Armstrong Creek
West Precinct Structure Plan
Flooding investigations

October 2011

Stage 2

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

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1. INTRODUCTION

This report documents the investigation of flooding behaviour undertaken as part of the preparation of the Armstrong Creek Western Precinct Structure Plan. The investigation includes wetland and basin designs along with creek protection works completed by Neil M Craigie as well as flood mapping and mitigation investigations completed by Water Technology. These investigations were commissioned by Villawood Properties on behalf of the West Consortium.

Neil M Craigie and Water Technology Pty Ltd were appointed as a team to complete the hydrologic, hydraulic and water quality modelling tasks for the Armstrong Creek West Precinct (ACWP). This report details the RORB and MIKE Flood modelling (hydrologic and hydraulic modelling) of the catchment from Ghazepore Road to immediately downstream of the Surf Coast Highway. The investigations consider the flood behaviour under the pre and post development catchment conditions, and outlined flood management treatments. The flood management treatments were aimed to mitigate any adverse impacts on flood behaviour due to the development of the ACWP.

Assumptions made in this report regarding subcatchment drainage and wetland location and sizing are based on the work completed by Neil M Craigie in a separate report titled *Armstrong Creek West Precinct (ACWP) Stormwater Management Strategy, Version 1 - Draft, September 2011* (Neil M Craigie, 2011). The report completed by Neil M Craigie focuses on the subcatchment urban drainage systems, sediment basin and wetland sizing and levelling and includes the results of MUSIC modelling to confirm compliance with best practice conditions and requirements.

The underlying principle of the assessment of flood management treatments was to eliminate any adverse flooding impacts due to the development. Particular consideration was given to maintaining pre-development (existing) peak flows into at the Surf Coast Highway and Airport Road.

1.1 Previous Studies

The Corangamite Catchment Management Authority (CCMA) undertook an investigation of the flood behaviour under the existing (undeveloped) and developed catchment conditions (CCMA, 2009). The CCMA investigations established the base case for the comparison of the flood behaviour under the developed conditions.

The following investigations have previously been completed by Water Technology and Neil M Craigie, as documented in the Stage 1 Flooding Investigations report (November 2010):

- Investigation of pre-development (existing) catchment conditions and flood behaviour; and,
- Investigation of developed catchment conditions and flood behaviour, based on the proposed land uses and modifications to existing drainage associated with the West Armstrong Creek Precinct.

The flooding investigations were undertaken using a RORB Runoff Routing model to estimate design flood hydrographs into Armstrong Creek and a MIKE FLOOD hydraulic model to investigate flood levels, flows and extents throughout the study area.

1.2 Scope

The purpose of this study is to assess flood behaviour under developed catchment conditions with flood mitigation measures in place. Arrays of retarding basins/wetlands have been designed for the precinct by Neil M Craigie for mitigation purposes. Enhanced floodplain storage through the use of culvert restrictions and barriers have also been introduced to the model to assist in mitigating the developed conditions flows to existing conditions. This report describes the hydraulic effect of this system and covers the following scope:

- Hydrologic modelling of the developed catchment;
- Description of flood mitigation measures employed;
- Hydraulic modelling of developed catchment with flood mitigation; and,
- Assessment of mitigated developed conditions flood behaviour against pre-development conditions

1.3 Study Area

The study area is defined as the Armstrong Creek catchment to the west of the Surf Coast Highway, earmarked for residential development. The Western Industrial Precinct (to the west of Airport Road, and to the south of Armstrong Creek) is being considered as part of a separate flooding investigation. For the purposes of this investigation, it was assumed that any flood management treatments for the Western Industrial Precinct would be located within that precinct, and would mitigate any adverse flood impacts arising from the industrial precinct. The flood behaviour (runoff) for the western industrial precinct was taken as for the existing (pre-development) conditions. Figure 1-1 displays the study area.

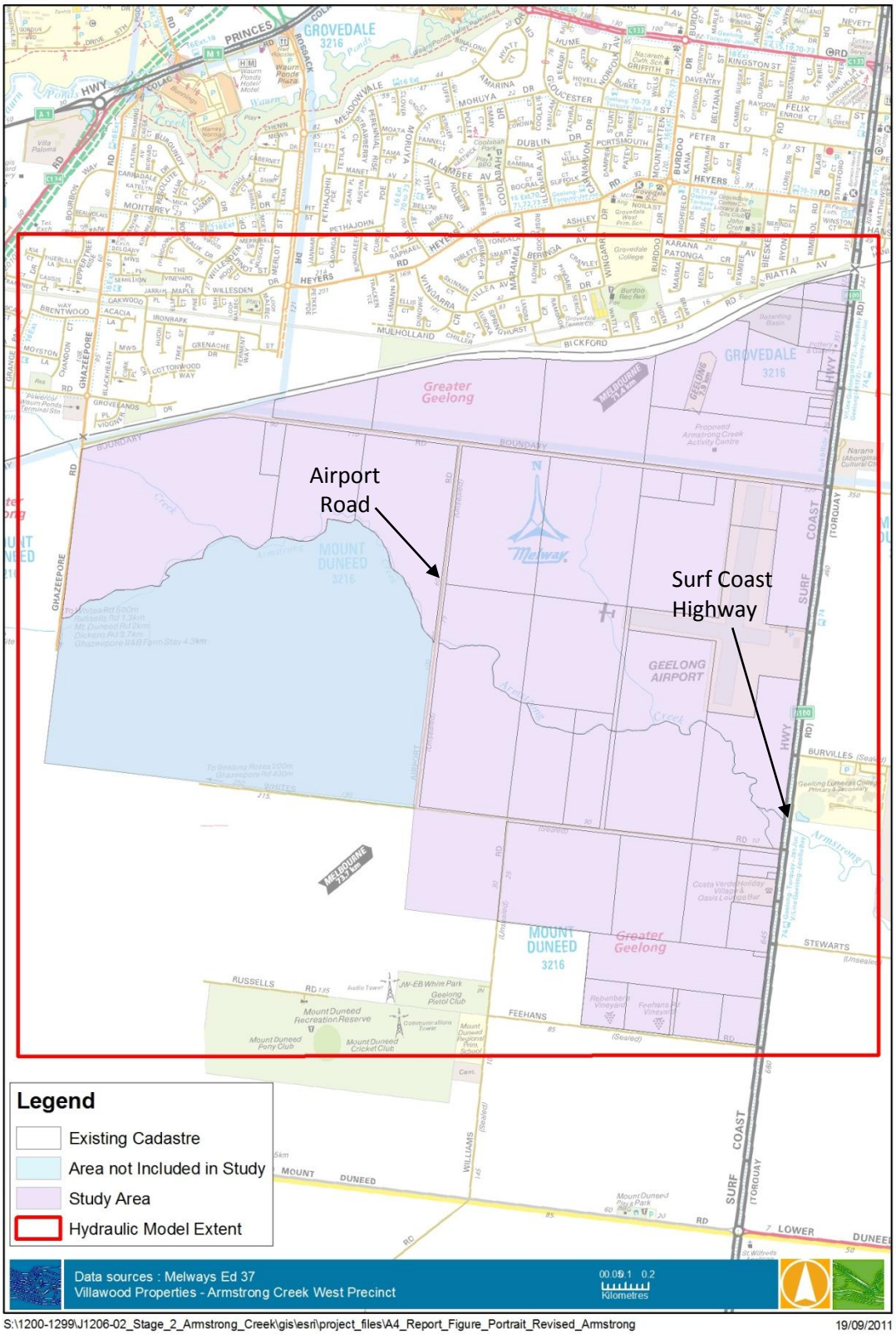

Figure 1-1 Study area (note: Western Industrial Precinct shaded blue is not part of this report)

2. EXISTING CONDITIONS FLOOD BEHAVIOUR

2.1 Overview

An assessment of the existing conditions flood behaviour was undertaken in the Stage 1 Flooding Investigations report (Water Technology, 2010). The results of the assessment are summarised in the following sections. For further information regarding run parameters, calibration, etc., please refer to the Stage 1 Investigation report (Water Technology, 2010).

2.2 Hydrologic Modelling

Design flood hydrographs were determined using an existing conditions RORB model adapted from the CCMA RORB model (2009) for input to the existing conditions hydraulic (MIKE FLOOD) model. The 12 hour duration storm was found to be the critical duration for the 100 year ARI flow at Airport Road and Surf Coast Highway. The hydrographs for hydraulic model inflows derived from the RORB model are shown in Figure 2-1 below.

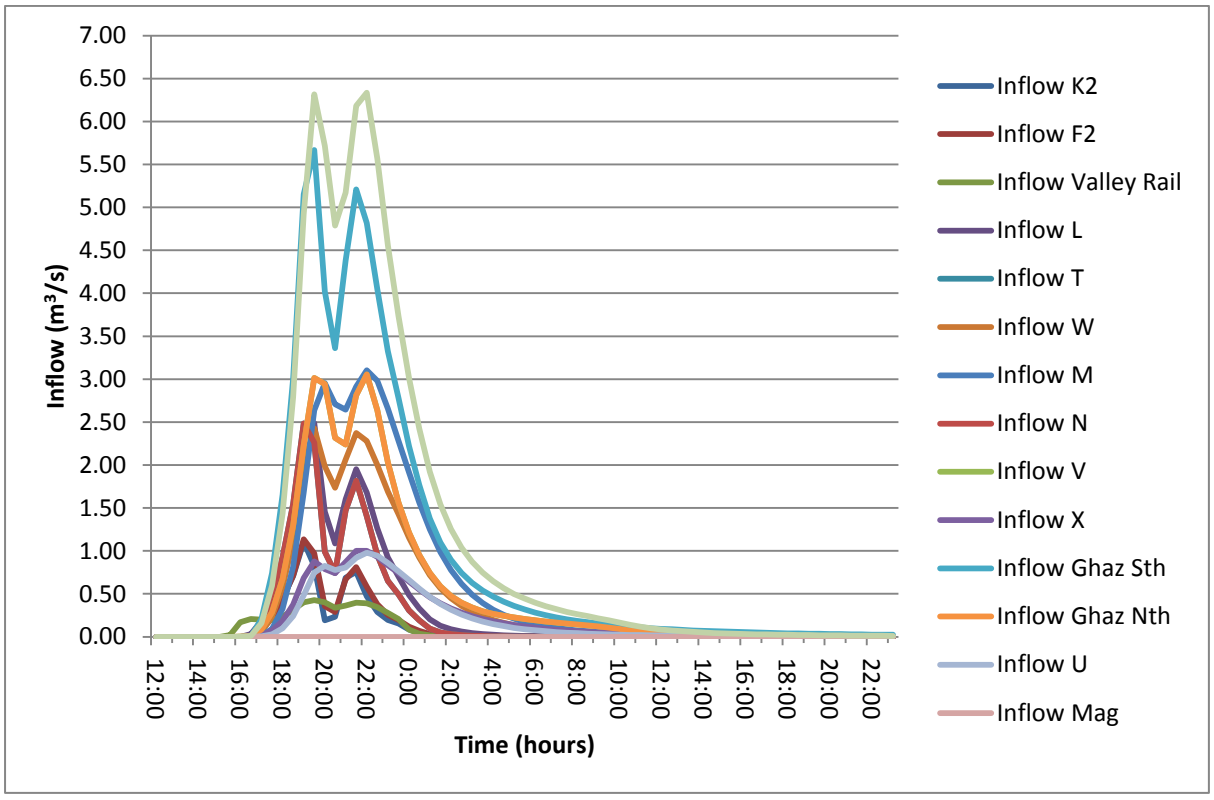

Figure 2-1 100 year ARI 12 hour duration hydrographs (m^3/s) for input to hydraulic model – Existing Conditions

2.3 Hydraulic Modelling

An existing conditions MIKE FLOOD 1D/2D hydraulic model was produced for the Stage 1 Flooding Investigations Report (Water Technology, 2010). The hydraulic model was employed for this report to establish the 'base case' scenario. Since the Stage 1 Investigations, the road crest levels of the Surf Coast Highway were surveyed along with the culvert array and amendments were made to the model to account for this. The existing conditions RORB modelling from the Stage 1 Investigations were again adopted and input to the hydraulic model.

Figure 2-3 displays the flood behaviour for the 100 year flood events under the existing conditions, for the residential development areas to the north of Armstrong Creek, and to the south between Airport Road and the Surf Coast Highway.

Deeper flood waters (greater than 0.5 m) were generally confined to the immediate corridor along Armstrong Creek, particularly upstream (west) of Surf Coast Highway. Shallow flow (less than 0.2 m shaded yellow and pale blue) occurred across the Surf Coast Highway in the 100 year event. Away from the creek corridor, the flows across the floodplain were generally less than 0.2 m in depth.

The general flood extent is consistent with the flood mapping in Water Technology (2007). Some differences have arisen due to the use of different topographic data, and design flood hydrographs. Further, minor overland flow paths were not mapped in this investigation.

The flow hydrographs at Airport Road and Surf Coast Highway were extracted from the model and are shown in Figure 2-2 below. The peak flows of 15.8 m^3/s at Airport Road and 24.0 m^3/s at Surf Coast Highway were derived from the MIKE FLOOD model and will be adopted as the existing conditions flows at these locations. Under developed conditions the flows at these locations will need to be comparable to existing conditions to ensure no adverse impacts on neighbouring properties.

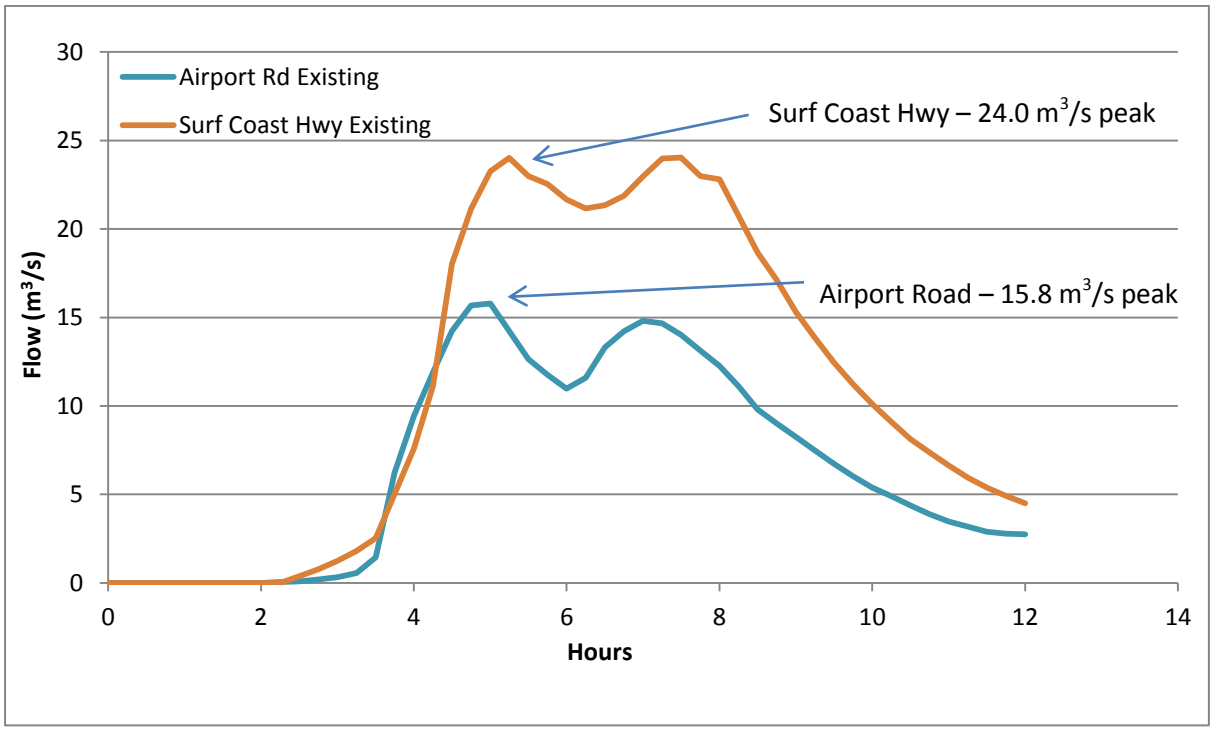

Figure 2-2 100 year ARI, 12 hour duration hydrographs (m^3/s) at Airport Road and Surf Coast Highway

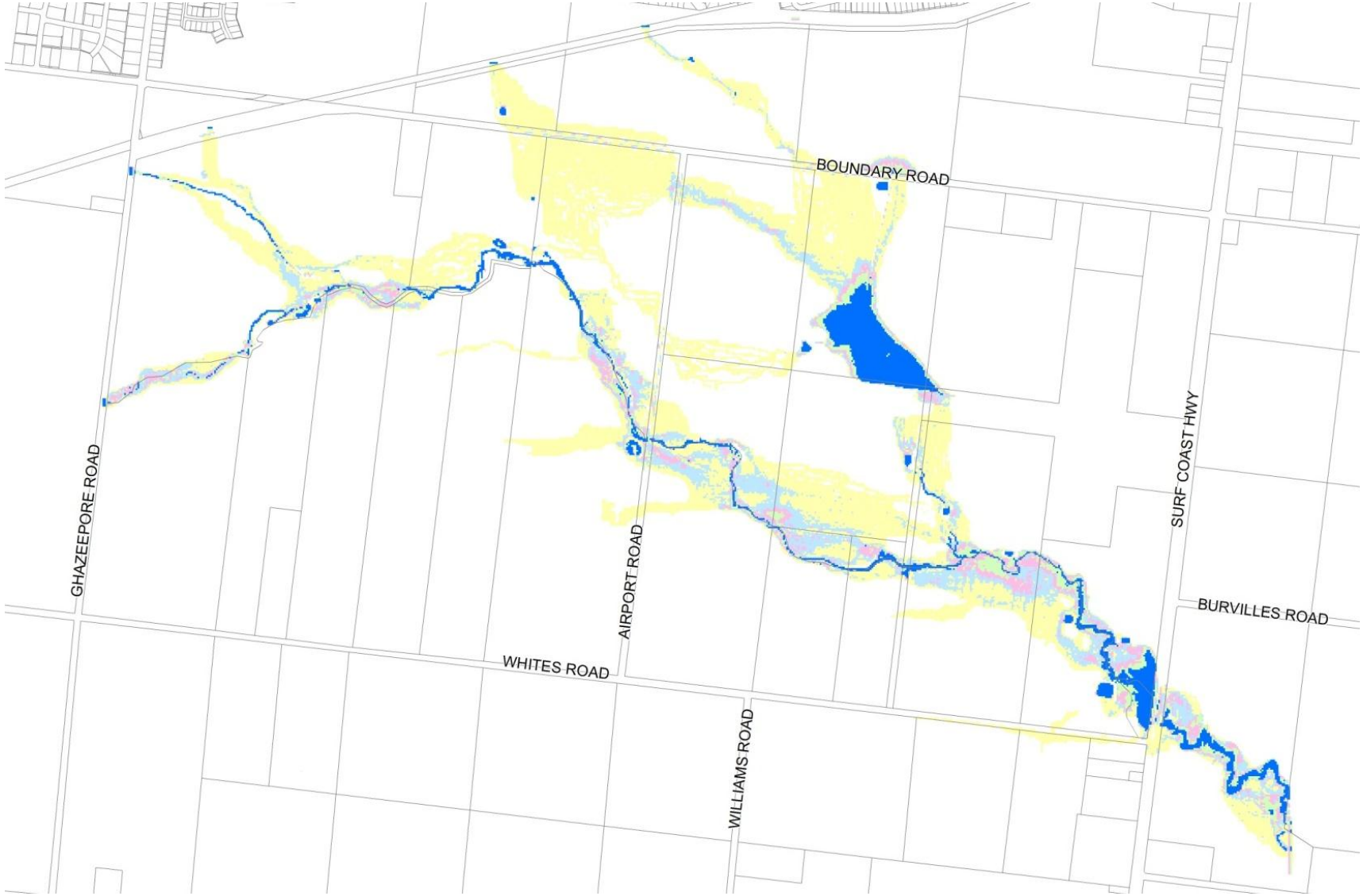

Figure 2-3 Design flood depths and extents – 100 year existing catchment conditions

3. DEVELOPED CONDITIONS FLOOD BEHAVIOUR

3.1 Overview

Proposed land use within the West Armstrong Creek Precinct will consist of residential and commercial development, and public open space. The proposed development will increase the impervious surface, and realign and modify current drainage paths within the catchments.

The underlying principle of the assessment of flood management treatments was to eliminate any adverse high flow flooding impacts due to the development. Particular consideration was given to maintaining pre-development peak flows at Airport Road and the Surf Coast Highway. Geomorphic impacts of low flow high frequency increases are considered in the water quality strategy (Craige, 2011).

For this precinct, the principal flood management treatment proposed is a number of wetland/retarding basins. A centralised flood management approach has been adopted with proposed wetlands/retarding basins located adjacent to Armstrong Creek. These locations enable the enhancement of the values and the amenity of Armstrong Creek, provides for efficient use of drainage infrastructure, and minimises ongoing maintenance requirements. The conceptual wetland/retarding basin arrangements are consistent with the Urban Growth Plan.

The hydrologic and hydraulic models discussed in the Stage 1 Flooding Investigations report (Water Technology, 2010), were revised to reflect these changes due to the proposed development.

Further, the flood management treatments have a dual purpose to mitigate the impacts on stormwater runoff quality, as well as flood behaviour. All indicative wetlands are sited to minimise vegetation disturbance and to make best use of the terrain as to minimise earthworks. Modification to the position of these wetlands is considered undesirable. Further details of stormwater quality modelling are provided in the report provided by Neil M Craigie (2011).

3.2 Flood Mitigation Measures

3.2.1 Wetlands and Retarding Basins

As discussed in the Stage 1 Flooding Investigations report (Water Technology 2010), the proposed development (without mitigation), leads to a considerable increase in the peak flow and flood volume. To alleviate these increases, Neil M Craigie prepared an initial conceptual wetland/retarding basin arrangement (see Figure 3-1 for locations). The aim of the wetlands/retarding basins is to provide temporary storage of runoff, and thus limit peak flow rates into Armstrong Creek. SB1 (Sedimentation Basin 1) shown in previous reports has been removed from the modelling. It is understood by Water Technology that SB1 is for the future industrial precinct and does not offer flood protection or water quality treatment for the residential precinct.

This conceptual design located retarding basins/wetlands at the significant sub-catchment outlets to Armstrong Creek. The layout and design of the wetland/basins was an iterative process working to balance the requirements of native vegetation conservation, existing road alignments and proposed development layouts, etc. This has resulted in various re-designs of the wetlands throughout the process with the goal maintaining the water quality and quantity objectives while minimising disturbance. The potential to distribute the wetlands and basins was limited due to the Airport Road and Surf Coast Highway creek crossings as well as the proposed development road crossings of the creek.

The wetlands/retarding basins will be formed using existing depressions, with excavation and the construction of minimal embankments where required. As noted, this location enables the

enhancement of the values and the amenity of Armstrong Creek, provides for efficient use of drainage infrastructure, and minimises ongoing maintenance requirements.

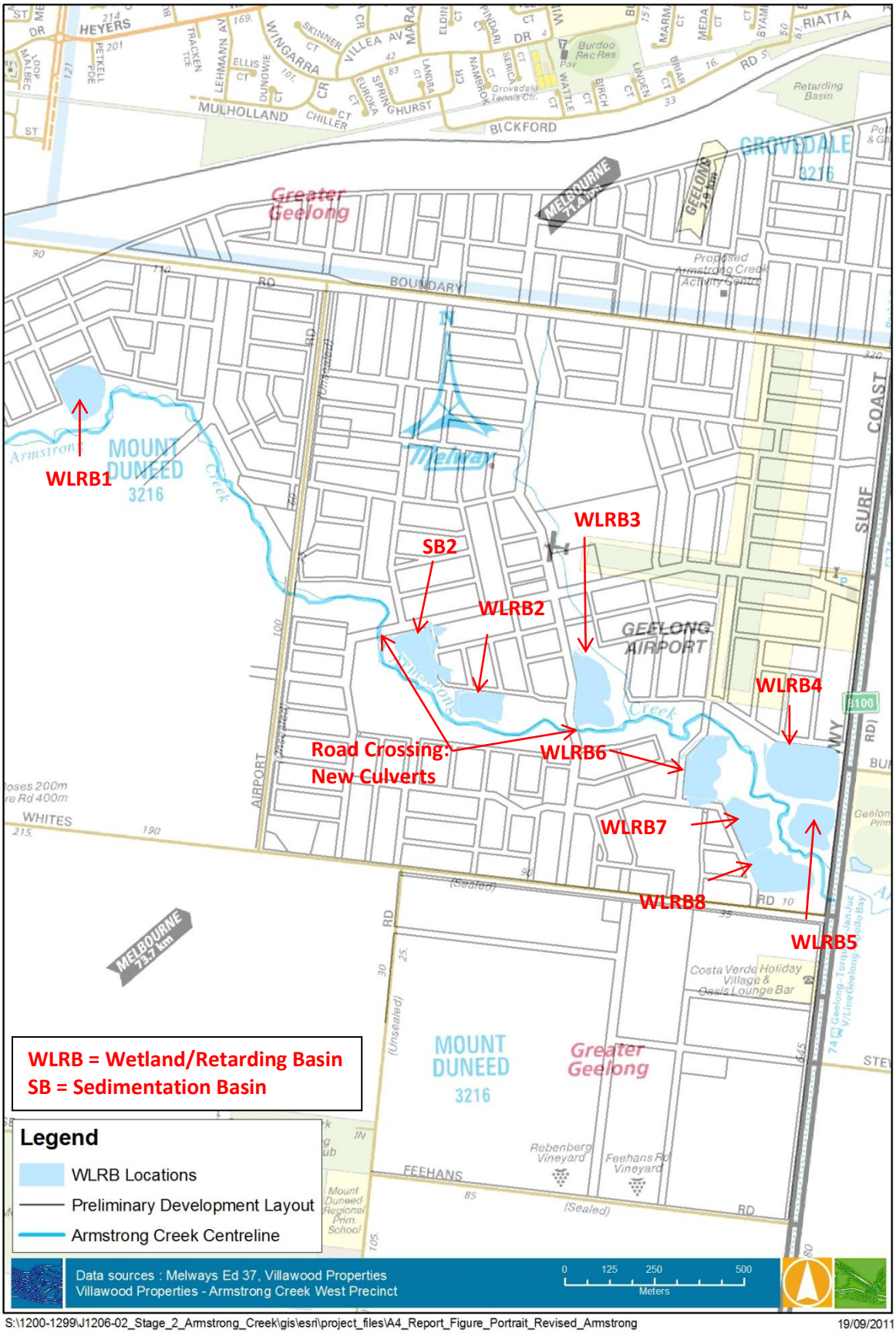

Figure 3-1 Locations of proposed Wetland/Retarding Basins (Design by Neil M Craigie)

Generally, shallow overland flowpaths to the north and south of Armstrong Creek will be piped as part of the drainage infrastructure. In particular, the tributary flowing from the corner of Ghazeepore and Boundary Roads is likely to be piped as part of the VicRoads' proposed 4C alignment works. The tributary currently through the Airport will remain as open waterway to the south of the current runway.

For this assessment, it was assumed that VicRoads would provide treatments to offset any change in runoff behaviour arising from the 4C alignment. Consultation with VicRoads will be undertaken as part of future investigations.

As well as providing flood storage, the wetlands will provide storm water treatment. Details of the stormwater quality aspects are shown in the report provided by Neil M Craigie.

The CCMA (2009) calculated a total required detention storage of 85,620 m^3 for the entire western precinct. This included a detention storage of 11,700 m^3 for the western industrial precinct. Removing this allowance for the western industrial precinct leaves a detention storage for the residential area of 73,920 m^3. Table 1 in the report provided by Neil M Craigie summarises the catchments and design parameters for each of the treatment assets along the Armstrong Creek corridor. The total flood storage available as shown in Table 1 (Neil M Craigie, 2011) is 80,800 m^3.

The conceptual wetland arrangement therefore provides flood storage in line with the CCMA estimate. Further details of the wetland/retarding basin designs and hydraulic controls are shown in the report provided by Neil M Craigie.

It is noted that the City of Greater Geelong does not support the use of rainwater tanks for flood management purposes. Villawood will promote the use of rainwater tanks on site throughout the development, with any available storage in the tanks potentially adding to the available flood storage within the catchment in developed conditions. Storage from rainwater tanks has not been included in our calculations or modelling.

As noted, this detention storage does not include an allowance for the western industrial precinct. It was assumed that the sufficient detention storage would be provided within the industrial precinct to mitigate runoff from the proposed industrial precinct.

3.2.2 Other Flood Mitigation Treatments

To achieve the required flow values at both Airport Road and Surf Coast Highway, further mitigation treatments were required. The additional mitigation treatments also have the added benefit of protecting the Surf Coast Highway from overland flow in a 100 year ARI event which is flooded to depths of greater than 300 mm in existing conditions.

Culvert constrictions and a low wall along the Surf Coast Highway were both incorporated to increase the available flood storage within the ACWP.

The two road crossings shown in Figure 3-1 were sized by Neil M Craigie and Brown and Tomkinson to pass the 100 year flow. Through iterations in the hydraulic model, constricting the downstream set of culverts to 2 no. 1.5 x 3m culverts (c.f. 4 no. 1.5 x 3m culverts) proved to provide good attenuation of flows between Airport Road and Surf Coast Highway. The iterations also focused on ensuring that the head drop across the constriction was no greater than 1m, and preferably close to 0.5m to reduce the depth of water ponding against the road embankment and to minimise the amount of fill required on the surrounding properties. Further discussion of the performance of the culvert constriction is provided in Section 3.4.

A low wall along the Surf Coast Highway is also proposed. The low wall has two benefits, it assists in reducing flows on the downstream side of the Highway by creating more flood storage at the peak of the event within the ACWP and it also protects the Highway from inundation in a 100 year ARI event which is inundated to depth of up to 300mm in existing conditions. The wall would be required to extend above the 100 year ARI flood level of 23.95m AHD plus an appropriate freeboard. The road surface at the crossing varies between approximately 23.15 m AHD and 23.92 m AHD. Further design and survey of the area will be required for the detailed design stage of the project and may result in alternative arrangements to achieve the same retention (road resheet etc.).

3.3 Hydrologic Modelling

3.3.1 Developed Conditions RORB Model

The significant changes in catchment layout proposed by the development resulted in the need to re-route the existing RORB model (adapted from the CCMA RORB model 2009) to match the proposed flow paths in developed conditions. The routing modifications included simulated piped diversions in developed areas and high flow bypasses around selected wetland/basins. Fraction Impervious values in the RORB model were matched to the developed conditions MUSIC model created by Neil Craigie to ensure consistency across the study. The developed conditions RORB model included all catchment routing to the hydraulic model inflow points, with routing downstream of these points to be calculated in the hydraulic model, ie. the proposed wetlands/storage basins were not modelled in the RORB model but were accounted for in the hydraulic model.

3.3.2 Model Calibration

The calibration from the existing conditions RORB model was maintained for the developed conditions model through the preservation of the kc : d_{av} ratio of 2.16 as shown below in Table 3-1.

Table 3-1 RORB Model Calibration Details

	Existing Conditions RORB Model 2009	Developed Conditions RORB Model 2011
Kc	14.00	7.32
d_{av}	6.48	3.39
Kc:d_{av}	**2.16**	**2.16**

3.3.3 Modelling Parameters

IFD Parameters

As per the existing conditions modelling, the IFD (Intensity Frequency Duration) parameters used were calculated for the centroid of the study area as shown in Table 3-2.

Table 3-2 IFD Parameters

Location	2y1h	2y12h	2y72h	50y1h	50y12h	50y72h	Skew	F2	F50	Zone
Armstrong Creek	18.00	3.49	0.90	34.41	6.01	1.80	0.43	4.28	14.81	1

Temporal and Areal Patterns

As per the existing conditions modelling, temporal patterns were filtered, areal pattern details were uniform and the Siriwardena and Weinmann Areal Reduction Factor method was used with a total catchment area of 30.20 km^2.

Run Parameters

As per the existing conditions modelling, the loss parameters were constant and the 'm' value was set to 0.80. The catchment initial loss (IL) was set to 15mm and the runoff coefficient (RoC) was set to 0.60 in the 100 year ARI event to represent the greater urbanisation of the catchment. The IL value remained constant across all ARI's and durations, while the RoC was varied across ARI's as per Melbourne Water's current recommended methodologies (Melbourne Water Flood Mapping Guidelines and Technical Specification Nov 2010) and as shown in Table 3-3.

Table 3-3 Runoff Coefficient Values Used

ARI Event	Runoff Coefficient for Urban Catchments
5 year	0.25
10 year	0.35
100 year	0.60

Diversions

A number of diversions were included in the RORB model to simulate the high flow diversions around WLRB2,3,4 and 6. The high flow diversions allow up to 5 year ARI flows to pass through the wetland/retarding basins with any flows over this limit bypassing to the creek. The flow rate bypassing the wetland/retarding basins is shown below in Table 3-4.

Table 3-4 Wetland/Retarding Basin Bypass Flow Rates

Wetland/Retarding Basin ID	5 Year ARI High Flow Bypass (m^3/s)
WLRB2	4.16
WLRB3	6.64
WLRB4	1.77
WLRB6	0.49

RORB Results

The RORB model was used to create design flood hydrographs for input to the hydraulic model. The full range of storm durations were run in RORB (15 minutes – 72 hours) with the 9 hour storm found to be the critical duration for the 100 year ARI flows at both Airport Road and Surf Coast Highway. The 9 hour storm duration hydrographs were extracted from RORB and input to the hydraulic model and modelled as the critical event. The hydrographs extracted from the RORB model are shown in Figure 3-2 with hydrograph inflow locations to the hydraulic model shown in Figure 3-3. Please note,

although Sedimentation Basin 1 (SB1) is listed as an inflow point, the basin was removed for the final model runs with the inflow simply discharging to the existing ground surface at this site.

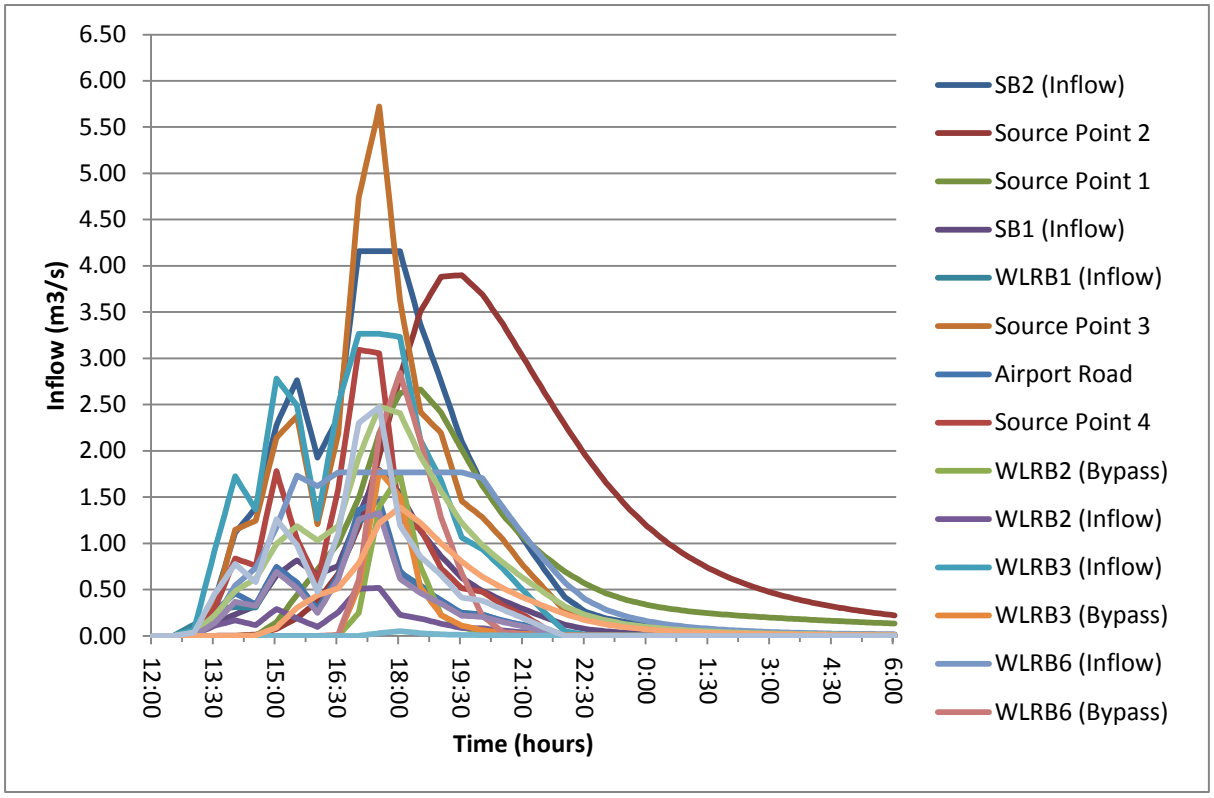

Figure 3-2 **100 year ARI 12 hour duration hydrographs (m^3/s) for input to hydraulic model – Developed Conditions**

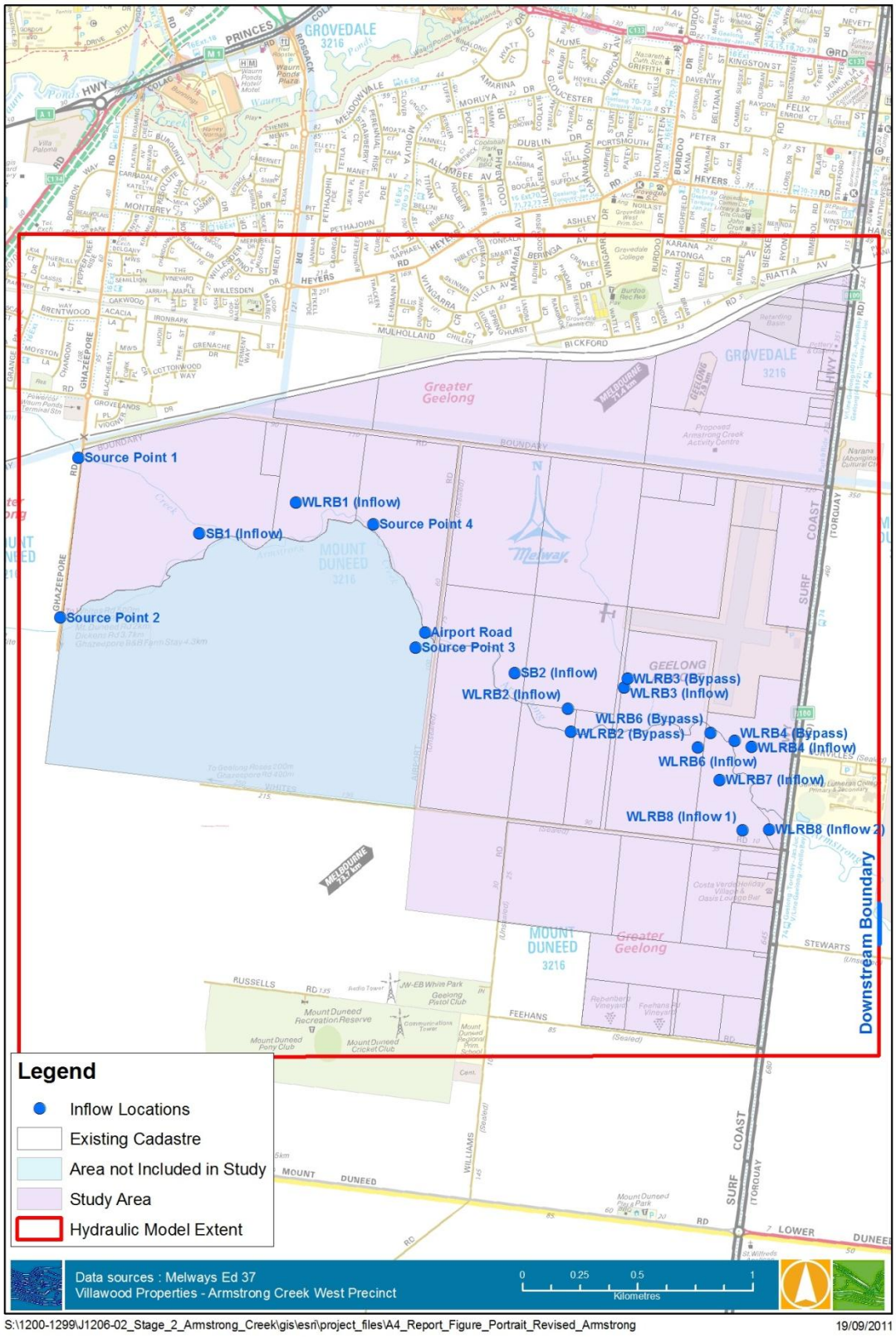

Figure 3-3 RORB Hydrograph Inflow Locations to the Hydraulic Model

3.4 Hydraulic Modelling

The existing MIKE FLOOD model was modified to include:

- Fill pad boundaries – the fill areas were raised in the model grid to simulate filling above the 100 year ARI flood level;
- Wetlands/Retarding Basins and Sediment Basins – the wetland treatment train designed by Neil M Craigie was included in the model grid;
- Road Crossings – Two proposed road crossings were included in the model:
    - The western crossing (as shown in Figure 3-4) was included as 4 no. 3.0m x 1.5m box culverts, with the road above the 100 year ARI flood level.
    - The eastern crossing (as shown in Figure 3-4) was included as 2 no. 3.0m x 1.5m box culvert, with the road above the 100 year ARI flood level to create the required flow constrictions.
- Pipes between wetlands to simulate outlet structures as shown in the report provided by Neil M Craigie; and,
- The inclusion of a low barrier above the 100 year ARI flood level along the Surf Coast Highway to further constrict flows and provide 100 year ARI protection to the Highway.

The model was run with a Manning's n value of 0.05 within the deep wetland/retarding basin sections with a higher Manning's value of 0.075 used on the waterway to represent the highly vegetated nature of the existing channel.

The developed topography (2D model grid) is shown in Figure 3-4 below. The inflows shown in Figure 3-3 were applied as boundary inflows (at Ghazeepore Road North and South Branches) and as 2D source points.

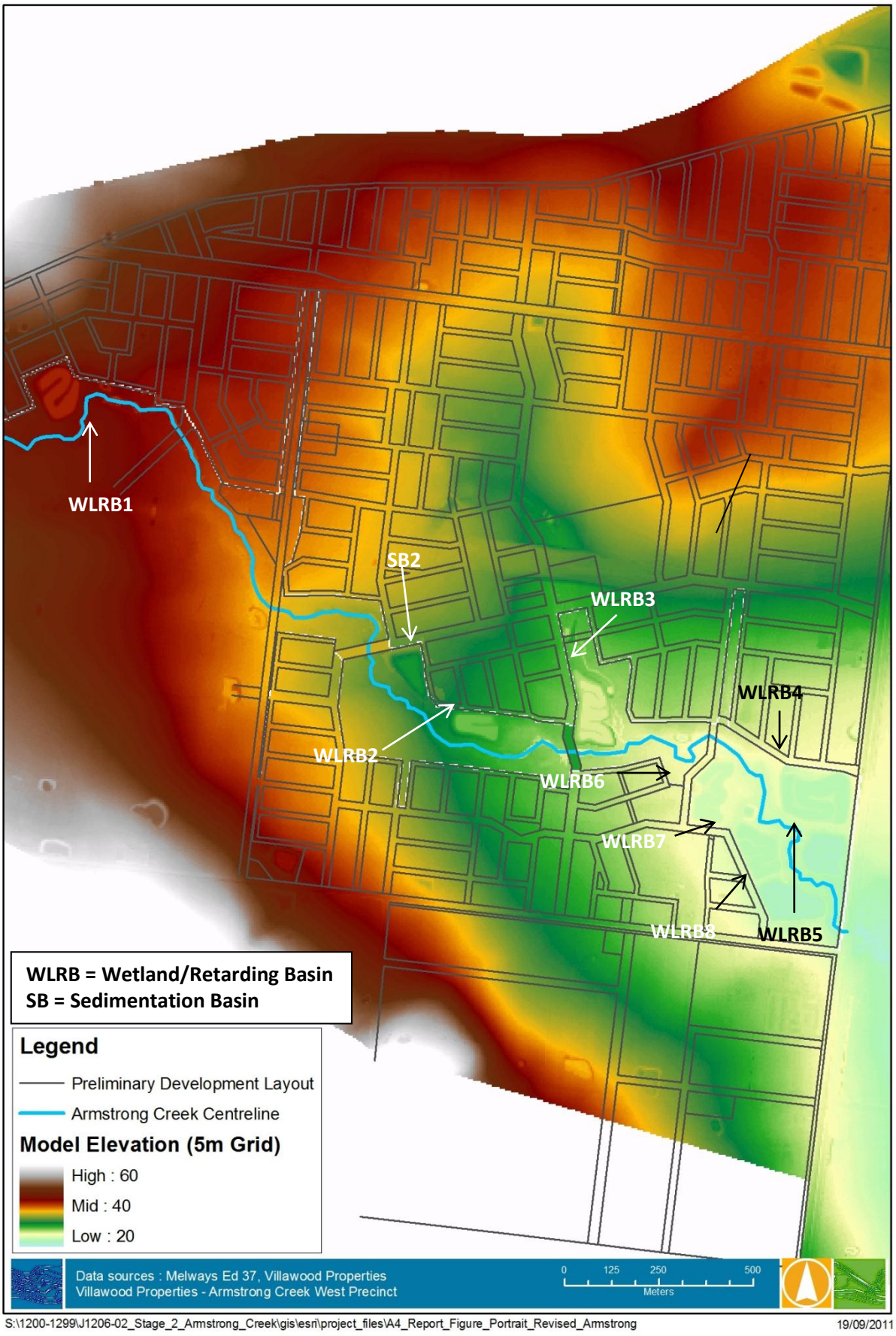

Figure 3-4 **Model Topographic Grid – Developed Conditions (please note: Development Areas Filled in Hydraulic Model)**

The flood extent and maximum depth for the 100 year flood events under developed conditions is shown in Figure 3-5 below. A WSE plot and 0.5 m contours are shown in Figure 3-6. Many of the overland flow paths observed in the existing conditions flood extent have been constrained by the fill pads. Flood extents for the other ARI events modelled are shown in Appendix A.

Deeper flood waters (greater than 0.5 m) were observed in the wetlands and sediment basins, and also upstream of the Surf Coast Highway and the proposed road crossings. Shallow flow (less than 0.2 m shaded yellow and pale blue) was seen in most other areas. No flow is seen across the Surf Coast Highway in either event, an improvement from existing conditions.

Note that the area of pooling upstream of the eastern proposed road crossing occurred because the road crossing was constricted to 2 no. 3 x 1.5m culverts. This allows the 100 year developed flow to be attenuated below the existing peak flow by using the storage behind the road crossing embankment. This arrangement was varied through the model runs to achieve an acceptable head drop across the road crossing while also attenuating the required volume.

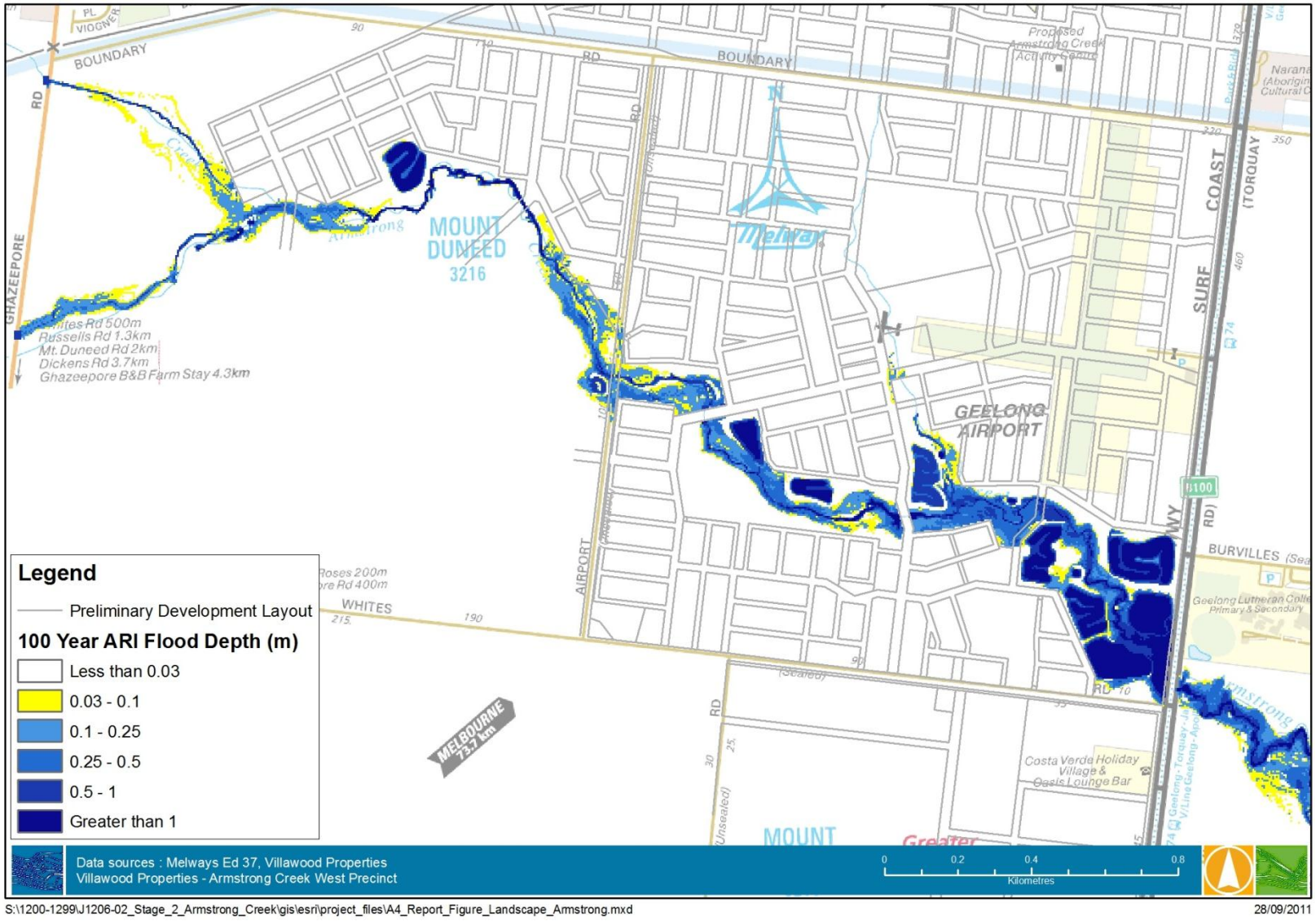

Figure 3-5 Design flood levels and extents – 100 year developed catchment conditions

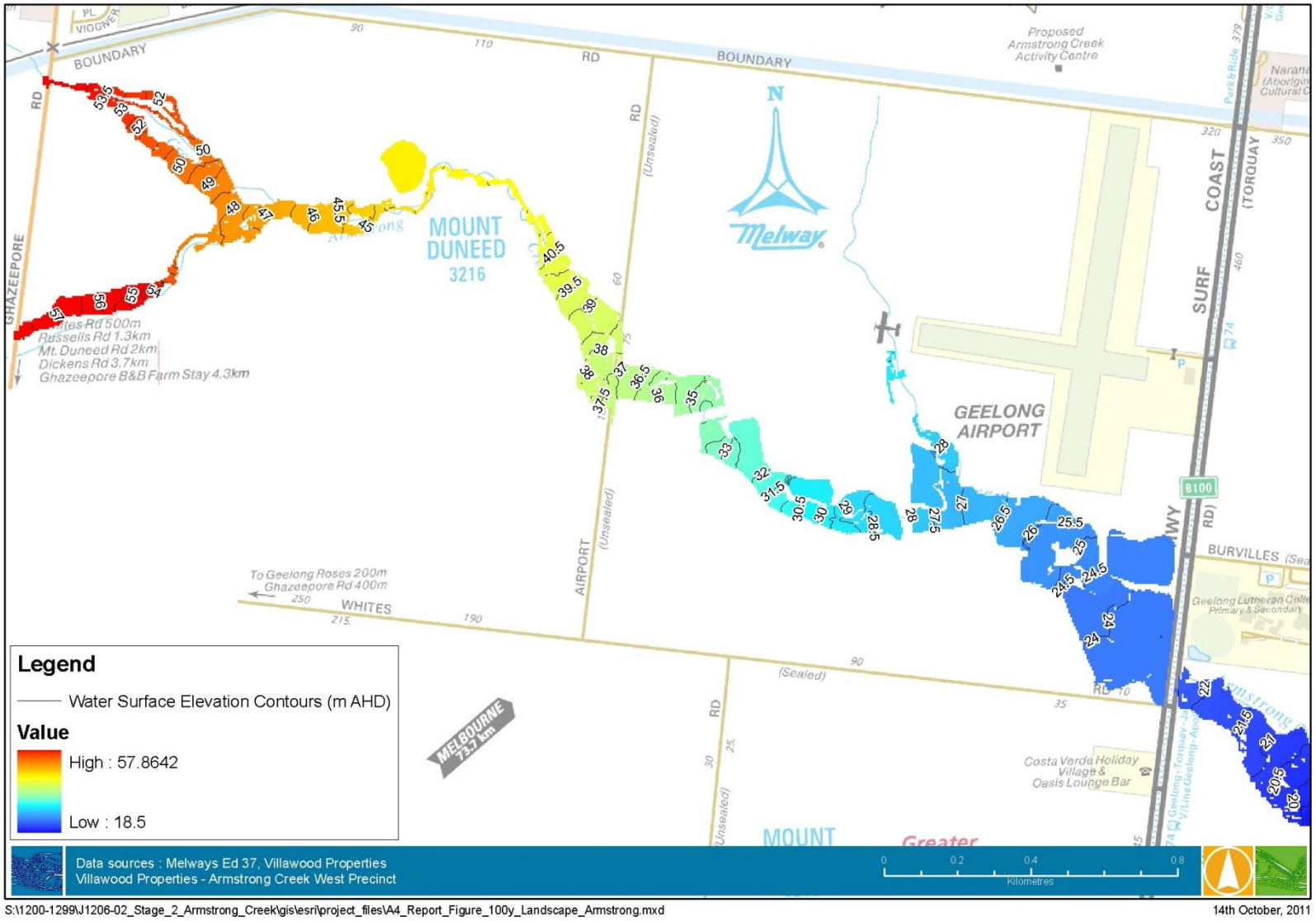

Figure 3-6 Water Surface Elevation (WSE) plot and 50cm contours – 100 year developed conditions

The flow hydrographs at Airport Road and Surf Coast Highway were extracted from the model and are shown in Figure 3-7 below. The 100 year ARI peak flows at Airport Road and Surf Coast Highway under existing and developed conditions are summarised in Table 3-5 below. The results show a decrease in flows observed at Airport Road when compared to existing conditions and a small increase at Surf Coast Highway. The flows measured at the Highway were weighed up against the head drop across the culvert constriction, with the goal of limiting the head loss to less than 500mm. The results shown in Figure 3-8 indicate that the head drop is restricted to approximately 500mm as flow is constricted through the 2 no. 1.5 x 3m culverts. The flow rate at Surf Coast Highway could be reduced further by increasing the culvert constriction and hence increasing the head drop across the road. Alternatively, increasing the available retarding basin storage within the ACWP or allowing more confined flooding of the Highway in the 100 year ARI event would also reduce flow rates at the Highway, although the latter option would be likely to pose a safety risk to road users.

With the water surface at 28.3m AHD upstream of the culvert, approximately 3,000m^3 of fill will be required on the two properties on either side of the creek immediately adjacent to the culvert when assuming a 300mm freeboard requirement.

Given the hydrology error margins, and possible mitigation techniques the current proposed mitigation is considered an acceptable solution for the proposed development.

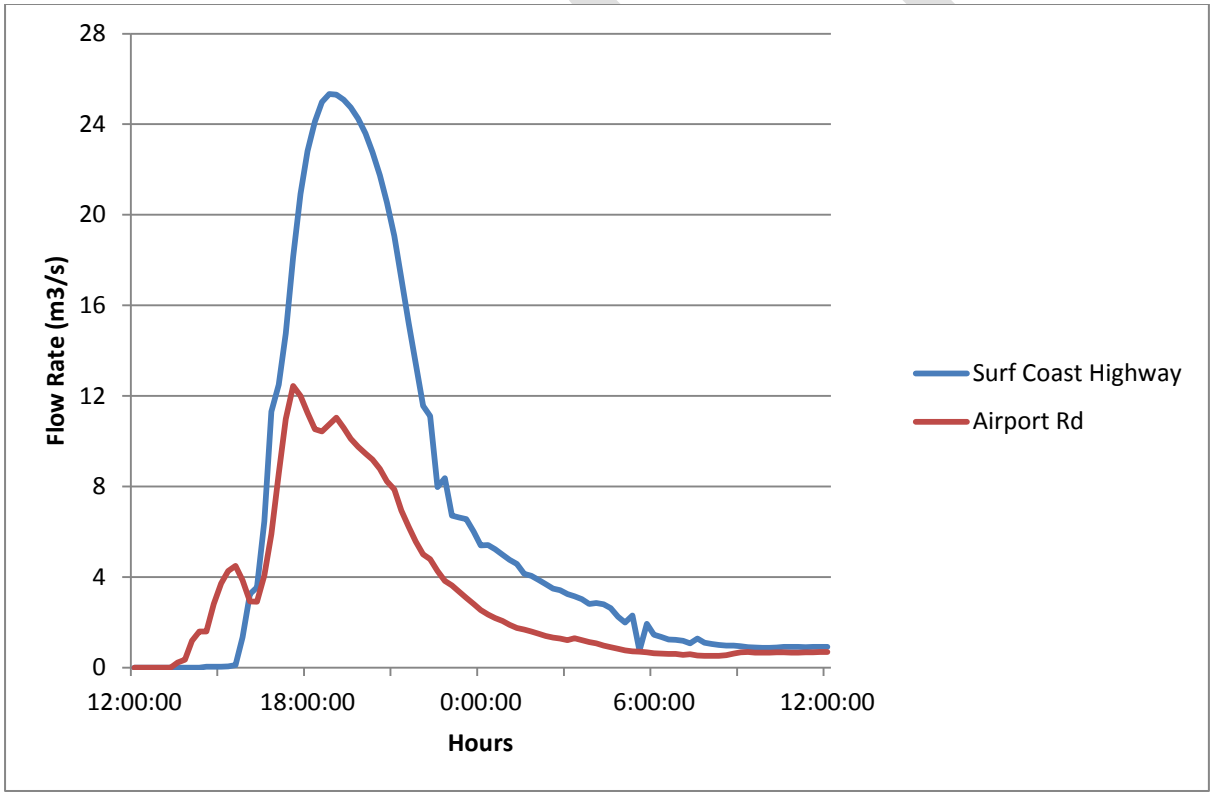

Figure 3-7 100 year ARI 12 hour duration hydrographs (m^3/s) at Airport Road and Surf Coast Highway under developed conditions

Table 3-5 Existing and Developed Peak Flows at Airport Road and Surf Coast Highway

	Airport Road peak flow (m^3/s)	Surf Coast Highway peak flow (m^3/s)
Existing Conditions	15.8	24.0
Developed Conditions	12.4	25.3
Difference (Existing v. Developed)	- 27%	+ 5%

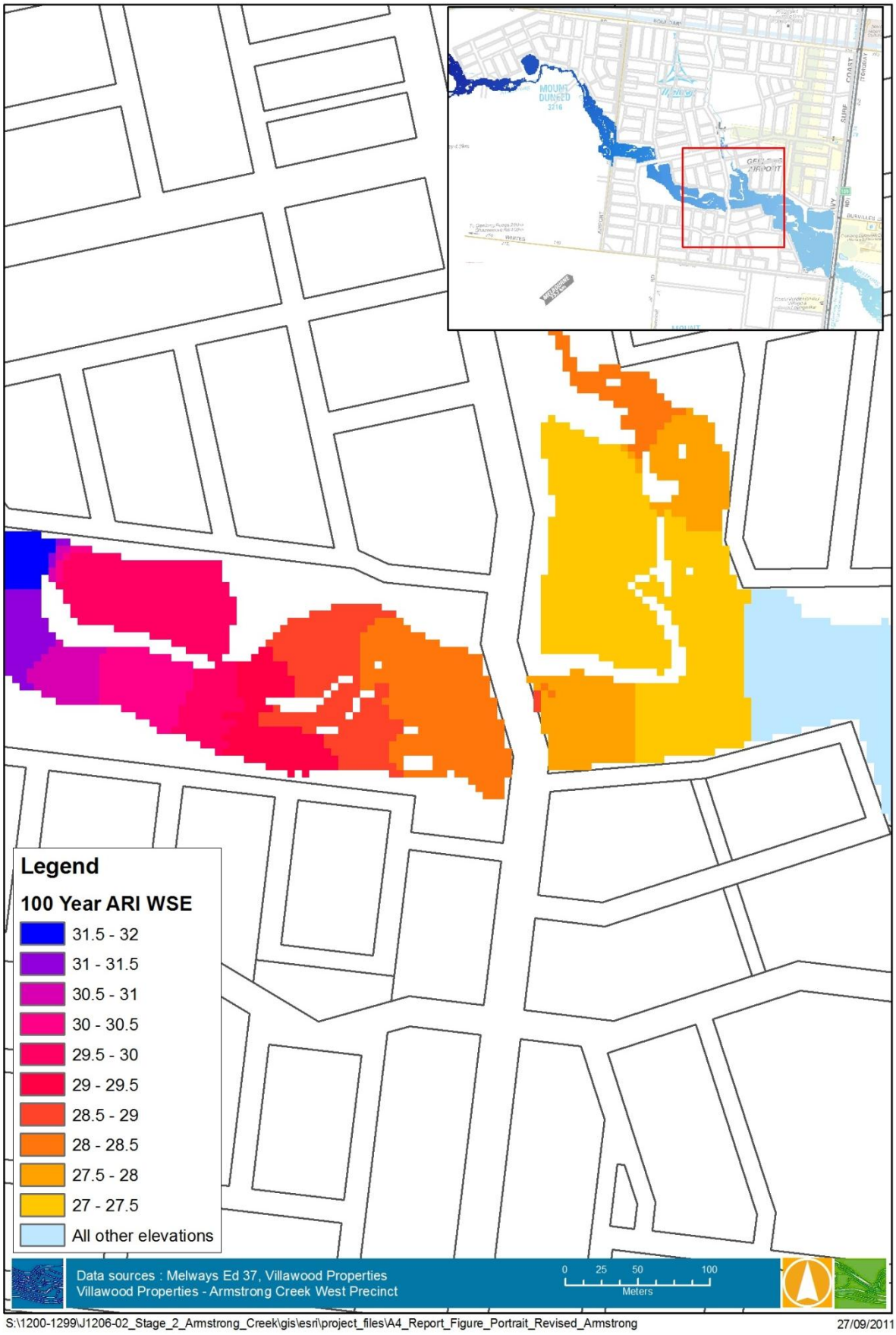

Figure 3-8 Water Surface Elevations (WSE) at the culvert constriction showing a head drop of approximately 500mm

4. CONCLUSIONS AND ASSUMPTIONS

This study has shown the comparison between existing and developed conditions hydrological and hydraulic modelling with the aim of limiting flows at Airport Road and Surf Coast Highway to existing conditions.

The following conclusions can be made:

- The results show that through the use of wetland/retarding basins, culvert constrictions and a low wall along the Surf Coast Highway; the 100 year ARI flows in developed conditions when compared with existing conditions are significantly less at Airport Road and slightly higher at Surf Coast Highway. The works proposed have the added benefit of protecting the Surf Coast Highway from inundation in the 100 Year ARI event which is flooded to depths up to 300mm in existing conditions;
- Large head drops at culvert constrictions have been eliminated and limited to a maximum of 500mm; and
- The wetlands have been located at the most suitable locations to minimise vegetation loss whilst maintaining quality and quantity objectives.

The following assumptions have been made:

- All information provided to Water Technology regarding the proposed development layout is up to date at the time of the publishing of this report;
- Sedimentation Basin 1 shown in earlier reporting has been removed;
- Existing drainage crossings of the Railway line will remain into the future as the only external catchment flow inputs to the ACWP;
- The existing flood storage available at the Airport behind the east-west runway will be removed as part of the redevelopment and hence its storage capacity is removed;
- All other existing retarding basins outside the study are that contribute to the flows passing through the site will remain in place; and,
- Drainage layouts will broadly follow the existing road boundaries and natural fall of the land.

5. REFERENCES

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Water Technology and Neil M Craigie (2010). *Armstrong Creek West Precinct Structure Plan Flooding Investigations: Stage 1.* November 2010.

APPENDIX A FLOOD EXTENTS FOR REMAINING ARIs

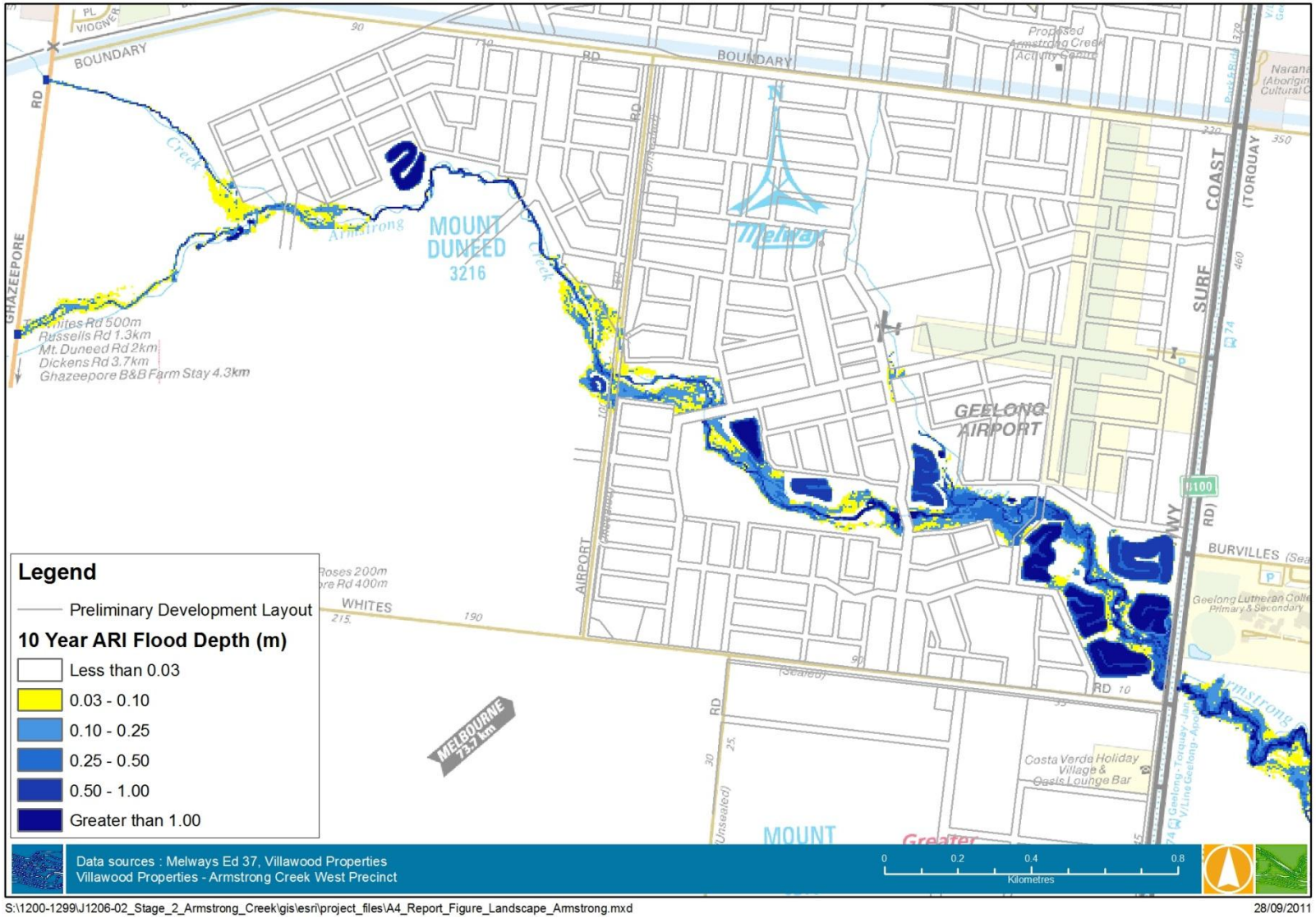

Figure A - 1 Design flood levels and extents – 10 year developed catchment conditions