PARSONS BRINCKERHOFF

UPL - WEZ WARNERVALE ECOLOGICAL REVIEW
HUDSON PACIFIC GROUP

Figure 1 Ecological constraints
Warnervale, N.S.W.

1.1 Desktop review on eastern site

The eastern side of the subject site contains approximately 40% cleared and/or disturbed areas of low ecological constraint associated with a previous quarry (Figure 1). However, the remaining vegetated areas are generally of moderate to high ecological constraint value as they contain large areas of the EEC, Swamp sclerophyll forest on coast floodplains as listed under the *Threatened Species Conservation (TSC) Act*, presence of the Threatened species Wallum Froglet and *Angophora inopina* listed as Vulnerable under the TSC Act and Commonwealth EPBC Act, good condition habitats for other locally occurring Threatened species, hollow bearing trees and/or constitute part of a local north – south wildlife corridor.

In general it is considered that the majority of the low and moderate ecological constraint areas (Figure 1) provide potential areas for development (Figure 2). Some areas of moderate ecological constraint utilised for development may potentially require ecological offsets to be provided. Any development within the subject site will require the maintenance of an ecological wildlife corridor running north - south through the subject site and is likely to constrain development along the entire length of the northern boundary. The north-eastern corner of the subject site was identified as the most appropriate location for the retention of this corridor as it corresponds with an area of moderate ecological constraint, known Threatened species locations and good condition vegetation (Figure 2). The moderate ecological constrained area in the southeast corner of the subject site is considered to be potentially viable for development only if access can be arranged offsite from the south. This area is unlikely to be considered suitable for development if access is require within the site across the wildlife corridor and high ecological constraint area to the north.

1.2 Review and provide comment on SP2 water management zoned areas

The SP2 water management-zoned areas have been reviewed from an ecological constraints perspective. While the large disused quarry pits are currently full of water, these areas are highly disturbed and contain low natural ecological values.

The WEZ SP2 zoned land also incorporates some small fragments and linear areas of the EEC, Swamp sclerophyll forest on coast floodplains as listed under the TSC Act, and has been identified as high ecological constraint areas within Figure 1. These small areas, while of high ecological value, are unlikely to be practically incorporated into areas for conservation land management without significant expense and effort and as such have been zoned within the WEZ for removal for the SP2. Similarly these areas have been considered for potential development (Figure 2) in an alternative use scenario of the SP2 zoned lands.

1.3 Review WEZ apparent inconsistencies in industrial zoning

The WEZ has mapped two parcels of land to in the very northeast and southeast corners of the site for potential development. This zoning appears to be largely based on regional scale desktop constraint analysis with little site specific consideration. The subsequent areas mapped by the WEZ for industrial zoning generally correspond with the cleared, disturbed lands or non-Threatened vegetated areas outside of identified priority regional corridor network.

Within the eastern portion of the site the WEZ zoned industrial areas are largely vegetated however they contain the locally common and 'adequately reserved' (Murray & Bell 2007) vegetation community, Narrabeen Buttonderry Footslopes Forest. They also are located outside of the identified priority regional corridor network.

Conversely, the western portions of the site included within the WEZ zoned conservation areas contain portions of disturbed regrowth and/or cleared areas that correspond with the EEC, River flat eucalypt forest on coastal floodplains as listed under the TSC Act and/or are located within the WEZ 'Major' wildlife corridor.

1.4 Review western site industrial zoned area

Development of the western portion of the site may be limited by high value ecological constraints (Figure 1), corresponding with remnants of the EEC, River flat eucalypt forest on coastal floodplains and/or the WEZ Major wildlife corridor. This site also contains a portion of medium ecological constraint areas associated with disturbed regrowth EEC, River flat eucalypt forest on coastal floodplains. It is proposed that given the high level of disturbance within the regrowth areas of the EEC, this area could potentially be used for development (Figure 2). This is consistent with the previous ecological review and proposed rezoning (PB 2008).

1.5 Proposed area proposed around the existing dwelling

In addition to the larger potential development area within the western portion of the site (Figure 2), an area surrounding the existing dwelling located adjoining to Sparks Road is considered a potentially low ecological constraint. While this area currently exists within the WEZ zoned conservation lands and is surrounded by the EEC, River flat eucalypt forest on coastal floodplains, the high levels of disturbance, including existing gardens, lawn and dwellings are unlikely to be practically rehabilitated without considerable expense and effort.

Given the low ecological constraint value of this area it may be possible to maintain this residence as a single dwelling entitlement of approximately 4,000 m^2 as depicted in Figure 2.

Figure 2 Potential development envelopes
Warnervale, N.S.W.

1.6 Modification to zoning in draft LEP

The proposed current modifications to the zoning provide addition areas of development whilst retaining significant ecological values for the site. Figure 3 shows the current modifications to the zoning, whilst Section 1.7 below outlines the key ecological outcomes for the site.

1.7 Key outcomes and recommendations

A summary table comparing the biodiversity outcomes for the Draft LEP zoning and modified zonings within the site is provided below in Table 1.

Table 1 Ecological comparison of proposed zonings

Biodiversity Value	Draft LEP (2007)	Proposed Zoning Modification 2008	Proposed Zoning Modification 2010
Threatened Species	Loss of entire *Angophora inopina* population with study area	Retention of *Angophora inopina*	Retention of *Angophora inopina*
Remnant vegetation	5.4 ha (24%) loss	1.3 ha (6%) loss	5.8 ha (25%) loss
Disturbed regrowth	No loss	1 ha (100%) loss	1 ha (100%) loss
High quality habitat	3 ha loss	No loss	2.1 ha loss
Habitat trees	Loss of 14 trees (70%)	Loss of 3 trees (14%)	Loss of 10 trees (50%)
Endangered ecological community Swamp Sclerophyll Forest on Coastal Floodplains	1.7 ha (22%) loss	1.7 ha (22%) loss	1.2 ha (10%) loss
Endangered ecological community River-flat Eucalypt Forest on Coastal Floodplains	0 ha loss	0.3 ha (5%) loss	0.4 ha (8%) loss
Consolidation of Industrial/conservation zones	Three separate industry parcels	One parcel of industry land	Two separate industry parcels, with the retention of existing residence as a third parcel
Corridor (Primary)	Minimum width 90 m	Minimum width 85 m	Minimum width 85 m
Corridor (Secondary)	Minimum width 55 m	Minimum width 62 m	Minimum width 55 m
Edge to area ratio of conservation zone	High	Lower	Lower
Zoning			
Conservation	22 ha	21 ha	18 ha
Industrial	14.6 ha	18.0 ha	26.2 ha
Water Management	8 ha	5.6 ha	0.0 ha
Residential	0 ha	0 ha	0.4 ha
Total	**44.6 ha**	**44.6 ha**	**44.6 ha**

Figure 3 Proposed Zoning (PB 2011)
Warnervale, N.S.W.

Table 1 clearly demonstrates that some of the sites biodiversity values will be significantly improved by the proposed modifications in comparison to the original draft LEP. In particular, these modifications will significantly improve the retention of recorded retention of Swamp Sclerophyll Forest, threatened species and habitat trees. These improved retention rates will primarily be offset by the loss of highly disturbed regrowth vegetation, improved design and consolidation of the industrial and conservation zoned lands.

These improved retention rates will primarily be offset by the loss of highly disturbed regrowth vegetation, improved design and consolidation of the industrial and conservation zoned lands.

The relatively minor proportional increase in the loss of the Endangered Ecological Community, River-flat Eucalypt Forest on Coastal Floodplains and the slight reduction in the primary corridor width in line with a realistic potential area for rehabilitation, is adequately compensated for by these proposed biodiversity benefits. In addition these modifications will also result in the following improvements:

- a reduced edge to area ratio of the industrial/conservation zones
- reduction in the potential edge effects to conservation lands
- improved buffers of up to 250 m to locally significant wetlands
- maintain the viability of the primary and secondary wildlife corridors with realistic rehabilitation options.

Yours sincerely

Alex Cockerill
Team Manager – Ecology
Parsons Brinckerhoff Australia Pty Limited

PEA Consulting
Ecologists and Ecohydrologists specialising in the assessment, management and restoration of complex terrestrial and wetland ecosystems
35 Hannan St
Maitland, NSW 2320
Australia
E info@peaconsulting.com.au
P 0439 134 689

11 August 2011
Jason Wasiac
JW Planning
Suite 13/478 The Esplanade
Warners Bay NSW 2282

ATTN: Jason

RE: Site Visits, Results and Ecological advice for Mountain Rd, Warnervale Rd.

Dear Jason,

Following our site meeting on Tuesday 9th August I conducted a short site visit that night and a field survey the next day. During our meeting I suggested that there may be an opportunity to test (validate) the significance of communities and habitats described by Wyong Council consultants, specifically in relation to the value of corridors on the site (especially the eastern block). The methods proposed during our meeting included the quantitative analysis of data collected in areas on the subject site that were claimed to be important and from areas within the WEZ proposed to be cleared.

The purposes of night field surveys were to fully identify the habitat of Wallum forglet onsite and locate other areas which could be important habitat. On the morning of the 10th August I walked (3hrs) over the site with a focus on looking at groundwater and drainage characteristics in conjunction with searching for important habitats and communities.

During these surveys I identified the following on your site:

- A groundwater dependent ecosystem- Freshwater wetland and Paperbark swamp forest (both EEC's);
- Habitat for the threatened frog Wallum forglet

The groundwater dependent ecosystem includes the area shown as purple lines in the attached figure. This area is a groundwater seepage zone, which has formed a wetland environment that is likely to stay wet for long durations. It supports a diverse range of

wetland species and a moderate size population (<200) of the significant frog species Wallum forglet.

The infrastructure ponds do not form part of this frog's habitat, their purpose as I understand is to trap water for piping to other facilities. One could conclude that this is to jointly reduce impacts on Porters Creek wetland and more directly on the Wallum froglet habitat in WEZ. The purple hatched lines on the attached map highlight the Wallum froglet significant area of habitat on the subject site. Whilst this area is important in local terms, infrastructure such as roads should be achievable with appropriate design. This is largely consistent with the WEZ; however the WEZ zones have not been digitally overlayed for this purpose.

The red polygon (Figure 1) largely fits within the area identified on the WEZ as a corridor. It was obvious during surveys that this area is largely void of remnant vegetation. One can assume that the purpose of the E2 zoning for this area is for future connectivity, and it could be argued that this corridor could be re-located between the large infrastructure dams. However, this is not really an ecological argument.

Unfortunately for your client I concur with the conservation of the wetland on their site. Any attempt to modify this would I believe be futile. There is clear opportunity to include the small triangle area south of the existing building into the industrial zoning for the client. Surveys of that area did not identify any ecological issues that would limit its inclusion.

If you require any further information please don't hesitate to contact the undersigned.

Yours sincerely,

John-Paul King
B.Appl. Sc, B.Env.Sc, Dip, Nat.Res.Man
Director
Ecologist/Ecohydrologist

Pacific Environmental Associates Pty ltd

Figure1. Mud map of important habitat survey results for Mountain Rd, Warnervale Rd. Purple lines represents Wallum froglet habitat and Wetland EEC habitats. Red diagonal lines represent area shown in the WEZ as "corridor", this area is void of remnant vegetation and in its current form has little value.

DHI
WATER & ENVIRONMENT

Wyong Employment Zone
Additional Flooding Assessment

Final Report

Final Report November 2006

DHI
WATER & ENVIRONMENT

PO Box 5014
Chatswood West NSW 1515
Australia

Tel: +61 2 8440 5700
Fax:
e-mail: dhi@dhiwae.com
Web: www.dhiwae.com

Wyong Employment Zone Additional Flood Modelling

Final Report

Client	Client's representative
Wyong Shire Council	Scott Duncan

Project	Project No
Wyong Employment Zone Additional Flood Modelling	50371
Authors Julie Landrein Grantley Smith	Date 16 November 2006
	Approved by Grantley Smith

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CONTENTS

TABLES

FIGURES

APPENDICES

1 EXECTUTIVE SUMMARY

DHI Water and Environment Pty Ltd (DHI) was engaged by Wyong Shire Council (WSC) to undertake additional floodplain modelling as an annex to the existing "Buttonderry Creek Flood Study, Precincts 11, 13 and 14" completed by Matrix Plus Consulting (November 2005).

The area is drained by two main catchments: Buttonderry Creek and Mountain Road Tributary. The study used computational flood models developed for the Matrix Plus study (2005) as a basis for assessment of a range of floodplain development proposals.

Review of the Matrix Plus (2005) study and the hydraulic model used for the analysis showed that key parts of the study area floodplain storage were not represented effectively in the hydraulic models. The study models were supplemented with ground survey data specifically arranged for this study.

A range of floodplain development proposals were evaluated including a detailed floodplain development strategy prepared on behalf of the developer by Buzz Engineering and Environmental Solutions in Precinct 14.

Other development proposals specifically assessed included:

- Filling of land to the south of Sparks Road near the intersection of Mountain Road; and
- Filling of land on Jack Grant Avenue near Warnervale airport.

Proposed development was assessed for potential flood impacts by comparing hydraulic model results for the existing floodplain with model results post development.

Proposed floodplain filling assessed by Matrix Plus (2005) between the F3 Freeway and Sparks Road, and areas on the Mountain Creek tributary floodplain was reviewed as part of this study. These proposed development areas were then included in the assessment of other areas so that the cumulative impacts of all development areas could be assessed.

The works on the floodplain in this study and previous studies proposed to limit flood impact are:

- Restricting the extent of fill areas;
- Provision of compensatory storage;
- Incorporation of a significant flood storage basin within the Mountain Road tributary catchment;
- Provision of a 50m wide floodway within the Mountain Road Tributary floodplain; and

- Provision of a flood channel either around or through the proposed fill area immediately south of the F3 freeway.

Proposed development on the floodplain in Precincts 11, 13 and 14, and on the Warnervale Airport Lands has been assessed to negligible impact on 1%AEP flood levels in most areas in terms of peak flood levels, average peak velocities and peak flow rates. Some change to flood behaviour is expected in the immediate vicinity of some of the proposed fill though this impact is typically managed on the development site.

The F3 Freeway and Hue Hue Road serve to provide defacto flood detention storage at the 1% AEP level which serves to significantly reduce the flood flows downstream of these elevated road embankments. Due to the control of the F3 Freeway embankment, proposed development of Precinct 14 will have a negligible impact downstream of the Freeway.

Assessment of the proposed development in Precinct 14 shows that the development will significantly alter the existing flow behaviour of the area between Hue Hue Road and the F3 Freeway. Floodplain areas presently flooded by broad, shallow overland flows will be filled to accommodate the proposed development and the existing overland flood flows confined to an engineered channel. While the approach to accommodating flooding within the Precinct 14 development area is generally sound, the proposed roughness coefficients for the engineered channel "F2" are considered optimistic. Further consideration of the design of the engineered channel to accommodate flooding is required at DA stage to ensure that the potential for adverse out of channel flood impacts to neighbouring properties and the presently proposed development site itself are minimised. The proposed development allocates areas for the flood channel and flood storage solely on the Terrace Towers site. Widening of the channel and flood storage requirements onto the adjacent property Lot 9 DP239704 through negotiation with the property owners could be considered at DA stage.

Some redistribution of flood volume immediately upstream of the F3 Freeway embankment will occur under the proposed development scenario. While peak levels at the Buttonderry Creek channel culverts will remain similar to the existing flood case, levels will change by up to 0.3m in the flooded area to the east of the main channel. While the peak flood 1% AEP flood levels remain more than 0.5m below the top of the Freeway embankment, the NSW RTA should be informed of the likely localised change to peak flood levels adjacent the embankment.

The proposed development strategy previously analysed by Matrix Plus Consulting (2005) allowed for allocation of additional storage on the Mountain Road tributary floodplain to compensate for proposed filling on this floodplain upstream of Sparks Road. The "brick pits" area of the Mountain Road tributary area now forms an integral part of the IWCM storm water harvesting plan. The compatibility of the proposed floodplain storage in the Matrix Plus Consulting (2005) report with the water harvesting scheme requirements requires further analysis at DA stage.

2 INTRODUCTION

DHI Water and Environment Pty Ltd (DHI) was engaged by Wyong Shire Council (WSC) to undertake additional floodplain modelling as an annex to the existing "Buttonderry Creek Flood Study, Precincts 11, 13 and 14" completed by Matrix Plus Consulting (November 2005).

The objective of this study was to assess the flood impact of currently proposed floodplain development for Precincts 11, 13 and 14 of the Wyong Employment Zone (WEZ) at Warnervale. The area includes two main watercourses, Buttonderry Creek and the Mountain Road tributary. Matrix Plus Consulting (2005) had previously examined development options and defined the limits of filling on flood prone land in these areas.

Matrix Plus's report recommended that development in Precinct 14 would likely have to adhere to various criteria in order to limit any significant impacts on upstream and downstream flood behaviour due to the development. Proposed development options for Precinct 14 have been refined on behalf of the developer in the report "Floodplain Development Strategy, Precinct 14 Warnervale (Part of Wyong Employment Zone)" by Buzz Engineering and Environmental Solutions (BEES) (September 2006).

The additional hydraulic modelling undertaken in this report was separated into three different parts; A, B and C. The objective of Part A was to assess the impact on flooding of several different filling and development scenarios on flood behaviour within Precinct 14 (BEES 2006). Part B investigated filling and development options on land immediately to the south of Sparks Road. The feasibility of limited filling on the edge of Warnervale Airport property was assessed in Part C. Flooding at Sparks Road was also investigated and potential options for increasing the level of flood protection of the road were assessed.

2.1 Scope of Work

The scope of work undertaken for this study can be summarised as:

- Review of the report "Buttonderry Creek Flood Study Precincts 11, 12 and 14" Matrix Plus Consulting, November 2005;
- Review and update of the existing hydraulic model as used in the Matrix Plus (2005) flood assessment;
- Assessment of flood impacts for specific current floodplain development proposals in Precincts 11, 12 and 14;
- Assessment of cumulative flooding effects of the combined development proposals; and
- Assessment of various options to provide additional flood protection for Sparks Road.

2.2 Available Information

The investigations described in this report relied on the following data sets:

- Digital MIKE-11 hydraulic model data sets provided by Wyong Council as developed by Matrix Plus (2005);
- Digital catchment runoff hydrographs for the 1% AEP flood event as developed by Matrix Plus (2005);
- Spatial data sets provided in GIS format by Wyong Council including:
  - Roads, property and drainage boundaries;
  - 2m ground contours;
  - Proposed floodplain fill footprints;
  - Geo-referenced aerial photography;
  - Data layers showing major flooding constraints; and
  - Proposed WEZ zoning.
- Ground survey information including:
  - Floodplain cross section profiles in Precinct 14 provided by Trehy Ingold Neate Surveyors;
  - Cross section profiles in the vicinity of Warnervale Airport south of Sparks Road as provided by Johnson Partners (2006) (JP_Survey_sections.xls); and
  - Spot levels in the vicinity of Warnervale Airport by Rolls and Associates Surveyors (2001).

2.3 Previous Studies

Several previous studies are relevant to the existing flood assessment in Precincts 11, 13 and 14 of the WEZ.

Buttonderry Flood Investigation. Final Report Paterson Consultants, (December 1997).
The original flood study model of the Buttonderry Creek floodplain was developed for this project and included an assessment of flood risk for Buttonderry Creek between the F3 Freeway and Warnervale Airport including the Mountain Road tributary. The study established a RORB hydrological model for predicting catchment runoff and a MIKE-11 model of the floodplain areas to assess flood depths, flow velocities and flood flow distributions in the study area. This study also assessed the potential development on the floodplain and made recommendations to limit the impacts on flood behaviour.

Water Quality Management for Precincts 11 and 13 Industrial Estate, Australian Water Technologies (February 2004).
This study revised the Paterson Consultants (December 1997) hydraulic model on the Mountain Road tributary floodplain and provided more detailed modelling in this area. Improvements to the hydraulic model included additional survey of the culverts along

Sparks Road and road levels for the Sparks Road/Mountain Road intersection. The study included assessment of stormwater management devices for the control of runoff from proposed industrial development in this area.

Buttonderry Creek Flood Study, Precincts 11, 13 and 14 – Matrix Plus Consulting (November 2005)

Matrix Plus acquired the digital hydrological and hydraulic model files from the previous Paterson Consultants' (1997) and AWT (2004) and used these as the basis for a comprehensive assessment of the potential for floodplain development in Precincts 11, 13 and 14 of the WEZ. In the first instance the study updated the previous models to include:

- A revision of the level of detail for the contributing catchment area west of the F3 Freeway. Additional detail was incorporated into the RORB model layout in this area to allow a more rigorous assessment of catchment runoff contributing to flooding in Precinct 14. Refer to the Matrix Plus 2005 report for a more detailed description of the RORB model adjustment;
- Revision of design rainfall intensities for a range of storm durations for the 1% AEP risk level;
- Additional survey of the culverts under the F3 Freeway (survey provided by Trehy Ingold and Neate Surveyors);
- Extension of the hydraulic model through additional cross sections in the Precinct 14 area (cross section survey provided by Trehy Ingold and Neate Surveyors); .

The study then used the updated model to assess potential for floodplain development in a range of proposed land parcels in Precincts 11, 13 and 14. Assessment of flood impacts was reported in terms of changes in flood level, changes in flood discharge quantities and flood velocities, development options in flood storage areas, likely impacts of a Probable Maximum Flood (PMF) event and integration of Water Sensitive Urban Design (WSUD) strategies for the region.

The Matrix Plus Consulting study (2005) concluded that:

- The Freeway acts as a flood control providing a defacto storage basin on the western side of the Freeway. This control has the effect of restricting any increase in catchment runoff flows following the development of Precinct 14;
- The proposed development downstream of the Freeway is limited and doesn't cause a significant change in flood behaviour except in areas where development is over a major water course. In these areas impacts are limited to the vicinity of the development;
- Flooding impacts associated with the development of Buttonderry Creek floodplain are significantly offset by the elimination of overland flows from the Mountain Road tributary into the Buttonderry Creek floodplain by the reconstruction of Mountain Road;
- Development of the Mountain Road catchment and the elimination of flows across Mountain Road into the Buttonderry Creek floodplain does increase flood

flows in the Mountain Road tributary but the 1% AEP flood flows are confined to the proposed 50m wide floodway corridor;

- The proposed wetland and storage area within the Mountain Road tributary catchment provides sufficient flood storage to ensure that the flood levels at the Sparks Road culverts are not increased as a result of the proposed development; and
- Filling areas proposed in the study will not have significant impacts on flood levels, flow velocities or flood discharges outside the proposed development precincts provided the recommended mitigation measures are implemented;

Recommendations to limit the impact of development on flood behaviour in Precincts 11, 13 and 14 included:

- Provision of 20,000 m^3 of compensatory flood storage upstream of the Freeway;
- Provision for a 400m long flood culvert or an open channel (open channel preferred for environmental reasons) east of the Freeway to convey flood flows through the proposed development area immediately downstream of the Freeway;
- Elimination of the flood culverts under Mountain Road proposed in previous studies;
- Provision of a 50m wide floodway to contain the 1% AEP flood flows in the Mountain Road precinct; and
- Provision of flood storage within the proposed wetland in the Mountain Road Tributary.

3 HYDRAULIC MODEL REVIEW

The study uses the hydraulic model adopted and revised by Matrix Plus (2005) as the basis of floodplain development assessment. The hydraulic model (Mike-11) originated with the Buttonderry Creek Flood Study, Paterson (1997), was upgraded for further modelling undertaken by Australian Water Technologies (2004) and further adjusted by Matrix Plus (2005). A summary of the evolution of the model is provided in Section 2 above with details of the model adjustments provided in the quoted report references.

Flood flows applied for the 1% AEP flood event are as developed by Matrix Plus (2005) using the RORB model of the catchment refined for the additional model detail required to assess development in Precinct 14 of the WEZ.

The first task of this study was to review the suitability of the model to assess the development proposed for the floodplain. The review included:

- Methodology for prediction of catchment runoff hydrographs;
- Suitability of a 1D modelling approach to assess flooding behaviour on the floodplain; and
- Suitability of cross section survey used to define the floodplain volume and conveyance (flow carrying capacity) of the floodplain;

3.1 Existing Floodplain Model Review

A site inspection of the floodplain indicated that the upper floodplain is dominated by the elevated road embankments of Hue Hue Road and the F3 Freeway. Downstream of the Freeway, floodplain slopes are moderate to flat. Flood flow behaviour on the floodplain is likely to be characterised by moderate flow velocities and broad, relatively shallow flood depths typically in the order of 0.5m to 1m deep outside of the defined creek channels (where they exist). Several contributing subcatchments have no identifiable channel and flooding from these catchments will be characterised by shallow overland flows which follow the local ground slope. Flooding in this area will also be strongly influenced by the elevated Sparks Road and Mountain Road embankments.

While the one dimensional modelling approach of Mike-11 is suitable for assessing the bulk changes in flood level on the floodplain due to the proposed development, the cross section averaged outputs provided by the model require careful interpretation. The shallow broad nature of flood flows on much of the floodplain is considered to be more two dimensional in behaviour than one dimensional. The results are indicative at best of likely changes to flow velocities and flow distributions. Analysis of the local impacts of proposed fill would be better represented at the detailed design stage by a two dimensional modelling approach where redistribution or redirection of local flood flows is considered an important issue.

The hydraulic model circa Matrix Plus (2005) has been developed using a range of cross section surveys from various sources. The vertical accuracy of the cross sections which have been measured by traditional total station methods is considered suitable for the present study.

Records of the spatial location of cross sections in the major part of the floodplain had not been included in the Mike-11 model used in the Matrix Plus report. Historically, limitations in digital spatial data management techniques have limited the ability to provide a spatial reference to hydraulic models. This is the case with the model used in the Matrix Plus (2005) report. While not mandatory for defining basic flood behaviour, the lack of spatial indexing of the model makes interpretation of model results including flood inundation extents more difficult.

While these limitations to the model might restrict its suitability for a comprehensive contemporary flood study, the existing Matrix Plus (2005) Mike-11 model is considered suitable for this planning scale flood assessment. The model was adopted as the basis of this study with some modifications.

Spatial referencing. The Matrix Plus (2005) model has been spatially indexed to assist in the interpretation of the model results into flood inundation mapping for the 1% AEP flood event, pre and post development. No maps or plans were available that showed the exact locations of original Mike-11 model's flow branches and cross sections. This being the case, cross sections and flow branch locations were located as best as possible using available sketches in Paterson (1997) and by comparing model cross section shape and height with the available 2m contours and geo-referenced aerial photography.

Schematisation of the F3 Freeway culverts. During the process of spatially referencing the hydraulic model, a minor inconsistency in the discretisation of the culverts under the Freeway was discovered. This inconsistency in the way the model branches were connected was corrected by confirming the available culvert survey and revising model layout on the basis of a site inspection.

Extension of model upstream of Hue Hue Road including Hue Hue Road culverts. BEES (2006) identified the potential for additional informal storage on the floodplain upstream of the elevated Hue Hue Road embankment. The model was extended upstream of Hue Hue Road to account for this potential storage using cross sections provided by Trehy Ingold Neate surveyors.

Figure 1and Figure 2 show the revised spatial Mike 11 model layout and the approximated cross-section locations. The nomenclature used to identify the various model flow branches is also presented on these Figures.

A review of the approach applied to catchment hydrology in previous studies revealed that the catchment has no gauged flow data. In the absence of a suitable flow gauging station in the catchment, the regional approach to catchment runoff estimation is considered appropriate practice.

3.1.1 Existing Scenario Model Roughness Coefficient

The roughness values used in the existing model were established during previous studies Paterson (1997) and reviewed by Matrix Plus and found to be consistent with catchment conditions. A Manning's 'n' value of 0.06 is applied for all cross-sections in the model domain with the exception of four cross-sections:

- Buttonderry Creek Ch 0.0;
- Buttonderry Creek Ch 2530.0;
- Mountain Rd Ch 0.0; and
- Mountain Rd Ch 1850.0;

These cross sections have a Manning's n coefficient of 0.20 applied.

The value of 0.06 is consistent with the scattered trees and grass cover observed in the Buttonderry Creek and Mountain Road tributary floodplains. This judgement is based both on Matrix Plus's 2005 report and field observations. Chow (1953) states that a floodplain with the following characteristics may be defined as having a Manning's 'n' value of 0.06 "light brush and trees, in summer".

The value of 0.20 is a value which indicates dense vegetation and specifically, according to Chow (1953) is consistent with a floodplain of dense willows. The value of 0.2 is the highest value recommended in Chow (1953).

3.2 Developed Floodplain Model

Developed floodplain conditions used the model configured by Matrix plus as a starting point. The proposed development scenarios assessed in this report were as provided by BEES in Precinct 14 (plan in Appendix A) and by Council in Precincts 11 and 13 (Figure 5 and Figure 6). Developments on the floodplain outside the areas specifically addressed below were as described by Matrix Plus (2005). These likely impacts of all developments including those proposed by Matrix Plus (2005) are reported on in the following sections of this report.

3.2.1 Developed Scenario Roughness

Developed scenario roughness values in Precinct 14 were supplied by BEES consulting.

The Manning's "n" value applied for the "F2" in the developed scenario is 0.030. This is based on conceptual design work from BEES. A value of 0.031 is used based on a clean straight channel. It is noteworthy that Chow also recommends that an excavated channel with a weedy lining will have a Manning's 'n' value of 0.030.

Council has provided guidance with respect to channel roughness in the "F2" engineered channel and recommended that a Manning's "n" roughness value of 0.080 be adopted to reflect the likely long term condition of the channel flow conveyance.

According to discussions between DHI and BEES the latter recognises that some maintenance will be necessary in order to maintain the applied roughness values for branch "F2".

Manning's "n" roughness coefficients in other areas of the floodplain were as per the existing floodplain condition.

4 INVESTIGATION OF FLOODPLAIN DEVELOPMENT STRATEGY IN PRECINCT 14

Consideration of the Matrix Plus reporting indicated that there may be further opportunities for developing land in Precinct 14 via refinement of the model by inclusion of de-facto storage areas upstream of Hue Hue Road and by including mitigation works.

Proposed development options for Precinct 14 were developed by BEES.

The methodology used to assess the proposed development was:

1. run the model configured for existing catchment and floodplain conditions to establish a base case for 1% AEP flood conditions;
2. adjust the model configuration to represent the proposed developed case. This was achieved primarily by changing the model cross sections as provided by BEES. to represent the developed conditions.
3. simulate the adjusted model for the 1% AEP flood event to establish predicted flood behaviour for the developed floodplain;
4. compare pre and post development model outputs to establish potential impacts due to the proposed development.

Modelling investigated the impact on the 1% AEP flood levels, peak discharges and velocities for the following scenarios provided by BEES:

- Revised Base Case (Existing Flooding)
- Option 1A - Revised Concept Layout
- Option 1B - Revised Concept Layout
- Option 2 - Increase of Compensatory Flood Storage
- Option 3A - Finalised Cross sections

These scenarios were run for a range of design storm event durations: 2, 4, 6 and 9 hours for the 1% AEP event.

The model development for the four tested scenarios and their impact on floods are discussed in the following sections.

4.1 Revised Base Case (Existing Flooding)

Investigations undertaken by BEES (2006) showed that there are three areas upstream of Hue Hue Road that are likely to create informal flood detention behind the road embankment thus potentially altering peak flows and flood levels downstream of Hue Hue Road in Precinct 14. The existing case hydraulic model was extended upstream of Hue Hue Road using cross section and culvert survey information provided by Trehy Ingold Neate Surveyors.

Branches "B1" (Buttonderry Creek) and "B2" (Southern Watercourse) were extended upstream of Hue Hue Road. Another branch, "B1-South", was also added to the model upstream of Hue Hue Road, between "B1" and "B2". "B1-South" is connected to "B1"

at chainage 210 m just downstream of Hue Hue Road. A broad crested weir structure was added to the model to represent the overtopping level of Hue Hue Road on each of these model branches. Culverts were also included to convey the flow through the road embankment. The upstream inflow boundaries were adjusted to fit the new model setup. The original tributary inflows were proportioned by pro rata of contributing catchment area. On this basis the flow to branch "B1" was reduced to 95% of its original total flow with the remaining 5% applied to the new "B1-South" model branch.

The invert levels of the culverts through the F3, freeway Sydney to Newcastle, were adjusted in accordance with the data provided by Trehy Ingold Neate Surveyors.

A branch "LinkB2-B1South" was added to the model. This model branch represents a bypass that conveys flow in a northerly direction, from the watercourse "B2" to "B1-South", along the upstream edge of Hue Hue Road. The link channel branch is approximately 400 m long. Topographical data for this link was estimated from available survey information provided by Trehy Ingold and Neate as presented in Appendix C as the cross-section data upstream of Hue Hue Road on branches "B2" and "B1-South".

Figure 3 shows the revised model layout for the existing floodplain for Precinct 14.

4.2 Option 1A (Revised Concept Layout)

Option 1A includes the piping of low flows on the tributary "B2" (from model chainage 13.50 to 480 m). The pipe replaces the existing ill-defined channel from downstream of Hue Hue Road to upstream of the confluence with "B1". The dimensions of the proposed pipe are 2400 mm wide x 900 mm high. A channel parallel to "B2", "B2-Overflow", was added to the model and connected to "B2" to represent excess flows that cannot enter the pipe and pass overland as residual flows. These residual flows are proposed to be conveyed by a roadway in the development.

Changes were also made to Buttonderry Creek, branch "B1". The original cross-sections used by Matrix Plus Consulting were altered to represent developed conditions with some limited encroachment into the floodplain. A 30 m clear span bridge was included at chainage 372 m on "B1" to represent the road way link to the development on the western side of the creek channel. The deck level of the bridge was defined to be RL 22 m. Flood storage was also added on the left bank of downstream cross-sections (chainages 490, 560 and 630 m).

Compensatory flood storage was added to the downstream cross-sections of the central watercourse, branch "F1" (named "B3" in the proposals) and to the by-pass channel "F1-F2" by lowering the ground surface level by 1 m on the right bank.

The existing (partially man-made) northern channel (branch "F2") cross-sections were altered to include a relocated "natural" channel and a proposed road on the left side of the existing cross-sections. The new channel bed level is higher than the survey for the existing natural channel level. The new channel Manning's "n" roughness was set to 0.03 as per the BEES design.

4.3 Option 1B (Revised Concept Layout)

Option 1B includes the same changes as Option 1A except for the bridge crossing Buttonderry Creek. In this case, a 60 m pier bridge was implemented instead of the 30 m clear span bridge at chainage 372 m on "B1".

4.4 Option 2 (Increased Compensatory Flood Storage)

On the basis of the model results for Option 1A and Option 1B, changes for Option 2 were made from the hydraulic model built in Option 1A. These modifications include new cross-sections at the downstream end of "F2" (chainages 910 and 980 m). Ground levels were lowered by 1 m to increase the flood storage area to the east of the current Terrace Towers holdings.

4.5 Option 3A

Following assessment of the Option 1A, 1B and 2 a final configuration of the proposed development, Option 3A, was devised by BEES. Model cross sections were altered by BEES to integrate proposed compensatory storage within the water quality treatment facilities. The option also included alterations to the proposed development layout including increased set backs from the F3 Freeway embankment. Option 3A used the preferred 30m wide bridge crossing of Buttonderry Creek. The proposed layout is presented in Appendix A (reproduced from BEES, 2006). The proposed cross sections assume full filling of the adjacent property Lot 9 DP239704.

4.6 Model results

Peak flood levels, discharges and flow velocities were extracted from the Mike 11 results files at regular locations along each model branch. A full set of model results is presented in Appendix B. A summary of the results at selected locations is presented in Tables 1-3. An envelope approach was taken to result analysis where the values extracted are the maximums for all of the 1% AEP design storm durations tested.

Summary results and flood impacts at key locations throughout the WEZ area are plotted on Figure 12, Figure 13 and Figure 14.

Table 1: Peak Flood Level comparison at key locations for Precinct 14

Location	Mike 11 Chainage	Peak Flood Levels (m AHD)					
		Original Base Case	Revised Base Case	Option 1A	Option 1B	Option 2	Option 3A
B2, u/s* proposed pipe	B2 13.50	-	25.22	25.27	25.27	25.27	25.29
B2, d/s* proposed pipe	B2 490.00	19.88	19.62	19.62	19.62	19.62	19.62
B1, d/s of Hue Hue Road	B1 0.00	22.38	22.33	22.33	22.33	22.33	22.34
B1, u/s proposed bridge	B1 350.00	20.51	20.45	20.38	20.28	20.38	20.33
B1, d/s proposed bridge	B1 420.00	20.33	20.26	20.19	19.96	20.19	20.16
B1, d/s channel	B1 745.00	19.88	19.62	19.62	19.62	19.62	19.62
F2, u/s channel	F2 90.00	24.72	24.71	24.77	24.77	24.77	24.77
F2, d/s channel	F2 490.00	20.77	20.64	21.66	21.66	21.66	21.66
F2, Additional flood storage, option 2	F2 980.00	19.31	19.1	19.38	19.38	19.26	19.34
F1, u/s channel	F1 280.00	19.5	19.21	19.39	19.37	19.29	19.36
F1, d/s channel	F1 550.00	19.5	19.21	19.39	19.37	19.29	19.36
F1-F2, u/s channel (after confluence with F2)	F1-F2 0.00	19.5	19.1	19.38	19.36	19.28	19.34
F1-F2, d/s channel (before confluence with F1)	F1-F2 350.00	19.3	19.21	19.39	19.37	19.29	19.36

*(u/s = upstream, d/s = downstream)

Table 2: Peak Flow comparison at key locations for Precinct 14.

Location	Mike 11 Chainage	Peak Discharge (m3/s)					
		Original Base Case	Revised Base Case	Option 1A	Option 1B	Option 2	Option 3A
B2, u/s* proposed pipe	B2 13.50	-	4.6	4.1	4.1	4.1	4.3
B2, d/s* proposed pipe	B2 490.00	6.2	6.5	9.6	9.8	9.5	8.2
B1, d/s of Hue Hue Road	B1 0.00	67.7	63.6	63.6	63.6	63.6	63.6
B1, u/s proposed bridge	B1 350.00	69.1	66.5	66.9	67.1	66.9	67.1
B1, d/s proposed bridge	B1 420.00	69.4	66.9	67.7	67.9	67.7	67.7
B1, d/s channel	B1 745.00	70	68.9	68.5	68.3	68.6	67.8
F2, u/s channel	F2 90.00	31.6	31.6	31.4	31.4	31.4	31.4
F2, d/s channel	F2 490.00	36.5	36.5	37	37	37	37.0
F2, Additional flood storage, option 2	F2 980.00	33	35.3	42.9	42.9	37.3	39.3
F1, u/s channel	F1 280.00	2.9	2.9	3.3	3.3	3.3	3.3
F1, d/s channel	F1 550.00	11.6	9	6	5.3	4.9	5.4
F1-F2, u/s channel (after confluence with F2)	F1-F2 0.00	20.6	9.7	24.5	24.5	19.4	21.5
F1-F2, d/s channel (before confluence with F1)	F1-F2 350.00	20.5	0	9.7	9.7	5.9	11.6

*(u/s = upstream, d/s = downstream)

Table 3: Peak Velocity comparisons at key locations for Precinct 14.

Location	Mike 11 Chainage	Peak Velocities (m/s)					
		Original Base Case	Revised Base Case	Option 1A	Option 1B	Option 2	Option 3A
B2, u/s* proposed pipe	B2 13.50	-	3	0.8	0.8	0.8	0.8
B2, d/s* proposed pipe	B2 490.00	0.5	0.8	1.2	1.2	1.2	1.9
B1, d/s of Hue Hue Road	B1 0.00	2.4	2.3	2.3	2.6	2.6	2.3
B1, u/s proposed bridge	B1 350.00	0.8	0.8	0.8	0.8	0.8	0.5
B1, d/s proposed bridge	B1 420.00	1.4	1.4	1.9	1.9	1.8	1.0
B1, d/s channel	B1 745.00	0.6	0.7	0.3	0.3	0.3	0.2
F2, u/s channel	F2 90.00	1	1	0.8	0.8	0.8	0.8
F2, d/s channel	F2 490.00	1.1	0.7	2.7	2.7	2.7	2.7
F2, Additional flood storage, option 2	F2 980.00	0.7	0.7	2.1	2.1	0.2	1.3
F1, u/s channel	F1 280.00	0.4	0.4	-	-	-	1.4
F1, d/s channel	F1 550.00	0	0	0.1	0.1	0.1	0.0
F1-F2, u/s channel (after confluence with F2)	F1-F2 0.00	1.8	0.2	0.3	0.3	0.2	0.6
F1-F2, d/s channel (before confluence with F1)	F1-F2 350.00	2.1	0	0	0	0	0.3

*(u/s = upstream, d/s = downstream)

Peak water levels are plotted on selected model cross-sections for 'B1', 'F1' and 'F2' on Precinct 14. These cross-sections are presented in Appendix C.

Flood extent maps of the WEZ area for the Revised Base Case and Option 3A (Developed Case) are presented on Figure 4 and Figure 5.

4.7 Discussion

4.7.1 Revised Base Case - Impact

The aim of the extension of the hydraulic model upstream of Hue Hue Road was to enable informal flood storage detention expected behind the road to be correctly represented. The model results show that the inclusion of the flow detention reduces peak flows and flood levels downstream of Hue Hue Road in a large section of Precinct 14. Flood levels are reduced by 0.05 to 0.2 m on model branches "B2" and "B1" for the revised existing case. The "base case" model was also updated to ensure that all culverts under the F3 freeway matched the surveyed level data. The adjustment of the invert levels of the culverts under the F3 Freeway in the model was found to lower peak flood levels upstream of the freeway especially downstream of model branches "F1" and "F2". Peak discharges are also lower than those computed in the original hydraulic model due to the additional defacto detention storage upstream of Hue Hue Road included in the revised model.

4.7.2 Option 1A and 1B

Model results indicate that the proposed bridge over the "B1" floodplain is not expected to adversely impact on the 1% AEP flood behaviour. Computed water levels upstream and downstream of the bridge over "B1" are predicted to be lower than the peak levels for the existing floodplain for both design options (30 m clear span bridge and 60 m pier-bridge). Peak flow and velocity rates are predicted to increase slightly in the vicinity of the bridge. Flood levels are expecting to be lower with a 60 m pier bridge (Option 1B) than a 30 m clear span bridge (Option 1A). However Option 1A levels remain lower than the existing levels. Peak water levels are predicted to be approximately 1.50 m below the design bridge deck level.

The proposed pipe replacing the natural channel of "B2" has been assessed as not having the capacity required to convey peak 1% AEP flows. As a consequence, water accumulates between Hue Hue Road and the new pipe headwall, increasing peak levels slightly by 0.05 m locally at this location. About 0.3 m^3/s is predicted to flow over the top of the pipe headwall and flow down the road way proposed as a secondary flow path.

Flood levels on "F1" are increased despite the additional flood storage at this location. The increase in flood levels on this branch is caused by a redistribution of flow volume from the Buttonderry Creek branch. Redistribution of flows from the Buttonderry Creek floodplain into the areas east along the F3 Freeway is enabled by the reduction of ground levels on the Buttonderry Creek floodplain with the installation of the proposed stormwater treatment ponds.

Water levels increase significantly on the northern channel "F2" as a consequence of the new channel to be implemented on the left side of the existing floodplain. The formalised channel bed level is expected to be higher than the existing surveyed cross-section invert. While peak flood levels for the 1% AEP event are somewhat higher than for the

existing case, the flow levels are predicted to remain in the new channel below the crest of the road proposed to be built on the right bank of the new channel. However, it should be noted that the peak levels are predicted approximately 0.2 m below the road crest. In the downstream part (chainages 800 to 1000 m), flood levels exceed the top of the bank and flow over the road in this option.

4.7.3 Option 2

In Option 2, additional flood storage has been added downstream of the northern tributary stream, "F2", approximately where flows are expected to overtop the projected road in Option 1. With the storage in place, peak water levels are reduced by a further 0.05 to 0.3 m ensuring that flood flows remain within the proposed design channel.

4.7.4 Option 3A

Option 3A supersedes both Option 1 and Option 2. This option included alterations to most of the cross sections in the lower part of Precinct 14 on the basis of feedback from the Option 1 and 2 assessments. Model cross sections were altered by BEES to integrate proposed compensatory storage within the water quality treatment facilities. The option also included alterations to the proposed development layout including increased set backs from the Freeway embankment. Option 3A used the preferred 30m wide bridge crossing of Buttonderry Creek.

Model results show that flood levels and velocities are reduced on part of the B1 branch in the vicinity of chainage 420m. This is due to the ground levels between the B1 and F1 branches being lowered compared to the existing case.

Flood levels on the F2 branch increase compared to the revised base case but are constrained within proposed engineered channel on this branch. Cross section profiles on this branch showing peak water levels are presented in Appendix B. The sections show that in many parts of the channel the peak water level is within 0.3m of the crown of the road circuiting the proposed development. Road crest levels adjacent to F2 800-900 m are close to being overtopped.

Analysis of the engineered channel on the F2 branch using Council's recommended Manning's "n" coefficient of 0.080 indicated that there would be significant out of channel flooding on the development site should the state of the channel capacity be reduced by increased vegetation growing in the channel.

Further consideration of the design of the engineered channel to accommodate flooding is required at DA stage to ensure that the potential for adverse out of channel flood impacts to neighbouring properties and the presently proposed development site itself are minimised. The proposed development allocates areas for the flood channel and flood storage solely on the Terrace Towers site. Widening of the channel and flood storage requirements onto the adjacent property Lot 9 DP239704 through negotiation with the property owners could be considered at DA stage.

4.7.5 *Allowing for possible additional future development*

It is noteworthy that further development within the "F2" sub-catchment in Precinct 14 is probable given that there is an area of 15 Ha to the north and that this area will also drain via the reconfigured "F2" creek path. Potential filling in the adjacent area Lot 9 DP 239704 area has been included in the modelling for this study in all Options considered.

Should development occur in these areas then it will be important to ensure that peak runoff flows and volumes from the new development remain consistent with the analysis undertaken for Option 3A in this analysis.

5 REVIEW OF PROPOSED DEVELOPMENT OPTIONS BETWEEN THE F3 FREEWAY AND SPARKS ROAD

Several parcels of land have been earmarked for development by Council and assessed in Matrix Plus (2005) for the potential to impact flood behaviour. The areas for development are numbered 1 to 5 on Figure 5.

These development options have been reviewed as part of the existing study and included in modelling assessments conducted for development specifically identified as part of the present study scope. Each development area identified in Figure 5 is commented on in turn below.

Area 1 – Land Parcel immediately south of the F3 Freeway

Matrix Plus (2005) recommended that this parcel of land be developed *"provided a 400m long culvert or channel was provided to convey flows the development"*. Our analysis of the modelling undertaken by Matrix Plus indicates that the option of a culvert sized at 2 culverts 3m wide by 1.5m high under the fill pad is not tenable. The modelling indicates that a large proportion of the flow at the 1% AEP level would overtop the headwall. The option of an open channel is preferred. If the channel is to skirt the perimeter of the fill rather than split the site, then the channel transition out of the Freeway culverts and around the fill pad will need to be carefully designed.

The site will be isolated in the 1% AEP event and larger events. Suitable evacuation routes and flood emergency planning is required for the site.

Area 2 – Mid Buttonderry Creek Floodplain

Model analysis by Matrix Plus (2005) reproduced for this study indicates that filling of this area can be undertaken without any adverse impact to peak 1% AEP flood levels on a broad scale. Shaping of the fill pad should be considered in order to limit the impact of the development on redirecting and concentrating flows around the site.

An inspection of available aerial photography for this area indicates that local overland flow paths flowing south from the north of the site may be interrupted by the filling of this land parcel. Care should be taken in the final design of the development to address the potential local drainage issues of the site filling.

Area 3 – Upper Mountain Road Tributary

Existing flooding in this part of the floodplain is characterised by shallow overland flows with no single identifiable flow path. Filling of the site can be undertaken as long as a suitably sized channel is designed to constrain flooding within the 50m wide corridor allowed for in the existing WEZ zoning.

Area 4 – Flood Storage and Wetland

Matrix Plus (2005) adopted the proposed wetland and detention storage proposed by AWT (2004). This storage has become an important part of the consideration of flooding in the development strategy for the WEZ and is required in order to limit the impact of development in this part of the Mountain Road Tributary on areas downstream of Sparks Road.

In addition to this, "brick pits" area of the Mountain Road tributary area now forms an integral part of the IWCM storm water harvesting plan. The compatibility of the proposed floodplain storage in the Matrix Plus Consulting (2005) report with the water harvesting scheme requirements requires further analysis at DA stage.

Area 5

Development of this area includes constraining flood flows to a 50m wide corridor. A review of modelling undertaken for the Matrix Plus (2005) report indicates that while flood levels will be elevated above existing levels following development in this area, the flood impact will be limited to areas local to the development site.

6 INVESTIGATION OF FILLING OPTIONS SOUTH OF SPARKS ROAD

6.1 Preamble

This section covers Part B of this study as stated in Section 2. It presents results for the flooding assessment for areas identified for potential development to the south of Sparks Road. The objective of Part B was to investigate filling and development options on land to the south of Sparks Road. The feasibility of limited filling on the edge of land adjacent to Warnervale Airport was assessed in Part C of this study.

6.2 Investigation of Filling Options

In both Part B and Part C, the model assessment has involved the following tasks:

- Define flood behaviour for the 1% AEP flood event for "base case" floodplain conditions;
- Update the model to include the proposed floodplain development;
- Run the updated model for the 1% AEP flood;
- Compare pre and post development cases to assess likely flood impacts.

Modelling for this assessment has taken into account all proposed development in the WEZ area upstream (north) of Sparks Road including the filling options assessed by Matrix Plus (2005) and the most recently proposed development options for Precinct 14 discussed in Part A of this study.

The filling and development options for Part B and Part C are presented in Figure 4 and Figure 5 and described in more detail below.

6.3 Part B: Investigation of Development Options - South of Sparks Road, Warnervale.

The objective of Part B was to investigate the proposed filling of property on the south side of Sparks Road, to the east of the Sparks Road intersection with Mountain Road. The property is approximately 400 m long and 100 m wide (highlighted as the green property parcel on Figure 6) and is crossed by the Mountain Road tributary channel. About 60% of this proposed filling area is presently predicted to be inundated in the 1% AEP flood event.

As limited ground survey was available for this part of the floodplain, a land survey brief was prepared by DHI for the area south of Sparks Road. Johnson Partners Pty Ltd were engaged to measure the land survey and subsequently provided DHI with the five cross section profiles as located on Figure 6.

The existing hydraulic model was modified to include these new surveyed sections on the Buttonderry Creek and Mountain Rd tributary model branches, south of Sparks Road.

Wyong Shire Council also provided detail survey levels of Warnervale Airport prepared by Rolls & Associates Surveyors (2001). The model cross-sections were also supplemented with this survey to account for potential flooded areas in the airport.

The proposed development was assessed by altering existing model cross sections to include the proposed fill on both the east and west banks of the Mountain Rd tributary channel. It was assumed that access to the eastern end of the site would be via a bridge over the channel, the bridge level to be at the same level as Sparks Rd. The fill was also set to be the level of Sparks Road at the crossing of Mountain Road tributary – nominally RL 10.1m AHD.

6.3.1 Part B Results

Model results are summarised in Table 4. The results indicate that filling of this property on both the eastern and western sides of the channel will result in an increase of flood levels both upstream and downstream of Sparks Road. Levels are predicted to rise by up to 0.5m upstream of Sparks Road and by up to 0.65m downstream of Sparks Road. The predicted flood level impacts are significant. In addition, the property is directly downstream of the preferred flow path for flows overtopping Sparks Road in the case of culvert blockage. For these reasons, filling and development of the complete property is not recommended.

A second development scenario was also tested. In this case fill was placed on the east side of the channel only but the road and the bridge over Mountain Road Tributary are still in to access the area. Results presented in Table 4 for this option show that predicted impacts for this development option are small – in the order of 0.02m. We are aware that vehicular access to the east side of the property is limited; however development of this part of the property is the only option from a flooding perspective.

6.4 Part C: Investigation of Development Options near Warnervale Airport

The objective of Part C was to investigate the filling of two land parcels on the edge of Warnervale Airport (Figure 6). The first property is located on the east of Jack Grant Avenue while the second land parcel is located south of the airport's runway.

The existing cross-sections in the hydraulic model of Buttonderry Creek were extended using available survey data provided by Council (Warnervale Airport and Jack Grant Avenue, 2001) to ensure that the development areas were adequately represented. The adjusted model including all proposed development north of Sparks Road was adopted as the base case for comparison purposes.

The post-development model was revised to include the proposed Part C land fill.

6.4.1 Part C Model Results

Table 4 lists predicted 1% AEP flood levels calculated on Buttonderry Creek and Mountain Road tributary for the existing floodplain and the post-development 1% AEP flood event with and without the proposed Part C development.

Cross-sections with the maximum water levels for the existing and the post-development flood event are plotted in Appendix D.

The results show that in the vicinity of the proposed fill, water levels are predicted to increase slightly by approximately 0.02 m compared to the future development scenario without the Part C development. Fill areas for Part C will have a negligible impact on flood levels upstream at Sparks Road. No impact on water levels is evident further downstream as the levels are to be controlled by the downstream boundary condition on the Buttonderry Creek branch in the Porters Creek Wetland.

Modelling of PMF conditions was outside the scope of this report which has adopted the 1% AEP event as a design flow. Paterson (1997) estimated that flows in the PMF would be 3-4 times the 1% AEP flow and have flood depths up to 0.8m higher than the 1% AEP event.

In Section 7 below, which considers overtopping of Sparks Road, flows of up to 2.5 times the 1% AEP event were considered. On the basis of the results from modelling flows 2.5 times the 1% AEP event, it could be concluded that flooding on the south side of Sparks Road would inundate wide areas of the airport lands, but to shallow depths characterised by low, slow moving flows. While road access to the properties identified for development in Part C could be expected to be cut, the flows would not be to dangerous levels. Evacuation of the properties by heavy vehicle is anticipated to be possible. Any development of these sites should be approved on the basis that the development is flood compatible in order to limit flood damages and allow swift recovery following an extreme flood event. Emergency planning for the sites is also recommended.

Table 4: Flood Level Comparison – Part B and C.

		Water Level (m AHD)						
Location	Mike11 Chainage (m)	(1) Existing Floodplain	(2) Future Development	(3) Filling Part B	(4) Filling Part B (east only)	(5) Filling Part C	(6) Filling Part B & C	Difference (6) -(2)
Upstream of Sparks Rd	BUTTONDERRY 2480	9.17	9.45	9.52	9.47	9.45	9.52	0.07
Downstream of Sparks Rd	BUTTONDERRY 2520	9.12	9.16	9.15	9.13	9.16	9.15	-0.01
	BUTTONDERRY 2650	8.66	8.69	8.82	8.71	8.68	8.82	0.13
Fill - Part B (10.11 mAHD)	BUTTONDERRY 2700	8.56	8.58	8.73	8.61	8.58	8.73	0.15
Fill Part C	BUTTONDERRY 2960	7.81	7.82	7.82	7.82	7.82	7.82	0.00
	BUTTONDERRY 3080	7.33	7.35	7.35	7.35	7.35	7.35	0.00
	BUTTONDERRY 3270	6.94	6.96	6.96	6.96	6.96	6.96	0.00
	BUTTONDERRY 3740	6.51	6.54	6.54	6.54	6.54	6.54	0.00
	BUTTONDERRY 3940	6.17	6.19	6.19	6.19	6.2	6.2	0.01
	BUTTONDERRY 4040	6.07	6.09	6.09	6.1	6.11	6.11	0.02
	BUTTONDERRY 4170	5.95	5.96	5.96	5.96	5.99	5.99	0.03
Fill Part C	BUTTONDERRY 4300	5.91	5.91	5.91	5.91	5.92	5.92	0.01
	BUTTONDERRY 4410	5.9	5.9	5.9	5.9	5.9	5.9	0.00
	BUTTONDERRY 4490	5.89	5.89	5.89	5.89	5.89	5.89	0.00
	BUTTONDERRY 4570	5.89	5.89	5.89	5.89	5.89	5.89	0.00
	BUTTONDERRY 4650	5.88	5.88	5.88	5.88	5.88	5.88	0.00
	BUTTONDERRY 4900	5.88	5.88	5.88	5.88	5.88	5.88	0.00
	BUTTONDERRY 5250	5.88	5.88	5.88	5.88	5.88	5.88	0.00
Downstream Boundary	BUTTONDERRY 5500	5.88	5.88	5.88	5.88	5.88	5.88	0.00
Upstream of Sparks Rd	MOUNTAIN 1540	9.86	9.56	10.07	9.56	9.56	10.07	0.51
Downstream of Sparks Rd, Filling Part B	MOUNTAIN 1565	9.13	9.17	9.82	9.14	9.17	9.82	0.65
Fill Part B	MOUNTAIN 1650	8.66	8.69	8.82	8.71	8.68	8.82	0.13

7 FLOOD OVERTOPPING ASSESSMENT OF SPARKS ROAD

7.1 Preamble

Wyong Shire Council records report a number of floods overtopping Mountain Road and Sparks Road at Warnervale. In particular, a flood is reported to have overtopped Sparks Road in 1989 post the road upgrade completed in 1985.

Matrix Plus (2005) concluded that:

- overtopping of Sparks Road would not occur for 1% AEP design flood conditions;
- no new culverts should be installed under Mountain Road; and
- the southern end of Mountain Road (just before the intersection with Sparks Road) should be raised to reduce flood overtopping Sparks Road.

A 1985 design road profile of Sparks Road was provided by Wyong Shire Council (dwg # 6334) and used by DHI to assess overtopping issues on the road.

Four sets of culverts cross Sparks Road in the vicinity where floods overtopping Sparks Road were reported. All four sets of culverts are incorporated in the existing Mike-11 hydraulic model. Culverts on flow branches "Jack Grant", "Bypass" culvert and Buttonderry Creek are located west of Mountain Road and "Mountain" branch culvert is located to the east of Mountain Road. The lowest section of road crest on Sparks Road is located at the Mountain Road tributary channel crossing ("Mountain" culvert). Figure 7 shows the location of the culverts under Sparks Road.

7.2 Assessment of Floods Overtopping at Sparks Road

In the first instance, a review of the representation of Sparks Road in Mike-11 hydraulic model provided by Matrix Plus (2005) was undertaken. Small changes were made to adjust the Sparks Road crest level in the model to comply with the 1985 design road profile provided by Council. It was also identified that the culverts under Sparks Road on the Mountain Road tributary branch were not correctly incorporated in the model. These culverts were included in the model on the basis of available survey information of culvert sizes and invert levels (Table 5).

Table 5: Culvert Sizes and Inverts under Sparks Road.

Culvert Name	Upstream Invert Level (m AHD)	Culvert Size
By Pass Culvert	9.00	5*2.5m W*1.2m H
Buttonderry Culvert	7.83	5* 2.5m W *1.8m H
Mountain Culvert	7.78	4*2.5m W*1.5m H

The model was then run for two scenarios: Existing floodplain conditions; and fully developed floodplain conditions.

The fully developed floodplain was based on a future development scenario provided in the Matrix Plus (2005) report with some modification as directed by Council. The future development scenario includes several areas of floodplain modification both upstream and downstream of the F3 Freeway as described in the preceding sections of this report. The fully developed floodplain scenario is illustrated in Figure 5.

1% AEP flood levels in the updated model for the existing floodplain were compared to the Matrix Plus (2005) results (see Table 6) for the same flood event. In general, differences between the two sets of model are small. However, in the vicinity of the Mountain Road tributary channel, the peak water level upstream of Sparks Road has increased by approximately 0.7m. This difference is due to the implementation of the correct culvert arrangement in the model at this location. The results from the revised model were considered as the existing case for further comparison.

The model results reported in Table 6 and Figure 8 indicate that peak water levels for the 1% AEP design flood event are unlikely to overtop Sparks Road under either existing or fully developed floodplain conditions. The maximum flood level for 1% AEP existing floodplain conditions is 0.26m below the lowest section of the Sparks Road at the Mountain Road tributary channel crossing. At the same location for future floodplain conditions the 1% AEP flood level is 0.57m below the Sparks Road crest on the eastern side of Mountain Road. Note that the future development case modelled here supposes that the land on the north eastern side of the Sparks Rd / Mountain Road intersection is filled with no opportunity for exchange of flow across Mountain Road at this location. While Sparks Road is not overtopped in the future development case, the limited opportunity for exchange of flow between the east and west sides of Mountain Road result in an increase in peak level on the Buttonderry Creek (west) side of Mountain Road of approximately 0.8m and a decrease in levels on the eastern side of Mountain Road compared to peak levels on the existing floodplain. However Mountain Road is likely to be overtopped about 150m north of Sparks Road (Drain, 150m) in the future development case.

While the Matrix Plus (2005) report states that the "Developed Conditions" case has no connection across Mountain Road near Sparks Road, the work undertaken in association with the current analysis to make the hydraulic model spatial revealed that the model used in the Matrix plus analysis did indeed have such a connection in place. The effect of the connection is reflected in the difference in level on the Buttonderry Creek branch in where the present analysis predicts a peak level for fully developed floodplain conditions of 9.45m AHD compared to the Matrix Plus prediction of 9.37m AHD. The lower peak water level in the Matrix Plus report for future conditions can also be attributed to an amount of artificial storage in the model located between the F3 Freeway and the fill pad adjacent to the southern side of the freeway. The Matrix Plus study addressed flow passage past this development area using a culvert. In the revised developed case flow has been directed around the fill in an open channel and the open channel passes higher flows to the downstream area, hence the higher level in the analysis.

Table 6: Flood Levels at Sparks Road – Existing and Future Development Case

Location	Distance from F3	Sparks Rd Level	Max Water Levels - Existing Case					Max Water Levels - Developed Case				
			1% Matrix	1%	1% * 1.5	1% * 2	1% * 2.5	1% Matrix	1%	1% * 1.5	1% * 2	1% * 2.5
	m	mAHD	mAHD	mAHD	mAHD	mAHD	mAHD	mAHD	mAHD	mAHD	mAHD	mAHD
Jack Grant	2230	11.83	11.21	11.21	11.27	11.38	11.49	11.21	11.21	11.29	11.41	11.57
Bypass Culvert	2440	11.01	10.15	10.13	10.31	10.46	10.65		10.17	10.38	10.68	10.87
Buttonderry Culvert	2510	10.85	9.21	9.17	9.7	10.32	10.56	9.37	9.45	10.21	10.62	10.81
Mountain Culvert	2860	10.11	9.14	9.85	10.14	10.37	10.49	9.11	9.54	9.89	10.12	10.3
Drain at 150m*	-	10.05*	-	9.95	10.24	10.49	10.66	-	10.22	10.5	10.78	10.96
Drain at 260m*	-	10.26*	-	9.71	10.13	10.43	10.61	-	10.01	10.39	10.72	10.9

** Locations on Mountain Road (see Figure 7)*

The catchment flow required to overtop Sparks Road was then determined by running the Mike-11 hydraulic model with factored 1% AEP hydrographs. The 1% AEP catchment runoff hydrographs were proportionally increased until the model results indicated that Sparks Road was overtopped. Flood levels at Sparks Road are summarised in Table 6 and Figure 9 and Figure 10 for the existing and the future development cases. Water levels are also compared at two locations along the drain running on the west side of Mountain Road at location shown in Figure 7.

1% AEP hydrographs were increased by multipliers of 1.5, 2 and 2.5. Results in Table 6 and Figure 9 and Figure 10 show that for existing floodplain conditions, Sparks Road would be overtopped east of Mountain Road by about 0.03m for an event 1.5 times greater than the 1% AEP event. An event 2 times greater than the 1% AEP for the future development case would just cause flow to crest Sparks Road also at the location east of Mountain Road.

The model results indicate that Mountain Road is likely to be overtopped approximately 150m north of Sparks Road for flood events greater than 1.5 times the 1% AEP in the existing case and for flood events greater than the base 1% AEP hydrograph for the future development case.

Blockage of the Sparks Road culverts was also considered. The 1% AEP existing and future development scenarios were run with the culverts partially blocked under Sparks Road. Two cells out of five were blocked at the Buttonderry Creek crossing and two cells out of the four at the Mountain Road tributary crossing were blocked respectively. The model results for culvert blockage are reported in Table 7 and Figure 9 for the 1% AEP case. The results show that approximately 50% culvert blockage during the 1% AEP flood event will result in Sparks Road being overtopped by 0.07m at the low point at the Mountain Rd tributary channel culverts.

Next, the influence on 1% AEP flood levels of raising Mountain Road above the 1% AEP level was analysed. This scenario was tested specifically for the existing floodplain case by removing the flow linkages over Mountain Road between Buttonderry Creek and the

Mountain Road tributary including the overflow paths Moorak (at Drain 150m north of the intersection) and Overflow#3 (at Drain 260m). Note that in the future development case Buttonderry Creek and Mountain Road tributary are also disconnected as the land east of Mountain Road is to be filled. The model results presented in Table 7 show that provided the culverts under Sparks Road function to their full capacity, raising Mountain Road above the 1% AEP peak flood level will not cause Sparks Rd to overtop during the 1% AEP flood event.

Table 7: Flood Levels at Sparks Road – Changes in flow conditions. – Culvert Blockage

Location	Distance from F3	Sparks Rd Level	Max Water Levels - Existing Case			Max Water Levels - Developed Case			
			1%	1% - No Link	1% - Culverts blocked	1%	1% - Culverts blocked	1% Link Channel Buttonderry-Mountain	1% Culverts Blocked + Link Channel Buttonderry-Mountain
	m	mAHD	mAHD	mAHD	mAHD	mAHD	mAHD	mAHD	mAHD
Jack Grant	2230	11.83	11.21	11.21	11.21	11.21	11.21	11.21	11.21
Bypass Culvert	2440	11.01	10.13	10.13	10.13	10.17	10.33	10.17	10.22
Buttonderry Culvert	2510	10.85	9.17	9.2	10.01	9.45	10.32	9.49	10.19
Mountain Culvert	2860	10.11	9.84	9.85	10.18	9.54	10.11	9.47	10.16
Drain at 150m*	-	10.05*	9.95	10.01	10.19	10.22	10.44	10.22	10.38
Drain at 260m*	-	10.26*	9.71	9.77	10.14	10.01	10.39	10.01	10.3

* Location on Mountain Road (see Figure 7)

Having undertaken this preliminary analysis to establish the criteria by which Sparks Road might overtop, a series of options aimed at increasing the level of protection for overtopping of Sparks Road were tested. Options tested included:

a) A link channel along the north side of Sparks Road that connects Buttonderry Creek and Mountain Road tributary channel was included for the future development case. Three box culverts (2.4 * 1.8m, invert level at 8.5m) were inserted under Mountain Road;

b) For the future development scenario, the same link channel and culverts as for the case above connect Buttonderry Creek and Mountain Road Tributary channel. Two additional box culverts were also added to the existing four box culverts under Sparks Road at the Mountain Road tributary channel; and

c) Same as the case above with five box culverts under Mountain Road and eight under Sparks Road on the Mountain Road tributary channel.

Flood level results for these scenarios are presented in Table 8 and Figure 11 for flows twice the size as the base 1% AEP hydrograph.

Table 8: Flood Levels at Sparks Road – Changes in flow conditions – Upgrade Options

Location	Distance from F3	Sparks Rd Level	Max Water Levels - Developed Case		
			Option a)	Option b)	Option c)
	m	mAHD	mAHD	mAHD	mAHD
Jack Grant	2230	11.83	11.41	11.41	11.41
Bypass Culvert	2440	11.01	10.58	10.53	10.51
Buttonderry Culvert	2510	10.85	10.47	10.4	10.33
Mountain Culvert	2860	10.11	10.28	10.12	9.9
Drain at 150m	-	10.05*	10.7	10.68	10.64
Drain at 260m	-	10.26*	10.61	10.57	10.53

** Mountain Road Level*

The results in Table 8 indicate that by augmenting the culverts under Sparks Road at the Mountain Road tributary channel by adding 2 additional culvert cells and linking the Buttonderry Creek channel with the Mountain Road tributary channel, Sparks Road will be provided with additional protection up to two times the 1% AEP flood event

7.3 Discussion

The impact of raising Mountain Road to be above the 1% AEP flood level between Buttonderry Creek and Mountain Road tributary on the existing floodplain is minor with an increase of 0.03m on Buttonderry Creek and 0.01m on the Mountain Road tributary with no overtopping of Sparks Road anticipated.

Partial blockage of the culverts under Sparks Road contributes to an increase of the flood levels at Sparks Road. Sparks Road is predicted to be overtopped east of Mountain Road for the 1% AEP event for both the existing and the future development cases when the Sparks Road culverts are partially blocked. Mountain Road is also widely overtopped by flood waters to the north of Sparks Road when these culverts are partially blocked.

Under existing conditions, Sparks Road has protection for floods up to 1.5 times the 1% AEP event and under future conditions 2 times the 1% AEP event because the future case includes raising Mountain Road which keeps additional flow volume to the west of Mountain Road.

The creation of a link channel parallel to Sparks Road that connects Buttonderry Creek and Mountain Road tributary channel for the future development case has the effect of equalising the flood levels either side of Mountain Road. Mountain Road is still overtopped by the 1% AEP event further north of Sparks Road.

The inclusion of a channel linking the floodplains east and west of Mountain Road in combination with an augmentation of the Sparks Road culverts on the Mountain Road tributary channel will provide additional protection for overtopping for floods up to twice the 1% AEP event.

While each of the proposed options will provide an increased level of protection for Sparks Road, the expense of augmenting the existing drainage structures with additional culvert cells does not provide a significant benefit over the existing system which already provides protection of Sparks Road to better than 1% AEP levels.

8 CONCLUSIONS AND RECOMMENDATIONS

The existing Buttonderry Creek model has been updated to better represent present floodplain conditions. The updated model has been used to assess several proposed options for development of land in the WEZ for flooding impacts. These development proposals in general concur with the development guidelines noted in the Matrix Plus (2005) report.

For Precinct 14, the results from the model analysis of the proposed development options show:

- Informal water detention exists behind Hue Hue Road in 1% AEP flood conditions. Inclusion of this informal detention storage generally lowers peak flood levels and peak flows on the floodplain in Precinct 14. Analysis in this report extends the modelling to take this effect into account;

- The proposed changes to the floodplain on flow branch "B1" in Option 1 and Option 2 and Option 3 (proposed bridge and new cross-sections) are predicted to have no adverse impact on flood behaviour;

- Development of the "B2" flow path with a piped section for low flows combined with a formalised overland flow path down a proposed roadway is expected to increase flood levels locally upstream of the proposed pipeline headwall. A formalised overland flow path proposed to convey flows which overtop the headwall will need to be carefully designed to effectively capture these excess flows and convey them safely across the developed site;

- Higher flood levels reported for the "F2" flow path for both Options 1 and 2 are due to the implementation of a "designed" channel with a higher invert than in the model survey for the existing case. The crest level of the proposed road running parallel to the design channel is overtopped by flows in the downstream section of the proposed channel in Options 1A and 1B. However, the additional flood storage included in Option 3 ensures that flows remain in-bank with the design Manning's "n" roughness coefficients applied in the engineered channel. Nevertheless water levels remain approximately 0.2 m below the road crest level in the upstream part of the proposed channel and in the lower part of the "F2" branch between chainages 800-900 m the road is close to being overtopped in the design case.

- While the approach to accommodating flooding within the Precinct 14 development area is generally sound, the proposed roughness coefficients for the engineered channel "F2" are considered optimistic. Further consideration of the design of the engineered channel to accommodate flooding is required at DA stage to ensure that the potential for adverse out of channel flood impacts to neighbouring properties and the presently proposed development site itself are minimised. The proposed development allocates areas for the flood channel and flood storage solely on the Terrace Towers site. Widening of the channel and

flood storage requirements onto the adjacent property Lot 9 DP239704 through negotiation with the property owners could be considered at DA stage.

- Some redistribution of flood volume immediately upstream of the F3 Freeway embankment will occur under the proposed development scenario. While peak levels at the Buttonderry Creek channel culverts will remain similar to the existing flood case, levels will change by up to 0.3m in the flooded area to the east of the main channel. While the peak flood 1% AEP flood levels remain more than 0.5m below the top of the Freeway embankment, the NSW RTA should be informed of the likely localised change to peak flood levels adjacent the embankment. Confirmation of the compensatory flood storage behind the F3 Freeway in line with Matrix Plus Consulting's original recommendations is required at DA stage.

In Precincts 11 and 13 between the F3 Freeway and Sparks Road, the review of proposed development suggests that that the proposed development is unlikely to affect flood behaviour outside the immediate vicinity of these developments. These areas are identified on Figure 5

- Area 1 can be developed without significant impact to downstream flood levels provided careful design of a channel to convey flows past the site is undertaken at detailed design. Special care in design needs to be exercised to accommodate the transition of flow out of the Freeway culverts if the channel is to skirt the proposed fill channel rather than split it;

- Area 1 will be isolated in events equal to and greater than the 1% AEP flood event. A suitable evacuation route and flood evacuation planning will be required if the site is to be developed;

- Area 2 can be undertaken without any adverse impact to peak 1% AEP flood levels on a broad scale. Shaping of the fill pad should be considered in order to limit the impact of the development on redirecting and concentrating flows around the site. Local overland flow paths flowing south from the north of the site may be interrupted by the filling of this land parcel. Care should be taken in the final design of the development to address the potential local drainage issues of the site filling;

- Area 3 on the upper part of the Mountain Road Tributary floodplain has flooding characterised by shallow overland flows with no single identifiable flow path. Filling of the site can be undertaken as long as a suitably sized channel is designed to constrain flooding within the 50m wide corridor allowed for in the existing WEZ zoning;

- The proposed development strategy previously analysed by Matrix Plus Consulting (2005) allowed for allocation of additional storage on the Mountain Road tributary floodplain to compensate for proposed filling on this floodplain upstream of Sparks Road. The "brick pits" area of the Mountain Road tributary area now forms an integral part of the IWCM storm water harvesting plan. The compatibility of the proposed floodplain storage in the

Matrix Plus Consulting (2005) report with the water harvesting scheme requirements requires further analysis at DA stage.

- Development of Area 5 includes constraining flood flows to a 50m wide corridor. A review of modelling undertaken for the Matrix Plus (2005) report indicates that while flood levels will be elevated above existing levels following development in this area, the flood impact will be limited to areas local to the development site.

The complete filling of land to immediately the south of Sparks Road near the intersection with Mountain Road is not recommended. Partial filling of the site with fill on the east side of the channel only and bridged access over the Mountain Road Tributary channel to the site is possible by carefully maintaining the channel conveyance downstream of Sparks Road.

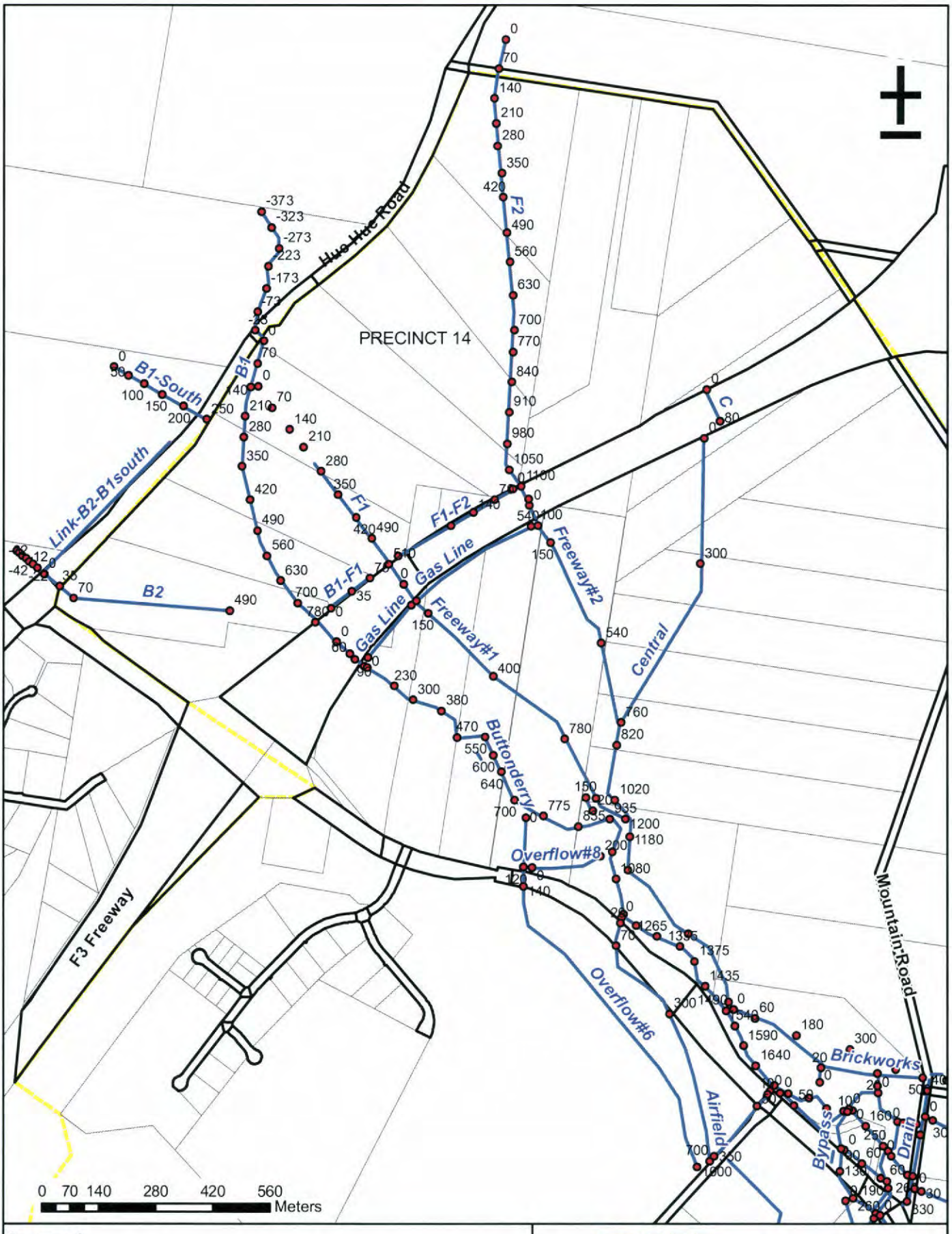
Filling of the identified development areas adjacent to the Warnervale Airport is possible with negligible impact to the broad scale flood behaviour. It is important to note that these areas have the potential to be isolated for floods larger than the 1% AEP event. Development of these sites will require comprehensive flood emergency planning. Any development of these sites should be approved on the basis that the development is flood compatible in order to limit flood damages and allow swift recovery following an extreme flood event.

Copies of all modelling and GIS files developed for the analysis reported here, along with survey commissioned by DHI specifically for this study have been provided to Council on a CD accompanying this report.

9 REFERENCES

1. Matrix Plus Consulting Pty Limited, "Buttonderry Creek Flood Study – Precincts 11, 13 and 14", Final Report, November 2005.
2. Paterson Consultants, "Buttonderry Creek Flood Investigation", Final report October 1997.
3. Australian Water Technologies, "Water Quality Management for Precincts 11 and 13 Industrial Estate, Wyong Flood Study." Final, February 2004.
4. Rolls & Associates Surveyors, "Detail Survey of Warnervale Airport Jack Grant Avenue Warnervale", 10/08/2001, Drawing 804OA.
5. Survey south of Sparks Road provided by Johnson and Partners Pty Ltd surveyors. JP_Survey_sections.xls (2006)
6. Buzz Engineering and Environmental Solutions, "Floodplain Development Strategy Precinct 14 Warnervale (Part of Wyong Employment Zone)". September 2006.

FIGURES



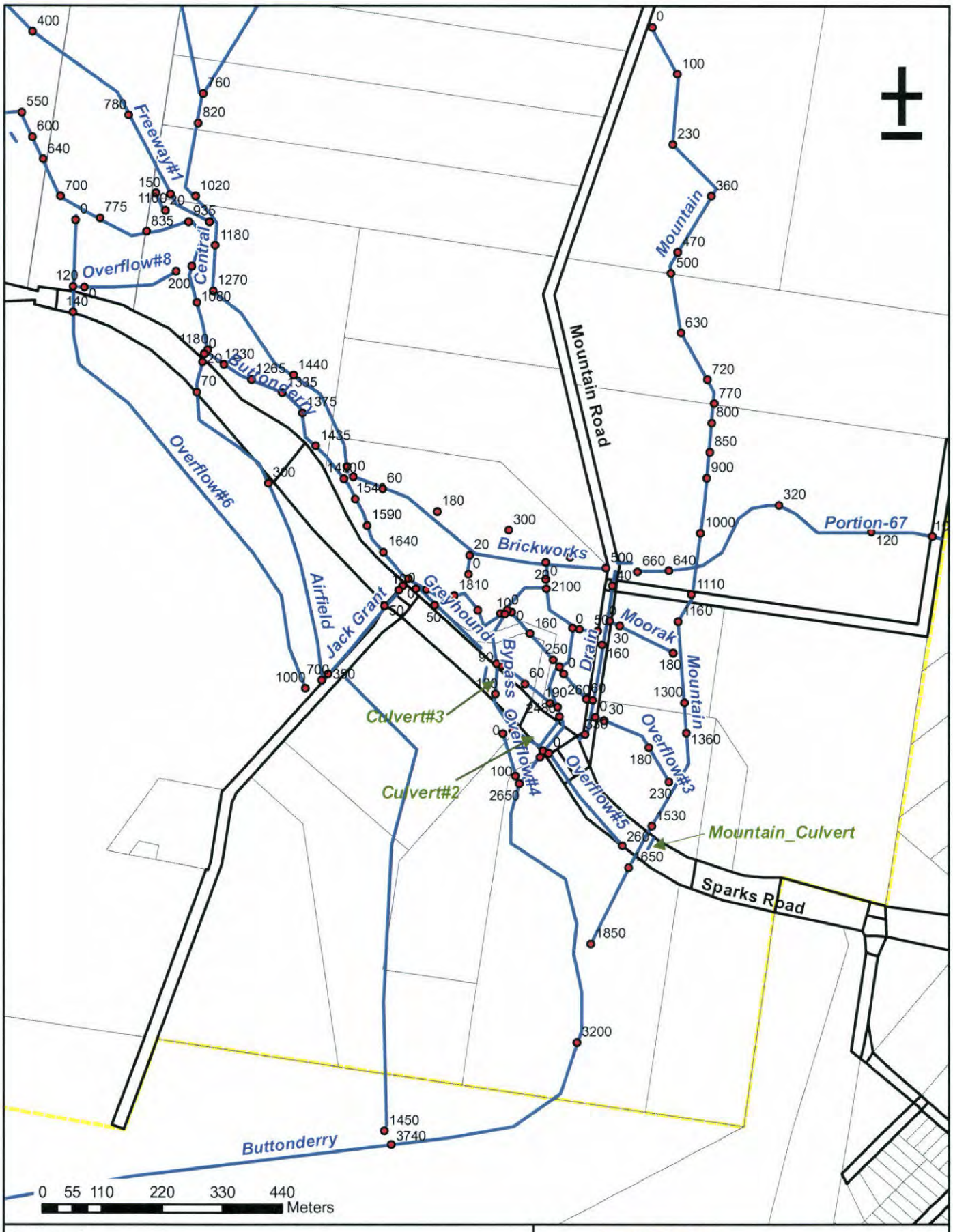
Legend

- Approximate Location of Cross-sections (Chainage in m)
- Mike 11 Network
- Roads
- Cadastre
- Full WEZ Boundary

DHI WATER & ENVIRONMENT

Figure 1

Model Cross-Section Location
Northern Part of WEZ



Legend

- Approximate Location of Cross-sections (Chainage in m)
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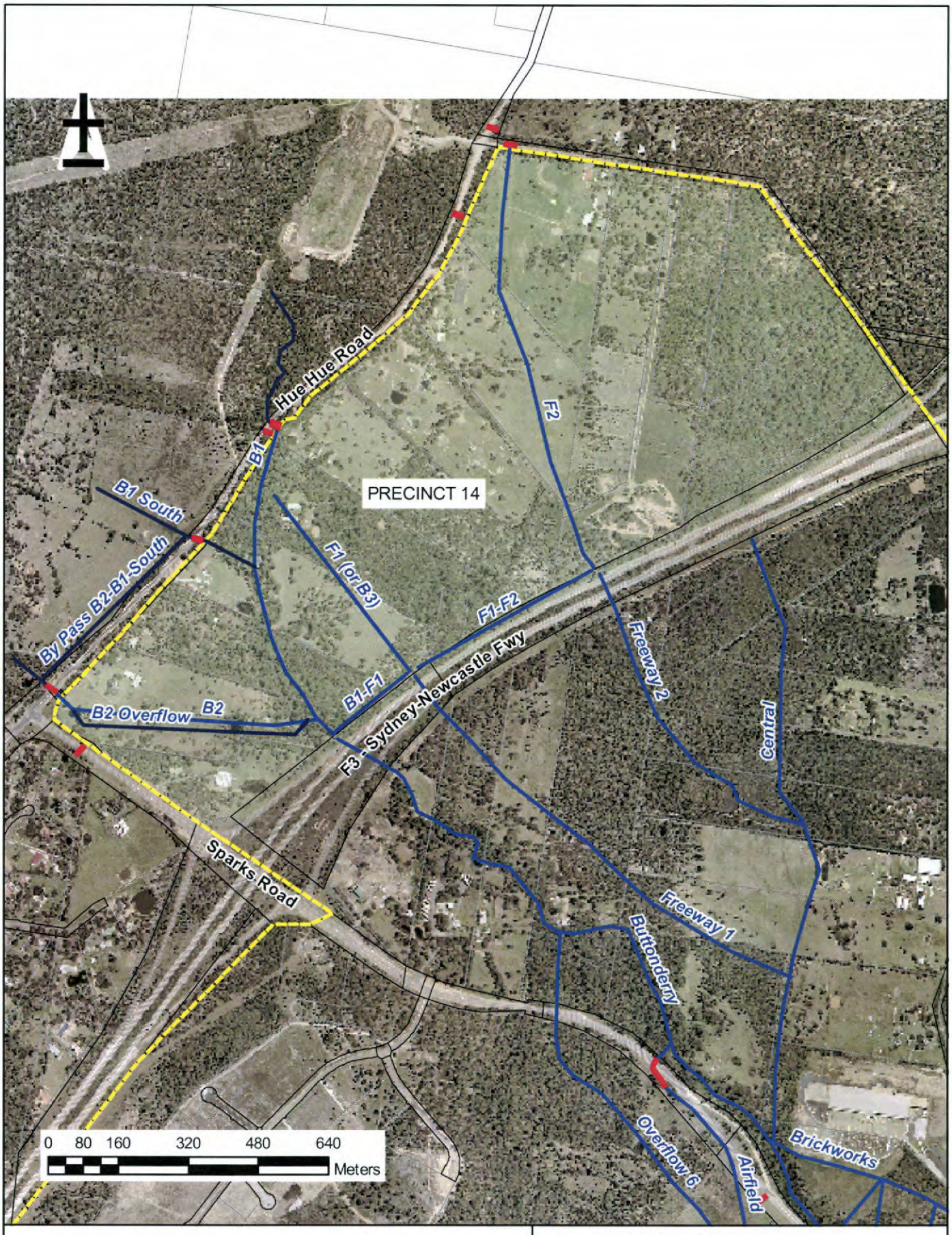
- Roads
- Cadastre
- Full WEZ Boundary

DHI WATER & ENVIRONMENT

Figure 2

Model Cross-Section Location
Southern Part of WEZ



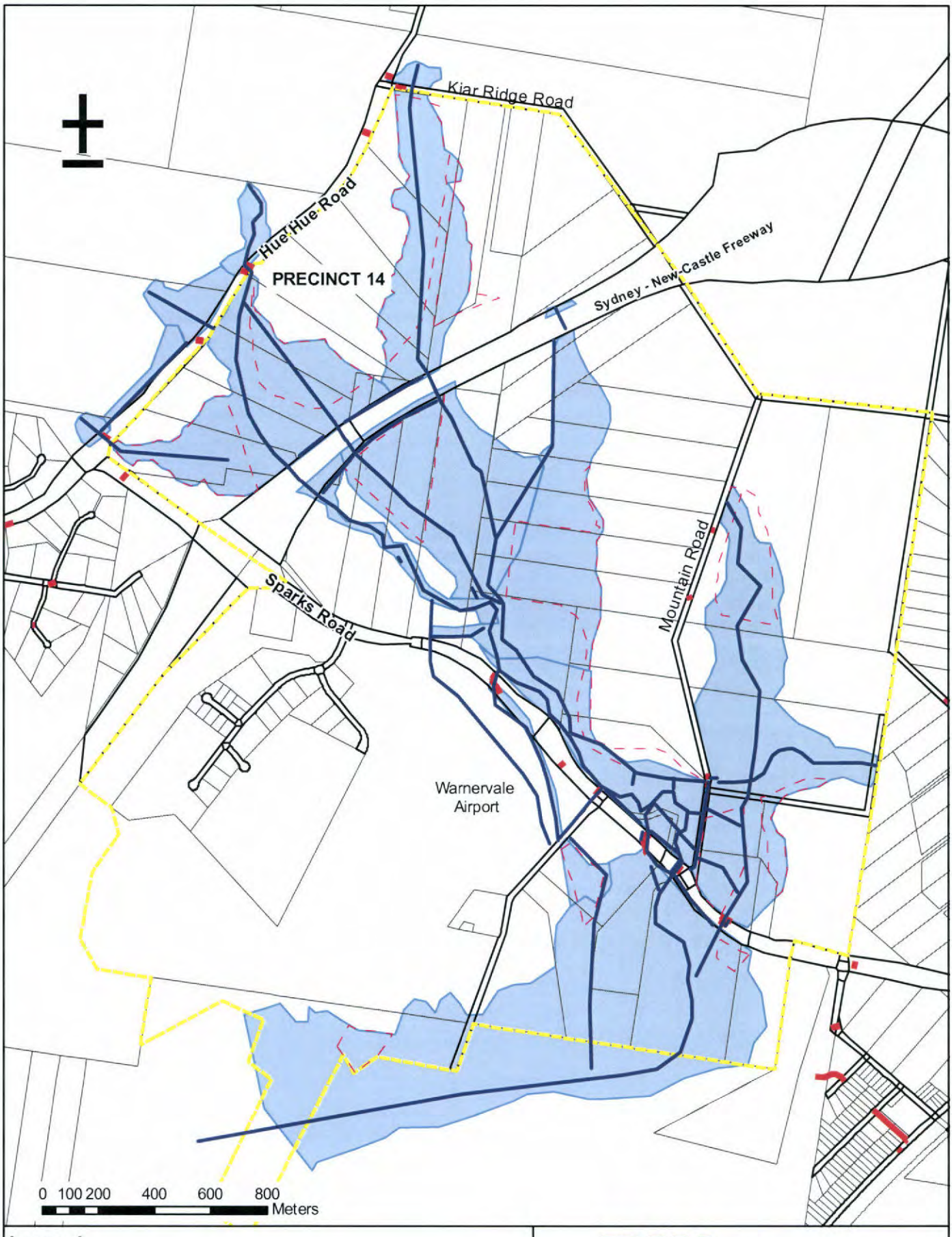
Legend

- Drainage feature (updated)
- Mike 11 Network Original
- Mike 11 Network Additional
- Roads
- Precinct 14
- Cadastre
- Full WEZ Boundary

DHI WATER & ENVIRONMENT

Figure 3

Hydraulic Model Layout
Precinct 14



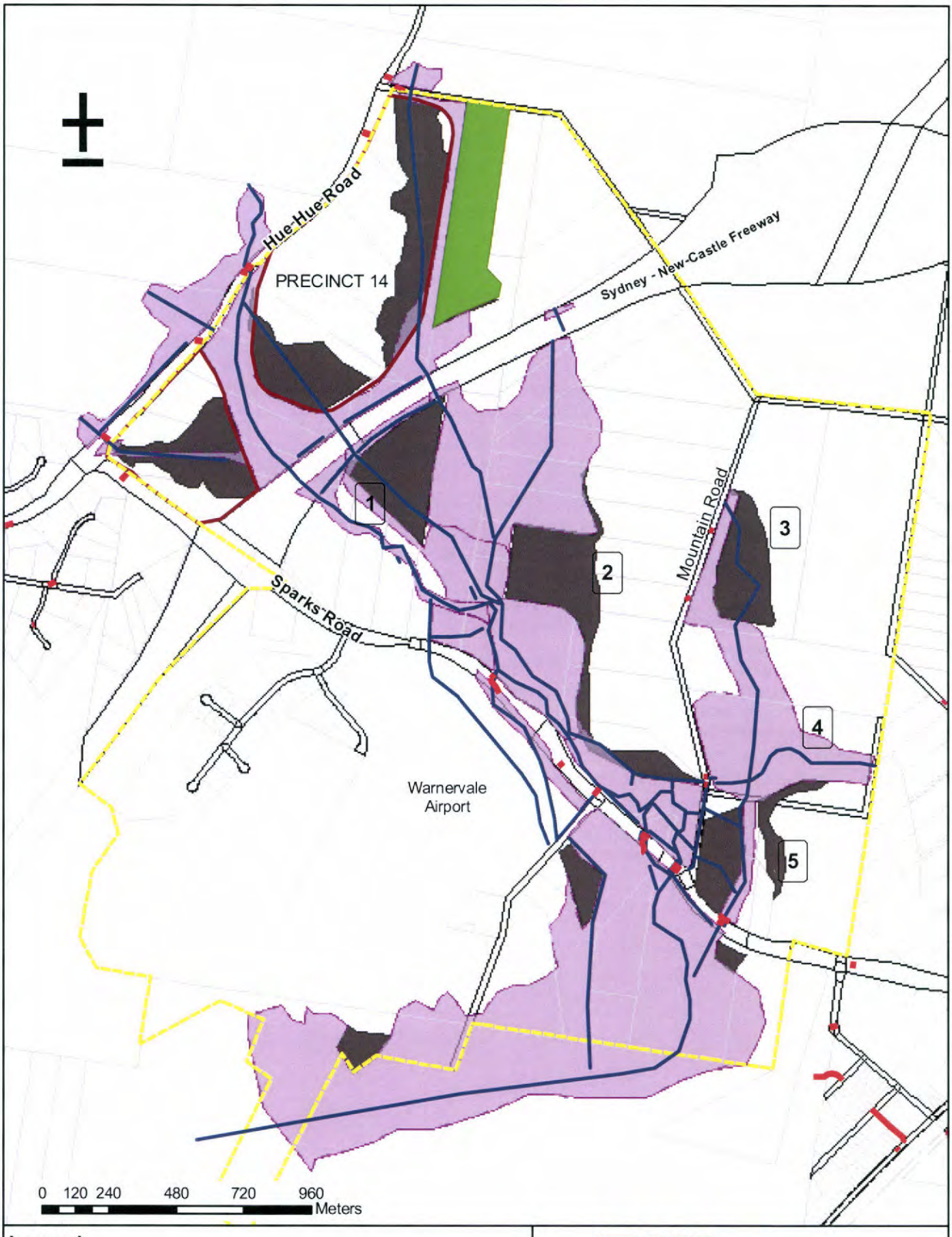
Legend

- 1% Flood Extent - Existing
- Mike 11 Network
- Drainage feature (updated)
- Proposed Fill on Floodplain
- Full WEZ Boundary
- Cadastre
- Roads

DHI WATER & ENVIRONMENT

Figure 4

Flood Extent Map
WEZ Area
1% AEP Existing Case



Legend

- 1% Flood Extent - Future Development
- Mike 11 Network
- Drainage feature (updated)
- Proposed Fill on Floodplain
- WEZ Zone 4e
- WEZ Zone 4c
- Full WEZ Boundary

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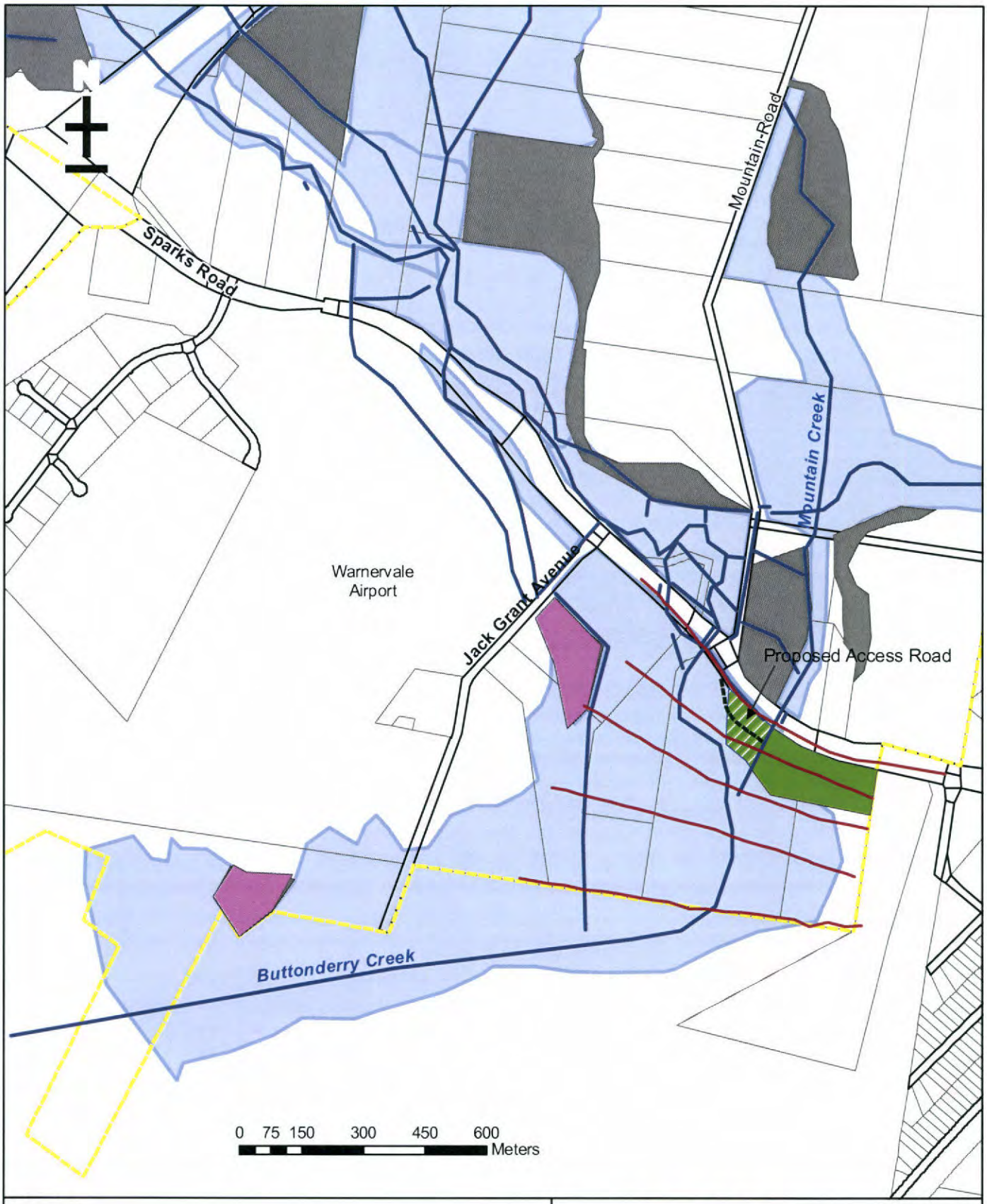
Figure 5

Flood Extent Map
WEZ Area
1% AEP Future Development



Legend

- 1% Flood Extent - Future Development

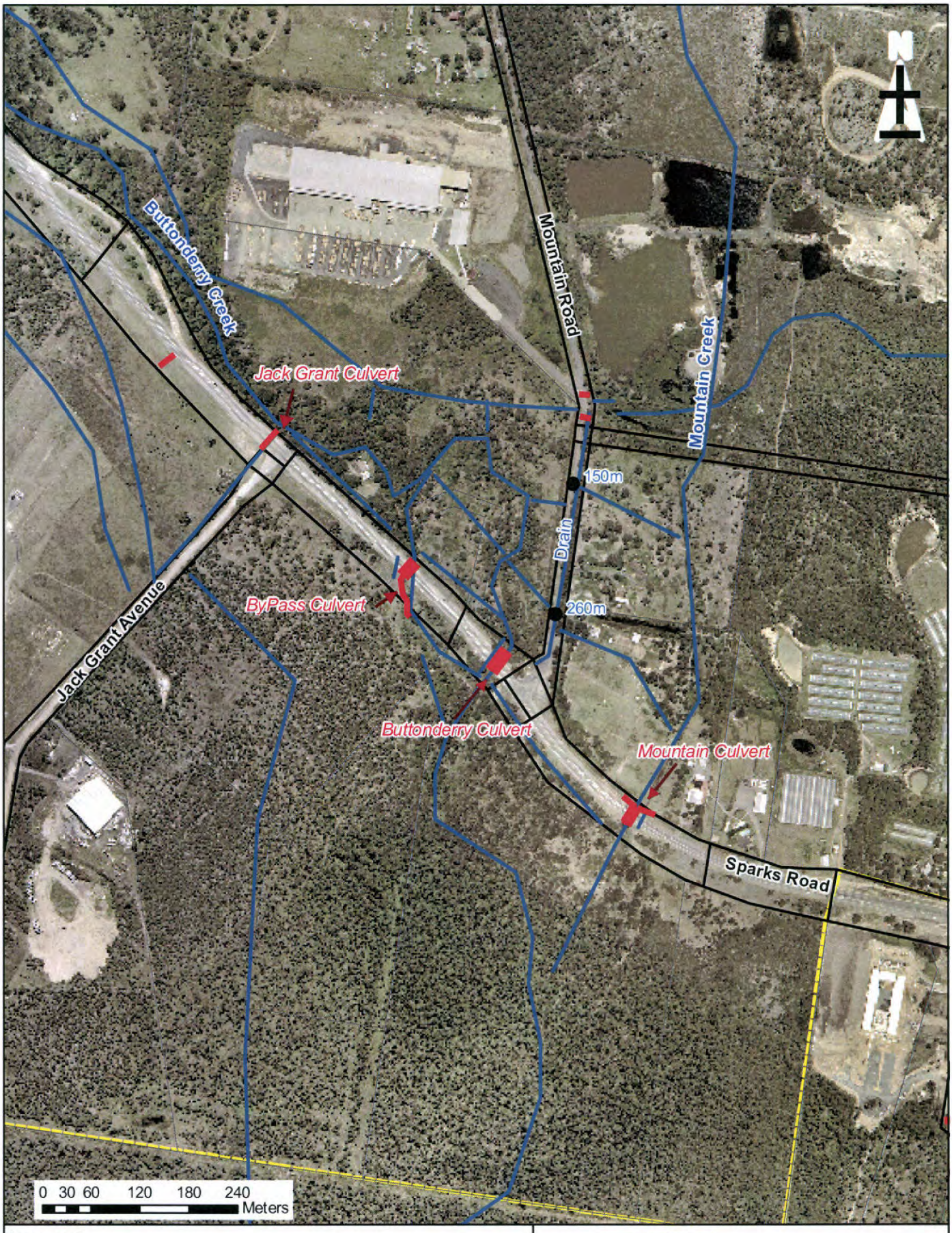
Filling & Development Investigation Areas

- Part B - East
- Part B - West
- Part C
- Surveyed Sections
- Mike 11 Network
- Cadastre
- Other Proposed Filling Areas
- Roads
- Full WEZ Boundary

DHI WATER & ENVIRONMENT

Figure 6

Location of the Future Fillings and Development Areas for Part B and C



Legend

- Drainage feature (updated)
- Mike 11 Network
- Roads
- Cadastre
- Full WEZ Boundary

DHI WATER & ENVIRONMENT

Figure 7

Sparks Road Culvert Location

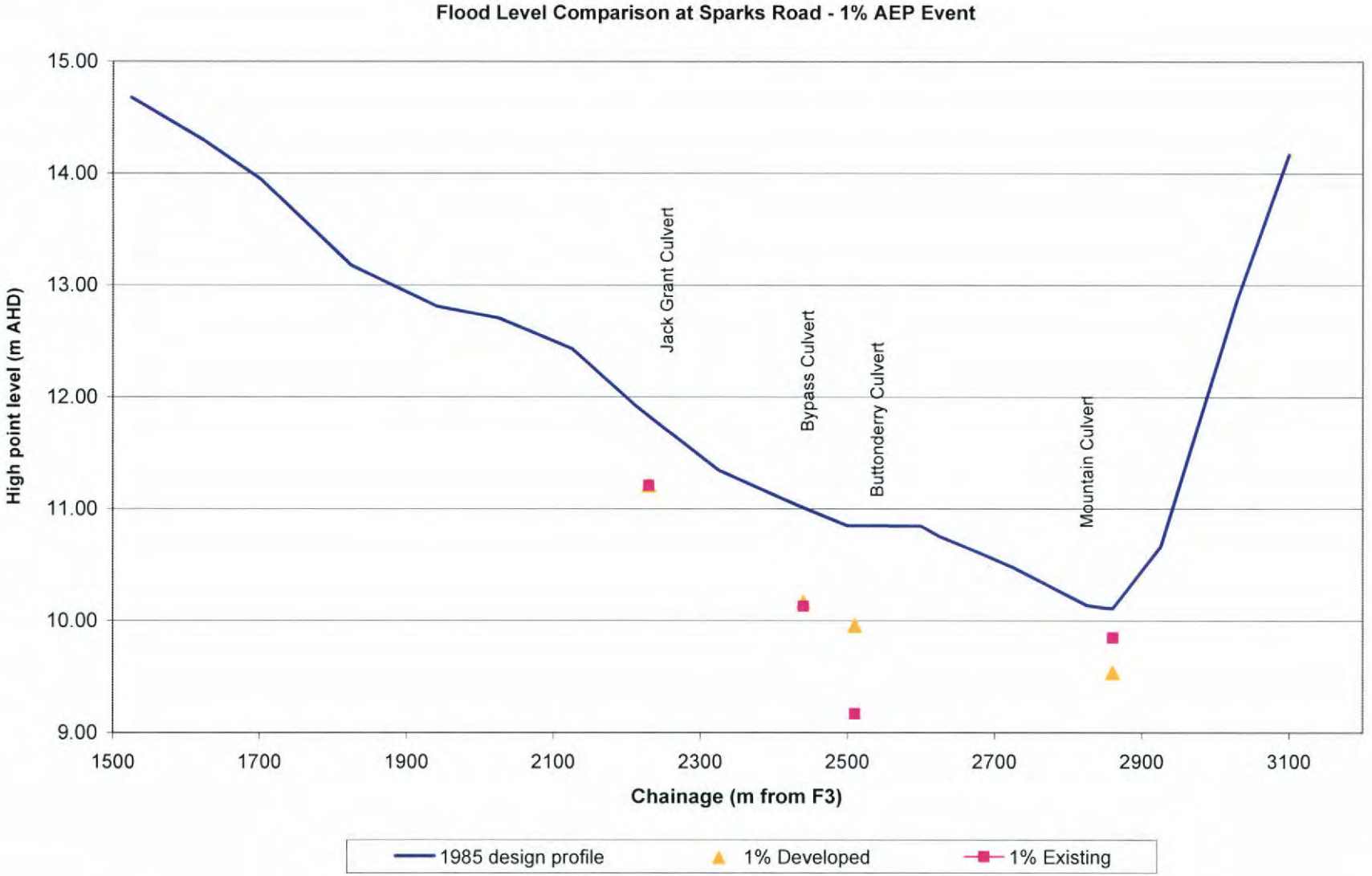

Flood Level Comparison at Sparks Road - 1% AEP Event
High point level (m AHD)
15.00
14.00
13.00
12.00
11.00
10.00
9.00
1500
1700
1900
2100
2300
2500
2700
2900
3100
Chainage (m from F3)
Jack Grant Culvert
Bypass Culvert
Buttonderry Culvert
Mountain Culvert
1985 design profile
1% Developed
1% Existing

Figure 8

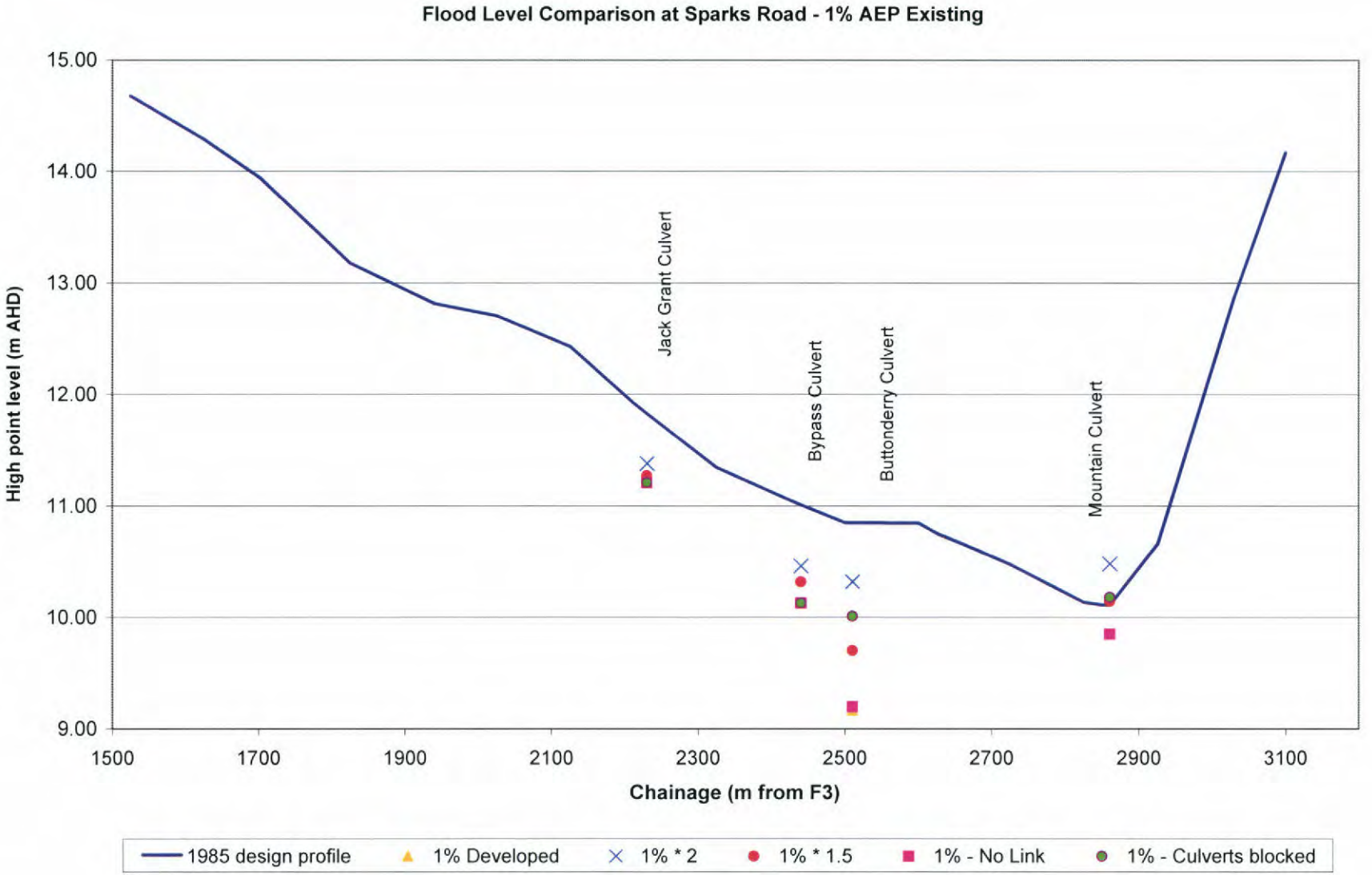

Flood Level Comparison at Sparks Road - 1% AEP Existing
High point level (m AHD)
15.00
14.00
13.00
12.00
11.00
10.00
9.00
1500
1700
1900
2100
2300
2500
2700
2900
3100
Chainage (m from F3)
Jack Grant Culvert
Bypass Culvert
Buttonderry Culvert
Mountain Culvert
1985 design profile
1% Developed
1% * 2
1% * 1.5
1% - No Link
1% - Culverts blocked

Figure 9

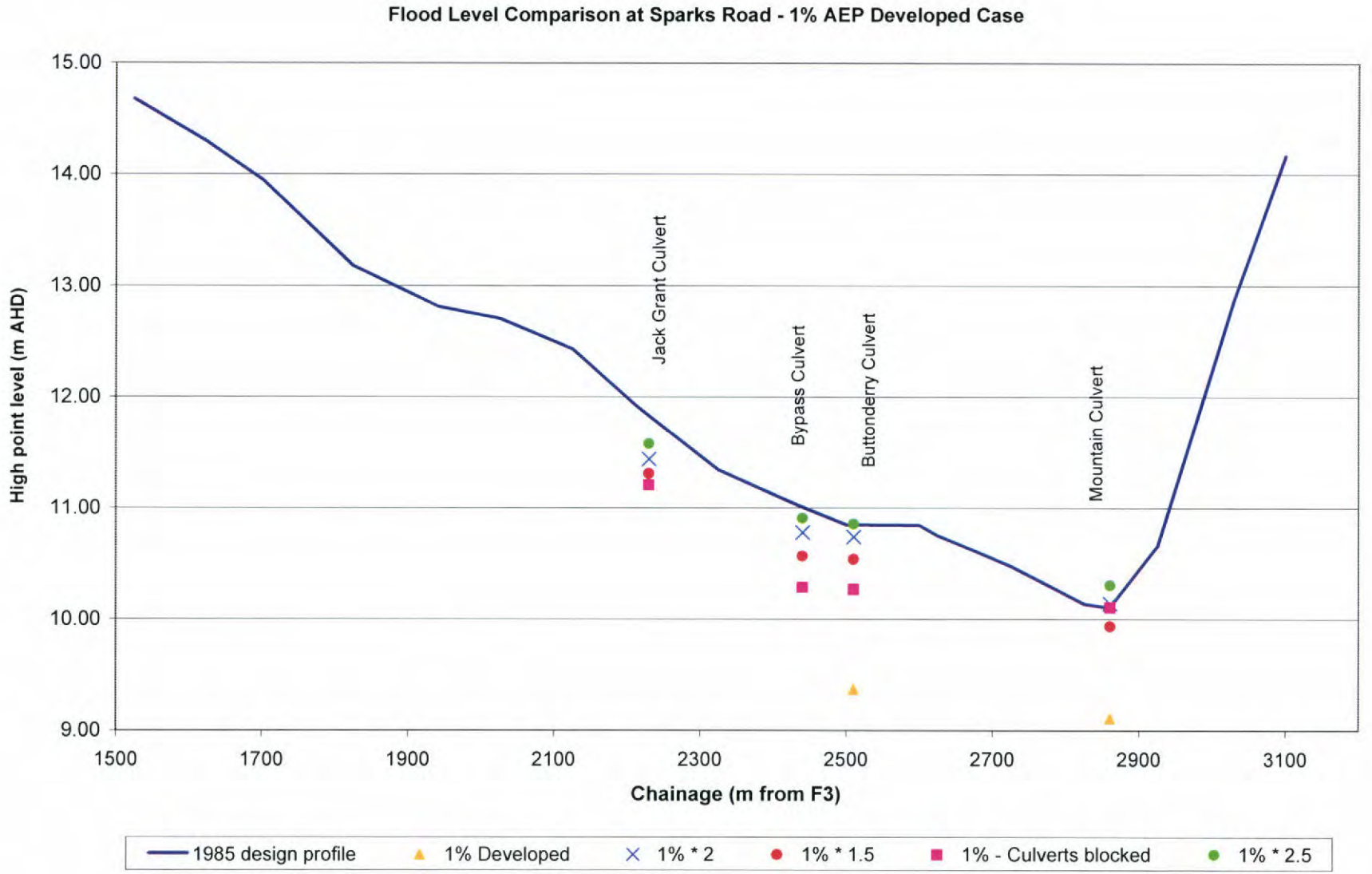
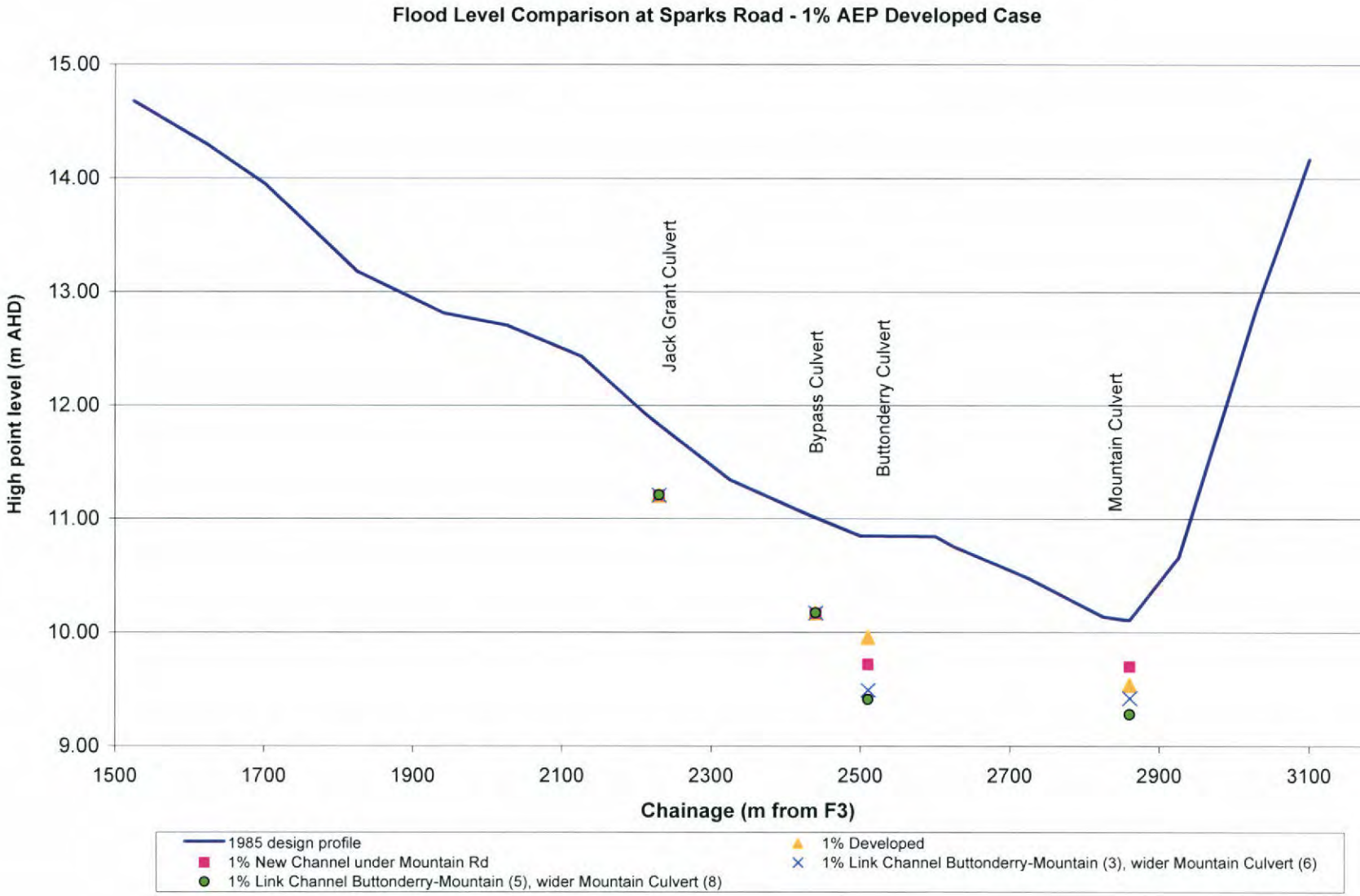
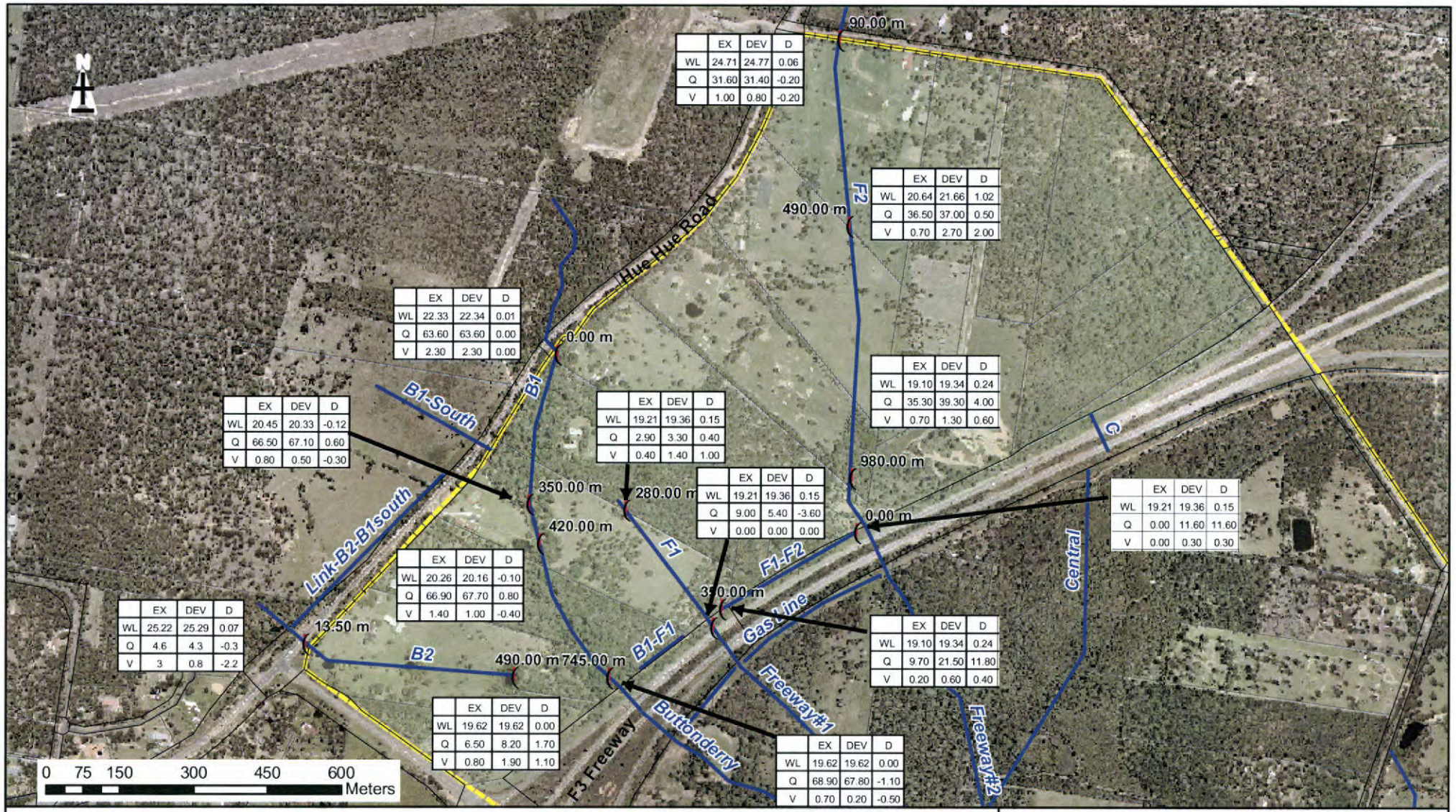

Flood Level Comparison at Sparks Road - 1% AEP Developed Case
High point level (m AHD)
15.00
14.00
13.00
12.00
11.00
10.00
9.00
1500
1700
1900
2100
2300
2500
2700
2900
3100
Chainage (m from F3)
Jack Grant Culvert
Bypass Culvert
Buttonderry Culvert
Mountain Culvert
1985 design profile
1% Developed
1% * 2
1% * 1.5
1% - Culverts blocked
1% * 2.5

Figure 10


Flood Level Comparison at Sparks Road - 1% AEP Developed Case
High point level (m AHD)
15.00
14.00
13.00
12.00
11.00
10.00
9.00
1500
1700
1900
2100
2300
2500
2700
2900
3100
Chainage (m from F3)
Jack Grant Culvert
Bypass Culvert
Buttonderry Culvert
Mountain Culvert
1985 design profile
1% New Channel under Mountain Rd
1% Link Channel Buttonderry-Mountain (5), wider Mountain Culvert (8)
1% Developed
1% Link Channel Buttonderry-Mountain (3), wider Mountain Culvert (6)



	EX	DEV	D
WL	24.71	24.77	0.06
Q	31.60	31.40	-0.20
V	1.00	0.80	-0.20

	EX	DEV	D
WL	20.64	21.66	1.02
Q	36.50	37.00	0.50
V	0.70	2.70	2.00

	EX	DEV	D
WL	22.33	22.34	0.01
Q	63.60	63.60	0.00
V	2.30	2.30	0.00

	EX	DEV	D
WL	19.10	19.34	0.24
Q	35.30	39.30	4.00
V	0.70	1.30	0.60

	EX	DEV	D
WL	20.45	20.33	-0.12
Q	66.50	67.10	0.60
V	0.80	0.50	-0.30

	EX	DEV	D
WL	19.21	19.36	0.15
Q	2.90	3.30	0.40
V	0.40	1.40	1.00

	EX	DEV	D
WL	19.21	19.36	0.15
Q	9.00	5.40	-3.60
V	0.00	0.00	0.00

	EX	DEV	D
WL	19.21	19.36	0.15
Q	0.00	11.60	11.60
V	0.00	0.30	0.30

	EX	DEV	D
WL	20.26	20.16	-0.10
Q	66.90	67.70	0.80
V	1.40	1.00	-0.40

	EX	DEV	D
WL	25.22	25.29	0.07
Q	4.6	4.3	-0.3
V	3	0.8	-2.2

	EX	DEV	D
WL	19.10	19.34	0.24
Q	9.70	21.50	11.80
V	0.20	0.60	0.40

	EX	DEV	D
WL	19.62	19.62	0.00
Q	6.50	8.20	1.70
V	0.80	1.90	1.10

	EX	DEV	D
WL	19.62	19.62	0.00
Q	68.90	67.80	-1.10
V	0.70	0.20	-0.50

Legend

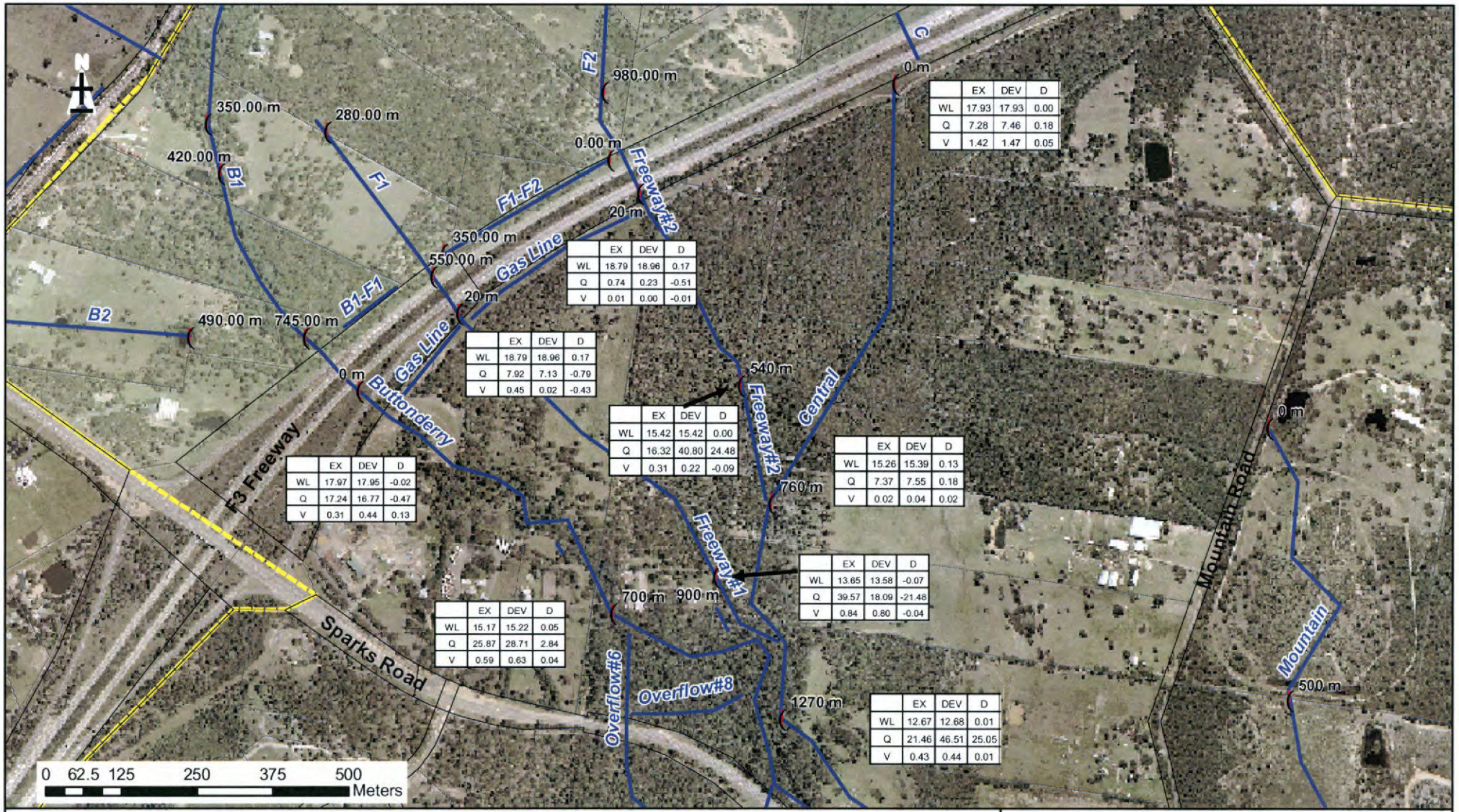
- Key Locations
- Mike 11 Network
- Roads
- Cadastre
- Precinct 14
- Full WEZ Boundary

D: Change (DEV-EX)
WL: 1% AEP Flood Level (mAHD)
Q: 1% AEP Discharge (m3/s)
V: 1% AEP Velocity (m/s)
EX: Existing conditions
DEV: Developed Conditions, Option 3A

DHI WATER & ENVIRONMENT

Figure 12

Flood Result Comparison
1% AEP Event - Precinct 14



	EX	DEV	D
WL	17.93	17.93	0.00
Q	7.28	7.46	0.18
V	1.42	1.47	0.05

	EX	DEV	D
WL	18.79	18.96	0.17
Q	0.74	0.23	-0.51
V	0.01	0.00	-0.01

	EX	DEV	D
WL	18.79	18.96	0.17
Q	7.92	7.13	-0.79
V	0.45	0.02	-0.43

	EX	DEV	D
WL	15.42	15.42	0.00
Q	16.32	40.80	24.48
V	0.31	0.22	-0.09

	EX	DEV	D
WL	17.97	17.95	-0.02
Q	17.24	16.77	-0.47
V	0.31	0.44	0.13

	EX	DEV	D
WL	15.26	15.39	0.13
Q	7.37	7.55	0.18
V	0.02	0.04	0.02

	EX	DEV	D
WL	13.65	13.58	-0.07
Q	39.57	18.09	-21.48
V	0.84	0.80	-0.04

	EX	DEV	D
WL	15.17	15.22	0.05
Q	25.87	28.71	2.84
V	0.59	0.63	0.04

	EX	DEV	D
WL	12.67	12.68	0.01
Q	21.46	46.51	25.05
V	0.43	0.44	0.01

Legend

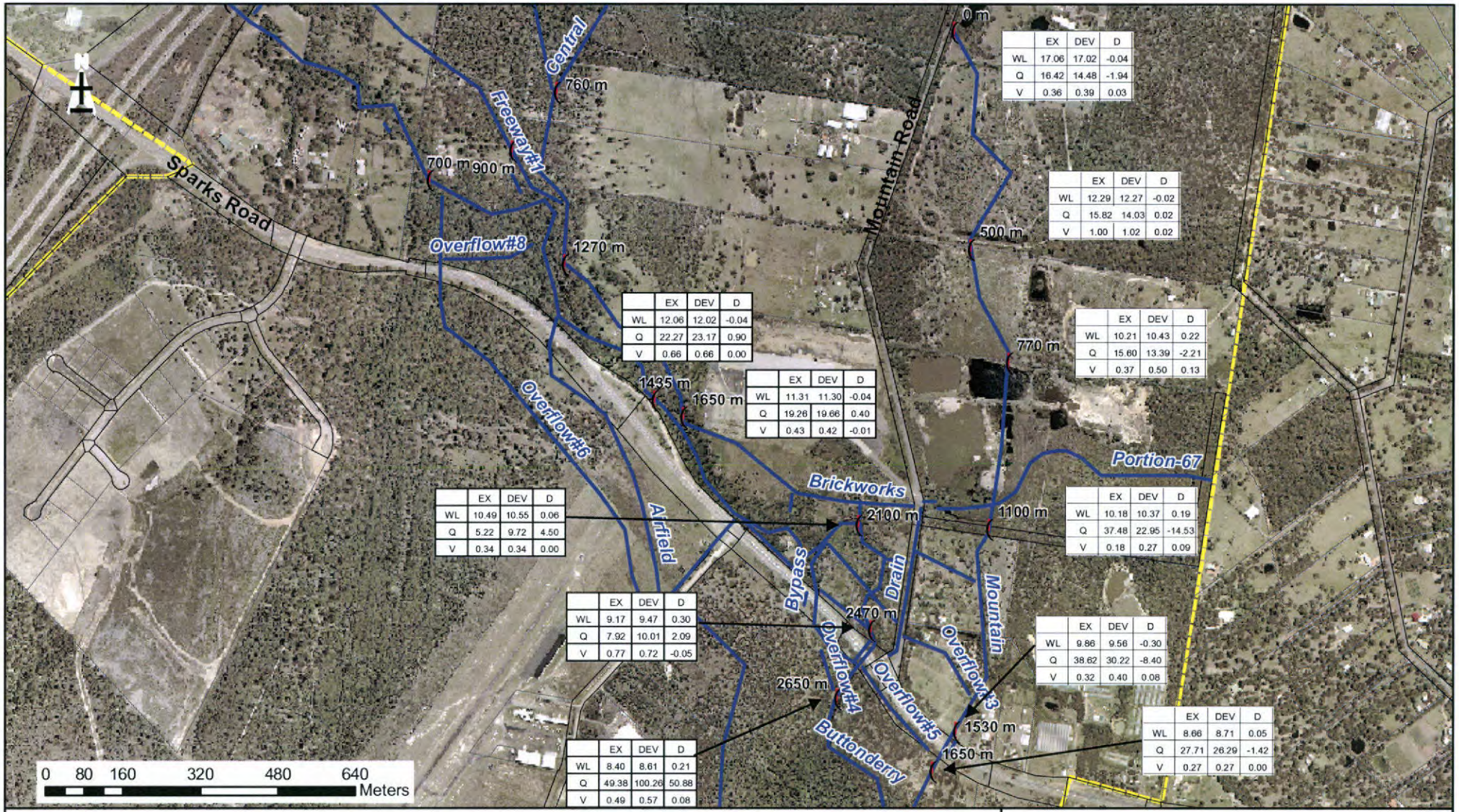
- Key Locations
- Mike 11 Network
- Roads
- Cadastre
- Precinct 14
- Full WEZ Boundary

D: Change (DEV-EX)
WL: 1% AEP Flood Level (mAHD)
Q: 1% AEP Discharge (m3/s)
V: 1% AEP Velocity (m/s)
EX: Existing conditions
DEV: Developed Conditions, Option 3A

DHI WATER & ENVIRONMENT

Figure 13

Flood Result Comparison
1% AEP Event - Buttonderry Creek,
Area Downstream F3 Freeway



	EX	DEV	D
WL	17.06	17.02	-0.04
Q	16.42	14.48	-1.94
V	0.36	0.39	0.03

	EX	DEV	D
WL	12.29	12.27	-0.02
Q	15.82	14.03	0.02
V	1.00	1.02	0.02

	EX	DEV	D
WL	12.06	12.02	-0.04
Q	22.27	23.17	0.90
V	0.66	0.66	0.00

	EX	DEV	D
WL	10.21	10.43	0.22
Q	15.60	13.39	-2.21
V	0.37	0.50	0.13

	EX	DEV	D
WL	11.31	11.30	-0.04
Q	19.26	19.66	0.40
V	0.43	0.42	-0.01

	EX	DEV	D
WL	10.49	10.55	0.06
Q	5.22	9.72	4.50
V	0.34	0.34	0.00

	EX	DEV	D
WL	10.18	10.37	0.19
Q	37.48	22.95	-14.53
V	0.18	0.27	0.09

	EX	DEV	D
WL	9.17	9.47	0.30
Q	7.92	10.01	2.09
V	0.77	0.72	-0.05

	EX	DEV	D
WL	9.86	9.56	-0.30
Q	38.62	30.22	-8.40
V	0.32	0.40	0.08

	EX	DEV	D
WL	8.40	8.61	0.21
Q	49.38	100.26	50.88
V	0.49	0.57	0.08

	EX	DEV	D
WL	8.66	8.71	0.05
Q	27.71	26.29	-1.42
V	0.27	0.27	0.00

Legend

- Key Locations
- Mike 11 Network
- Roads
- Cadastre
- Precinct 14
- Full WEZ Boundary

D: Change (DEV-EX)
WL: 1% AEP Flood Level (mAHD)
Q: 1% AEP Discharge (m3/s)
V: 1% AEP Velocity (m/s)
EX: Existing conditions
DEV: Developed Conditions, Option 3A

DHI WATER & ENVIRONMENT

Figure 14

Flood Result Comparison
1% AEP Event - Mountain Road