Williamtown SAP

Flooding and Water Cycle Management Report

Department of Planning and Environment

Reference: 510674

Revision: 4

2023-01-23

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Document control record

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Document control						aurecon
Report title		Flooding and Water Cycle Management Report				
Document code		B.3.2E	**Project number**		510674	
File path		Https://aurecongroup.sharepoint.com/sites/521943/3_Develop/Master Reports/B.1 Flooding and WCM/Revised Structure Plan/B.3.2E Draft Flooding and Water Cycle Management Report_Nov2022.docx				
Client		Department of Planning and Environment				
Client contact		Caitlin Elliott	**Client reference**			
Rev	**Date**	**Revision details/status**	**Author**	**Reviewer**	**Verifier** (if required)	**Approver**
0	2021-05-26	Stage 3 Draft Submission	YM, WL	PG	PG	GL
1	2021-11-26	Stage 3 Draft Submission	YM, WL	PG	PG	GL
2	2022-02-17	Stage 3 Final Submission	YM, WL	PG	PG	GL
3	2022-11-29	Structure Plan updates	YM	PG	PG	GL
4	2022-01-23	Minor updates	SJ, YM	YM		GL
Current revision		**4**				

Approval			
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Glossary

Abbreviation	Term
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AIDR	Australian Institute of Disaster Resilience
ARR	Australian Rainfall and Runoff
ARI	Average Recurrence Interval
BoM	Bureau of Meteorology
CZMP	Coastal Zone Management Plan
DAREZ	Defence and Aerospace Related Employment Zone
DECC	Department of Environment, Climate Change
DPE	Department of Planning and Environment (formerly Department of Planning, Industry and Environment)
DRNSW	Department of Regional NSW
DCP	Development Control Plan
DRM	Direct Rainfall Method
EIS	Environmental Impact Statements
FFA	Flood Frequency Analysis
FPA	Flood Planning Area
FPCC	Flood Planning Constraint Categories
FPL	Flood Planning Level
FRMS&P	Floodplain Risk Management Study & Plan
GPT	Gross Pollutant Trap
GDEs	Groundwater Dependant Ecosystems
HVFMS	Hunter Valley Flood Mitigation Scheme
IFD	Intensity-Frequency-Duration
JSF	Joint Strike Fighter
LiDAR	Light Detection and Ranging
LEP	Local Environment Plan
LGA	Local Government Area
MHL	Manly Hydraulics Laboratory
MARV	Mean Annual Runoff Volume
NAL	Newcastle Airport

Abbreviation	Term
NRAR	Natural Resources Access Regulator
NorBE	Neutral or Beneficial Effect
OEH	Office of Environment and Heritage
PFAS	Per- and Polyfluoroalkyl Substances
PSC	Port Stephens Council
PSHD	Port Stephens Height Datum
PMF	Probable Maximum Flood
REF	Review of Environmental Factors
RAAF	Royal Australian Air Force
SHLF	Snowy Hydro Legacy Fund
SAPs	Special Activation Precincts
SES	State Emergency Services
SEPP	State Environmental Planning Policy
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
WM Act	Water Management Act
WBNM	Watershed Bounded Network Model
WAC	Williamtown Aerospace Centre
WAP	Williamtown Aerospace Park (Precinct)
Williamtown SAP	Williamtown Special Activation Precinct
WSDS	Water Sensitive Development Strategy

Executive Summary

The Williamtown Special Activation Precinct (Williamtown SAP) presents a unique opportunity to develop within the same region as the existing Newcastle Airport and RAAF Defence base. This precinct aims to capitalise on the existing aeronautical infrastructure to draw in local and international industries, bringing together the opportunity for innovation and aerospace opportunities.

This report presents the Baseline, Scenarios and Structure Plan assessments. The Baseline assessment discusses the constraints and opportunities of the proposed precinct area. The Scenarios assessment takes these constraints and opportunities and applies them to the various scenarios that were derived from the first Enquiry by Design (EDB) workshop. The scenarios are then tested against performance criteria and management measures derived to facilitate the potential Structure Plan scenarios. The prescribed management measures reflect the constraints and opportunities identified in the Baseline assessment however talk directly to Williamtown SAP areas that can and cannot be developed, or where specific management measures are required to allow the Structure Plan to occur.

The initial Williamtown SAP Structure Plan was developed from the second EDB workshop. This derived a structure plan that considered the constraints and findings from the Baseline and Scenarios assessments. This stage delves deeper into the measures and infrastructure specifically required to facilitate the structure plan and provide confidence in the land-take requirements. There has since been further strategic decisions resulting in a change in strategy to remove the western sub-precinct which has resulted in the Williamtown SAP structure plan shown in Figure E-0-1.

General Study area overview

The general study area (As shown in Figure 1-2, Section 1.2.1) extends across a large region, covering multiple sub catchments that can broadly be considered as two main catchments. The western portion is located within the Hunter River estuary catchment and drains into Fullerton Cove. The eastern portion of the study area drains into the Port Stephens estuary catchment via Tilligerry Creek. Both of these receiving environments are regionally significant for their ecological and social values.

The final Williamtown SAP structure plan is located within the Fullerton Cove catchment, draining in a southerly direction towards the low-lying floodplain before flowing to Fullerton Cove. The existing land use within the Fullerton Cove catchment is predominantly rural with open drains providing stormwater drainage for frequent storm events. These drains are mostly located across the southern catchments to the south-east of the Newcastle Airport and RAAF base. They have limited capacity and overbank flooding occurs in events as frequent as the 50% AEP (1 in 2-year AEP event) during local storm events. The flat terrain of the floodplain also results in long periods of inundation, reaching in the order of six to eight days. Coincidental flooding in the Hunter River and Port Stephens can cause longer periods of flooding.

Flooding and drainage overview

The study area can experience three different modes of flooding broadly defined as:

- Regional Flooding - Hunter River flood events;
- Local Flooding - Rainfall on the local catchment areas; and
- Tidal Inundation - Tides in Fullerton Cove and Port Stephens.

These three modes of flooding represent different scales of storm events and cause flooding across the study area to varying degrees. The regional flooding is the more predominant source of flooding and has informed the flood planning levels for the area.

The flood prone nature of the study area under current and potential climate change scenarios is a significant constraint. It presents challenges for the Structure Plan from a flood immunity and flood impact perspective. Achieving flood immunity requires extensive bulk filling of the floodplain to create developable land that will remain free of future regional and tidal flooding under sea level rise scenarios. This must be done in a way that preserves local flooding behaviour and avoids causing flood impacts to existing development.

Surface water quality overview

- Stormwater runoff from the precinct will discharge to the sensitive receiving environments of Fullerton Cove. A mangrove wetland surrounds Fullerton Cove within the Kooragang Nature Reserve. Whilst the existing local drainage channels have limited ecological value, a risk based approach to managing stormwater runoff has been adopted that limits changes to existing pollutant loading, runoff patterns and groundwater recharge rates which thereby reduces the risk of water quality or hydrologic changes within downstream wetlands. This approach is adopted in the absence of locally derived stormwater management targets for Fullerton Cove.

Groundwater interaction

PFAS contamination is one issue that requires careful consideration. It has been identified in areas around the RAAF Defence base and has been investigated over the years. It is understood that the issue is actively being managed, however the stormwater and water cycle management measures will be required to not exacerbate the PFAS mobilisation risk.

Flooding and water cycle management aspects of the Williamtown SAP have the potential to interact with PFAS contamination and high groundwater levels. High ground water levels limit the opportunity to adopt regional flood detention or allow for effective compensatory offset flood storage within the floodplain. The close proximity of the Hunter Water drinking water catchment (DWC), SEPP 14 wetlands around Fullerton Cove and various other sensitive environments compounds these issues.

Structure plan assessment

The structure plan is shown in Figure E-0-1.

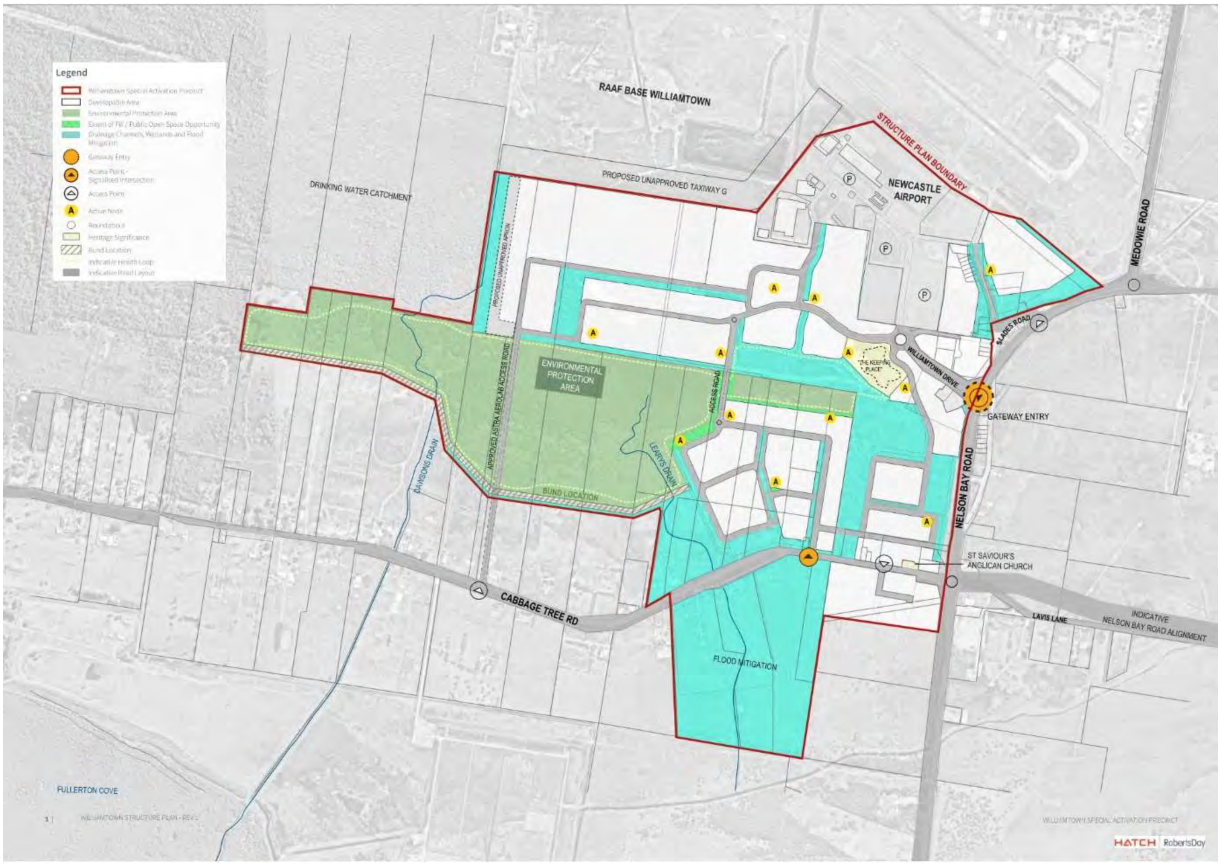


Figure E-0-1 – Williamtown SAP Structure Plan

The Williamtown Special Activation Precinct lies within flood prone lands and has therefore presented the challenge of achieving a level of flood protection, balancing flood impacts from local and regional flooding, and considering the various ecological, groundwater and airport land use constraints mentioned above.

Bulk filling has been proposed to provide the flood protection to the Structure Plan . However, adding to the bulk fill requirement is the need to provide additional filling to facilitate drainage of the site. To minimise the bulk fill, the stormwater strategy has adopted an internal distributed approach that looks to manage the quantity and quality closer to the source. A series of flat longitudinal wetlands and channels are proposed that are also able to convey floods while provide detention are proposed. Areas to the south of Cabbage Tree Road are also proposed to offset any residual flood impacts that cannot be managed on site.

The central corridor contains a bio-conservation area which also acts as a detention basin and flood storage offset area. The Structure Plan obstructs overland flow heading south towards Cabbage Tree Road and also consumes the existing flood storage areas. The displaced floodwater is then distributed across the bio-conservation corridor and drains through designated floodways through the Structure Plan. This provides a benefit to the Williamtown SAP by limiting the distribution of impacts to the floodplain south of Cabbage Tree Road.

Flooding and Water Cycle Management measures to facilitate Williamtown SAP

Whilst the Williamtown SAP itself is not a remediation project for the region, it aims to limit flood, surface water and groundwater impacts beyond the Williamtown SAP boundary.

The following flood management measures are proposed:

- Flood storage offsets – Compensatory excavation aims to offset the loss of floodplain storage due to bulk filling required to create lots that are free of 1% AEP flooding under the proposed future climate scenario.
- Structure Plan bulk fill extent limitations – The Structure Plan extent encroaches into the floodplain. This measure assesses the limitations of the bulk filling that would inform appropriate land-use types commensurate with the flood risk.
- Stormwater detention storage– Targeted to manage the impact of change in flood behaviour, loss of flood storage and local runoff upstream of existing development.
- Additional land for flood impact offset - Aims to minimise the cost of flood mitigation infrastructure and allow for controlled flood impacts to occur on Williamtown SAP land.

With respect to water cycle management measures, specific measures were proposed to facilitate Williamtown SAP. These water cycle management measures utilise a combination of Water Sensitive Urban Design and stormwater reuse including:

- Rainwater capture and reuse within all new buildings
- Gross pollutant traps on new allotments
- Filtration and evapotranspiration of road runoff in passively irrigated street trees and biofiltration to manage runoff and implement urban cooling benefits
- Precinct scale wetlands at the end of the stormwater pipe network to achieve the stormwater and water quality targets.
- Lining of the drains and diversion of runoff to drains downstream of the Hunter Water drinking water catchment
- Prevent uncontrolled infiltration and potential migration of PFAS into stormwater drainage by lining drains, sealing pit and pipe networks

The proposed water sensitive urban design measures and proposed land use changes are predicted to provide water quality benefits to downstream receiving waters for total suspended solids and total phosphorus, but total nitrogen loads are shown to increase slightly. Under this management approach, there is a low risk of impacts to the Tomago sand bed aquifer given the change in recharge volume is negligible, however the mean annual freshwater runoff discharging to Fullerton Cove may increase by around 15 to 20%. This could potentially result in local changes in salinity and water level variation in the downstream wetlands. The impact of this increase in freshwater runoff on sensitive environments within Fullerton Cove should be assessed during delivery phase of the Williamtown SAP process with consideration to the significance of impact in comparison to existing climatic variation.

There may be a sustainable load or capacity for the downstream environment to accommodate higher loads of nutrients, sediments or freshwater volumes, however this should only be quantified through the application of the Risk Based Framework protocol (Dela-Cruz 2017).

1 Introduction

1.1 Purpose

This Flooding and Water Cycle Management Report provides a summary of the strategic context pertaining to the flooding and water cycle management to facilitate the Williamtown Special Activation Precinct (Williamtown SAP). It also provides a basis to help inform a streamlined planning process for fast-tracking Williamtown SAP by identifying associated opportunities and constraints from the onset. This report sets out to present:

- An analysis of the existing flooding and water cycle management in the area.
- details of existing flood behaviour in and around the area.
- Assesses the potential water quality issues associated with Williamtown SAP.
- Identifies potential flood constraints and opportunities for Williamtown SAP.

In addition to summarising the existing flood information already available for Williamtown and surrounding areas, flood modelling has also been undertaken specifically for the SAP. This modelling forms a key tool for the derivation of flood and water cycle management strategies to facilitate Williamtown SAP.

1.2 Background Context

The Department of Planning and Environment (DPE), Department of Regional NSW (DRNSW) and Regional Growth NSW Development Corporation have worked together to establish of Special Activation Precincts (SAPs) across the state. This joint government agency initiative is an innovative approach to plan and deliver infrastructure projects in strategic regional locations in NSW. These SAP programs are funded by the $4.2b Snowy Hydro Legacy Fund (SHLF), which is managed by DRNSW. Investment in these specific areas of Regional NSW is aimed to drive significant economic development and jobs creation in regional areas. It is part of the NSW government's 20-Year Economic Vision for the state. One of the core drivers is that there is limited amount of readily developable land in NSW. To resolve this, each SAP is designed to resolve environmental, drainage and other development constraints in a coordinated precinct scale approach as opposed to a site by site basis.

The Williamtown SAP's vision is based on six key visions as shown in Figure 1-1. The strategic need for growth in the Hunter Region involves:

- **The Place** – leveraging the vicinity of the Royal Australian Air Force (RAAF) and civil aviation operators attract local employment
- **Environment and Sustainability**– regionally coordinated approach to flooding, water cycle management and contamination while preserving and enhancing the natural environment;
- **Infrastructure and Connectivity** – providing infrastructure to resolve development constraints to reduce investment barriers to entry and enable effective connections to nearby Hunter Region infrastructure;
- **Connection to Country** – To preserve, respect and integrate Aboriginal cultural heritage, particularly the Worimi people; and
- **Social and Community Infrastructure** – Enabling high skill employment, innovation, education and skill training opportunities and commercial investment;
- **Economy and Industry** – facilitate development of additional employment land for Defence and aerospace industries;

Figure 1-1 – Williamtown SAP Visions

1.2.1 Williamtown SAP Location

Williamtown is located approximately 13.5km north of the Newcastle CBD in New South Wales, within the Hunter Region.

The Hunter Region has the largest share of both regional population growth and regional employment and is in the state's fastest growing corridor (Sydney to Newcastle). Greater Newcastle is the centrepiece of the Hunter Region with 95% of residents living within 30 minutes of the strategic centre.

Newcastle Airport and the Port of Newcastle are recognised as global gateways targeted to enable the region and the state to satisfy the demand from growing Asian economies for products and services associated with education, health agriculture, resources and tourism (Hunter Regional Plan, 2036). The Hunter Regional Plan 2036 identifies that the region's ongoing economic prosperity will depend on its ability to capitalise on its global gateway assets and as such cites a need to expand the capacity of Newcastle Airport and the Port of Newcastle.

The Williamtown SAP study area (shown in Figure 1-2) covers an area of approximately 11,408ha and is low-lying coastal land on the edge of Fullerton Cove and Stockton Beach of land within Port Stephens local government area in the Hunter Region and Greater Newcastle area of NSW. It is centred around the Williamtown Aerospace Precinct (WAP).

The Williamtown SAP is focused on leveraging employment and investment opportunities associated with its strategic location to the Williamtown Aerospace Precinct (WAP) which includes:

- RAAF Base Williamtown which F35 Australia Joint Strike Fighter (JSF) fleet is based in. The area has also been affected by Per- and Polyfluoroalkyl Substances (PFAS) contamination associated with past activities conducted at the Williamtown RAAF Base;
- Newcastle Airport which is jointly owned by Port Stephens Council and Newcastle City Council, leased from the Department of Defence and shares their airport runway with RAAF Base Williamtown;

- The Defence and Aerospace Related Employment Zone (DAREZ) which is intended for the development of aerospace and defence specific industries in close proximity to the adjoining Newcastle Airport;
- Bushland vegetation is prominent in the area with some areas containing threatened flora and fauna species as well as important wetland areas;
- Rural and agricultural lands;
- Small rural and low density residential clusters including the township of Salt Ash, Williamtown and Fullerton Cove;
- Commercial and light industrial clusters associated with the airport and RAAF Base alongkey road corridors;
- The Tillgerry State Conservation Area;
- The Grahamstown Lake is located to the north of Fullerton Cove; and
- The study area is also crossed by several transport infrastructure assets including roadways.

The study area is presented in Figure 1-2.

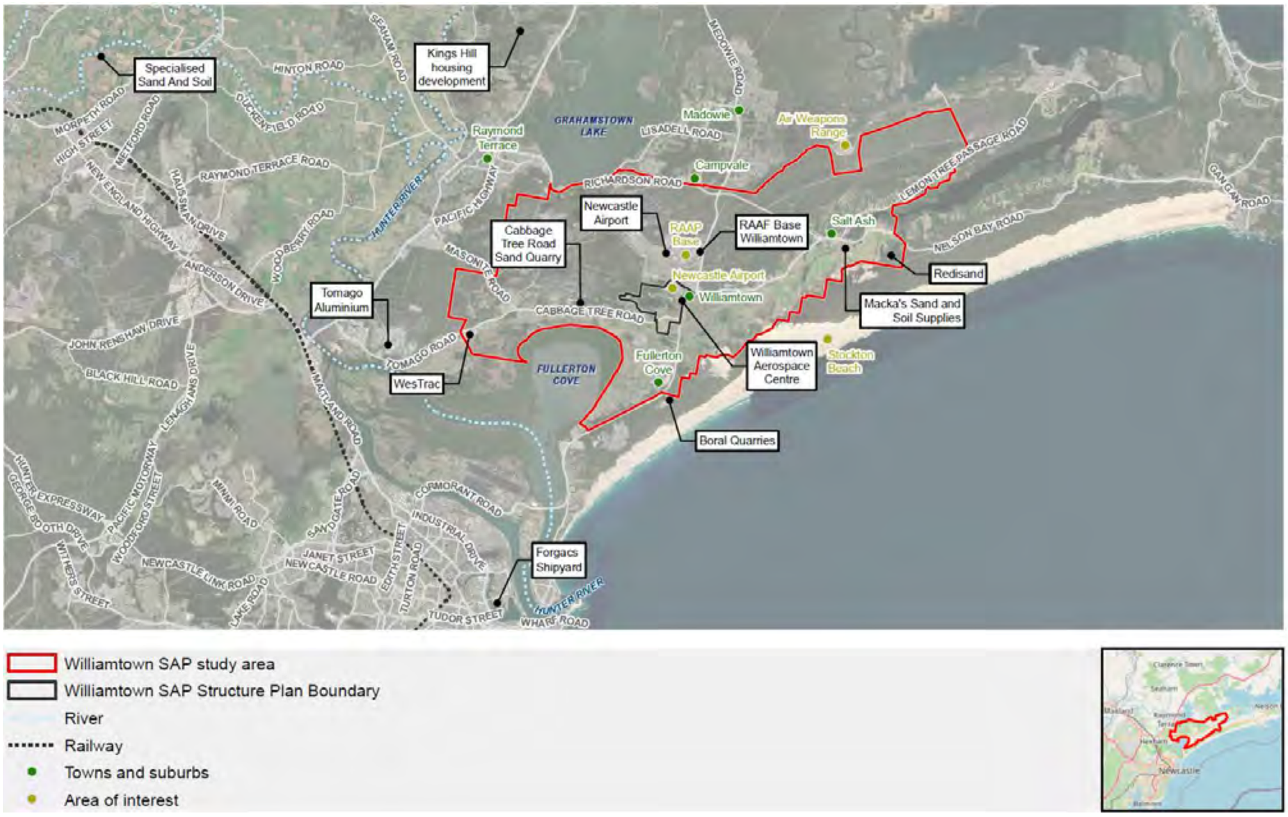


Figure 1-2 – Williamtown SAP Study Area

1.2.2 Williamtown Flooding and Water Cycle Management Context

Water cycle management will be affected by the presence of the Drinking Water Catchment across a large portion of the study area, the proximity to sensitive environments including Ramsar and other significant wetlands, local contamination issues, and the proximity to the airport (and associated constraints on artificial water bodies).

From a flooding perspective, the existing flooding behaviour in the study area is characterised by the following systems:

- Inundation from the Hunter River;
- Tide inundation from Fullerton Cove and Port Stephens; and

- Inundation from local catchments including Windeyers Creek, Dawsons Drain, the Moors Drain, Tilligerry Creek and other minor drainage channels.

There are a number of major hydraulic features identified within the Williamtown SAP which effect on the flooding regime in the study area and a local and regional catchment scale. The main hydraulic features are outlined below.

- Stormwater trunk drainage network (open drains);
- Nelson Bay Road which provides a significant hydraulic control and limits the flooding of Williamtown from Fullerton Cove;
- Fullerton Cove Levee and flood gates, which protect the Fullerton Cove and Williamtown areas from tidal inundation and flooding from the Hunter River catchment in frequent flood events; and
- Levees and flood gates on the Tilligerry Creek at Salt Ash, which provide some protection against tidal flooding from the Port Stephens.

Figure 1-3 shows the major hydraulic features in the study area. There are also several cross-drainage culverts under road crossings however these have not been presented for clarity. Further detail on these hydraulic structures is presented in this report.

The Tomago Sand beds and associated bore field are designated as a Drinking Water Catchment, a key constraint to water cycle management. The extent of the Tomago and Stockton aquifers is shown in Figure 1-4. Further discussion on the aquifer is provided in Section 2.3.5.

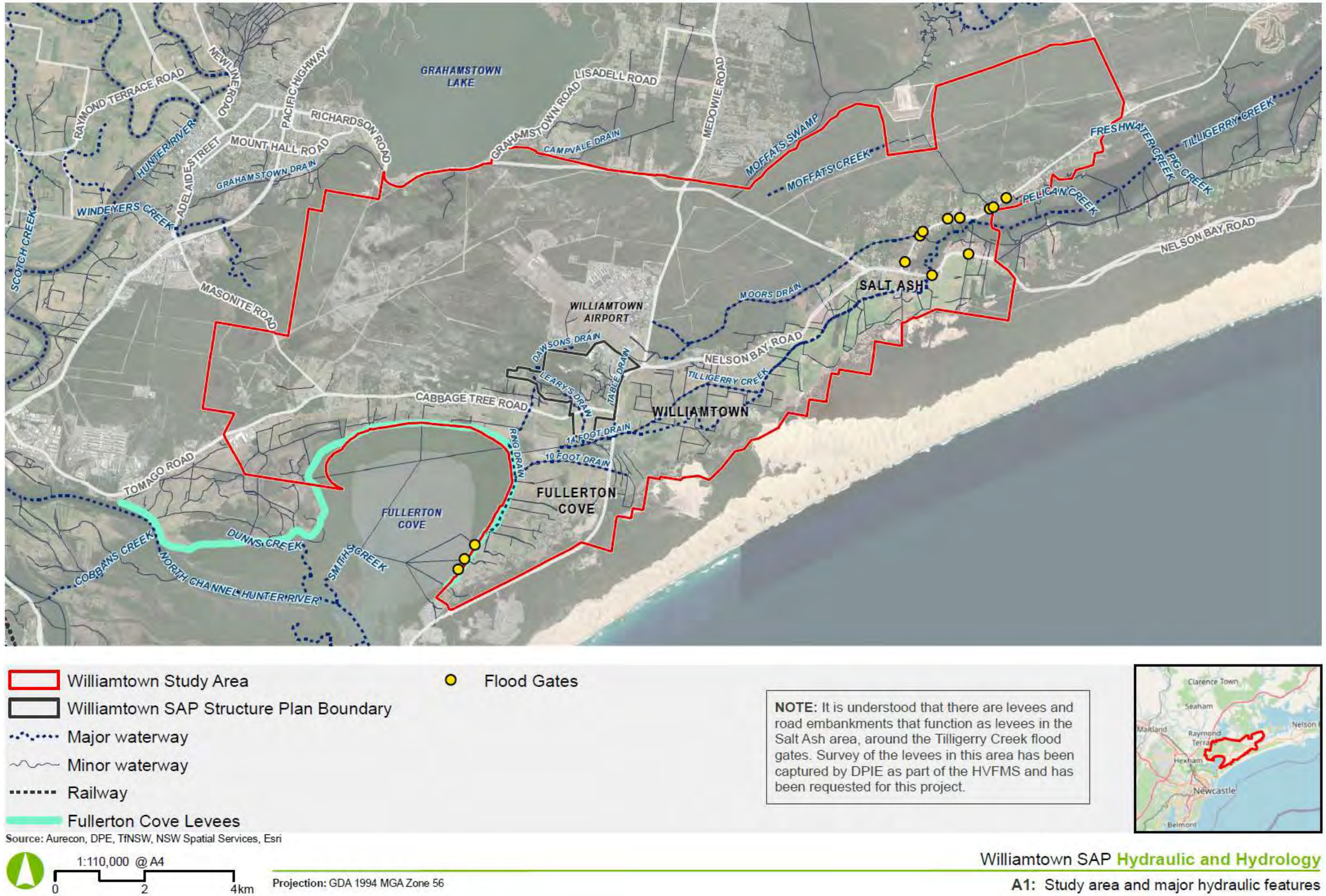


Figure 1-3 – Study area and major hydraulic features

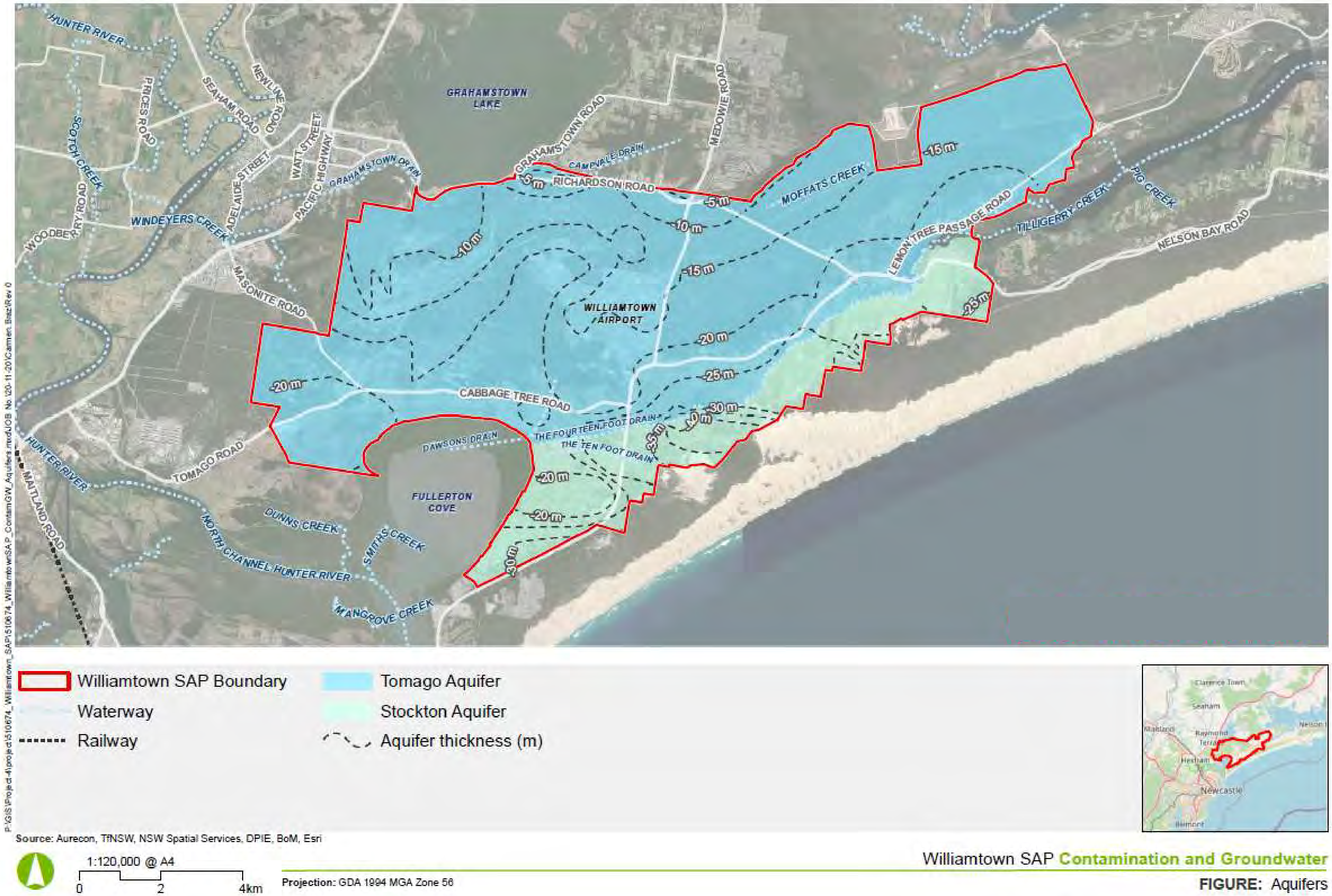


Figure 1-4 – Groundwater aquifer

2 Baseline Assessment

2.1 Relevant Legislation, Policy and Guidelines

Table 2-1 – Relevant legislation

Legislation	Description and how this guideline will impact the project
Water Management ACT 2000 (NSW)	The Water Management Act 2000 (NSW) (WM Act) is administered by the NSW Department of Planning and Environment (DPE) (formerly NSW Department of Planning, Industry and Environment) and is intended to ensure that water resources are conserved and properly managed for sustainable use benefitting both present and future generations. The WM Act is also intended to provide a formal means for the protection and enhancement of the environmental qualities of waterways and their in-stream uses as well as to provide for protection of catchment conditions. The intent and objectives of the WM Act have been considered as part of this assessment. Provisions of the WM Act require the development of management plans to deal with flooding regimes and the way they are managed in relation to risks to property and life and to ecological impacts. The WM Act also defines approvals required for carrying out works situated near a river or floodplain via flood work approvals or drainage work approvals.
Water Sharing Plans	Water Sharing Plans are a statutory obligation under the WM Act which define the rules of how water will be allocated and traded in NSW. The following Water Sharing Plans apply to the Williamtown SAP: ▪ The eastern portion of the study area is managed under the Karuah River Water Source ▪ Western portion is managed under the Hunter Unregulated and Alluvial Source ▪ The northern portion of the site is managed under the Tomago Groundwater Source ▪ Southern portion is managed under the Stockton Groundwater Source ▪ The North Coast Fractured and Porous Rock Groundwater Source covers the entire Williamtown SAP and incorporates the Tomago and Stockton Groundwater Sources The extents of the above listed management areas are shown in the Williamtown SAP Hydrogeology Report. No runoff harvesting dams or in-river dams for water supply purposes are proposed as part of the water cycle management strategy. Rainwater harvesting from roofs, constructed wetlands for treatment and detention basins will be utilised to control urban runoff. Details of the proposed water supply arrangements for the Williamtown SAP are discussed in the Utility Report. Any water supply works for construction purposes would require relevant approvals under the WM Act.

Table 2-2 – Relevant Policies and Guidelines

Document	**Description and how this guideline will impact the project**
DCP Amendment Part B5 Flooding	Port Stephens Council's Development Control Plan related to flooding.
Port Stephens Council Development Control Plan (DCP), Amendment No. 14 (September 2020)	Outlines the development control plan for the developments within the Port Stephens LGA
Floodplain Risk Management Policy (Port Stephen Council, 2019)	Policy for managing the flood risks across the Port Stephens Local Government Area (LGA)
Australia Rainfall and Runoff (ARR) 2019 and 1987 Editions	The *Australian Rainfall and Runoff* (ARR) guideline is a governing document for hydrological and hydraulic analysis. It provides designers and analysts with tools, information and data for the assessment of design flood estimation in Australia. ARR 1987 has been a long-standing guideline to flood estimation in the industry. This has now been updated to ARR 2019 which brings with it updated rainfall data, patterns and methodologies. The flood studies that underpin this Baseline Study have been developed using ARR 1987 and present a gap in the flood assessments moving forward.
Using MUSIC in Sydney Drinking Water Catchment, WaterNSW Standard, (Water NSW, 2019)	WaterNSW has developed this guideline to help manage stormwater pollution in drinking water catchments. The principles of this guideline can be applied to the Hunter Water drinking water bore field catchments by demonstrating that Williamtown SAP would have a Neutral or Beneficial Effect on surface and groundwater quality.
Hunter Estuary Coastal Zone Management Plan (BMT, 2017)	The CZMP has proposed a management strategy to introduce an environmental planning requirement for all new development to achieve no net increase in pollutant loads in runoff, through best practice stormwater management. The CZMP stated that this strategy is not currently in place.
Risk based framework for considering waterway health outcomes in strategic land-use planning decisions (OEH, 2017)	This state protocol champions a risk-based approach to stormwater management. The protocol calls for effects-based assessments to inform stormwater controls and land use decisions rather than adopting generic stormwater controls An effects-based assessment has not been undertaken for the region at this stage. Given the proximity of downstream Ramsar wetlands, it is prudent to apply an approach that achieve no net increase in pollutant loads in runoff and this is consistent with the Risk based framework. Therefore, the risk-based framework will be applied by identifying the most cost-effective strategy for stormwater management to achieve no net increase in pollutant loads to protect the Drinking Water catchment and sensitive waterways.
Port Stephen Flood Hazard mapping 2021	Flood hydraulic and hazard category mapping supplied by Port Stephens Council.
NSW MUSIC Modelling Guidelines (BMT, 2015)	Provides MUSIC modelling approach and inputs which have been adopted for use as recommended by the PSC WSDS guidelines BMT (2011)
Floodplain Risk Management Guide, Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways' (OEH, 2015)	Provides advice on approaches that can be used to derive ocean boundary conditions and design flood levels for flood investigations in coastal waterways considering the interaction of catchment flooding and oceanic inundation.

Document	Description and how this guideline will impact the project
Water Sensitive Development Strategy Guidelines, Port Stephens Council (BMT, 2011)	This guideline sets out the approach for preparing Water Sensitive Urban Design Strategies. MUSIC modelling inputs and assumptions have been adopted from this guideline.
NSW 'Practical Consideration of Climate Change (DECC, 2007)	Presents an approach on how climate change could be considered in practice.
NSW Floodplain Development Manual (NSW Government 2005)	The *Floodplain Development Manual* (former Department of Infrastructure, Planning and Natural Resources, 2005), the *Flood Prone Land Policy* and *Floodplain Risk Management Guidelines* provide guidance to local and NSW Government for managing floodplains and flood risk. The main objective of the guidelines is to reduce the impact of flooding and flood liability on owners and occupiers of flood-prone property and reduce public and private losses. The policy recognises the benefits of use, occupation and development of flood-prone land. The guideline forms the basis of which the management of flooding and development should be considered in this project. It also informs the definition of hazard categories that will assist in defining suitable developable land.
Australian Institute of Disaster Resilience (AIDR) Handbook	Generally, provides guidance on national principles and practices for disaster resilience. More specifically, the handbook provides the definition on the required flood emergency response classification of the floodplain (in accordance with AIDR Guide 7-2 (2014)) and flood planning constraint categories (FPCCs 1 to 4 in accordance with AIDR Guide 7-5 (2017)). This will assist in informing the developmental constraints of flooding across the Williamtown SAP.

2.2 Document and Data Collection

The Williamtown SAP is a heavily studied region with numerous flooding and drainage investigations conducted to date as well as many ongoing studies. This is largely due to the complex site constraints including low lying topography, ground water, tidal influences, and major infrastructure in the area such as Newcastle Airport and Williamtown RAAF base. The following is a summary of the studies considered in this baseline assessment and their status and fitness for purpose.

2.2.1 Documents, Developments and Local Study Review

Documents, developments and local studies interacting or impacting the study area have been collected for review and consideration in the construction of the Williamtown SAP structure plan. The documents reviewed are presented in Table 2-3. Where applicable, references have been made throughout the report where the relevant studies have been referred to.

Table 2-3 – Documents, Developments and Local Studies

Development/Study	Description	Assumption/Status
DCP amendment Part B5 Flooding	Defines the amended development control plans relating to flood prone areas.	Reviewed
Port Stephens Council Development Control Plan (DCP), Amendment No. 14 (September 2020)	Outlines the development control plan for the developments within the Port Stephens LGA	Reviewed

Study: Hydraulic and Cost Benefit Assessment of the Impact of the Climate Change on the Hunter Valley Mitigation Scheme-Summary Report (2020)	This report reviews the flood studies and results from a range of previous studies and provides estimation of the potential future climate change effects on the existing mitigation infrastructures and then investigates options to improve the mitigation options against the future changes in the flood behaviour.	Not available. The study is still in progress. Not discussed further in the report.
Floodplain Risk management Policy (Port Stephen Council, 2019)	Policy for managing the flood risks across the Port Stephens Local Government Area	Reviewed
Study: Williamtown Drainage Study (Umwelt 2018)	Local drainage study of the local catchment. It has been informed by relevant studies from Port Stephens Council with regards to model verification and drainage infrastructure beyond the project scope. The study investigates potential management options to improve drainage however does not recommend specific works. It more so aims to understand sensitivity of drainage works on reducing flood levels.	Defence commissioned project. Report only reviewed.
Study: Williamtown – Salt Ash Floodplain Risk Management Study & Plan (BMT 2017)	Considered the previous studies, undertaken hydrology and hydraulics, assessed the flood behaviour, prepared flood maps (maps related to floodplain management and flood control plans in particular) and has developed floodplain management options.	Reviewed
Study: Anna Bay and Tilligerry Creek Flood Study 2017 (Jacobs 2017)	This flood study has been conducted on behalf of Port Stephens Council for Anna Bay and Tilligerry Creek catchment area. The purpose of this study has been to investigate the existing and future flood risks in the study area and to provide information for the development of the subsequent flood risk management study and plan.	Reviewed

Study: Medowie Floodplain Risk Management Study and Plan (WMA Water 2016)	This study has been prepared by WMA Water for Port Stephens Council and provides the basis for the future management of the flood prone lands in the Campvale and moffats Camp catchments.	Reviewed
Port Stephen Flood Hazard mapping 2016	flood hazard category map published by Port Stephens Council	Reviewed
Study: Williamtown Drainage Study (Umwelt 2014)	Local drainage study of the local Williamtown catchment commissioned by PSC. The study focused on the investigation of drainage improvement for drain discharging to Fullerton Cove.	Reviewed
Study: Williamtown/Salt Ash Flood Study Review (BMT 2012)	A review of the Williamtown and Saltash flood study. Minor updates were made. Establishes the flood conditions under climate change scenarios of 2050 and 2100.	Reviewed
Development & Study: Williamtown Aerospace Park (WAP) Flood Assessment and Stormwater Strategy for Subdivision Development Application (PB 2010)	This assessment was conducted on behalf of Hunter Land Pty Ltd to support the Williamtown Aerospace Park development (otherwise known as the DAREZ site). Whilst the planning controls referenced in the report are generally out dated, relevant information was reviewed and included in the report.	Report reviewed (without appendices)
Study: Potential Impacts of WAP and DAREZ/NAL Development on the Fullerton Cove Drainage System (Umwelt 2011)	Study to determine what level of ongoing discharge from the development can be supported to minimise potential flood impacts on downstream properties.	Reviewed however has not been included in this submission due to timing of receipt.
Development & Study: Williamtown Defence and Airport Related Employment Zone (DAREZ) (GHD 2007)	The project looks to consolidate the detailed investigations and analysis undertaken for the subject site and to present the outcomes for a Structure Plan. It also provides justification to rezone that land suitable for defence and airport related employment generating development.	Reviewed

Study: Williamtown Salt Ash Flood Study (BMT 2005)	Flood study of the Williamtown and Salt Ash catchments.	Reviewed
Study: Lower Hunter Floodplain Cumulative Development Impact Study and Plan	**Stage 1** This scoping study stage (Stage 1) which aims to collate the available information, identify and determine the needs of the stakeholders and recommend a methodology for the subsequent stages of the project.	Study currently in progress being undertaken by UNSW Water Research Laboratory.
	Stage 2 Use the models developed in Stage 1 to assess the sensitivity of the floodplain to filling. The assessment will analyse the cumulative impact of future development (including significant infrastructure upgrades such as road and rail) on flood characteristics. The impact assessments will examine a range of floods and climate change considerations and determine acceptable levels of fill in specific areas	
Letter report: NL182640 Astra Aerolab Development Project, Williamtown – Stormwater and Flooding Advice	Brief documentation advice provided by Northrop to the Newcastle Airport focusing on the stormwater and flood impact management for the Astra Aerolab development (DAREZ).	Reviewed - Supplied by Northrop
Letter report: NL182640 Astra Aerolab Development Project, Williamtown – Water Quality Management Plan	Brief documentation advice provided by Northrop to the Newcastle Airport focusing on the water quality management for the Astra Aerolab development (DAREZ).	Reviewed -Supplied by Northrop

2.2.2 Data Collection

Table 2-4 – Summary of the data supplied for review

Title	Data type	Source/Comment	Date received
LiDAR	LiDAR 1m DEM tiles (asc)	Aerometrex (Capture Date: 4/10/2020)	29/10/2020
Flood Models and Modelling Results (Williamtown/Salt Ash, Medowie and Anna Bay/Tilligerry Ck)	TUFLOW hydraulic models and results Hydrology models for Anna Bay and Medowie only were made available	Port Stephens Council	13/11/2020

Title	Data type	Source/Comment	Date received
Tilligerry Creek flood gates	Excel and GIS	Anna Bay and Tilligerry Creek Flood Study. Understood to have been supplied by DPE at the time of the Anna Bay and Tilligerry Creek Flood Study (2017).	13/11/2020
MUSIC modelling Rainfall Data	MUSIC file	MUSIC Link – Port Stephens Council	Sourced from MUSIC
MUSIC modelling hydrological parameters	PDF	Port Stephens Council	Sourced online.
MUSIC modelling pollutant parameters	MUSIC file	MUSIC Link – Port Stephens Council	Sourced from MUSIC
Flood models and modelling results from the Astra Aerolab study	TUFLOW hydraulic models and results XPSTORM hydrological model	Northrop	3/6/2021
NL182640_ULTIMATE DESIGN SURFACE.12daz NL182640_ULTIMATE DESIGN SURFACE.dwg	Design models for Astra Aerolab development	Northrop Design earthworks models	3/6/2021
Civil WAE Oct 2020 dm.pdf	Design drawings	Northrop	3/6/2021

2.3 Catchment Characteristics

2.3.1 Climate and Rainfall

Climate statistics for Williamtown RAAF base are provided in Figure 2-1 below.

Rainfall data reviewed by BMT (2011) indicated that the average annual rainfall varies significantly within the Port Stephens Local Government Area (LGA) from approximately 950 mm in the west of the LGA to over 1350 mm in the east. Based on this analysis average rainfall within the eastern portion of the study area is likely to be 10% higher than in the western portions of the study area.

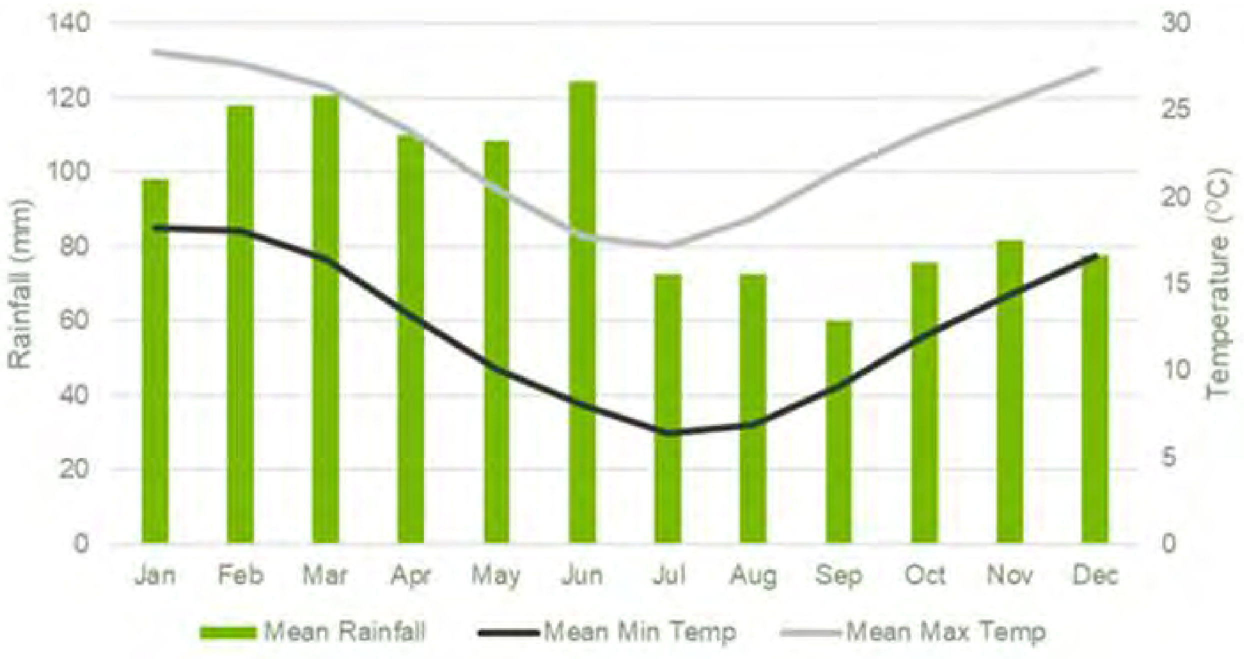


Figure 2-1 – Average monthly rainfall and temperature (Williamtown RAAF, BOM Station 061078) (BOM, 2021)

2.3.2 Local Topography and Catchment

The western portion of the study area is located within the Hunter River estuary catchment and the eastern portion in the Port Stephens estuary catchment. Refer the local floodplain catchment map in Figure A4 in Appendix A.

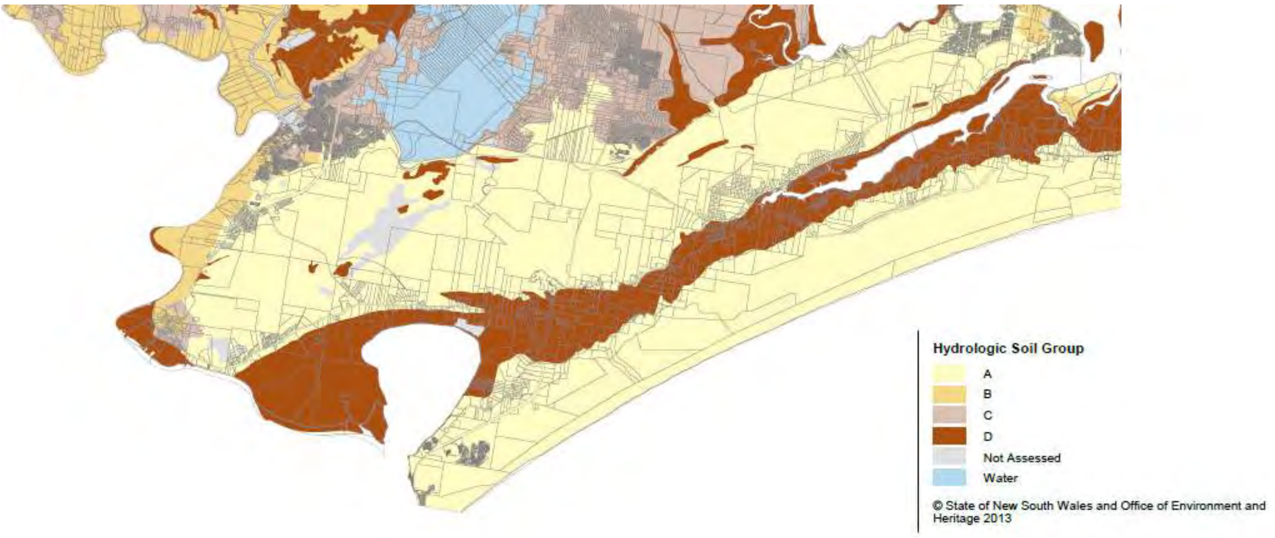
The study area typically ranges between below sea level within low lying floodplain in the southern portions of the site and around Fullerton Cove to around 10 m AHD on the northern portion of the airport with some isolated pockets of higher ground. Elevations also rise sharply at the coastal dunes on the southern boundary. The study area topography is shown in Figure A2 Appendix A.

The study area is generally relatively flat within the 0 to 5% gradient range with isolated steeper slopes above 10% gradient. Refer Figure A3 in Appendix A.

The majority of the study area drains in a southerly direction towards the low-lying floodplain before flowing either westerly towards Fullerton Cove or easterly towards Tilligerry Creek. The northern fringes of the study area drain towards Grahamstown Creek. The local floodplain catchments are shown in Figure A4 in Appendix A.

The study area is characterised by large areas of bushland in the northeast, rural pasture within the lower lying floodplain areas, the Williamtown airport and surrounding infrastructure land uses in the centre of the study area and a minor portion of urban development. Soils and groundwater

The local Hydrologic Soil Groups are shown in Figure 2-2, and Table 2-5. The study area is generally underlain by high permeability soils (Soil Group A) with some low permeability soils (Soil Group D) within lower flying floodplain areas.



Extract from Port Stephens Hydrologic Soil Group Mapping

Figure 2-2 – Hydrologic Soil Group

Table 2-5 – Hydrologic Soil Group Description

Hydrologic Soil Group	Description
A	Soils having high infiltration rates, even when thoroughly wetted and consisting chiefly of deep, well to excessively-drained sands or gravels. These soils have a high rate of water transmission. For design purposes, it is assumed that the Antecedent Moisture Condition is "Rather wet" (refer to Australian Rainfall and Runoff (ARR) 2016, Table 5.3.11) and the Horton Maximum (Initial) Infiltration Rate is 83.6 mm/hr, the Minimum (Final) Infiltration Rate is 25 mm/hr and the Shape Factor/Decay Rate k is 2 /hour (refer ARR 2016, Table 5.3.12).
C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of transmission. For design purposes, it is assumed that the Antecedent Moisture Condition is "Rather wet" (refer to ARR 2016, Table 5.3.11) and the Horton Maximum (Initial) Infiltration Rate is 33.7 mm/hr, the Minimum (Final) Infiltration Rate is 6 mm/hr and the Shape Factor/Decay Rate k is 2 /hour (refer ARR 2016, Table 5.3.12).
D	soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a high-water table, soils with a clay layer, and shallow soils over nearly impervious material. These soils have a very slow rate of transmission. For stormwater design purposes, it is assumed that the Antecedent Moisture Condition is "Rather wet" (refer to ARR 2016, Table 5.3.11) and the Horton Maximum (Initial) Infiltration Rate is 7.4 mm/hr, the Minimum (Final) Infiltration Rate is 3 mm/hr and the Shape Factor/DecayRate k is 2 /hour (refer ARR 2016, Table 5.3.12).

Note: Descriptions taken from Port Stephens Hydrologic Soil Group Mapping (Port Stephens, 2013)

The local groundwater levels and quality are described within the Hydrogeology report and would be considered as part of the development of the water cycle management strategy during the next phase.

2.3.3 Existing Land Use

The existing land zoning within the study area is shown in Figure A5 in Appendix A. The study area predominantly consists of RU2 Rural Landscape, E1 National Parks and Nature Reserves in the north and SP1 special activities and SP2 infrastructure land zoning around Williamtown airport. The land uses are consistent with the extent of flooding in the region with rural farmlands generally located within the floodplain. The same predominant regional land zonings occur within the Williamtown SAP Structure Plan Boundary.

2.3.4 Sensitive Receiving Environments

The location of sensitive aquatic environments identified within the study area are shown in Figure A6 in Appendix A and summarised in subsequent sections. Sensitive aquatic environments and groundwater dependant ecosystems are discussed in further detail in the Environmental report and Hydrogeology report respectively.

2.3.5 Drinking Water Catchment

Much of the study area is situated upon the Tomago Sandbed aquifer and its associated Drinking Water Catchment area as shown in Figure A6 in Appendix A. The northern fringes of the Williamtown SAP Structure Plan Boundary extend into the Drinking Water Catchment.

The Tomago Sandbed aquifer consists of around 20 metres (but reaches 50 metres in some locations) of fine sand above an impervious clay and rock layer (Hunter Water, 2011). Rainwater lands directly on the sand surface to replenish the aquifer. The water table is around 4.8 metres above sea level when full and 1.8 metres above sea level when empty (Hunter Water, 2011). A network of more than 500 bores are used to extract water prior to treatment at Grahamstown Water Treatment Plant before being piped to consumers in Newcastle and the Hunter Region.

There are specific and stringent requirements for developing in the catchment which are further discussed in Section 2.10 with respect to water quality. Potential constraints in relation to water supply from the Tomago groundwater source are discussed in the Hydrogeology and Utilities reports.

2.3.6 Ramsar Wetlands

The Hunter Estuary wetland system, within the Hunter Wetlands National Park is listed under the Ramsar convention on wetlands. The park supports extensive areas of mangrove forest, swamp oak forest and saltmarsh. The extent of the Ramsar wetland, located downstream of the Williamtown SAP boundary is shown in Figure A6 in Appendix A

2.3.7 Nationally Important Wetlands

The following wetland systems, cited in the Directory of Important Wetlands in Australia are receiving waters of the Williamtown SAP Structure Plan Boundary:

- Mangrove system around Fullerton Cove within the Kooragang Nature Reserve;
- Fullerton Cove.

The locations are shown in Figure A6 in Appendix A.

Other nearby nationally important wetlands which are not receiving waters of the Williamtown SAP Structure Plan Boundary include:

- Tilligerry Creek (located within the study area);
- Mangroves in the Racecourse Swamp and Salt Ash Air Weapons Range surrounding Saltwater Creek; and
- Port Stephens Estuary.

2.3.8 Coastal Management SEPP Wetlands

A number of the wetlands described above are also listed as SEPP (Coastal Management) 2018 coastal wetlands as shown in Figure 2-3.

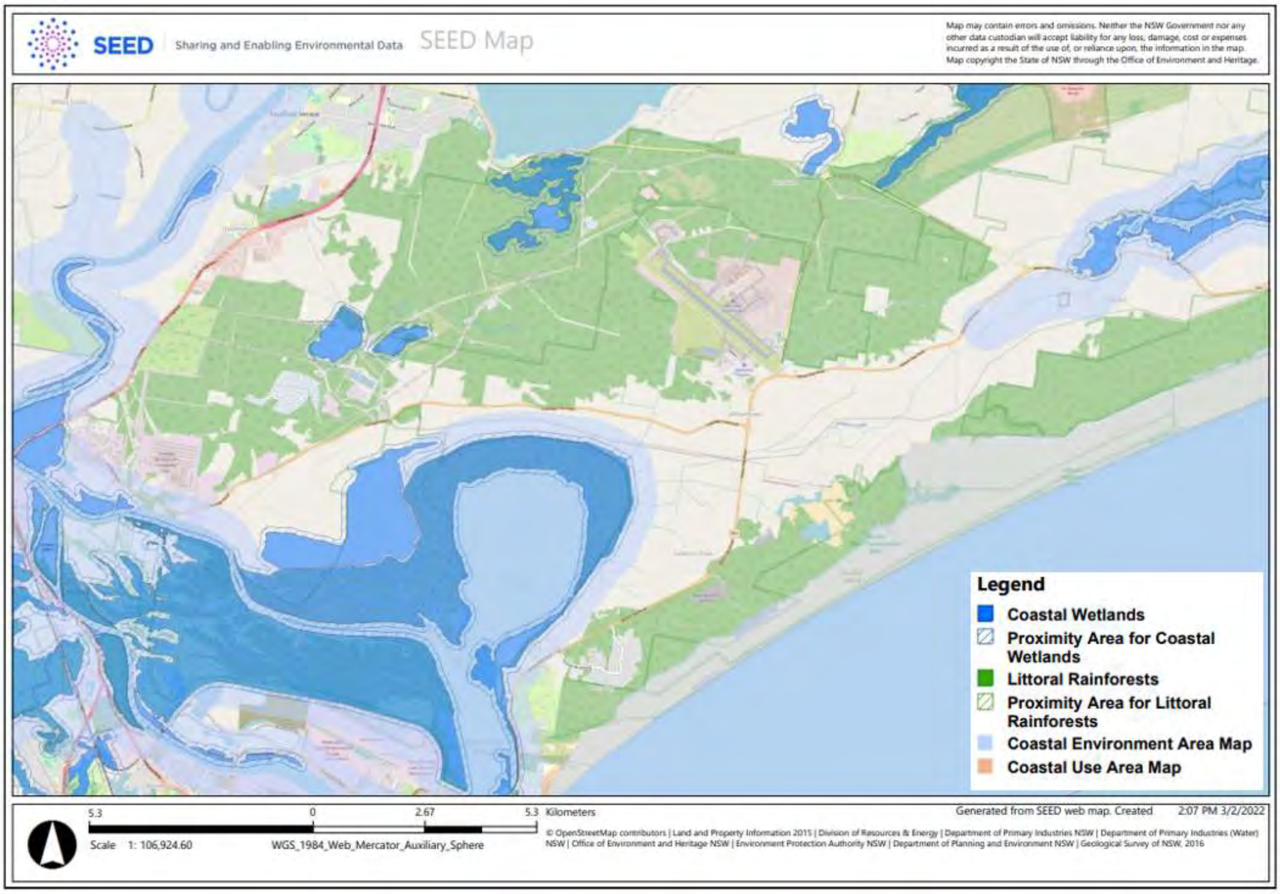


Figure 2-3 – Coastal Management SEPP Coastal Wetlands (Source: SEED Map (2022))

2.3.9 LEP Wetlands

The PSC LEP 2013 has mapped a number of wetlands within the study area. The impact of Williamtown SAP on these identified wetlands would need to be considered. These are shown in Figure A6 in Appendix A.

2.3.10 Groundwater Dependant Ecosystems

Known, high potential and moderate potential Aquatic Groundwater Dependant Ecosystems (Aquatic GDEs) are identified within the study area, the locations of which are shown in the Hydrogeology report. The identified Aquatic GDEs are surface water bodies that are dependent on groundwater.

2.4 Flooding Mechanisms

The study area experiences flooding from three different mechanisms. These can be broadly defined as:

- **Regional Flooding** – Hunter River flood events;
- **Local Flooding** – Rainfall on the local catchment areas; and
- **Tidal Inundation** – Tides in Fullerton Cove and Port Stephens.

These three mechanisms are of different scales and influence flood levels across the study area to varying degrees. The regional flooding is the more predominant source of flooding and has informed the flood planning levels for the area. These mechanisms are further discussed in the following sections.

2.4.1 Regional Flooding

As noted, flooding from the Hunter River catchment is considered regional flooding and is also the predominant flooding mechanism for the Study area. It has the potential to impact flooding to varying degrees, which can be generally classed into the following categories (note that these are not related to any categories associated with flood warning):

- **Minor Flooding**- for minor floods, Hunter River flood levels may not overtop the Fullerton Cove levee however would likely prevent the localised rainfall runoff from draining due to high tailwater conditions.
- **Moderate Flooding**- in moderate flooding, overtopping of the Fullerton Cove levee may occur and inundate the floodplain. These floodwaters would spill across the lower lying flood storage areas.
- **Major Flooding**- in a major Hunter River flood, overtopping of the Fullerton Cove levee would occur filling up storages and, depending on the flood level, would drive flood flow against the catchment grade eastward to Port Stephens via Tilligerry Creek.

Under major flooding, overland flow travelling towards Port Stephens interacts with several hydraulic controls. Nelson Bay Road is the most significant crossing controlling floodwaters. The culverts under Nelson Bay Road act as a control to flood flow and once its capacity is exceeded, overtopping of the road would occur. Indicative flow directions under regional flood conditions can be seen in Appendix A (Figure A7).

Current flood mapping for the 1% AEP event is shown in Appendix A (Figure A9). Flooding in this event has overtopped the Fullerton Cove levee as expected and is seen to flood the Fullerton Cove/Williamtown and Tilligerry Creek floodplains. Flood depths are in the order of 0.5-1m across the flood storage areas along this stretch, except for a small section at Salt Ash that sees shallower flood depths in the order of 0.2m or less. Across the local catchment areas small flood storage depressions are seen scattered about, predicting flood depths of 0.5m or less.

Under the changed climate 1% AEP conditions (Appendix A, Figure A10), flood depths are expected to increase to 1-2m across the Fullerton Cove/Williamtown and Tilligerry Creek floodplains. Flood depths are seen to be less variable compared to present day 1% AEP conditions. Flooding across the local catchments away from the floodplain appears to be similar to the present day 1% AEP event.

Under the Probable Maximum Flood (PMF) conditions (Appendix A, Figure A11), flooding is widespread reaching depths of 4m or higher across most of the flooded area. Depths become shallower in the order of 2-4m along the lower reaches of Tilligerry Creek near Salt Ash as it heads toward Port Stephens.

Peak flood velocities for the 10%, 5%, 1% AEP events and climate change scenario are shown in Appendix A. The figures indicate that during 10% and 5% AEP events, peak flood velocities are less than 0.25 m/s in the majority of the flooding in the study area and only in small scattered areas, reach about 0.8 m/s. Within Tilligerry Creek flood velocities in isolated locations reach 2m/s.

During the 1%AEP event, peak velocities increase slightly to approximately 0.7m/s south of Tomago Road, adjacent to Fullerton Cove. Under the climate change event, peak flood velocities are slightly higher again, generally reaching 0.9 m/s adjacent to Fullerton Cove.

Peak velocities along Cabbage Tree and Nelson Bay Roads, near the intersection, increase to 2.3 m/s. This is in the vicinity of the roads however they stay less than 0.25m/s across much of the floodplain within the study area.

Peak flood velocities for PMF event are also shown in Appendix A. The figure indicates that the peak flood velocities are largest within the Tilligerry Creek reaching 3m/s. South of Cabbage Tree Road peak velocity reaches 3.5m/s. South of Tomago Road peak velocities of 0.5 to 1.5 m/s ore seen. Across the rest of the study area, peak velocities reach about 0.5 to 0.7 m/s.

2.4.2 Local Flooding

Local flooding is defined as being caused by rainfall over the local catchment areas. This specifically is flood producing rainfall over the following catchments:

- Windeyers Creek, located to the north-east, which drains directly into the Hunter River.
- The Moors Drain flowing between the Williamtown RAAF base and Salt Ash into Tilligerry Creek.
- Tilligerry Creek between Fullerton Cove and Nelson Bay Road, Salt Ash.
- Minor drainage channels draining to Tilligerry Creek, Fullerton Cove. Or directly to Hunter River

Generally, local catchment flooding is less extensive and shallower in comparison to the regional flooding; however, has the potential to coincide with the regional flooding or tidal inundation. This limits the ability for the local catchment to drain due to high water levels at the outlet therefore resulting in increased inundation durations across the flood storage areas of the local catchments. Indicative flow directions under local catchment flood conditions can be seen in Appendix A (Figure A17).Local flooding was investigated in the Umwelt (2018) Drainage Study and the Williamtown/Salt Ash (BMT 2017) Study. The Umwelt (2018) study covers the area downstream (south) of the Newcastle Airport where as the BMT (2017) study covers a similar area plus further upstream (north-west) of the airport.

The Umwelt (2018) study presented local catchment flooding for the 1% AEP and 1% AEP plus climate change, which is shown in Figure 2-4 and Figure 2-5. Flooding in the 1% AEP event is seen to be in the order of 0.1-0.3m with three notable areas reaching depths of around 1m. These are located adjacent to Fullerton Cove, immediately east of Nelson Bay Road (between the Fourteen Foot and Ten Foot Drains) and further east approximately halfway between Fullerton Cove and Salt Ash.

Under the future climate 1% AEP conditions (Figure 2-5), peak flood depths are more consistent along the floodplain reaching around 1m between Fullerton Cove and approximately half way to Salt Ash. Flooding across the northern side of Nelson Bay Road, away from the main floodplain, appears to be similar in depth compared to the present day 1% AEP event.

The local catchment flooding from the Williamtown/Salt Ash BMT (BMT 2017) study was supplied as GIS flood data from PSC. This has been mapped for the available events in combination with the Medowie Study (WMA 2015) and the Anna Bay and Tilligerry Creek (Jacobs 2017) study. This is presented in Appendix A (Figure A18 and A19), along with the 5% AEP event, to illustrate the coverage of current local catchment flood modelling.

The Williamtown/Salt Ash (BMT 2017) study is not clear on how the local catchment modelling has been undertaken. The model only covers the area north of Tilligerry Creek and the Fourteen Foot Drain. Then it appears as though the results have been merged with the regional flood model results for the final mapping.

The 1% AEP flood depths from the Williamtown/Salt Ash (BMT 2017) study show some consistency with the Umwelt (2018) assessment where they overlap. Flood depths on the northern side of Cabbage Tree Road are in the order of 0.5m to 1m. A similar magnitude to that modelled in the Umwelt (2018) study was also observed based on the flood mapping shown in Figure 2-4.

Peak 1% AEP flood velocities from the Umwelt (2018) study are shown in Figure 2-6. As can be seen, flood velocities are relatively low in the order of 0.25m/s across the modelled area with isolated areas of approximately 0.5m/s. This is as anticipated due to the flat nature of the catchment and indicates that scour risk would be low, limiting the need for extensive scour protection.

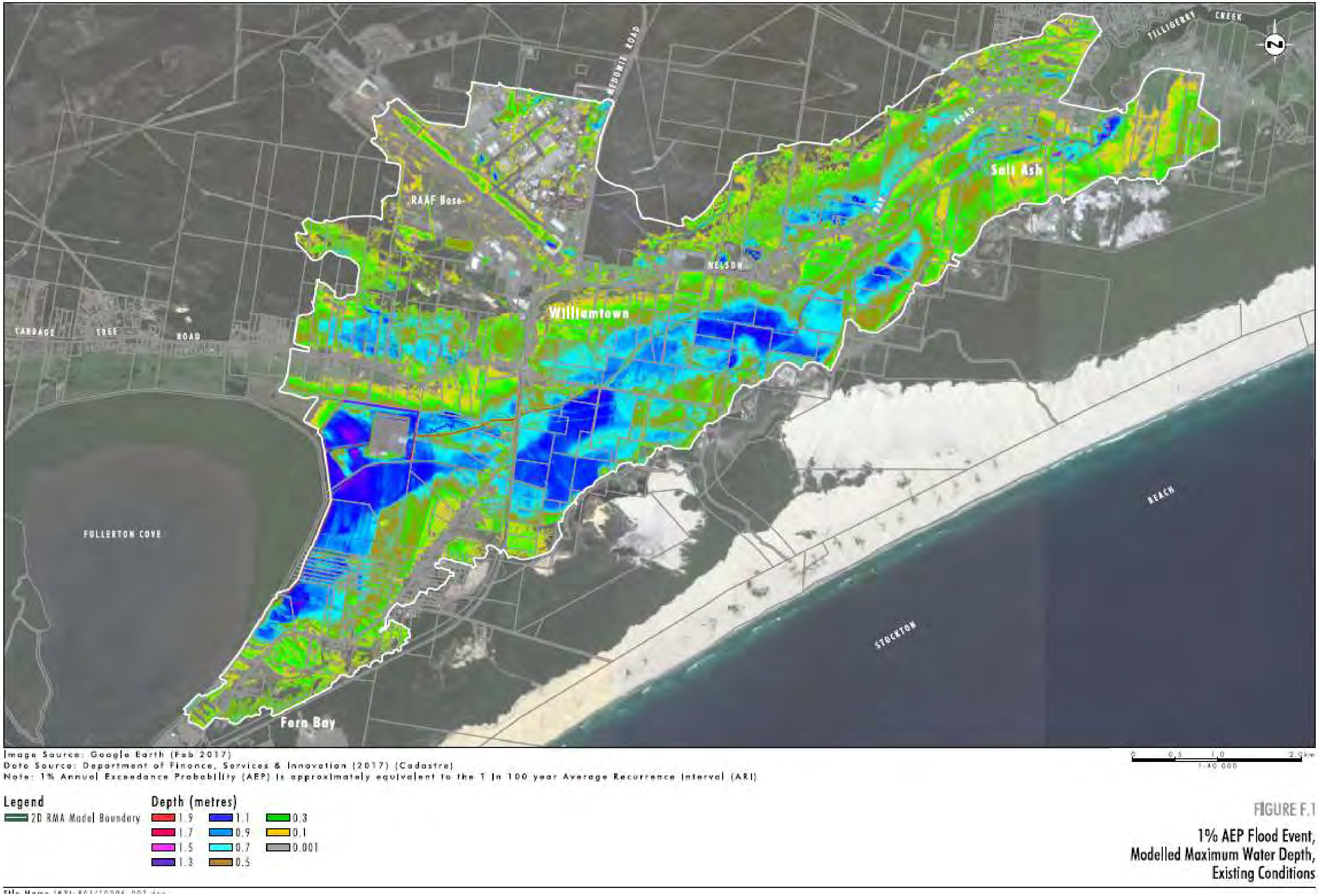


Figure 2-4 – Umwelt 1% AEP design peak flood depths under local catchment flooding conditions (Source: Umwelt 2018)

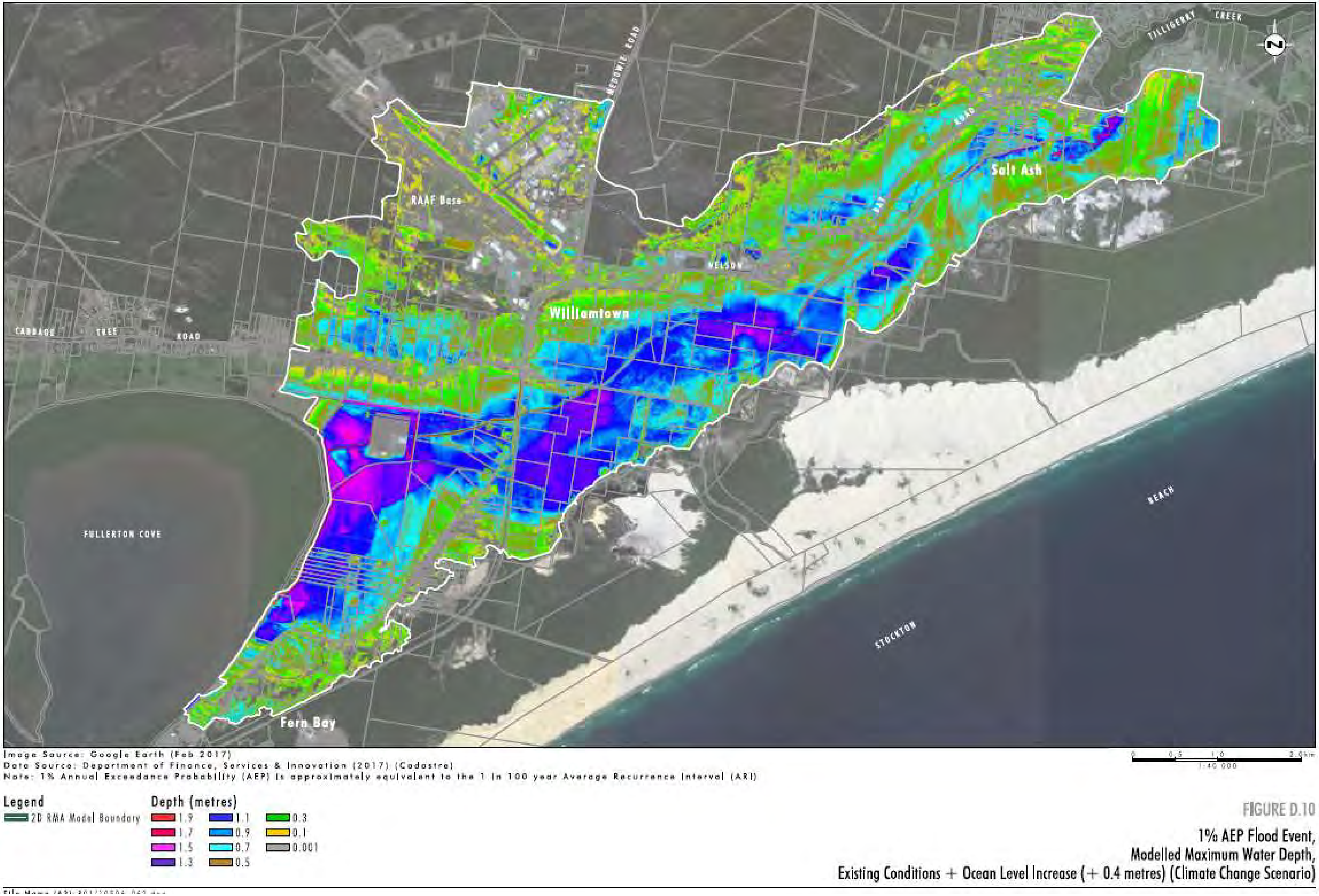


Figure 2-5 – Umwelt 1% AEP plus climate change design peak flood depths under local catchment flooding conditions (Source: Umwelt 2018)

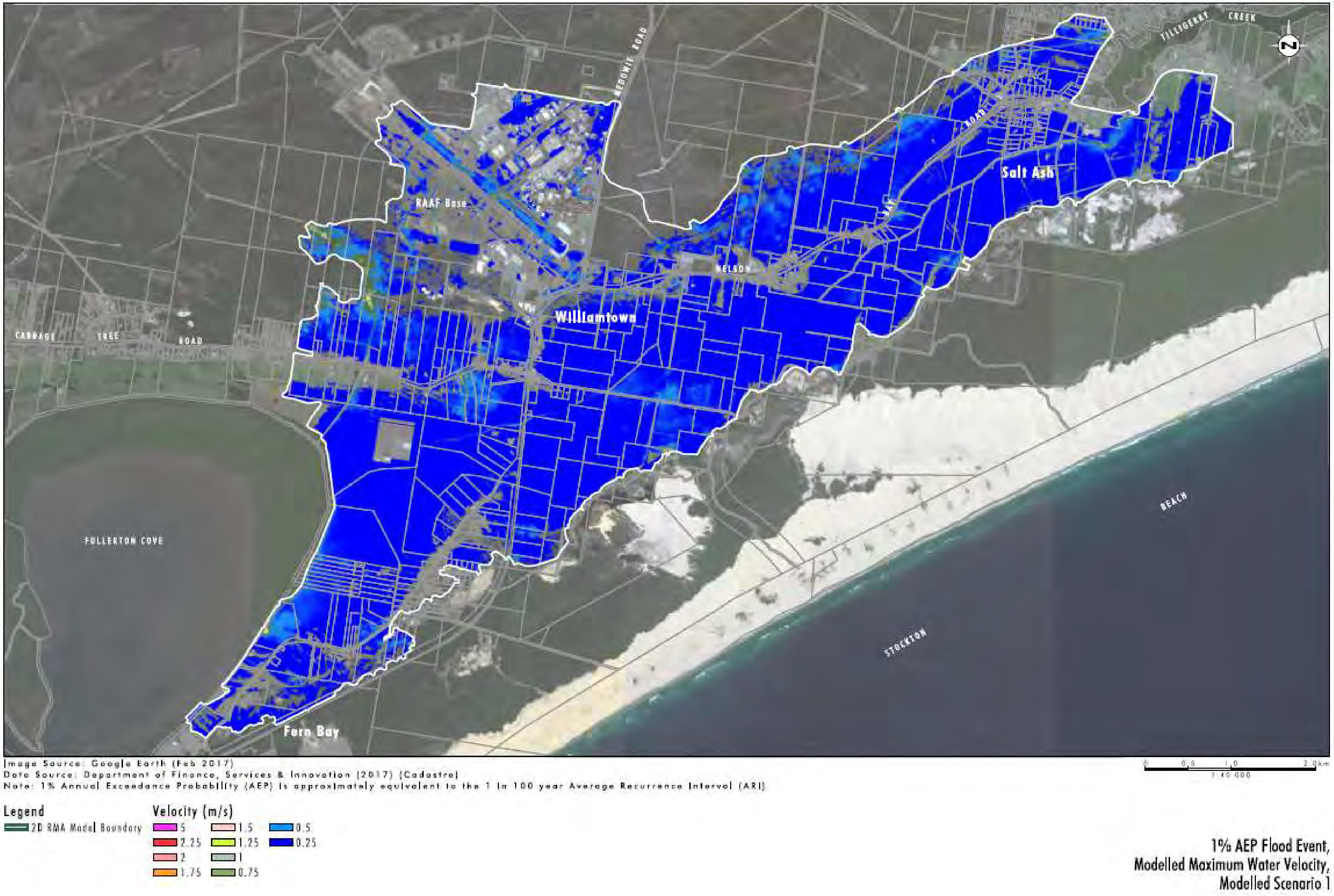


Figure 2-6 – 1% AEP design peak flood velocities under local catchment flooding conditions (Source: Umwelt 2018)

2.4.3 Tidal Inundation

Flooding resulting from tidal inundation impacts the lower lying areas of the floodplains. Drainage of the local catchment areas is completely dependent on the water levels in Fullerton Cove and Post Stephens therefore indirectly influencing flooding by limiting the ability for local drainage to discharge freely. The extent of inundation from tidal processes has however been limited by the system of levees and floodgates that look to protect the low-lying areas.

The tidal planes for the Lower Hunter adopted for the current flood planning is shown in Table 2-6.

Table 2-6 – Tidal planes for Hunter River at Mallabula Point (BMT 2017 sourced from Manly Hydraulics Laboratory (MHL) 2012)

Tidal Plane	2022 Water Level (m AHD)*
High Water Solstices Springs (HHWSS)	1.08
Mean High Water Springs (MHWS)	0.69
Mean High Water (MHW)	0.56
Mean High Water Neaps (MHWN)	0.42
Mean Sea Level (MSL)	-0.01
Mean Low Water Neaps (MLWN)	-0.44
Mean Low Water (MLW)	-0.58
Mean Low Water Springs (MLWS)	-0.71
Indian Spring Low Water (ISLW)	-0.99

* Conversion to AHD from Port Stephens Height Datum (PSHD) = -0.949m (MHL, 2012)

Although it is understood that tidal inundation is one of the modes of flooding, historical data on coastal flooding is not presented in the current studies.

Flooding from tidal influence is most susceptible to climate change. It is understood that the current levee and flood gate network is able to manage tidal inundation i.e. is higher than the current mean water levels presented in Table 2-6, however increases in sea levels due to climate change will see the current infrastructure at risk of not providing the same level of protection. This impacts on the frequency of tidal inundation and duration of inundation across the susceptible areas. For example, the Mean High Water Springs (MHWS) tide, which occurs approximately every fortnight reaches a mean level of 0.69m AHD. With the predicted increase in sea level of 0.9m in the Year 2100 (PSC flood planning condition), the MHWS level would reach approximately 1.7m AHD. Based on the Williamtown/Salt Ash flood modelling the lowest road level encircling Tilligerry Creek, that functions as a levee, shows a low point of approximately 1.73m AHD.

Future development within the tidal areas will need to be carefully considered given the frequency of predicted inundation. Should the Structure Plan be proposed in the lower lying areas, it would ultimately need to be filled at a minimum and assessment would need to be undertaken to determine the tidal flooding impacts on Structure Plan as well as Structure Plan impacts on flood levels.

2.5 Riparian Corridors

The following sections outline the riparian corridors in the precinct. The Williamtown SAP will need to consider the integration and embellishment of riparian corridors to promote stream integrity and ecology. The streams in the region provide a vital function of draining the low-lying lands and their conveyance and function needs to be maintained. The following sections outline the planning controls and location of streams in the region. These streams will need to be validated based on site inspection to map their actual extents and alignments.

2.5.1 Planning Requirements

Controlled activities carried out in, on, or under waterfront land are regulated by the Water Management Act 2000 (WM Act). The Natural Resources Access Regulator (NRAR) administers the controlled activity provisions of the WM Act.

Waterfront land includes the bed and bank of any river, lake or estuary and all land within 40 metres of the highest bank of the river, lake or estuary.

NRAR requirements

The NRAR, 2018 'Guidelines for controlled activities on waterfront land, riparian corridors' recommends a vegetated riparian zone width based on watercourse order as classified under the 'Strahler' system, refer Section 2.5.2. The width of the vegetated riparian zone should be measured from the top of the highest bank on both sides of the watercourse, refer Figure 2-7. The NRAR vegetated riparian zone and total riparian corridor width requirements as stipulated in the NRAR (2018) are stated in Table 2-7.

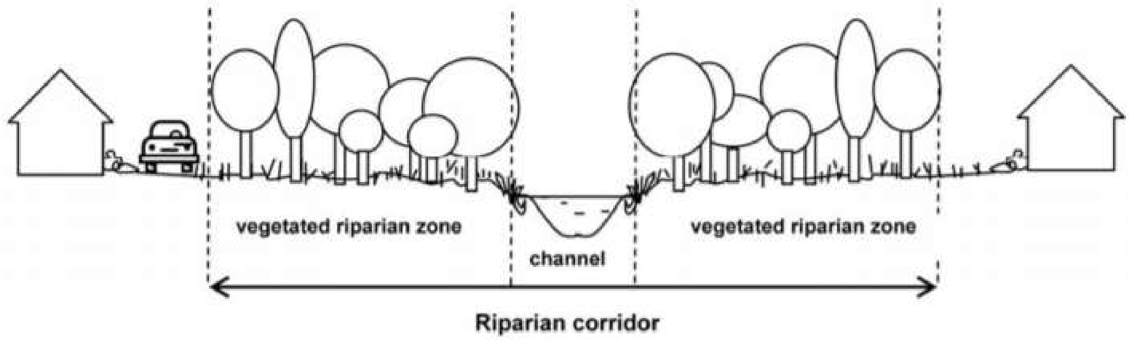


Figure 2-7 – Riparian Corridor Arrangement, NRAR (2018)

Table 2-7 – NRAR Riparian Corridor Requirements

Watercourse Type	Vegetated riparian zone	Total riparian corridor width
1st order watercourses	10 m	20 m + channel width
2nd order watercourses	20 m	40 m + channel width
3rd order watercourses	30 m	60 m + channel width
4th order watercourses and greater (includes estuaries, wetlands and other parts of rivers influenced by tidal waters)	40 m	80 m + channel width

Council requirements

Port Stephens council development control plan (DCP) riparian corridor requirements are slightly more stringent than those stipulated within NRAR (2018). The Port Stephens council DCP requires an additional vegetated buffer and increased width of vegetated riparian zone for the 1st and 3rd order watercourses. The Port Stephens council DCP riparian corridor requirements are outlined in Table 2-8.

Table 2-8 – Port Stephens Council Riparian Corridor Requirements

Watercourse Type	Total buffer[1]	Vegetated riparian zone	Vegetated buffer	Total riparian corridor width
1st and 2nd order watercourses	30 m	20 m	10 m	60 m + channel width
3rd order watercourses or above	50 m	40 m	10 m	100 m + channel width

Extends from the top of bank on either side of the channel and includes the vegetated riparian zone and vegetated buffer

2.5.2 Local Watercourse Orders

The 'Strahler' system of ordering watercourses is used to identify riparian corridor widths, refer Figure 2-8.

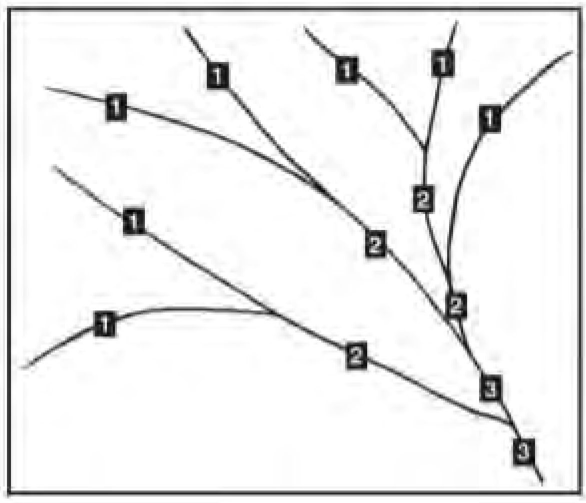


Figure 2-8 – Strahler System, NRAR (2018)

The order of the watercourses within the study area have been classified using the Strahler system. Due to being more stringent, the Council riparian corridor width requirements are recommended to be adopted within the study area. Other riparian corridor requirements including the averaging rule would be in accordance with NRAR (2018). The Strahler stream order is shown in Figure A20 in Appendix A.

2.5.3 Preliminary Riparian Corridor Extent

It is understood that riparian corridor mapping has not been completed for the study area. Therefore, no data was available to show the relevant riparian corridors.

A preliminary riparian corridor width was determined based on the PSC's requirements applied to the watercourse centreline, refer Figure A20 in Appendix A. This corridor would need to be extended to incorporate the channel width once the top of bank of the waterways has been mapped.

2.6 Flooding Related Development Controls

PSC has developed a Development Control Plan (DCP) to inform permissible development and activities in the Local Government Area. The DCP compliments the Local Environment Plan (LEP), supporting the aims and objectives of the LEP. The DCP outlines in more detail the development types that are permissible in the flood planning area.

There are several documents prepared by PSC which provide guidance for planning and development within flood prone land at a local level. These documents include the following:

- Port Stephen Council Development Control Plan (DCP), 11 January 2021.
- Port Stephen Council Floodplain Risk Management Policy, April 2018.
- Port Stephen Flood Hazard Mapping (hazard and hydraulic categorisation), 2021.
- DCP Amendment Part B5 Flooding, December 2020.

The Williamtown SAP has the opportunity to resolve and provide further guidance and requirements for flooding requirements through the creation of the Masterplan and Delivery Plan. The Williamtown SAP should aim to achieve higher industry standards where possible and build in resilience over and above these requirements. However, where requirements are overly conservative or not up to date then there may be opportunities to revise these strategies.

The flood hazard and hydraulic categories map is a combination of provisional flood hazard and hydraulic categories. The DCP, with support of the floodplain risk management policy, describes allowance for and type of potential development (development suitability) within each flood hazard and hydraulic category zone presented in the map.

2.6.1 Hazard and Hydraulic Categorisation Distribution

PSC's current flood hazard and hydraulic categorisations across the Williamtown SAP area is presented in Appendix A (Figure A21). This categorises the flood risk and type of flooding that is expected to occur under the flood planning scenario. It is used in combination with the DCP to identify areas where certain planning controls are required. The following can be interpreted with respect to the Williamtown SAP area based on Figure A21 in Appendix A:

- Part of the proposed study area immediately to the north of the Nelson Bay Road is categorised as **Low Hazard Flood Fringe**. This seems to be due to flood protection provided by the Nelson Bay Road against the tidal inundation and also the rising topography.
- Part of the proposed study area to the south of the Nelson Bay Road is predominantly classified as High Hazard Flood storage with **High Hazard Floodway** further south centrally located along the Fullerton Cove and Tillligery Creek floodplains**.**
- Majority of the area bound by Nelson Bay Road to the east and Cabbage Tree Road to the south is categorised as **High Hazard Flood Storage** with areas of **Low Hazard Flood Storage** and **Low Hazard Flood Fringe** around the perimeter of the mapped extents to the north and west.

2.6.2 DCP – Amendment Part B5 Flooding

Council's DCP has recently been amended to incorporate an updated Part B5 Flooding. It presents a simpler approach to advice on the limitations and types of development that can occur in areas of different flood risk (hazard and hydraulic category).

Figure 2-9 has been extracted from the current DCP document and shows the development suitability applicable for each flood hazard and hydraulic category (Figure A21 in Appendix A). This table (Figure 2-9) can be summarised as follows:

- **Minimal Risk Flood Prone Land:** No planning control is applicable
- **Flood Fringe (Low Hazard/High Hazard):** All developments may be suitable except for developments vulnerable to emergency response or sensitive infrastructure
- **Flood Storage (Low Hazard/High Hazard):** All developments may be suitable except for developments vulnerable to emergency response or sensitive infrastructure
- **Overland flowpath (Low Hazard/High Hazard):** All developments may be suitable except for developments vulnerable to emergency response or sensitive infrastructure

- **Low Hazard Floodway:** Non-residential subdivisions may be possible subject to a performance-based solution. Other listed development may be suitable.
- **High Hazard Floodway:** not suitable for residential subdivision and residential accommodation, Non-residential subdivisions may be possible subject to a performance-based solution. Other listed development may be suitable.

Development suitability

	Flood Hazard Categories (as identified on a flood certificate)	Minimal Risk Flood Prone Land	Low Hazard Flood Fringe	High Hazard Flood Fringe	Low Hazard Flood Storage	High Hazard Flood Storage	Low Hazard Overland Flow Path	High Hazard Overland Flow Path	Low Hazard Floodway	High hazard Floodway
Development vulnerable to emergency response and critical infrastructure		S	U	U	U	U	U	U	U	U
Residential accommodation (other than a dwelling house)		NA	S	S	S	S	S	S	U	U
Residential subdivision		NA	S	S	S	S	S	S	U	U
Dwelling house		NA	S	S	S	S	S	S	PB	PB
Farm buildings		NA	S	S	S	S	S	S	S	S
Fill		NA	S	S	S	S	S	S	S	S
Non-residential subdivision		NA	S	S	S	S	S	S	PB	PB
All other development		NA	S	S	S	S	S	S	PB	PB

Key

U	Unsuitable land use on flood prone land
NA	Suitable, no applicable development controls
S	Suitable, subject to development controls
PB	A **performance based solution** may be provided to demonstrate that the proposed land use is suitable

Figure 2-9 – Development suitability matrix extracted from DCP (Source: Port Stephens Council, 2020)

2.7 Review of Previous Studies and Modelling

The Williamtown and Salt Ash area has been subject to numerous comprehensive studies over the years investigating drainage, flood risk and flood risk management. This has been driven by the sensitive and complex nature of drainage and flooding across the area. Over time, each subsequent study has built on the previous bringing updated modelling, findings and recommendations.

All available relevant studies have been reviewed (Table 2-3) with key information and data presented thought this report. Documentation of the reviews in this section covers only the latest relevant studies for simplicity. These studies include the following with more information in Appendix D:

- Williamtown – Salt Ash Floodplain Risk Management Study & Plan, BMT WBM Pty Ltd (BMT 2017)
- Anna Bay and Tilligerry Creek Flood Study, Jacobs Group Pty Limited, (Jacobs 2017)
- Medowie Floodplain Risk Management Study and Plan, WMAwater (WMA 2015)
- Williamtown Drainage Study, Umwelt (Umwelt 2018)

2.7.1 Comparison of Flood Models

The four studies discussed in the previous section all overlap the Williamtown SAP study area to some degree. The primary study and model covering the majority of the area is the Williamtown and Salt Ash flood model. This model will form the basis of the modelling for this project moving forward.

All available models and/or documentation of modelling was compared and has been summarised in Table 2-9. This summary provides a point of comparison and reference of the different studies capturing their key parameters, assumptions and limitations.

Table 2-9 – Comparison of recent relevant studies

Point of comparison	Williamtown/Salt Ash Study (BMT 2017)	Anna Bay & Tilligerry Creek (Jacobs 2017)	Medowie Study (WMA 2015)	Williamtown Drainage Study (Umwelt 2018)
Intent of the study	Understand regional catchment flooding for flood planning purposes	Understand regional catchment flooding for flood planning purposes	Understand regional catchment flooding for flood planning purposes	A relative comparison of the effectiveness of certain drainage management options for drainage improvement.
Study limitations	Local flooding limited by representation of infiltration through sandy soils and topographic representation of the catchment Local flood mapping is indicative only	As per Williamtown/Salt Ash Study with regards to the Hunter River regional flood modelling	Not clearly discussed. Assessment would be limited to the accuracy of the input data.	Local flood mapping is for relative impact assessment of drainage improvements and not for flood planning
Australian Rainfall and Runoff Guideline	ARR 1987	ARR 1987	ARR 1987	ARR 2016 Note: not fully compliant with AR&R 2016. Focused on developing a detailed model of study area with updated rainfall and tailwater conditions for relative comparisons of options.
Studies that modelling is based on.	▪ Williams River Flood Study (BMT 2009) ▪ Williamtown/Salt Ash Flood Study (BMT 2005) ▪ Lower Hunter Flood Study -Green Rocks to Newcastle (PWD, 1994)	Williamtown-Salt Ash Floodplain Risk Management Study & Plan (FRMS&P) (BMT, 2015)	Medowie Drainage and Flood Study (WMAwater, 2012)	Williamtown/Fullerton Cove Drainage Study (Umwelt 2014)
Hydrological modelling	XP-RAFTS (Not supplied for the Hunter River) Local catchment applied Direct Rainfall	XP-RAFTS for local catchments	Direct Rainfall initially the Runoff Routing model (WBNM) as an updated methodology to overcome scattered shallow depth mapping.	Direct Rainfall Flood hydrographs from external catchment using hydrologic model (XP-Storm)

Point of comparison	Williamtown/Salt Ash Study (BMT 2017)	Anna Bay & Tilligerry Creek (Jacobs 2017)	Medowie Study (WMA 2015)	Williamtown Drainage Study (Umwelt 2018)
Updates made to model for the respective study	▪ Updated topographical data ▪ Updated Hunter River design flood flows ▪ Additional climate change scenario modelling	The BMT (2015) TUFLOW model was extended to cover the study area of this flood study.	A hydrological model was built using the Watershed Bounded Network Model (WBNM) to drive inflows for the hydraulic model instead of using Direct Rainfall Method (DRM)	▪ used BOM IFD 2016 instead of 1987 ▪ used OEH Guidelines 2016 hydrodynamic wave as tailwater boundary ▪ updated the existing hydrodynamic model (Umwelt, 2014) to include Moors Drain and Tilligerry Creek ▪ updated model terrain regarding recent developments
Catchment Loss model	Initial Loss/Continuing Loss	Initial Loss/Continuing Loss	Initial Loss/Continuing Loss	Horton Infiltration
Loss values	Not documented or in supplied model files	Design losses for the local catchment modelling. ▪ Predominantly clayey: IL 10mm, CL 2.5mm/hr ▪ Predominantly sandy: IL 10mm, CL 6mm/hr ▪ Sand dunes: IL 35mm, CL 25mm/hr ▪ Impervious/paved areas: IL 1mm, CL 0mm/hr	Initial Loss – 50mm Continuing Loss – 5mm/h	$Fp = Fc + (Fo + Fc)e{-kt}$ Where: Fo = 25.4 mm/hr (maximum infiltration rate) Fc = 1.27 mm/hr (minimum (asymptotic) infiltration rate) k = 0.002 1/sec (decay parameter) t = time (sec)

Point of comparison	Williamtown/Salt Ash Study (BMT 2017)	Anna Bay & Tilligerry Creek (Jacobs 2017)	Medowie Study (WMA 2015)	Williamtown Drainage Study (Umwelt 2018)
Model geometry (Lidar)	NSW LPI data – 2013 capture	NSW LPI data – 2013 capture as per Williamtown/Salt Ash. Also includes patches for larger study area.	Council supplied 2007 LiDAR Capture.	2017 Landform – 2013 LiDAR supplemented with site survey information and data regarding recent developments and changes within the catchment since 2014 (such as Maria's Farm Veggies).
Model resolution (Grid Size)	20m	20m	10m	High resolution 2D RMA Model Mesh (triangular elements, with horizontal areas (planar) ranging from less than 1 m^2 to approximately 11,184 m^2)
Modelling approach for open drains	2d channel	2d channel	1d and 2d channel	2D channel
Flood probability combinations for the ***Local*** *1% AEP event*	Not documented and relevant model files missing	10% AEP Hunter River, 1% AEP Local catchment, 5% AEP Port Stephens tide	1% AEP	No regional flooding included 1% AEP local catchment 5% AEP Ocean tide level*
Flood probability combinations for the ***Regional*** *1% AEP event*	1% Hunter, 10% Local, 50% Port Stephens tide	1% AEP Hunter River, 10% AEP Local catchment, 50% AEP Port Stephens tide	No regional flood interaction	No regional flood interaction
Inflow boundary	Hunter River: Flood hydrograph (9000m^3/s) Local catchment: 1987 IFD data	Hunter River inflows as per Williamtown/Salt Ash Study Local catchment inflows on the Tilligerry Creek floodplain in this study area, estimated in XP-RAFTS hydrologic modelling.	Local catchment: 1987 IFD data	2016 IFD rainfall data & Flood hydrographs from 34xternal catchment using hydrologic models (XP-Storm)

Point of comparison	Williamtown/Salt Ash Study (BMT 2017)	Anna Bay & Tilligerry Creek (Jacobs 2017)	Medowie Study (WMA 2015)	Williamtown Drainage Study (Umwelt 2018)
Downstream boundary condition	1.5m AHD – Peak 50% AEP dynamic ocean tide level derived based on 0.85m (Base peak water level) plus 0.65m (50% AEP Storm Surge) Local model: Fixed water level at 0.9m AHD	1.44m AHD – Peak 50% dynamic ocean tilde level	Campvale Water Pumping Station – Stage Discharge Swan Bay outlet – Fixed water level of 0.1m above channel invert Salt Ash outlet – Fixed water level of 0.1m above channel invert	1.4m AHD – Peak 5% AEP dynamic ocean tide*
Calibration and/or validation	The hydrologic and hydraulic models used in this study were previously calibrated and verified to available historical flood event data (1995, 1990 and 2000) Accordingly, a model re-calibration was not required.	Local catchment XPRAFTS model has been calibrated and verified against flooding observations of the April 2015 and January 2016 storm events. Calibration of the Hunter River and parts of the Tilligerry Creek floodplain was undertaken as a part of the Williamtown – Salt Ash FRMS&P and preceding flood studies, and has not been revisited in this study.	Calibrated against 2007 event and validated against 2009 and 1990 events. Also, to further test the change in hydrological approach, the peak flood levels of the revised model were compared with the results of the previous model from the Flood Study (WMAwater, 2012)	Full calibration of the model has not been undertaken. In order to verify that the extended model mesh outputs from this study were valid, results were compared to the results produced by Umwelt in 2014. Detailed model verification has been undertaken in Umwelt's 2014 Study against published flood levels in the Williamtown / Salt Ash Flood Study (BMT, 2005).

* Based on Figure 5.2 and Table 5.2 OEH (DPE) Guidelines: Maximum design ocean levels based on estuaries classification and entrance type guidance (ie. 5% AEP event)

^ No model available for review. Data based on reporting.

2.7.2 Modelling Gaps

As noted in Section 2.7.1, the Williamtown/Salt Ash (2018) flood model will be adopted for the Williamtown SAP flood risk modelling. This model will capture the regional flood risk and provide consistency with PSC current flood planning data.

The adopted base flood model was reviewed in the context of the Williamtown SAP. The identified gaps from the review along with proposed management measures have been summarise in Table 2-10.

Table 2-10 – Summary of modelling gaps and proposed management approach

Study Gap	Description	Management approach
ARR Guidelines (ARR 1987 vs 2019)	The current studies adopt ARR 1987 guidelines except for the Umwelt (2018) study, which adopts ARR 2016 data only ie. 2016 rainfall. No existing studies have been updated to the latest ARR 2019 guidelines.	PSC has undertaken extensive flood modelling of the regional catchment within the study area. This modelling has been adopted for their current flood planning. As the Williamtown SAP project would not be able to satisfactorily update the modelling to ARR 2019 to a level suitable for PSC's flood planning purposes, no changes to the regional flooding is proposed. However, the local modelling focusing on the proposed Williamtown SAP will capture the latest ARR guidelines from a drainage assessment perspective.
Flood gate representation	On review of the structures in the Williamtown/Salt Ash model, not all flood gates identified in the DPE data near Tilligerry Creek have been represented in the model within the Williamtown SAP (BMT 2017) study area. Only the main flood gate on Tilligerry Creek is represented. This is likely due to the focus of the Williamtown/Salt Ash study being regional flooding and only the main flood gate was critical. Alternatively, limited data on the structures was available.	In line with the regional modelling, no updates to the flood gates will be made. Under the critical regional flood event, the flood gates would have limited influence on flood behaviour. However, from a local flooding perspective, there is a potential for a greater influence. Flood gate data should be reviewed at the next design stage if available.
Representation of drains	The current model shows that the drainage channels are represented in 2D. This has been based on the underlying model LiDAR data and limited to the data accuracy.	The updated LiDAR data for the project will provide improved representation of the channels (drains) and provide more confidence in the hydraulic capacity and proposed works for drainage improvements. This is due to more accurate LiDAR data compared to the existing studies. Detailed survey may be required at subsequent stages of the Williamtown SAP for the purposes of design. This would only be possible once an understanding of respective drain(s) is known and the works required for drainage management are determined.
LiDAR data	The current modelling is based on 2013 LiDAR capture processed as a 5m DEM. This resolution is considered too coarse for a local drainage and flooding assessment. From a regional flooding perspective, this is considered reasonable given the model has a grid resolution of 20m.	For the local modelling, the 2020 LiDAR captured for the Williamtown SAP project will be adopted. This will provide the latest landform representation.

2.8 Drainage System Review

The drainage system across the Williamtown SAP study area consists of multiple stormwater open drains, culverts, levees and flood gates. These drainage elements are further discussed in the following sections. The drainage system is critical to alleviating the ponding and tidal impacts on a daily basis across the Williamtown SAP. The functionality of the drainage network has an interrelationship with local groundwater recharge in the upper catchment and groundwater expression in low lying areas. There is merit in widening drains to improve drainage, however this needs to be carefully considered in conjunction with aquifer interactions and the potential for impacted groundwater movement (discussed further in the Contamination study). The following sections outline the drainage network which operates during local and regional storm events.

2.8.1 Drains

The drains are the main conveyance infrastructure and are mostly located across the southern portion of the Williamtown SAP area i.e. south-east of the Newcastle Airport and RAAF base. The open drains convey stormwater to either Tilligerry Creek or Fullerton Cove. These drains are located in very flat terrain with elevated groundwater tables further impacting on conveyance capacity. Overbank flooding occurs in events as frequent as the 50% AEP (1 in 2-year AEP event) in local catchment flooding conditions. Estimated drain capacity across the main drainage lines under local catchment flooding conditions is shown in Appendix A (Figure A22). Flooding in these flat reaches blurs the catchment boundaries as runoff mixes between the local drains and Tilligerry Creek. Furthermore, the flat reaches also result in significant inundation time, reaching in the order of six to eight days subject to tailwater conditions in Fullerton Cove and Port Stephens.

Drainage asset ownership is understood to be mixture of DPE (formerly known as OEH), PSC and some privately owned (Umwelt 2018). The privately owned drains have been identified by PSC as those of greatest concern. An absence of easement allocation, or inadequate easement widths, has presented a challenge for PSC with regards to maintenance responsibilities. Given the sensitive nature of drainage across this area, poor maintenance can have a significant influence on the hydraulic conveyance capacity of the drains, potentially impacting on upstream properties (Umwelt 2018).

A number of drains in the Williamtown area form part of the Hunter Valley Flood Mitigation Scheme (HVFMS). As such, these drains fall under the management of DPE and are understood to include:

- Ring drain and levee;
- Sections of Dawsons Drain;
- Fourteen foot Drain;
- Ten Foot Drain; and
- Tilligerry Creek.

Being part of the HVFMS, changes or modifications to this infrastructure falls under the Provisions of the Water Management Act 2000. This consequently requires approval of the Minister; however, with some of these assets also falling within private properties (Umwelt 2018), land owner agreement would also be required. Furthermore, subject to the magnitude of the works proposed, respective environmental assessments and approvals would be required.

A summary of the major drainage lines and alignments are presented in Table 2-11 and Figure 2-10 (as well as Appendix A) respectively.

Table 2-11 – Major drainage lines (Refer Figure 2-10)

Drain	Description
Dawsons Drain	Conveys discharge from RAAF base flowing in a south-west direction, passing under Cabbage Tree Road before discharging into the Fullerton Cove Ring Drain.
Moors Drain	Moors Drain discharges into the tidal part of Tilligerry Creek, approximately 7.3km east of the Base. The drain flows through Salt Ash under Richardson Road, Salt Ash Avenue, Hideaway Drive and Lemon Tree Passage Road.

Drain	Description
Ten Foot Drain	Aerial imagery suggests that the drain is approximately 3km long, starting to the east of Nelson Bay Road near the foot of the sand dunes and flowing in a westerly direction under Nelson Bay Road and Fullerton Cove Road until it discharges into the Fullerton Cove Ring Drain (AECOM, 2016b). Modelling indicates a drain capacity of less than the peak discharge during a 2 year ARI storm event (Umwelt, 2018).
Leary's Drain	Leary's Drain is relatively short commencing north of north of Cabbage Tree Road and discharging into Fourteen Foot Drain, approximately 1 km south of Cabbage Tree Road. It is understood that Leary's Drain provides for a low groundwater sufficient for agricultural purposes (Umwelt, 2018). A limited easement over Leary's Drain, which covers only the drain formation, extends from Fourteen Foot Drain and Cabbage Tree Road. This section is understood to be referred to as Middle Drain by PSC (Umwelt 2018).
Fourteen Foot Drain	A review of aerial imagery suggests that the drain starts southeast of the RAAF Base. Previously, the drain flowed for a distance of 5km in a southwest direction under Lavis Lane and under Nelson Bay Road, discharging into the Fullerton Cove Ring Drain. However, a new greenhouse development at 157 and 183 Cabbage Tree Road has included a diversion of Fourteen Foot Drain at approximately 3.9km along its length. This includes a diversion in a southern direction into Ten Foot Drain and has been called the Link Drain. Part of Fourteen Foot Drain has been filled in to enable the development (Umwelt, 2018). Modelling indicates a drain capacity typically between the 10% and 1% AEP storm events (Umwelt, 2018).
Fullerton Cove Ring Drain	The drain runs along the eastern side of the Fullerton Cove Ring Levee. The levee is an earth embankment that forms a barrier between the Fullerton Cove Ring Drain and Fullerton Cove. The levee was built to protect the area from both tidal inundation and moderate Hunter River floods (Umwelt, 2018).
Tilligerry Creek	The headwaters of Tilligerry Creek originate to the southeast of the RAAF Base. A review of aerial imagery suggests that the exact starting point of Tilligerry Creek depends on the wetness of the catchment, with the upper limits representing a flow path under Lavis Lane rather than a clearly defined channel. Tilligerry Creek flows for approximately 8.9km in a northeast direction through fields and under a number of access tracks, until it passes under Oakfield Road and Oakfield Drive in Salt Ash. There are a series of flood gates just upstream of Nelson Bay Road, where Tilligerry Creek transitions to more estuarine morphology before discharging into Port Stephens approximately 14km downstream. The Tilligerry Creek floodgates comprise of four hinged flap gates mounted on 1.8m diameter circular pipes (DPI 2009).
Windeyers Creek	Windeyers Creek flows directly into the Hunter River, in the north-west of the study area. The Hunter River influences the Windeyers Creek water levels due to backwater levels. When the Hunter River is in flood, the Windeyers Creek gradient can be reserved with the Hunter River filling the local Windeyers floodplain. The area of the catchment overlapping with the Williamtown SAP area is mostly seen to drain via overland sheet flow as opposed to concentrated channel flow.
Campvale Drain and Moffats Swamp	Campvale Drain is a constructed channel that flows into Grahamstown Dam. The drain itself is outside of the Williamtown SAP area in the northern end, with only a small part of the drain's catchment overlapping the study area. Adjacent to the Campvale catchment is the Moffats Swamp catchment, which drains northward with even a smaller overlap with the Williamtown SAP area.
Grahamstown Drain	Grahamstown Drain also falls out of the Williamtown SAP area to the north-west however upper reaches of its catchment fall within the project area. This area drains northward towards Grahamstown Dam.

Council have also identified that the ownership of the drains has been a constraint to management and rehabilitation works with there being inconsistency of ownership and easements from Council's perspective. As part of the Williamtown SAP there is an opportunity to resolve some of these barriers and to unify the riparian corridors and easements to ensure uniformity.

Figure 2-10 – Williamtown and Salt Ash existing drainage network including flood gates

2.8.2 Flood Gates

The area south of Newcastle Airport and the RAAF base, is a strip of low-lying area bound by the sand dunes to the south and Tilligerry Creek and Fullerton Cover to the east and west respectively. Due to this topography and location, the area would experience tidal inundation from Fullerton Cove and Tilligerry Creek. Past demand for agricultural land use across this area has seen the installation of the current drains to facilitate drainage of stormwater. Flood gates were also installed at a number of drainage outlets to Tilligerry Creek and Fullerton Cove to prevent tidal inundation. It is understood that these flood gates are mechanical and operate under hydrostatic pressure.

It is understood that the system comprises a total of 46 gates (DPE 2009) across the region, of which none fall within the Williamtown SAP boundary, based on data supplied by DPE. The capacity of the flood gates is not well documented; however, can be correlated to the capacity of the incoming drain where known. Under local catchment flood conditions, the indicative capacity of the incoming drains and consequently the key flood gates can be estimated from Figure A22 in Appendix A. The approximate locations of the flood gates within the Williamtown SAP area are presented in Figure 2-10.

2.8.3 Culverts

The key culvert structures across the Williamtown/Salt Ash and Tilligerry Creek floodplains are located along the road corridors. The culvert structures are a mixture of concrete pipes and box culverts.

Nelson Bay Road is the most significant crossing controlling floodwaters travelling from Fullerton Cove to Port Stephens. The culverts and the road embankment act as a dam, controlling flood flow and overtopping Nelson Bay Road once the capacity of the culvert is exceeded. Overtopping of Nelson Bay Road south of Cabbage Tree Road intersection (i.e. at the Fourteen Foot and Ten Foot Drain crossings) is initiated at the 0.5% AEP design event, with a peak design flood level upstream of the road of around 1.9 m AHD (BMT 2017). Key hydraulic structures along the road corridors is presented in Figure 2-11.

Figure 2-11 – Key culvert structures along the main road corridors (BMT 2012)

2.8.4 Levees

Although not technically drainage infrastructure, levees across the study area play a part in the system by preventing inundation of the floodplain from Hunter River flooding or high ocean levels. The levees also redirect local catchment flow and possibly hydraulically influence regional flooding.

Based on the existing studies of the Williamtown/Salt Ash and Tilligerry Creek catchments, it is understood that there is a levee along the perimeter of Fullerton Cove. The literature also vaguely refers to a levee at Salt Ash, likely to be in the vicinity of the Tilligerry Creek flood gate network. A request for GIS data of the levee network was made at the time of this Study however was not provided. A review of the representation of the levees and impact on the Structure Plan should be considered at the next design stage, should the information be made available.

Fullerton Cove levee

The Fullerton Cove Ring Levee was built to protect the Tomago Sandbeds area from nuisance tidal inundation and moderate Hunter River floods. The levee is part of the HVFMS (Hunter Valley Flood Mitigation Scheme) and provides protection to the Tomago and Fullerton Cove floodplains. It is understood that the levee provides flood protection for only frequent events less than the 5% AEP event (BMT 2017). The overtopping elevation of the levee is documented to be at approximately 1.33m AHD at the time of survey (BMT 2005).

The Fullerton Cove levee horizontal and vertical alignments are shown in Figure 2-10 and Figure 2-12 respectively.

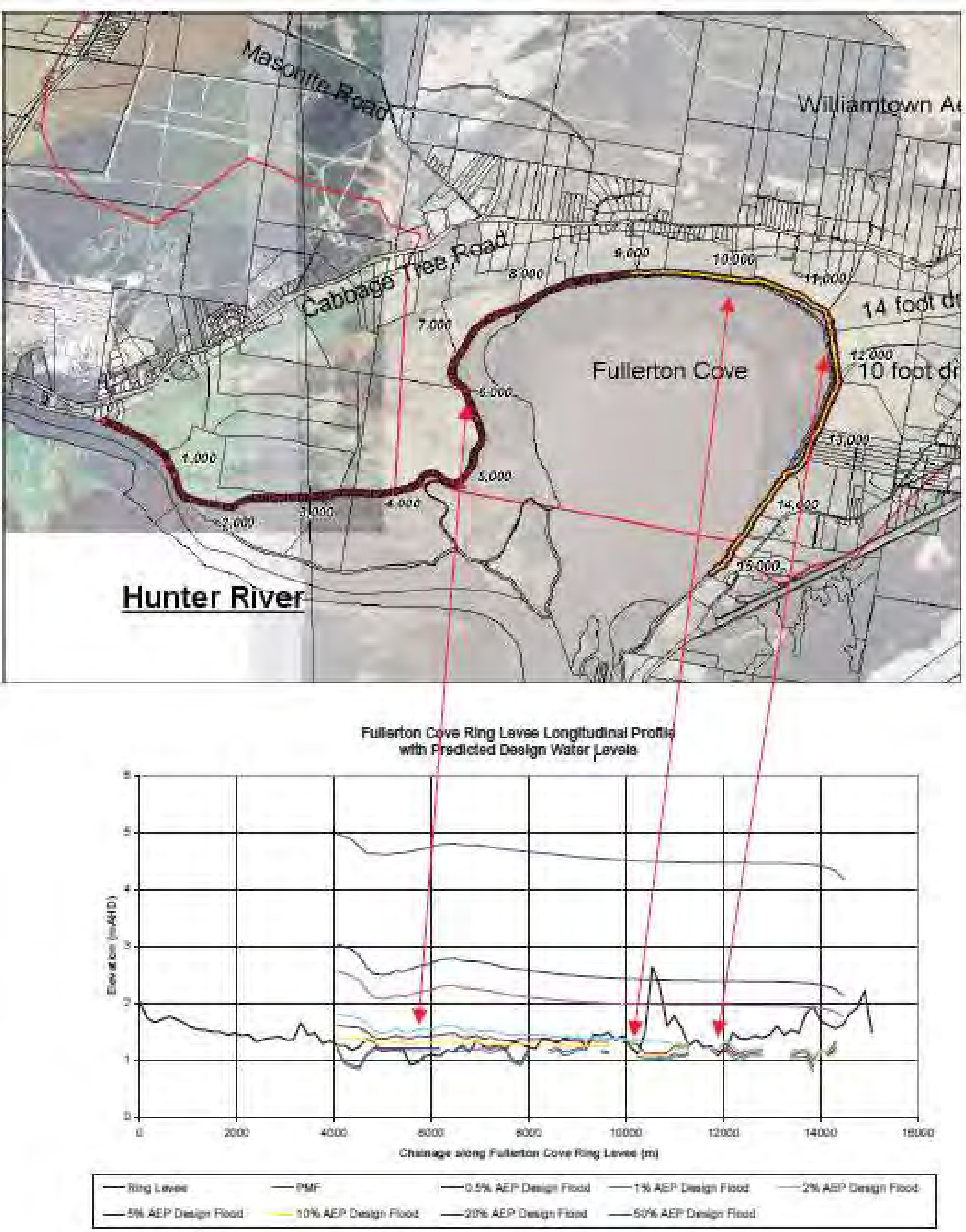


Figure 2-12 – Representation of the Fullerton Cove levee Extracted from Williamtown Salt Ash Flood Study (BMT 2005)

2.9 Lower Hunter Cumulative Development

The Lower Hunter region, of which the Williamtown SAP is a part of, is predicted to have an increase in population of 130,000 over the next 20 years (Hunter Regional Plan 2036). The increase in population will require significant development across the region. A proportion of this development would likely be across floodplain areas. To accommodate this, filling of the floodplain would be required reducing the volume of flood storage and impacting on flood conveyance areas. On an individual basis, this filling may not present a discernible change to the floodplain function however from a cumulative perspective, the impacts could compound and influence flood behaviour.

As part of the Floodplain Management Program grant scheme, Port Stephens Council, Maitland City Council and City of Newcastle Council have been awarded funding for the *Lower Hunter Floodplain Cumulative Development Impact Study and Plan*. This study will investigate the impact of current and predicted future filling of the floodplain to understand the flood risks and identify suitable fill extents, configurations and locations for future filling of the floodplain that can occur without unacceptable cumulative impacts.

The Study has been split into 3 stages:

- Stage 1 – Data collection and scoping phase
- Stage 2 – Modelling and sensitivity assessments
- Stage 3 – Recommendations for catchment wide strategies, policies, and development controls to manage the cumulative filling of the Lower Hunter floodplain

Through discussions with DPE, it is not anticipated that the findings and the modelling undertaken in Stage 2 will impact the Williamtown SAP project. The future filling to be investigated as part of the *Lower Hunter Cumulative Development Impact Study and plan* will be around Maitland and Raymond Terrace areas. The anticipated findings at this early stage is that the floodplain is not sensitive to filling, subject to the configuration. In addition, with the Williamtown SAP located some distance downstream, any downstream impacts are not anticipated to extent that far.

2.10 Water Cycle Management

2.10.1 Council Water Quality Controls

Port Stephens Council (PSC) DCP water quality targets vary depending on lot size and whether the lot is located within the Drinking Water Catchment (refer Figure A6 in Appendix A).

The DCP water quality targets are stated in Table 2-12. Council's 'water quality stripping targets' otherwise known as pollutant load reduction targets are provided in **Table 2-13**. A summary of the Neutral or Beneficial Effect (NorBE) criteria for the Drinking Water Catchment and how it relates to stormwater management is provided in section 2.10.2.

Table 2-12 – Council Water Quality Targets

Type of development or site area	Water Quality Targets	
	Development within a Drinking Water Catchment	*Development outside a Drinking Water Catchment*
Lots with a site area equal to or greater than 2500 m^2	Before water is released into public drainage, the water quality outcomes shall achieve: ▪ NorBE; or ▪ Councils water quality stripping targets Whichever achieves the better water quality outcomes	Before water is released into public drainage it must achieve Council's water quality stripping targets

PSC also sets water quality stripping targets for releases to sensitive catchments within their Water Sensitive Development Strategy Guidelines (BMT, 2011). These are more stringent than the PSC DCP targets for TN and TP, but less stringent than the DCP target for TSS and equivalent for Gross Pollutants, refer Table 2-13.

Given all areas outside the Drinking Water Catchment drain to sensitive aquatic environments (refer Figure A6 in Appendix A) it is recommended that as a minimum:

- TN, TP and Gross Pollutant targets for sensitive catchments are to be adopted from BMT (2011)
- the more stringent PSC DCP 2014 TSS target is adopted for sensitive catchments

Table 2-13 – Pollutant load reduction targets

Pollutant	Mean annual pollutant load reduction target			
	Drinking Water catchment Target	PSC DCP Target	BMT (2011) Target	PSC Sensitive Catchment Target
Total nitrogen	NorBE	45%	50%	50%
Total phosphorus	NorBE	60%	65%	65%
Total suspended solids	NorBE	90%	85%	90%
Gross pollutants	NorBE	90%	90%	90%

2.10.2 NorBE Criteria and Modelling Requirements

The Port Stephens council DCP stipulates that development over a certain site area within the Drinking Water Catchment achieves a Neutral or Beneficial Effect (NorBE) on water quality (refer Table 2-12). Water NSW defines NorBE is satisfied if new development:

- Has no identifiable potential impact on water quality, or
- Will contain any water quality impact on the development site and prevent it from reaching any watercourse, waterbody or drainage depression on the site, or
- Will transfer any water quality impact outside the site where it is treated and disposed of to standards approved by the consent authority

Port Stephens council require MUSIC modelling to be undertaken to demonstrate a NorBE has been achieved.

Water NSW has produced a standard on how to demonstrate NorBE by MUSIC modelling in their "Using MUSIC in Sydney Drinking Water Catchment" standard (Water NSW, 2019). In the absence of a known equivalent guideline for Port Stephens, the modelling approach outlined in this guideline is considered to be appropriate for use in the study area. Modelling inputs would be adjusted to suit the local conditions.

Water NSW (2019) states that to ensure a development and its treatment systems achieve NorBE, it must meet the following criteria by comparing before and after development pollutant loads and concentrations generated in MUSIC:

- Mean annual pollutant loads and hydrologic characteristics must be modelled for the existing site considering the soil types and land uses on the site
- The mean annual pollutant loads for the post-development case (including mitigation measures) should aim for 10% less than the pre-development case for total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN). For gross pollutants, the post development load only needs to be equal or less than pre-development load.
- Pollutant concentrations for TP and TN for the post-development case (including mitigation measures) must be equal to or better compared to the pre-development case for between the 50th and 98th percentiles over the five year modelling period when runoff occurs. Periods of zero flow are not accounted for in the statistical analysis as there is no downstream water quality impact. To demonstrate this, comparative cumulative frequency graphs, which use the Flow-Based Sub-Sample

Threshold for both the pre and post development cases must be provided. As meeting the pollutant percentile concentrations for TP generally also meets the requirements for TSS, cumulative frequency analysis is not required for TSS. Cumulative frequency is also not applied to gross pollutants.

Given the Drinking Water Catchment in the study area is associated with groundwater which may or may not interact with surface water resource, the following preliminary assumptions are proposed where a NorBE criteria applies (subject to location specific constraints):

- Post development MUSIC baseflow (groundwater) mean annual pollutant load to be 10% less than the pre-development MUSIC baseflow mean annual pollutant load
- Post development MUSIC stormflow (surface runoff) mean annual pollutant load to be 10% less than the pre-development MUSIC stormflow mean annual pollutant load
- Pollutant concentrations in both baseflow and stormflow to be as per Water NSW (2019) requirements for each resource.
  - The following sections describe how MUSIC modelling has been applied to demonstrate that the proposed water cycle management strategy achieves the water quality objectives for the various receiving waters.

2.10.3 Risk-Based Water Quality Criteria

Given the high ecological value of the downstream Ramsar wetlands the it is appropriate to adopt pollution stripping targets using the NSW Government's policy on establishing stormwater quality targets for sensitive receptors; ***Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions***. This framework could not be fully applied within the time constraints on the masterplan process. In adopting a risk-based approach, it is appropriate to apply the highest level of stormwater pollution stripping that can be achieved without overly burdening the Precinct's urban design outcomes, stormwater infrastructure land take or bulk earthworks / fill levels across Precinct required to drive stormwater through the treatment devices.

It is therefore considered appropriate to adopt PSC's Sensitive Catchment water quality criteria as a minimum and achieve stormwater pollution stripping that result in no change in pollutant loads or concentrations to the downstream Ramsar wetlands as a result of the proposed change in land use from rural-residential to industrial.

- This is considered to be -risk the approvals process and allow for future optimising-down the level of protection following completion of a Risk-based Framework process in fullor during detailed design.

Table 2-14 – Adopted water quality targets

Water Quality Targets	
Minimum performance criteria	Ideal performance criteria to minimise risk of impact on receiving waters
Adopted Council sensitive catchment water quality stripping targets[1]: ▪ 50% reduction in TN ▪ 65% reduction in TP ▪ 90% reduction in TSS ▪ 90%reduction in gross pollutants	No change in pollutant loads when compared with rural residential land use No change in pollutant concentrations by demonstrating the following: ▪ Mean annual pollutant loads for the post-development case match the pre-development case for total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN). TP and TN concentrations for the post-development case (including mitigation measures) must be equal to or better compared to the pre-development case for between the 50th and 98th percentiles over the five-year modelling period when runoff occurs

[1]TN, TP and Gross Pollutant targets for sensitive3.3.5 catchments are adopted from BMT (2011). The more stringent PSC DCP 2014 TSS target is adopted for TSS.

2.10.4 Imperviousness of Williamtown SAP

With consideration to the high permeability within existing sandy soil areas (refer Figure 2-2) and controls in place to protect the local Drinking Water Catchment (refer section 2.10.2), reducing the maximum impervious surface area allowable on lots as a planning control could potentially play a key role in managing Williamtown SAP impacts to waterways and groundwater as well as providing urban greening and cooling benefits to the community.

The current Port Stephens council DCP requirements for impervious surfaces on lots are listed in **Table 2-15**.

Table 2-15 – Council maximum impervious surfaces

Land-Use Zone	Maximum Impervious Area (% of Lot)
E4, R5, RU1, RU2, & RU3	Refer Table 2-16 below
E1, E2, E3, IN4, RE1, RE2, SP1, SP2, W1 & W2	Merit based approach
R1, R2 & RU5	60
R3	75
B5, B7. IN1 & IN2	90
B1, B2, B3 & B4	100

Table 2-16 – Council lot area impervious surfaces (specified land use only, refer Table above)

Land-Use Zone	Maximum Impervious Area (% of Lot)
>5000	7.5
2000 to 5000	30
900 to 2000	40

<900	60

2.10.5 Typical Water Quality Treatment Train

Council's standard and sensitive catchment water quality stripping targets (refer section 2.9.4 are readily achieved by way of typical WSUD treatment trains. Examples of typical treatment trains are listed in Table 2-17.

The local constraints which may prohibit the implementation of these typical treatments in some (or all) portions of the study area are discussed in section 3. Alternative measures to respond to these constraints while achieving the adopted pollution stripping targets are outlined in section 3.5.2.

Table 2-17 – Examples of typical water quality treatments for different development zones

Development type	On lot / at source treatments	End of pipe – primary treatments	End of pipe – secondary / tertiary treatments
Residential development	Rainwater harvesting Rain gardens (biofiltration) Proprietary filtration devices Pit inserts (litter traps)	Gross pollutant traps Swales	Bioretention basins Infiltration systems Constructed wetlands[1]
Roads and public areas	Street trees (biofiltration) Rain gardens (biofiltration) Swales Pit inserts (litter traps)		
Commercial and Industrial development	Rainwater harvesting Rain gardens (biofiltration) Gross pollutant traps Proprietary filtration devices		

[1] Constructed wetlands are not appropriate within 3km bird strike zone and not appropriate between 3 to 8 km bird strike zone without mitigation. Refer section 3.3.5.

2.10.6 MUSIC Modelling

As part of the baseline analysis for the study area, MUSIC modelling was undertaken to:

- understand the runoff and infiltration regime for different rainfall zone, soil type and existing surface types
- understand how different zones of the study area may be impacted by Williamtown SAP
- understand the implications of the water quality targets on land take and how different areas may be more preferable for Williamtown SAP
- formulate strategies for managing stormwater pollutants to achieve water quality objectives.

MUSIC Modelling was conducted in accordance with the BMT (2011). Modelling inputs and assumptions as per BMT (2011) and the NSW MUSIC modelling guidelines (BMT 2015) were adopted as described in **Table 2-18**. Rainfall data assumptions for MUSIC modelling are recommended in BMT (2011) and included in **Table 2-19**. The rainfall zones are shown in Figure A25, Appendix A. A breakdown of the land zone footprints within the study area and respective MUSIC node assumptions as per BMT (2015) is provided in Appendix A.

Table 2-18 – MUSIC Modelling inputs and assumptions

Model Assumption	Input / Assumption
Climate	Zone B in western portion of study area and Zone C in eastern portion of study area as per Port Stephens Council Water Sensitive Development Strategy Guidelines (BMT 2011). Refer Figure A25, Appendix A and **Table 2-16**
Soil type	Clay or Sand based on Port Stephens Council Hydrological Soils mapping of existing soils
Rainfall runoff parameters	As per BMT (2011)
Pollutant parameters	As per NSW MUSIC Modelling Guidelines (BMT WBM, 2015
Surface Type	As per BMT (2015)
Effective impervious area	As per BMT (2015)

Table 2-19 – MUSIC rainfall data

Rainfall Zone	Dataset	Duration	Scaling Factor	Mean Annual Rainfall (mm)
Zone B	Williamtown RAAF rainfall data	1998 to 2007	1.0	1125
Zone C	Williamtown RAAF rainfall data	1998 to 2007	1.1	1238

Table 2-20 – Existing Land Use MUSIC Assumptions

Land Zone	Footprint (ha)	Adopted MUSIC node for runoff quality parameters
B1	1.9	Business
B7	89.8	Industrial
E1	4335.1	Forest
E2	33.6	Forest
E3	69.7	Rural
RE1	2.2	Residential
RU2	4083.3	Agricultural
SP1	1362.0	Industrial
SP2	1316.9	Industrial
W2	48.9	Business

Due to being the predominant existing land zones within the study area (refer Figure 2-2), an assessment was undertaken for:

- Rural Landscape (RU2)
- National Parks and Nature Reserves (E1)

To understand the potential changes in stormwater pollutant loads resulting from the Williamtown SAP, the results were compared with an example IN2 light industrial development.

Modelling was undertaken for each of the rainfall zones relevant to the study area as per BMT (2011). Rainfall Zone C has 10% more rainfall than Rainfall Zone B. Modelling was conducted for 1 ha catchments to compare the impact of the Williamtown SAP on a like for like basis to inform the Williamtown SAP constraints analysis. Other key assumptions for the modelling are provided in Appendix B.

Figure 2-13 shows the relative contributions of baseflow and stormflow volumes and pollutant load for the sandy and clay soils within Zone B. Full results are provided in Appendix B.

The results indicate that:

- it would be significantly more challenging to achieve NorBE requirements within existing bushland and uncleared land (e.g. E1 land zoning) due to less runoff and pollutant load being generated during pre-development, existing conditions
- achieving NorBE requirements in existing rural / agricultural areas will be significantly more challenging where sandy soils occur than in the clay soil areas
- pollutant load infiltrating to groundwater will typically decrease as a result of the increase in impervious surface through the Williamtown SAP so there is opportunity to infiltrate some additional runoff from the Williamtown SAP without impacting the underlying groundwater resource

NorBE analysis

Modelling was carried out to understand how much pollutant stripping would be required to achieve NorBE targets where typical rural lands are converted to industrial lands. The results are provided in Table 2-21 and indicate that:

- where development occurs within sandy soils within the Drinking Water Catchment rainwater and stormwater harvesting and reuse strategies in addition to typical treatment trains are likely to be required.
- NorBE requirements for clay soils are less stringent than the adopted pollutant load reduction targets for sensitive catchments (refer Table 2-13). As such, the adopted sensitive catchment targets would take precedent. In any case, there are expected to be limited clay soil areas within the Drinking Water Catchment
- It is noted that an equivalent development on bushland (e.g. E1 land use) would require 98% (TSS), 97% (TP) and 96% (TN) pollutant load reduction from stormwater flows to achieve the NorBE targets. This is considered to be a significant constraint to the Williamtown SAP and has been accounted for in recommendations on developable areas.

Further discussion on the implications of the NorBE targets are provided in section 3.3.4.

Table 2-21 – Indicative NorBE requirements

Pollutant	NorBE pollutant load reduction required for example Industrial land use[1]			
	Stormflow – Sand	Baseflow – Sand	Stormflow – Clay	Baseflow – Clay
TSS	92%	0%	72%	0%
TP	80%	0%	31%	0%
TN	86%	0%	55%	0%

[1] Based on an Industrial development with an effective impervious area of 70% on existing rural (RU2) land use

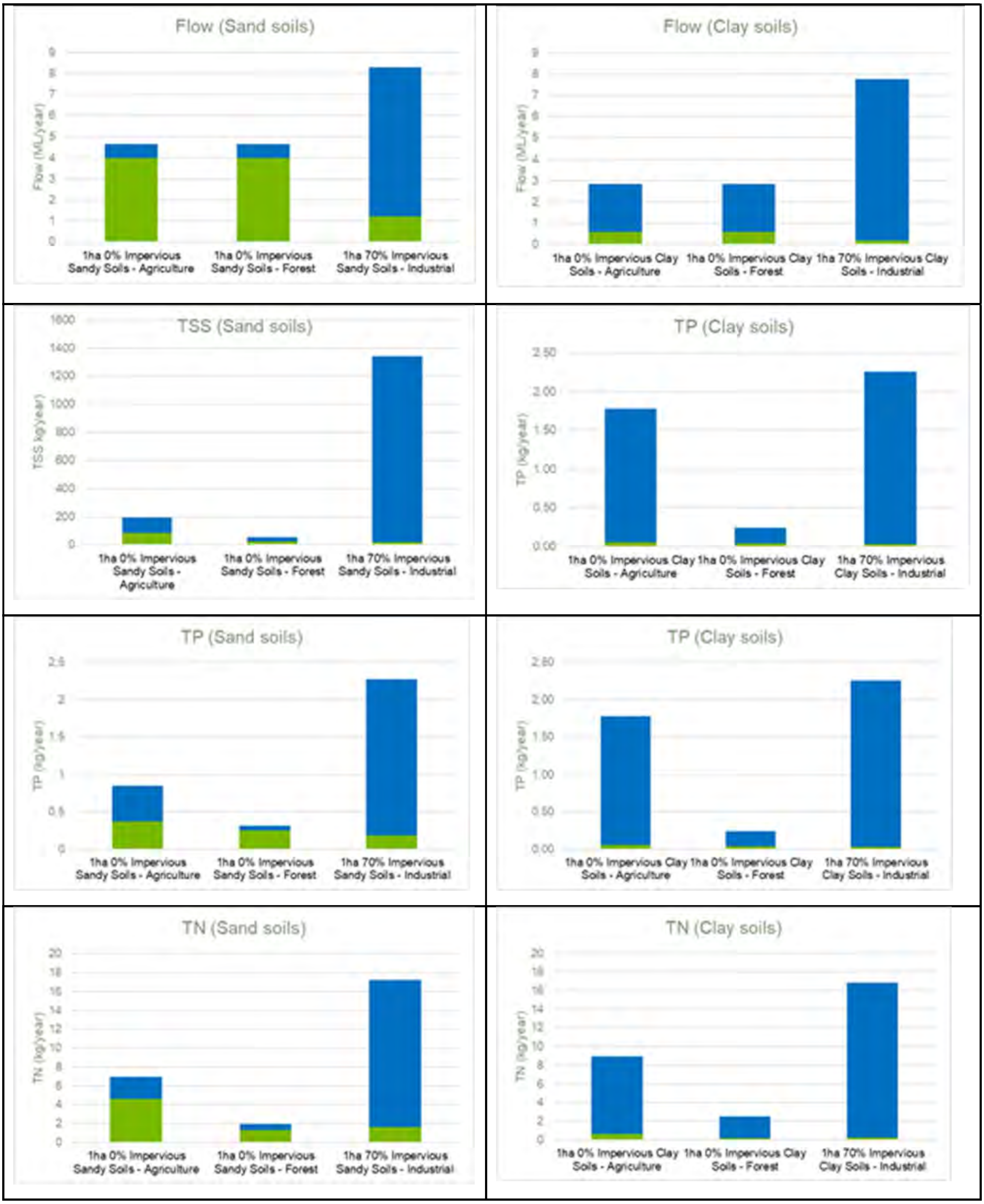


Figure 2-13 – Flow and pollutant comparison for varying soil and land use

MUSIC modelling during Scenario Analysis

Once the Williamtown SAP location was identified, a site-specific baseline (pre-development) modelling exercise for the area and its local catchment was undertaken to confirm targets for the water cycle management strategy. Modelling assumptions listed above were cross checked with locally relevant hydrogeological and water quality data.

A post development MUSIC model was then prepared to test various strategies against the objectives and identify a preferred water cycle management / water quality treatment strategy for the Williamtown SAP. This assessment considered how pollutant load generation varies on different development surfaces (refer **Figure 2-14**) and where feasible apply appropriate source controls (e.g. harvest and reuse Roof water to capture nitrogen instead of relying on filtration) to maximise the cost effectiveness of the proposed strategy.

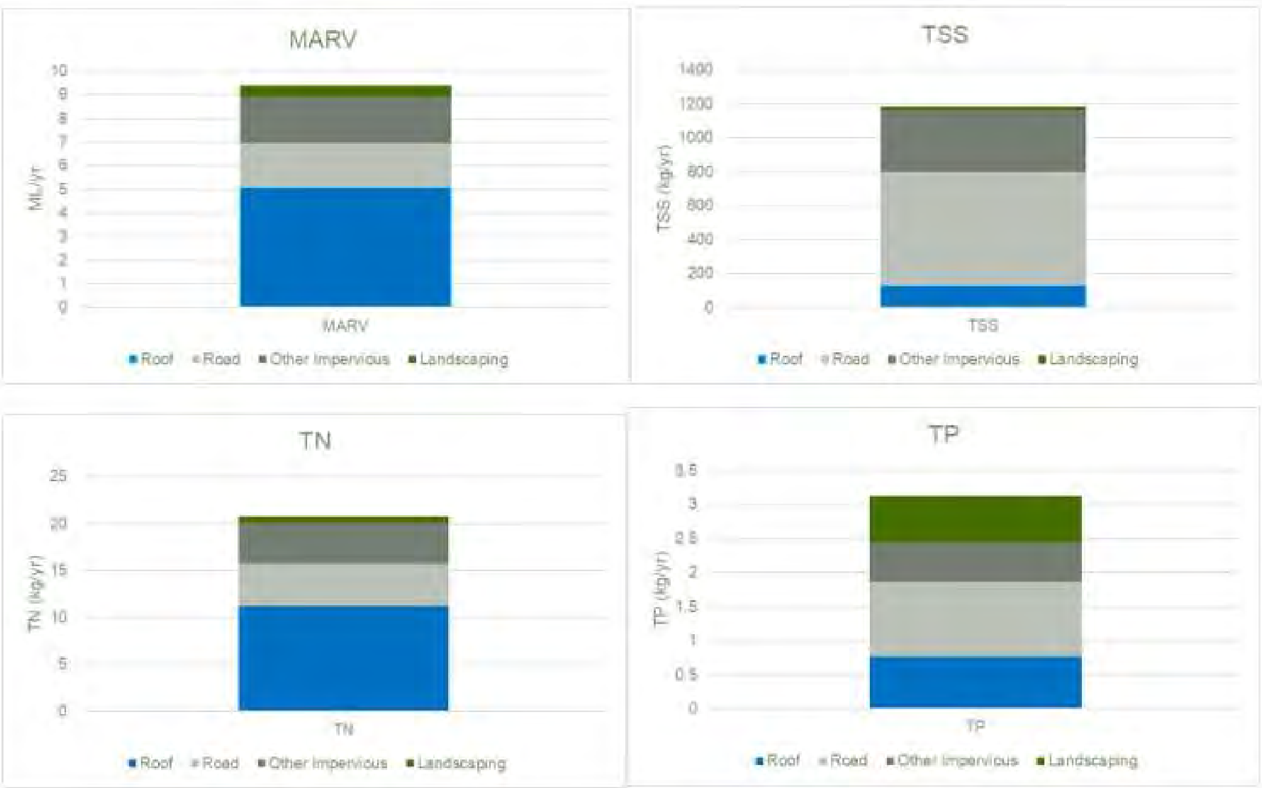


Figure 2-14 – Relative flow and pollutant generation on difference surfaces on industrial lot

2.11 Climate Change

A review of climate change considerations across the keys studies has been undertaken to investigate the followings:

- Applicable policies/guidelines for estimation of the climate change parameters for this current study
- Investigate the climate change assessment undertaken for the previous studies
- Provide a brief outcome of the investigation
- The Implications of the climate change for this current study

2.11.1 Frameworks, Policies and Guidelines

Australian Rainfall and Runoff (ARR) 2019 guidelines provides interim climate change parameters. These parameters are considered the latest available predictions on the future climate conditions. ARR 2019 predicts a worst case increase in rainfall intensity of 9% and 19.7% per cent for the years 2050 and 2090 respectively.

The following documents were reviewed to investigate the sea level rise as a result of the climate change:

- The East Coast Cluster Report – Climate Change Projections for Australian Natural resources Management Regions (Dowdy et al, 2015); and
- NSW Sea Level Rise Policy Statement (Department of Environment, Climate Change and Water NSW (DECCW),2009)

Based on the outcome of the investigation, adoption of sea level rises of 0.4m and 0.9m are recommended for the years 2050 and 2100 for assessment of the climate change.

The previous flood studies have also been reviewed to form an understanding of their methodology, parameters, and assumptions.

2.11.2 Effects of Climate Change on Flooding

PSC's DCP and PSC's Floodplain Risk management Policy define the **Flood Planning Level (FPL)** as follows:

Flood Planning level (FPL) *is the level of the 1% AEP flood event in the year 2100 plus 0.5m of freeboard, except for overland flooding areas where a freeboard of 0.3m is applied.*

Therefore, it is critical to have an accurate estimation of the climate change effects projected for the year 2100 to allow determination of the FPL.

2.11.3 Effects of Climate Change on Drainage

The impacts of sea level rise on groundwater levels are unknown at this time, however it is acknowledged that there is a high risk of salt water intrusion beyond the Fullerton Cove levee and Stockton dunes that would need to be actively managed to prevent permanently elevated groundwater from impacting the study area.

Therefore, it is critical to have a flexible drainage approach that can accommodate 2100 tidal levels by either having freeboard above future tide levels or provide opportunities for actively managing tidal ingress behind the Fullerton Cove levee (eg. pumping).

2.11.4 Climate Change Investigation Summary

Williamtown-Salt Ash Floodplain Risk Management Study (BMT, 2017) is identified to be more relevant to the current study compared to the Williamtown Salt Ash Flood Study (2012) as it is more recent and that it has been specifically prepared for flood risk management purpose.

A comparison between Williamtown-Salt Ash Floodplain Risk Management Study (BMT, 2017) and Anna Bay and Tilligerry Creek Flood Study 2017 (which cover the proposed study area combined) have generally adopted similar methodologies and parameters for assessing the effects of the climate change in the flooding regime of the study area. A summary of the comparison is outlined below.

- Years 2050 and 2100 are considered in both studies
- Both studies consider a projected sea level rise of 0.4m and 0.9m for the years 2050 and 2100 respectively
- Both studies adopted increased rainfall intensity of 20% for the year 2050
- Williamtown-Salt Ash Floodplain Risk Management Study (BMT, 2017) adopts an increased rainfall intensity of 20% for the Year 2100 whereas the Anna Bay and Tilligerry Creek Flood Study 2017 adopts an increased rainfall intensity of 30% for the year 2100
- Overall, the climate change assessment for both studies are reasonable consistent.

Based on the above, it can be concluded that the sea level rise values adopted in the previous studies is compliant with the requirements of the latest applicable guidance and policies.

Refer to **Table 2-22** for a summary of the climate change parameters adopted in the previous studies and recommended in the applicable references.

Table 2-22 – Comparison of adopted Climate Change Parameters Between Different References

Reference Document	Years Projected	Sea Level Rise	Rainfall Intensity
Applicable Guidelines/Policies	▪ 2050 ▪ 2090 and 2100	▪ 0.4m ▪ 0.9m (for the Year 2100)	▪ 9% ▪ 19.7% (for the year 2090)
Williamtown Salt Ash Flood Study (2012)	▪ 2050 ▪ 2100	▪ 0.4m ▪ 0.9m	▪ 10% and 30% ▪ 10% and 30%
Williamtown-Salt Ash Floodplain Risk Management Study (BMT, 2017)	▪ 2050 ▪ 2100	▪ 0.4m ▪ 0.9m	▪ 20% ▪ 20%
Anna Bay and Tilligerry Creek Flood Study (Jacobs 2017)	▪ 2050 ▪ 2100	▪ 0.4m ▪ 0.9m	▪ 10% and 20% ▪ 20% and 30%

3 Baseline Constraints

3.1 Flooding and Drainage Constraints

The baseline study has identified several constraints that impact on the Williamtown SAP either directly or indirectly. These constraints have been summarised and presented in **Table 3-1** in order of criticality. It is critical to note that the constraints and suggested management approaches are indicative and requires modelling to confirm and demonstrate the effectiveness of any measures. This is due to the complexity of the flooding across the area.

Table 3-1 – Summary of identified constraints and potential management for consideration in the Williamtown SAP.

Identified Constraint	Description	Consideration/Potential Management Approach
Flood prone areas	Considered to be the most significant constraint for the flooding and drainage discipline. Approximately 70% of the Investigation area is currently defined as flood prone based on Council's flood hazard and hydraulic categorisation mapping. This presents a significant constraint to the Williamtown SAP and requires careful consideration in terms of management. Further discussion of this constraint is presented in the following section.	The flood prone areas are a notable constraint however there is opportunity to manage flooding in a way to either provide benefit to the Williamtown SAP or that limits impact on surrounding properties. Some potential management measures are presented below with more specific opportunities discussed in Section5.4.3. Offsetting loss of flood storage through compensatory flood storage in low value land areas. Formalising the flood ways to allow for further encroachment of the Williamtown SAP into the flood prone area ie. Balancing demand for the floodplain with demand for the Williamtown SAP. Increase existing drainage capacity to reduce flood levels and increase developable land.
Drainage capacity	The existing drainage across the Study area is mainly open channels and culverts. Existing studies have identified that these structures have limited capacity and already not meeting current design standards for major trunk drainage. Further burden on the existing drainage system would be unacceptable and likely impact upstream and/or downstream development.	All proposed drainage infrastructure should consider the most appropriate design capacity and associated impact on upstream and downstream flood levels. Provision of flood detention (distributed or centralised) to limit increased burden on existing drainage infrastructure. Allow for dedicated flood ways with sufficient capacity for local catchment flooding. This would look to either compliment or replace the existing drainage lines. Upgrading of any key existing drainage infrastructure to meet a more desirable design capacity and associated asset flood immunity.

Identified Constraint	Description	Consideration/Potential Management Approach
Flood inundation duration	Flood inundation duration is a major constraint that it is controlled by natural process i.e. tide levels and terrain slope. Current inundation durations are in the order of days depending on the flood mechanism. The tidal processes limit and/or prevent the discharge of local catchment flooding when tide levels are high. Compounding this is the shallow terrain gradient that limits rate which flood water leaves the catchment.	the Williamtown SAP would need to assess the impact on inundation duration and where impacts occur, options such as more efficient drainage would limit the impact. An option to improve the efficiency of the main drains (e.g. smooth drain lining) may offset the shallow gradients. However, a balance against environmental values of and aesthetics would need to be considered. This constraint should also be considered where the Williamtown SAP encroaches into flood prone land. It may impact on access to the respective areas and therefore influence the types of development that the area attracts. Management of this constraint would be through the Master Planning process, which would consider accessibility.
Climate change	This constraint incorporates all aspects of climate change (i.e. sea level rise and increased rainfall intensity). PSC have incorporated future climate flood conditions to the year 2100 (i.e. incorporation of sea level rise and increased rainfall intensity) into its flood planning.	To align with PSC's flood planning conditions, the Williamtown SAP should also be designed to incorporate climate change for flood management. This constraint would be managed through modelling, which would investigate the flood risk and assess flood management options.
Asset ownership	Not all drainage infrastructure has clear easements and /or suitable easements. The ones that are of concern are those that fall within the ownership of private landholders or have insufficient easement width to allow for sufficient and safe access.	Where the Williamtown SAP proposes to modify or replace existing drainage, allowance of suitable easements must be incorporated to allow for clear ownership and maintenance accessibility.
Existing drainage system infrastructure	This extends to all aspects of the existing drainage system (drains, culverts flood gates, levees etc). The existing drainage infrastructure provides a level of service with regards to flood management and protection. Where the Williamtown SAP impacts on existing infrastructure (e.g. new roads, development fill etc.) it has the potential to impact on the current level of service.	The Williamtown SAP should consider the impact on the existing drainage performance and look to either maintain or improve the performance. This can be achieved through hydraulic modelling of the Williamtown SAP and assessing the impact. Once the impact is understood, appropriate mitigation can be proposed. This mitigation would potentially include: Avoidance of impacts to existing drainage infrastructure. Upgrading of existing drainage infrastructure to compensate for any impacts on capacity and performance. Realignment of drains and culverts to provide the same (or better) level of service whilst accommodating for the Williamtown SAP. Provision of additional drainage culverts to offset any flow constrictions caused by the Williamtown SAP. Provision of flood detention and/storage to offset any impacts on existing flood behaviour.

Identified Constraint	Description	Consideration/Potential Management Approach
Emergency evacuation	Given the flood prone nature of the Study area, safe evacuation routes should be allowed for where possible to limit the instance of trapped areas of the Williamtown SAP. This is of particular importance given the long inundation durations.	Safe flood free evacuation routes should be allowed for in the Williamtown SAP. No specific management measures can be put in place to overcome this constraint. Appropriate planning through flood modelling of potential routes will inform the proposed road network corridors.
Detention	Any potential development in the study area is anticipated to result in increased fraction impervious, increased peak discharges from the site and therefore increased discharges into the waterways.	Design and construction of the detention basins may be required to attenuate the post development discharges to the pre-development rates. This will require additional lands to be taken up from the total available footprint which is considered a constraint on the Williamtown SAP. However, combined design of the detention basins and stormwater quality systems or construction of the detention basins within undevelopable lands may be considered to address this constraint.
Concurrent studies	It is understood that the lower Hunter Valley Councils (Maitland, Newcastle and Port Stephens) have obtained funding for the *Lower Hunter Floodplain Cumulative Development Impact Study and Plan* which investigates the impact of cumulative development (both recent existing and future development) across the lower Hunter River floodplain.	The Williamtown SAP project is currently in progress. The management approach for this constraint would be to obtain any reporting as soon as it can be made available. Review the findings and feed any further constraints back into this project as required and/or practical. If the information is not made available in time then, document accordingly for future projects to be aware.
Draining groundwater reserves	Potential for shallow groundwater to enter subsurface drainage systems. This could potentially impact the local groundwater regime and groundwater resources, particularly where drainage systems if located within the drinking water catchment.	Management measures would be site / application specific. The water cycle management plan will incorporate strategies to minimise impacts to the groundwater regime, in particular where impacts to groundwater resources within the drinking water catchment could potentially occur.

3.1.1 Flood Prone Areas

As noted in **Table 3-1**, flood prone areas (i.e. areas at risk of flooding) are considered a primary constraint to the Williamtown SAP. Based on the regional Hunter River catchment flooding mechanism (refer Section 2.4) in combination with corresponding degrees of tidal inundation and local flooding, approximately 70% of the Study area is currently at risk of flooding. Appendix A (Figure A24) shows the current extent of flood prone land across the precinct under various flood events. The flood risk is extensive and would impact on the developability of the area.

Developing within flood prone land is possible subject to the level of flood risk and specified land use of the area. This would need to be in accordance with current floodplain development practices (ie. NSW Floodplain Development Manual (2005)) and consistency with PSC development controls.

From an engineering perspective, bulk filling is typically an approach to prevent the land from flooding and provide flood protection for the development. This however has the potential to impact on flood behaviour resulting in increases in flood levels to nearby private properties. This occurs as a result of the bulk fill displacing or redirecting flood water, worsening the flooding to areas that are currently flooded. It could also result in flooding areas that may not have previously been flood prone. This result would not be acceptable therefore requiring flood management and/or mitigation measures to be implemented and demonstrated to be effective prior to development consent.

3.2 Other Physical and Environmental Constraints

3.2.1 Soils and Groundwater

The soil permeability is likely to be high in the sandy portions of the study area (Tomago Sandbeds) and with lower permeability in the lower lying floodplain areas in the south of the study area. Whilst permeability is high in the sandy soils, shallow groundwater may also act as an infiltration constraint.

Providing stormwater management to protect the Tomago Sandbed Drinking Water Catchment will be a critical component of the water cycle management strategy. Filtration of stormwater prior to discharge is unlikely to be a cost effective means of achieving NorBE criteria (refer section 3.3.4), and rainwater and stormwater harvesting strategies are likely to be required should development be proposed within the Drinking Water Catchment.

Hunter Water have also expressed a need for:

- recharge volumes to the Tomago Sandbed resource to be maintained
- avoidance of increased drainage of the groundwater resource
- management of potential groundwater mounding due to reduced evapotranspiration and increased imperviousness.

The approach to managing these constraints will need to be carefully considered within the Water Cycle Management strategy to minimise impacts to the groundwater regime and groundwater resource.

Groundwater levels and groundwater quality are described within the Hydrogeology Report.

3.2.2 Existing Contamination

There is potential for groundwater and surfaces waters within the study area to be contaminated with PFAS. The stormwater strategy will need to manage the risk of potential interactions which may result in stormwater contamination which could impact downstream sensitive environments.

3.2.3 Flow Volumes and Frequency

There are a number of waterways within the study area that are constructed drainage channels. Changes in the frequency and volume of runoff as a result of the Williamtown SAP is unlikely to have a significant detrimental impact on these constructed channels but some waterlogging, slumping and erosion could occur.

The capacity of those channels may be limited and additional stormwater runoff volumes from the Williamtown SAP may impact on the frequency and duration of nuisance flooding due to more frequent overbank flooding.

Changes in frequent flow hydrology to coastal wetlands around Fullerton Cove are unlikely to result in significant impacts as water levels are governed by tidal fluctuations in these coastal systems.

3.2.4 Sensitive Environments

Sensitive aquatic environments are identified in Sections 2.3.4 to 2.3.10. All areas of the study area either ultimately drain to one of these sensitive aquatic environments or are situated within the Drinking Water Catchment. The Williamtown SAP Structure Plan Boundary drains to the sensitive wetlands of Fullerton Cove and is partially located within the Drinking Water Catchment.

Pollutants within stormwater runoff or where runoff generated on the Williamtown SAP is infiltrated to groundwater could potentially result in impacts to the sensitive aquatic environments. As described in section 2.10.1, as a minimum the more stringent of the PSC DCP and the PSC Water Sensitive Development

Strategy Guidelines (BMT, 2011) targets for sensitive catchments should be adopted for areas outside the Drinking Water Catchment which drain to sensitive aquatic environments.

All the identified sensitive wetland systems are coastal or groundwater dependant wetlands, with their wetting and drying regime likely to be primarily dominated by tidal and groundwater influences rather than surface runoff. Therefore, increases in runoff volume as a result of the Williamtown SAP are unlikely to significantly impact the coastal and groundwater dependant wetlands, however this impact would need to be further considered during the next stage.

Discussions with Hunter Water indicate that recharge to the Tomago sandbeds should not be reduced as result of the Williamtown SAP. This will require the water cycle management strategy to ensure at least as much rainfall volume is infiltrated post development without impacting groundwater quality.

3.3 Planning Constraints for Future Development

3.3.1 Council Onsite Detention Requirements

The PSC DCP states that on-site detention / on-site infiltration is required where:

- The post development flow rate or volume exceeds the pre-development flow rate or volume; or
- Impervious surfaces exceed the total percentage of site area listed under Figure BD; or
- It is identified under section D Specific Areas of the PSDCP 2014; or
- The stormwater catchment is identified to have stormwater issues

On-site detention / on-site infiltration is to be:

- Sized so that the post-development flow rate and volume equals the pre-development flow rate and volume for all storm events up to and including the 1% annual exceedance probability (AEP) storm event
- Provided by either underground chambers, surface storage or a combination of the two and are generally positioned:
  - Under grassed areas for any cellular system (which can be easily maintained)
  - Under hardstand areas such as driveways for any concrete tank structures
- A Neutral or Beneficial Effect (NorBE) on water quality must be designed for all storm events

Umwelt (2018) states that detention storage is used in a number of developments within the area to reduce peak flows into the drainage system. This includes the Williamtown Aerospace Centre (WAC) located south of the airport. The WAC includes a large detention basin in low lying area within the south-east corner of the site which attenuates stormwater into Nelson Bay Road table drain at a peak rate and duration designed to match previous discharge from the site (Umwelt, 2018).

Umwelt (2014) notes that if not carefully managed, continued development within the Newcastle Airport may place further pressure on the Nelson Bay Road table drain conveyance capacity.

3.3.2 Drainage Infrastructure

As discussed in Table 3-1, ownership of the drainage network is fragmented across PSC, private landowners and DPE. This current arrangement presents a constraint in the following ways:

- Access – multiple owners of the drainage infrastructure will need to be consulted to request access. Appropriate access agreements would need to be developed and presented to the landowners.
- Approvals – All owners will require approvals on an individual basis. Furthermore, with part ownership being with DPE, State level approvals process would be required and trigger the need for a Review of Environmental Factors (REF) or Environmental Impact Statements (EIS)

3.3.3 Council's Flood Planning Level and Hazard Mapping

The typical definition of the flood planning level for Councils in NSW is the 1% AEP plus 0.5m. This would form the basis for design level for the Williamtown SAP. However, PSC have adopted another approach and incorporated future climate (year 2100) changes into its flood planning level ie. 1% AEP plus climate change predictions for the year 2100 plus 0.5m freeboard. The climate change component incorporates a 20% increase in rainfall intensity and 0.9m increase in sea level rise on top of the current 1% AEP design scenario. This would then result in higher design levels that the Williamtown SAP would need to achieve and potentially increase the sensitivity that the Williamtown SAP would have on flood levels. In contrast, it does provide the Williamtown SAP with greater resilience to flood risk into the future.

It is understood that as part of this DCP amendment, the currently defined flood hazard (refer Figure A21, Appendix A) will also be updated and therefore has the potential to present future constraints on the master planning undertaken at this stage. This would likely only affect more at a local scale however will require review at later stages to confirm the development type is consistent with the requirements and/or limitations of the updated hazard categories.

3.3.4 NorBE and the Drinking Water Catchment

Based on the baseline modelling conducted (refer section 2.10.6), NorBE targets may be equivalent to a pollutant load reduction of 92% for TSS, 80% for TP and 86% for TN where development occurs within sandy soils in a rural / agricultural area. Equivalent development on bushland (e.g. E1 land use) would require 98% (TSS), 97% (TP) and 96% (TN) pollutant load reduction from stormwater flows to achieve the NorBE targets.

Figure 3-1 shows biofiltration footprint as a percentage of development area vs pollutant load reduction for the example industrial catchment analysed (refer section 2.10.6). The modelling assumed a GPT was upstream of the bioretention basin.

Figure 3-1 demonstrates that it is unlikely to be feasible to achieve the NorBE targets for TP and TN by filtration alone for a development in rural land within the sandy soils of the Drinking Water Catchment. Therefore, rainwater and stormwater harvesting strategies are likely to be required should development be proposed within the Drinking Water Catchment. The opportunities identified and considered are included in section 5.4.3.

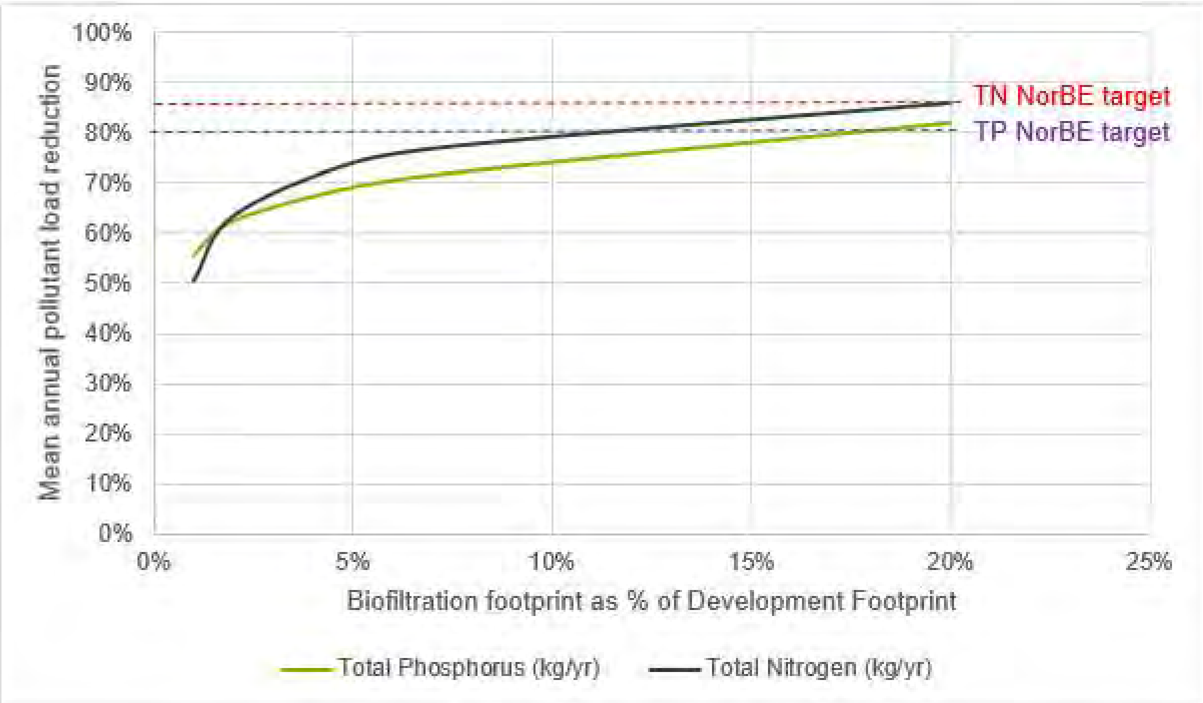


Figure 3-1 – Indicative biofiltration footprint to achieve water quality targets for example industrial development

3.3.5 Bird Strike Boundary

In accordance with the PSC DCP B7.D various development types including artificial water bodies are to be avoided within 3 km (Group C) of the airport runway or provide measures that prevent food sources attracting wildlife within 3 and 8km (Group B) of the airport runway. The Bird Strike boundaries are shown in Appendix A (Figure A25), which shows that the majority of the study area, with the exception of the eastern fringes, is in either Group B or Group C.

This control would limit the introduction of new open water bodies as part of a WSUD strategy, such as constructed wetlands. Stormwater measures such as swales, bioretention basins, detention basins and infiltration basins are considered to be appropriate within these zones providing water is not retained for significant periods (timeframe to be confirmed, nominally <72 hours) after a storm event.

3.4 Implications to Precinct Planning

A spatial summary of the key environmental and planning constraints to water cycle management is summarised in Figure A25 in Appendix A. As can be seen from the figure, there are several constraints that cover the Williamtown SAP Structure Plan Boundary with varying degrees of influence on developability including Bird Strike management zones, the Drinking Water Catchment, flooding, high infiltration soils and very slow infiltration soils. This presents a significant challenge to process against the constraints from other disciplines.

To facilitate the determination of developable land, based around the water cycle management and flooding constraints, a classification approach has been adopted and is presented in Table 3-2. A spatial representation of these categories is also represented for flooding and water cycle management in Appendix A (Figure A26 and A27).

The project brief calls for the assessment of flood planning constraint categories (FPCCs) in accordance with the *Australian Disaster Resilience Guide 7-5 – Flood Information to Support Land Use Planning (AIDR 2017)*. This approach has not been assessed as part of this project as it was considered similar to the comprehensive approach the PSC DCP adopts. The DCP follows a similar concept, considering flood hazard and hydraulic categorisation as the constraint categories for different development types. Given the similarities in output, the adoption of the DCP was considered more appropriate for this study for consistency with PSC flood planning. In addition, not all inputs for the FPCC methodology were available from the flood model output data to undertake the AIRD (2017) methodology.

Table 3-2 – Developability classification based on flooding and water quality constraints

ID	Levels of developability	Flooding: Flood free land	Flooding: Minimal risk Flood prone land	Flooding: Flood Fringe (Low and High Hazard)	Flooding: Flood Storage	Flooding: Floodway (Low and High Hazard)	Water Cycle Management: A – Within Drinking Water Catchment & E1, E2 or SP1 Land Zoning [2]	Water Cycle Management: B – Within Drinking Water Catchment but outside E1, E2 and SP1 Land Zoning [2]	Water Cycle Management: C – Outside Drinking Water Catchment & within Sensitive Aquatic Environment Catchment	Water Cycle Management: D – Outside Sensitive Aquatic Environment Catchment and Drinking Water Catchment
1	May be developed with standard controls	✓	✓	✓						✓
2	May be developable but with additional mitigation to standard controls[1]				✓ (Low Hazard Flood Storage)				✓	
3	May be developable but with significant mitigation[1]				✓ (High Hazard Flood Storage)			✓		
4	Developments Discouraged[1]					✓	✓			

[1] Developability from a flooding perspective is subject to further flood modelling and flood risk assessment

[2] Bushland areas within the Drinking Water catchment that are not E1, E2 or SP1 land have not been delineated but are also considered to be Category 4 due to the significant difficulty in achieving NorBE requirements

4 Model Development

4.1 Regional Hydraulic Model

The Williamtown Salt Ash Floodplain Risk Management Study and Plan (BMT 2017) regional hydraulic model was taken as the basis of the current study to simulate the critical flow behaviour across the floodplain. The TUFLOW model developed as part of that study was used to assess flood impacts of the preliminary scenarios derived from the first EDB workshop. The following section summarises the key aspects of the original model development by BMT (2017).

The BMT (2017) TUFLOW model utilised a fully hydrodynamic 1D/2D TUFLOW model created by linking the hydraulic models from the Williams River Flood Study (BMT 2009) and the Williamtown/Salt Ash Flood Study (BMT 2005). The Williams River hydraulic model covering the Williams River catchment and the Lower Hunter River was extended to incorporate the additional area modelled by the Williamtown / Salt Ash Study covering the Tilligerry Creek floodplain from Fullerton Cove to Salt Ash.

The composite hydraulic model was a fully hydrodynamic 1D/2D TUFLOW model based on a 2D domain grid resolution of 20 m and 1D representation of hydraulic structures including the hydraulic controls of Nelson Bay Road and the Tilligerry Creek floodgates.

LiDAR aerial survey data acquired through the Department of Planning Central and Hunter Coasts LiDAR Project, January 2007 was used for representation of the general floodplain. Comparison of the 2007 and 2013 LiDAR with the ground survey data in the Fullerton Cove and Tomago localities held by BMT, confirmed the 2007 LiDAR data set to be a better match. The provided 2007 LiDAR data was a 2 m resolution gridded bare earth Digital Elevation Model (DEM) which had been undergone ground filtering algorithms.

Additional changes were also made to the model topography to create a smooth transition between areas covered by bathymetric survey (in-channel regions) and areas covered by photogrammetric survey (floodplain regions) and to incorporate recent development in the lower Hunter floodplain such as rail infrastructure in the Hexham locality, and the major industrial development of WesTrac along Tomago Road. Drainage channels, creeks, and other significant hydraulic controls, such as elevated road embankments i.e. Nelson Bay road, Cabbage tree road, Tomago Road and Lemon Tree Passage Road, were incorporated into the model topography using 3D breaklines.

The new model boundary inputs were consistent with those adopted in both studies. The Hunter River flood inputs were extracted from the Lower Hunter River Flood Study (L&T, 1994) and local catchment flow hydrographs were output from the XPRAFTS hydrological models. A downstream tidal water level boundary was applied to Tilligerry Creek consistent with the Williamtown / Salt Ash Study and the downstream tidal level boundary at Newcastle Harbour was consistent with the adopted boundary in the Lower Hunter flood model being developed for Newcastle City Council by DHI.

The Williamtown / Salt Ash Flood Study tested a range of coincident design flood conditions and found that the critical condition when determining the 1% AEP flood levels within the study area were as follows:

- 1% AEP flow conditions on the Hunter River at Raymond Terrace.
- 50% AEP flood conditions in Port Stephens and Newcastle Harbour; and
- 10% AEP local catchment inflows

Similarly, in the BMT 2017 hydraulic model, the adopted Hunter River inflow hydrograph at Green Rocks and Williams River were representative of a 1% AEP flow condition. The time series used for the downstream boundary at Newcastle Harbour was considered tidally varying with a peak level of 0.85m AHD. A design storm surge condition was applied on top of the tidal boundary to provide a 50% AEP peak level. The surge had a duration of 40 hours which produced a peak level of 1.17m AHD in combination with the tide.

The tidal boundary used for Newcastle Harbour was also adopted for the downstream boundary conditions in Tilligerry Creek. The Port Stephens Flood Study and the Port Stephens Design Flood Levels – Climate Change Review suggest that a 50% AEP flood level of around 1.5m AHD is appropriate at Taylors Beach located at the mouth of Tilligerry Creek. Therefore, the storm surge component was scaled to provide a peak level of 1.5m AHD.

Local catchment inflows for the Hunter River downstream of Raymond Terrace and within the Williamtown / Salt Ash study area were derived from the hydrological models. The 10% AEP 48-hour duration inflows were adopted, as consistent with the Williamtown / Salt Ash Flood Study.

For climate change scenarios, local catchment inflows were increased by 10%, 20%, 30% and the downstream boundaries were increased by 0.4m and 0.9m to represent sea level rise for 2050 and 2100 respectively.

The hydrological and hydraulic models from both the Williamtown / Salt Ash Flood Study and the Williams River Flood Study were previously calibrated and verified to available historical flood event data to determine the values of key model parameters. Accordingly, a model re-calibration was not required.

4.2 Local Hydraulic Model

To assess local flooding, a direct rainfall TUFLOW model of the area was developed on the catchments immediately upstream of the Precinct. This approach was considered appropriate due to the flat nature of the catchment which would be heavily influenced by floodplain storage. The traditional separate hydrological and hydraulic modelling approach would prove more challenging to represent the floodplain storage in a hydrological model.

Initially the model covered an area of about 100 square kilometres extending from Fullarton Cove to Tilligerry Creek as part of the scenario testing. As the Williamtown SAP location was refined, the model extent was trimmed to an area of about 40 square kilometres, reducing model run times to a somewhat more reasonable duration.

A summary of the inputs adopted in the hydraulic modelling is provided in the following sections.

4.2.1 Model Topography

The model topography was developed using LiDAR data captured by Aerometrex in October 2020. The LiDAR data was provided as a Digital Elevation Model (DEM) with a 1m resolution. The 1m DEM was used to extract breaklines along the road crests to dictate the exact elevations of critical controls including Nelson Bay Road, Cabbage Tree Road and Fullerton Cove Levee.

4.2.2 TUFLOW Version and Grid size

TUFLOW version 2020-10-AA was adopted for the development of the current local hydraulic model. This version supports variable cell sizes using a quadtree mesh which allows larger cells to be used in flat areas and smaller cells where the terrain is variable or along primary flow paths. To prevent increasing the run time unnecessarily, a grid size of 20m was adopted as the base grid size and a smaller grid size of 5m around the study area and a grid size of 2.5 m over the main flow paths to represent the conveyance capacity of the drains more accurately. These flow paths were identified from the aerial imagery and DEM.

4.2.3 Design Rainfall, Temporal Patterns, and loss model

The design rainfall and temporal patterns adopted for the modelling were extracted from Australian Rainfall and Runoff (ARR, 2016) using the ARR Data Hub. The ARR Data Hub is a tool that allows for easy access to the design inputs required to undertake flood estimation.

The location for which this data was extracted is shown in Table 4-1. The ARR Data Hub also links to the Bureau of Meteorology 2016 Rainfall IFD data system which provides the design rainfall depths for different storm probabilities and durations. All the collected data is then combined to define the design rainfall and pattern to apply to the study area.

Table 4-1 – Adopted hydrological parameters

Parameter	Value
Location	Longitude: 151.8448, Latitude: -32.8024
River Region	South East Coast
Temporal Patterns	Hunter River
Initial Loss	13.0 mm
Continuing Loss	2.8 mm/hr

4.2.4 Rainfall Losses and Roughness Values

The catchment covering the Williamtown SAP site is made up of two separate catchment areas of about 42.5km2 for the eastern catchments draining to Fullerton Cove and 37.0km2 for the western catchments draining towards Tilligerry Creek. In some areas, the catchment boundary between the two can be difficult to determine with the direction of flow influenced by the direction of flooding and hydraulic gradients.

The catchments comprise grassland floodplains to the south with development generally restricted to the Williamtown RAAF Base, Cabbage Tree Road and Nelson Bay Road alignments.

The extent of dense vegetated areas were identified from a high-resolution aerial imagery. For these areas, the Manning's roughness value used was 0.10 and for the rest of the floodplain, a value of was 0.045 was adopted.

An initial loss and continuing loss model were adopted for the hydraulic modelling. ARR 2019 provides guidance on losses. The Anna Bay and Tilligerry Creek Flood Study (Jacobs 2017) had undertaken a more extensive analysis of catchment losses and model calibration. Given the proximity of the Anna Bay and Tilligerry Creek (2017) Study, the same continuing losses were adopted for this assessment. The Anna Bay and Tilligerry Creek (2017) Study had accounted for clayey and sandy soil catchments. Both soil types adopted the same design initial loss (10mm) however the sandy soils adopted a marginally higher continuing loss (6mm/h). For simplicity at this stage, the more conservative clayey soil continuing loss of 2.5mm/h was adopted for all soil types.

Adopted losses and Manning's n roughness values are shown in Table 4-2.

Table 4-2 – Adopted Loss values and Manning's n

Land-use	Impervious %	Initial Loss	Continuous Loss	Manning's n
Default Floodplain	0	13	2.5	0.045
Dense Vegetation	0	25	2.5	0.100
Roads	100	1	0.0	0.014
Proposed Developments				
Channels	100	1	0.0	0.045
Detention Basins	100	1	0.0	0.050
Developments	85	1.95	0.4	0.070

4.2.5 Hydraulic Structures

There are limited underground drainage networks across the modelled catchment. Most drainage structures are culverts and rural channels. The culverts were incorporated as 1D elements linked to the 2D domain in the hydraulic model. Culvert details were extracted from the Astra Aerolab hydraulic model. Where not captured, culvert details from the regional model were adopted or where aerial imagery indicated the presence of culverts. Some of these additional culverts were in locations that could change the model results, especially during small events. Their properties were estimated based on the aerial imagery and the 1m DEM.

4.2.6 Boundary Conditions

The Direct Rainfall method (which applies rainfall directly to the 2D cells) was adopted for the local model. The rainfall boundary was applied across the full model extent. For downstream boundary conditions, a combination of a dynamic tidal tailwater with a peak level of 0.85 m AHD at Fullerton Cove and height/flow type with a very shallow water slope of 0.0005 m/m along the trimmed edges were adopted. The dynamic tidal boundary was based on the modelling adopted in the BMT (2017) study.

4.2.7 Design Events

The local assessment was undertaken for the 20%, and 1% AEP and 1% AEP plus climate change for the year 2100. The 1EY event was simulated to understand the inundation duration impact within the bio-conservation area. The climate change event adopted an increase of 20% in rainfall intensity for the 1% AEP event however no change to tailwater conditions was applied to simulate a free draining condition for the low tailwater level scenario to limit the drowning effect of the impacts. It was identified that higher tailwater conditions reduce the impact of the Williamtown SAP and does not present a true free draining scenario given the flat floodplain characteristics.

A series of runs were undertaken to identify the critical duration and temporal pattern. A constant cell size of 15m was adopted for the critical duration assessment and the duration of 1440 minutes and temporal pattern number 8 were selected for the current hydraulic assessment. However, a review of this is required in the next design stage as the critical duration assessment was not able to be revisited following final updates to the Structure Plan.

4.2.8 Summary of Adopted Parameters

The summary of adopted parameters for the local model are presented in Table 4-3.

Table 4-3 – Local flood model parameters

Parameter	Value	Comment
Inflow boundary approach	Rain on grid	Direct rainfall applied across the full catchment.
Model grid size	20m, 5m and 2.5m representing the relevant drains	The finer grid is applied via TUFLOW's quadtree mesh feature
Rainfall	2016 BOM design rainfall	As per ARR methodology
ARR methodologies	2019	Adopted where relevant
Preburst	As per ARR Datahub	Preburst rainfall included. Complete storm loss applied.
Forest Initial loss (pervious)	25mm	Based on Umwelt maximum infiltration rate. There is uncertainty with this value as it covers mostly the Tomago Sand beds. Resolution of this will unlikely occur at this stage as it calls for further analysis, model testing and verification. Consistency with the Umwelt (2018) and BMT (2017) studies is the current objective
Forest Continuing loss (pervious)	2.5mm/h	
Floodplain Initial loss (pervious)	13mm	As per ARR Datahub
Floodplain Continuing loss (pervious)	2.5mm/h	Anna Bay flood study (2017)
Initial loss (Impervious)	Varies	Varies with proposed land use across the Williamtown SAP. Proportional to impervious fraction

Parameter	Value	Comment
Continuing loss (Impervious)	0mm/h	
Tailwater conditions (Low tailwater level scenario)	0.85mAHD	The 0.85mAHD dynamic tide representing a free draining scenario.
Tailwater conditions (High tailwater level)	1.6mAHD	Represents a blocked outlet to Fullerton Cove. The BMT (2017) flood Study adopted 1.5mAHD, which incorporates storm tide and wave setup. Based on the tidal planes (Table 6-3) a Mean High Water Springs level plus 0.9m sea level rise gives 1.6mAHD and has therefore been adopted at this stage. A review of higher levels to be considered.

4.2.9 Astra Aerolab Integration

As per the outcomes of the final Enquiry by Design Workshop, the DAREZ development area (Astra Aerolab) has been incorporated into the Williamtown SAP Masterplan. The Astra Aerolab Stage 1 development have been completed and it is understood that the construction of the following has been undertaken:

- Eastern portion of Basin 2
- Downstream portions of two of the central drainage channels
- Tail-out works downstream of Basin 2

The key elements from the provided Astra Aerolab modelling were incorporated into the local flood model development. Not all structures and features were able to be represented in the Williamtown SAP modelling due to time constraints therefore would require review at the next design stage.

4.2.10 Model Verification

The performance of the local flood model is presented in Table 4-4. On average the model is simulating peak flood levels approximately 0.02m lower in comparison to the Umwelt (2018) Study excluding the locations downstream of Cabbage Tree Road. These minor differences would generally be attributed to the following:

- Hydrological loss models are different with Umwelt (2018) adopting Horton infiltration compared to an initial and continuing loss model.
- difference in hydraulic modelling software (TUFLOW vs RMA);
- modelling of the full catchment in 2D (Williamtown SAP) compared to a combined hydrological and hydraulic model (Umwelt (2018)); or
- applied ground elevation data (2020 capture for Williamtown SAP compared to 2013 capture used in the Umwelt (2018) Study). In general, the current Williamtown SAP local flood model is slightly lower in comparison to the Umwelt (2018) Study

Downstream of Cabbage Tree Road, water level differences are higher by 0.25m to 0.27m. This can be due to the different tailwater levels adopted between the models, where the Williamtown SAP model adopts a high tailwater level of 1.6mAHD compared to 1.4mAHD from the Umwelt (2018) modelling.

Table 4-4 – Local flood model validation against Umwelt (2018) drainage study

Drain Name	Location Description	Approx. ground level from Umwelt Study (mAHD) (A)	1% AEP UMWELT Peak Flood Level (mAHD) (B)	Williamtown SAP 1m DEM Ground level (mAHD) (C)	Ground Level Diff (m) (C-A)	Williamtown SAP 1% AEP flood level (mAHD) (D)	Peak Water Level diff (m) (D-B)
Dawson Drain	Upstream of Cabbage Tree Road	1.15	2.05	1.14	-0.01	2.00	-0.05
Dawson Drain	Downstream of Cabbage Tree Road	1.68	1.36	1.34	-0.34	1.61	0.25
Dawson Drain	Junction with Ring Drain	0.60	1.34	0.63	0.03	1.60	0.26
Leary's Drain	Upstream of Cabbage Tree Road	1.05	1.95	1.04	-0.01	1.93	-0.02
Leary's Drain	Downstream of Cabbage Tree Road	1.25	1.61	1.25	0.00	1.69	0.08
Nelson Bay Road Table Drain	Upstream of Cabbage Tree Road	1.40	1.71	1.46	0.06	1.86	0.15
Nelson Bay Road Table Drain	Downstream of Cabbage Tree Road	1.40	1.44	1.40	0.00	1.61	0.17
Fourteen Foot Drain	Downstream of Nelson Bay Road	0.50	1.35	0.50	0.00	1.61	0.26
Ten Foot Drain	Upstream of Fourteen Foot Drain Diversion	0.35	1.34	0.32	-0.03	1.61	0.27
Ring Drain	Upstream of Ten Foot Drain 1	0.20	1.34	0.23	0.03	1.60	0.26
Ring Drain	Downstream of Ten Foot Drain 2	0.35	1.33	0.33	-0.02	1.60	0.27

4.2.11 Items for Further Investigation

The floodplain characteristic is primarily storage based, rather than conveyance based. Notwithstanding this, there are some smaller sections of the floodplain where flooding is controlled by conveyance, located further upstream in the catchment. As such, the modelling undertaken to develop and manage the flood impacts is very sensitive to the discretisation of the existing floodplain and proposed flood management measures. This, coupled with a limited project timeframe, meant that some elements of the modelling were not able to be refined or optimised. The key aspects that should be further investigated at the next design stage are as follows:

- Resolve difference between adopted loss model parameters in previous studies.
- Undertake a gap analysis across survey and design information from the Astra Aerolab Stage 1 developments, in addition to gaps in key structures outside of the Williamtown SAP precinct.
- Refinement of spatial model roughness and fraction imperviousness representation.
- Review of the critical duration and temporal pattern as this was not able to be revisited following final updates to the Structure Plan.

4.3 MUSIC Modelling

MUSIC modelling has been used to inform an effects-based assessment to quantify the effectiveness of the WSUD management responses intended to protect the quality of drinking water supplies and maintain the health of the downstream estuaries.

MUSIC modelling was used to iteratively size a water sensitive urban design (WSUD) strategy that achieves the specific stormwater performance targets across the study area.

4.3.1 Model Inputs

For the purposes of the Scenarios analysis, modelling was conducted based on the inputs described in **Table 2-18** and **Table 2-19**.

4.3.2 Model Approach

A number of 1 ha MUSIC models were developed for rapid testing of existing land uses and new high impervious and new low impervious development types.

The WSUD treatment strategy proposed for these new development types represents the book-ends to the range of mitigation measures required (section 5.3.2) to achieve the adopted numerical criteria (section 5.2.2) selected for stormflow, baseflow and pollutant loads for each of the study area zones and development scenarios.

The key assumptions adopted for the scenario modelling are summarised in Table 4-5.

Table 4-5 – Scenario modelling key assumptions

Land use	Stormwater Management Approach	
Existing airside land uses	No stormwater treatment is proposed for existing airport;	As per Section 2.10.6
Future development	Requires a WSUD strategy to achieve the pollutant reductions and water balance impact mitigation for local groundwater sources or downstream estuaries (Stormwater Performance Target)	Development land uses were categorised as either high intensity (high imperviousness) or low intensity (low imperviousness)
DAREZ subdivision	Council pollutant load reduction targets have been applied and no further modelling has been undertaken	High intensity urban development

5 Scenario testing

In the development of the Structure Plan, a range of scenarios were tested to identify the preferred Structure Plan.

This section of the report provides a summary of the scenario development during the first EbD workshop held on 10 and 11 February 2021 which developed visions and concepts, identified challenges and developed innovative solutions at a precinct-wide level across all technical streams. Scenarios were developed and refined by Roberts Day for the Williamtown SAP Study area. They considered land use, transport, infrastructure, PFAS, environmental, social, aboriginal heritage and economic matters in conjunction with the Precinct vision.

The scenarios tested identify the Williamtown SAP limitations, constraints and infrastructure that would be required to support the scenario. This information was subsequently used at the second EbD workshop to inform the Structure Plan (Section 6).

5.1 Scenario Testing Methodology

Constrained land identified in the baseline assessment were evaluated to determine suitability for development. This included areas of high hazard flooding, the Hunter Water drinking water catchment and other critical considerations relating to flooding and water quality. These baseline investigations informed a range of structure plan scenarios based on holistic themes which aimed to maximise certain regional opportunities. As part of the subsequent scenario testing phase of the Williamtown SAP strengths, weaknesses, risk and opportunities of each scenario were assessed.

Flooding and water quality assessments were based on specific testing criteria listed in Table 5-1, which aims to identify a preferred structure plan. The criterial capture the key considerations of a development scenario which would minimise flooding and water quality impacts.

Following the individual specific technical assessments, several rounds of stakeholder review and multi-disciplinary workshops were conducted to explore all the technical findings, provide a holistically balanced approach to managing constraints and develop the preferred Williamtown SAP structure plan.

Table 5-1 – Testing criteria

Criteria	Description
Flood impact on existing community	Potential impacts on flooding resulting from the scenario are acceptable.
Infrastructure requirement	The potential magnitude of infrastructure required to facilitate the Williamtown SAP.
Location of development with respect to Drinking Water Catchment	Siting of development within the drinking water catchment will require NorBE water quality targets to be achieved.
Achievement of precinct vision	Does the scenario align with the precinct’s visions relating to flooding and water cycle management

5.1.1 Water Cycle Management Assessment

Constraints analysis

An analysis of the local constraints was undertaken to inform the development of a water cycle management strategy which responded to the local constraints including:

- Protection of drinking water catchment
- PFAS plume and groundwater recharge
- Sensitive downstream receptors and associated water quality requirements

- Flat and low-lying terrain and implications that WSUD measures would have on filling, earthworks and flood storage
- Shallow groundwater and potential interactions between contaminated groundwater and surface water infrastructure
- Bird strike risk to aviation associated with water ponding within WSUD elements
- Future urban heat impacts and ability for WSUD measures to contribute to thermal comfort
- Table 5-6 in section 5.3.2 provides a description of how the water cycle management strategy and management measures respond to the various local constraints.

MUSIC modelling

MUSIC modelling was undertaken to test a range of WSUD measures and develop a treatment train which responded to the various local constraints (refer Table 5-6) and to achieve the adopted pollution stripping targets (refer Table 5-2).

Specific 'leaky' treatment train elements were tested in sand soil zones (refer Figure 5-1) but were omitted due to potential PFAS interactions. The proposed WSUD measures are described in more detail in section 5.3.2.

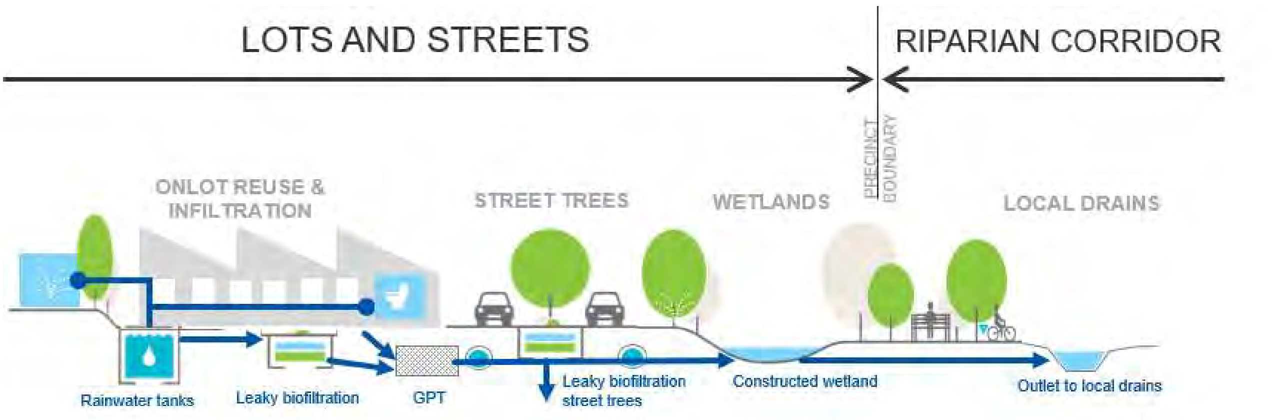


Figure 5-1 – WSUD treatment train in sandy soils where ground water recharge rates are important within Hunter Water lands

Figure 5-2 – WSUD treatment train in clay soils where groundwater recharge is to be avoided

WSUD measures were iteratively sized for low and high imperviousness development scenarios to achieve the pollution stripping targets (refer Table 5-2).

Surface water and groundwater balance

A notional water balance was undertaken in MUSIC (eWater) software to test the effectiveness of the proposed WSUD strategies for the adopted high impervious and low intensity impervious land use typologies in a variety of different existing land zonings. This demonstrated the feasibility of achieving the stormwater management targets (particularly where NorBE applies) and where additional mitigation is required to manage the residual load in runoff and groundwater recharge volumes.

The modelling indicated that:

- In existing bushland areas (E1, E3 and some SP1 lands) it is not feasible to achieve both the groundwater recharge rate and to achieve NorBE pollutant load reductions for water infiltrating to groundwater. While both cannot be met, it is possible to meet one or the other objective.
- In sandy soil zones, a combination of on lot and streetscape infiltration could be used to recharge groundwater if NorBE requirements do not prohibit this approach
- In clay soil zones, runoff volumes to downstream sensitive receptors may be increased by around 2.3 to 3.8 ML/year/Ha of new development (compared to greenfield) with the adopted WSUD measures in place. In sandy soil areas runoff volumes to downstream sensitive receptors may be increased by around 1.8 to 2.4 ML/year/ Ha of new development with the adopted WSUD measures in place.

The modelling demonstrated that the proposed strategy would significantly reduce the volumes of stormwater and associated pollutants from entering downstream sensitive receptors by maximising the opportunities to reuse, evapotranspire and evaporate stormwater volumes through WSUD measures. The sizing of each measure was incrementally increased to the point of diminishing returns. It is unlikely that additional stormwater volume reductions could be achieved without implementing a regional stormwater harvesting scheme where roof water is captured in precinct storages as part of a secondary clean water collection system. The clean water could be pumped to local water markets (refer section 5.3.2). Around 1 to 2.6 ML/year could be collected from each Ha of new development to top up regional bulk water supply and match the existing runoff volumes to sensitive receiving environments. However, this precinct scale harvesting opportunity was not adopted for the final strategy.

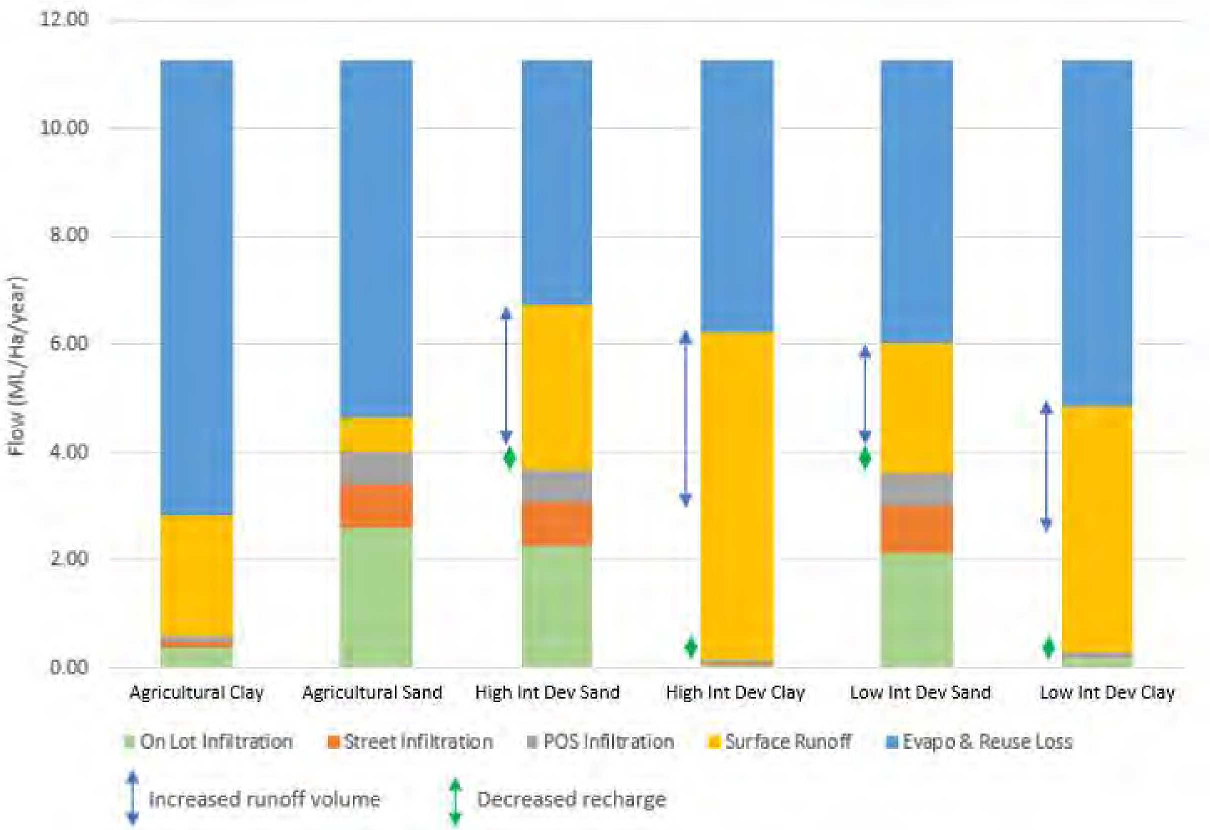


Figure 5-3 – Water balance analysis for a combination of soil types (sand or clay), existing/baseline land use conditions (agricultural) and high and low intensity development

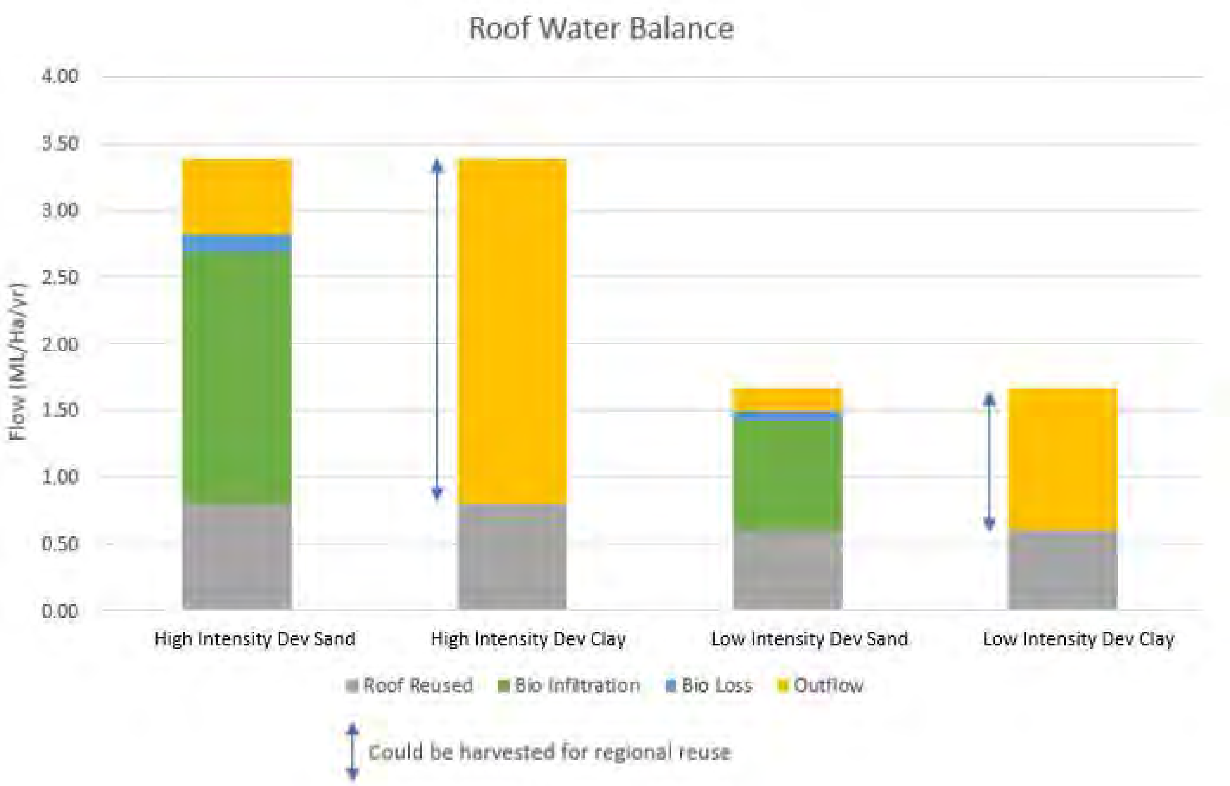


Figure 5-4 – Opportunity for precinct scale roof water harvesting volumes via clean water collection

Drinking water catchment diversions

To facilitate development occurring within drinking water catchments, it may be possible to divert untreated or partially treated stormwater away from those areas and enable NorBE targets to be achieved.

5.2 Scenario Performance Objectives

5.2.1 Flooding Objectives

The following performance objectives have been proposed in relation to flooding and floodplain management for the Williamtown SAP:

- No adverse flood impact in regional and local flooding on properties up to the 1% AEP plus year 2100 climate change.
- Limit peak flow to predevelopment conditions where discharge is upstream off existing development in events up to the 1% AEP event.
- The Williamtown SAP to be flood free up to the 1% AEP, 2100 climate change event (20% rainfall increase plus 0.9m sea level rise).
- A freeboard of 500mm to be adopted above the adopted design level for all building floor levels and critical infrastructure

With respect to flood impact limits and the design flood planning level, discussions are currently in progress to test and understand what an acceptable level of risk to the project is as a whole. Due to the cost implications of filling and land forming required to accommodate these flood criteria; this decision is significant.

5.2.2 Water Cycle Management Objectives

The following performance objectives were adopted in relation to water cycle management when testing the scenarios.

Table 5-2 – Water cycle management performance objectives

Objective	Stormwater Performance Target for New Development
Minimise water quality impacts from surface water runoff to sensitive receiving environments	Achieve the adopted sensitive catchment targets for mean annual pollutant load reduction (TSS – 90%, TP – 65%, TN – 50%, Gross pollutants–s - 90%). Refer **Table 2-13**.
Development within the drinking water catchment will have an acceptable impact on drinking water quality	Neutral or Beneficial Effect (NorBE) be demonstrated through stormwater pollutant load reductions for stormwater discharged to either surface water and groundwater
Minimising changes in groundwater recharge to Tomago sand beds to protect resource and minimise changes in groundwater flow which may impact PFAS mobilisation	Development located upon sandy soils (as defined by Council hydrological soil mapping) to recharge a minimum of 80% of predevelopment mean annual recharge volume 1.

[1] Where development occurs within existing E1 and E2 land zonings or in bushland areas of SP1 land in the Drinking Water Catchment, it may not be feasible to meet the both the NorBE pollution reduction targets and 80% groundwater recharge targets.

5.2.3 Riparian Corridor Objectives

The riparian corridor objectives are defined in the Biodiversity Report, which aligns with the NRAR riparian corridor requirements, refer Table 2-7. No change to riparian corridors is proposed.

5.3 Management Measures

5.3.1 Flooding Measures

One of the key management measures identified in the Baseline assessment was compensatory excavation of the floodplain to offset the loss of flood storage resulting from bulk filling. At a local scale this does provide some benefit however in the regional flood event (critical flood scenario), the opportunity to reclaim flood storage in other areas across the Precinct is not considered feasible. This is primarily due to the magnitude of lost flood storage from the Williamtown SAP scenarios compared to the magnitude of the flood.

Food modelling was undertaken to test the sensitivity of the floodplain to changes in landform; filling in the floodplain to create flood free Williamtown SAP within the full extent of the precinct.

The scenarios were tested that encroached into different zones of the floodplain by differing amounts. Modelling showed that to avoid flood impacts under each scenario, consideration and further testing is required to preserve the combined effect of flood storage and conveyance through the management measures presented in Table 5-3.

Table 5-3 – Proposed management measures to facilitate the Williamtown SAP

Management Measure	Objectives	Description
Floodplain storage offsets	Prevent flood impacts on upstream and adjacent development	Excavating and creating new zones of active floodplain storage that compensate for earthworks that fill in critical zones that provide existing floodplain storage.
Floodway reserves through the precinct	Prevent flood impacts on upstream and adjacent development	Setting back development to allow for overland flow channels which aim to preserve the of the floodplain capacity for conveyance of flood events.

Management Measure	Objectives	Description
Development scenario bulk fill extent limitations	Prevent flood impacts on upstream and adjacent development	Reshaping and trimming of the Structure Plan scenario footprints to balance the impact of bulk filling in flood sensitive areas.
Detention basins	Prevent flood impacts on downstream development	This caters for the local flooding scenario and aims to manage the increase in peak flows upstream of existing development.
Non-structural management	Accommodate flood impacts by managing land use	Alternative measures (such as including additional land that is impacted by changed flooding conditions) to manage the flood risk that are not related to drainage and flooding infrastructure upgrades.

It was identified through flood modelling that the augmentation of the Nelson Bay Road crossing provides no benefit towards mitigating adverse flood impacts. This was due to the complex flood behaviour of the system where additional flow capacity under Nelson Bay Road allows for a greater backwater influence and/or reverse flow, which shifts the time of peak flood levels to result in a worse flood impact. Maintaining the existing culvert capacity was found to provide the best balance of adverse impacts for each scenario.

Floodplain storage offsets

Options to offset floodplain storage were reviewed by contemplating opportunities and constraints within and outside of the Williamtown SAP Structure Plan boundary.

There is limited opportunity to gain flood storage within the floodplain due to the proximity of shallow groundwater levels have been identified at approximately 0.5m AHD, east of Fullerton Cove. This presents a limitation on the ability to gain any meaningful floodplain storage across the area as it would be consumed by groundwater and be ineffective during flood events.

Traditional opportunities to gain flood storage within the floodplain are through excavating flood fringe areas. However, there are limited opportunities across the study area to excavate into the edges of the floodplain due to topographical constraints. This could be revisited at a later time if an earthworks strategy identifies a viable local source of fill material around the Williamtown SAP area.

Flood way reserves

The floodway is often defined as the zone that conveys notionally 80% of the flood waters in a given event. Flood way reserves have been proposed through the Williamtown SAP where the proposed bulk filling encroaches into the floodplain. This measure is similar to the typical stormwater management approach of using a combination of trunk drainage channels and road reserves to convey flood waters. Conceptually this is shown in Figure 5-5 illustrating the area which would convey the regional flood flows. The width of these would be in the order of 100 to 300 meters, subject to further refinement.

Given the extent of flooding it is likely that multiple corridors would be required. The risk to this approach is that it presents an increased flood risk to people in the area in the event of a flood. This would require a 'shelter in place' emergency management plan as it will unlikely be possible to evacuate safely. Despite this risk it presents the best balance for developing in regional floodplains.

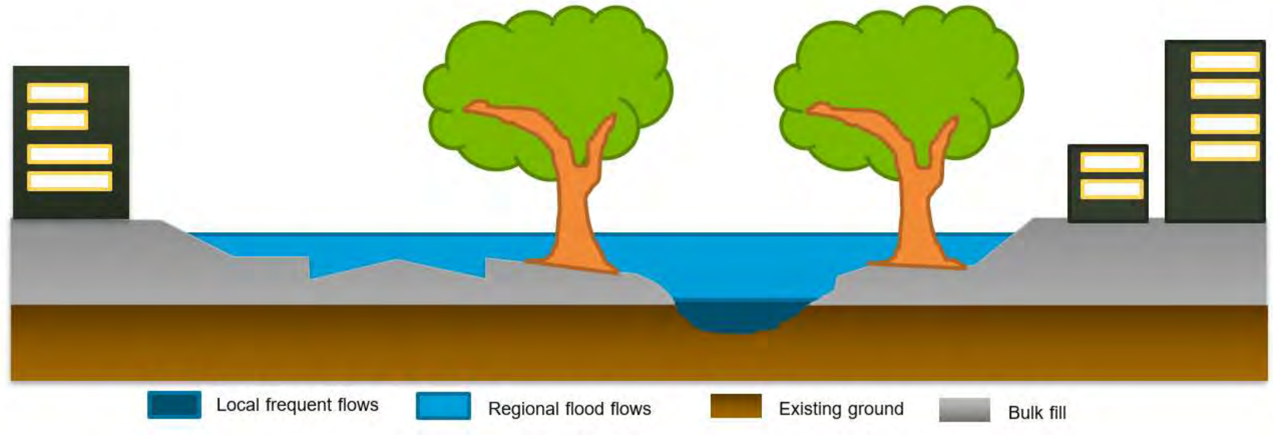


Figure 5-5 – Illustration of flood way reserve section view

Bulk fill extent limitations

Setting back development from floodways is the most effective way of mitigating flood impacts which will impact on the Williamtown SAP footprint within the precinct.

Less flood sensitive land uses can be adopted in these areas. One example of this is an energy corridor where solar arrays can be placed across the floodplain and the critical buildings located outside of the flood risk areas as much as possible.

Non-structural management

Preliminary modelling results indicated that residual adverse flood impacts across existing flood affected properties would be likely. The magnitude of impacts are predicted to be in the order of 20-60mm of increased flood depth subject to the configuration of the bulk filling. It is not clear at this stage whether this increase in impact effects buildings without survey of existing floor levels. The incremental damages in the context of an already flooded property needs to be assessed on a case by case basis. Despite this, the intent would be to mitigate any adverse impacts to the extent possible.

Where the limit or financial viability of structural measures are reached, or a balanced approach is desired, non-structural measures can complement the structural measures to achieve the desired outcomes. Two non-structural approaches to managing adverse flood impacts would be:

- Inclusion of additional sacrificial land to allow flood impacts to occur. Although not considered non-structural, the alternative to this would be house raising. This may be considered more cost effective in some instances.
- Flood impact compensation for the differential in flood damages resulting from the Williamtown SAP.

Management option risks and summary

The proposed management measures have been assessed at high level and may require further refinement. Table 5-4 presents the high-level risk and consequences of the proposed measures.

Table 5-4 – Potential risks associated with each management measure

Management Measure	Risks	Consequence
Flood storage offsets	Insufficient flood storage is able to be accessed. Flood storage proposed does not provide noticeable benefit due to disproportional volume of flooding.	Reduction in developable areas would be required to meet the same impact objective however there would consequently be a reduction in bulk filling volumes.

Management Measure	Risks	Consequence
Flood way reserves	Flood ways proposed require wider reserve widths.	Reduction in developable areas however there would consequently be a reduction in bulk filling volumes.
Bulk fill extent limitations	Bulk fill extents require further retraction	Reduction in developable areas however there would consequently be a reduction in bulk filling volumes.
Detention basins	Additional detention basins required	Proportional loss of developable land to accommodate additional detention basins.
Non-structural management	Additional land for flood impact management – resistance from property owners. Disagreement on fair buy back value. Compensation – dispute from affected landowners on compensation value.	Additional land for flood impact management – beneficial for the Williamtown SAP allowing adverse impacts to occur freely without direct public safety issues Compensation – Additional indirect costs

The flood impact assessment of the proposed scenarios identified that there is a trade-off between the following:

- achieving full developability of the various scenarios; and
- consequential adverse impact on flooding that extends across existing properties outside of the Williamtown SAP boundary.

This situation is not unexpected given the extent of the Williamtown SAP requiring bulk filling in the floodplain. However, the complexity of the flood behaviour (refer Section 2.4) in different areas presented a challenge as it impacts on flood storage and/or conveyance to varying degrees. This complexity creates an iterative situation and presents multiple possible solutions to facilitate the Williamtown SAP.

As noted in the measures, a combination of structural and non-structural management measures are required, however due to the 'bulk fill limitation' measure being the primary management of impacts, the non-structural measures are effectively the management of residual impacts following the implementation of the structural measures. This results in the trade-off situation discussed earlier.

To manage the trade-off, an outcome focused approach can be considered. The focus areas are based on three broad flood management outcomes that supplement and compliment the objectives (refer Section 5.2.1). They also aim to reflect the different interests in the project. These outcomes are:

1. **Maximum development** – Focuses on maximising developability
2. **Balance Outcome** – Aims for a balance between developability and adverse impacts
3. **Conservative Outcome** – Focuses on minimising adverse flood impacts outside of the Williamtown SAP

The pros and cons of for each outcome focus is presented in Table 5-5.

Table 5-5 – Pros and Cons of the level of flood management

Outcome focus	Degree of flood impact management	Pros	Cons
1 – Maximum development	No mitigation of adverse flood impacts	Maximum developability	Maximum indirect costs associated with the inclusion of additional land for flood impact management.

Outcome focus	Degree of flood impact management	Pros	Cons
2 – Balance Outcome	Moderate mitigation of adverse flood impacts	Balance between adverse impacts and developability	Still requires indirect costs associated with the inclusion of additional land for flood impact management
3 – Conservative Outcome	Full mitigation of adverse flood impacts	No indirect costs associated with the inclusion of additional land for flood impact management	Minimum developability

Dawsons Drain outlet to Fullerton Cove – Ring Drain bypass

PSC has highlighted the proposal to discharge Dawsons Drain directly to Fullerton Cover, bypassing the Ring Drain. The primary intent of this option was to improve the drainage efficiency of this catchment and reduce the occurrence of out of bank flooding. However, it has been identified in targeted investigations that the works along Dawsons Drain have only a marginal benefit (Umwelt 2018). Reductions in flood levels of between 40-80mm are expected with the works in place, providing insufficient flood level reductions to contain local catchment flood waters within the channel. This would still result in widespread flooding and prolonged inundation.

Further to the above, the Dawsons Drain works are classified as designated development due to the potential impact on the SEPP (Coastal Management) 2018 wetlands in Fullerton Cove. This would trigger the need for an Environmental Impact Assessment for the works with specialist investigations.

5.3.2 Potential Water Cycle Management Measures

Strategy and management measures

A range of potential water cycle management measures were developed to deliver water quality targets adopted to protect the highly valued environment downstream of the precinct and respond to the local constraints. The strategy and management measures developed during scenario testing are described in Table 5-6 and Table 5-7 respectively. Some of the measures and strategies were not adopted for the Structure Plan, refer Table 5-9.

Table 5-6 – Water cycle management responses to constraints

Constraint Type	Objective / Target	Water Cycle Management Measure / Strategy
Drinking water catchment	NorBE to be achieved for development runoff being infiltrated to Tomago sand bed within Drinking Water Catchment	Roof water from development located in the Drinking Water catchment to be infiltrated on-lot via a biofiltration system with unlined base. The biofiltration will treat runoff prior to infiltration to meet NorBE target. Road runoff to be filtered in biofiltration street tree prior to infiltrating through base (if NorBE can be achieved). Street tree arrangement to be designed to meet NorBE target.
Drinking water catchment	NorBE to be achieved for stormwater discharges to drains located within Drinking Water Catchment	Line new drains, seal pit and pipe network and divert excess stormwater during low flow rain events (<3 month ARI) from development within the Drinking Water Catchment to drains outside the Drinking Water Catchment.

Constraint Type	Objective / Target	Water Cycle Management Measure / Strategy
Drinking water catchment	Preserving recharge to Tomago sand beds within the Drinking Water Catchment to minimise impact to the resource	Recharging of treated roof water and road runoff as described above.
Sensitive receptors	Achieve the adopted sensitive catchment pollutant load reduction targets	On lot treatment, street treatment and end of pipe treatment to be provided by WSUD measures
Sensitive receptors	Minimise increases in freshwater runoff volumes to sensitive tidal waterways downstream	Proposed WSUD measures (rainwater reuse, infiltration, evapotranspiration and evaporation of runoff) to preserve runoff volumes to receptors. Detailed assessment of potential impacts to sensitive receptors of Fullerton Cove and Tilligerry Creek as a result of increased runoff volumes to be undertaken. If impacts are significant, consider opportunity for a precinct scale roof water harvesting system (refer Water cycle management opportunities).
PFAS	Replicating existing groundwater recharge to Tomago sand beds to avoid influencing local groundwater conditions which may impact the PFAS plume	Infiltration systems to be provided on lot (biofiltration with unlined base) and in the street (biofiltration street tree with unlined base) where development occurs on sandy soils.
PFAS	Additional runoff volumes to drains located within sandy soils may increase exfiltration from drains and influence the PFAS plume	Prevent uncontrolled infiltration by lining drains, sealing pit and pipe networks and, if required, divert stormwater low flows (<3 month ARI) from development within sandy soils to drains located within the less permeable clay soils.
PFAS	Major influx of PFAS contaminated groundwater into drainage system	New drains to be lined and pit and pipe network to be sealed. Base of infiltration systems to be sufficiently above high groundwater level.
PFAS	Minor influx of PFAS into drainage system	Wetlands will be provided to treat runoff prior to release to local waterways. Whilst these will generally not be specifically designed for PFAS treatment purposes, they may provide some treatment of PFAS. Whilst strategy is focussed on prevention of PFAS inflows to new drains, for catchments within high risk plume areas, incorporating inline dedicated PFAS treatment (activated carbon or similar) to be considered on a risk basis. This treatment could be incorporated into the wetland outlet works if required as part of more detailed investigations.
Shallow groundwater	High groundwater level	New drains to be lined and pit and pipe network to be sealed.
Flat terrain	Avoiding excessive fill to facilitate stormwater treatment.	Wetlands adopted as preferred end of pipe treatment measure as bioretention basins require around 1.5 m change in elevation across the system vs around 0.5 m in a wetland. Using wetlands would dramatically reduce fill requirements.

Constraint Type	Objective / Target	Water Cycle Management Measure / Strategy
Bird strike zone	Constructed wetlands may attract bird life	Wetlands to be designed to inhibit the attraction of birds. This would include measures such as the minimisation of open water zone lengths and steepening banks where appropriate.
Urban heat	Urban heat impacting local workers / community	Street trees and wetlands to be provided to cool development.

WSUD treatment train to deliver the water quality targets

Table 5-7 – Proposed WSUD elements to deliver water quality targets

WSUD measure	Description
Rainwater tanks	Rainwater tanks \to supply non-potable water demand internally (toilet flushing) and externally (landscape irrigation).
On lot biofiltration with unlined base	In sandy soil areas it was proposed to infiltrate roof runoff on lot to mimic pre-development groundwater recharge rates. In order to protect groundwater quality a biofiltration system with an unlined (leaky) base is proposed so runoff is filtered prior to infiltration.
GPT	A GPT on each allotment will remove litter and sediment from stormwater runoff prior to discharge to the street drainage system. The GPT was proposed on lot rather than as an end of pipe measure as better treatment performance was achieved.
Biofiltration street trees	Biofiltration street trees to be implemented to treat stormwater runoff at source within the streets and provide urban cooling benefits.
Wetlands	It is proposed to provide constructed wetlands as an end of pipe treatment system to achieve the water quality targets for sensitive catchments. Wetlands are proposed instead of biofiltration basins as whilst wetlands take up a greater footprint, the change in elevation to facilitate drainage across the system is much less (around 0.5 m for wetlands compared to 1.5 m for biofiltration). Due to the flat grades onsite, an additional 1 m to facilitate drainage of the biofiltration basin would require significant additional bulk filling. If fill requirements are determined to not be a concern in certain locations, biofiltration basins may be preferable due to their reduced footprint. The constructed wetlands would need to be designed to avoid attracting bird life. This may include mitigation such as limiting open wate zones (non-macrophyte zones) to specific lengths and steepening batters.

WSUD locations

The on-lot treatment and street trees will be dispersed throughout the precincts. Wetlands will be provided in public open space areas adjacent to the riparian corridors and upstream of the local drains at local catchment low points. Both measures would require easements if they became Council assets.

Water cycle management opportunities

Urban development of rural catchments poses a significant change in stormwater runoff volumes discharged to sensitive estuarine waterways and reduced recharge of groundwater resources.

Figure 5-4 shows how there is significant roof water potentially available for reuse within the precinct with an excess for regional harvesting and reuse. Infiltration of roof runoff within clay soil areas is difficult to achieve and on-lot water demands are likely to be relatively low, therefore providing a centralised roof water collection and harvesting system may open up opportunities to reuse this relatively clean resource within a regional water market. This could include pumping roof water harvested from the precinct to Grahamstown Dam or a nearby industrial high-water user.

As well as providing water conservation benefits this opportunity could help to protect the receiving environments downstream which may be sensitive to changes in hydrology and the increased freshwater runoff volumes to tidal zones. Further assessment is required to determine how ecological systems at Fullerton Cove or Tilligerry Creek may be impacted by changes in hydrology and increased freshwater runoff volumes. This opportunity was not further explored but is identified as a potential option that requires further investigation through multiple stakeholders.

5.3.3 Assumptions and Limitations

Flooding

The following assumptions and limitations are implicit in the precinct flood management measures assessment:

- The proposed flood management measures and infrastructure elements have been determined based on a combined, high level quantitative and qualitative approach. These are conceptual in nature and demonstrate the feasibility of flood management measures. These measures have not been optimised or completely resolved. Further optimisation of the measures is required to confirm the most cost effective design and performance of the design scenarios will require further iterative design and demonstration of proof during concept design.
- Ensuring that that the precinct sits above the future regional flood level with allowance for potential sea level rise has been adopted as a critical design criterion. This criterion informs the bulk filling strategy and the follow-on need to mitigate impacts to the local floodplain caused by the bulk filling strategy.
- Consideration of drainage infrastructure is limited to trunk drainage only comprising detention basins and floodways.
- Pit and pipe drainage within the precinct has not been designed but allowance is made to deliver a minor drainage network that can be graded to the proposed detention basin and point of discharge locations.
- Drainage from minor external catchments has not been completely resolved but can be integrated into the precinct stormwater management strategy during concept design.
- The future precinct will maintain natural drainage paths.
- The local flood model has been developed to inform high level decisions on drainage and flooding. It has not been developed to inform design flood levels and habitable floor levels through the precinct.

Water Cycle Management

The following assumptions and limitations have been made in the assessment:

- The proposed WSUD and water cycle management infrastructure elements have been sized based on factoring MUSIC modelling results for select land uses. The modelling reflects a typical development typology for each land use but it is likely that each site will vary with consideration of roof area and effective imperviousness.
- Future development MUSIC modelling results were developed for two land uses only. These results were applied to other land uses conservatively with consideration to the assumed effective impervious.
- No detailed analysis of water quality assessments NorBE has been undertaken for development within bushland areas (E1, E3 or parts of SP1). These areas may require some additional downstream treatment due to less runoff being infiltrated on allotments and these should be considered within the precinct strategy.

- All development will be designed to drain to treatment facilities under gravity.
- No stormwater treatment is required for passive tourism, conservation, infrastructure land uses or the approved DAREZ subdivision. For the purposes of the MUSIC modelling the DAREZ subdivision was assumed to achieve council DCP pollutant load reduction targets. Passive tourism and conservation areas were assumed to be revegetated to form bushland rather than retained as rural land use.
- Stormwater diversion structures required to achieve NorBE in Drinking Water Catchment were estimated by calculating the length of 2nd order waterways and above in future development areas located within the Drinking Water catchment. This length was multiplied by two to allow for a diversion either side. An average pipe size of 375mm pipe was assumed to be adequate to cater for low flows being diverted.
- For the purpose of the Scenarios comparison, the rainfall was assumed to be consistent across all development areas, based on rainfall band B only.

5.4 Opportunities

5.4.1 Flooding

Nelson Bay Road Upgrade

BMT (2012) identified Nelson Bay Road as a hydraulic control to regional flooding from the Hunter River. Existing culvert capacity beneath the road act as a flow constriction point slowing the spread of flood water from the Hunter River that spills north into the Williamtown floodplain and towards Port Stephens via Tilligerry Creek. Increasing the vertical alignment of the Nelson Bay Road and a section of the Cabbage Tree Road may provide a local benefit in the case of increased flood levels resulting from climate change

This benefit would need to be balanced against the potential impact on the west side of Nelson Bay Road. Modelling by BMT (2012) predicts that increasing the vertical alignment of Nelson Bay Road and a section of the Cabbage Tree Road would cause an increase in flood levels by approximately 20-100mm across the southern extent of the precinct and the Fullerton Cove floodplain (west of Nelson Bay Road) including areas of the Precinct and a predicted decrease of 50-200mm east of the road along the Tilligerry Creek floodplain.

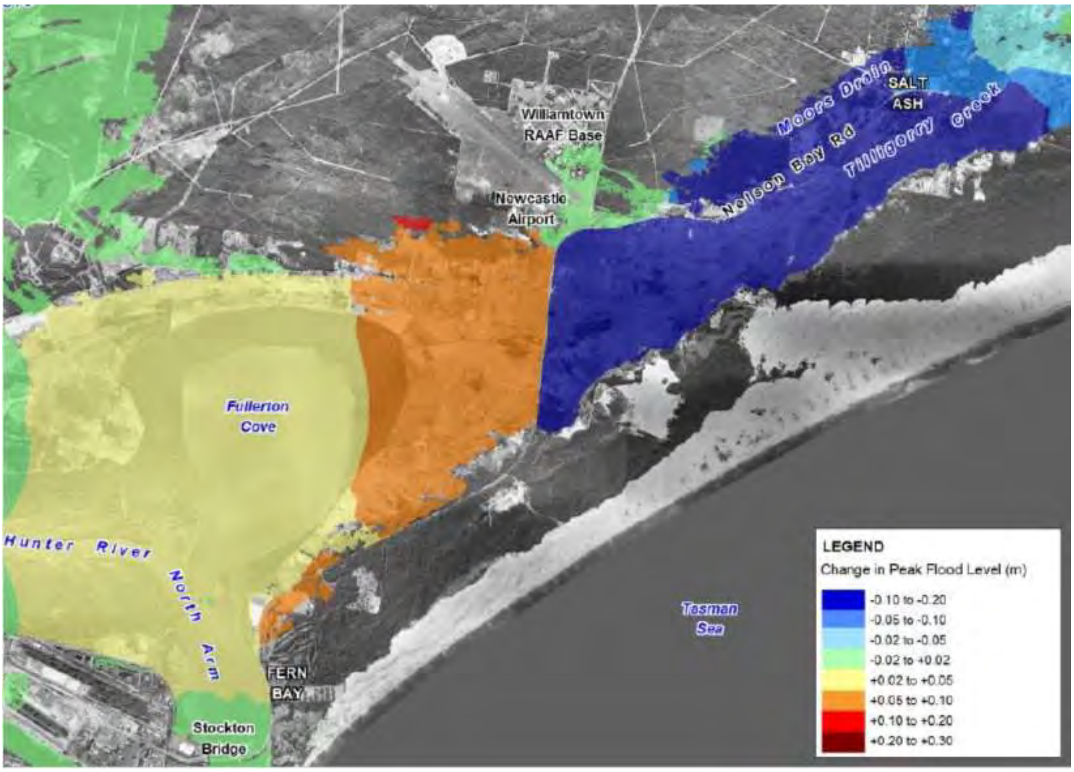


Figure 5-6 – Change in peak flood levels under Climate change scenario (Year 2100) as a result of raising of Nelson Bay Road (Source: BMT 2012)

Salt Ash/Tilligerry Creek Flood Gate Modifications

The flood gates around Tilligerry Creek provide protection to the low lying areas of the Tilligerry Creek floodplain from tidal inundation. It is understood that under current tidal cycles, the flood gates operate as designed and provide the appropriate protection, however given the predicted climate change impacts, their level of service will likely decrease. In addition, increases in local catchment runoff is expected and the existing capacity of the flood gates will limit the rate of discharge therefore potentially increasing the already long inundation durations (BMT 2017).

In terms of improvements to flood conditions under a major regional flood event, the augmentation is not expected to provide any benefit (BMT 2017). The opportunity to augment the flood gate capacity is limited to improving the drainage efficiency and preparedness for progressive sea level rise. Along with any flood gate augmentation, corresponding levee raising would be required to maintain the tidal inundation protection from rising sea levels.

Dawsons Drain outlet to Fullerton Cove – Ring Drain bypass

The Dawsons Drain catchment area was identified as an area for potential future development by PSC. The proposal to improve the drainage was driven by the need to improve drainage across the area to facilitate the development. The current hydraulic performance of the drain is not in accordance with current design standards for trunk drainage and any reasonable improvement is desired to facilitate development to occur.

The drain currently conveys runoff from sections of Williamtown Airport. This accounts for approximately 29% of the current expected total flow in Dawsons Drain. Downstream of the Cabbage Tree Road, the drain functions less as a stormwater conveyance structure with its primary purpose to manage ground water levels and irrigation water to the surrounding lands (Umwelt 2018).

The drain has been identified to have a 20% AEP capacity upstream of Cabbage Tree Road and 1% AEP capacity downstream (Umwelt 2018). This is largely a result of Cabbage Tree Road culverts constricting flows, which was identified in the same study to have less than a 50% AEP capacity.

The proposed works to improve the drainage along Dawsons Drain would include constructing a new discharge point for Dawsons Drain to bypass the Ring Drain (refer Figure A28 in Appendix A) This provides additional discharge capacity of the drainage network and a steeper hydraulic gradient. Augmentation of the Cabbage Tree Road culverts and installation of flood gates at the outfall to Fullerton Cove would also form part of the works. The flood gates would be required to prevent tidal inundation, as with all outlets to Fullerton Cove. In addition, general channel works would be needed to desilt and regrade the channel to improve hydraulic efficiency.

It has been identified through modelling that the above works along Dawsons Drain have only a marginal benefit (Umwelt 2018). Reductions in flood levels of between 40-80mm are expected with the works in place, not providing sufficient flood level reductions to contain local catchment flood waters with the channel. Despite this, this option is considered an opportunity to further investigate within the context of the Williamtown SAP, which would have less constraints compared to those PSC would have had when deriving this option.

Drainage Easements and Ownership

The existing drainage channels are understood to be either privately owned or only have easements from top of bank with no allowance for safe maintenance access. As part of the Williamtown SAP, there is opportunity to delineate and assign appropriate easements along the drainage corridors that take into account and facilitate:

- Any riparian reserves or aspirations for rehabilitation of riparian zones
- Safe access of vehicles for inspection and maintenance activities

- Clear transfer of ownership to the appropriate government authority that will commit to the required responsibilities of the drainage asset ownership.

General Drainage Upgrades

At the local catchment scale, the exiting drainage network is noted to be undersized and has the potential to be augmented to improve drainage efficiency and reduce flood risk. The Williamtown SAP may increase the burden on the existing system depending on the level of flood detention that can be achieved. Upgrades to the existing drainage network were investigated by Defence (Umwelt 2018) as part of their drainage study to understand the sensitivity of drainage upgrades.

The Umwelt (2018) study identified that the suggested drainage works (Appendix A, Figure A28) would only provide marginal reductions to local catchment flood levels (20-70mm) and some reductions in inundation durations (1-8 hours). In addition, the ultimate option tested (Appendix A, Figure A28) included an augmentation to the Tilligerry Creek flood gates. The Study notes that there are some minor increases at the start of the storm in flood levels upstream of the floodgates however there are notable decreases as the storm progresses. In terms of inundation duration, it is predicted that there would be shorter periods (4-6 hours) of wetting and draining of the floodplain. It is understood that this fluctuating nature of wetting and draining is attributed to tidal influence which prevents floodwater from draining from the catchment.

Reductions in peak flood levels across the floodplain as a result of the general drainage upgrades are presented spatially in Figure 5-7.The reductions are widespread across the floodplain however are only minor reductions as noted previously. The fact that flood levels are not sensitive to drainage improvement works and that the critical storm duration is the 48 hour event (Umwelt 2018), indicates that drainage is downstream controlled. It effectively acts as large flood storage basin and cannot drain out efficiently therefore floods the lower lying areas.

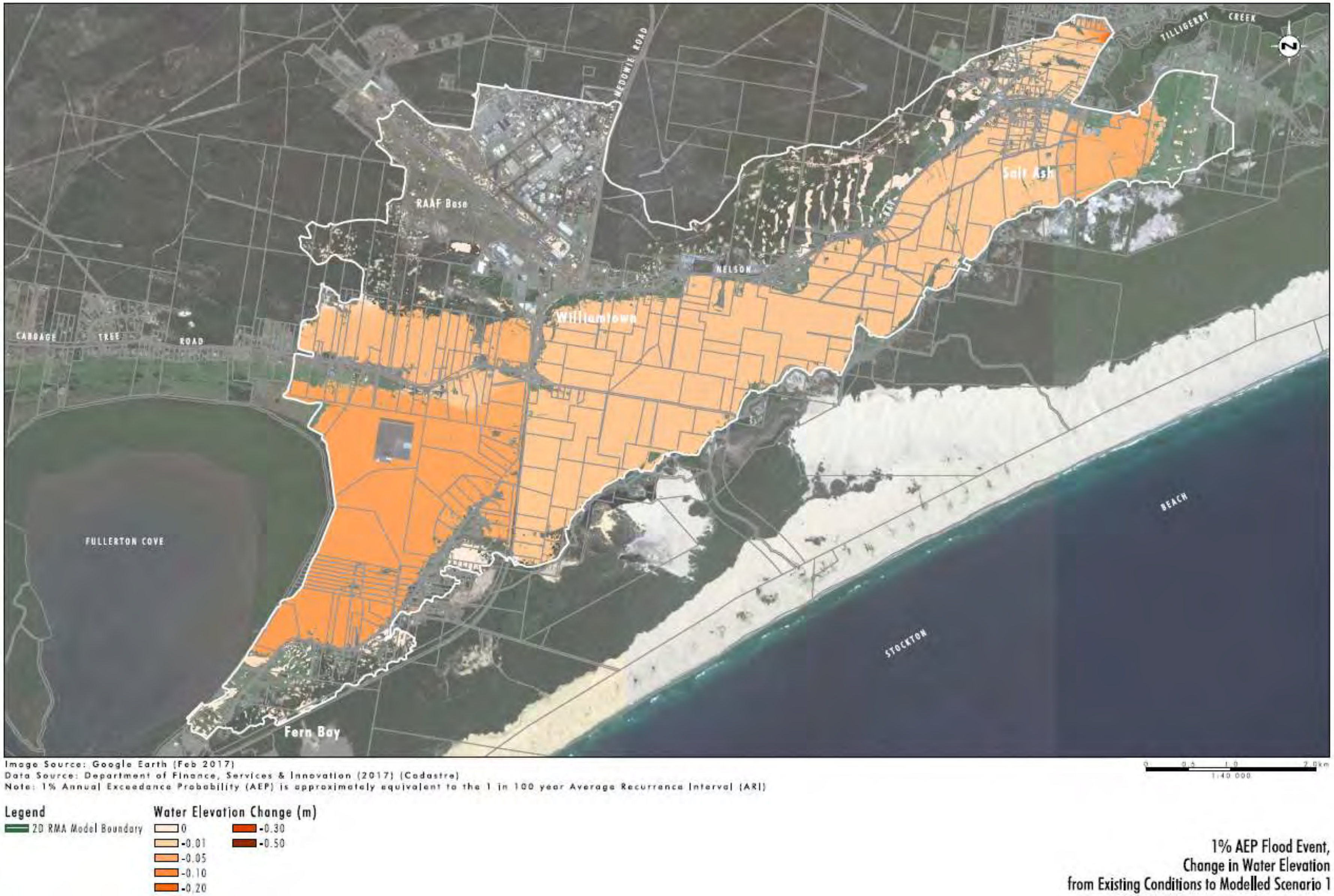


Figure 5-7 – Change in 1% AEP water elevation from existing conditions for the works presented in Appendix A, Figure A28 (Source: Umwelt 2018)

Flood impact management lands

There are several existing private properties within the Williamtown SAP area that will surround the Williamtown SAP and consequently would become sensitive receivers to the SAP if no flood management strategy is implemented. These properties would typically be adjacent to or downstream of the Williamtown SAP eg. south of Cabbage Tree Road, therefore would likely experience the greatest magnitude of any adverse impacts.

In some instances, the adverse flood impact may be too significant to reasonably mitigate within the Williamtown SAP. This scenario would warrant the consideration of including additional land outside of the Williamtown SAP to form part of the Williamtown SAP to allow flood impacts to occur and/or allow for other flood management elements such as floodplain storage offsets. This opportunity has been incorporated in the adopted flood management strategy to mitigate adverse flood impacts to surrounding private properties.

Floodplain Storage Offsets

Filling of the floodplain (bulk filling) is typically the approach taken when building in flood prone areas (also refer Section 3.1.1). This provides flood protection to the Williamtown SAP however can consequently result in the displacement of floodwater through loss of floodplain storage. The displaced floodwater usually manifests in increased flood levels in the area of bulk filling, where the flooding is largely classified as flood storage. The magnitude of increases would generally be related to the volume of lost flood storage, where a larger fill volume would correlate to a larger flood level increase. However, this can vary subject to the floodplain geometry and scale of the filling.

Subject to the hydraulic behaviour of the affected flooding, compensating for the loss of flood storage caused by the bulk filling can be applied to offset the loss. This would typically be in the form of excavating a similar volume to the fill volume below the flood level. This concept is presented in Figure 5-8 showing the filling within the floodplain and the compensatory fill to offset the loss resulting from bulk filling.

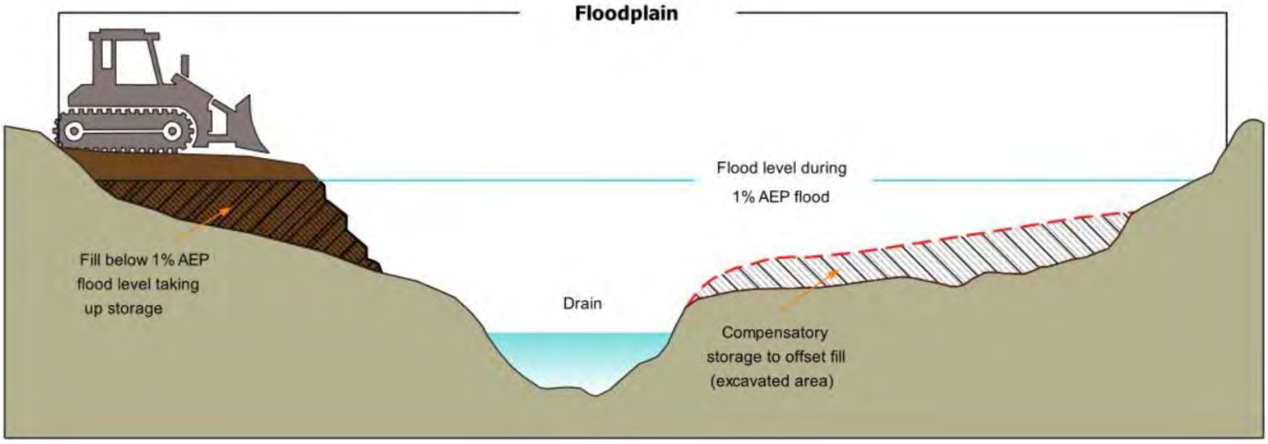


Figure 5-8 – Concept of floodplain storage offset

This approach can be applied in certain areas of the Williamtown SAP where bulk filling is adopted within flood storage area. Where this would unlikely be possible is where the ground water levels are high. In these areas, excavating the compensatory (offset) flood storage area would fill with groundwater and not provide the offset storage benefit required. An alternative to excavation may be to access more of the floodplain by allowing it to intentionally flood as the compensatory (offset) flood storage area. This could be across low value land (see previous section) to allow increases in flood levels to occur safely.

Where flooding is classified as floodway, these areas are more dependent on conveyance and bulk filling would typically result in increases in flood levels (afflux) upstream of the bulk fill area. Under this scenario, flood storage offsets may not be as effective and consideration of maintaining or compensating for the loss of flow conveyance would be required. This could be in the form of diversion channels that facilitate flow to bypass the bulk fill areas offsetting the impact of flow blockage.

Alternative Floodplain Management Strategy

Acknowledgement: The following section is based on a study undertaken by Aurecon and Sydney Water, 2017

Frequently in the design of the Structure Plan the Flood Planning Level (FPL) is adopted as the existing (pre-development) flood level for a major flood event. The FPL would typically relate to the 1% AEP design flood event and incorporate a 500mm freeboard. A good deal of effort and expense can then be made to keep any increase in flood levels minimal without necessarily assessing whether an increase can readily be tolerated through the development process. For example:

- Where the flood level increases affect green field or sparse rural residential land with homes that will be superseded through the short to medium term development process, then an increase in flood level may be deemed acceptable or manageable through flood insurance.
- There may be intermediate scenarios that are not quite clear but a flood level increase may be deemed acceptable following a negotiated arrangement with affected land owners, possibly compensation or local specific flood mitigation works.

Clearly there are other examples where any increase in flood levels is not acceptable:

- Where there are existing homes that will persist past the development process and these homes already face a significant flood risk an increase in flood level poses an increased risk to life and property.

In line with the principles of the NSW Flood Policy and the Floodplain Development Manual, a merit based approach should be applied when making these considerations. Where tolerable, design flood heights should be permitted to rise modestly to accommodate the orderly development of the floodplain, including:

- Good faith preservation of the floodplain storage-discharge characteristics across a broad range of flood events.
- Provide adequate flood protection for sensitive existing land uses such as residential homes.
- Long term creek and waterway rehabilitation targets and forms, as well as protection and enhancement of waterways and floodplains in good condition.
- Nurturing and restoring where appropriate the important relationship between creeks and their floodplain, reducing in-bank flow velocities and enhancing creek form stability.
- Long term riparian corridor vegetation and habitat rehabilitation.
- Edge landfill schemes to make more land suitable for and less land precluded from development occupation.
- To facilitate efficient road and lot layouts and deliver a geometrically smooth delineation between the working floodplain and occupied land.
- Permit moderate afflux limits to facilitate cost effective bridge spans.
- Accommodate minor infrastructure within the floodplain to support recreational and transport activity such as cycle and pedestrian routes.
- Potentially require an increase in local floodplain storages where identified within a broader catchment wide strategy to store and convey increased flood volumes associated with catchment urbanisation. There is significant potential in this concept to transform the management of urban stormwater runoff, to move away from detention basin-centric approaches and toward more integrated and distributed storage for floodwaters that can contribute to a broader range of objectives.

With respect to this project, the above alternative strategy presents an opportunity that looks to challenge the traditional approaches to land development. The project area is an ideal candidate to consider such an approach given that there is a demand for development.

5.4.2 Water Cycle Management

Potential water cycle management opportunities are described in Table 5-8.

Table 5-8 – Summary of water cycle management opportunities

Opportunity	**How the opportunity could potentially benefit the community and receiving environment**				
	Flooding	**Water quality**	**Mimicking hydrology**	**Urban cooling**	**Urban greening**
Planning control to reduce maximum impervious area on lot					
Reduce the maximum impervious area allowable on lots as a planning control to allow rainfall to percolate through pervious surfaces to recharge the local aquifer, reduce runoff volumes and associated pollutant loads as well as providing urban cooling and increased green space. This will reduce the required treatment footprint / size of infrastructure.					
How the opportunity could potentially benefit the community and receiving environment	Flooding Water quality		Mimicking hydrology	Urban cooling	Urban greening
		✓	✓	✓	✓
Siting development and treatments outside Drinking Water Catchment					
Siting development (if possible) and water quality treatment systems (or their discharge points) outside / downstream of the Drinking Water Catchment. This is unlikely to be feasible in some catchments due to the extent of the Drinking Water Catchment. Areas not within the Drinking Water Catchment are also Flood prone so this may limit the siting of treatment facilities as well.					
How the opportunity could potentially benefit the community and receiving environment	Flooding	Water quality	Mimicking hydrology	Urban cooling	Urban greening
		✓			
Setting planning controls to drive rainwater harvesting					
The aim of this control would be to reduce the volume of runoff that needs to be treated through filtration measures, reduce treatment footprints and assist in achieving water quality targets, while preserving the volumes of groundwater top up. A planning control could be site specific (e.g. 80% of non-potable water usage to be provided by rainwater) or generic (e.g. 50% annual runoff volume reduction on lot). There are currently no Port Stephens council planning controls for reuse of rainwater for industrial or commercial development. Planning controls could also be implemented for residential development (if proposed) which go further than BASIX. It would be a challenge to reduce the treatment facilities based on a single specific water reuse target given the uncertainty of industry water use particularly in logistics centres, and in any case the water use of likely development in this precinct is expected to be low. A mean annual runoff volume (MARV) reduction target could enable treatment systems down gradient to be reduced in size on the basis that the reduced runoff volume is controlled on lot. Other approaches such as infiltration and evapotranspiration could also be used to achieve this target. This approach would therefore be preferred and aligns with similar controls starting to be adopted in Western Sydney and interstate (Victoria). It is noted that rainwater tanks do not explicitly provide a benefit to long duration extreme flood events, however there are merits in using rainwater tanks to reduce WSUD infrastructure that takes up floodplain storage.					
How the opportunity could potentially benefit the community and receiving environment	Flooding	Water quality	Mimicking hydrology	Urban cooling	Urban greening
		✓	✓		

Opportunity	How the opportunity could potentially benefit the community and receiving environment				
	Flooding	**Water quality**	**Mimicking hydrology**	**Urban cooling**	**Urban greening**
Precinct stormwater harvesting					
Stormwater harvesting facilities at a precinct scale to supply water to local industry, irrigation (or other water users / needs). The aim of this would be to reduce the volume of runoff that needs to be treated downstream and assist in achieving water quality targets. However, committing to a harvesting scheme to supply water to industry during the planning phase (and realising the benefits in terms of runoff reduction as part of a strategy) is a challenge given uncertainties around industry water demand.					
How the opportunity could potentially benefit the community and receiving environment	Flooding	Water quality	Mimicking hydrology	Urban cooling	Urban greening
		✓	✓	✓	✓
On lot infiltration					
Planning controls to drive on lot infiltration facilities for roof runoff. Roof runoff may be suitable for infiltration once filtered within the Drinking Water Catchment. This would be demonstrated by modelling. This approach may reduce treatment footprint and downstream facilities. This opportunity is dependent on suitability of infiltration. Where elevated groundwater occurs, infiltration rates may not be high. Infiltration of roof water could occur via raised garden beds (acting as bioretention) adjacent to buildings to increase filtration above shallow groundwater. Passive irrigation of garden beds and street trees could also provide cooling benefits					
How the opportunity could potentially benefit the community and receiving environment	Flooding	Water quality	Mimicking hydrology	Urban cooling	Urban greening
	✓	✓	✓	✓	✓
On lot rainwater reuse strategies					
Promote the use of rainwater irrigation and other reuse including as a way of reducing runoff and pollutant loads. The CRC for Low Carbon Living has identified misting as a means of cooling the urban environment and reducing energy usage for cooling. This is particularly relevant for industrial sites where water usage is low and energy usage is high for cooling within buildings. This could be one of a range of strategies to achieving an on lot runoff volume reduction target as discussed above.					
How the opportunity could potentially benefit the community and receiving environment	Flooding	Water quality	Mimicking hydrology	Urban cooling	Urban greening
		✓	✓	✓	
Onsite (on lot) stormwater detention					
Providing onsite stormwater detention could reduce detention basin footprint requirements downstream and respond to hydraulic constraints associated with local flooding and high groundwater. The benefits of incorporating an onsite detention strategy can be tested in the flood modelling during the next phases of design. Where flooding is controlled by runoff volumes, it may be more appropriate to apply a stormwater volume management approach.					
How the opportunity could potentially benefit the community and receiving environment	Flooding	Water quality	Mimicking hydrology	Urban cooling	Urban greening
	✓		✓		

5.4.3 Opportunity Assessment

The identified opportunities were screened against the potential scenarios that were short listed. Each opportunity identified and whether it was adopted is presented in Table 5-9.

Table 5-9 – Summary of adopted opportunities

Opportunity	Description	Comment
	Flood Management	
Nelson Bay Road Upgrade	With Nelson Bay Rd as a key hydraulic control across the floodplain, lifting the road elevation may present the opportunity to control floodwaters in such a way that it would provide a beneficial flood outcome for the Williamtown SAP.	**Not adopted** Provides minimal benefit to the Williamtown SAP. Works extend beyond the proposed SAP extent.
Salt Ash/Tilligerry Creek Flood Gate Modifications	Modification to floodgate arrangement to improve the level of service under increasing climate change impacts.	**Not adopted** Provides minimal benefit to the Williamtown SAP. Works extend beyond the proposed SAP extent.
Dawsons Drain outlet to Fullerton Cove – Ring drain bypass	Construct a new Dawsons drain outfall into Fullerton Cove. This arrangement bypasses the Ring drain and alleviates pressure on the drainage network downstream.	**Not adopted** Provides minimal benefit to the Williamtown SAP. Works extend beyond the proposed SAP extent.
Drainage easements and ownership	Consolidation of fragmented ownership of the drainage network. Allocation of easements to allow for improved access and maintenance.	**Adopted** Ownership of the drainage network and allowance for drainage easements within the proposed Williamtown SAP boundary has been adopted.
General drainage upgrades	General upgrades to culverts and drains to improve drainage performance.	**Not adopted** Only marginal improvements predicted. Provides minimal benefit to the Williamtown SAP. Works mainly extend beyond the proposed Williamtown SAP extent.
Additional land to offset flood impacts	Inclusion of additional land to allow adverse flood impacts to occur as opposed to augmenting structural mitigation measures.	**Adopted** Additional land has been included in the Structure Plan for the function of flood impact offset areas (flood storage offsets).
Flood storage offsets	Areas where flood storage can be reclaimed or to offset the loss of current flood storage due to bulk filling of the floodplain.	**Adopted** Flood storage offset areas have been identified to assist in the management of adverse flood impacts associated with filling the bulk filling within the Williamtown SAP.
Potential fill locations	Careful selection of locations where bulk filling is tolerable with limited adverse impacts on flooding.	**Adopted** Location where filling could occur has been adopted.

Opportunity	Description	Comment
Alternative floodplain management strategy	A concept of rehabilitating and creating flood storage and detention within the trunk drainage reserve.	**Not adopted** Not applicable to this floodplain characteristic. Better suited to floodways rather than flood storage areas.
	Water Cycle Management	
Planning control to reduce maximum impervious area on lot	Limit impervious surfaces on lot to safeguard the proposed wetland strategy	**Adopted** Delivery plan to set control which considers both on lot rainwater reuse and on lot perviousness
Siting development and treatments outside Drinking Water Catchment	Locate development outside the Drinking Water Catchment to avoid the need for excessive infrastructure to achieve NorBE (particularly in existing bushland areas)	**Partially Adopted** Where possible development was sited outside the Drinking Water Catchment and downstream of any groundwater borefield.
Setting planning controls to drive rainwater harvesting	Development control to ensure rainwater harvesting is implemented on lot to reduce downstream (wetland) infrastructure requirements and safeguard treatment strategy.	**Adopted** Delivery plan to set control which considers both on lot rainwater reuse and on lot perviousness
Precinct stormwater harvesting	Stormwater or rainwater harvesting facilities at a precinct scale to supply water to local industry or for irrigation.	**Not Adopted** Rainwater harvesting on lot proposed.
On lot infiltration	On lot infiltration to recharge aquifer and reduce runoff volume to be treated at wetlands downstream.	**Not Adopted** Not adopted due to NorBE constraints. Could be considered on a development lot basis if NorBE achievable.
On lot rainwater reuse strategies	Promote the use of rainwater irrigation and other reuse including as a way of reducing runoff and pollutant loads.	**Adopted** Rainwater harvesting on lot proposed. Delivery plan to set control which considers both on lot rainwater reuse and on lot perviousness.
Onsite (on lot) stormwater detention	Provide onsite detention storages on lot to reduce the need for precinct / regional flood detention infrastructure	**Not Adopted** Current analysis indicates that there is satisfactory storage in the proposed channels and wetlands (above normal water levels) followed by discharging into the regional detention basin (bio-conservation area).

6 Structure Plan

6.1 Methodology and Approach

Section 6 of the report provides a summary of the scenario development during the second EbD workshop held on the 27th to 30th of April 2021. This workshop involved the further testing of the previously prepared scenarios and development of the Williamtown SAP Structure Plan. Like in the previous EbD workshop, the Structure Plan considers land use, transport, infrastructure, PFAS, environmental, social, aboriginal heritage and economic matters in conjunction with the Williamtown SAP vision.

Figure 6-1 provides an outline of the key principles which were incorporated into the masterplan.

Figure 6-1 – The 7 Williamtown SAP Principles which governed the masterplan

The Structure Plan leverages the preferred elements of all the scenarios developed, further explores the items under investigation and avoids the earmarked no-go zones. The previously identified strengths and opportunities of each scenario were pursed while weaknesses and threats mitigated. This approach was taken to maximise the positive development outcomes rather than considering the previous scenarios as options and adopting one as the preferred structure plan.

6.2 Proposed Structure Plan

The Structure Plan refined by Roberts Day is centred around the existing Williamtown Airport Precinct, which includes Newcastle Airport, Williamtown RAAF base and Astra Aerolab. The Williamtown SAP incorporates a core development area south of the existing airport. The Williamtown SAP is to incorporate a flexible approach to land uses which prioritise aerospace, freight and logistics, commercial, advanced manufacturing and defence industries. The proposed Williamtown SAP is generally focused north and east of the environmental protection area. The plan shown in Figure 6-2 adheres to the existing drainage and flooding characteristics and incorporates the inclusion of the Dawson's and Leary's drain reserve. Additionally, it maintains hydrological regime for the biodiversity corridor, facilitates controlled flooding throughout the Williamtown SAP and utilises floodplains South of Cabbage Tree Road to offset impacts.

Refer to Hatch Roberts Day report for further details regarding the structure plan (*Williamtown SAP Final Enquiry by Design Workshop Outcome Report, dated 30/04/2021*)

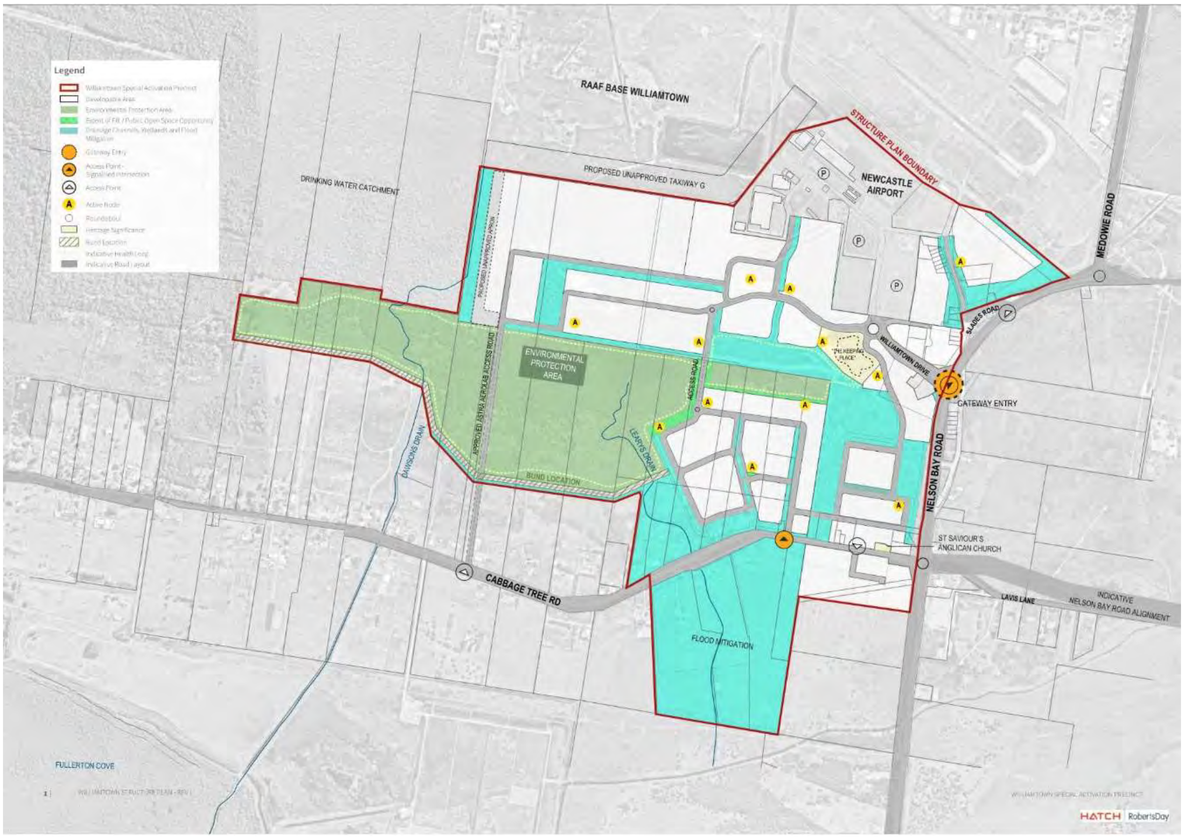


Figure 6-2 – Williamtown SAP Structure Plan

6.3 Stormwater Strategy Development

6.3.1 Strategy Evolution

The development of the stormwater management strategy evolved to accommodate the various constraints that have come to light as the project progressed.
The initial strategy adopted a standard drainage and water quality approach for industrial precincts and took the form of regional scale stormwater management (ie. detention basins and biofiltration) infrastructure. This regional approach sought to consolidate drainage infrastructure in for maintenance and simplify land acquisition whilst maximising developability of the precinct.

Other stormwater scenarios included multiple separated catchment areas, distributed across the Williamtown SAP. The geographic separation and flat topographic gradients of the catchments did not lend itself to an efficient regional stormwater management strategy. It needed to respond to the fragmented catchments individually therefore a central regional system to service the Williamtown SAP was not a feasible approach.

Servicing fragmented catchments with individual stormwater management infrastructure was considered. The area for the regional infrastructure was initially identified for the floodplain areas, which allowed for developable land to be located outside of the higher risk floodway areas. However, as the constraints were identified in more detail, this approach was further challenged by the following:

- Flat topographic gradients – presented a challenge for draining stormwater over precinct scale distances and consequently requiring significant excavation depths or bulk fill levels to accommodate the drainage gradients. The excavation was not feasible due to the water level constraints of the receiving waterways. Therefore, bulk fill levels were impacted and at the same time was identified as a significant cost component to the project.
- Greater land-take requirements for infrastructure in the floodplain downstream of the SAP– flatter topographic gradients would result in shallower detention basins (ie. Less storage) therefore consequently requiring larger footprints to achieve the same volumes. Despite the infrastructure being proposed on lower value land, the land-take required was not seen as efficient.

- Regional flood impacts – With the infrastructure proposed across the less developable areas ie. Floodplain areas, and larger due to flatter gradients, the influence on regional flooding would become more significant. Regional flooding is widespread with flat hydraulic gradients. This means that small changes to flood levels due to development within the floodway would have adverse flood impacts spread across large areas of existing properties.
- High groundwater levels – the potential locations for regional stormwater management infrastructure are also within areas of high groundwater levels. This impacts on the stormwater management infrastructure by limiting the depths which can be excavated otherwise constant infiltration of groundwater into the detention basin or wetland would occur and render the storage ineffective. This constraint compounds with the flat topographic gradients and greater land-take requirements noted above.
- Climate change – Future coastal inundation due to climate change is predicted to be extensive across the Williamtown floodplain and Salt Ash floodplains. This would require further lifting and filling of the precinct to prevent the regional infrastructure becoming drowned and ineffective.
- PFAS mitigation strategy – The use of certain PFAS mitigation measures such as geosynthetic clay liners (GCL) and powder activation carbon (PAC) have been explored. The proposed adaptive management strategy is contingent on several concurrent factors such as Defence remediation works, SAP development, and PFAS migration through the groundwater and surface water (if at all). The dynamic plan is outlined in the PFAS and non-PFAS contamination report which details the current PFAS mitigation strategy, the connections between all applicable disciplines such as flooding and water cycle management and alternative solutions that were considered.

The constraints on regional stormwater management presented a strong case against the regional approach. The logical response was to adopt a distributed approach that saw the infrastructure within the Williamtown SAP, closer to the source. This overcame the identified constraints with the main disadvantage being a reduction in developable area.

6.3.2 Precinct Strategy Development

With the strategy to incorporate stormwater management into the arrangement and location of stormwater infrastructure was tested to optimise function while minimising the resulting need for bulk filling.

The existing topography is very flat and low, hence flow path lengths and level changes have a significant impact on the fill requirement. The preferred strategy aims to minimise flow path lengths and level changes as much as possible by utilising swales and wetlands, where possible, to convey flows at lower grades and with lower requirements for level changes.

The options investigated to develop the drainage and water quality strategy is outlined as follows:

- Initially, a water quality treatment strategy involving wetlands to treat the entire precinct south of Cabbage Tree Rd was investigated but deemed unsuitable. This along with drainage requirements presented significant bulk fill levels due to drainage lengths.
- Bio-retention systems were tested within the Williamtown SAP and provided the required level of pollutant stripping and require flow splitting and staging during precinct establishment. Bioretention was preferred if
  - Stormwater could be distributed across the biofiltration surface areas without significant level changes to drive flow splitting.
  - Treated stormwater could be drained away from the biofiltration without creating long flow path lengths and grade changes in collection pipes
  - Biofiltration could be consolidated into single basins as much as possible and divided into cells no greater than 1000 m^2
  - High flows could be managed without scouring or displacing biofiltration media and plants
- Hydrocon (permeable) pipe arrangement to exfiltrate stormwater into bioretention media below surface (to reduce elevation differential over the system) and via a surcharge pit, with high flows

overflowing into an adjacent drainage corridor was deemed unsuitable because the grades for its entire length resulting in increased fill requirements

- Distributing wetlands within the precinct, and locating the wetlands closer to the source, overcomes grade constraints but require a relatively large treatment footprint to achieve the adopted pollution stripping objectives. Wetlands were considered to be the preferred strategy given
  - less level change is required between wetland inlets and outlets
  - Wetlands could accommodate high flows given low velocities
  - Wetlands provide pollution stripping, stormwater conveyance, flood conveyance and attenuation where required at flat grades
  - Wetlands accommodate extended periods of ponding without creating management issues, unlike swales

A combination of wetlands and biofiltration were selected as the benefits of each could be paired together to achieve the adopted pollution stripping targets while overcoming the management issues associated with flat grades and the resulting extent and duration of inundation associated with frequent rain events.

The outcome of the strategy investigation is presented in Figure 6-3, which shows the water quality, drainage and grading arrangement proposed for the Williamtown SAP. The general intent of the strategy is to maximise onsite water quantity and quality measures to reduce bulk filling requirements, although there is a minor reduction in developable land within the Williamtown SAP boundary.

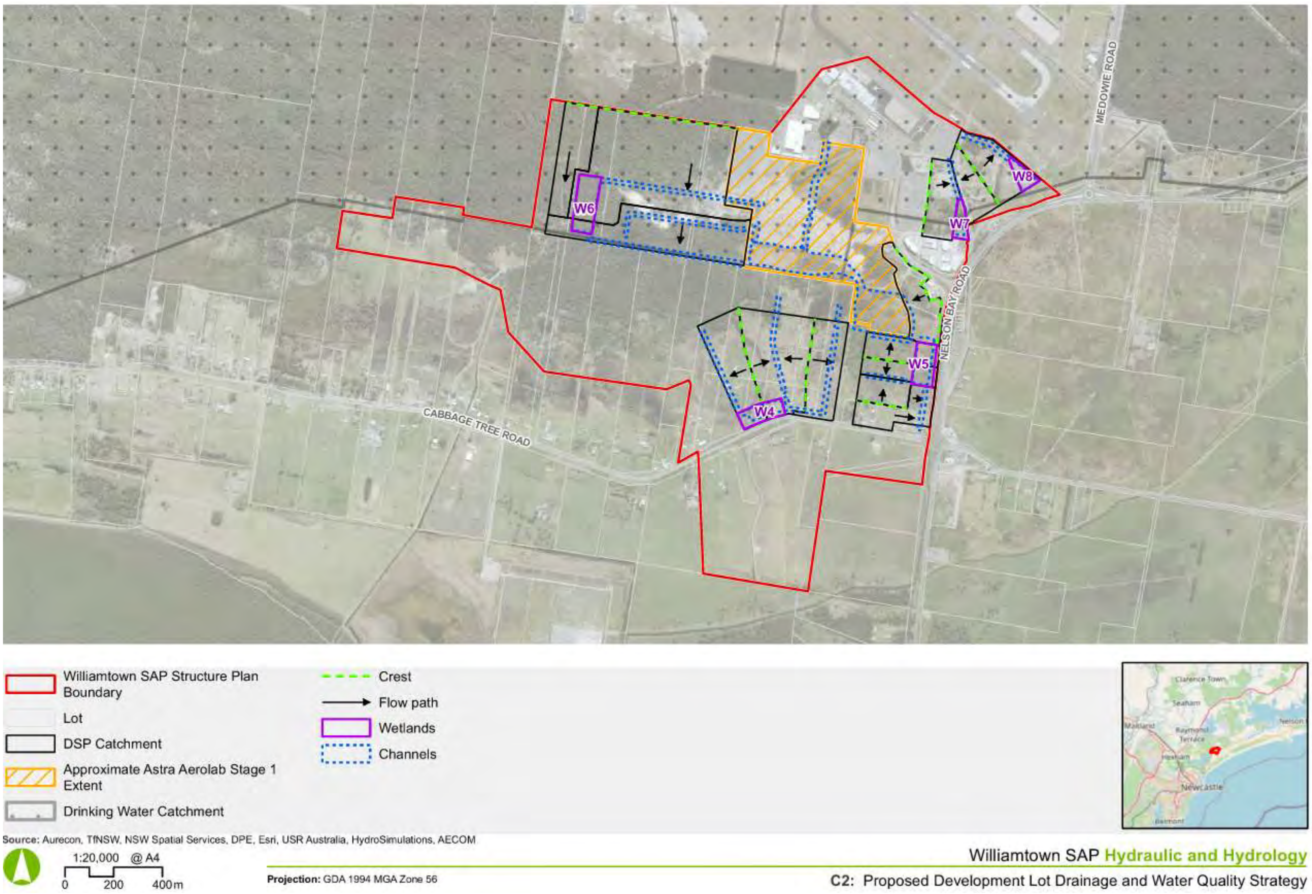


Figure 6-3 – Proposed development lot drainage and water quality strategy

Table 6-1 below presents the key design parameters that underpin the strategy and influence the bulk filling requirements.

Table 6-1 – Adopted key design criteria

Parameter	Value	Comment/Justification
Channel longitudinal grades within the Williamtown SAP extent	0.1%	This represents the trunk drainage conveyance mechanism that directs water to the points of discharge from the Williamtown SAP. It is noted that the physical construction of a near zero grade channel may not be practical given construction tolerances. However, precedence has been set by Astra Aerolab who have been through this process and have received PSC approval for a near zero grade design channel.
Wetland longitudinal grades	0%	Typically considered acceptable to promote required residence time for settlement and nutrient uptake.
Longitudinal Road to create intermediate sag and crests (sawtooth arrangement)	0.3%	Minimum pavement longitudinal grades for drainage as per Port Stephen Council's engineering guidelines. Road cross-fall grades are expected to remain at a typical 3% grade.
Lot surface grading from gullies to ridges	0.5%	Minimum 0.5% is considered necessary to facilitate underground on-lot pipe drainage and minor road grades that then discharge to the trunk channel and wetlands. This approach will accommodate steeper saw-tooth grading patterns where necessary.
Tailwater level control for drainage and water quality design	1.6mAHD	Design intent is to have the wetland and channel outlet inverts at this level as a minimum. The level was set based on downstream Mean High Water Springs (MHWS) Tide level + 900mm increase for climate change. This also ensures the wetlands and drains are above groundwater level. There is an opportunity to lower tailwater conditions following further risk investigation and acceptance of design requirements regarding climate change.
Bulk filling fill batter slopes existing interfacing land	V1:H4	Adopted maximum batter slope to grade bulk filling back to existing surface levels

6.3.3 Birdstrike Management

Proposed WSUD features that function as wetlands are required within the Williamtown SAP which incrementally increases the surface area of water bodies in proximity to the airport, within the birdstrike zone area. The measures proposed for the management of the birdstrike risk are as follows:

- Steep batters below the extended detention level of wetland macrophyte zones to reduce foraging habitat
- Steep batters of the wetland inlet /sedimentation pools to reduce foraging habitat
- Wetland is within the Williamtown SAP so will frequently be disturbed by people and vehicles
- Macrophyte planting will be designed to limit open water for large birds landing
- Smaller open water areas to limit larger birds landing
- This approach replicates what has already been proposed and constructed for Astra Aerolab site plus additional measures as noted above.

Overall, with the management features outlined above, the Williamtown SAP is not expected to represent an increased birdstrike risk compared to the existing wetlands currently present within the low lying areas of the site.

6.3.4 Bulk Filling

Bulk filling is a significant component of the proposed Williamtown SAP. From baseline analysis of the Williamtown SAP Study area (Section 3.1.1), bulk filling was identified as a need driven by the fact that the majority of the potential developable areas were within flood prone land and drainage function will be affected by future tidal levels under sea levels predictions (ie. +900mm). The level of bulk filling was not quantified at the time however it was noted that volumes would have a significant impact on the cost of delivery.

At that time, the approximate design level for bulk filling was based on achieving flood immunity to the 1% AEP event for the year 2100 (Climate change). Adding a freeboard on top would increase fill levels by 300 to 500mm, subject to the project's tolerance for additional bulk filling. If the freeboard was not incorporated, it would have been incorporated in the form of either floor level controls or residual filling by individual developers to achieve a total of 500mm freeboard.

As the stormwater strategy evolved (Section 6.3), the feasibility assessment identified that the key driver for the volume of bulk filling included other factors relating to the development rather than flood protection from external flooding. These factors include:

- Drainage outlet levels from the precinct to be above the predicted climate change levels for the year 2100 (refer Section 6.3.6). This was to allow free discharge and limit the risk of saltwater ingress into the wetland system.
- Minimising interaction with contaminated soil by limiting depth of excavation into existing ground levels.
- Minimising depth of infrastructure to limit groundwater exfiltration into open channels and wetlands.
- Drainage network grades to achieve positive drainage from the outlet to the underground drainage network servicing the individual lots.
- Development fill pad grades and road grades to achieve suitable cover to the underground drainage network
- Configuration of the Williamtown SAP where drainage lengths further from the outlet result in higher fill elevations to maintain minimum cover.

A typical section of the constraints around tailwater levels that consequently impact on bulk fill levels is shown in Figure 6-4. It illustrates the alternative tailwater level options that could be adopted which informs the flow on effect I has on bulk fill levels.

Adopting minimum grades for the above-mentioned elements influence the bulk fill level to a greater extent than external flooding. This is in keeping to the minimum end of industry standard design criteria for most of the elements. The resulting bulk fill volumes based on the proposed strategy is shown in Table 6-2.

Table 6-2 – Indicative Bulk earthworks estimates

Site	Total Cut (m^3)	Total Fill (m^3)	Balance (m^3)
Williamtown SAP	137,000	1,486,000	1,486,000

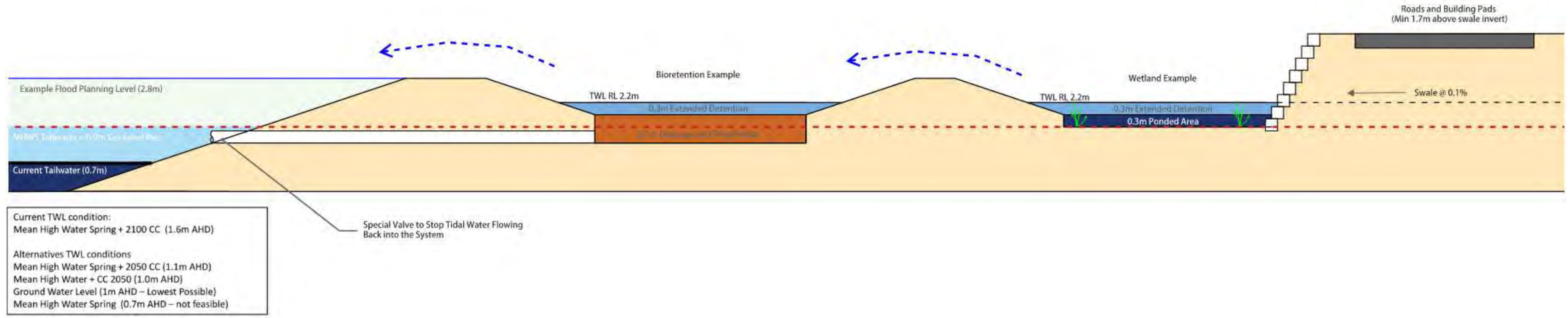


Figure 6-4 – Typical section depicting various tailwater level options and the influence on bulk fill design levels

6.3.5 Trunk Drainage Design Criteria

Trunk drainage prescribed for the precinct comprises open channels, floodways, flood storage and precinct scale wetlands. The trunk drainage scheme allows for minor pit and pipe drainage networks and outlet structures to be designed at subsequent design stages.

The key constraints for the channel and floodway sizing were the adopted levels, bulk filling volumes and the land take requirement (aesthetics and connectivity) for drainage easements. The proposed open channels were sized initially for water quality then incorporated the floodway conveyance function to fit within the remaining space.

A check of floodway function was undertaken through a hydraulic analysis using *DRAINS* software. The results indicate that the current channel capacity is sufficient to convey flows to the wetlands. The DRAINS analysis was based on the following parameters:

- 2016 BOM rainfall
- ARR 2019 temporal patterns
- Tailwater level of 1.6m AHD (consistent with the stormwater strategy – refer Section 6.3.6Table 6-1)
- ILSAX hydrological model

The capacity of the channels would accommodate peak flows up to the 1% AEP event with limited freeboard to the anticipated road level (Figure 7-26). Subject to design development, conveyance of overland flow along the road network at shallow depths may occur in rare events, which is not an uncommon approach to managing flood flow in larger flood events.

6.3.6 Climate Change Influence on Bulk Filling

Although the grades of the trunk roads and wetlands are set relatively flat, the key driver for bulk filling is to mitigate flood impacts from climate change and drainage impacts from increased tide and sea levels. The proposed criteria which the strategy is based on seeks to provide trunk drainage with an outlet level that is set to the future predicted high tide level.

The coastal hazard and management study for Williamtown is understood to be currently in progress, based on discussions with Port Stephens Council (PSC). In the absence of this information, and for the purposes storm frequencies associated with water quality management, the current tidal plane levels plus sea level rise was adopted. This was based on the Mean High Water Springs (MHWS) tide (0.69mAHD as per Table 6-3) plus predicted sea level rise of 0.9m, giving approximately 1.6mAHD as the current design tailwater level for water quality and drainage. Although Fullerton Cove levee currently provides for protection from tidal inundation, the impact of sea level rise are being observed today with overtopping of the levee under king tide events, according to anecdotal information from the Hunter Valley Flood Mitigation Scheme (HVFMS) managers. Through consultation with the scheme managers, no future projects for the augmentation of the levee are currently in planning. Furthermore, groundwater levels may increase due to the influence of sea level rise, further inundating low lying areas. In consequence, it was decided to assume that the levee would not provide the future climate resilience necessary to optimise bulk filling to the minimum possible levels.

The Structure Plan levels with flood mitigation, ie. detention basin, would require being set at an elevation of approximately 3.2 mAHD (excluding 500mm freeboard) to be flood free up to the 1% AEP, year 2100 event. This level could be challenged during subsequent stages of the Williamtown SAP design development by allowing general controlled flooding of the precinct but requiring individual lots to achieve the flood protection level objective. This latter proposal would need to be further developed and tested against the expectations of the businesses that are likely to occupy this area.

Table 6-3 – Tidal planes for Hunter River at Mallabula Point (*Source: BMT (2017)*)

Tidal Plane	2022 Water Level (m AHD)*
High Water Solstices Springs (HHWSS)	1.08

Tidal Plane	2022 Water Level (m AHD)*
Mean High Water Springs (MHWS)	0.69
Mean High Water (MHW)	0.56
Mean High Water Neaps (MHWN)	0.42
Mean Sea Level (MSL)	-0.01
Mean Low Water Neaps (MLWN)	-0.44
Mean Low Water (MLW)	-0.58
Mean Low Water Springs (MLWS)	-0.71
Indian Spring Low Water (ISLW)	-0.99

Note: *Conversion to AHD from Port Stephens Height Datum (PSHD) = -0.949m (MHL, 2012)

6.3.7 Water Quality Treatment

Various water quality treatment concepts were developed to check fill requirements and inform the strategy development as discussed above. The preferred treatment train is shown in Figure 6-5, which was adopted to avoid groundwater interaction.

Given the Williamtown SAP is downstream of the drinking water catchment bore field and is only a minor portion of the overall aquifer, impacts to the Tomago sand bed aquifer as a result of the reduced recharge are considered to be minimal. An estimate of the change in groundwater recharge is provided within the water balance in Section 7.6. Further discussion on this issue is provided within the Hydrogeology report.

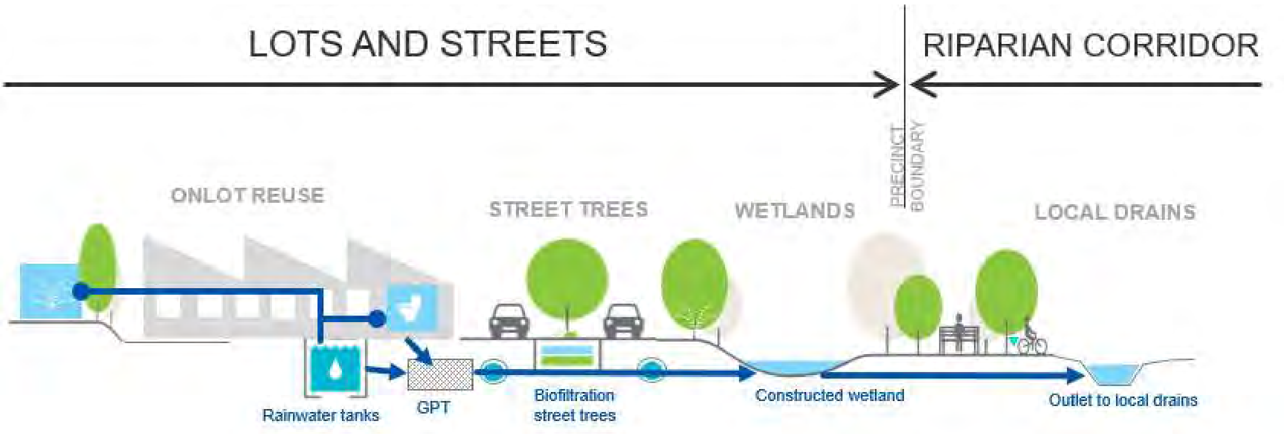


Figure 6-5 – Preferred WSUD treatment train

Further detail is provided in section 7.4.

6.3.8 PFAS Mobilisation

The risk of PFAS mobilisation has been managed at several levels of this project. The greatest risk of PFAS mobilisation from a flooding and Water Cycle management has been identified at a Water Cycle Management scale. Based on current understanding of PFAS movement (refer Figure 6-6) and the length of time since PFAS was identified. PFAS mobilisation under a flood scenario is considered to be minor in comparison to more frequent events (ie. sub yearly events). Frequent storm events have a cumulative effect and present a more significant influence on mobilisation compared to a less frequent regional flood event. Furthermore, the Williamtown SAP will be limited to the fringes of the regional flood extents as much as possible to mitigate flood impacts. Consequently, these areas are influenced to a greater extent by local flooding and the water quality management strategy.

In accordance with current PFAS plume modelling, the future development in the vicinity of the Defence Base will occur above the PFAS plume extents. Stormwater and groundwater management measures (refer section 5.1.1 and 5.3.2) were proposed to limit changes to existing groundwater recharge rates, and therefore reduce the risk of the Williamtown SAP altering groundwater and plume behaviour. However, a GCL has been proposed to prevent migration of PFAS into the fill material. This limits the potential for groundwater recharge where the GCL is installed. The impact of the GCL on recharge of the Tomago sand bed aquifer is discussed in the Contamination and Hydrogeology report. It was concluded that a GCL is unlikely to have a significant impact on aquifer recharge or PFAS mobilisation rates.

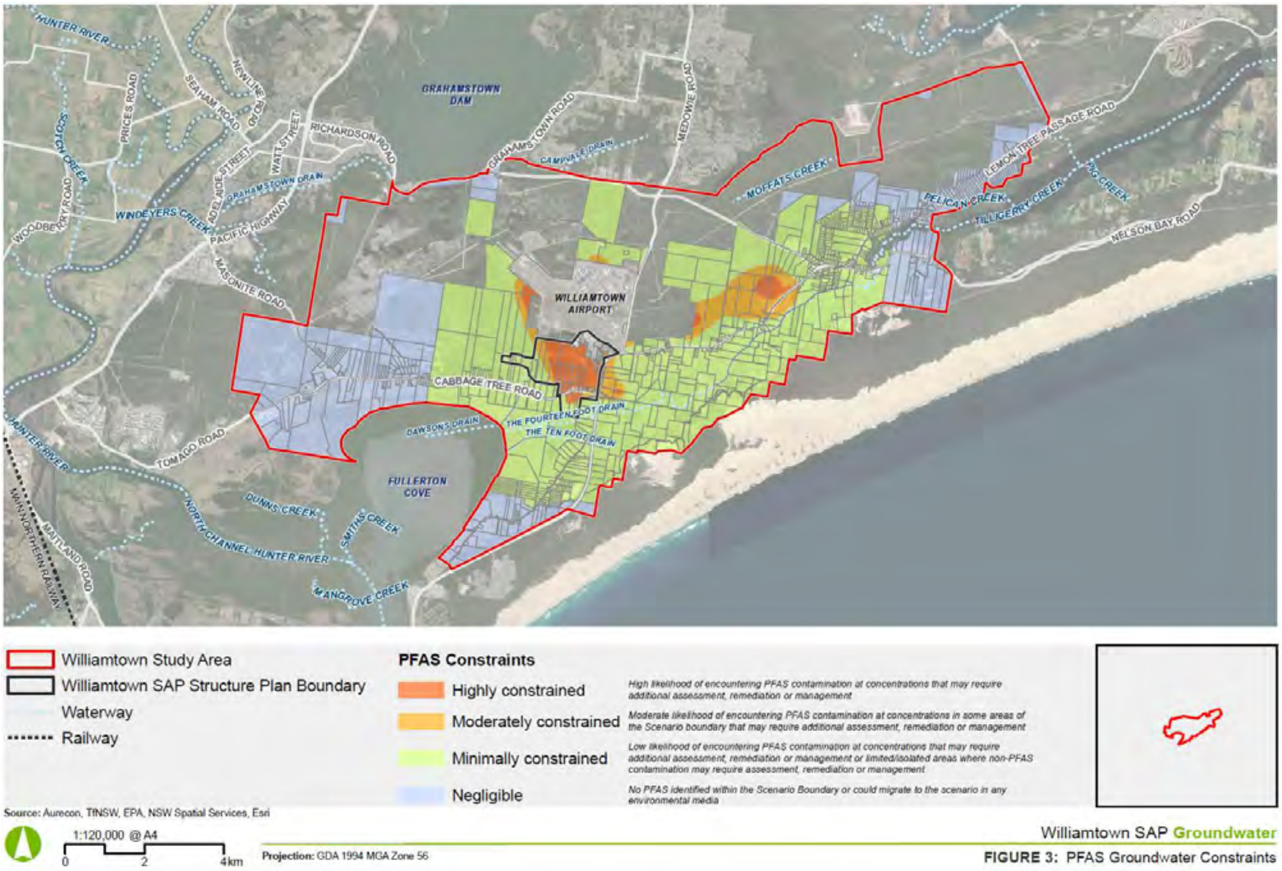


Figure 6-6 – PFAS Groundwater contamination constraints

7 Preferred Flood and Water Cycle Management Plan

A combination of on-lot and precinct scale stormwater management has been proposed to support the structure plan which respond to the various constraints while ensuring the flood management, drainage and pollution stripping objectives are met.

The proposed flood and WCM approach includes:

- Rainwater tanks to offset potable water use
- Gross Pollutant Traps (GPT's) on the lot maintained by private owners
- Pit and pipe drainage on the lot
- Pit and pipe drainage within streets to convey runoff from minor rain events
- Longitudinal drainage channels (open swale drainage infrastructure) to convey flood flows between roads
- Cross drainage culverts to convey flood flows under roads
- Constructed wetlands and biofiltration basins to achieve stormwater pollutant load reduction targets and minimise changes in water quality concentrations to downstream sensitive receiving environments
- Detention basins located within publicly owned land, to be owned and operated by Council, to be constructed as part of initial activation works and become community features.

Flooding and WCM elements will manage the full range of flows up to and including the 1% Annual Exceedance Probability (AEP) event. The role of the WCM elements is summarised in table below.

Table 7-1 – Overview of functional elements of the flood and water cycle management strategy

	On Lot (Private)	**Within Street Network (Public)**	**Precinct Scale (Public)**
Stormwater Quality (events up to 4 equivalent-events-per-year)	Rainwater tanks to supply 80% of non-potable water demands on the allotment Gross pollutant traps to remove 100% of gross pollutants and 64% of sediment loads from the allotment	Street scape passively irrigated trees and/or plantings – to deliver urban cooling outcomes, as well as reduce stormwater pollution loads from streets and reduce stormwater runoff volumes	Constructed wetlands - Detain low flows to contribute towards pollution reduction targets and distribute flows across biofiltration Biofiltration – Achieve stormwater water quality targets
Minor Drainage Network (events up to 10% AEP)	Pit and pipe (notionally 450mm and 600mm reinforced concrete pipes (RCP)	Pipes within local roads (notionally 600 RCPs and shallow box culverts) Swale drains – contain flows with freeboard to top of bank Culverts at road crossings – convey flows with freeboard to carriage way level	Open channels – convey flows generated within the Precinct to detention basins Culverts - convey flows under roads with freeboard to carriage way level

	On Lot (Private)	Within Street Network (Public)	Precinct Scale (Public)
Major Drainage (events up to 1% AEP)	Overland flow paths – convey flood waters within building setbacks	Roadside swale drains – convey majority of flood flows away from the Williamtown SAP Overland flow in streets – engaged when pipe and swale capacity is exceeded and provide 500mm freeboard to adjacent buildings. Also provide safe conditions for pedestrians and vehicles (depth and velocity)	Cut off drains – divert external flood waters around the Williamtown SAP in the Precinct Open channels and culverts – as above Detention above wetlands – details runoff from the Precinct to preserve downstream flood levels in local flood events Detention storage in riparian corridors and bio conservation areas – details runoff from the Precinct and external areas to preserve downstream flood levels in local flood events.

The specific benefits of the preferred integrated flood and WCM management strategy ensures:

- Functionality of the proposed drainage elements within the constraints of the existing downstream and upstream drainage elements
- Appropriate level of rainwater reuse to suit industrial development while providing flexibility, avoiding over-reliance on stormwater reuse to achieve pollution stripping targets
- High levels of stormwater pollution stripping and minimal risk of water quality impacts to downstream Ramsar wetlands while balancing developable land and footprints for WCM (stormwater quality) basins.
- Flexibility of staging water quality basins to suit the level of development within each catchment, and deferring construction of all water quality elements at one time
- Ability to use wetlands to distribute flows evenly across multiple large biofiltration basins areas and control the distribution of water into several biofiltration basins
- Optimal finished surface levels and drainage gradients that minimise the volume of earthworks volumes required to make the drainage, water quality and flood management strategy functional.
- Flexibility to optimise wetland and biofiltration basins further to achieve more or less pollution stripping as required to accommodate different industrial business types in the Precinct or remove reliance on passively irrigated street trees
- Dual function of land as flood detention, conservation land and water quality infrastructure.

7.1 Flood Management Strategy

With bulk filling required to provide multiple functions for the Williamtown SAP e.g., site grading, drainage, flood protection etc. (refer Section 6.3.4), filling of the floodplain will consume flood storage at the selected development location and as such will displace floodwater. This results in changes in flood behaviour, typically being increases in flood levels to adjacent properties and considered an adverse flood impact. To mitigate and manage these impacts, it is proposed to implement the following strategies to mitigate and offset the flood impact on and from the Williamtown SAP.

- Bulk filling to achieve flood protection
- Regional detention basin

- Cutoff drains
- Culvert upgrades
- Minor channel regrading
- Offset flood storage areas
- Bypass for Astra protection

The proposed flooding management measures are presented spatially in Figure 7-1 and a summary of each presented in Table 7-2.

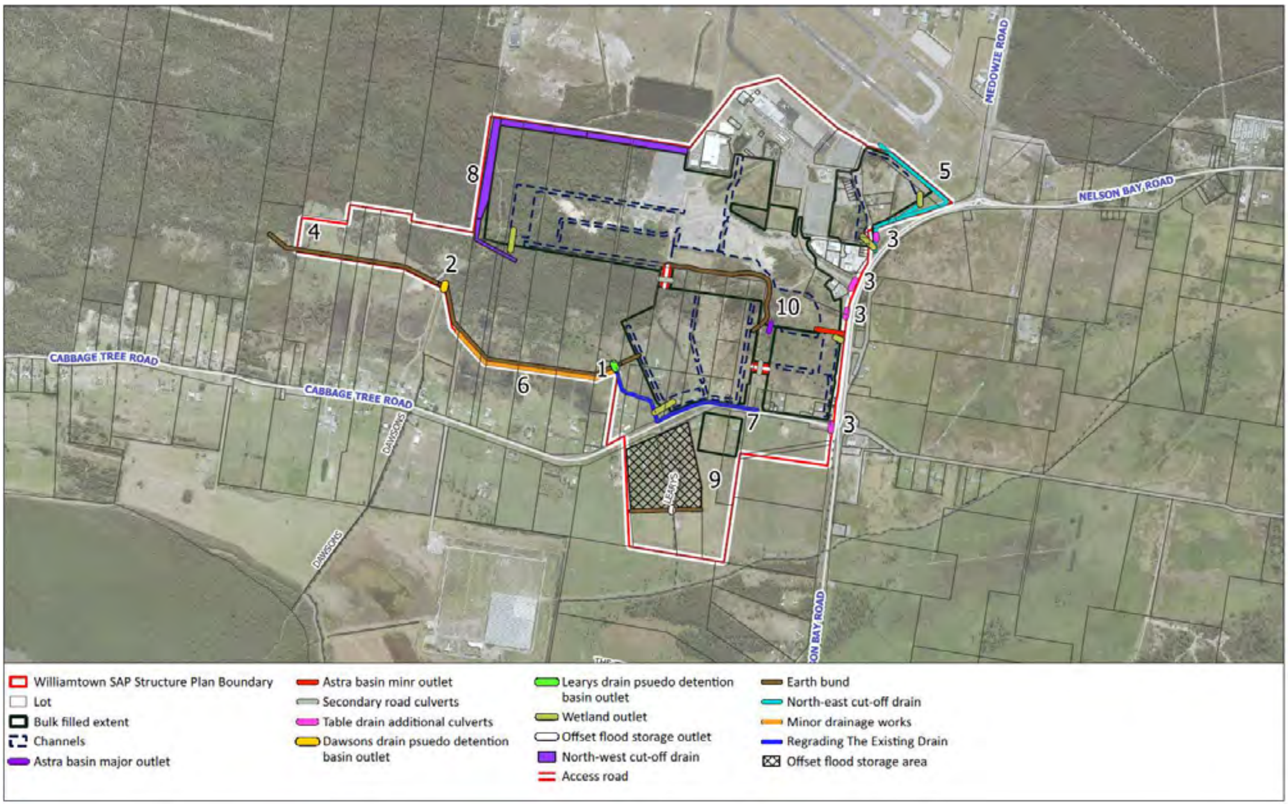


Figure 7-1 – Proposed flood management measures to facilitate the Williamtown SAP

Table 7-2 – Proposed management measures to facilitate the Williamtown SAP

ID (Figure 7-1)	Management Measure
1	Basin outlet control structure on Learys Drain To attenuate flows and offset/limit flood impacts to the downstream floodplain
2	Basin outlet control structure on Dawsons Drain To attenuate flows and offset/limit flood impacts to the downstream floodplain.
3	Additional culverts along the Nelson Bay Rd table drain to improve drainage capacity for the north-eastern upstream areas (next to the intersection of Medowie Road and Nelson Bay Road).
4	Earth bunding To create the regional detention storage area (ie. detention basin) that mitigates adverse impacts downstream due to the Williamtown SAP bulk filling of the floodplain.
5	North-east cut-off drain To reduce the flood levels to the north-east along the airport boundary by constructing a new flow path and diverting floodwaters to the Nelson Bay Road table drain.

ID (Figure 7-1)	Management Measure
6	Minor drainage lines through bio-conservation area discharging into Learys drain and new drainage line along Learys drain To reduce the inundation duration of flooding in very frequent events
7	Regrading Cabbage Tree Road table drain To facilitate the transfer of floodwaters into Learys drain and prevent the overtopping of Cabbage Tree Road
8	Northern cut-off drain To mitigate flood impacts next to the Lake Cochran and divert flows around the Williamtown SAP bulk filling.
9	Floodplain storage offsets south of Cabbage Tree Road Prevent flood impacts on downstream development by excavating the area to offset loss of flood storage in more frequent events.
10	Astra Aerolab high flow bypass To mitigate downstream impacts and disconnect the existing development from higher tailwater levels in the proposed regional detention basin.

7.1.1 Regional Detention Basin

As previously noted, the proposed bulk filling of the Williamtown SAP displaces floodwater westward due to the loss of flood storage in the floodplain. This sees increases in flood levels resulting in unacceptable impacts to adjacent properties. This impact is primarily attributed to external catchment flooding, rather than due to the drainage and flooding internal the Williamtown SAP.

Given the bio-conservation area will form part of the Williamtown SAP, this provided an opportunity to use the area for flood storage and offset the loss of flood storage resulting from the Williamtown SAP. External flood water originates from the north-western catchment area (drinking water catchment) and travels south towards Fullerton Cove. Runoff from the upstream catchment would be detained and throttled at Dawsons Drain and Learys Drain by bunding the bio-conservation area and detaining floodwater within that area (refer Figure 7-1 and Table 7-2).

Several iterations of the bund alignment were investigated to balance cost, community disruption and performance. The main metric was flood levels which required a balance between the impacts upstream of the detention basin and downstream flood impacts. This also needed to be checked and balanced between the local and regional flooding mechanisms to confirm flood impacts are aligned with the design criteria.

Alternative bund lengths and alignments in close proximity to the Williamtown SAP fronting Cabbage Tree Road were trialled. These initially included north-south road options which aimed to use the road embankment as a bund, however it's not until further west that there is sufficient upstream catchment to provide sufficient storage or detention of flows to offset the Williamtown SAP.

Through the iterative balancing of flood levels inside the detention basin and downstream, a two staged outlet structure was required. This consisted of a low flow outlet with a high flow weir. This allowed for throttling of flows in frequent flood events, when impacts are sensitive, whilst allowing a greater volume of discharge in larger flood events when the impacts are not as sensitive. The staged outlet concept is exemplified by the sketch shown in Figure 7-2.

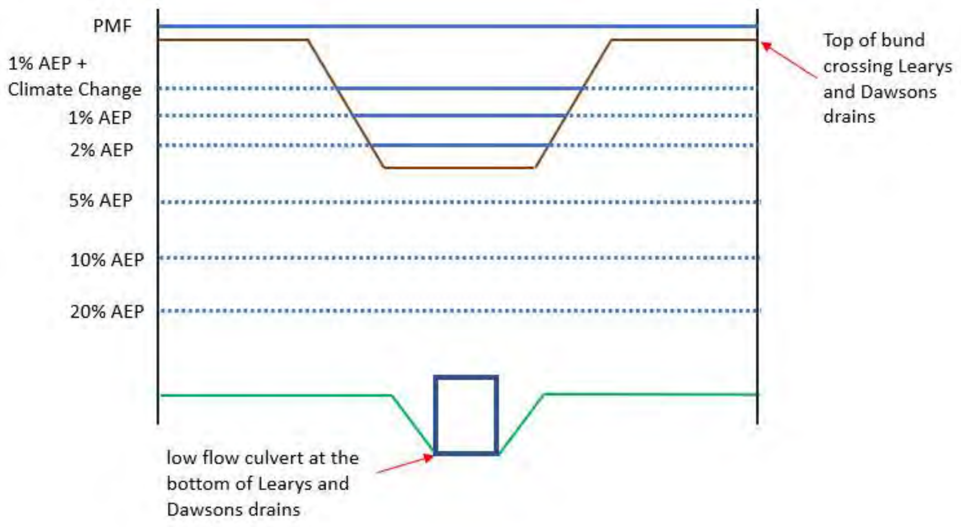


Figure 7-2 – Detention basin outlets across Learys and Dawsons Drain

7.2 Flood Impact Assessment

7.2.1 Flood Impact

The Structure Plan was assessed against the regional and local flooding modes. It has been identified that the local and regional flooding regimes conflict in terms of requirements to minimise flood impacts.

This is driven by the predominant direction of flow in each flood scenario, whereby local flooding flows from north to south. These flows could be restricted to take advantage of the ability to control and mitigate downstream impacts. However, under regional flooding, flows backwater through the Williamtown SAP area from south to north. Consequently, a balancing of the flow paths is required to converge the competing mechanisms where practical.

Table 7-3 shows the proposed flood design criteria for the precinct at this stage. All flood impact mapping is presented in Appendix C.

Table 7-3 – Adopted flood protection design criteria

Parameter	Value	Description
Flood protection	1% AEP + Year 2100 climate	Based on Williamtown Salt Ash Flood Study (BMT 2017) which applies 20% increase in rainfall plus 0.9m sea level rise.
Freeboard	500mm	Above the 1% AEP plus year 2100 climate change. Partly may be executed by the developer on a lot basis. Development pads to be at minimum regional flood level

Regional flooding

The regional flood assessment is based on the BMT (2017) regional flood modelling. No changes to the model were made apart from the local catchment breakup to accommodate the Williamtown SAP configuration.

The proposed Williamtown SAP was represented in the model as full blockages to floodwaters as defined by the footprints. The initial flood impact of the precinct on regional flooding, the proposed mitigation measures and associated results are shown in Appendix C (Figures C2 to C5). The colours in the figures show the changes in flood levels (afflux) due to the Williamtown SAP compared to predevelopment conditions. Cream, oranges, and red indicate an increase in flood level due to the Structure Plan and blues indicate decreases. White indicates no change from pre-development conditions. Bright green indicates areas that were previously wet but now dry and bright purples vice versa.

Regional flood behaviour in flood events more frequent than the 1% AEP have limited impact on the proposed Williamtown SAP location. In these events, flood waters overtopping Fullerton Cove levee do not reach Cabbage Tree Road, therefore only provide a tailwater influence on any overland flow traversing Cabbage Tree Road from the north to south. This scenario is comparable to the local flood model simulation which provides better resolution than the regional model's 20m grid size. As a result, the regional flood scenario has only been assessed for the 1% AEP and 1% AEP plus year 2100 climate change with the flood risk for more frequent events being assessed through the local flood modelling scenario.

The afflux results for the 1% AEP plus year 2100 climate change show that there is an increase in flood levels south of Cabbage Tree Road. This is believed to be a result of changes in flood behaviour more so than loss of flood storage. Through multiple simulations it was identified that constricting the transfer of floodwater between the north and south of Cabbage Tree Rd at both Dawsons drain and Learys drain provides the best arrangement to limit impacts across the Fullerton Cove to Tilligerry Creek floodplain. This supports the theory that the impact is less driven by loss of flood storage. There is some residual adverse impact seen across the floodplain south of Cabbage Tree Road however these are negligible in the order of 11mm and believed to be an artefact of the representation of the Williamtown SAP rather than a predicted impact on flood levels.

Local flooding

The earthworks model of the Williamtown SAP was represented in the local flood model (refer Section 6.3.2). Further development of this earthworks design will be undertaken at the concept design stage, including more detail and alignment with all design disciplines.

A summary of the local flood impact results for the 1% AEP event are presented in Table 7-4 and refer to the respective figures in Appendix C. When reviewing the tabled results, the identified locations are in reference to the Williamtown SAP precinct location.

Table 7-4 – Local flood modelling results

Appendix C Figure reference	Local flood model scenario	Description & Results
Figure C6	Unmitigated flood impacts 1% AEP + year 2100 climate change	Unmitigated flood impacts with the Williamtown SAP in place. Adverse flood impacts are seen in several locations, including: 1- **North-east**: which is due to loss of flood storages along the eastern edge of the Williamtown SAP. This led to an increase in flood levels and overtopping of the minor road adjacent the Williamtown SAP, which impacted the area to the east by about 50 mm. 2- **North (downstream of Lake Cochran)**: The northern development has occupied part of the natural flow path and reduced the existing flood storages, leading to an increase in flood levels along the northern edge by about 170mm. 3- **North-west (Hunter Water lands)**: due to the loss of existing flood storage by the Williamtown SAP. This has led to an increase in flood levels to the west and northwest of the Williamtown SAP, ranging from 80mm next to the development to around 10mm further to the west. 4- **bio-conservation area**: Within the bio-conservation area and upstream of Cabbage Tree Road, an increase of 20 to 40 mm in peak flood levels are expected. 5- **South of Cabbage Tree Road**: South of Cabbage Tree Road, flood levels increase about 20mm.
Figure C7	Mitigated flood impacts 20% AEP [Low tailwater]	Through the implementation of the flood management measures described above, the following resulting impacts are noted: 1- **North-east**: No impact. Water levels through the table drain are lower compared to the existing condition. 2- **North (downstream of Lake Cochran)**: No impact due to the north-west cut off drain incorporation 3- **North-west (Hunter Water lands)**: No impact. Water levels are slightly lower than the existing condition. 4- **Bio-conservation:** water levels are higher by about 530mm. **South of Cabbage Tree Road**: No impact with water levels lower than the existing conditions.

Appendix C Figure reference	Local flood model scenario	Description & Results
Figure C8	Mitigated flood impacts 1% AEP + year 2100 climate change [Low tailwater]	Through the implementation of the proposed management measures, the resulting impacts are as follows: 1- **North-east:** The impact to the northeast was eliminated by considering a cut-off drain between the eastern edge of the Structure Plan and the adjacent minor road. To prevent the increase of flood levels further downstream of the new cut-off drain, additional culverts were included along the table drain. Consequently, flood levels along the table drain decreased by about 10 to 20mm. 2- **North (downstream of Lake Cochran)**: The northern impact was resolved with a cut-off drain along the northern and western sides of the Structure Plan. The north-west cut-off drain was connected to the bio-conservation area to prevent further increase of flood levels to the west of the Structure Plan. 3- **North-west (Hunter Water lands)**: The impact to the northwest cannot be eliminated as it is a result of the pseudo detention basin backwater. The impacts ranging from 580mm next to the Structure Plan to about 70mm further to the west. 4- **Bio-conservation area:** This area forms the pseudo detention basin with outlet control structures crossing Dawsons and Learys drains. As a result, the flood levels within enviro precinct increase by about 1210mm and decrease to the south of the proposed bund by about 10 around Learys drain and up to 60mm to the west of Dawsons drain. 5- **South of Cabbage Tree Road**: The impact to the south of Cabbage Tree road was mitigated by the pseudo detention basin strategy within the bio-conservation area. The pseudo detention basin will require outlet control structures across Dawson drain to control outflows. There are some residual impacts along the edges of the basin which are within the Williamtown SAP boundary.

Based on the results, the Low Tailwater (LTW) level scenario is the critical scenario for impacts. The HTW scenario does not predicted to result in adverse impacts as shown in the respective figures in Appendix C.

In summary, the only residual impacts (orange and red shaded areas) occurring outside of the Williamtown SAP boundary are those on Hunter Water land - This area is only impacted in rarer events with increases in flood levels up to 600mm. Despite the increase in flood levels, flood waters are able to drain. No adverse impacts are predicted in more frequent events, which would have otherwise had an impact on the current ecological communities.

Bio-conservation area

The bio-conservation area located centrally within the Williamtown SAP has been identified as an environment which may be impacted by changes in hydrological regime (refer to biodiversity report for details). This area will be used as a flood detention zone for temporary floodwater storage area as part of the flood management measures. As such flood levels will increase within this area during storm events and will drain naturally and return to normal states after upstream flows cease to enter the precinct. It is understood that frequent inundation poses a risk to the ecology and changes in ponding depth during frequent rain events is a concern. Rarer floods, being less frequent, pose less risk of impact.

An assessment has considered the impact of the proposed flood management strategy on the bio-conservation area. This was done by assessing the inundation duration of flooding in very frequent events. Initially, results indicated that inundation with that area did not recede. This was a consequence of the bulk filling across some of the existing drainage lines. In response, it is proposed that minor drainage lines are constructed to facilitate flood detention whilst preserving the dominant hydrologic regime that supports the ecology of the bio-conservation area.

The location of the reporting point within the Bio-conservation area is shown in Figure 7-3 and resulting flood level - duration is shown in Figure 7-4 for the 1EY event.

While the plot shows that modelled outlet works from a flood detention perspective, the outlet needs to be carefully optimised to prevent the bio-conservation area draining more rapidly than normally occurs. Optimisation of the outlet should mean that the

- Water level is preserved in frequent events while providing a similar period of inundation in frequent events.

- Achieves the desired flood attenuation in flood events.

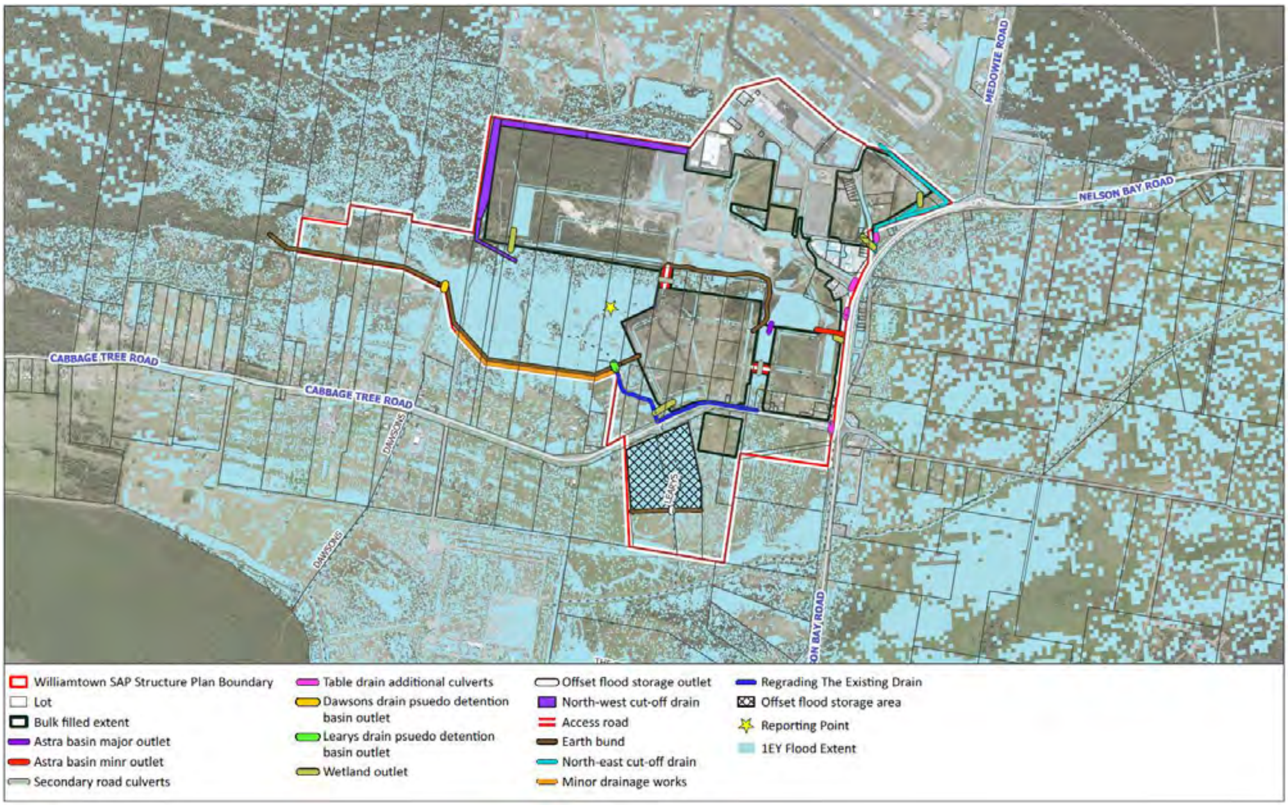


Figure 7-3 – Location of the reporting point within the Bio-conservation area

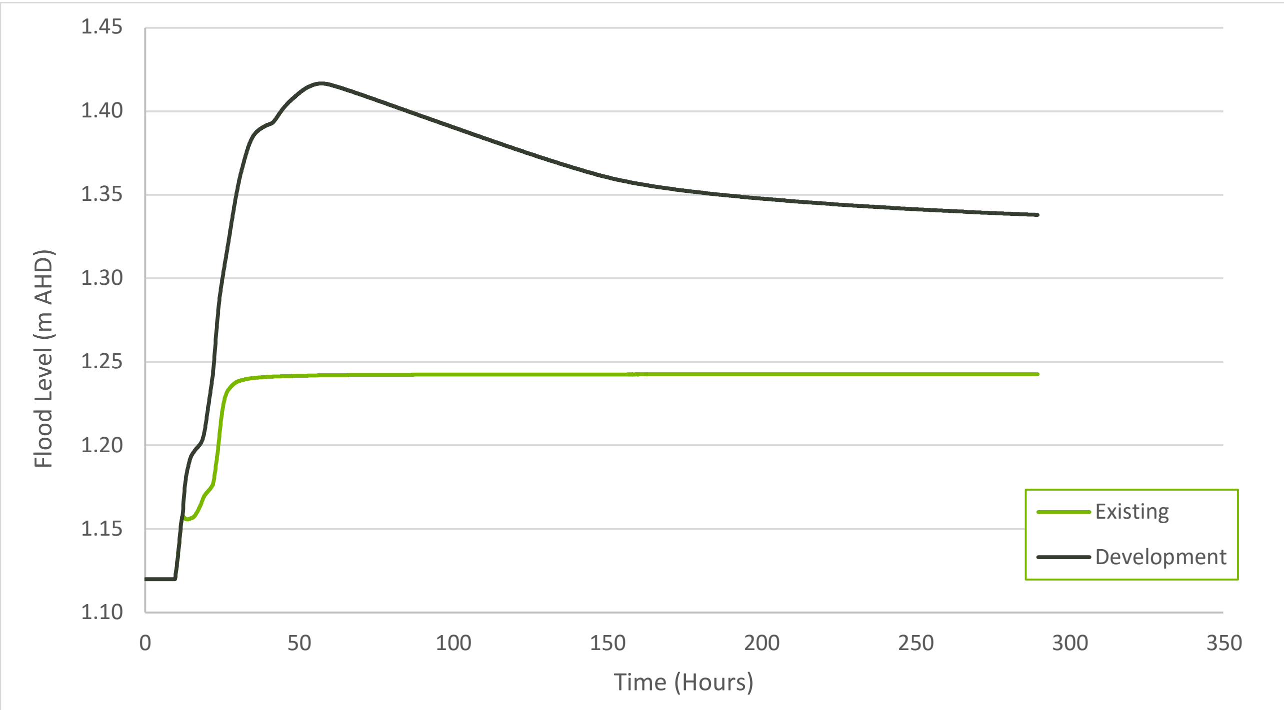


Figure 7-4 – 1 Exceedance per Year (1EY) flood level hydrograph within the Bio-conservation area

7.3 Detention Basin Performance

7.3.1 Design and Performance Details

One of the proposed flood management strategies to offset the flood impacts of the Williamtown SAP development is to implement a detention basin using an earth bund as shown in Figure 7-5.

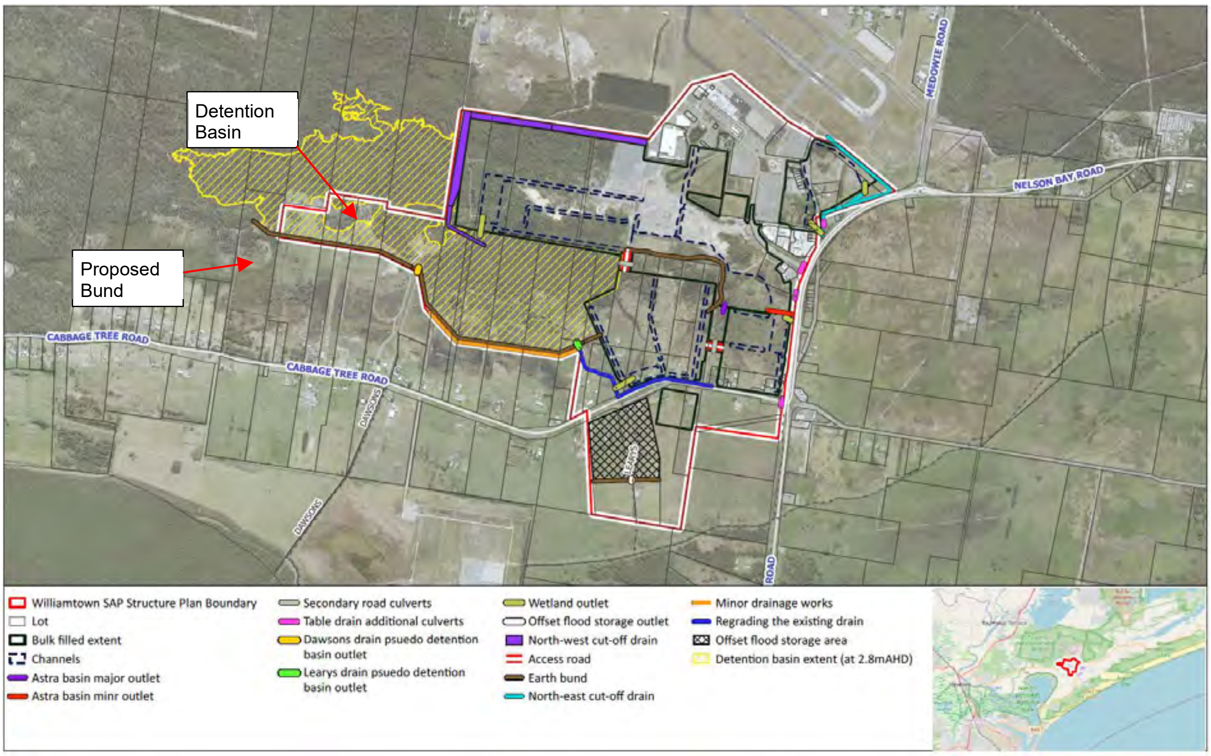


Figure 7-5 Proposed detention basin and the earth bund

The inflow to the detention basin originates from the north-western catchment area (drinking water catchment) which travels south towards Fullerton Cove. The upstream catchment has an area of about 930 ha (shown in Figure 7-6).

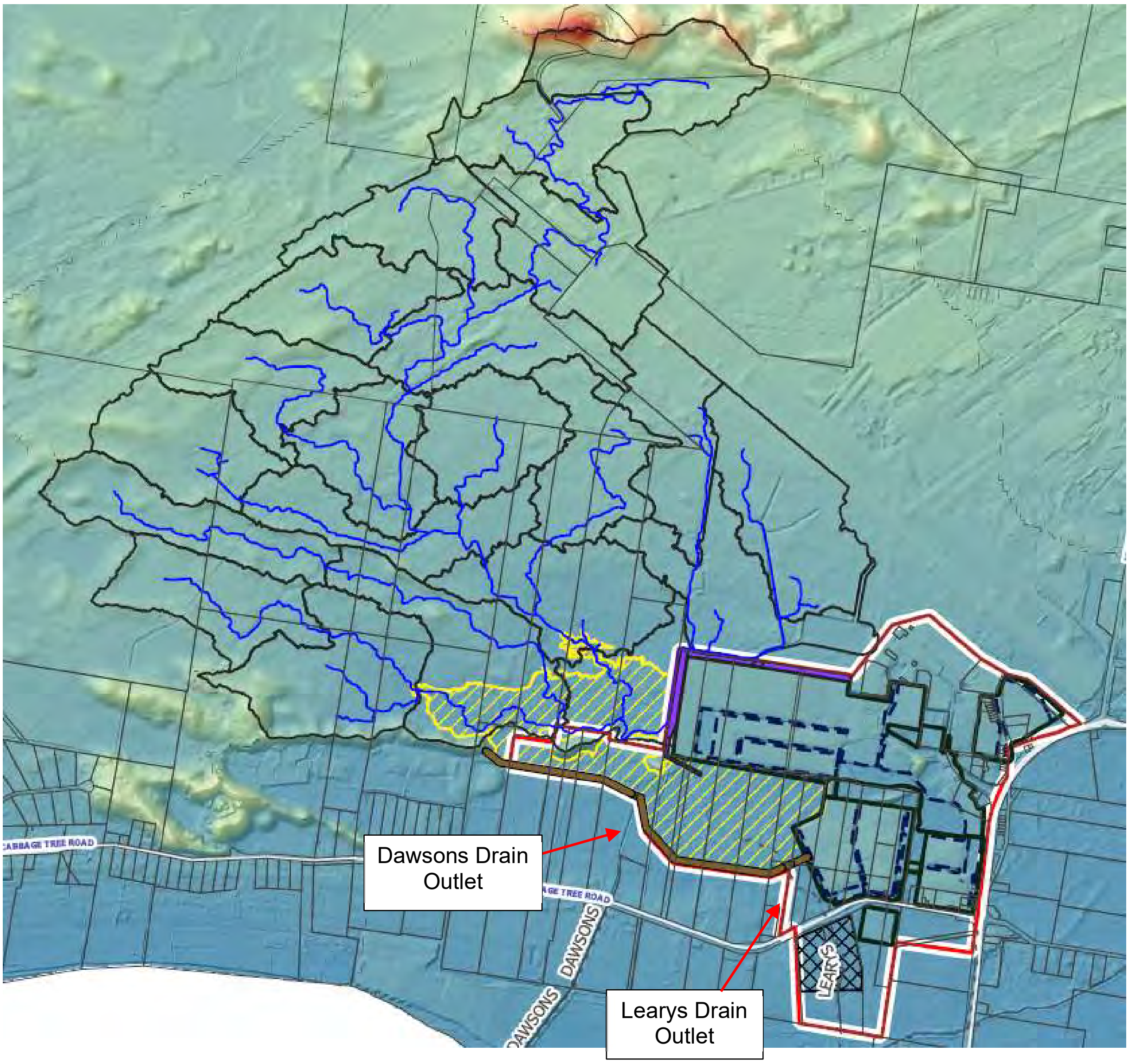


Figure 7-6 Upstream catchment of the detention basin

A typical section was considered for the proposed bund (as shown in Figure 7-7) which is a homogeneous earth fill bund with a central clay core. The average bund height is 2.2m from toe to crest with a crest level at 3.7m AHD (includes 500mm freeboard from the climate change peak flood levels). The proposed bund length is about 2 km, and the upstream and downstream faces are designed with a slope of 3H:1V and the crest width is 3m.

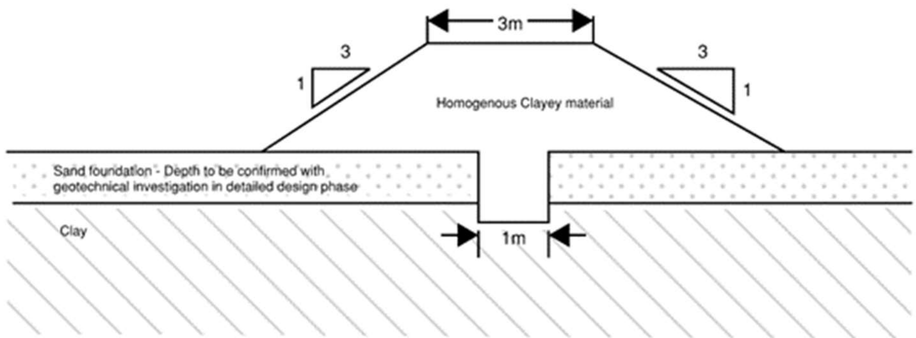


Figure 7-7 Typical bund cross-section

Through the iterative balancing of flood levels inside the detention basin and downstream, a two staged outlet structure was required. This consisted of a low flow outlet (a 300mm RCP along Learys drain with upstream IL of 0.99 and downstream IL of 0.95 and a 900mm width x 600mm high RCBC along Dawsons drain with upstream IL of 0.69 and downstream IL of 0.64) with a high flow weir (at 2.8 m AHD). This allowed for throttling of flows in frequent flood events, when impacts are sensitive, whilst allowing a greater volume of discharge in larger flood events when the impacts are not as sensitive. The staged outlet concept is exemplified by the sketch shown in Figure 7-8.

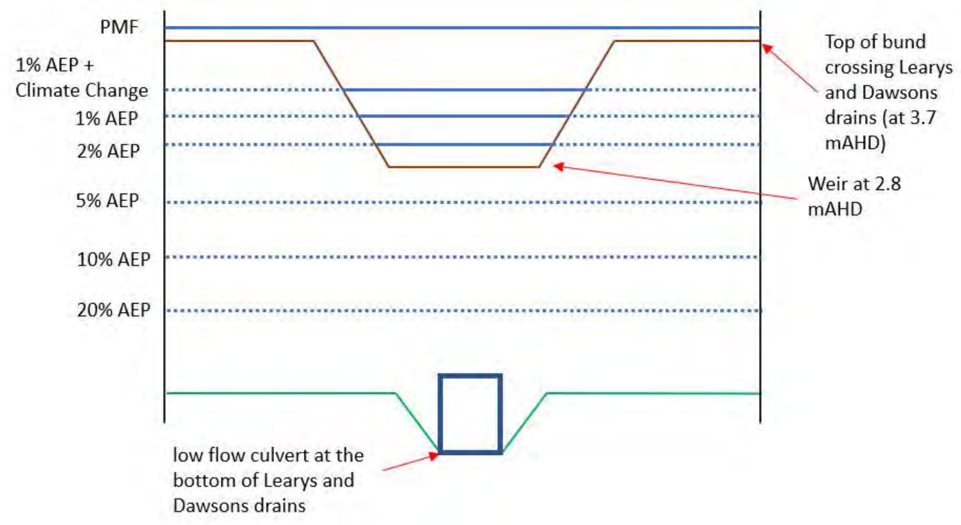


Figure 7-8 Detention basin outlets across Learys and Dawsons Drain

The detention basin has an estimated storage capacity of 940 ML at weir level (2.8 m AHD). The stage-storage and the stage-discharge relationships of the detention basin are presented in Figure 7-9 and Figure 7-10.

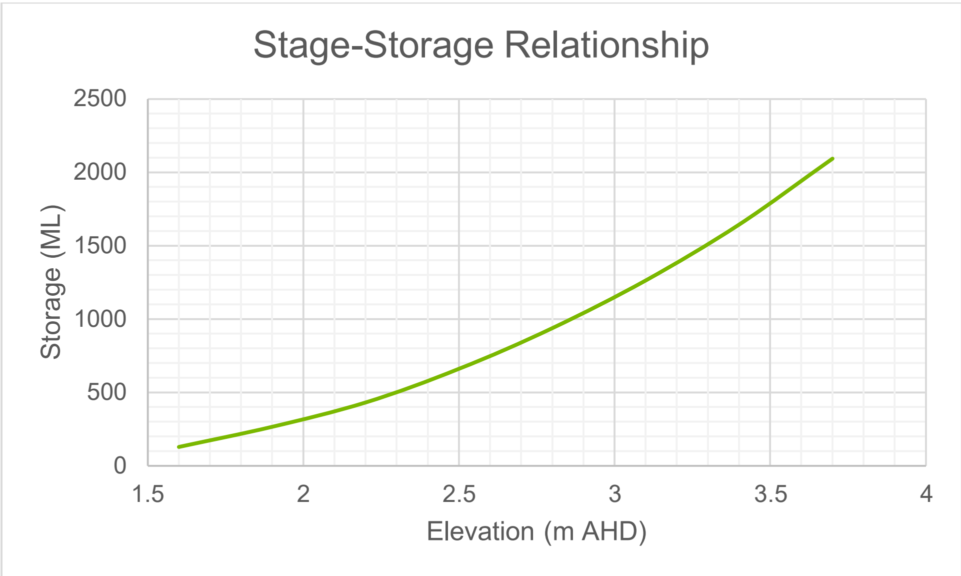


Figure 7-9 Regional detention basin stage-storage relationship

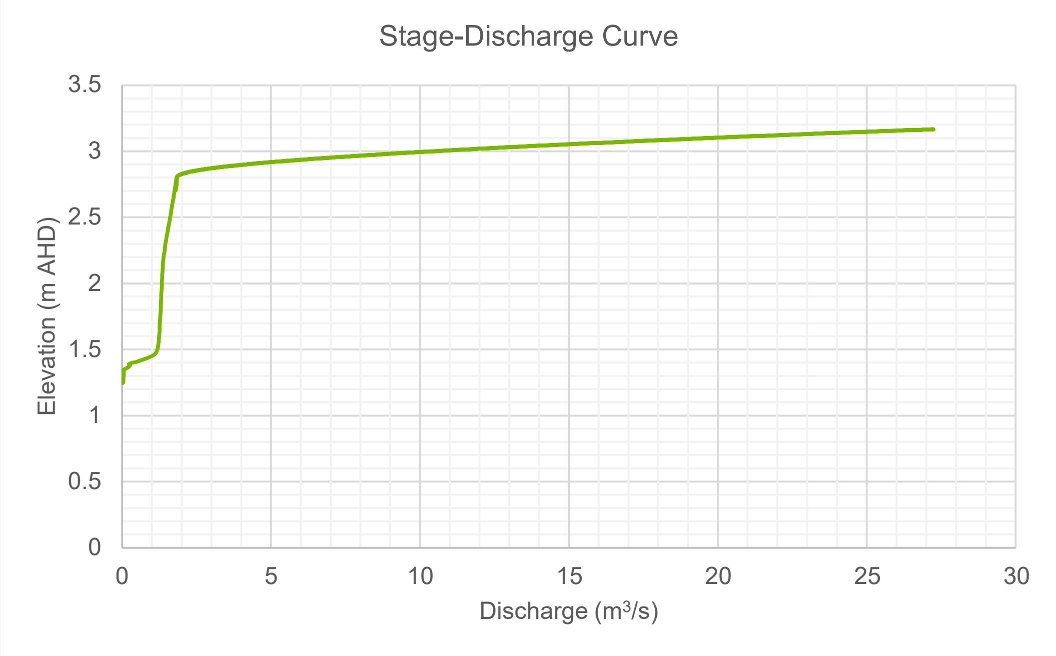


Figure 7-10 Regional detention basin stage-discharge relationship

A summary of the basin characteristics and hydraulic performance is presented in Table 7-5.

Table 7-5 Detention basin characteristics

Parameter	Value
Bund Embankment Height (mAHD)	3.70
Peak Discharge – Dawsons (1% AEP + Climate Change) (m^3/s)	14.24
Peak Discharge - Learys (1% AEP + Climate Change) (m^3/s)	13.00
Peak Discharge - Dawsons (10% AEP) (m^3/s)	1.33
Peak discharge - Learys (10%) (m^3/s)	0.14
Peak Water Level (1% AEP + Climate Change) (m AHD)	3.17
Peak Water Level (10% AEP) (m AHD)	2.28
Freeboard to Embankment (1% AEP + Climate Change) (m)	0.53
Minimum depth at peak (1% AEP + Climate Change) (m)	1.20
Maximum depth at peak (1% AEP + Climate Change) (m)	2.30
Outlet configurations – Dawsons Drain	1No. 0.9m (w) x 0.6m (h) + Weir at 2.8 m AHD
Outlet configurations – Learys Drain	1No. 0.3m (dia.) + Weir at 2.8 m AHD

7.3.2 Declared Dam Determination

A failure impact assessment was undertaken to establish whether the proposed detention basin for the Williamtown SAP development would be classified as a “declared dam”. This was done in accordance with the provisions of the new regulatory framework, comprising the Dams Safety Act 2015 (“the Act”), the Dams Safety Regulations 2019 (“the Regulations”) and associated methodologies.

Based on the Regulation an existing dam in the following types or classes may be a declared dam if it satisfies one or more of the following:

a) a dam wall that is more than 15 metres high,
b) a dam that Dams Safety NSW is reasonably satisfied would, if there were to be a failure of the dam
   i) cause a major or catastrophic level of severity of damage or loss, or
   ii) endanger the life of a person,
c) a dam, or proposed dam, that is a prescribed dam within the meaning of the Dams Safety Act 1978 immediately before the repeal of that Act.

In assessing whether a failure of a dam would cause damage, loss or danger referred to in item (b) above, Dams Safety NSW is to have regard to the Consequence Category Methodology (CCM). Dams Safety NSW has published notice n2019-3443, "*Declared dams consequence category assessment and determination methodology*".

For the assessment of consequence category, two types of dam failure must be considered (Based on Dam Safety NSW, Societal and individual risk rating methodology for Dams Safety Act 2015):

a) failures that occur without any attendant natural flooding, giving rise to the 'Sunny Day' Consequence Category (SDCC), and
b) failures that occur in association with a natural flood, giving rise to the Flood Consequence Category (FCC). The FCC should be based on the incremental consequence over natural flood and be limited to above a 300mm increment.

Methodology

The methodology adopted in this assessment is outlined below:

- Undertake breach parameter characterisations
- Hydraulic modelling using TUFLOW to estimate the extent and characteristics of the flooding downstream resulting from dam break
- Estimation of the Population at Risk (PAR) for each of the failure scenarios
- Undertake a Consequence Category Assessment (CCA)

Assumptions and limitations of advice

- The intent of this assessment was to determine whether the proposed detention basin would be classified as a declared dam. As such, the assessment presented is only preliminary and requires further assessment in the next design phase with respect to the failure mechanisms, Population at Risk, Potential Loss of Life and Consequence Category Assessment.
- No survey of the buildings at risk, the nature of the sites and number of people living in them were available for this assessment. The footprint elevation of the buildings was estimated from 1-meter LiDAR and number of residents of the building were assumed based on the Guideline for Failure Impact Assessment of Water Dams, DNRME 2018
- For the Sunny Day Failure assessment, it was assumed that the water level in the detention basin at the beginning of the failure was at the elevation of the weir (2.8 m AHD). Although, for this particular hydraulic structure (detention basins), this seems to be a conservative scenario. Because a detention basin dries up after a flood event. This will be discussed in more detail in the next sections.
- At this stage of the study, a typical section has been assumed for the proposed bund. If the section changes in future, there may be a need to review the dam break assessment.
- No Potential Loss of Life (PLL) has been estimated and the Consequence Category Assessment is based on the calculated PAR.

- Design input from a geotechnical and dam engineer has not informed the breach locations and breach parameters for this preliminary assessment. This will be required in the next design stage of the project.

Dam Break Assessment

Failure Mode and Scenarios

Dam failure can occur with or without a wet weather event. Therefore, the following dam failure events were modelled as part of this study:

- **Sunny Day Failure (SDF)** – This scenario represents an embankment failure with no rainfall within the detention basin catchment or downstream area. The scenario assumes that water level is at the weir level at the time of the breach while the low flow culverts continue to discharge flow. The assumed failure mechanism is internal erosion in the embankment.
- Since the detention basin is mostly dry between flood events, this is considered a conservative scenario. This scenario was investigated because, due to the small dimensions of the proposed outlet structures, the discharge of the basin after a flood event can take several days (Therefore, the sunny day failure can occur after the rainfall event) Also, other factors such as blockage of the outlet structures as a result of sedimentation can make the discharge time longer.

  Although, this should be noted that in order for the water level inside the detention basin to reach the level of the weirs (2.8 m AHD), a flood greater than the 5% AEP event is needed.
- **Slumping Failure** – This scenario represents an embankment sudden failure due to earthquake. This scenario also assumes that the failure occurs in a sunny day and water level is at the weir level at the time of the breach.
- **Flood Failure** – This scenario represents a breaching failure of the wall while receiving inflow from a flood event. For the purpose of this study the PMF were assessed.

To understand the incremental effect of the dam failure, the following no-failure scenarios were also assessed:

- **Sunny Day with no Dam failure** – In this scenario, the initial water level was considered at the elevation of the weirs along Learys drain and Dawsons drain (i.e., 2.8 m AHD). No dam break failure however flow is allowed to discharge from the low flow culverts. This will allow to assess the incremental impact of the sunny day failure.
- **Flood with no Dam Failure** – This scenario represents a flood event occurring with no dam failure to assess the incremental impact of the dam failure scenario. The PMF events were assessed for this purpose.

Dam failure analysis identifies feasible dam failure modes that would cause maximum consequence. The following failure modes (as presented in Table 7-6) were considered for this dam break assessment:

Table 7-6 Dam Break Failure Event

Scenario	Failure Event Description	Failure Mechanism
1	Sunny Day failure	Internal erosion (a pipe form through the embankment)
2	Slumping Failure	A sudden failure due to earthquake
3	PMF (with and without dam failure)	Overtopping (which as a result, a part of the bund erodes)

The hydraulic model was run for the scenarios mentioned above and the peak flood levels of the dam failure scenarios were compared with the results of the "no dam failure" scenarios, to identify the incremental impacts. This was undertaken to identify whether there is an increase in safety risk because of the dam failure.

Dam Breach Event Characteristics

For assessment of the characteristics of a dam breach scenario, the development times and geometry of a dam breach are required. This was undertaken based on the Froelich 2018 (Empirical Model of Embankment Dam Breaching).

Four locations along the proposed bund were selected to investigate the consequences of the dam failure. (As shown in Figure 7-11). These were simplistically selected at the basin outlets and a location midway between the outlets. The critical location will be identified later based on PAR. These four locations are as follows:

- At Learys drain outlet weir (Dam Break 1)
- At Dawsons drain outlet weir (Dam Break 2)
- Between Learys drain and Dawsons drain outlet weirs (Dam Break 3)
- West of Dawsons drain outlet weir (Dam Break 4)

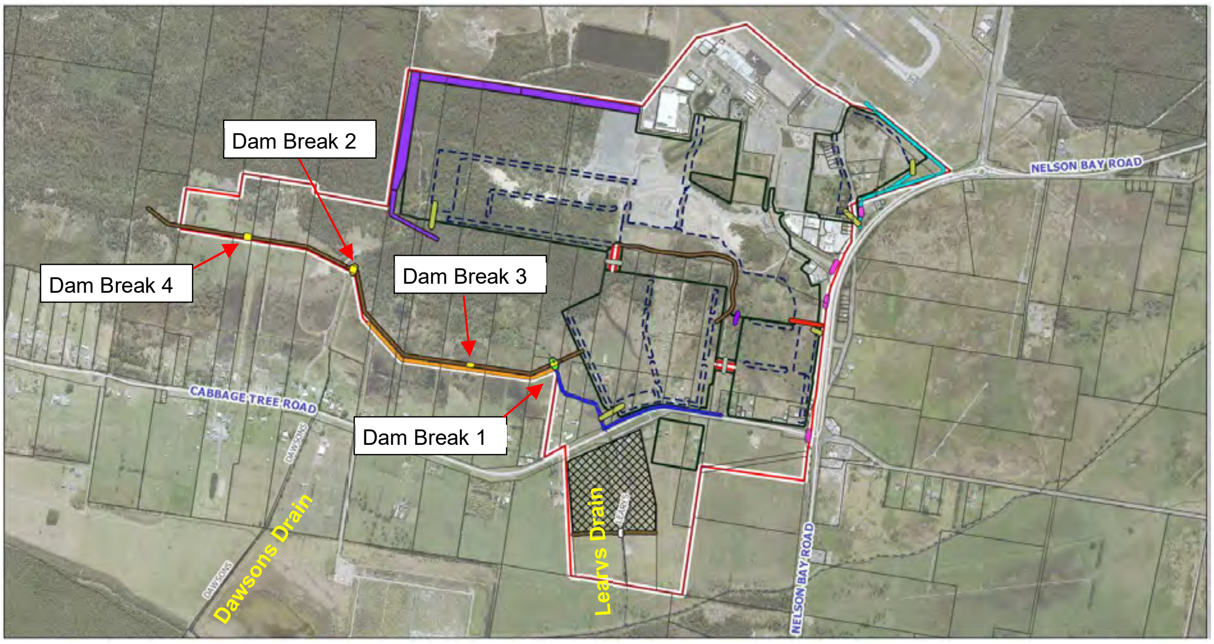


Figure 7-11 The locations of dam break scenarios

The breach parameters were calculated for the above locations and the average of the calculated numbers was adopted. As a result, a breach development time of 2.5 hours and a breach width of 30 m was selected for both the SDF and FF scenarios. The breach time of 15 minutes was adopted for the Slumping failure which is a sudden failure due to earthquake. A sensitivity assessment was also undertaken for the Sunny Day Failure, increasing the breach width to 45m breach. The adopted breach parameters are represented in Table 7-7.

Table 7-7 Adopted Breach Parameters

Scenario	Breach Mechanism	Water Level	Time for breach to fully develop	Average width of the Breach
SDF	Piping	at weir level (2.8 m AHD)	2.5 hours	30 m
Slumping Failure	Slumping	at weir level (2.8 m AHD)	15 minutes	30 m
FF (PMF)	Overtopping	Approx. 3.82 m AHD (above the bund crest)	2.5 hours	30 m

Scenario	Breach Mechanism	Water Level	Time for breach to fully develop	Average width of the Breach
Sensitivity Test	-	at weir level (2.8 m AHD)	2.5 hours	45 m

Hydraulic modelling

The hydraulic model covers an area of about 40 square kilometres, including the upstream catchment of the detention basin and the downstream areas extending to Fullarton Cove.

The model topography was developed using LiDAR data captured by Aerometrex in October 2020. The LiDAR data was provided as a Digital Elevation Model (DEM) with a 1m resolution.

TUFLOW version 2020-10-AA was adopted for the development of the current local hydraulic model. To prevent increasing the run time unnecessarily, a grid size of 20m was adopted as the base grid size and a smaller grid size of 5m around the study area and a grid size of 2.5 m over the main flow paths to represent the conveyance capacity of the drains more accurately.

PMP depths were calculated based on the PMP estimation guidelines prepared by the Bureau of Meteorology (BoM). To calculate the PMP depths, the loss values presented in Table 7-8 were adopted based on the recommendations of ARR (2019):

Table 7-8 PMP Loss Values

Area Class	Loss Parameter	Recommendation	Adopted Loss values
Rural Loss Values for Use with Design Burst (Book 8, Chapter 4, Section 3)	IL_b	Very low values of IL_b are recommended. For humid and sub—humid regions of south-eastern Australia, an IL_b value of zero is recommended	IL_b=0 mm CL = 1 mm/h
	CL	For humid and sub—humid regions of south-eastern Australia, CL values would be unlikely to be greater than 1 or 2 mm/h for use with PMP design burst. A value of 1 mm/h seems reasonable where no other data are available.	
Urban Loss Values for Use with Design Burst (Book 8, Chapter 4, Section 3)	IL_b	For effective impervious areas it is recommended to adopt a burst initial loss of 0 mm	IL_b=0 mm CL = 0 mm/h
	CL	For effective impervious areas it is recommended to adopt a burst continuing loss of 0 mm	

Shorth duration PMP depths (<6 hours) were calculated using the Generalised Short-Duration Method (GSDM). For longer durations (>24 hours), as the catchment is located within the GSAM-GTSMR Coastal Transition zone, PMP depths were calculated based on both methods. In the next step, an envelope curve was created between the short and long duration values (as shown in Figure 7-12).12-hours and 18-hours PMP depths were estimated by interpolating between the values of the envelope curve:

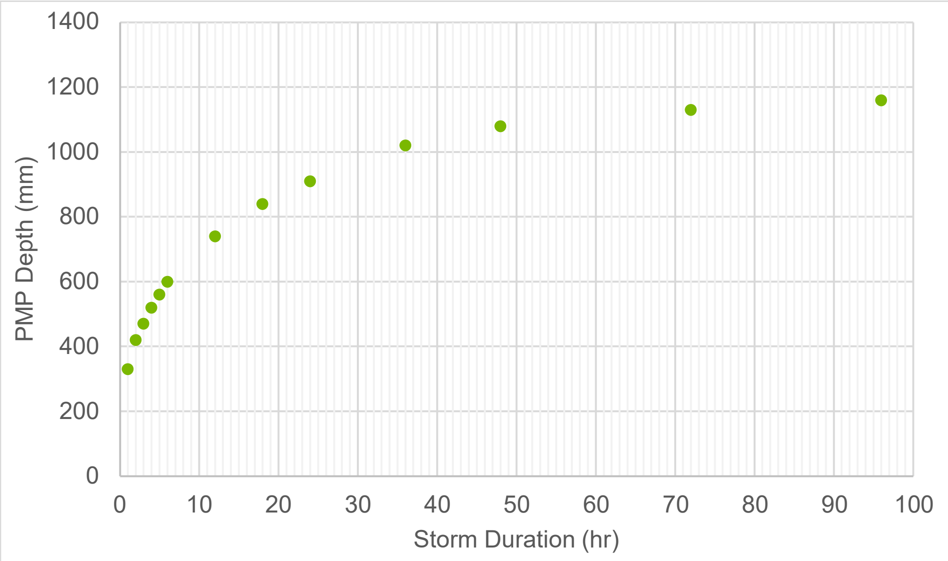


Figure 7-12 PMP Depth Envelope Curve

The hydraulic model was run for a range of durations (up to 12-hours) and temporal patterns to identify the critical event. For the GSDM durations, the eleven temporal patterns suggested by Jordan et. Al. (2005) and for the 12 hours PMP, the temporal pattern extracted from BoM were adopted.

For the area covering the detention basin and the upstream catchment, the 6-hours duration and AS66 temporal pattern were identified as the critical ones and were used for this dam break assessment.

The calculated breach parameters were applied in the TUFLOW model to estimate the flood extents, levels, and velocities. The width of the breach was considered equal to the average width calculated. The breach starts when the water level in the basin reaches 2.8 mAHD and fully develops in the calculated time as specified in Table 7-7.

TUFLOW modelling Results

PMP Flood Failure Assessment

During a 6-hour PMP storm event, the inflow hydrograph into the detention basin is estimated as shown in Figure 7-13, with a peak flow rate of 280m^3/s, which occurs at 5 hours from the start of the rainfall.

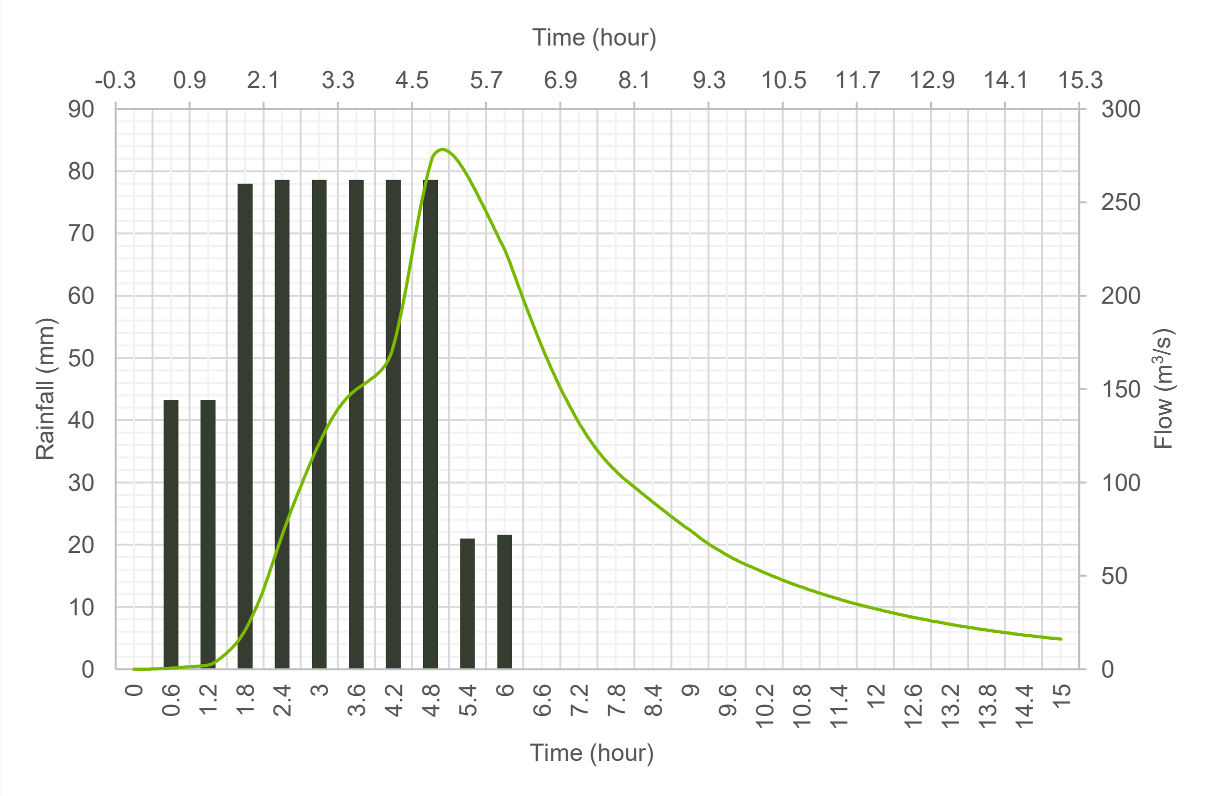


Figure 7-13 PMP hyetograph and inflow hydrograph into the proposed detention basin

Under the PMP event, the Learys drain and Dawsons drain culverts discharge flow from the detention basin (as shown in Figure 7-14). Once the flood levels within the detention basin reach 2.8 mAHD, the Learys drain and Dawsons drain weirs start to engage reaching a peak flow rate of about 70 m^3/s. After 4 hours from the start of the rainfall event, water levels reach the crest of the proposed bund (3.7 m AHD). During the next 4 hours, floodwaters overtop the bund along its entire length.

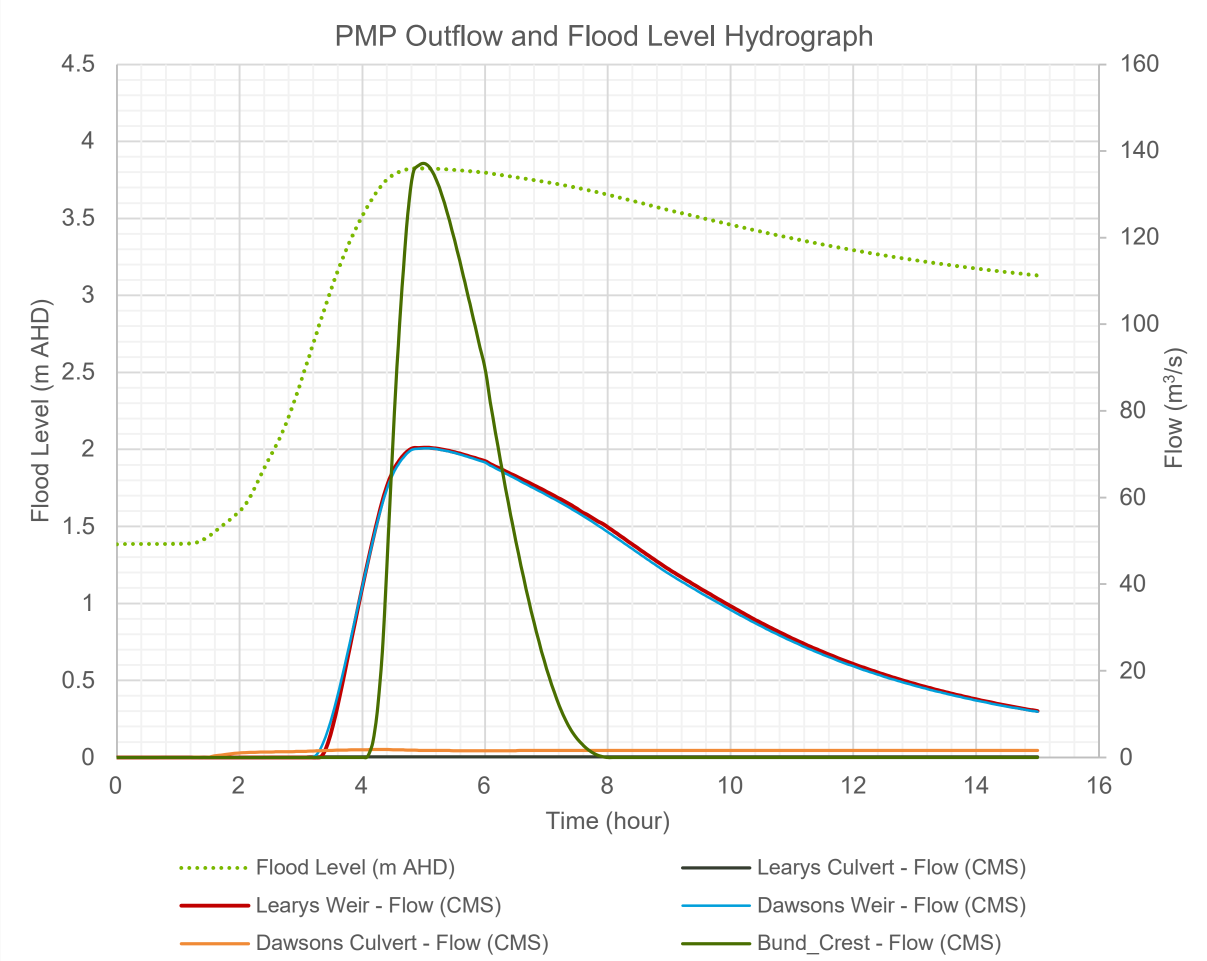


Figure 7-14 PMP Outflow and flood level hydrograph

For a PMP Flood Failure Scenario, four locations were selected for the dam break as mentioned in Section 0. The expected flood impact zones for these scenarios are presented in Figure 7-15, Figure 7-16, Figure 7-17 and Figure 7-18. The colours in the figures indicate the change in flood levels as a result of the breach in accordance with the legend.

The peak incremental impacts for the selected dam break locations are presented in Table 7-9. It was concluded that among the selected locations, a dam break at Dawsons weir and middle of Learys and Dawsons weirs can produce a bigger impact compared to the other ones.

Table 7-9 Summary of the PMF flood failure results

Flood Failure scenarios	Peak Incremental Impacts
PMF Flood Failure (at Learys weir)	80 mm
PMF Flood Failure (between Learys and Dawsons weirs)	90 mm
PMF Flood Failure (at Dawsons weirs)	85 mm
PMF Flood Failure (west of Dawsons weirs)	40 mm

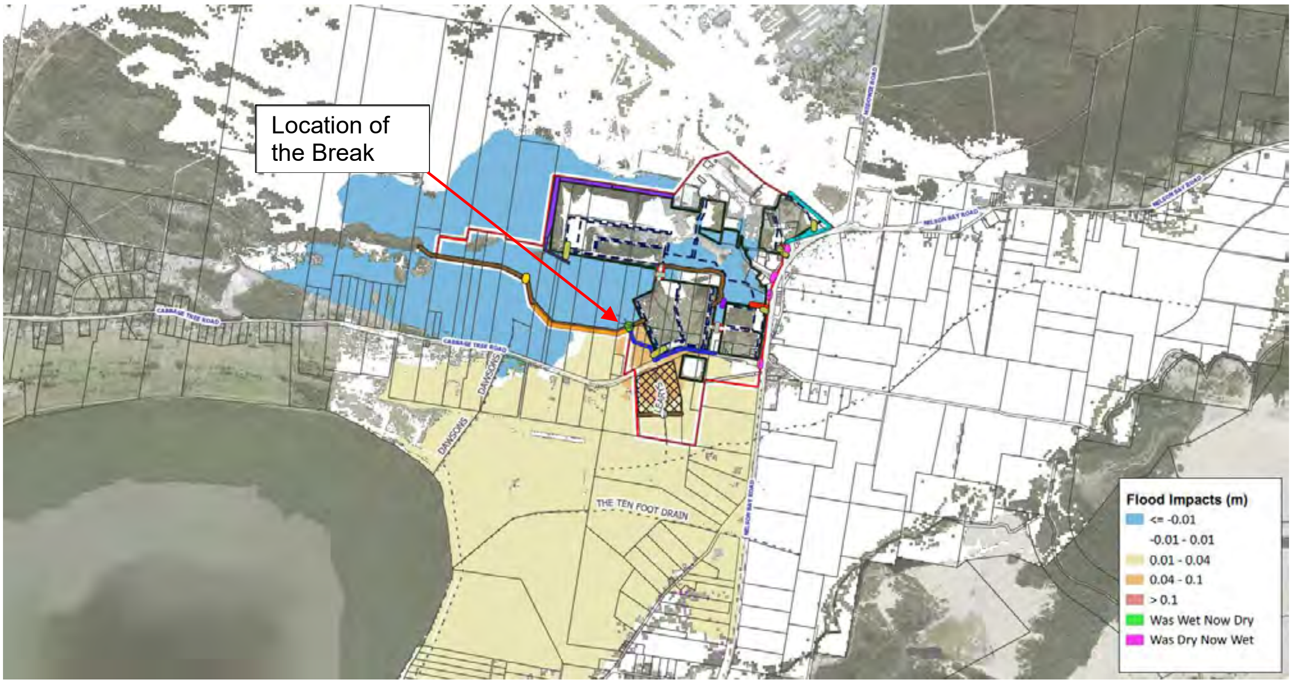


Figure 7-15 PMP Flood Failure (at Learys drain outlet weir)

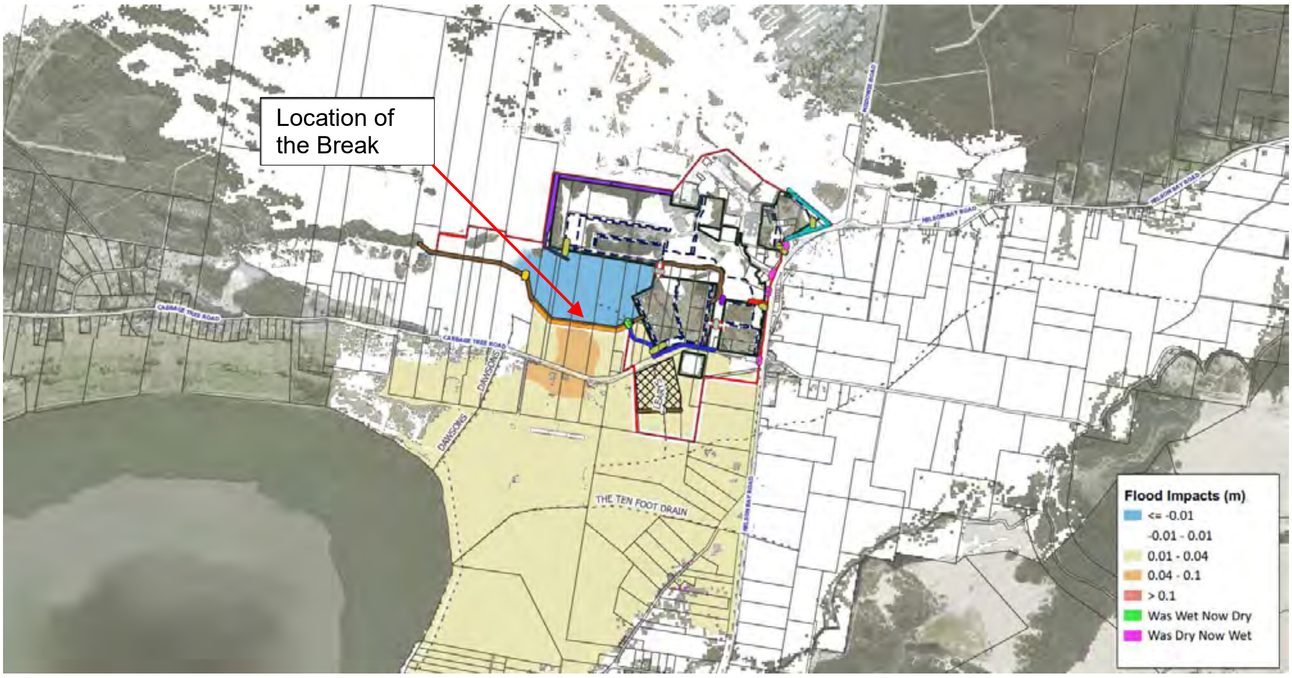


Figure 7-16 PMP Flood Failure (between Learys drain and Dawsons drain outlet weirs)

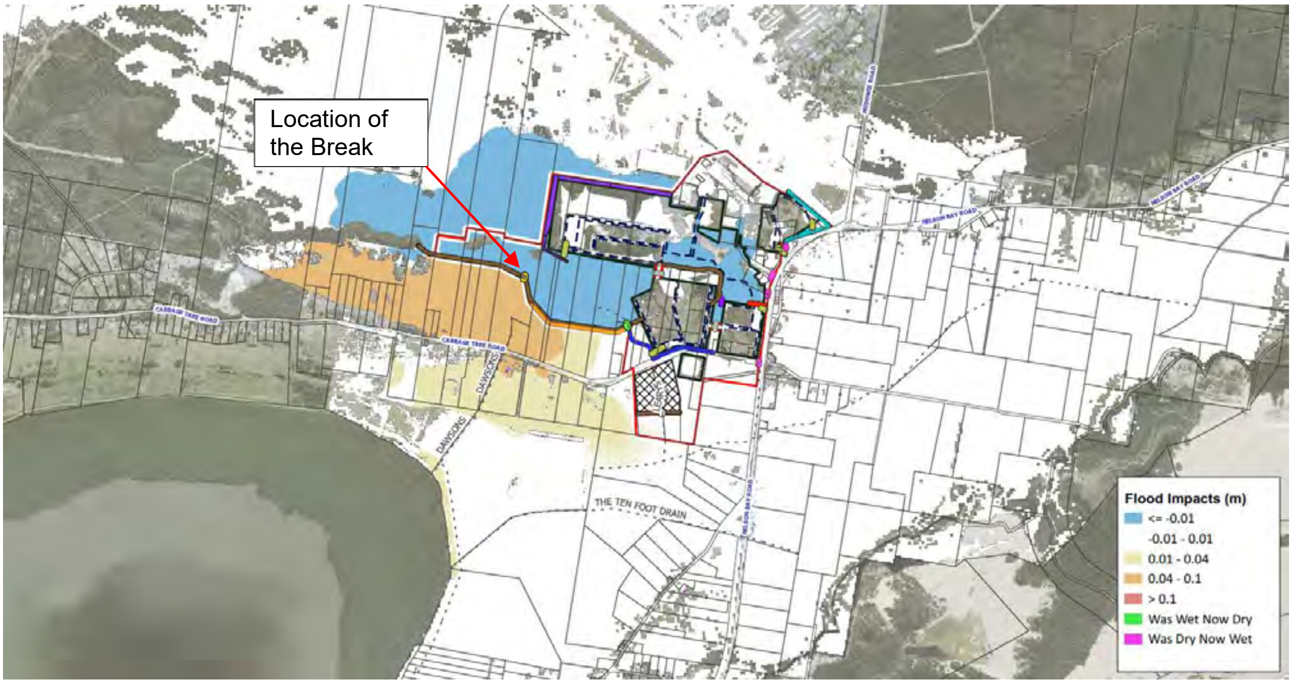


Figure 7-17 PMP Flood Failure (at Dawsons drain outlet weirs)

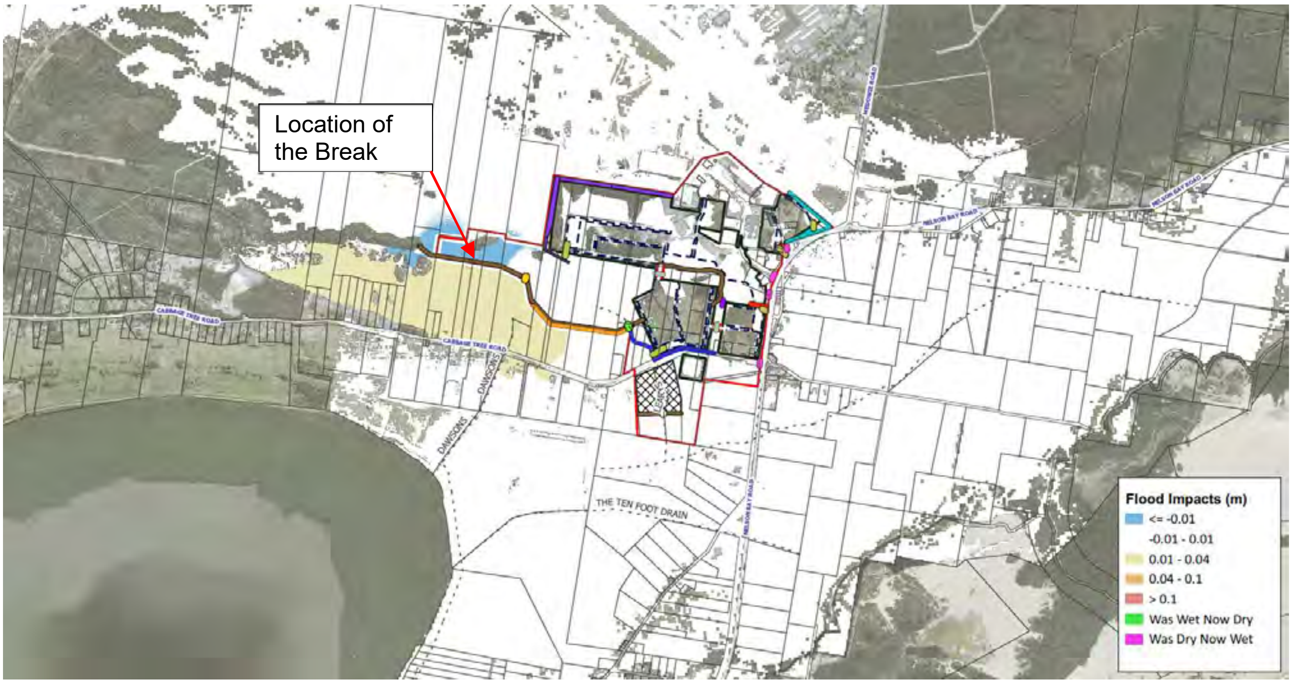


Figure 7-18 PMP Flood Failure (west of Dawsons drain outlet weir)

Sunny Day Failure Assessment

For the Sunny Day Failure scenario, it was assumed that at the beginning of the failure, the water level within the detention basin is at the weir level (2.8 m AHD).

This scenario is considered to occur when the basin is full as a result of a past rainfall event and the failure occurs after the rain has stopped while the outlet structures (Low level culverts) are still discharging water. In this scenario, no rainfall is assumed in the downstream areas, and the downstream water levels are as a result of discharge from the low-level culverts and breach.

Four locations were selected for the dam break as mentioned in Section 0. The outflow hydrographs from the breaches during each scenario are shown in Figure 7-19.

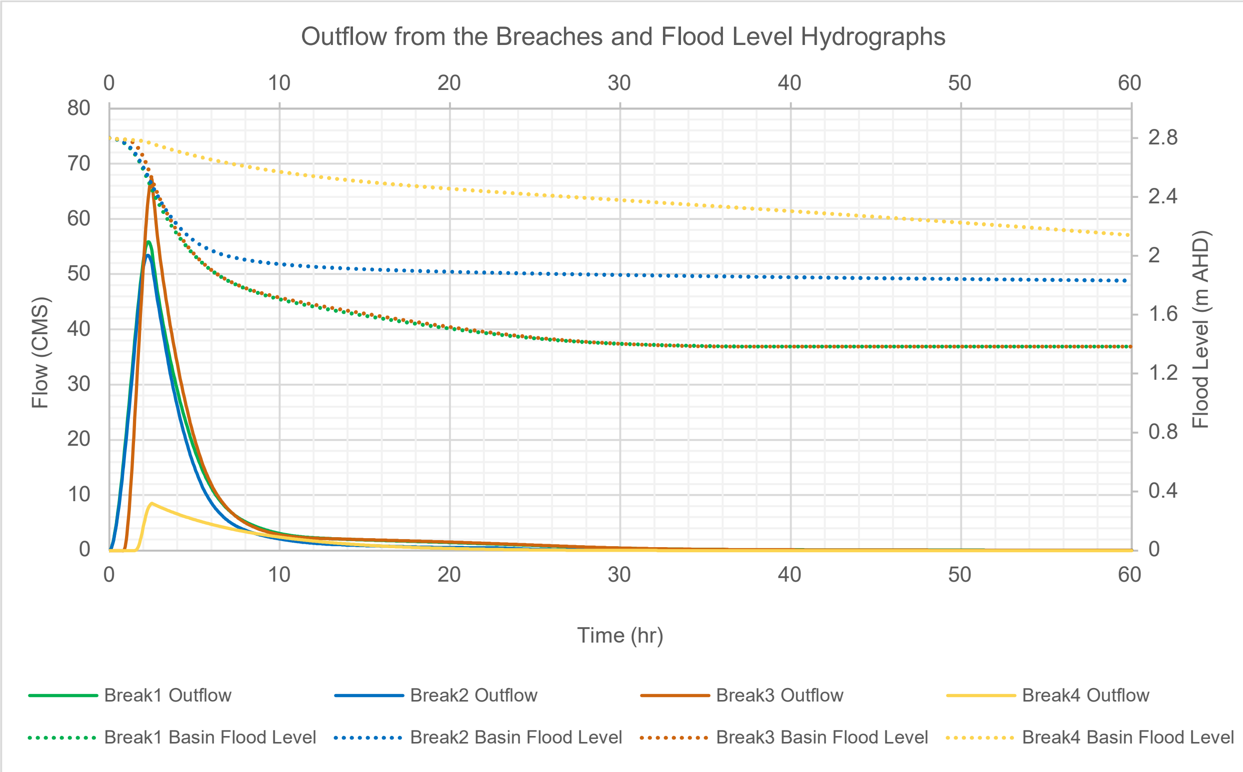


Figure 7-19 Outflow from the breaches and flood level hydrographs in the SDF scenarios

The expected impact zones for the Sunny Day failure scenario are presented in Figure 7-20, Figure 7-21, Figure 7-22 and Figure 7-23. The inundated areas south of the Fourteen Foot drain and east of Nelson Bay Road mainly happen in non-residential areas. Also, among the locations selected for potential dam failure, it seems that the breach at "Dawsons drain outlet weir" and "between Dawsons drain and Learys drain" result in higher impacts compared to the other scenarios.

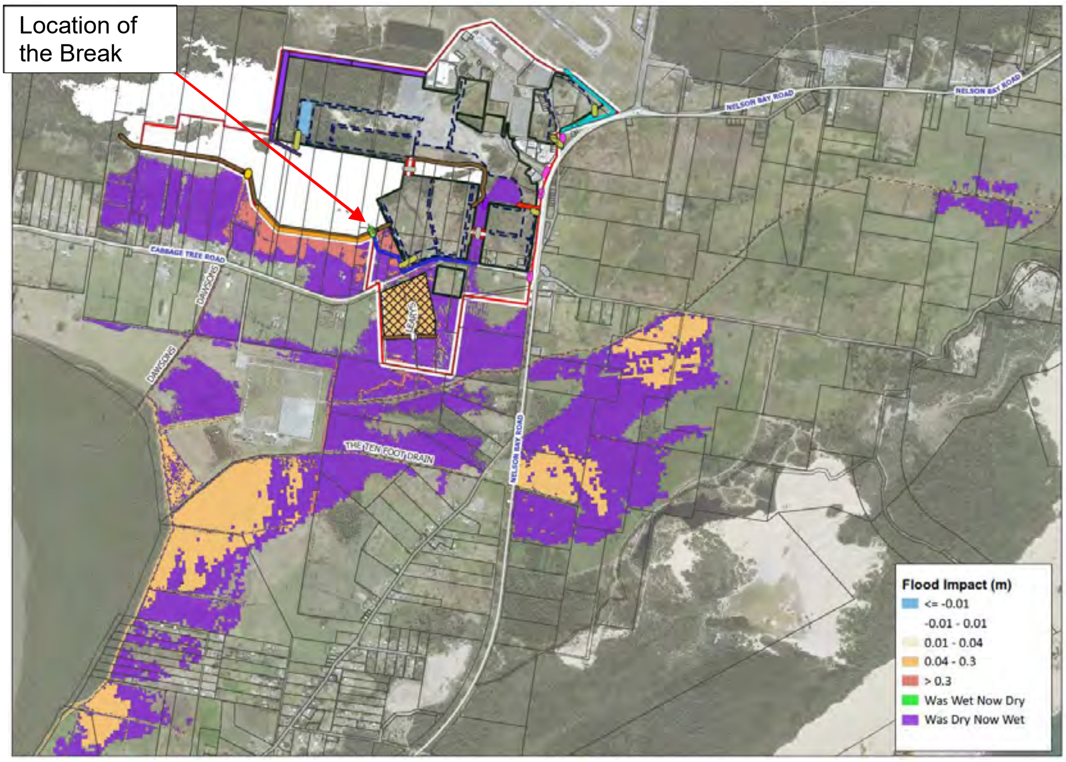


Figure 7-20 Sunny Day Failure (at Learys drain outlet weir)

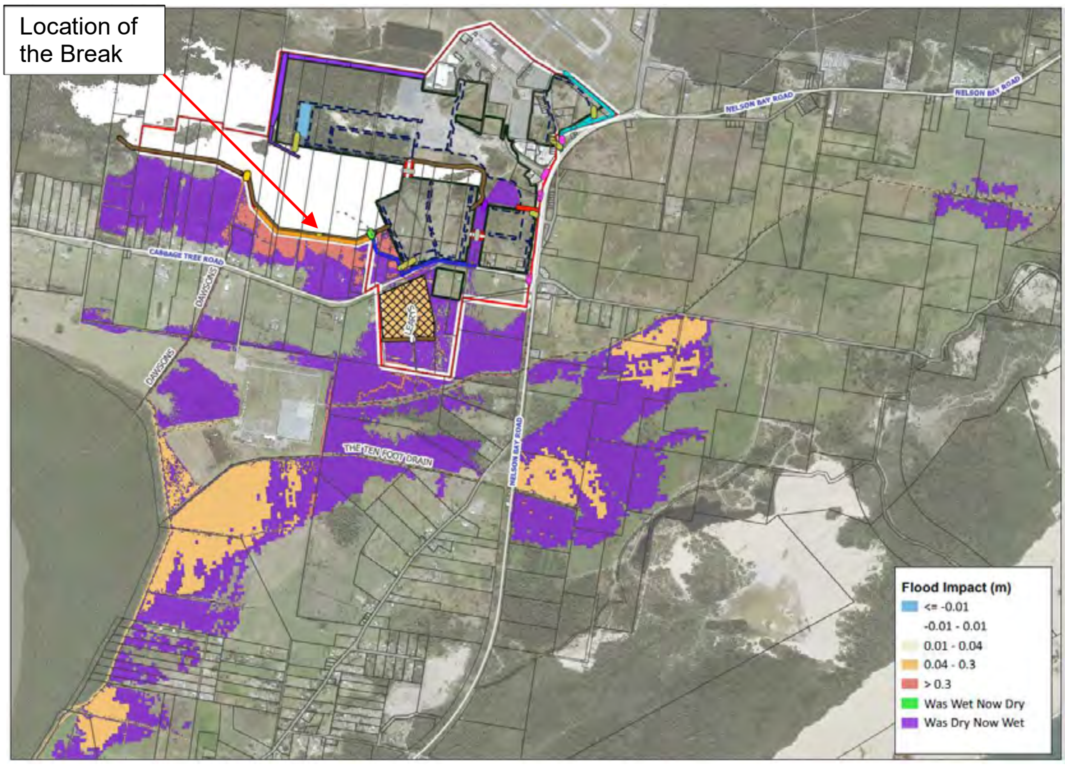


Figure 7-21 Sunny Day Failure (between Learys drain and Dawsons drain outlet weirs)

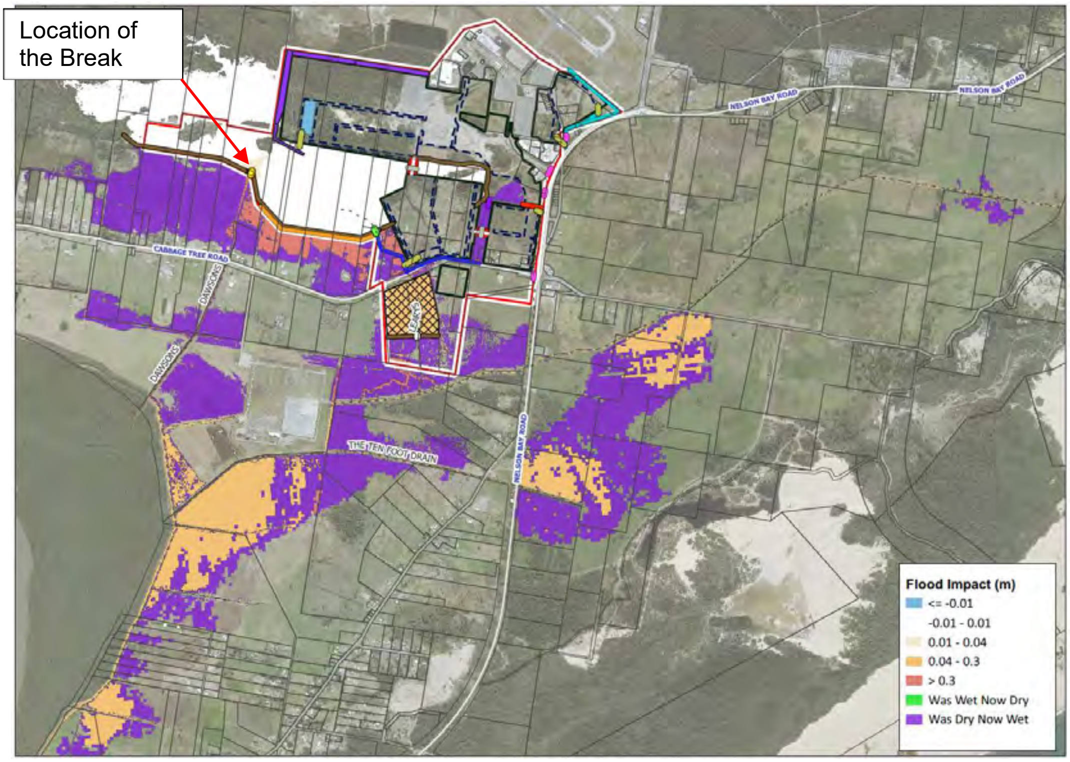


Figure 7-22 Sunny Day Failure (at Dawsons drain outlet weirs)

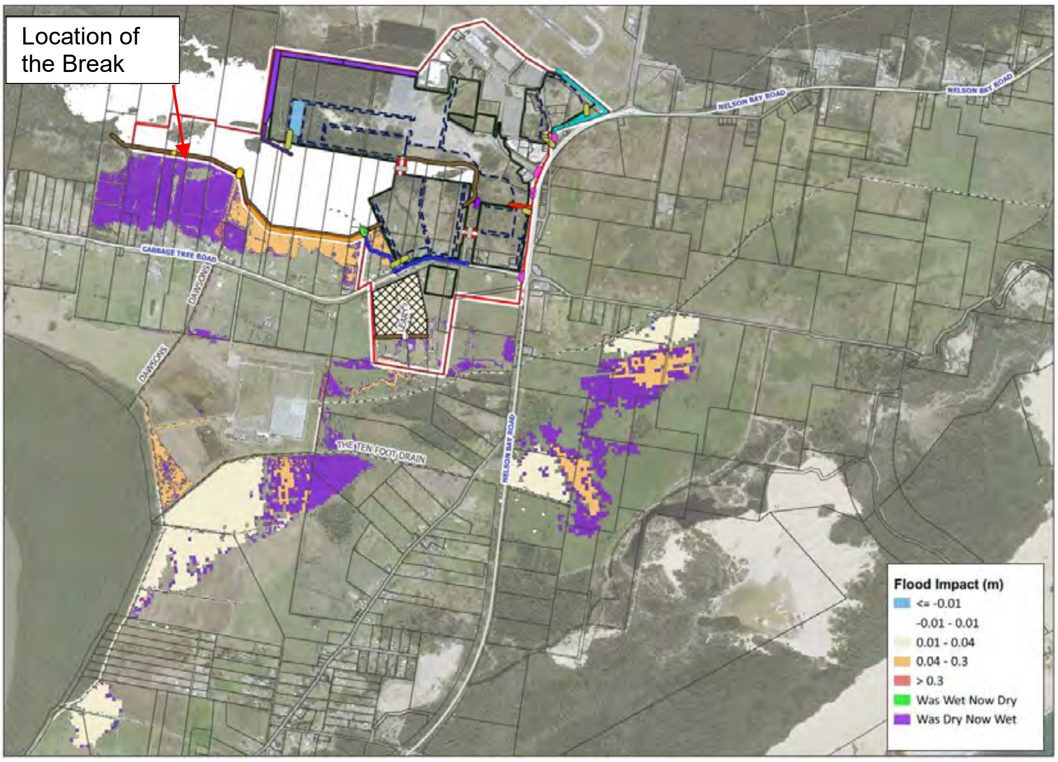


Figure 7-23 Sunny Day Failure (west of Dawsons drain outlet weirs)

Slumping Failure Assessment

The time for breach to fully develop was shortened to 15 minutes to calculate the incremental impacts of a slumping failure due to an earthquake. Same as an SDF, it was assumed that at the beginning of the failure, the water level within the detention basin is at the weir level (2.8 m AHD).

The maximum difference between the incremental impacts of the Slumping Failure compared to the Sunny Day Failure was 10mm (mostly less than 5mm). As a result, only SDF results were used in the subsequent stages of the assessment.

Estimating Consequence Categories

Based on the definition provided in ANCOLD (2012), the consequence assessment is the process of collecting information about the consequences of a potential dam break, identifying the severity of these consequences and thus determining Consequence Categories for the dam.

The Consequence Category is a function of risk to human life and severity of damage and loss. The risk to human life can be expressed according to two methods, one based on Population at Risk (PAR) and the other based on Potential Loss of Life (PLL). The PAR method simply considers the number of people present within the area of inundation. The PLL approach is considered a more refined method as it accounts for several additional factors such as warning time, exposure and velocity.

The current Consequence Category assessment is based on the Population at Risk (PAR). Also, for the potential severity of the damage and losses, the following estimates were determined subjectively based on engineering judgment:

- estimated total infrastructure cost
- estimated environmental impacts
- estimated health and social impacts

As mentioned before, the assessment has been undertaken for both dam failure scenarios:

- failures that occur without any natural flooding, giving rise to the "Sunny Day Consequence Category" (SDCC)
- failures that occur in association with a natural flood, giving rise to the "Flood Consequence Category" (FCC). The FCC is based on the incremental consequence over natural flooding and is limited to above a 300 mm increment (Dam Safety NSW, Societal and individual risk rating methodology for Dams Safety Act 2015).

Population at Risk (PAR)

The Population at Risk (PAR) includes all people who would be directly exposed to flood waters assuming they took no action to evacuate. A building is included in the PAR assessment if it is within the inundation zone and any part of the ground on which the building is located is inundated by a minimum of 300 mm. There are two types of PAR:

Total PAR: The Total PAR is the PAR within the total flood inundation zone. The total flood inundation zone includes that area affected by a natural flood event and any additional area flooded as a consequence of a dam break event.

Dam Break PAR: The Dam Break PAR is based on the determination of Total PAR minus the PAR affected by a natural flood event immediately prior to the dam break.

In a Flood Failure event, there may be extensive floodplain inundation prior to the dam break event. In this condition, ANCOLD (2012) suggest the following criteria to determine those people who can be discounted from the Dam Break PAR:

- PAR affected by pre-dam break flood water, defined by DV > 0.6m2/s, D_{max} >1.2m or Vmax>1.5m/s
- PAR who has had at least 12 hours warning of the event.

PMF Flood Failure Assessment

Considering that the incremental impacts as a result of a PMP Flood Failure were estimated to be less than 300 mm (as summarized in Table 7-10), the value of the incremental PAR is determined to be zero for this flood failure scenario.

Table 7-10 Summary of the PMF flood failure results

Flood Failure scenarios	Peak Incremental Impacts	Dam Break PAR
PMF Flood Failure (at Learys weir)	80 mm < 300mm	0
PMF Flood Failure (between Learys and Dawsons weirs)	90 mm < 300mm	0
PMF Flood Failure (at Dawsons weirs)	85 mm < 300mm	0
PMF Flood Failure (west of Dawsons weirs)	40 mm < 300mm	0

Sunny Day Failure Assessment

The Sunny Day Failure scenarios mostly impact the properties located north of Cabbage Tree Road. The incremental impacts to the areas downstream of the Cabbage Tree Road mostly occur in rural areas and the incremental impacts are less than 300mm. Seventeen (17) properties were identified from the aerial imagery in this area (as shown in Figure 7-24). These properties are located at a distance of 250 to 500m from the proposed bund.

Of the seventeen (17) properties, only five (5) properties are estimated to get inundated during an SDF scenario as presented in Table 7-11. The number of people that may be present at these locations are needed to determine the Dam Break PAR.

It should be noted that, for the purpose of this assessment, only the flood extent within the footprint of the main residential building has been considered. Being a rural residential area, there are several ancillary buildings and sheds which are submerge however were not included in the PAR assessment.

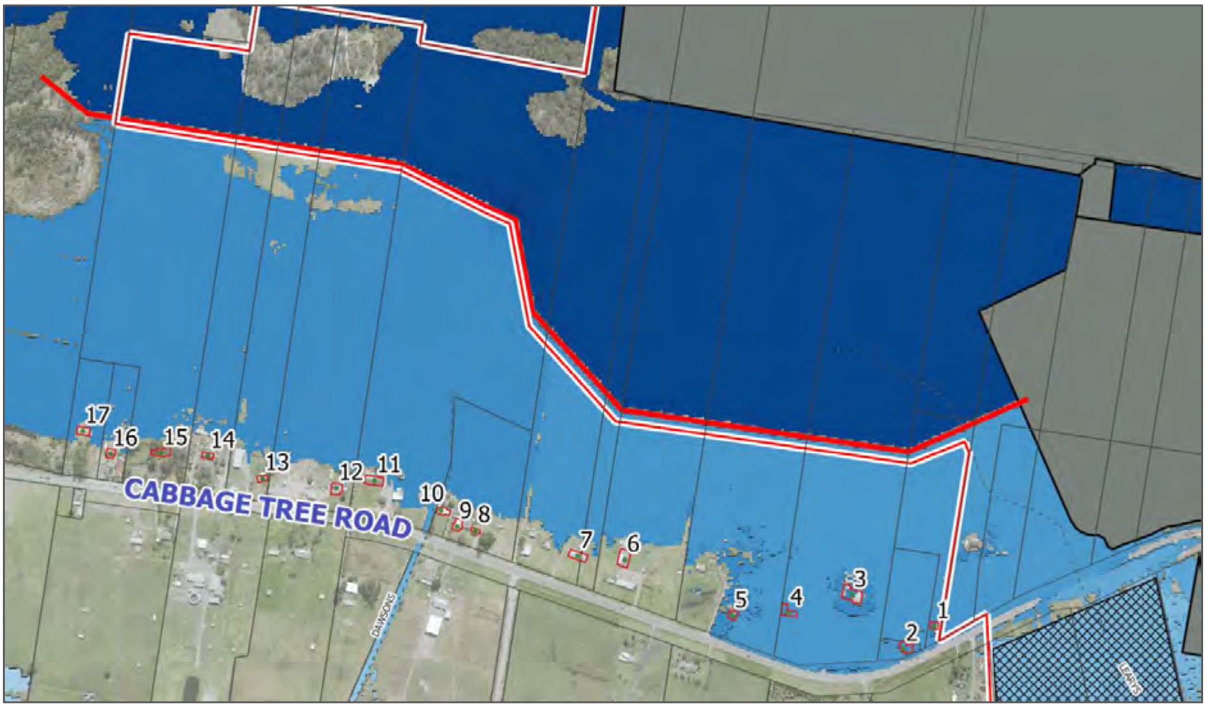


Figure 7-24 Properties at risk in Sunny Day Failure events

Table 7-11 Sunny Day Failure Population at Risk

Property ID	**Prior to Dam break (Criteria used to determine population at risk)**			**Post Dam break**		**Population at Risk**		
	Footprint of Dwelling Wet	D x V < 0.6 m^2/s (refer Note 2)	D x V > 0.6 m^2/s (refer Note 2 and 3)	12 hr Prior Notification (refer Note 3)	Footprint of Dwelling Wet	Maximum Depth of Inundation within the Footprint of Dwelling (mm)	Total PAR	Dam break PAR
1	No	N/A	N/A	N/A	Yes	367	Yes	Yes
2	No	N/A	N/A	N/A	Yes	421	Yes	Yes
3	No	N/A	N/A	N/A	Yes	94	No	No
4	No	N/A	N/A	N/A	Yes	387	Yes	Yes
5	No	N/A	N/A	N/A	Yes	199	No	No

Note:

1- *Dwellings refer to any area where people assemble e.g., School, Work Site, houses)*
2- *Additionally, D_{max} should not exceed 1.2 m V_{max} should not exceed 1.5 m/s*
3- *Where this condition applies, it is assumed that evacuation has taken place prior to the dam break event and therefore the dwelling should not be included in the Dam break Par count*

The number of residents of these properties are not known. It can be assumed that the buildings are residential, each with 2.1 equivalent population (in accordance with the Guideline for Failure Impact

Assessment of Water Dams, 2018) and occupied both day and night. Therefore, the Sunny Day Dam Break PAR is estimated to be 6.3 people.

Cabbage Tree Road

It was also investigated whether Cabbage Tree Road users may be at risk if the dam failure occurs. The only part of Cabbage Tree Road impacted during the Sunny Day Failure is about 200 meters at the intersection with Learys drain. The peak flood impact in this scenario is estimated to be less than 200 mm, which will occur if the dam failure occurs at the confluence of the embankment and Learys drain.

During the PMF FF, the impacts are less than 50mm at the intersection with Learys drain and 40mm at Dawson drain crossing.

Based on the impact values mentioned above, no PAR was calculated for the road users.

Estimation of severity of damage and loss

The severity of damages and losses has been reviewed for the Consequence Category determination, in accordance with Dam Safety NSW methodology provided in notice (n2019-3443) (NSW Government Gazette No 137), Tables 3A to 3C. It was found that the severity of damages and loss could be rated as “Minor” in accordance with the NSW Government Gazette No 137.

The assessment of the consequences is represented in Table 7-12 to Table 7-14 below. Based on these tables and the marked-up impact definition, the highest severity of damages and losses is rated as “Minor”.

Table 7-12 Table 3A of Dam Safety NSW Gazette 137 - criteria to be used for estimating total infrastructure costs

Type	Minor	Medium	Major	Catastrophic
Residential, Commercial, Community Infrastructure, Dam replacement or repair cost	<$10M	$10M-$100M	$100M-$1B	>1$B

Table 7-13: Table 3B of Dam Safety NSW Gazette 137 - criteria to be used for estimating environmental impacts

Type	Minor	Medium	Major	Catastrophic
Duration of recovery	<1 year	1 to 5 years	5 to 20 years	>20 years
Waters	Discharge from dambreak would not contaminate waters	Discharge from dambreak would contaminate waters	Discharge from dambreak would significantly contaminate waters	Discharge from dambreak would contaminate waters over a very long period
Ecosystems	Discharge from dambreak is not expected to impact on ecosystems Remediation possible	Discharge from dambreak would have short term impacts on ecosystems with natural recovery expected.	Discharge from dambreak would have significant impacts on ecosystems with natural recovery expected to take many years	Discharge from dambreak would have significant long term or permanent impacts on ecosystems. Remediation unlikely.
Endangered Ecological Communities and Threatened Species	Minimal damage expected. Recovery within one year	Losses expected to be recovered over a number of years	Severe impacts. Recovery will take many years	Permanent loss or damage to endangered ecological communities or threatened species
Material detained by a tailings/ash dam	Not applicable			

Table 7-14: Table 3C of Dam Safety NSW Gazette 137 - criteria to be used for estimating health and social impacts

Health and social impacts	Minor	Medium	Major	Catastrophic
Human health (eg by contamination of water, lack of water or release of sewage or toxins)	<100 people affected	100 to 1000 people affected	>1000 people affected for greater than one month	>10 000 people affected for a year or more
Loss of services to the community (eg water, gas, electricity, communications or transport	<100 people affected	100 to 1000 people affected	>1000 people affected for greater than one month	>10 000 people affected for a year or more
Emergency services organisations staff or volunteers' deployment	<1000 person days	1000 to 10,000 person days	>10,000 to 100,000 person days	>100 000 person days
Dislocation of people	Persons required to move from their homes for a period of <100 person months	Persons required to move from their homes for a period of 100 to 1000 person months	Persons required to move from their homes for a period of >1000 to 10,000 person months	Persons required to move from their homes for a period >10,000 person months
Dislocation of businesses	Businesses cease trading for <20 business months	Businesses cease trading for 20 to 200 business months	Businesses cease trading for 200 to 2000 business months	Businesses cease trading for >2000 business months and numerous business failures
Employment affected	<100 jobs lost	100 to 1000 jobs affected	>1000 to 10,000 jobs affected	>10 000 jobs affected
Loss of heritage	Significant damage to a local heritage item	Significant physical damage to a local heritage item	Significant physical damage to a heritage item registered under the Heritage Act 1977 (NSW)	Significant physical damage to a heritage item registered under the Heritage Act 1977 (NSW) or that is the subject of an interim heritage order under that Act; Significant physical damage to a place included in the Commonwealth Heritage List within the meaning of the Environment Protection and Biodiversity Conservation Act 1999 of the Commonwealth, or a property inscribed on the World Heritage List within the meaning of that Act
Loss of recreational facility	Damage to a recreational area or facility of local significance	Loss of a recreational area or facility of State significance	Loss of a recreational area or facility of national significance	Loss of a recreational area or facility of national and international significance

Assessed Consequence Categories

The estimated "Minor" severity of damages and loss, in accordance with the NSW Government Gazette No 137 and the maximum PAR estimates found from this assessment (of approx. 6.3 people for the sunny day failure) this would result in a Consequence Category of "Significant" as shown in Table 7-15.

Table 7-15: Assessed Consequence Category

Population at Risk	Severity of Damage and Loss			
	Minor	**Medium**	**Major**	**Catastrophic**
Less than 1	Very Low	Low	Significant	High C
1 to less than 10	Significant (Note 2)	Significant (Note 2)	High C	High B
10 to less than 100	High C	High C	High B	High A
100 to less than 1000	(Note 1)	High B	High A	Extreme
1000 or more		(Note 1)	Extreme	Extreme

Note 1: With a PAR in excess of 100. It is unlikely damage will be minor. Similarly with a PAR in excess of 1000, it is unlikely damage will be classified as medium.
Note 2: Change to 'High C' where there is the potential of one or more lives being lost.

Sensitivity Test

As previously mentioned, during the Slumping Failure assessment, it was concluded that reducing the breach development time did not significantly change the incremental impacts.

Therefore, for the sensitivity test, it was decided to investigate only the result of increasing the average breach width to 45 m. This test was undertaken for the Sunny Day Failure, which produces higher incremental impacts, and only for the critical locations (Dam break at the Dawsons weir, and middle of Dawsons and Learys weirs)

It was concluded that by increasing the width of the breach at Learys weir, the incremental impacts increase, but this is less than 20 mm. For a breach between the Learys and Dawsons weirs, the maximum increase is 55 mm for the areas located to the north of Cabbage Tree Road. This does not change the number of properties impacted. For the areas to the south of Cabbage Tree Road, the difference is less than 20 mm.

Conclusion

A failure impact assessment was undertaken to determine whether the proposed detention basin for the Williamtown SAP development is a "declared dam". For this purpose, Tuflow modelling was used to estimate the extent and characteristics of the flooding downstream resulting from the considered dam failure scenarios. This included Flood Failure (for the PMP event), Sunny Day Failure, Slumping Failure and sensitivity scenarios.

It was concluded that the incremental impacts as a result of a PMP Flood Failure were less than 300 mm and therefore the value of the incremental PAR was determined to be zero people for this flood failure scenario.

The SDF was estimated to result in the maximum consequence, with three properties located north of Cabbage Tree Road experiencing flood depths more than 300mm. This results in a PAR of 6.3 people. The severity of damages and loss was rated as "Minor". Based on these results, the proposed detention basin is considered a "declared dam" under the provisions of the new regulatory framework, given that the failure of the proposed dam could endanger lives. Although, this should be re-evaluated in the next design stage with the collection of survey data of the impacted buildings and incorporation of any changes to the design of the detention basin capacity, the proposed bund design and the Williamtown SAP design in general.

It should be noted that since the detention basin needs a rainfall event greater than the 5% AEP to get full the Sunny Day Failure is considered a very conservative scenario. This scenario was investigated because, due to the small dimensions of the proposed outlet structures, the discharge of the basin after a flood event can take several days. Also, other factors such as blockage of the outlet structures as a result of sedimentation can make the discharge time longer.

Therefore, although this preliminary assessment has identified that the proposed detention basin is a declared dam, but the sunny day failure is assumed a very conservative approach and need a review in the next stage.

Recommendation

- As mentioned for the purpose of this study, a typical section has been assumed for the proposed bund. If the section changes in future, there may be a need to review the dam break assessment.
- This assessment is preliminary in nature with respect to the assumptions and design input. A review of the detention basin classification should be undertaken as the design develops.
- Undertake survey of the buildings at risk, the nature of the sites and number of people living in them.
- Undertake additional sensitivity assessment of the breach parameters, location of the breach etc in the next design stage
- Although this preliminary assessment has identified that the proposed detention basin is a declared dam, but the sunny day failure is assumed a very conservative approach and need a review in the next stage.

7.4 Emergency Management

The NSW State Emergency Services (SES) is the legislated Combat Agency for floods and is responsible for the control of flood operations. This includes the coordination of other agencies for flood management tasks. To facilitate the SES response in an event, the Local Flood Plan guides the response protocol using flood intelligence and BoM's predictions to guide the level of response required.

The Williamtown/Salt Ash Floodplain Risk Management Study and Plan (BMT 2017) had identified that flooding requiring the need for emergency response within the Williamtown/Salt Ash region would most likely be initiated under significantly larger floods. In this situation the SES would most likely be limited in their ability to respond to the flood emergency. This was identified for the following reasons:

- The SES is principally a volunteer organisation and the time required to mobilise personnel could exceed the warning time available on initiation of overtopping of Nelson Bay Road at Fullerton Cove;
- A major flood event in the Williamtown-Salt Ash area is driven by broader Hunter River flooding and therefore likely to coincide with major flooding of other communities in the Hunter Region, further stretching already limited emergency response resources;
- Some of the principal roads within the region are cut in major floods making access difficult for mobilising or responding; and
- There is generally insufficient time to undertake tasks such as sandbagging or evacuation to reduce impacts on property or people.

Flood warnings and travel times are based on flood levels at upstream flood gauges at Singleton, Greta, Maitland and Raymond Terrace. The Williamtown/Salt Ash Floodplain Risk Management Study and Plan (BMT 2017) determined specific flood warning trigger levels and timings that were linked to flood levels at existing flood level gauges at Raymond Terrace, Hexham Bridge and Stockton Bridge.

Being intrinsically linked to the flood behaviour to the broader Hunter River flooding, it is possible to establish appropriate flood warning and response triggers for the Williamtown/Salt Ash area. Figure 7-25 shows the relative design flood water levels at Raymond Terrace, Hexham Bridge and Stockton Bridge. Also shown is the design flood water levels upstream (west) of Nelson Bay Road.

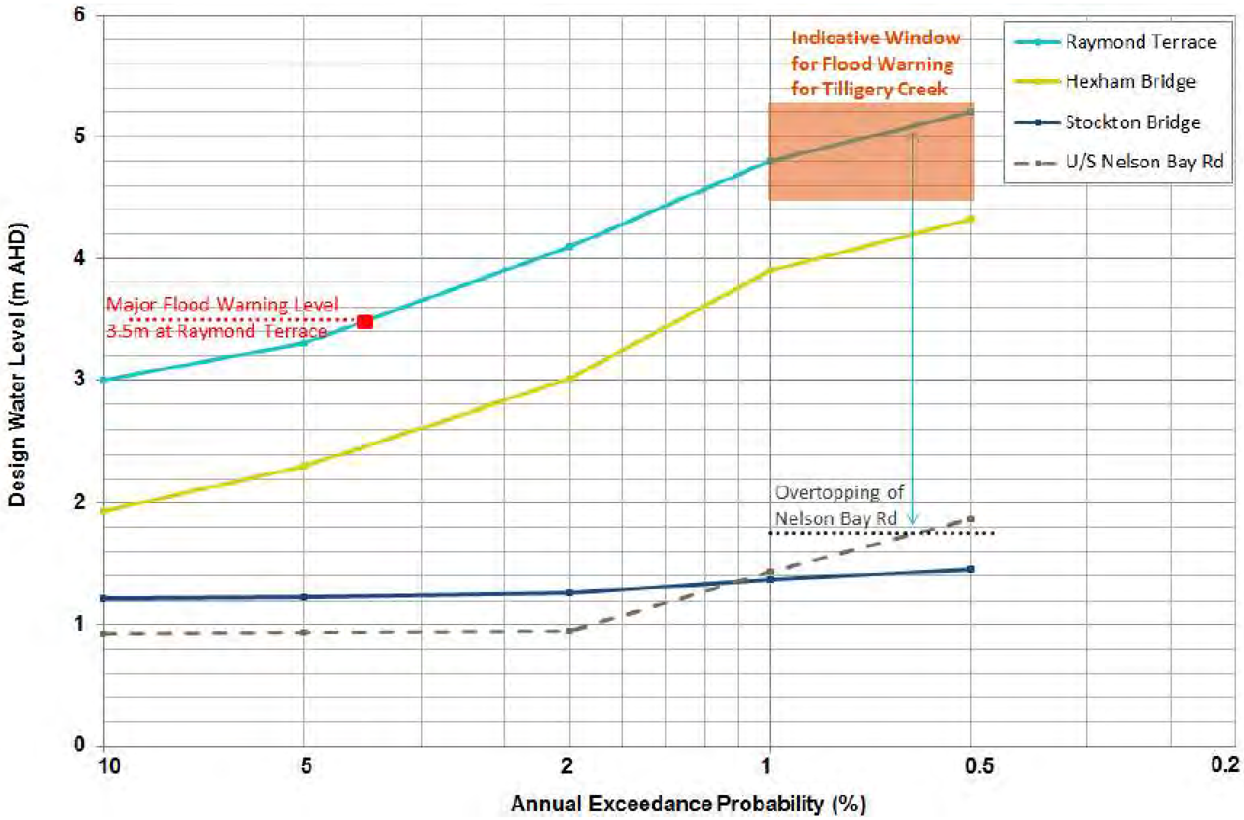


Figure 7-25 Suggested Tilligerry Creek flood warning window and Lower Hunter Flood gauges

A flood warning window proposed by BMT (2017) is presented in Figure 7-25 (orange area), which corresponds to a stage range at Raymond Terrace from 4.5m AHD. This would translate to the possibility of overtopping of Nelson Bay Road at Fullerton Cove should flood levels continue to rise.

It is important to note that the risk of overtopping Nelson Bay Road is predicted to occur in a flood event rarer than a 1% AEP event, when peak flood levels at Raymond Terrance exceed 5m AHD. This level is very high considering that the major flood warning level at Raymond Terrance is 3.5m AHD and therefore flood warning and emergency response based on flood levels would only be triggered following the issuing of flood warnings for Raymond Terrance.

7.4.1 Flood Emergency Response Classification

Under the revised PSC flood planning level (1% AEP for the year 2100 ie.1% AEP plus climate change), Nelson Bay Road does not achieve flood immunity along most sections. The section to the east at Salt Ash is predicted to be impacted by flooding more so compared to the western end at Fullerton Cove. Given Nelson Bay Road is the primary road corridor for the area, pavement raising works will likely occur incrementally over time to accommodate future climate changes. As a result, design levels of the Williamtown SAP roads should consider achieving flood immunity to the flood planning level (ie. 1% AEP for the year 2100) to provide resilience against future climate changes and facilitate evacuation connectivity to the future raised Nelson Bay Road.

With Nelson Bay Road largely achieving flood immunity in the 1% AEP event (BMT 2017), evacuation of the Williamtown SAP area would be via Nelson Bay Road. This would be subject to providing connector roads to Nelson Bay Road that also achieve a commensurate flood immunity or greater.

Although Nelson Bay Road does provide a high level of immunity and can facilitate flood evacuation, it should be noted that this is the only public evacuation route. There is the potential for evacuation via the fire trails across the northern section of the Williamtown SAP area, however this may require escorting/access by Hunter Water or defence as the property managers and owners of the northern lands.

The flood emergency response classification of the Williamtown SAP area has been determined based on the Australian Disaster Resilience Guidelines (AIDR 2017). This approach provides an understanding of areas that are at greatest risk of isolation or flooding in extreme events and the ability to egress from the flooded area. This analysis can inform the flood risk management process and strategic development.

The current cadastral properties across the Williamtown SAP area have been classified based on the suggested flood emergency response classifications from the guidelines. Where there are no properties defined in the cadastral data (ie. Area north of the Newcastle Airport) additional categories have been defined for the purposes of this study. The adopted flood emergency response classifications are presented in Table 7-16 and the spatial representation of the classifications is presented in Appendix A (Figure A23).

Table 7-16 – Flood emergency response classifications

Classification	Definition	Description
FEO	Flooded, Exit route, Overland escape	Areas that are not isolated in the PMF and have an exit route to community evacuation facilities via foot overland.
FER	Flooded, Exit route, Rising Road	Areas that are not isolated in the PMF and have an exit route to community evacuation facilities via a road that rises out of the floodplain.
FIE	Flooded, Isolated, Elevated	Areas that are isolated from community evacuation facilities by floodwater and there is elevated land on the property.
FIS	Flooded, Isolated, Submerged	Areas that are isolated from community evacuation facilities by floodwater and there is elevated land on the property.
NEO*	Not flooded, Exit route, Overland escape	Areas that are not flooded and able to evacuate on foot overland.
NER*	Not flooded, Exit route, Rising Road	Areas that are not flooded and able to exit via a raising road.
NIE*	Not flooded, Isolated, Elevated	Areas that are not flooded but isolated and there is elevated land on the property.

* Additional classifications defined for areas not bound by a cadastral boundary within the Williamtown SAP

The classification analysis is indicative and for the purposes of informing the emergency evacuation constraints under extreme flooding associated with different areas of the Williamtown SAP. The assessment was based on the following assumptions:

- Fire trails will allow for vehicular evacuation/egress.
- Properties intersect roads or fire trails are able to evacuation via vehicle.
- Although some properties can evacuate via road or fire trail, the connecting roads to the refuge shelters may be impassable. These areas are classified as FIE.
- Access to roads or fire trails is based on worst case flooding ie. At PMF flood peak.
- Flooding of Williamtown/Salt Ash catchment (I.e.Lower Hunter) is occurring at the same time as the Medowie catchment area.

The analysis indicates that there are only a small number of cadastral properties that can evacuate via road or on foot (FEO and FER). The remaining cadastral properties would likely be isolated (FIE or FIS) with the majority of those submerged (FIS). This is expected given the flood prone nature of the area.

Of the areas without cadastral data, a large proportion of the area is not flooded (NER) with the ability to evacuate via a rising road or fire trail.

7.4.2 Evacuation

The flood emergency response classification of the Williamtown SAP area under predevelopment conditions has been determined to be either FIE (Flooded, Isolated, Elevated) and FIS (Flooded, Isolated, Submerged) based on the Australian Disaster Resilience Guidelines (AIDR 2017) as shown in Appendix A (Figure A23). Following the proposed filling of the site from approximately 4.0mAHD to 5.5m AHD, the Williamtown SAP area will then become NIE (Not Flooded, Isolated, Elevated) to above the flood planning level of approximately 3.0m AHD. However, under the Probable Maximum Flood event the area would then become flooded and submerged.

With respect to evacuation, the proposed Williamtown SAP will be elevated to provide flood immunity to at least the current flood planning levels, however will become isolated in very rare to extreme (larger than the 1% AEP plus year 2100 climate change) events as Cabbage Tree Road and Nelson Bay Road become cut off. In such events, safe evacuation via road may not be possible therefore a 'shelter in place' approach is the only option.

As noted in the earlier Emergency Management section, sufficient flood warning is anticipated for this area. Provided that suitable systems and co-ordination with the SES are in place, there are acceptable options to either evacuate or shelter in place. For the key flood scenarios, the potential emergency management options are presented in Table 7-17

Table 7-17 – Emergency management in the event of a flood

Flood event	Shelter in place	Evacuate via Nelson Bay Road (any time evacuation)	Evacuate via Nelson Bay Road (early evacuation)
Up to and including the 1% AEP event	✓	✓ #	Not required
1% AEP + 2050 climate change	✓	✓#	Not required
1% AEP + 2100 climate change	✓	✓ #	Not required
PMF event	Not suitable unless building floors above 5.2mAHD and have outside access*	Not suitable	✓

#Subject to local flooding conditions as Medowie Road connection may experience overtopping, immediately north of the intersection with Nelson Bay Road.

*outside access is access to balconies or openable windows to allow for emergency rescue access or supply drop off in the event of prolonged isolation.

As the precinct develops, emergency management plans will need to be made. The local SES authority will also need to be made aware of the activation of the precinct so that emergency response can be focused around critical areas or services in the event of a significant flood.

7.5 Water Quality Management Strategy

As outlined above, the proposed water quality management approach adopts a water cycle management approach that includes a combination of the following elements to strip pollutants:

- Rainwater tanks to offset potable water use
- Gross Pollutant Traps (GPT's) on the lot maintained by private owners
- Street trees with passive irrigation or infiltration from road corridor runoff
- Swales to convey flows to downstream wetlands
- Constructed wetlands and biofiltration basins to achieve stormwater pollutant load reduction targets and minimise changes in water quality concentrations to downstream sensitive receiving environments

The following sections outline the proposed elements.

On-lot Rainwater Tanks

Roof runoff was assumed to be captured in rainwater harvesting tanks and reused for non-potable uses. The non-potable demand was assumed to be 50% of the total assumed water demand. The tanks were sized to meet 80% of the demand, with the exception of Airside and Manufacturing development which had significantly higher demands, these sub-precincts were sized to meet 60% of the assumed non-potable demand.

The lot impervious and roof characteristics assumed non-potable water demand and adopted rainwater tank size per hectare of development are listed in Table 7-18. It is recommended that development controls are implemented to maintain a minimum lot perviousness for different land uses to reflect Table 7-18.

Table 7-18 – On lot impervious and water demand assumptions

Sub-precinct	Lot Impervious (%)	Roof as factor of Lot Impervious Area	Non potable water demand (Kl/d/ha)	Adopted Rainwater tank size (KL/Ha)*
Defence and Aerospace	85	0.6	10.93	200
Defence and Aerospace (Direct Airside Access)	85	0.6	10.93	200
Research and Development	70	0.6	6.6	200
Advanced Manufacturing	85	0.6	10.93	200
Light Industrial	85	0.6	6.6	150
Commercial centre	90	0.7	6.6	130
Freight and Logistics	85	0.6	2.75	40

*Rainwater tanks should ultimately be sized on an individual basis to achieve the same outcomes in this strategy

It is recommended that a rainwater harvesting development control be set for the precinct to ensure delivery of objectives of this water quality treatment strategy. The target would preferably be based on a KL/ha/year value to achieve the outcomes achieved as part of the proposed strategy. Development proponents would then demonstrate how this is achieved on the site with their specific water demand and site configurations.

On-lot Gross Pollutant Traps

In order to prevent industrial litter and sediments being washed from the Williamtown SAP into the drainage swales, on lot gross pollutant traps are proposed. A nominal GPT unit was adopted for the assessments for removal of gross pollutants, TSS and some TP. The adopted gross pollutant trap MUSIC model parameters are provided in Appendix B. If other units are proposed at a later stage then analysis to confirm equivalent performance would be required.

While on-lot measures support flexible delivery time frames, there is a high risk of on-lot measures failing due to poor management and maintenance practices in private ownership. Evidence of this is generally anecdotal, however it is current best practice that precinct scale stormwater management infrastructure is delivered, established, and then handed over to Council for ongoing management through appropriate funding arrangements. Notwithstanding this, individual lot owners must be responsible for managing litter (gross pollutants) and sediment loads from their sites which are common pollutants of concern in industrial and commercial precincts. There is equity in private management of gross pollutants, since sediment and litter loads vary greatly across industry types while other generic pollutants are generally consistent across industry types.

Streetscape water quality treatment

Biofiltration street trees were assumed to be incorporated at a ratio of either 40 m^2 or 50 m^2 of filtration area per hectare of development. Biofiltration rain gardens could also be used with equivalent performance. It is proposed that road runoff passively irrigate the street trees / rain gardens and be treated prior to discharge to the drainage swales.

The drainage channels are proposed to minimise drainage grades and fill requirements but have not been modelled to account for their pollution reduction potential.

A sketch of the typical drainage channel arrangement is shown in Figure 7-26. Channels will be deep enough to facilitate piped connections from development under the roads and provide freeboard to ensure that sediment deposition would not affect drainage performance.

Given the near zero grade on the channels, it is proposed to provide subsurface drainage to prevent pooling on the surface and associated mosquito issues. Safe batter slopes and channel depths will dictate the channel width. Ultimately smaller diameter pipes will benefit this strategy.

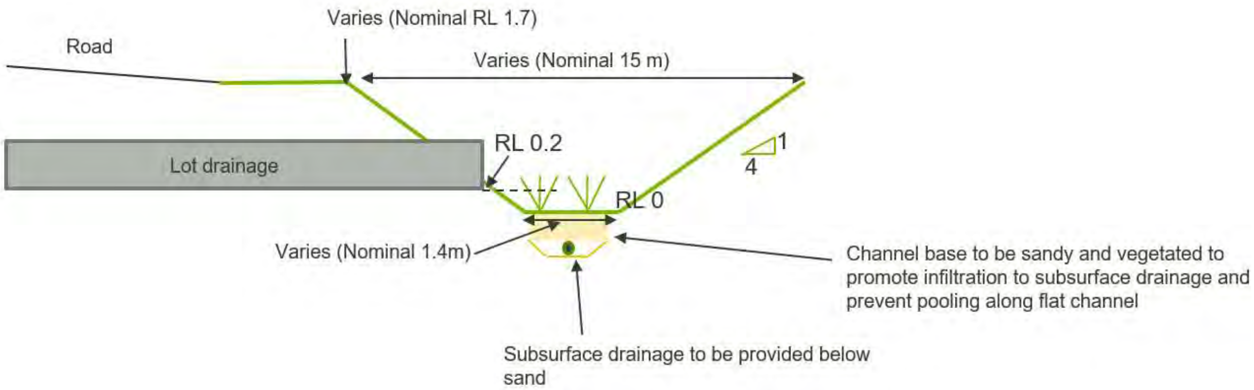


Figure 7-26 – Typical drainage swale arrangement

End of pipe water quality treatment

The preferred approach to meeting pollution stripping targets is through a combined wetland and biofiltration basin as shown in Figure 7-27. This configuration allows for flood conveyance as well as water quality treatment and resulted in the least amount of fill for the drainage and water quality strategies reviewed. More frequent high flows up to around a 50% AEP event would be diverted around the biofiltration and across the wetland at low velocities. More significant flood flows allowed to flow above the wetland and biofiltration. Further design development would include refining the high flow diversion arrangement and local shaping of the wetland for aesthetic / landscape design purposes and to prevent scour and wash out during floods.

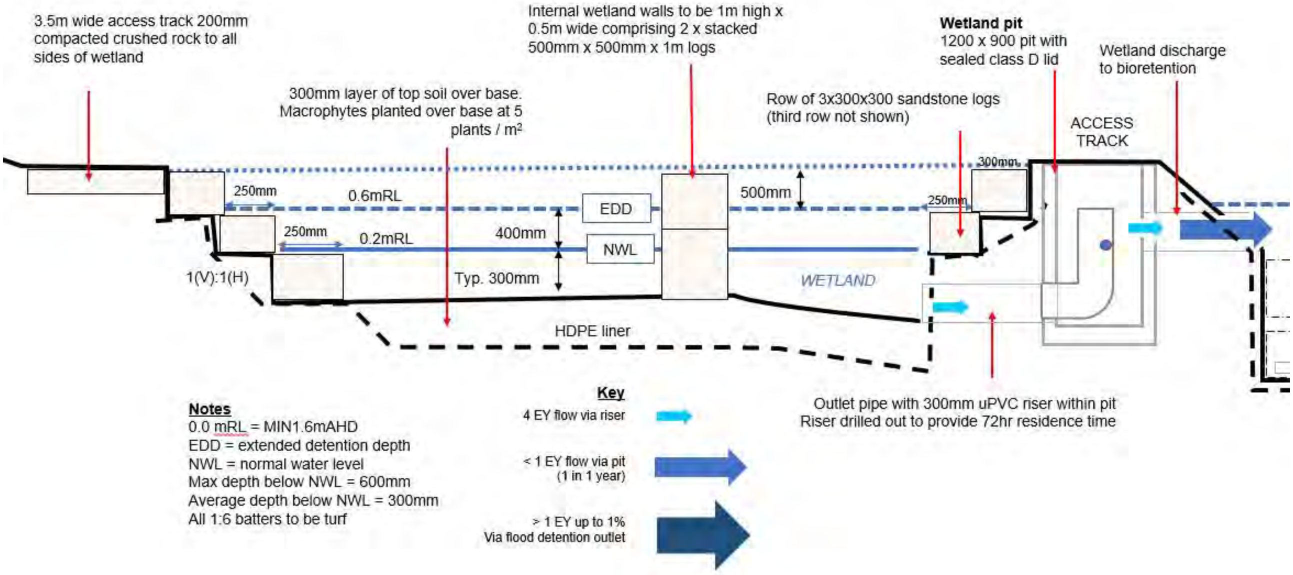


Figure 7-27 Indicative wetland configuration discharging to biofiltration

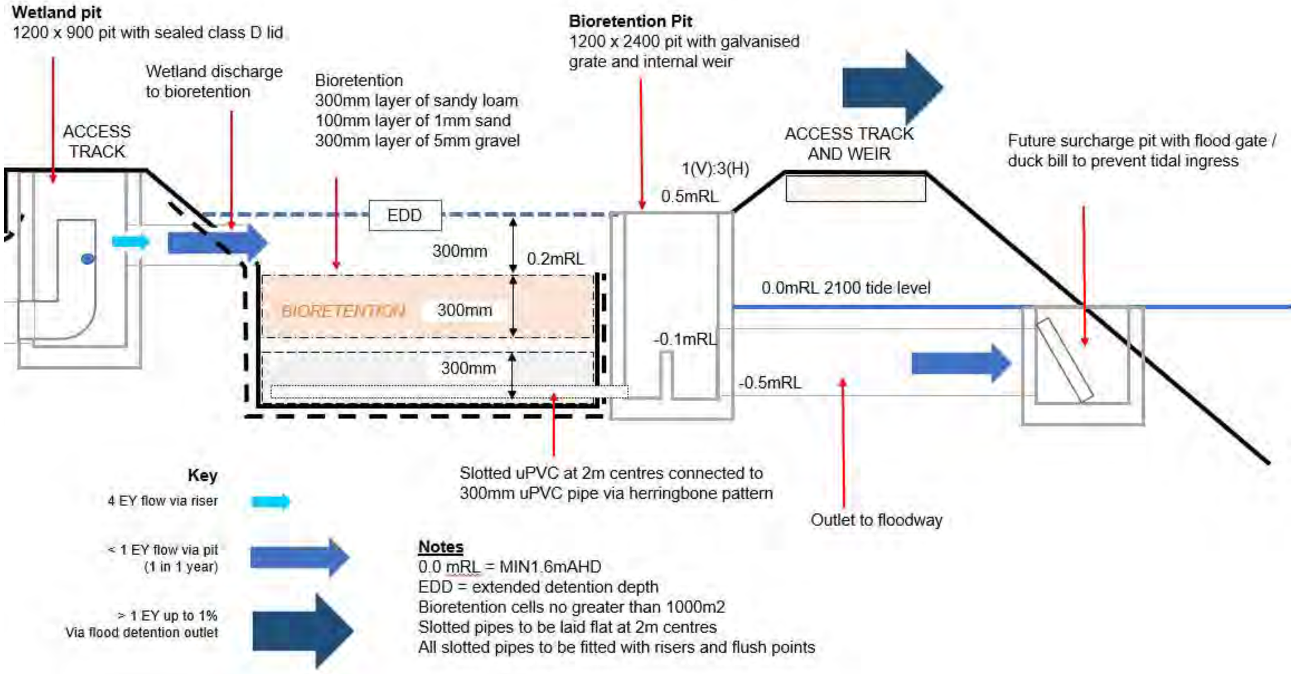


Figure 7-28 – Indicative biofiltration configuration downstream of wetland

The biofiltration and wetland surface area (as modelled in MUSIC) and total footprint of the wetland are presented in Table 7-19 and shown in Figure 6-3 for the assumed catchments based on an indicative filling arrangement.

The wetlands were sized based on the development footprints provided in the final structure plan. It should be noted that the schematic below must include specific bird management batter slopes and edge treatments during concept design to minimise wildlife strike risk.

Table 7-19 – WSUD details for a range of potential future soil types and land uses

Precinct	**Light Industrial (Clay)**	**Light Industrial (Sand)**	**Airside (Clay)**	**Airside (Sand)**	**Freight and Logistics (Sand)**	**Research & Development (Sand)**
Gross Pollutant Trap (CDS Nipper 506)						
High Flow By-pass ($m^3/s/ha$ of development)	0.04	0.04	0.04	0.04	0.04	0.04
Performance	All lots treated by GPT to the performance of a CDS Nipper 506					
Biofiltration Street Trees (per ha of development)						
Precinct	Light Industrial (Clay)	Light Industrial (Sand)	Airside (Clay)	Airside (Sand)	Freight and Logistics (Sand)	Research & Development (Sand)
Biofiltration Street Trees (per ha of development)						
Extended Detention Depth (m)	0.1	0.1	0.1	0.1	0.1	0.1
Filter Area (m^2)	40	50	40	50	50	50

Precinct	Light Industrial (Clay)	Light Industrial (Sand)	Airside (Clay)	Airside (Sand)	Freight and Logistics (Sand)	Research & Development (Sand)
Saturated Hydraulic Conductivity (mm/hr)	50	50	50	50	50	50
Filter Depth (m)	1	1	1	1	1	1
Base Lined	Y	Y	Y	Y	Y	Y

Table 7-20 – Wetland and biofiltration basin details and footprints required to ensure no change in water quality associated with land use change

Constructed Wetland Basin ID	W4	W5	W6	W7	W8
Inlet zone (m^2)	223	305	470	82	114
Marsh zone (m^2)	601	823	1270	222	308
Perimeter edge (ln.m)	439	554	836	304	432
500Hx500W internal walls (ln.m)	105	109	127	0	0
Wetland pits (units)	2	2	4	1	1
Bioretention ID	**W4**	**W5**	**W6**	**W7**	**W8**
Number of separate cells	2	2	4	1	1
Planted filter surface area (m^2)	1782	2438	3762	658	913
Slotted pipe network at 2m centres (ln.m)	713	975	1505	263	365
Risers with flush points	59	81	125	22	30
Maintenance access tracks (ln.m)	841	804	1275	448	539

7.6 Water Quality Impact Assessment

7.6.1 Music Model Inputs and Approach

Rainfall, hydrology and pollutant load model inputs for the final analysis were carried through from scenario testing described above4.3.

Table 7-21 provides the key strategy assumptions adopted for the final analysis and sizing in the structure plan. This hierarchy defined which land uses require a specific stormwater performance target.

MUSIC modelling parameter assumptions were as per **Table 2-18**.

Table 7-21 – Key MUSIC model assumptions

Land use	Stormwater Management Approach	Adopted MUSIC Node Typology
All existing land uses	No treatment of stormwater is proposed	Varies based on existing land use
Defence and Aerospace / Airside	Located within drinking water catchment. Requires a WSUD strategy to achieve pollution stripping targets for groundwater and stormwater and achieve the adopted sensitive catchment pollutant load reduction targets	Industrial
Freight and Logistics		Industrial
Research and Development		Industrial
Commercial Centre		Within Astra Aerolab (not modelled)

Land use	Stormwater Management Approach	Adopted MUSIC Node Typology
Flexible: ▪ Research and Development ▪ Advanced Manufacturing ▪ Light Industrial ▪ Commercial Centre Due to likely being the most prominent land use and also representative of average land use characteristics the flexible land use was modelled as Light Industrial.	Requires a WSUD strategy to achieve the sensitive catchment pollutant load reduction targets	Industrial

A precinct wide MUSIC model has been developed for the existing lands uses as well as the proposed structure plan with proposed water cycle management elements.

7.6.2 Surface Water Quantity

A water balance assessment was undertaken using MUSIC to test the effects of the precinct development and strategy on stormwater runoff and groundwater recharge to the receiving environment.

The modelling indicates that:

- When within the Williamtown SAP Structure Plan Boundary groundwater recharge is reduced by 98% from pre-development conditions and stormwater runoff volumes increased by 224%.
- However, when considering the local water balance, the post-development groundwater recharge volume within the precinct development is reduced by 8%. As noted above, in the context of the entire groundwater recharge across the aquifer, the overall loss of groundwater recharge to the entire aquifer is likely to be very small.
- The recharge volume reduction is only around 1% of the net recharge to the wider Tomago sand bed aquifer (36,000 ML/year), therefore the reduced local recharge is considered to have a negligible impact on the resource. Refer to the Contamination and Hydrogeology Report for further discussion.
- When considering the local water balance (r mean annual stormwater runoff volumes from the local catchment will be increased by 38%. This amount is mitigated by the water cycle management approach, and it is unlikely that this volume can be further reduced without regional stormwater harvesting where stormwater is used for irrigation of the park spaces or transferred to another storage (eg Grahamstown Dam).
- The Fullerton Cove catchment (around 3,705 ha) is around 2.5 times larger than the local surface water catchment investigated (around 1,564 ha), therefore mean annual freshwater runoff discharging to Fullerton Cove may increase by around 15 to 20%. The increase in volume is associated with rainfall events that exceed the capacity of rainwater tanks and wetlands. Increased stormwater volumes would not be expected during every event but would generally occur during moderate and larger storm events. An increased mean annual freshwater runoff volume could potentially change the salinity and local water level variation in the receiving wetlands. The impact of this increase in freshwater runoff on sensitive environments within Fullerton Cove may be assessed during future stages.

Table 7-22 – Final analysis water balance

		Rainfall	Stormflow	Baseflow	Re-use Supplied	ET Loss
Williamtown SAP Development Extent	Pre-development (ML/year)	2451	379	416	0	1658
	Post-development (ML/year)	2451	1229	9	452	760
	Impact (%)	0%	224%	-98%		-54%

Surface Water Catchment Extent	Pre-development (ML/year)	18631	2263	5320	0	11077
	Post-development (ML/year)	18631	3113	4913	452	10179
	Impact (%)	0%	38%	-8%		-8%

Flow duration curves have been prepared to show the potential change in flows leaving the precinct boundary are provided in Figure 7-29 and Figure 7-30.

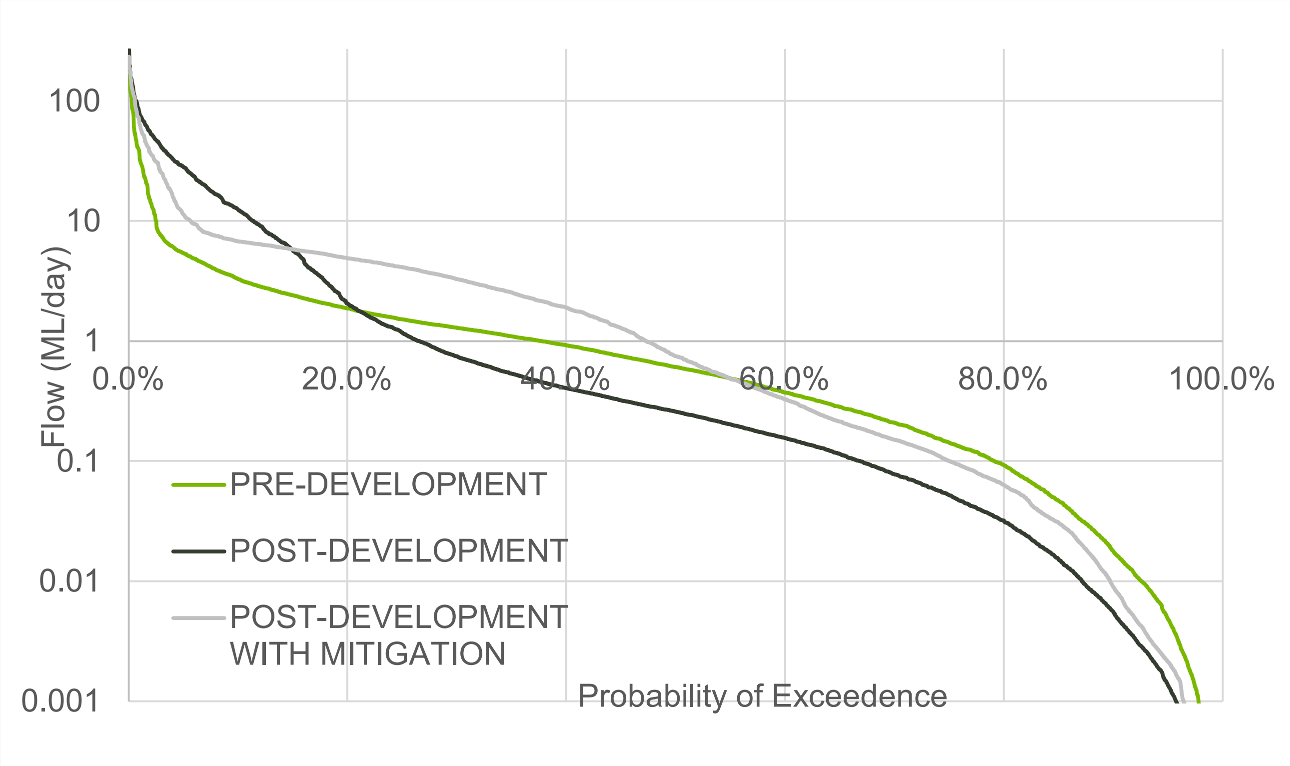


Figure 7-29 – Fresh water runoff flow duration curves for runoff from Precinct

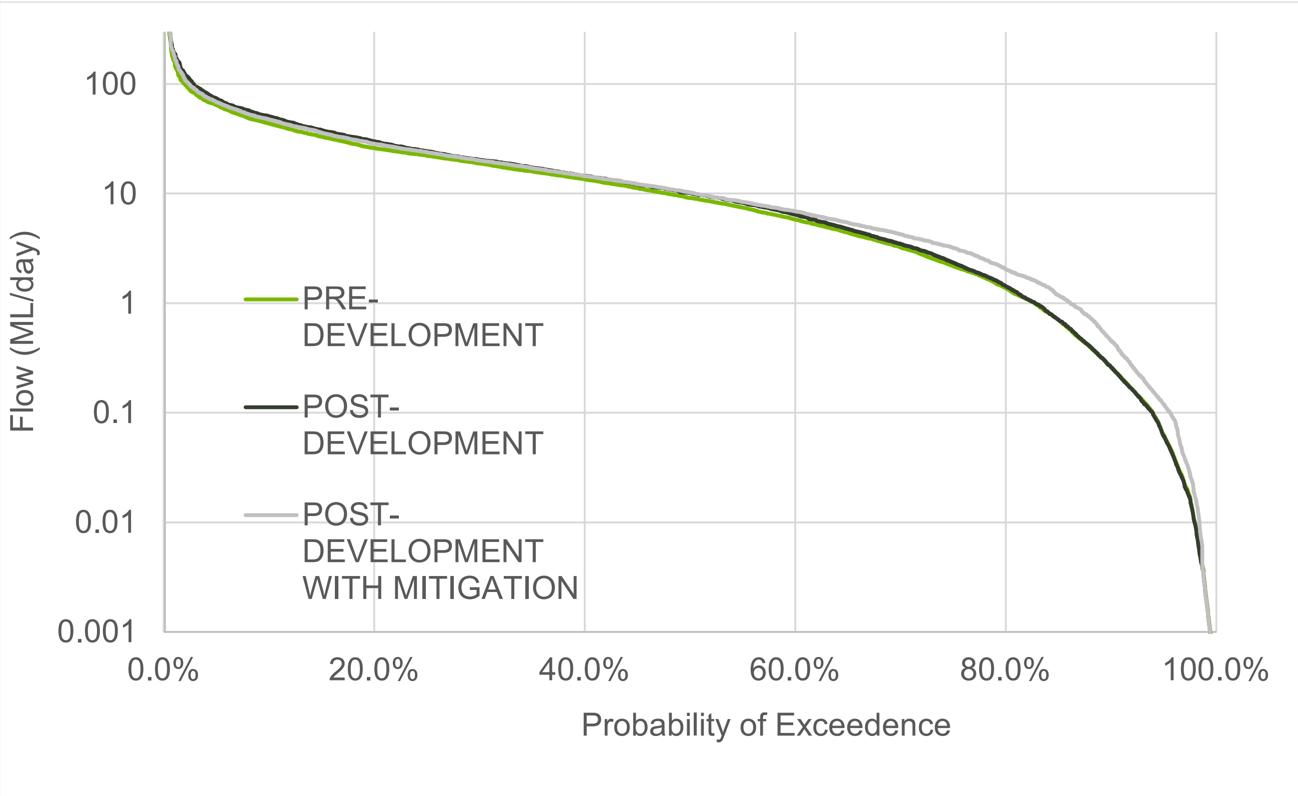


Figure 7-30 – Fresh water runoff flow duration curves for runoff from Precinct and local catchment upstream of Precinct

7.6.3 Surface Water Quality

A pollutant load balance assessment was undertaken using MUSIC to test the effects of the precinct development and WSUD strategy on pollutant loading to the receiving environment.

Pollutant Loads

Pollutant loads were considered in the absence of target water quality concentrations for storm events. The results are provided in Table 7-23.

The modelling indicates that designated levels and water quality basins footprints will ensure:

- Adopted Council sensitive catchment water quality stripping targets can be achieved
- No change in pollutant loads when compared with rural residential lands within the Precinct

Table 7-23 – Pollutant load balance

Catchment	Result type	TSS	TP	TN	Comment
Williamtown SAP	Pre-development (kg/yr)	30,600	84	682	Council pollution stripping targets can be achieved Ideal pollution reduction targets can be achieved to minimise risk of land use change on Ramsar wetlands
	Post-development untreated (kg/yr)	109,000	215	1,620	
	Post-development treated (kg/yr)	6040	52	612	
	Change as a function of untreated loads	-94%	-76%	-62%	
	Change as a function of pre-development loads	-80%	-39%	-10%	

Pollutant Concentrations

A comparison of likely pollutant concentrations exported from the Precinct was undertaken using MUSIC software. A comparison of pre and post development pollutant concentrations are presented below in Figure 7-31 to Figure 7-33. The concentrations were generated based on assumptions for baseflow and stormwater pollutant concentrations and have not been calibrated to local water quality background concentrations in the receiving drains.

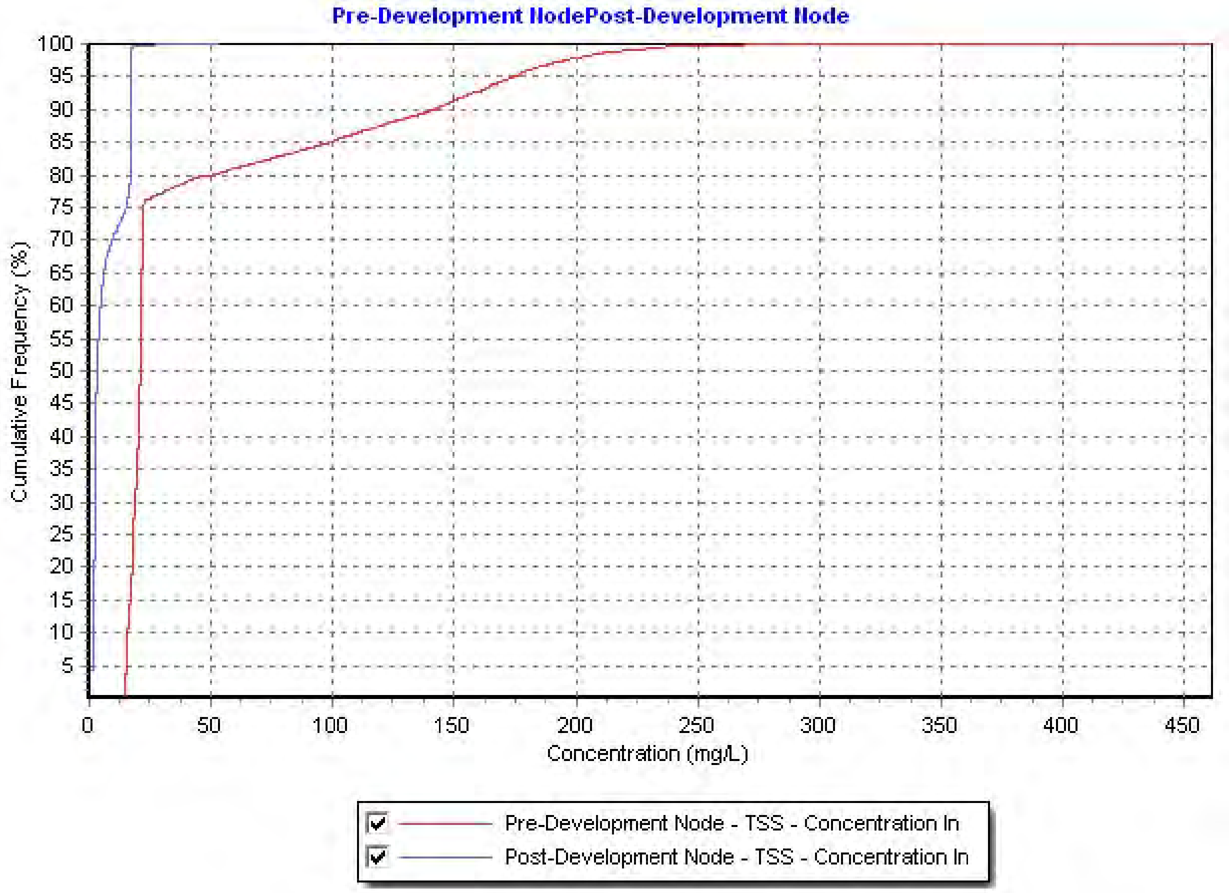


Figure 7-31 – TSS concentrations in stormwater downstream of SAP

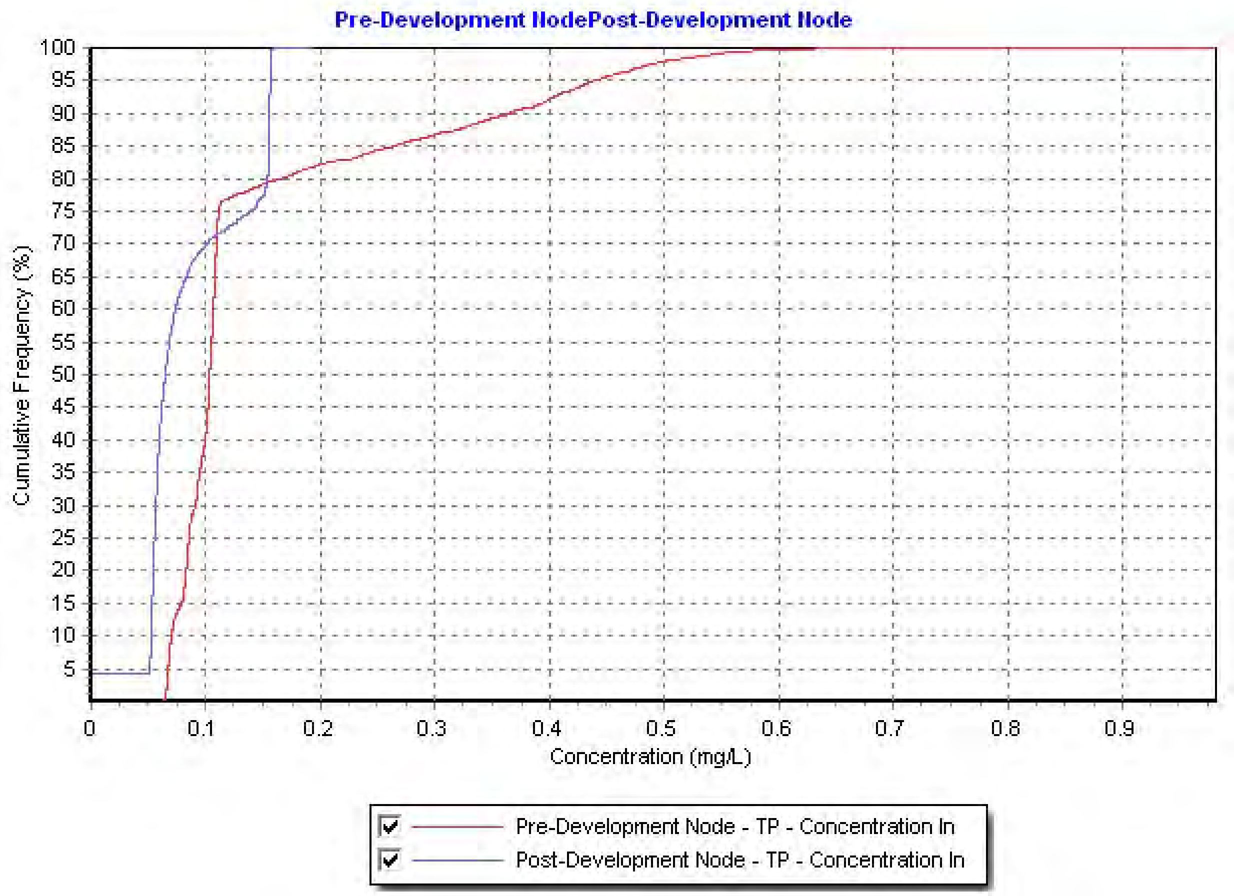


Figure 7-32 – TP concentrations in stormwater downstream of SAP

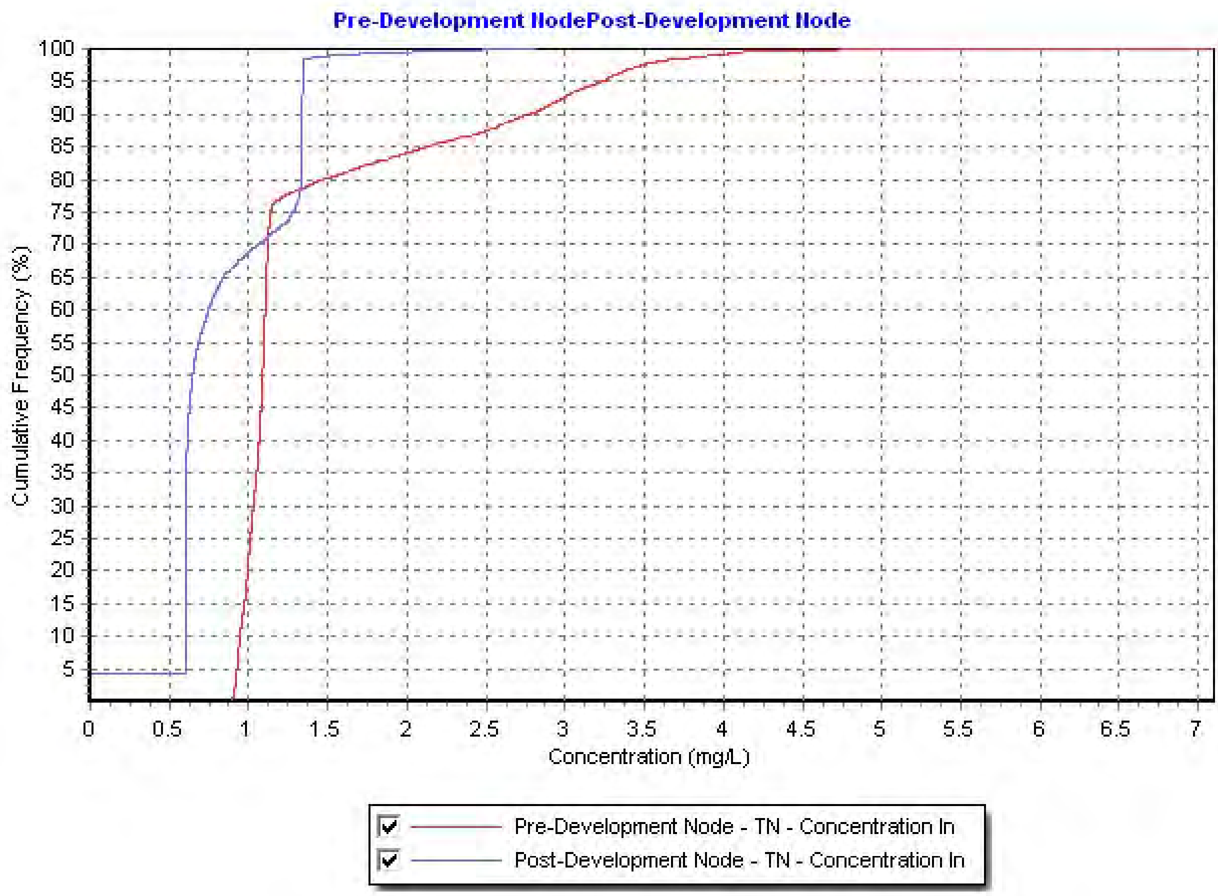


Figure 7-33 – TN concentrations in stormwater downstream of SAP

The plots show that the proposed water cycle management strategy will ensure pollutant loads generally would not exceed existing pollution concentrations from the rural residential lands within the Precinct boundary. The exception to this is for a potentially small exceedance of TN concentration by 0.2 mg/L however this may be further optimised during subsequent design, and there is generally a reduction TN concentrations for the rest of the time.

Regardless of this small change in pollutant concentrations, this provides good certainty that the proposed stormwater management approach would result in a negligible change in TSS, TP or TN concentrations entering the downstream Ramsar Wetlands. On this basis, there is also likely to be a negligible change in other potential industrial pollutants entering the downstream waterway.

7.6.4 Water Balance

A water balance assessment was undertaken using MUSIC to test the effects of the Williamtown SAP and WSUD strategy on stormwater runoff and groundwater recharge to the receiving environment.

The modelling indicates that:

- When only taking into account the Williamtown SAP Structure Plan Boundary (refer Figure 7-34), groundwater recharge is reduced by 98% from pre-development conditions and stormwater runoff volumes increased by 224%.
- When considering the local water balance (refer Figure 7-34), the post-development groundwater recharge volume within the Williamtown SAP is reduced by 8%. As noted above, in the context of the entire groundwater recharge across the aquifer, the overall loss of groundwater recharge to the entire aquifer is likely to be very small.

- The recharge volume reduction is only around 1% of the net recharge to the wider Tomago sand bed aquifer (36,000 ML/year), therefore the reduced local recharge is considered to have a negligible impact on the resource. Refer to the Contamination and Hydrogeology Report for further discussion.
- When considering the local water balance (refer Figure 7-34), mean annual stormwater runoff volumes from the local catchment will be increased by 38%. This amount is mitigated by the WSUD approach and it is unlikely that this volume can be further reduced without regional stormwater harvesting where stormwater is transferred to another storage (eg Grahamstown Dam).
- The Fullerton Cove catchment (around 3,705 ha) is around 2.5 times larger than the local surface water catchment investigated (around 1,564 ha), therefore mean annual freshwater runoff discharging to Fullerton Cove may increase by around 15 to 20%. The increase in volume is associated with rainfall events that exceed the capacity of rainwater tanks and wetlands. Increased stormwater volumes would not be expected during every event, but would generally occur during moderate and larger storm events. An increased mean annual freshwater runoff volume could potentially change the salinity and local water level variation in the receiving wetlands. The impact of this increase in freshwater runoff on sensitive environments within Fullerton Cove should be assessed during future design stages.

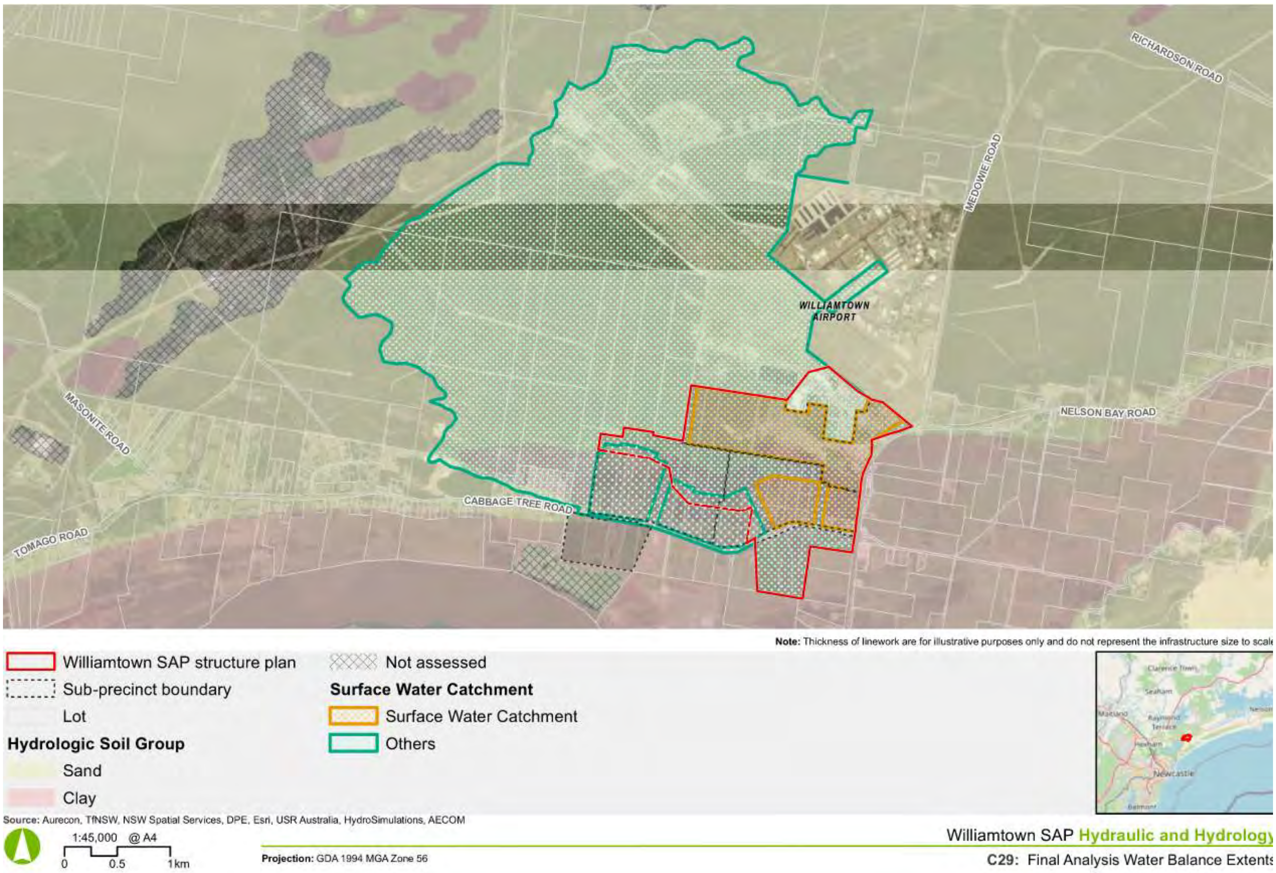


Figure 7-34 – Final analysis water balance extents

Table 7-24 – Final analysis water balance

		Rainfall	Stormflow	Baseflow	Re-use Supplied	ET Loss
Williamtown SAP Development Extent	Pre-development (ML/year)	2451	379	416	0	1658
	Post-development (ML/year)	2451	1229	9	452	760
	Impact (%)	0%	224%	-98%		-54%
	Pre-development (ML/year)	18631	2263	5320	0	11077

Surface Water Catchment Extent	Post-development (ML/year)	18631	3113	4913	452	10179
	Impact (%)	0%	38%	-8%		-8%

7.6.5 Pollutant Load Balance

A pollutant load balance assessment was undertaken using MUSIC to test the effects of the precinct development and WSUD strategy on pollutant loading to the receiving environment. Pollutant loads were considered in the absence of target water quality concentrations for storm events. The results are provided in Table 7-25.

The modelling indicates that the structure plan provides sufficient area for stormwater to be managed in a way that achieves will ensure:

- Council's sensitive catchment water quality stripping targets
- No change in pollutant loads when compared with rural residential lands within the Precinct

Table 7-25 – Pollutant load comparison between balance

Catchment	Result type	TSS	TP	TN	Comment
Williamtown SAP Development Extent	Pre-development (kg/yr)	30,600	84	682	Council pollution stripping targets can be achieved Ideal pollution reduction targets can be achieved to minimise risk of land use change on Ramsar wetlands
	Post-development untreated (kg/yr)	109,000	215	1,620	
	Post-development treated (kg/yr)	6040	52	612	
	Change as a function of untreated loads	-94%	-76%	-62%	
	Change as a function of pre-development loads	-80%	-39%	-10%	

Activation area	Required Management elements	Comments
Astra Aerolab portion of SAP	Cutoff drains to the north and north-east. Bunding generally around the south-eastern corner of the precinct along Cabbage Tree Rd and Nelson Bay Rd. Culvert upgrades along Nelson Bay table drain.	Refer Figure C4 in Appendix C No flood storage offset area requirements south of Cabbage Tree Road.
Entire SAP area	Cutoff drains to the north and north-east. Bunding required from the western edge of the ultimate SAP precinct to connect into Learys Drain. Bund alignments could potentially follow Cabbage Tree Rd (ie. No set back from Cabbage Tree Rd). Controlled outlets on Learys and Dawsons Drains. Western cut-off drain.	Refer Figure C1 in Appendix C

7.7 Key Project Assumptions, Risks and Limitations

7.7.1 Assumptions

The following general assumptions should be noted when reviewing this assessment:

- The intent of the proposed strategy is to avoid works along existing major regional drains such as Dawsons Drain, Learys Drain and the Nelson Bay Road table drain. However, as the design details emerge, minor works will likely be required to create positive drainage and allow areas trapped by bulk filling to drain out under gravity, which includes minor regrading of existing channel sections with localised low points and revegetation of the channels. That said, the intent of these minor works are to facilitate drainage of nuisance flows and indicative assessments show that it will not materially impact the existing flood conveyance regime beyond the Williamtown SAP boundary in major events.
- The ownership, maintenance and operation regimes for the drainage, water quality and flood management infrastructure has not been considered at this stage and is to be determined as the design evolves and following further discussions with the relevant agencies.
- A flexible design approach has been adopted to interface with the Williamtown SAP based on information available at the time of the assessment. This is particularly relevant for the Taxiway extension/ Dawson Drain interface where possible options have been considered to allow as much flexibility in the future connections. However, it is assumed that future interfaces will ultimately either adapt or modify the infrastructure, whilst maintaining its intended function, to provide the desired outcome.

7.7.2 Risks

Risks associated with the assessment can be summarised as follows:

- Internal drainage within the Williamtown SAP has been investigated at a precinct scale for the major trunk drainage only. This has informed an estimated channel size and hydraulic performance which has been applied across the Williamtown SAP. As the design develops and a drainage design is undertaken, minor variations in the required major trunk drainage channel capacities and alignment may vary to accommodate additional detail not captured at Master Planning stage.
- Major trunk drainage channels have been designed with a longitudinal grade of 0.1%. This may be outside of typical construction tolerance and may be challenging to construct with precision. However, this is based on precedence of very low grade channels at the adjoining approved Astra Aerolab development. Furthermore, the adoption of this grade was driven by the influence on the significant bulk filling and flood immunity requirements and the interfacing requirements to the existing Astra Aerolab Stage 1 and Newcastle Airport.
- Nuance ponding that results from flat channels can be managed by incorporating a low level sub surface drainage pipe to remove water over several days to reduce mosquito risk
- The representation of the Astra Aerolab design in this plan is indicative only and will require detailed coordination at design stage.
- Differences in flood behaviour and impact results between the Northrop assessment of the Astra Aerolab development and the Williamtown SAP modelling are a typical outcome of two separate assessment methodologies. In the absence of recorded historical data, calibration of the models cannot occur. Reliance is on general consistency against other similar studies. Differences will remain and may influence the effectiveness of the management measures proposed.
- It isn't clear what the Astra Aerolab development adopted in their design performance requirements. However, upon an indicative assessment, it does not appear to adhere to the same design performance requirements as proposed for the Williamtown SAP (ie. flood protection, allowance for climate change and acceptability of flood impact on adjacent properties). Future stages of the Astra Aerolab that are incorporated into the Williamtown SAP project are proposed to adopt the more stringent flooding and water quality design performance requirements.

7.7.3 Limitations

The accuracy of the flood modelling is limited to the level of detail and accuracy of the input data. This consequently influences the decisions and outcomes of the flood assessment that inform critical aspects of the Master Plan such as:

- Flood impacts
- Bulk fill volumes
- Land-take requirements

Further to the above, the analysis presented is limited to the level of detail at a master planning stage. The items noted will gradually converge to some degree as the design evolves through the design stages and further detail is built into the modelling. However, this it is still mostly dependent on data availability such as survey information.

7.7.4 Items for Further Investigation

Issues identified that cannot be resolved within the Master Planning timeframe and require further investigation are:

- Incorporation of additional drainage and topographic detail (eg. RAAF base, Newcastle airport and constructed Astra Aerolab development) to improve the representation of local flooding around the Williamtown SAP. This is currently limited to lidar survey provided as field survey information is not available at this stage. This will improve the drainage representation in the flood model and hence reliability of the results and management outcomes.
- Consideration of updating the regional flood model to ARR 2019 methodologies and data. This effort is typically associated with a study as part of the DPE Floodplain Management Program and may not fall within the scope of an SAP given the Floodplain Management Program review process would likely not be incorporated.
- Refinement of the regional flood model should be reviewed against the adopted local models. Council’s regional model has been adopted with minimal changes for this assessment for consistency with flood planning. Some discrepancies between the regional flood model and the local model would need to be reconciled.
- Optimisation of the flood management measures has not been undertaken at this stage due to time constraints. This includes optimisation of the outlet to the Bio-conservation area to better match the dominant hydrologic regime. A review of areas where management measures can be optimised should be investigated at the next design stage.
- Review availability of floodgate survey information for all Fullerton Cove discharge points and identification of floodgate types/operation.
- Assess the potential increased freshwater runoff volume impacts to Fullerton Cove

7.8 SWOT Analysis

The SWOT analysis for the proposed structure plan is show in Table 7-26.

Table 7-26 – SWOT analysis of the structure plan

Strengths	Weaknesses
▪ The configuration of the precinct is able to accommodate the predominant overland flow directions. ▪ The Structure Plan has identified dedicated areas for flood impact offsets South of Cabbage Tree Road. ▪ The developments are located south of the drinking water catchment and although the majority of the northern developments are located within the drinking water catchment, their southern boundaries are outside it which provides a point of discharge for treated stormwater.	▪ Is located within a flood storage area therefore displaces floodwater to adjacent areas. This requires flood mitigation to offset this impact that reduces developable land. ▪ Due to existing flat grades in the area, extensive bulk filling is required to facilitate stormwater drainage and flood protection. ▪ Large portions of the northern developments are located within the drinking water catchment on existing bushland. It is not feasible to achieve NorBE pollutant load targets and mimic pre-development recharge where development is proposed within the existing bushland areas. To achieve NorBE to groundwater, no infiltration will be allowed from the WSUD measures and drainage systems will be lined. Whilst desirable to replicate groundwater recharge from a resource management and PFAS plume perspective, the impact of the reduced recharge to the Tomago sand aquifer is considered to be negligible. To achieve NorBE to surface waters, wetland outlets will discharge to receiving waters downstream of the drinking water catchment. Therefore, whilst the location of the northern developments within the drinking water catchment are not ideal, the impact can be managed.

Threats	Opportunities
▪ The effectiveness of the flood management measures may change subject to design development and incorporation of more detail into the analysis. ▪ Limited demand for stormwater reuse within precinct means runoff volumes increase to Fullerton Cove which may prove sensitive to changes in freshwater inflows. ▪ Sea level rise may prevent the water quality treatment facilities from operating as intended in the future. ▪	▪ Reduce the bulk fill requirement by adopting a lower flood protection level for the Williamtown SAP in general, or sections of. Individual lots may still be required to achieve the full flood protection to the 1% AEP plus year 2100 climate change, which would be the developer's responsibility. ▪ Reduce the level of resilience to climate change with respect to tailwater levels for water quality. Currently the water quality strategy is to discharge above the estimated sea level rise prediction. This is based on the year 2100 predictions which is informing the Williamtown SAP levels and bulk fill volumes. ▪ Limit the need for full flood detention (ie. smaller basins) to manage Williamtown SAP flows and allow flood impacts within the flood impact offset areas. This would however require increasing the Structure Plan land requirements (south of Cabbage Tree Road). ▪ Centralised roof water harvesting system could supply water to Grahams Town Dam, nearby market or as dual reticulation for each precinct.

Threats	Opportunities
	This would reduce freshwater runoff volumes to enhance protection of Fullerton Cove. ▪ Opportunity to reduce the footprint of the WSUD infrastructure by considering underground detention and treatment.

8 Recommendations

The following recommendations are to be considered for refinement and incorporation into the Williamtown Activation Precincts SEPP and Delivery Plan. This will ensure consistency with the flood management and water cycle management assessment.

Flood Management

- The Structure Plan must be configured to utilise the bio-conservation area as flood detention to mitigate adverse flood impacts resulting from the project while preserving the dominant hydrologic regime in the bio-conservation area. This extends to internal precinct drainage where feasible.
- Peak 1% AEP flood levels within the Astra Aerolab basin should not be altered and exceed 2.67mAHD to maintain the current level of freeboard to the lots adjacent to the eastern basin.
- Pre-purchasing of properties (or part thereof to accommodate the proposed flood management bund) is required, prior to bulk filling.
- Flood immunity to the Williamtown SAP should achieve at least 1% AEP plus year 2100 climate change plus 500mm freeboard.
- Flood compatible building controls should be developed in line with the PSC DCP.
- Identified flood management works for staging phases should be implemented to manage flood impacts resulting from the Williamtown SAP.
- Formalisation of drainage lines to drain trapped low points resulting from the Williamtown SAP bulk filling is required to achieve desired detention function within the Bio-conservation area.
- Flood modelling at each stage is required to refine and confirm the flood impacts and management measures presented in this assessment.

Water Cycle Management

- PSC Sensitive Catchment pollutant load reduction targets (refer **Table 2-13**) are to be achieved to ensure objectives can be achieved as the development progresses.
- Gross pollutant traps are to be provided on all development allotments with equivalent performance to the units adopted in this assessment
- Development controls should prescribe on lot rainwater reuse and on lot perviousness limits equivalent to the adopted assumptions in Table 7-18
- Development controls should prescribe street-scape biofiltration and/or passively irrigated street trees to deliver greening and cooling benefits throughout the SAP streetscape while achieving the adopted pollutant load reduction targets
- Wetland bathymetry and street tree species must be designed to manage bird strike risk (refer section 6.3.3)

It is recommended that the predicted increases in surface water runoff and total nitrogen to Fullerton Cove be further assessed to better understand the impact on the wetlands at Fullerton Cove. If the increase in freshwater discharge from the precinct is assessed to pose a negligible impact to the receiving wetlands than no further refinement is required to the WSUD strategy.

The location and footprint of the proposed wetlands accommodates the current staging plan. Wetlands should be established and remain offline until at least 80% of the urban areas in the catchment are developed to minimise the risk of poor sediment control affecting wetland performance. Conversion of basins to their final wetland arrangement should be staged ahead of development to protect water quality downstream.

9 Conclusion

The Williamtown SAP area is characterised as a low-lying rural floodplain. Drinking water catchment areas (groundwater) occur within the northern portion of the area and sensitive estuarine wetlands are located downstream of the Williamtown SAP Structure Plan Boundary.

Impact from the proposed precinct can be mitigated through an integrated drainage, stormwater quality and flood detention strategy through the use of swales and wetlands to manage minor and major runoff in an integrated way.

Flooding

Flooding presents a significant constraint as the project area is affected by local (upstream) and regional (downstream) flooding mechanisms. Development is compatible with flood risk however needs carefully designed flood management controls. Furthermore, the existing trunk drainage network is undersized, constrained by tidal processes and flooding is sensitive to changes in flow distribution.

Drainage and flooding have been the subject of multiple investigations. This is an indication of the complexity of the flooding and drainage issues and the challenges in deriving satisfactory management solutions to facilitate the Williamtown SAP. To understand these complexities, modelling of the local and regional flood behaviour was undertaken to quantify the potential impacts of developing the Williamtown SAP. With this understanding, the modelling was then used to analyse flood management options required to mitigate the adverse flood impacts.

- Bulk filling is required to facilitate development within the study area, however the resulting loss of floodplain storage and conveyance can have a significant impact on flood behaviour. The required bulk filling must strike a balance with adversely changing flood behaviour whilst providing a cost-effective solutions to the delivery of the SAP. Through the flood analysis, the design of floodplain management measures to mitigate and offset flood impacts was derived which includes the implementation of the following measures:
- Flood detention to mitigate impacts on downstream development;
- Floodplain storage offsets and preserving floodway capacity to mitigate impacts on upstream and adjacent development;
- Augmentation of existing drainage works to improve effectiveness of flood mitigation works; and
- Incorporating land that is anticipated to have residual flood impacts into the Structure Plan Boundary.

Providing appropriate setbacks between existing development and the SAP is critical to managing external local flooding impacts. Modelling has demonstrated an acceptable outcome by incorporating cut-off drains that collect and redirecting overland flow to the nearest downstream discharge locations.

Road crossings over Dawsons and Learys Drains will also result in increased flood levels across the bio-conservation area which creates a pseudo flood detention basin effect and creates an opportunity to offset lost floodplain storage. Taking advantage of this outcome, the road crossings connecting the developments either side of Dawsons drain and Learys drain are designed to restrict flow discharging south of Cabbage Tree Road. This helps to control flow and limit flood impacts to within acceptable levels downstream, managing the flood adverse flood impacts. To accommodate the Structure Plan, it is necessary to incorporate additional floodplain storage within lands south of Cabbage Tree Road to offset a portion of the lost flood storage and to allow flood impacts to occur within the Williamtown SAP boundary.

Modelling shows that the SAP can be made immune from flooding and without causing unacceptable flood impacts on surrounding lands with careful checking of flood impacts during future design phases.

Stormwater Quality and Water Cycle Management

The proximity of the Drinking Water Catchment associated with the Tomago sandbeds as well as sensitive environments including a number of important wetlands requires careful management of stormwater quality impacts.

- The proposed water sensitive urban design treatment strategy responds to the location and constraints of the future structure plan as well as the proposed incorporation of liners for PFAS management which prevented the use of infiltration systems to recharge the underlying sandy aquifer. The adopted treatment strategy includes:

- Rainwater harvesting tanks and GPTs on each alotment
- Partial treatment of road runoff through passively irrigated street trees and swales
- Wetlands and bioretention basins at the end of each catchment to achieve the water quality targets and concentrations discharged to Fullerton Cove.

The preferred strategy following the EbD workshop was to site the stormwater treatment wetlands south of Cabbage Tree Road. This approach was initially investigated, but drainage and filling constraints led to a strategy which focussed on providing the wetlands within the SAP boundary. The wetlands, minor and major storm event drainage and stormwater detention were all incorporated into localised drainage corridors throughout the SAP.

Groundwater recharge via stormwater infiltration on the lot and street trees was not incorporated into the final strategy due to implications to groundwater contamination.

In order to achieve the adopted pollution stripping targets for the all treated stormwater will be discharged to the receiving drains downstream of the Drinking Water Catchment boundary resulting in a small but negligible reduction in groundwater recharge rates.

The structure plan provides sufficient space to deliver the water cycle management strategy that achieves the adopted pollution stripping targets. These targets ensure that the proposed land use changes do not alter the downstream water quality risks to the Ramsar wetlands.

10 References

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Water NSW, 2019, Using MUSIC in the Sydney Drinking Water Catchment, 2nd edition

Appendix A
Baseline Figures

ID	Figure name / report figure title
A1	Study area and major hydraulic features (Williamtown and Salt Ash existing drainage network including flood gates)
A2	Local Topography
A3	Local ground surface slope
A4	Local catchments
A5	Land Zoning
A6	Sensitive Aquatic Environments
A7	Indicative flow direction under regional flood conditions
A8	10% AEP design peak flood depths and levels under regional flooding conditions (Source: BMT 2017)
A9	1% AEP design peak flood depths and levels under regional flooding conditions (Source: BMT 2017)
A10	1% AEP plus climate change design peak flood depths and levels under regional flooding conditions (Source: BMT 2017)
A11	PMF peak flood depths and levels under regional flooding conditions (Source: BMT 2017)
A12	10% AEP design peak flood velocities under regional flooding conditions (Source: BMT 2017)
A13	5% AEP design peak flood velocities under regional flooding conditions (Source: BMT 2017)
A14	1% AEP design peak flood velocities under regional flooding conditions (Source: BMT 2017)
A15	1% AEP plus climate change design peak flood velocities under regional flooding conditions (Source: BMT 2017)
A16	PMF design peak flood velocities under regional flooding conditions (Source: BMT 2017)
A17	Indicative flow directions under local catchment flow conditions (Source: BMT 2005)
A18	5% AEP design peak flood depths and levels under local flooding conditions
A19	1% AEP design peak flood depths and levels under local flooding conditions
A20	Riparian Corridors constraints
A21	PSC's Current flood hazard and hydraulic categories
A22	Estimated drainage capacity of key drainage lines under local catchment flooding conditions (Source: Umwelt 2018)
A23	Flood emergency response classifications
A24	Flood extents for various flood events across the SAP area
A25	Water cycle management constraints summary
A26	Flooding developability constraints
A27	Water quality treatment developability constraints
A28	General drainage augmentation works (Source: Umwelt 2018)
A29	Aquifers

Williamtown Study Area

Williamtown SAP Structure Plan Boundary

Major waterway

Minor waterway

Railway

Fullerton Cove Levees

Flood Gates

NOTE: It is understood that there are levees and road embankments that function as levees in the Salt Ash area, around the Tilligerry Creek flood gates. Survey of the levees in this area has been captured by DPIE as part of the HVFMS and has been requested for this project.

Source: Aurecon, DPE, TfNSW, NSW Spatial Services, Esri

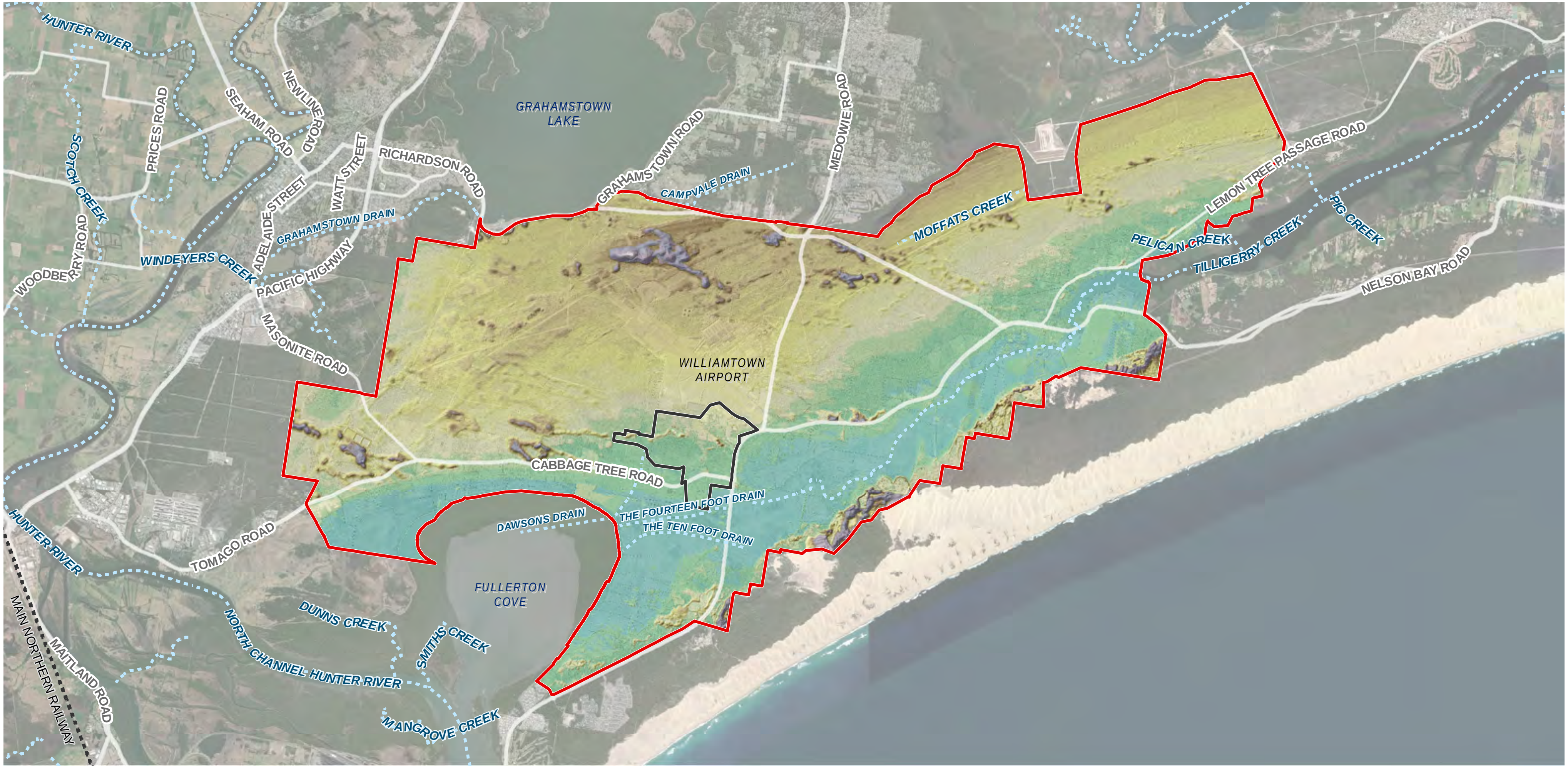
1:110,000 @ A4

0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

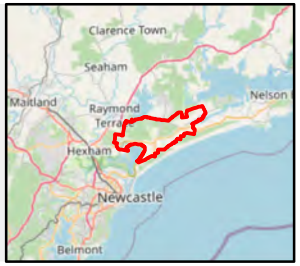
A1: Study area and major hydraulic features



	Williamtown Study Area
	Williamtown SAP Structure Plan Boundary
	Waterway
	Railway

Elevation (m AHD)

< 1; 1 - 2; 2 -3; 3 - 4; 4 - 5; 5 - 6; 6 - 7; 7 - 8; 8 - 9; 9 - 10; 10 - 11; 11 - 12; 13 - 14; 14 - 15; 15 - 16; 16 - 20; 21 - 25; 26 - 30; 31 - 35; 36 - 40; 41 - 45; 46 - 48



Source: Aurecon, DPE, TfNSW, NSW Spatial Services, Esri

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0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A2: Local topography

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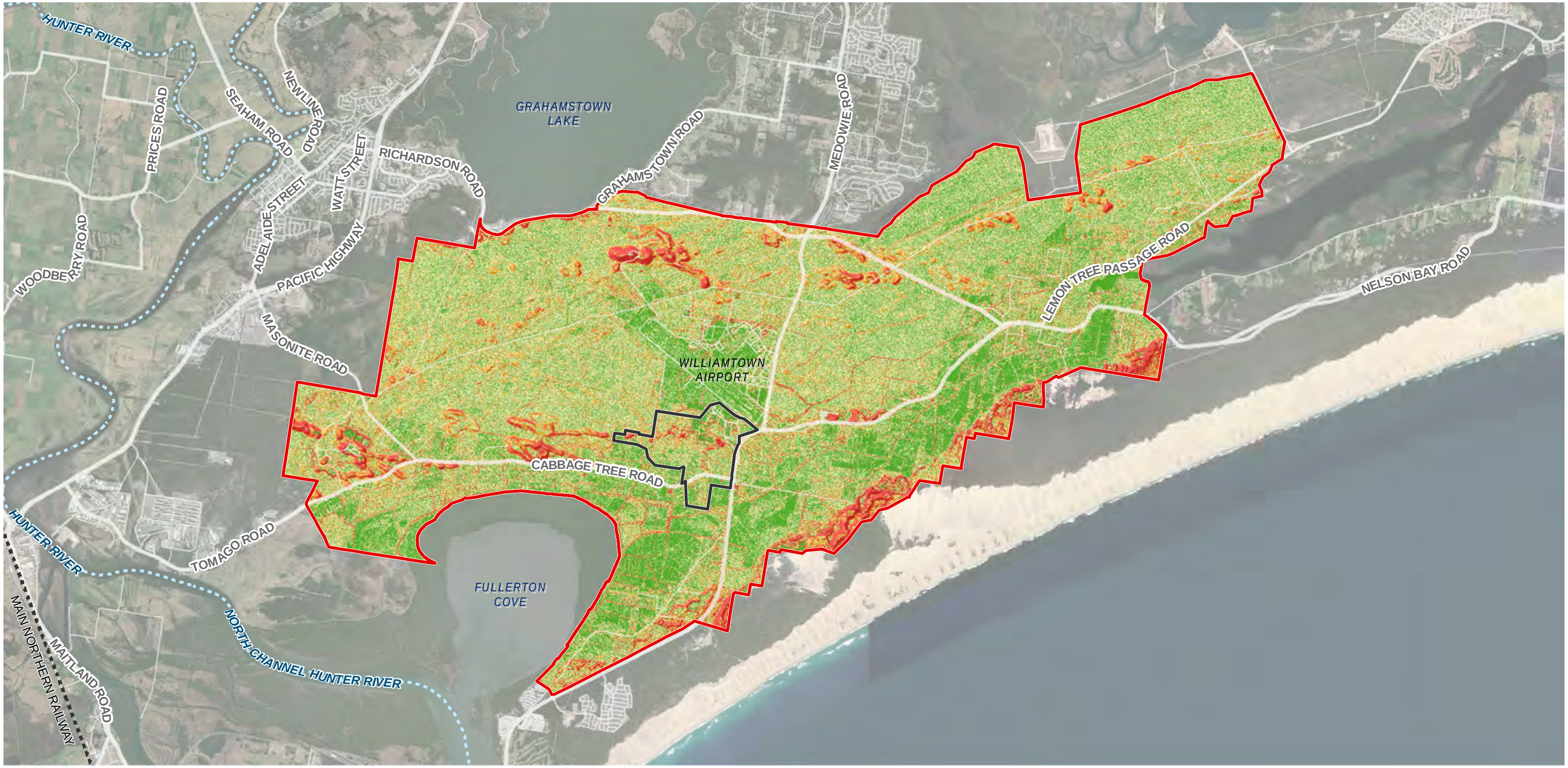

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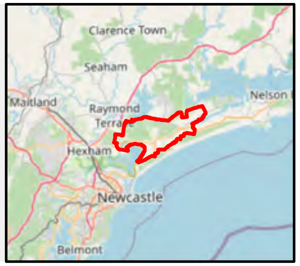
Williamtown Study Area
Williamtown SAP Structure Plan Boundary
River
Railway

Slope (Percent Rise)
0 - 2
2 - 5
5 - 10
>10



Source: Aurecon, DPE, TfNSW, NSW Spatial Services, Esri

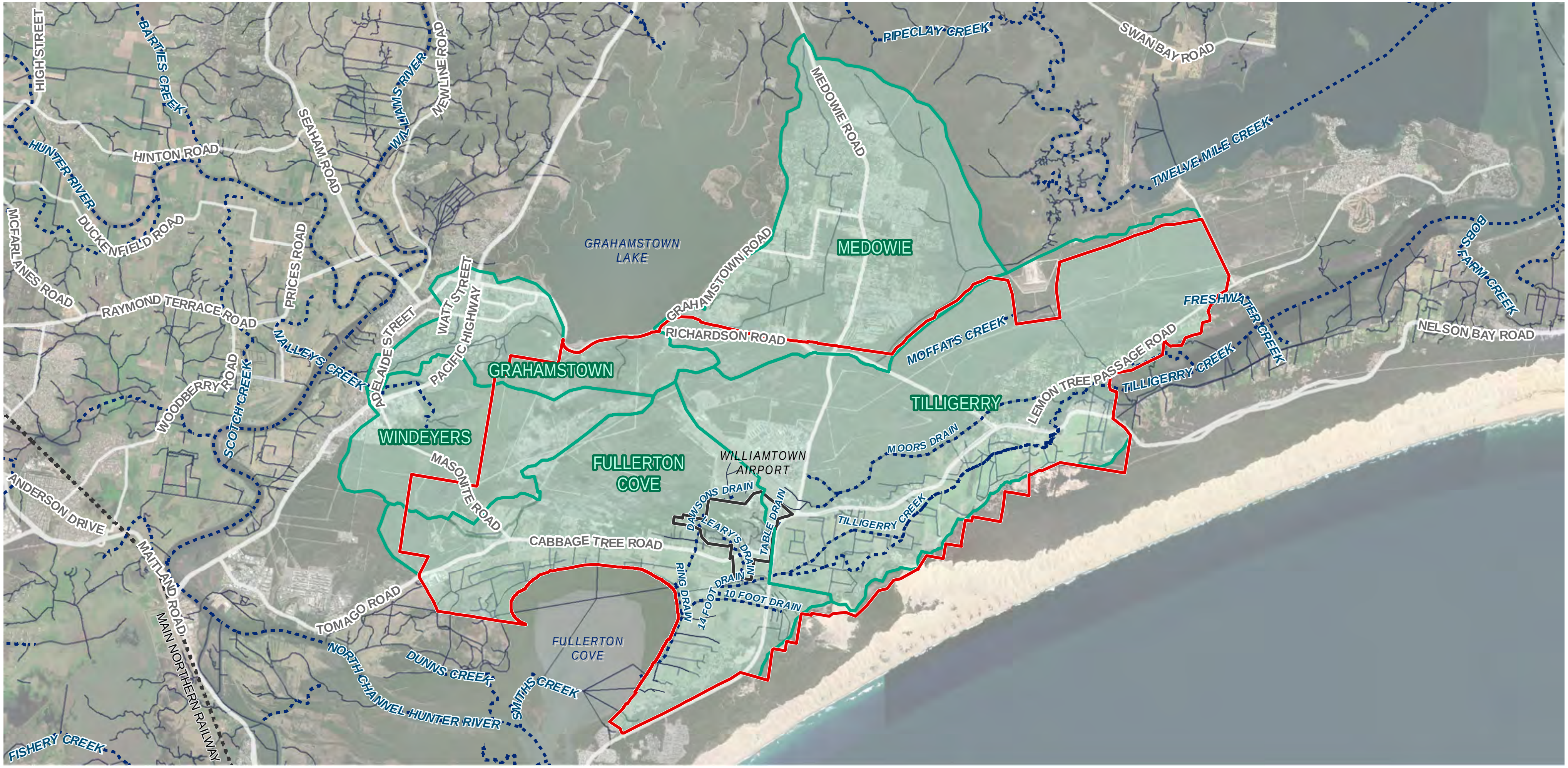
1:120,000 @ A4
0 2 4km

Projection: GDA 1994 MGA Zone 56

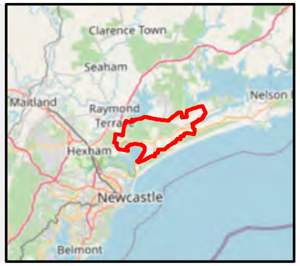
Williamtown SAP **Hydraulic and Hydrology**

A3: Local ground surface slope

aurecon



- Williamtown Study Area
- Williamtown SAP Structure Plan Boundary
- Major waterway
- Minor waterway
- Catchments



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Source: Aurecon, DPE, TfNSW, NSW Spatial Services, Esri

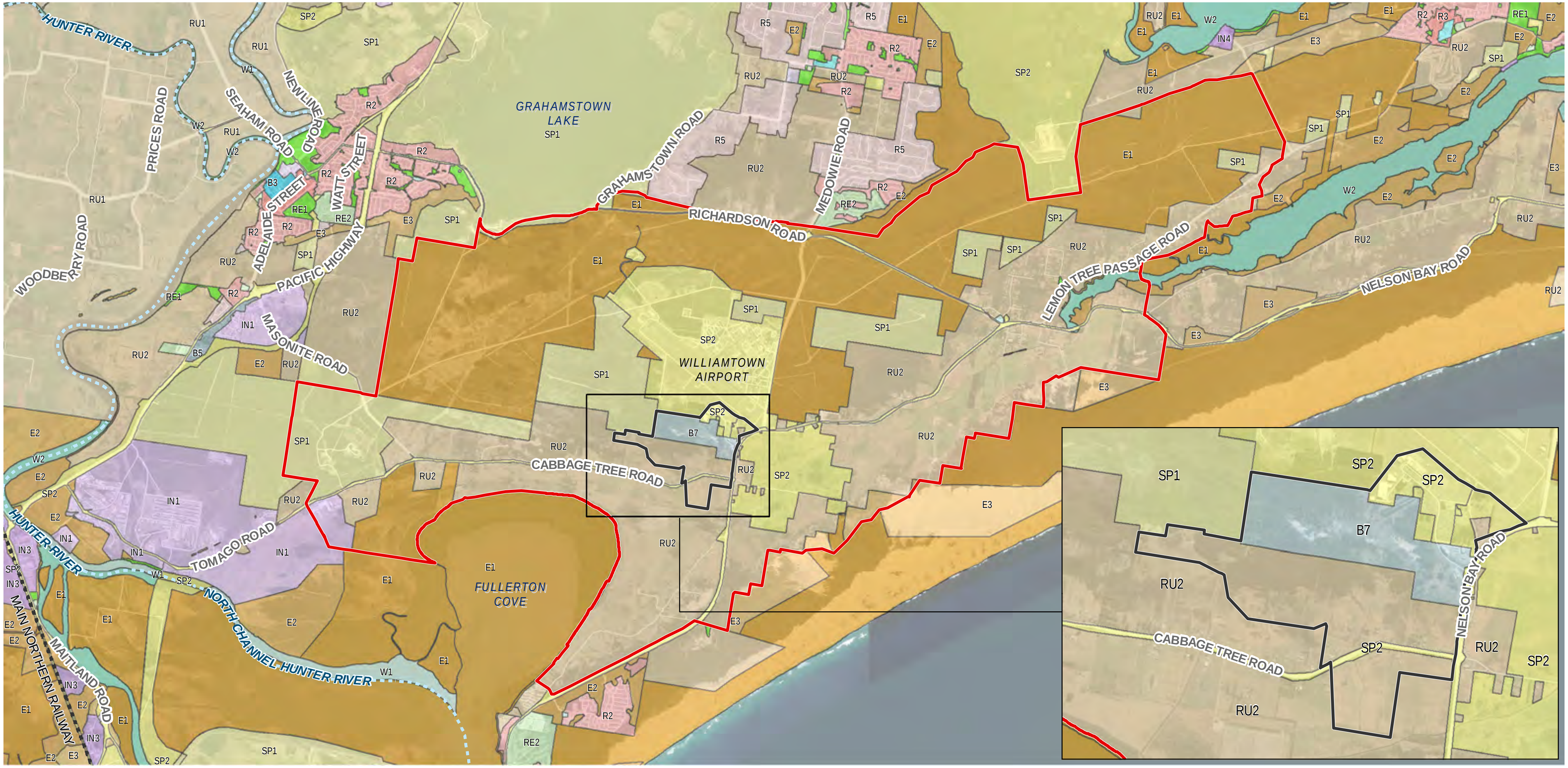
1:145,000 @ A4

0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A4: Local drainage catchments



Williamtown Study Area	
Williamtown SAP Structure Plan Boundary	
River	
Railway	

Land Zoning

- B1 Neighbourhood Centre
- B2 Local Centre
- B3 Commercial Core
- B5 Business Development
- B7 Business Park
- E1 National Parks and Nature Reserves
- E2 Environmental Conservation
- E3 Environmental Management
- IN1 General Industrial
- IN2 Light Industrial
- IN3 Heavy Industrial
- IN4 Working Waterfront
- R1 General Residential
- R2 Low Density Residential
- R3 Medium Density Residential
- R5 Large Lot Residential
- RE1 Public Recreation
- RE2 Private Recreation
- RU1 Primary Production
- RU2 Rural Landscape
- SP1 Special Activities
- SP2 Infrastructure
- W1 Natural Waterways
- W2 Recreational Waterways

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Source: Aurecon, DPE, TfNSW, NSW Spatial Services, Esri

1:120,000 @ A4

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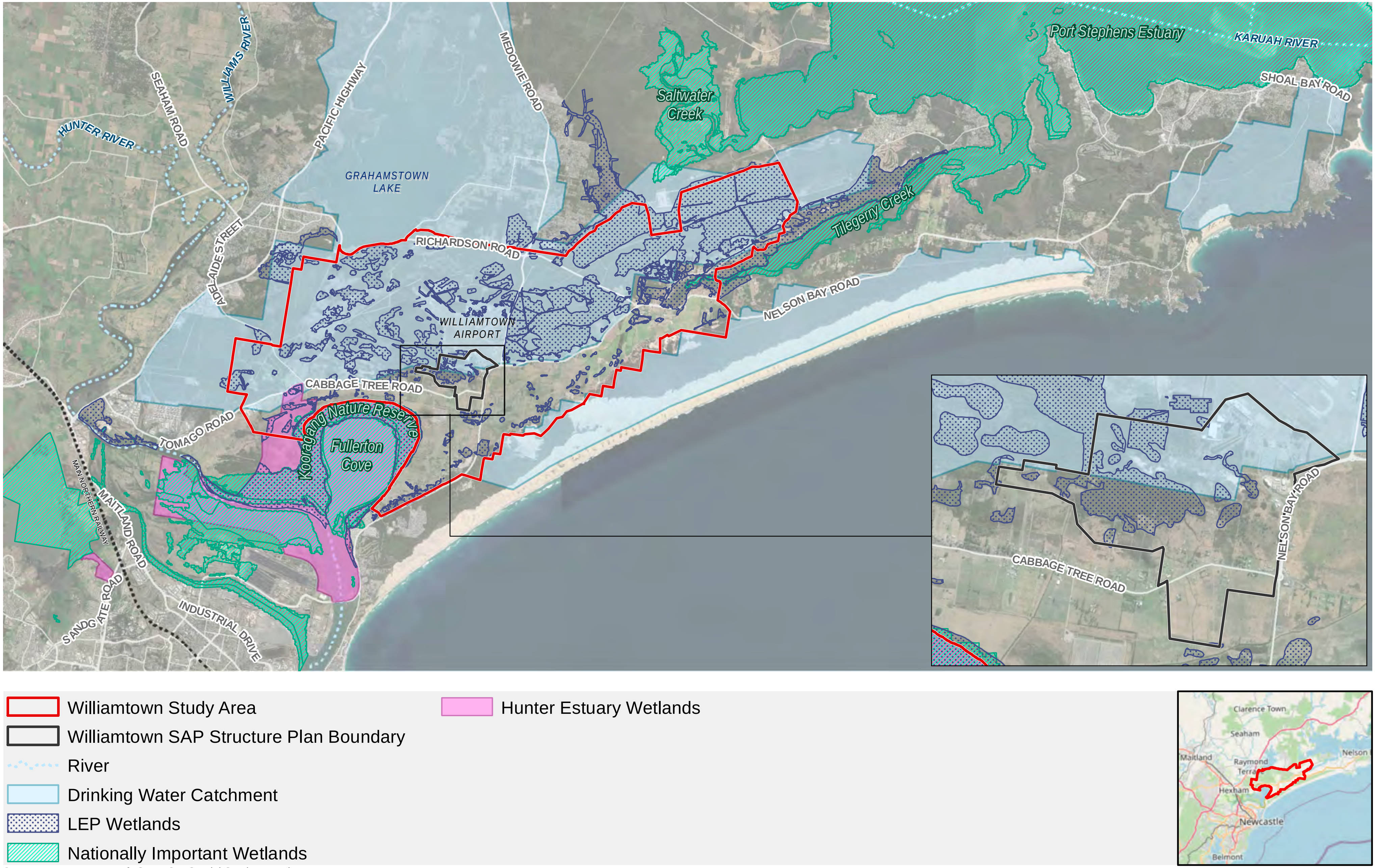
Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A5: Land zoning



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Source: Aurecon, DPE, TfNSW, NSW Spatial Services, Esri

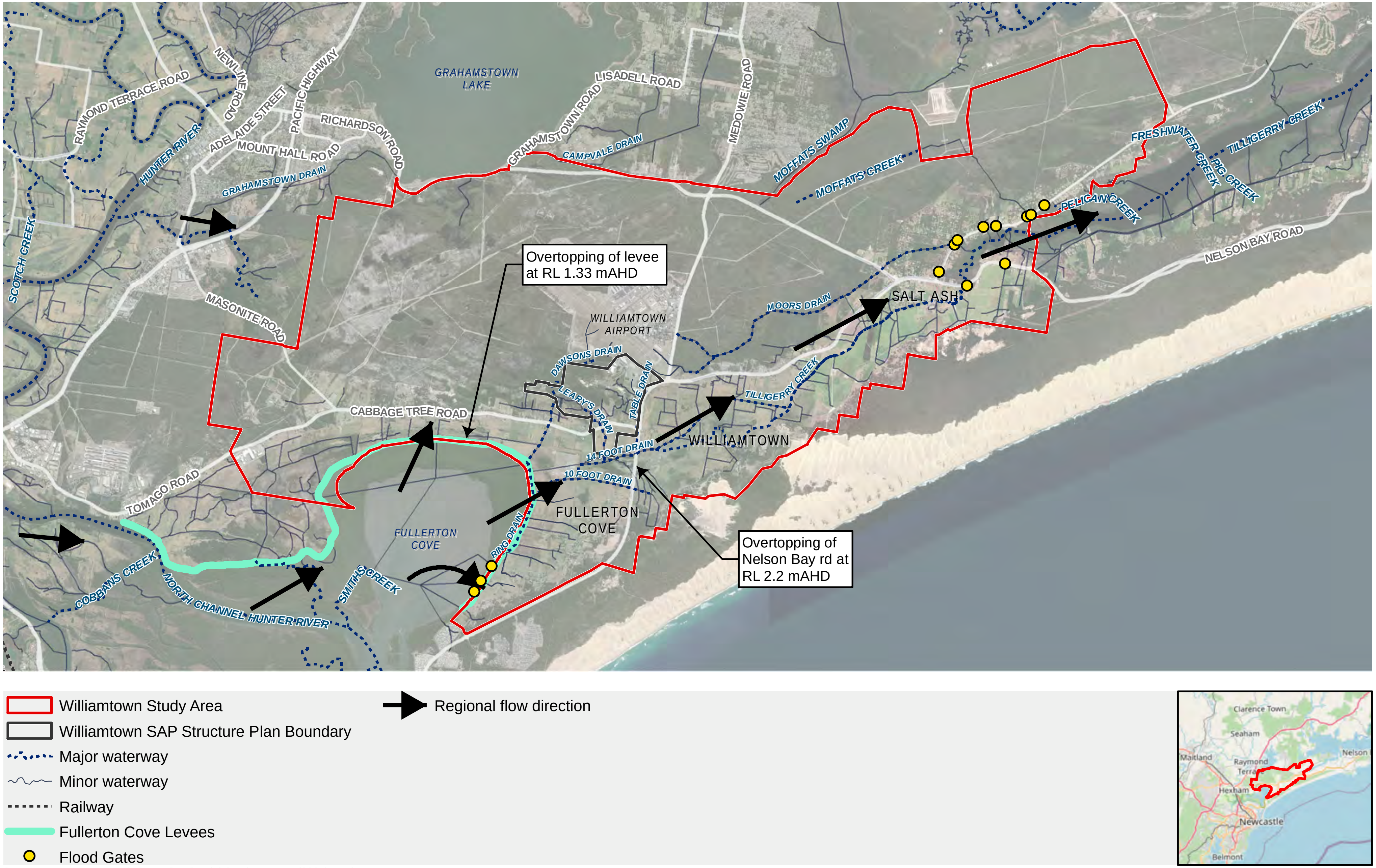
1:185,000 @ A4

0 3 6km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A6: Senstive surface water environments



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Source: Aurecon, DPE, TfNSW, NSW Spatial Services, BMT (2005), Esri

1:110,000 @ A4

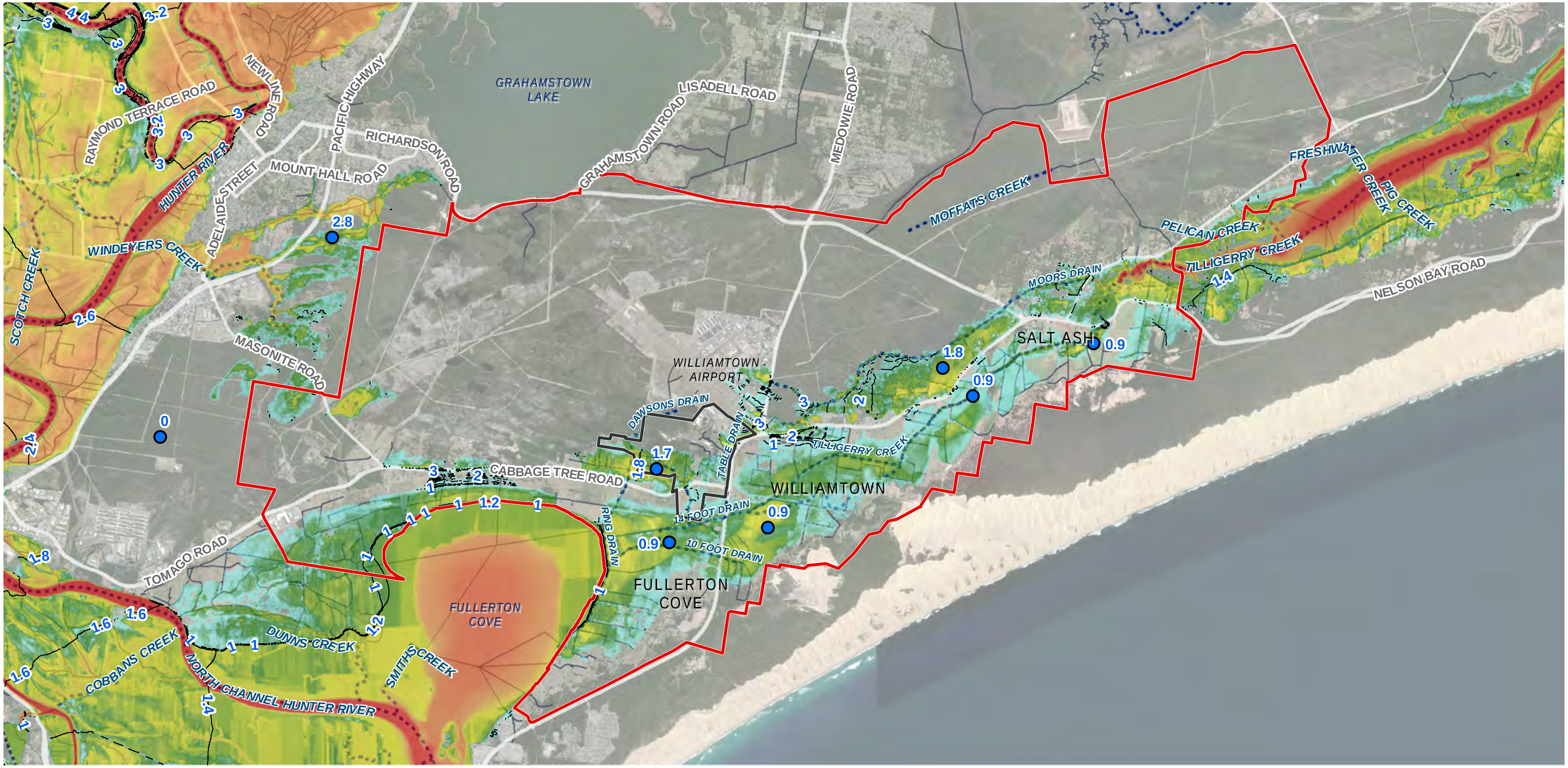
0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A7: Indicative flow direction under regional flood conditions

aurecon



Williamtown Study Area

Williamtown SAP Structure Plan Boundary

Major waterway

Minor waterway

Railway

Peak Flood Depth (m)

>4

2

1

0.5

<0.2

Water level contour (mAHD)

Water level spot height

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Source: Aurecon, DPE, TfNSW, NSW Spatial Services, BMT (2017), Esri

1:110,000 @ A4

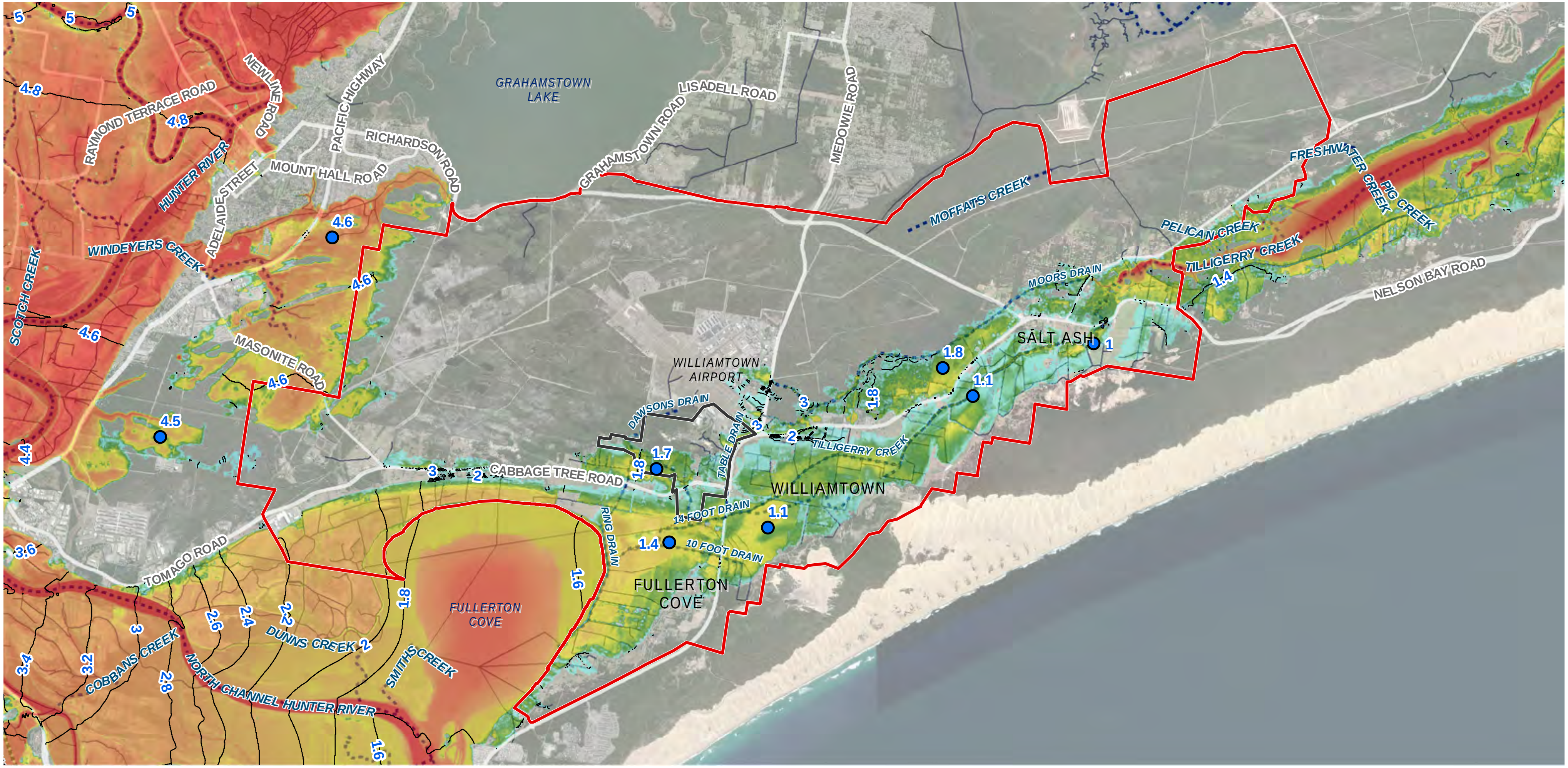
0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A8: 10% AEP design peak flood depths and levels under regional flooding conditions (Source: BMT 2017)

aurecon



Williamtown Study Area
Williamtown SAP Structure Plan Boundary
Major waterway
Minor waterway
Railway

Peak Flood Depth (m)
>4
2
1
0.5
<0.2

Water level contour (mAHD)
Water level spot height

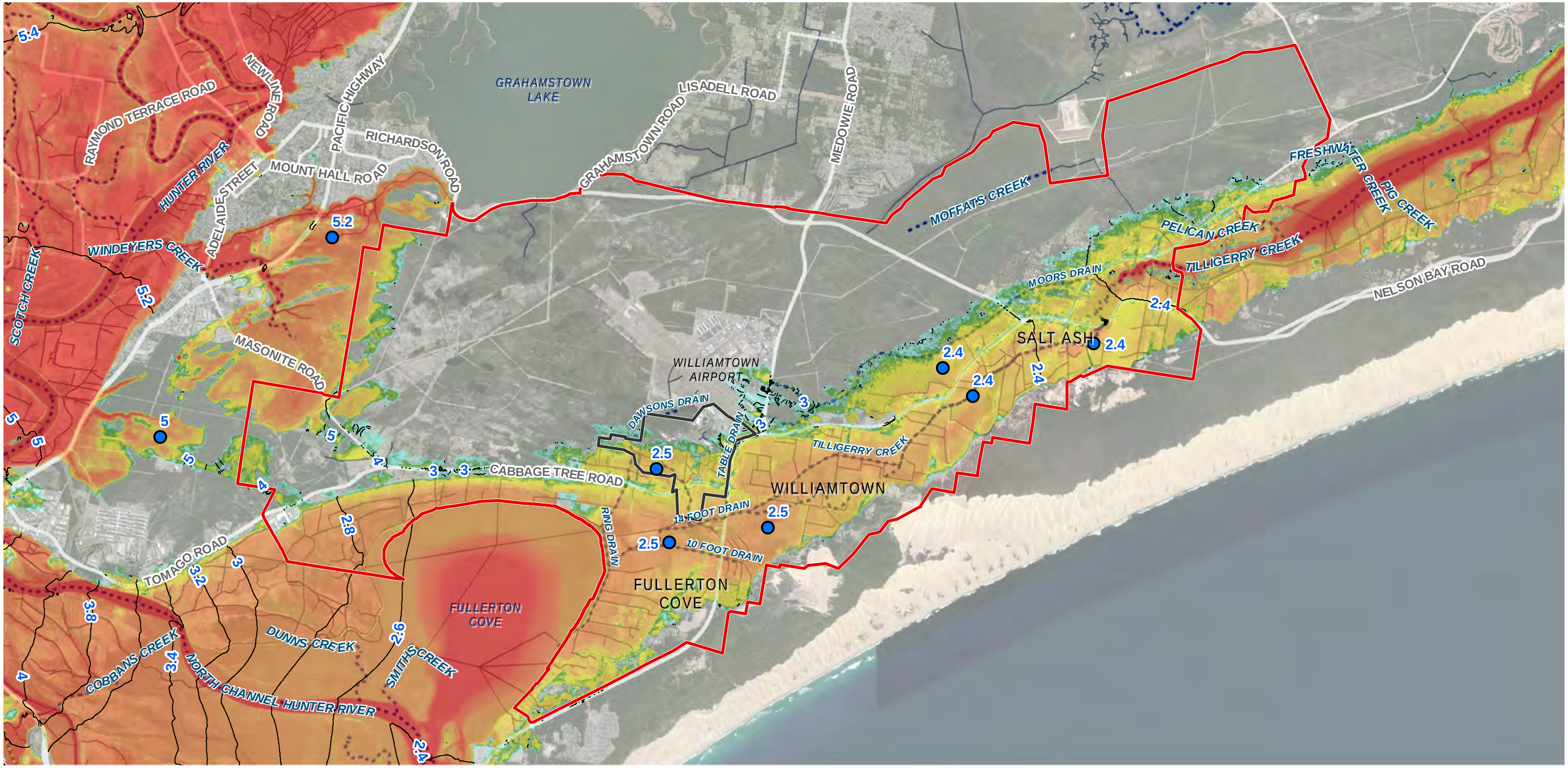
Source: Aurecon, DPE, TfNSW, NSW Spatial Services, BMT (2017), Esri

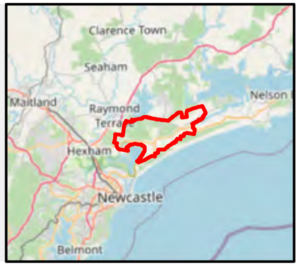
1:110,000 @ A4
0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

FIGURE A9: 1% AEP design peak flood depths and levels under regional flooding conditions (Source: BMT 2017)





Williamtown Study Area
Williamtown SAP Structure Plan Boundary
Major waterway
Minor waterway
Railway

Peak Flood Depth (m)
>4
2
1
0.5
<0.2

Water level contour (mAHD)
Water level spot height

Source: Aurecon, DPE, TfNSW, NSW Spatial Services, BMT (2017), Esri

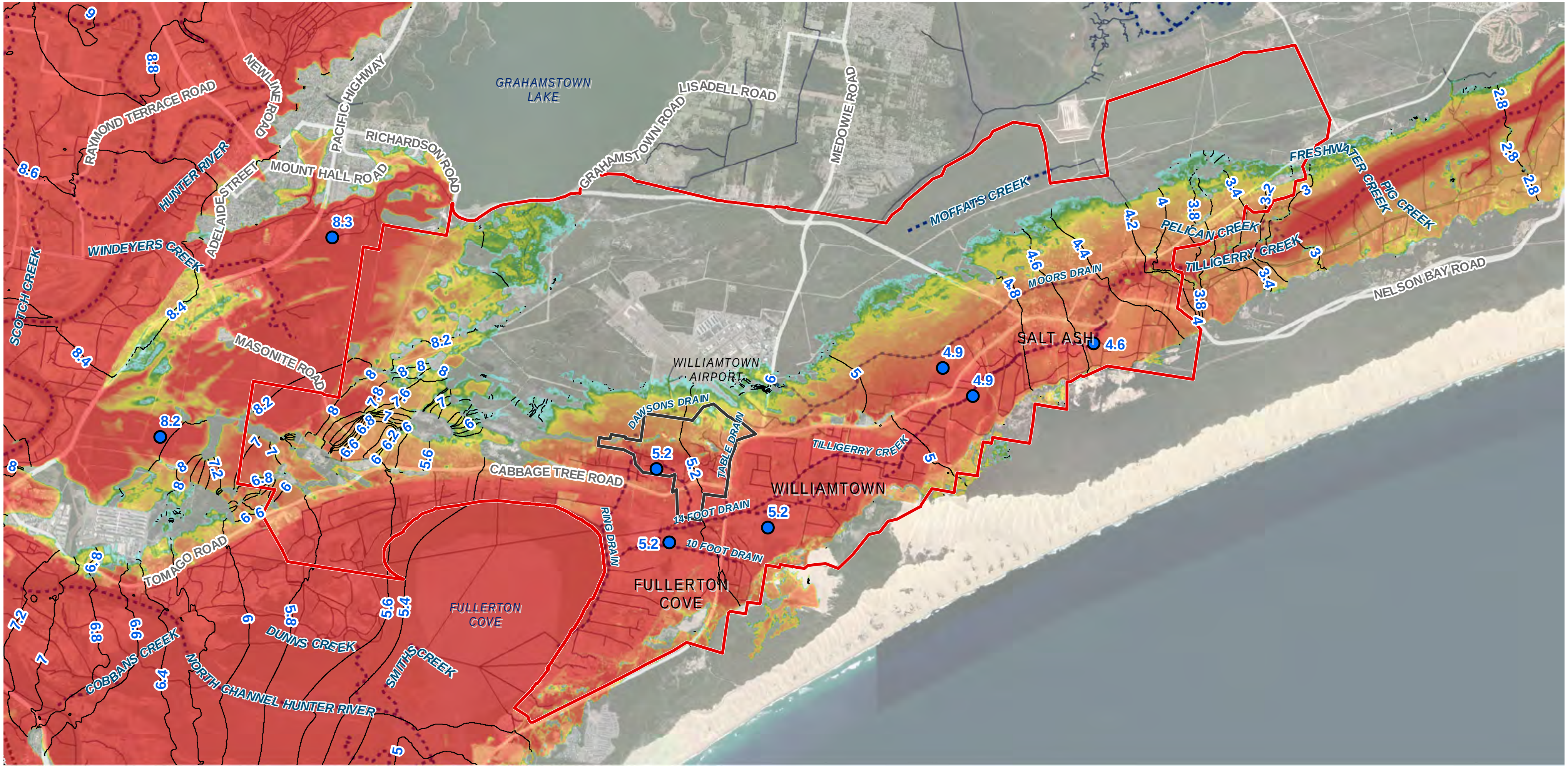
1:110,000 @ A4
0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A10: 1% AEP plus climate change design peak flood depths and levels under regional flooding conditions: +0.9m Sea Level Rise + 20% Flow (Source: BMT 2017)

aurecon



Williamtown Study Area
Williamtown SAP Structure Plan Boundary
Major waterway
Minor waterway
Railway

Peak Flood Depth (m)
>4
2
1
0.5
<0.2

Water level contour (mAHD)
Water level spot height

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Source: Aurecon, DPE, TfNSW, NSW Spatial Services, BMT (2017), Esri

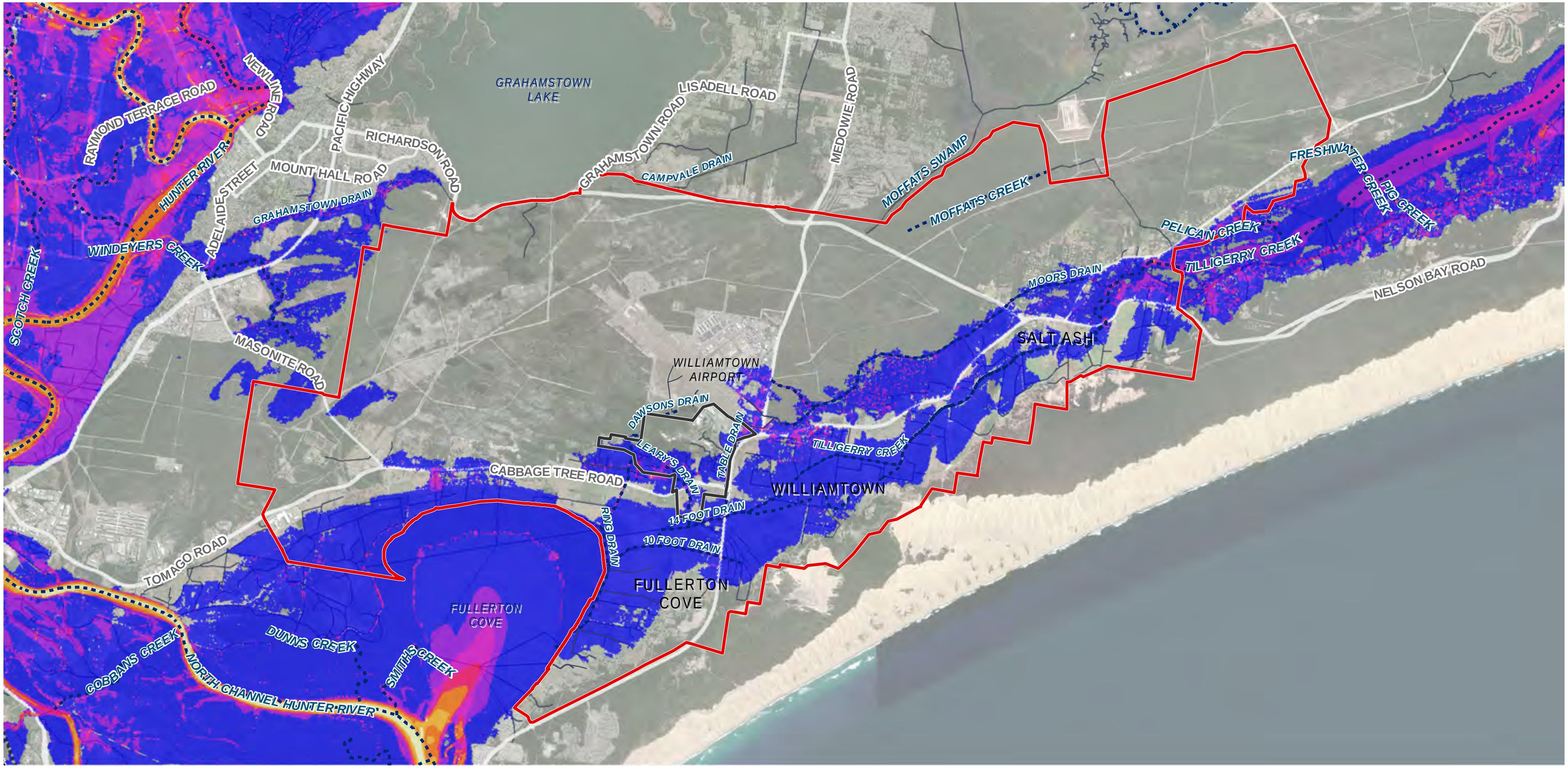
1:110,000 @ A4
0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A11: PMF peak flood depths and levels under regional flooding conditions (Source: BMT 2017)

aurecon



Williamtown Study Area
Williamtown SAP Structure Plan Boundary
Major waterway
Minor waterway
Railway

Peak Velocity (m/s)
0 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1 - 1.5
1.5 - 2
>2

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Source: Aurecon, DPE, TfNSW, NSW Spatial Services, BMT (2017), Esri

1:110,000 @ A4

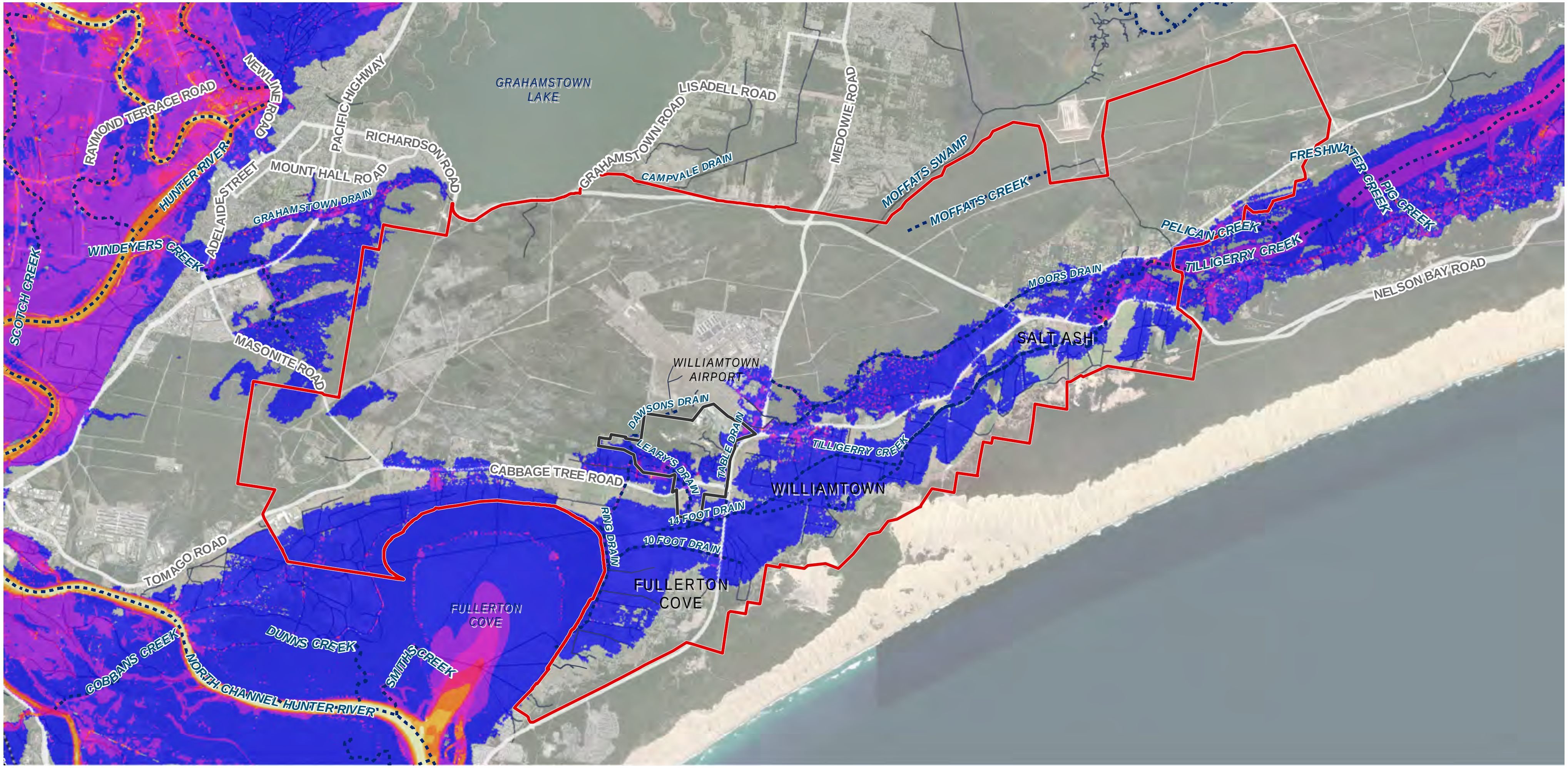
0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A12: 10% AEP design peak flood velocities under regional flooding conditions (Source: BMT 2017)

aurecon



Williamtown Study Area	
Williamtown SAP Structure Plan Boundary	
Major waterway	
Minor waterway	
Railway	

Peak Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- >2

Source: Aurecon, DPE, TfNSW, NSW Spatial Services, BMT (2017), Esri

1:110,000 @ A4

0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A13: 5% AEP design peak flood velocities under regional flooding conditions (Source: BMT 2017)

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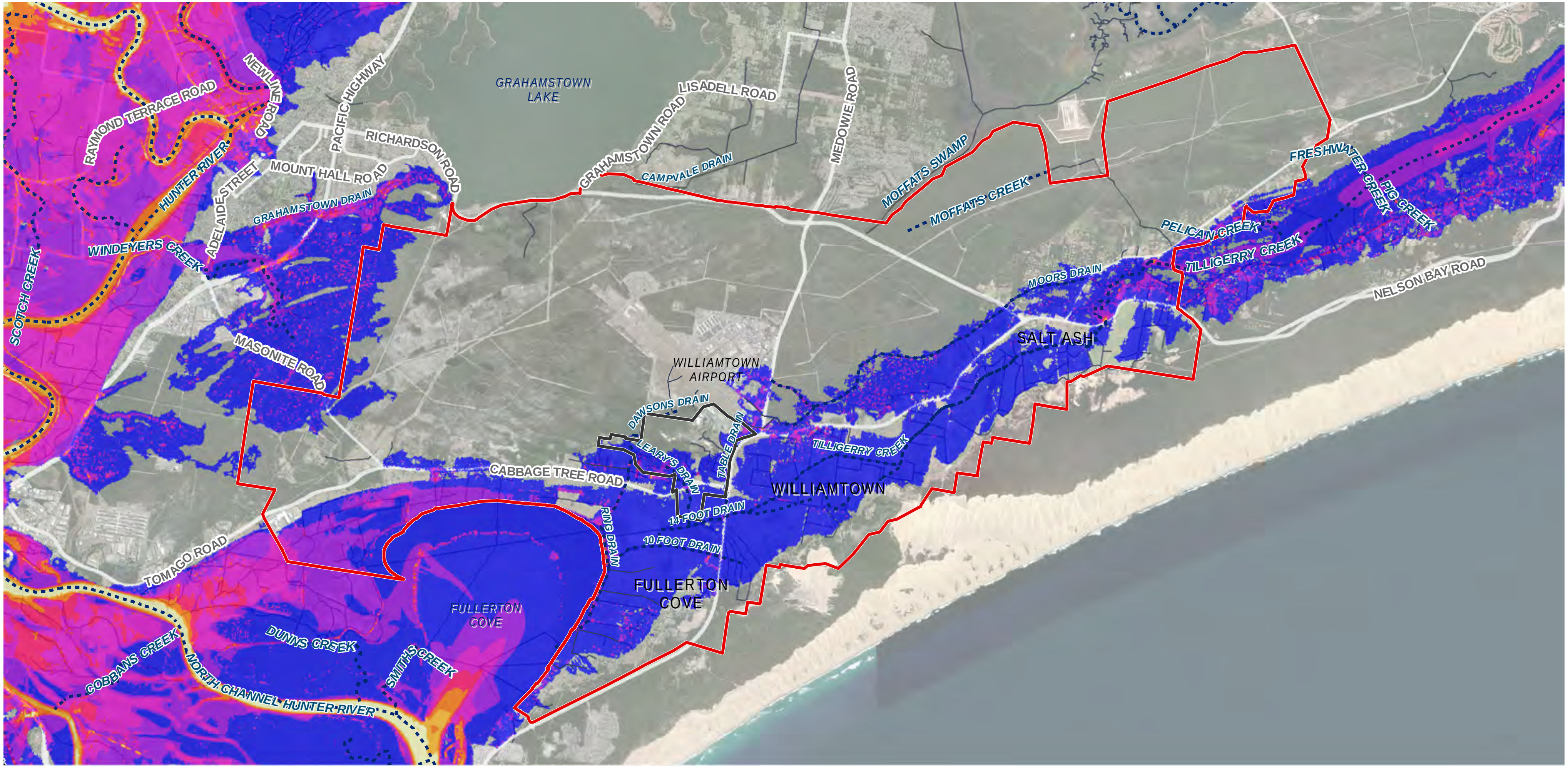

Williamtown Study Area

Williamtown SAP Structure Plan Boundary

Major waterway

Minor waterway

Railway

Peak Velocity (m/s)

0 - 0.25

0.25 - 0.5

0.5 - 0.75

0.75 - 1

1 - 1.5

1.5 - 2

>2

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Source: Aurecon, DPE, TfNSW, NSW Spatial Services, BMT (2017), Esri

1:110,000 @ A4

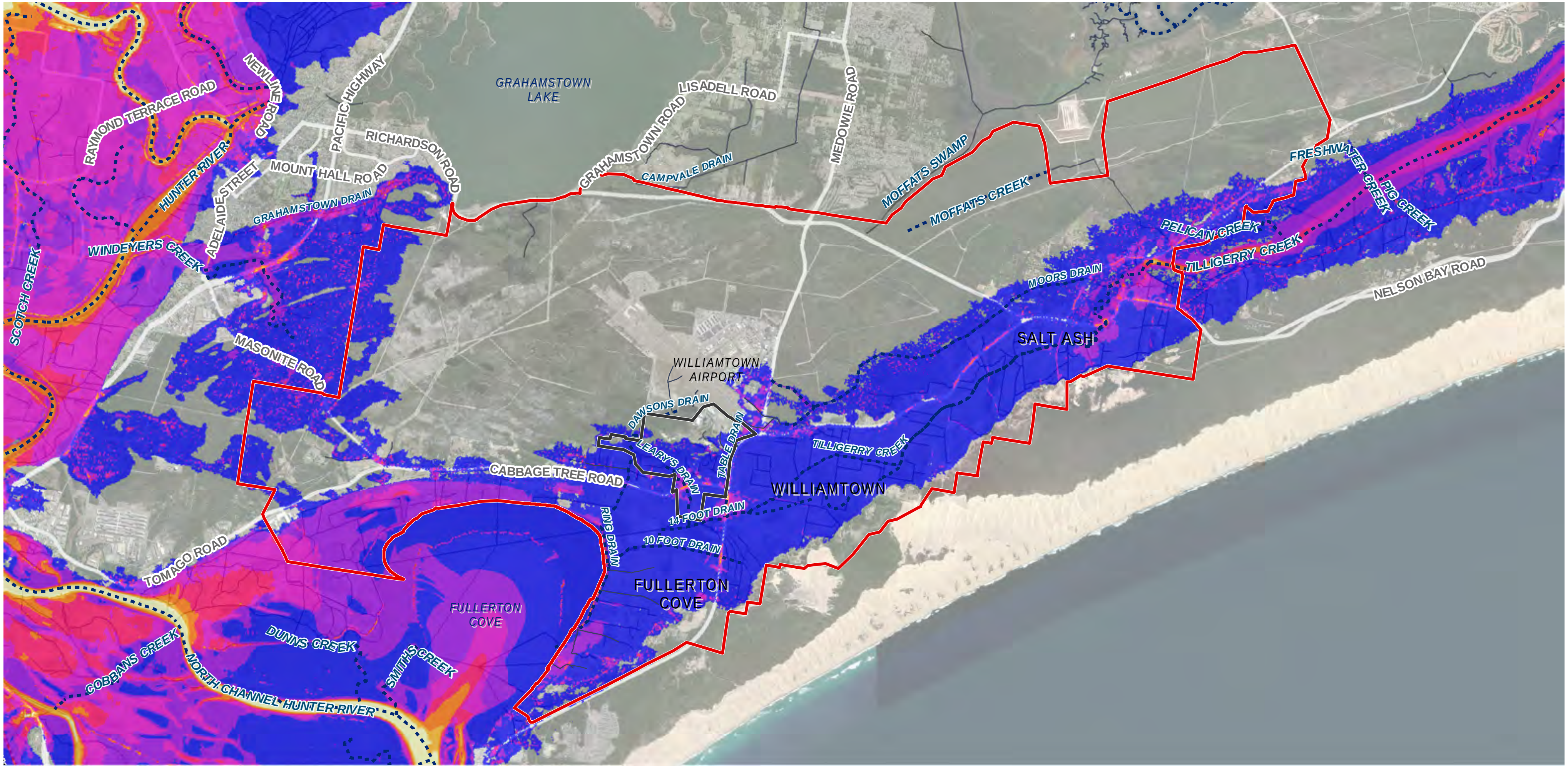
0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A14: 1% AEP design peak flood velocities under regional flooding conditions (Source: BMT 2017)

aurecon



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Williamtown Study Area	**Peak Velocity (m/s)**		0.75 - 1
Williamtown SAP Structure Plan Boundary	0 - 0.25		1 - 1.5
Major waterway	0.25 - 0.5		1.5 - 2
Minor waterway	0.5 - 0.75		>2
Railway			

Source: Aurecon, DPE, TfNSW, NSW Spatial Services, BMT (2017), Esri

1:110,000 @ A4

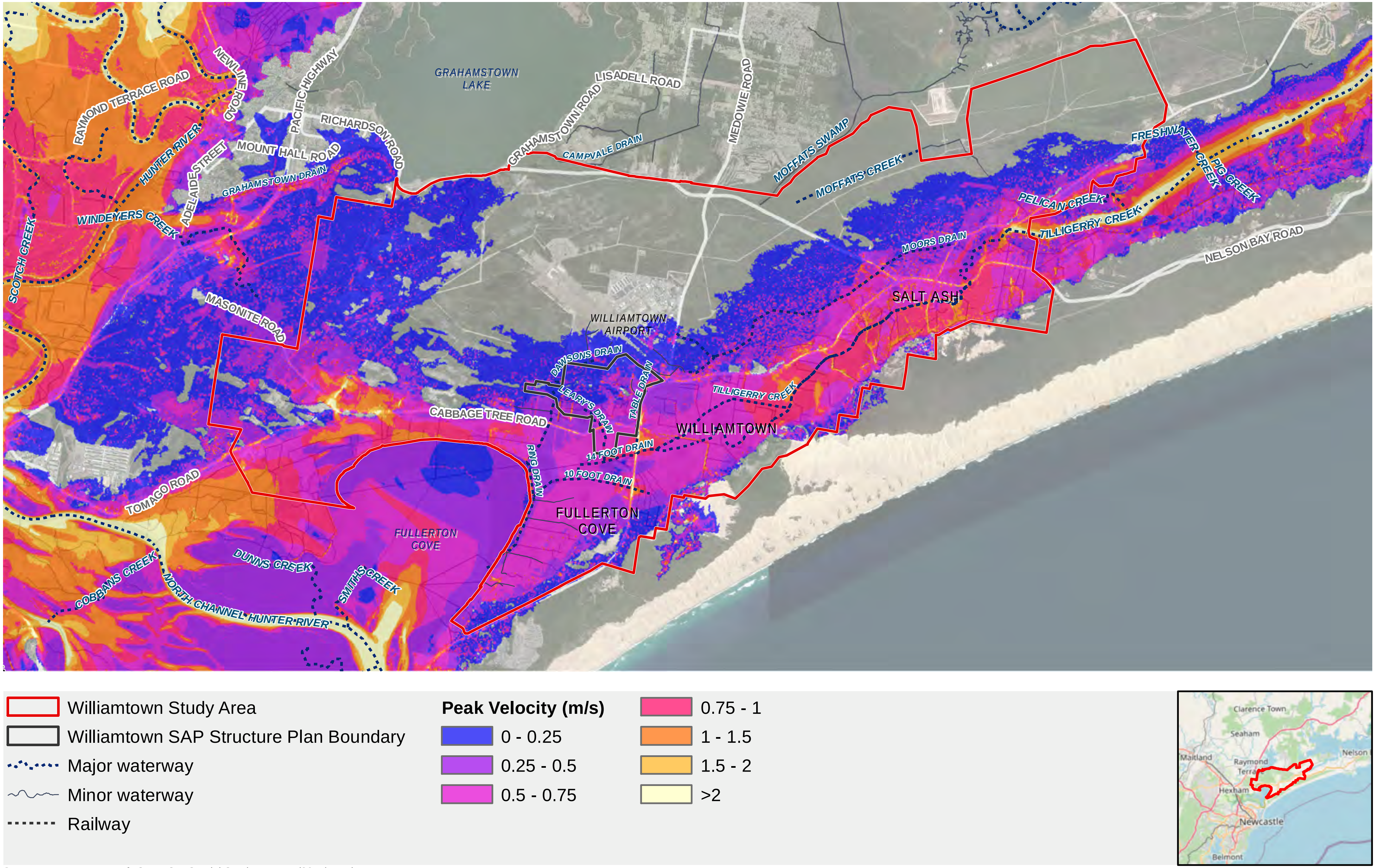
0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A15: 1% AEP plus climate change design peak flood velocities under regional flooding conditions: +0.9m Sea Level Rise + 20% Flow (Source: BMT 2017)

aurecon



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Source: Aurecon, DPE, TfNSW, NSW Spatial Services, BMT (2017), Esri

1:110,000 @ A4

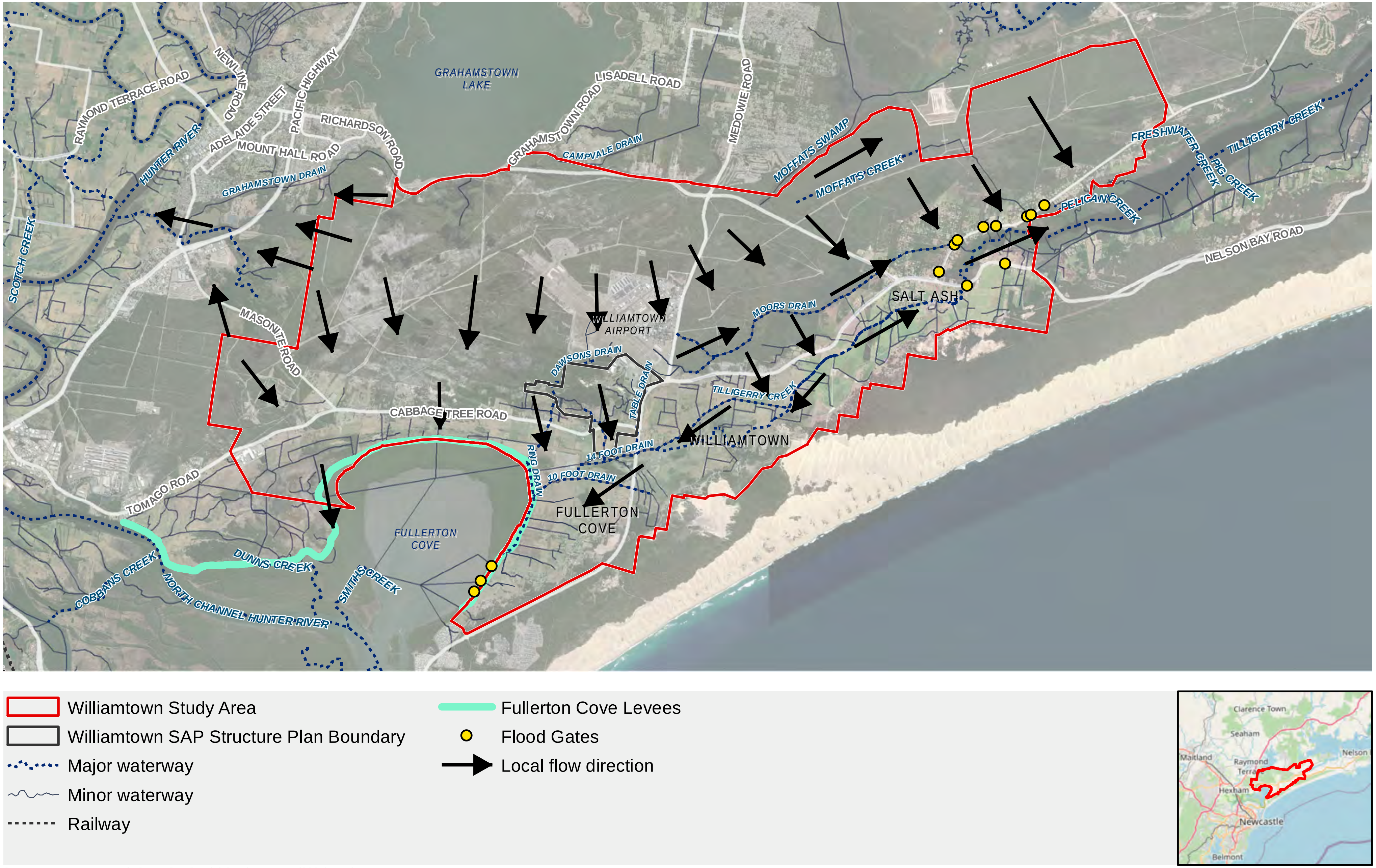
0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A16: PMF design peak flood velocities under regional flooding conditions (Source: BMT 2017)

aurecon



Williamtown Study Area
Williamtown SAP Structure Plan Boundary
Major waterway
Minor waterway
Railway
Fullerton Cove Levees
Flood Gates
Local flow direction

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Source: Aurecon, DPE, TfNSW, NSW Spatial Services, BMT (2005), Esri

1:110,000 @ A4

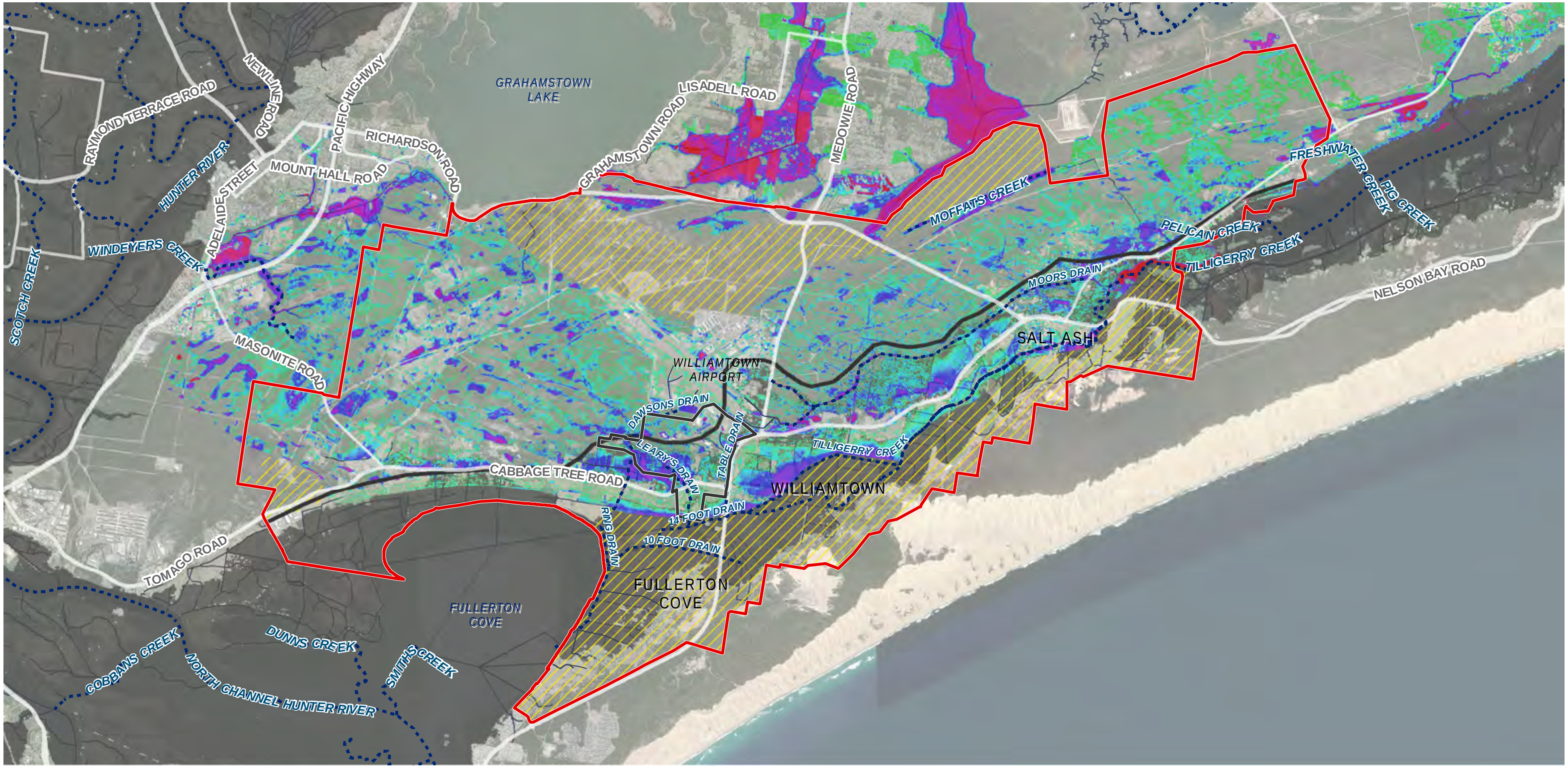
0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A17: Indicative flow directions under local catchment flow conditions (Source: BMT 2005)

aurecon



Williamtown Study Area
Williamtown SAP Structure Plan Boundary
Major waterway
Minor waterway
Regional 5% AEP flood extent
Edge of regional flood extent
No flood data coverage

Peak Flood Depth (m)
>1.5
0.8
0.4
0.2
0

NOTE: The Umwelt (2018) drainage study does cover the area south of the Fourteen Foot Drain and Tilligerry Creek however has not been presented here as no GIS data was available at the time of this report.
The current local flood mapping is based on available information and is limited by the limitations of the respective studies at the time of their assessment.

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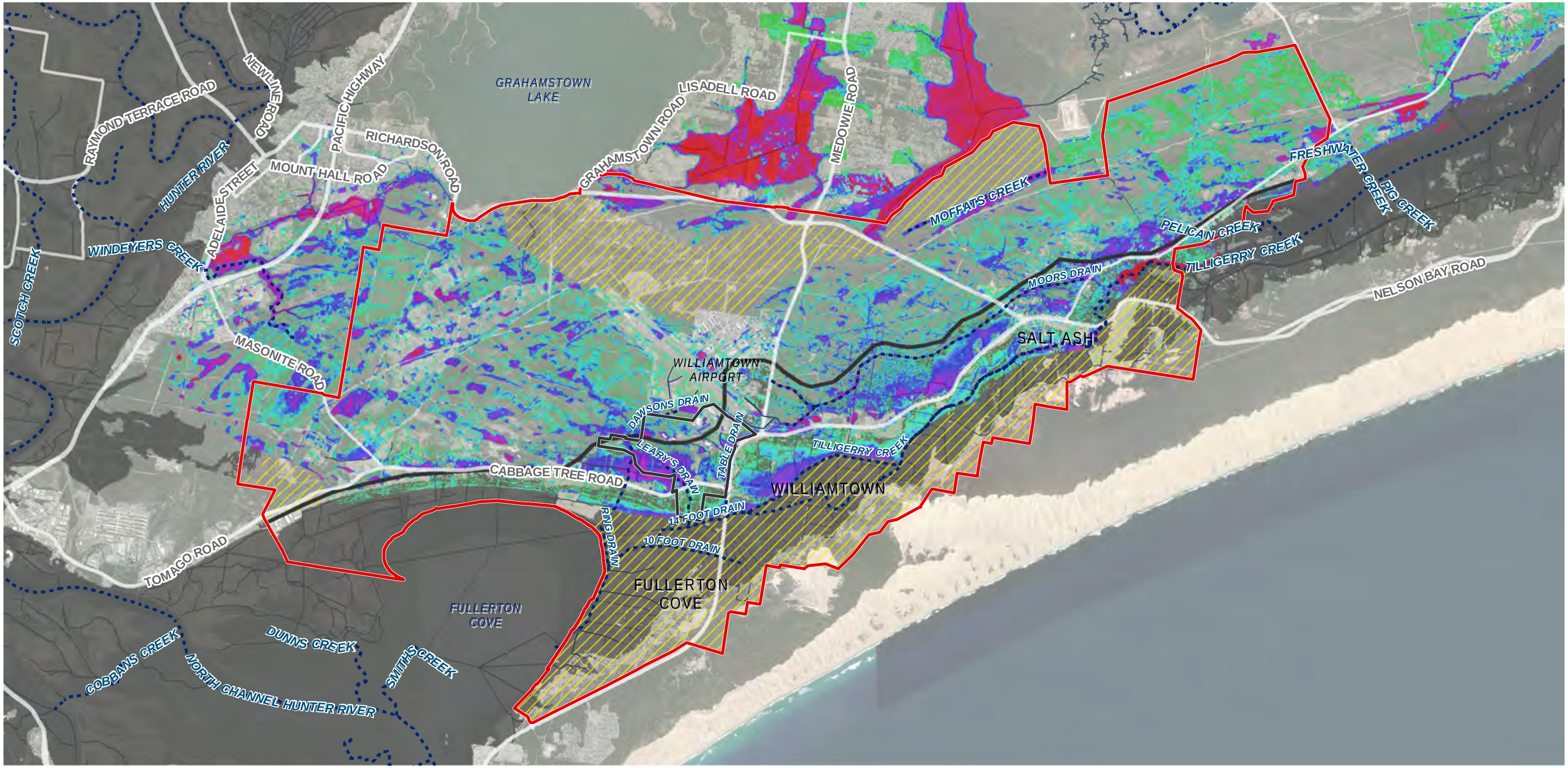
Source: Aurecon, DPE, TfNSW, NSW Spatial Services, BMT (2017), Esri

1:110,000 @ A4
0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A18: 5% AEP design peak flood depths and levels under local flooding conditions



Williamtown Study Area

Williamtown SAP Structure Plan Boundary

Major waterway

Minor waterway

Regional 1% AEP flood extent

Edge of regional flood extent

No flood data coverage

Peak Flood Depth (m)

- >1.5
- 0.8
- 0.4
- 0.2
- 0

NOTE: The Umwelt (2018) drainage study does cover the area south of the Fourteen Foot Drain and Tilligerry Creek however has not been presented here as no GIS data was available at the time of this report.
The current local flood mapping is based on available information and is limited by the limitations of the respective studies at the time of their assessment.

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Source: Aurecon, DPE, TfNSW, NSW Spatial Services, BMT (2017), Esri

1:110,000 @ A4

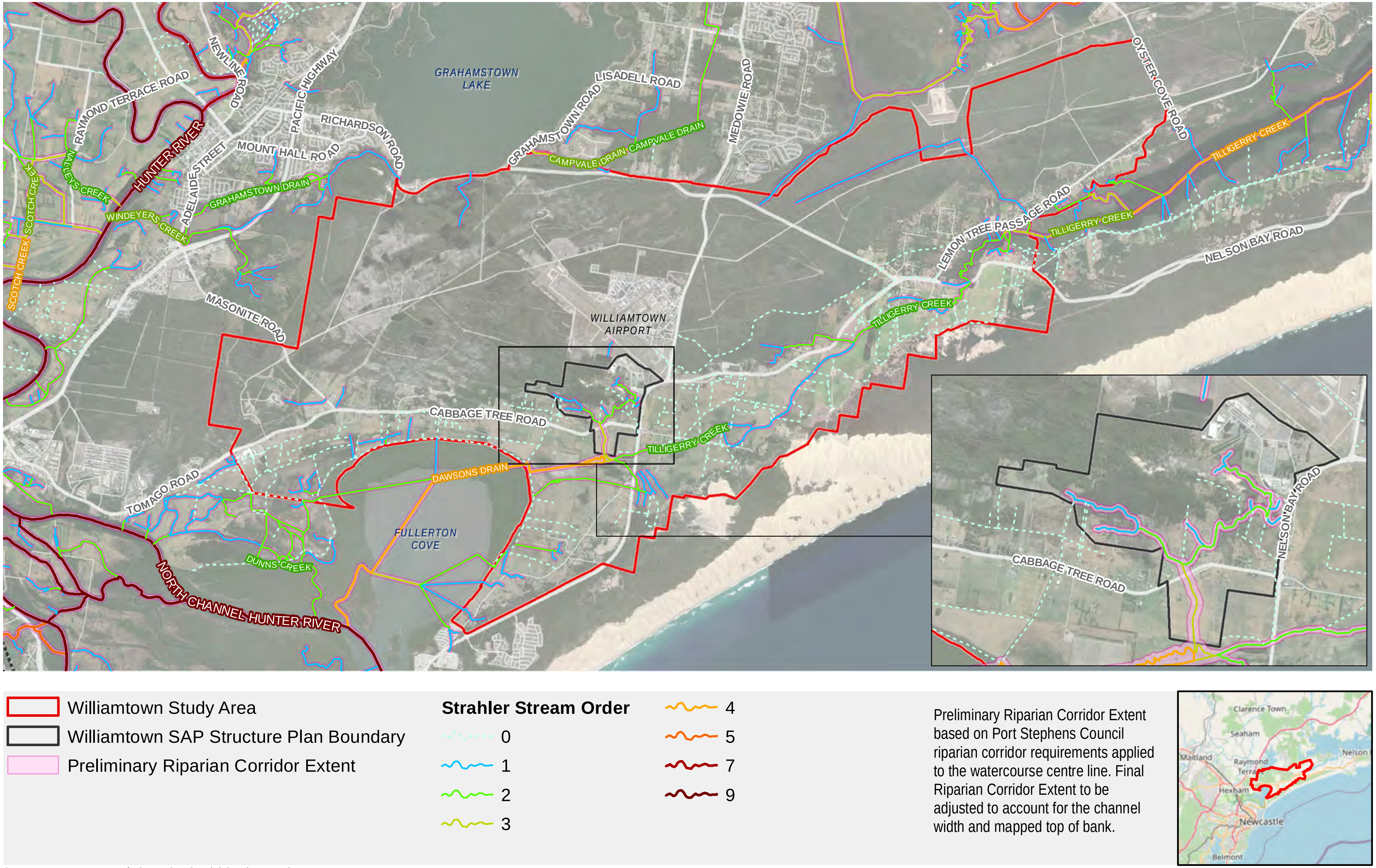
0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A19: 1% AEP design peak flood depths and levels under local flooding conditions

aurecon



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Williamtown Study Area
Williamtown SAP Structure Plan Boundary
Preliminary Riparian Corridor Extent

Strahler Stream Order
0
1
2
3
4
5
7
9

Preliminary Riparian Corridor Extent based on Port Stephens Council riparian corridor requirements applied to the watercourse centre line. Final Riparian Corridor Extent to be adjusted to account for the channel width and mapped top of bank.

Source: Aurecon, DPE, TfNSW, NSW Spatial Services, Esri

1:110,000 @ A4
0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A20: Riparian corridor constraints

Williamtown SAP Structure Plan Boundary	Low Hazard Flood Storage
Williamtown Study Area	Low Hazard Flood Fringe
River	High Hazard Overland Flowpath
Railway	High Hazard Floodway
Limit of PSC's Hunter River Estuary Hazard Data	High Hazard Flood Storage

NOTE: Presented flood hazard and hydraulic categorisation is being updated by Council at the time of reporting. Data presented is a merge of Council previous data and the Jacobs (2017) Anna Bay and Tilligerry Creek Flood Study.

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Source: Aurecon, DPE, TfNSW, Port Stephens Council, Jacobs, NSW Spatial Services, Esri

1:110,000 @ A4

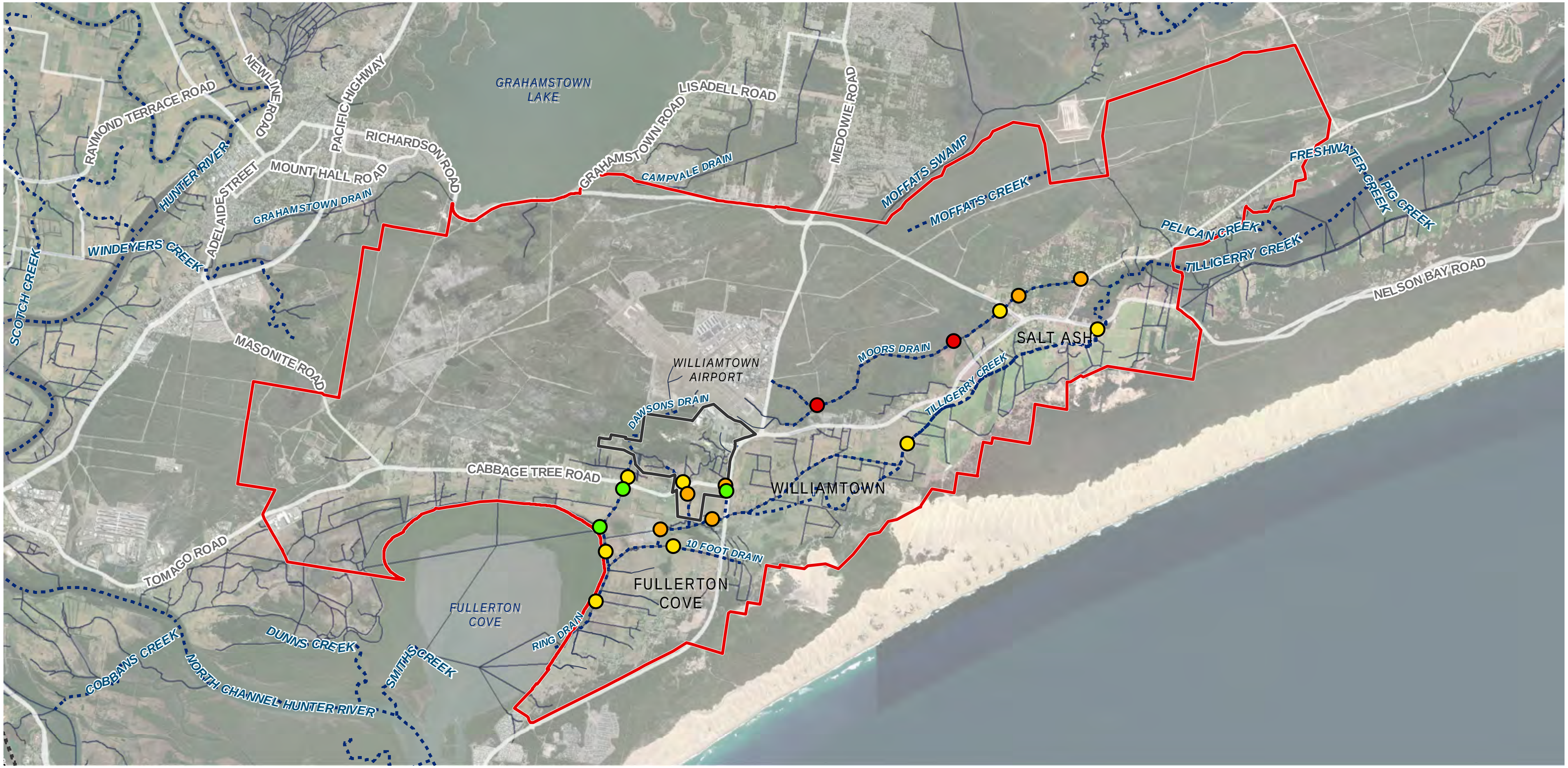
0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A21: PSC's Current flood hazard and hydraulic categories

aurecon



- Williamtown Study Area
- Williamtown SAP Structure Plan Boundary
- Major waterway
- Minor waterway
- Railway
- 1% AEP 48 hour design storm event
- 10% AEP 48 hour design storm event
- 20% AEP 48 hour design storm event
- 50% AEP 48 hour design storm event

NOTE: Ocean Levels - Maximum 1.4 mAHD (1% AEP Storm Event) and Maxiumum 1 mAHD (10%, 20%, and 50% AEP Storm Event)

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Source: Aurecon, DPE, TfNSW, NSW Spatial Services, Esri

1:110,000 @ A4

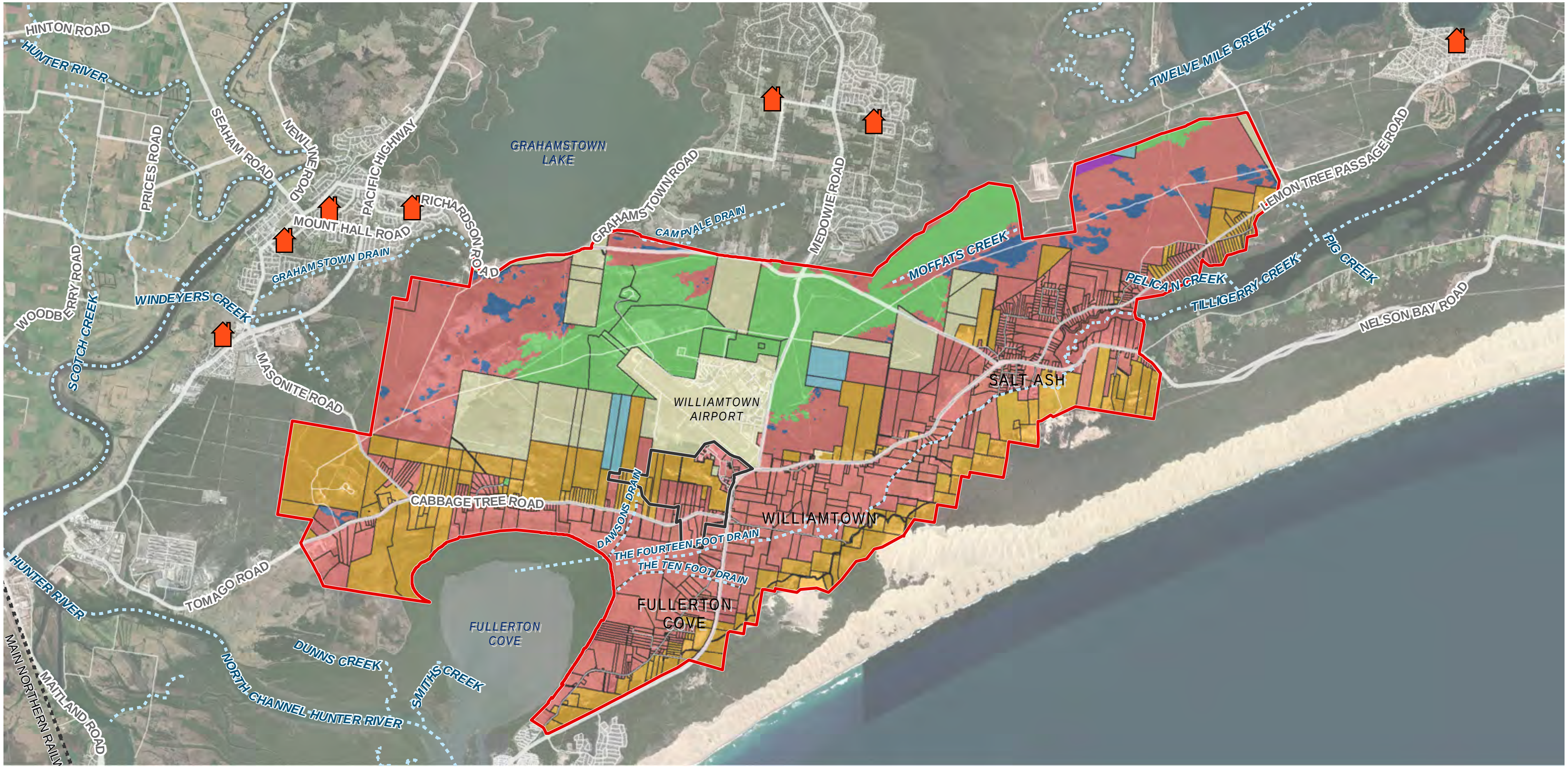
0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A22: Estimated drainage capacity of key drainage lines under local catchment flooding conditions (Source: Umwelt 2018)

aurecon



Williamtown Study Area

Williamtown SAP Structure Plan Boundary

Waterway

Railway

Flood Evacuation Centers (based on the Port Stephens emergency sub plan, 2013)

Lot

Sealed and unsealed roads

Flood Emergency Response Classifications

FEO: Flooded, Exit route, Overland escape

FER: Flooded, Exit route, Rising Road

FIE: Flooded, Isolated, Elevated

FIS: Flooded, Isolated, Submerged

NEO: Not flooded, Exit route, Overland escape *

NER: Not flooded, Exit route, Rising Road *

NIE: Not flooded, Isolated, Elevated *

Additional classifications defined for areas not bound by a cadastral boundary within the Williamtown SAP

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Source: Aurecon, DPE, TfNSW, NSW Spatial Services, Esri

1:120,000 @ A4

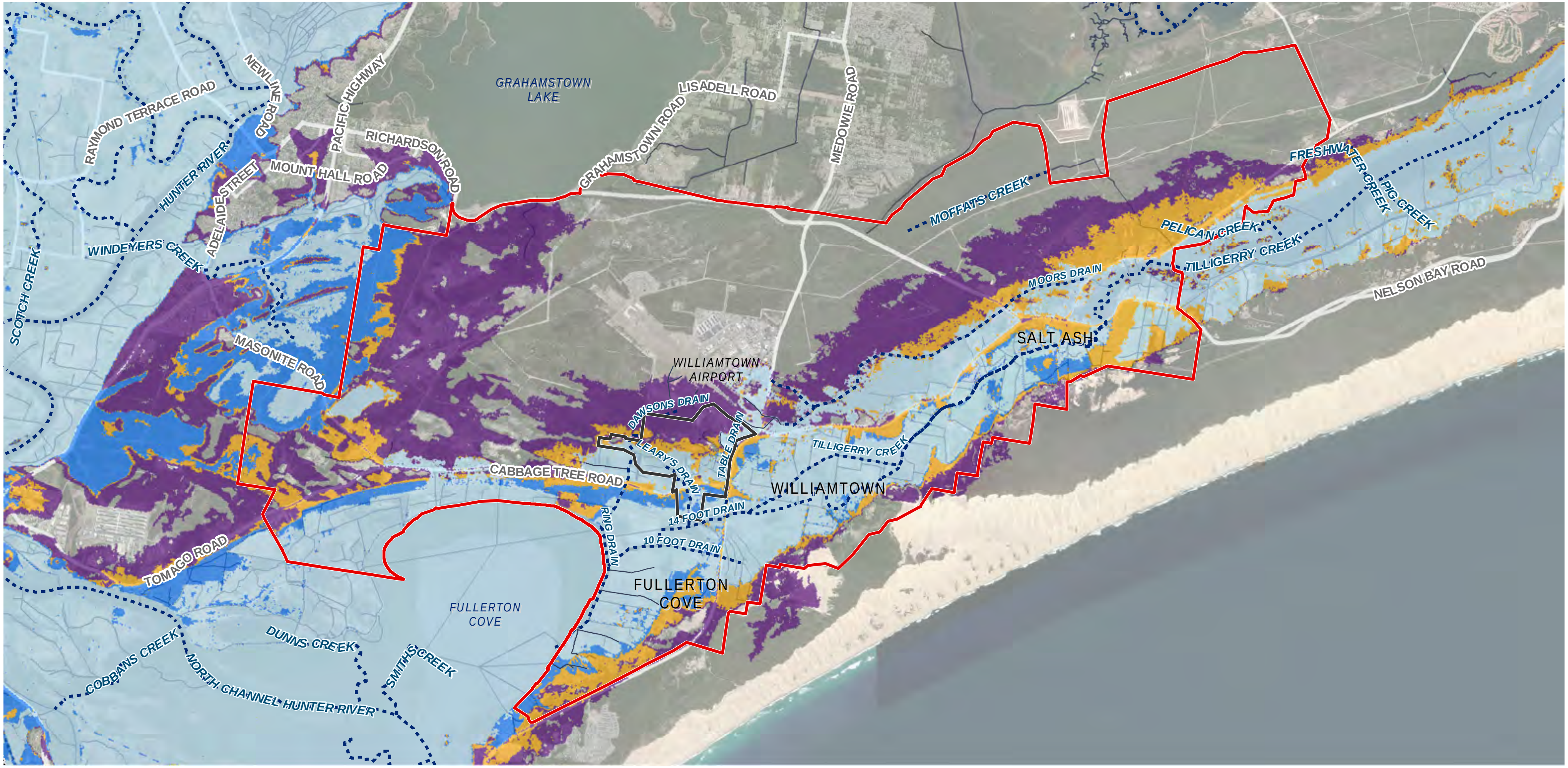
0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A23: Flood emergency response classifications

aurecon



Williamtown Study Area
Williamtown SAP Structure Plan Boundary
Major waterway
Minor waterway
Railway

Flood Extents
10% AEP Design Event
1% AEP Design Event
2100 Planning Condition
PMF Design Event

P:\GIS\Project-4\project\510674_Williamtown_SAP\510674_WilliamtownSAP_HH_A24_Flood_Extent_Comparison.mxd\JOB No.\04-02-22\Qi.Shen\Rev 0

Source: Aurecon, DPE, TfNSW, NSW Spatial Services, BMT (2017), Esri

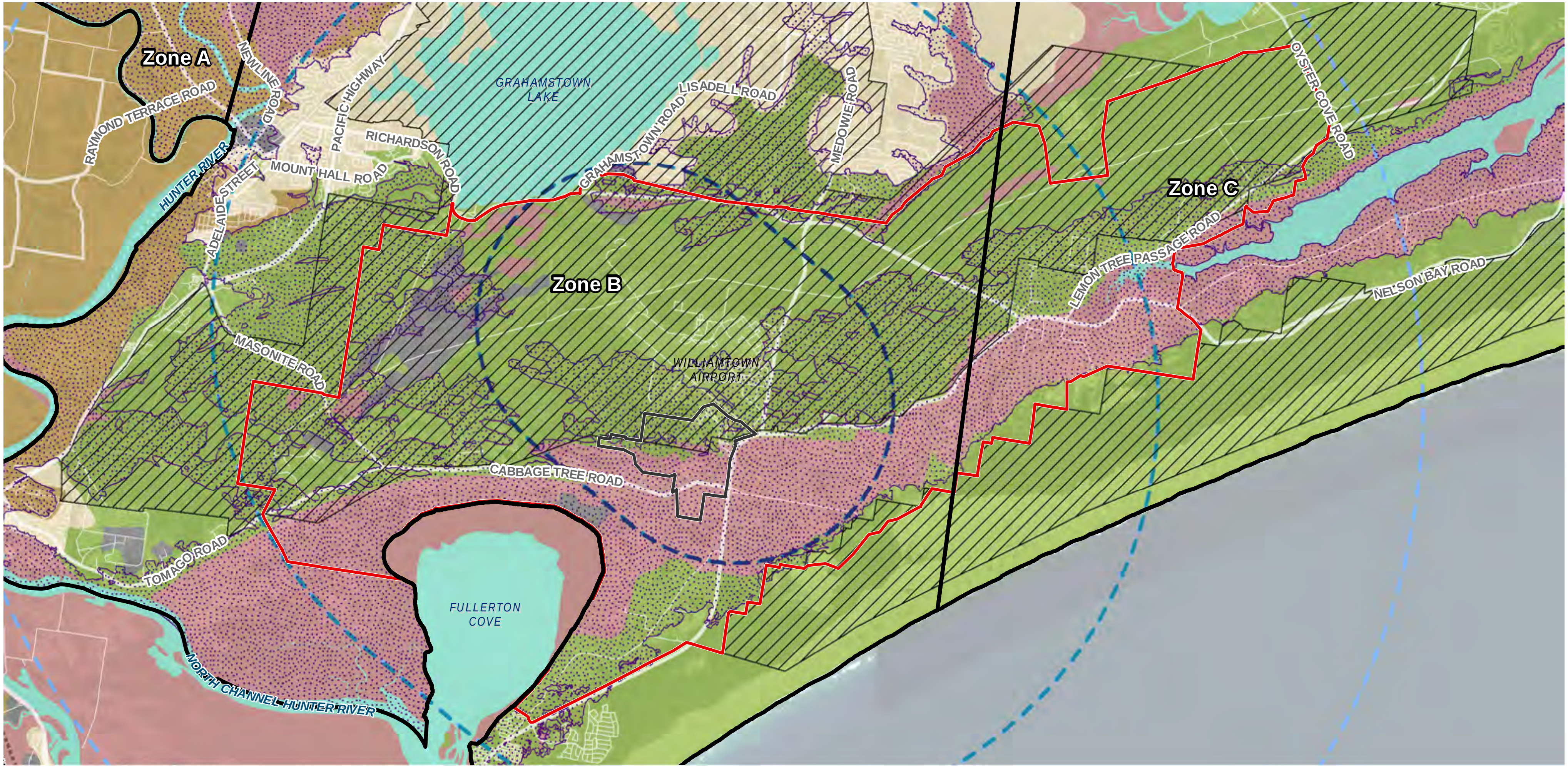
1:110,000 @ A4
0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A24: Flood extents for various flood events across the SAP area

aurecon



Williamtown Study Area
Williamtown SAP Structure Plan Boundary
River
Flood Planning Area
Drinking Water Catchment
MUSIC Rainfall Zone

Bird Strike Group*
Bird Strike Group A
Bird Strike Group B
Bird Strike Group C

Hydrologic Soils Group
A High infiltration
B Moderate infiltration
C Slow infiltration
D Very slow infiltration
Not assessed
Water

*Following Commonwealth NASF Guidelines

Source: Aurecon, DPE, TfNSW, NSW Spatial Services, Esri

1:110,000 @ A4

0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A25: Water cycle management constraints summary

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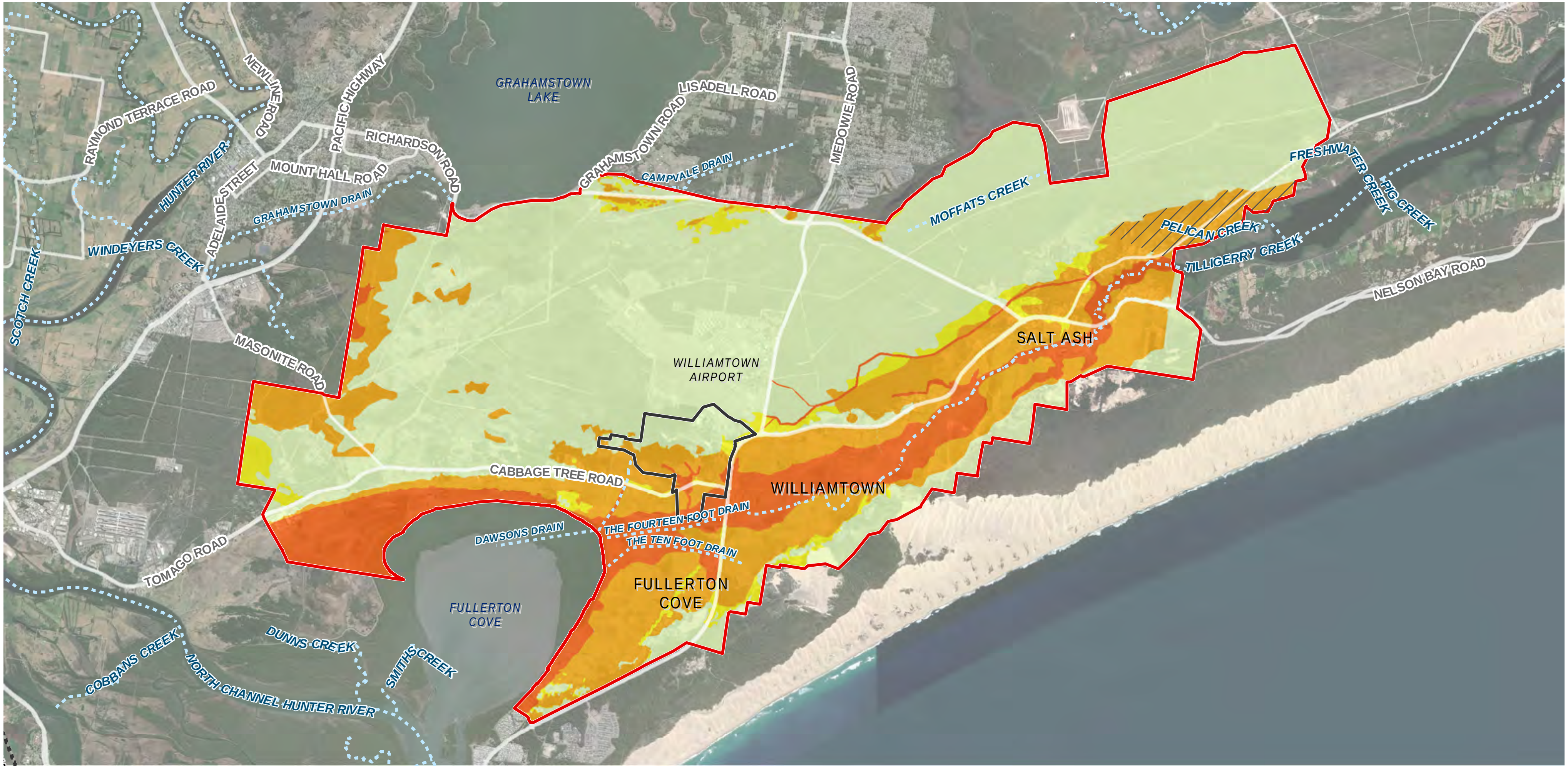
aurecon



P:\GIS\Project-4\project\510674_Williamtown_SAP\510674_WilliamtownSAP_HH_A26_Flooding_Developability_Constraints.mxd\JOB No.\04-02-22\Qi.Shen\Rev 0

Williamtown Study Area
Williamtown SAP Structure Plan Boundary
Waterway
Railway

Constraint Category

	Category 1	*May be developed with standard controls*
	Category 2	*May be developable but with additional mitigation to standard controls*
	Category 3	*May be developable but with significant mitigation*
	Category 4	*Developments Discouraged*
	Refer to Note	

NOTE: Area of inconsistent hazard and hydraulic categories between Port Stephens Council (PSC) hazard mapping, Williamtown/Salt Ash Study (BMT 2017) data and Anna Bay and Tilligerry Creek Study (Jacobs 2017). Developability category based on worst case data in this area. Hazard mapping is currently being updated by PSC at the time of this study and will be updated when available.

Source: Aurecon, DPE, TfNSW, NSW Spatial Services, Esri

1:110,000 @ A4

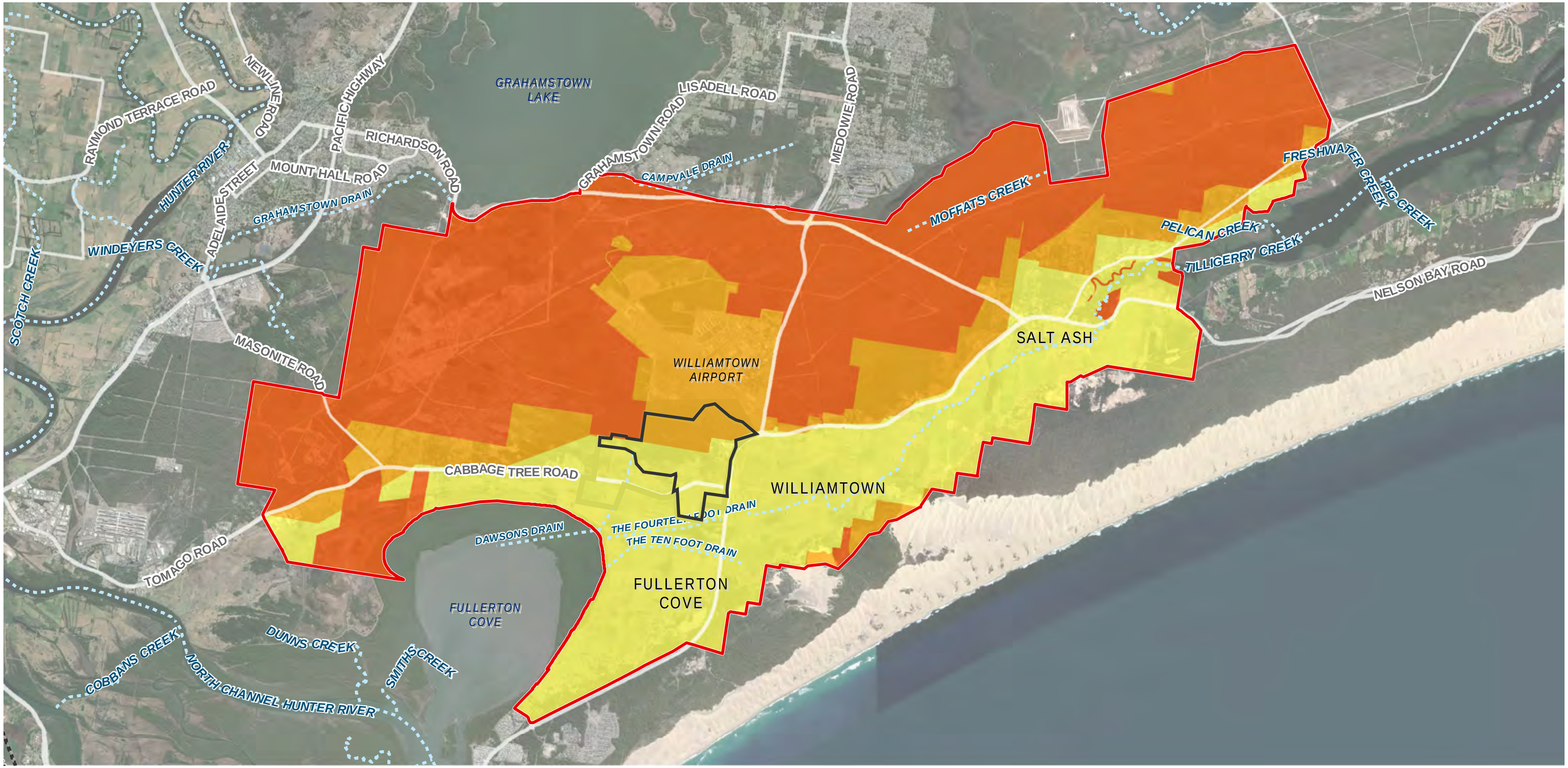
0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A26: Flooding developability constraints

aurecon



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Williamtown Study Area

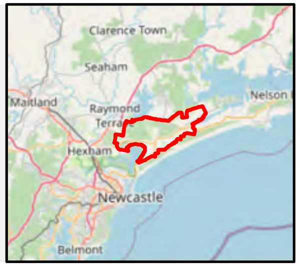
Williamtown SAP Structure Plan Boundary

Waterway

Railway

Constraint Category

Category 2	*May be developable but with additional mitigation to standard controls*
Category 3	*May be developable but with significant mitigation*
Category 4	*Developments Discouraged*



Source: Aurecon, DPE, TfNSW, NSW Spatial Services, DPIE, Esri

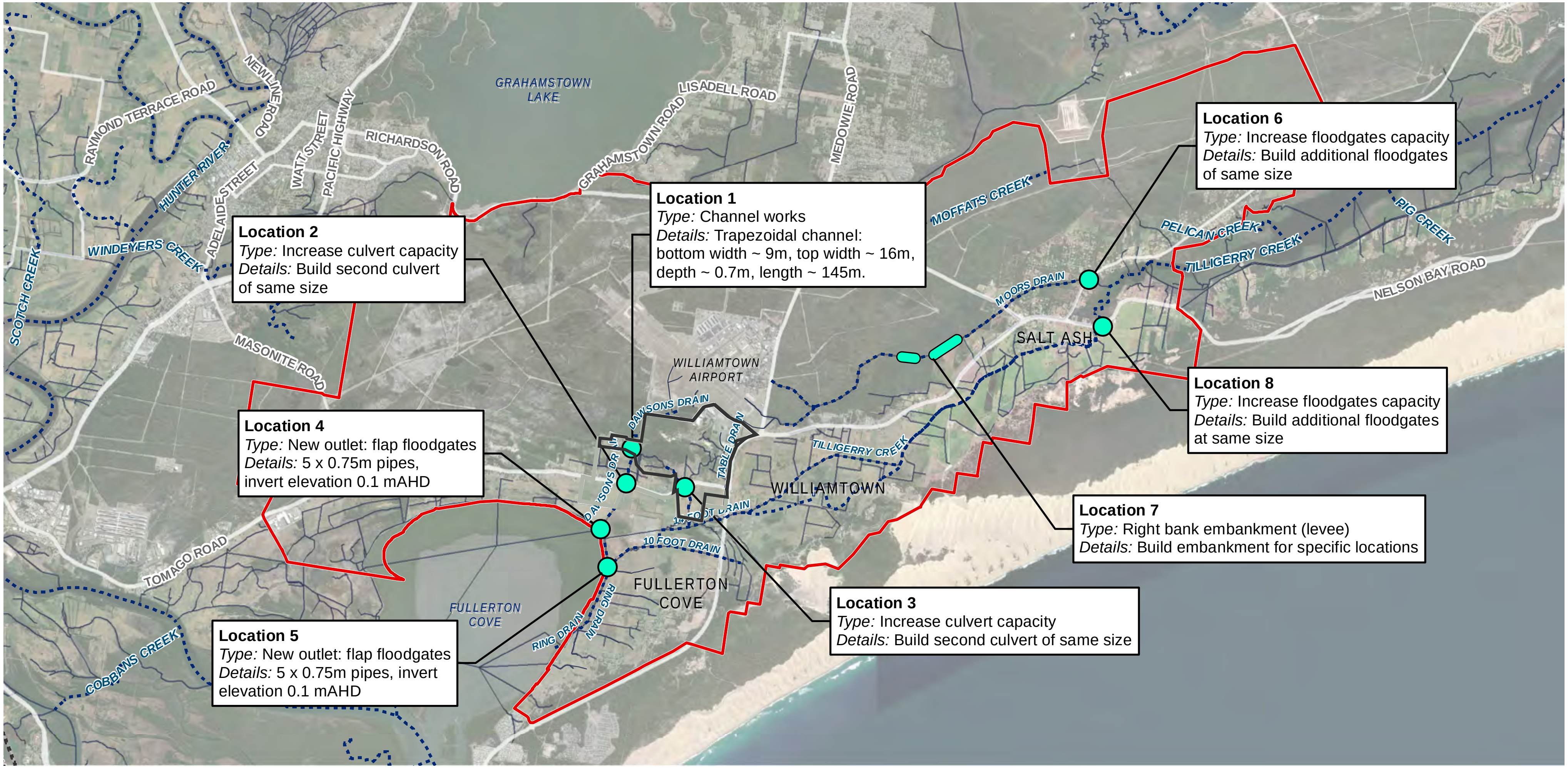
1:110,000 @ A4

0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A27: Water quality treatment developability constraints



Williamtown Study Area

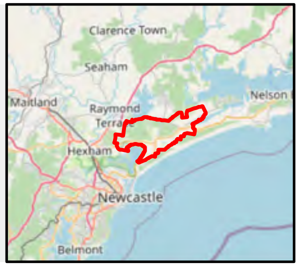
Williamtown SAP Structure Plan Boundary

Major waterway

Minor waterway

Railway

Drainage augmentation locations



Source: Aurecon, DPE, TfNSW, NSW Spatial Services, Esri

1:110,000 @ A4

0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A28: General drainage augmentation works (Source: Umwelt 2018)

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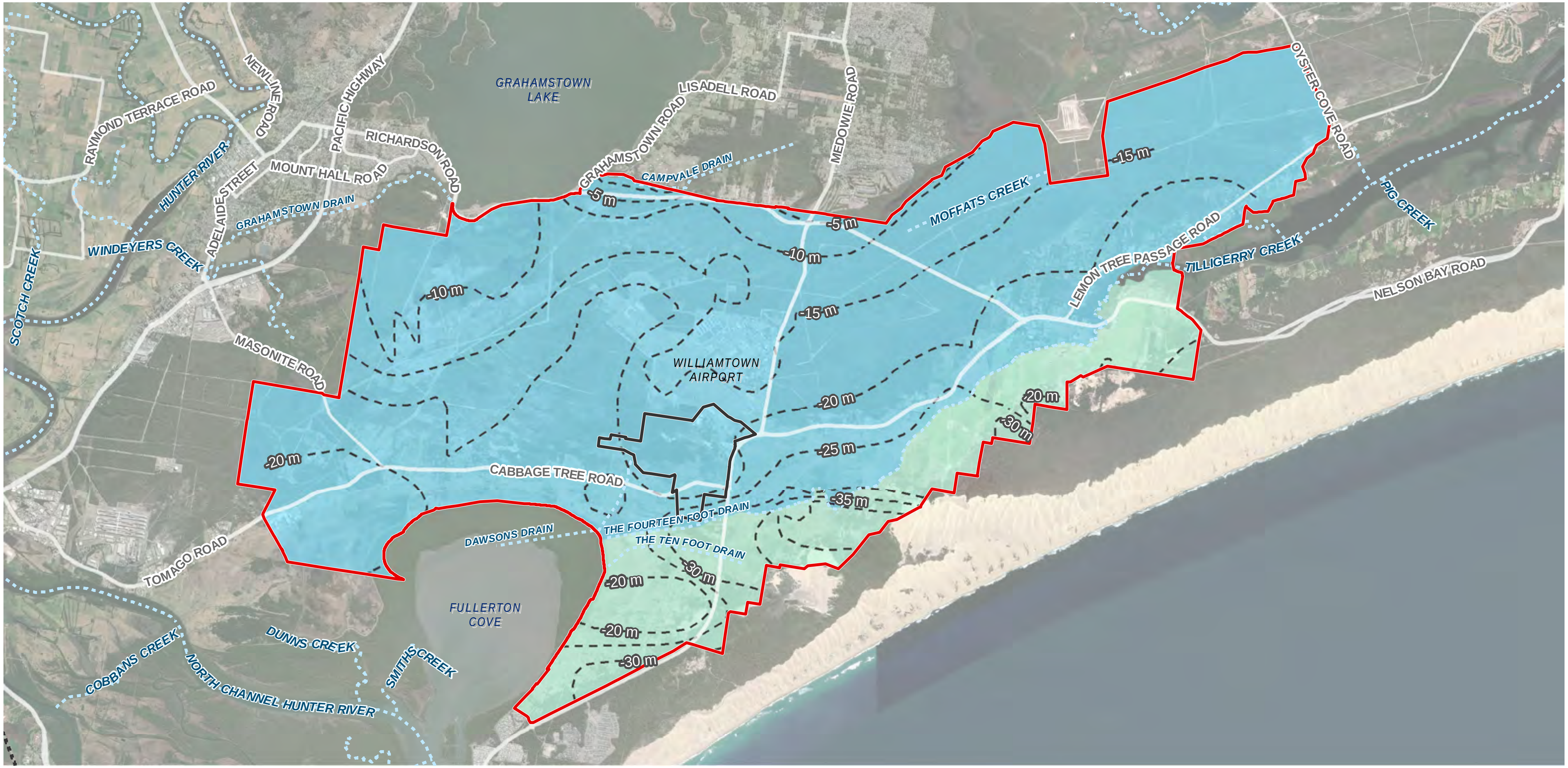
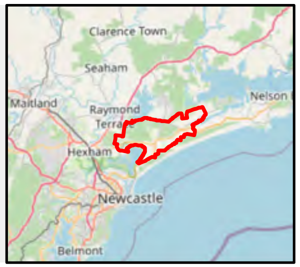


Williamtown Study Area
Williamtown SAP Structure Plan Boundary
Waterway
Railway
Tomago Aquifer
Stockton Aquifer
Aquifer thickness (m)



P:\GIS\Project-4\project\510674_Williamtown_SAP\510674_WilliamtownSAP_HH_A29_Aquifers.mxd\JOB No.\08-12-22\Qi.Shen\Rev 0

Source: Aurecon, DPE, TfNSW, NSW Spatial Services, DPIE, BoM, Esri

1:110,000 @ A4

0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Hydraulic and Hydrology**

A29: Aquifers

Appendix B
MUSIC Modelling Results

Baseline - Rainfall Zone B Modelling

Scenario	Rural Sand	Rural Clay	Bushland Sand	Bushland Clay	Industrial Sand	Industrial Clay
Land Use	RU2	RU2	E1	E1	IN1	IN1
Adopted MUSIC Land Use	Agricultural	Agricultural	Forest	Forest	Industrial	Industrial
Soil Type	Sand	Clay	Sand	Clay	Sand	Clay
Modelled Area (ha)	1	1	1	1	1	1
Effective Impervious Area	0%	0%	0%	0%	70%	70%
Rainfall (ML/yr)	11.25	11.25	11.25	11.25	11.25	11.25
Stormwater Runoff (ML/yr)	0.65	2.27	0.65	2.27	7.09	7.58
Infiltration / Baseflow (ML/yr)	4.00	0.58	4.00	0.58	1.20	0.17
Evapotranspiration (ML/yr)	6.60	8.40	6.60	8.40	2.96	3.50
Total Outflow (ML/yr)	4.65	2.85	4.65	2.85	8.29	7.75
TSS (kg/yr)	196	435	53	103	1341	1383
TP (kg/yr)	0.85	1.77	0.31	0.24	2.28	2.26
TN (kg/yr)	6.95	8.97	1.93	2.52	17.20	16.83
Gross Pollutants (kg/yr)	0	0	0	0	215	215

Baseline - Rainfall Zone C Modelling

Scenario	Rural Sand	Rural Clay	Bushland Sand	Bushland Clay	Industrial Sand	Industrial Clay
Land Use	RU2	RU2	E1	E1	IN1	IN1
Adopted MUSIC Land Use	Agricultural	Agricultural	Forest	Forest	Industrial	Industrial
Soil Type	Sand	Clay	Sand	Clay	Sand	Clay
Modelled Area (ha)	1	1	1	1	1	1
Effective Impervious Area	0%	0%	0%	0%	70%	70%
Rainfall (ML/yr)	12.38	12.38	12.38	12.38	12.38	12.38

Scenario	Rural Sand	Rural Clay	Bushland Sand	Bushland Clay	Industrial Sand	Industrial Clay
Stormwater Runoff (ML/yr)	0.87	2.92	0.87	2.92	7.93	8.55
Infiltration / Baseflow (ML/yr)	4.67	0.68	4.67	4.67	1.40	0.20
Evapotranspiration (ML/yr)	6.84	8.78	6.84	4.79	3.05	3.63
Total Outflow (ML/yr)	5.54	3.60	5.54	7.59	9.33	8.75
TSS (kg/yr)	262	542	67	157	1484	1573
TP (kg/yr)	1.16	2.27	0.37	0.56	2.54	2.53
TN (kg/yr)	8.51	11.28	2.33	4.41	19.27	19.07
Gross Pollutants (kg/yr)	0	0	0	0	229	229

Scenario Testing – Modelling of WSUD Strategy

Land Use	High Intensity Development Sand	High Intensity Development Clay	Low Intensity Development Sand	Low Intensity Development Clay
Rainfall Band	B	B	B	B
Adopted MUSIC Land Use	Industrial	Industrial	Industrial	Industrial
Soil Type	Sand	Clay	Sand	Clay
Modelled Area (ha)	1	1	1	1
Effective Impervious Area	85%	85%	50%	50%
Rainfall (ML/yr)	11.25	11.25	11.25	11.25
Stormwater Runoff (ML/yr)	3.05	6.07	2.44	4.55
Infiltration / Baseflow (ML/yr)	3.67	0.16	3.60	0.29
Evapotranspiration (ML/yr)	4.53	5.03	5.22	6.42
Total Outflow (ML/yr)	6.72	6.22	6.03	4.83
TSS (kg/yr)	109.8	122	93.3	115
TP (kg/yr)	0.656	0.621	0.655	0.535
TN (kg/yr)	7.31	8.4	7.02	6.65
Gross Pollutants (kg/yr)	0	0	0	0

Structure Plan Modelling – WSUD Parameters

Precinct	Light Industrial (Clay)	Light Industrial (Sand)	Airside (Clay)	Airside (Sand)	Freight and Logistics (Sand)	Research & Development (Sand)
Rainwater Tanks						
Low Flow By-pass (m^3/s)	0	0	0	0	0	0
High Flow By-pass (m^3/s)	100	100	100	100	100	100
Number of Tanks	1	1	1	1	1	1
Rainwater Tank Volume (kL)	150	150	200	200	40	200
Depth above overflow (m)	0.2	0.2	0.2	0.2	0.2	0.2
Surface Area (m^2)	15	15	15	15	15	15
Initial Volume (kL)	15	15	15	15	15	15
Overflow Pipe Diameter (mm)	50	50	50	50	50	50
Re-use: Max Drawdown height (m)	10	10	13.333	13.333	2.667	13.333
Re-use: Daily Demand (kL/day)	6.6	6.6	10.93	10.93	2.75	6.6
Gross Pollutant Trap (CDS Nipper 506)						
Low Flow By-pass (m^3/s)	0	0	0	0	0	0
High Flow By-pass (m^3/s)	0.04	0.04	0.04	0.04	0.04	0.04
Street Trees						
Low Flow By-pass (m^3/s)	0	0	0	0	0	0
High Flow By-pass (m^3/s)	100	100	100	100	100	100
Extended Detention Depth (m)	0.1	0.1	0.1	0.1	0.1	0.1

Precinct	Light Industrial (Clay)	Light Industrial (Sand)	Airside (Clay)	Airside (Sand)	Freight and Logistics (Sand)	Research & Development (Sand)
Surface Area (m^2)	40	50	40	50	50	50
Filter Area (m^2)	40	50	40	50	50	50
Unlined Filter Media Perimeter (m)	0.01	0.01	0.01	0.01	0.01	0.01
Saturated Hydraulic Conductivity (mm/hr)	50	50	50	50	50	50
Filter Depth (m)	1	1	1	1	1	1
TN Content of Filter Media (mg/kg)	400	400	400	400	400	400
Orthophosphate Content of Filter Media (mg/kg)	40	40	40	40	40	40
Exfiltration Rate (mm/hr)	0	0	0	0	0	0
Base Lined?	Y	Y	Y	Y	Y	Y
Vegetation Properties	Vegetated with Effective Nutrient Removal Plants					
Overflow Weir Width (m)	14	14	14	14	14	14
Underdrain Present?	Y	Y	Y	Y	Y	Y
Submerged Zone with Carbon Present?	N	N	N	N	N	N
Filtration in Fill						
Low Flow By-pass (m^3/s)	N/A	0	N/A	0	0	0
High Flow By-pass (m^3/s)		100		100	100	100
Extended Detention Depth (m)		0		0	0	0

Precinct	Light Industrial (Clay)	Light Industrial (Sand)	Airside (Clay)	Airside (Sand)	Freight and Logistics (Sand)	Research & Development (Sand)
Surface Area (m^2)		1000 (Garden) + 1500 (Open Space) + 2000 (Streets)		1000 (Garden) + 1500 (Open Space) + 2000 (Streets)	1000 (Garden) + 1500 (Open Space) + 2000 (Streets)	1000 (Garden) + 1500 (Open Space) + 2000 (Streets)
Exfiltration Rate (mm/hr)		180		180	180	180
Filter Area (m^2)		1000 (Garden) + 1500 (Open Space) + 2000 (Streets)		1000 (Garden) + 1500 (Open Space) + 2000 (Streets)	1000 (Garden) + 1500 (Open Space) + 2000 (Streets)	1000 (Garden) + 1500 (Open Space) + 2000 (Streets)
Filter Depth (m)		0.5		0.5	0.5	0.5
Filter Median Particle Diameter (mm)		0.7		0.7	0.7	0.7
Saturated Hydraulic Conductivity (mm/hr)		360		360	360	360
Depth below underdrain pipe (% of Filter Depth)		0		0	0	0
Overflow Properties		2		2	2	2

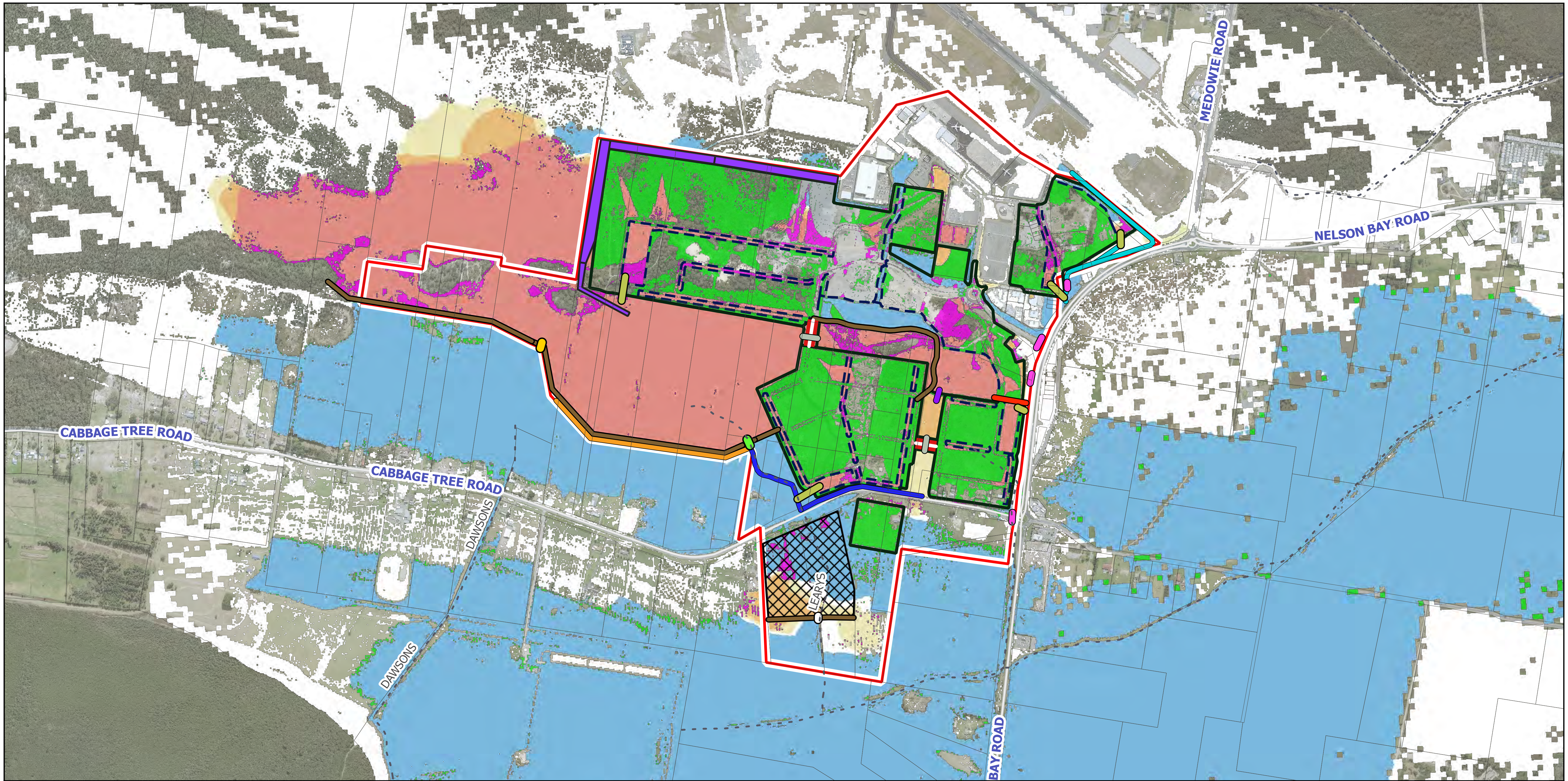
Wetland	W1		W2		W3	W4	W5	W6			W7		W8
Typology		Light Industrial						Airside		Freight & Logistics		Research & Development	
Soil Type	Clay	Sand	Clay		Clay	Clay	Clay	Clay	Sand	Sand	Sand	Sand	Sand
	Swales												
Length (m)	22	22	33		27	28	26	15	15	N/A	9	9	16
Bed Slope (%)	0.1	0.1	0.1		0.1	0.1	0.1	0.1	0.1		0.1	0.1	0.1
Base Width (m)	1.4	1.4	1.4		1.4	1.4	1.4	1.4	1.4		1.4	1.4	1.4

Wetland	W1		W2		W3	W4	W5	W6			W7		W8
Top width (m)	15	15	15		15	15	15	15	15		15	15	15
Vegetation Height (m)	0.25	0.25	0.25		0.25	0.25	0.25	0.25	0.25		0.25	0.25	0.25
		Wetlands											
Low Flow By-pass (m^3/s)	0	0	0		0	0	0	0	0	0	0	0	0
High Flow By-pass (m^3/s)	100	100	100		100	100	100	100	100	100	100	100	100
Inlet Pond Volume (m^3)	0	0	0		0	0	0	0	0	80	0	0	0
Surface Area (m^2)	310	230	260		280	270	275	310	150	600	535	270	150
Extended Detention Depth (m)	0.4	0.4	0.4		0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Permanent Pool Volume (m^3)	93	69	78		84	81	83	93	45	180	161	81	45
Initial Volume (m^3)	93	69	78		84	81	83	93	45	180	161	81	45
Vegetation Cover (% of surface area)	50	50	50		50	50	50	50	50	50	50	50	50
Exfiltration Rate (mm/hr)	0	0	0		0	0	0	0	0	0	0	0	0
Evaporative Loss as % of PET	125	125	125		125	125	125	125	125	125	125	125	125
Equivalent Pipe Diameter (mm)	19	16	17		18	17	17	19	13	26	24	17	13
Overflow Weir Width (m)	6	6	6		6	6	6	6	6	6	6	6	6
Notional Detention Time (hrs)	64.7	67.7	67.8		65.2	70.4	71.7	64.7	66.9	66.9	70	70.4	66.9

Appendix C
Flooding and Water Cycle Management

ID	Figure name / report figure title
C1	Proposed Flood Management Measures
C2	Unmitigated Regional Flood Impact for the 1%AEP+Climate Change
C3	Mitigated Regional Flood Impact for the 1%AEP
C4	Mitigated Regional Flood Impact for the 1%AEP+Climate Change
C5	Mitigated Regional Flood Impact for the PMF
C6	Unmitigated Local Flood Impact for the 1%AEP+Climate Change - Low tailwater level (0.85mAHD)
C7	Mitigated Local Flood Impact for the 20%AEP - Low tailwater level (0.85mAHD)
C8	Mitigated Local Flood Impact for the 1%AEP+Climate Change - Low tailwater level (0.85mAHD)
C9	Mitigated Local Flood Impact for the PMF- Low tailwater level (0.85mAHD)
C10	Unmitigated Local Flood Impact for the 1%AEP+Climate Change - High tailwater level (1.6mAHD)
C11	Mitigated Local Flood Impact for the 20%AEP - High tailwater level (1.6mAHD)
C12	Mitigated Local Flood Impact for the 1%AEP+Climate Change - High tailwater level (1.6mAHD)

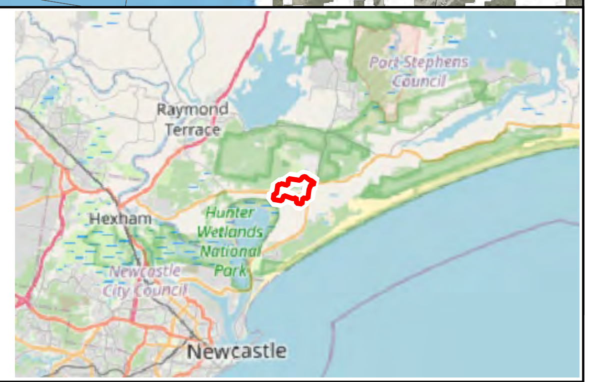
aurecon



- Williamtown SAP Structure Plan Boundary
- Bulk filled extent
- Major waterway
- Lot
- Astra basin major outlet
- Astra basin minr outlet
- Secondary road culverts
- Table drain additional culverts
- Dawsons drain psuedo detention basin outlet
- Learys drain psuedo detention basin outlet
- Wetland outlet
- Offset flood storage outlet
- North-west cut-off drain
- Access road
- Earth bund
- North-east cut-off drain
- Minor drainage works
- Regrading The Existing Drain
- Channels
- Offset flood storage area

Flood Impact (m)

- <= -0.01
- -0.01 - 0.01
- 0.01 - 0.04
- 0.04 - 0.1
- > 0.1
- Was Wet Now Dry
- Was Dry Now Wet



D:\01- Williamtowan SAP Concept Design

0 600 1200 m

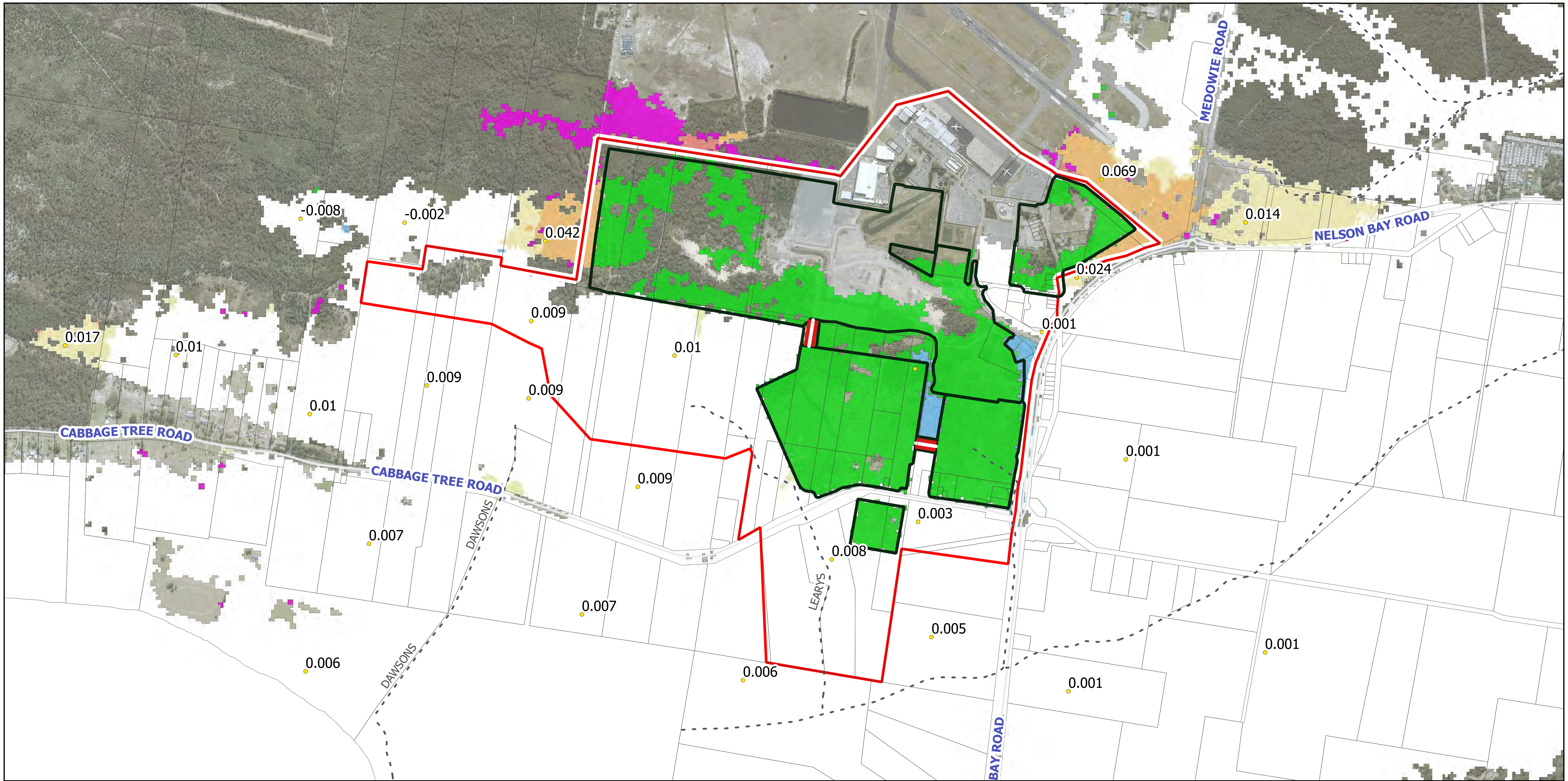
A3 Scale: 1:15000

Projecion: GDA 1994 MGA Zone 56

Williamtown SAP

C1: Proposed flood management measures

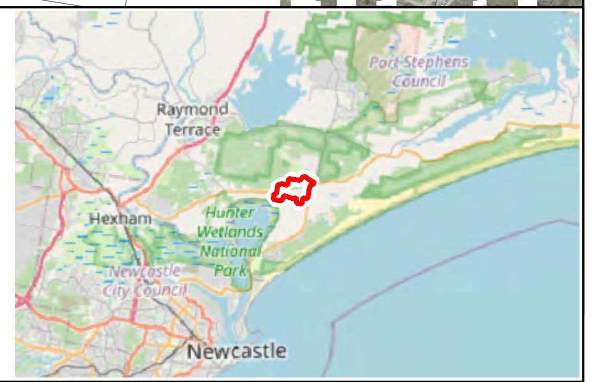
aurecon



Williamtown SAP Structure Plan Boundary
Bulk filled extent
Major waterway
Lot
Access road
Flood Impact (m)

Flood Impact (m)

<= -0.01
-0.01 - 0.01
0.01 - 0.04
0.04 - 0.1
> 0.1
Was Wet Now Dry
Was Dry Now Wet



D:\01- Williamtown SAP Concept Design

0 600 1200 m

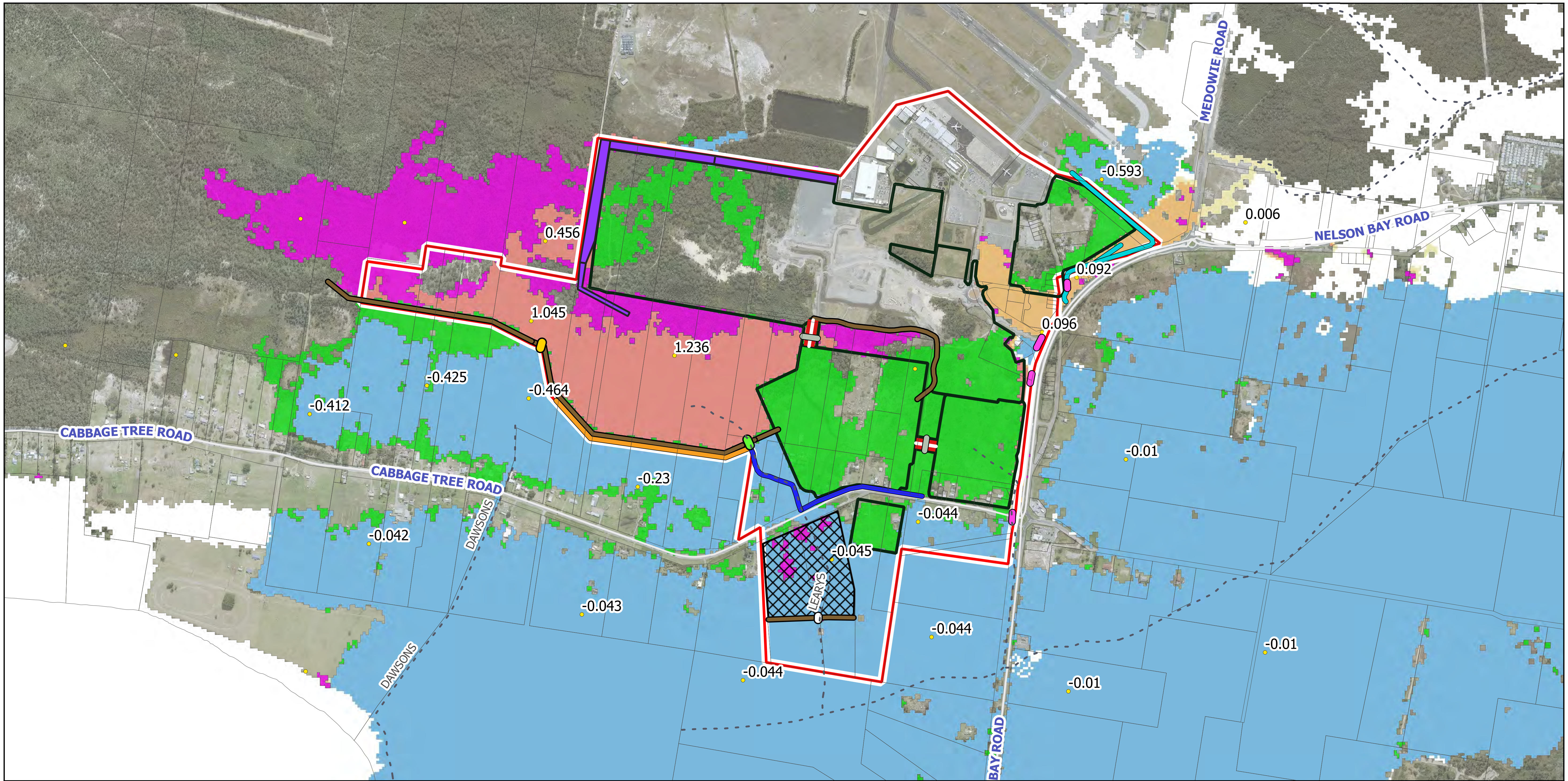
A3 Scale: 1:15000

Projecion: GDA 1994 MGA Zone 56

Williamtown SAP

C2: Unmitigated Regional Flood Impact for 1%AEP+Climate Change

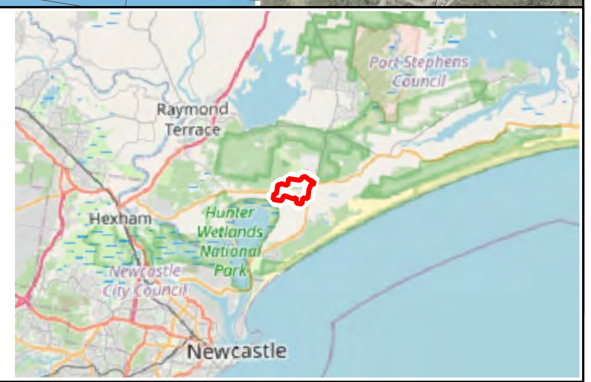
aurecon



- Williamtown SAP Structure Plan Boundary
- Bulk filled extent
- Major waterway
- Lot
- Secondary road culverts
- Table drain additional culverts
- Dawsons drain psuedo detention basin outlet
- Learys drain psuedo detention basin outlet
- Offset flood storage outlet
- North-west cut-off drain
- Access road
- Earth bund
- North-east cut-off drain
- Minor drainage works
- Regrading The Existing Drain
- Offset flood storage area
- Flood Impact (m)

Flood Impact (m)

- <= -0.01
- -0.01 - 0.01
- 0.01 - 0.04
- 0.04 - 0.1
- > 0.1
- Was Wet Now Dry
- Was Dry Now Wet



D:\01- Williamtowan SAP Concept Design

0 600 1200 m

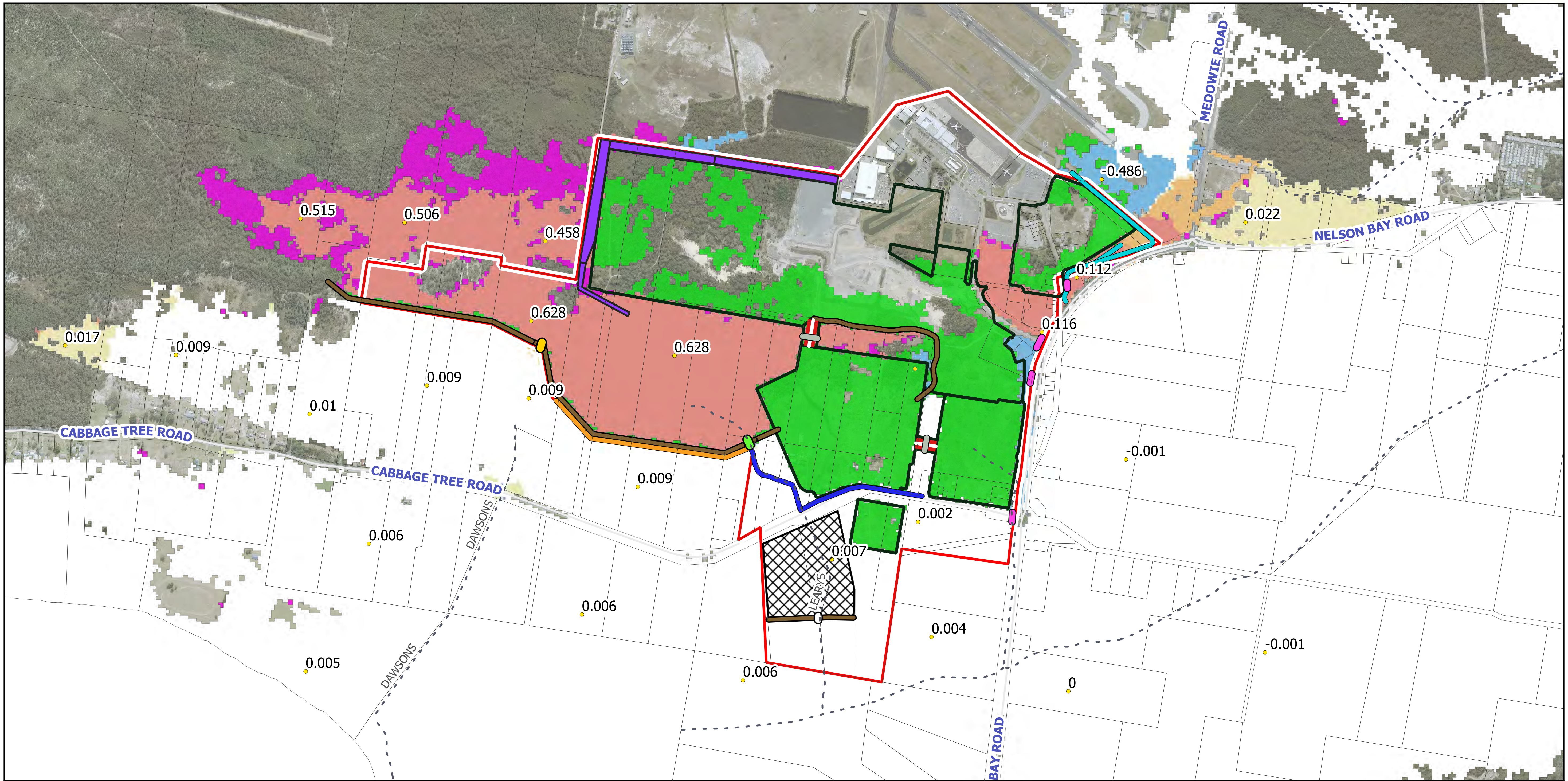
A3 Scale: 1:15000

Projecion: GDA 1994 MGA Zone 56

Williamtown SAP

C3: Mitigated Regional Flood Impact for 1%AEP

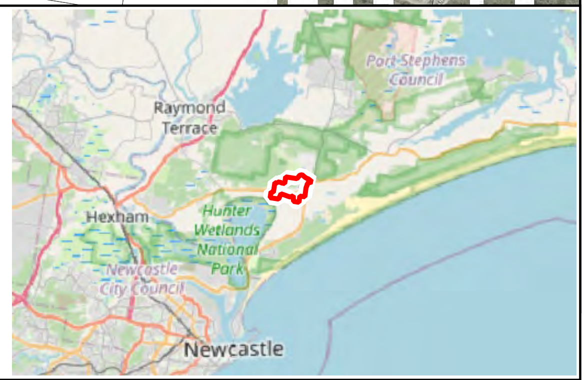
aurecon



- Williamtown SAP Structure Plan Boundary
- Bulk filled extent
- Major waterway
- Lot
- Secondary road culverts
- Table drain additional culverts
- Dawsons drain psuedo detention basin outlet
- Learys drain psuedo detention basin outlet
- Offset flood storage outlet
- North-west cut-off drain
- Access road
- Earth bund
- North-east cut-off drain
- Minor drainage works
- Regrading The Existing Drain
- Offset flood storage area
- Flood Impact (m)

Flood Impact (m)

- <= -0.01
- -0.01 - 0.01
- 0.01 - 0.04
- 0.04 - 0.1
- > 0.1
- Was Wet Now Dry
- Was Dry Now Wet



D:\01- Williamtown SAP Concept Design

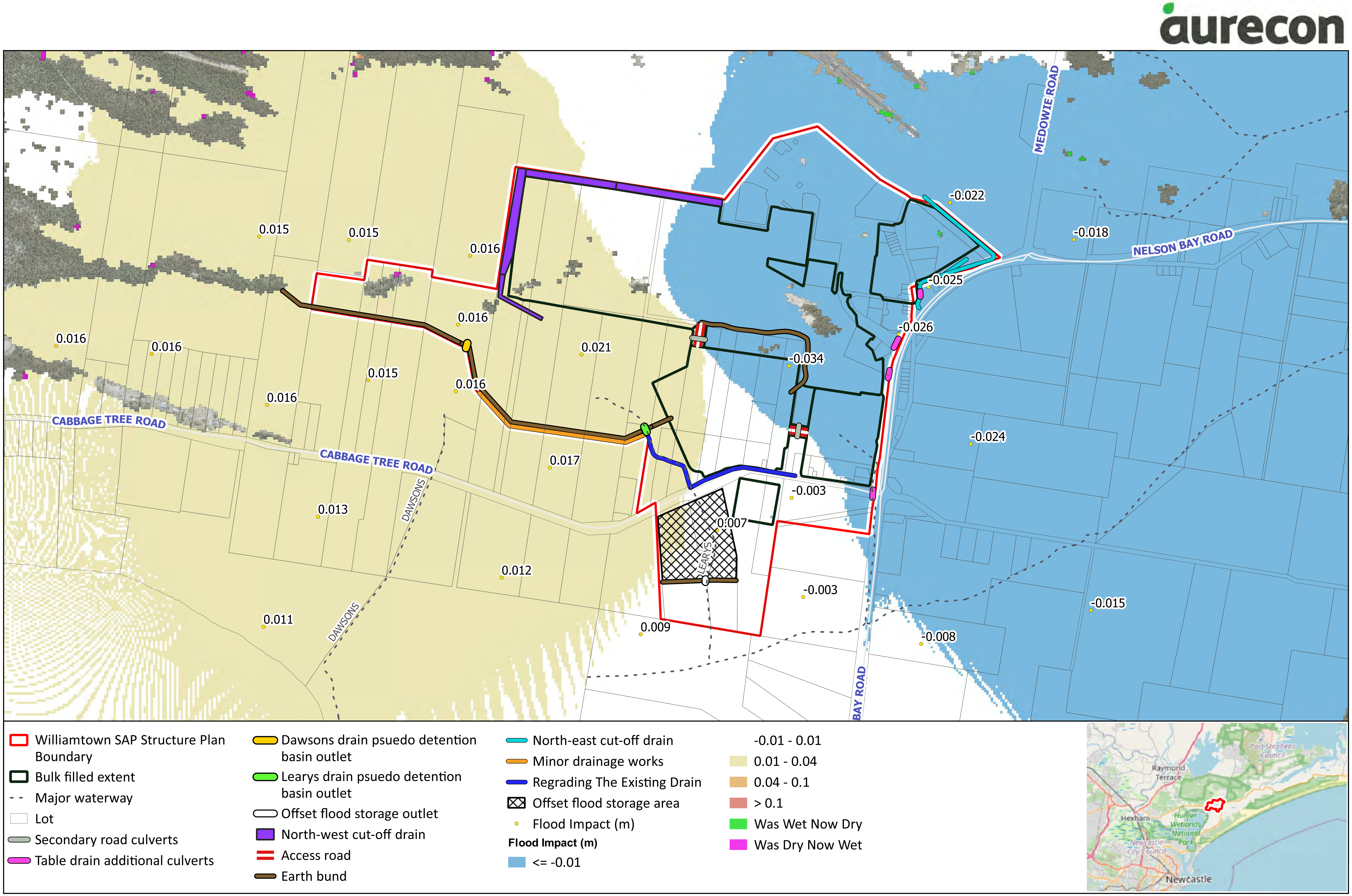
0 600 1200 m

A3 Scale: 1:15000

Projecion: GDA 1994 MGA Zone 56

Williamtown SAP

C4: Mitigated Regional Flood Impact for 1%AEP+Climate Change



D:\01- Williamtowan SAP Concept Design

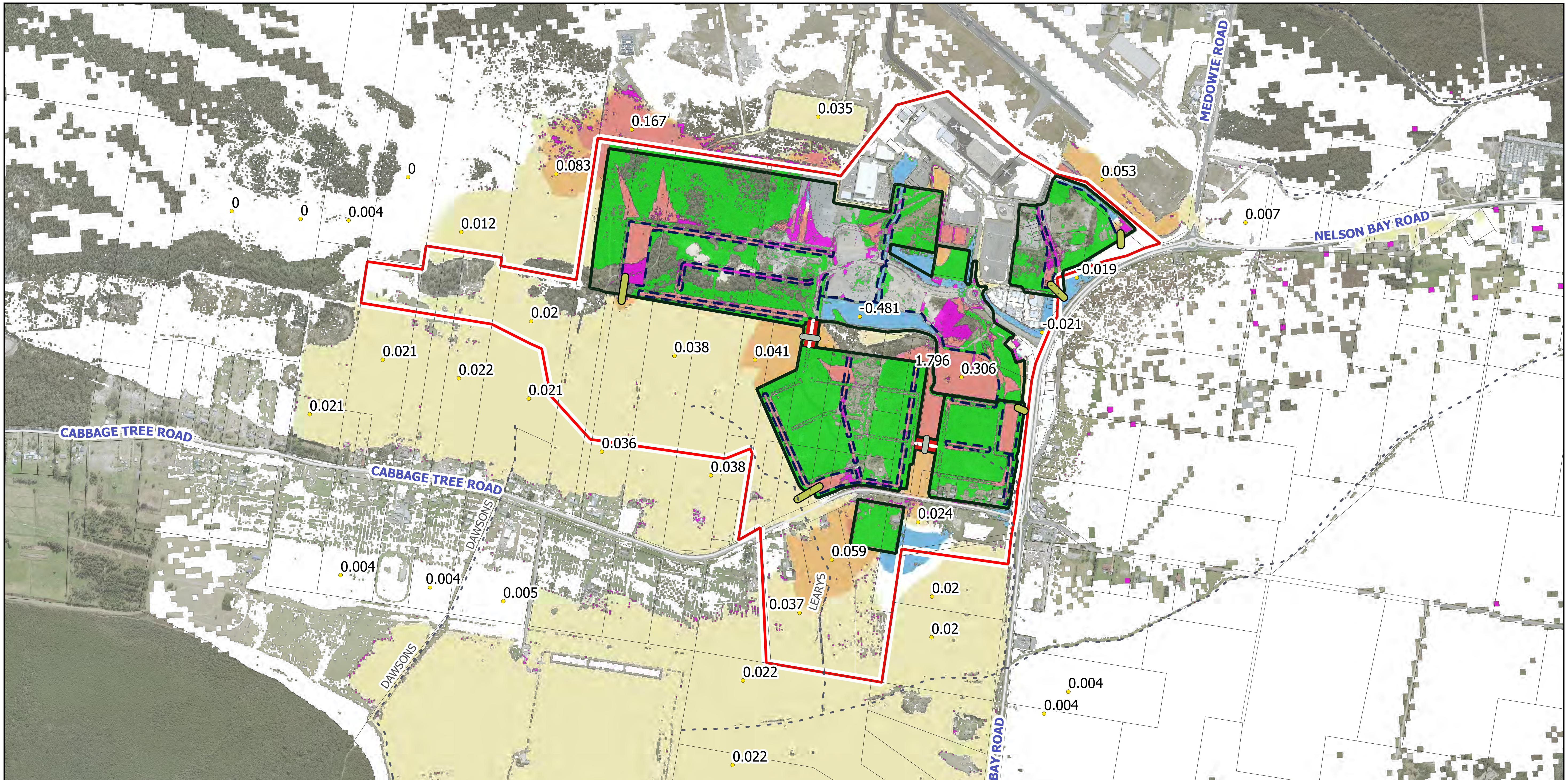
0 600 1200 m

A3 Scale: 1:15000

Projecion: GDA 1994 MGA Zone 56

Williamtown SAP

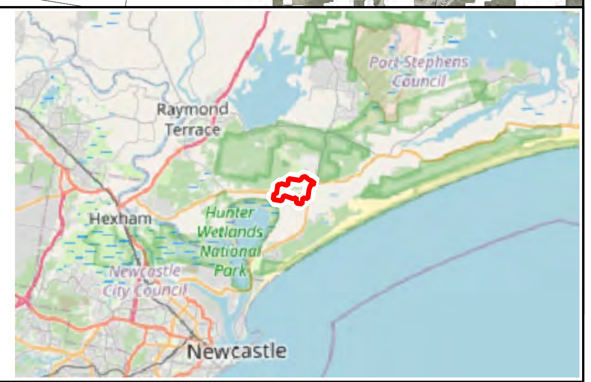
C5: Mitigated Regional Flood Impact for PMF



- Williamtown SAP Structure Plan Boundary
- Bulk filled extent
- Major waterway
- Lot
- Secondary road culverts
- Wetland outlet
- Access road
- Channels
- Flood Impact (m)

Flood Impact (m)

- <= -0.01
- -0.01 - 0.01
- 0.01 - 0.04
- 0.04 - 0.1
- > 0.1
- Was Wet Now Dry
- Was Dry Now Wet



D:\01- Williamtown SAP Concept Design

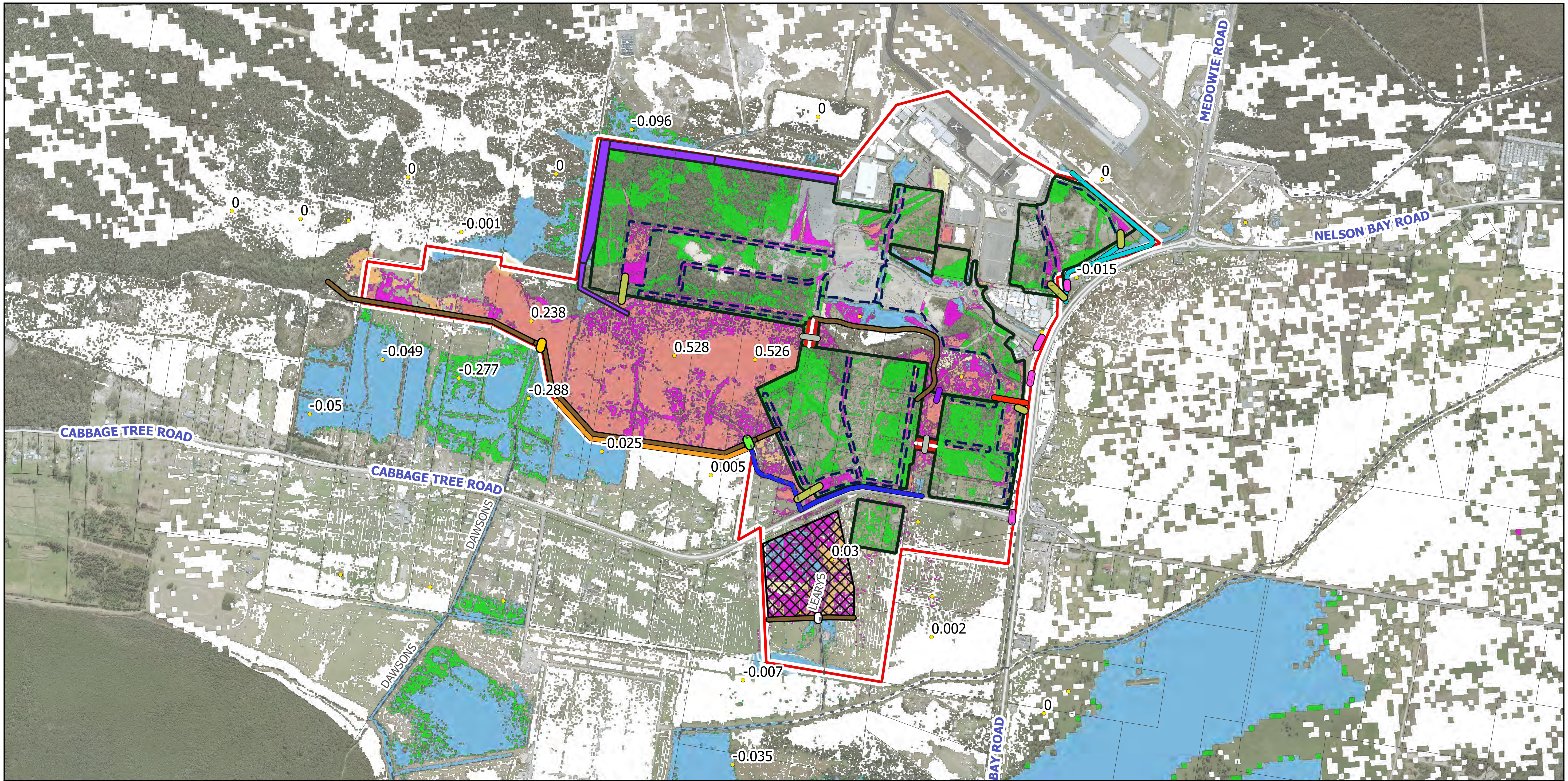
0 600 1200 m

A3 Scale: 1:15000

Projecion: GDA 1994 MGA Zone 56

Williamtown SAP

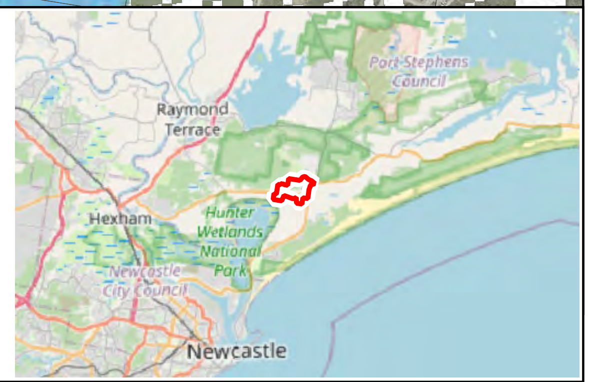
C6: Unmitigated Local Flood Impact for 1%AEP+Climate Change [Low Tailwater]



- Williamtown SAP Structure Plan Boundary
- Bulk filled extent
- Major waterway
- Lot
- Astra basin major outlet
- Astra basin minr outlet
- Secondary road culverts
- Table drain additional culverts
- Dawsons drain psuedo detention basin outlet
- Learys drain psuedo detention basin outlet
- Wetland outlet
- Offset flood storage outlet
- North-west cut-off drain
- Access road
- Earth bund
- North-east cut-off drain
- Minor drainage works
- Regrading The Existing Drain
- Channels
- Offset flood storage area

Flood Impact (m)

- <= -0.01
- -0.01 - 0.01
- 0.01 - 0.04
- 0.04 - 0.1
- > 0.1
- Was Wet Now Dry
- Was Dry Now Wet



D:\01- Williamtowan SAP Concept Design

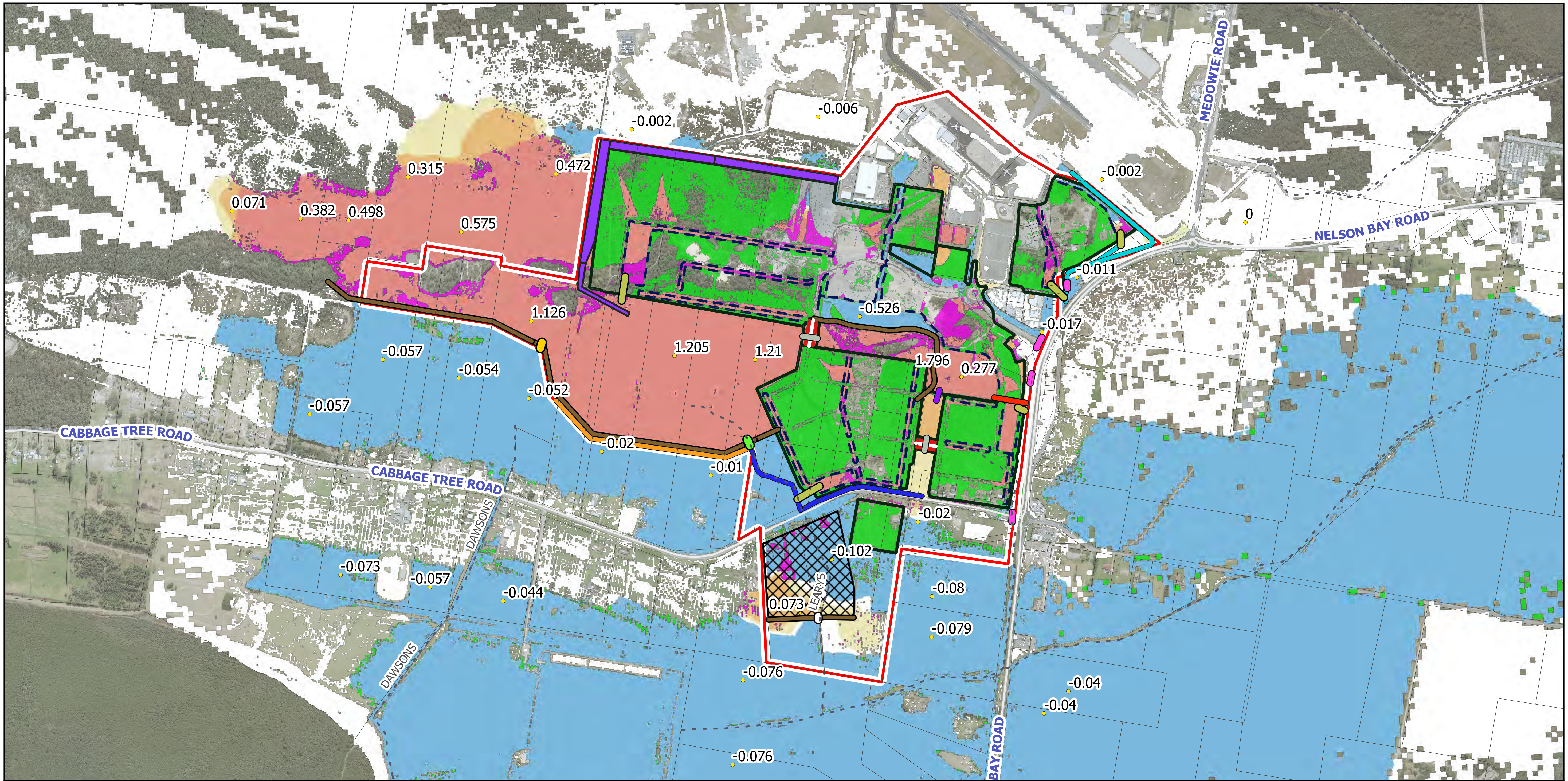
0 600 1200 m

A3 Scale: 1:15000

Projecion: GDA 1994 MGA Zone 56

Williamtown SAP

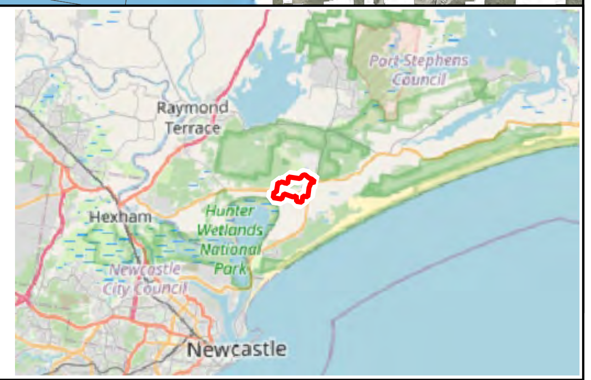
C7: Mitigated Local Flood Impact for 20%AEP [Low Tailwater]



Williamtown SAP Structure Plan Boundary
Bulk filled extent
Major waterway
Lot
Astra basin major outlet
Astra basin minr outlet
Secondary road culverts
Table drain additional culverts
Dawsons drain psuedo detention basin outlet
Learys drain psuedo detention basin outlet
Wetland outlet
Offset flood storage outlet
North-west cut-off drain
Access road
Earth bund
North-east cut-off drain
Minor drainage works
Regrading The Existing Drain
Channels
Offset flood storage area

Flood Impact (m)

<= -0.01
-0.01 - 0.01
0.01 - 0.04
0.04 - 0.1
> 0.1
Was Wet Now Dry
Was Dry Now Wet



D:\01- Williamtowan SAP Concept Design

0 600 1200 m

A3 Scale: 1:15000

Projecion: GDA 1994 MGA Zone 56

Williamtown SAP

C8: Mitigated Local Flood Impact for 1%AEP+Climate Change [Low Tailwater]

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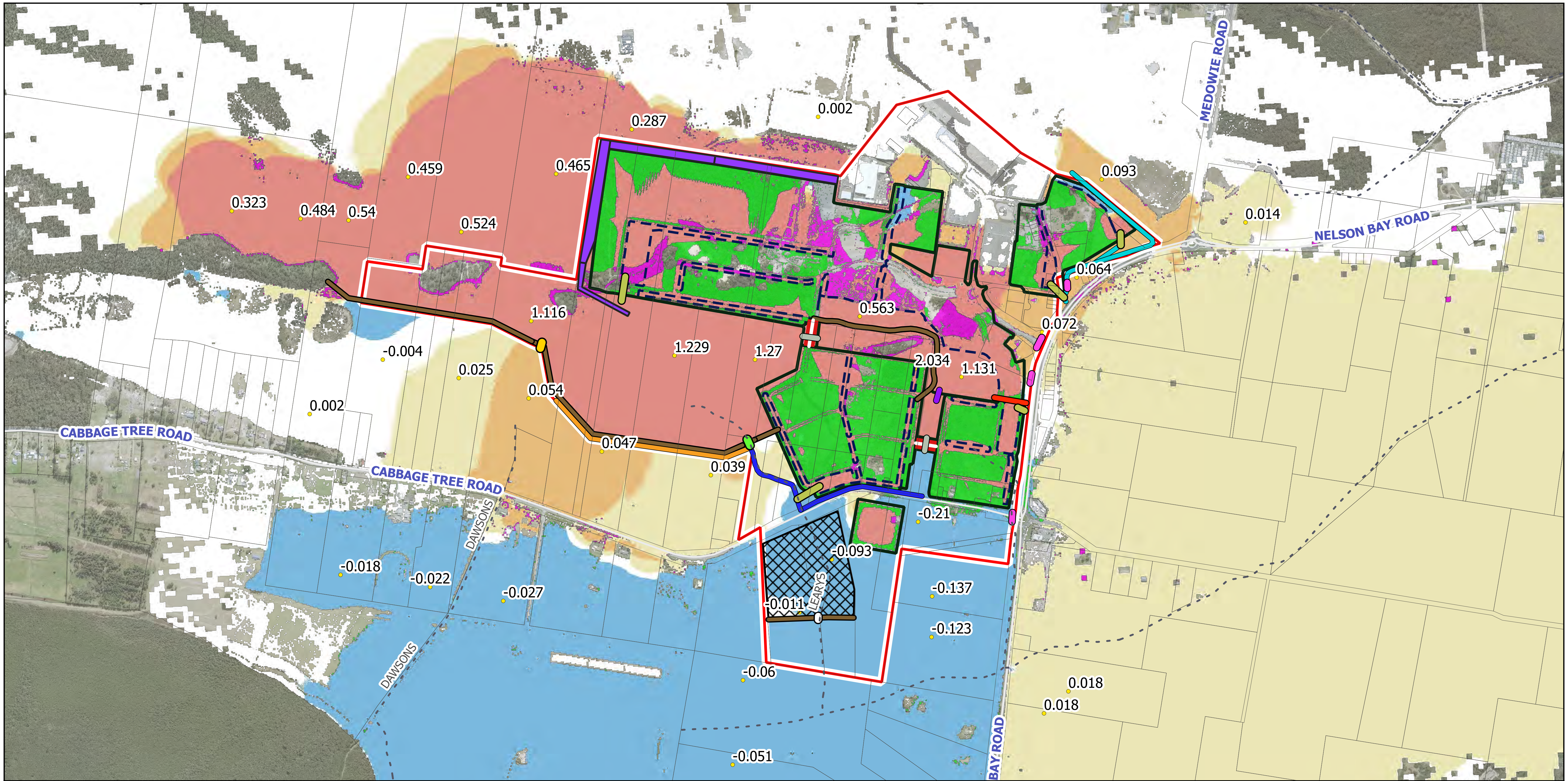
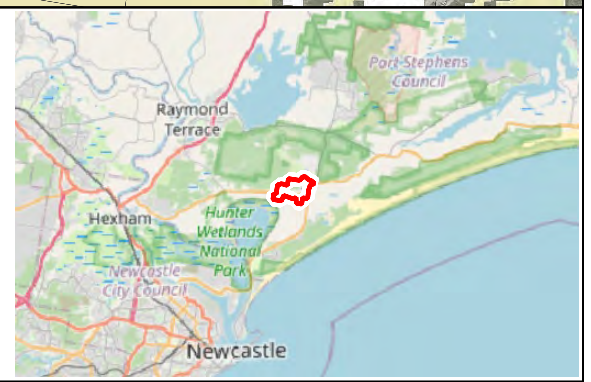


- Williamtown SAP Structure Plan Boundary
- Bulk filled extent
- Major waterway
- Lot
- Astra basin major outlet
- Astra basin minr outlet
- Secondary road culverts
- Table drain additional culverts
- Dawsons drain psuedo detention basin outlet
- Learys drain psuedo detention basin outlet
- Wetland outlet
- Offset flood storage outlet
- North-west cut-off drain
- Access road
- Earth bund
- North-east cut-off drain
- Minor drainage works
- Regrading The Existing Drain
- Channels
- Offset flood storage area
- Flood Impact (m)

Flood Impact (m)

- <= -0.01
- -0.01 - 0.01
- 0.01 - 0.04
- 0.04 - 0.1
- > 0.1
- Was Wet Now Dry
- Was Dry Now Wet



D:\01- Williamtowan SAP Concept Design

0 600 1200 m

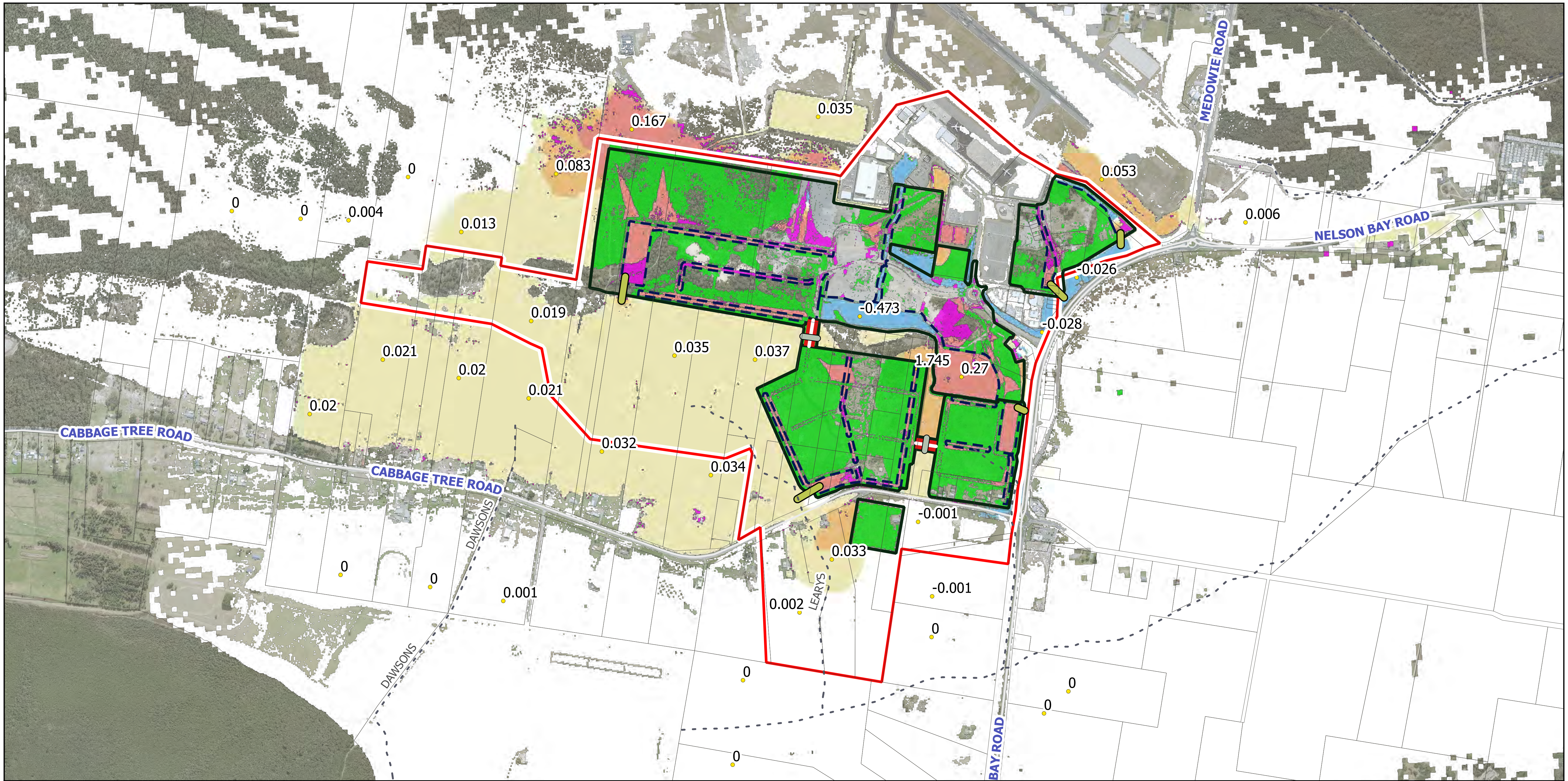
A3 Scale: 1:15000

Projecion: GDA 1994 MGA Zone 56

Williamtown SAP

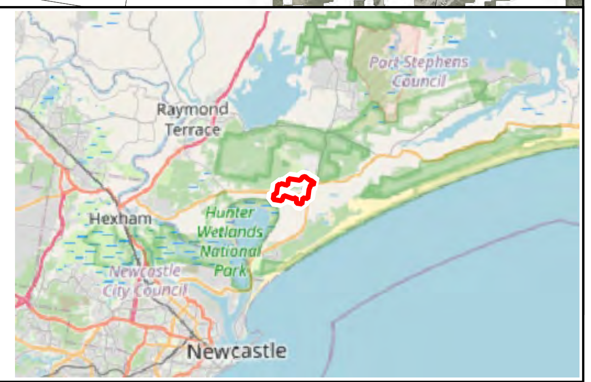
C9: Mitigated Local Flood Impact for PMF [Low Tailwater]

aurecon



Williamtown SAP Structure Plan Boundary
Bulk filled extent
Major waterway
Lot
Secondary road culverts
Wetland outlet
Access road
Channels
Flood Impact (m)

Flood Impact (m)
<= -0.01
-0.01 - 0.01
0.01 - 0.04
0.04 - 0.1
> 0.1
Was Wet Now Dry
Was Dry Now Wet



D:\01- Williamtowan SAP Concept Design

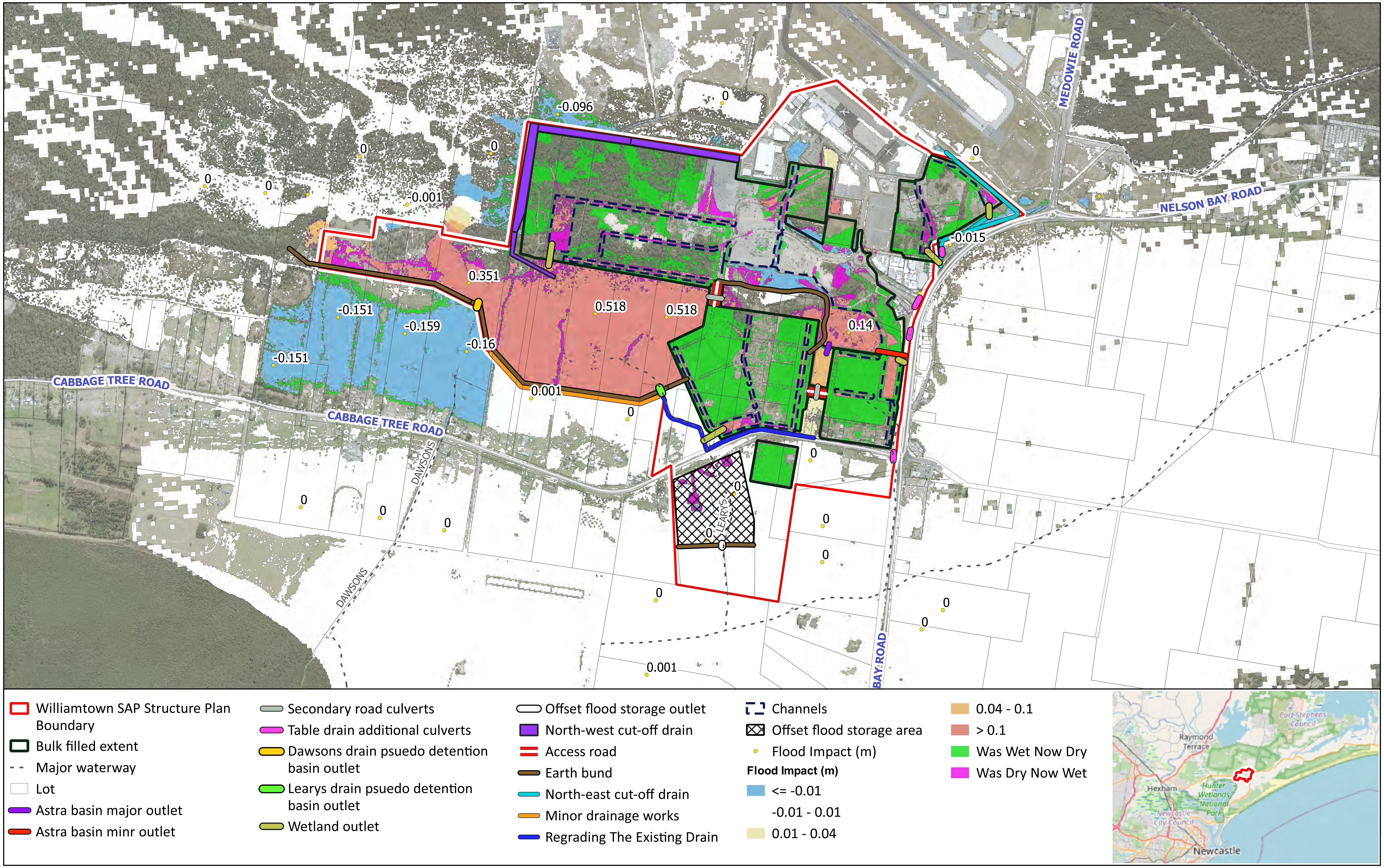
0 600 1200 m
A3 Scale: 1:15000

Projecion: GDA 1994 MGA Zone 56

Williamtown SAP

C10: Unmitigated Local Flood Impact for 1%AEP+Climate Change [High Tailwater]

aurecon



D:\01- Williamtowan SAP Concept Design

0 600 1200 m

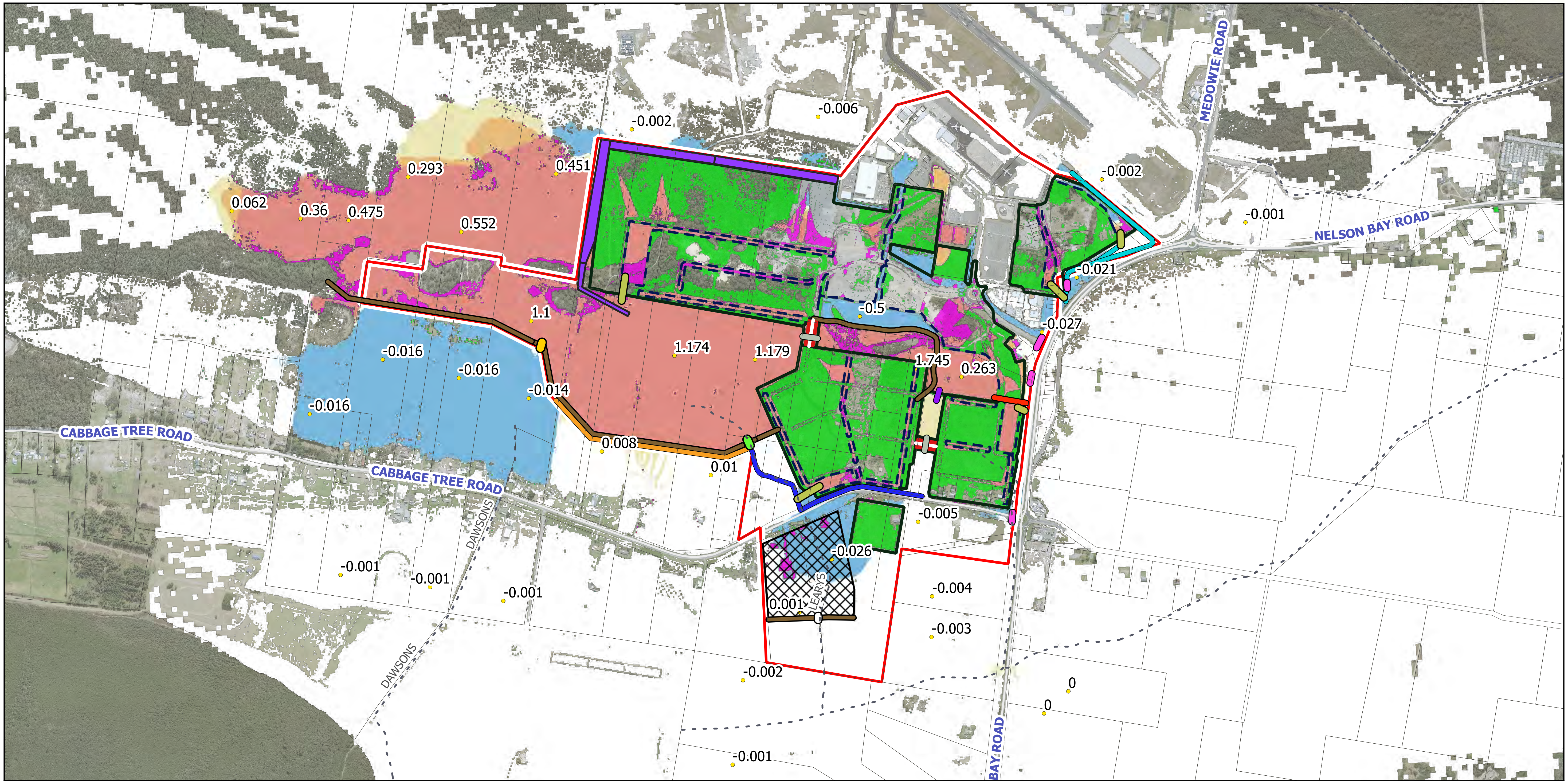
A3 Scale: 1:15000

Projecion: GDA 1994 MGA Zone 56

Williamtown SAP

C11: Mitigated Local Flood Impact for 20%AEP [High Tailwater]

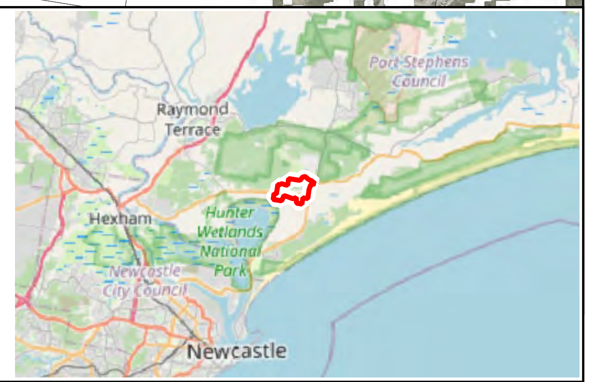
aurecon



- Williamtown SAP Structure Plan Boundary
- Bulk filled extent
- Major waterway
- Lot
- Astra basin major outlet
- Astra basin minr outlet
- Secondary road culverts
- Table drain additional culverts
- Dawsons drain psuedo detention basin outlet
- Learys drain psuedo detention basin outlet
- Wetland outlet
- Offset flood storage outlet
- North-west cut-off drain
- Access road
- Earth bund
- North-east cut-off drain
- Minor drainage works
- Regrading The Existing Drain
- Channels
- Offset flood storage area
- Flood Impact (m)

Flood Impact (m)

- <= -0.01
- -0.01 - 0.01
- 0.01 - 0.04
- 0.04 - 0.1
- > 0.1
- Was Wet Now Dry
- Was Dry Now Wet



D:\01- Williamtowan SAP Concept Design

0 600 1200 m

A3 Scale: 1:15000

Projecion: GDA 1994 MGA Zone 56

Williamtown SAP

C12: Mitigated Local Flood Impact for 1%AEP+Climate Change [High Tailwater]

Appendix D
Review of Previous Studies

Williamtown – Salt Ash Floodplain Risk Management Study & Plan (BMT 2017)

The study was undertaken by BMT WBM Pty Ltd (BMT) for PSC in 2017 in order to identify the existing flooding characteristics and to provide and assess management measures and strategies to manage flood risk in the study area (i.e. Nelson Bay Road Upgrades, Salt Ash Flood Gate Modification, Preparation of Local Drainage Strategies, Hunter River Levee Review, Voluntary Purchase Schemes, Voluntary House Raising, Flood Proofing etc.). Also, as part of the Floodplain Risk Management Plan, the study has described how to manage flood liable lands according to future conditions.

The main objectives of this study included:

- Identify and assess measures for the mitigation of existing flood risk;
- Identify and assess planning and development controls to reduce future flood risks; and
- Present a recommended floodplain management plan that outlines the best possible measures to reduce flood damages in the Williamtown / Salt Ash locality.

In 2005, during The Williamtown / Salt Ash Flood Study, a hydraulic model was developed by BMT (formerly BMT WBM and WBM Oceanics). In order to complete the Flood study and to conduct further modelling of the Lower Hunter River system, the Williams River Flood Study and Williamtown Salt Ash Flood Study Review were undertaken by BMT in 2009 and 2012, respectively.

These models were considered as the basis of the Williamtown – Salt Ash Floodplain Risk Management Study & Plan (2017) and were updated and extended in order to cover a wider extent.

The key updates in the revised model compared to the previous studies include the following:

- Updated topographical data using the 2013 LiDAR data set acquired by NSW Land and Property Information.
- Update of Hunter River design flood flows through revised flood frequency analysis (FFA) at Raymond Terrace.
- Inclusion of Williamtown and Salt Ash local catchment rainfall.
- Additional climate change scenario modelling.

The hydrologic and hydraulic models used in this study were previously calibrated and verified against 1955, 1990 and 2000 historical events. Accordingly, a model re-calibration was not performed since the topography, cell size and other parameters, such as roughness values, were consistent with the original models (albeit with some minor local modifications).

It was noted that the local catchment mapping presented in this study was only indicative and may be refined during more detailed local overland flow studies (considering the local soil characteristics and small-scale drainage features).

Anna Bay and Tilligerry Creek Flood Study (Jacobs 2017)

This study was prepared by Jacobs for PSC for the Anna Bay and Tilligerry Creek floodplain areas. The study objective was to investigate the existing and future flood risks in the study area and to provide guidance on land use planning and future development on the floodplain in accordance with the first and second stages of the management process.

A XP-RAFTS model was developed for hydrologic modelling to establish inflow hydrographs at local sub-catchments for a range of flood events between the 20% AEP and the PMF and under future climate conditions. Given the hydrologic models developed in previous studies did not fully cover the study area or were too coarse according to the objectives of this study, model sub-catchments were included and defined in sufficient detail to cover the study area.

The hydrologic model was validated by comparing the local sub-catchment peak runoff rates for 1% AEP event, against estimates for sub-catchments of similar size from Williamtown-Salt Ash FRMS&P (BMT 2015)

The hydraulic modelling of the Lower Hunter River was undertaken using the TUFLOW model developed by BMT (2015), which was extended to cover the entire study area. No calibration of the model was undertaken. Local models were developed for the townships of Anna Bay and Tanilba Bay. These fall outside of the Williamtown SAP area and are not considered relevant. The local modelling was calibrated against flooding observations during April 2015 storm and verified against January 2016 storm.

The study considered the three flooding mechanisms for this area, including flooding due to local runoff, overtopping of the levee system surrounding Fullerton Cove due to flooding in the Hunter River or elevated ocean tide and overtopping of the levee system at Salt Ash due to flooding in Port Stephens. It also considered the performance of floodgates, hydraulic structures and the overflows from the stormwater drainage network.

The outputs of this study included:

- Mapping of flooding characteristics (depth, level, velocity), flood hydraulic and hazard categories
- Determine the Flood Planning Level (FPL) and Flood Planning Area (FPA), based on the 1% AEP event intensity
- Identify the flood emergency response categories
- Analyse potential mitigation options for selected flood problem areas

This study largely falls outside of the Williamtown SAP area and adopts the same Lower Hunter flood model developed as part of the Williamtown / Salt Ash Floodplain Risk Management Study and Plan (BMT 2017). A such, the input from this study was limited to the flood modelling outputs to cover a small section of Tilligerry Creek at the far eastern end of the Williamtown SAP area.

Medowie Floodplain Risk Management Study and Plan (WMA 2015)

This study includes the Floodplain Risk Management Study and Plan for Medowie which has been prepared by WMAwater on behalf of PSC. It provides the basis for the future management of flood prone lands in the Campvale and Moffats Swamp catchments.

In 2012, in order to carry out the first stage of the floodplain risk management process, the Flood Study was undertaken by WMAwater which was used as the basis of the second and third stages of the process during the current study. The existing model from the Flood Study included the TUFLOW model in which the Direct Rainfall Method (DRM) was used.

As a result of using this method, the model results included a scattered inundation with shallow flood depths in the study area, which could complicate the presentation of results, especially the determination of the Flood Planning Area (FPA). To solve this problem, it was decided to use a hydrological model. For this purpose, the Watershed Bounded Network Model (WBNM) was used. The inflow hydrographs derived from this model were later fed to the TUFLOW model to replace the previous Direct Rainfall Model inputs.

The new hydrology model was calibrated using the June 2007 event and then validated against February 1990 and February 2009 events. Later using the inflow hydrographs generated by this model, TUFLOW was ran for 1% AEP event. The results of this simulation were compared with the results of the previous model from the Flood Study, which showed a good agreement between these models, with the difference that in the new model, scattered inundation was eliminated.

The revised model was used to investigate the existing condition and determine flood liable land for a range of design events and identified four dwellings susceptible to above floor flooding in the 1% AEP event. The floodplain management issues were assessed and recommendations were made through proposed management options.

The study only partially overlaps with the Williamtown SAP along the northern boundary. The input from this study was limited to the flood modelling outputs to cover a small section of overlap with the Williamtown SAP area.

Williamtown Drainage Study (Umwelt 2018)

In mid-2017, The Department of Defence (Defence) engaged Umwelt (Australia) Pty Limited (Umwelt) to conduct a study on the existing condition of Local drainage network in Williamtown / Fullerton Cove and to provide options to improve the current situation.

During this study, a detailed computer model was used to simulate the existing conditions of the drainage network and to evaluate the proposed options to improve the efficiency of the system.

Hydraulic modelling has been performed using the RMA-2 finite element hydrodynamic modelling package in which the direct rainfall method has been used. Also, in order to estimate the inflow hydrograph from the upstream catchments outside the RMA model extents, the XP-Storm software has been used, which includes the RAFTS runoff-routing model.

The model is based on a study conducted by Umwelt in 2014 for PSC, during which a hydrodynamic model was developed. During the current study, this model has been updated and expanded to include Tilligerry Creek.

Full calibration of the Umwelt (2014) hydrodynamic model was not possible, due to lack of sufficient quality and verified flood levels in the study area. However, the model was evaluated according to the flood levels reported in the Williamtown / Salt Ash Flood Study (BMT, 2005). Also, to evaluate the expanded model developed in the current study, the results were compared with the results produced by Umwelt in 2014, which showed the similarity of the two models.

Examination of the current situation using the developed model, showed that while some parts of the drainage network have sufficient capacity to transfer peak flows in excess of the 10 per cent (%) AEP event, but most of the network does not have sufficient capacity.

In the next step, in order to help the current situation, various engineering options were tested, including flood gates, channel widening, culvert upgrades which helped to decrease flood depths across the floodplain. Although this reduction was small due to the conditions of the study area (i.e. low lying with a low drainage gradient and single discharge point). The proposed options were tested for the 1% and 10% AEP events.

Appendix E
March 2021 rainfall event

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Australia

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E newcastle@aurecongroup.com
W aurecongroup.com

Memorandum

To	**DPIE**	From	**Yannick Michel, Sepideh Jafari**
Copy	**Greg Lee, Adrian Lu**	Reference	**510674**
Date	**2021-04-09**	Pages (including this page)	**19**
Subject	**March 2021 Storm Event Review**		

1 Introduction

Aurecon has been requested to provide a review of the March 2021 rainfall event. This event occurred during the Williamtown SAP Master Planning investigation and presented an opportunity to incorporate a brief review of the event as an Appendix to the Flooding and Water Cycle Management Specialist Study.

This memo reviews the relevant available rainfall data and site photos following the rainfall event and sets out to answer two key questions:

- Was the observed flooding due to regional or local flooding mechanisms?
- What magnitude of rainfall event occurred?

2 Data collection

Available relevant data was collected and reviewed to inform what happened during the event in terms of rainfall and river level. The collected data is discussed further below.

Two rainfall gauges were identified around the study area located at the Williamtown RAAF and Hexham bridge. The Williamtown RAAF gauge data including daily rainfall was extracted from the Bureau of Meteorology (BOM) website and the Hexham bridge gauge data including daily and hourly rainfalls and stream water levels was extracted from the WaterNSW website. Also, two stream flow gauges were identified on the Hunter River at Green Rocks and Raymond Terrace. The gauge locations and data extracted are represented in Figure 2-1 and Table 2-1 respectively.

Figure 2-1 Rainfall and river gauge locations (aerial image source: Google imagery)

Table 2-1 Summary of collected hydrological and hydraulic data

Gauge ID	Name	Longitude	Latitude	Data Type	Source
210432	Hunter River at green rocks	151.692	-32.728	Stream Water Level	https://realtimedata.waternsw.com.au/
210448	Hexham bridge	151.683	-32.833	Daily Rainfall	https://realtimedata.waternsw.com.au/
210448	Hexham bridge	151.683	-32.833	Hourly Rainfall	https://realtimedata.waternsw.com.au/
210448	Hexham bridge	151.683	-32.833	Stream Water Level	https://realtimedata.waternsw.com.au/
210452	Hunter River at Raymond Terrace	151.744	-32.753	Stream Water Level	https://realtimedata.waternsw.com.au/
61078	Williamtown RAAF Base	151.84	-32.79	Daily Rainfall	http://www.bom.gov.au/climate/data

2.1 Rainfall Data

As noted in Section 2, there is a rainfall gauge at the Williamtown RAAF base, which provides good insight on rainfall over the Williamtown SAP area. However, rainfall data following a storm event is available for free as daily totals from BOM (noting that sub-daily data can be purchased). At this resolution it is difficult to isolate higher intensities that may have resulted in local flooding. A nearby rainfall station at Hexham Bridge does allow exporting of sub-daily rainfall and was therefore used as a proxy to identify sub-daily intensities at Williamtown.

Initially, daily rainfalls at the Hexham Bridge gauge were compared to the Williamtown gauge to understand the similarities at both locations. This comparison is shown in Figure 2-2 and as can be seen there are general consistencies in the two datasets. Based on this, it is reasonable to use the Hexham hourly rainfall to inform the likely intensities at Williamtown for this high-level analysis.

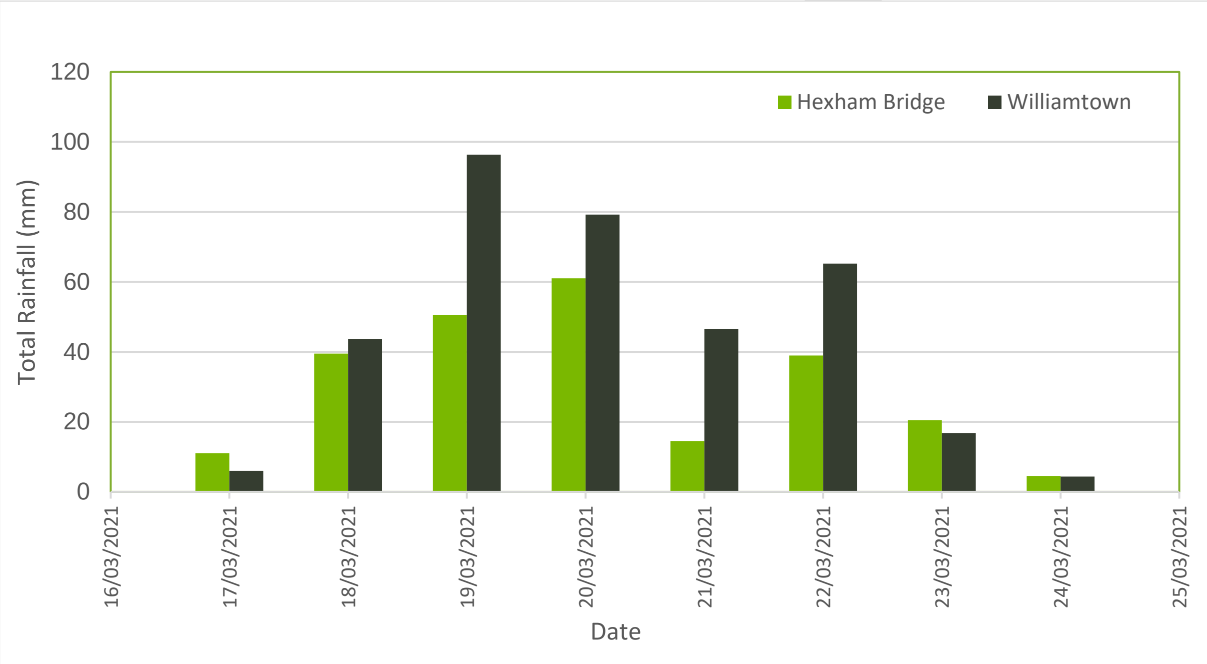

Figure 2-2 – Comparison of daily rainfall totals at Williamtown and Hexham bridge

The hourly rainfalls at Hexham Bridge are shown in Figure 2-3 and cumulative rainfall is shown in Figure 2-4. The recorded sub-daily data does indicate that there were several rainfall bursts between the 18th to the 21st, with the highest hourly peak being 16.5mm on the 20th March.

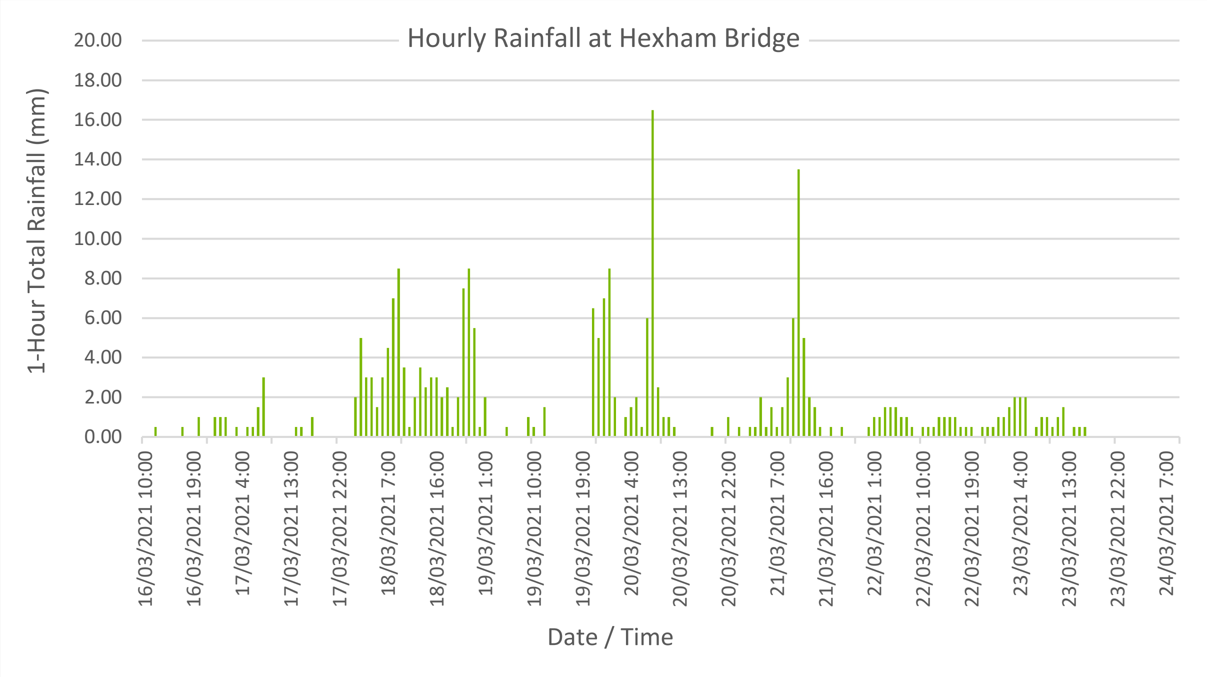

Figure 2-3 Hourly rainfall totals at Hexham Bridge

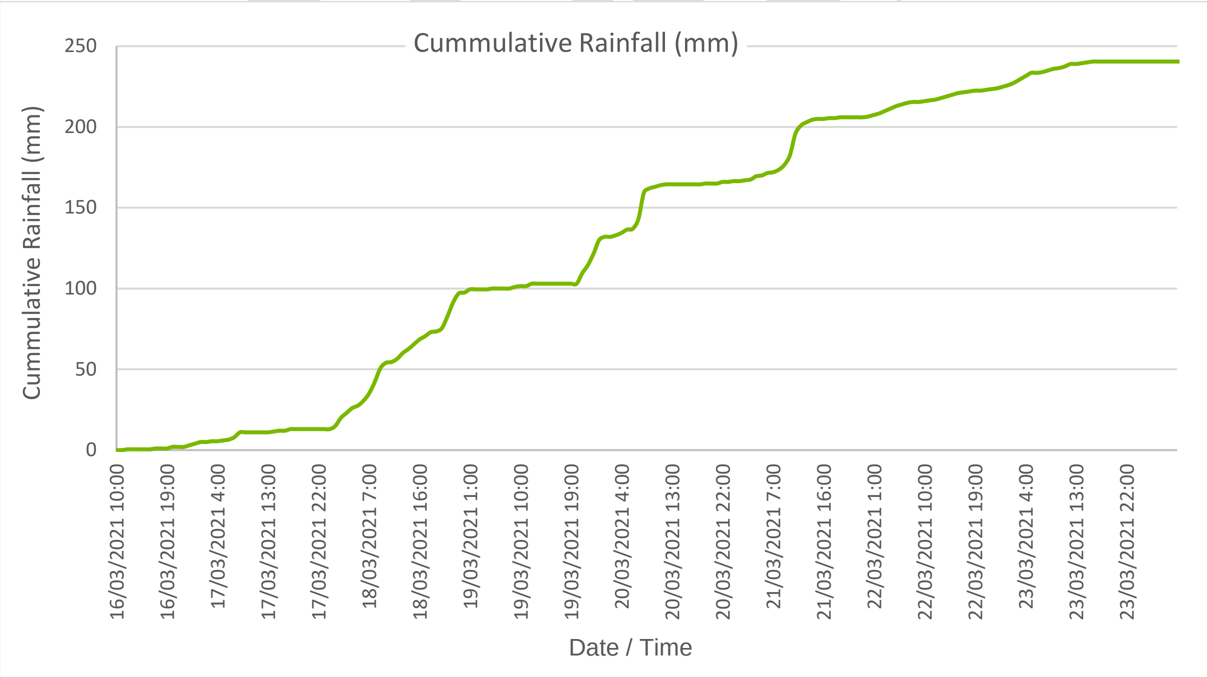

Figure 2-4 Cumulative hourly rainfall totals at Hexham Bridge

2.2 River Data

Hunter River water levels for the period capturing the event were extracted at Hexham Bridge and Raymond Terrace. The recorded water level data at these locations were extracted and plotted against their respective flood warning levels and shown in Figure 2-5 and Figure 2-6.

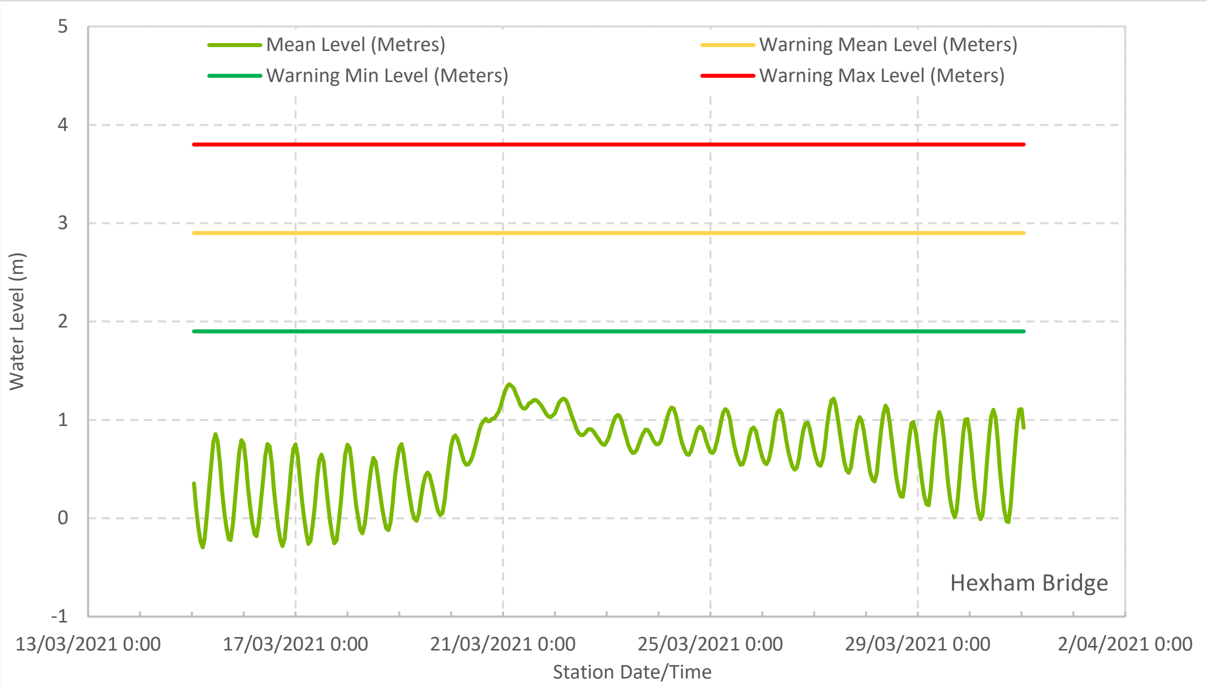

Figure 2-5 Hunter River height gauge data recorded at Hexham Bridge

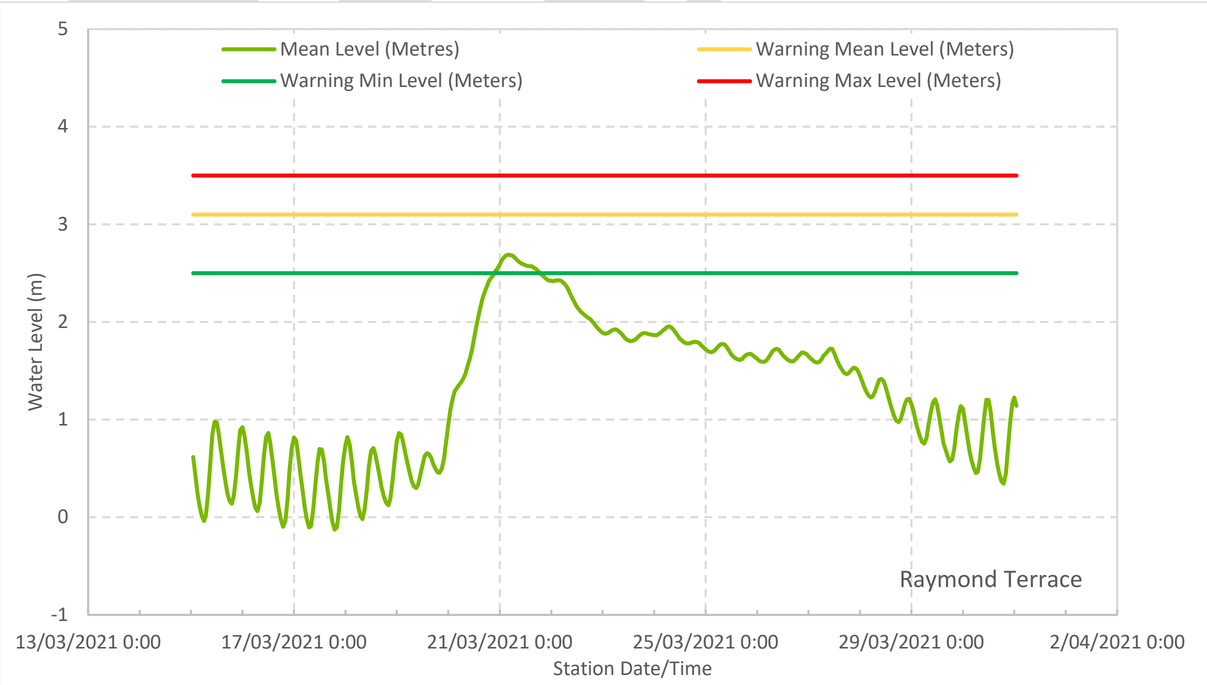

Figure 2-6 Hunter River height gauge data recorded at Raymond Terrace

2.3 Site Visit

On the 24th March a site visit was undertaken around part of Williamtown to photograph the flooding at the time of the visit. Key sites were identified based on areas of expected flooding and /or were safely accessible.

The locations that were visited and had visible standing water are presented in Figure 2-3. Larger images at these locations are attached to the end of this memo.

Figure 2-7 – Photo locations

3 Findings

3.1 Rainfall analysis

Using the Hexham hourly rainfall, the depths recorded at Hexham Bridge were scaled up based on the daily rainfall data at Williamtown and used in the subsequent rainfall analysis. The daily ratios adopted are shown in Table 3-1.

Table 3-1 Calculated ratios between the Hexham Bridge and Williamtown daily rainfall totals

Date and time	Hexham Bridge	Williamtown	Ratio
17/03/2021	11.0	6.0	0.55
18/03/2021	39.5	43.6	1.10
19/03/2021	50.5	96.4	1.91
20/03/2021	61.0	79.2	1.30

Date and time	Hexham Bridge	Williamtown	Ratio
21/03/2021	14.5	46.6	3.21
22/03/2021	39.0	65.2	1.67
23/03/2021	20.5	16.8	0.82
24/03/2021	4.5	4.4	0.98
Total Depth:	**240.5**	**358.2**	**1.49**

The ratios presented in Table 3-1 were applied to the Hexham Bridge hourly rainfall. The scaling considered that the daily rainfall depths from BOM are reported from 9 am the day before to 9 am on the same day. As such the calculated ratios were applied to the same time periods consistently. The scaled Hexham Bridge hourly rainfall depths are shown in Figure 2-5.

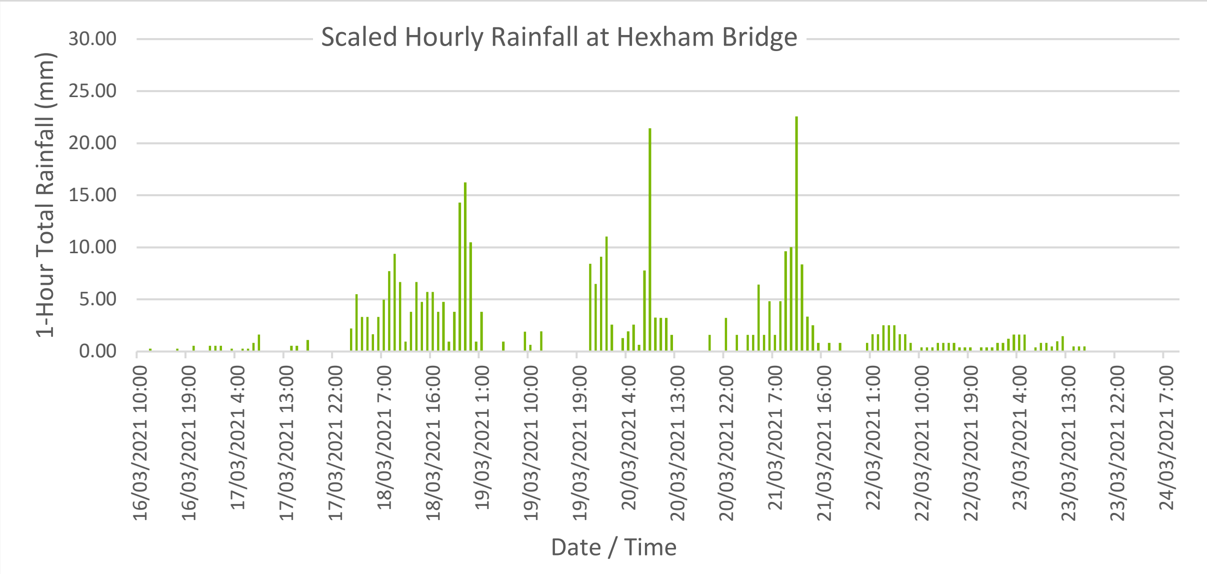

Figure 3-1 Scaled hourly rainfall at Hexham Bridge

The IFD design rainfall depths for Williamtown were extracted from the BOM website and was used to compare against the observed rainfall. Peak rainfall depths for different durations from 1 hour to 36 hours were plotted against the Williamtown IFD curves.

For longer durations, the entire event from 16/03/2021 9:00:00 am to 24/03/2021 9:00:00 am was assumed as one rainfall event. Rainfall depths for this were plotted separately in Figure 3-5.

The rainfall burst periods were identified where there was a dry period separating blocks of rainfall of equal to or greater than 4 hours. Using this approach, three independent bursts were identified:

- From 18/03/2021, 1:00 to 19/03/2021, 12:00 (duration 36 hours with a total depth of 147.57mm)
- From 19/03/2021, 21:00 to 20/03/2021, 12:00 (duration 16 hours with a total depth of 100.84mm)
- From 20/03/2021, 19:00 to 21/03/2021, 19:00 (duration 25 hours with a total depth of 68.05mm)

Each identified burst is presented in Figure 3-2 to Figure 3-4 respectively.

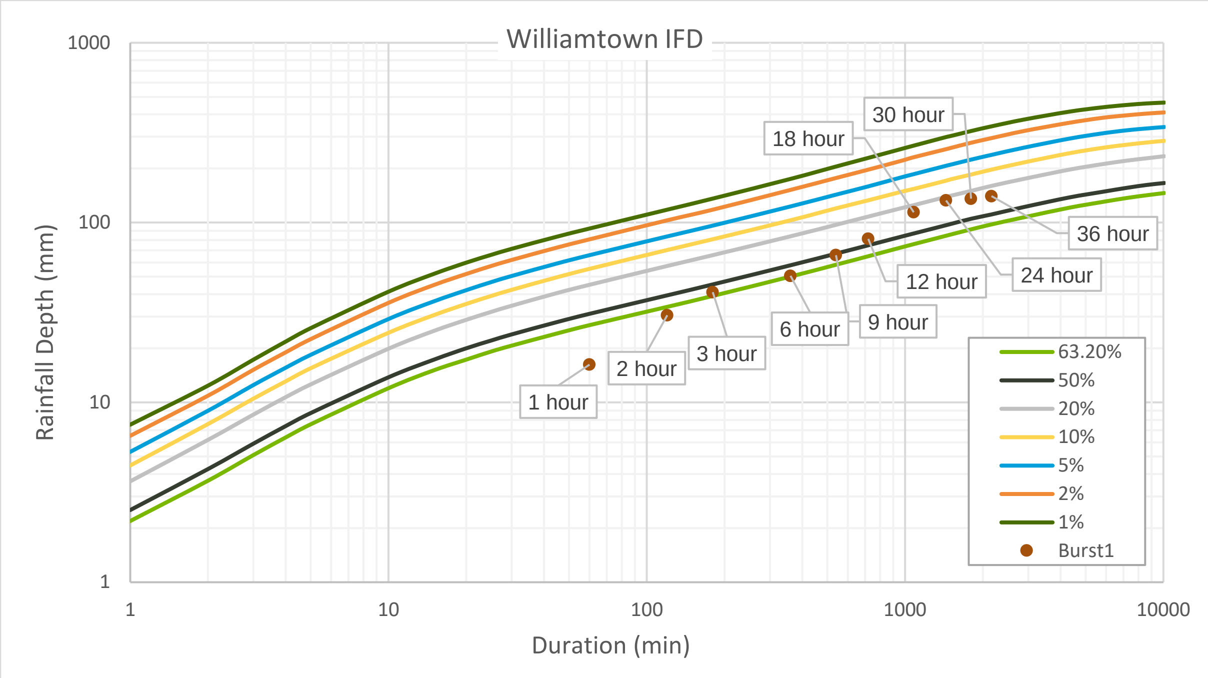

Figure 3-2 Burst No.1 (18/03/2021 1:00 to 19/03/2021 12:00) compared to design rainfall at Williamtown

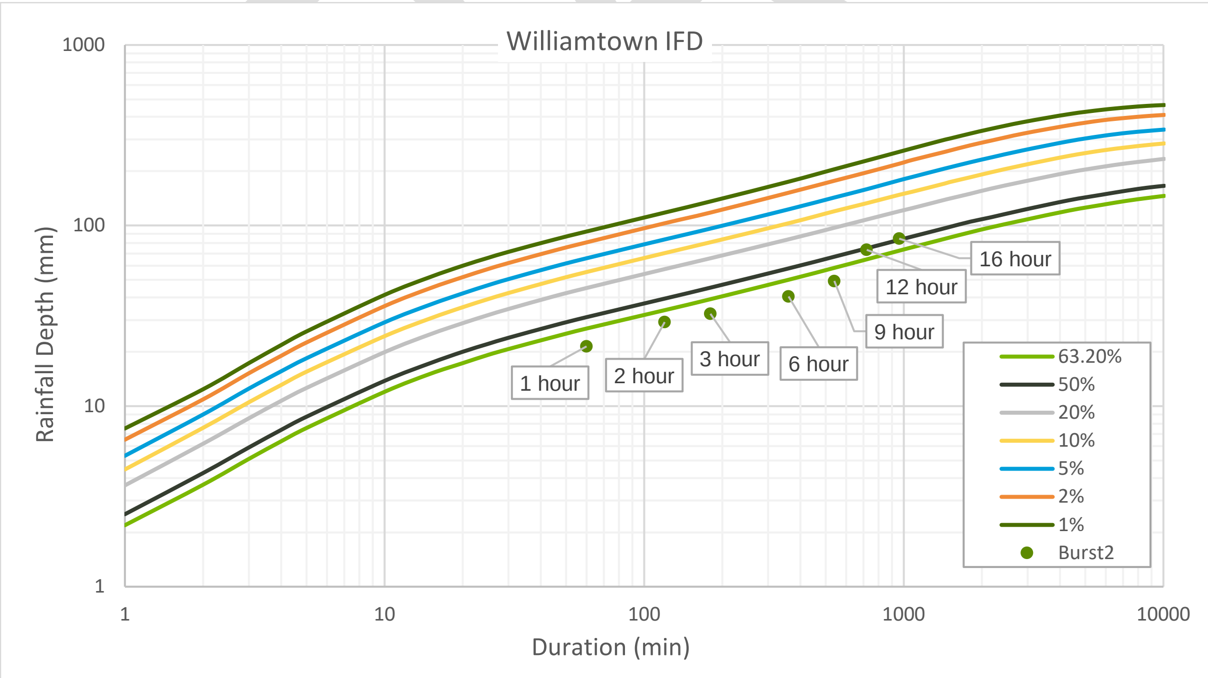

Figure 3-3 Burst No.2 (19/03/2021 21:00 to 20/03/2021 12:00) compared to design rainfall at Williamtown

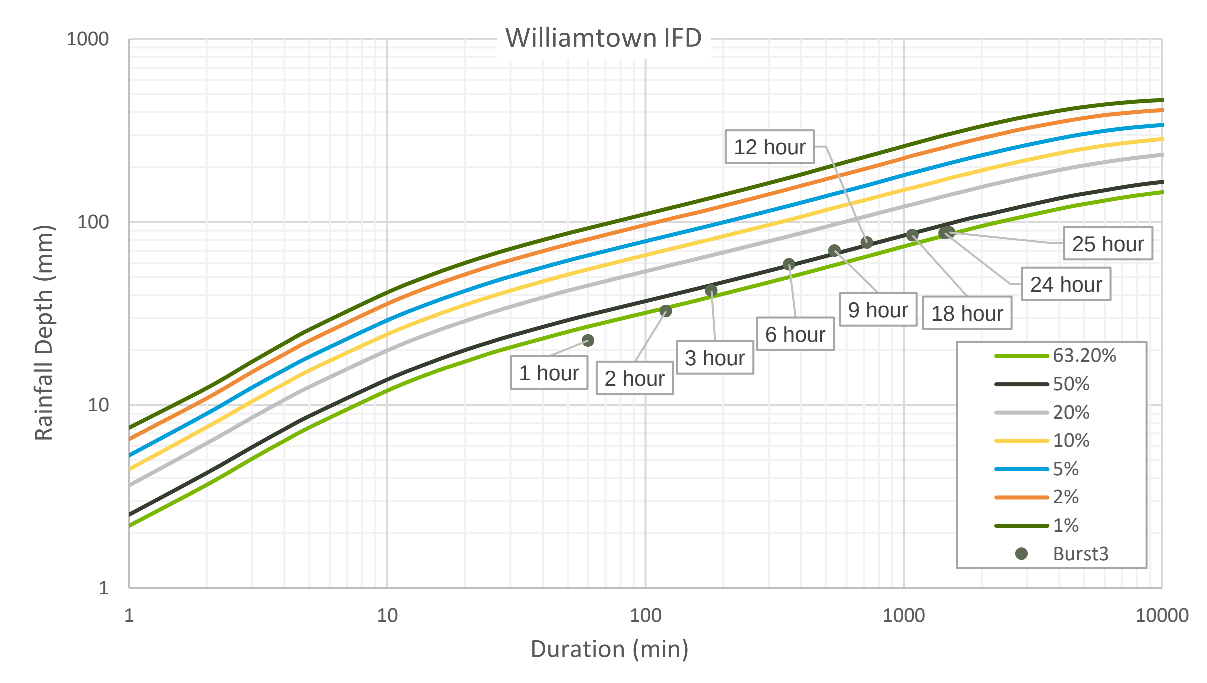

Figure 3-4 Burst No.3 (20/03/2021 19:00 to 21/03/2021 19:00) compared to design rainfall at Williamtown

March was generally a wet month resulting in wetter antecedent conditions. This in combination with the chatchment characteristics, Burst No.1 likely caused the peak flood level in areas impacted by conveyance whereas the subsequent bursts (Burst No.2 and Burst No.3) influenced the duration of inundation for areas impacted by flood storage. To understand this combination, the three bursts were compared to the design rainfall and shown in Figure 3-5.

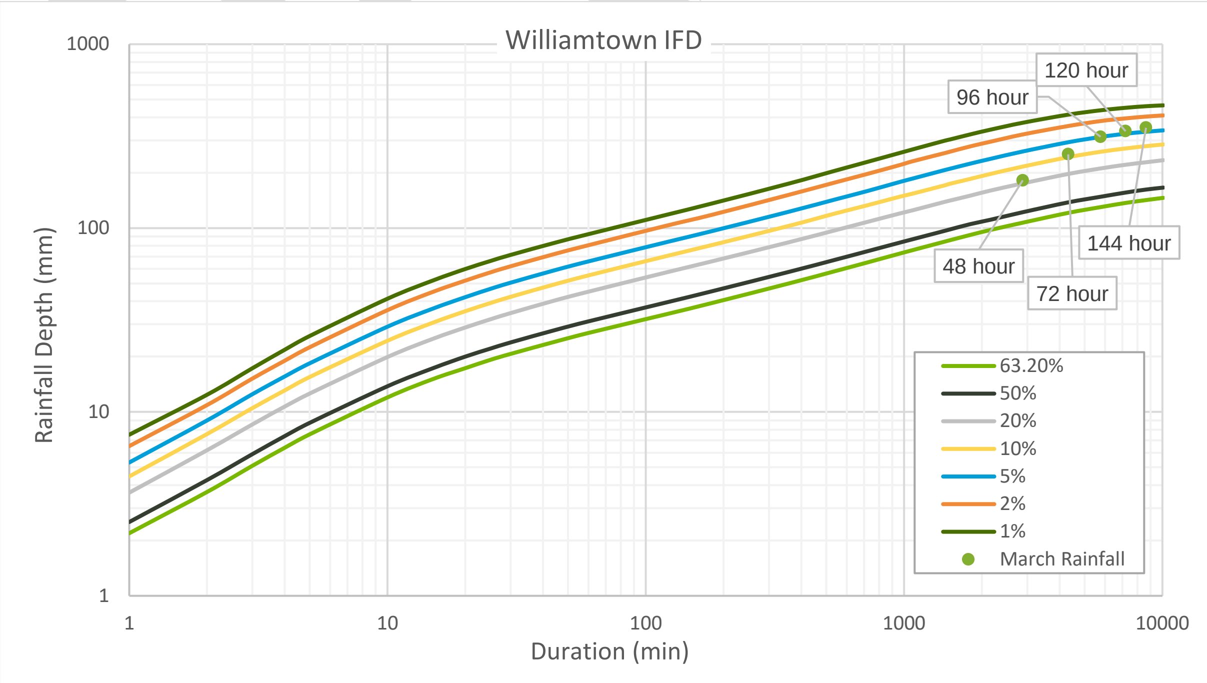

Figure 3-5 Longer rainfall duration compared to design rainfall at Williamtown

As individual bursts, the data indicates that the recorded rainfall from the March event would have likely had an event magnitude of up to a 20% AEP event (Burst No.1). However, based on existing hydraulic modelling, the reported critical duration for the Fullerton Cove catchment is in the order of 36 to 48 hours. This implies that the catchment is more sensitive to rainfall volumes, driven by the flat topopgraphy and tidal influence at the outfall to Fullerton Cove.

When looking at the the longer storm durations (Figure 3-5) the 48 hour duration also shows that the rainfall corresponds to a 20% AEP event. Longer durations are seen to increase in magnitude as expected however deviate from what is critical for this catchment.

3.2 River data analysis

For the Williamtown area to experience regional scale flooding, floodwater would have originated from the Hunter River system. Overtopping of the Fullerton Cove levee would have occurred, inundating the floodplain area bound by Nelson Bay Road to the east, Cabbage Tree Road to the north and Fullerton Cove Levee to the west. Anecdotally this was not the case during or following the flood event.

Based on the recorded levels from the Hunter River at Hexham and Raymond Terrace (Figure 2-5 and Figure 2-6), the peak flood level occurred on the 21st March reaching about 1.3m AHD and 2.7m AHD respectively. Hydraulic simulations of the Lower Hunter River system predicts that for Fullerton Cove levee to overtop (Location 1 in Figure 3-6), Hexham and Raymond Terrace would need to reach about 3.0m AHD and 4.1mAHD respectively. These levels were clearly not reached based on the recorded flood levels which supports the anecdotal information.

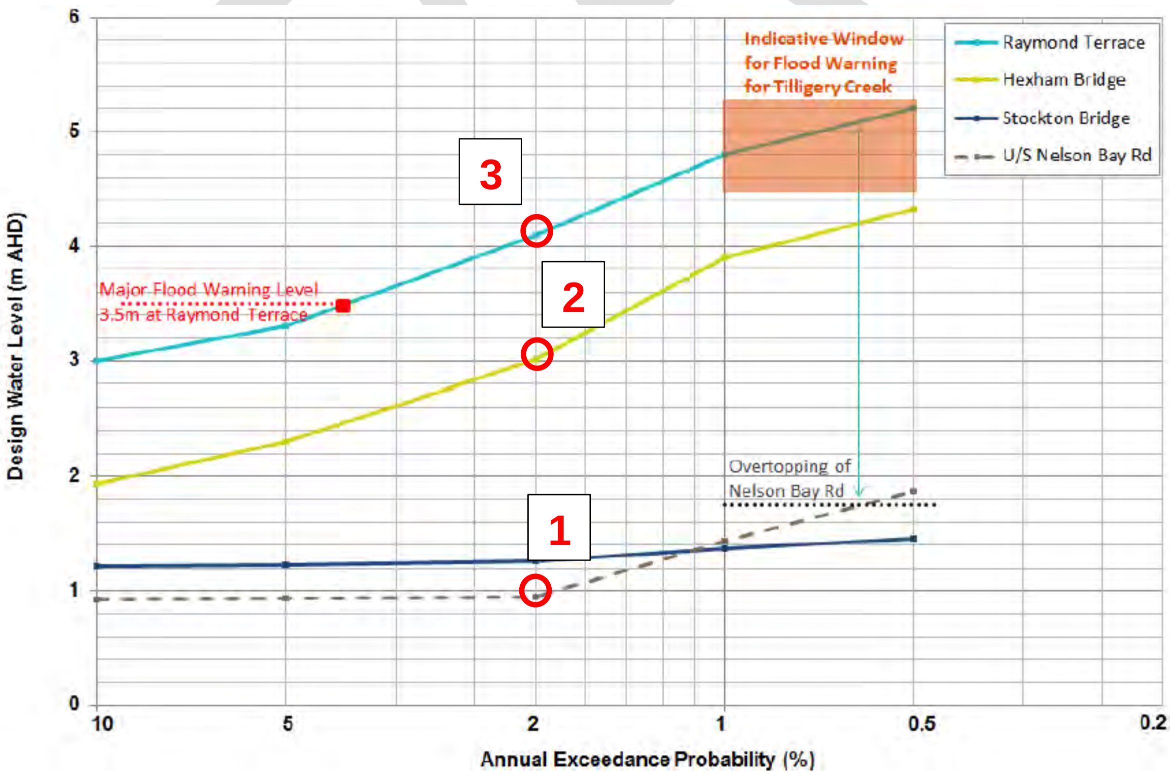

Figure 3-6 – Design water levels at Lower Hunter Flood gauges (Source: Williamtown Salt Ash Flood Study, BMT 2017)

4 Assumptions and limitations

The following assumptions and limitations apply to this assessment:

- Data used for the assessment is based on readily available river and daily rainfall data.
- Hexham hourly rainfall was scaled up based on the Williamtown rainfall gauge data.
- Independent bursts were identified based on dry periods nominally equal to or greater than 4 hours.
- Assessment based on a simple analysis of data to determine a probable estimate of the rainfall annual exceedance probability.

5 Conclusions

The assessment has undertaken a review and simple analysis of rainfall and river gauge information with the objective to understand the likely magnitude of the event. The following summarises the key findings:

- The data indicates that the recorded rainfall from the March event would have likely had an event magnitude of up to a 20% AEP event.
- No overtopping of Fullerton Cove was reported indicating that the resulting flooding was not driven by a regional flooding mechanism.
- The flooding observed across the Williamtown region was a result of local flooding from the local catchment.

Site photos – Refer to Figure 2-7 for locations

Photo 1

Photo 2

Photo 3

Photo 4

Photo 5

Photo 6

Photo 7

Photo 8

Photo 9

Photo 10

Photo 11

Photo 12

Photo 13

Photo 14

Photo 15

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