormwater network to account for increased intensity. Point source water quality treatment measures.
Annual rainfall reduction	Less water available in stormwater detention basins or wetlands that are dependent on permanent water for vegetation growth and fauna.	Include drought tolerant plans, multiple depth zones across basins.
Increased temperatures	Increased evaporation of water from permanent stormwater basins and wetlands.	Provide tree cover to minimise direct sunlight and reduce evaporation and maintain evapotranspiration.

5.4.7 Summary and development conditions for surface water

Table 5.7 Summary of surface water assessment

Area	Stormwater quantity	Stormwater quality	Planning considerations
Inland Port	Land available, precinct or lot scale possible Utilise ISMC	Land available, precinct or lot scale possible Utilise ISMC	WSUD Rainwater collection
Industrial area (south)	Land available, precinct or lot scale possible Utilise ISMC	Land available, precinct or lot scale possible Utilise ISMC	WSUD Rainwater collection
West of Bohena Creek	Management at the lot scale	Management at the lot scale	WSUD Rainwater collection
Residential	Management at the lot scale Utilise ISMC	Management at the lot scale Utilise ISMC	BASIX
Roads	Include linear infrastructure as part of road corridor Utilise ISMC for overland flows and detention	Include linear treatment as part of road corridor Utilise ISMC for polishing treatment measures	

5.4.7.1 Integrated stormwater management corridors

The integrated stormwater management corridors (ISMC) are intended to provide multiple functions to account for more regular runoff events, maintain existing overland flow paths, provide areas for storage, allow for groundwater recharge and stormwater treatment to minimise the impact of development across the SAP investigation area. These corridors should include:

- existing farm dams
- drainage infrastructure, including culverts, roadside swales, detention basins, wetlands etc.

These corridors have been used to indicatively locate regional stormwater infrastructure which can be sized once the impervious areas across the precinct have been determined. Figure 5.9 and Figure 5.10 show the indicative locations of stormwater infrastructure which are located within the stormwater management corridors and consider the October 2022 flood event (refer to Appendix A).

5.4.7.2 Water sensitive urban design (WSUD)

Water sensitive urban design (WSUD) is the integration of urban planning with the management, protection and conservation of the urban water cycle that ensures that urban water management is sensitive to natural hydrological and ecological processes. WSUD aims to ensure developments are designed, constructed and maintained to minimise negative impacts on the water cycle (Blacktown City Council, 2023).

The ISMC have been identified to ensure there is provision in the structure plan for stormwater management, however, a decentralised approach to stormwater quantity and quality is proposed as it is more attuned to the natural hydrological and ecological processes of the existing environment. This means that at site and point source measures are recommended and the ISMC be utilised as part of the complete stormwater network and allow for existing overland flow paths to be maintained. With regards to WSUD, key criteria for developments are:

- to match the post development runoff to the pre development or natural water runoff regime as closely as possible
- to ensure no impacts to adjoining properties with respect to flooding and the local hydrologic regime.

Common types of WSUD include:

- raingardens – above-ground and infiltration
- swales
- constructed wetlands
- porous pavement
- rainwater and stormwater harvesting
- green infrastructure – green roofs, green facades and tree pits
- infiltration trenches.

5.4.7.3 BASIX

The Building Sustainability Index (BASIX) requirements apply to all residential dwelling types and are part of the development application process in NSW (NSW Government 2023). Refer to BASIX | Planning Portal - Department of Planning and Environment (nsw.gov.au).

5.5 Surface water cycle findings

Key findings of the assessment include:

- the structure plan includes land for stormwater quality and quantity management at the Inland Port and residential areas
- the conditions of approval will need to stipulate lot by lot water quality management measures and stormwater quantity measures for the Industrial area (south) and east and west of Bohena Creek areas
- the proposed SAP link and residential access roads will need to include attenuation and linear water quality treatment measures within the road corridor
- projected climate change impacts should be considered for the sizing of WSUD features with particular consideration of prolonged dry periods and increased rainfall intensity.

6 Recommendations and conclusions

The Narrabri SAP investigation area includes the Inland Port, land to the west of Bohena Creek, and land east and south of the N2IP. The investigation area also includes land east of the Inland Rail alignment and residential land to the east of the Newell Highway. Much of the land included in the SAP investigation area lies within the flood extent of the PMF event but there is land outside of the flood planning area (NSC LEP 2012) and 1% AEP flood extent. However, being within the PMF extent does not preclude development as due consideration of the flood risk can be managed with appropriate development controls.

This flooding and surface water cycle assessment of the proposed structure plan should be used to inform the next stage of the precinct plan. The flooding assessment used existing available design flood information, including flood depths, flood function and flood hazard to understand the existing and future climate change flood risk. The existing flood risk information was used to identify no-go areas of land to minimise the impacts of flooding on future communities. The flood information was also used to understand the existing flood risks for the proposed roads and connections.

The surface water cycle assessment focused on ensuring there is suitable land for stormwater quantity and quality management and maintaining existing overland flow paths. The volume of rainwater was estimated using historic rainfall data and estimated roof areas for the non-residential areas.

The proposed structure plan avoids the floodways and high hazard H5-H6 areas of both Bohena Creek and the Namoi River floodplain. The residential areas are largely beyond the PMF which is an essential lesson learned from recent flood events. The SAP investigation area proposed land uses are located in the PMF extent, but the flood affectation does not preclude development.

The proposed structure plan and specifically the Inland Port and residential area includes corridors for integrated stormwater management that are intended to provide multiple functions to account for more regular runoff events, maintain existing overland flow paths, provide areas for storage, allow for groundwater recharge and stormwater treatment to minimise the impact of development across the SAP investigation area.

The east Bohena Creek area (beyond the inland port), Light Industrial area (south), and west of Bohena Creek area do not include ISMC but their land uses do not preclude their inclusion. The focus of this corridor should be on managing the individual lot layout to minimise impacts.

The slope of most of the SAP Investigation area is from south to north towards the Namoi River and road links and stormwater infrastructure should align with the slope of the land. This will provide evacuation routes and maintain existing overland flow paths.

The lessons learned from the 2022 flood events have been considered when developing the proposed planning conditions for the structure plan and complement the existing Narrabri Local Environment Plan 2012 objectives for flood prone land, which are as follows:

(*a) to minimise the flood risk to life and property associated with the use of land,*
(b) to allow development on land that is compatible with the flood function and behaviour on the land, taking into account projected changes as a result of climate change,
(c) to avoid adverse or cumulative impacts on flood behaviour and the environment,
(d) to enable the safe occupation and efficient evacuation of people in the event of a flood.

It is therefore recommended that planning and development conditions for the structure plan are:

Flood prone land

- Flood Planning Level – set the flood planning level for all habitable floor levels for the precinct to the 1% AEP plus 500 mm.
- Define the flood planning area (FPA) to include the PMF flood extent and stipulate flood related planning controls to be required including:
  - no net loss of flood storage due to cut and fill or loss of flood conveyance or significant diversion of flood flows or significant changes to hydraulic flood hazard conditions that impact on private property or impact on safe access or on evacuation routes
  - fill and compensatory excavation must not change the flood function or flood hazard classification of land external to the site
  - flood compatible building design for all buildings within the FPA – including types of materials, fencing types around overland flow paths
  - property specific emergency management plans be prepared for non-residential developments within the FPA
  - hazardous industries require containment of storage establishments up the PMF plus consideration of freeboard to account for local wave action.

Stormwater management

- Define the integrated stormwater management corridors as layers in the LEP with the purpose to:
  - maintain existing overland flow paths
  - preserve areas for rainfall infiltration and potential groundwater recharge zones
  - provide opportunities for connection to country through watercourses and overland flow paths
  - provide green networks that provide for water flows
  - be part of the natural stormwater network and facilitate the more natural flow and release of stormwater flows.
- Require all new developments to include rainwater tanks – to provide some water to meet demands, but ensure piping and pumps are protected from flooding.
- Require point source pollution control – as best as possible, manage stormwater runoff at the source within new developments through Water sensitive urban design (WSUD).
- All new roads to include linear stormwater quantity and quality management measures.
- Account for the impacts of projected climate changes to stormwater through:
  - size stormwater network to account for increased intensity. Point source water quality treatment measures
  - include drought tolerant plans, multiple depth zones across basins
  - provide tree cover to minimise direct sunlight and reduce evaporation and maintain evapotranspiration.
- Require proposed stormwater management solutions to be tested against NSW Water Quality Objectives.

The targets for water quality treatment measures to be in line with the Namoi Surface Water Resource Plan values as presented in Table 6.1.

Table 6.1 Water quality targets for Water Quality Zone B2 Namoi Valley, upland zone, streams and rivers

Water quality target	Value
Turbidity (NTU)	15
Total Phosphorus (ug/L)	45
Total Nitrogen(ug/L)	490
Dissolved oxygen (mg/L ; or % saturation)	90–110
pH	7.5–8.5
Salinity (EC uS/cm)	End of valley targets (as absolute values) Median (50th%ile) – 475 (EC uS/cm) Peak (80th%ile) – 715 (EC uS/cm) Salt load Mean – 127,000 (tonne/yr)
Temperature	Between 20th and 80th percentile of natural monthly water temperature
Toxicants (must not exceed values in the 3.4.1 of the ANZECC guidelines)	The protection of 99% species

7 References

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Appendix A

October 2022 flood event

A1 October 2022 event

The October 2022 rainfall and flood events have provided an opportunity to check the proposed structure plan against an actual event. The rainfall totals for the Namoi River upstream and downstream of Narrabri are presented in Figure A.1 below and show that Gunnedah recorded 89 mm, Narrabri recorded 107 mm and Mount Lindsay (east of Mount Kaptuar) 167 mm for the period of 20–26th October. For Narrabri 75 mm was recorded as a daily total for 21st October.

Satellite imagery of the flood event was available from the European Union Copernicus Sentinel Data. The satellite imagery SENTINEL-2 is a European wide-swath, high-resolution, multi-spectral imaging mission. Its high-resolution optical images have a multispectral imager and provides a set of 13 spectral bands spanning from the visible and near infrared to the shortwave infrared. (Sentinel-2 L1C (sentinel-hub.com), accessed 27/10/2022 5:12 PM).

The imagery is shown in Figure A.1 below and has been georeferenced to real world location to enable comparison against the flood modelling design data for Bohena Creek and Namoi River. The recurrence interval of the event has not been determined yet but the flood extents compare well. It is likely that the event is less than a 1% AEP event but the comparison has identified a few areas with ponded water that will need to be considered as part of managing overland flows within the structure plan. These are identified in Figure A.1.

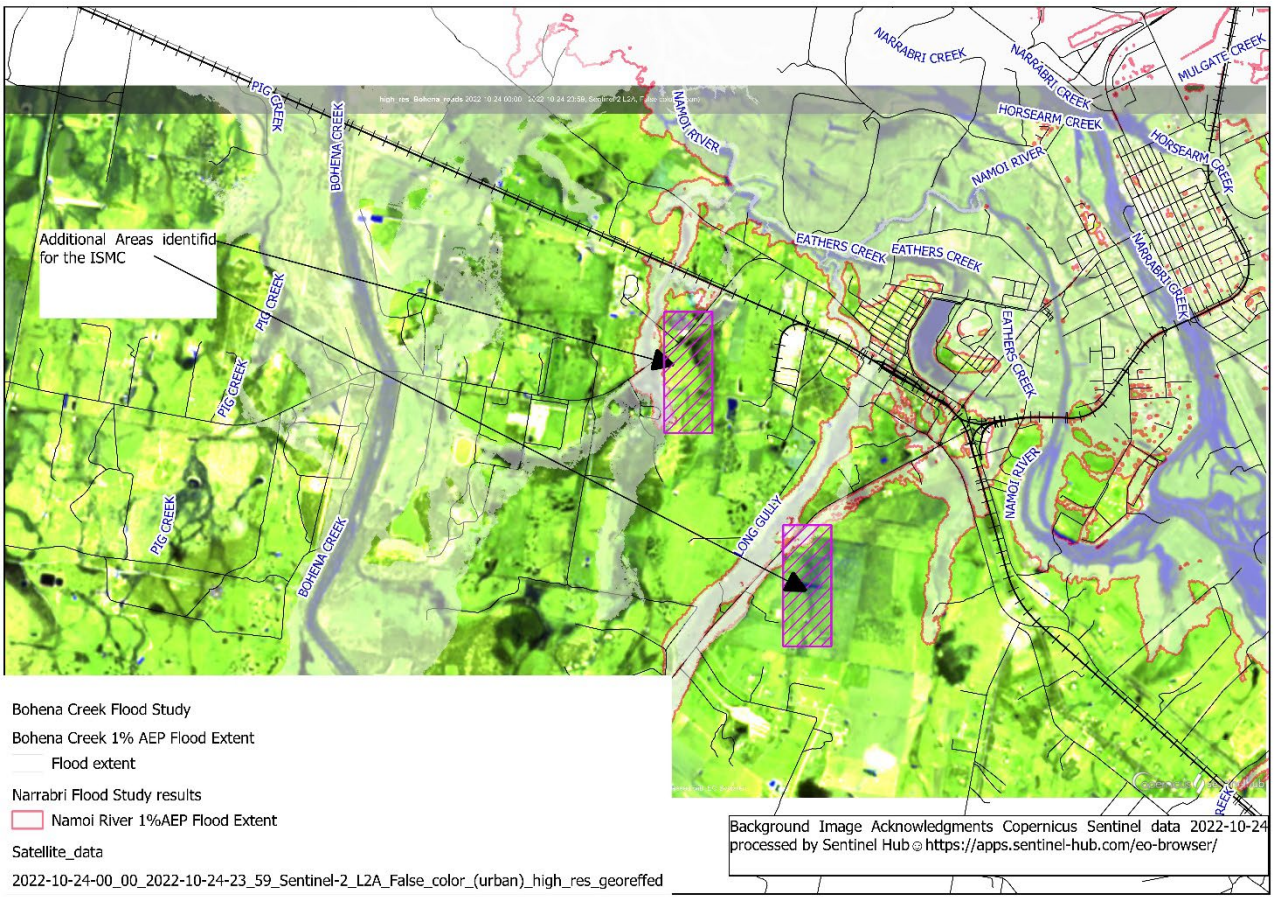

Figure A.1 October 2022 flood event and 1% AEP design flood extent for Bohena Creek and Namoi River

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