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Ref: 301015-03582
File: lr301015-03582gar_dba141120-Vineyards Estate, Worrigee Flooding Memo.doc

Umbene Pty Ltd
c/o Catylis Pty Ltd
PO Box 566
CHURCH POINT NSW 2105

12th November 2014

Attention: Mr Scott Frazer

Dear Scott,

VINEYARDS ESTATE DEVELOPMENT, WORRIGEE
SITE FLOOD ASSESSMENT

I refer to your request for WorleyParsons to prepare a flood assessment for the proposed development at Vineyards Estate, Worrigee. In response, we are pleased to provide in the following, our report documenting the findings of our investigation which has been undertaken in accordance with the scope of work outlined in our fee proposal dated 11th August 2014.

1. INTRODUCTION

A semi-rural residential subdivision is proposed for two lots (Lots 587 and 586, DP 1048099) on Worrigee Road at Worrigee, near Nowra. The lots fall within the Worrigee Urban Release Area (WURA) and include a property owned by Umbene P/L and an adjoining property owned by Bob and Joan Coney. The subdivision will involve the development of 116 lots of varying sizes ranging from 2,500m^2 to 12,000m^2 and an average lot area of 4,000m^2. The development is referred to as the Vineyards Estate.

A range of studies are required as part of the planning process and the outcomes of these will be the inputs to the Development Control Plan (DCP) that is to be developed for the development.

As per Shoalhaven City Council's (Council) letter to Umbene Pty Ltd dated 17th June 2014, further details are required regarding flood behaviour within the development site.

The purpose of this memorandum is to present the outcomes of a flood assessment that has been undertaken for the site in accordance with Council's requirements. The assessment has included a review of the previous flood investigations relating to regional and local flooding and provides recommendations relating to potential flood constraints affecting the proposed development.

2. STATUTORY CONTROLS

The planning instruments and guidelines which apply to the proposed development include:

- *Shoalhaven Development Control Plan* (DCP) (Shoalhaven Council, 2014)
- *Floodplain Development Manual* (NSW Government Department of Infrastructure, Planning and Natural Resources, 2005)

3. PREVIOUS FLOOD INVESTIGATIONS

WorleyParsons has previously investigated regional and local flooding behaviour at the site. The investigations included the development of a detailed two-dimensional hydrodynamic flood model using the RMA-2 software suite to simulate regional flooding of the Shoalhaven River. The regional RMA-2 model was adapted to model local catchment flooding by increasing the resolution of the model network to better capture local hydraulic features such as channels and streams.

The results of the flood investigations are presented in the following two letter reports which are presented in **Appendix A** and **B**, respectively:

i. WorleyParsons (5th October 2007), Letter to Mr Frank van den Brink of The Catylis Group titled '*Vineyards Estate, Worrigee: Summary of Flood-Related Investigations*' (**Appendix A**)

ii. Patterson Britton & Partners (6th March 2009) Letter to Mr Richard Hughes of The Catylis Group titled '*Vineyards Estate Development at Worrigee: Local Catchment Flood Study*' (**Appendix B**)

4. EXISTING FLOOD CHARACTERISTICS

4.1 Regional Flood Characteristics

The development site is located to the west of Brundee Swamp which forms part of the southern floodplain of the Shoalhaven River. During large floods there is potential for floodwaters to overtop the banks of the Shoalhaven River and inundate the adjoining floodplain, including low-lying sections of the subject site.

WorleyParsons previously developed a two-dimensional flood model of the Lower Shoalhaven River, the results of which are detailed in the letter report by WorleyParsons (Oct, 2007) included in **Appendix A**. Results of the flood modelling indicate that the site would be affected by the 100 year ARI flood.

A summary of the existing flood characteristics at the site is presented in **Table 1**. Detailed survey information for the site has been used to determine that the typical elevation of the site is between 0 and 12 mAHD.

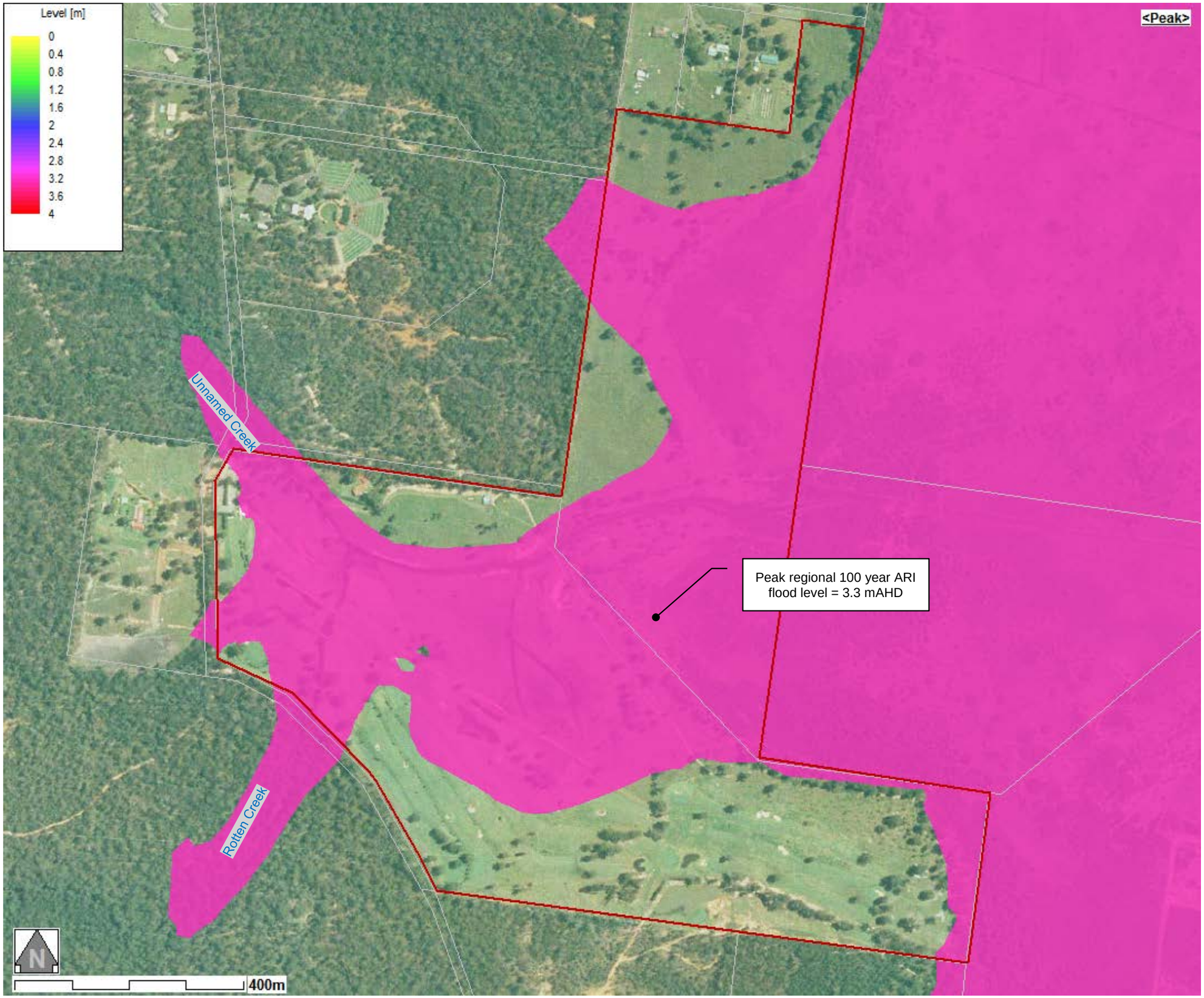
Table 1: Summary of Regional Flooding Characteristics

Flood Characteristics	100 Year ARI Design Flood
Peak Flood Level (mAHD)	3.3
Peak Flood Depth (m)	4.6

Peak flood levels at the site during regional 100 year ARI design flooding are presented in **Figure 1**. Peak flood depths at the site during regional 100 year ARI design flooding are presented in **Figure 2**.

The regional flooding results were processed to obtain flood hazard mapping according to the methodology presented in the *Floodplain Development Manual* (NSW Government Department of Infrastructure, Planning and Natural Resources, 2005). Flood hazard categories at the site during regional 100 year ARI design flooding is presented in **Figure 3**. Hydraulic categories at the site during regional 100 year ARI design flooding are presented in **Figure 4**.

FIGURE 1



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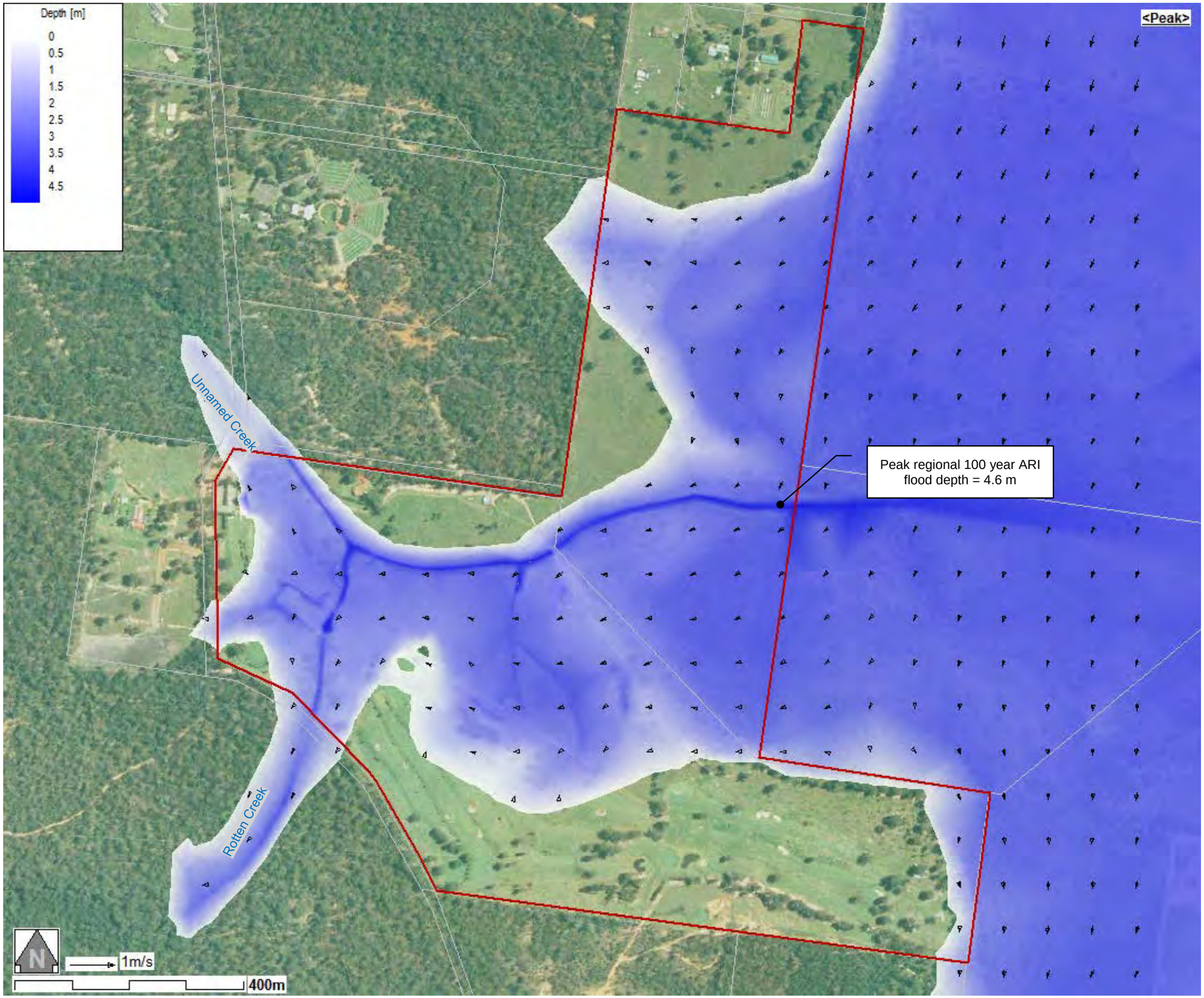
PEAK FLOOD LEVELS AT THE SITE DURING REGIONAL 100 YEAR ARI DESIGN FLOODING

FIGURE 2



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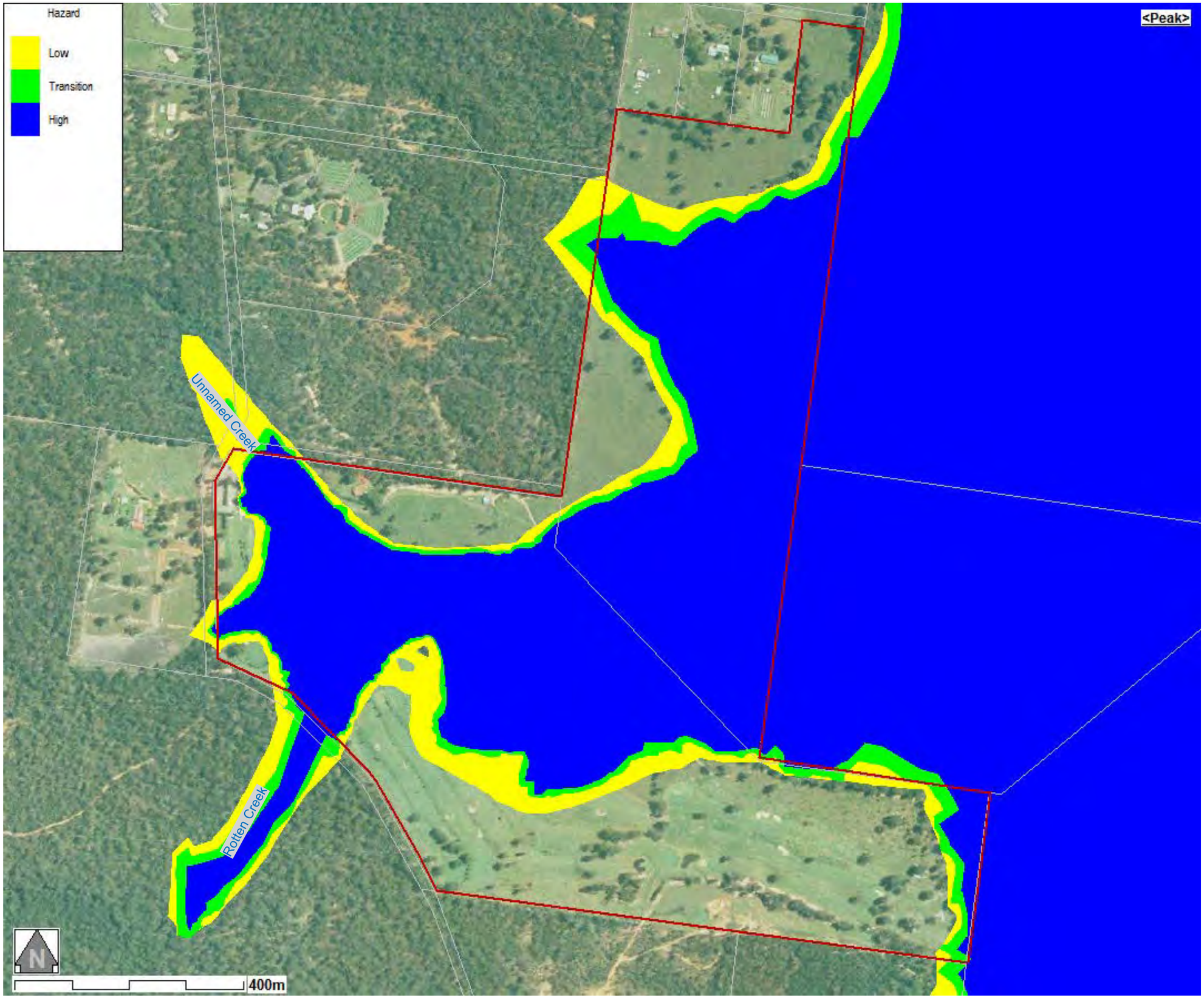
PEAK FLOOD DEPTHS AT THE SITE DURING REGIONAL 100 YEAR ARI DESIGN FLOODING

FIGURE 3



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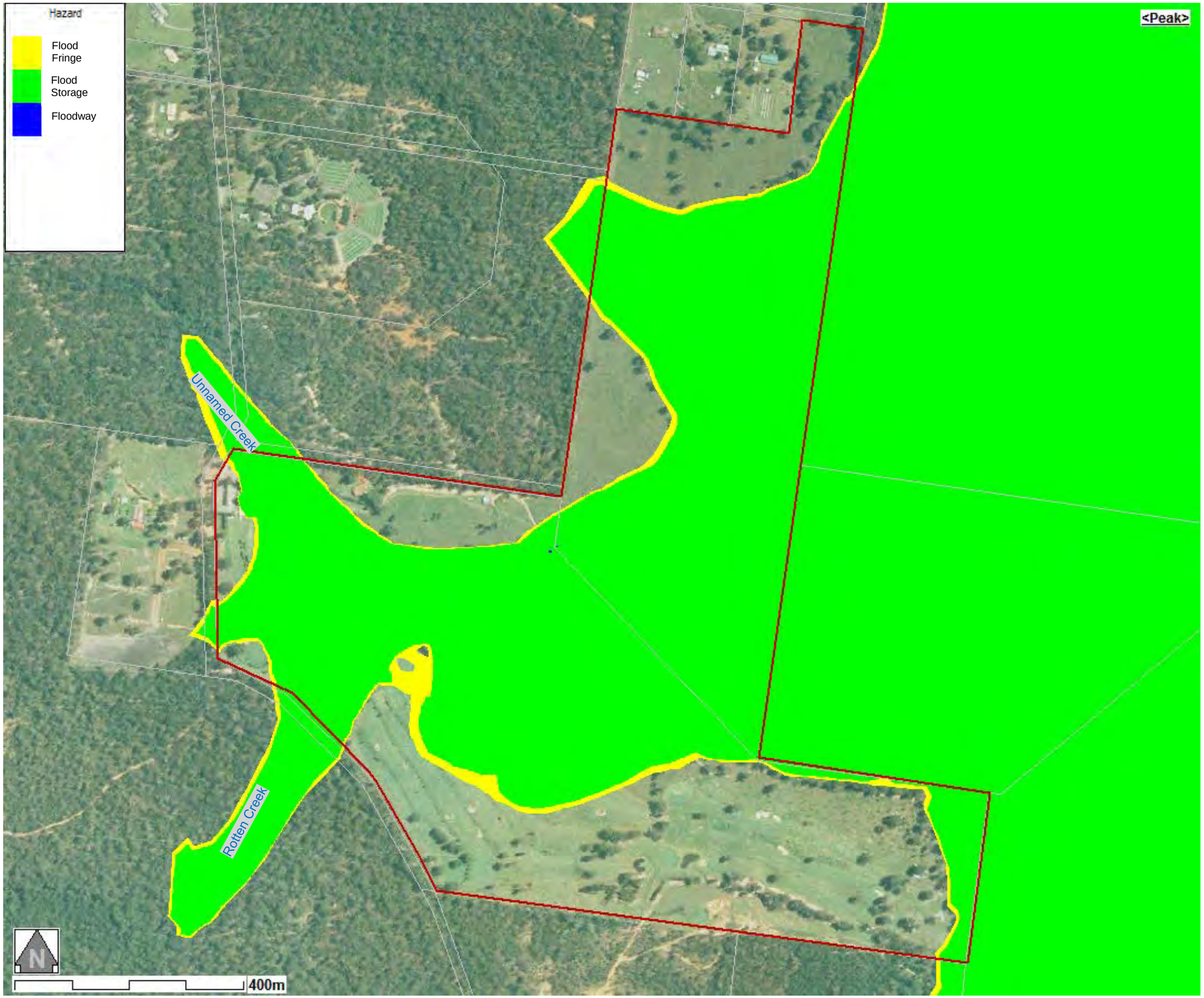
FLOOD HAZARD AT THE SITE DURING REGIONAL 100 YEAR ARI DESIGN FLOODING

FIGURE 4



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HYDRAULIC CATEGORIES AT THE SITE DURING REGIONAL 100 YEAR ARI DESIGN FLOODING

4.2 Local Flood Characteristics

In addition to regional flood modelling that considered flooding within the Lower Shoalhaven River, a two-dimensional flood model was also developed to assess flood flows within the creeks that drain through the site.

A hydrologic model was used to define outflow hydrographs from the upstream catchment extending to the north and west of the site. The extracted hydrographs were then used to define upstream boundary conditions to the local RMA-2 flood model. Downstream boundary conditions were based on low flow conditions in the Lower Shoalhaven River, that is, it was assumed that catchment flooding does not occur concurrently with local catchment flooding. A detailed outline of the modelling procedure and results are provided in the letter report included in **Appendix B**.

The results of the flood modelling for existing conditions show that the peak 100 year ARI flood level is expected to reach 2.25 mAHD at the Worrigee Road crossing of Rotten Creek. Peak flood levels at the site during local 100 year ARI design flooding are presented in **Figure 5**. Peak flood depths at the site during local 100 year ARI design flooding are presented in **Figure 6**.

Assessment of flood mapping indicates that the flood hazard varies across the site. Flood hazard at the site during local 100 year ARI design flooding is presented in **Figure 7**. Hydraulic categories at the site during local 100 year ARI design flooding are presented in **Figure 8**.

5. POTENTIAL FLOOD CONSTRAINTS

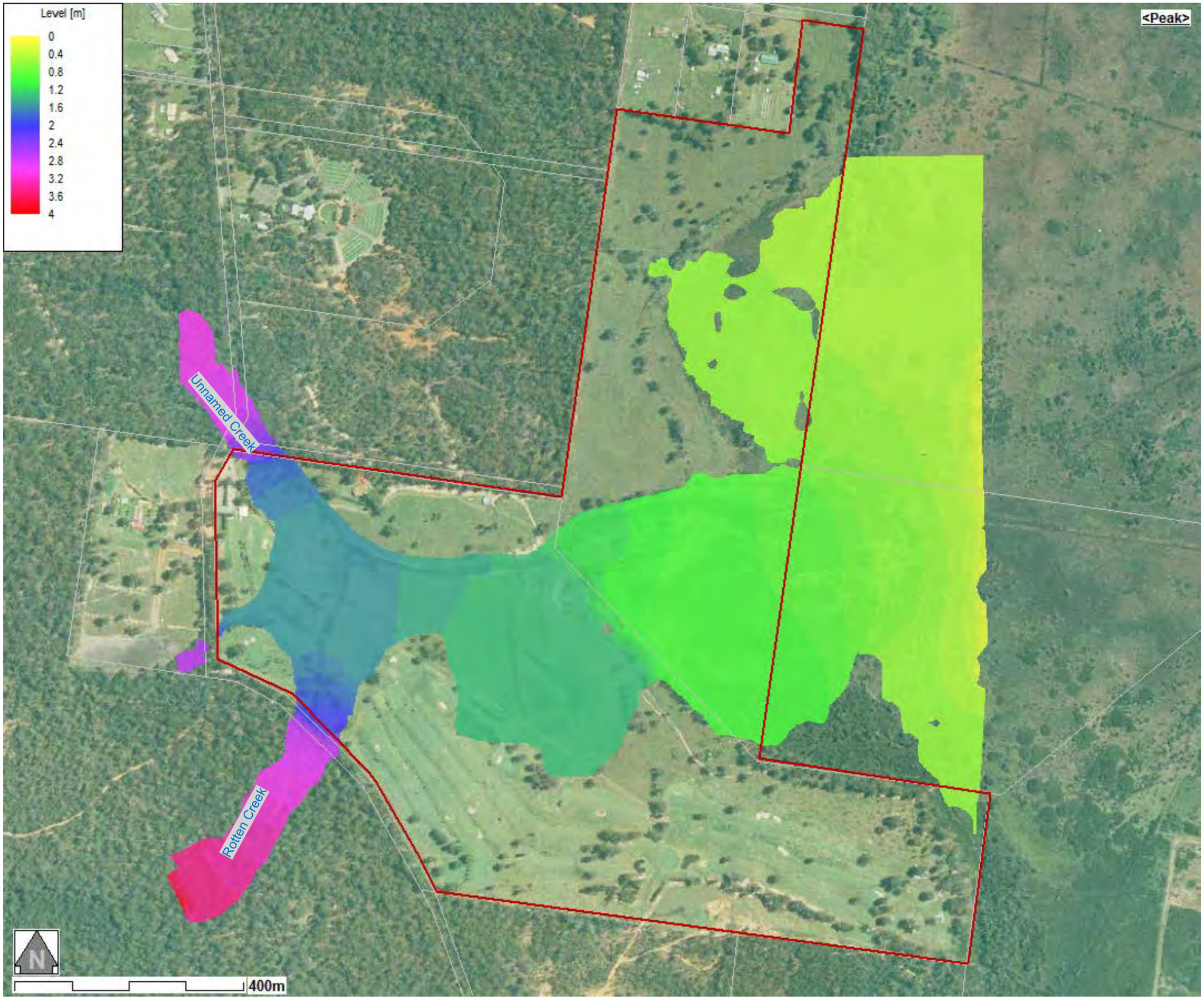
The Shoalhaven Development Control Plan (Shoalhaven Council, 2014) (the “DCP”) contains Shoalhaven Council’s Risk Management Matrix, which provides a framework for development on flood prone land. The Risk Management Matrix specifies a minimum floor level of the peak 100 year ARI flood level plus a freeboard of 0.5 metres for habitable buildings on flood prone land. As discussed in the previous section, the flood hazard and hydraulic categories vary across the site.

Any filling undertaken across the site has the potential to block the path of floodwaters carried by the streams that drain the catchments that extend to the west of the site. This may alter flood behaviour in the vicinity of the development site, which in turn may adversely impact on upstream properties and on flood conditions in the vicinity of Worrigee Road.

6. PRELIMINARY EVACUATION ASSESSMENT

During a 100 year ARI flood event in the Lower Shoalhaven River, inundation of the low-lying section of Worrigee Road (near the intersection with Stevens Road) occurs approximately 21.5 hours after the commencement of the storm event. The existing road will be cut off by floodwaters for approximately 16 hours.

FIGURE 5



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PEAK FLOOD LEVELS AT THE SITE DURING LOCAL 100 YEAR ARI DESIGN FLOODING

FIGURE 6

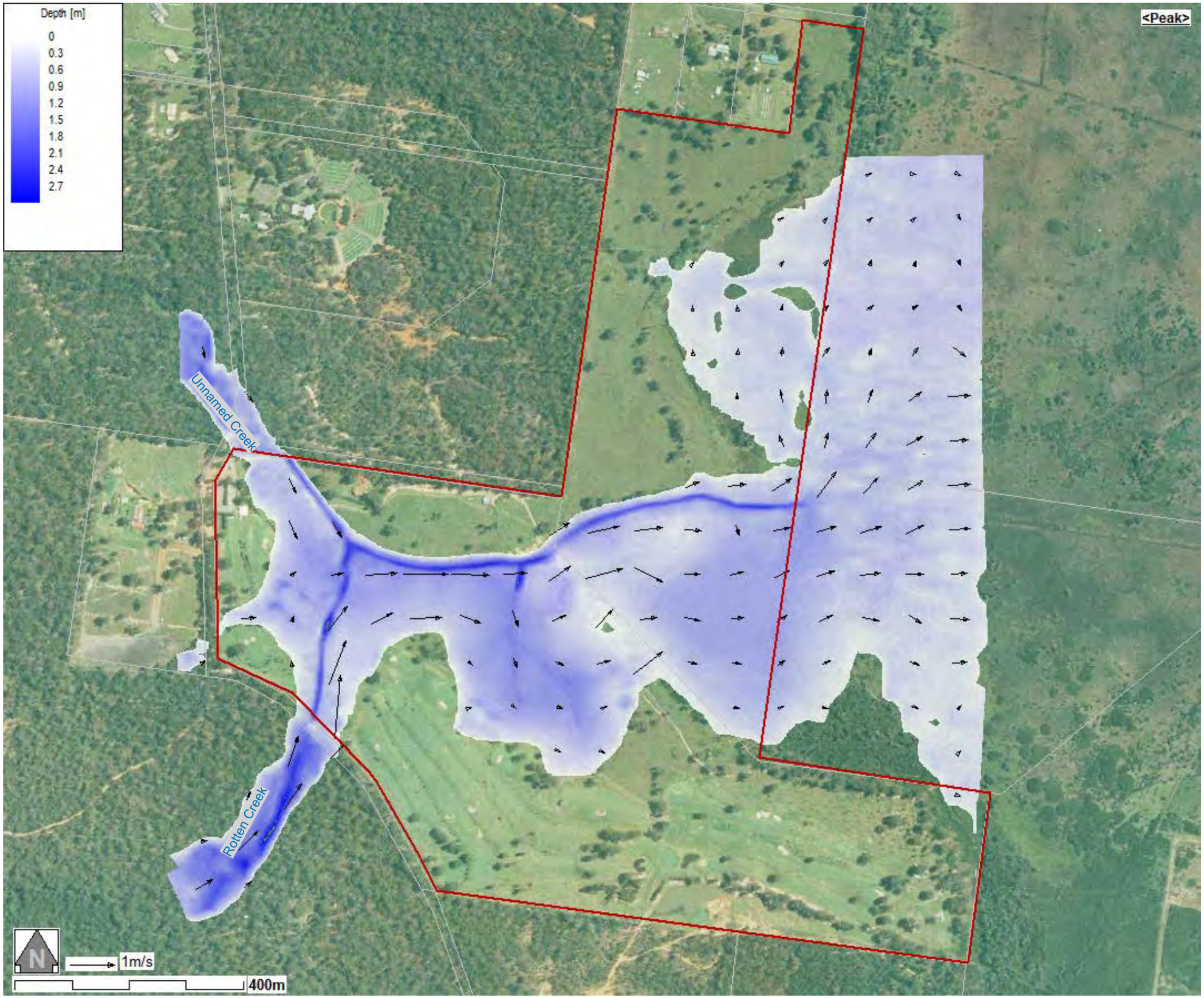

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Fig6-Depth.docx

PEAK FLOOD DEPTHS AT THE SITE DURING LOCAL 100 YEAR ARI DESIGN FLOODING

FIGURE 7

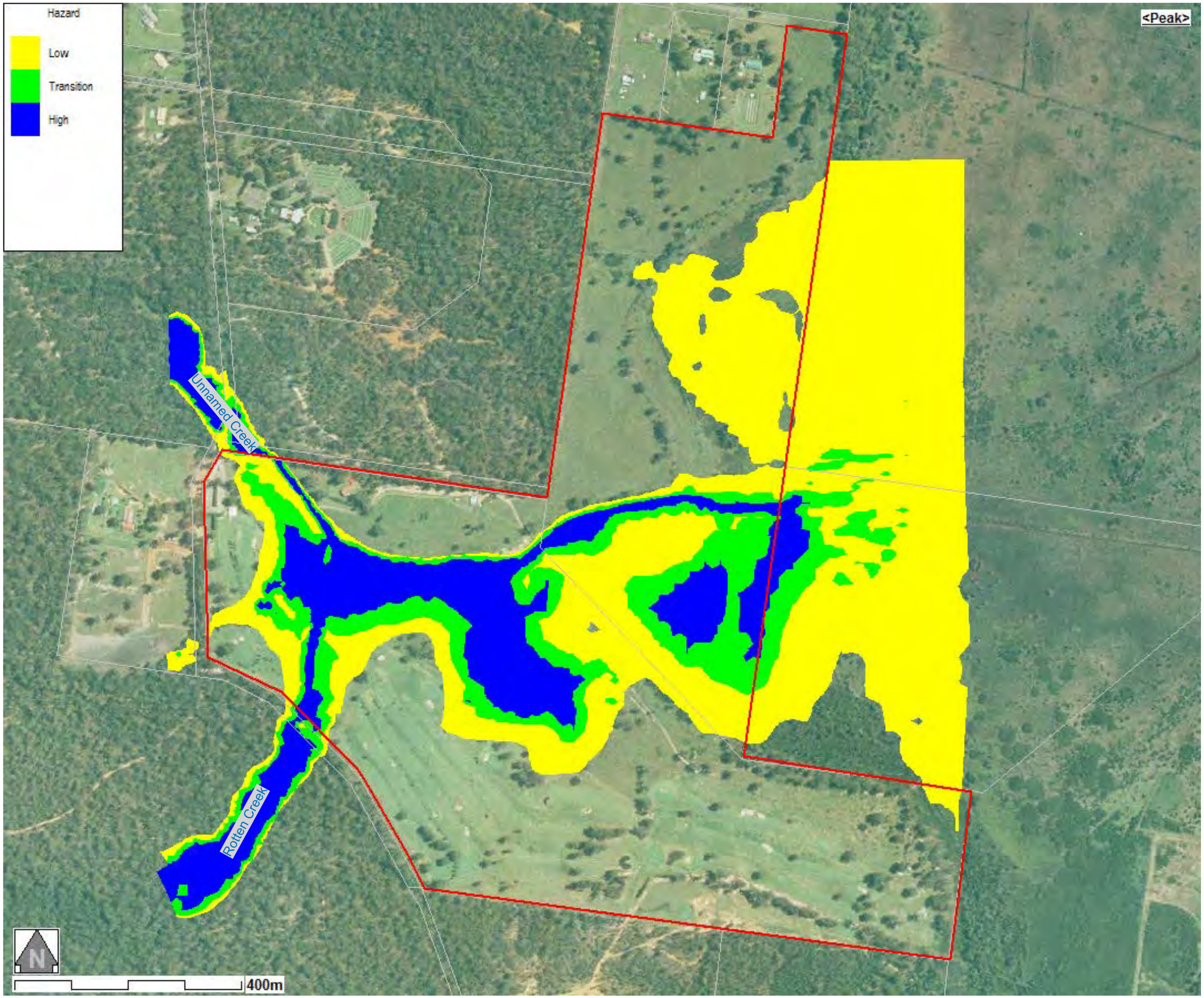

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Fig7-Hazard.docx

FLOOD HAZARD AT THE SITE DURING LOCAL 100 YEAR ARI DESIGN FLOODING

FIGURE 8

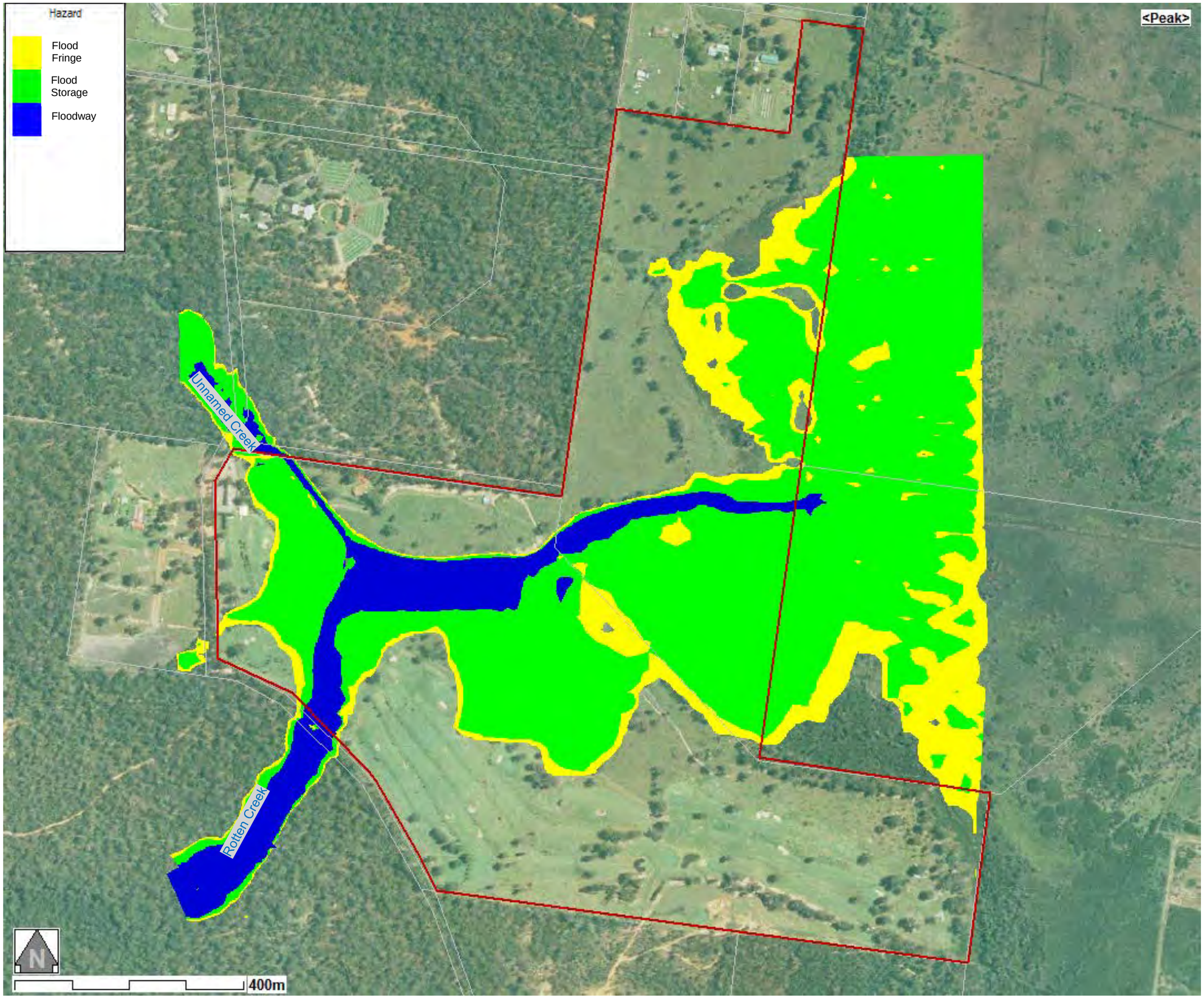

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Fig8-Categories.docx

HYDRAULIC CATEGORIES AT THE SITE DURING LOCAL 100 YEAR ARI DESIGN FLOODING

Table 2 Regional Flood Warning Assessment (Existing Site Conditions)

	Forest Road	Worrigee Road (at intersection with Forest Rd)	Worrigee Road (at intersection with Stevens Rd)	Stevens Road	Coney Road
LOWER SHOALHAVEN RIVER FLOOD SCENARIO	100 YEAR ARI				
PEAK FLOOD LEVEL *(mAHD)*	3.3				
LOW POINT IN THE ROAD *(mAHD)*^	1	2.0	1.2	1.1	1
TIME TO FLOOD PEAK*	26 hrs	26 hrs	26 hrs	26 hrs	26 hrs
TIME TO INUNDATION OF ROAD*	19.5 hrs	21.5 hrs	21.5 hrs	21.5 hrs	21.5 hrs
DURATION OF FLOODING	50 hrs	17.5 hrs	16 hrs	50 hrs	50 hrs

** timing from commencement of flood.*

^ levels based on available ALS data for that area

Table 3 Local Flood Warning Assessment (Existing Site Conditions)

	Forest Road	Worrigee Road (at intersection with Stevens Rd)
LOCAL CREEKS FLOOD SCENARIO	100 YEAR ARI	100 YEAR ARI
PEAK FLOOD LEVEL *(mAHD)*	2.25	2.9
LOW POINT IN THE ROAD *(mAHD)*^	1	1.4
TIME TO FLOOD PEAK*	3.5 hrs	3 hrs
TIME TO INUNDATION OF ROAD*	2 hrs	2 hrs
DURATION OF FLOODING	6 hrs	6 hrs

** timing from commencement of flood.*

^ levels based on available ALS data for that area

7. CONCLUSIONS AND RECOMMENDATIONS

This report has presented a summary of the outcomes of flood-related investigations that have been completed for the Vineyards Estate development at Worrigee.

The following conclusions can be drawn from the results of the regional flood modelling investigations previously undertaken by WorleyParsons (2007):

- The results of additional hydrodynamic model simulations completed using a fully two-dimensional hydrodynamic model indicate that a more reliable 100 year recurrence flood level

estimate for the site would be 3.31 mAHD. This incorporates an allowance for increases in ocean levels associated with climate change.

- Although a layout for the proposed development is yet to be developed, a preliminary assessment of 'post-development' flood behaviour indicates that filling of the site will generate only small increases in peak 100 year recurrence flood levels and flow velocities in the vicinity of the development site.

The following conclusions can be drawn from the results of the local flood modelling investigations previously undertaken by WorleyParsons (2009):

The study shows that Worrigee Road is cut by floodwaters during major storms within the catchment upstream from the site. The depth of flooding will be even greater during a major Shoalhaven River flood, reaching a depth over the roadway of greater than 2 metres at the peak of the design 100 year recurrence event.

Worrigee Road provides the only evacuation route for land that is proposed for rezoning to residential land uses. However, given the relatively short inundation time resulting from local catchment flooding, elevating the flood evacuation route to link the southern and northern parts of the site may not be necessary.

We believe that it will be necessary to complete further detailed hydrodynamic investigations once a preferred fill plan for the site is developed, and to demonstrate that the proposed development and site filling will not have a significant impact on flood conditions. A Flood Impact Assessment (FIA) report would also need to be prepared to document the findings of the modelling assessment and to serve as supporting documentation for the Development Application (DA) to Council.

8. REFERENCES

- WorleyParsons (*5 October 2007*), *'Vineyards Estate, Worrigee: Summary of Flood Related Investigations'* (**Appendix A**)
- WorleyParsons (*6 March 2009*), *'Vineyards Estate Development at Worrigee: Local Catchment Flood Study'* (**Appendix B**)
- NSW Government Department of Infrastructure, Planning and Natural Resources (2005) *Floodplain Development Manual*
- Shoalhaven Council (2014) *Shoalhaven Development Control Plan 2014*

I trust that the above report meets your information requirements.

Please feel free to contact myself or Chris Thomas on +61 2 8923 6866 should you require clarification of any item.

Yours faithfully
WorleyParsons

Reviewed by

Dov Ben-Avraham
Engineer, Water Resources

Chris Thomas
Manager, Water Resources
Australia East

WorleyParsons

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APPENDIX A

WorleyParsons (*5 October 2007*), '*Vineyards Estate, Worrigee: Summary of Flood Related Investigations*'

WorleyParsons
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Incorporating
Patterson Britton & Partners Pty Ltd

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reception@patbrit.com.au
WorleyParsons Services Pty Ltd

5 October 2007

Ref: lr5061djt071002-Vineyards Estate - Preliminary Flood Report.doc

Mr Frank van den Brink
The Catylis Group
PO Box 506
NORTH SYDNEY NSW 2059

Dear Frank

VINEYARDS ESTATE, WORRIGEE
SUMMARY OF FLOOD-RELATED INVESTIGATIONS

I refer to your proposal to develop a parcel of land located at Worrigee, south-east of Nowra, for residential purposes. The land is identified in the Nowra-Bomaderry Structure Plan as a "Future Living Area" and occupies an area of approximately 100 hectares.

As shown in **Figure 1**, the development site is located adjacent to Brundee Swamp which forms part of the southern floodplain of the Shoalhaven River. During large floods there is potential for floodwaters to overtop the banks of the Shoalhaven River and inundate the adjoining floodplain, including low-lying sections of your site.

As you would be aware, we have completed a range of flood-related investigations for the site. The investigations have aimed to:

- determine the veracity of Shoalhaven City Council's current 100 year recurrence flood level estimate for the site; and,
- assess the potential for development of the land to adversely impact on flood behaviour during large Shoalhaven River floods.

Accordingly, we are pleased to provide in the following a summary of the outcomes of the investigations that we have completed to-date. It is understood that this information will be used as a basis for assessing potential development options for the site.

1. BACKGROUND

Design flood behaviour along the Lower Shoalhaven River is currently defined using the results of hydraulic computer modelling that was originally undertaken as part of the *'Lower Shoalhaven River Flood Study'* (*1990*). The hydraulic model of the Shoalhaven River was developed using the CELLS software, which is a quasi two-dimensional modelling package that was originally developed in South Africa in the mid 1970s.

The results from the Flood Study indicate that the entrance topography at Shoalhaven Heads significantly influences flood behaviour along the river downstream of Nowra. Accordingly, separate design flood simulations were undertaken for the Flood Study using the CELLS model assuming that the entrance at Shoalhaven Heads was 'open' and 'closed'. The results of the 'closed' entrance simulations were adopted by Council for planning purposes as they provide the most conservative flood levels estimates within the lower reaches of the river.

The results of the CELLS modelling indicate that the current peak 100 year recurrence flood level at the development site is 3.48 mAHD. This peak flood level estimate was derived assuming that the Shoalhaven River entrance is 'closed' and that peak inflows from the Shoalhaven River catchment occur in conjunction with elevated ocean levels at Shoalhaven and Crookhaven Heads.

However, Appendix C of the DNR (*now DECC*) guideline document titled, *'Floodplain Risk Management Guideline No 5 – Ocean Boundary Conditions'* (*in draft, November 2004*) outlines that the initial results of research show that there is little evidence of any correlation between catchment floods and elevated ocean water levels. Accordingly, it is considered that the current design flood level estimates for the lower Shoalhaven River are overly conservative. Therefore, we have undertaken additional investigations to develop a more reliable 100 year recurrence flood level estimate for the development site in accordance with Guideline No. 5.

2. REVISED 100 YEAR RECURRENCE FLOOD LEVEL FOR DEVELOPMENT SITE

2.1 Hydrodynamic Model Development

A new, fully two-dimensional hydrodynamic model of the southern floodplain of the Shoalhaven River was developed for the project. It was considered that a fully two-dimensional model would more reliably simulate flood behaviour in the vicinity of the proposed development. Furthermore, the development itself can be more reliably represented in such a model. The hydrodynamic model was developed using the RMA-2 software. The layout of the RMA-2 model is shown in **Figure 2**.

The RMA-2 model was used to simulate the 100 year recurrence flood for both the 'open' and 'closed' Shoalhaven River entrance conditions. The results generated by the RMA-2 model were verified against the results generated by the existing CELLS model and were found to reproduce peak 100 year recurrence flood levels at the development site to within 40 mm. This indicates that the RMA-2 model is generating reliable estimates of design flood

behaviour in the vicinity of the development site and is suitable for more detailed flood-related investigations.

2.2 Guideline No. 5 – Ocean Boundary Conditions

As discussed, peak flood levels within the lower reaches of the river system are strongly influenced by the ocean level and entrance conditions at the time of the flood. Accordingly, it is difficult to establish a 'typical' design flood due to the various combinations of entrance, ocean level and catchment runoff conditions that could potentially occur in isolation or concurrently. That is, no two floods are exactly the same and it is difficult to define an 'standard' design flood.

In recognition of the need to provide a consistent approach to defining ocean boundary conditions for flood modelling in coastal catchments, the DNR (*now DECC*) developed a guideline document titled, *'Floodplain Risk Management Guideline No 5 – Ocean Boundary Conditions'* (*in draft, November 2004*). Guideline No 5 provides advice on the derivation of appropriate ocean boundary conditions for a variety of ocean entrance types.

Guideline No. 5 has been applied to a number of coastal catchments throughout NSW. This includes Burrill Lake, which is located within the Shoalhaven City Council Local Government Area.

2.3 Hydrodynamic Model Results

The verified RMA-2 model was used to simulate a range of design floods in accordance with recommendations outlined in DECC's Guideline No. 5 to develop a revised 100 year recurrence flood level estimate for the site. This involved developing a 'design envelope' by using the highest peak flood level generated from flood modelling that was undertaken assuming:

- a large design flood (*e.g., the 100 year recurrence flood*) occurs during a normal (*neap*) tidal cycle; and,
- a small design flood (*e.g., the 10 year recurrence flood*) occurs in conjunction with elevated ocean levels (*i.e., 2.6 mAHD*).

For both design flood simulations it was assumed that the Shoalhaven River entrance remained closed throughout the flood in order to provide a conservative estimate of peak flood levels in the vicinity of the development site. The peak results from both flood simulations were combined to produce the final 100 year recurrence design envelope for the Lower Shoalhaven River.

Peak floodwater depths and velocity vectors were extracted from the design flood envelope and are presented in **Figure 3**. **Figure 3** indicates that the lower-lying sections of the site would be inundated at the peak of the 100 year recurrence flood. However, flow velocities across the site are predicted to remain below 0.05 m/s (*i.e., very low*).

Predicted peak flood levels in the vicinity of the development site were also extracted from the design flood envelope and show that the revised peak 100 year recurrence flood level at the development site is predicted to be **3.29 mAHD**. That is, the adoption of the methodology outlined in Guideline No. 5 reduces peak 100 year recurrence flood levels at the development site by approximately 190 mm relative to Shoalhaven City Council's current design flood level estimates (*as defined by the CELLS model*).

2.4 Impact of Sea Level Rise

Guideline No. 5 notes that no specific allowance for increases in ocean level associated with greenhouse effects should be incorporated into the derivation of the 'design envelope' as the elevated ocean levels specified in the guideline are considered to be conservative. Nevertheless, the guideline does recommend assessing the impact of further increases in peak ocean levels as part of a sensitivity analysis.

Accordingly, additional hydrodynamic model simulations were completed to assess the sensitivity of the predicted 100 year recurrence flood level at the site to increases in ocean levels.

Guideline No. 5 states that median sea levels are predicted to rise by between 0.075 and 0.15 metres by 2040. In order to provide a conservative estimate of the impact of sea level rise on the development site, the flood simulations outlined in Section 2.3 were re-run assuming an increase in ocean level of 0.2 metres (*i.e., 0.05 metres above the predicted upper bound median sea level increase value*).

The results of the design flood simulations were combined to produce a revised design flood envelope for the 100 year recurrence flood. Based on this, the peak 100 year recurrence flood level at the development site, incorporating a 0.2 metre allowance for sea level increases, is predicted to be **3.31 mAHD**. That is, a 0.2 metre increase in peak ocean levels is predicted to increase peak 100 year recurrence flood levels at the site by just 0.02 metres. This shows that peak 100 year recurrence flood levels at the site are relatively insensitive to increases in ocean levels.

Nevertheless, it is recommended that a peak 100 year recurrence flood level of **3.31 mAHD** should be adopted for the site.

3. IMPACT OF FILLING OF THE DEVELOPMENT SITE ON LOCAL FLOOD BEHAVIOUR

2.1 Indicative Fill Plan

As discussed, lower-lying sections of the development site are predicted to be inundated at the peak of the 100 year recurrence flood. Accordingly, it will be necessary to undertake selected filling across the land to maximise the development potential and so that a suitable building platform can be constructed to meet Shoalhaven City Council's minimum floor level requirement. Council's DCP No. 106 requires that the floor level of any new residential development be at least 500 mm above the peak 100 year recurrence flood level.

A development layout and associated fill plan for the development is yet to be prepared. However, in order to provide a conservative initial assessment of the potential for filling across the site to impact on existing flood behaviour, the indicative fill plan shown in **Figure 4** was adopted. It should be recognised that the fill plan shown in **Figure 4** is likely to significantly over-estimate the extent of filling that will be completed to accommodate future residential development across the site. Accordingly, we consider that it will be necessary to complete additional modelling once a more reliable fill plan is developed for the site.

2.2 Impact of Filling on Local Flood Behaviour

The hydrodynamic model that was developed to define 'existing' flood behaviour in the vicinity of the development site, was updated to reflect the fill proposal shown in **Figure 4**. The modified model was then used to re-simulate the design 100 year recurrence flood for 'post-development' conditions. The magnitude of any changes in flood behaviour arising from the proposed filling was then established by comparing hydrodynamic model results from the 'existing' and 'post-development' scenarios.

Peak 100 year recurrence depths and velocity vectors were extracted from the results of the 'post-development' modelling and are presented in **Figure 5**. **Figure 5** indicates that the filling will prevent inundation of that section of the site where filling is proposed. However, the flood extent will remain unchanged across the remainder of the floodplain.

The predicted peak 100 year recurrence flood level for the post-development scenario was determined to be 3.32 mAHD. That is, the filling shown in **Figure 4** is predicted to increase peak 100 year recurrence flood levels in the vicinity of the site by 10 mm.

Flow velocity difference mapping was also developed to assess the impact of the floodplain filling on peak flow velocities. Difference maps are created by comparing peak flow velocity estimates at each node in the hydrodynamic model network from simulations undertaken for both 'existing' and 'post-development' scenarios. This effectively creates a contour map of predicted changes in peak flow velocities and allows easy determination of the impact of the filling on existing flow velocities.

Flow velocity difference mapping was developed for the 100 year recurrence flood and is presented in **Figure 6**. Increases in peak flow velocity are represented as different shades of red and decreases in peak flow velocity are represented as shades of blue. The white areas indicate changes in peak flow velocity of less than 0.05 m/s (*i.e., negligible changes*).

Figure 6 shows that the filling is predicted to generate a small, localised increase in peak 100 year recurrence flow velocity of 0.06 m/s. This is predicted to occur outside of the development site, however, does not extend across any existing development.

Overall, the filling shown in **Figure 4** is predicted to generate small increases in peak flood level and flow velocity. However, the magnitude of the increases are not predicted to expose any existing development to an increase in flood hazard or flood damages relative to existing conditions.

4. CONCLUSIONS

This report has presented a summary of the outcomes of flood-related investigations that have been completed for the Vineyards Estate development at Worrigee.

The following conclusions can be drawn from the results of the investigations:

- Shoalhaven City Council's current 100 year recurrence flood level estimate for the development site is 3.48 mAHD. This is considered to be overly conservative.
- The results of additional hydrodynamic model simulations completed using a fully two-dimensional hydrodynamic model indicate that a more reliable 100 year recurrence flood level estimate for the site would be 3.31 mAHD. This incorporates an allowance for increases in ocean levels associated with climate change.
- Although a layout for the proposed development is yet to be developed, a preliminary assessment of 'post-development' flood behaviour indicates that filling of the site will generate only small increases in peak 100 year recurrence flood levels and flow velocities in the vicinity of the development site.

Accordingly, it is considered that development of the site, incorporating filling up to the limit shown in **Figure 4**, could proceed and would not produce any unreasonable impacts on existing flood behaviour.

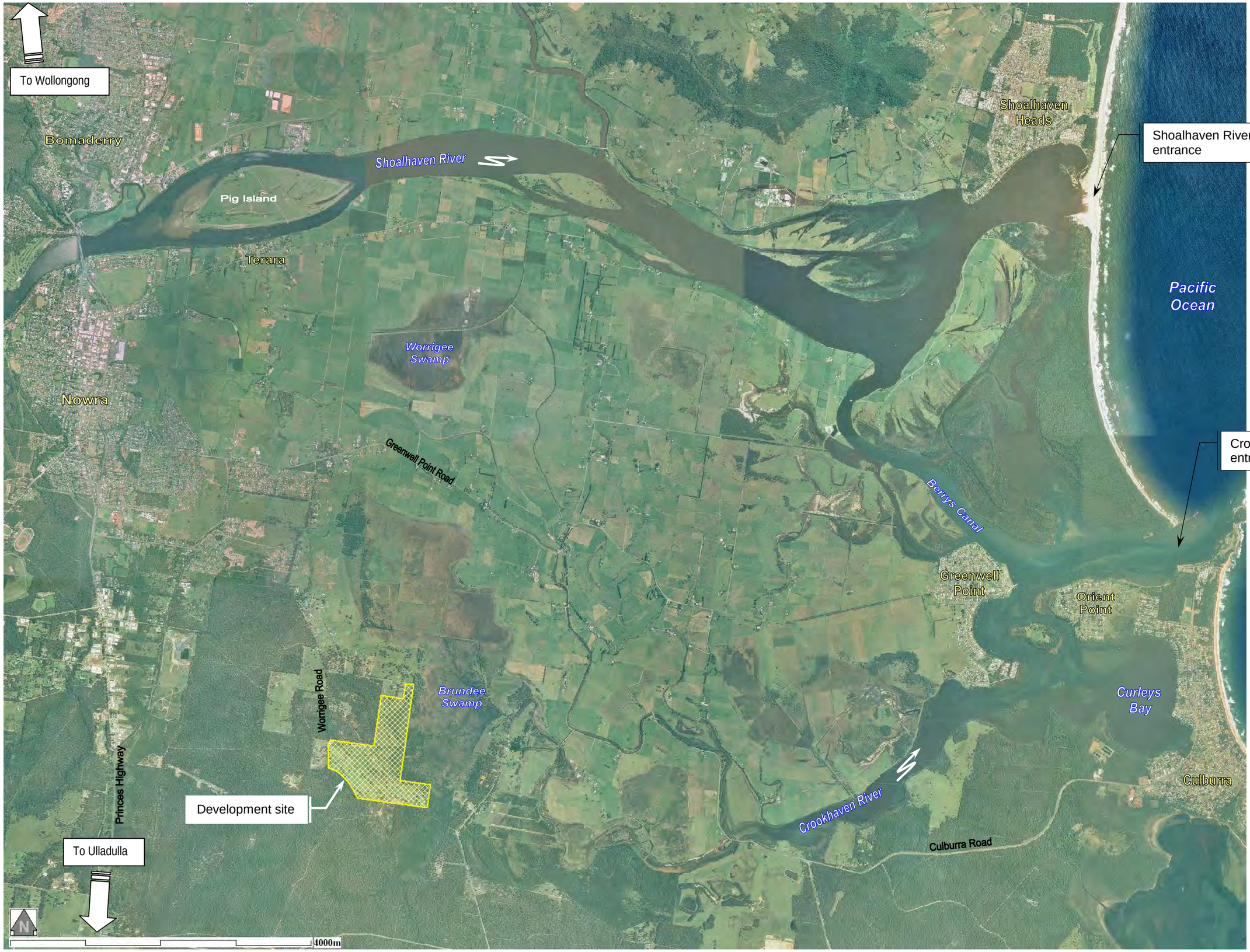
Nonetheless, we believe that it will be necessary to complete further detailed hydrodynamic investigations once a preferred fill plan for the site is developed. Furthermore, the outcomes of the more detailed investigations will need to be documented in a bound Flood Impact Assessment report in a format suitable for submission to Council. We would be happy to proceed with these more detailed investigations once a fill plan for the site has been finalised.

We trust that the above report addresses your needs. Please feel free to contact Chris Thomas or myself should you require any further information.

Yours faithfully
WorleyParsons

David Tetley
Project Engineer
WorleyParsons

FIGURE 1



LEGEND

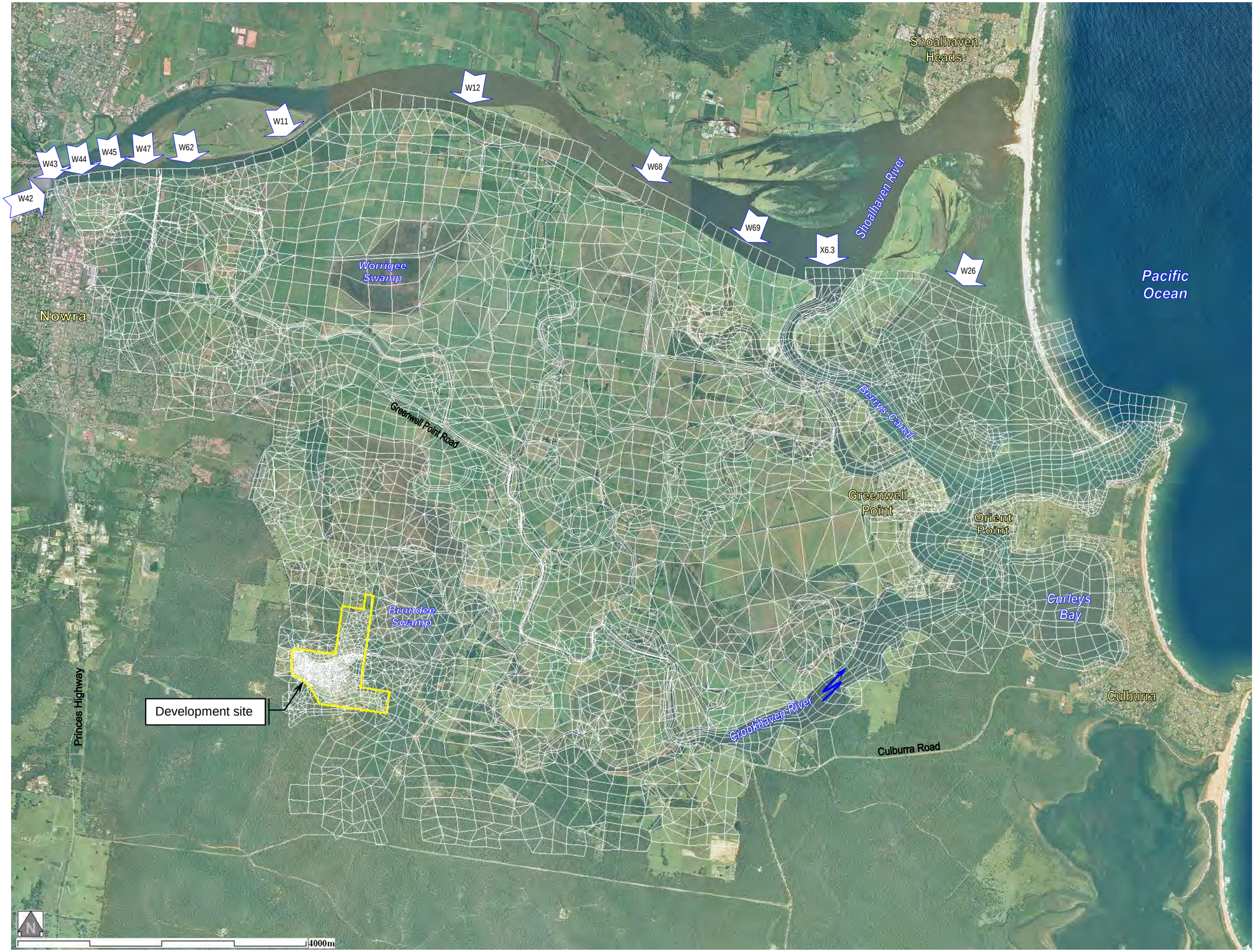
Development site

NOTES *Aerial photography dated 2005*

Patterson Britton
& Partners Pty Ltd
Rp6315-Vineyards Estate FS
Fig1-Location.doc

LOCATION OF THE PROPOSED DEVELOPMENT SITE

FIGURE 2



LEGEND

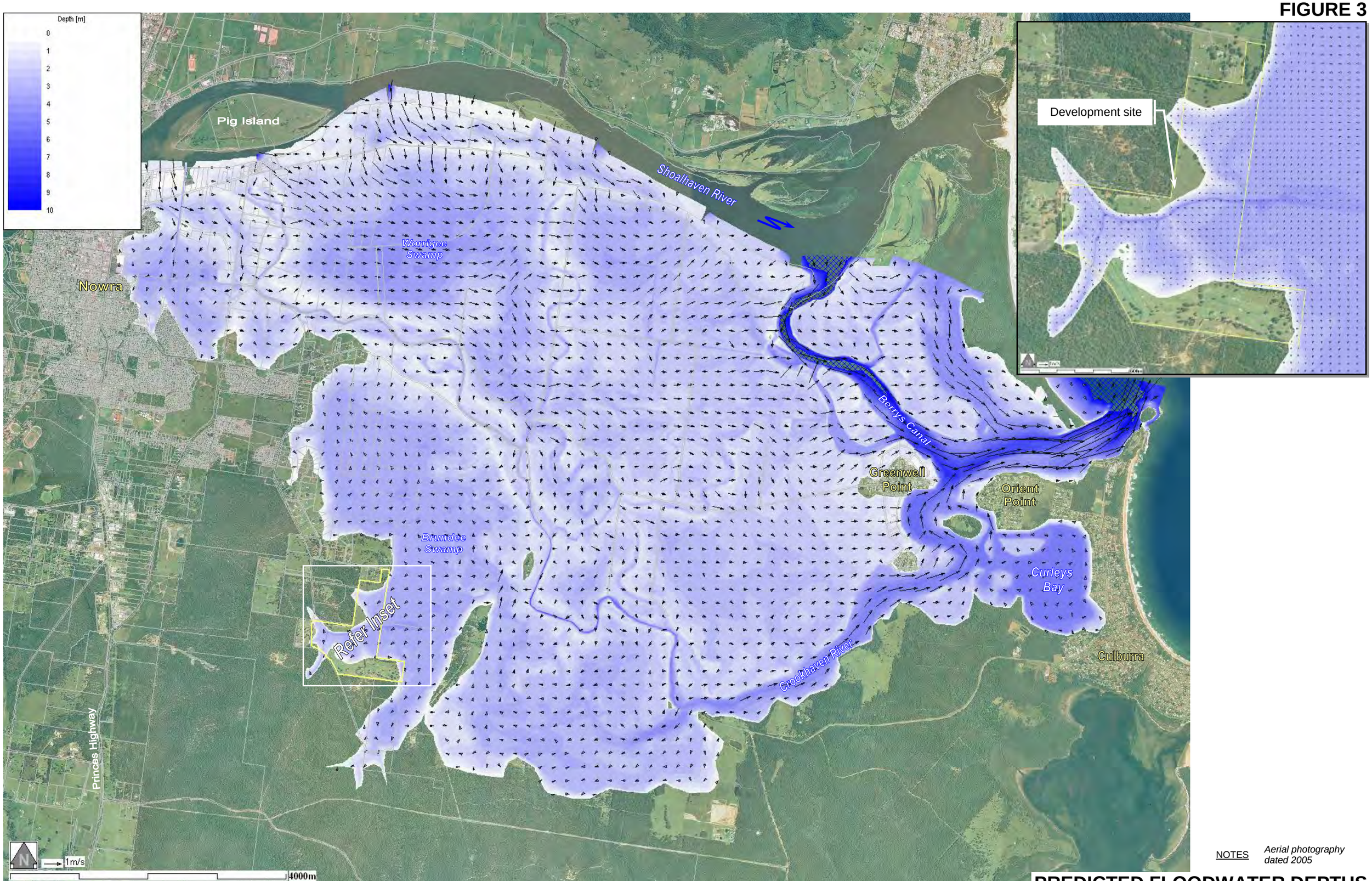
	RMA-2 model finite element
W25	Location of RMA-2 model inflow and corresponding CELLS weir number

NOTES *Aerial photography dated 2005*

Patterson Britton
& Partners Pty Ltd
Rp6315-Vineyards Estate FS
Fig-RMA Network.doc

LAYOUT OF RMA-2 MODEL NETWORK

FIGURE 3

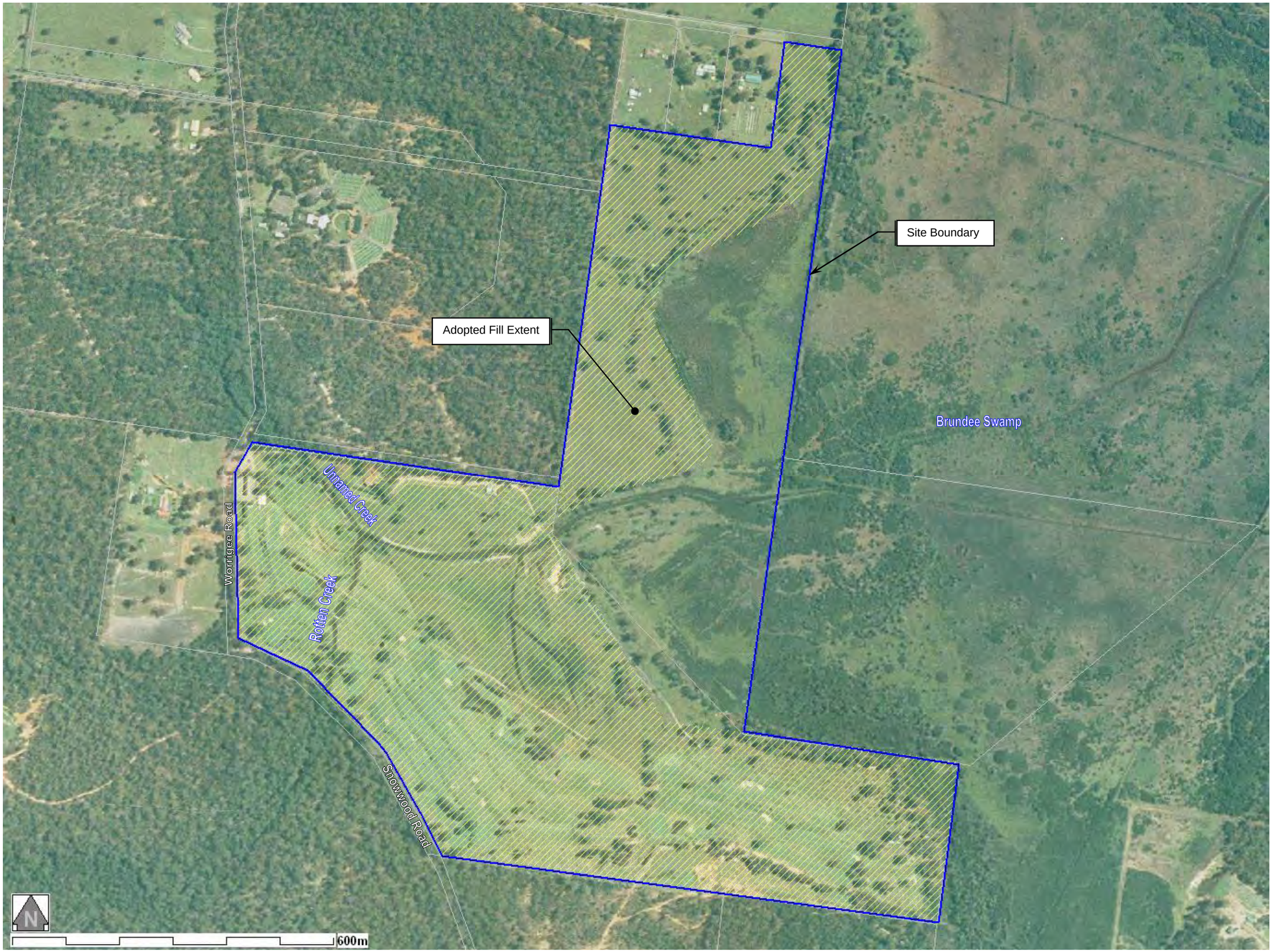


NOTES *Aerial photography dated 2005*

PREDICTED FLOODWATER DEPTHS AND VELOCITIES AT THE PEAK OF THE 100 YEAR RECURRENCE FLOOD FOR EXISTING CONDITIONS

Patterson Britton
& Partners Pty Ltd
Rp6315-Vineyards Estate FS
Fig-Existing Depths & Velocities.doc

FIGURE 4



LEGEND

Development site

Assumed extent of area to be filled to above predicted 100 year recurrence flood level

NOTES *Aerial photography dated 2005*

Cadastre dated 2002

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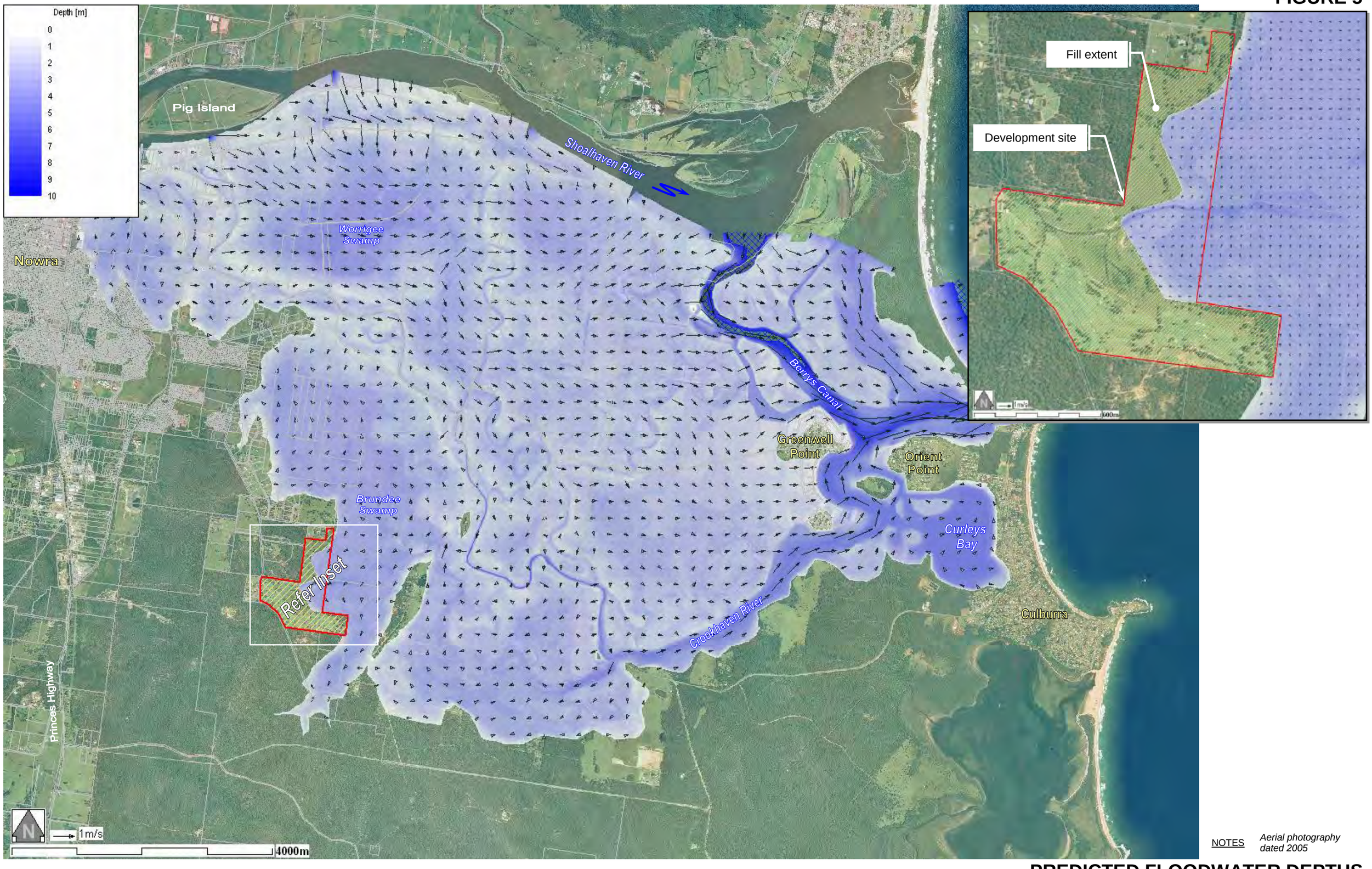
Fig-Fill Extent.doc

ADOPTED EXTENT OF FILLING FOR POST-DEVELOPMENT FLOOD SIMULATIONS

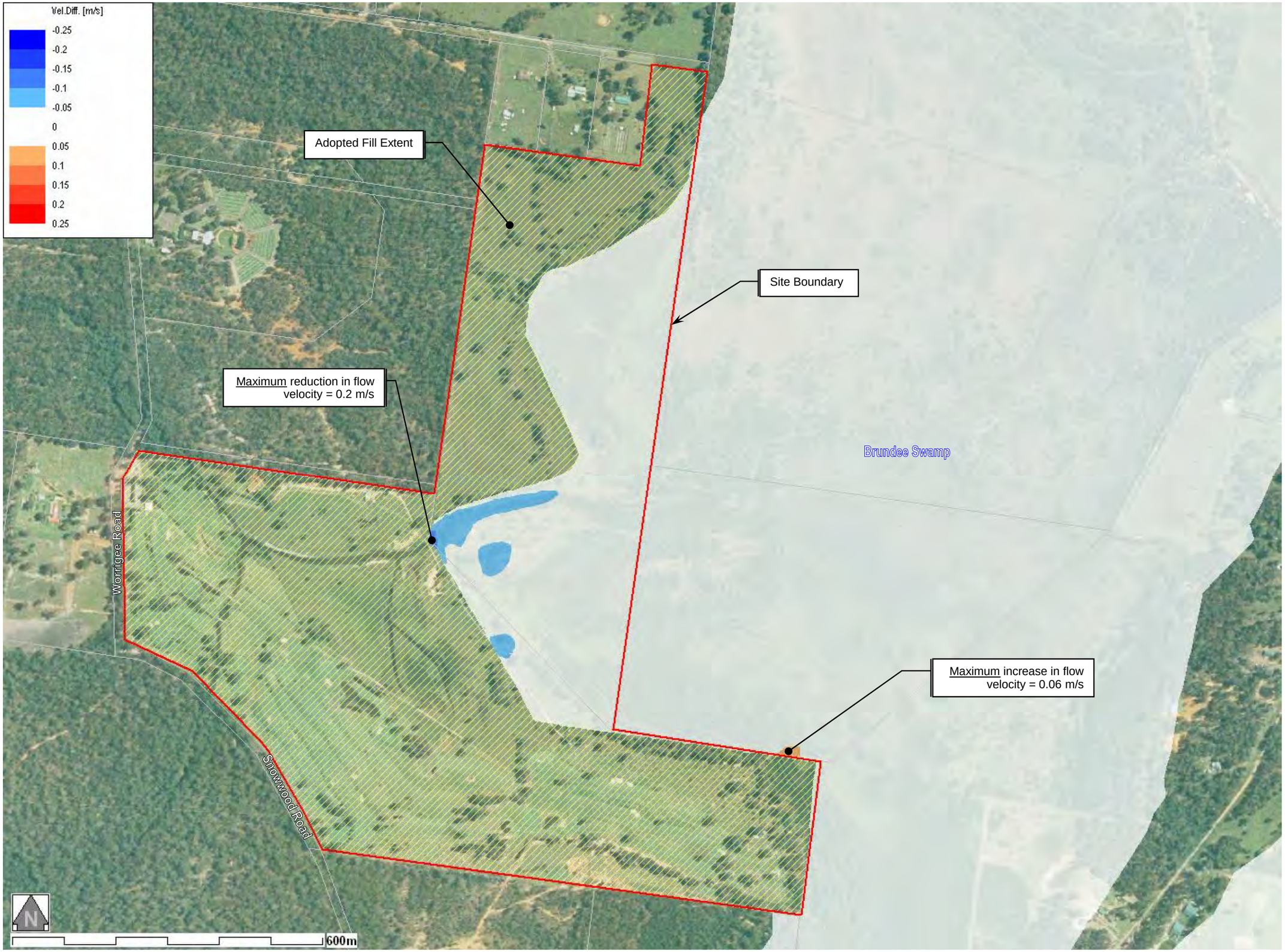
FIGURE 5



NOTES *Aerial photography dated 2005*

PREDICTED FLOODWATER DEPTHS AND VELOCITIES AT THE PEAK OF THE 100 YEAR RECURRENCE FLOOD FOR POST-DEVELOPMENT CONDITIONS

Patterson Britton
& Partners Pty Ltd
Rp6315-Vineyards Estate FS
Fig-Post-development Depths & Velocities.doc



LEGEND

Development site

Assumed extent of area to be filled to above predicted 100 year recurrence flood level

NOTES *Aerial photography dated 2005*

Cadastre dated 2002

Patterson Britton
& Partners Pty Ltd

Rp6315-Vineyards Estate FS
Fig-Fill Extent.doc

PREDICTED CHANGE IN PEAK 100 YEAR RECURRENCE FLOW VELOCITIES

WorleyParsons

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APPENDIX B

WorleyParsons (*6 March 2009*), '*Vineyards Estate Development at Worrigee: Local Catchment Flood Study*'

WorleyParsons
resources & energy

Infrastructure and Environment
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Facsimile: (02) 8923 6877
www.worleyparsons.com
WorleyParsons Services Pty Ltd
ABN 61 001 279 812

Ref: 6315/04
File: lr6315_04arm_crt090304-Vineyards Local Catchment FS.doc

Mr Richard Hughes
The Catylis Group
PO Box 506
NORTH SYDNEY NSW 2059

6th March 2009

Dear Richard,

VINEYARDS ESTATE DEVELOPMENT AT WORRIGEE LOCAL CATCHMENT FLOOD STUDY

As requested, we have undertaken investigations to assess the impact that the Vineyards Estate development could potentially have on flood flows carried by the two creeks that drain through the site to Brundee Swamp. Accordingly, I am pleased to outline in the following, the results of the hydrologic analysis and local catchment flood investigations that we have undertaken. The following report serves as our Local Catchment Flood Study for the proposed rezoning and residential development of the land.

1. BACKGROUND

Catylis plans to develop a parcel of land that is referred to as Lot 578 DP 1048099 Worrigee Road, Worrigee. The land is identified in the Nowra-Bomaderry Structure Plan as "Future Living Area 7" and occupies an area of approximately 96 hectares.

As shown in **Figure 1**, the development site is located adjacent to Brundee Swamp which forms part of the southern floodplain of the Shoalhaven River. During large floods there is potential for floodwaters to overtop the banks of the Shoalhaven River and inundate the adjoining floodplain, including low-lying areas of the site. As a result, it will be necessary to undertake some filling so that residential dwellings proposed as part of future development of the land can be constructed with floor levels above the peak 100 year recurrence flood level.

An assessment to determine the potential impact of filling of the site on Shoalhaven River flooding has been undertaken as part of a separate investigation. The results of these investigations are documented in a report prepared by Worley Parsons in October 2007 which is titled, *'Summary of Flood Related Investigations'* (*ref: lr6315_01djt071002-Vineyards Estate_Preliminary Flood Report.doc*).

The purpose of the October 2007 investigations was to determine a contemporary estimate of the100 year recurrence flood level at the site with due consideration of the relevant DECC guidelines and of the potential impact of sea level rise due to the climate change. The investigation also involved an assessment of the potential for the filling that is proposed at the site to adversely impact on flood characteristics across adjoining land.

Since then, work has been undertaken to determine the feasibility of undertaking bulk earthworks at the site and to establish an optimal area for residential development. The outcomes from the bulk earthworks investigations are documented in a letter report that was issued to Catylis on 6th June 2008.

During the bulk earthworks investigations, it became clear that any filling undertaken across the site has the potential to block the path of floodwaters carried by the streams that drain the catchments that extend to the west of the site (*refer* **Figure 1**). This may alter flood behaviour in the vicinity of the development site, which in turn may adversely impact on upstream properties and on flood conditions in the vicinity of Worrigee Road.

Accordingly, Catylis engaged Worley Parsons to investigate the potential impact of the filling proposed as part of the bulk earthworks concept on flood characteristics along the two streams that drain through the site and discharge to Brundee Swamp. The investigation was also to identify any mitigation measures that could be implemented to reduce any impacts, including reshaping of the bulk earthworks concept. This report documents the findings from those investigations.

2. HYDROLOGIC ANALYSIS

An assessment of the local catchment hydrology was undertaken to determine the peak flood flows that are discharged through the Vineyards Estate site during floods of varying severity. The catchment draining to the site extends approximately 2 kilometres to the north-west of Worrigee Road and has a total area of 791 hectares. Available aerial photography indicates that the vast majority of the catchment is densely forested.

2.1 Hydrologic Model Development

In order to determine peak flood flows that could potentially be discharged to the site, a hydrologic model of the catchment was developed. The hydrologic model was developed using the Runoff Analysis and Flow Training Simulation (*RAFTS-XP*) software package.

RAFTS-XP is a deterministic runoff routing model that simulates catchment runoff processes. It is recognised in *'Australian Rainfall and Runoff – A Guideline to Flood Estimation'* (*ARR 1998*), as one of the available tools for use in flood routing within Australian catchments. The adopted node and link arrangement for the RAFTS model is shown superimposed over the catchment plan in **Figure 1**.

As shown in **Figure 1**, the upper catchment was subdivided according to drainage lines interpreted from available aerial photography and topographic mapping. Catchment subdivision also considered the homogeneity of existing land use and vegetation cover. Sub-catchment characteristics such as area, slope, percentage imperviousness and roughness, were extracted from the mapping and incorporated within the model data-set.

Three primary waterways that drain through the proposed development site were identified. These are Rotten Creek, an "unnamed" creek that drains the northern section of the catchment, and a separate self contained sub-catchment that extends to the west of the site. **Table A** in **Attachment A** summarises the key inputs that were adopted in developing the RAFTS model.

2.2 Peak Local Catchment Flood Flows

The RAFTS model was used to simulate the design 100 year recurrence storm event for the full range of standard storm durations defined in ARR 1998. The results of the analysis were interrogated to determine the critical storm duration for the catchment draining to the Vineyards Estate development site. The 120 minute storm was identified as the critical storm for the design 100 year recurrence event.

The RAFTS model was used to simulate the standard range of design storms including the 1, 5, 10, 20, 50, 100 and 200 year recurrence events. The Probable Maximum Precipitation (PMP) event was also simulated. Peak flows generated from the modelling for the range of design events that are listed in **Table 1** for each of the three creek systems at their point of discharge to the site.

A Watershed Bounded Network Model (*WBNM Model*) was also developed in order to validate the results derived from the RAFTS model. The WBNM model was used to simulate the design 100 year recurrence event and generated a peak flow at the downstream end of the site of 118 m^3/s. The RAFTS model generated a peak 100 year recurrence flood discharge of 122 m^3/s at the same location (*i.e., at node 1.03*).

Accordingly, the closeness of the results generated by both models suggests that they reliably reflect runoff processes from the catchments that drain through the Vineyards Estate site.

Table 1 PREDICTED PEAK DESIGN STORM DISCHARGES FROM THE LOCAL CATCHMENT FOR THE THREE STREAM CORRIDORS

DESIGN STORM (*Average Recurrence Interval in years*)	ROTTEN CREEK CATCHMENT (m^3/s)	UNNAMED CREEK (m^3/s)	CATCHMENT WEST OF THE SITE (m^3/s)
RAFTS MODEL REFERENCE NODE	**1.02**	**6.01**	**5.00**
1	12.0	4.4	0.6
5	33.2	13.2	1.5
10	41.5	16.6	1.9
20	53.4	21.2	2.5
50	67.6	25.8	3.2
100	80.3	30.7	3.8
200	93.6	35.1	4.4
PMF	258	115	11

3. ASSESSMENT OF EXISTING LOCAL CATCHMENT FLOOD LEVELS

3.1 Hydraulic Model Development

A separate two-dimensional hydrodynamic flood model was developed to route local catchment flows through the development site. The model was developed using the RMA-2 software package and was based on the RMA-2 model that had been developed previously for the regional flood impact assessment. The major modification involved a change to the model network to better reflect the channels and floodplains of the streams that drain through the site.

3.2 Upstream and Downstream Boundary Conditions

In order to simulate local catchment flooding, it was necessary to define upstream and downstream boundary conditions for adoption within the RMA-2 flood model.

The upstream boundary condition was defined by the flood hydrographs generated from the RAFTS hydrologic modelling of the catchment extending to the north and west of the site.

The downstream boundary condition was based on the adoption of low flow conditions in the Shoalhaven River and the application of normal depth criteria to flows carried along the lower reaches of Rotten Creek before discharge to Brundee Swamp. A fixed downstream tailwater elevation of 0.0 mAHD was determined and applied for the local catchment flood analysis.

Hence, the local catchment flood analysis was based on the assumption that flooding in the local catchment does not occur concurrently with flooding of the lower Shoalhaven River.

3.3 Flood Modelling Results for the Existing Site Conditions

The RMA-2 flood model was used to simulate the design 100 year recurrence local catchment flood. Predicted peak flood levels for existing conditions were extracted from the results and were used to generate contours of peak flood level extending across the site. Contour mapping showing the variation in peak flood level along Rotten Creek and the Unnamed Creek, and across the low lying areas of the site, is presented in **Figure 2**.

As shown in **Figure 2**, the peak 100 year recurrence flood is predicted to reach an elevation of 2.25 mAHD at the Worrigee Road crossing of Rotten Creek. This level is higher than the road surface at this location and means that Worrigee Road is likely to be cut by floodwaters during major storms in the area. Notably, floodwaters are predicted to reach an elevation of 3.31 mAHD during a design 100 year recurrence Shoalhaven River flood (*WorleyParsons, 2009*).

Figure 3 shows the variation in floodwater depth across the site and the predicted distribution of flood flow velocity at the peak of the flood. It confirms that Worrigee Road will be overtopped at both the Rotten Creek crossing and at the Unnamed Creek crossing.

4. IMPACT OF THE DEVELOPMENT ON LOCAL CATCHMENT FLOOD CHARACTERISTICS

4.1 Description of the Proposed Development

The proposed development involves excavation of low lying areas of the floodplain and selected filling along the fringes of areas of the site that are at elevations above the predicted regional 100 year recurrence flood level (*i.e., due to flooding of the Shoalhaven River*).

A conceptual representation of the bulk earthworks proposed as part of the development is shown in **Figure 4**. As shown, off-line water features will be constructed in areas where excavation is proposed and the existing creek lines in the western areas of the site will be retained.

4.1 Impact on Local Catchment Flooding

The potential impact of the fill proposal on local catchment flooding was analysed using a version of the RMA-2 flood model that was modified to reflect the post-bulk earthworks site topography. The modified RMA-2 flood model was then used to simulate the design 100 year recurrence flood for the adopted 100 year recurrence local catchment storm.

The results of the flood modelling were compiled and used to generate contour mapping of predicted peak flood levels for post development conditions. The associated mapping for peak 100 year recurrence flood levels is shown in **Figure 5**. The variation in peak 100 year recurrence floodwater depth and flow velocity is presented in **Figure 6**.

Impact on Peak Flood Levels

Flood level difference mapping was generated to assess any change in peak flood levels due to the bulk earthworks proposal outlined in **Figure 4**.

A flood level difference map provides a graphical representation of the magnitude and location of predicted changes in flood level by comparing water levels generated at each node in the hydraulic model from simulations for pre and post-development scenarios. This effectively creates a contour map of predicted post-development “affluxes” and allows easy determination of the impact of the proposed development on peak flood levels.

Figure 7 presents the flood level difference mapping. It indicates a maximum increase in the peak flood level of 0.25 metres would arise as a consequence of the proposed development.

However, this increase in predicted peak 100 year recurrence flood level is located within the development site. In fact, inspection of **Figure 7** indicates that all increases in peak flood level are located wholly within the site (*refer to red shaded areas in* **Figure 7**). Furthermore, the modelling shows that some reduction in peak flood levels is predicted along sections of the Unnamed Creek and Rotten Creek upstream from the site.

Impact on Peak Flow Velocity

Difference mapping was also generated to quantify increases in peak flow velocities that could arise as a consequence of the proposed fill scenario.

The velocity difference map that was generated for the design 100 year recurrence local catchment flood is presented in **Figure 8**. It shows that the proposed fill scenario will increase peak flow velocities within the Vineyard Estate site, and that these increase will typically occur along existing waterway corridors. Velocity increases of up to 1.5 m/s are predicted.

However, the areas where increases are predicted are generally limited to areas within the development site. A small increase in velocity is predicted just off the northern side of the site, in the vicinity of the "unnamed" creek. The modelling suggests that the proposed filling will cause an increase in velocity of 0.4 m/s at this location. However, it should be noted that this location is within the natural creek depression and does not extend across any area of existing development. Accordingly, it is not considered to present any issues in terms of associated changes in flood hazard.

5. CONCLUSIONS

The bulk earthworks plan that has been developed for the Vineyards Estate site involves filling of the local floodplains of two small creeks that drain through the development site. However, the extent of this filling has been determined with due consideration of the need to maintain the conveyance capacity of these streams so that local catchment runoff can be discharged through the site post-development.

In order to ensure that this filling doesn't adversely impact on peak flood levels upstream from the site, investigations were undertaken to assess post development flood characteristics under a local catchment flooding scenario. Based on the results of flood modelling completed for the 100 year recurrence local catchment event, it is considered that the proposed development will have no measurable impact on peak flood levels upstream from the site. Although some increases in floodwater depth and velocity area predicted, these are either located:

- on-site or just off site where no development exists; or,
- within existing waterways that carry a large proportion of the flood flow under existing conditions.

Therefore, it is considered that the proposed fill plan will not have any adverse impact on peak flood levels and flow velocities during local catchment flood scenarios.

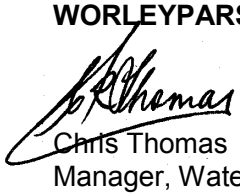
The study also shows that Worrigee Road will be cut by floodwaters during major storms within the catchment upstream from the site. The depth of flooding will be even greater during a major Shoalhaven River flood, reaching a depth over the roadway of greater than 2 metres at the peak of the design 100 year recurrence event. Worrigee Road provides the only evacuation route for land that is proposed for rezoning to residential land uses as part of Council's planned revision to the Shoalhaven Local Environmental Plan. Therefore, it would seem imperative to ensure that any development of the land incorporated an elevated flood evacuation route to link the southern and northern parts of the site so as to prevent isolation of future residents in the south during major flooding.

WorleyParsons

resources & energy

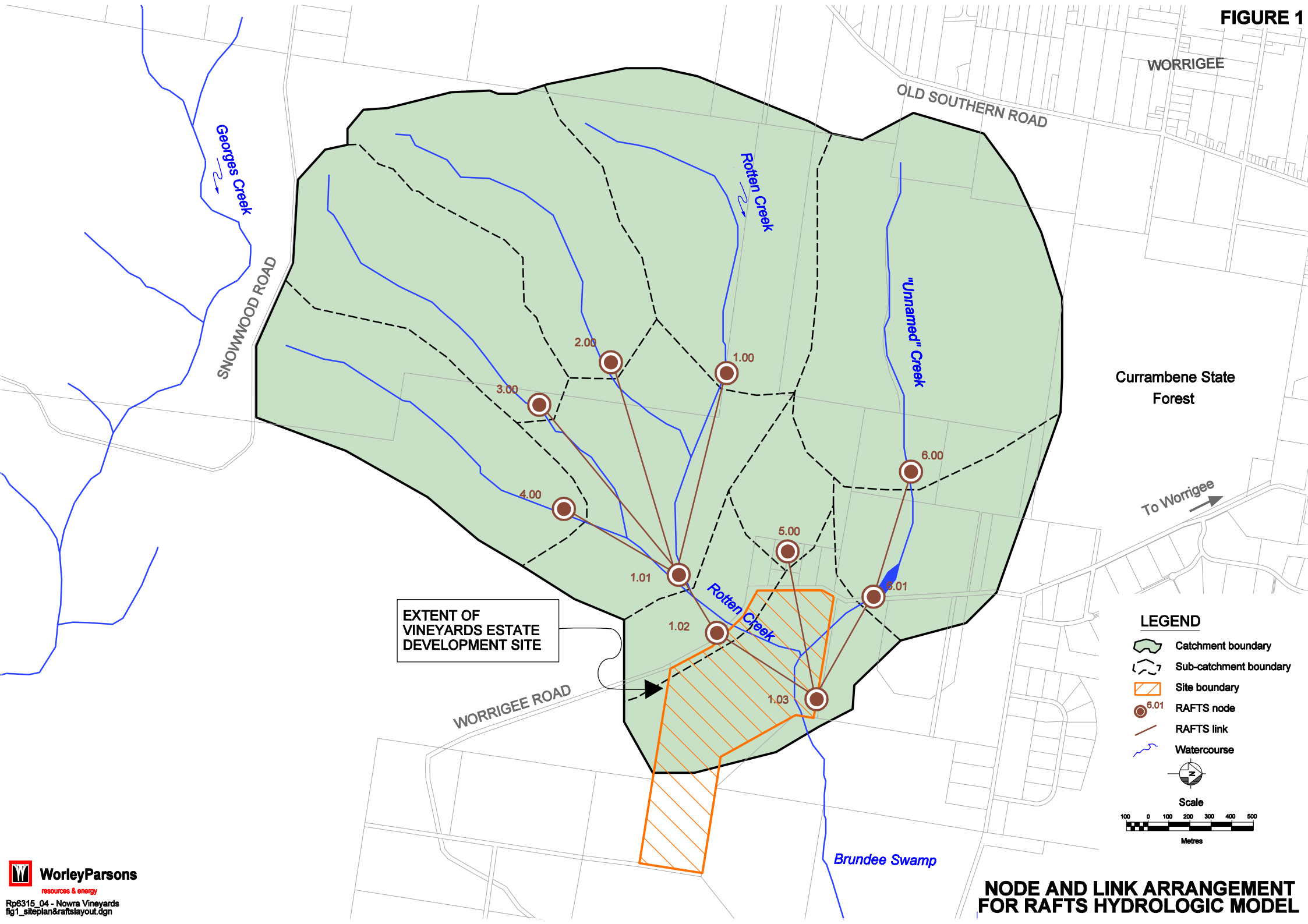
I trust that this report addresses your needs and provides sufficient flood related data to allow Catylis to refine the bulk earthworks concept for the site and to progress the rezoning approval process. Please feel free to contact me should you require any further information

Yours faithfully
WORLEYPARSONS



Chris Thomas
Manager, Water Resources

FIGURE 1



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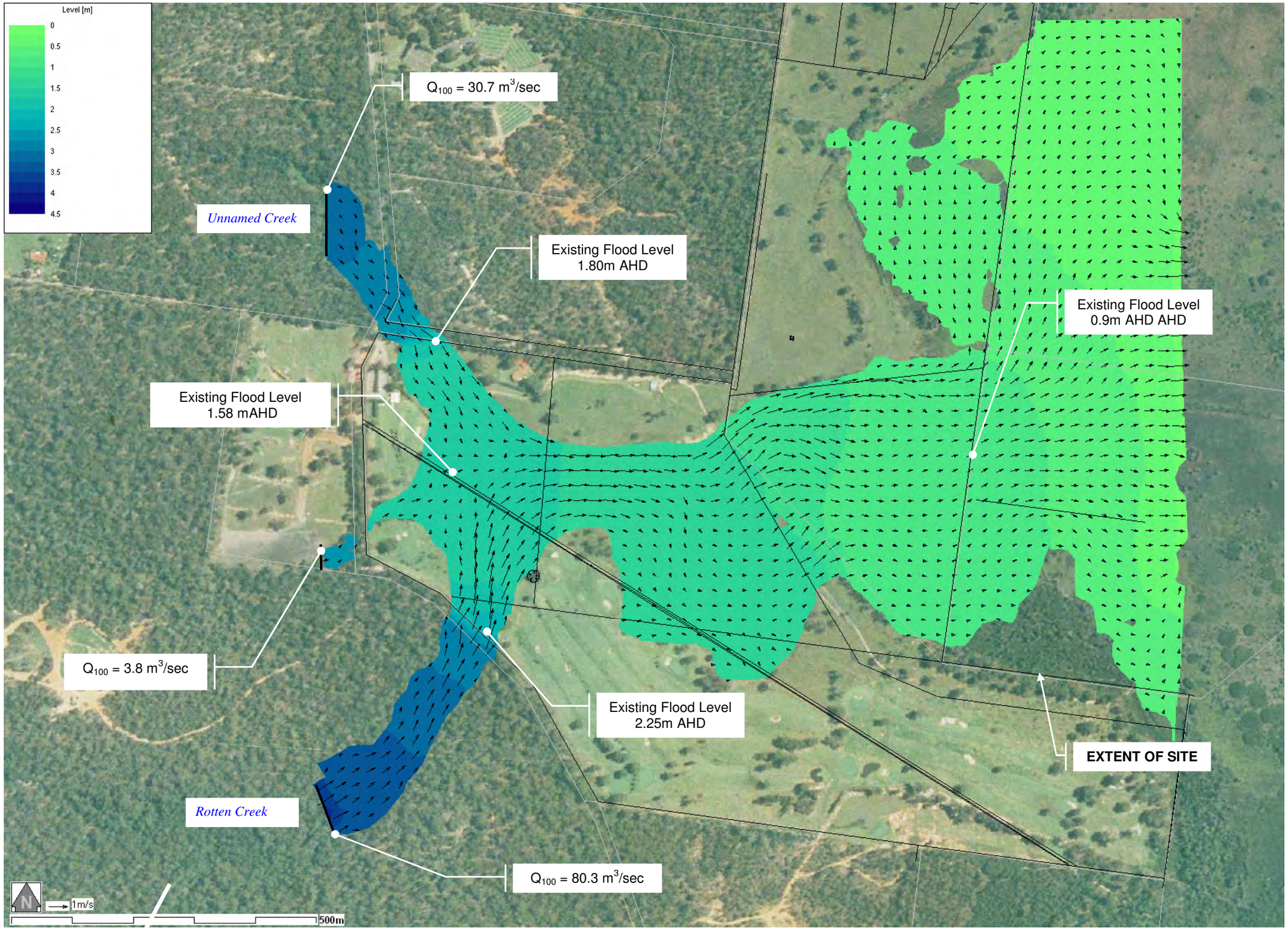
Rp6315_04 - Nowra Vineyards
fig1_siteplan&raftslayout.dgn

NODE AND LINK ARRANGEMENT FOR RAFTS HYDROLOGIC MODEL



LEGEND

- Site Boundary

N

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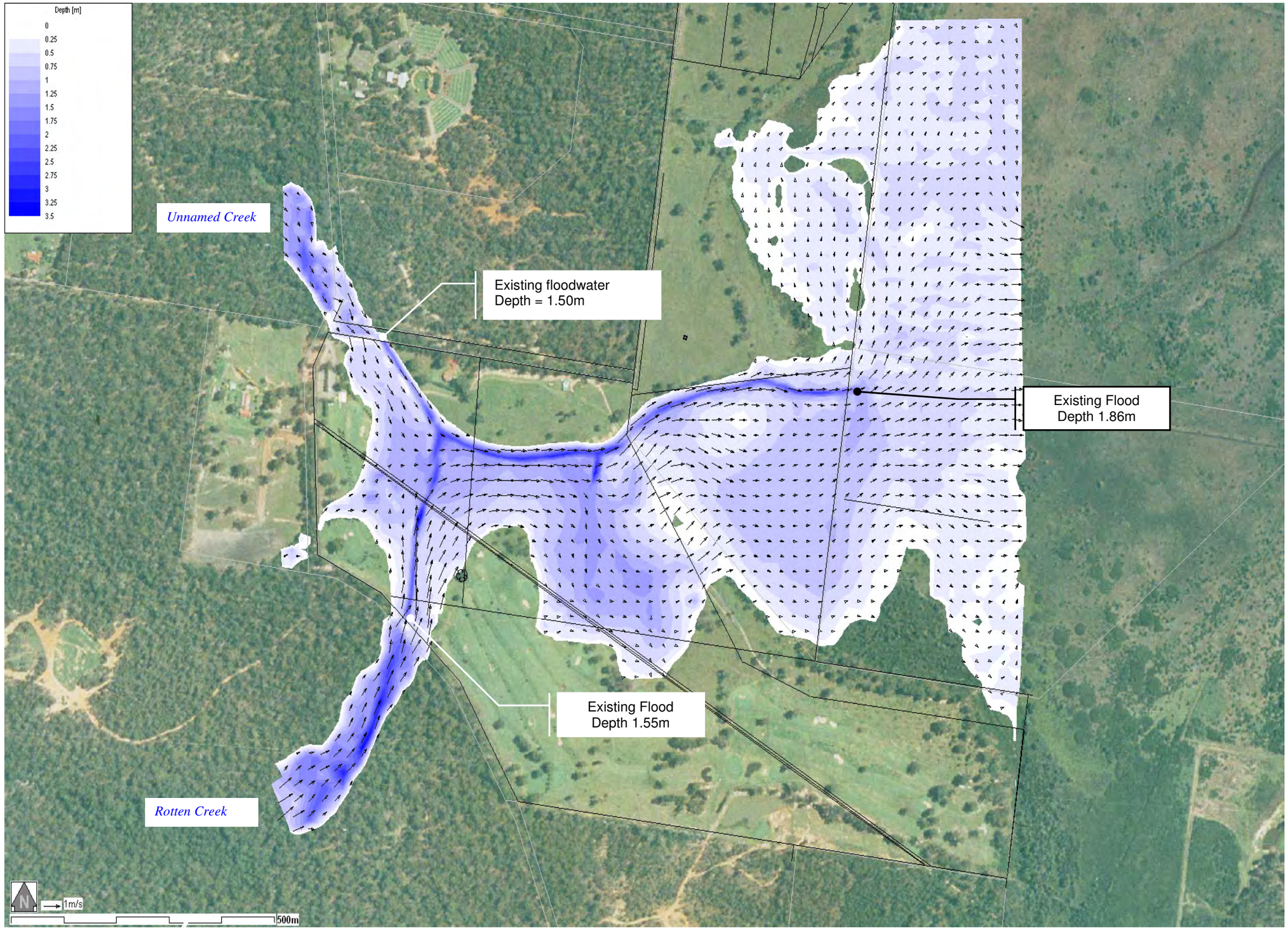
6315_04-Nowra Vineyard hydrologic investigation
Fig2-100year flood extent.doc

'EXISTING CONDITIONS' FLOOD EXTENT FOR THE LOCAL CATCHMENT 100 YEAR RECURRENCE FLOOD



LEGEND

- Site Boundary

N

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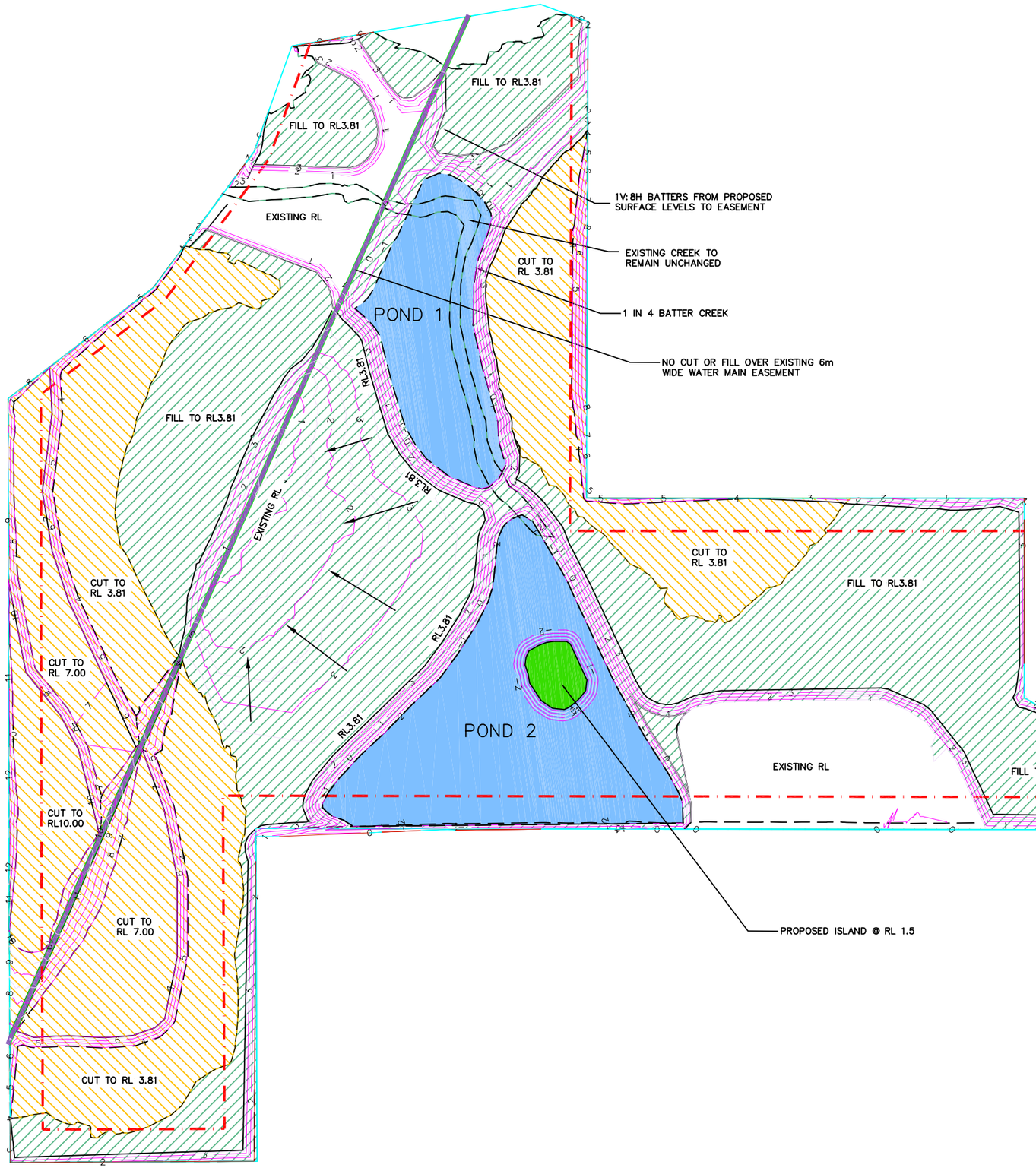
6315_04-Nowra Vineyard hydrologic investigation
Fig3-100year flood depth existing.doc

PREDICTED FLOODWATER DEPTH FOR THE LOCAL CATCHMENT 100 YEAR RECURRENCE FLOOD FOR 'EXISTING CONDITIONS'

FIGURE 4



N

POND DETAILS

	BASE RL (mAHD)	WATER DEPTH (m)	AREA (Ha)
POND 1	−1.5	2.0	4.1
POND 2	−2.0	2.0	8.0

BULK EARTHWORKS VOLUMES

TOTAL CUT	−648,000m]	
TOTAL FILL	724,000m]	
BALANCE	76,000m]	FILL

TOTAL DEVELOPABLE AREA = 44.1Ha

BASED ON:

- AREA ABOVE RL 3.81mAHD
- NO DEVELOPMENT OVER WATER MAIN CORRIDOR
- NO DEVELOPMENT IN APZ

LEGEND

- EXISTING SURFACE CONTOUR (1m INTERVAL)
- PROPOSED SURFACE MINOR CONTOUR (0.5m INTERVAL)
- PROPOSED SURFACE MAJOR CONTOUR (1.0m INTERVAL)
- PROPOSED TOP OF BATTER
- PROPOSED BOTTOM OF BATTER
- PROPOSED ASSET PROTECTION ZONE

0 100 200 300m

1:3000 (A1) 1:6000 (A3)

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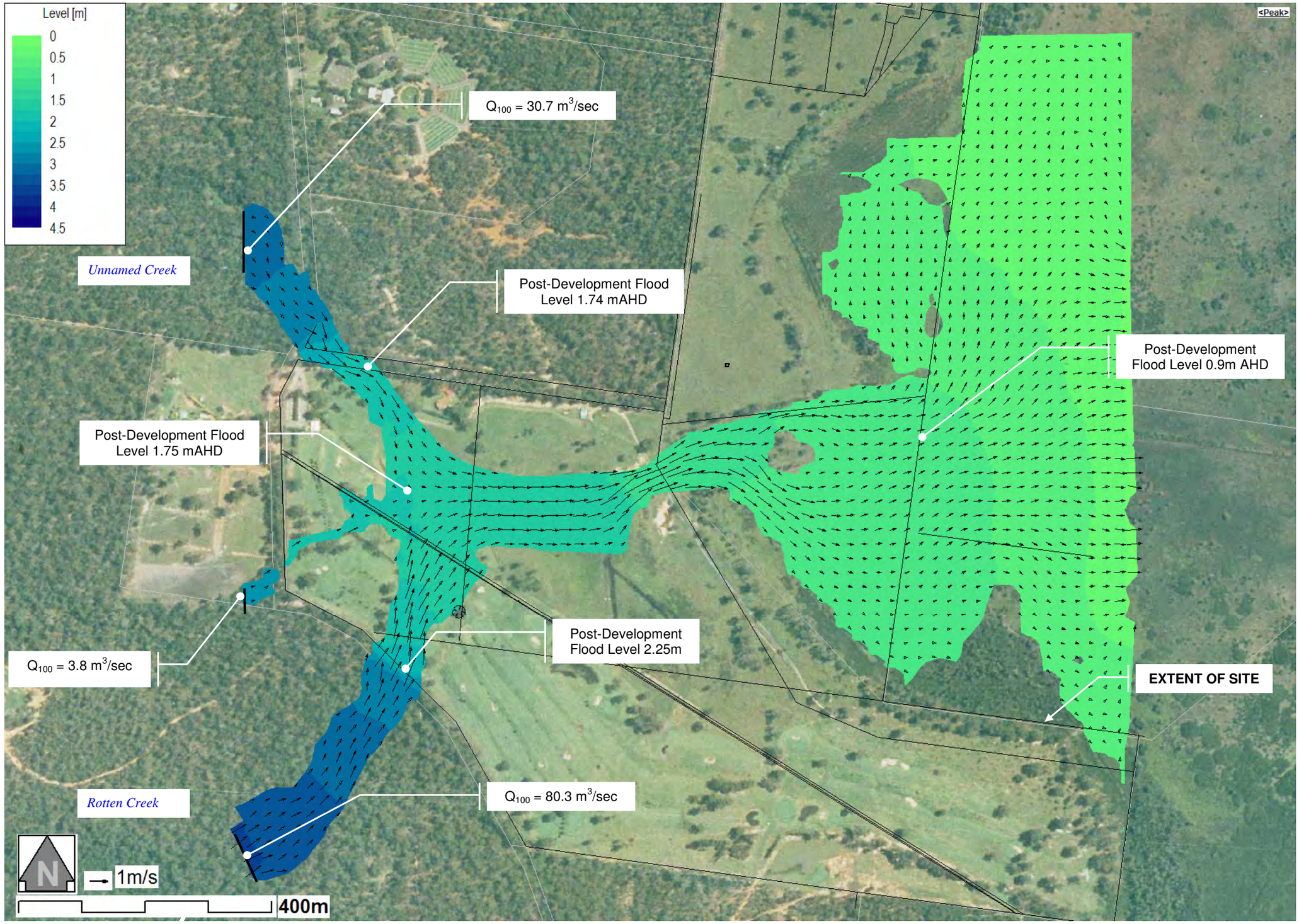
VINEYARDS ESTATE DEVELOPMENT AT WORRIGEE
BULK EARTHWORKS CONCEPT OPTION- POND 2 WITH ISLAND

FIGURE 5



LEGEND

- Site Boundary

N

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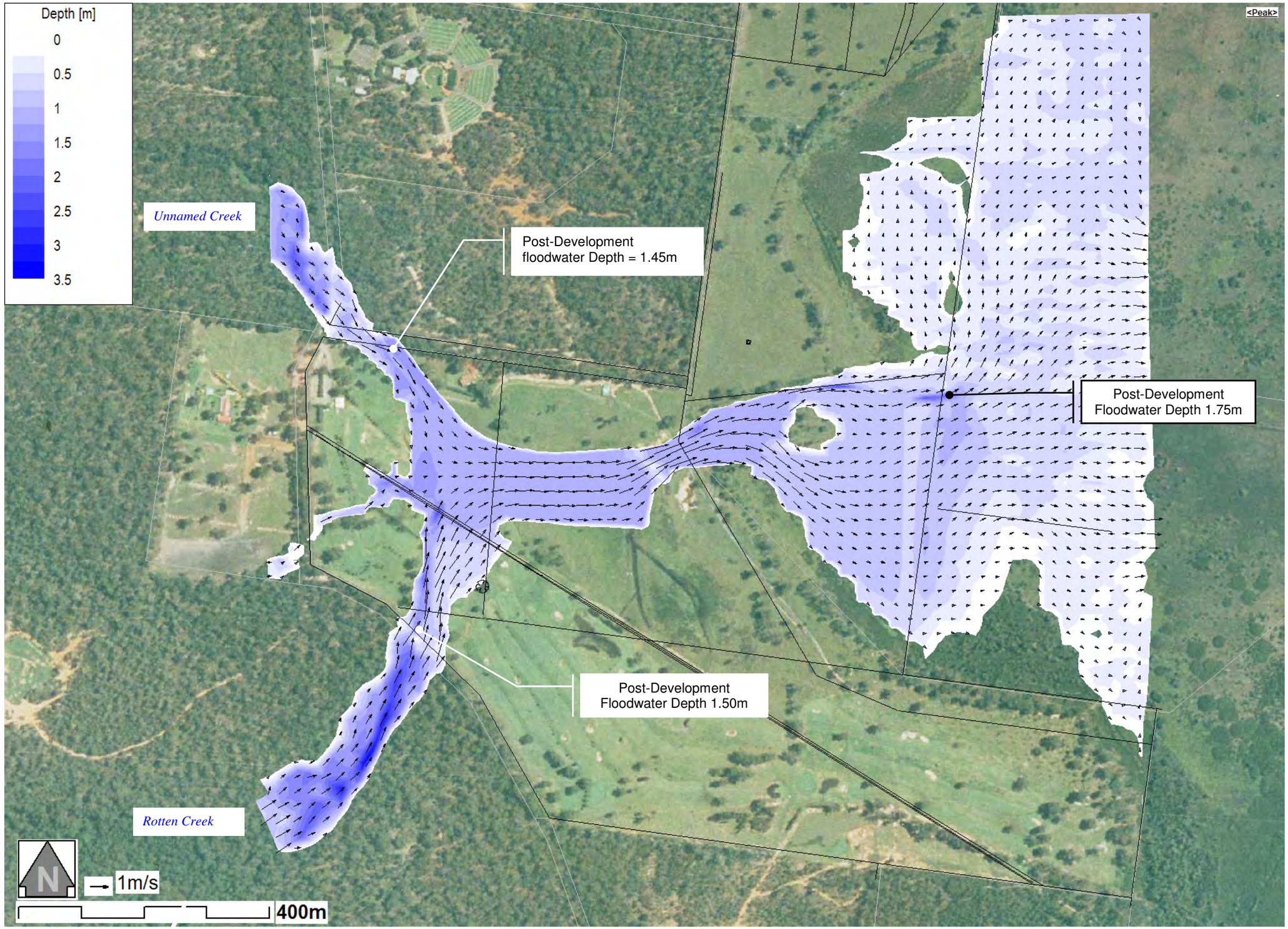
6315_04-Nowra Vineyard hydrologic investigation
Fig1-100year flood extent proposed conditions.doc

FLOOD EXTENT FOR THE LOCAL CATCHMENT 100 YEAR RECURRENCE FLOOD WITH THE PROPOSED CUT AND FILL PLAN

FIGURE 6



LEGEND

- Site Boundary

N

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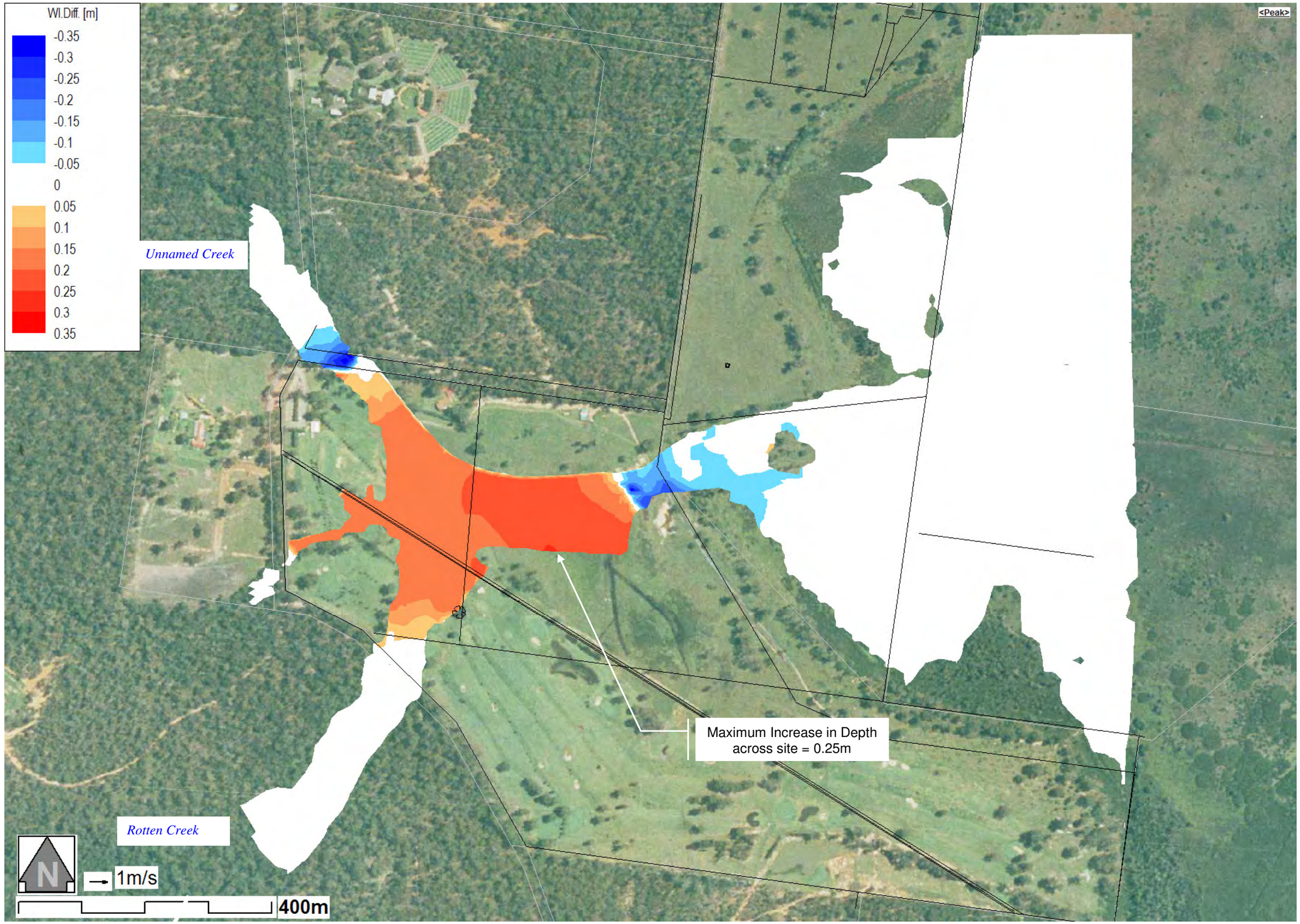
6315_04-Nowra Vineyard hydrologic investigation
Fig6-100year flood depth proposed.doc

PREDICTED FLOODWATER DEPTH FOR THE LOCAL CATCHMENT 100 YEAR RECURRENCE FLOOD FOR THE PROPOSED CUT AND FILL OPTION



LEGEND

- Site Boundary

N

PREDICTED WATER LEVEL DIFFERENCES FOR THE THE LOCAL CATCHMENT 100 YEAR RECURRENCE FLOOD (PROPOSED- EXISTING)

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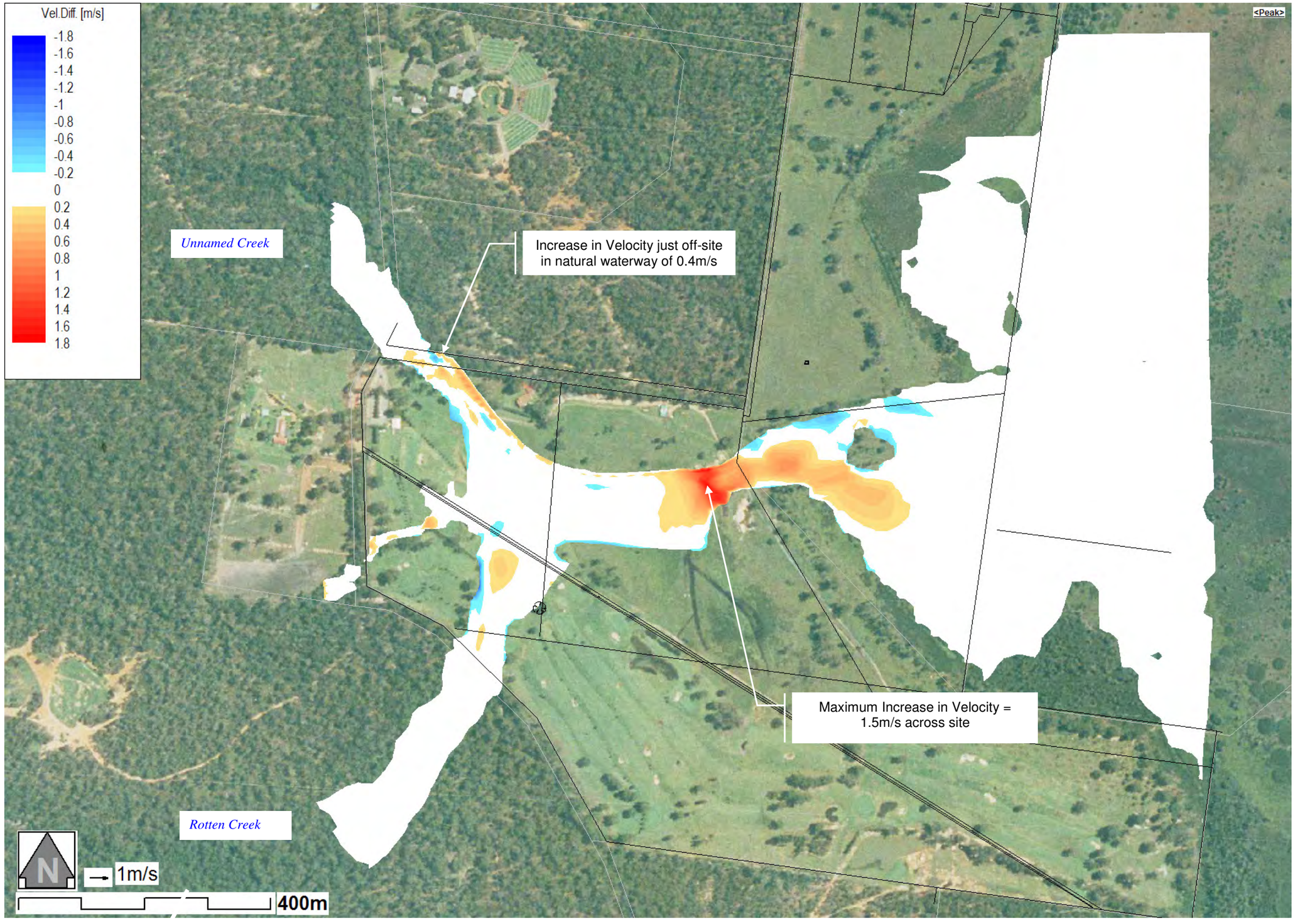
6315_04-Nowra Vineyard hydrologic investigation
Fig7-100year DifferencesWL (Proposed-Existing).doc

FIGURE 8



LEGEND

- Site Boundary

N

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6315_04-Nowra Vineyard hydrologic investigation
Fig5-100year DifferencesVel (Proposed-Existing).doc

PREDICTED CHANGE IN VELOCITY FOR THE LOCAL CATCHMENT 100 YEAR RECURRENCE FLOOD (PROPOSED- EXISTING)

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ATTACHMENT A

RAFTS HYDROLOGIC MODEL PARAMETERS

Table A1 ADOPTED PARAMETERS FOR LOCAL CATCHMENT RAFTS HYDROLOGIC MODEL

Hydrologic Model Node	Sub-catchment Area (ha)	Catchment Slope (%)	Impervious Areas				Pervious Areas				% Impervious
			Impervious Area (ha)	Mannings 'n'	Initial Loss (mm)	Continuing Loss (mm/hr)	Pervious Area	Mannings 'n'	Initial Loss (mm)	Continuing Loss (mm/hr)	
1.00	127.4	2.4	3.8	0.08	1.5	0.5	123.6	0.08	10.0	5.0	3
3.00	85.5	3.7	2.6	0.08	1.5	0.5	83.0	0.08	10.0	5.0	3
4.00	95.0	2.3	2.9	0.08	1.5	0.5	92.2	0.08	10.0	5.0	3
2.00	94.1	2.5	2.8	0.08	1.5	0.5	91.3	0.08	10.0	5.0	3
1.01	96.6	1.9	2.9	0.08	1.5	0.5	93.7	0.08	10.0	5.0	3
1.02	30.2	1.5	0.9	0.08	1.5	0.5	29.3	0.08	10.0	5.0	3
6.00	174.2	2.0	5.2	0.08	1.5	0.5	169.0	0.08	10.0	5.0	3
6.01	66.3	1.8	2.0	0.08	1.5	0.5	64.3	0.08	10.0	5.0	3
5.00	22.0	1.5	0.7	0.08	1.5	0.5	21.3	0.08	10.0	5.0	3
1.03	109.5	1.5	3.3	0.07	1.5	0.5	106.2	0.07	10.0	5.0	3
	900.79		27.0				873.8				3.00