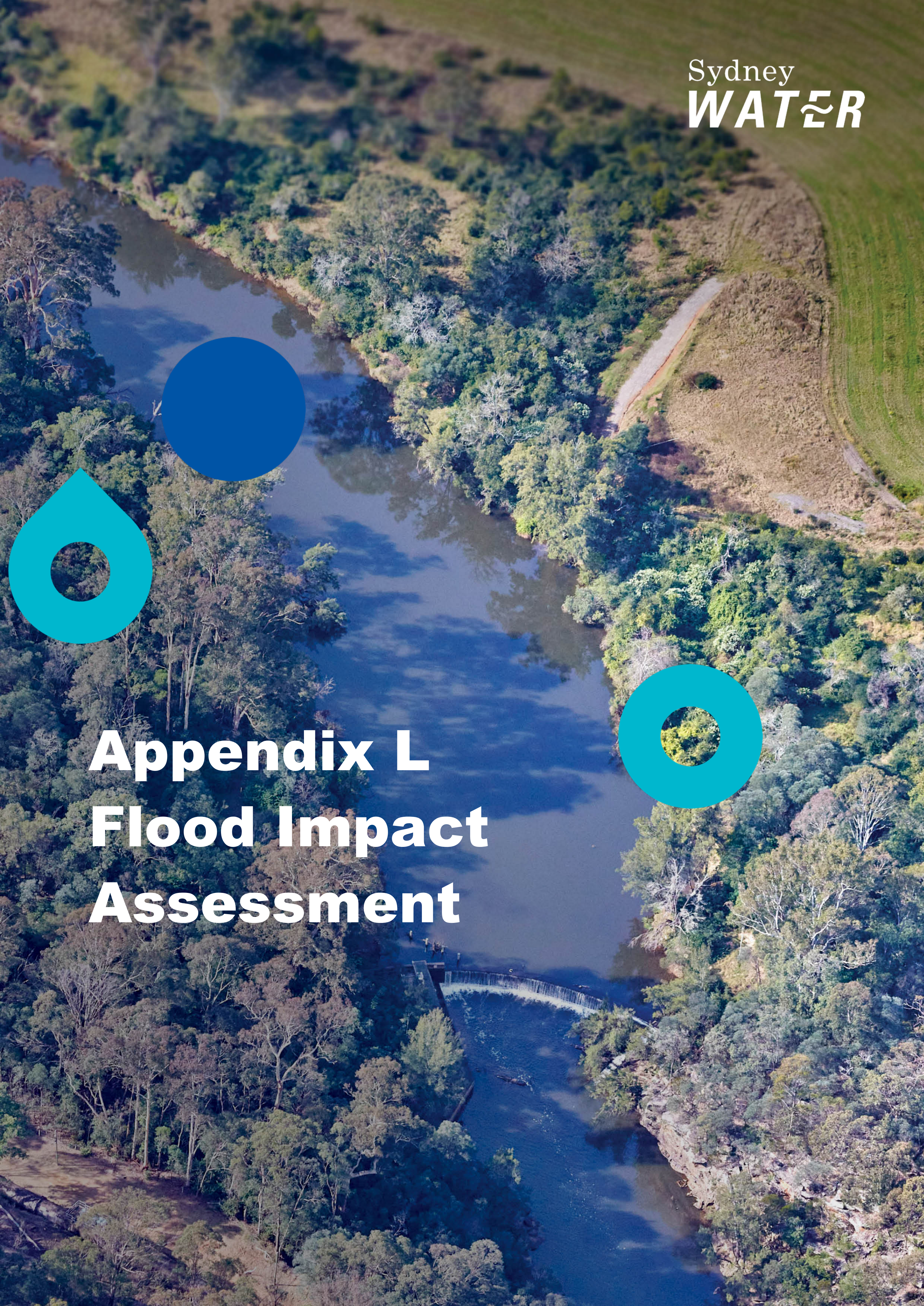


Appendix L
Flood Impact Assessment

Upper South Creek Advanced Water Recycling Centre

Flood Impact Assessment

Executive Summary

Sydney Water is planning to build and operate a wastewater treatment plant, known as the Upper South Creek Advanced Water Recycling Centre (USC AWRC), to service the South West and Western Sydney Aerotropolis Growth Areas. This report has been prepared to support the USC AWRC Environmental Impact Statement (EIS). The objective of the study is to investigate and address the potential impacts of the proposed USC AWRC, Treated Water Pipeline, Environmental Flows Pipeline, Brine Pipeline and all ancillary infrastructure on existing flooding conditions during the construction and operational phases.

For the construction period, the contractor should identify the flooding risks at selected construction compound locations and laydown areas. This can be done through detailed construction planning, developing appropriate construction site layouts and staging of construction activities (particularly at the compound sites and waterway crossings identified to be susceptible to flooding). Appropriate mitigation measures should be included in the Environmental Management Plan (or similar), which also address flood evacuation procedures during the construction phase.

During the operational phase, negligible flood impacts are expected from the proposed pipelines as they will all be buried underground. There are above ground structures along the pipelines, such as the flow split structure at Wallacia, air valves along the brine pipeline and scour valves that may have localised flood impacts but would have negligible to no impact on adjacent properties.

Given the environmental flows discharge into the Warragamba River and the primary discharge into the Nepean River are insignificant compared to the flood flows in the rivers, impacts on the existing flooding conditions of these waterways a result of the discharges will be negligible. While the discharge structures at these locations and the proposed access road downstream of Warragamba River are located within the 1% Annual Exceedance Probability (AEP) flood extent, the size of these structures is insignificant compared to the rivers cross sections, resulting in negligible changes to flooding conditions.

For the permanent USC AWRC site works, detailed hydrological and hydraulic modelling of the study area was undertaken to characterise the local hydrology and flooding behaviour and to establish the baseline flooding conditions. Both the hydrology and hydraulic baseline models were validated against the Penrith City Council's reference flood study (WorleyParsons 2015) showing a very good agreement. The hydraulic model was then updated with the topographical changes resulting from the proposed development to allow assessment of the impacts on baseline flooding conditions. The flood impact assessment modelled a range of events from frequent to extreme, to determine the following:

- Flood impacts of the Proposal
- Changes in hydraulic classification of the site
- Evacuation routes for a range of events
- Alignment of this study in response to a series of NSW guidelines including Floodplain Development Manual, Floodplain Risk Management Guidelines, and Standard Secretary's Environmental Assessment Requirements (SEARs)

The Proposal area is located on a topographically high point between South Creek and Kemps Creek above the Flood Planning Level (FPL). This means that the built surface of the proposed infrastructure will remain free from inundation. The USC AWRC site is immune from flooding for all the modelled storm events up to and including the Probable Maximum Flood (PMF) event. The modelling results of the proposed development under 10% AEP, 1% AEP, 0.5% AEP and 0.2% AEP events were similar to the pre-development results with some local flood level reductions along the western boundary of the site. Modelling of detention basins were undertaken as part of the surface water technical study and it was evident that due to their sufficient capacity to store runoff from storm events up to 1% AEP, negligible adverse impact on the existing flooding conditions is expected.

Based on the modelling results, for all design events up to 0.2% AEP, the project would not impact flood behaviour significantly, nor it would result in any detrimental impacts to other developments or land. The project would not cause any redirection of flow, significant changes in flow velocities, flood levels, hazards and hydraulic categories. In summary, no significant adverse effect is expected to flood behaviour on, adjacent to, or downstream of the site, as a result of developing the proposal. However, under the PMF event, the elevated site pad does encroach into the PMF floodplain, resulting in a blockage of flow and loss of flood storage, which subsequently increases flood levels upstream of the site along Kemps Creek in the order of 100 mm. These flood level increases are localised and do not impact on any significant infrastructure or emergency evacuation routes, with the exception of flooding of the site access road, which occurs in the PMF event.

As the development would not impact on the local flooding behaviour, or impede access to existing road networks, it is not expected to have any impacts on the existing community emergency management arrangements for flooding.

It should be noted that the conclusions presented in this report are based on the reference design received during this assessment. The findings are subject to change as the design develops. A reassessment is recommended at subsequent design stages to capture any changes that may influence the flood impact of the project.

Job title		Upper South Creek Advanced Water Recycling Centre		**Job number** 505018	
Document title		Flood Impact Assessment		**File reference:** as above	
Document ref					
Revision	**Date**	**Filename**	505018_USC AWRC EIS_Flood Water_DRAFT_Rev1		
Draft Rev0	10/08/20	**Description**	First draft issued to SWC for review		
			Prepared by	**Checked by**	**Approved by**
		Name	AH/SJ	PG	DE
		Signature			
Draft 2	29/11/2020	**Filename**	505018_USC AWRC EIS_Flood Study_DRAFT2		
		Description	Second draft issued to SWC for review		
			Prepared by	**Checked by**	**Approved by**
		Name	AH/SJ	YM	DE
		Signature			
Draft Final Draft Final rev1	20/04/2021 30/07/2021	**Filename**	505018_USC AWRC EIS_Flood Study_Draft_Final		
		Description	Draft final issue to SWC		
			Prepared by	**Checked by**	**Approved by**
		Name	AH/SJ	PG/AB	DE
		Signature			
	03/09/2021	**Filename**	505018_USC AWRC EIS_Flood Study_Final		
		Description	Final issue to SWC		
			Prepared by	**Checked by**	**Approved by**
		Name	AH	PG/AB	DE
		Signature			

Issue Document Verification with Document ✓

aurecon ARUP

Glossary and Abbreviations

Term	Abbreviation	Definition
Advanced Water Recycling Centre	AWRC	Proposed centre for treatment of the wastewater prior to reuse applications or discharge, which includes liquids treatment, advanced water treatment, solids treatment, odour treatment, and residuals management
Afflux		It refers to the predicted changes usually in flood levels, between pre- and post-development conditions.
Ancillary infrastructure	-	Permanent infrastructure to support operation of the USC AWRC and may include a range of infrastructure such as access roads and provision of utilities such as power.
Annual Exceedance Probability	AEP	A measure of the frequency of a rainfall event. It is the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year. For example, a one per cent event is a rainfall event with a one per cent chance of being exceeded in magnitude in any given year.
Aurecon and AECOM joint venture	AAJV	Aurecon and AECOM joint venture
Australian Height Datum	AHD	A common reference level used in Australia which is approximately equivalent to the height above sea level in meters.
Australian Rainfall and Runoff	ARR	A national guideline document, data and software suite that can be used for the estimation of design flood characteristics in Australia.
Average Dry Weather Flow	ADWF	ADWF consists of average daily wastewater flows and groundwater infiltration (GWI). ADWF is the average flow that occurs on a daily basis with no evident reaction to rainfall.
Average Recurrence Interval	ARI	The Average Recurrence Interval, like the Annual Exceedance Probability, is a measure of the frequency of a rainfall event. The average, or expected, value of the periods between exceedances of a given rainfall total accumulated over a given duration. For example, a 100-year Average Recurrence Interval event occurs or is exceeded on average once every 100 years. It is important to note that the ARI is an average period and it is implicit in the definition of the ARI that the periods between exceedances are generally random.
Bureau of Meteorology	BOM	An Executive Agency of the Australian Government responsible for providing weather services to Australia and surrounding areas.
Brine pipeline	-	A pipeline to transport brine (salty/concentrated wastewater). Brine water is a by-product of reverse osmosis in the wastewater treatment process.

Term	Abbreviation	Definition
Catchment	-	The land area draining through the main channel, as well as tributary streams, to a particular location. It always relates to an area above a specific location.
Commonwealth Scientific and Industrial Research Organisation	CSIRO	An Australian Government agency responsible for scientific research
Critical State Significant Infrastructure	CSSI	Critical State Significant Infrastructure projects are high priority infrastructure projects that are essential to the State for economic, social or environmental reasons.
Department of Environment & Climate Change	DECC	Forming part of the NSW Office of Environment and Heritage, the NSW Department of Environment, Climate Change and Water works towards a healthy environment and manages the state's natural resources. The Department includes the National Parks and Wildlife Service.
Department of Infrastructure, Transport, Regional Development and Communications	DITRDC	A department of the Australian Federal Government responsible for managing infrastructure and regional development policy, communicating policy and programs, cultural affairs, and arts.
Department of Planning, Industry and Environment	DPIE	The New South Wales Department of Planning, Industry and Environment is a department of the New South Wales Government responsible for effective and sustainable planning and the development of industry to support the growth in the state of New South Wales, Australia.
Design Flood	-	A hypothetical flood representing a specific likelihood of occurrence (for example the 100 yr ARI or 1% AEP flood).
Development	-	Existing or proposed works that may or may not impact upon flooding. Typical works are filling of land, and the construction of roads, floodways and buildings.
Diameter Nominal	DN	The internal diameter of a pipe.
Discharge	-	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, meters per second (m/s)
Effective Impervious Area	EIA	The portion of total impervious area (TIA) that is hydraulically connected to the drainage system.
Environmental Impact Statement	EIS	A publicly available document that provides information on a project, including its environmental impacts and mitigation measures, and is used to inform development consent decisions
Environmental Planning and Assessment Regulation	EP&A Regulation	Sets out the statutory requirements for infrastructure funding contribution collection and use in NSW.

Term	Abbreviation	Definition
Flood	-	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse.
Flood fringe areas	-	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Floodplain	-	Area of land which is subject to inundation by floods up to and including the probable maximum flood event.
Flood Frequency Analysis	FFA	The statistical analysis on the peak flow rates in a waterway.
Floodplain Risk Management Study and Plan	FRMSP	A study on management of land which is determined to be flood affected.
Flood Planning Level	FPL	The combination of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans.
Floodway areas	-	Areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
Flow time-series	QT	A flow hydrograph used as a boundary condition which assigns a flow into the model.
Generalised Short Duration Method	GSDM	A method for estimating the probable maximum precipitation for durations up to three or six hours in Australia.
Geographic Information System	GIS	Computer software system that analyses and displays geographically referenced information
Global Climate Models	GCMs	GCMs representing physical processes in the atmosphere, ocean, cryosphere and land surface, are the most advanced tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentration.
Greater Western Sydney	GWS	A region of the metropolitan area of Greater Sydney that generally includes the north-west, south-west, central-west, and far western sub-regions within Sydney's metropolitan area.
Horizontal Directional Drilling	HDD	Horizontal directional drilling techniques are used for the steerable installation of new pipelines, ducts and cables. The term applies to a crossing in which a pilot bore is drilled, and then enlarged to the size required to accommodate the product pipe.
Hydrograph	-	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.

Term	Abbreviation	Definition
Intensity-Frequency Duration	IFD	Describes the relationship between rainfall intensity, rainfall frequency and rainfall duration.
Impact assessment area	-	The area within which project impacts may occur. This will be larger than the actual impact area to give some flexibility with regards to exact construction locations. This may be refined as the infrastructure reference design progresses.
Intergovernmental Panel on Climate Change	IPCC	The United Nations body for assessing the science related to climate change.
Light Detection and Ranging	Lidar	A remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth.
Local Government Area	LGA	Local Government Areas cover incorporated areas of Australia. Incorporated areas are legally designated parts of a State or Territory over which incorporated local governing bodies have responsibility.
Mean Annual Pan Evaporation	MAE	
Mean Annual Precipitation	MAP	
NSW and ACT Regional Climate Modelling	NARCliM	A research partnership between the NSW and ACT governments and the Climate Change Research Centre at the University of NSW.
North West Growth Centre	NWGC	The North West Growth Centre is approximately 10,000 ha in size and is located within the boundaries of Blacktown, Hawkesbury and Hills Shire local government areas.
Office of Environment and Heritage	OEH	A former division of the Government of New South Wales between April 2011 and July 2019 and was responsible for the care and protection of the environment and heritage,
Probable Maximum Flood	PMF	The probable maximum flood is the maximum flood which can theoretically occur based on the worst combination of the probable maximum precipitation and flood-producing catchment conditions that are reasonably possible at a given location.
Project	-	The construction and operation of the Upper South Creek Advance Water Recycling Centre (AWRC), pipelines and all ancillary infrastructure. Construction of the USC AWRC is subject to environmental approval and has been identified as critical infrastructure. There are many stages and we are at the very early planning. Detailed construction staging will be established by the detailed design contractor. Noting that the timelines aren't finalised, it's expected that construction will start in mid-2022.
Reduced level	RL	The height or elevation above the point adopted as the site datum for the purpose of establishing levels.

Term	Abbreviation	Definition
Regional Climate Models	RCMs	RCMs were primarily developed with the aim of downscaling climate fields produced by coarse resolution global climate models (GCMs), to provide fine-scale climate information for impact studies, but they have evolved into general and multipurpose modelling tools.
Representative Concentration Pathway	RCP	The RCPs try to make predictions of how concentrations of greenhouse gases in the atmosphere will change in future as a result of human activities.
Runoff	-	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
Secretary's Environmental Assessment Requirements	SEARs	Issued by the Secretary of the NSW Department of Planning and Environment for projects declared by the Minister of Planning as Critical State Significant Infrastructure. These SEARS provide the technical requirements for the impact assessment of each potential key issue, including the desired performance outcome, requirement and current guidelines.
Scientific Information for Land Owners	SILO	A daily time series of meteorological data at point locations, consisting of station records which have been supplemented by interpolated estimates where observed data are missing.
Source-Area	SA	A boundary condition defining the polygons of sub-catchment areas for applying a source (flow) or rainfall directly onto 2D domains
South West Growth Centre	SWGC	The Greater Sydney area of Camden, Campbelltown and Liverpool local government areas with approximately 17,000 ha area
Stage-discharge	HQ	A water level versus flow relationship used in modelling to define the model outflow condition.
State Emergency Services	SES	The New South Wales State Emergency Service, an agency of the Government of New South Wales, is an emergency and rescue service dedicated to assisting the community in times of natural and man-made disasters.
Study area	-	General location or region where work may be undertaken. In the context of this report, the area which the assessment covers and presented.
Temporal Patterns	TP	The proportion of total rainfall in different periods within a given rainfall duration.
Total Impervious Area	TIA	The total coverage by impervious surfaces in an area.
Treated water pipeline	-	The pipelines that will convey the highly treated water to the existing environment. The pipelines will transport water from the USC AWRC to the discharge points at the Nepean and Warragamba Rivers. These pipelines will range in size from about 0.6 m to 1.5 m in diameter and will generally consist of steel, glass reinforced plastic and polyethylene pipe materials.

Term	Abbreviation	Definition
Triangulated Irregular Networks	TIN	A representation of a continuous surface consisting entirely of triangular facets, used mainly as Discrete Global Grid in primary elevation modelling.
Upper South Creek	USC	The catchment in which the USC AWRC will be located. South Creek discharges to the Nepean River which flows directly into the Hawkesbury River and then discharges out to the Pacific Ocean
Wastewater	-	The used water from baths, showers and washing machines (‘greywater’) and toilets (‘blackwater’) and enters into the sewerage system. About 99% of this is water with the remaining 1% composed of the components added to water during the previous use.
Western Sydney Airport	WSA	Western Sydney International Airport, locally Badgerys Creek Airport, or simply Western Sydney Airport, will become Sydney's second airport, located within the suburb of Badgerys Creek.
Western Sydney Employment Area	WSEA	The Western Sydney Employment Area is located in Sydney’s west and is established to supply employment land close to major road transport and provide jobs for Western Sydney.
Western Sydney Planning Partnership	WSPP	A local government-led initiative that brings Blacktown, Blue Mountains, Camden, Campbelltown, Fairfield, Hawkesbury, Liverpool, Penrith and Wollondilly councils together with key State agencies.

Table of Contents

Figures

Tables

1 Introduction

1.1 Background

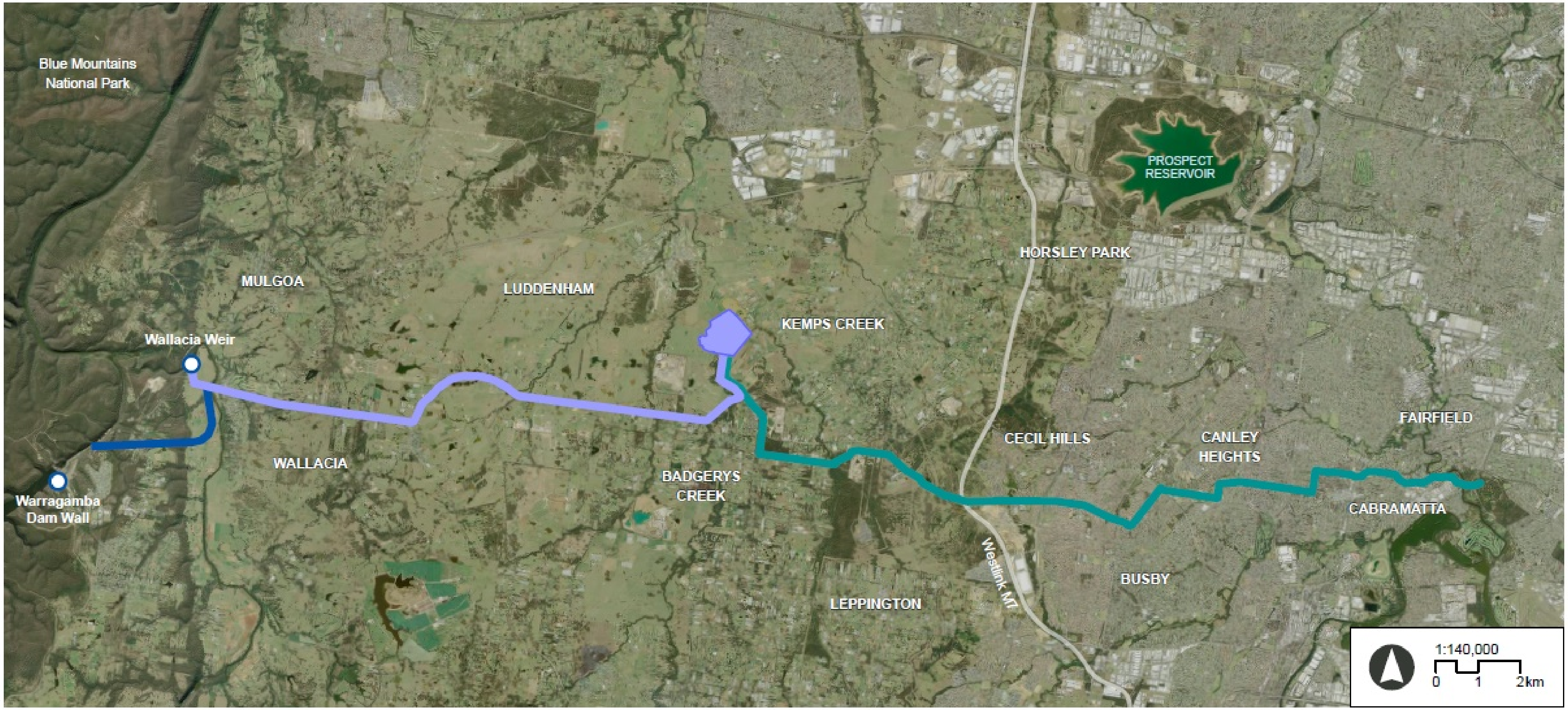
Sydney Water is planning to build and operate a wastewater treatment plant, known as the Upper South Creek Advanced Water Recycling Centre (USC AWRC), to service the South West and Western Sydney Aerotropolis Growth Areas.

This report has been prepared to support and inform the USC AWRC Environmental Impact Statement (EIS) by addressing the Secretary's Environmental Assessment Requirements (SEARs) issued by the Secretary of the Department of Planning, Industry and Environment (DPIE) relevant to flooding. An EIS is a publicly available document that provides information on a project, including its environmental impacts and mitigation measures, and is used to inform development consent decisions.

This report describes the flooding behaviour under the existing and post-developed (design case) conditions, identifies potential impacts during both construction and operational phases, including the cumulative impacts resulting from the other active projects in the area, and discusses the site evacuation routes under various flooding conditions.

1.2 Project Description

The proposal includes a wastewater treatment plant in Western Sydney, known as the USC AWRC, to service the South West and Western Sydney Aerotropolis Growth Areas. Together, this Water Recycling Centre and the associated treated water and brine pipelines, will be known as the 'project'. An overview of the location of the proposed infrastructure is provided in **Figure 1-1**.

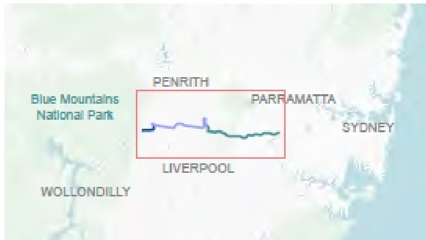


Upper South Creek Advanced Water Recycling Centre

Treated Water Pipeline

Brine Pipeline

Environmental Flows Pipeline



Projection: GDA 1994 MGA Zone 56
Project infrastructure locations are indicative and will be refined during design

Figure 1-1 Project Overview

Further details of each component of the project are provided below in **Table 1-1**.

Table 1-1 Key Project Features

Project feature	Description
USC AWRC	• a wastewater treatment plant with the capacity to treat up to 50 ML of wastewater per day, with ultimate capacity of up to 100 ML per day • the USC AWRC will produce: – high-quality treated water suitable for a range of uses including recycling and environmental flows – renewable energy, including through the capturing of heat for cogeneration – biosolids suitable for beneficial reuse – brine, as a by-product of reverse osmosis treatment
Treated water pipeline(s)	• a pipeline about 17 km long from the USC AWRC to the Nepean River at Wallacia Weir, for the release of treated water • infrastructure from the USC AWRC to South Creek to release excess treated water and wet weather flows • a pipeline about five kilometres long from the main treated water pipeline at Wallacia to a location between the Warragamba Dam and Warragamba Weir, to release high-quality treated water to the Warragamba River as environmental flows
Brine pipeline(s)	• a pipeline about 24 km long that transfers brine from the USC AWRC to Lansdowne, in south-west Sydney, where it connects to Sydney Water's existing Malabar wastewater network. The timing and scale of future stages will be phased to respond to drivers including population growth rate and the most efficient way for Sydney Water to optimise its wastewater systems.

Sydney Water is planning to deliver the project in stages, with Stage 1 comprising:

- building and operating the USC AWRC to treat an Average Dry Weather Flow (ADWF) of up to 50 ML per day
- building all pipelines to their ultimate capacity, but only operating them to transport and release volumes produced by the Stage 1 USC AWRC

The timing and scale of future stages will be phased to respond to drivers including population growth rate and the most efficient way for Sydney Water to optimise its wastewater systems.

The 17 km Treated Water mains corridor is mostly located in the Penrith Local Government Area (LGA), with a short end segment of the pipeline located in the Wollondilly Shire Council area. The underground pipeline is partially located in the catchment of South Creek and its tributaries including Badgerys Creek and Cosgrove Creek, and the catchment of Warragamba River and its tributary Jerrys Creek.

The 5 km environmental flows pipeline corridor is in the Wollondilly Shire Council area. The underground pipe starts from the Treated Water and environmental flows Split Arrangement Site to the discharge point between the Warragamba Dam and the Warragamba Weir. The mains corridor is within the catchments of Warragamba River and Nepean River.

The 24 km underground Brine Discharge Main crosses the boundaries of the Penrith LGA, Liverpool LGA and Fairfield LGA and is located within the catchments of South Creek, Kemps Creek, Hinchinbrook Creek, Clear Paddock Creek, Green Valley Creek, Cabramatta Creek and Prospect Creek, which are tributaries of the larger South Creek and Georges River systems.

The USC AWRC site is located within the Penrith LGA in Greater Western Sydney (GWS), northwest of Elizabeth Drive and Mamre Road intersection. It has an area of 80 hectares with elevations ranging from 35 to 41m Australian Height Datum (mAHD). The proposed USC AWRC location is within the South Creek catchment, which is a tributary of the Hawkesbury River. Currently, the site is on undeveloped land located in a semi-rural floodplain with sparse trees. Flooding is a concern through this site, as it is bounded by South Creek to the west with 96 km^2 upstream catchment and to the east by Kemps Creek draining 60 km^2 catchment.

1.3 Study Objectives

The objective of the Flood Impact Assessment is to assess and address potential flood impacts associated with the construction and operational phases of the project. It also aims to provide guidance on ways of mitigating and managing the potential impacts to minimise potential environmental degradation.

The assessment covers the USC AWRC site as well as a 25 m wide impact assessment area along the pipeline alignments (treated water pipeline, brine pipeline and environmental flows pipeline). The buffer area has been included to allow for uncertainty within the current pipeline alignment and changes that may need to occur during detailed design.

A reference design has been developed for the project to inform the Impact Assessment studies.

Several studies have been undertaken in parallel to cover various aspects relating to the potential water environment impacts. These studies and the extent of each study's considerations are indicated below:

Surface Water Impact Assessment	Hydrodynamic and Water Quality Impact Assessment	Flood Assessment	Groundwater Impact Assessment	Ecohydraulic and Geomorphology Assessment	Aquatic and Riparian Ecosystem Assessment
• Construction and operational impacts related to local runoff and stormwater management at the AWRC site as well as along the pipeline routes	• Treated water releases and impacts on the chemistry and water quality of the Warragamba and Nepean rivers and South Creek	• Assessment of potential impacts on local and downstream flooding regimes associated with discharge infrastructure and landform changes, and temporary construction activies along pipelines	• Construction and operational impacts to local and regional groundwater sources related to proposed activities at the AWRC site as well as along the pipeline routes	• Potential impacts to ecohydrology and geomorphology of the Warragamba and Nepean rivers and Wianamatta-South Creek	• Potential impacts associated with the proposed works on riparian and aquatic flora and fauna

1.4 Previous Studies

Several studies have been undertaken relevant to the project as presented in **Table 1-2**.

Table 1-2 Previous Studies

Study	Description	Author
Flood Study Report-South Creek	Flood discharges throughout the South Creek catchment were determined through an XP-RAFTS hydrologic model calibrated to the August 1986 and April 1988 flood events.	NSW Department of Water Resources (1990)
South Creek Floodplain Risk Management Study and Plan (FRMSP)	This Floodplain Risk Management Study investigated what can be done to minimise the effects of flooding in the South Creek study area and recommended a strategy in the form of a Floodplain Risk Management Plan.	Bewsher (2004) for the NSW State Emergency Services (SES)
Flood Study for Orphan School Creek, Green Valley Creek and Clear Paddock Creek	This study includes results of the flood study for Orphan School Creek, Clear Paddock Creek and Green Valley Creek (the “Three Tributaries” of Prospect Creek.	SKM (2008)
Prospect Creek Floodplain Management Plan Review	This document provides a review of the Prospect Creek Floodplain Management Plan based on a review of previous floodplain management studies and other flood investigations carried out in the study area, including the Lower Prospect Creek Floodplain Management Study (Willing & Partners, 1990), the Upper Prospect Creek Floodplain Management Study (Willing & Partners, 1993), and the Review of Prospect Creek Flood Levels (Cardno Willing, 2004). The Plan reviews previous floodplain management measures proposed for Prospect Creek and provides a revised floodplain management plan for the full length of Prospect Creek.	Bewsher (2010)
Upper South Creek Flood Study	As part of the Study a hydraulic model has been built which was calibrated to the 1988 event. Two smaller events (~10-year Average Recurrence Interval (ARI)) were used for validation purposes (1991 and 1992 events).	WMA (2012) for the NSW Office of Environment & Heritage
Nepean River Flood Study	The study involved hydrology & hydraulic assessment of Upper Nepean River within the Camden Local Government Area, comprising a catchment area of about 1,800km² upstream of Warragmba River.	WorleyParsons (2015) for Camden City Council
Water Management Flood Modelling and Riparian Corridor Study, South West Growth Centre (SWGC) and Western Sydney Employment Area (WSEA)	The NSW Department of Planning & Environment engaged Cardno to provide Water Management, Flooding and Riparian Corridor Study services for the: • SWGC Structure Plan, excluding any Precincts already released; • Precincts not yet released in the North West Growth Centre (NWGC), including Shanes Park and West Schofields; and • The WSEA.	Cardno (2015) for the NSW Department of Planning and Environment

Study	Description	Author
Updated South Creek Flood Study	The study involved the development of a 2D hydrodynamic model of the South Creek floodplain using the RMA-2 software package and was validated based on modelling of the 1986 and 1988 historic floods	WorleyParsons (2015) for Penrith City Council
Upper South Creek FRMSP	Cardno was commissioned by Camden Council to undertake a FRMSP for the USC Study Area.	Cardno (2017) for Camden Council
Hawkesbury-Nepean Valley Regional Flood Study	The Hawkesbury-Nepean Valley Regional Flood Study is a technical document describing the flood behaviour of the main Hawkesbury-Nepean River from Bents Basin near Wallacia downstream to Brooklyn Bridge, and associated backwater flooding.	WMA Water (2019)
Western Sydney Aerotropolis South Creek Flood Study	Comprehensive flood modelling has been undertaken for the entire South Creek catchment by Aurecon and AECOM joint venture (AAJV). The XP-RAFTS hydrology model has been used to simulate the rainfall-runoff process with 435 sub-catchments. A 1D/2D hydraulic model has been undertaken using TUFLOW based on Australian Rainfall and Runoff (ARR) 2016 utilising a 10 m grid resolution.	AAJV (2019) for Sydney Water

The Western Sydney Aerotropolis South Creek Flood Study (2019) formed the basis of the AWRC study. Additional information for developing the current hydrology and hydraulic models is included in **Sections 4.3** and **4.4**.

1.5 Desktop review

Multiple sources of publicly available information, relevant to the local and regional surface water conditions were identified and data from these sources were collated and reviewed as part of this report, to inform the following hydrological characteristics:

- Local and regional climatic conditions
- Stream flows
- Surface water quality, including potential sources of surface water contamination
- Topography.

Several investigations and reports containing information on surface water, hydrology and water quality have been undertaken in the study area. A summary of the previous investigations and reports from which hydrological characteristics have been derived is provided in **Table 1-3**.

Table 1-3 Summary of previous investigations and reports

Document Title	Author	Date Published
South Creek Source Model Calibration	Alluvium	2019
M12 Motorway EIS – Appendix M Surface water quality and hydrology assessment	RMS	2019

Document Title	Author	Date Published
Western Sydney Airport EIS – Appendix L1 Surface water hydrology and geomorphology	GHD	2015
Western Sydney Airport EIS – Appendix L2 Surface water quality	GHD	2015
Environmental field survey of Commonwealth land at Badgerys Creek	SMEC	2014
Second Airport EIS	PPK	1999

1.6 Reference design

The assessment is based on the current reference design at the time of this study. It includes the location and extents of the USC AWRC site main components (bulk earthworks, detention basins, access road, wetland, swale), pipeline alignments and temporary facilities during construction.

This design will be subject to design development in subsequent project stages. A reassessment is recommended at these stages to capture any changes that may influence the flood impact of the project.

2 Legislation, Policy and Guidelines

The assessment has been undertaken in accordance with the Secretary's Environmental Assessment Requirements (SEARs) provided in **Section 3** and with reference to the legislation, policy and guidelines summarised in **Table 2-1**.

Table 2-1 Legislation and policy context

Legislation/Policy	Brief description, salient parts and intent	Relevance
Australian Rainfall and Runoff	ARR is a national guideline document, data and software suite that can be used for the estimation of design flood characteristics in Australia. A major revision of these Guidelines was released in 2016, which has been the basis of the AWRC study.	It is pivotal to the safety and sustainability of Australian infrastructure, communities and the environment. It is an important component in the provision of reliable and robust estimates of flood risk.
NSW Government's Floodplain Development Manual (Department of Natural Resources, 2005)	The New South Wales Floodplain Development Manual (former Department of Infrastructure, Planning and Natural Resources, 2005) concerns the management of flood-prone land within NSW. It provides guidelines in relation to the management of flood liable lands, including any development that has the potential to influence flooding, particularly in relation to increasing the flood risk to people and infrastructure.	The guidelines and manual have primarily been incorporated in to support councils in preparing and implementing floodplain risk management plans. However, the guidelines provide insight into the preferred modelling methodologies and documentation. This will be relevant to ensure the flooding assessment adequately addresses council's requirements.
PS 07-003 New guideline and changes to section 117 direction and Environmental Planning and Assessment (EP&A) Regulation on flood prone land	This circular provides an overview of a new guideline to the Floodplain Development Manual and changes to the EP&A Regulation 2000 and section 117 Direction on flood prone land	This circular provides advice on a package of changes concerning flood-related development controls on residential development on land above the 1-in-100-year flood and up to the Probable Maximum Flood (PMF). These areas are sometimes known as low flood risk areas.

Legislation/Policy	Brief description, salient parts and intent	Relevance
Practical Consideration of Climate Change - Flood risk management guideline (DECC, 2007)	This document provides guidance on how to incorporate climate change considerations when assessing floodplain risks through advising on the following: • Assessing climate change impacts through modelling sensitivity analyses. • Determining whether climate change is a key issue at a particular location. This depends upon the impacts on flood damages and increased frequency of exposure of people to flood hazard. • Incorporating climate change in floodplain risk management plan development considerations, and in new and current works projects and planning strategies. Outlining some potential climate change management strategies for existing and future development and associated practical issues.	It is recommended that this guideline be used as the basis for examining climate change in projects undertaken under the State Floodplain Management Program and the 2005 Floodplain Development Manual.
Controlled Activities – Guidelines for Watercourse Crossings (NSW Office of Water, 2010)	Watercourse crossings are a controlled activity under the Water Management Act 2000 (WM Act). The guidelines relate to the design and construction of watercourse crossings and ancillary works, such as roads on waterfront land.	Crossings have the potential to disrupt the hydrologic and hydraulic functions of a watercourse affecting local flooding conditions. The guidelines set out ways to minimise these impacts during design and construction. Sydney Water are exempt from having to submit to the DPIE Water for approval of controlled activities.

Legislation/Policy	Brief description, salient parts and intent	Relevance
Penrith Council Development Control Plan (2014)	This document sets out controls in relation to local flood planning mainly to: • Ensure floodplain risk management minimises the potential impact of development and other activity upon the aesthetic, recreational and ecological value of the waterway corridors. • Maintain the existing flood regime and flow conveyance capacity and avoid significant adverse impacts on flood behaviour. • Reduce the impact of flooding and flood liability on individual owners and occupiers. • Limit the potential risk to life and property resulting from flood events. • Contain the potential for flood losses in all new developed areas by the application of effective planning and development controls.	

3 SEARs

This report has been prepared to support and inform the EIS by addressing the SEARs relevant to flooding as listed in **Table 3-1.**

Table 3-1 Scope of work to address project specific SEARs

Requirement	Scope of work undertaken to address	Section
29. Mapping the following features relevant to flooding as described in the Floodplain Development Manual 2005 (NSW Government 2005) including: a) flood prone land. b) flood planning area, the area below the flood planning level. c) hydraulic categorisation (floodways and flood storage areas) d) flood hazard.	Mapping of the below features for the South Creek catchment for both Existing Case and Design Case are provided in Sections 6.2 and 6.3, as described in the Floodplain Development Manual 2005 (NSW Government 2005): a) flood prone land. b) flood planning area, the area below the flood planning level. c) hydraulic categorisation (floodways and flood storage areas) d) flood hazard. Existing mapping of the above features in other catchments, including the Nepean and Warragamba Rivers, will not be impacted by the proposal. This is owing to the fact that the qualitative flood impact assessment identified negligible impacts on these floodplains as a result of the project, and it is therefore not required that modelling be undertaken.	Sections 6.1, 6.2 and 7.2
30. The Proponent must assess and (model where required) the impacts on flood behaviour during construction and operation for a full range of flood events up to the probable maximum flood (considering sea level rise and storm intensity due to climate change).	**All project components (construction phase)** A qualitative assessment was undertaken to identify the potential impacts of the project components on existing flooding conditions during construction period. The results of this assessment are presented in Section 7.1, which indicate insignificant impacts. **Pipelines and discharge structures** A qualitative assessment was carried out to identify the potential impacts of the other project components (pipelines, pumping stations, discharge structures etc.) on existing flooding behaviour during the operations phase of the project. This assessment indicated insignificant impact on flooding conditions as a result of the other project components. **AWRC site** For the operations phase, the Existing Case and Design Case flooding behaviour of South Creek and Kemps Creek were characterised through detailed hydrology and hydraulic numerical modelling for the proposed USC AWRC site (Sections 6.2 and 6.3). The results of this modelling were used to undertake a quantitative flood impact assessment. The results of this assessment are presented in Section 7.2.4. This assessment suggests insignificant	Section 7.1 Sections 7.2.1, 7.2.2 and 7.2.3 Section 7.2.4

Requirement	Scope of work undertaken to address	Section
	adverse impacts on flooding conditions for modelled events up to and including 0.2% AEP event. For the modelled PMF event, the modelling shows increased water levels immediately upstream of the site in Kemps Creek.	
31. Modelling must consider and document:		
a) existing council flood studies in the area and examine consistency to the flood behaviour documented in these studies.	The hydrology and hydraulic models of South Creek were built by consideration of the Updated South Creek Flood Study (WorleyParsons, 2015), which is currently being adopted by Penrith City Council as the reference flood study. Further details including validation of these models against the Council flood study are provided in Sections 4.3 and 4.4.7. The modelled peak flows were also compared and validated against At-site flood frequency analysis data and the peak flow estimates from Regional Flood Frequency Estimation Model as detailed in Section 4.4.7.	Sections 4.3, 4.4.7
b) the impact on existing flood behaviour for a full range of flood events including up to the probable maximum flood, or an equivalent extreme flood.	Hydrology and hydraulic modelling were used to assess the impacts on flooding conditions of South Creek for a range of flood events from 10% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF.	Section 7.2.4
c) impacts of the development on flood behaviour resulting in detrimental changes in potential flood affection of other developments or land. This may include redirection of flow, flow velocities, flood levels, hazard categories and hydraulic categories	The impacts of the proposed development on flooding behaviour of South Creek were assessed for the USC AWRC site and the results presented.	Section 7.2.4
d) relevant provisions of the NSW Floodplain Development Manual 2005.	The proposed reference design also applies Council's floodplain development control plan (Penrith Development Control Plan 2014) which has been prepared in accordance with the NSW Floodplain Development Manual. Siting the AWRC has included consideration of floodplain hazard and flood impact. Modelling and mapping is undertaken in accordance with the provisions of the NSW Floodplain Development Manual 2005. Specific requirements with regards to modelling and mapping are listed in SEARs item 29. For categorisation and mapping of flood hazard, the recommended approach in the Australian Rainfall & Runoff Guidelines (2019) was used. Modelling indicates that the project will not make any changes to the flood prone land, flood planning area, hydraulic categorisation, and flood hazard classification.	Section 6.2.4

Requirement	Scope of work undertaken to address	Section
e) consideration of scenarios where the pipelines are shut down or used infrequently.	The assessment presents a qualitative assessment of the discharge flow rates and their impact on flooding conditions of the waterways, using comparison of the discharge rates with waterway flood flows. This assessment was performed for the South Creek, Warragamba River and Nepean River discharge locations and identified negligible impacts.	Sections 7.2.2 to 7.2.4
f) impacts to South Creek under all scenarios, specifically where South Creek and the Warragamba Pipelines intersect.	This has been addressed quantitatively. Because the pipelines are underground negligible impacts on flooding conditions is expected to occur as a result of the project pipelines.	Section 7.2.1
g) consideration of backflow impacts during flood events.	The hydraulic modelling of South Creek identified no backflows in waterways as a result of the project for all the modelled events up to and including 0.2% AEP. Under the modelled PMF event backflow occurred in Kemps Creek immediately upstream of the USC AWRC site pad.	Section 7.2.4.7
h) assessment of the hydrological flows into South Creek from both wet and potential dry weather flows, including consideration of the effects on downstream receiving environments, specifically the Warragamba Pipelines infrastructure (footings etc).	This assessment was undertaken qualitatively using the values of the dry and wet-weather flows and waterways' peak flood flows at South Creek, Nepean River and Warragamba River.	Sections 7.2.2 to 7.2.4
32. The EIS must assess the impacts on the proposed development on flood behaviour, including:		
a) whether there will be detrimental increases in the potential flood affectation of other properties, assets and infrastructure.	Numerical hydrology and hydraulic modelling was caried out for the proposed USC AWRC site as detailed in Sections 6.2 and 6.3. The results of this assessment are presented in Section 7.2.4 and suggest insignificant adverse impacts on flooding conditions for modelled events up to and including 0.2% AEP event. For the modelled PMF event, the modelling shows increased water levels immediately upstream of the site in Kemps Creek. However, the flood level increases are localised and do not impact on any significant infrastructure. For the other components of the project (pipelines, discharge structures etc.), qualitative assessments were carried out to identify the potential impacts on existing flooding behaviour, which indicated insignificant when considering impacts on local properties, assets and infrastructure as detailed in Sections 7.2.1, 7.2.2 and 7.2.3.	Section 7.2.4
b) consistency with Council floodplain risk management plans.	The assessment has been consistent with the risk management plans of the local council where the proposed developments are located (Penrith City Council, Wollondilly City Council, Liverpool City Council and Fairfield City Council). These are addressed for both construction and operations phase.	Sections 7.1 and 7.2

Requirement	Scope of work undertaken to address	Section
c) consistency with any Rural Floodplain Management Plans.	No Rural Floodplain Management Plan was applicable to the extent of the study area.	n/a
d) compatibility with the flood hazard of the land.	The flood impact assessment indicates compatibility with the flood hazard of the land within each local council's jurisdiction area along the pipeline corridors and at the USC AWRC site and discharge locations.	Sections 7.1 and 7.2
e) compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land.	The quantitative and qualitative flood impact assessments were performed indicate compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land.	Sections 7.1 and 7.2.
f) whether there will be adverse effect to beneficial inundation of the floodplain environment, on, adjacent to or downstream of the site.	The flood impact assessment concluded insignificant adverse impact on beneficial inundation of the floodplain environment. Hydraulic modelling of the USC AWRC site under the developed conditions shows improved flood storage immediately downstream of the site in South Creek, which enhances beneficial inundation of the floodplain. Flood impacts associated with the transfer and discharge infrastructure are shown to be negligible.	Section 7 (Section 7.2.4)
g) whether there will be direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of riverbanks or watercourses.	The proposed developments will not have an adverse impact on existing flooding conditions. As such there will be no increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of riverbanks or watercourses. These potential impacts, which are also associated with the proposed wastewater discharges have been assessed and documented in the *Aquatic Ecology, Ecohydraulic and Geomorphology Impact Assessment*.	Section 7
h) any impacts the development may have upon existing community emergency management arrangements for flooding. These matters are to be discussed with the NSW SES and Council.	The proposed development will not have an impact on the existing community emergency management arrangements for flooding. Details of the evacuation routes and emergency management arrangements during flood events are included.	Section 7.4
i) whether the project incorporates specific measures to manage risk to life from flood. These matters are to be discussed with the NSW SES and Council.	Flood evacuation routes and emergency management measures are provided. The project does not incorporate specific measures to manage risk to life from flood.	Section 7.4

Requirement	Scope of work undertaken to address	Section
j) emergency management, evacuation and access, and contingency measures for the development considering the full range or flood risk (based upon the probable maximum flood or an equivalent extreme flood event). These matters are to be discussed with and have the support of Council and the NSW SES.	It is recommended that, in consultation with the NSW SES and Penrith City Council, a Flood Preparedness Plan is developed for the USC AWRC site to ensure alignment with community evacuation arrangements and implemented during both construction and operational phase.	Section 7.4
k) any impacts the development may have on the social and economic costs to the community as consequence of flooding.	The project is not expected to have any significant impacts on the social and economic costs to the community as a consequence of flooding.	Section 8

4 Assessment Methodology

The assessment sets out to describe the existing environment, including climatic conditions, land use data, topography, catchment hydrology and the hydrological and hydraulic models used. This will focus on the study area, which extends beyond the project to suitably capture the characteristics and flood behaviour of the catchment.

The analysis component investigates flood conditions in the pre- and post-development scenarios. This will be undertaken using the Upper South Creek TUFLOW flood model. The model will be cut down to facilitate the simulation process. Modelling results including flood depths, levels, velocities and hazards will be derived and presented as flood maps.

Flood hazards around the study area will also be investigated. This will be based on the method presented in ARR 2019 which defines six hazard classifications that relate to specific vulnerability thresholds. Furthermore, hydraulic categorization will also be calculated based on a combination of flood velocity and flood depth to define the flood fringe, flood storage and floodway characteristics of the floodplain across the study area.

The results will be reviewed to identify the extent of the areas affected by the project components in the construction and operational phases. The assessment and discussion on the impact assessment will cover:

- The USC AWRC site
- The Treated Water, Brine and Environmental Flows Pipelines (including ancillary structures)
- The treated water and environmental flow discharge structures
- Access roads and waterway crossings

The temporary components of the project and activities during the construction phase are not known at this stage however preliminary construction compound sites available. As a result, this will be qualitatively assessed by reviewing the flood risk of the preliminary construction compounds using a desktop assessment approach. General management measures to minimise potential impacts will be proposed.

The permanent project components identified to potentially affect flooding behaviour will be quantitatively assessed through detailed numerical modelling, followed by proposed mitigation measures to eliminate and minimise the impacts.

The cumulative impacts of recently completed, ongoing and proposed projects and possible evacuation routes from the AWRC site will be presented.

The following sections present the key project components, the likelihood of their influence on flood flows and the approach adopted for assessment of their potential impacts on flooding conditions.

4.1 The Treated Water, Brine and Environmental Flows Pipelines

As discussed in **Section 1.2**, the project includes construction of three pipelines including:

- An approximately 17 km pipeline, which will convey treated water from the USC AWRC to the Nepean River at Wallacia Weir.

- An approximately 5 km pipeline connecting the main treated water pipeline at Wallacia to the discharge point between the Warragamba Dam and the Warragamba Weir at its downstream for the release of environmental flows.
- A Brine pipeline with an approximate length of 24 km, which will transfer brine from the USC AWRC site to Lansdowne to be connected to the existing Malabar wastewater network.

As all the above pipelines are proposed to be buried underground, they will not introduce any changes to the existing landform and as such not expected to have any impacts on the existing flooding regime. Qualitative impact assessment was undertaken for the above-ground structures along the pipelines, such as the flow split structure at Wallacia, air valves along the brine pipeline, scour valves and the headwall structure on the treated water pipeline that may have localised flood impacts but would have negligible impact on adjacent properties. Also, the proposed discharge structure at the environmental flows discharge point was reviewed for potential flood impacts.

Any potential impacts on flooding from the pipelines will be limited to the temporary structures and activities during the project construction, which should be identified and managed by the contractor through an Environmental Management Plan.

4.2 The Upper South Creek Advanced Water Recycling Centre

The proposed USC AWRC includes several above-ground structures and facilities, which have the potential to affect the flooding regimes of South Creek and Kemps Creek. To identify and quantify these potential impacts, numerical hydrologic and hydraulic modelling of the contributing catchments and the local waterways will be undertaken as discussed in the subsequent sections.

As part of the Western Sydney Aerotropolis South Creek Flood Study (AAJV, 2019), a XP-RAFTS hydrology model and a 1D/2D TUFLOW model (refer to **Section 4.3** and **Section 4.4**) were prepared for the South Creek catchment and validated against previous studies. These models were used as the basis for development of the models in the AWRC study.

The hydrological model allows defining the catchment rainfall-runoff behaviour and producing the estimated stormwater flows resulting from storm events in the form of flood hydrographs, which will inform the hydraulic model.

Using the outputs of the hydrologic model and other data, the hydraulic model simulates the flow behaviour of the drainage network, overland flow paths and produces the estimated flood levels, flow discharges and velocities.

The following key tasks were undertaken during the flood impact assessment:

1. The inflows for the sub-catchments of the entire South Creek floodplain were extracted from the XP-RAFTS model for all design events which later were fed into the hydraulic model as boundary conditions.
2. Owing to the large extent of the AAJV (2019) TUFLOW model and its focus, a relatively coarse grid size of 10 m was adopted in that model. As the focus of the AWRC study is the USC AWRC and its vicinity, the model was downscaled to cover a smaller area and a finer grid size of 3m was used instead, to improve the resolution of the model results.
3. Flow hydrographs were used as upstream inflow boundary conditions in the downscaled model and a Stage-discharge (HQ) boundary condition was imposed at about 4.5 km downstream of the USC AWRC location. In the 2D domain, the active area and the Source-Area (SA) boundary (2d_sa) layers were modified accordingly to represent this new extent.

4. The Existing Case model was used to identify the existing flooding behaviour at the proposed USC AWRC site and its vicinity.
5. As the updated South Creek Flood Study (WorleyParsons, 2015) is the local Council's current reference flood study for the study area, the hydrology and hydraulic models were validated against this study using the ARR 1987 data.
6. The design scenario was defined in the form of modifying land surface topography of the Existing Case based on the USC AWRC design layouts.
7. Design case results were compared to the Existing Case to identify the impacts of the proposed development on flooding.
8. For construction phase, the indicative locations of construction compounds and waterway crossings were assessed for flood impacts on a qualitative basis.

4.3 Hydrologic Modelling

The XP-RAFTS hydrological model was used to derive inflows for the sub-catchments of the hydraulic model in the existing scenario and then slightly modified to produce inflows associated with developed scenario.

The XP-RAFTS model covering the entire South Creek catchment comprised 435 sub-catchments. Sub-catchments hydrographs were sourced from the XP-RAFTS model for the 10% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF events for both pre- and post-development scenarios and used as boundary conditions in the hydraulic model.

A summary of the inputs used in the hydrology model is provided in the following sections.

South Creek Sub-catchments

The South Creek catchment covers an area of approximately 431 km^2, which was divided into 435 sub-catchments for the purpose of hydrologic modelling as shown in **Figure 4-1**.

To represent the variability of roughness values associated with different land surfaces, the catchment was subdivided into five different material types as shown in **Table 4-1**, along with their adopted impervious percentage and Manning's 'n' values. The Effective Impervious Area (EIA) was assumed 60% of the Total Impervious Area (TIA). Based on the recommendations of ARR2016, an EIA/TIA ratio of 50% to 70% was deemed appropriate for urban catchments and adopted in the model.

Table 4-1 Impervious percentage and Manning's 'n'

Land Use Description	Manning's 'n'	Impervious fraction (%)
Building	0.025	100
Concrete/Paving	0.015	100
Trees/crops	0.100	0
Water	0.025	100
Grass	0.035	0

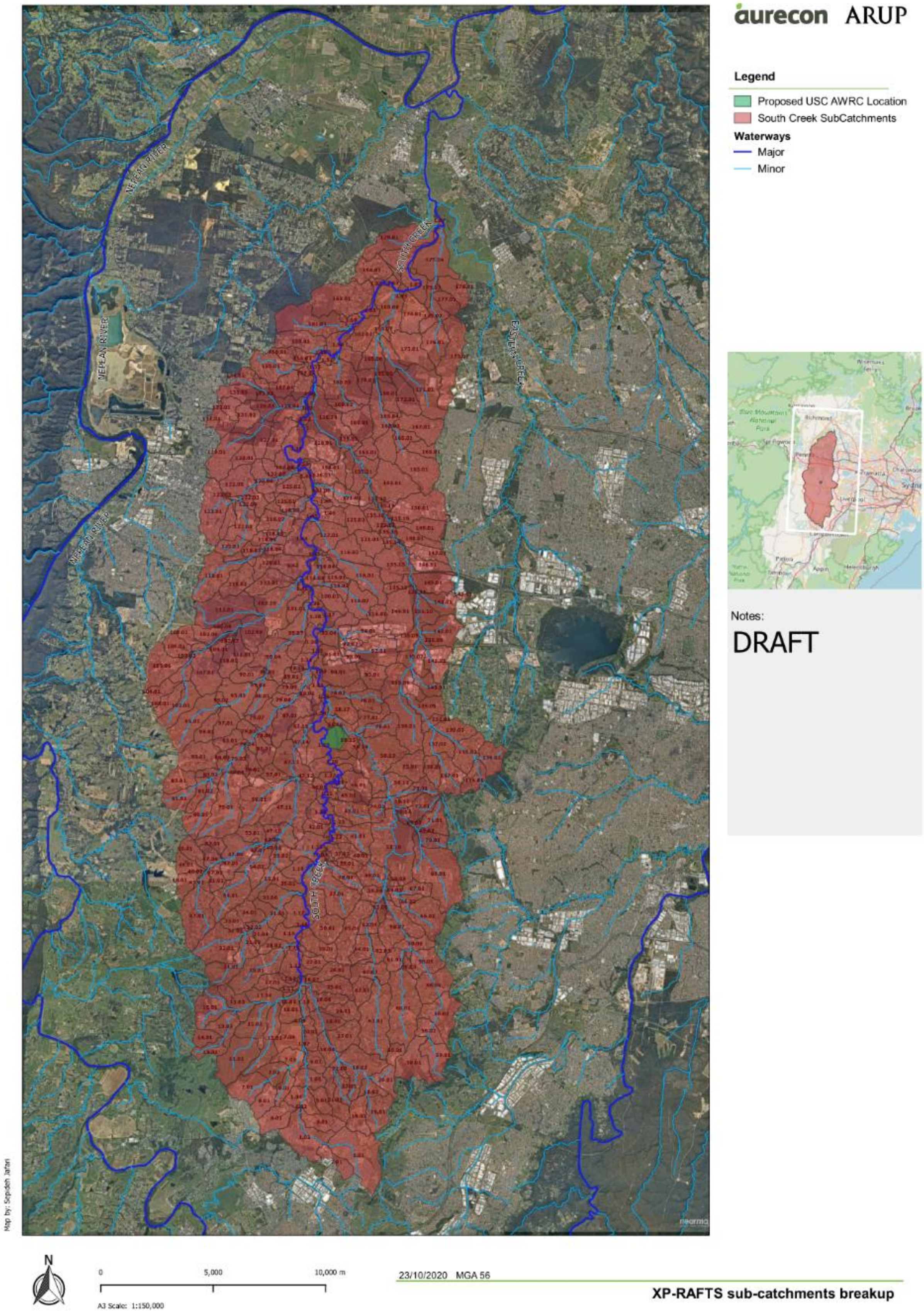


Figure 4-1 XP-RAFTS Sub-Catchments Breakup for USC AWRC site flood assessment

Stream Routing

The time delay lag calculated by Bransby-Williams formula (Queensland Government, 2007), was employed to represent the routing of runoff along the main watercourses into downstream sub-catchments.

Rainfall Data

The 10% AEP, 1% AEP, 0.5% AEP and 0.2% AEP design storm depths were extracted from the ARR Data Hub. The PMP depths were calculated based on the 'Generalised Short Duration Method' (GSDM) procedure (BOM, 2003).

Rainfall Losses

The initial and continuing rainfall loss parameters adopted in the Flood Study Report-South Creek (1990) were used by AAJV (2019) in their study as they calibrated these loss coefficients to historic events (the significant 1986 and 1988 flood events). These initial losses varied by sub-catchment for pervious areas with initial losses ranging from 32.6 to 35.9 mm, and a continuing loss of 0.94 mm/h. For impervious areas an initial loss of 1 mm and a continuing loss of 0 mm/h were adopted. These values were adopted in the current assessment of 1% AEP and PMF events.

ARR 2016

The ARR 2016 methodology was used to simulate the design flows. Eight sets of Intensity-Frequency Duration (IFD) parameters were extracted from BOM, along with the temporal pattern ensembles, pre-burst losses, and aerial reduction factors derived from ARR Data Hub. This was done to represent the spatially varying rainfall across the catchment. The locations of the extracted IFD tables were chosen based on the WorleyParsons (2015) report as shown in shown in **Table 4-2**, to allow comparison of the model results. The extents of the IFD data allocation are shown in **Figure 4-2**.

The 1% AEP critical duration (based on the maximum flow) for the USC AWRC was identified as 12 hours.

Table 4-2 IFD tables specifications

Name	Coordinates		Design Rainfall Depth (mm)	
	Longitude	Latitude	10% AEP – 12 hours	1% AEP – 12 hours
Narellan	150.798	-34.003	108	172
Bangor	150.75	-33.965	102	163
Bringelly	150.757	-33.93	104	166
Elizabeth Drive	150.767	-33.873	104	166
Mt Vernon	150.82	-33.898	107	170
Badgerys CK	150.742	-33.862	106	168
Hewitt	150.785	-33.788	105	168
St Marys	150.782	-33.752	104	166

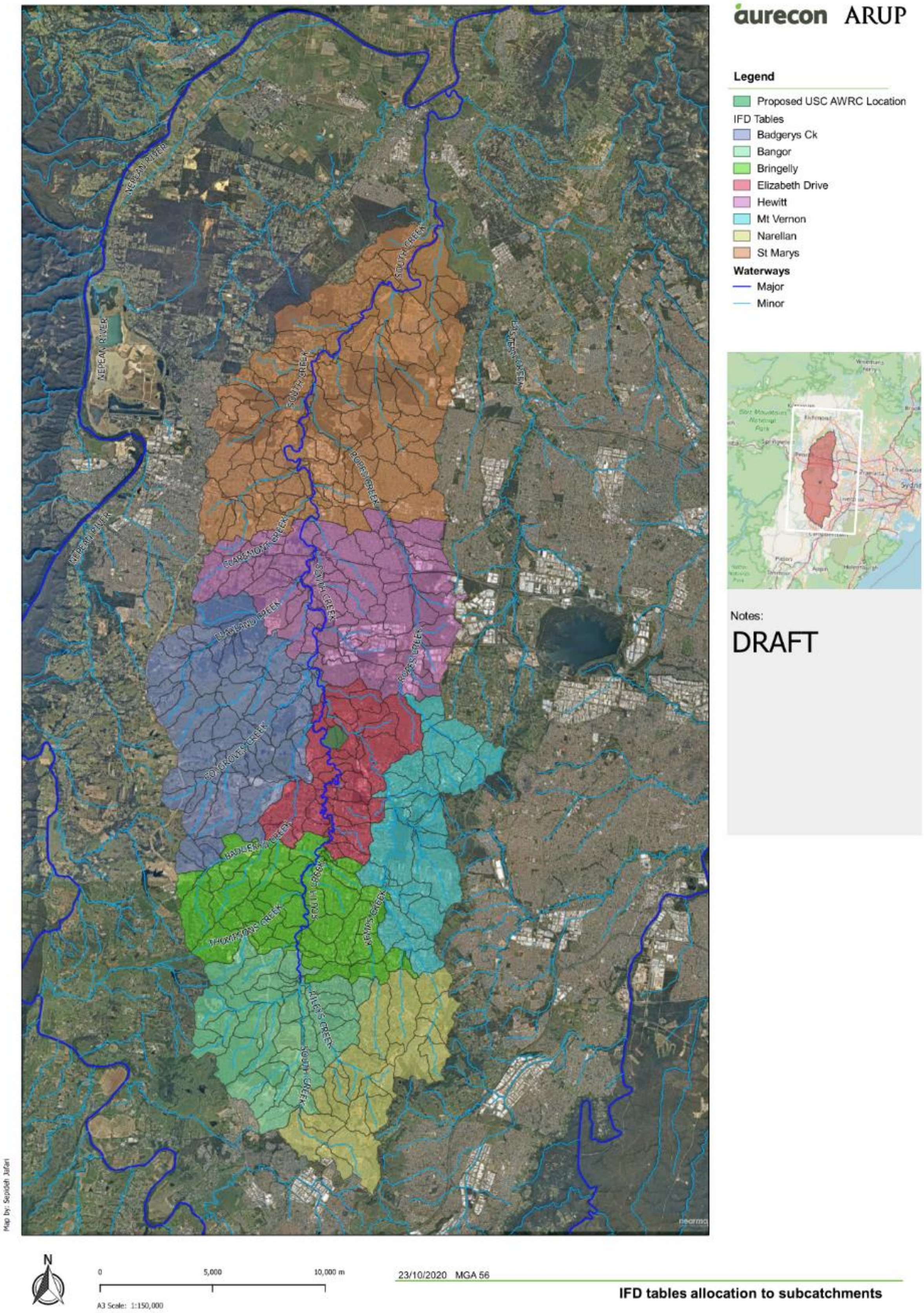


Figure 4-2 IFD Tables Allocation to Sub-Catchments

Validation of the hydrology model

Using the ARR1987 data, the XP-RAFTS model was validated against the Penrith City Council's reference flood study (WorleyParsons 2015), which was done using the ARR1987 data and calibrated based on historical floods in 1986 and 1988. The peak discharge rates at key locations were used to compare the two models. For this purpose, the XP-RAFTS model was run for the 1% AEP 36-hour storm (The critical storm duration at the downstream model extent identified in the 2015 study) based on the ARR1987.

A comparison based on the peak discharges extracted from the USC AWRC XP-RAFTS model and WorleyParsons (2015) is presented in **Table 4-3**.

Table 4-3 Comparison between 1% AEP XP-RAFTS flows and WorleyParsons (2015) models (ARR1987)

Parameter Value		XP-RAFTS Sub-catchment ID		Peak 1% AEP 36-hr Discharge (m^3/s)		% Difference in flows
		WorleyParsons Model	AWRC Model	WorleyParsons Model	AWRC Model	
South Creek	Upstream of Bringelly Rd	1.08	1.13	312	314	1%
	Upstream of Elizabeth Drive	1.13	1.25	479	470	-2%
	Upstream of M4 Motorway	1.23	1.43	1164	1107	-5%
	Upstream of Great Western Highway	1.25	1.44	1175	1119	-5%
Kemps Creek	Bringelly Road	9	62.02	33	32	-3%
Cosgroves Creek	2.5 km downstream of Elizabeth Drive	12.02	79.05	93	95	2%
Badgerys Creek	Upstream of Badgerys Creek Road	5	47.07	53	57	8%

The comparison in **Table 4-3** showed that the differences at the selected locations were less than 10%. At the locations upstream of the proposed development along the South Creek and Kemps Creek, the model results have better agreement with the difference in results being less than 3%.

4.4 Hydraulic Modelling

The 1D/2D TUFLOW model was used to determine the flow direction, flood depths, velocities and hazard in the study area under the existing and design conditions. The TUFLOW model simulated overland flow in two-dimensional (2D) space and through hydraulic structures such as bridges and culverts.

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

4.4.1 Aerial Photography and Base map data

The aerial imagery used in this study was sourced from Nearmap (captured April 2020). Road and LGA boundaries were extracted from the NSW Government, Six Maps Data Centre.

4.4.2 Model topography and grid size

The LiDAR data captured in 2019 was used as the primary source of topographic information, which was used to derive the ground surface levels in the TUFLOW model. A computational grid cell size of 3m was adopted in the TUFLOW model. A topographical representation of the catchment is shown in **Figure 4-3**.

4.4.3 Bridges and culverts

Bridge and culvert locations were sourced from the TUFLOW model by AAJV (2019) as the model that contains the latest survey data. **Table 4-4** summarises the hydraulic structures data located in the downscaled TUFLOW model extent.

Table 4-4 Summary of the hydraulic structures in the TUFLOW model

Parameter	Value
Culverts	2 culverts at the Elizabeth Drive and one downstream of Tadpole Lake
Bridges	2 bridges along the Badgerys Creek at the intersection with Pitt Street and Elizabeth Drive, 2 bridges along the South Creek at the intersection with Elizabeth Drive and Orchard Hills, 1 bridge along the Kemps Creek at the intersection with Elizabeth Drive

4.4.4 Boundary conditions

The downstream boundary condition at the Hawkesbury-Nepean River and South Creek confluence was sourced from WorleyParsons (2015) study as shown in **Table 4-5**. The downstream boundary condition was applied as a fixed water level. Each simulation was run with the similar design AEP tailwater.

Table 4-5 Downstream Tailwater

Design Event	Tailwater Level (m AHD)
10% AEP (10 Year ARI)	12.3
1% AEP (100 Year ARI) (including Climate Change scenario)	17.3
0.5% AEP (200 Year ARI)	18.7
0.2% AEP (500 Year ARI)	20.2

Design Event	Tailwater Level (m AHD)
PMF	26.4

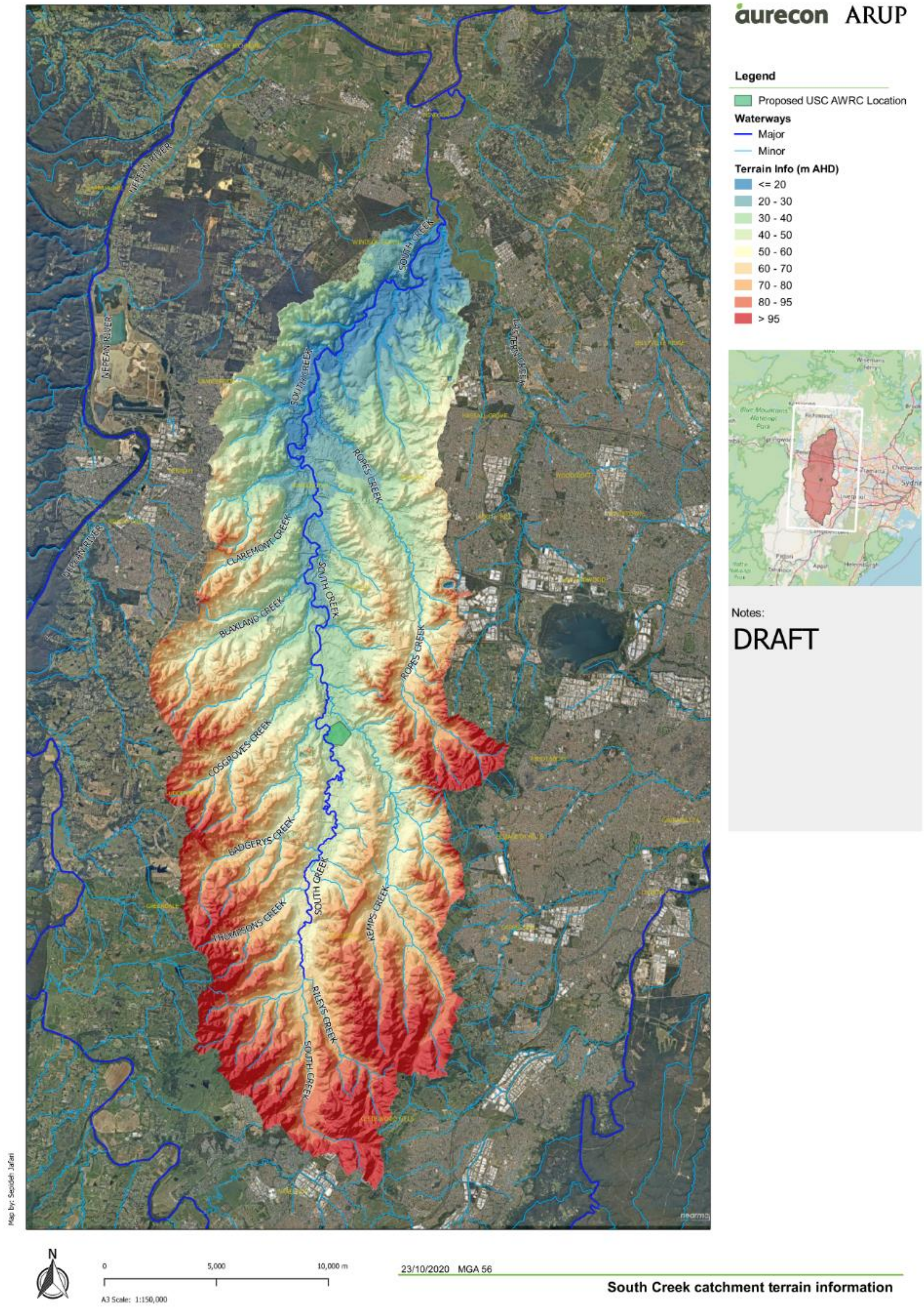


Figure 4-3 South Creek Catchment Terrain Information

In addition to the downstream boundary conditions, the delineated sub-catchments in the hydrological model were used to create SA inflow polygons as internal boundaries. The inflow hydrographs for each sub-catchment obtained from XP-RAFTS were applied in the hydraulic model, using SA boundary approach (2d_sa).

At the confluence with Eastern Creek, there were two locations (sub-catchments EC40 and EC48) where flow-time boundaries (shown in **Figure 4-4**) were taken from the AAJV (2019) model to represent the Eastern Creek upstream catchment hydrology. The inflows were originally taken from the *Eastern Creek Catchment Hydrological Assessment – Blacktown City Council* (WMAWater, 2013). The TUFLOW model layout of the entire South Creek catchment is shown in **Figure 4-5**.

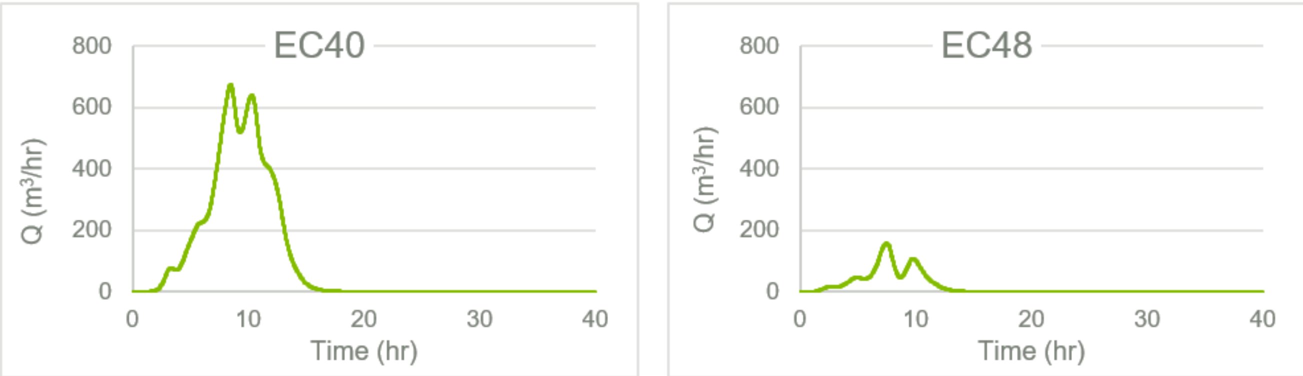


Figure 4-4 The EC40 and EC48 sub-catchment hydrographs

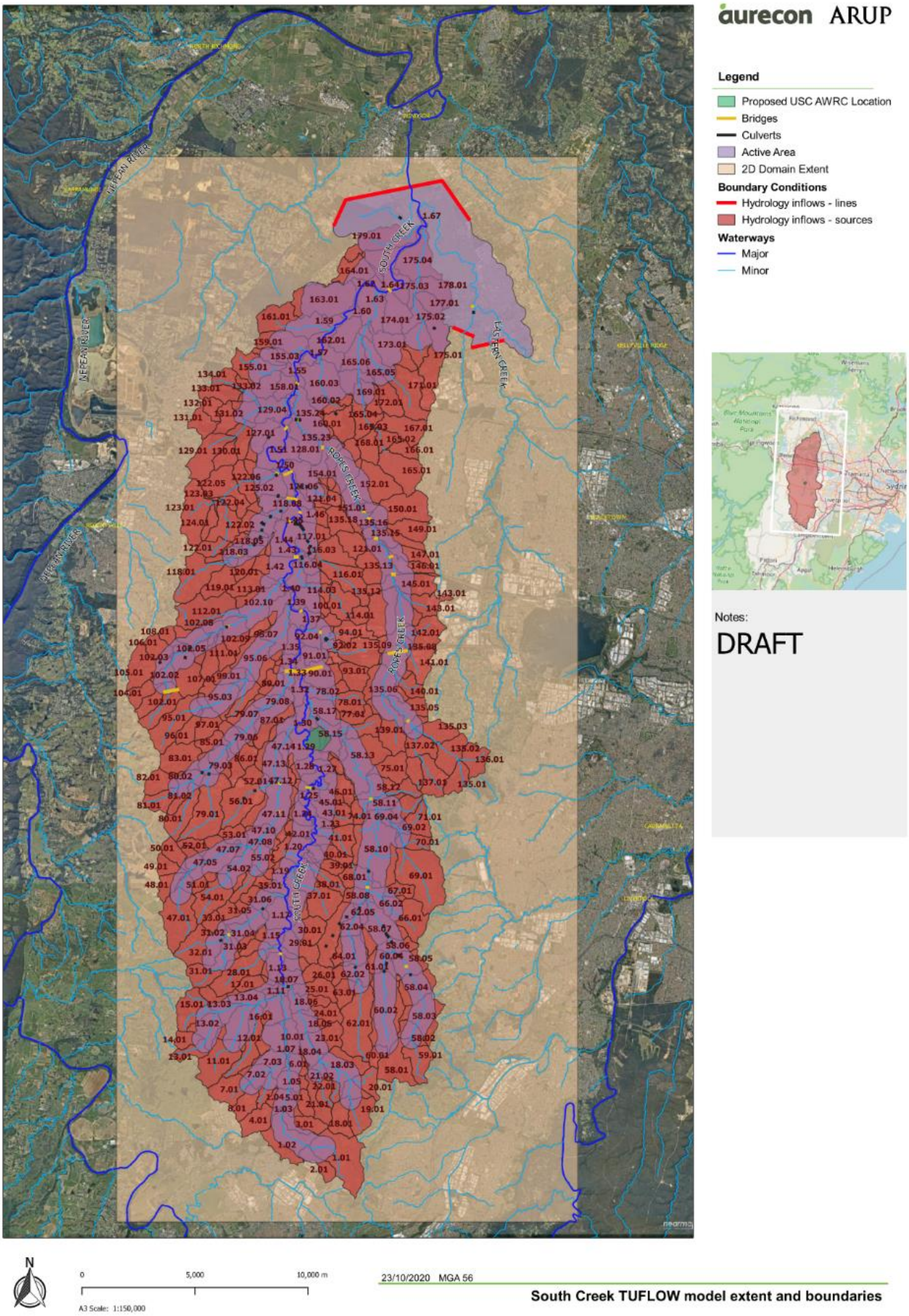


Figure 4-5 South Creek TUFLOW Model Extent and Boundaries

4.4.5 Land use

Land use data is required to estimate surface roughness coefficients (Manning's "n"). The data used was based on *Environment Planning Instrument - Land Zoning* (NSW Planning and Environment, 2008) Geographic Information System (GIS) data. This data was used for the purpose of maintaining consistency with that used in the South Creek Flood Study (WorleyParsons, 2015), currently adopted by Penrith City Council. Updates to the model's Manning's roughness values were made as part of the AAJV (2019) updates. These updates were based on aerial images and site observations to represent the floodplain more accurately.

The adopted roughness values for each land use are presented in **Table 4-6** and the spatial representation of the hydraulic roughness is shown in **Figure 4-6**. Open water land use was used for proposed detention basins and wetland.

Table 4-6 Adopted Surface Roughness Values (Manning's n) for different land uses

Material Type	Manning's n Coefficient
Moderately vegetated creek channel	0.100
Heavily vegetated creek channel	0.120
Grassed floodplain and sparse trees	0.050
Floodplain with moderate coverage of trees	0.080
Floodplain with dense trees	0.120
Urban Floodplain	0.040
Industrial Development	0.090
Roadways	0.020
Lightly vegetated creek channel	0.080
Residential	0.080
Rural Residential	0.060
Open Water	0.035
Concrete lined channels	0.015

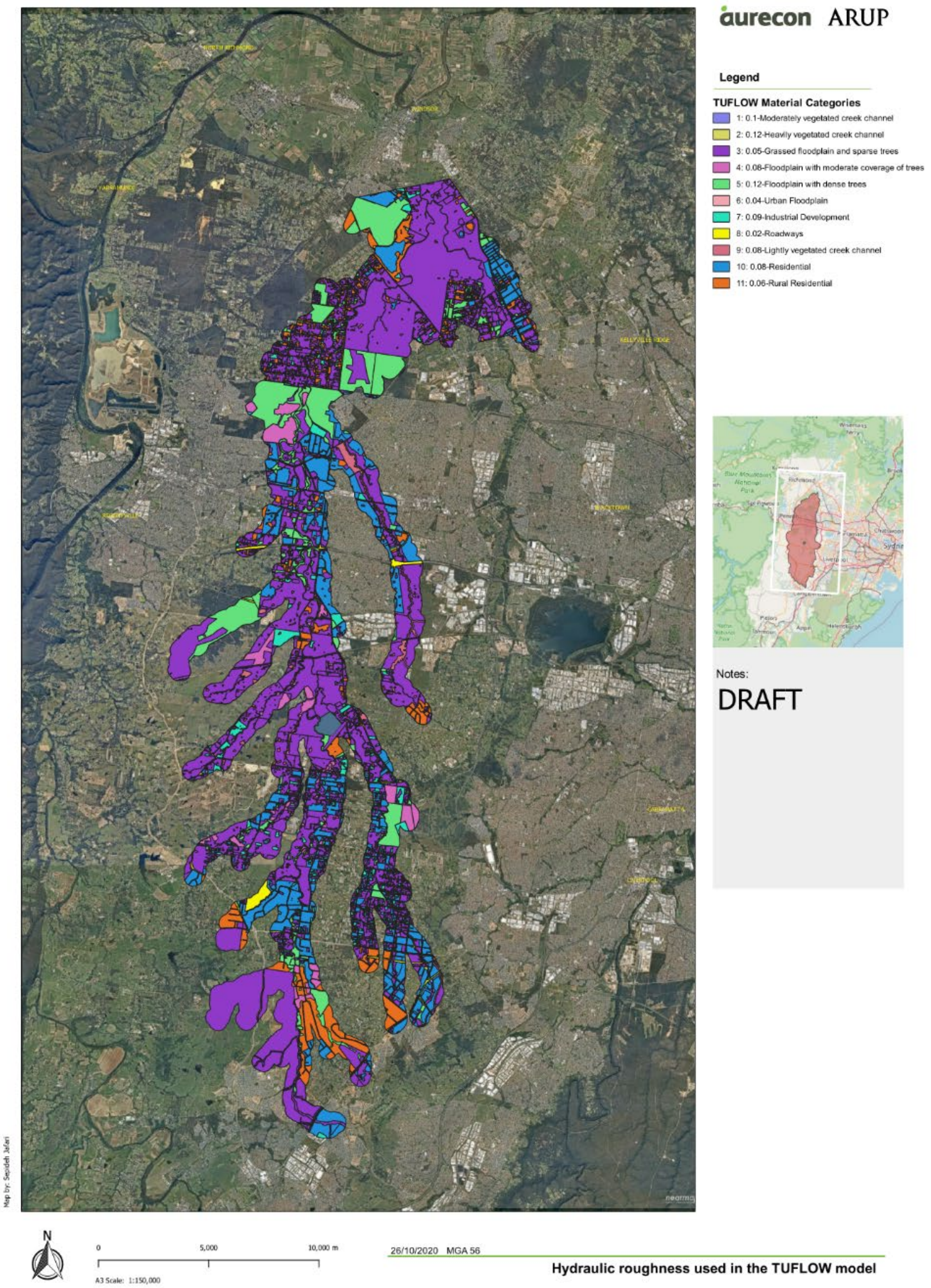


Figure 4-6 Hydraulic Roughness Used in the TUFLOW Model

4.4.6 Refinement of the hydraulic model

The limitations of coarse resolution AAJV (2019) model is appropriate for the regional scale coverage; however, is not considered refined enough for this study area. As such, the AAJV (2019) TUFLOW model covering the entire South Creek catchment was downscaled to a limited extent surrounding the project are to allow for a finer computational grid cell size of 3m without significant increase in the simulation time.

To provide a downscaled model (with appropriate upstream boundary condition), four flow extraction locations (PO lines) were added to the coarse South Creek TUFLOW model, as shown in **Figure 4-7.** These flow extraction locations extracted flow time-series (QT) of Kemps Creek, South Creek, Badgerys Creek and Cosgroves Creek upstream catchments for all design events and temporal patterns (TPs).

The boundary conditions were located far enough away from the proposed development to prevent the influence of boundary effects on flood levels around the study area. This was evaluated through comparisons against the full uncut AAJV (2019) model.

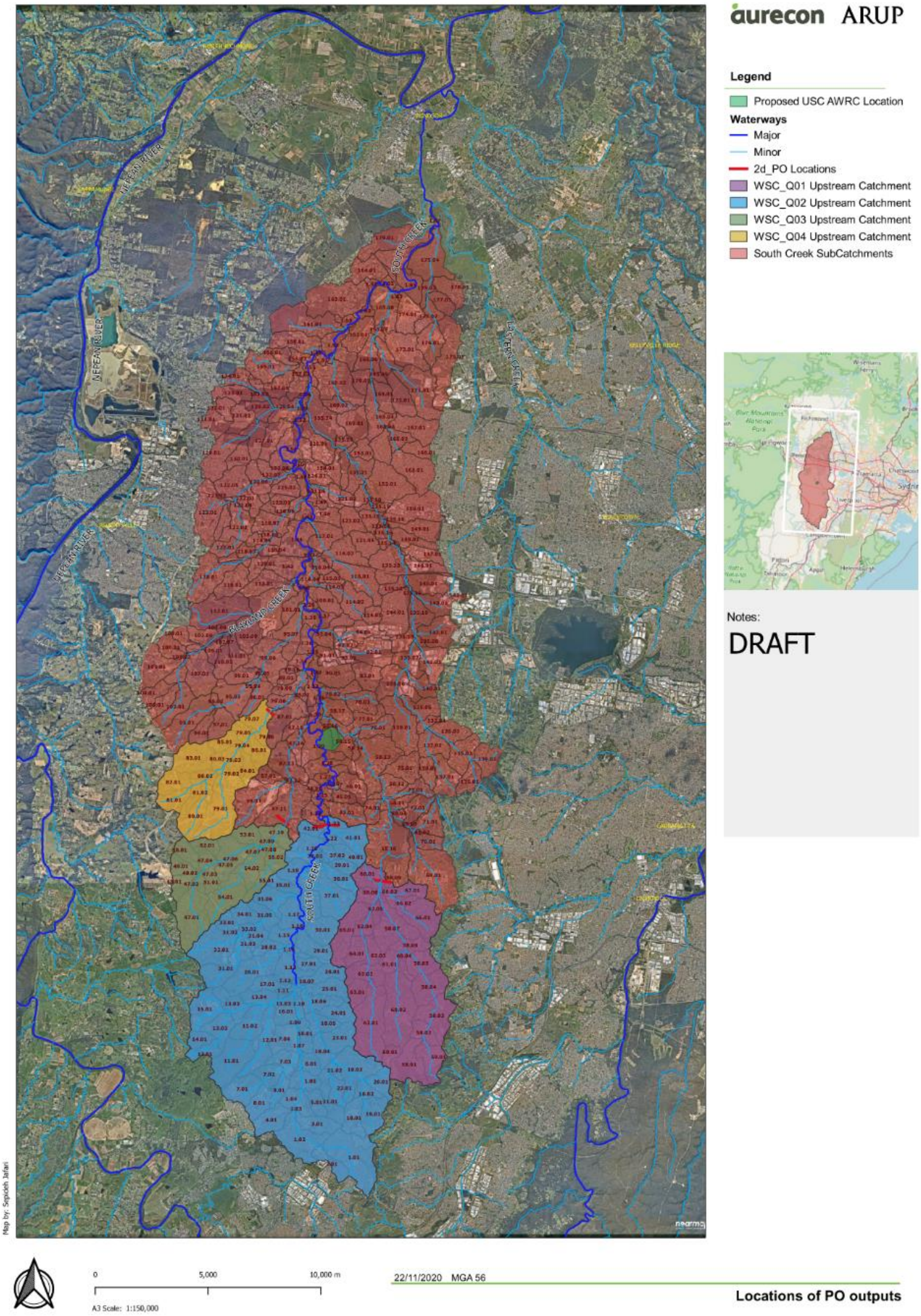


Figure 4-7 Location of PO Outputs

These hydrographs later were used as the upstream boundary conditions for the downscaled hydraulic model to represent their respective upstream catchment flows. The inflow hydrographs at these locations are shown in **Figure 4-8.**

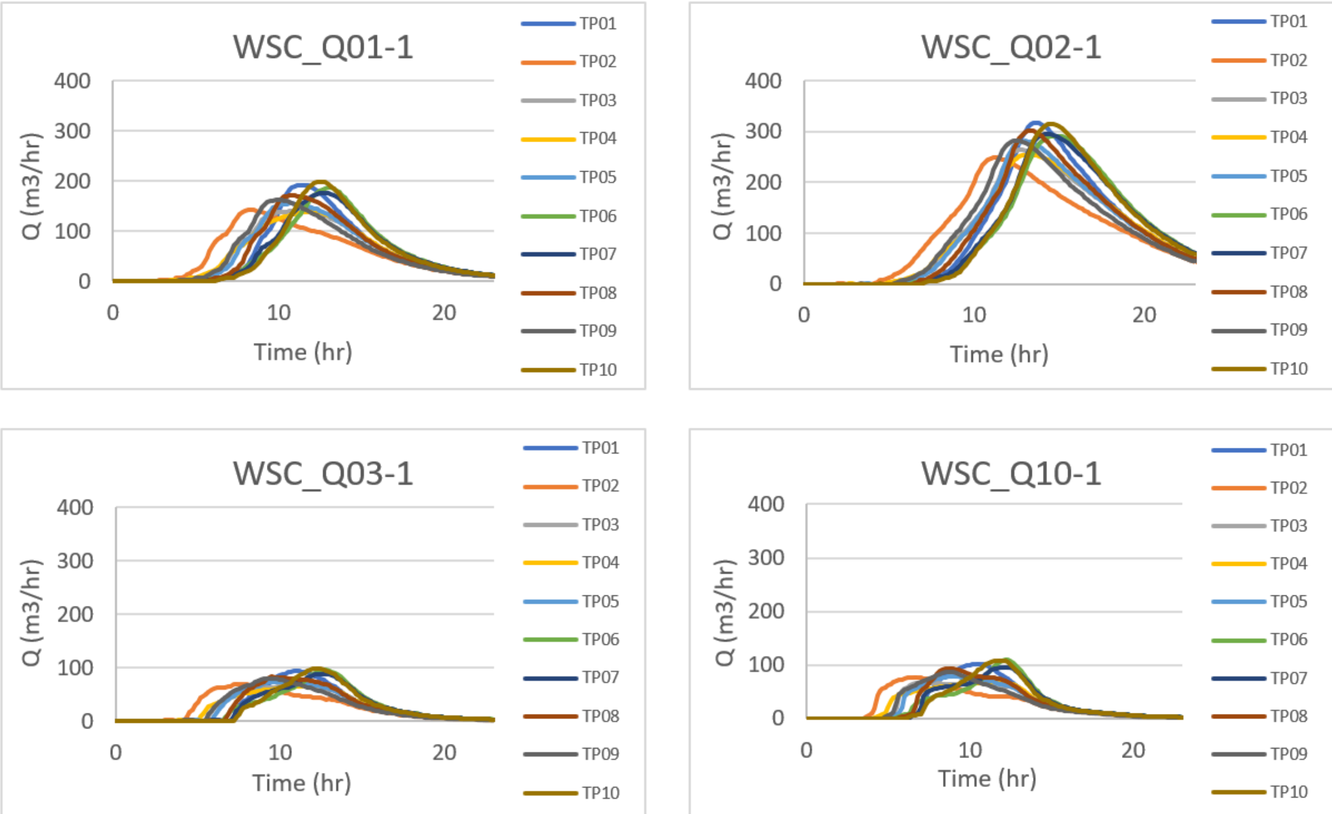


Figure 4-8 The 1% AEP 12-hour Upstream Inflow hydrographs used in the downscaled Model

At the downstream end of the new model extent a normal depth HQ boundary condition (2D-HQ) was applied. This boundary condition assigns a water level based on the total flow across the line. TUFLOW can automatically generate the HQ curve if a slope is specified in the attribute table of this boundary condition.

To prevent the water levels around the proposed development being influenced by the boundary condition, it was located well away from the area of interest.

A comparison was made between the downscaled and the original AAJV (2019) model to confirm that the water level differences due to the changes in boundary conditions are reasonable.

The downscaled model extent with assigned boundary conditions is shown in **Figure 4-9.**

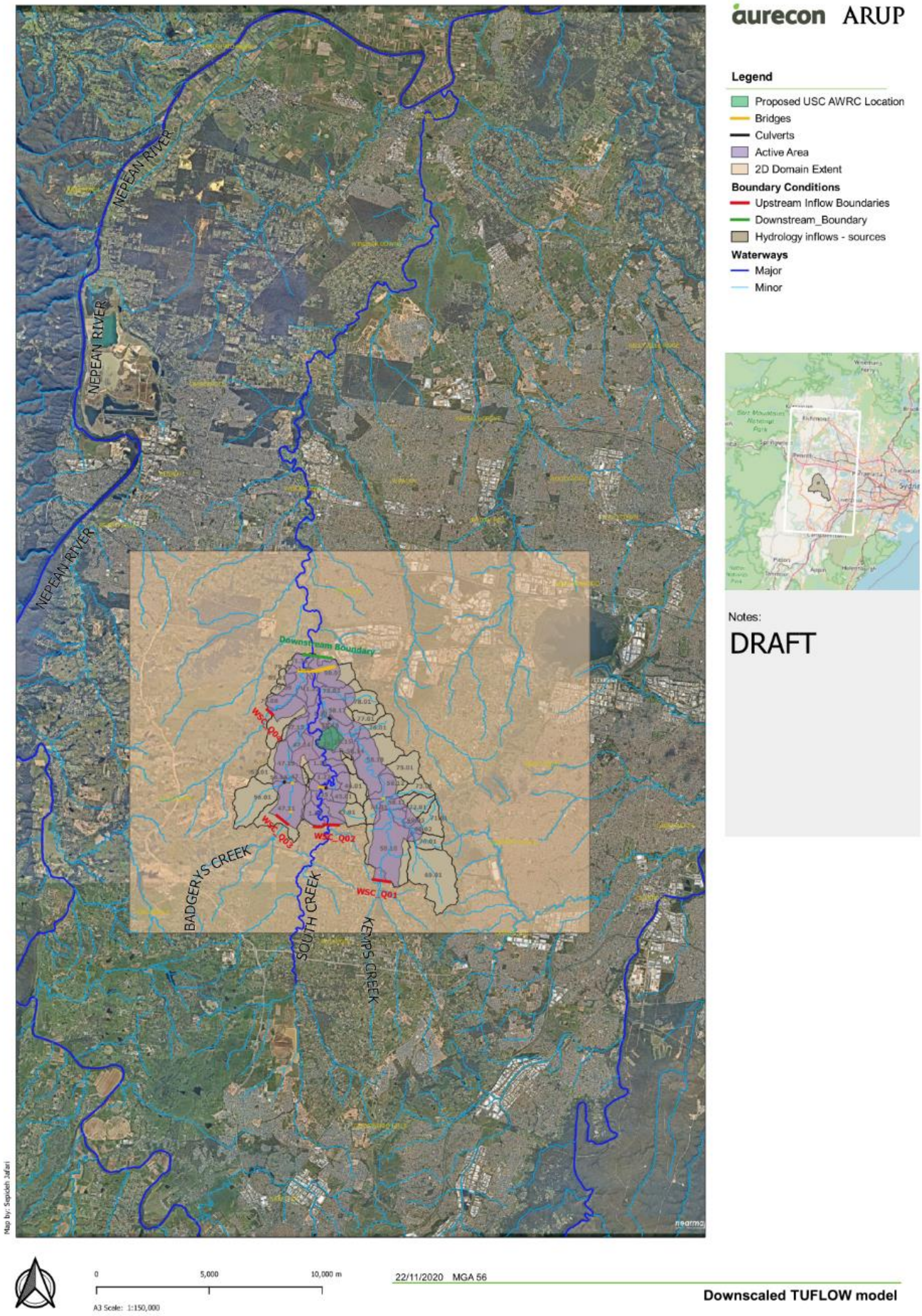


Figure 4-9 Downscaled TUFLOW Model extent

4.4.7 Validation of the hydraulic model

Validation of the downscaled South Creek TUFLOW model was undertaken by comparing against the WorleyParsons (2015) study. Since the WorleyParsons (2015) study was based on ARR1987, the current model was rerun using the ARR1987 1% AEP rainfall data and temporal patterns.

A comparison of flood extents around the USC AWRC site is shown in **Figure 4-10**. The map presented in **Figure 4-11** shows the differential in levels from the two models. **Table 4-7** presents a comparison between the peak flood levels from the two models at key locations shown in the corresponding figure.

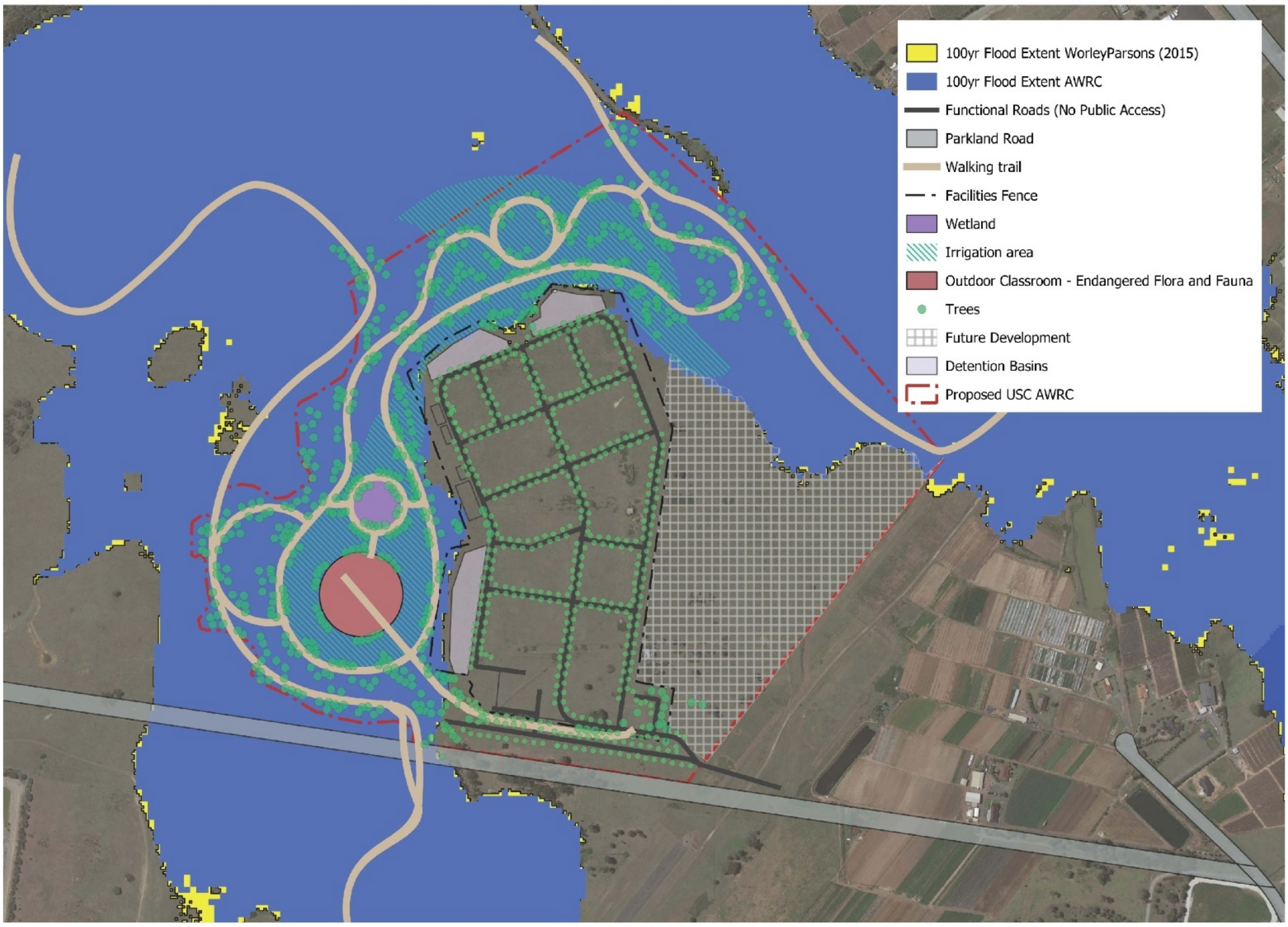
The comparison of flood levels showed that the difference across the majority of the floodplain within the area of interest is in the range of ±200 mm (locations 6, 7 12, 13, 16 from **Table 4-7**). This is considered reasonable given that differences are likely a result of the different software used (i.e. TUFLOW has been used by the AWRC study for hydraulic modelling compared to RMA-2 software used by WorleyParsons (2015)). In addition, WorleyParsons (2015) used a combination of ALS datasets from 2002 to 2006 while the present study has used 2019 Lidar.

A comparison of the topographic datasets was undertaken and spatially presented in **Figure 4-12**. The comparison showed some consistencies between points with higher topographic levels corresponding higher flood levels compared to the Worley Parsons (2015) study. However, this is not consistently the case and likely related to the different software solution schemes and model reporting locations.

Table 4-7 Design Flood Levels Comparison with WorleyParsons (2015) based on ARR1987

Creek name	Key Locations	1% AEP Levels WorleyParsons Flood Study (2015) (mAHD)	1% AEP Levels AWRC study (mAHD)	Difference (m)
South Creek	1- Bellfield Avenue	57.44	57.20	-0.24
	2- Wynyard Avenue	56.32	56.31	-0.01
	3- Fifteenth Avenue	51.48	51.66	0.18
	4- Watts Road	49.71	49.67	-0.04
	5- Overett Avenue	43.59	43.58	-0.01
	6- Downstream Elizabeth Drive	41.72	41.79	0.07
	7- Upstream of study area	39.07	39.08	0.01
	13- Downstream of study area	36.51	36.69	0.18
	17- Upstream Erskine Park	33.77	34.10	0.33
Kemps Creek	8- Fifteenth Avenue	57.31	57.11	-0.20
	9- Gurner Avenue	55.40	55.40	0.00
	10- Cross Street	48.11	48.08	-0.03
	11- Downstream Elizabeth Drive	46.50	46.65	0.15
	12- Upstream of study area	39.30	39.40	0.10
Badgerys Creek	14- Upstream Elizabeth Drive	46.68	46.79	0.11
	15- Downstream Elizabeth Drive	45.37	45.62	0.25

Creek name	Key Locations	1% AEP Levels WorleyParsons Flood Study (2015) (mAHD)	1% AEP Levels AWRC study (mAHD)	Difference (m)
	16- Upstream of South Creek confluence	38.47	38.68	0.21



Source: Aurecon, Sydney Water, LPI, Nearmap, ESRI, Worley Parsons
Date: 12/03/2021

1:13,000
0 100 200m

Advanced Water Recycling Centre

Projection: GDA2020 MGA Zone 56

Figure 4-10 WorleyParsons (2015) and AWRC study 1% AEP flood extents using ARR 1987 Guidelines

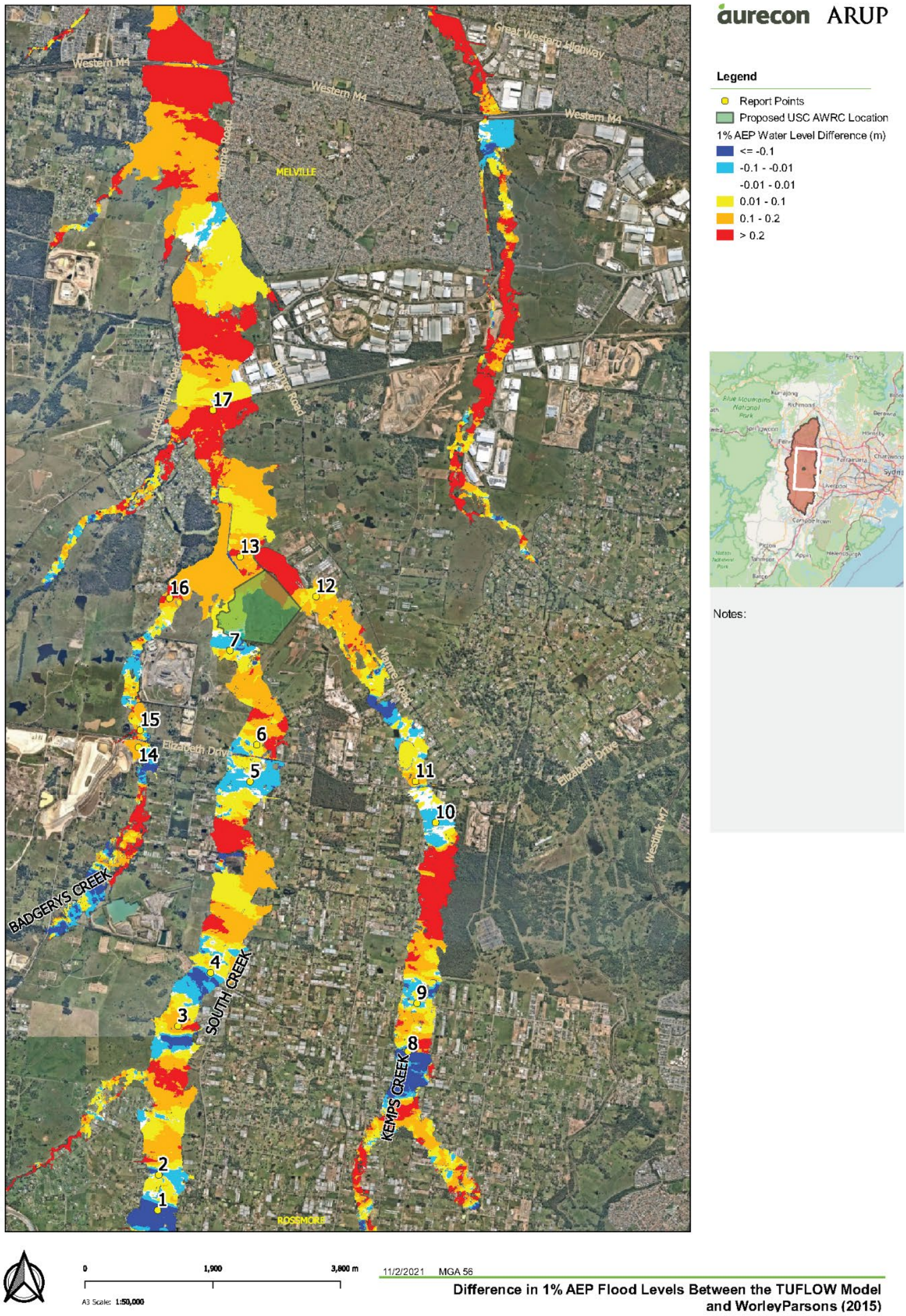


Figure 4-11 Difference in 1% AEP Flood Levels Between AWRC Model and WorleyParsons (2015)

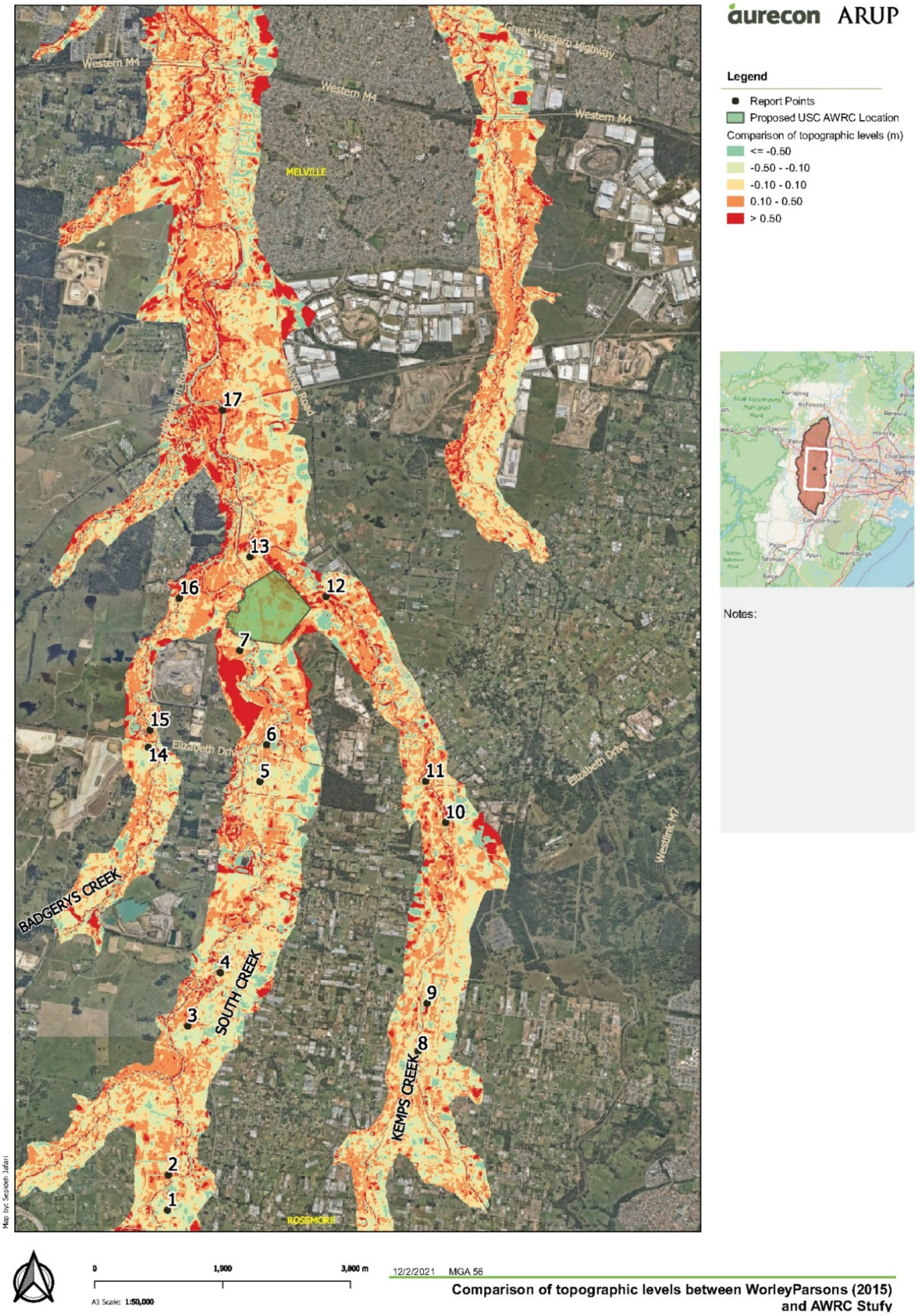


Figure 4-12 Comparison of topographic levels between WorleyParsons (2015) and AWRC Study

A comparison was also made between the modelled flowrates and those estimated from different methods using the observed streamflow records of South Creek at Mulgoa Road, just upstream of Elizabeth Drive (Gauge No.212320). The NSW Office of Environment & Heritage undertook a review of ARR design inputs for NSW (WMA Water, 2019) using the historical flow records at NSW streamflow gauges. **Figure 4-13** presents the comparison provided in this study between the various methods of estimating the peak flow at the Mulgoa Road gauge.

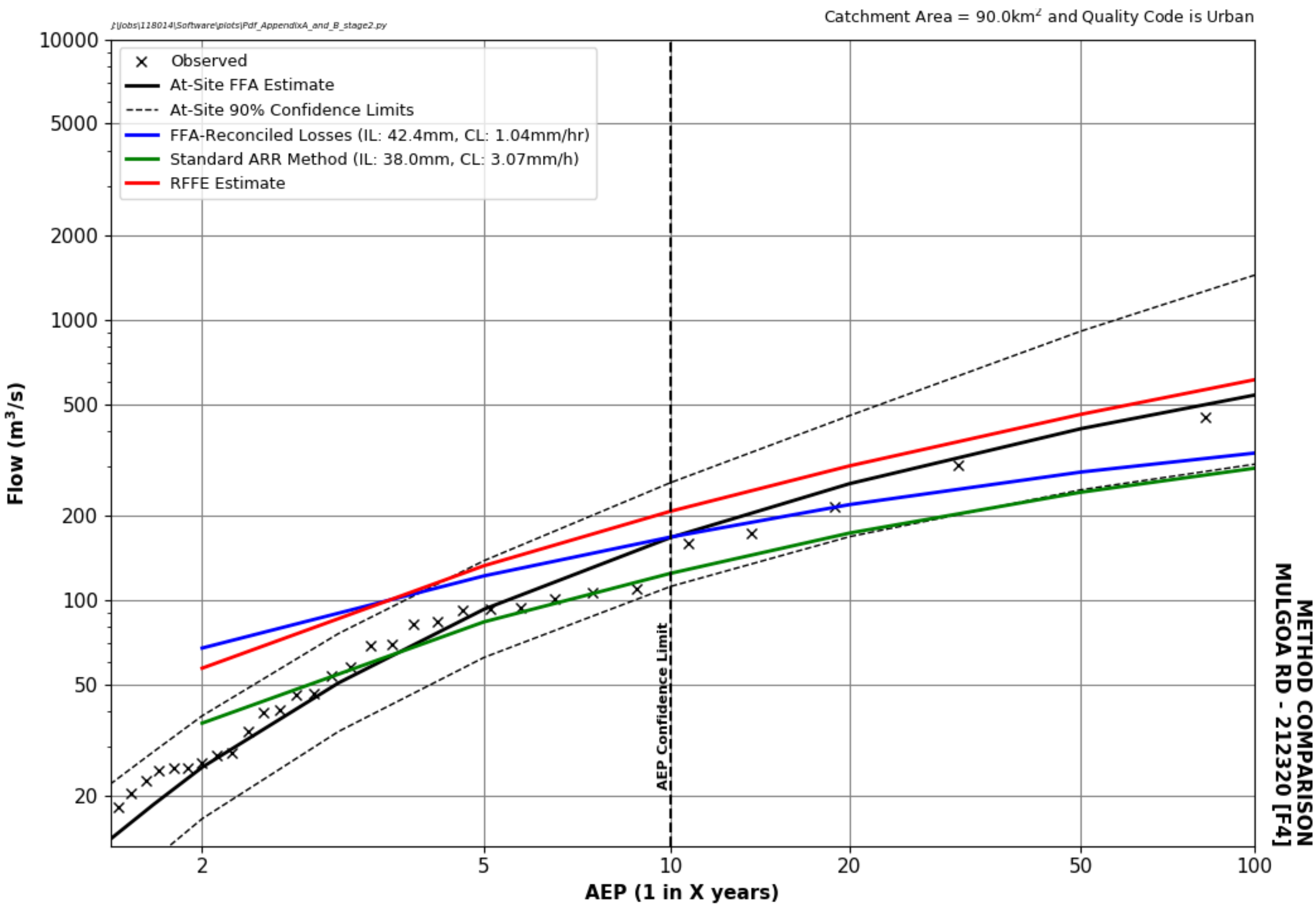


Figure 4-13 Comparison of flow estimation methods at Mulgoa Rd Gauge (WMA Water, 2019)

The modelled flowrates at the location of this gauge are presented in **Table 4-8**. They are within the 90% Confidence Limits in **Figure 4-13** and in very good agreement with the flood frequency estimates associated with the application of standard ARR 2016 methods (green curve in the figure).

A flood study of South Creek was also undertaken by Advisian using the RMA-2 hydraulic model (2020). The modelled 1% AEP flow from this study is also included in **Table 4-8.**

Table 4-8 Modelled South Creek flood flowrates upstream of Elizabeth Drive

Event modelled	WorleyParsons (ARR 1987)	OEH Study^ (At-site FFA*)	OEH Study^ (ARR 2016)	Advisian Study (ARR 2019)	AWRC Study (ARR 2016)
10% AEP flowrate (m³/s)	-	170	124		115
1% AEP flowrate (m³/s)	450	538	295	492	290

Event modelled	WorleyParsons (ARR 1987)	OEH Study^ (At-site FFA*)	OEH Study^ (ARR 2016)	Advisian Study (ARR 2019)	AWRC Study (ARR 2016)
0.5% AEP flowrate (m^3/s)	520	-	-	-	321
0.2% AEP flowrate (m^3/s)	600	-	-	-	384
PMF	1680	-	-	-	1651

^ Now known as DPIE
* Flood Frequency Analysis

As seen in, **Figure 4-13** the green curve (and the modelled flows of the current study) is close to the lower boundary of the 90% Confidence Limit envelope. This envelope has been generated based on the data points from the Mulgoa Road gauge, which are estimated peak flows from the rating curve of this gauge for the observed flood levels. It is expected that the discharge estimates at this location for high flows are associated with inaccuracy, as also identified in the Upper South Creek Flood Study, in which the gauge was used as a source of stage rather than discharge for the following reasons (WMA Water, 2012):

- lack of gauge ratings carried out for high flows
- the gauge can be backwatered by retardation of flow at Elizabeth Drive (a mechanism likely to be exacerbated by blockage during flood events).

This suggests that the OEH study may have overestimated the 1% AEP discharge rate using the At-site FFA, and the modelled 1% AEP discharge rate of 290m^3/s would be a more representative of the catchment flows at this location for such event.

It should be noted that while the results of the current study have been used for the purpose of flood impact assessment, the AWRC design levels were based the more conservative flood levels from the Worley Parsons (2015) study. This approach was to mitigate any uncertainties in the calibration data and ARR 2019 results.

A review of the AWRC model calibration should be undertaken at the detailed design stage to capture any new information or uncertainties in the current calibration information.

To build more confidence in the conclusions of the current assessment, an additional scenario was also modelled in which the peak flow rate at Elizabeth Drive was set to the 1% FFA flow of 538 m^3/s. This was done to ensure the flooding impacts for that flow rate will be captured and the conclusions of the current study remain valid for the FFA flow. Further details of this assessment are provided in **Section 7.2.4.8**.

4.4.8 Scenarios modelled

As part of this assessment, two flood scenarios were modelled:

Existing Case (This is representative of the existing site conditions):

- The downscaled TUFLOW model with 3m resolution

Design Case (This is to represent the proposed development including the design terrain information):

- The downscaled TUFLOW model with 3m resolution and the provided finished surface of the proposed development.

The following steps were undertaken to simulate the design scenario:

- Topographic changes: Triangulated Irregular Networks (TIN) were developed to define the developed surface levels.
- Manning's modifications: The roughness coefficients were adjusted to reflect the changes in land use within the proposed development.
- Impervious areas: It was calculated that the impervious area of the catchment [sub-catchment number 1.29 (refer to **Figure 4-5**)] increased by 10% as a result of the proposed development, based on area calculations.

The Design Case was set up and run for 10% AEP, 1% AEP, 1% AEP plus climate change, 0.5% AEP, 0.2% AEP, the 1% AEP FFA flow and PMF. The model was run for the critical durations and the ensemble of rainfall TPs. The median peak flood depths, levels and velocities and hazard categories across the modelled design events were obtained for the purpose of flood impact assessment.

Comparisons were made between the peak flood levels for each of these scenarios to investigate and identify the potential impacts resulting from the project to the existing flooding conditions.

4.4.9 Design events

The current analysis includes the 0.2%, 0.5%, 1% and 10% AEP, the 1% AEP FFA flow and the PMP storm events. The assessment of the potential effects of climate change on the 1% AEP events was also included in the current assessment.

To investigate the impact of climate change, an increase of 10% and 20% in rainfall intensity was applied to the model inflow boundaries, in accordance with the recommendations in the Floodplain Risk Management Guideline-Practical Consideration of Climate Change (DECC, 2007).

As the proposed development is sufficiently far away from the Hawkesbury River, it is not expected to be affected by the changes in sea levels resulting from climate change. As such, the sensitivity test was undertaken based on an increase of 10% and 20% in rainfall intensity only.

The 12-hour 1% AEP storm and 6-hour PMP storm event were identified to be the critical storm durations at the proposed location of the site. These events along with 10% AEP design storm were assessed for the ensemble of storm TPs. The ARR2016 provides 10 recommended TPs per storm duration.

The adopted design storm event was based on the patterns that generated the upper median flood height at the subject property.

4.4.10 Summary of hydraulic model data

An overview of the data and information used in the hydraulic model are presented in **Table 4-9**.

Table 4-9 USC AWRC hydraulic model setup overview

Parameter	Information
Hydraulic Modelling Approach	TUFLOW software version Build 2018-03-AC – GPU - HPC
Aerial Imagery	Nearmap captured April 2020
Coordinate System	GDA94/MGA zone 56
Model Extent	As shown in **Figure 4-9**.
Scenarios	The existing case and design case scenarios
Design Events	10% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMP
Topography	LiDAR 2019
Grid Size	3m
Land Use	Based on **Table 4-6** and **Figure 4-6**.
Upstream Boundary	Flow-Time (QT) boundary obtained from XP-RAFTS model in scenario 1, Flow-Time (QT) boundary obtained from TUFLOW model in scenario 2 and 3
Downstream Boundary	HQ boundary conditions
Internal Boundaries	SA polygons based on the XP-RAFTS model
Bridges and Culverts	Based on **Table 4-4**

4.5 Impact assessment

The impact assessment will be performed by identifying the potential impacts of the proposed development, including its temporary components and related activities during the construction and operational phases, and assessing the significance of the observed impacts.

The methodologies adopted for the modelling analyses, which were used to inform the assessment, are described in **Section 7**.

5 Existing Environment

5.1 Climate

5.1.1 Historical records

The Bureau of Meteorology (BOM) database was used to identify weather observation stations close to the study area. The identified stations were further assessed to determine the most representative set of records. The results are summarised in **Table 5-1**.

Table 5-1 Local rainfall gauges metadata

Gauge ID	Location	Distance (km)	Elevation (m)	Years active	Percent complete	MAP*
067066	Erskine Park Reservoir	5.9	85	Jul 2013 – Mar 2020 [7 yr]	99%	649
067108	Badgerys Creek AWS	6.2	81	Nov 1995 – Mar 2020 [25 yr]	93%	706
067119	Horsley Park Equestrian Centre AWS	7.6	100	Oct 1997 – Mar 2020 [23 yr]	97%	748
067114	Abbotsbury (Fairfield)	8.0	75	Dec 2000 – Mar 2020 [20 yr]	94%	700
067084	Orchard Hills Treatment Works	8.6	93	Dec 1970 – Jan 2020 [50 yr]	97%	780
067019	Prospect Reservoir	13.3	61	Jan 1887 – Mar 2020 [133yr]	99%	874
***Mean Annual Precipitation (MAP) is calculated over the years with complete datasets**						

The following primary factors were used to assess the data records:

- Completeness of rainfall record
- Distance from the USC AWRC site
- Record length

Considering the above factors, the Badgerys Creek AWS and Orchard Hills Treatment Works stations were analysed further. Comparing only the period with overlapping data (and excluding months with any missing data), the MAP for the two sites were calculated as 698 mm and 714 mm, respectively, over this period. As the two gauges show correlated measures on a monthly and annual basis, the Orchard Hills station's data record was selected as the representative record, given the longer and more complete dataset.

Representative evaporation data was sourced from the Scientific Information for Land Owners (SILO) database (SILO, 2020). The metadata associated with the stations closest to site is summarised in **Table 5-2**.

Table 5-2 Details of gauges with available evaporation data close to study area

Gauge ID	Location	Elevation (m)	Data availability	MAE[1] (mm)
67068	Badgerys Creek McMasters F.stn	65	Jan 1970 – Apr 2020	1,475
67108	Badgerys Creek AWS	81	Jan 2010 – Apr 2020	1,493
67084	Orchard Hills Treatment Works	93	Jan 1970 – Apr 2020	1,459

The annual total rainfall and pan evaporation values over the 1971 to 2019 monitoring period (excluding the years with prolonged periods of missing data) are shown in **Figure 5-1**. Review of the historical data associated with this station reveals a variable annual rainfall rate. Wetter years, i.e. 1978 and 1990, may experience rainfall in excess of 1,200 mm and drier years record less than 500 mm. The pan evaporation data fluctuates between 1,200 mm and 1,900 mm with an increasing trend observed in the total annual evaporation since 2012.

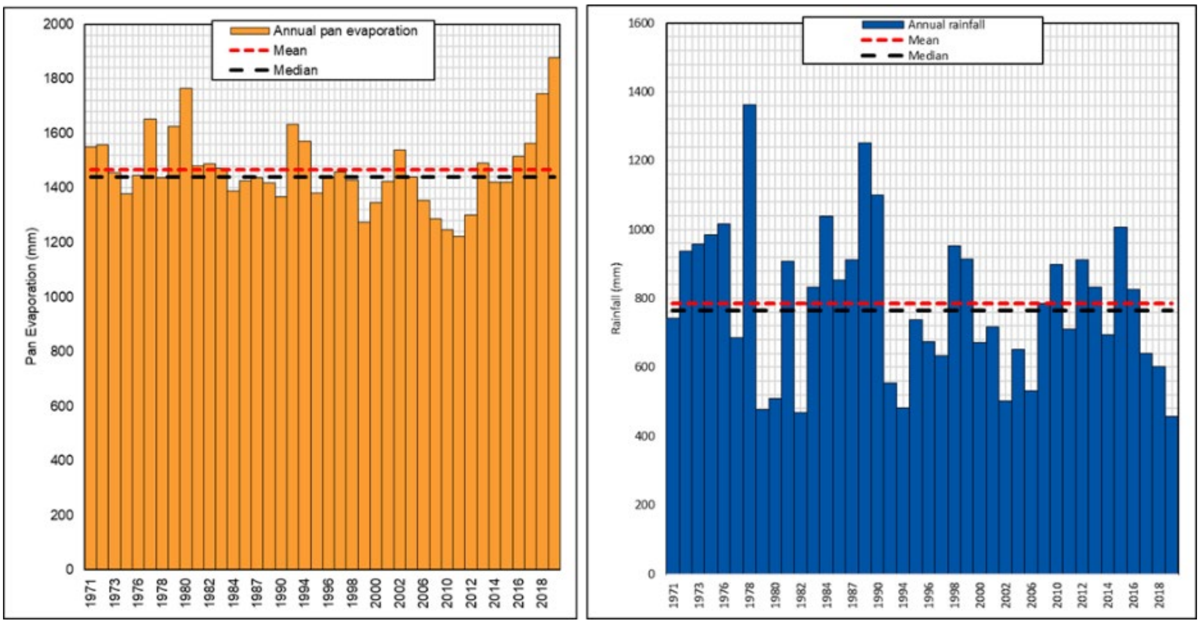


Figure 5-1 Average annual evaporation and rainfall measured - Orchard Hills station (1971-2019)

To better visualize the distribution of the rainfall and evaporation data for each calendar month, a box and whisker and plot chart was developed (**Figure 5-2**). This monthly breakdown, data suggests generally “wet season” from November to May” and “dry season” from June to October. **Figure 5-2** also indicates that in all the months the average evaporation exceeds the average rainfall with December having the highest evaporation rate.

[1] *MAE: Mean Annual Pan Evaporation; Selected site in bold*

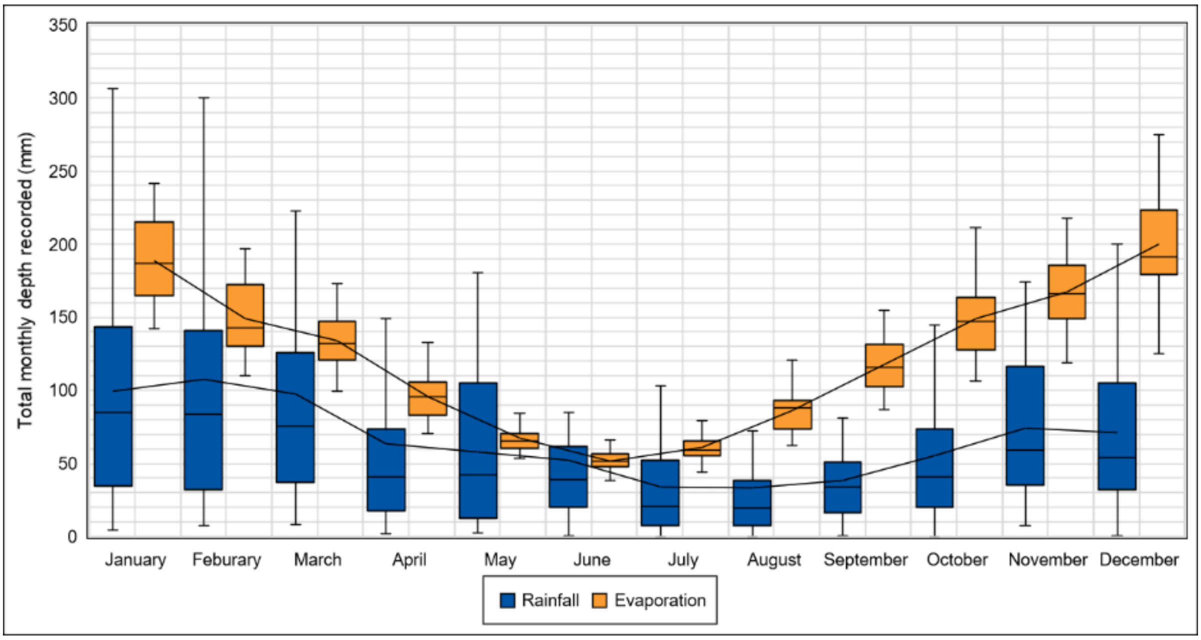


Figure 5-2 Range of total monthly rainfall and evaporation (1971-2019)

Notes: Whiskers show 10th and 90th percentiles. Boxes depict median values, upper and lower quartiles. Trend lines reflect monthly averages.

Design rainfall depths were obtained from the BOM website for the USC AWRC site location. The storm depths associated with various AEP's for the 1-hour and the 24-hour duration events are indicated in **Table 5-3**.

Table 5-3 Daily Rainfall depths associated with different AEP storm events

AEP	1-Hr Rainfall depth (mm)	24-Hr Rainfall depth (mm)
0.5%	76.5	249
1%	70.1	229
2%	62.0	203
5%	51.9	169
10%	44.4	144
20%	37.0	119
50%	26.5	85.0

As temperature data, and its inherent variance, is not as critical as rainfall and evaporation to the local hydrological modelling, the record length at the Badgery's Creek station (067108) was deemed sufficient. Analysis of the these records, presented in **Figure 5-3,** indicates a temperate climate with warm to hot summers (average maximum temperatures around 30°C) and cooler winter periods with average maximum temperatures below 20°C and minimum temperatures averaging around 5°C.

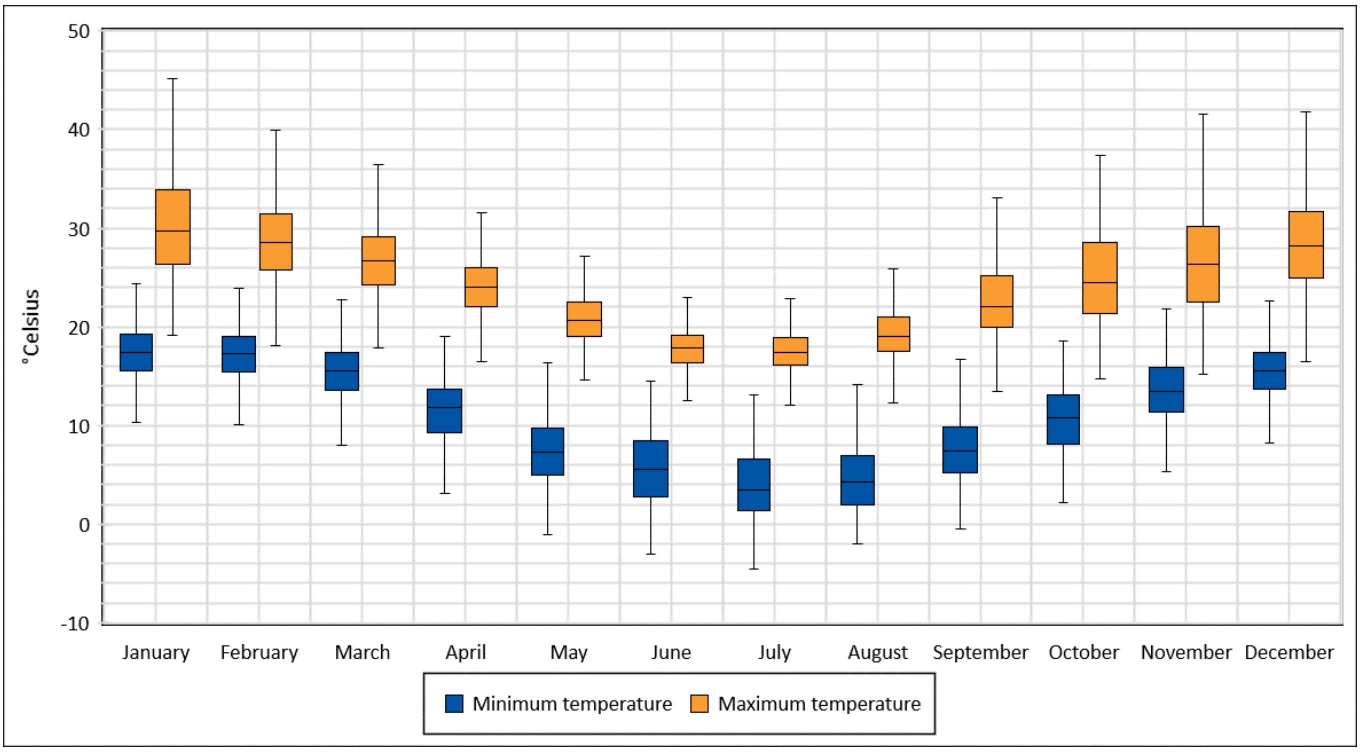


Figure 5-3 Monthly maximum and minimum temperature ranges (1996-2019)

Notes: Whiskers show 10th and 90th percentiles. Boxes depict median values, upper and lower quartiles.

5.1.2 Climate change

Consideration of potential climate change is a crucial factor in assessing the future water resources, as it has the potential to influence the rainfall intensities and subsequent magnitude and frequency of flood flows. The NSW Department of Environment & Climate Change (DECC)'s "*Practical Consideration of Climate Change - Flood risk management guideline*" *(DECC,2007)* is the standard guidelines in NSW to incorporate climate change data in flood assessments and was used to assess expected local climatic changes.

There are two models of climate data in use in Australia which are applicable to this study area. The national model, Commonwealth Scientific and Industrial Research Organisation model (CSIRO), and a local model, the NSW and ACT Regional Climate Model (NARCliM). The CSIRO data is not as granular as NARCliM, which uses downscaled Regional Climate Models (RCMs) derived from Intergovernmental Panel on Climate Change (IPCC)'s Global Climate Models (GCM) to project their findings across three time periods.

Utilising NARCliM, the Office of Environment and Heritage (OEH) (now known as the Department of Planning, Industry and Environment (DPIE)) undertook the Climate change impacts on surface runoff and recharge to groundwater study (2015) that predicted near future (2020-2039) and far future (2060-2079) changes to rainfall, runoff and recharge to groundwater. **Table 5-4** presents a summary of the statistical analysis from this study for Metropolitan Sydney.

Table 5-4 Percent changes to multi-model mean annual rainfall, surface runoff and recharge

	Percentage change in near future (2020-2039)			Percent change in far future (2060-2079)		
State planning region	**Rainfall**	**Runoff**	**Recharge**	**Rainfall**	**Runoff**	**Recharge**
Metropolitan Sydney	0.4	4.0	-5.0	8.1	17.6	12.5

The results of this model for the Hawkesbury catchment are presented in **Table 5-5**. In summary, the OEH (2015) study predicted that changes in near future, were likely to be a reduction in the rainfall and recharge to the groundwater and increase in the surface runoff, while in far future, the model predicted an increase in all three parameters (rainfall, surface runoff and recharge to the groundwater).

Table 5-5 Percentage change in rainfall, runoff and groundwater recharge for the Hawkesbury catchment

	Percentage change in near future (2020-2039)			Percent change in far future (2060-2079)		
State planning region	**Rainfall**	**Runoff**	**Recharge**	**Rainfall**	**Runoff**	**Recharge**
Hawkesbury Nepean Catchment	-0.1	0.9	-9.3	6.1	13.4	5.6

Understanding of the physical processes that cause extreme rainfall, coupled with modelled projections, indicate with high confidence a future increase in the intensity of extreme rainfall events, although the magnitude of the increases cannot be confidently projected. The publication does not provide details regarding changes to flood-producing rainfall events other than to confirm that changes to rainfall intensity are predicted.

Practical Consideration of Climate Change publication references modelling carried out by the CSIRO in 2007 for the NSW Government to assess the impacts of climate change on rainfall intensities. The results showed a trend of increased rainfall intensities for the 40-year ARI one-day rainfall event across New South Wales (**Table 5-6**).

Table 5-6 CSIRO indicative change in rainfall and evaporation one-day total (CSIRO, 2007)

Location	40 Year 1-day rainfall total projected change 2030	40 Year 1-day rainfall total projected change 2070	Evaporation projected change 2030	Evaporation projected change 2070
Sydney Metropolitan	-3% to +12%	-7% to +10%	+1% to +8%	+2% to +24%
Hawkesbury Nepean	-3% to +12%	-7% to +10%	+1% to +8%	+2% to +24%
New South Wales Average	-2% to +15%	-1% to +15%	+1% to +12%	+3% to +38%

These expected rainfall and evaporation changes largely support the predictions presented in **Table 5-5**, as higher intensity storms will result in higher runoff volumes, whereas the increased evaporation rates will likely lead to reduced recharge, as suggested in the near future results. In the current flood assessment, two climate scenarios were modelled for the 1% AEP event, including 10% and 20% increase in rainfall intensities.

Temperature projections for Eastern Australia indicate higher average temperatures for the near future (2030) with the daily average expected to rise between 0.5 and 1.4°C above the average value recorded between 1986 and 2005. By late in the century (2090), for a high emission scenario Representative Concentration Pathway (RCP) 8.5 the projected range of warming is 2.8 to 5.0 °C. Under an intermediate scenario RCP4.5 the projected warming is 1.3 to 2.6 °C. (OEH, 2014).

5.2 Land use

The USC AWRC site as well as a large portion of the pipeline alignments are located within the Western Sydney Aerotropolis growth area, which is currently undergoing rezoning on a regional scale. The information detailed below was accurate at the time of this study development, however these future changes are expected to change the bulk of the rural and primary production zoned areas to industrial, commercial and residential areas.

LGA land zoning information has been used to define the current land use within the study area. The majority of the current land use along the treated water and environmental flow pipelines consists of RU2 Rural Landscape and RU1 - Primary Production, intersecting a small area of rural village and public recreation at Wallacia. A large portion of the adjacent land along Elizabeth Drive in Badgerys Creek is zoned as SP1 – Special Activities, indicating the location of the Western Sydney International Airport which is currently under construction and expected to be complete and operational by 2026 (DITRDC, 2020).

The USC AWRC is located within land currently zoned as RU2 – Rural Landscape, with portions coinciding with areas adjacent to South Creek and Kemps Creek zoned as E2 – Environmental Conservation. The site falls within the Kemps Creek Precinct of the Western Sydney Aerotropolis which is slated for rezoning. Land uses within the Kemps Creek Precinct and Western Sydney Aerotropolis will be dominated by enterprise lands comprising industrial and logistics land uses.

The brine pipeline alignments intersect areas zoned as RU4 – Primary Production Small Lots to the south-east of the USC AWRC, before passing through a mixture of Low / Medium Density Residential, Public Recreation and Business Development areas around Cecil Hills, Bonnyrigg and Cabramatta.

Based on this, the majority of the study area consists of permeable landscapes, with the exception of the urbanised areas along the brine pipelines, where the presence of impervious roads and buildings will mean that a large portion of precipitation will be captured by stormwater systems and infiltration to groundwater will be limited.

It should be noted that the assessment has been undertaken based on the current land use and a reassessment may be needed in later stages, to capture potential changes in flooding behaviour due to ongoing development in the area.

5.3 Topography

Available Light Detection and Ranging (LiDAR) data with 1-m resolution was used to define the physiographic context of the project. The USC AWRC site is located within a regional alluvial plain associated with the South Creek and Kemps Creek watercourses (**Figure 5-4**). The topography in the area is predominately flat, with a gentle slope towards the north as indicated by the surface elevation data presented in **Figure 5-5** . Elevations across the centre of the site generally range between 35 to 40 mAHD.

Figure 5-4 Flat topography of the USC AWRC site (Photo taken from SW corner of site looking NE)

The treated water pipeline (**Figure 5-6**) follows gently sloping topographies, with elevations generally ranging from 30 m to 90 mAHD, from the low-lying areas around the South Creek/Kemps Creek (35 – 40 mAHD) through to the Nepean River valley (35 mAHD), traversing a small ridge in the vicinity of The Northern Road, Luddenham (90 mAHD).

The brine pipeline alignment, shown in **Figure 5-7**, heading out east from the USC AWRC site at 40 mAHD elevation, follows gently sloping topographies, rising from 40 mAHD, rising to reaching a high point at Cecil Hills (80 mAHD) before sloping down again towards Prospect Creek and the Georges River in Fairfield at 10 mAHD.

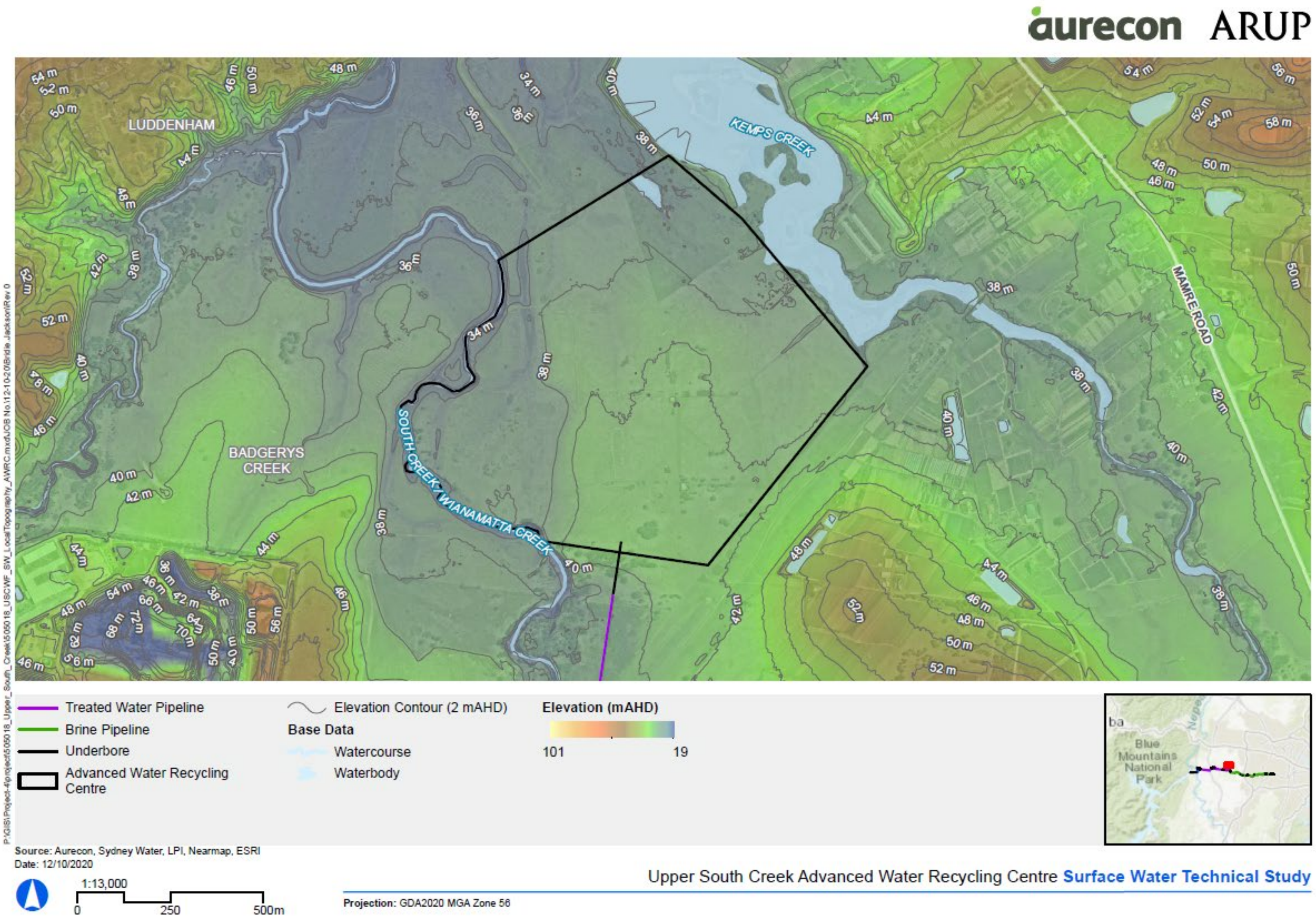


Figure 5-5 Topography - AWRC site

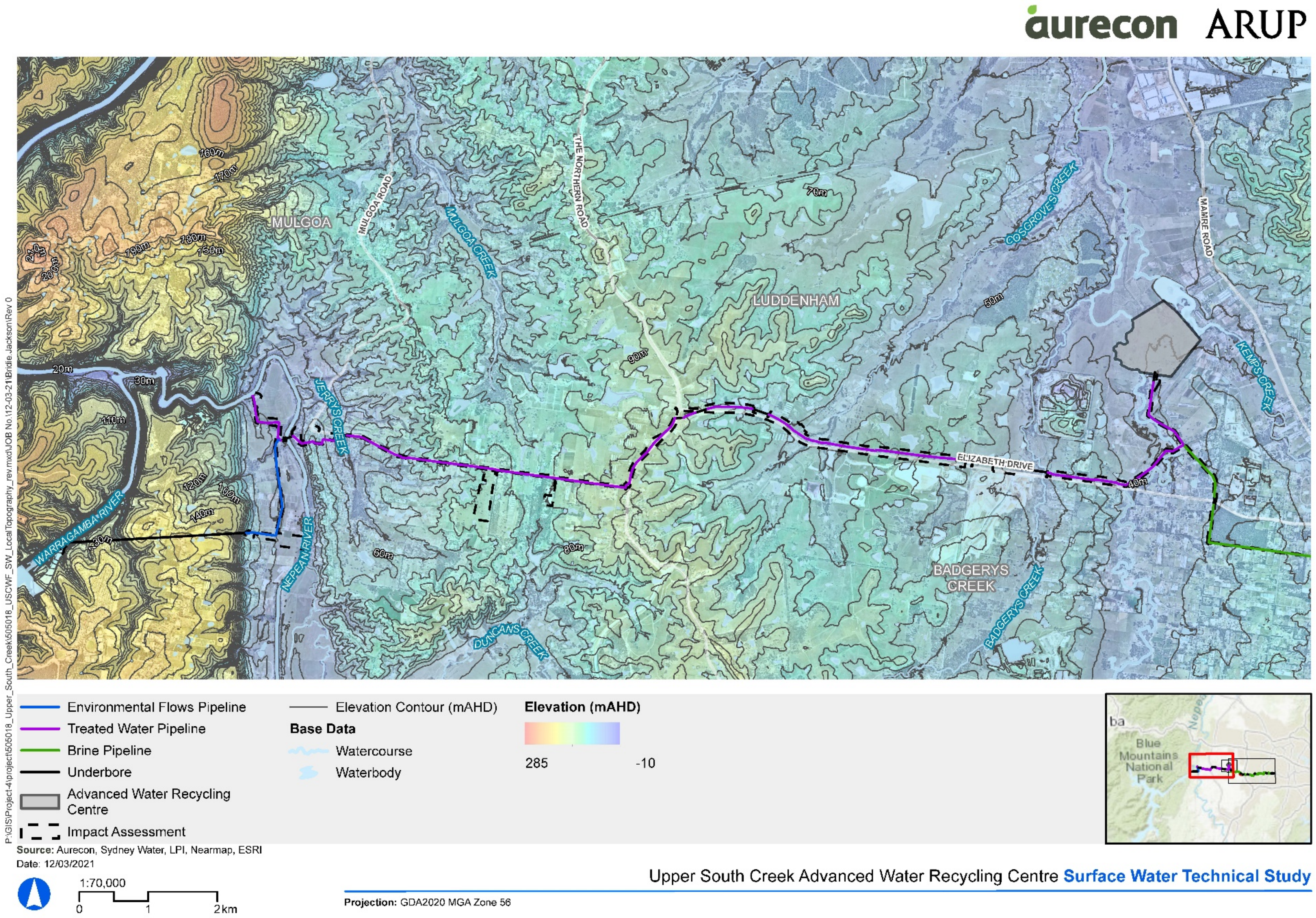


Figure 5-6 Topography - Treated water and Environmental flows pipelines

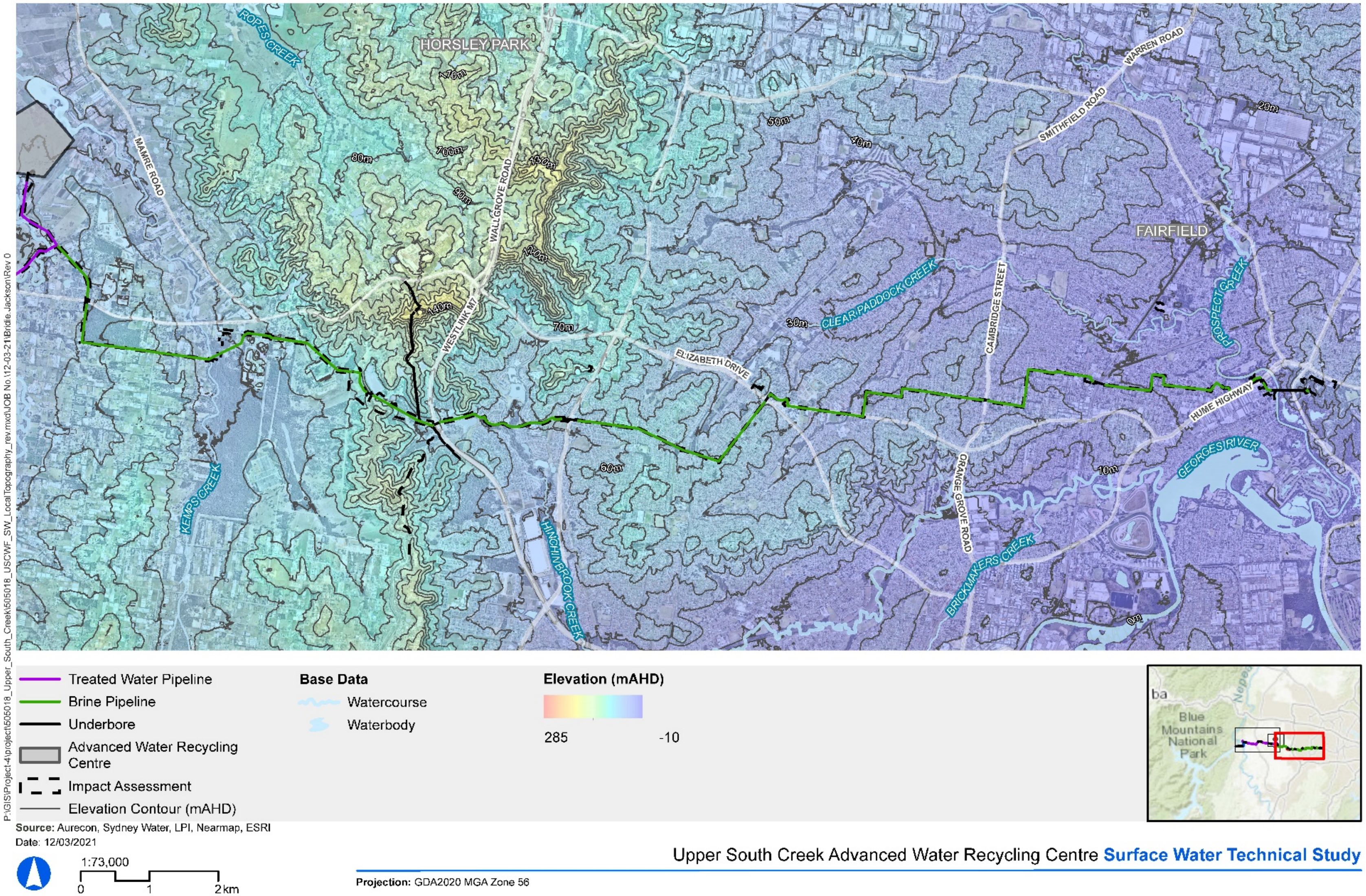


Figure 5-7 Topography - Brine pipeline

The environmental flows pipeline continues south along a plateau adjacent to the Nepean River valley before turning west towards the Warragamba River. Shortly after this direction change, the pipeline route encounters a fairly steep ridge with the surface elevation increasing from 61 m to 153 m within a distance of 300 m (slope of 31%). At this point the proposed construction methodology is a tunnelled section cutting into the east side of the ridge line at 66 m and exiting on the west side of the ridge line at an elevation of 34 m close to the Warragamba River for release The complete elevation profile for the pipeline along its 4.5 km length, is presented in **Figure 5-8**.

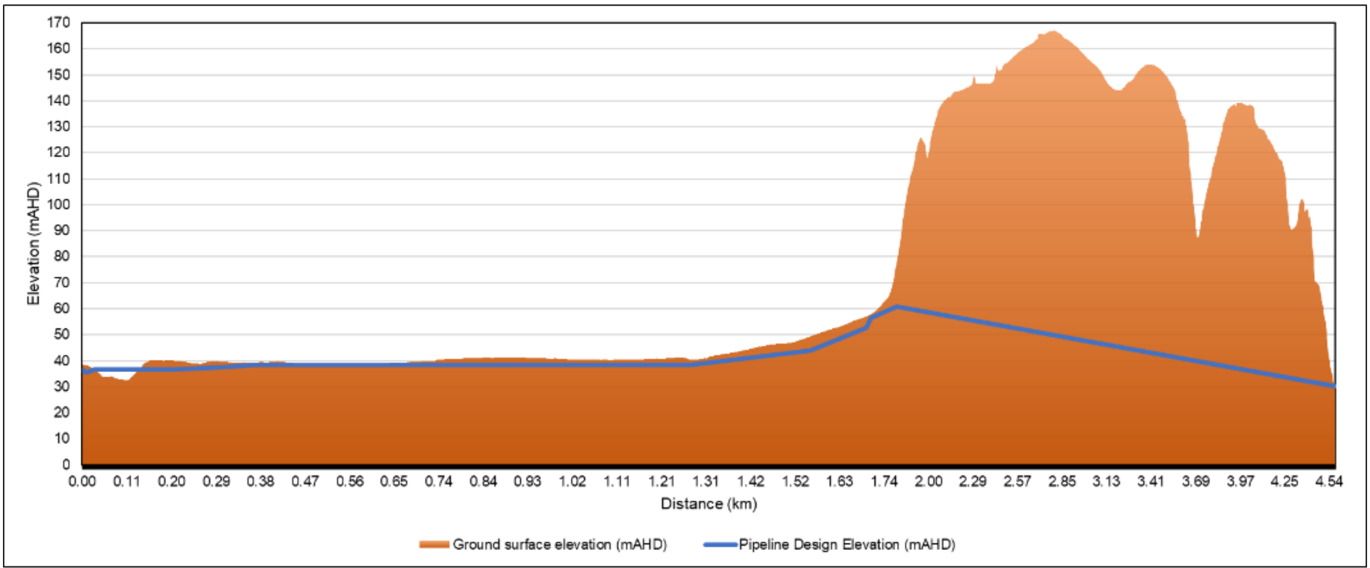


Figure 5-8 Elevation profile along the environmental flows pipeline

Within the local surrounding area, the landscapes are typified by a mixture of urbanised areas associated with current residential and commercial developments, and open areas of grasslands and low rolling hills.

5.4 South Creek Catchment Hydrology

5.4.1 Catchment descriptions (for AWRC and pipeline alignments)

The USC AWRC site and the majority of the pipeline alignments are located in the Wianamatta-South Creek and Hawkesbury-Nepean catchment. A portion of the brine pipeline is in the Georges River catchment.

The Hawkesbury-Nepean catchment provides drinking water, agricultural and fisheries produce, recreational opportunities and tourism resources for the metropolitan area of Sydney and is one of the largest coastal basins in NSW with an area of 21,400 km^2 (NSW DPI, 2017). Over its 470 km length, it originates from the headwaters of the Nepean River in Goulburn before joining the Hawkesbury River in the west of Sydney and draining to Broken Bay, a semi–mature tide-dominated drowned valley estuary and large inlet of the Tasman Sea located about 50 kms north of Sydney central business district. The approximate saline limit is at Wisemans Ferry, but the tidal limit is 85 km further upstream at Yarramundi.

The Georges River, which has a catchment area of approximately 960 km^2, is one of the most highly urbanised catchments in Australia. It flows approximately 100 km from the headwaters on the Illawarra escarpment and Appin down to the river mouth at Botany Bay. The water is fresh above Liverpool Weir and is tidal and saltier below the weir down to Botany Bay.

The majority of the project lies within the Lower Nepean River Management Zone of the Hawkesbury-Nepean Catchment. A significant proportion of the Hawkesbury-Nepean Catchment is protected in national parks and water catchment reserves; however, the centre and associated pipelines lie primarily within the South Creek sub-catchment which has been extensively modified and disturbed as a result of urbanisation and associated land clearing. The hydrology of the South Creek catchment has been significantly altered due to a decrease in pervious surfaces which has in turn altered the geomorphological regime and ecological habitat features of the watercourses. The Hawkesbury River is the ultimate downstream existing environment and is located about 29 km from the project at the closest point.

AWRC – Wianamatta-South Creek

Wianamatta-South Creek is a significant tributary of the Hawkesbury River. South Creek was renamed Wianamatta Creek on the 28 March 2003 by the Geographical Names Board of NSW. It was renamed after the Wianamatta Aboriginal Tribe local to Windsor but the name "South Creek" wasn't dropped on the basis of the name was a long standing name and should not be lost in historical context (Enacademic, 2020).

The watercourse originates around Oran Park, flowing generally north, where it is joined by other tributaries such as Badgerys Creek and Kemps Creek before reaching its confluence with the Hawkesbury River, near Windsor. The creek descends 94 m over its 70 km course. Several farm dams and minor waterbodies exist within the study area.

The South Creek catchment covers around 620 km^2 and extends from Narellan to the confluence with the Hawkesbury River. Large areas of the catchment have been urbanised and future changes are expected due to the extensive developments in the Western Sydney Aerotropolis growth area.

The confluence of Kemps Creek and Badgerys Creek into South Creek is about three kilometres north of Elizabeth Drive. The South Creek catchment upstream of the confluence with Badgerys's Creek covers an area of approximately 96 km^2, the extent of which is shown in **Figure 5-9**.

The August 1986 flood and the April 1988 flood are two major flood events that have occurred in the South Creek catchment. It is estimated that the 1988 event was in the order of 1% AEP. There have been other significant floods that have occurred in 1867, 1956, 1961 and 1978.

The channel width and flow velocity varies significantly within the stretch of the creek directly adjacent to the USC AWRC site as indicated in photos provided in **Figure 5-10** taken along the river banks, looking downstream.

AWRC - Kemps Creek

Kemps Creek is a tributary of South Creek and is a fourth order stream in the vicinity of the USC AWRC site. The creeks source is approximately 2 km east of Catherine Fields and it flows for about 17 km through the suburbs of Rossmore, Bringelly, Austral and Kemps Creek before discharging to South Creek just north of the USC AWRC site. The creek flows through a predominately semi-rural setting, although urbanisation has increased in recent years (Liverpool City Council, 2003).

Kemps Creek catchment has been known to experience flooding problems likely due to limited hydraulic capacity in the creek channels, filling activities on the floodplain and inadequate hydraulic capacity at culverts and bridges (Liverpool City Council, 2003). As a result of this, extensive earthworks have been undertaken in the catchment to control water including construction of dams to provide storage, construction of channels or banks to divert flow of water and widening the creek channel to reduce flood levels as well as the frequency and extent of inundation (Liverpool City Council, 2003). Land use within the Kemps Creek sub-catchment largely includes agriculture (grazing, market gardens, poultry), residential, commercial and extractive industries. Kemps Creek has a catchment area of approximately 59 km^2, the extent of which is shown in **Figure 5-9**.

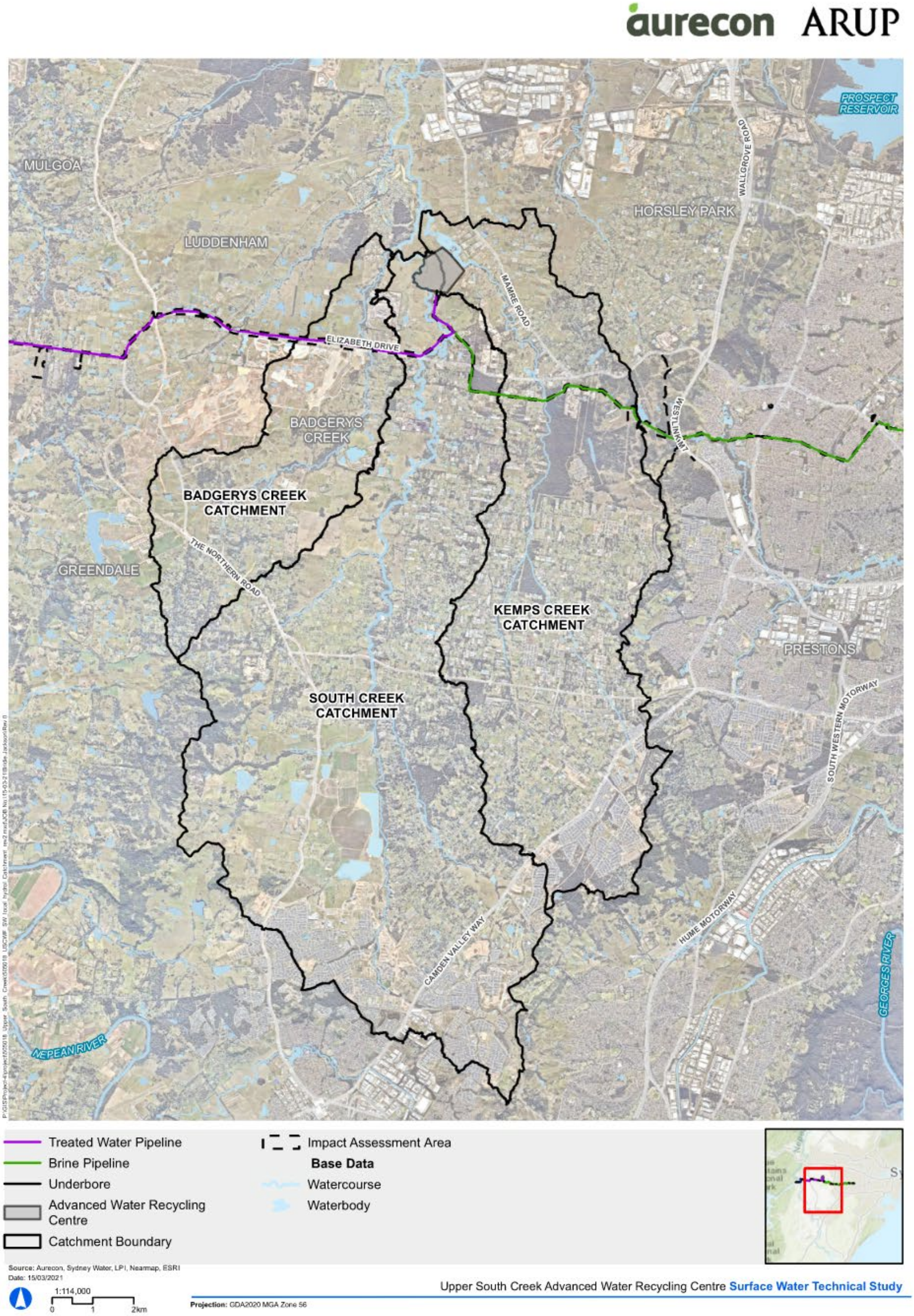


Figure 5-9 Upstream contributing catchments

Figure 5-10 South Creek adjacent to AWRC site (photos taken looking downstream)

Watercourses traversed by the discharge pipelines

The Warragamba River, Nepean River, Georges River, and numerous tributary streams are within the study area. To describe the hierarchy of the streams within the study area, the Strahler order system is used. This method is the preferred method used in the Water Management Regulation 2018 (NSW Government, 2018). Hydro line spatial data, a dataset of mapped watercourses and waterbodies in NSW, is used and streams are sequentially numbered from the top of the catchment to the bottom (NSW Department of industry, 2020). While Sydney Water is exempt from riparian lands legislation, the Strahler system is an indicator of catchment size, regional significant and potentially hazardous construction conditions.

The result of the Strahler order analysis for the streams directly adjacent to the USC AWRC as well as those traversed by the pipelines, is summarised in **Table 5-7** and the results indicated graphically in **Figure 5-11** through **Figure 5-13**. Watercourses with a Strahler order of 2 and higher are listed, as well as the sections traversing existing farm dams (T5 & T9). The associated prescribed riparian corridor width for each watercourse is provided following the latest guidance from Guidelines for Controlled Activities on Waterfront Land – Riparian Corridors (NSW Department of Industry, 2018).

At the time of preparing this report, existing flooding conditions data were available for some of the catchments traversed by the discharge pipelines, which were taken into consideration in establishing the existing flooding conditions of those catchments. These are listed in **Table 1-2** and below:

- Western Sydney Aerotropolis, South Creek Flood Study (AAJV, 2019).

- Prospect Creek Floodplain Management Plan Review (Bewsher, 2010).
- Flood Study for Orphan School Creek, Green Valley Creek and Clear Paddock Creek (SKM, 2008).
- Hawkesbury-Nepean Valley Regional Flood Study (WMA Water, 2019).
- Updated South Creek Flood Study. prepared for Penrith City Council in association with Liverpool, Blacktown and Fairfield City Councils (WorleyParsons, 2015).
- Nepean River Flood Study. prepared for Camden City Council (WorleyParsons, 2015).
- Upper South Creek Flood Study (WMA Water, 2019)

Table 5-7 Strahler order analysis of water crossings and creeks bordering AWRC site

ID	Location name	Strahler Order	Riparian corridor width*	Catchment
AWRC site – Local watercourses				
A1	South Creek (West of AWRC site)	6	40 m	Hawkesbury-Nepean
A2	Kemps Creek (East of AWRC site)	4	40 m	
Treated Water Pipeline – Water crossings				
T1	South Creek	6	40 m	Hawkesbury-Nepean
T2	Unnamed tributary to South Creek	2	20 m	
T3	Badgerys Creek	4	40 m	
T4	Unnamed tributary to Badgery's Creek	3	30 m	
T5	Farm dams u/s of Badgerys Creek tributary	1	10 m	
T6	Unnamed tributary to Cosgroves Creek	2	20 m	
T7	Oaky Creek	3	30 m	
T8	Cosgroves Creek	4	40 m	
T9	Farm dam & unnamed tributary to Cosgroves Creek	2	20 m	
T10	Jerrys Creek	4	40 m	
T11	Nepean river	7	40 m	
T12	Baines Creek	3	30 m	
Environmental Flows Pipeline – Water crossings				
E1	Baines Creek	3	30 m	Hawkesbury-Nepean
E2	Megarritys Creek	3	30 m	
Brine Discharge Main – Water crossings				
B1	Unnamed tributary to Kemps Creek	2	20 m	Hawkesbury-Nepean
B2	Kemps Creek	4	40 m	
B3	Hinchinbrook Creek	2	20 m	Georges River
B4	Unnamed tributary to Hinchinbrook Creek	3	30 m	
B5	Green Valley Creek	2	20 m	

ID	Location name	Strahler Order	Riparian corridor width*	Catchment
B6	Prospect Creek	4	40 m	

* On either side of the waterway

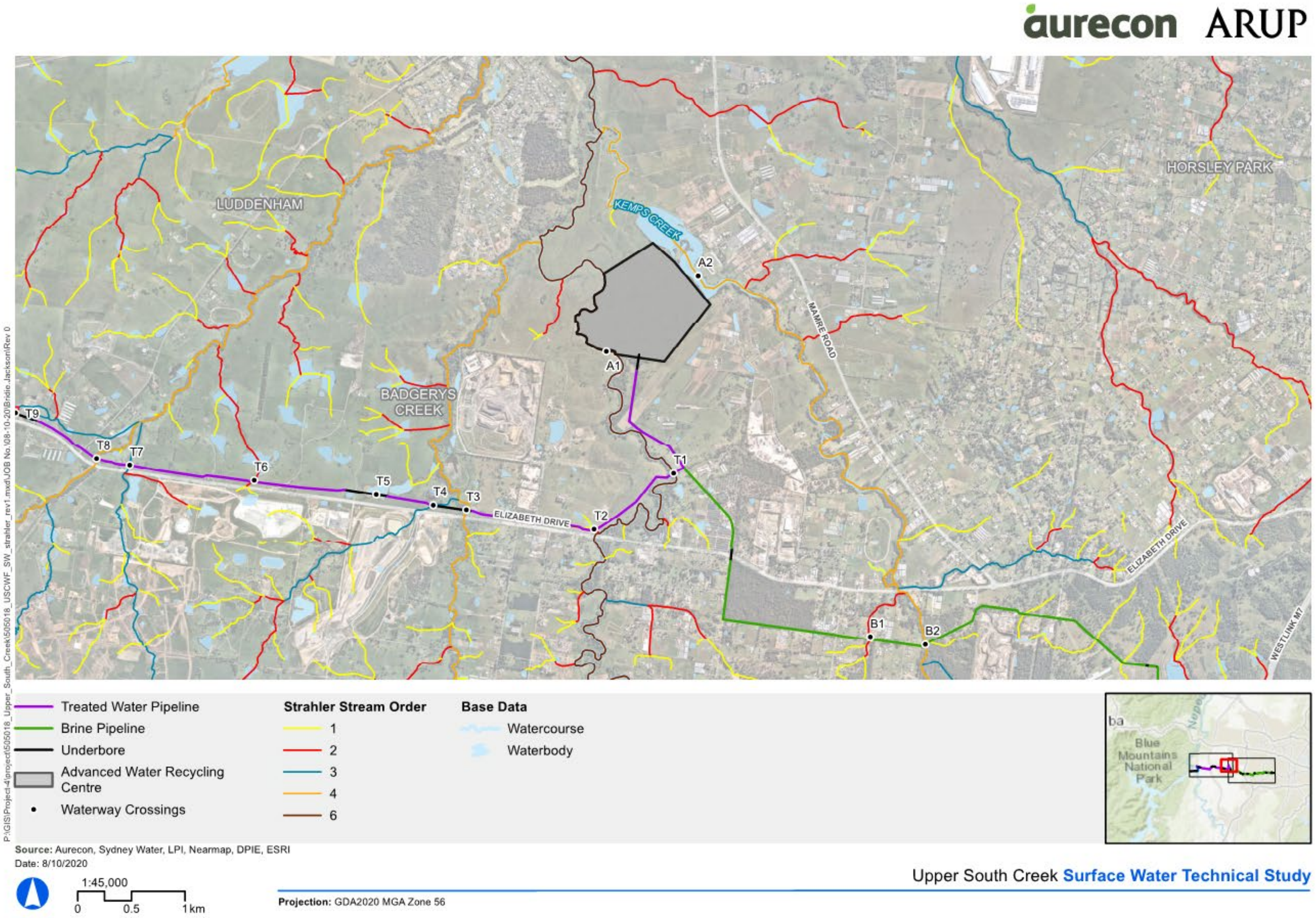


Figure 5-11 Strahler stream order - AWRC site

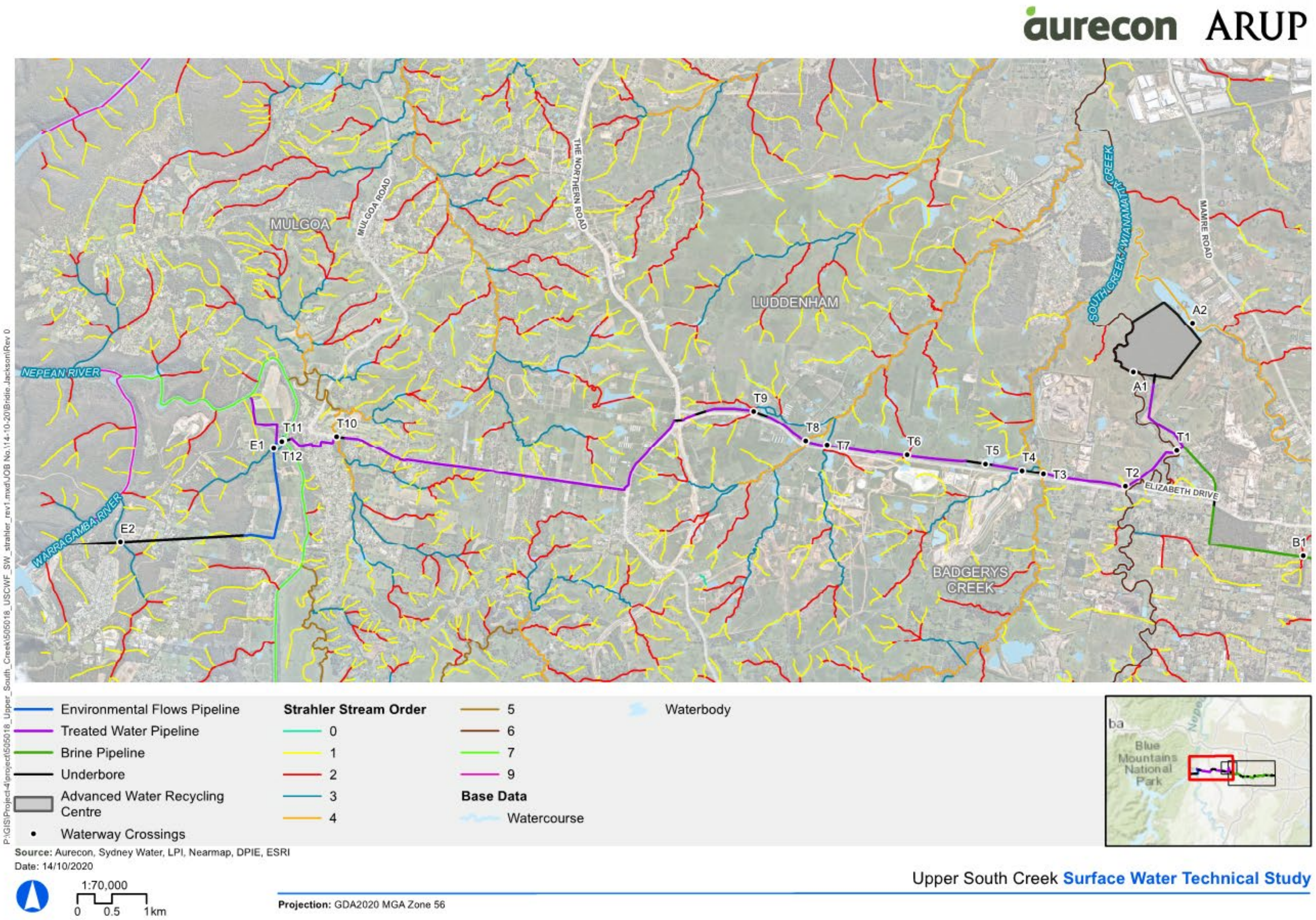


Figure 5-12 Strahler stream order – Treated water and Environmental flows pipelines

aurecon ARUP

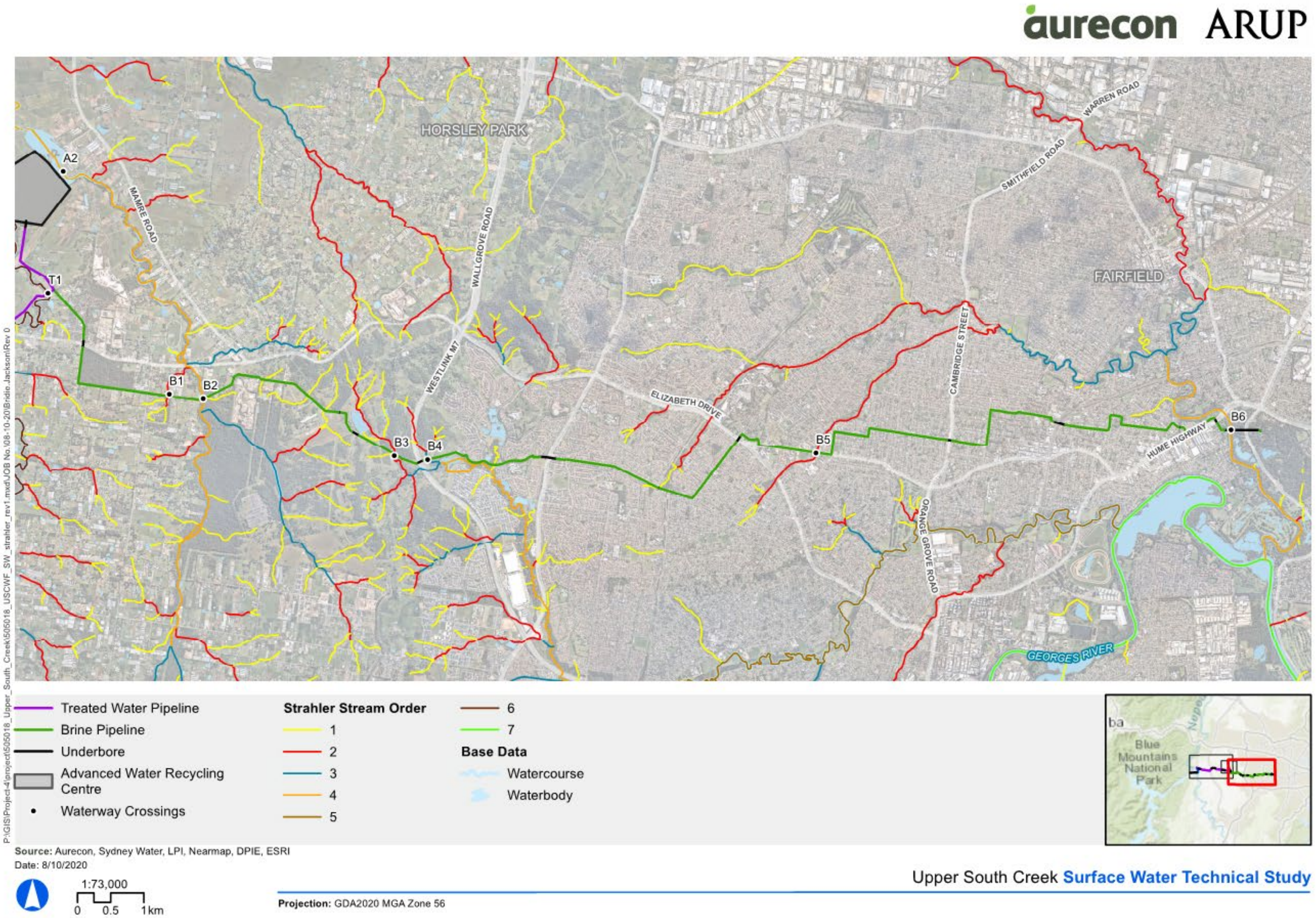


Figure 5-13 Strahler stream order – Brine pipeline

5.4.2 Stream flow

Monitoring

There are multiple stream flow gauges located within the South Creek catchment as indicated in **Table 5-8**. The site falls between two gauges:

- Gauge 21320 is located approximately 1.7 km upstream of the site, near the Elizabeth Drive crossing
- Gauge 212048 is located approximately 14.3km downstream of the site, near the Great Western Highway crossing

Table 5-8 Stream flow gauge

Gauge Number	Location	Waterway	Monitoring Start Date
212320	South Creek at Elizabeth Drive	South Creek	1/06/1970
212048	South Creek at Great Western Highway	South Creek	25/02/1986

The Elizabeth Drive gauge data (median flow of 0.1 ML/d or 0.001 m^3/s) records lower flow magnitudes than the recorded flows further downstream of the site, given the confluence with several tributaries within this reach as shown in **Figure 5-14**. The graph also indicates a large portion of the time with very low to no flows in South Creek where it passes the site (approximately 35% of the time with <0.001 ML/d). These very low flow conditions are significantly less likely 16 km further downstream at the second gauge. The maximum recorded flow at the Elizabeth Drive gauge is 38777.6 ML/day (449 m^3/s) recorded on 30 April 1988.

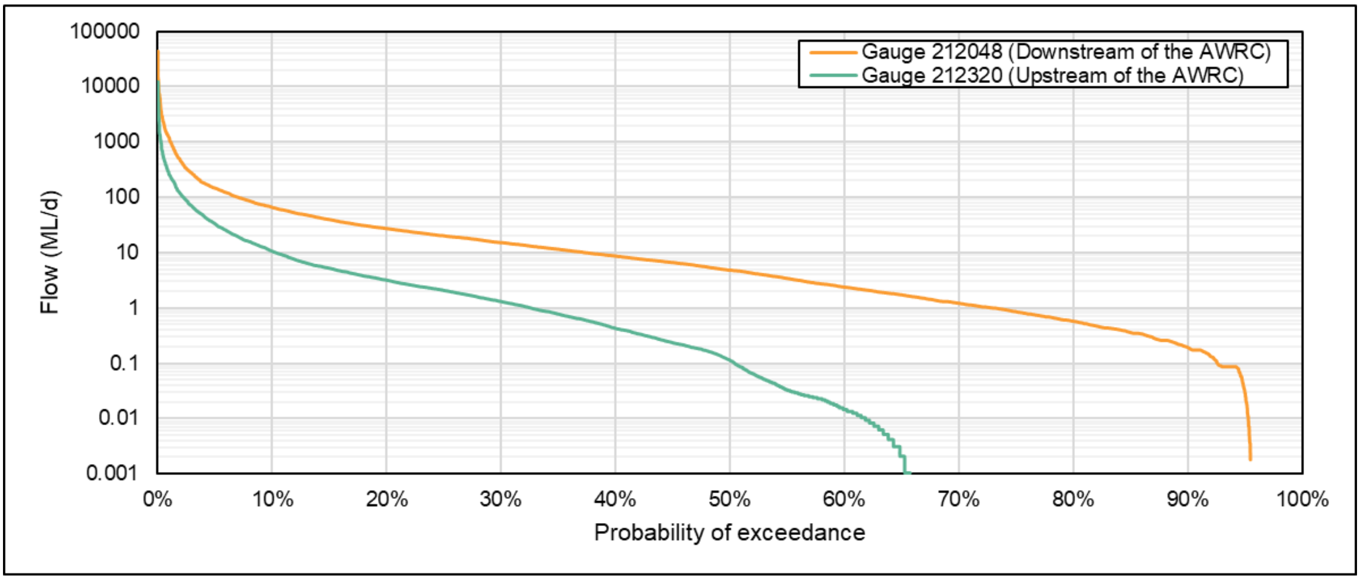


Figure 5-14 Comparison of the flow duration curves for gauge 212048 and 212320

5.5 Warragamba and Nepean Rivers

Existing flood conditions in the Nepean River are defined by the Hawkeswbury-Nepean Valley Flood Study (WMA Water, 2019). Flood conditions within the Warragamba River, downstream of the Dam spillway, are defined by flow rating data provided by WaterNSW. A summary of this study is provided in **Section 6.1**.

6 Flooding Conditions

The pre- and post-development scenarios were modelled for the USC AWRC site under the 10%, 1% AEP, 0.5% AEP, 0.2% AEP, PMP and 1% AEP plus climate change events.

The design event simulations were carried out for the critical duration of 12 hours for the ensemble of identified critical TPs (TP06, TP07 and TP08). The PMF event was simulated for the critical duration of 6 hours.

The flood modelling undertaken was for the purpose of regional flood assessment and not considering the local flooding/runoff in detail.

The primary flood characteristics reported include flood depths, levels, velocities and hazard.

6.1 Warragamba and Nepean Rivers

The catchment area of Nepean River upstream of Wallacia weir, where the treated water discharge structure is located, is 1,760km². The streamflow guage at Wallacia weir provides historical records of Nepean River flow rates since 1925. The Nepean River Flood Study (WorleyParsons, 2015), which is the adopted flood study by Camden City Council provides estimation of flood levels for the Nepean River upstream of its confluence with the Warragamba River with Wallacia being the key reference location at the downstream extent of the study. According to this study, flooding events are rare within the study area. However, when such events do occur, flows escaping from the Nepean River are known to inundate the low lying areas of Camden and certain sections within South Camden and Elderslie. Floodplain areas along many of the tributaries of the river (particularly Narellan Creek and Matahil Creek) are also known to be affected by backwater flooding from the Nepean River during flood events. Although the current study focuses on flooding from the Nepean River, flooding from these and other tributary streams are thought to represent potential flooding sources in their own right during extreme rainfall events. Based on this study, the 50% AEP flood levels at Wallacia vary 25m AHD to 35m AHD while the 20% AEP, 5% AEP and 1% AEP flood level could reach as high as 35mAHD to 45m AHD. The extent of the 1% AEP floodplain extracted from the WorleyParsons (2015) Study is presented in **Figure 6-1**, which shows Wallacia at the downstream end of the modelled area.

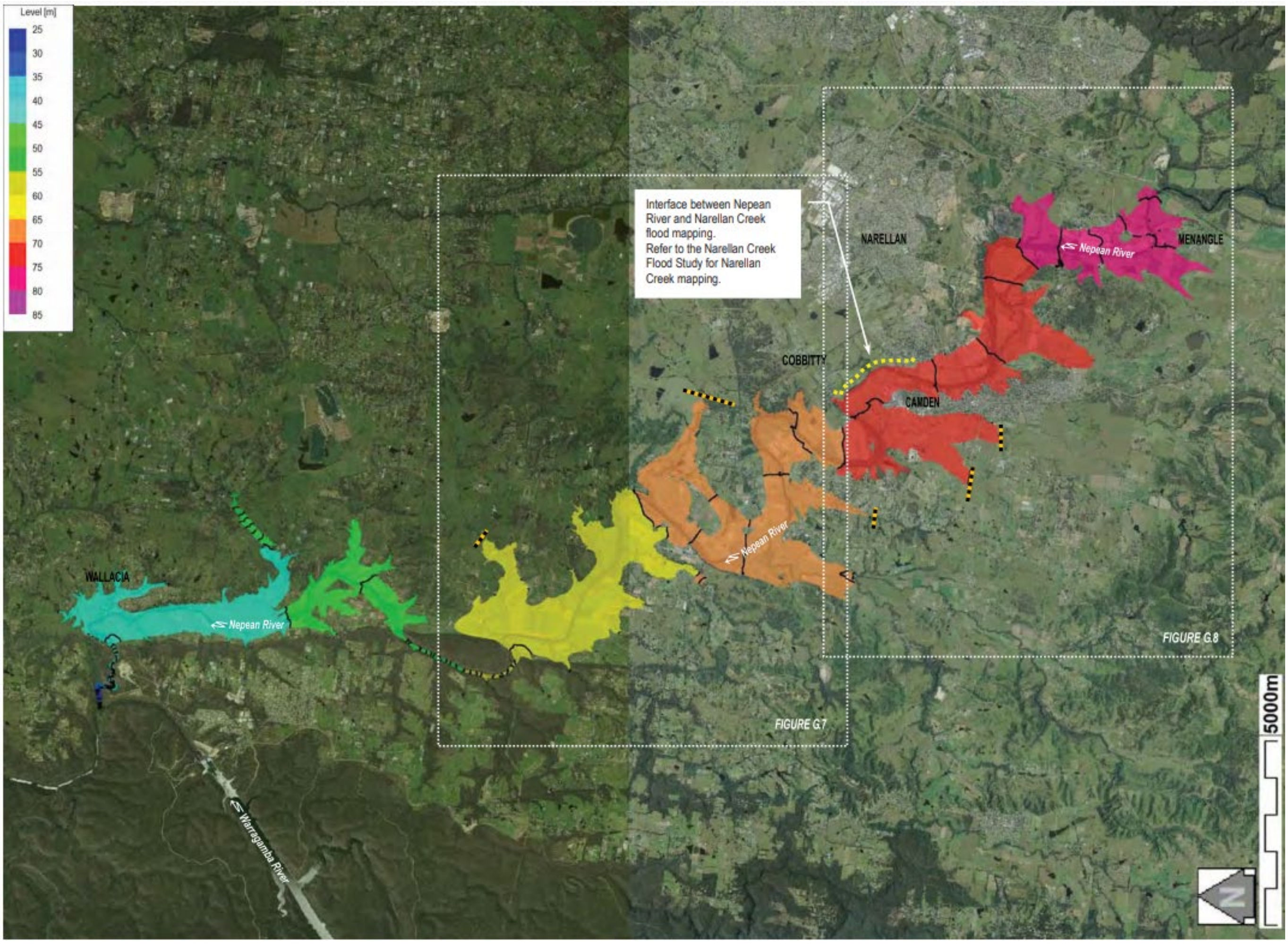


Figure 6-1 Nepean River 1% AEP floodplain (WorleyParsons, 2015)

The latest flood study on Nepean River is the Hawkeswbury-Nepean Valley Flood Study (WMA Water, 2019). Based on this study, Flood levels at Wallacia vary largely due to the constrictive effects of the Fairlight Gorge between Warragamba Dam and Penrith. The 10% AEP event has a level of 37.21 m AHD at Blaxlands Crossing, while the 1% AEP event has a level of 44.65 m AHD. In flood events up to a 10% AEP event, the flood extent remains restricted to the low-lying overbank floodplain areas of the Nepean River. In a 1% AEP event, significant areas of the are inundated by floodwaters. The PMF event reaches a level of 66.34 m AHD, some 21.7metres above the 1% AEP event – the largest increase in flood level between the 1% AEP and PMF events across the Hawkesbury-Nepean catchment. Wallacia is completely inundated in a PMF event. The extent of the 1% AEP flow at Wallacia is extracted from this study report and presented in **Figure 6-2**.

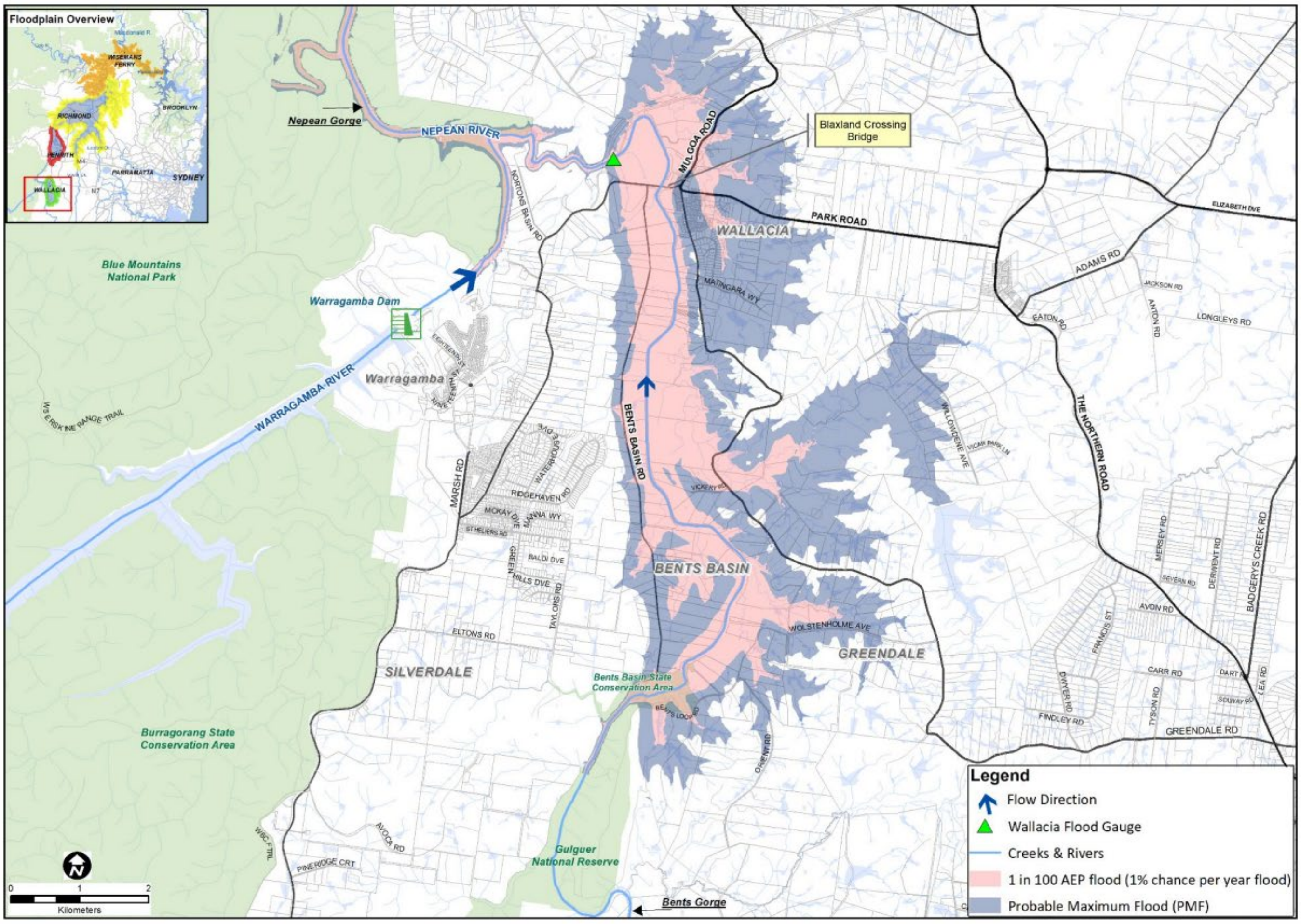


Figure 6-2 Nepean River floodplain at Wallacia (WMA Water, 2019)

The catchment area of Warragamba River upstream of the Warragamba Dam is 9,000km² and historical streamflow records are available at that location since 1960. The environmental flow discharge structure is located on Warragamba River between Warragamba Dam and Warragamba Weir. Because the structure is located downstream of the Warragamba Dam spillway, the flow rates at that location depend on how the spillway is operated. Advice was sought from WaterNSW on the flooding conditions of Warragamba River. Based on a recent flood frequency study for the Dam, the 1 in 100 Design outflow from the Dam would be in the order of 8,300 m^3/s (approx. 717,000 MLD). A flowrate this high is just off the end of the rating table for Warragamba Weir, just downstream of the environmental flow discharge point, but would likely result in a gauge height in the 27-28m depth range. The expected flow level at the Warragamba Weir is likely to be in the order of 44m AHD, excluding the waves and surface perturbations that would result from such a highly turbulent flow.

6.2 South Creek Existing Case Flood Behaviour

The pre-development flood model results are provided in this section.

6.2.1 Flood Depth and Level

Flooding within the proposed area is influenced by both the South Creek and Kemps Creek. South Creek flows along the west and Kemps Creek flows along the east side of the site. The two creeks join at a confluence in the north of the development site.

Flooding along South Creek in a large event is generally widespread with a flood width of approximately 450m in the vicinity of the study area. During the modelled 1% AEP event, the majority of the proposed development site remains relatively free of floodwaters. However, during the PMF event it may become inundated with water depths of up to 2 m, except for an area of about 13 ha which remains free of floodwaters. In this event, floodwater enters from the east and west sides of the proposed site, flowing in a northerly direction following the topography.

During the 1% AEP event, about 45 ha of the proposed land remains outside the flood extent which is area in which the indicative AWRC reference design is located to minimise its impact on the existing flooding conditions. The 1% AEP event (100-year ARI) flood extent derived from WorleyParsons (2015) study along with 1% AEP flood extent resulted from the current simulation are shown in **Figure 6-3**.

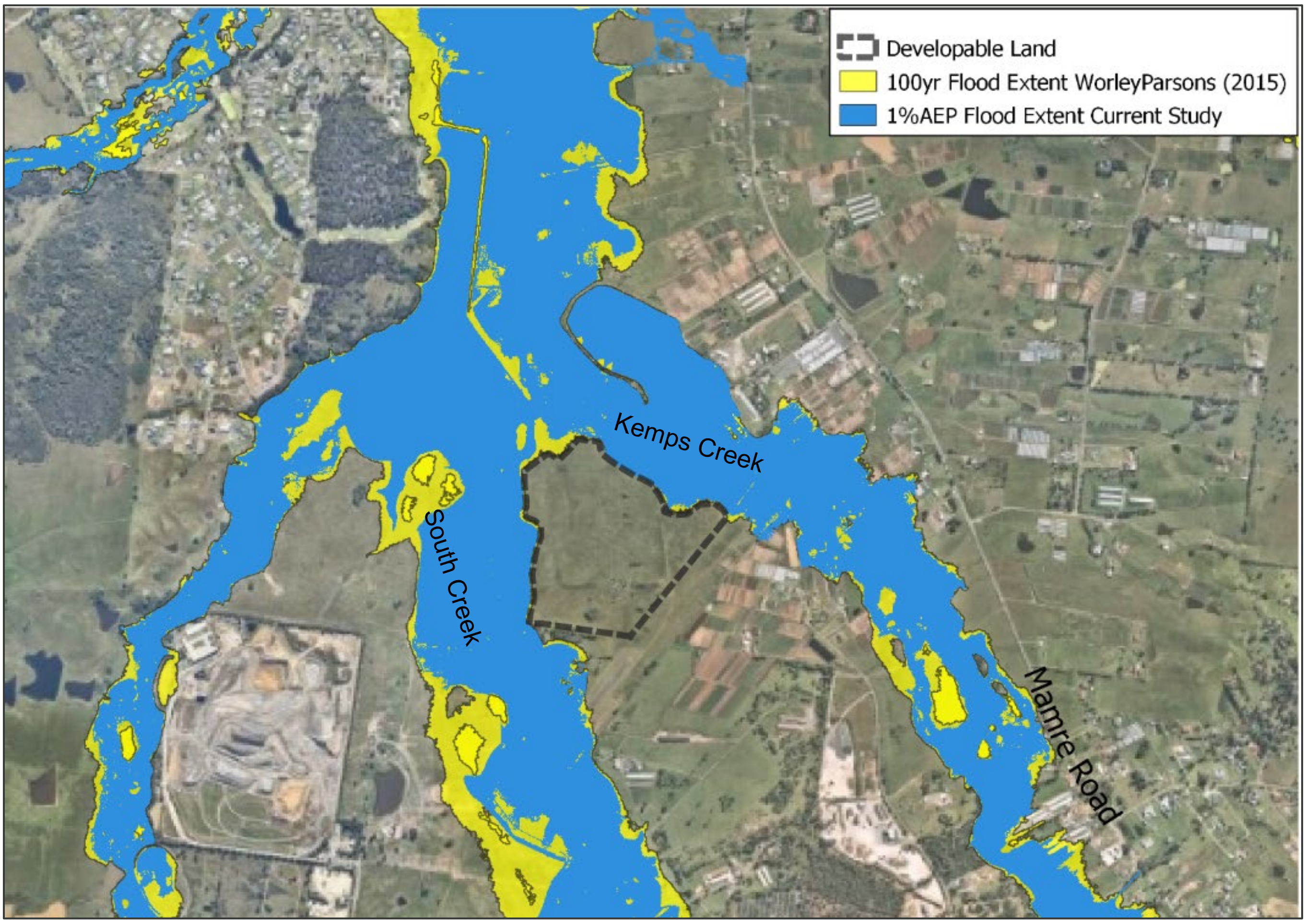


Figure 6-3 The 1% AEP flood extents based on WorleyParsons (2015) and AWRC study using ARR 2016

The existing peak flood depths and levels around the study area for 10% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF are shown in **Figure 6-4** through **Figure 6-9**.

Under the 10% AEP event, water levels along the west side of the proposed development site are in the range of 36.9 to 38.0 m AHD and along the east side in the range of 37.0 to 38.5 m AHD. In most flooded areas within the development boundary, the water depth is in the range of 0.25 to 0.7 m. Water depths along the thalweg of South Creek, which flows on the western side of the boundary, is in the range of 3.3 to 3.7m. The Tadpole Lake levee height (located a shorth distance on the northeast side of the site), is about 39.2 to 41.1 m AHD which results in a mostly stable water level of 38.4m AHD and water depth of 2m in Kemps Creek adjacent to the site.

Under the 1% AEP event, water levels rise by about 15% along the western side of the site and range from 37.5 to about 38.5 m AHD and along the eastern side from 37.5 to 39.2 m AHD. Inundated areas and water depths within the proposed development boundary increase so that about 45% of this area will be flooded in this event. Also, water depths increase along the thalweg of creeks (up to 4.4m in South Creek and 2.3m in Kemps Creek).

Flood depths and levels increase gradually in larger AEP events. In the largest modelled AEP event (0.2% AEP), water levels along the western side of the site range from 37.6 to about 38.7 m AHD and along the eastern side from 37.7 to 39.3 m AHD. The extent of flooded area within the boundary increases, but not significantly.

As discussed in Section 4.4.7, flood impacts were also assessed for a flow scenario in which South Creek peak flow at Elizabeth Drive (Mulgoa Road Gauge) is 538m^3/s. This scenario adopts a flow that is similar to the estimated 1% AEP South Creek peak flow from Flood Frequency Analysis (FFA) at the Elizabeth Drive flow gauge. It is understood that this flow scenario has been adopted by Council as the 1% AEP flow for flood planning purposes.

Under these flow conditions, water levels along the western side of the site range from 38.0 to 39.0 m AHD and along the eastern side from 38.0 to 39.5 m AHD. This scenario is called the 1% AEP FFA in mapping below.

Under the PMF event, most of the development site is inundated with water depths of more than 2m, except for an area of about 6.5 ha adjacent to the southwest border and some scattered patches. Water levels within the development site range from 39.5 m AHD along the north side to 41.2 m AHD in the southwest corner.

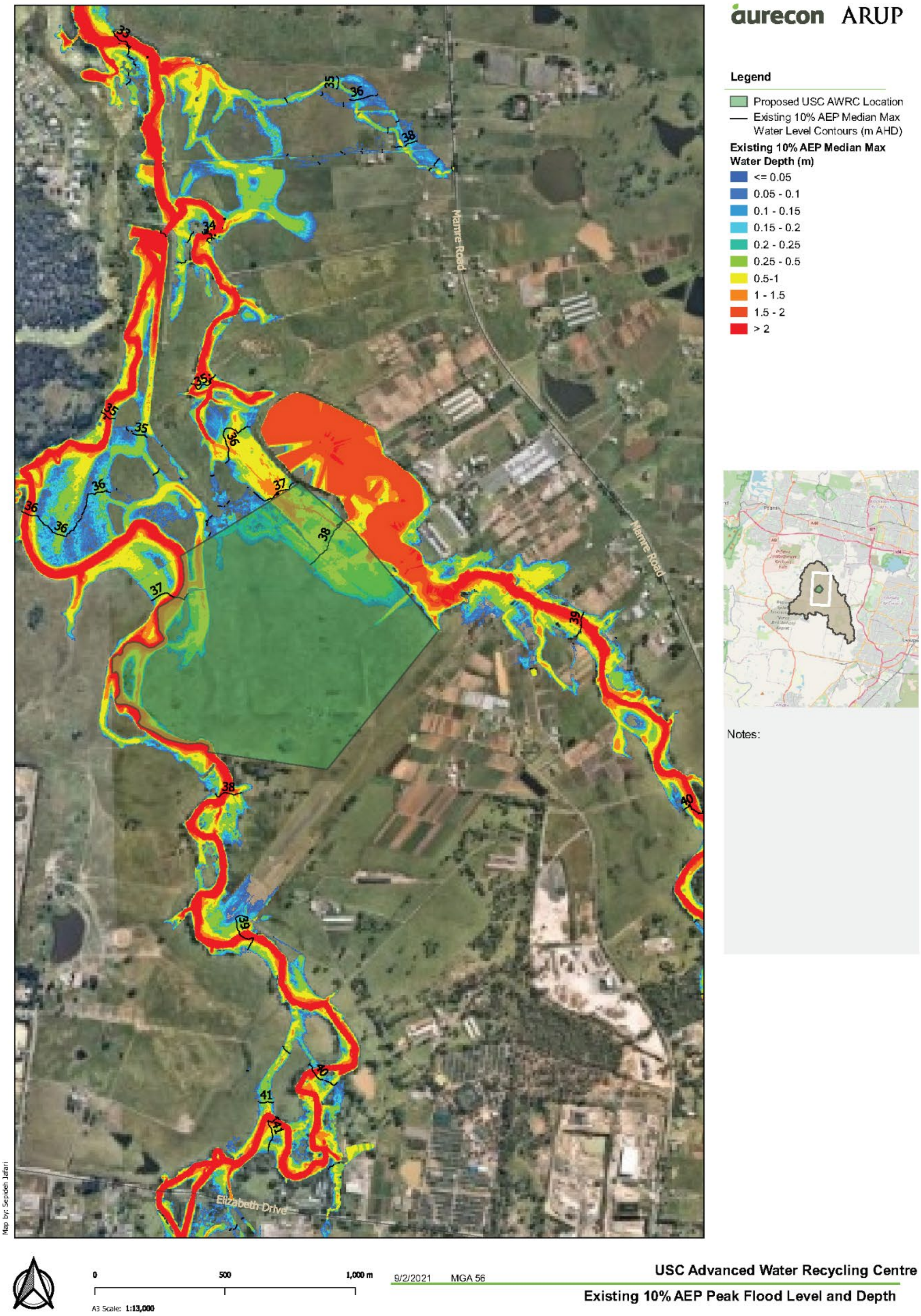


Figure 6-4 Existing case 10% AEP peak flood levels and depths

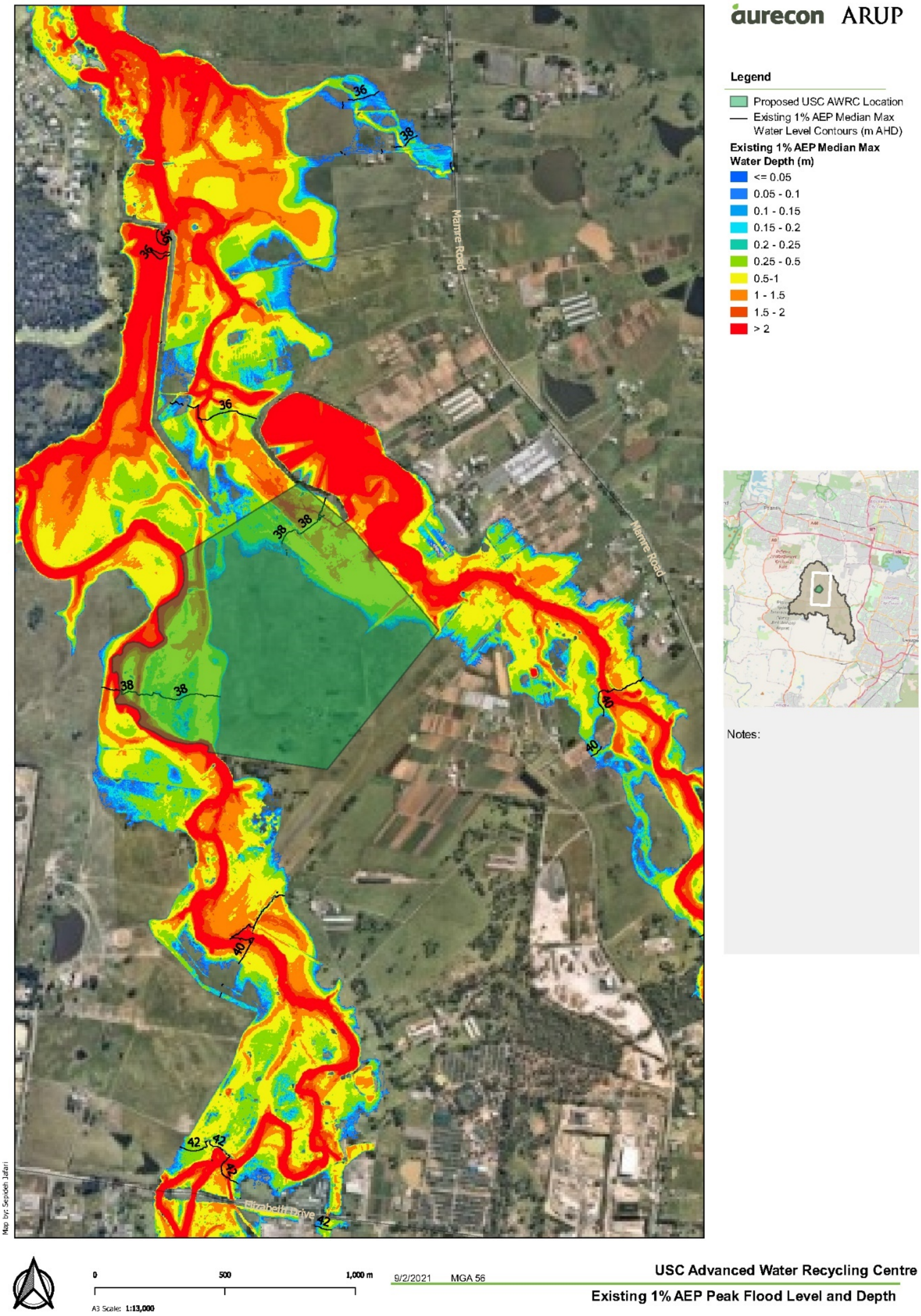


Figure 6-5 Existing case 1% AEP peak flood levels and depths

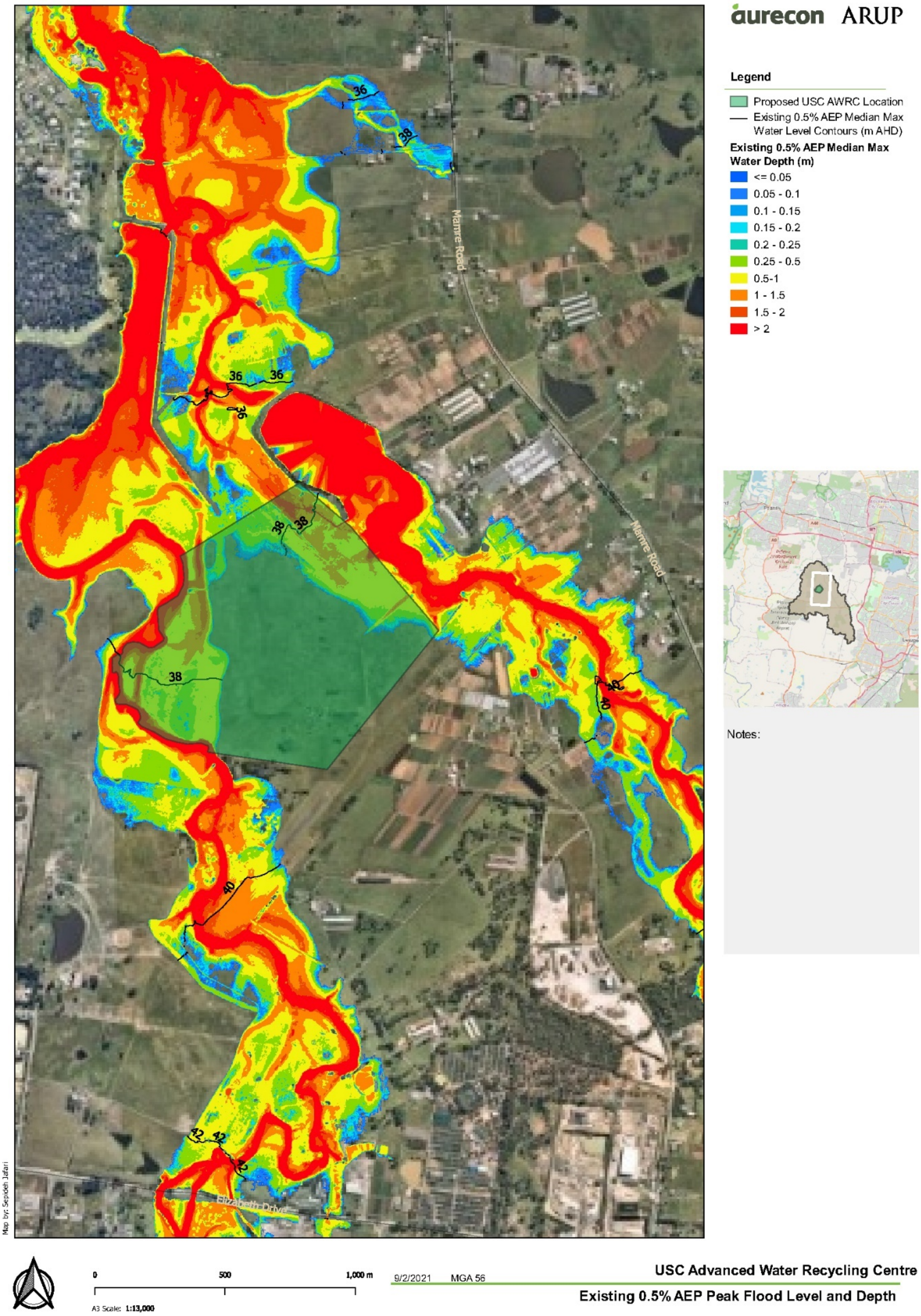


Figure 6-6 Existing case 0.5% AEP peak flood levels and depths

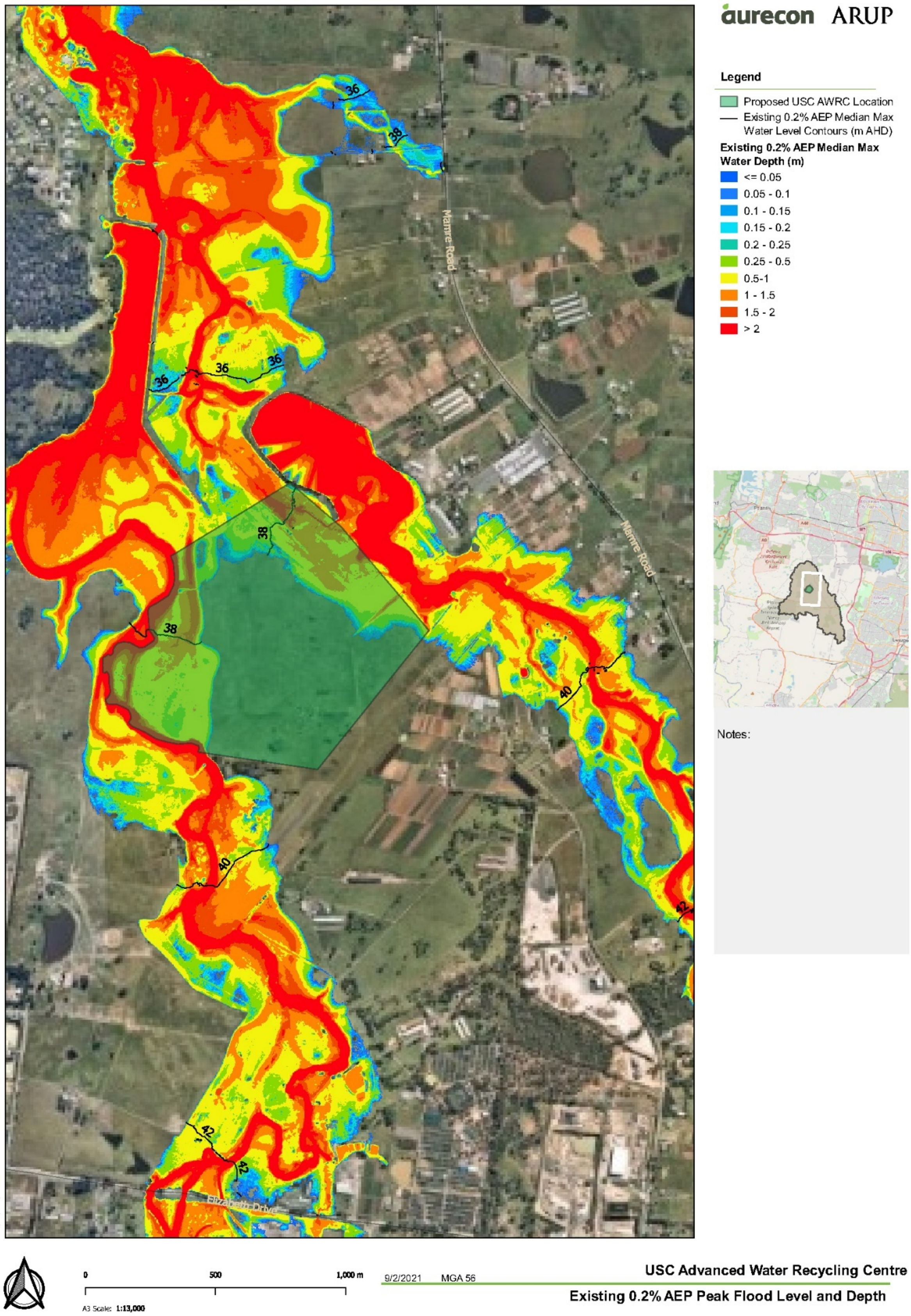


Figure 6-7 Existing case 0.2% AEP peak flood levels and depths

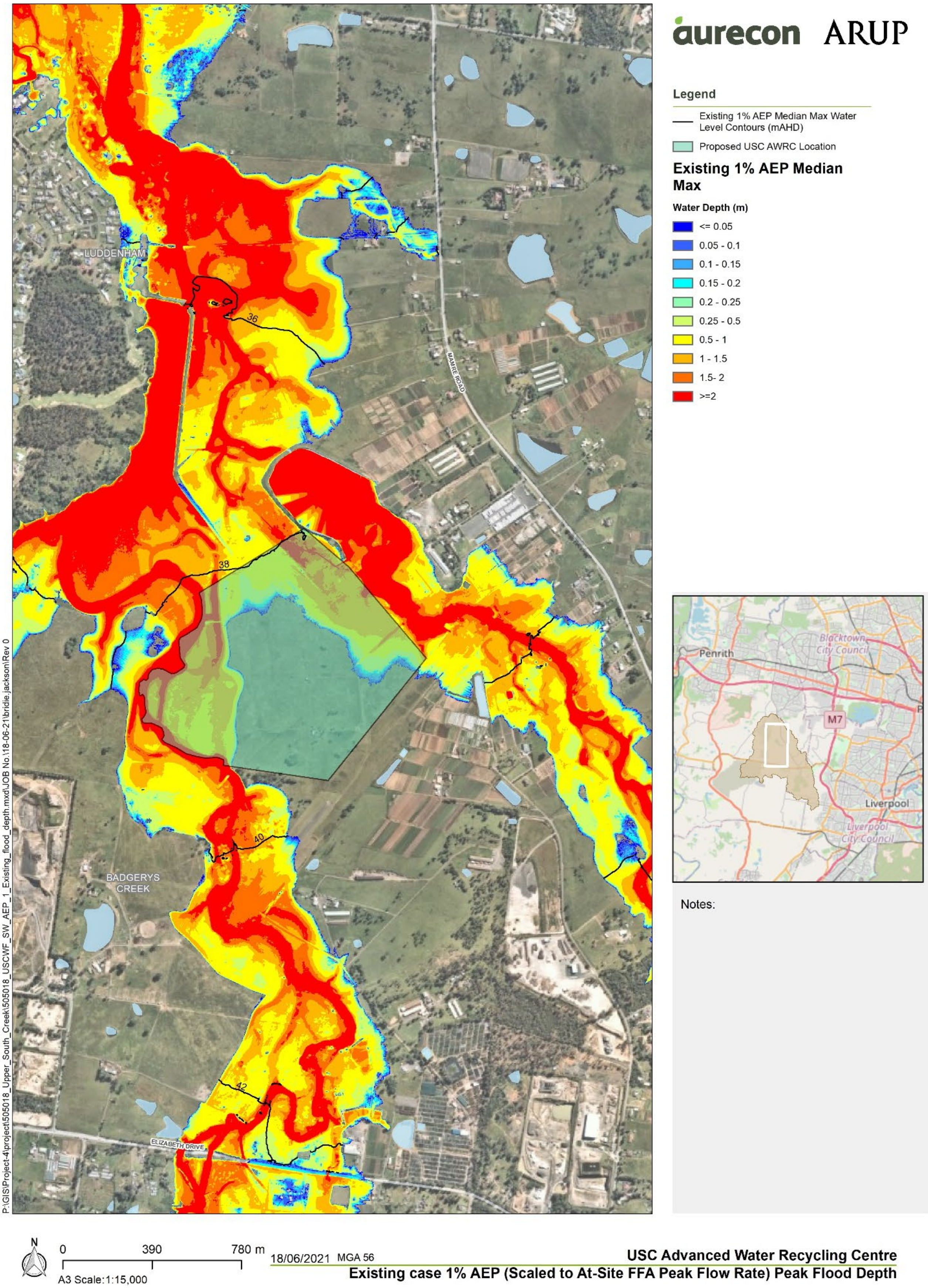


Figure 6-8 Existing case 1% AEP FFA peak flood levels and depths (538m³/s at Elizabeth Drive)

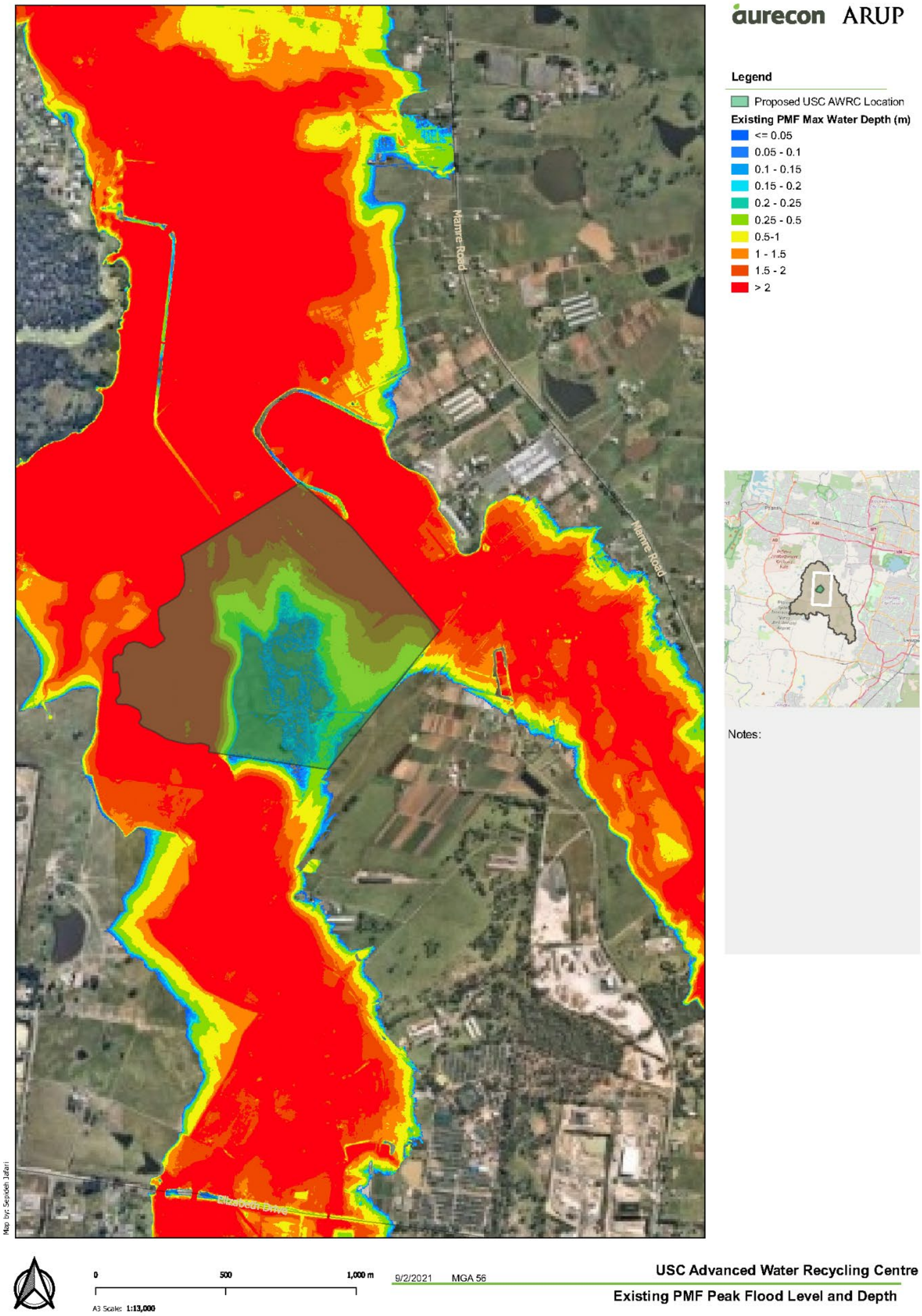


Figure 6-9 Existing case PMF peak flood levels and depths

6.2.2 Climate Change

The flooding impacts were also assessed for two climate change scenarios to identify the resilience of the propose development to climate change conditions, which would be in form of higher intensity storm events. To understand and compare the impact of climate change, increases of 10% and 20% were applied to rainfall intensity and the model inflow boundaries in accordance with the *Practical Consideration of Climate Change (DECC, 2007)*. The comparison shows that the impacts of 10% increase in rainfall intensity on flood levels are at or below 0.1 m and the impacts of 20% increase in rainfall intensity are less than 0.2 m to the flood levels in the study area. The water levels at a number of locations are reported in **Table 6-1** and graphically shown in **Figure 6-10**.

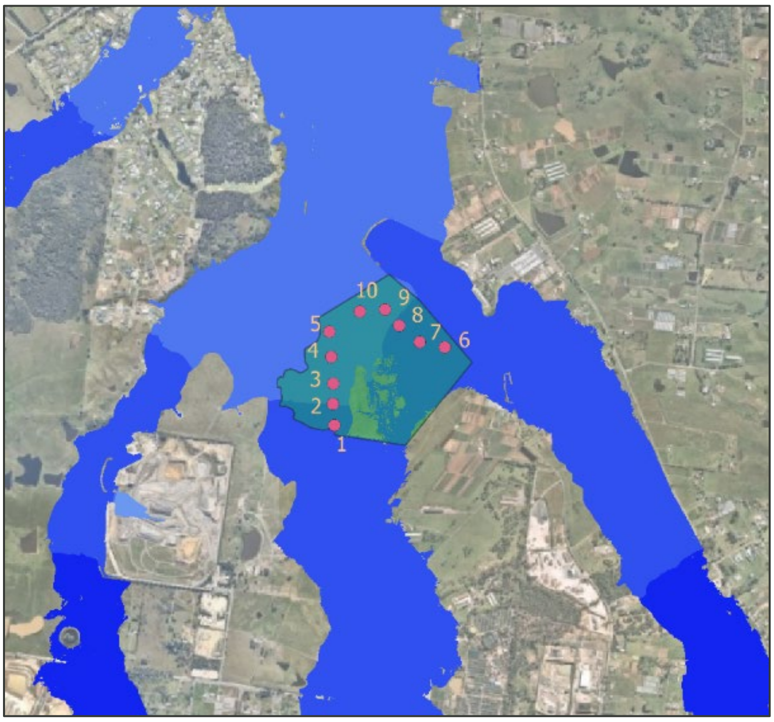


Figure 6-10 Location of Reporting Points

Table 6-1 Existing Water Levels (mAHD)

Point ID	10% AEP	1% AEP	0.5% AEP	0.2% AEP	1% AEP + 10%	1% AEP + 20%	1% AEP FFA	PMF
1	37.92	38.46	38.53	38.64	38.53	38.60	39.01	40.16
2	37.50	38.05	38.14	38.26	38.13	38.22	38.60	40.00
3	37.24	37.85	37.95	38.09	37.94	38.04	38.46	39.89
4	37.19	37.69	37.78	37.93	37.78	37.87	38.30	39.74
5	37.06	37.48	37.57	37.71	37.56	37.66	38.15	39.63
6	38.47	38.86	38.92	39.04	38.92	38.99	39.36	40.55
7	38.34	38.71	38.78	38.89	38.78	38.84	39.21	40.37
8	38.18	38.53	38.60	38.71	38.60	38.66	39.03	40.11
9	37.86	38.15	38.20	38.29	38.20	38.25	38.54	39.73
10	37.46	37.64	37.69	37.78	37.69	37.74	38.06	39.60

The existing peak flood depths and levels around the study area for climate change scenarios are shown in **Figure 6-11** and **Figure 6-12**.

As shown in **Figure 6-11**, under the 1% AEP event (10% rainfall increase), water levels along the western border range from 37.5 to 38.6 m AHD and along the eastern boundary from 37.6 to about 39.1 m AHD. For a 20% increase in rainfall intensity (shown in **Figure 6-12**), these numbers are slightly higher, ranging from 37.6 to 38.7 and from 37.7 to 39.15 m AHD, respectively.

PMF is the largest flood that could conceivably be expected to occur at a particular location. It is larger than any other flood including those resulting from climate change. As in our flood impact assessment we have demonstrated negligible impacts under PMF event, the proposed demonstrated is expected to be resilient for all more frequent events, including those resulting from climate change.

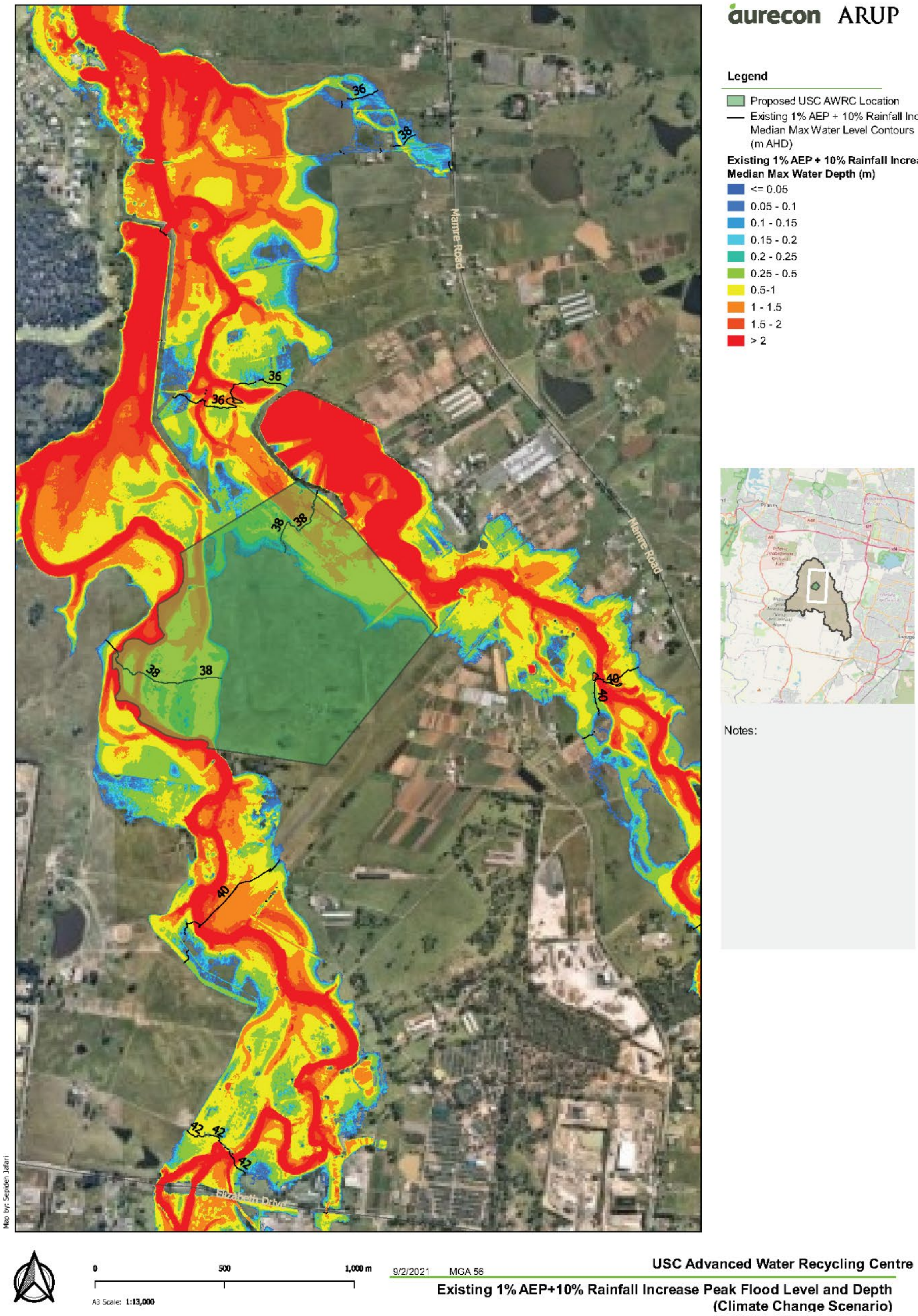


Figure 6-11 Existing case 1% AEP + 10% rainfall increase peak flood levels and depths (Climate Change)

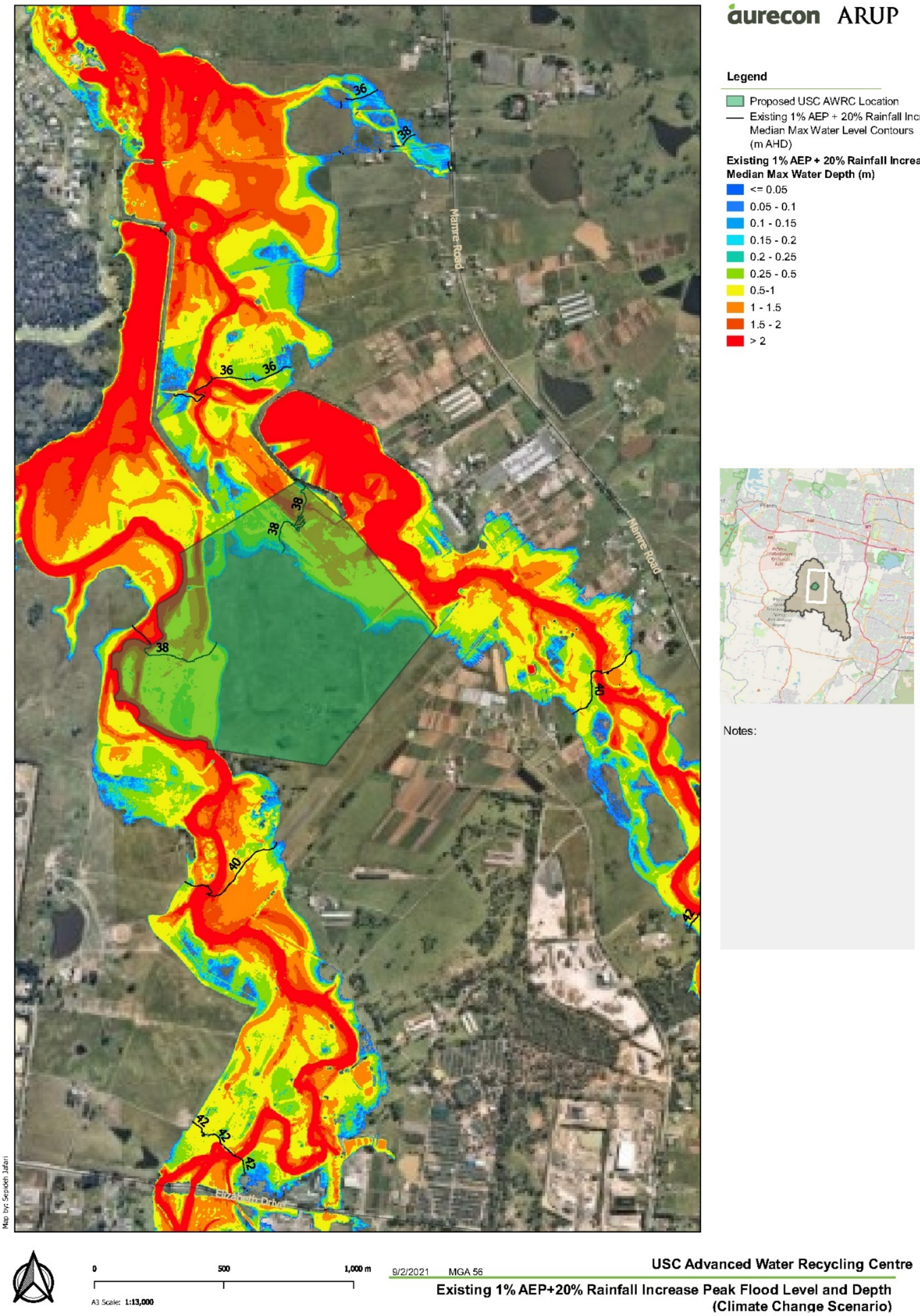


Figure 6-12 Existing case 1% AEP + 20% rainfall Increase Peak Flood Level and Depth (Climate Change)

6.2.3 Velocity

The existing peak flood velocities around the study area are shown graphically in Figure **6-13** through **Figure 6-20**.

As shown in **Figure 6-13**, Under the 10% AEP event, the maximum flood velocities which appear along the thalweg of creeks are about 1 m/s and majority of the inundated areas within the development site has flood velocities less than 0.6 m/s.

Under the 1% AEP event, (shown in **Figure 6-14**), flood velocities along South Creek thalweg increase to about 1.6 m/s and in limited sections within Kemps Creek to about 1.9 m/s. However, majority of the inundated areas within the development boundary experience lower velocities, mostly in the range of 0.35 to 0.65 m/s.

Under climate change scenarios (**Figure 6-15** and **Figure 6-16**), flood velocities increase slightly, reaching a maximum of 1.7 m/s in South Creek and a maximum of about 2 m/s inside Kemps Creek.

Flood velocities under 0.5% and 0.2% AEP events (shown in **Figure 6-17** and **Figure 6-18**) are limited to a maximum of 1.7 m/s in South creek and a maximum of about 2 m/s inside Kemps Creek, similar to the climate change scenarios.

Under PMF event shown in **Figure 6-20**, a large part of the development site is inundated with flood velocities more than 1 m/s and up to about 2 m/s.

Under the 1% AEP FFA event, flood velocities within the site boundary along South Creek thalweg increase in limited sections to 2.1 m/s and a maximum of 2.4 m/s in Kemps Creek.

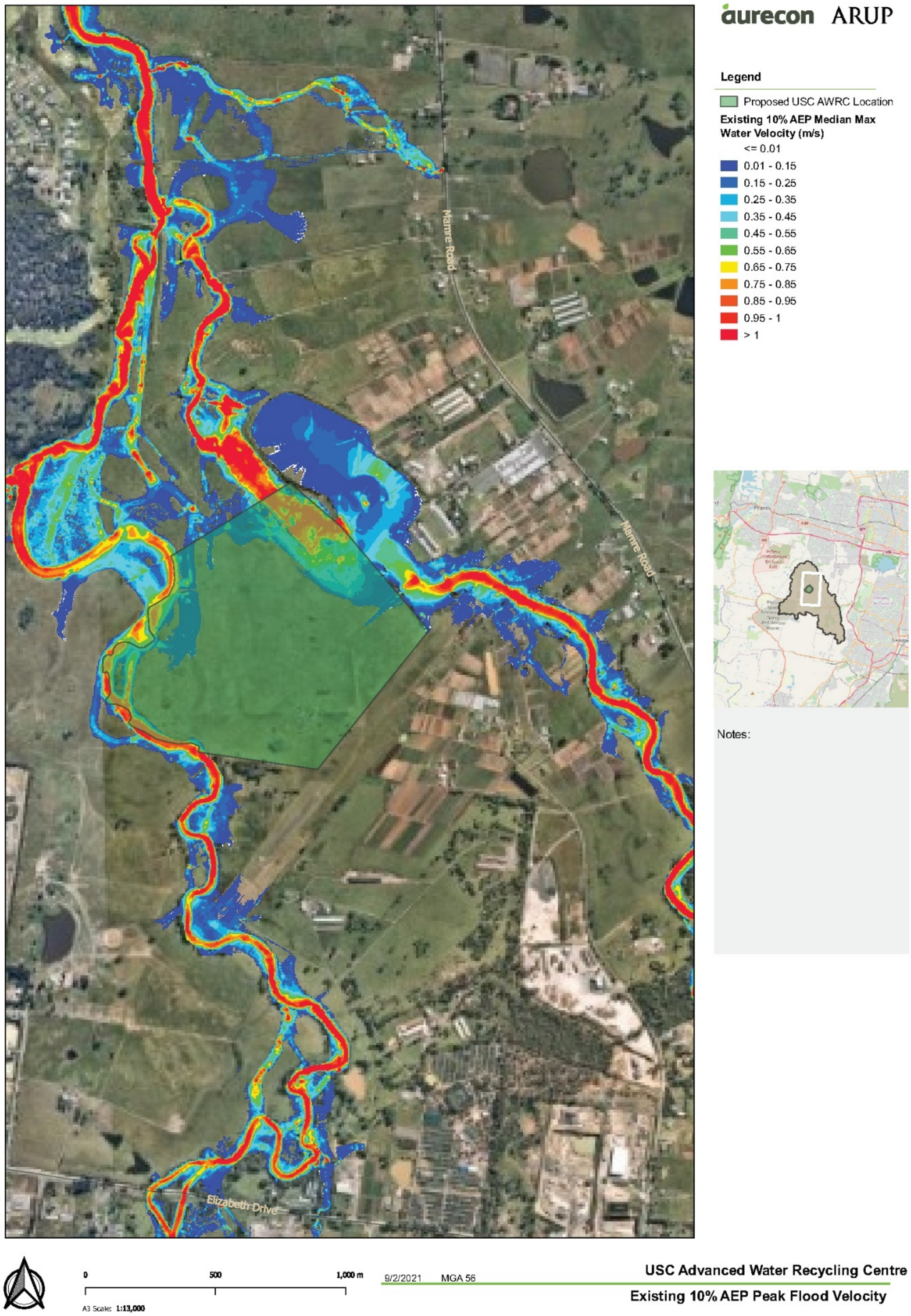


Figure 6-13 Existing case 10% AEP peak flood velocities

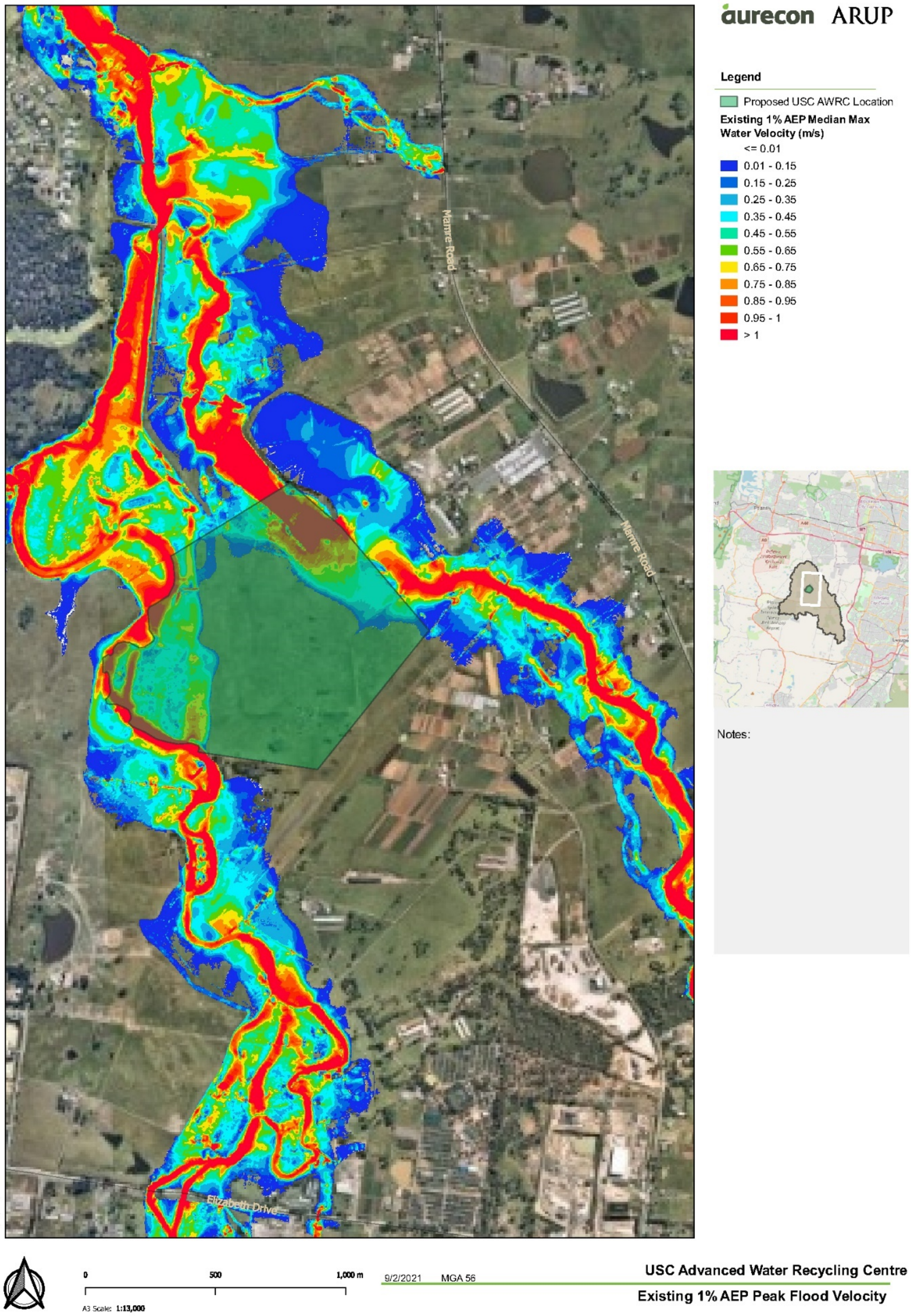


Figure 6-14 Existing case 1% AEP peak flood velocities

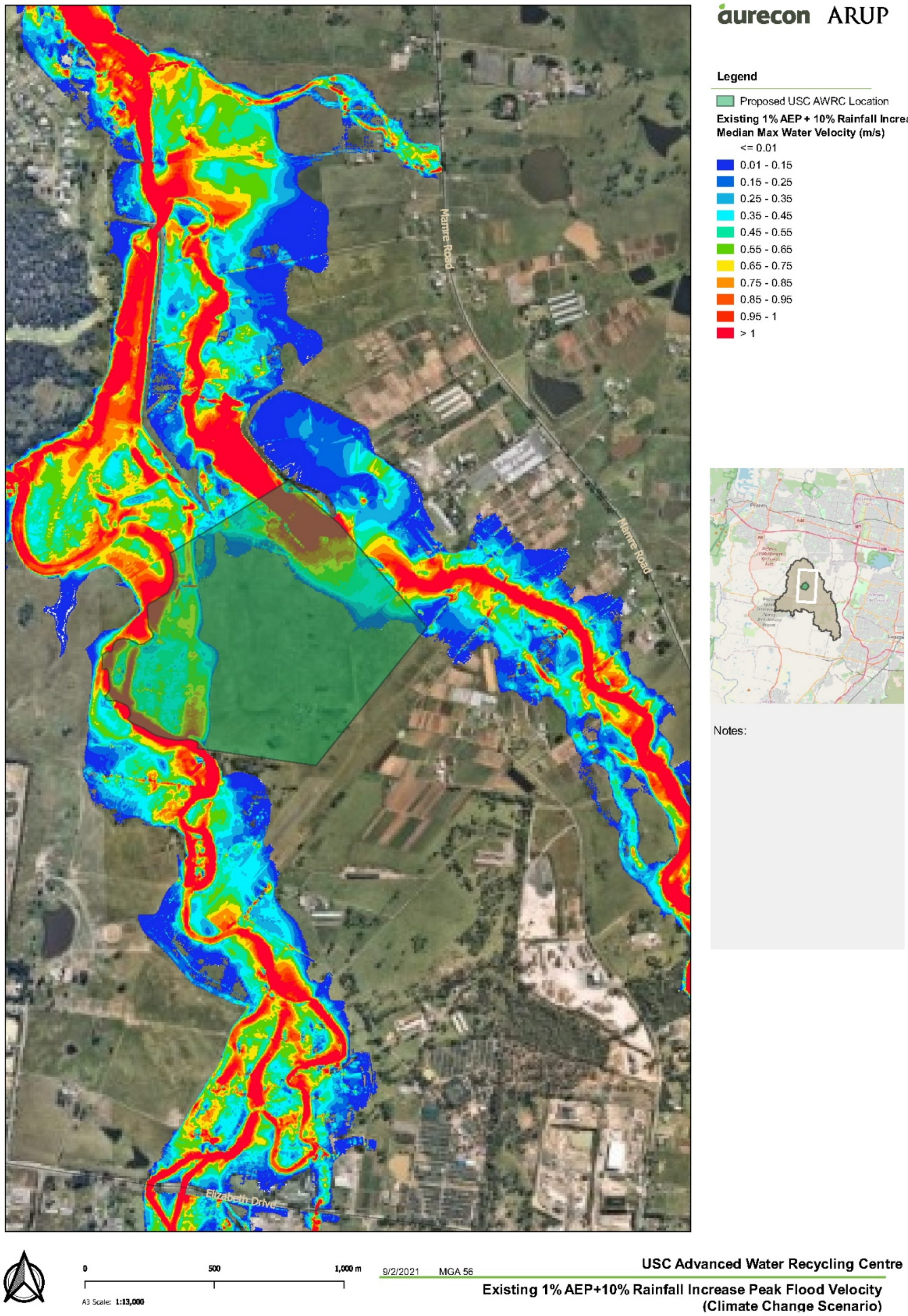


Figure 6-15 Existing case 1% AEP+10% rainfall increase peak flood velocities (Climate Change)

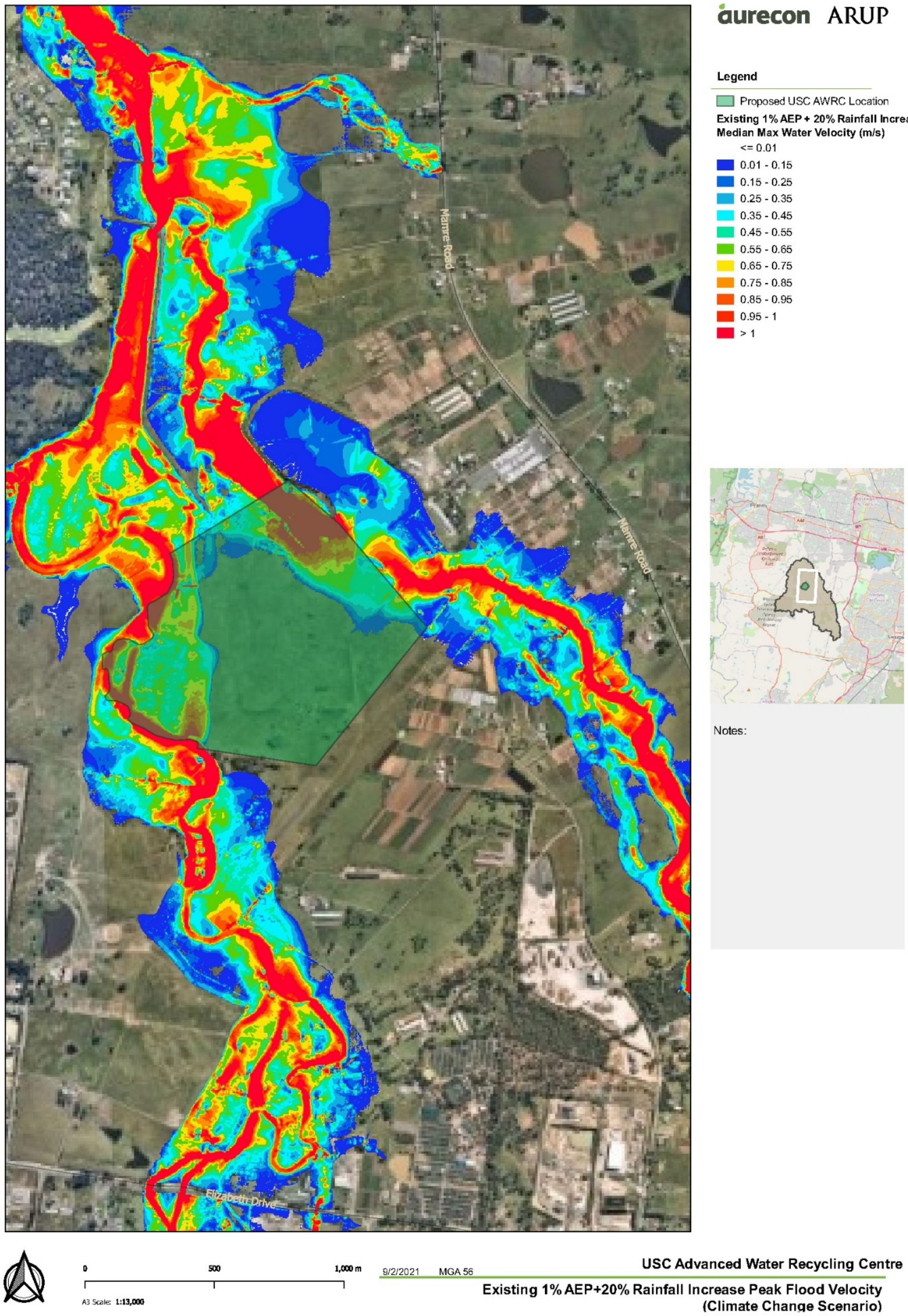


Figure 6-16 Existing case 1% AEP+20% rainfall increase peak flood velocities (Climate Change)

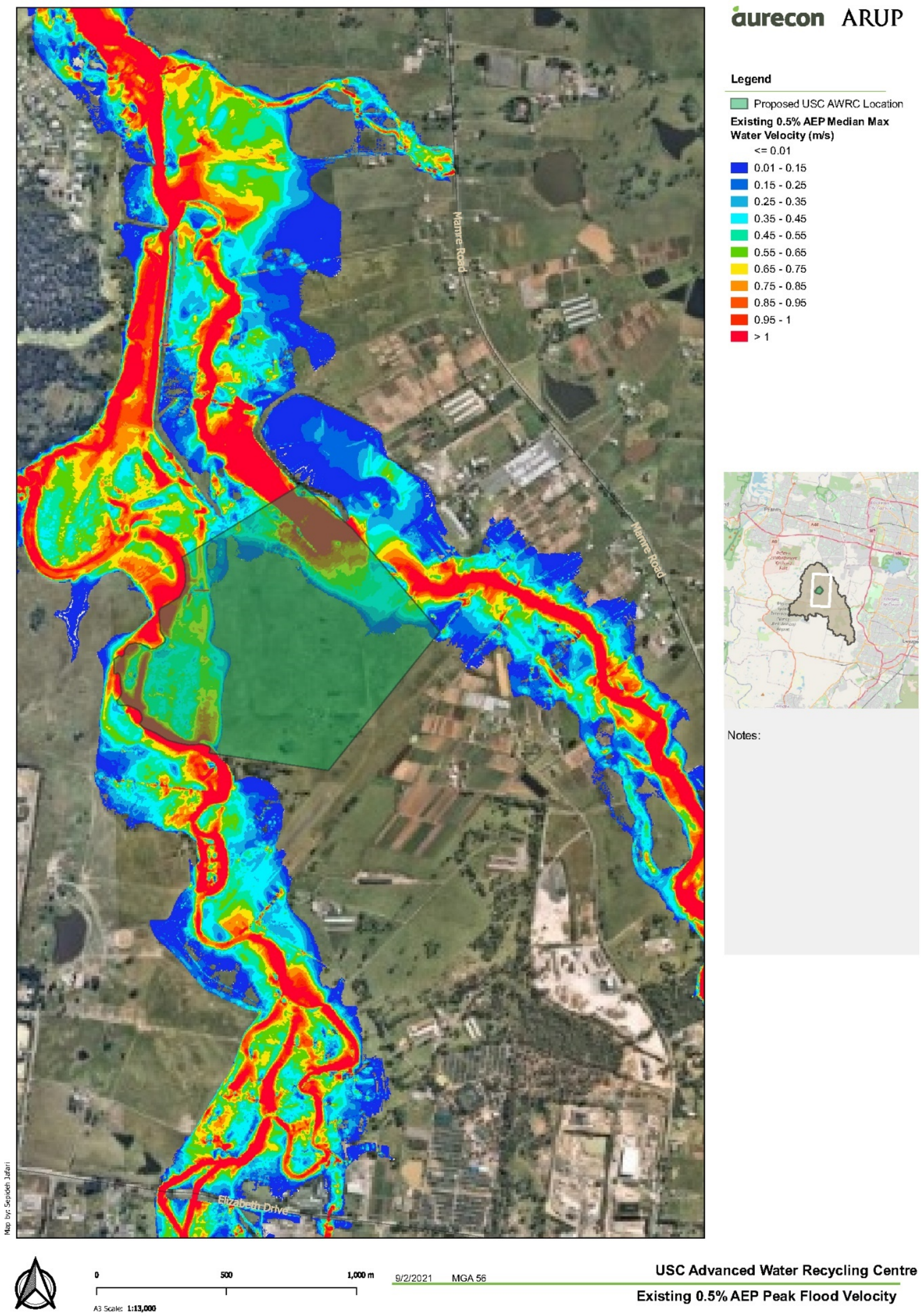


Figure 6-17 Existing case 0.5% AEP peak flood velocities

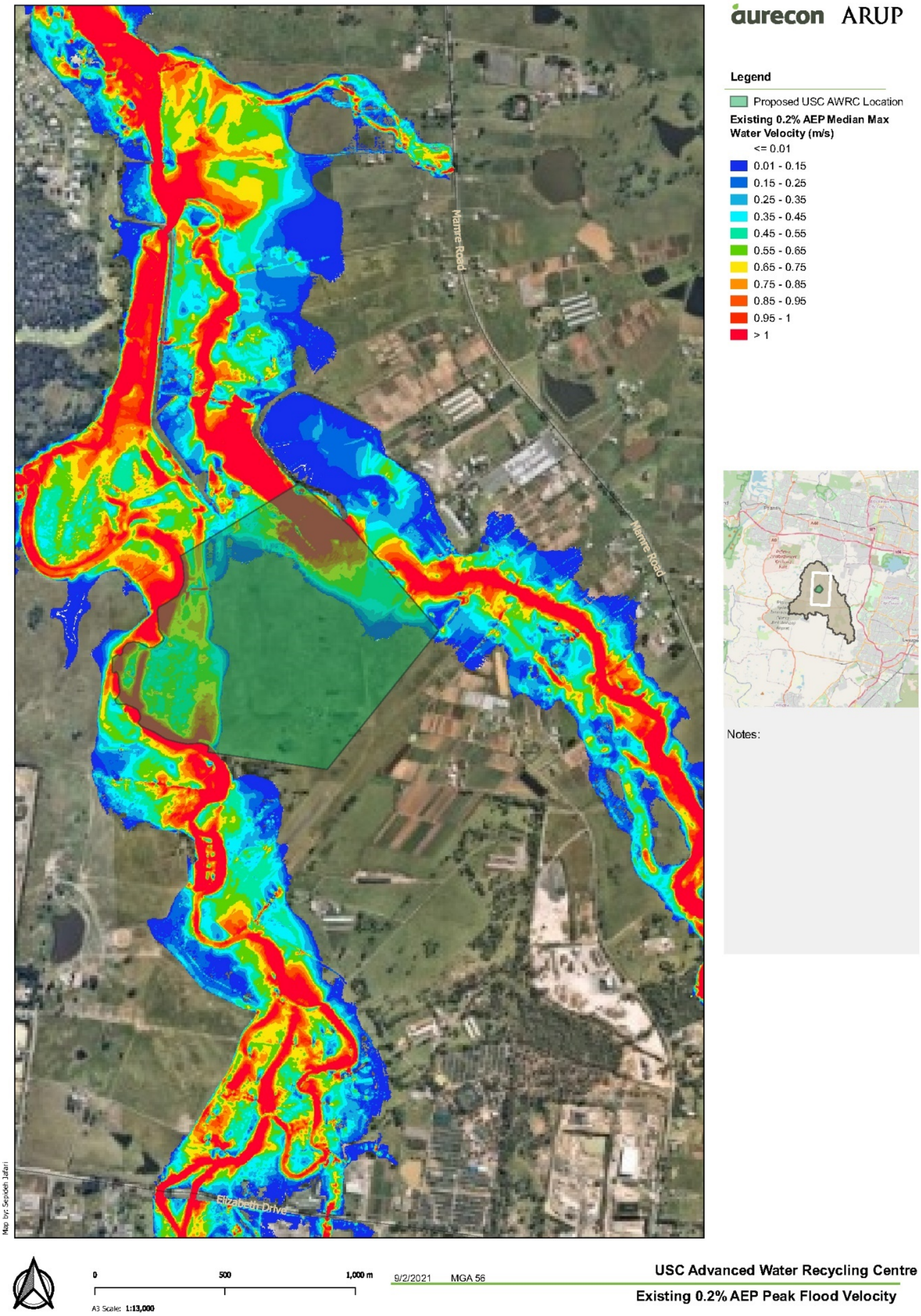


Figure 6-18 Existing case 0.2% AEP peak flood velocities

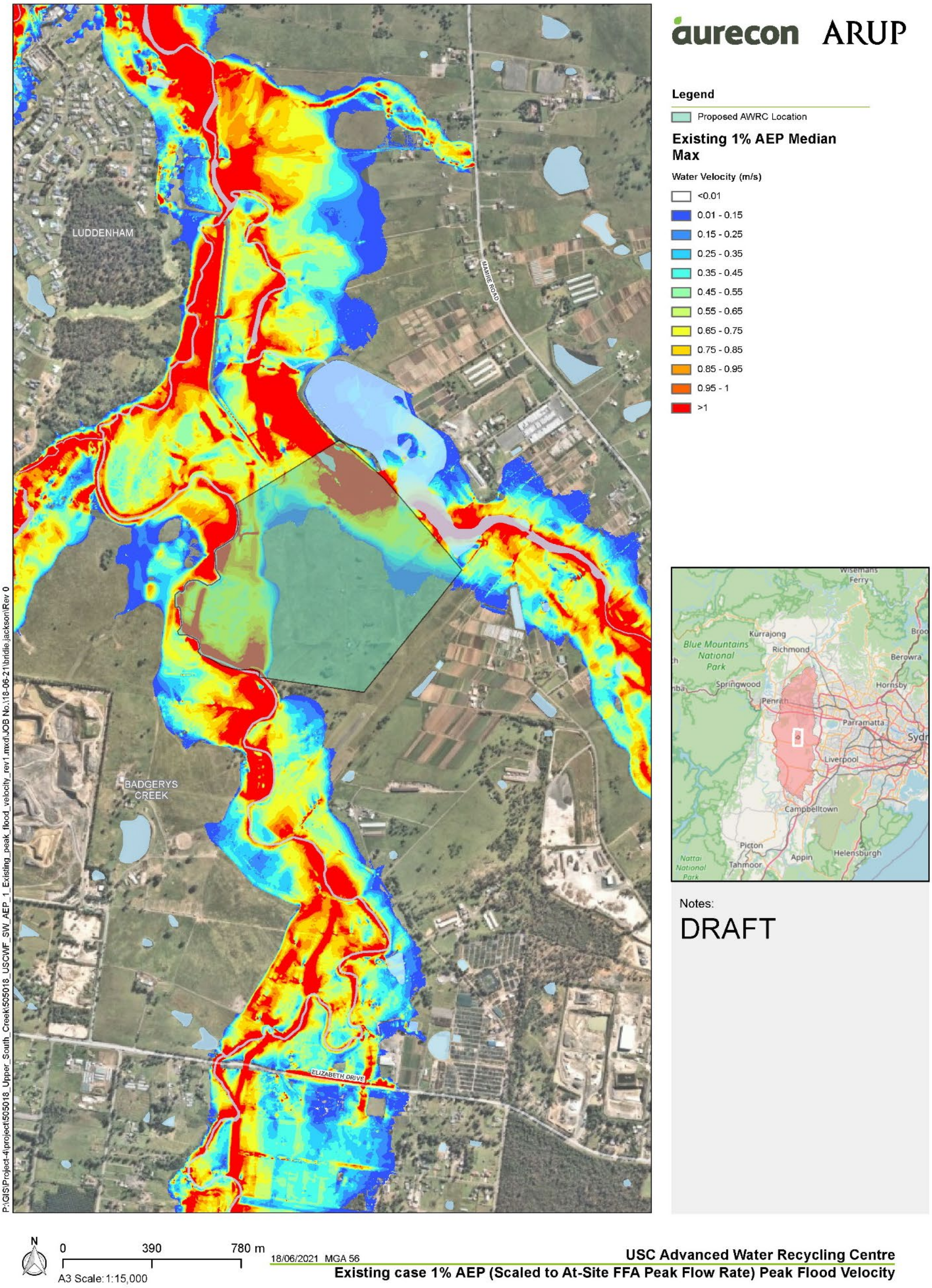


Figure 6-19 Existing case 1% AEP FFA peak flood velocities

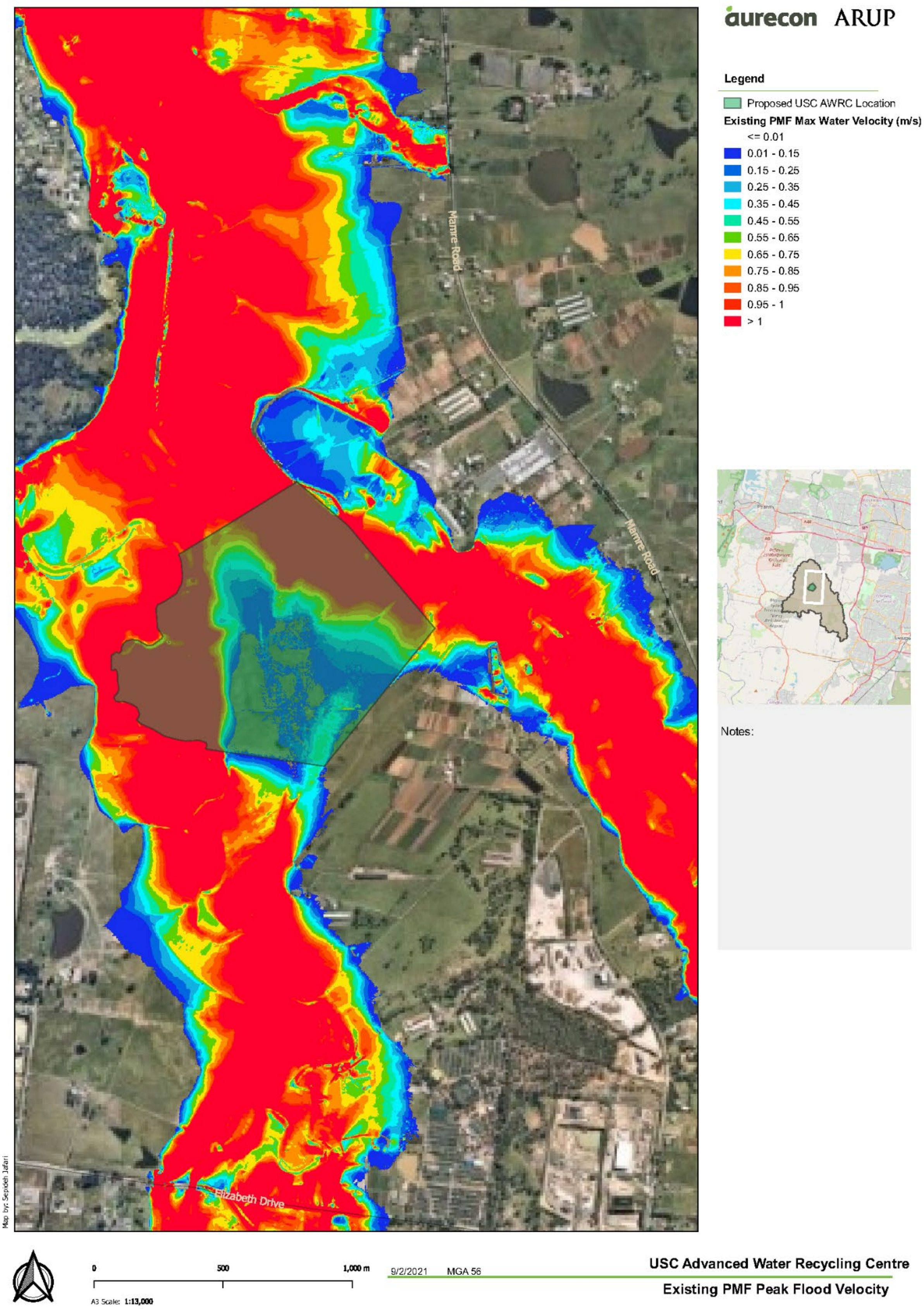


Figure 6-20 Existing case PMF peak flood velocities

6.2.4 Flood Hazard

The Australian Rainfall & Runoff Guidelines (2019) has suggested a set of curves to identify hazard categories based on the mechanisms associated with instability of people, vehicles, and buildings in flood flows.

The magnitude of flood hazard can be influenced by flood velocity, flood depth and combination of velocity and depth of floodwaters. These have been used in the generation of flood hazard curves in ARR 2019. The proposed set of curves and associated thresholds used in the hazard vulnerability classification are presented in **Figure 6-21** and **Table 6-2**.

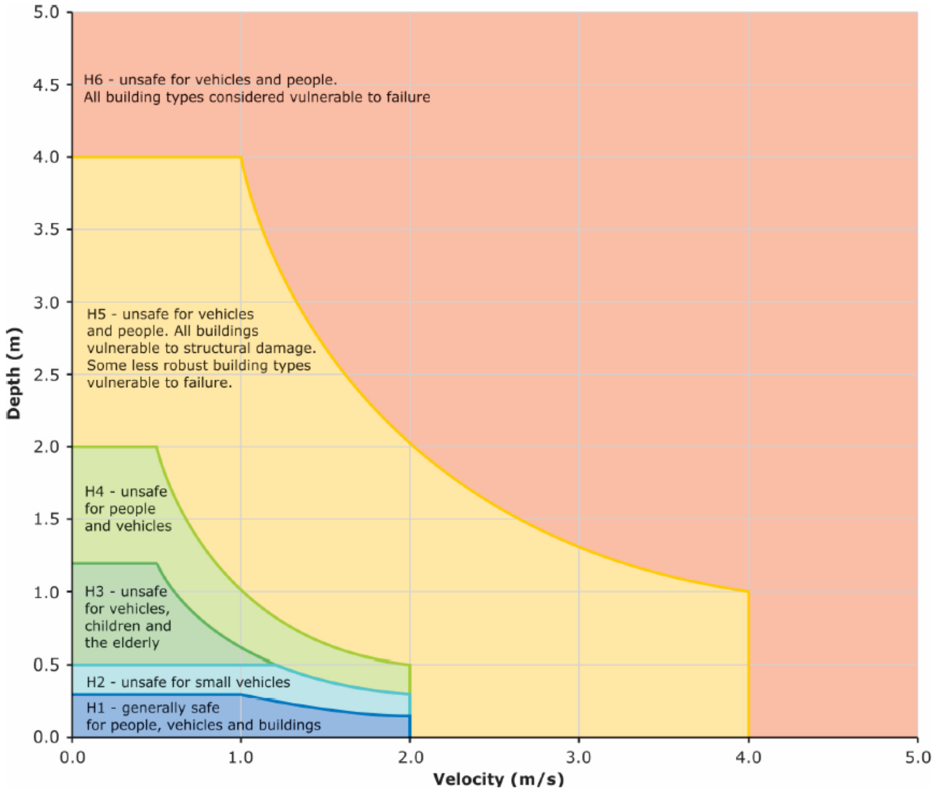


Figure 6-21 Combined Flood Hazard Curves (ARR 2019)

Table 6-2 Combined Hazard Curves – Vulnerability Thresholds Classification Limits (ARR 2019)

Hazard Vulnerability Classification	Description	Classification Limit (D and V in combination)	Limiting Still Water Depth (D)	Limiting Velocity (V)
H1	Generally safe for vehicles, people, and buildings.	D*V ≤ 0.3	0.3	2.0
H2	Unsafe for small vehicles.	D*V ≤ 0.6	0.5	2.0
H3	Unsafe for vehicles. children and the elderly.	D*V ≤ 0.6	1.2	2.0
H4	Unsafe for vehicles and people.	D*V ≤ 1.0	2.0	2.0
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.	D*V ≤ 4.0	4.0	4.0

Hazard Vulnerability Classification	Description	Classification Limit (D and V in combination)	Limiting Still Water Depth (D)	Limiting Velocity (V)
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.	D*V > 4.0	-	-

The existing flood hazard maps within the study area are shown in **Figure 6-22** to **Figure 6-29**.

Under the 10% AEP event shown in **Figure 6-22**, the inundated areas within the development boundary are mostly classified as H1 to H3. Areas of H4 and H5 due to high flow depth or a combination of high flow depth and velocity are seen in the channel and deeper flood storage areas as expected.

As mentioned in **Section 6.2.1**, approximately 46% of the proposed site is subject to inundation under the 1% AEP event. As shown in **Figure 6-23**, most of the inundated area is still seen to be classified as H1 to H3. The remaining inundated areas are H4 and H5 due to high flow depth or a combination of flow depth and velocity.

The H4 and H5 extents increase slightly through the very rare to extreme AEP events as shown in **Figure 6-24** through **Figure 6-27**.

Under the 1% AEP FFA event, approximately 53% of the proposed site is subject to inundation under the 1% AEP FFA event. As shown in **Figure** 6-28, the H1 to H3 categories make up 34% of the inundated area in this scenario, with the H4 and H5 making up 61% and H6 the remaining 5% through portions of the creek centrelines.

During the PMF event shown in **Figure 6-29**, most of the inundated area is classified as H5 which is unsafe for vehicles and people and any building in this area can be exposed to structural damage or failure.

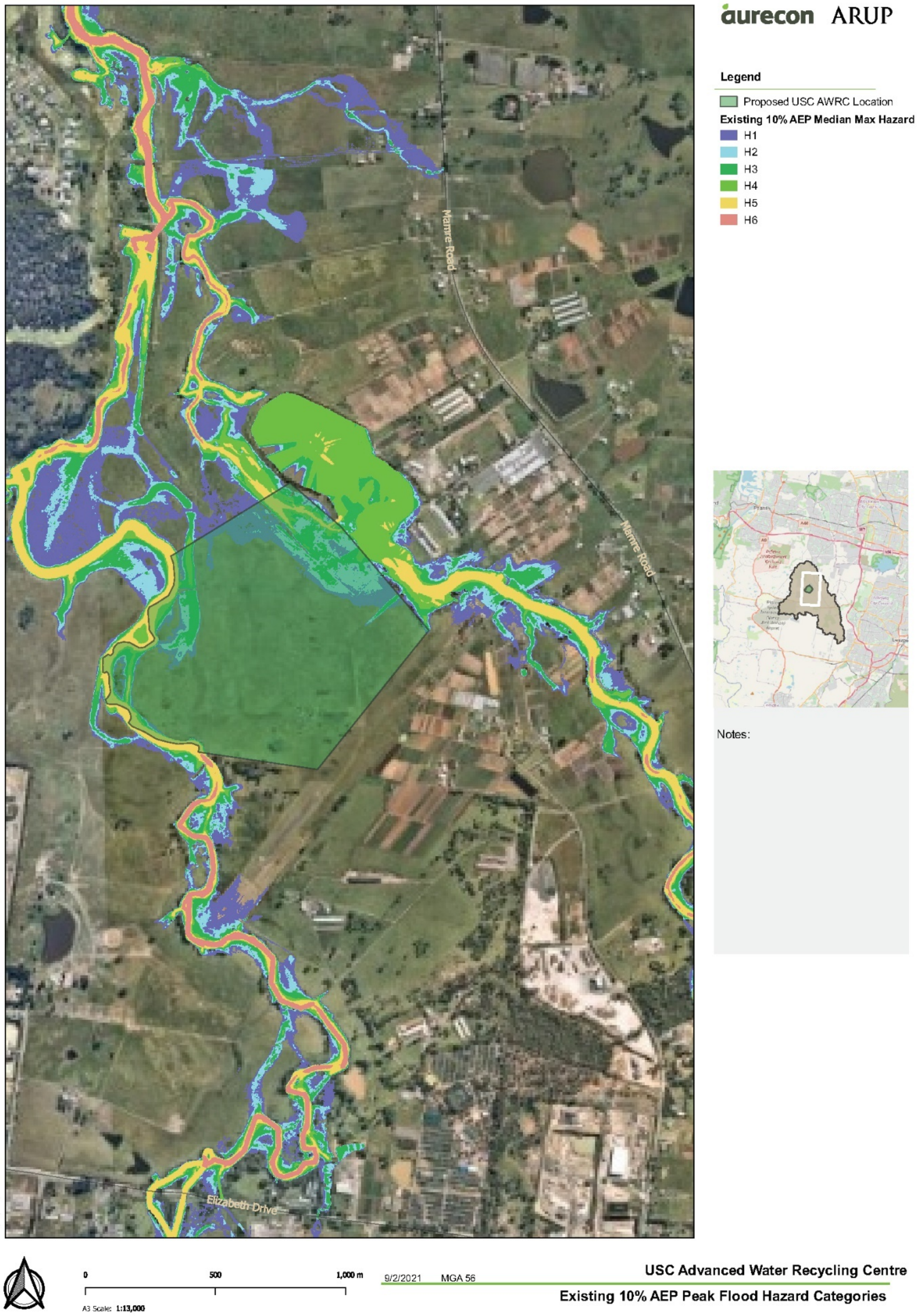


Figure 6-22 Existing case 10% AEP flood hazard categories

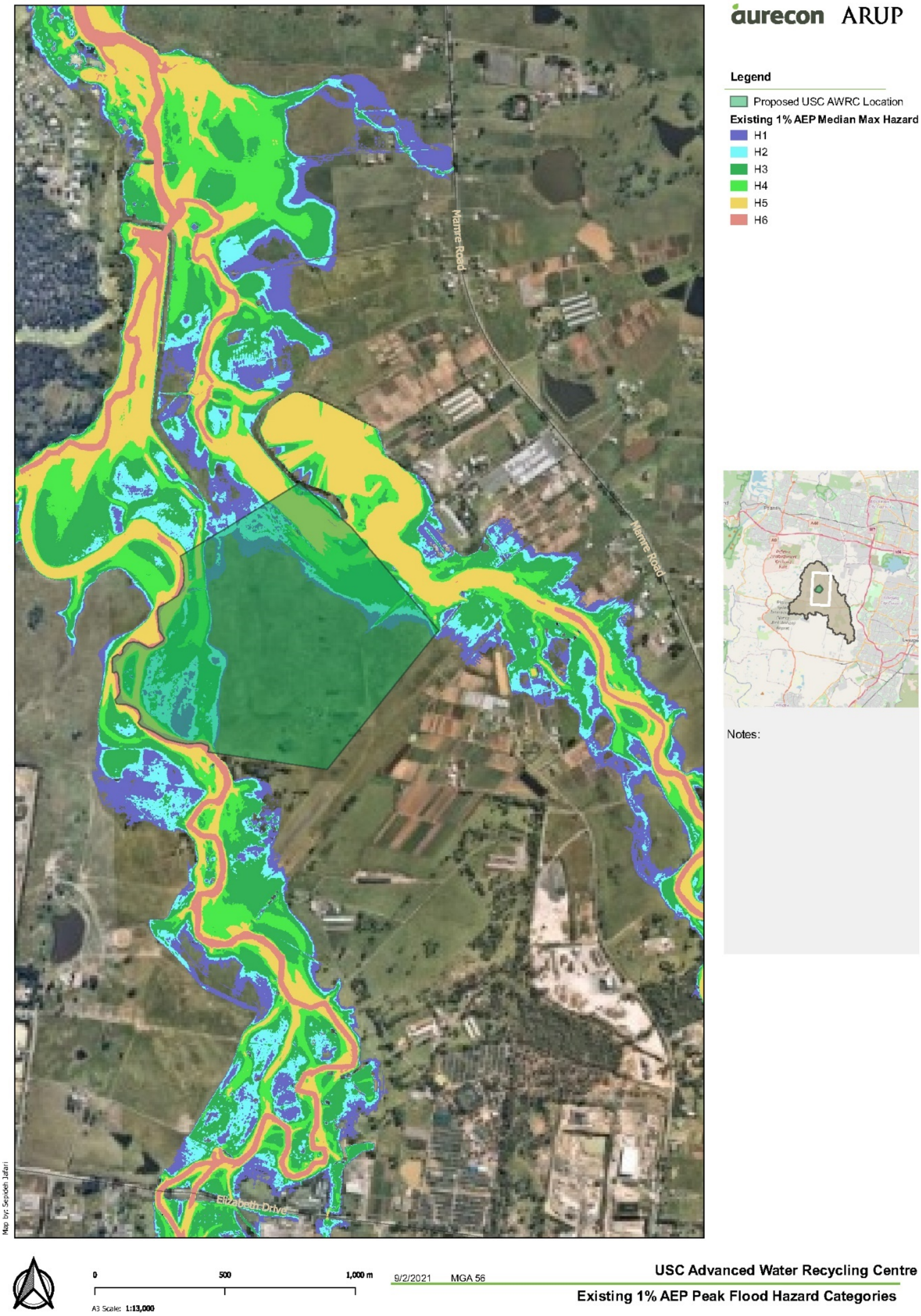


Figure 6-23 Existing case 1% AEP flood hazard categories

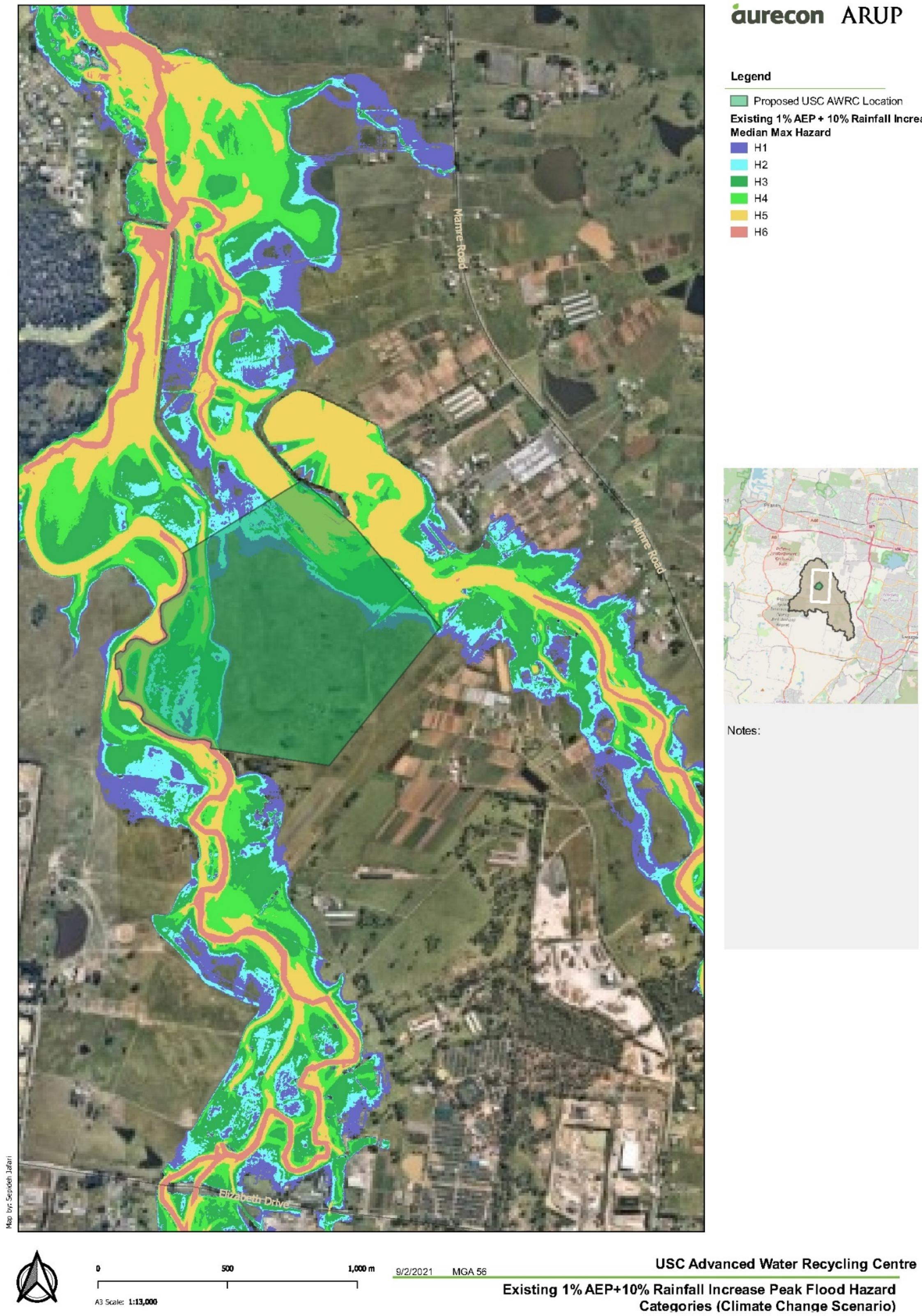


Figure 6-24 Existing case 1% AEP+10% rainfall increase flood hazard categories (Climate Change)

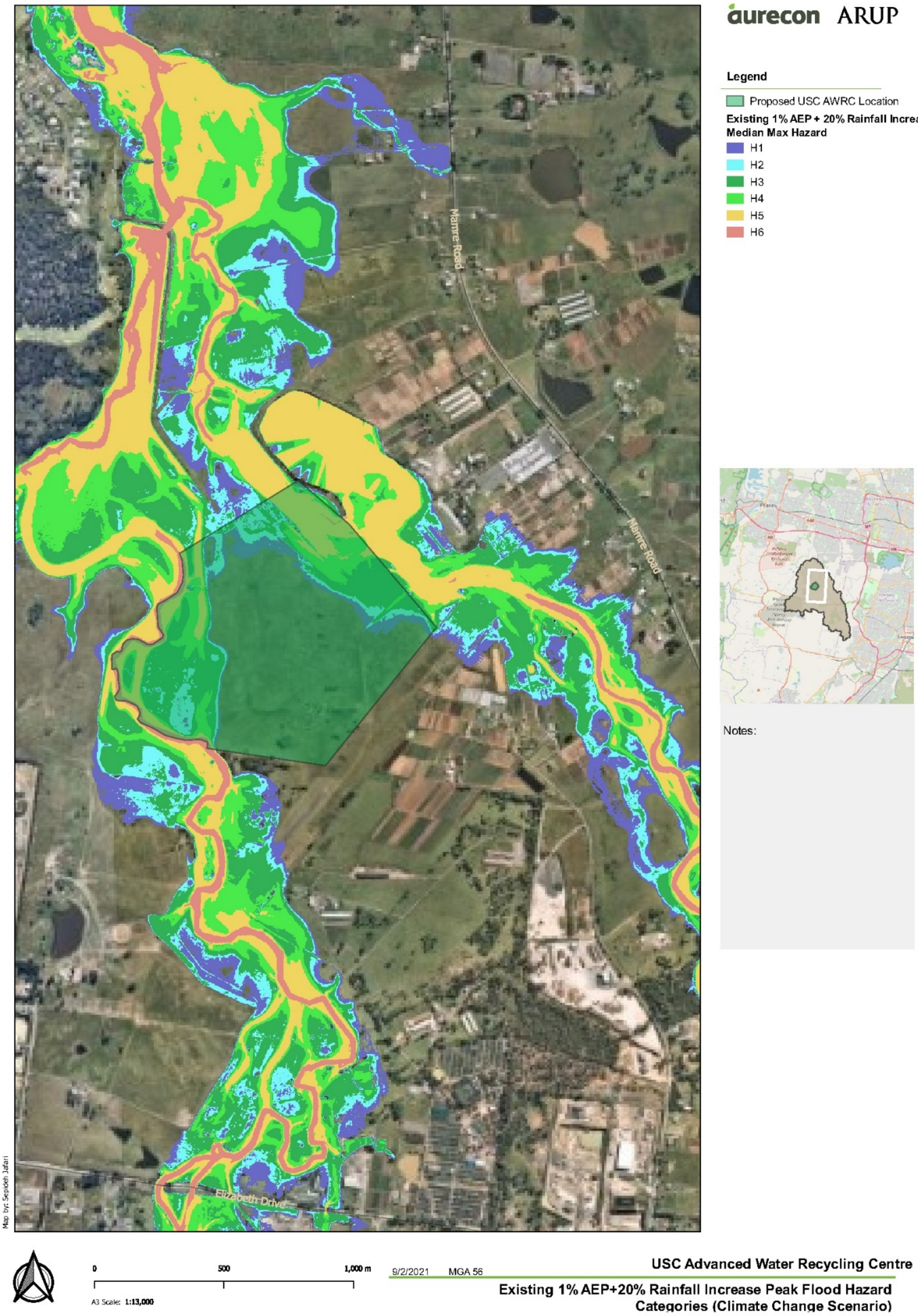


Figure 6-25 Existing case 1% AEP+ 20% rainfall increase flood hazard categories (Climate Change)

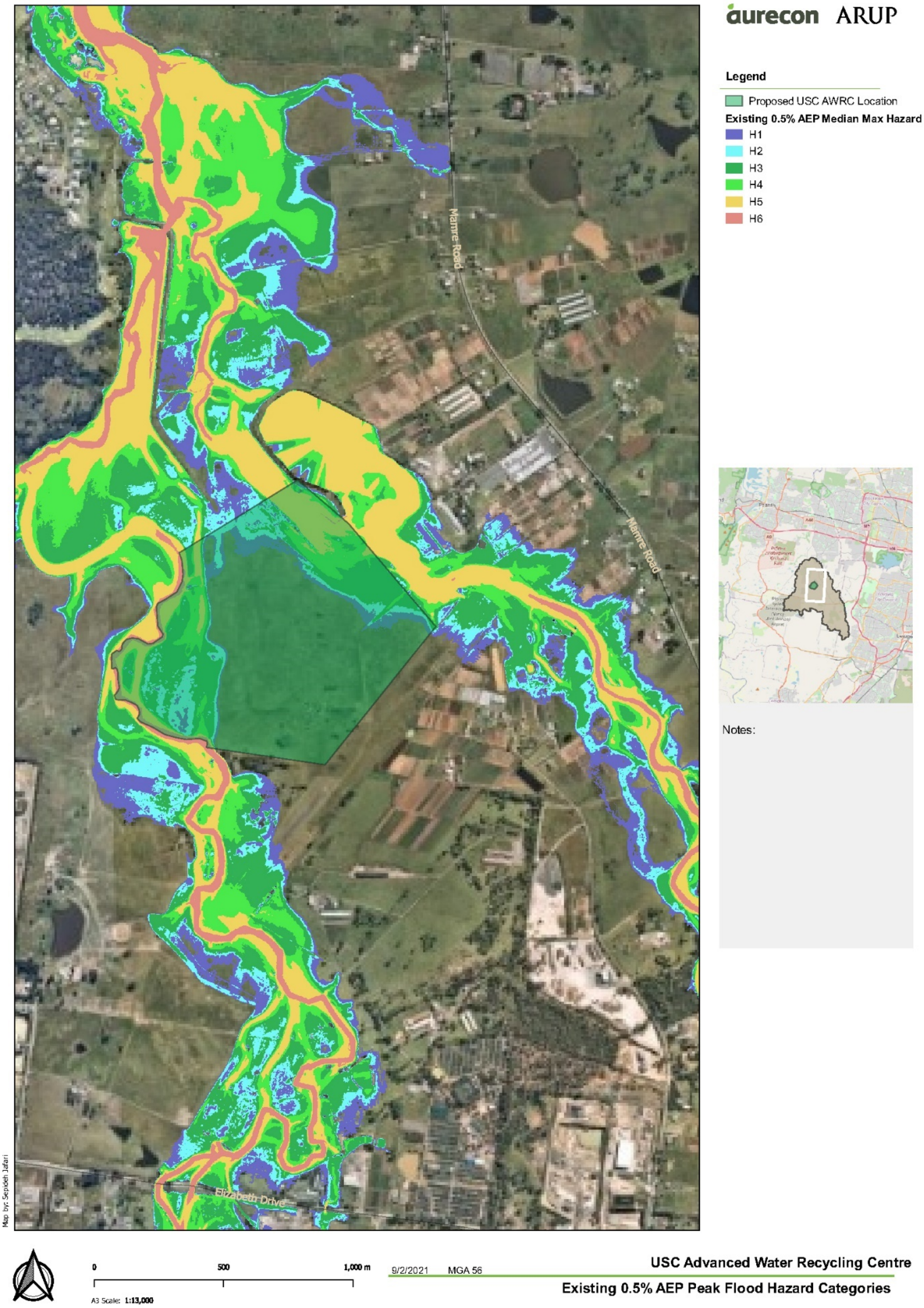


Figure 6-26 Existing case 0.5% AEP flood hazard categories

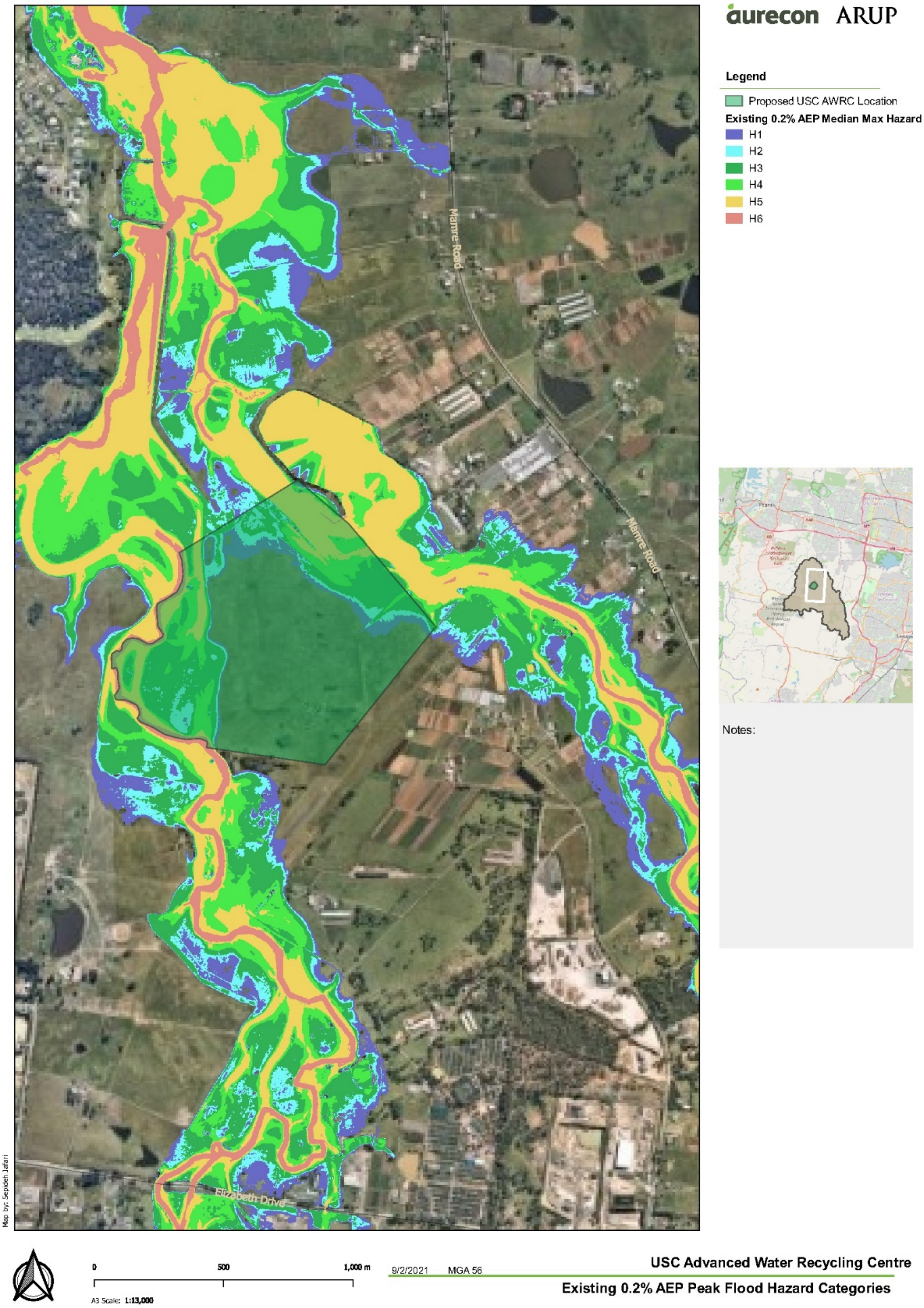


Figure 6-27 Existing case 0.2% AEP flood hazard categories

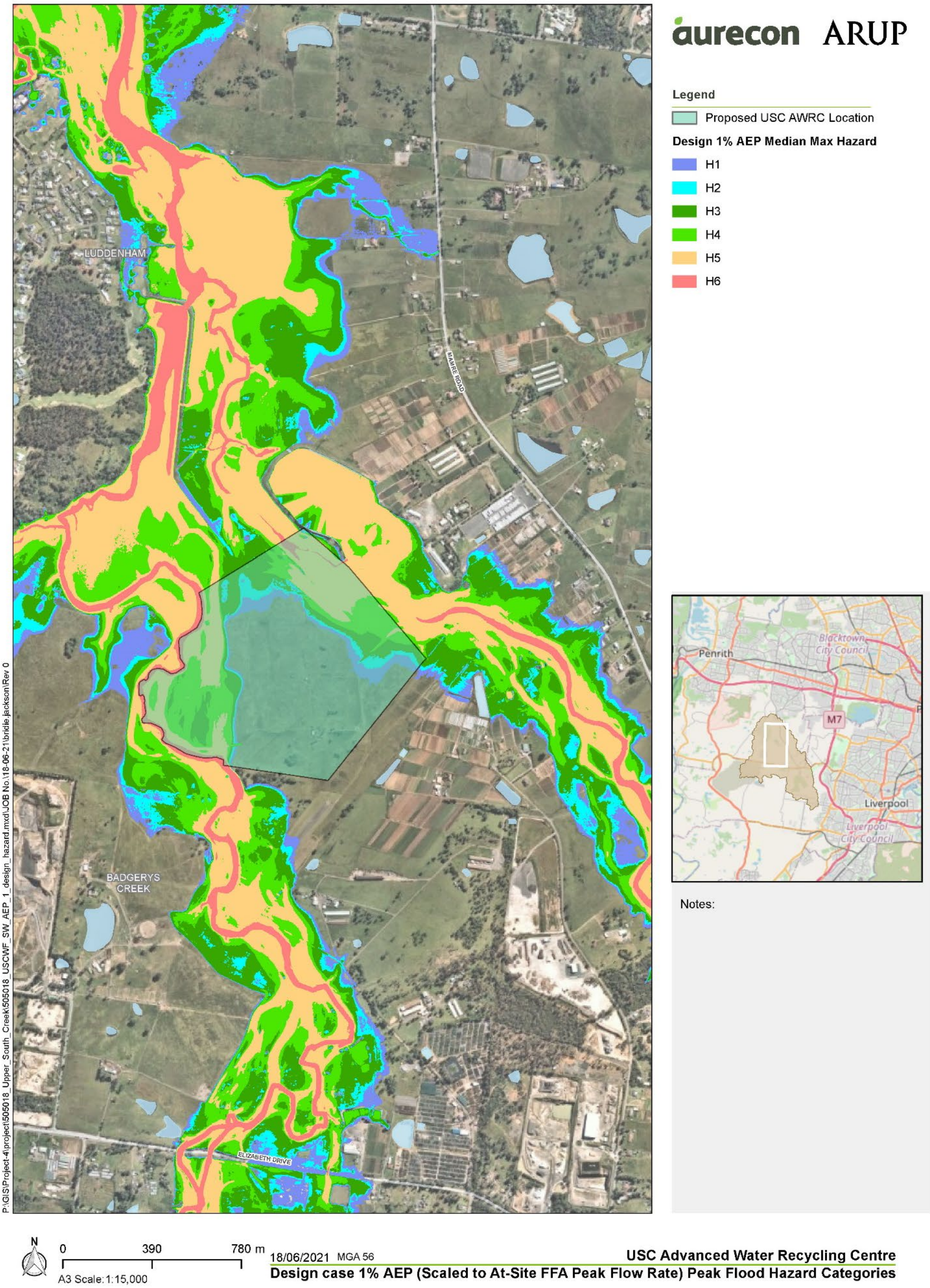


Figure 6-28 Existing case 1% AEP FFA flood hazard categories

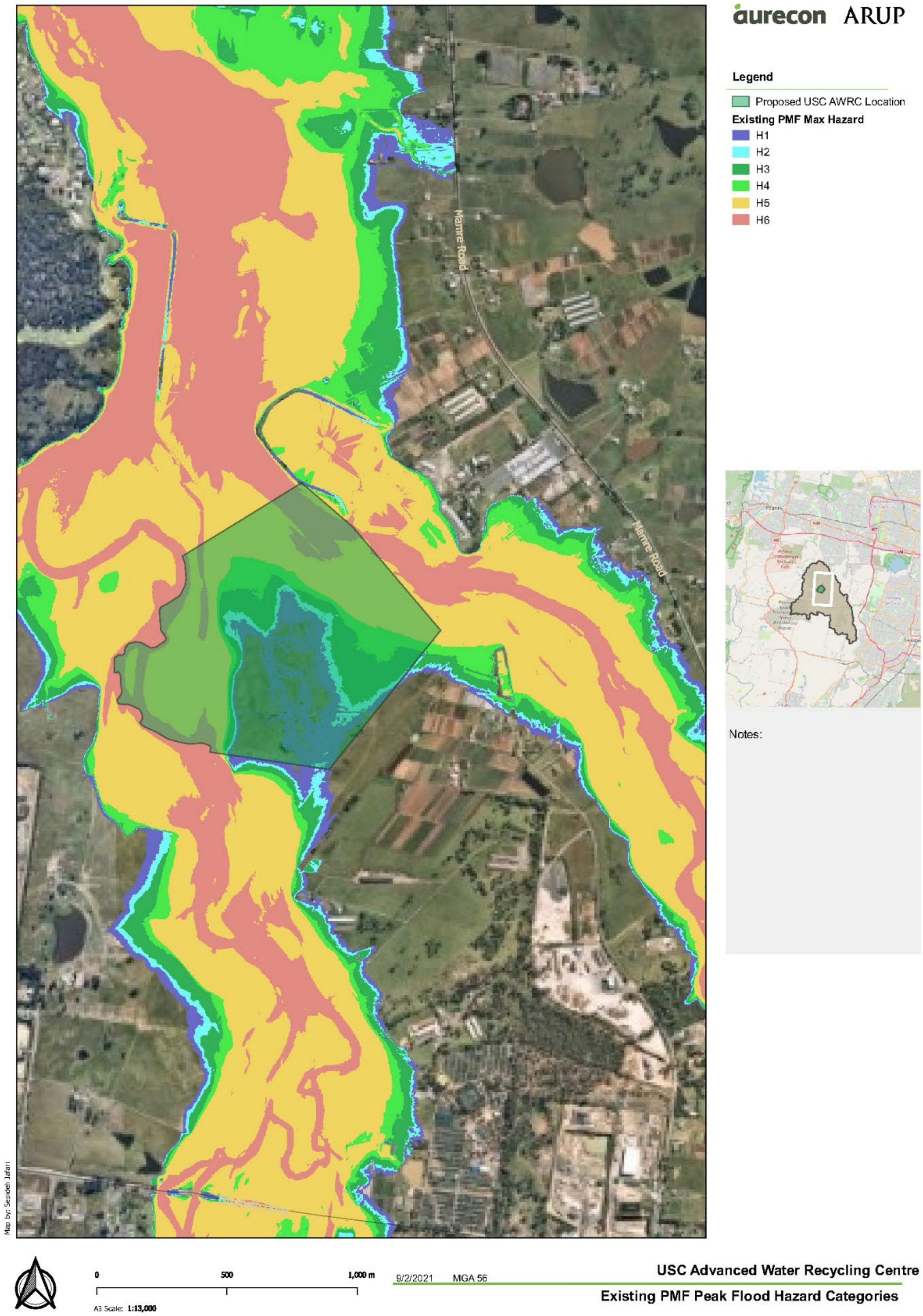


Figure 6-29 Existing case PMF flood hazard categories