Flood Report

Willyama High School

Prepared for NSW Department of Education / 2 June 2025

241616

TTW (NSW) PTY LTD (ACN 649 974 112)

(ABN 74 649 974 112) I Consulting Engineers

Level 6, 73 Miller Street, North Sydney NSW 2060

Your Partner in Engineering

Contents

1.0 Introduction ... 6

1.1 Guidance Documents ... 6

1.2 Site Description ... 6

2.0 Flood Planning Requirements ... 8

3.0 Previous Studies and available Flood information ... 11

3.1 Broken Hill Urban Stormwater Master Plan (2006) ... 11

3.2 Historical Flooding Events in Broken Hill ... 13

4.0 Hydraulic and Hydrologic Modelling ... 13

4.1 RORB and TUFLOW Model Development ... 13

4.2 Upstream Catchment Characteristics and Time of Concentration ... 16

4.3 Model validation ... 18

4.4 Site Survey ... 19

4.5 Critical Durations and Temporal Patterns ... 20

4.6 Flooding Impact Due to Climate Change ... 21

4.7 Flood Hazard Assessment ... 21

5.0 Existing Flood Model Results ... 23

6.0 Post-Development Modelling and Result ... 32

7.0 Flood Impact ... 44

8.0 Mitigation Measures ... 48

9.0 Conclusion ... 48

Appendix A 50

Appendix B 51

Rev	Date	Prepared By	Approved By	Remarks
1	25/02/2025	A.Vahidi	T.Moore	For Information
2	22/04/2025	A.Vahidi	T.Moore	Draft
3	2/06/2025	A.Vahidi	T.Moore	Final

Glossary and Abbreviations

Annual Exceedance Probability	AEP	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage
Australian Height Datum	AHD	A common national surface level datum often used as a referenced level for ground, flood and flood levels, approximately corresponding to mean sea level.
Average Recurrence Interval	ARI	The long-term average number of years between the occurrence of a flood equal to or larger in size than the selected event. ARI is the historical way of describing a flood event. AEP is generally the preferred terminology.
Bureau of Meteorology	BoM	An executive agency of the Australian Government responsible for providing weather services to Australia and surrounding areas.
Critical Duration		The critical duration is the storm duration for a given event magnitude that provides for the peak flood conditions at the location of interest.
Development Control Plan	DCP	A Development Control Plan is a document prepared by the Council which provides detailed guidelines which assist a person proposing to undertake a development. A DCP must be consistent with the provisions and objectives of a Local Environmental Plan (LEP).
Finished Floor Level	FFL	The level, or height, at which the floor of a building or structure (including alterations and additions) is proposed to be built.
Flood hazard		A source of potential harm or a situation with a potential to cause loss of life, injury and economic loss due to flooding. Flood hazard is defined as a function of the relationship between flood depth and velocity.
Flood Planning Level	FPL	The combination of the flood level from the defined flood event and freeboard selected for flood risk management purposes.
Freeboard		A factor of safety typically used in relation to the setting of floor levels or levee crest levels. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the floodplain, such as wave action, localised hydraulic behaviour etc.
Local Environmental Plan	LEP	LEPs provide a framework that guides planning decisions for local government areas through zoning and development controls. Zoning determines how land can be used (for example, for housing, industry, or recreation).
Probable Maximum Flood	PMF	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.

Representative Concentration Pathways	RCP	RCPs make predictions of how concentrations of greenhouse gases in the atmosphere will change in future as a result of human activities. The four RCPs range from very high (RCP8.5) through to very low (RCP2.6) future concentrations.

Executive Summary

This Flood Report has been prepared to support the Review of Environmental Factors (REF) for the proposed redevelopment of Willyama High School in Broken Hill, NSW. The report addresses flood-related risks and design requirements in accordance with relevant guidance from the Broken Hill City Council Development Control Plan (DCP), Flood Risk Management Guideline LU01, June 2023, and industry best practices.

The study incorporates hydrologic and hydraulic modelling using RORB and TUFLOW to assess the existing and post-development flood conditions. The modelling covers a range of design flood events, including 10%, 1%, 0.2%, 0.05% AEP and the Probable Maximum Flood (PMF), as well as future climate change impacts. Site-specific topographical data and updated civil design layouts were used to ensure model accuracy.

Key outcomes of the assessment include:

- The proposed development does not cause a significant increase in flood levels (i.e., afflux of less than 10 mm) under all modelled events except the PMF.

- For the PMF event, a maximum afflux of approximately 70 mm is observed at several properties already affected by flooding, with existing flood depths exceeding 0.5 m.

- The site is subject to both regional and local flooding, with PMF durations being short (less than 30 minutes), resulting in limited opportunity for safe evacuation.

- Finished Floor Levels (FFLs) for all new buildings are designed to be above the greater of the PMF level or the 1% AEP + 500mm freeboard. The FFLs are 292.70 m AHD for Block A, 293.30 m AHD for Block B for Block C.

- Flood risk mitigation strategies have been recommended, including raising floor levels, using flood-resilient materials, and implementing a site-specific Flood Emergency Response Plan (FERP).

As part of the proposed development, a deck structure with a channel beneath it will be constructed between Blocks B and C. For modelling purposes, a 50% blockage factor has been adopted for the channel to reflect the proposed stairs and channel blockage. To ensure the continued functionality of this channel and minimise flood risks, it is recommended that the channel be inspected and cleaned at least once per year, and after any significant flood event, to prevent blockage and maintain adequate flow capacity.

1.0 Introduction

This Flood Impact and Risk Assessment has been prepared by TTW on behalf of NSW Department of Education(the department) to assess the potential environmental impacts that could arise from the redevelopment of Willyama High School at 300 Murton Street, Broken Hill Lot 5858 DP757298 (the site).

This report has been prepared to address flood-related engineering design considerations for the development site, ensuring compliance with the relevant requirements of Broken Hill City Council's Development Control Plan (DCP) and NSW Government's Flood Risk Management Guideline LU01 – Management of Flood Liable Land.

This report accompanies a Review of Environmental Factors (REF) that seeks approval for the redevelopment of Willyama High School, which involves the following works:

- Construction of new three-storey school buildings along the McGowen Lane frontage, including learning hubs, specialist facilities, an administration and library.
- Construction of a multi-purpose hall with frontage to Murton Street.
- Tree removal.
- Construction of car parking, waste storage and loading area.
- Associated site landscaping and open space improvements.
- Public domain works including kiss and drop zone and service connections

For a detailed project description, refer to the Review of Environmental Factors (REF) prepared by EPM Projects.

1.1 Guidance Documents

The following documents have been reviewed and referenced in preparing this report:

- Australian Institute of Disaster Resilience (AIDR) Guideline 7-3: Flood Hazard (2017)
- Considering Flooding in Land Use Planning Guideline DPE 2021
- Department of Environment and Heritage – Flood Risk Management Guideline LU01, June 2023
- Department of Planning, Housing and Infrastructure – Planning Circular PS 24-001, Update on addressing flood risk in planning decisions, 1st March 2024
- NSW Department of Planning and Environment (2023) Flood Risk Management Manual https://www.environment.nsw.gov.au/topics/water/floodplains/floodplain-manual
- Broken Hill City Council – Urban Stormwater Master Plan, Broken Hill (2006), Ref. No. 20050089RA2C
- Broken Hill City Council – *Development Control Plan* (2016)
- NSW Government. NSW Maps Viewer. Spatial *Collaboration Portal - Map Viewers*. Retrieved from https://www.nsw.gov.au.
- Engineers Australia. Australian Rainfall and Runoff 2019.

1.2 Site Description

The site has frontage to Murton Street (200 metres along south-west), McGown Lane (400m metres along the south), Radium Street (165 metres along the north-west) and the desert to the north-east and east. The site comprises a single allotment, legally described as Lot 5858 in deposited plan (DP) 757298 with an approximate site area of 8.1ha. The site is in the northeastern corner of Broken Hill City, approximately 1.8km from the city centre and 2.4km from the Broken Hill railway station.

Figure 1- Aerial of the site (Nearmap 27 Sept 2024)

Figure 2 - *Aerial of the site (NSW Spatial Viewer)*

The masterplan drawings provided by School Infrastructure illustrate that most of the new school buildings are aligned parallel to Murton Street and McGowan Lane, as shown in Figure 3. The proposed sports field is located to the north of the school, maintaining the same footprint as the existing sports field and preserving its size for recreational activities.

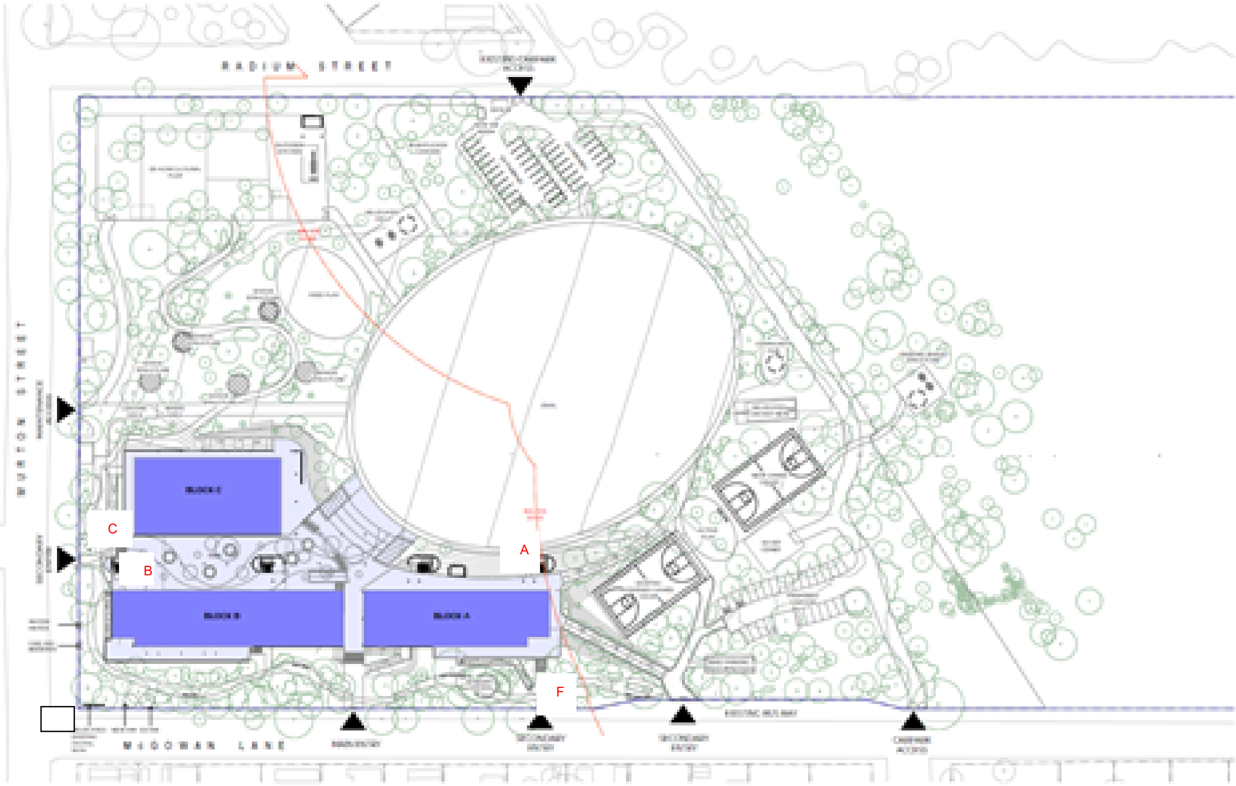


Figure 3- Site Architectural Plan-Provided by Woods Bagot

2.0 Flood Planning Requirements

The Broken Hill Development Control Plan 2016 serves as a guideline for this study. According to this plan (Page 15, Section 3.1), as shown in the excerpt below, all new developments involving buildings or structures—including alterations and additions—within residential, business, industrial, and rural zones subject to the Broken Hill Local Environmental Plan (LEP) 2013 must adhere to the following controls:

- New development and associated works must not adversely affect the level of floodwaters on adjoining properties.
- A building floor level must be determined for the site to minimise the risk and hazard of inundation.
- New developments and associated works must not adversely affect floodwater levels on adjoining properties.
- If the proposed development site is adjacent to a major overland flow path or creek, as defined in this report, the floor level must be at least 300 mm above the 1% AEP flood level.

- New development and associated works must not adversely affect the level of floodwaters on adjoining properties.
- A building floor level must be determined for the site to minimise the risk and hazard of inundation.
- Where the proposed development site is not located in close proximity to a major overland flow path or creek, floor levels must be a minimum of 300mm above the adjacent top of kerb level.
- Where the proposed development site is adjacent to a major overland flow path or creek as defined by this report, floor levels must be a minimum of 300 mm above the 100 year ARI flood level.

Figure 4- Snip from Broken Hill Development Control Plan 2016

The following flood management criteria are considered good practice across NSW Councils and commonly adopted across schools projects. Whilst these exceed the requirements of the Broken Hill DCP we would recommend they are adopted given the flood risk to the site:

- Minimum floor level (FPL): 1% AEP + 500 mm freeboard or PMF (where shelter in place is proposed), whichever is greater.
- Structural design: To be based on PMF flood forces including debris.
- Construction materials: Use flood-compatible materials beneath the FPL.

As the PMF flood is short in duration (around 30 minutes), there is often insufficient time for safe evacuation. In such cases, sheltering in place becomes necessary.

These controls aim to ensure that new developments are resilient to flooding risks and do not contribute to increased flood hazards for neighbouring properties. Compliance with these guidelines is essential for maintaining safety and mitigating potential damage in the event of flooding.

The flood levels for the 1% AEP and PMF events, along with the proposed FPL, are summarized in in the Table 1. Refer to Figure 3 for the location of points A, B and C within the site.

Table 1- Required flood planning levels.

Location	Point	Maximum Adjacent Flood Level (m AHD)			Proposed FPL (m AHD)
		1% AEP	1% AEP + 500mm	PMF	
Block A	A	291.46	291.96	292.63	292.70
Block B	B	291.87	292.37	293.27	293.30
Block C	C	291.74	292.24	293.30	293.30

Schools Infrastructure School Site Selection and Development guideline suggests a school site should be located above the 1 in 200-year flood and provide flood free access as per the extract below. It is acknowledged that this in not provided at Willyama however given it is an existing school site the new building will improve flood resilience from the existing school.

> **Flood**
> The site (or a significant portion of the site) will be located above the 1 in 200-year flood level and provide flood free access for pedestrians and vehicles (in particular, emergency vehicles during a flood event).
>
> Buildings should be located on land that is above the Flood Prone Land contour (where possible - subject to specialist advice).

School Site Selection and Development (October 2020) – page 7

A full list of the proposed building openings is shown in Figure 5, with the corresponding PMF and 1% AEP flood levels provided in Table 2

Figure 5- Location of Proposed Building Openings

Table 2- Flood planning conditions for the proposed buildings openings

Opening	1% AEP Flood level+ 500 mm (m AHD)	PMF Flood Level (m AHD)	Proposed Floor Level (m AHD)	FPL met
A1	291.50+500	292.65	292.70	Met
A2	291.50+500	292.65	292.70	Met
A3	291.30+500	291.80	292.70	Met
A4	291.25+500	291.75	292.70	Met
A5	291.20+500	291.75	292.70	Met
A6	291.17+500	291.60	292.70	Met
A7	291.17+500	291.60	292.70	Met
A8	291.15+500	291.90	292.70	Met
A9	291.47+500	292.60	292.70	Met
B1	291.95+500	293.35	293.35	Met
B2	292.55+500	293.20	293.30	Met
B3	292.55+500	293.20	293.30	Met
B4	291.85+500	293.20	293.30	Met
B5	291.85+500	293.15	293.30	Met
B6	291.80+500	293	293.30	Met
B7	291.80+500	293	293.30	Met
B8	291.70+500	292.80	293.30	Met
B9	291.65+500	292.75	293.30	Met
B10	291.60+500	292.70	293.30	Met
B11	291.55+500	292.65	293.30	Met
B12	291.50+500	292.65	293.30	Met
B13	291.50+500	292.65	293.30	Met
C1	292.25+500	293.35	293.30	Met
C2	292.15+500	292.95	293.30	Met
C3	292.10+500	292.95	293.30	Met
C4	292.10+500	292.95	293.30	Met
C5	292.10+500	292.95	293.30	Met
C6	292.20+500	293.35	293.35	Met
C7	292.20+500	293.35	293.35	Met
C8	291.95+500	293.35	293.35	Met

Flood modelling results indicate that all proposed building openings meet the flood planning level requirements.

3.0 Previous Studies and available Flood information

3.1 Broken Hill Urban Stormwater Master Plan (2006)

The Broken Hill Urban Stormwater Master Plan (2006) is the primary study available for managing stormwater in the city. Commissioned by Broken Hill City Council, the plan provides a strategic framework for evaluating the existing drainage infrastructure, identifying deficiencies, and proposing upgrades to improve flood protection, road safety, and stormwater reuse opportunities.

The key findings of this report are as follows:

- The city's drainage system primarily relies on overland flow paths, with limited underground drainage.
- Five major catchments were analysed: The Living Desert, Mulga Creek, Cemetery Creek, Railwaytown, and South Broken Hill.

- Several locations experience frequent flooding due to inadequate drainage capacity, impacting properties and traffic flow.
- Hydrological modelling using the ILSAX model assessed existing drainage performance and informed upgrade priorities.

Based on this study, the site is located within the Living Desert catchment, as shown in Figure 6.

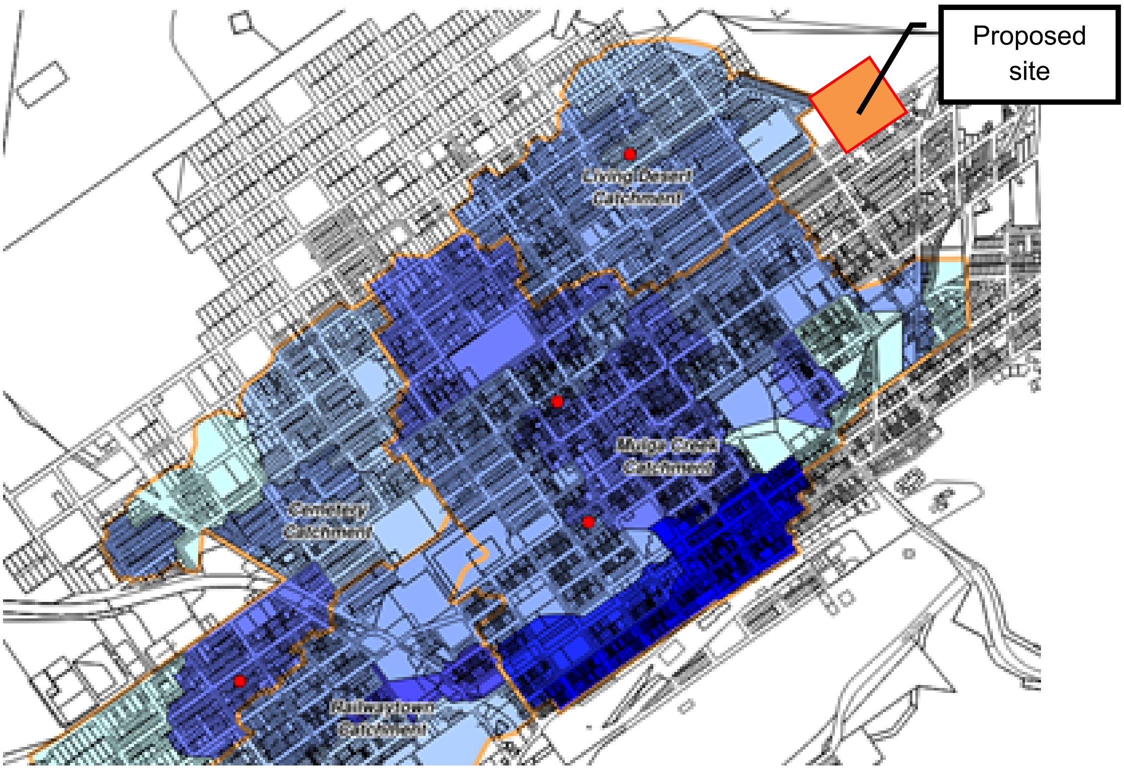


Figure 6- Extent of The Living Desert Catchment

This report identifies flooding issues at Radium Street, McCulloch Street, and Murton Street.

The analysis indicates that the portion of Radium St to the east of Murton St forms the downstream section of the main overland flow path for The Living Desert catchment. The road levels on Radium St are significantly lower than those on adjacent roads, and the road profile at this location incorporates a low flow channel between the Murton St and Brooks St culvert crossings. The capacity of this channel is exceeded even during lower ARI events, leading to flooding of the trafficable section of Radium St.

A major concern at this location is the use of Radium St, including the low flow channel, as a parking lane for the adjacent school.

Additionally, the report highlights that the northern portion of the living desert catchment drains to the east via Wyman St. The existing drainage system in the southern portion of this catchment provides a 20-year ARI standard of protection or higher, except at the low points in McCulloch St and Murton St, where protection is below a 1-year ARI standard.

In this study, hydrological modelling of the catchment was conducted using the ILSAX model, known as the 'Program for Urban Stormwater Drainage Design and Analysis' (O'Loughlin, 1993). ILSAX is a computer-based rainfall-runoff routing tool that simulates water flow through a drainage network. Runoff from each sub catchment is estimated using the time-area method, based on specified rainfall temporal data, a rainfall loss model, and the time of concentration unique to each sub catchment. The model accounts for both initial and continuous losses.

This study utilized ILSAX's functionality, enabling users to define coefficient values for calculating runoff from pervious areas. An initial loss of 35 mm and a continuous loss rate of 3 mm/hr, derived from the rainfall hyetograph, were applied to estimate runoff.

3.2 Historical Flooding Events in Broken Hill

A review of newspaper articles and social media reports reveals that Broken Hill has experienced significant flash flooding events, notably in March 2022 and January 2024. In March 2022, approximately 140 mm of rain fell in parts of the city. This excessive rainfall was sufficient to inundate the streets with floodwaters. In January 2024, over 100 mm of rain was recorded within a span of just two days, exceeding the total rainfall the outback city had received in the previous six months. The drainage system in Broken Hill was not designed to accommodate such large volumes of rain, leading to reports of sewage spills. Roads became flooded, and power outages were reported in the nearby town of Silverton, which is adjacent to Broken Hill.

4.0 Hydraulic and Hydrologic Modelling

4.1 RORB and TUFLOW Model Development

A RORB model has been developed as a hydrological model, and a TUFLOW model has been prepared for this site.

RORB is a hydrological modelling software used for flood estimation. It is a rainfall-runoff and flood routing model developed in Australia, primarily designed to simulate water movement through catchments and river systems. It is widely applied in floodplain management and infrastructure planning across Australia.

TUFLOW is a hydrodynamic modelling software used to simulate water flow in rivers, floodplains, estuaries, and coastal areas. It is extensively utilized in flood modelling, stormwater management, and hydraulic engineering.

The general Rorb and TUFLOW model setup is summarised in Table 3.

Table 3- Model's setup

Model Setup	Details
TUFLOW modelling setup	Tuflow.2025.0.0-GPU
	HPC- SGS
	5m cell size
Rorb modelling setup	Routing Parameter (Kc): 1.83 (based on ARR Book VII, Eq. 7.6.17 for South Australia, A<100A < 100A<100 km²)
	m= 0.8
	IL = 35 mm and CI = 3 mm/hr (Based on information provided Broken Hill Urban Stormwater Master Plan study)

A detailed catchment delineation has been conducted for the site and its surrounding area. The analysis indicates that the Living Desert catchment, previously identified in the *Broken Hill Urban Stormwater Master*

Plan study, consists of two smaller sub catchments that discharge into an unnamed creek at two distinct locations, as shown in Figure 4.

Additionally, Figure 4 also illustrates the site is subjected to two distinct flooding conditions: local flooding and regional flooding.

Figure 7- Catchment delineation detail

The pervious and impervious fractions of each catchment are estimated and incorporated into the RORB model to account for surface runoff characteristics, as shown in Table 4.The RORB output is then extracted and applied as a 2D source area (SA) at the centroids of each catchment to represent inflows into the model, ensuring that runoff from the upstream catchments is accurately distributed across the 2D model domain. Additionally, the HQ boundary condition, which defines the relationship between water level (head) and flow (m^3/s), is used as the downstream boundary condition. The TUFLOW model setup is shown in Figure 8 and the school site sits within catchment A6.

Table 4- Sub Catchments- Characteristics

Sub Catchment	Area(km2)	Impervious (%)	Pervious (%)
A1	1.28	0%	100%
A2	0.94	20%	80%
A3	0.413	0%	100%
A4	0.69	60%	40%
A5	1.09	0.10%	90%
A6	**1.1**	**75%**	**25%**

Figure 8- TUFLOW Model Setup

Furthermore, the Intensity-Frequency-Duration (IFD) data for frequent events was obtained from the data hub for the site and is presented in Figure 9 and Table 2. Additionally, the Probable Maximum Precipitation (PMP) flood depth was calculated using the Generalised Short-Duration Method (GSDM) for events up to three hours, and this is also shown in Table 2.

Figure 9- location of point where IFD's were extracted.

Table 5- IFDs Extracted from Data Hub for Broken Hill (mm)

		AEP			
Duration	**10 %**	**1%**	**0.2 %**	**0.05%**	**PMP**
30 mins	49.2	46.9	66.6	87	230
1 h	30.7	57.9	82	107	340
1.5 h	34.4	64.7	91.7	119	385
2 h	37.4	70.0	99.3	130	427
3h	42.0	78.3	112	146	483
4.5 h	47.5	87.9	126	166	-
6 h	51.9	95.7	138	181	-
9 h	59.0	108	156	205	-
12 h	64.5	117	169	223	-

The valid Manning's 'n' ranges for different land use types, as recommended by ARR 2019 (Table 6.2.2), were used for this assessment. These values are shown in Table 6.

Table 6- Manning 'n' value recommended by ARR 2019

Land use type	**Manning 'n'**
Residential areas – high density	0.2 – 0.5
Residential areas – low density	0.1 – 0.2
Open pervious areas, minimal vegetation (grassed)	0.03 – 0.05
Open pervious areas, moderate vegetation (shrubs)	0.05 – 0.07
Open pervious areas, thick vegetation (trees)	0.07 – 0.12

4.2 Upstream Catchment Characteristics and Time of Concentration

The investigation of the Lidar data reveals that the elevation of the catchment upstream of the school ranges from 314 m AHD to 292 m AHD, indicating relatively gentle topography with an average slope of around 1% to 2%. Although this slope is gentle, the area's sparse vegetation increases the risk of flash flooding at the school. The lack of dense vegetation reduces the soil's ability to absorb rainfall, heightening the likelihood of rapid runoff during intense precipitation events. The upstream catchment longitudinal slope is shown in Figure 10.

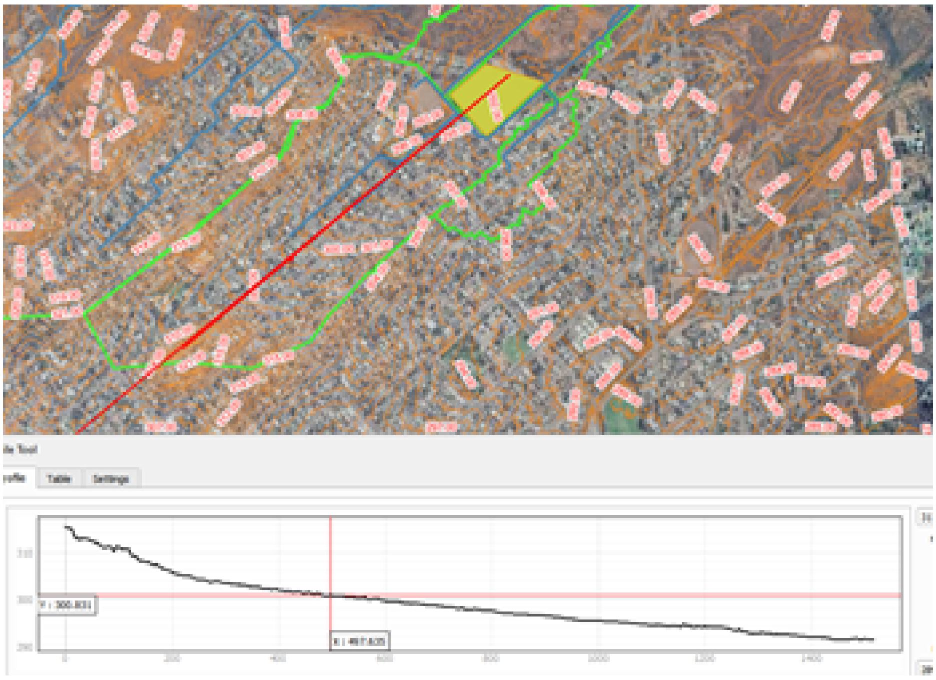


Figure 10- Longitudinal Profile of Upstream Catchment

The time of concentration for this catchment is calculated using the NRCS (SCS) sheet flow travel time equation:

$$t_o = 6.94\ \frac{(n\ x\ L)^{0.6}}{I^{0.4}S^{0.3}}$$

Where:

- t_o = Overland flow travel time (mins)
- L = Flow path length (m)
- I = Rainfall intensity for the design AEP event (mm/h)
- n = Manning's n roughness 0.15
- S = slope of surface (%)

For catchment B, L= 1466 m, n = 0.015 , and S = 0.015, using the above equation:

$$t_o = 6.94\ \frac{(0.15\ x\ 1466)^{0.6}}{I^{0.4}x0.015^{0.3}}$$

Therefore:

$$t_o x\ I^{0.4} = 622.11$$

The tabulation of $t_o x\ I^{0.4}$ is prepared as shown in Table 7

Table 7- Tabulated $t_o x\, I^{0.4}$ for different durations and AEPs

Duration, t_o		
	10% AEP	**1% AEP**
5	33	43
10	61	78
20	105	136
30	143	184
45	192	247
60	235	304
90	314	405
180	516	661
270	689	882

The value of $t_o x\, I^{0.4}$ corresponds to an overland flow time between 180 to 270 mins for 10% AEP and 90 to 180 mins for 1% AEP. By interpolation from Table 7, $t_o = 235\, mins$ for a 10% and $t_o = 165\, min$ for a 1% AEP.

4.3 Model validation

Due to the lack of reliable data for model calibration and validation, the model parameters recommended in the Broken Hill Urban Stormwater Master Plan study have been adopted for this assessment. Additionally, a Drains model has been developed for the catchment using these parameters (consistent with the original study), and the flow hydrograph has been generated for the median of the critical duration in terms of flow (30-minute storm, TP 27). Figure 11 illustrates the location where the hydrograph was extracted, while presents a comparison of the two hydrographs.

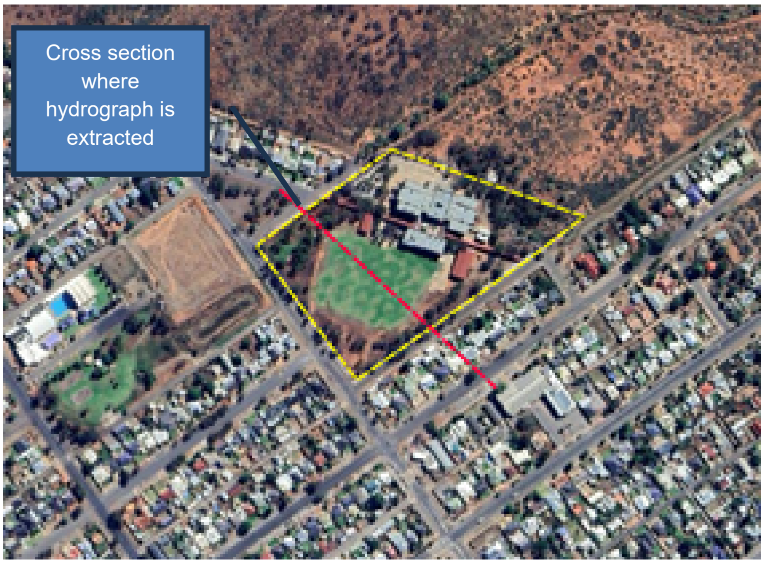


Figure 11— Location of Hydrograph Extraction

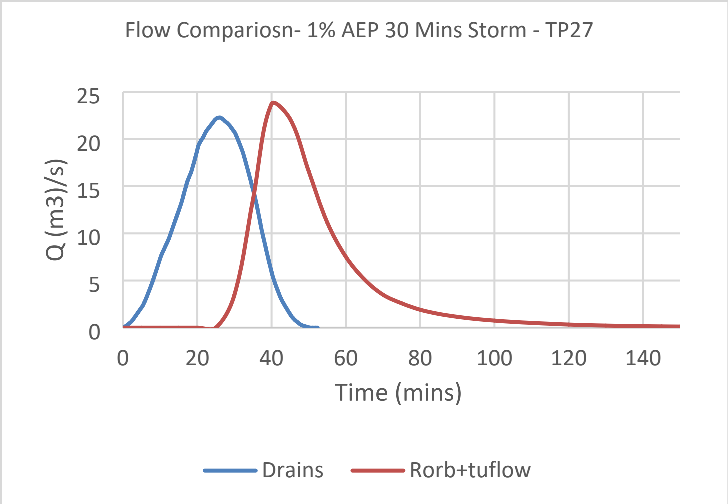


Figure 12- Hydrograph Comparison

The modelling results indicate that the peak flows of both models are highly comparable, with a similar flood volume. However, there is a notable difference in the timing of the peak flow. The rainfall hyetograph shows that the highest rainfall intensity occurs approximately 20 minutes after the onset of rainfall. Given that the catchment has a gentle slope and doesn't have a properly designed drainage network and also the time of concentration, calculated using the SCS sheet flow travel time equation, is approximately 165 minutes for 1% AEP Storm, the RORB+TUFLOW modelling results appear to provide a more accurate representation of the catchment's response as it results in delayed runoff and a longer time of concentration.

4.4 Site Survey

For the existing (pre-development) scenario, the model was refined by incorporating new site survey data with higher spatial resolution. The first survey, conducted by the Wumara Group on 22/07/2024, focused on the area within the school premises. The extent of this survey is illustrated in Figure 13

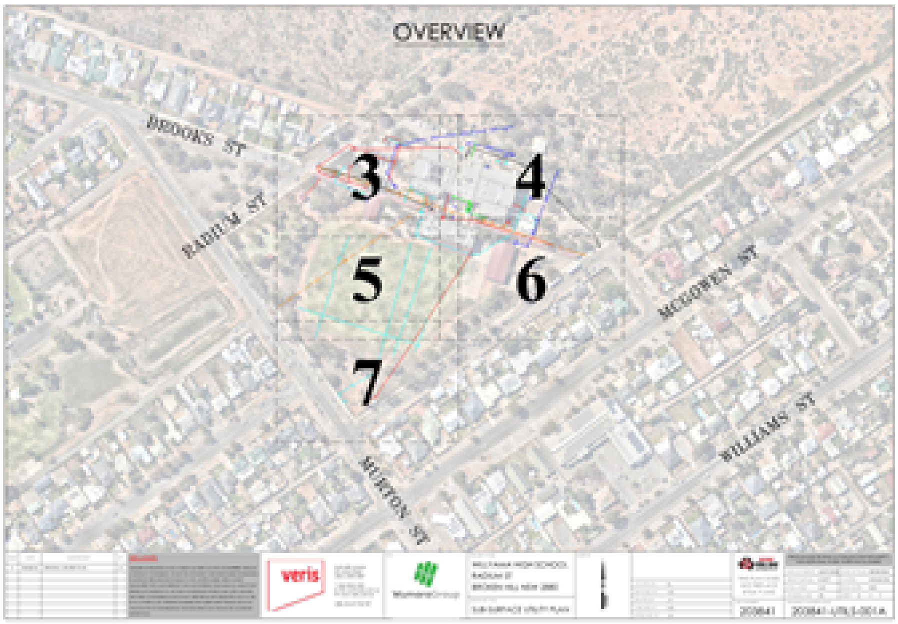


Figure 13- Extent of the First Site Survey Conducted by Wumara Group

To obtain a more comprehensive representation of the surface features, a second survey was conducted by Mosel Surveyors on 17/12/2024. The extent of this survey is illustrated in Figure 14.

This additional survey expanded coverage beyond the school boundary, capturing critical details of the surrounding road network and culverts at Radium Street. The inclusion of this supplementary data improves the accuracy of the model by enhancing the representation of key hydraulic structures and surface conditions.

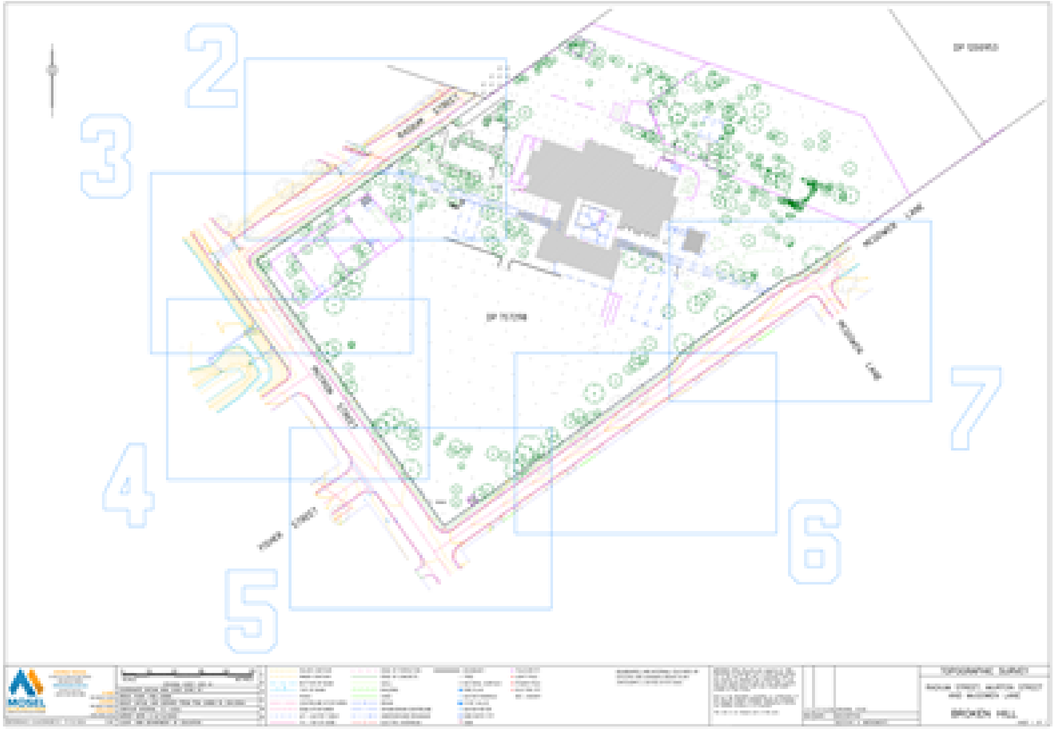


Figure 14- Extent of the Second Site Survey Conducted by Mosel

4.5 Critical Durations and Temporal Patterns

An assessment was conducted using TUFLOW to determine the critical duration and the median temporal pattern for the site in terms of flood level and depth. The ARR 2019 Ensembles Processing tool was used for this assessment. The TUFLOW model was run for all durations and patterns, and the median pattern was obtained. This is summarized in Table 8.

Table 8- Storm Critical duration and Median temporal patterns

	10 % AEP	1% AEP	0.2% AEP	0.05 % AEP	PMF
Critical duration and median temporal patterns	6-hour tp16	3-hour tp24	3-hour tp 28	3- hour tp 23	30 mins

4.6 Flooding Impact Due to Climate Change

Climate change is expected to have an adverse impact on rainfall intensities which have the potential to have significant impact on flood behaviour at specific locations. Climate change projections in NSW are generated from the NSW and ACT Regional Climate Modelling (NARCliM) project.

The NARCliM projections for total rainfall for the Sydney Metropolitan Region will decrease in spring and winter and increase in autumn and summer. The NARCliM projections for extreme rainfall are that both rainfall intensities and the frequency of extreme events will increase.

For this study, the approach recommended in Australian Rainfall and Runoff 2019 (ARR2019) is adopted. ARR2019 recommends using Representative Concentration Pathway (RCP) 2.6 and RCP 8.5 values. These values, available as percentages, should be used to factor the rainfall according to the data obtained from the ARR Data Hub. For this study, the worst-case scenario, RCP 8.5 for 2100, is adopted, and the rainfall intensity is assumed to have increased by 64%.

Figure 12 presents the rainfall climate change factors obtained from the ARR Data Hub, which have been applied in this project.

SSP5-8.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.2	1.18	1.17	1.16	1.14	1.13	1.13	1.12	1.11	1.11
2040	1.26	1.24	1.22	1.2	1.18	1.17	1.16	1.15	1.14	1.14
2050	1.34	1.31	1.29	1.26	1.24	1.23	1.21	1.2	1.18	1.18
2060	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2070	1.52	1.47	1.43	1.4	1.36	1.34	1.31	1.29	1.27	1.26
2080	1.63	1.57	1.52	1.48	1.43	1.4	1.37	1.35	1.33	1.31
2090	1.77	1.69	1.64	1.58	1.52	1.49	1.45	1.42	1.39	1.37
2100	1.86	1.77	1.71	1.64	1.58	1.54	1.5	1.47	1.43	1.41

Figure 15- Interim Climate Change Factor for the Site Location

4.7 Flood Hazard Assessment

The relative vulnerability of the community to flood hazard has been assessed by using the flood hazard vulnerability curves set out in '*Handbook 7 – Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia*' of the Australian Disaster Resilience Handbook Collection (2017).

These curves assess the vulnerability of people, *vehicles and* buildings to flooding based on the velocity and depth of flood flows. The flood hazard categories are outlined in Figure 16, ranging from a level of H1 (generally safe for people, vehicles and buildings) to *H6* (unsafe for vehicles and people, with all buildings considered vulnerable to failure). Table 9 outlines the threshold limits for each hazard category.

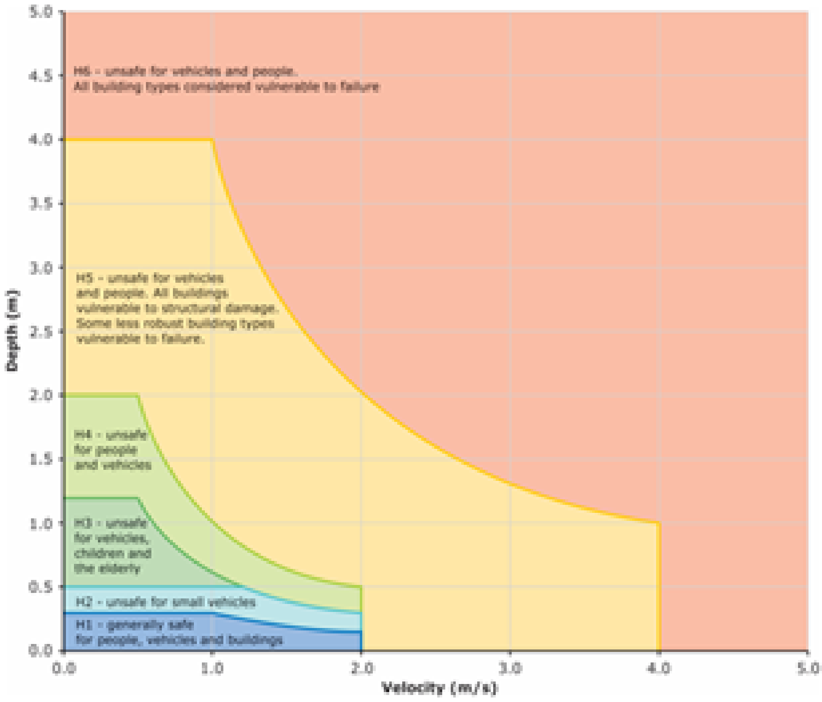


Figure 16- Flood hazard vulnerability curve (Source: Flood Risk Management Guide FB03 - Flood Hazard, NSW Department of Planning and Environment, 2022)

Table 9- Hazard vulnerability threshold limits

Hazard Classification	Description	Classification Limit (m2/s)	Limiting still water depth (D) (m)	Limiting velocity (V) (m/s)
H1	Generally safe for people, vehicles and buildings	D x V ≤ 0.3	0.3	2.0
H2	Unsafe for small vehicles	D x V ≤ 0.6	0.5	2.0
H3	Unsafe for vehicles, children and the elderly	D x V ≤ 0.6	1.2	2.0
H4	Unsafe for people and vehicles	D x V ≤ 1.0	2.0	2.0
H5	Unsafe for people and vehicles. All buildings vulnerable to structural damage.	D x V ≤ 4.0	4.0	4.0
H6	Unsafe for people and vehicles. All building types considered vulnerable to failure.	D x V > 4.0	–	–

5.0 Existing Flood Model Results

The flood model was run for multiple design flood events, including the 10% AEP, 1% AEP, 1% AEP climate change (CC), 0.2% AEP, 0.05% AEP and PMF. The results, including peak flood depths, flood levels, velocities, and hazard classifications, are presented in Figure 17 to Figure 34. The modelling indicates that floodwaters reach Murton Street, subsequently spreading across the school site, McGowen Lane, and Radium Street, before discharging into an unnamed creek.

For all events except the PMF event, flood levels within the project boundary remain consistent, ranging between 290 and 293 mAHD. Flow velocities are generally low, below 0.5 m/s, and the hazard classification is predominantly H1, indicating conditions that are generally safe for people, vehicles, and buildings. Under these conditions, the school `is not impacted by flooding from the unnamed creek.

For the PMF event, flood levels range from 291.0 mAHD to 293.5 mAHD, and the hazard classification varies, with H2, H3, H4 and H5 conditions observed. The differences in flood levels and hazard classifications compared to other events are due to the significantly higher rainfall intensity used in the PMF, which is derived from the GSDM, whereas the other events use rainfall intensities based on IFD curves.

Figure 17- 10% AEP Flood Depths and Levels-Existing Scenario

Figure 18-10% AEP Flood Velocities-Existing Scenario

Figure 19-10% AEP Flood Hazard- Existing Scenario

Figure 20- 1% AEP Flood Depths and Levels-Existing Scenario

Figure 21-1% AEP Flood Velocities-Existing Scenario

Figure 22-1% AEP Flood Hazard- Existing Scenario

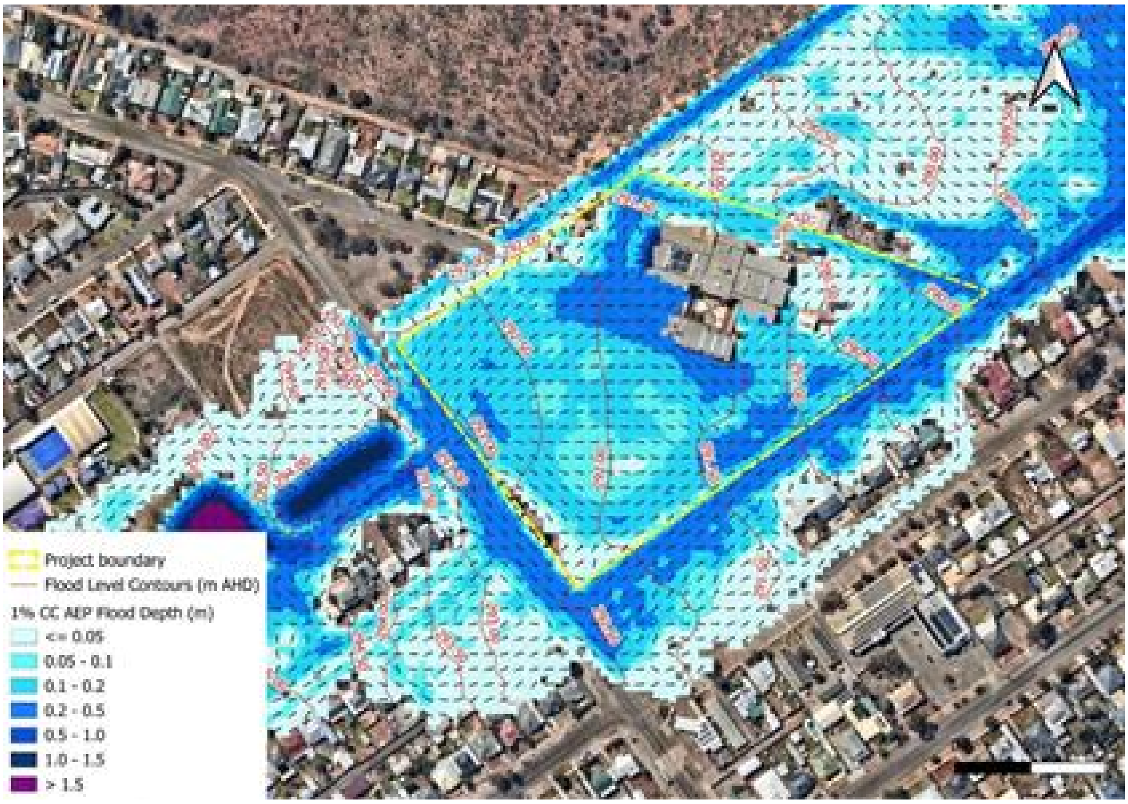


Figure 23 - 1% AEP CC Flood Depths and Levels Existing Scenario

Figure 24- 1% AEP CC Flood Velocities Existing Scenario

Figure 25-1% AEP CC Flood Hazard Existing Scenario

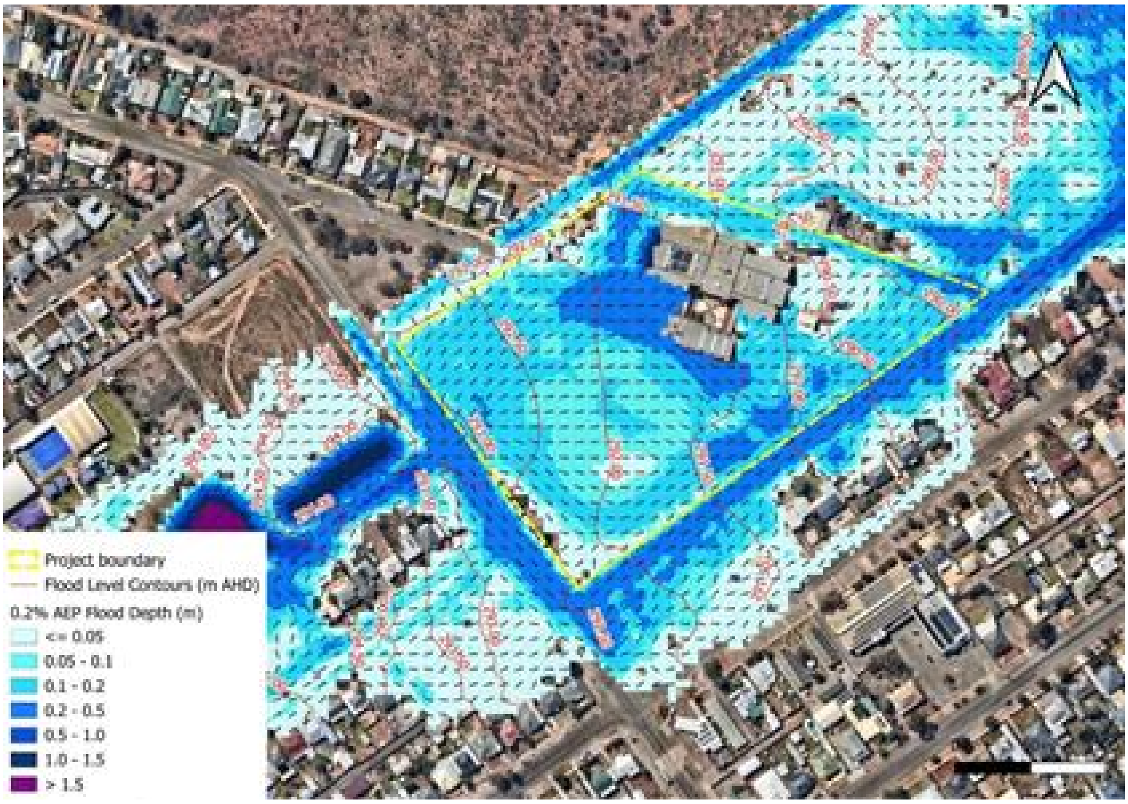


Figure 26-0.2% AEP Flood Depths and Levels-Existing Scenario

Figure 27-0.2% AEP Flood Velocities-Existing Scenario

Figure 28-0.2% AEP Flood Hazard-Existing Scenario

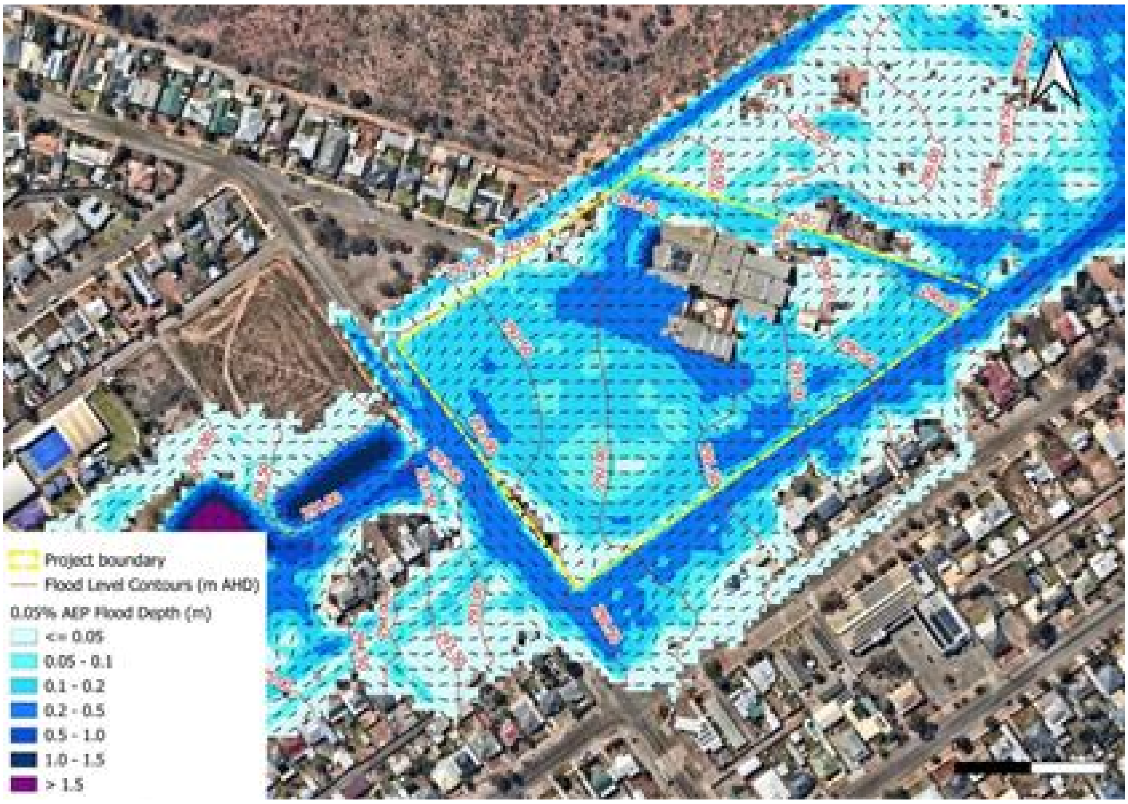


Figure 29- 0.05% AEP Flood Depths and Levels Existing Scenario

Figure 30- 0.05% AEP Flood Velocities Existing Scenario

Figure 31-0.05% AEP Flood Hazard Existing Scenario

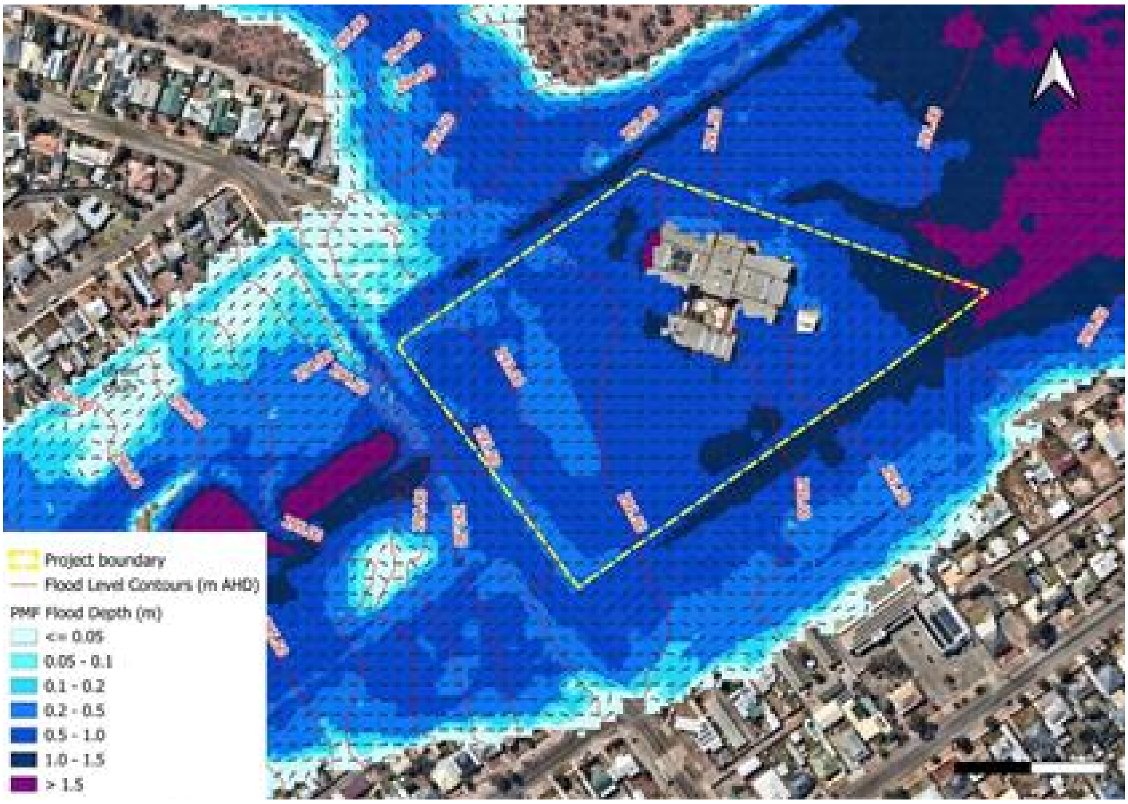


Figure 32- PMF Flood Depths and Levels- Existing Scenario

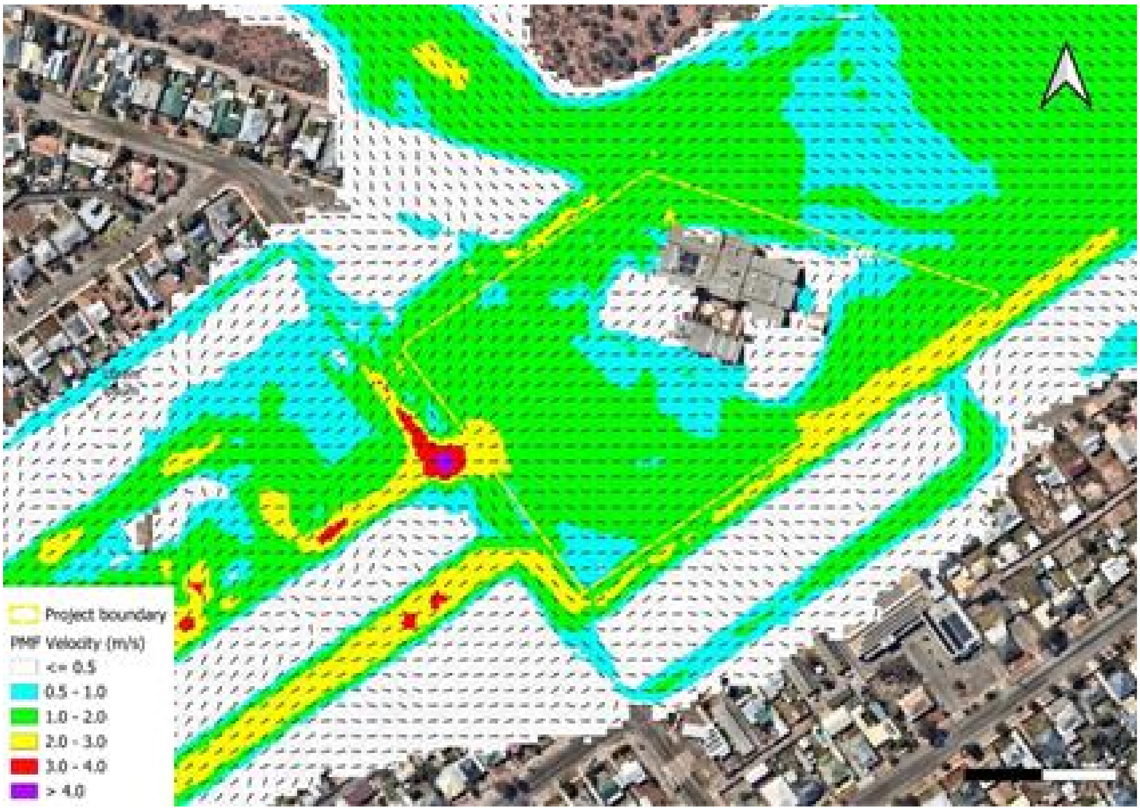


Figure 33- PMF Flood Velocities-Existing Scenario

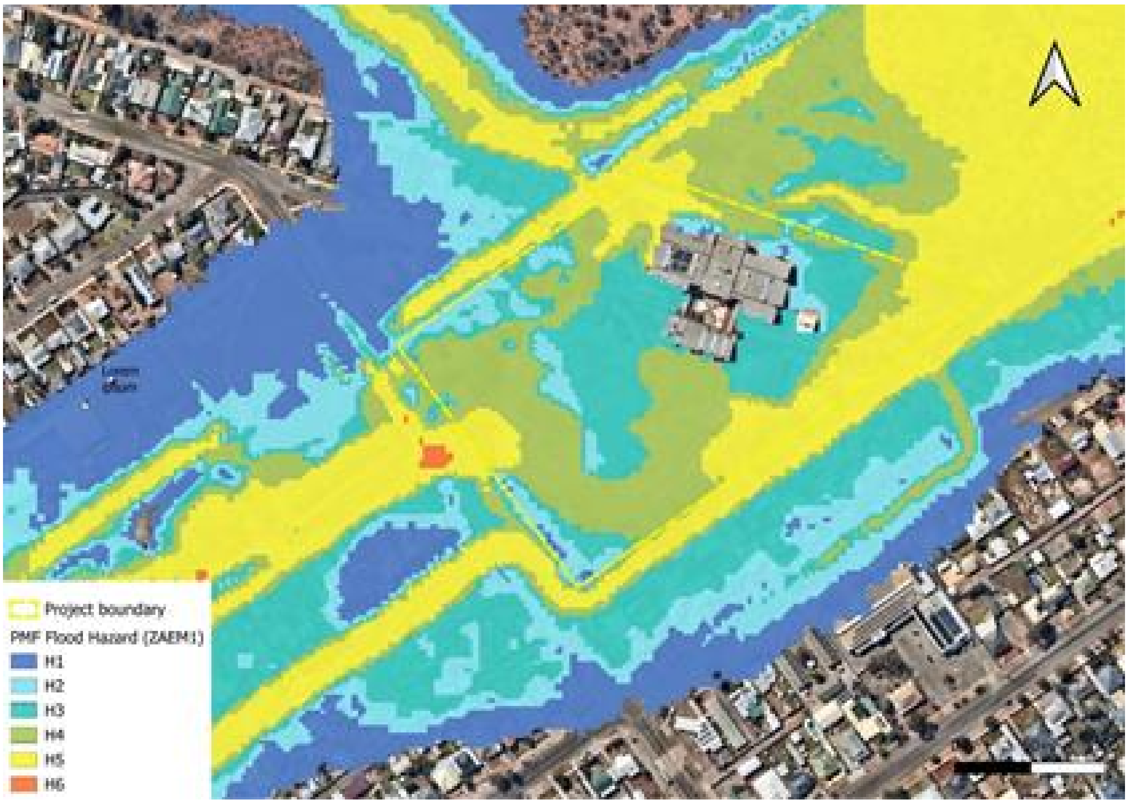


Figure 34- PMF Flood Hazard- Existing Scenario

6.0 Post-Development Modelling and Result

The flood model has been updated to incorporate the latest civil design, which reflects the proposed architectural layout and landscaping plans. The proposed school buildings have been excluded (nulled out) from the updated terrain model (TIN), and it is assumed that demolition of the existing buildings will occur prior to the construction of the new facilities. Natural ground levels are to be reinstated within the footprint of the demolished structures.

The proposed bulk earthworks, including the general lowering of the sports oval and landscaping to the west, are intended to mitigate flood impacts on surrounding properties during the PMF event and form a key component of the flood mitigation strategy. Additionally, it is assumed that the concrete edging along Murton Street will be removed to help reduce flood impacts on surrounding properties during PMF event. The proposed civil design cut, and fill is shown in Appendix A, while location of the existing concrete edging is shown in Figure 35 and Figure 36.

Figure 35

Figure 36

Furthermore, there is a deck with a channel beneath between Block B and C as it's shown in Figure 37.

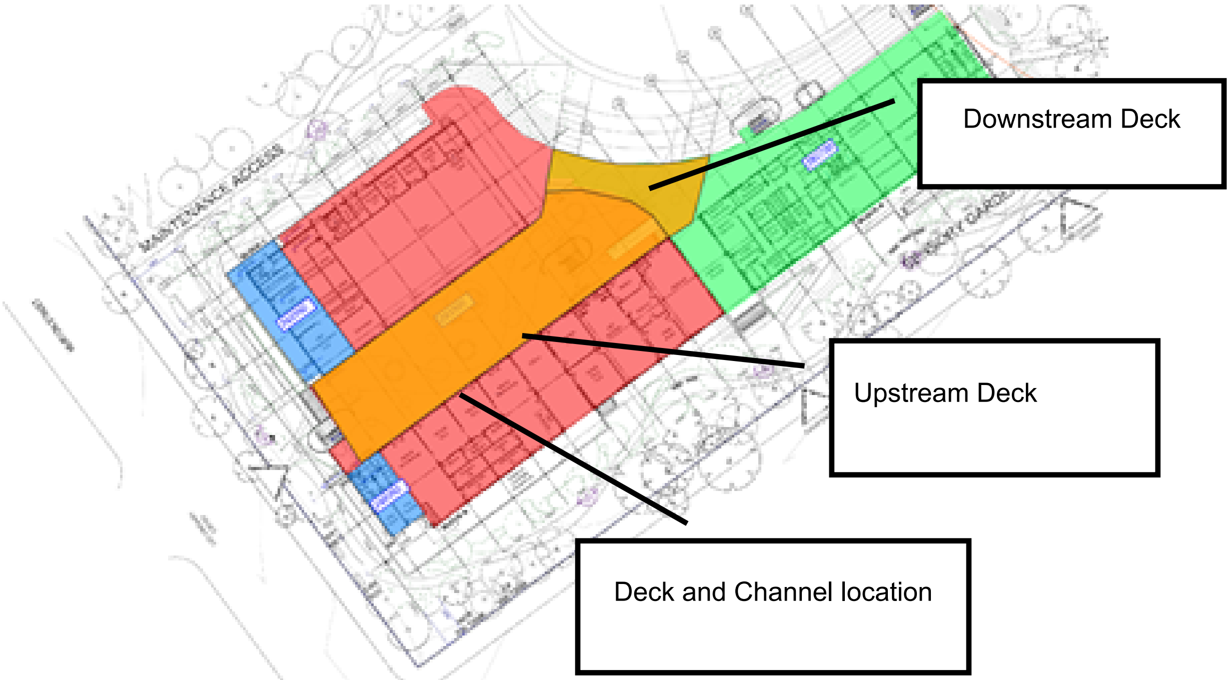


Figure 37- The location of the Deck between Block B and C

The deck, consisting of two separate sections — the upstream and downstream decks, as shown in Figure 37— has been modelled as a 2D friction layer within the TUFLOW model, with the following parameters adopted:

- The bottom of the channel is set at the proposed surface design level, starting at 292.00 m AHD.
- The upstream deck is set at 293.30 m AHD, and the downstream deck is set at 292.70 m AHD (top of deck level).
- The deck is 0.35 m thick, resulting in a bottom-of-deck level of 292.95 m for the upstream deck and 292.35 m for the downstream deck.
- The culvert under the deck is assumed to be 50% blocked.
- A 1 m handrail is included, with a 10% blockage allowance applied.

The civil design drawing for this channel configuration is provided in Appendix B.

The post development flood maps for 10% AEP, 1% AEP, 1% AEP CC, 0.05 % AEP and 0.02 % AEP are shown in

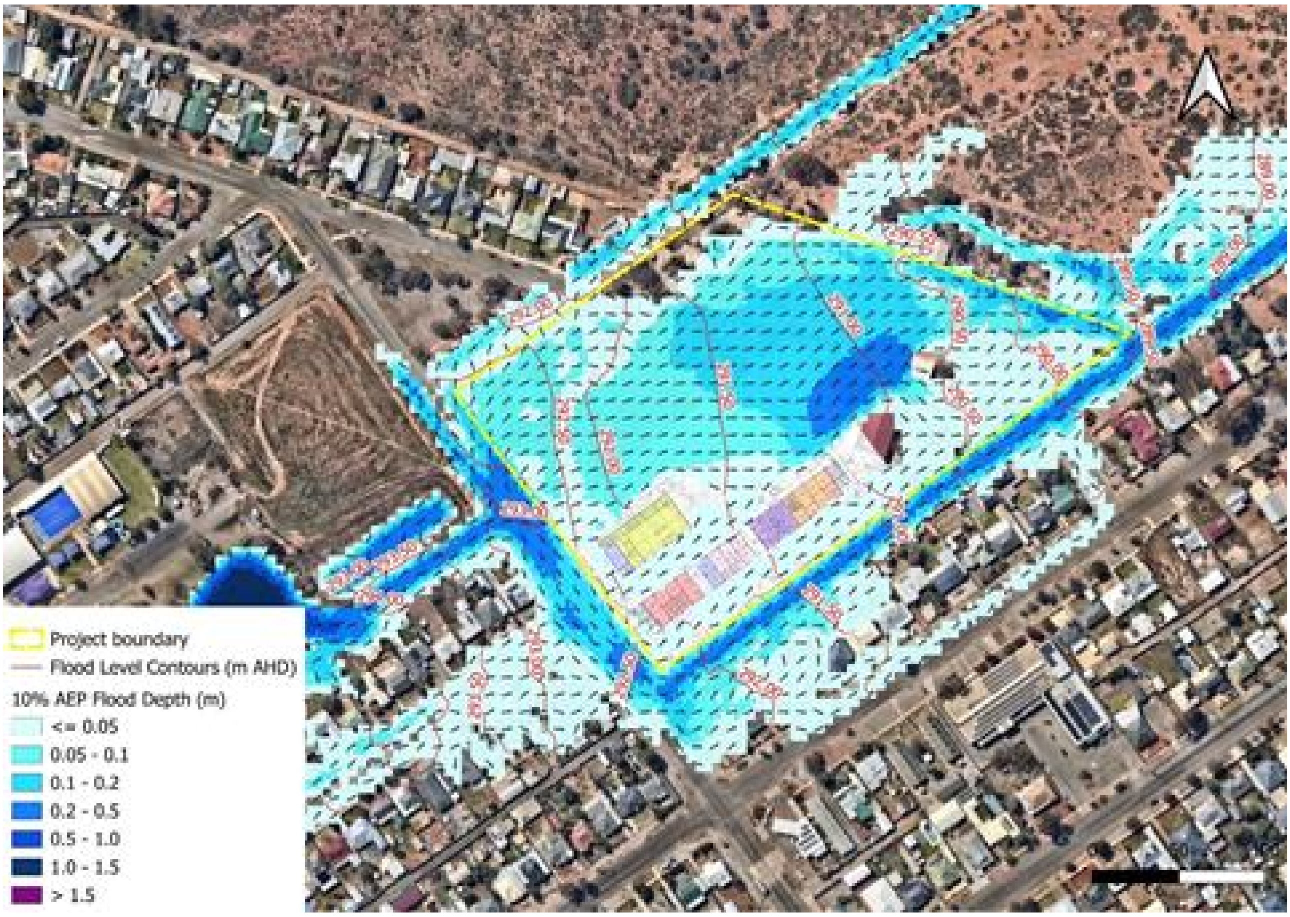


Figure 38 to Figure 55:

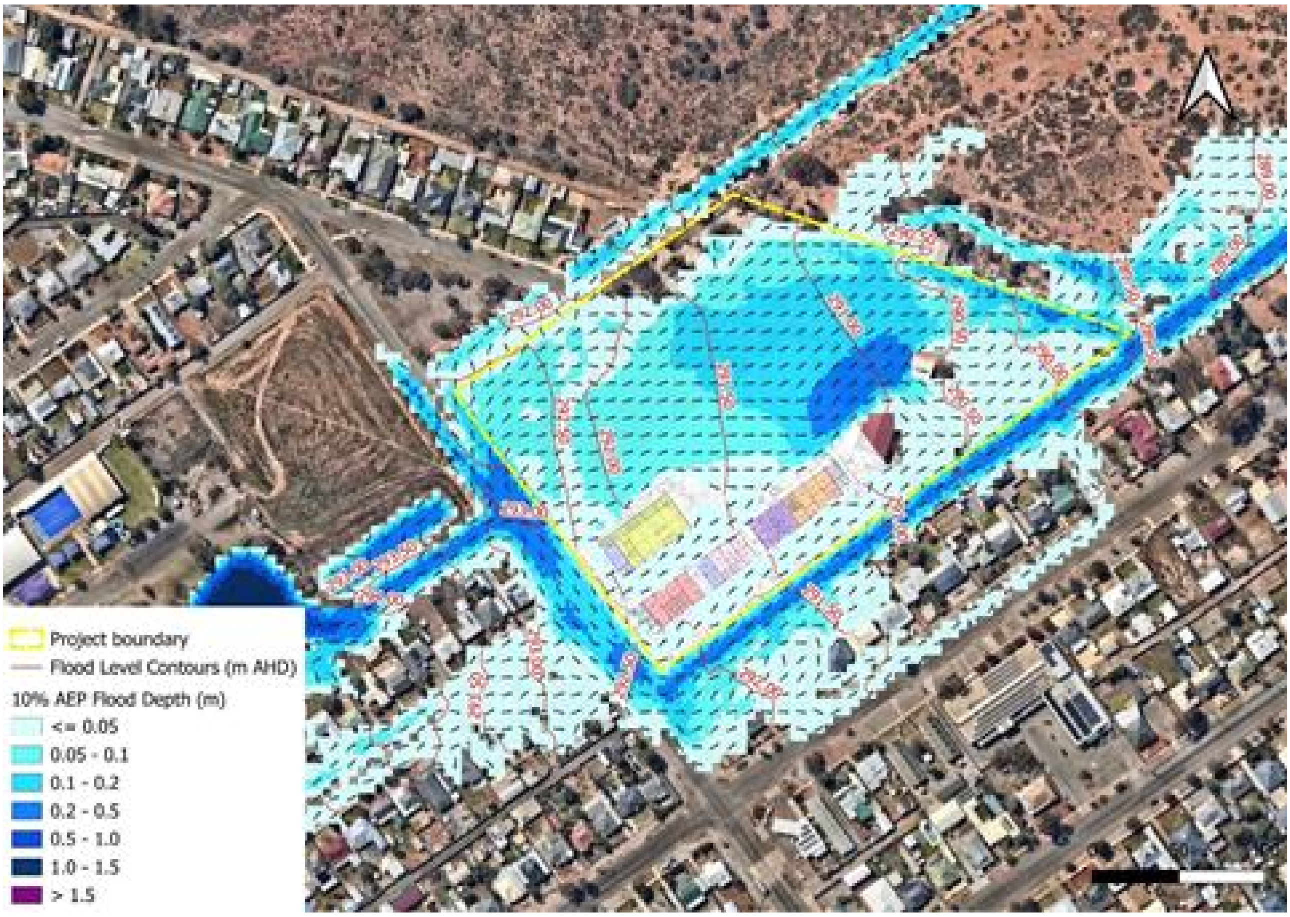


Figure 38-10% AEP Flood Depths and Levels Post-Development Scenario

Figure 39-10% AEP Flood Velocities Post-Development Scenario

Figure 40-10% AEP Flood Hazard Post-Development Scenario

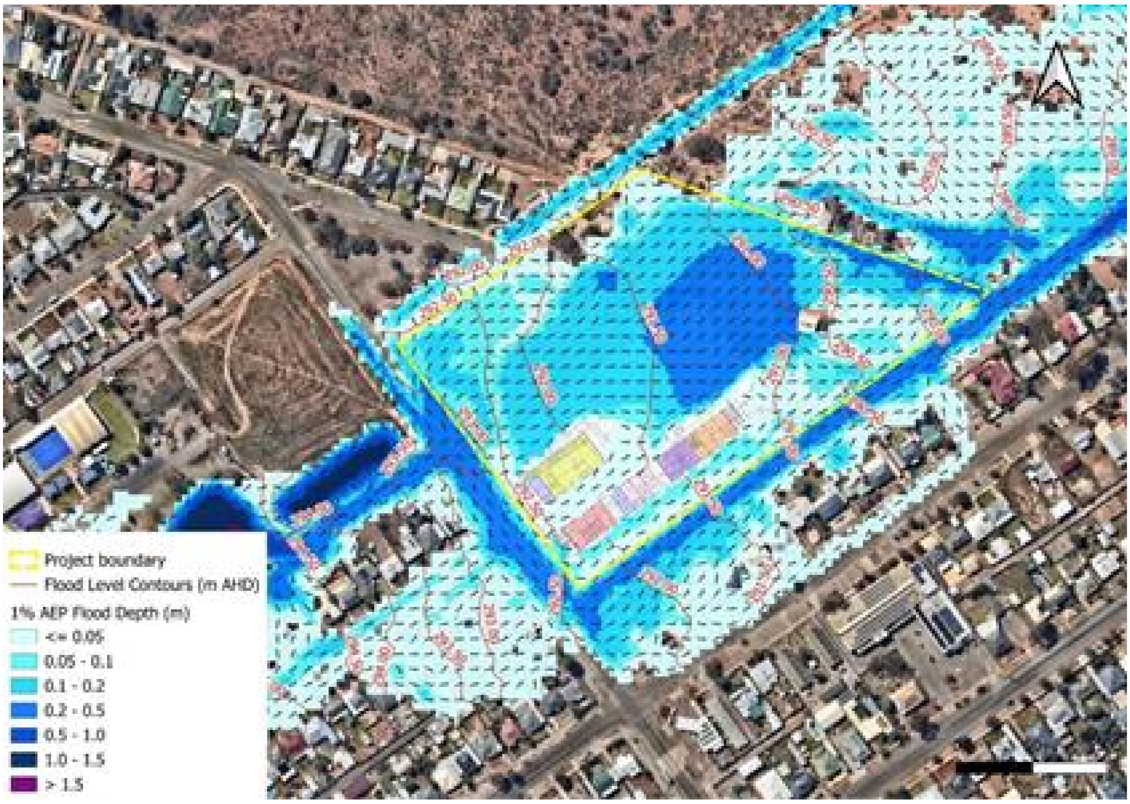


Figure 41-1% AEP Flood Depths and Levels Post-Development Scenario

Figure 42-1% AEP Flood Velocities Post-Development Scenario

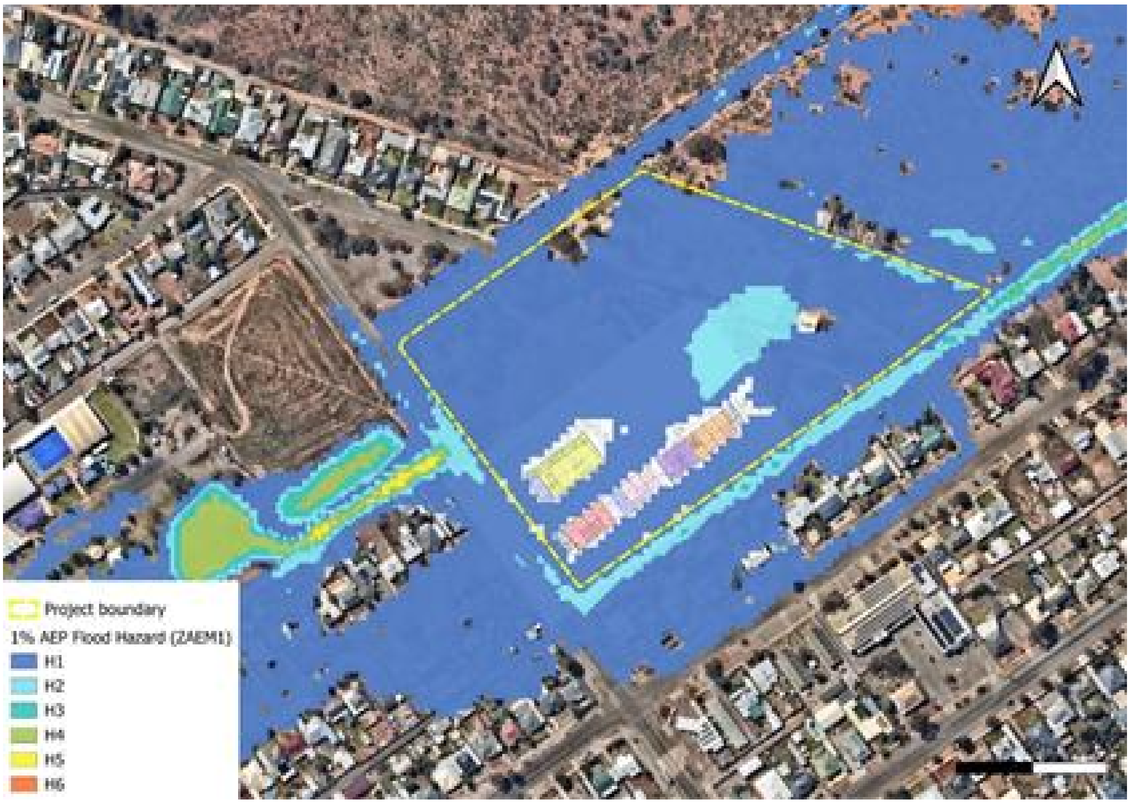


Figure 43-1% AEP Flood Hazard Post-Development Scenario

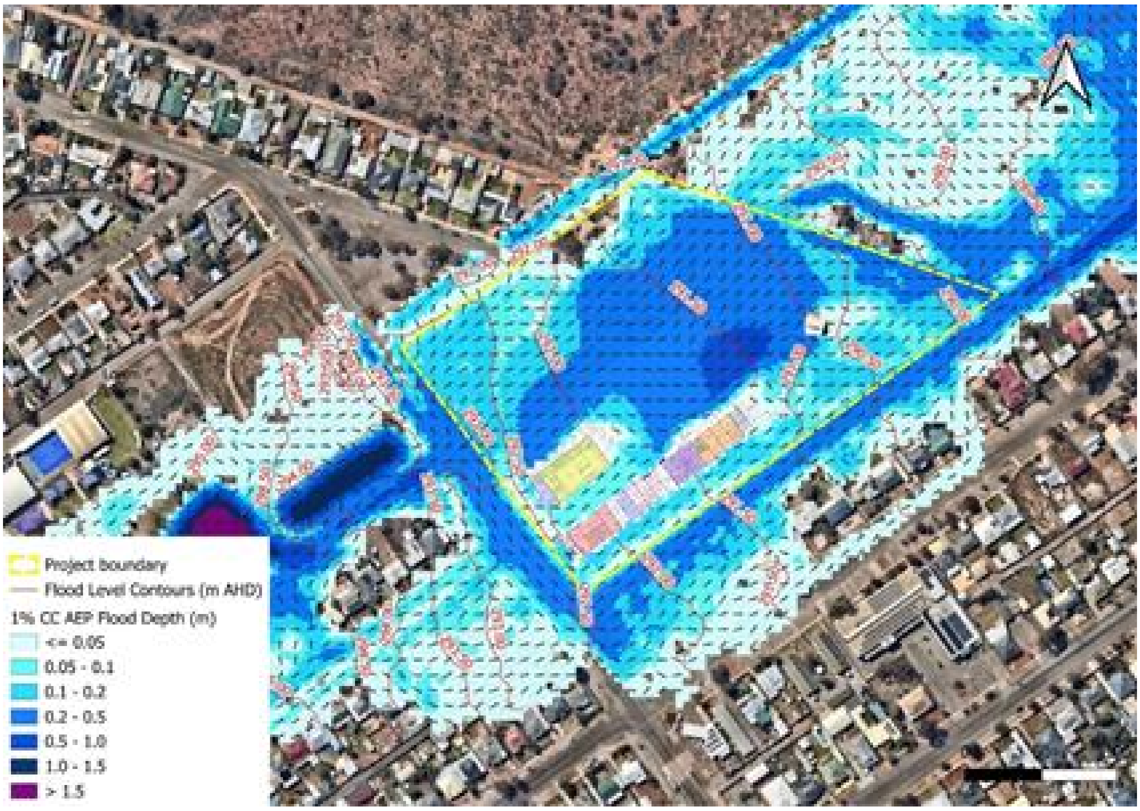


Figure 44 - 1% AEP CC Flood Depths and Levels Post-Development Scenario

Figure 45-1% AEP CC Flood Velocities Post-Development Scenario

Figure 46-1% AEP CC Flood Hazard Post-Development Scenario

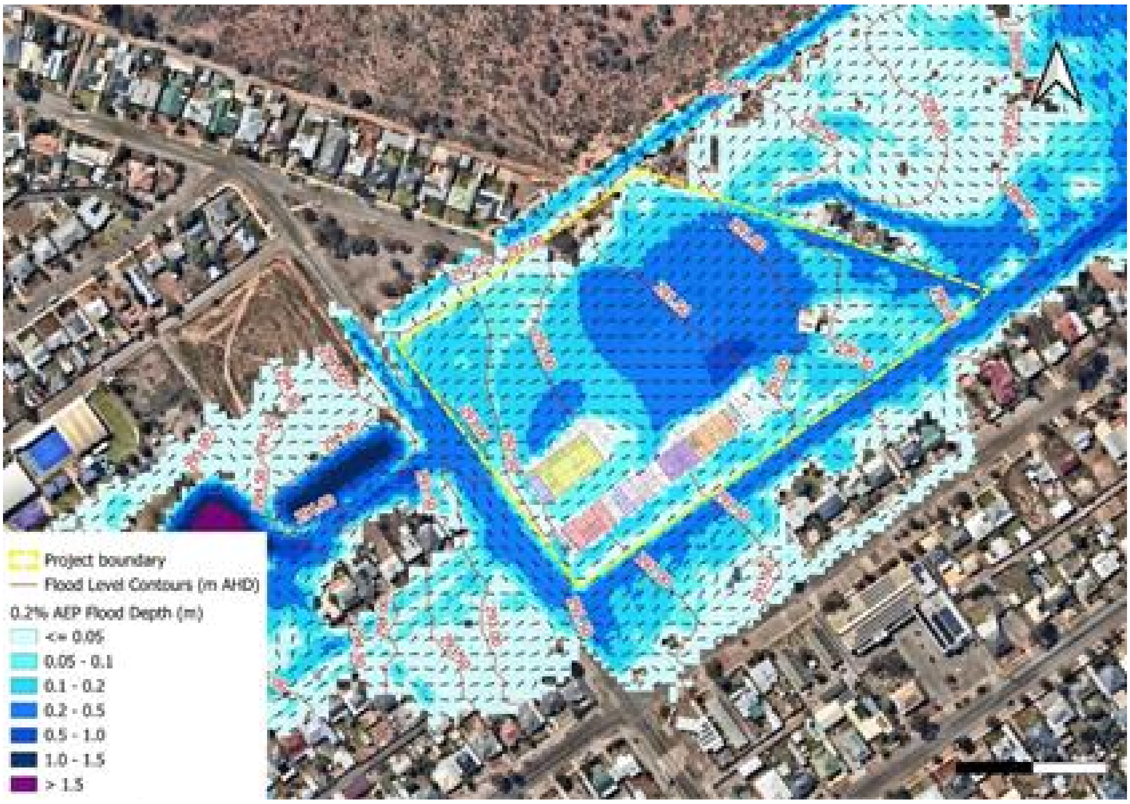


Figure 47-0.2% AEP Flood Depths and Levels Post-Development Scenario

Figure 48-0.2% AEP Flood Velocities Post-Development Scenario

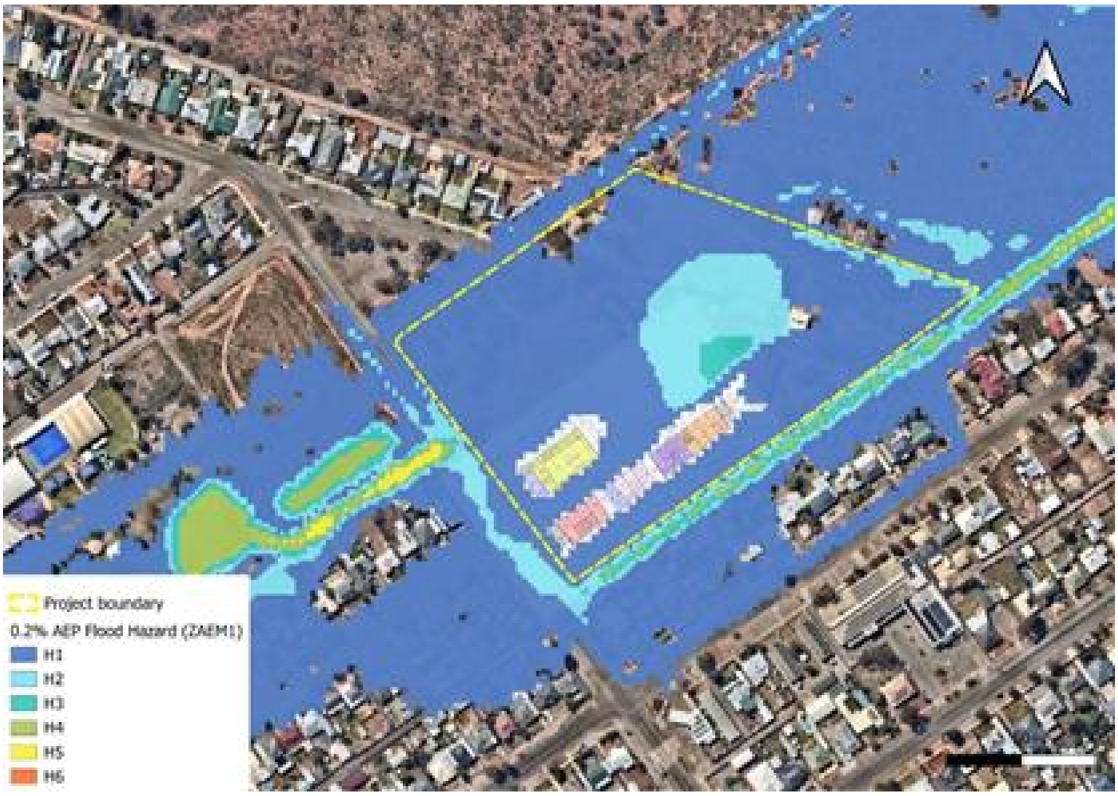


Figure 49-0.2% AEP Flood Hazard Post-Development Scenario

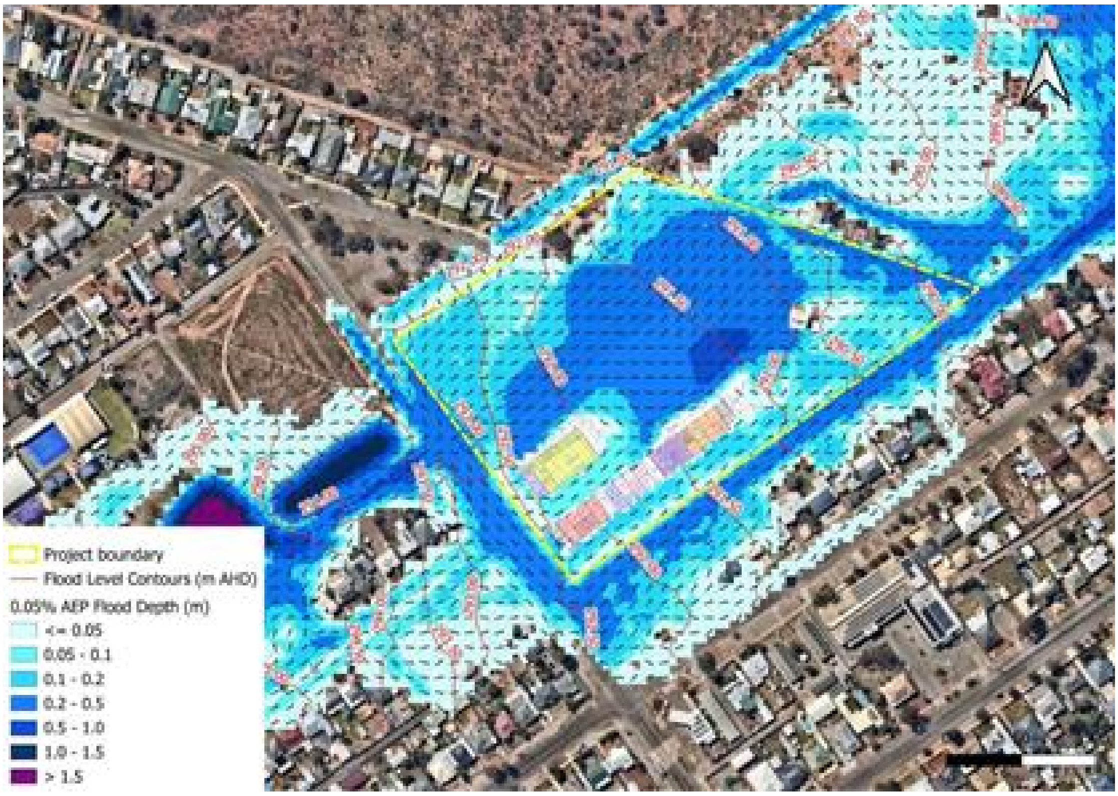


Figure 50- 0.05% AEP Flood Depths and Levels Post-Development Scenario

Figure 51-0.05% AEP Flood Velocities Post-Development Scenario

Figure 52-0.05% AEP Flood Hazard Post-Development Scenario

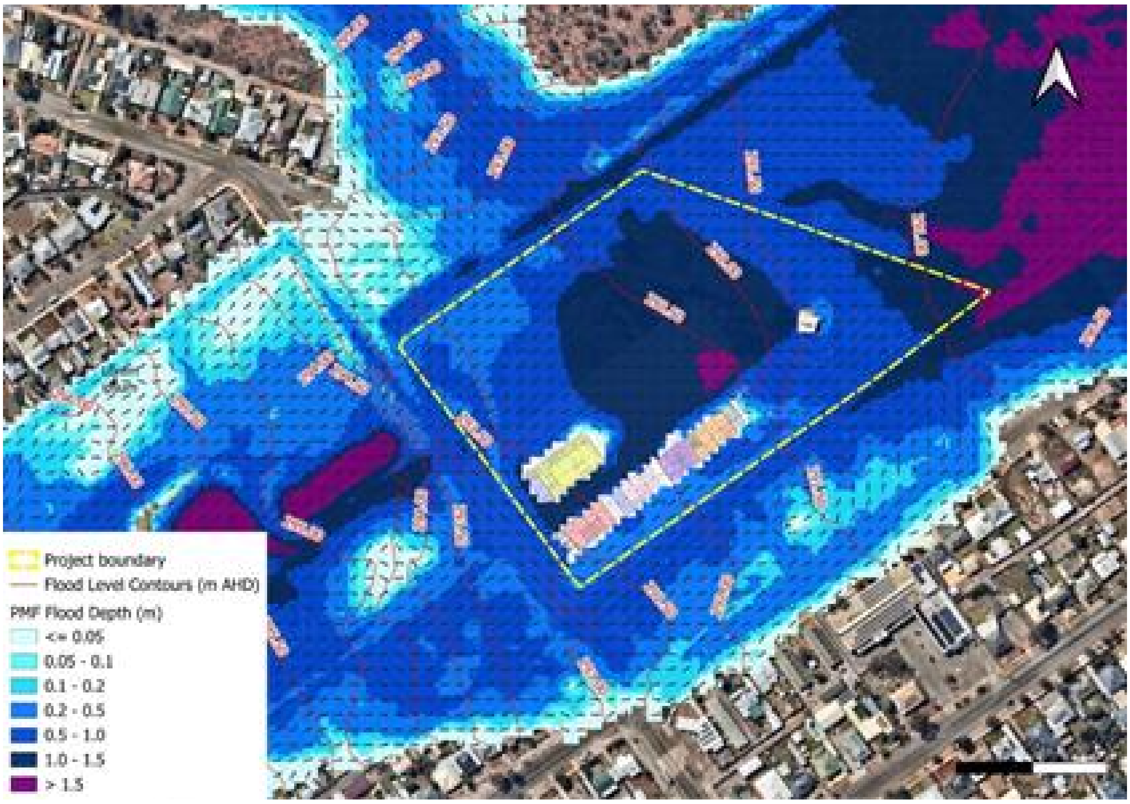


Figure 53- PMF Flood Depths and Levels Post-Development Scenario

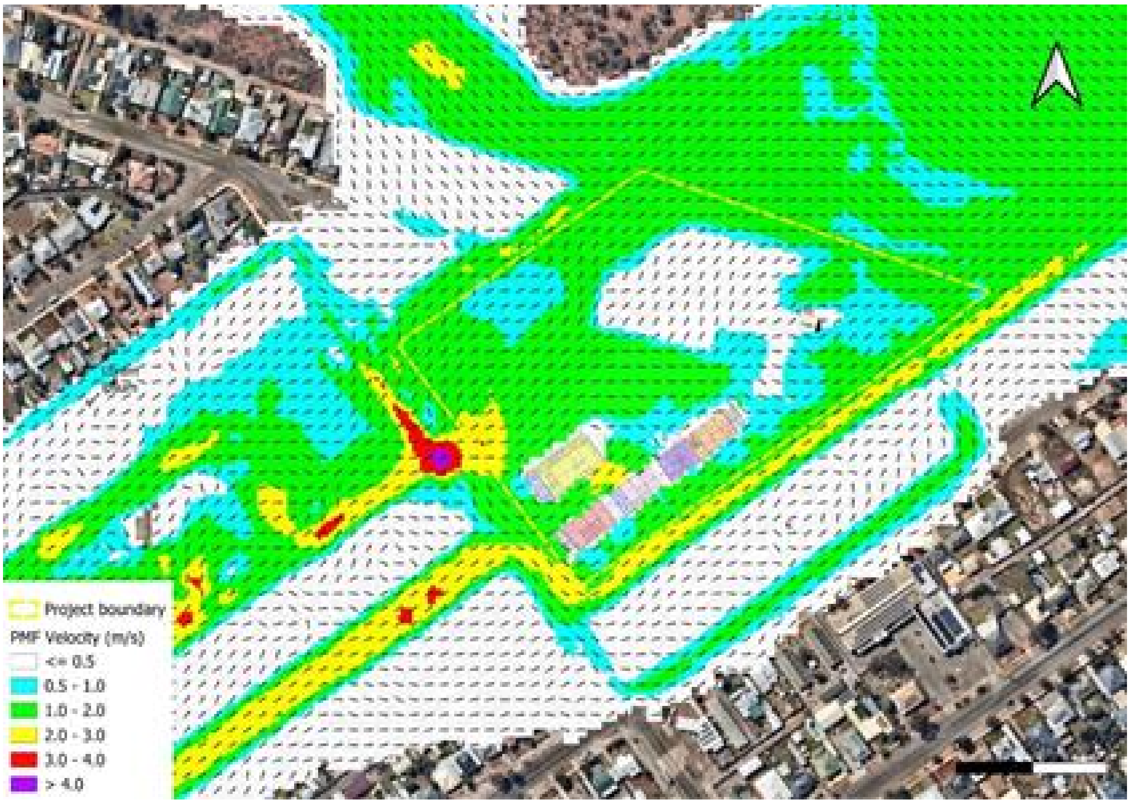


Figure 54- PMF Flood Velocities Post-Development Scenario

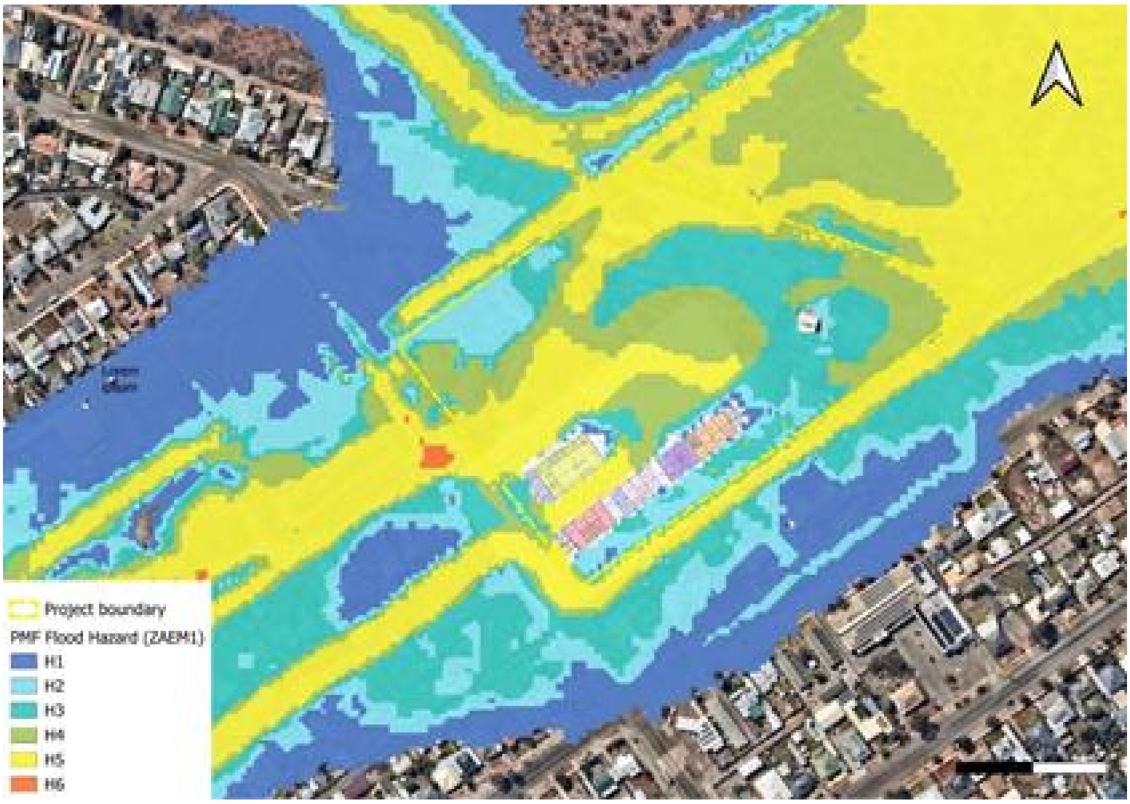


Figure 55- PMF Flood Hazard Post-Development Scenario

7.0 Flood Impact

A flood impact assessment has been carried out to ensure the proposed development would not result in either an unacceptable flood level increase onsite or worsening of the flood conditions over the neighbouring properties in the 10% AEP, 1% AEP, 1% CC AEP, 0.2% AEP,0.05% AEP and PMF events.

The flood afflux maps indicate no significant impact (less than 10 mm) on surrounding properties as a result of the development, except during the PMF event. For the PMF scenario, an afflux of approximately 70 mm is observed at several properties within the affected area, including 632, 634, and 636 McGowen Street, as well as properties along Murton Street and McGowen Lane, such as 628 and 599. It is noted that all of these properties are already impacted during the PMF event, with flood depths exceeding 0.5 metres. The corresponding afflux maps are presented in Figure 53 to Figure 58.

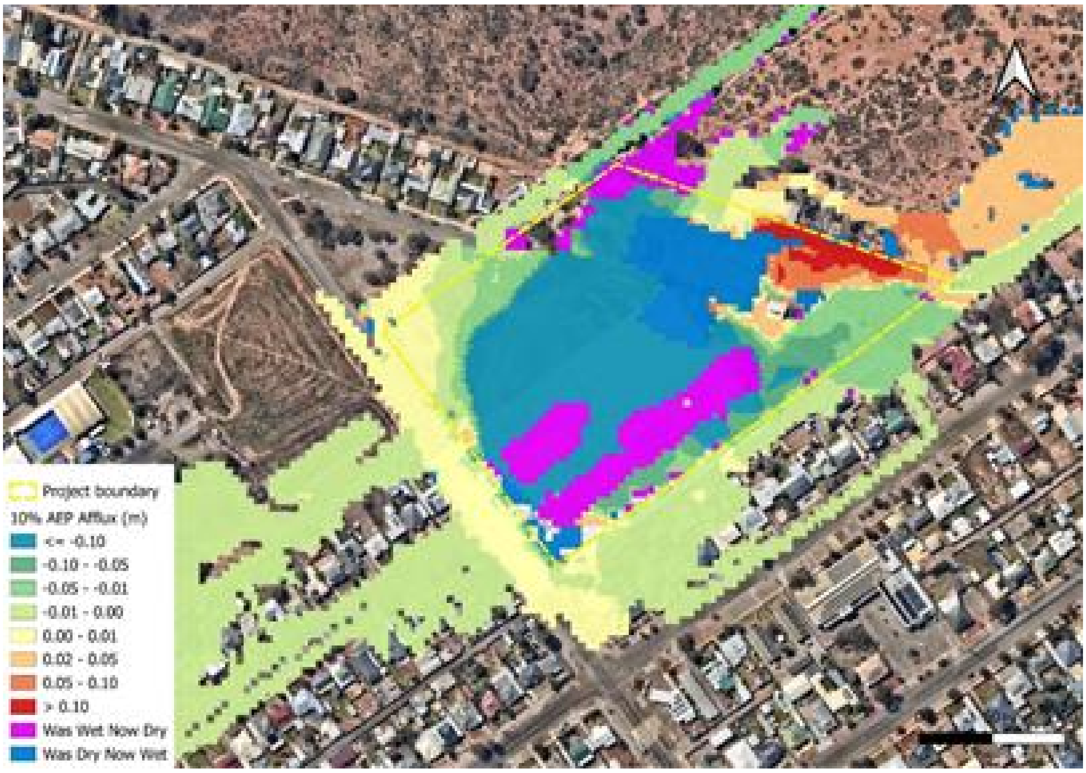


Figure 56- Afflux Map for 10% AEP Event (Post vs Pre Development)

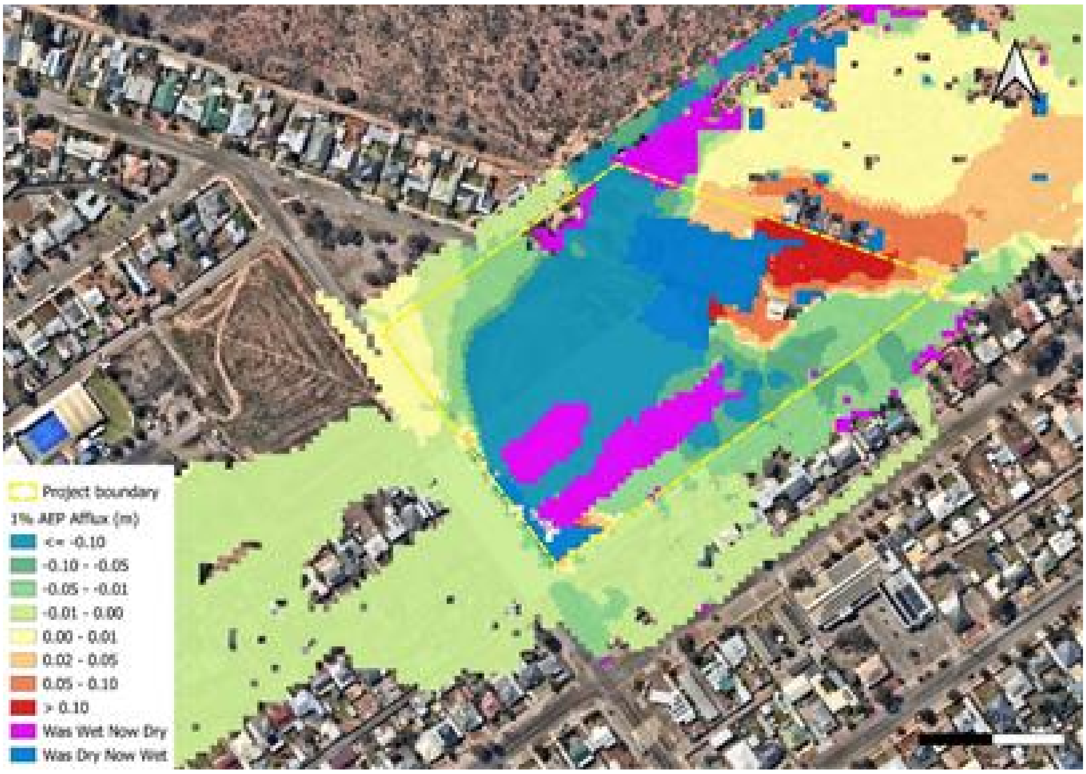


Figure 57- Afflux Map for 1% AEP Event (Post vs Pre Development)

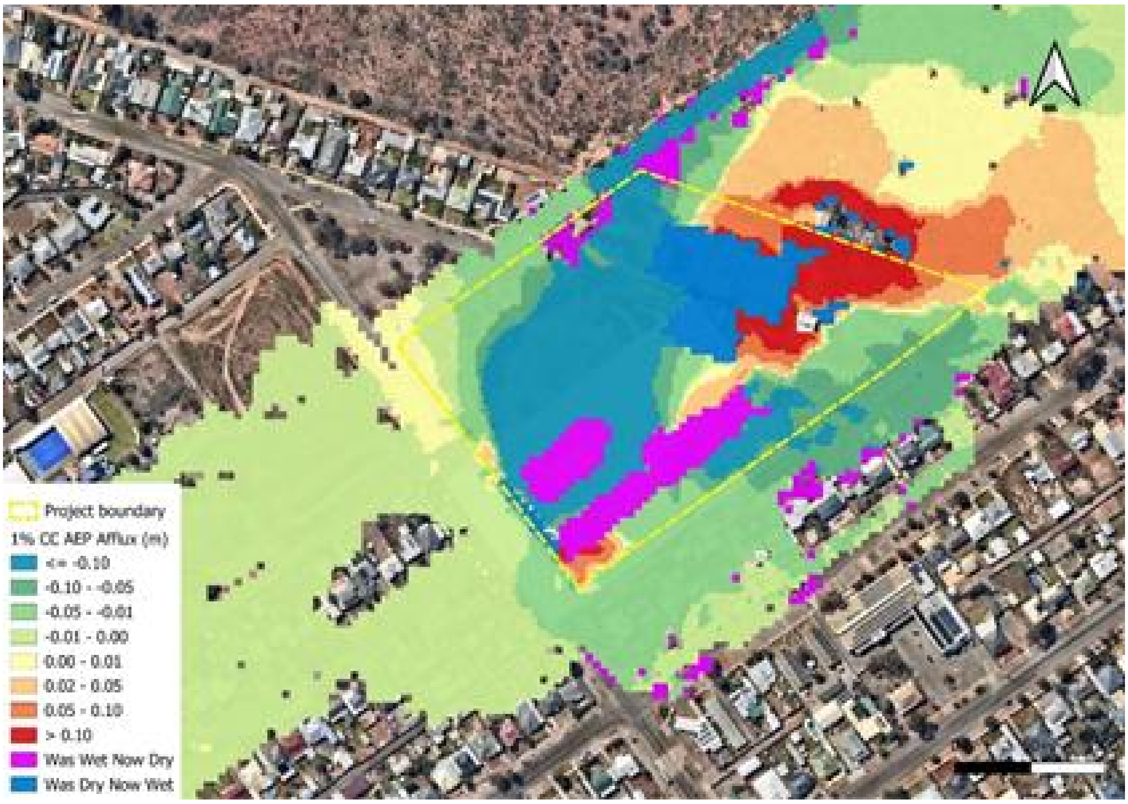


Figure 58- Afflux Map for 1% CC AEP Event (Post vs Pre Development)

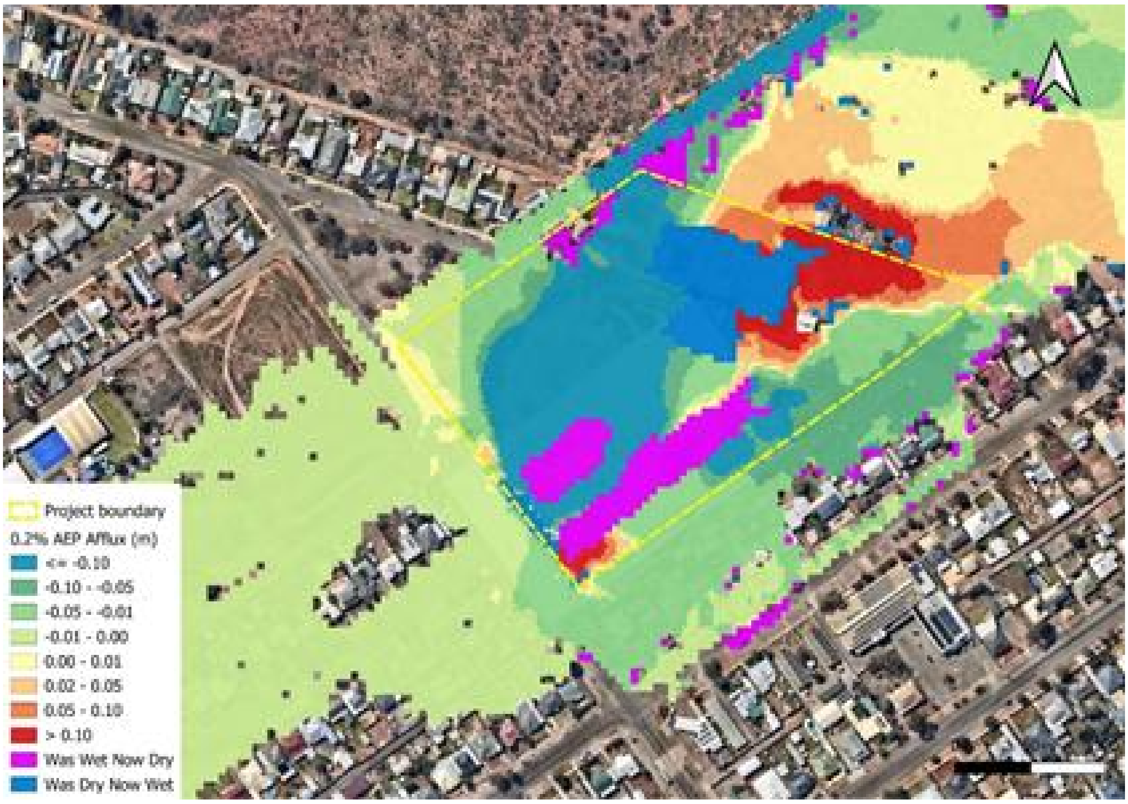


Figure 59- Afflux Map for 0.2% AEP Event (Post vs Pre Development)

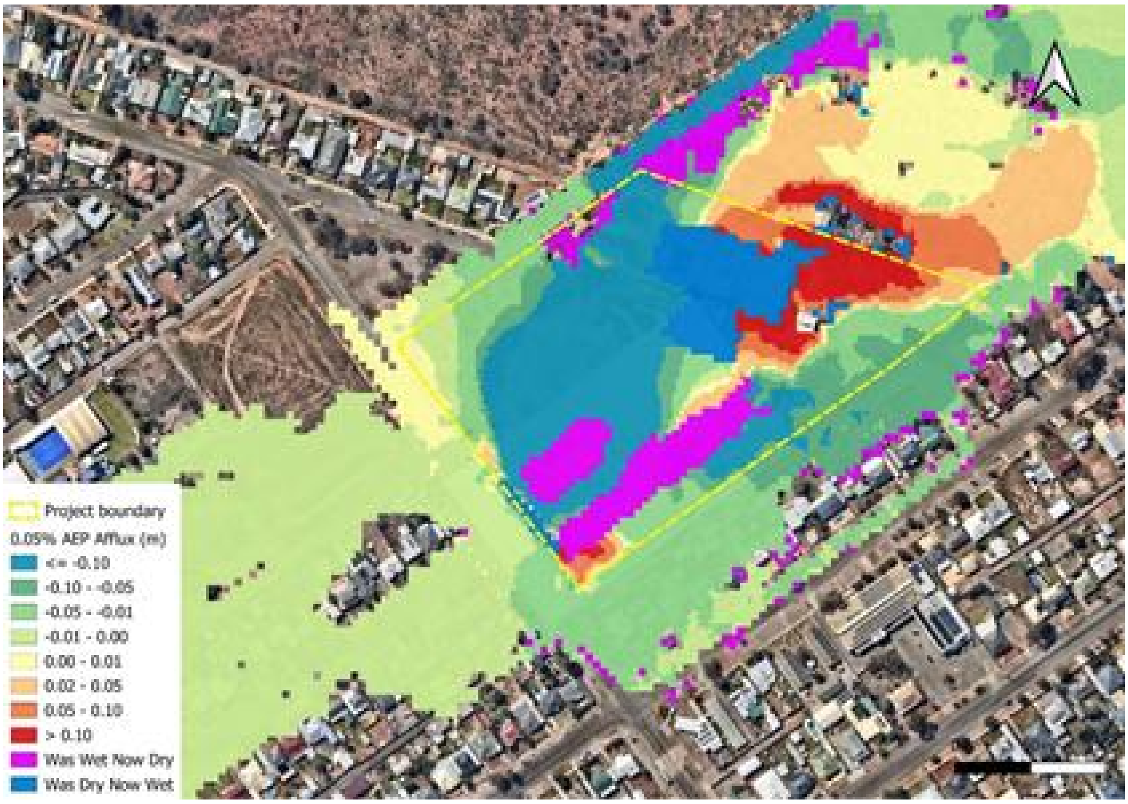


Figure 60- Afflux Map for 0.05% AEP Event (Post vs Pre Development)

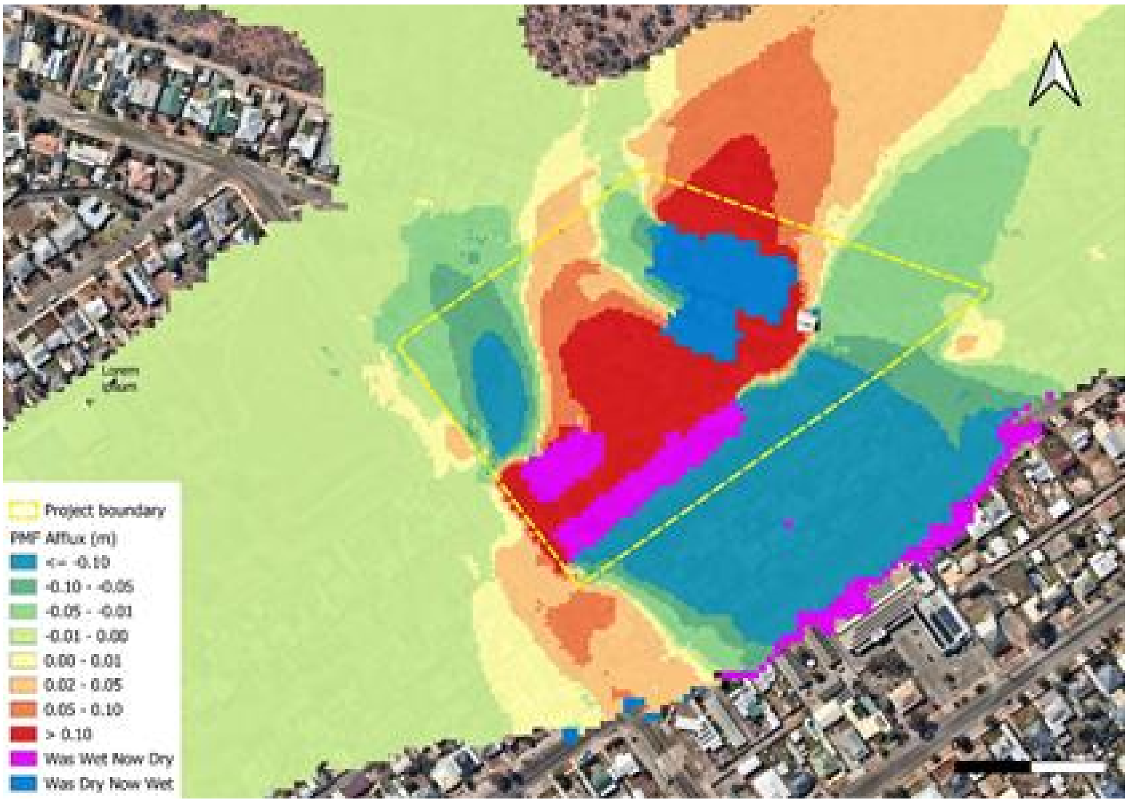


Figure 61- Afflux Map for PMF Event (Post vs Pre Development)

8.0 Mitigation Measures

To minimize flood risks and enhance the resilience of new developments, the following mitigation measures are recommended:

- **Implement a Flood Emergency Response Plan (FERP) prior to operation:**
  A site-specific plan should be developed before the school becomes operational, outlining evacuation procedures, shelter-in-place strategies, and emergency response actions for extreme flood events up to the PMF scenario, ensuring the safety of students, staff, and infrastructure.

- **Use flood-compatible materials below the Flood Planning Level (FPL) during the design and construction phases:**
  Materials selected for areas below the FPL should be capable of withstanding prolonged water exposure and minimising structural damage. These may include water-resistant flooring, reinforced concrete, and corrosion-resistant finishes.

- **Ensure the structural design accounts for PMF events during the design phase:**
  Buildings and critical infrastructure should be engineered during the design stage to withstand PMF-related forces such as buoyancy, hydrostatic pressure, and debris impact loads.

- **Conduct ongoing maintenance of the channel beneath the proposed deck during operation:**
  Once the site is operational, the channel should be inspected and cleared of debris at least once per year and after significant flood events to ensure full conveyance capacity and minimise flood risk.

These mitigation measures aim to enhance the safety and durability of developments while ensuring compliance with best practices for flood risk management. Adopting these strategies will help reduce potential flood impacts on both new structures and surrounding areas.

9.0 Conclusion

This flood assessment confirms that the proposed redevelopment of Willyama High School can proceed without introducing unacceptable flood risks to the site or surrounding properties. The hydrologic and hydraulic modelling, undertaken using industry-standard RORB and TUFLOW tools, demonstrates that flood impacts associated with the development are minimal across all design events, including under future climate change scenarios.

The post-development scenario shows no significant increase in flood levels for the 10%, 1%, 0.2%, 0.05% AEP events, with afflux remaining below 10 mm. For the PMF event, a maximum afflux of approximately 70 mm is observed; however, this occurs at properties already subject to high flood levels (greater than 0.5 m) and does not materially worsen existing flood conditions.

Importantly, the proposed development incorporates best-practice flood mitigation measures, including:

- Finished floor levels set above the PMF;
- Structural design considerations for PMF conditions;
- Flood-compatible construction materials below the FPL; and
- A site-specific Flood Emergency Response Plan (FERP) that accounts for the short duration and rapid onset of PMF flooding.

Additionally, regular maintenance of the channel beneath the deck structure between Blocks B and C is recommended. This includes inspections and cleaning at least annually, and after any major flood event, to ensure the structure remains clear of debris and continues to function effectively during storm events. It is noted that, for modelling purposes, a 50% blockage of the channel has been adopted in this study.

Flood modelling results indicate that all proposed building openings meet the flood planning level requirements,.

Prepared by

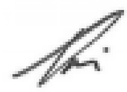
TTW (NSW) PTY LTD

Ali Vahidi

Senior Engineer
CPEng NER (5293949)

Authorised By

TTW (NSW) PTY LTD



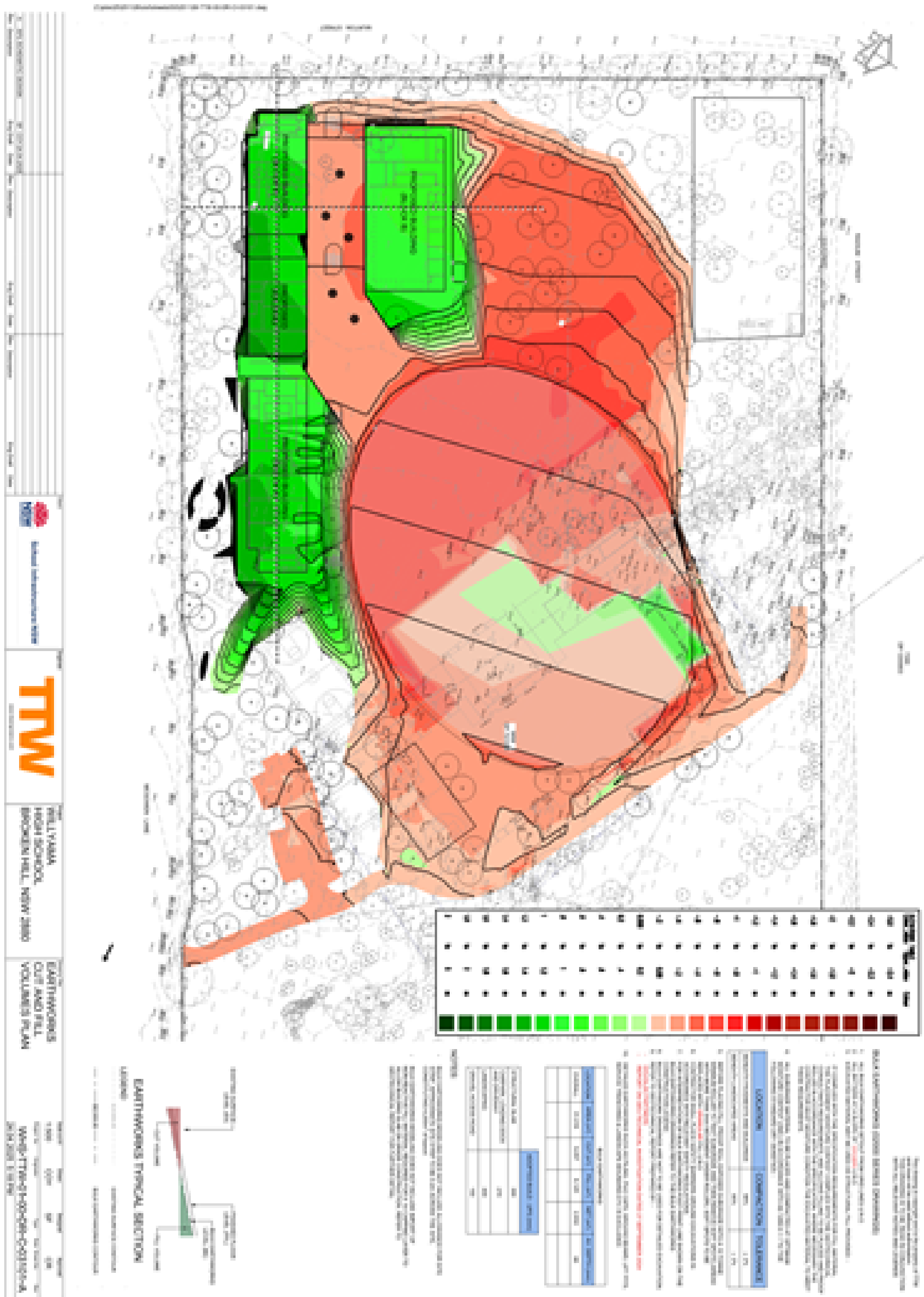
TIM MOORE

NSW Civil Manager

P:\2024\2416\241616\Reports\TTW\Flood\250528 Willyama_Flood Report.docx

Appendix A

Earthworks Cut and Fill Volumes Plan :



Appendix B

Civil design drawing for Channel Configuration