KUR-World

Appendix 19

Flooding Technical Report

Environmental Impact Statement

Reever and Ocean Developments

KUR-World Integrated Eco-Resort | Environmental Impact Statement

Flooding | Technical Report

251351-00

Issue 02 | 15 June 2018

Job number 251351-00

Arup Pty Ltd
Cairns Corporate Tower, Office 2, Level 10
15 Lake Street,
Cairns QLD 4870
Australia
www.arup.com

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Document Verification

ARUP

Job title		KUR-World Integrated Eco-Resort | Environmental Impact Statement		**Job number** 251351-00
Document title		Flooding | Technical Report		**File reference**
Document ref		251351-00		
Revision	**Date**	**Filename**	KUR-World Water and Wastewater Infrastructure Technical Report.docx	
Issue 01	27 Nov 2017	**Description**	First draft	
			Prepared by	Checked by	Approved by
		Name	Priyani Madan	Sam Koci	Nathan Lee Long
		Signature			
Issue 02	15 Jun 2018	**Filename**	Flooding Technical Report.docx	
		Description	Issued with Draft EIS for Agency Review	
			Prepared by	Checked by	Approved by
		Name	Priyani Madan/Hong Vu	Brian Sexton	Nathan Lee Long
		Signature			
		Filename		
		Description		
			Prepared by	Checked by	Approved by
		Name			
		Signature			

Issue Document Verification with Document ✓

Contents

Glossary of Terms

Term	Definition
Annual Exceedance Probability (AEP)	The probability each year of a certain size event being exceeded and reinforces that there is an ongoing flood risk every year.
Australian Rainfall and Runoff (AR&R)	A national guideline document, data and software suite that can be used for the estimation of design flood characteristics.
Annual Recurrence Interval (ARI)	The probability each year of a certain size event being exceeded which is expressed as a return period in years
Continuing Loss (CL)	The average loss rate during the remainder of the storm (rainfall that has not been captured by interception, infiltration and depression storages).
Digital Elevation Model (DEM)	A specialised database that represents the relief of a surface between points of known elevation.
Intensity-Frequency-Duration (IFD)	A rainfall statistics database
Initial Loss (IL)	Precipitation reaching the surface of a catchment prior to it resulting in runoff where major abstraction is from the infiltration process.
mAHD	Measurement in metres against the Australian Height Datum
Probable Maximum Flood (PMF)	The largest flood event that could possibly occur in a particular location.
Probable Maximum Precipitation (PMP)	The greatest depth of precipitation for a given duration meteorologically possible over a given-size storm area at a particular location at a particular time of year.
Regional Flood Frequency Estimation (RFFE)	A data driven approach which attempts to transfer flood characteristic information from a group of gauged catchments to the catchment location of interest.
Runoff Routing (RORB)	A type of software used to calculate a surface runoff hydrograph from rainfall.
Shuttle Radar Topography Mission (SRTM)	An international research effort that obtained digital elevation models on a near-global scale.
Two-dimensional Unsteady Flow (TUFLOW)	A type of software used to simulate free-surface water flow for urban waterways, rivers, floodplains, estuaries and coastlines.

1 Introduction

This report describes the existing flood conditions at the site and potential impact of the project on flooding within and in the vicinity of the site. Other relevant chapters of the EIS that link to this report include:

- Chapter 4, Project Description – describes the water demands and infrastructure requirements for the project, including water supply and storage, stormwater, wastewater and sewerage.
- Chapter 7.1, Stormwater Drainage Infrastructure – describes the proposed stormwater drainage infrastructure including stormwater quality and quantity mitigation measures.
- Chapter 9, Water Quality – describes existing waterways, discharges, water quality and measures to achieve water quality objectives.
- Chapter 10, Water Resources – describes the water resources in the study area, including surface and groundwater, and provides a summary of potential impacts and mitigation measures for water resources.
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2 Methodology

2.1 Terms for describing probability

The probability of a flood of a given size is expressed in **Annual Exceedance Probability (AEP)**, which refers to the probability each year of a certain size event being exceeded and reinforces that there is an ongoing flood risk every year (Australian Institute of Disaster Resilience, 2017). AEP is the preferred terminology over **Annual Recurrence Interval (ARI).** ARI refers to the probability expressed as a return period in years. This term is often misinterpreted and may mislead the community about ongoing flood risk after an event.

Table 1 shows the probability of experiencing a given-sized flood either once or twice in 80 years.

Table 1: Probability of experiencing a given-sized flood one or more times in 80 years (Australian Institute for Disaster Resilience, 2017).

Annual exceedance probability (%)	Approximate Average recurrence interval (years)	At least once (%)	At least twice (%)
5	20	98.4	91.4
2	50	80.1	47.7
1	100	55.3	19.1

In addition to the AEPs shown in Table 1, this assessment also makes reference to the **Probable Maximum Flood (PMF)**. The PMF refers to the largest flood event that could possibly occur in a particular location. Further details on the PMF derivation is described in Section 2.2.1. The flood extent of a PMF defines the floodplain (Australian Institute of Disaster Resilience, 2017).

Another term used in this report relating to the PMF is the **Probable Maximum Precipitation (PMP)**. The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given-size storm area at a particular location at a particular time of year, with no allowance made for long-term climatic trends. The PMP is the primary input into determining the PMF. (Australian Institute for Disaster Resilience, 2017)

2.1.1 Terms for describing modelling scenarios

The 'base case' scenario refers to the site's existing conditions pre-development.

The 'design case' scenario refers to the site post-development of KUR-world.

2.1.2 Legacy flood studies

Flooding behaviour in the Barron River Basin was investigated in Flood Mapping for the Barron River Basin, January 2015, for the Department of Natural Resources and Mines (DNRM) (Kellogg Brown & Root Pty Ltd 2015). In addition, flooding behaviour in the vicinity of the Kuranda township was investigated in the Flood Hazard Mapping - Kuranda and Myola, April 2013, for the Queensland Reconstruction Authority (QRA) (AECOM, 2013).

The Barron River Basin flood mapping (Kellogg Brown & Root Pty Ltd, 2015) was carried out for the 1% AEP and an extreme design event. The extreme design event was derived from PMP temporal patterns and rainfall intensities from a hydrological model. The two-dimensional (2D) TUFLOW hydraulic model utilised the "direct rainfall on grid" method and was based on a 30m grid digital elevation model (DEM). The flood mapping produced from this study was primarily intended for emergency management planning and response purposes. The model's coarse nature meant it did not include any creek bathymetry and therefore could not capture the conveyance, flood storage and detailed hydraulic behaviour required for this assessment. It has not been considered further in this assessment.

The Kuranda and Myola flood hazard mapping (AECOM, 2013) was carried out for the 2%, 1% and 0.5% AEP events using inflows derived from a validation event of February 1999. The two-dimensional TUFLOW hydraulic model was built at a 10 metre grid resolution, based on one metre LiDAR data, extending from the Myola gauge location to the Barron River Gorge waterfall. A flood frequency analysis at DNRM gauge 11001D (Barron River at Myola) was undertaken to estimate the peak discharge for a range of AEP events. This data was utilised to define boundary conditions of the Barron River in the hydraulic model used for the KUR-World flood risk assessment.

From the 2013 study, 1% AEP flood maps showed that Barron River (located near the KUR-World site) remained relatively channelised and did not interact with the site.

Creek bathymetry was not included in these previous studies and therefore would not provide suitable assessment of flow paths on the KUR-World site. Therefore, a hydrological and hydraulic model was developed specifically for this study to capture and assess the detailed flood behaviour throughout the KUR-World site. The methodology for the model development is described in Sections 2.2 and 2.3 below.

2.2 Hydrological methodology

2.2.1 Design rainfall estimation

The Far North Queensland Regional Organisation of Councils (FNQROC) Regional Development Manual (Far North Queensland Regional Organisation of Councils [FNQROC], 2014) prescribes Intensity-Frequency-Duration (IFD) rainfall data to be used in design. In general, FNQROC require that stormwater designs need to be consistent with the Queensland Urban Drainage Manual (QUDM) (Queensland Government Department of Energy and Water Supply et al., 2013) except where amended by the manual. QUDM is essentially based on the Rational Method and the advice on the Bureau of Meteorology's Design Rainfalls and IFD website (Australian Government Bureau of Meteorology, 2017) very clearly recommends that 3rd edition of Australian Rainfall and Runoff (Pilgrim, 1987; Canterford, 1987) is to be used with Rational Method.

The manual includes an IFD chart for Kuranda (FNQROC, 2014), which was adopted in this study for the KUR-World site. As the new IFDs from AR&R 2016 are now available, they were obtained for two locations within the catchment area to see how they compare to the FNQ values. The new IFDs were generally lower, sometimes significantly, except for longer duration events. Therefore, as a conservative approach, and to maintain alignment with FNQROC (2014), the new AR&R 2016 IFDs were not used in this study.

In order to apply the FNQROC (2014) IFDs, temporal patterns and other hydrology parameters were applied based on AR&R 1987. These parameters included:

- An areal reduction factor (Figure 1.6 AR&R Volume 1) of 1 (one) was conservatively adopted, for relatively small catchments.
- Temporal patterns for Zone 3 (site located within Zone 3) were used (Figure 3.2 AR&R Volume 1); 5%, 2% and 1% AEP.
- Sensitivity assessment was undertaken on selected model parameters for the 5%, 2% and 1% AEP event base case assessments as outlined below. Further refinement of these values was not undertaken as calibration data was not available (that is, the hydrological model was not calibrated).
- Calculation of the PMP has been undertaken in accordance with standard Australian approaches (Bureau of Meteorology 2003 and 2004).

2.2.2 Hydrology model development

A hydrology model was developed in the RORB runoff routing software for the purpose of design flow estimation for the flood impact assessment. RORB is a rainfall runoff model which routes streamflow through catchment storage, incorporating sub-catchment area, routing length, terrain perviousness, and rainfall losses.

Watershed catchments were delineated using a combination of LiDAR data and Shuttle Radar Topography Mission (SRTM) data (to supplement where LiDAR did not cover the entire catchment extent). The watershed catchments were assumed to be the same for both the base case and design case scenarios. The hydrological context of the KUR-World masterplan and the watershed catchments are shown in Figure 1. Note that the catchments delineated for this assessment differ from those defined for Chapter 9 Water Quality, and Chapter 7.4 Stormwater, however each are appropriate for the purpose for which the catchments have been defined.

Catchment parameters such as sub-areas, slopes, drainage lengths, rainfall and losses were calculated and incorporated within the RORB model. For the design case, the masterplan layout was used to estimate the pervious and impervious areas. From this, local sub-catchment flow hydrographs for the base case and design case were derived. The flow hydrographs were applied as inflows to the two-dimensional hydraulic model described in Section 2.3.

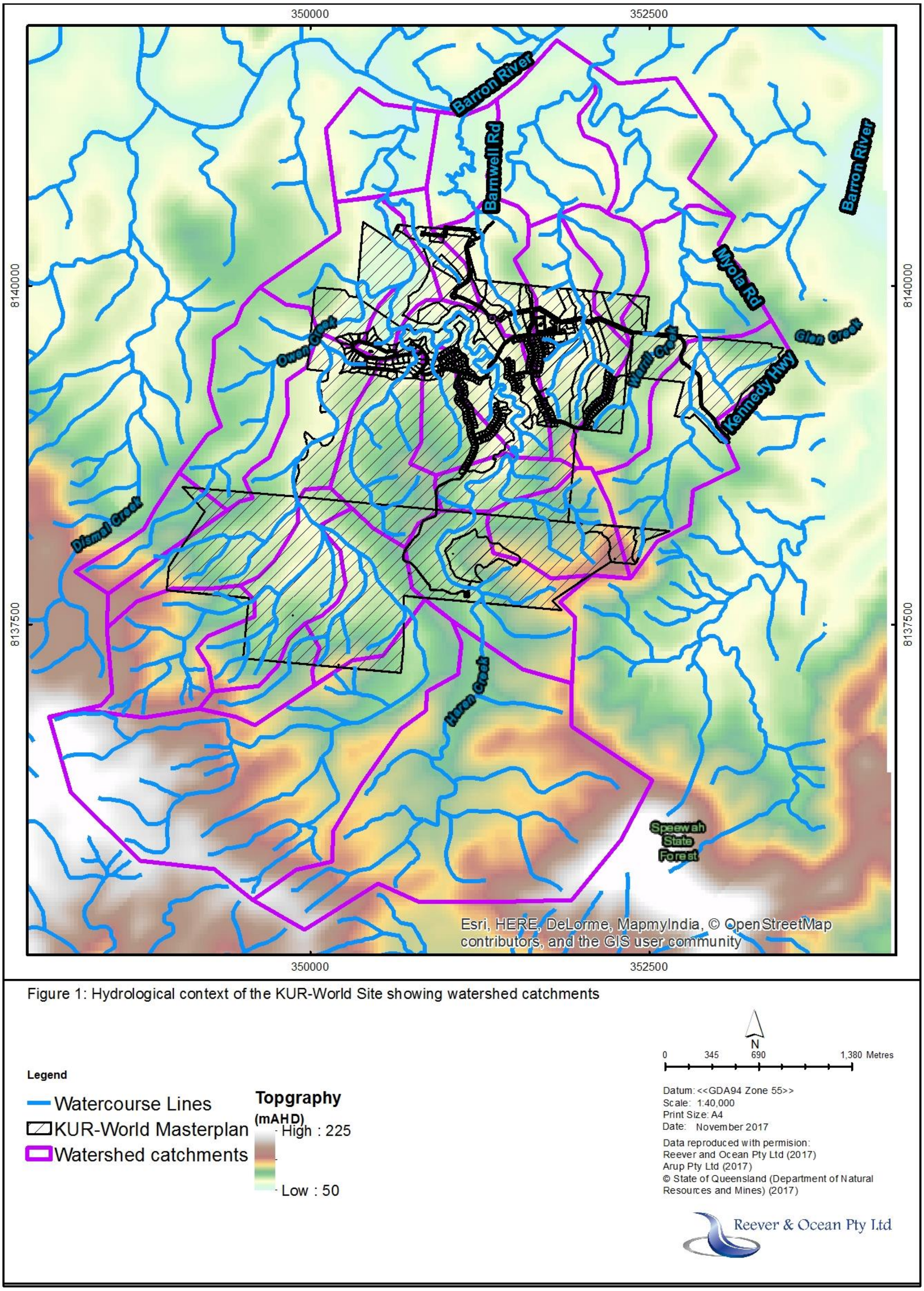

Figure 1: Hydrological context of the KUR-World site showing watershed catchments.

2.2.3 Critical duration analysis

The RORB model was used to estimate the local storm critical duration. The critical storm duration is the duration of the design storm which governs flood severity at a particular location. The critical duration storm is identified as the storm that generates the greatest peak flood levels for a particular location. It was identified that the local storm critical duration varied depending on the area of interest within the KUR-World site. This commonly occurs when assessing large floodplain areas. Two durations for each storm event were identified to be critical within the KUR-World site extent and are summarised in Table 2.

Hydraulic modelling of the design storm events with the two critical durations confirmed the hydrological critical duration analysis, that two durations are critical across the KUR-World site. For the majority of the flood extent, one duration for each AEP was identified as more critical. Often in flood studies certain durations prevail as the critical duration since the calculation is effectively a function of the catchment's shape. This is highlighted in yellow in Table 2.

Table 2: Critical durations for the KUR-World site.

AEP (%)	Critical durations (hours)	
5%	1	24
2%	1	24
1%	1	24
PMF	1	2

2.2.4 Sensitivity testing of hydrological parameters

Sensitivity testing was undertaken to understand the influence of the parameters applied in the RORB model. While no calibration data was available, several parameter combinations were tested, with results compared to the AR&R (2016) Regional Flood Frequency Estimation (RFFE) based on the total catchment area. Table 3: RORB parameter combinations tested, summarises the combinations tested and the recommendations for adoption. It should be noted that k_c is a RORB routing parameter, used in combination with routing parameter m = 0.8. No sensitivity testing was undertaken for the PMP event. The values are as per AR&R recommendations for extreme events. The adopted parameters were:

- k_c Weeks for all events
- Initial Loss (IL)= 2.5mm and Continuing Loss (CL)=15mm/h for the 5% AEP
- IL= 0mm and CL=2.5mm/h for the 2% and 1% AEP
- IL= 0mm and CL=1mm/h for the PMP event.

Table 3: RORB parameter combinations tested

Initial loss (IL) (mm)	Continuing loss (CL) (mm/hr)	k_c	Comment
15	10	4.46 – from Queensland (Weeks) method	For 5% AEP event, attains closest results to RFFE, but not selected for use (see other comments below).
2.5	15	4.46 – from Queensland (Weeks) method	Recommended for 5% AEP design event, underestimates slightly compared to RFFE. Consistent with AR&R advice for cases with no loss information available.
0	2.5	4.46 – from Queensland (Weeks) method	For 2% and 1% AEP events, attains closest results to RFFE. Also consistent with Barron River Basin study. For 5% AEP event, provides significantly higher peak flow than RFFE. Recommended for 2% and 1% AEP design events
0	2.5	10.17 – RORB default	Underestimates peak flow for 5%, 2% and 1% AEP events significantly. Not recommended.

2.3 Hydraulic methodology

A two-dimensional (2D) hydraulic TUFLOW model was developed for this flood risk assessment. TUFLOW dynamically models the hydraulic behaviour of the floodplain and outputs a detailed visual representation of the flood behaviour. It also allows a simple illustration of the flooding impacts of the proposed design through flood impact maps.

Standard industry guidelines such as AR&R 2016 (Ball et al., 2016) and the QUDM (Queensland Government Department of Energy and Water Supply et al., 2013) were used to develop the hydraulic model to capture the detailed flood behaviour across the KUR-World site. Note that no historic data was available to calibrate the hydraulic model to historic flood events.

The general setup of the TUFLOW model is illustrated in Figure 2.

2.3.1 Topography

The topography of the site was represented in the hydraulic model using a combination of the following:

- 1m LiDAR data extract from the 2010 Cairns and 2011 Tablelands LiDAR for the majority of the model in the upstream areas
- 25m Shuttle Radar Terrain Mission (SRTM) derived 1 second Digital Elevation Model data available through Geoscience Australia's ELVIS data portal – to supplement parts of the model extent where LiDAR coverage was not available. This was mainly in the downstream catchment reaches in which the Barron River runs.

- As creek definition is not captured in the SRTM data, creeks were manually defined in the model using aerial imagery using shape modifiers in TUFLOW (z lines – this application is standard TUFLOW modelling procedure for models of this nature).

2.3.2 Model inflow hydrographs and combined probability

Local design inflow hydrographs from the hydrological RORB model were applied to the TUFLOW model as Source Area (SA) inflows. In addition, regional flood boundary conditions in the Barron River were defined by applying an inflow hydrograph at the upstream end of the river and a stage-discharge relationship at the downstream end. The stage-discharge relationship is the defined relationship for the gauge site immediately downstream of the model's downstream boundary, DNRM gauge 11001D (Barron River at Myola).

The QRA Flood Hazard Mapping for Kuranda and Myola (AECOM, 2013) provided a flood frequency analysis at DNRM gauge 11001D (Barron River at Myola) which estimated the peak discharge for a range of AEP events. Design event flows were created by scaling the February 1999 flow hydrograph to achieve the estimated peak.

As stated in AR&R 2016:

A specific flood outcome, such as flooding above the floor level of a building or flooding above a certain threshold level where access to a property is cut, may occur as a consequence of different events whose occurrences may be considered to be independent of each other. An example of such separate events is flooding as a result of high river levels (Event A) and flooding caused by overflows from a local drainage system (Event B). If the river flooding typically occurs from an extensive storm system over a large catchment and the drainage flooding from thunderstorms over a small local catchment, then these events can be considered to be essentially independent. (Nathan & Weinmann, 2016)

The coincident event in the Barron River was selected in consideration of the significantly larger size of the Barron River catchment compared to the site's local catchment. The dominant flooding mechanism was identified to be the local catchment short duration (thunderstorm) events, given the steepness of the hydraulic gradient at the KUR-World site. For this reason, it is anticipated that alternative combinations of regional storm events in the Barron River contribute little to the overall flood risk at the site. The combination of design inflow hydrographs was applied in the hydraulic model as shown in Table 4.

Table 4: Combined design inflow hydrographs applied in the TUFLOW model.

Local inflow	Regional Barron River inflow
5%, 2% and 1% AEP	5% AEP
PMF	1% AEP

The 5%, 2% and 1% AEP local catchment events were run with the 5% AEP regional Barron River event, while the Probable Maximum Flood (PMF) local catchment event was run with the 1% AEP regional Barron River event. As no calibration data was available the hydrographs were applied with consideration of the following factors:

- Scale and responsivity of the large catchment of the Barron River compared to small local catchments at the KUR-World site.
- As no calibration data was available, a conservative approach was undertaken where the regional and local hydrographs were scaled for coincident peaks to ensure flood levels were not underestimated.
- In general, using the combined probability of having the same design flood event for both local and regional flows would result in a reduced probability overall.

Materials roughness

Manning's *n values* for the catchment areas were derived based on aerial photography and tables of Manning's n roughness tabulated in well-known hydraulic references (for example, Chow, 1959). Materials roughness parameters have been adopted as summarised in Table 5.

Table 5: Adopted roughness parameters in the TUFLOW model for the base case and design case.

Description	Manning's n	Base Case	Design Case
Forest – trees and shrubs at 1m spacing	0.15	✔	✔
Long grass on irregular surface with few trees	0.05	✔	✔
Residential area with high tree density	0.10	✔	✔
Channel (Barron River)	0.04	✔	✔
Farm theme park and equestrian centre	0.1		✔
Produce Garden	0.07		✔
Business and leisure hotel and function centre	0.3		✔
KUR-Village	0.2		✔
Rainforest education centre and adventure park	0.1		✔
KUR-World Campus	0.2		✔
Sporting Precinct	0.1		✔
Golf Clubhouse and function centre	0.3		✔
Golf Course	0.05		✔
Five Star Eco Resort	0.2		✔
Health and wellbeing retreat	0.2		✔
Premium villas	0.1		✔
Lifestyle villas	0.1		✔
Queenslander lots	0.1		✔
Services and infrastructure	0.2		✔
Environmental area	0.15		✔
Road/common property	0.03		✔
Dam	0.03		✔

Hydraulic structures

Seven bridges are included in the KUR-World masterplan (referred as KUR_B1 to KUR_B7). Detailed design of these structures will be undertaken in future stages, therefore assumptions were made for the structural layouts. This included:

- Bridge lengths assumed to cover the existing waterway area as estimated from aerial imagery and terrain data.

- Nominal values were applied for pier, deck and handrail/guardrail backwater losses.
- Typical dimensions were applied for the bridge substructure and superstructure.

Only major drainage structures (greater than 650mm in diameter) were incorporated into the model, as incorporating the minor drainage network would not add value to the overall flood risk and impact assessment. Two major culverts were included in the model which was sized as a 2no. 600 x 900 mm box culvert at both locations. The locations of each structure are shown in Figure 2.

Hydraulic model scenario summary

Table 6 details the difference in scenarios for the ‘base case’ and the ‘design case’.

Table 6: Summary of the base and design case scenarios.

	Base case	Design case
Design storm inflows	Inflow hydrographs based on pre-developed site	Inflow hydrographs based on post-developed site
Topography	SRTM + LiDAR + Creeks manually defined	Base case topography + KUR-World earthworks
Materials roughness	As shown in Table 5	As shown in Table 5
Bridges	None	Seven KUR-World bridges
Drainage network	None	One major KUR-World culvert

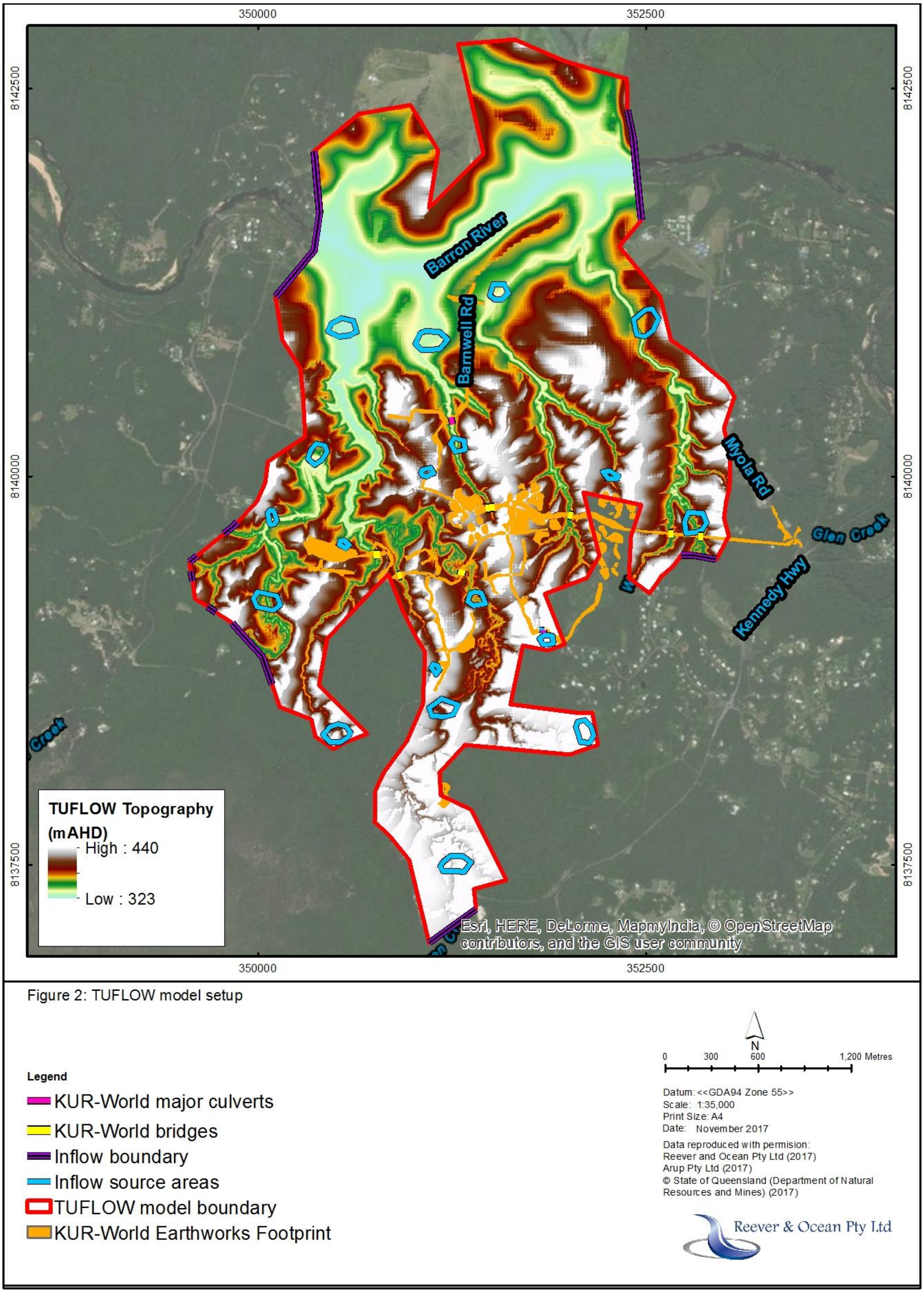

Figure 2: TUFLOW model setup

3 Findings

3.1 Hydraulic results

The TUFLOW model was simulated for the 5%, 2%, 1% AEP and PMF design storm events, under both the base case and design case conditions.

The peak water levels modelled for the 1% AEP design storm event under the base case and design case are shown in the maps in Figure 3 and Figure 3a respectively.

The peak velocities modelled for the 1% AEP design storm event under the base case and design case are shown in the maps in Figure 4 and Figure 4a respectively.

Figure 5 shows the flood extent as defined by the PMF.

The reference points were used to report the peak water levels and peak flood depths at critical locations across the site.

The modelled peak water levels and peak flood depths at a number of reference points across the site are summarised in Table 7 and Table 8 respectively. The locations of the reference points are shown in Figure 5, and correlate to the locations of critical proposed bridge crossings. There were no water levels or depths at bridge 'KUR_B4' and therefore it was excluded from the tables. It is noted that the bridge deck for bridge 'KUR_B3', which is at the main access road, is at approximately 349.6mAHD (Australian Height Datum), and therefore not overtopped until the PMF.

Table 7: Peak water level results for the base case and design case scenarios.

Bridge ID	Reference point	5% AEP peak water level (mAHD)		2% AEP peak water level (mAHD)		1% AEP peak water level (mAHD)		PMF peak water level (mAHD)	
		Base case	Design case	Base Case	Design Case	Base Case	Design Case	Base Case	Design Case
KUR_B1	A	342.52	343.21	342.76	343.44	342.87	343.52	345.88	345.93
KUR_B2	B	345.36	345.21	345.71	345.69	345.91	345.89	348.59	348.61
KUR_B3	C	348.15	348.19	348.75	348.79	349.01	349.05	351.62	351.73
KUR_B5	E	344.18	344.17	344.48	344.44	344.59	344.56	347.08	347.07
KUR_B6	F	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*	346.59	346.60
KUR_B7	G	343.87	343.87	344.16	344.17	344.33	344.33	346.82	346.82
-	H	340.27	343.64[1]	340.37	343.75[1]	340.42	343.79[1]	343.14	344.32

[1] Peak water level results indicate road will be overtopped with the assumed culvert dimensions (2no. 600 x 900 mm box culverts). Increase in peak water level to be mitigated at detailed design stage by increasing the culvert capacity to achieve 1%AEP flood immunity.

Table 8: Peak flood depth results for the base case and design case scenarios.

Bridge ID	Reference point	5% AEP peak flood depth (m)		2% AEP peak flood depth (m)		1% AEP peak flood depth (m)		PMF peak flood depth (m)	
		Base case	Design case	Base Case	Design Case	Base Case	Design Case	Base Case	Design Case
KUR_B1	A	2.34	3.03	2.57	3.25	2.68	3.34	5.69	5.75
KUR_B2	B	1.18	1.03	1.53	1.51	1.73	1.71	4.41	4.43
KUR_B3	C	3.47	3.50	4.07	4.11	4.33	4.36	6.94	7.04
KUR_B5	E	2.75	2.74	3.05	3.01	3.16	3.13	5.65	5.65
KUR_B6	F	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*	4.74	4.75
KUR_B7	G	1.78	1.78	2.08	2.08	2.24	2.25	4.73	4.73
-	H	0.721	0.219	0.82	0.322	0.868	0.367	3.595	0.896

*Sub-catchment leading to reference point B6 included as part of a larger sub-catchment and applied as inflow a short distance (~1.4km) downstream. This does not impact on flood immunity of the main entrance road located at this point. Results showed 7.64m of freeboard from the peak water level in the PMF event and the obvert of the bridge at reference point KUR_B6.

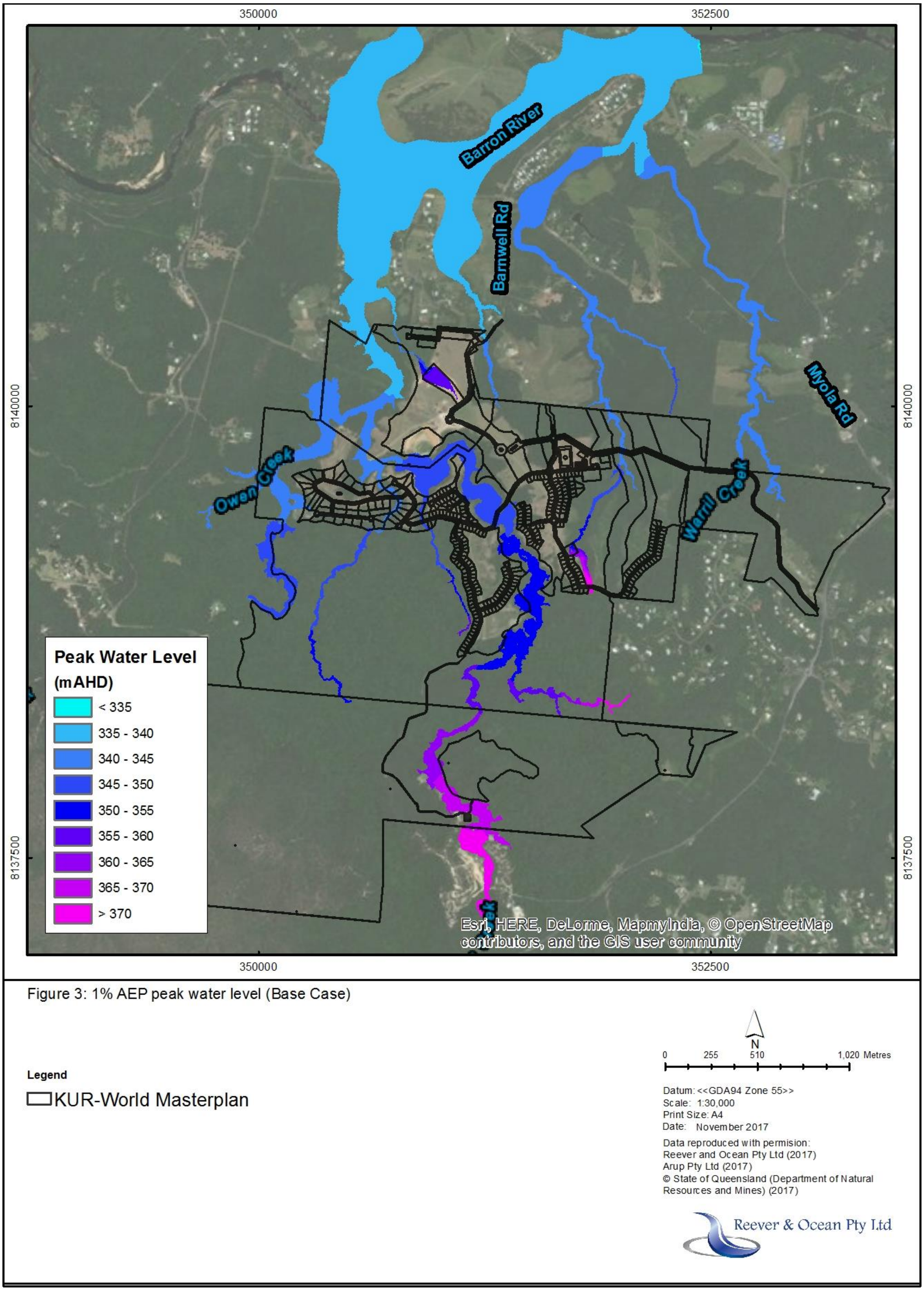

Figure 3: 1% AEP peak water level (Base Case)

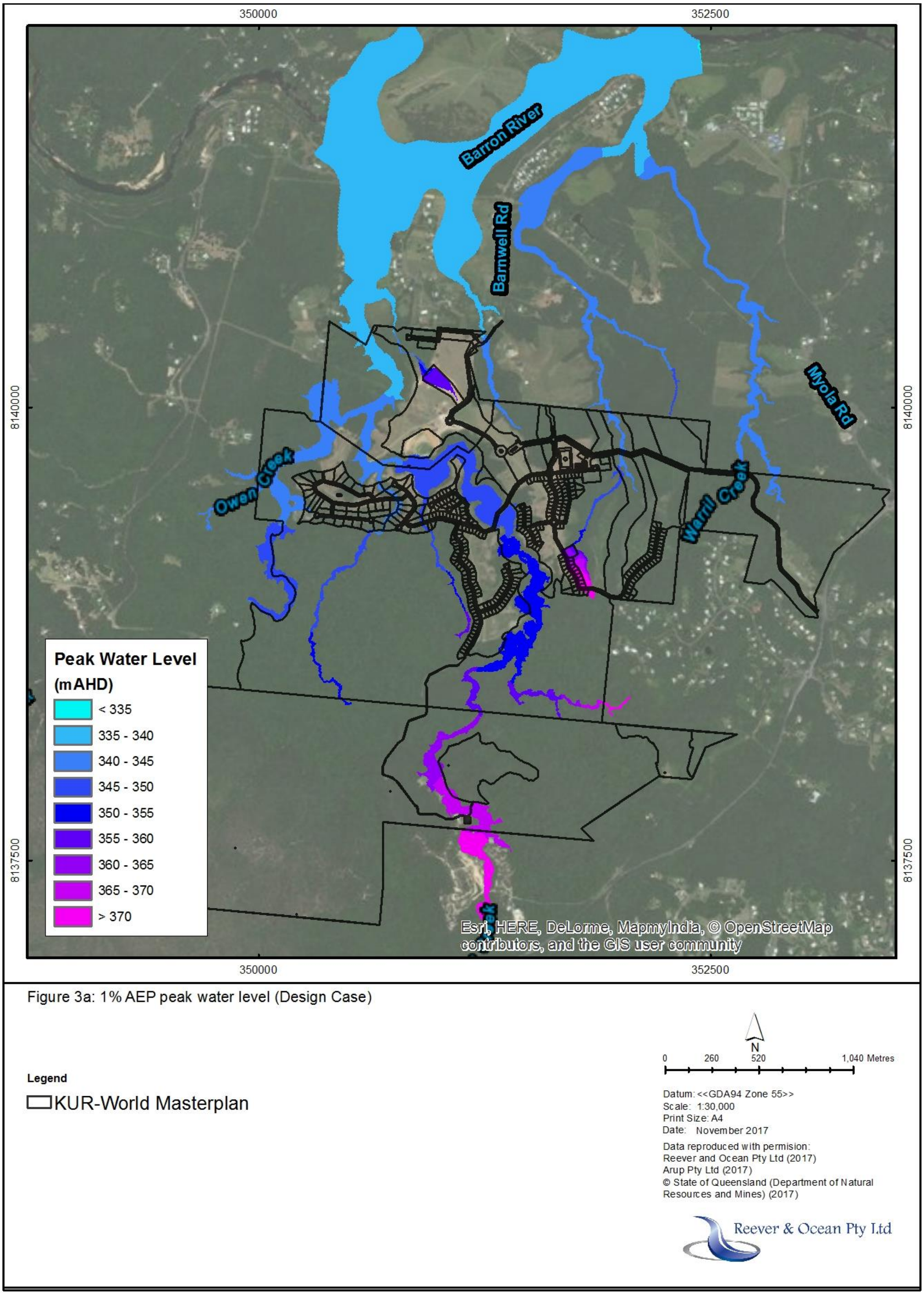

Figure 3a: 1% AEP peak water level (Design Case)

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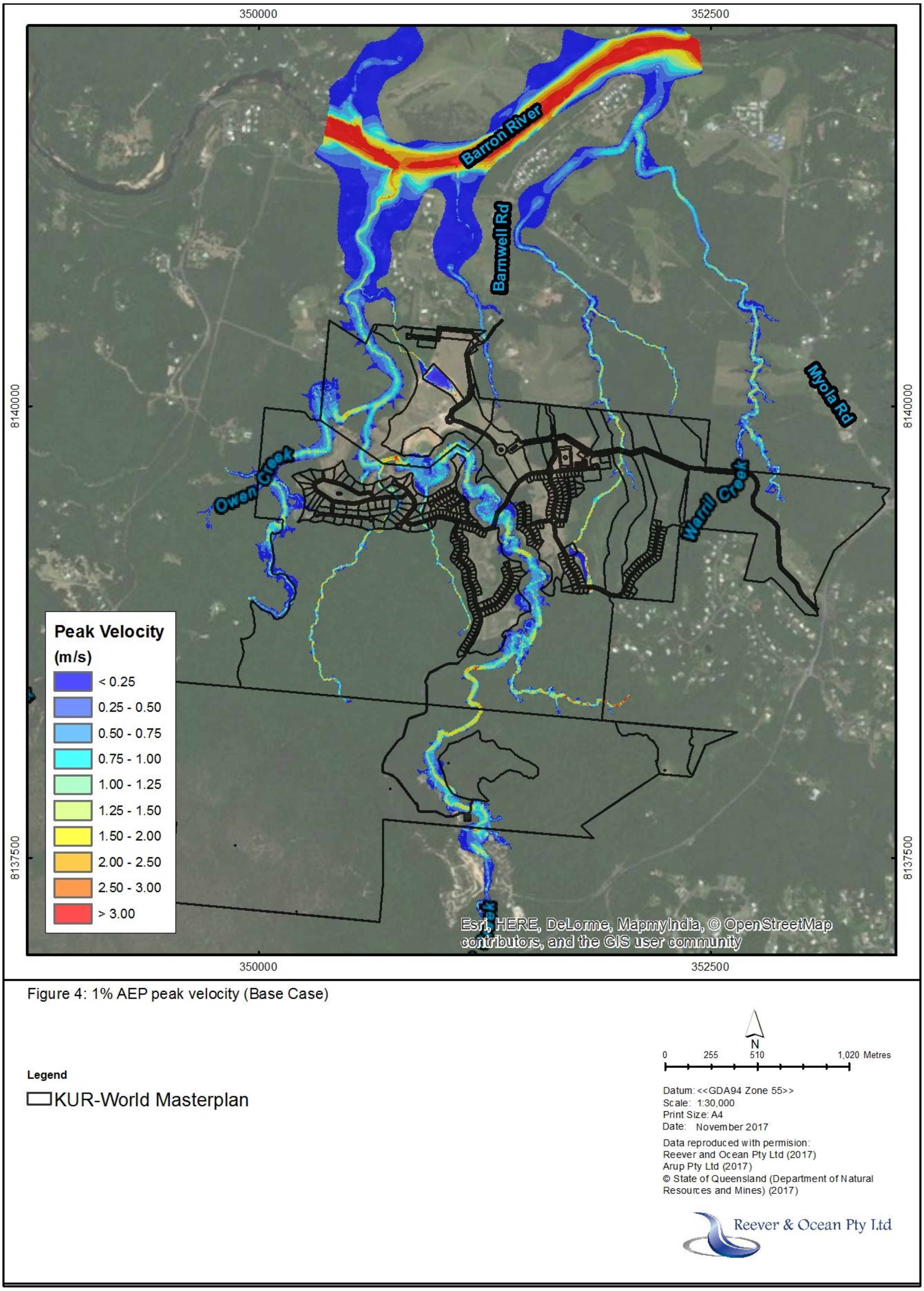

Figure 4: 1% AEP peak velocity (Base Case)

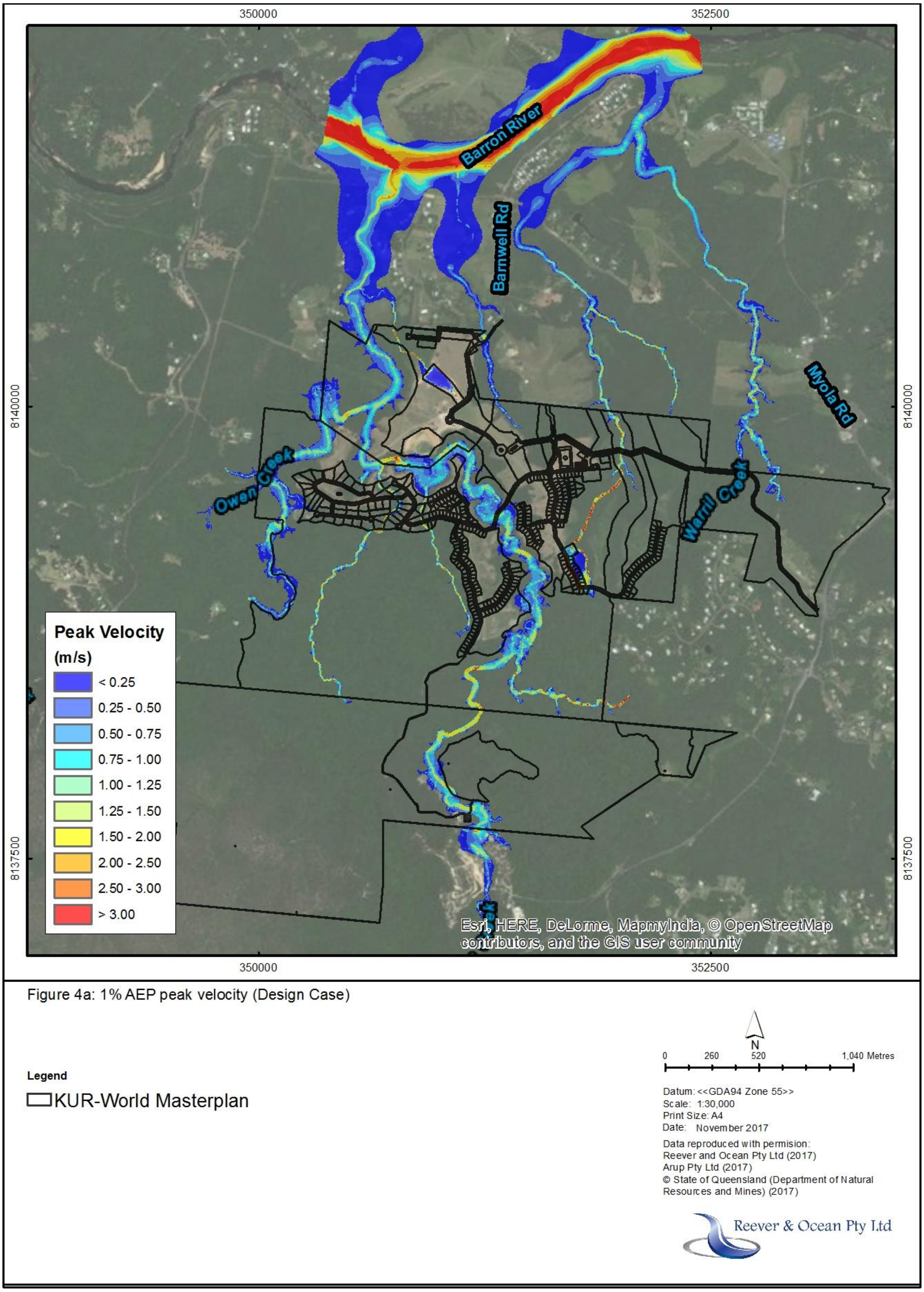

Figure 4a: 1% AEP peak velocity (Design Case)

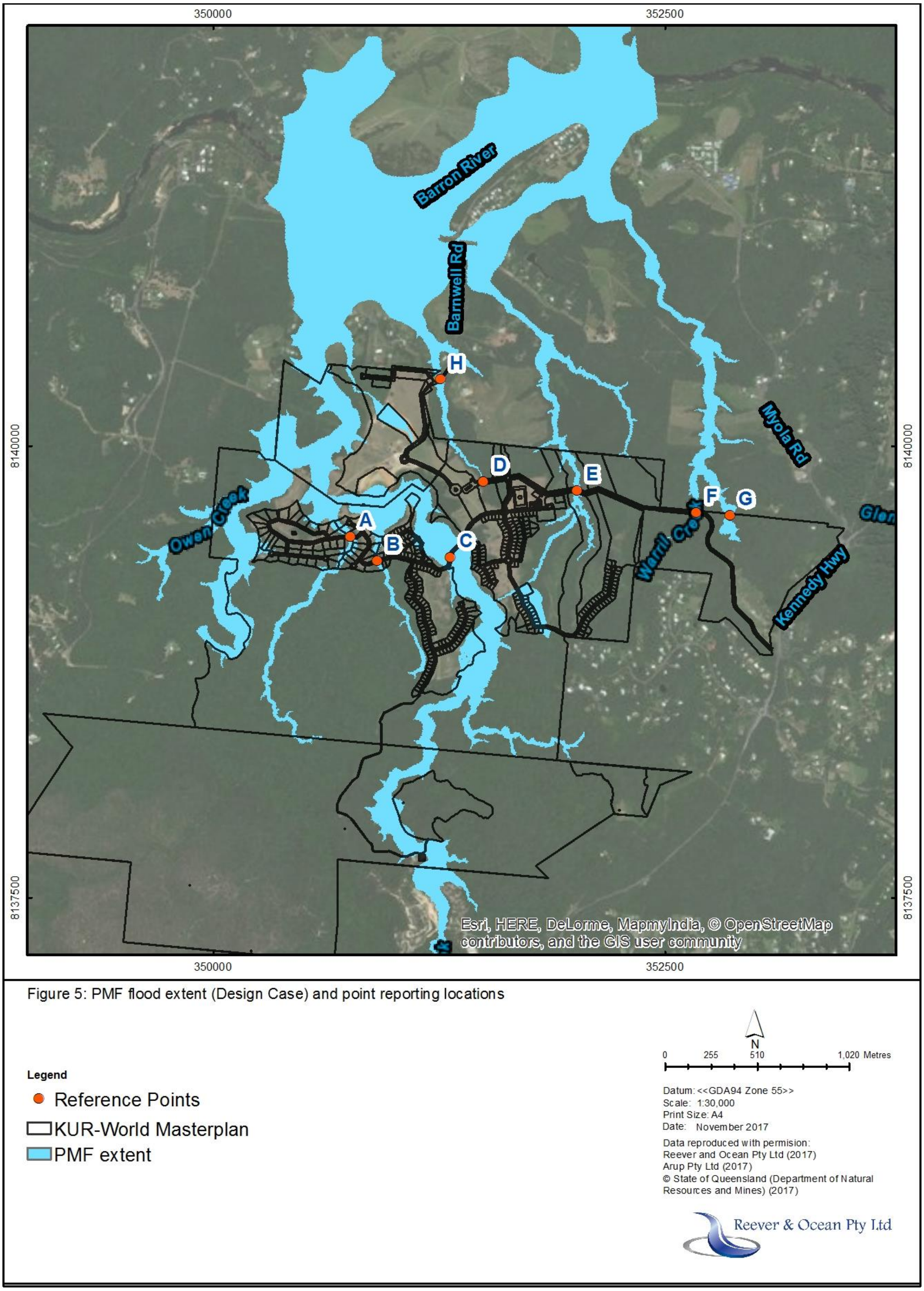

Figure 5: PMF flood (Design Case) and point reporting locations

4 Impact

4.1 Peak flood impact assessment

The peak flood impact assessment (PFIA) compared the difference in peak water levels from the design case to the base case for all modelled storm events, that is, the peak water levels of the design case **minus** the existing case. The results of this assessment are presented in Figure 6 to Figure 9.

Site specific flood impacts

Afflux is observed at reference **point H** where Barnwell Road crosses an unnamed drainage line in all events modelled however, this increase in water level is contained within the waterway. Afflux in this area is a function of the road crossing the existing waterway, where flows are then funnelled into culverts. Backwater effects cause an increase in peak water levels upstream of the culvert crossing. Detailed cross drainage design will be undertaken at the detailed design stage to size suitable culverts capable of minimising afflux.

There are localised increases in peak water level at reference **point A** for all events within the lots in the Stage 2 lifestyle villas where there is a flow path along the fringe of the lots. This is in the order of 690mm in the 5% AEP storm event. Changes to flood behaviour in this area will be mitigated by allocating drainage easements for existing drainage paths throughout the KUR-World site. Drainage easements will be incorporated into the design at the detailed design stage, and there is no proposed development within the existing drainage easements. All properties will be placed at the 1%AEP level with required freeboard in accordance with the local planning scheme.

Afflux was observed at the ‘KUR_B3’ bridge location (reference **point C**) for all events due to the placement of a road bridge crossing the wide floodplain width. This was in the order of 110mm, however the change in peak water levels is contained within the waterway corridor and does not impact on proposed property developments up to the 1%AEP flood event. It is noted that in the PMF event the main channel flood width encroaches into proposed property lots within the site. To mitigate the potential flood damage to properties, houses will be placed on raised building pads, above the 1% AEP flood level with a 500mm freeboard, or with a highset structure allowing flow to pass underneath.

Adjacent and downstream flood impacts

Flood impacts to properties adjacent to or downstream of the site were assessed. As shown in the peak flood impact maps, no adverse impacts were observed for properties adjacent or downstream to the KUR-World site. Changes to flood behaviour are generally contained within the KUR-world site. Hydraulic modelling has assumed that any additional stormwater runoff generated by the increase in impervious areas within the catchment are to be captured and attenuated within on-site retention basins. Therefore, adverse impacts caused by increases in peak water levels downstream of the site would be mitigated throught this attenuation. Basin sizing is to be undertaken at the detailed design stage, hence the retention basins were not included in the hydraulic modelling at this stage, noting that models of this scale typically do not contain that level of detail.

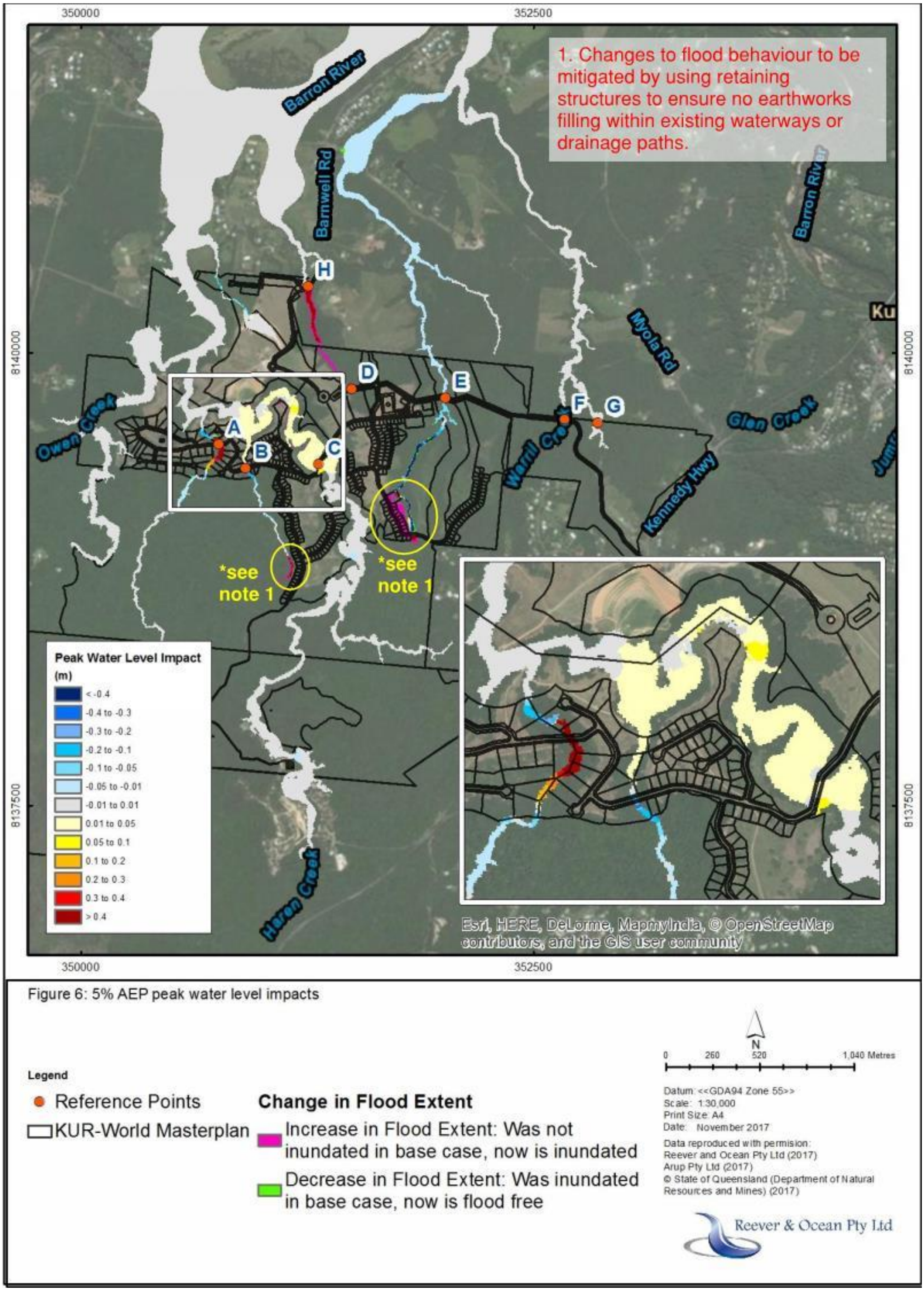

Figure 6: 5% AEP peak water level impacts

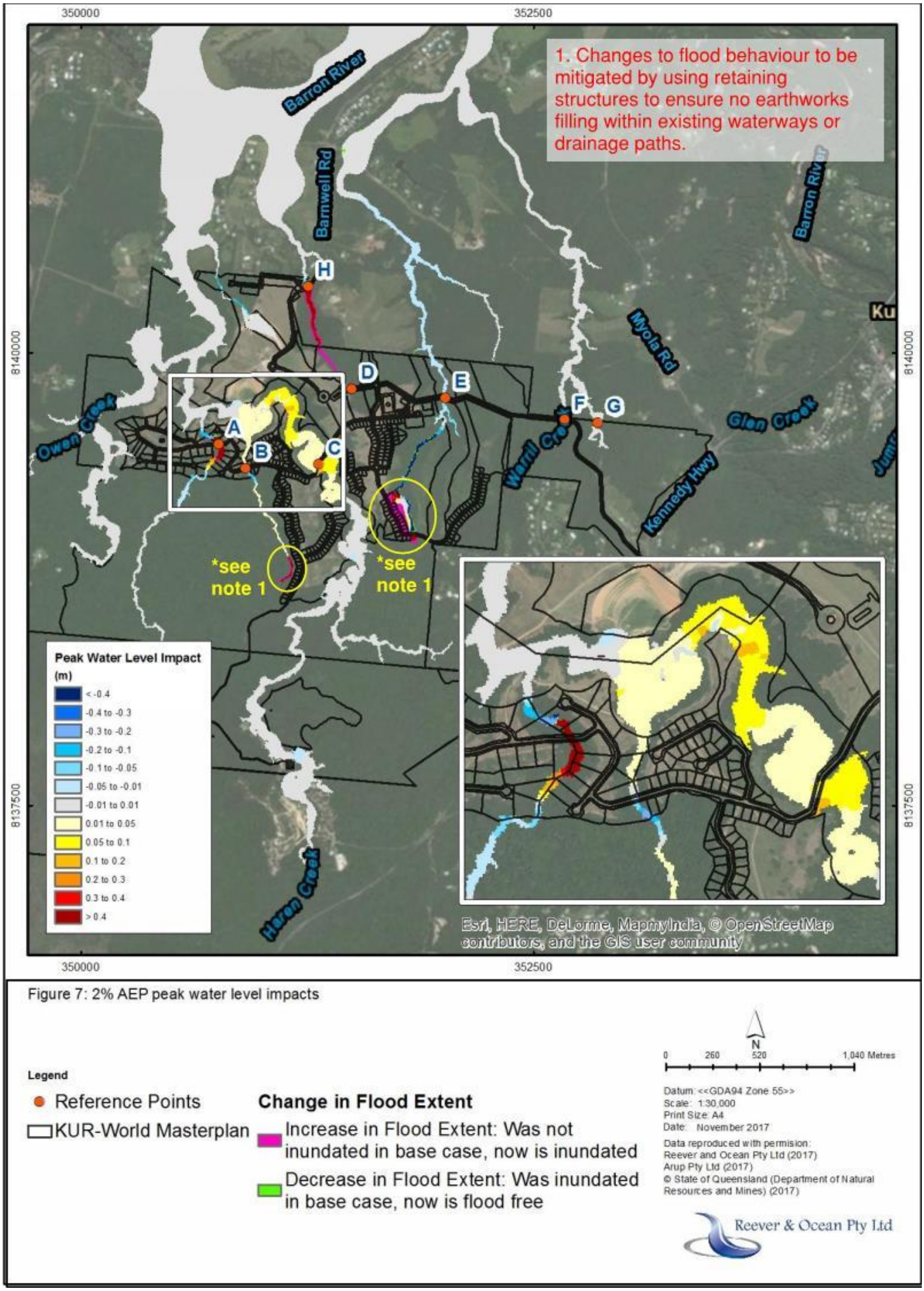

Figure 7: 2% AEP peak water level impacts

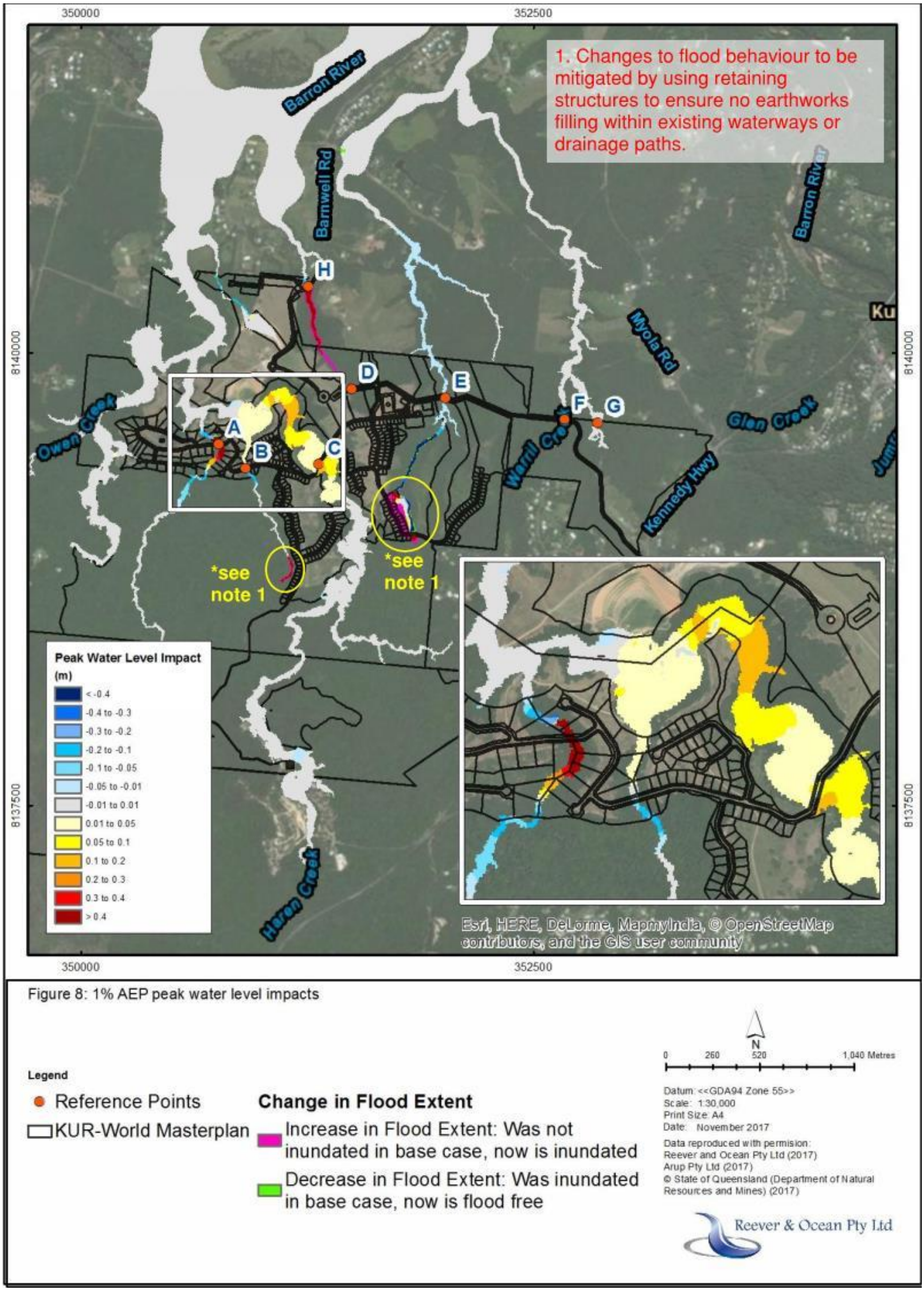

Figure 8: 1% AEP peak water level impacts

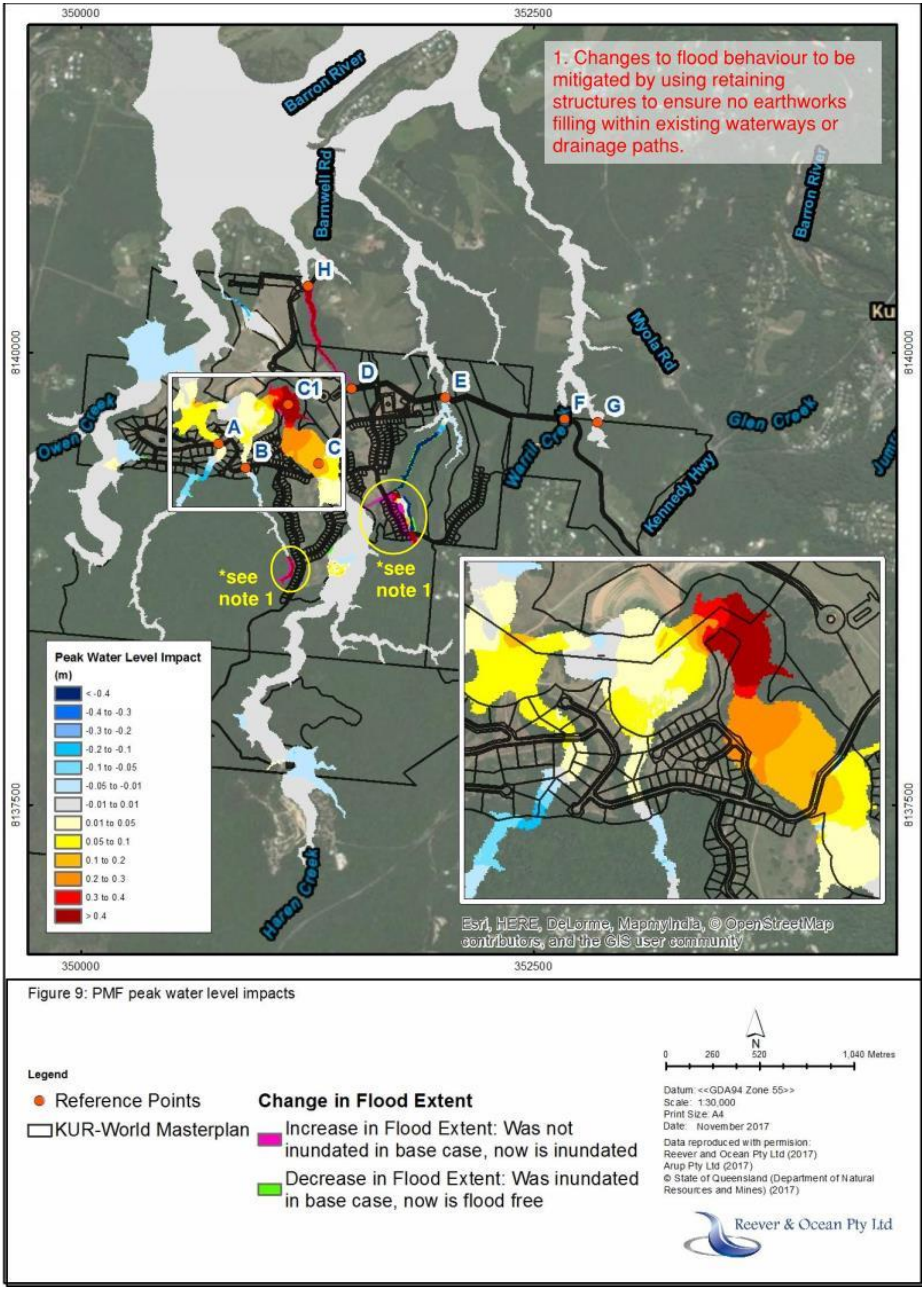

Figure 9: PMF peak water level impacts

4.2 Flooding hazard

The AR&R 2016 guidelines provides general flood hazard curves to specifically assist in emergency management planning. The flood hazard curves are combined curves that aim to inform the flooding risk to people, vehicles and buildings.

A flood hazard assessment of the site was undertaken for the design case using the flood hazard curves recommended in AR&R 2016. Two overall aims for this assessment included:

- identifying the risk for **people stability**
- assessing **vehicle stability** for emergency evacuation planning purposes during a 1% AEP flood event.

Building stability was not considered a risk as the KUR-World masterplan does not propose any buildings within the 1% AEP flood extent.

The peak flood hazard for the 1% AEP event design case is shown in Figure 10. The classification for hazard vulnerability is shown in Table 9.

Table 9: Combined Hazard Curves - Vulnerability Thresholds (Smith G P, Davey E K, and Cox R J, 2016)

Hazard Vulnerability Classification	Classification Limit (D and V in combination)	Limiting Still Water Depth (D)	Limiting Velocity (V)	Description
H1	D*V ≤ 0.3	0.3	2	Generally safe for vehicles, people and buildings.
H2	D*V ≤ 0.6	0.5	2	Unsafe for small vehicles.
H3	D*V ≤ 0.6	1.2	2	Unsafe for vehicles, children and the elderly.
H4	D*V ≤ 1.0	2	2	Unsafe for vehicles and people.
H5	D*V ≤ 4.0	4	4	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
H6	D*V > 4.0	-	-	Unsafe for vehicles and people. All building types considered vulnerable to failure.

Identified risk to human life

As mentioned previously, with respect to water level impacts there are flow paths through the edges of the proposed Stage 2 Lifestyle Villas. The flow paths are classified as H5 and H6, which means it is unsafe for all types of vehicle and people. The houses on these lots are likely to be built near the roads (away from the flow path, and with access/egress directly from the properties onto the adjacent roadway), and drainage easements will be created for the flow paths, thereby mitigating the risk associated with this flood hazard rating.

Identified risk to site access and roads

As discussed in Section 3, peak water level results indicate the road at reference **point H** will be overtopped with the assumed culvert dimensions (2no. 600 x 900 mm box culverts). Increases in peak water level to be mitigated at detailed design stage by increasing the culvert capacity to achieve 1%AEP flood immunity, thus mitigating the risks associated with site access via this road.

All roads crossing waterways have been designed to have 1%AEP flood immunity (with the assumption that the access road at point H will be suitably sized at detailed design stage to mitigate afflux impacts). This ensures access to property lots is made available in flood events up to the 1%AEP.

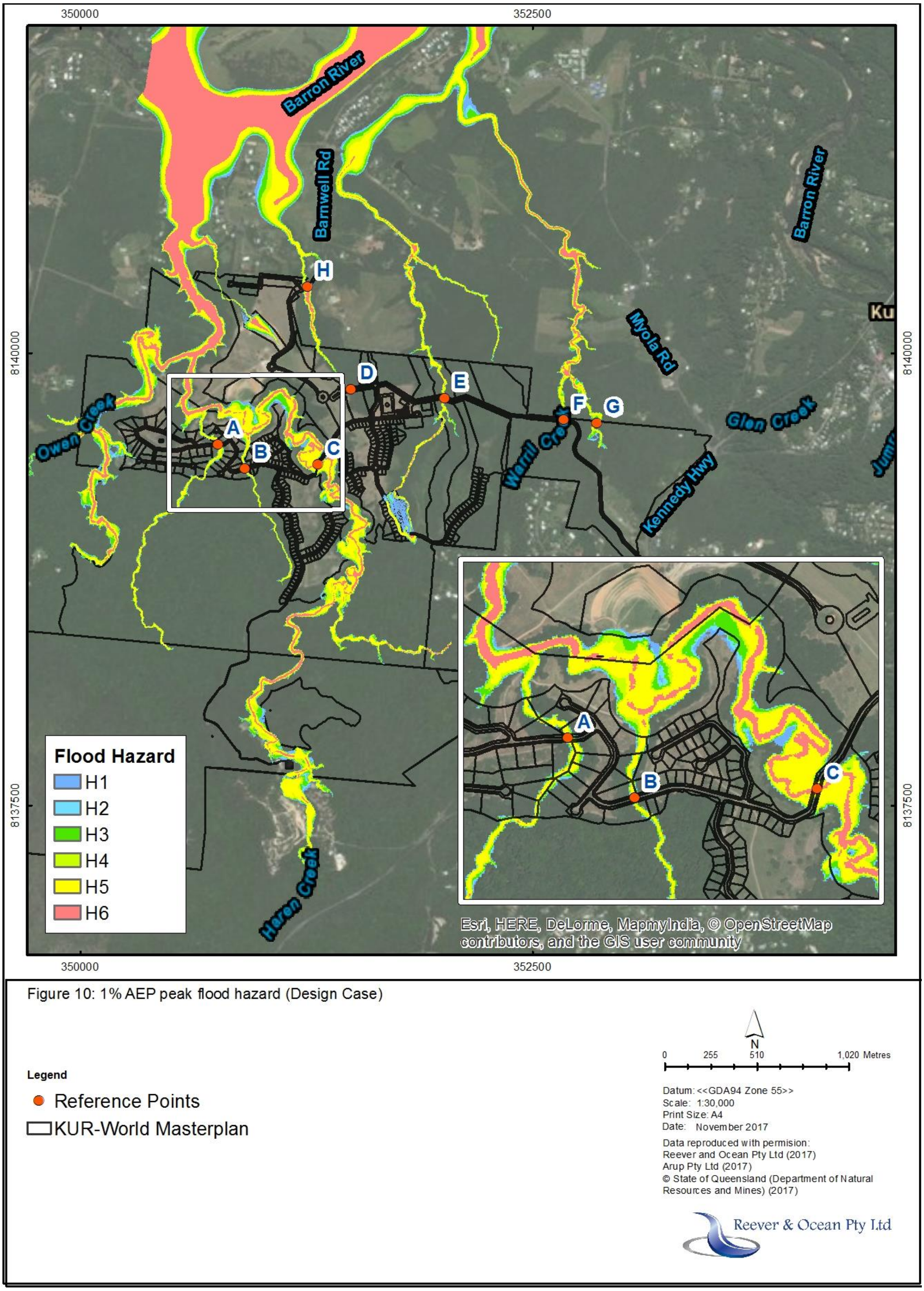

Figure 10: 1% AEP peak flood hazard (Design Case)

4.3 Climate Change

The projected impacts of climate change in the region include sea level rise, the potential for more frequent and intense storm events, and associated increases in storm tide risk to coastal areas.

Given the site's distance from the coast and elevation at around 320-440m AHD, sea-level rise and storm tide risk will have no impact on flooding at KUR-World.

The potential for more frequent and intense storm events is incorporated to some extent within the calculation of the PMP and assessment of the PMF. This approach has an appropriate degree of conservatism as the PMP accounts for climate change. This is in accordance with AR&R 2016 guidelines for climate change considerations.

4.4 Local floodplain erosion

An assessment was undertaken to identify if the proposed development would impact the site's existing risk of local floodplain erosion. The following factors were considered to determine if the design case hydraulic flood conditions of the 1% AEP would have an impact on erosion potential:

- Peak flood velocities
- Bed shear stress
- Proposed land uses
- Proposed changes to vegetative cover.

The change in velocity for the 1% AEP from the base case to the design case is shown in Figure 11. The most notable increase is through the lot edges of the Stage 1B lifestyle villas. There increase in velocity is in the order of 0.5m/s. Velocity increases and erosion impacts can be mitigated through providing sufficient rock cover of the flow path and appropriate vegetation.

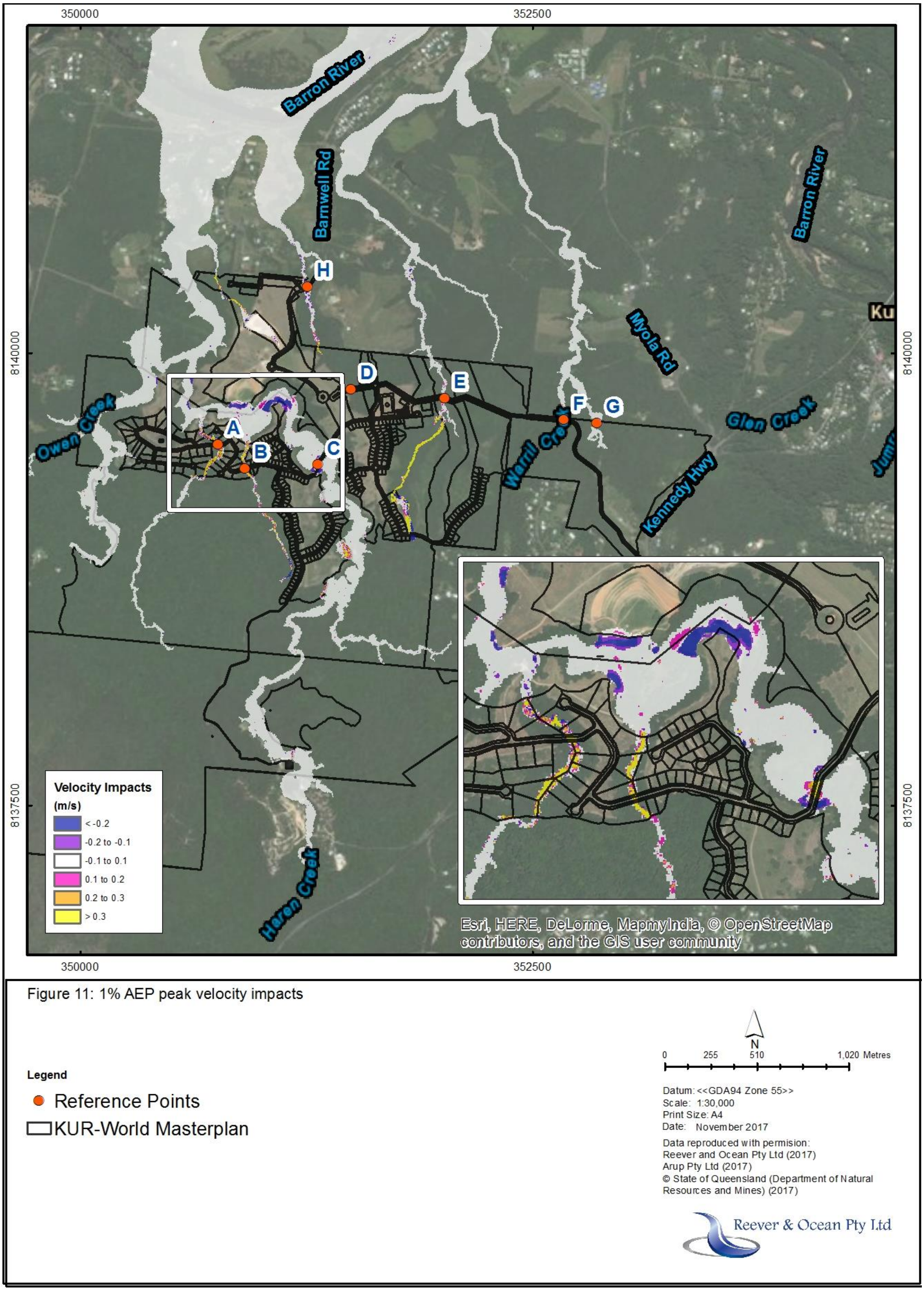

Figure 11: 1% AEP peak velocity impacts

5 Mitigation Measures and Conclusion

5.1 Disaster Management Planning

A site specific disaster management plan will be prepared for evacuation and emergency response during the construction and operation stages of KUR-World.

The plan will be developed in consultation with local and state agencies and cover three key areas:

1) Preparation for the flood and put in place emergency response plans by:
   - developing and managing local flood intelligence
   - undertaking emergency management planning for flooding and the risk to people, infrastructure and the environment
   - working closely with the relevant flood warning agencies to monitor potential floods
   - informing the community on how and when to react
   - considering future growth in the number of occupants in the floodplain and associated pressures on community-scale emergency management plans.
2) Mitigation measures to protect people, buildings, infrastructure, and the environment against flood hazards to include:
   - master planning layouts adopted such that no buildings or critical infrastructure are placed within the 1%AEP flood extent
   - stormwater attenuation basins to capture additional stormwater runoff caused by increase in impervious areas
   - allocating drainage easements to existing flow paths throughout the site.
3) Post-disaster response and recovery from a flood planning to include:
   - providing feedback on problems during events to responsible agencies
   - reviewing emergency management plans post flood events
   - work with community and follow through with emergency response and recovery plans.

6 References

AECOM. (2013). *Queensland flood mapping program flood investigation Kuranda 2013*. May 2015. [Online]. Available from: https://data.qld.gov.au/dataset/queensland-flood-mapping-program-2013-series/resource/c8fc78bb-95d9-46a0-a38b-c52161b47cfd. [Accessed: 24 February 2017].

Australian Government Bureau of Meteorology. (2017). *AR&R87 IFDs*. [Online]. Available from: http://www.bom.gov.au/water/designRainfalls/ifd-arr87/index.shtml. [Accessed: 24 February 2017].

Australian Institute for Disaster Resilience. (2017). *Managing the Floodplain: A Guide to Best Practice in a Flood Risk Management in Australia*. Melbourne: Australian Institute for Disaster Resilience.

Ball, J, Babister, M, Nathan, R, Week,s W, Weinmann, E, Retallick, M & Testoni, I (eds.). (2016). *Australian Rainfall and Runoff: A Guide to Flood Estimation*. Canberra: Geoscience Australia. Available from; http://book.arr.org.au.s3-website-ap-southeast-2.amazonaws.com/. [Accessed: 14 November 2017].

Bureau of Meteorology. (2003). *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method (GSDM)*. June 2003. Bureau of Meteorology: Melbourne, Australia.

Bureau of Meteorology. (2004). *Guidebook to the Estimation of Probable Maximum Precipitation: Generalised Tropical Storm Method. Included on compact disc Guide to the Estimation of Probable Maximum Precipitation.* March 2004. Generalised Tropical Storm Method, Hydro meteorological Advisory Service: Bureau of Meteorology.

Canterford, R P (ed.). (1987). *Australian Rainfall and Runoff: A Guide to Flood Estimation*. Vol. 2. Barton, ACT: Institution of Engineers, Australia.

Far North Queensland Regional Organisation of Councils (FNQROC). (2014). FNQROC Development Manual Operational Works Design Manual D4: Stormwater Drainage – Appendix A IDF Chart 13. Version 01/11. [Online]. Available from: http://www.fnqroc.qld.gov.au/files/media/original/003/d02/0f3/053/D4_IFD_Appendix_A__Design_Manual_-_FNQROC_Development_Manual_11-04_-_1_-_LIVE.pdf. [Accessed: 24 February 2017].

Kellogg Brown & Root Pty Ltd. (2015). *Flood Mapping for the Barron River Basin*. BEW457-TD-WE-REP-0019 Rev. 0. Brisbane: Kellogg Brown & Root Pty Ltd.

Nathan, R & Weinmann, E. (2016). 'Treatment of Joint Probability: Catchment Simulation for Design Flood Estimation', in Ball, J, Babister, M, Nathan R, Weeks, W, Weinmann E, Retallick, M & Testoni, I (eds). *Australian Rainfall and Runoff: A Guide to Flood Estimation*. Canberra: Geoscience Australia. Available from; http://book.arr.org.au.s3-website-ap-southeast-2.amazonaws.com/. [Accessed: 14 November 2017].

Pilgrim, D H (editor in chief). (1987). *Australian Rainfall and Runoff: A Guide to Flood Estimation*. Vol. 1. Revised Edition 1987. Barton, ACT: Institution of Engineers, Australia.

Queensland Government Department of Energy and Water Supply, Brisbane City Council & Institute of Public Works Engineering Australia Queensland Division Ltd. (2013). *Queensland Urban Drainage Manual: Third edition 2013 – provisional*. Third edition. Brisbane: Department of Energy and Water Supply. Available from: https://www.dews.qld.gov.au/__data/assets/pdf_file/0008/78128/qudm2013-provisional.pdf. [Accessed: 14 November 2017].

Smith, G P & Cox, R J. (2016). 'Chapter 7: Safety Design Criteria'. in Smith, GP., Davey, E K., & Cox, R J (eds.). *Australian Rainfall and Runoff: A Guide to Flood Estimation: Book 6 – Flood Hydraulics.* Geoscience Australia: Canberra. Available from: http://book.arr.org.au.s3-website-ap-southeast-2.amazonaws.com/#b6_c7_r18_b9_ch8. [Accessed: 14 November 2017].