STATE EMERGENCY SERVICE

TASMANIAN STRATEGIC FLOOD MAP DERWENT STUDY AREA DESIGN FLOOD MODELLING

ADDENDUM TO CALIBRATION REPORT

DECEMBER 2023

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Project Tasmanian Strategic Flood Map Derwent Study Area Design Flood Modelling	**Project Number** **120038**
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TASMANIAN STRATEGIC FLOOD MAP
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LIST OF ACRONYMS

AEP	Annual Exceedance Probability
AMS	Annual Maximum Series
ARF	Areal Reduction Factor
ARR	Australian Rainfall and Runoff
ATP	Areal Temporal Patterns
Bureau/BoM	Bureau of Meteorology
CC	Climate Change
CFEV	Conservation of Freshwater Ecosystem Values (DPIPWE/DNRE)
CL	Continuing Loss
DEM	Digital Elevation Model
DNRE	Department of Natural Resources and Environment Tasmania (formerly DPIPWE)
DPIPWE	Department of Primary Industries, Water and Environment
DRM	Direct Rainfall Method
DTM	Digital Terrain Model
FFA	Flood Frequency Analysis
FLIKE	Software for flood frequency analysis
FSL	Full Supply Level
GIS	Geographic Information System
GEV	Generalised Extreme Value distribution
HAT	Highest Astronomical Tide
HSA	Human Settlement Area
ICM	Infoworks ICM software (Innovyze)
IL	Initial Loss
IFD	Intensity, Frequency and Duration (Rainfall)
ISIS	ISIS 2D modelling software
LiDAR	Light Detection and Ranging
mAHD	meters above Australian Height Datum
NTC	National Tide Centre
PERN	Catchment routing parameter in RAFTS
Pluvi	Pluviograph – Rain gauge with ability to record rain in real time
PTP	Point Temporal Patterns
R	Channel routing param in WMAWater RAFTS WBNM hybrid model
RAF	RAFTS Adjustment Factor
RAFTS	hydrologic model
RCP	Representative Concentration Pathways (RCPs) (CC scenarios)
RORB	RORB hydrological modelling software
SES	State Emergency Service
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydrodynamic model)
TP	Rainfall Temporal Patterns

1. INTRODUCTION

This report is an addendum to the Tasmanian Strategic Flood Map Derwent and Derwent Estuary-Bruny Study Area Calibration Report (WMAwater, 2023). The study area, available data, model calibration, limitations and uncertainty statements are provided in the calibration report.

This report outlines the data, methodology and the results of modelling the design flood events for the Derwent and Derwent Estuary-Bruny Study Area.

2. DATA

2.1. Previous Flood Studies

Previous flood studies in the study area were provided to WMAwater as part of the project data library. The studies that include modelling areas within the Derwent and Derwent Estuary are listed in Table 1.

Table 1: Previous flood studies

Flood study name	Study year	Study area	Flood extents and layers available
New Norfolk Flood Plain Study (HEC)	1992	Lower River Derwent (New Norfolk)	Design flood levels and flood maps showing flood extents at different chainages for 5%, 2% and 1% AEP events.
Lower Jordan River Flood Plain Study (HEC)	1993	Bagdad Rivulet, River Jordan from upstream Pontville to Cove Hill	Design flood levels and flood maps showing flood extents at different chainages for 5%, 2% and 1% AEP events.
Sandy Bay Rivulet (Entura)	2013	Sandy Bay Rivulet from below Lower Reservoir through Dynnyrne and Sandy Bay to River Derwent Estuary-Bruny	Flood maps for 20%, 5%, 2%, 1%, 1% CC, 0.5%, 0.2% showing flood extent for depth
Hobart Rivulet Flood Study (Entura)	2014	Hobart Rivulet from Cascade Brewery to River Derwent Estuary-Bruny	Flood maps for 20%, 5%, 2%, 1%, 1% CC, 0.5%, 0.2% showing flood extent for depth
Kingston Beach Flood Study (Kingborough Council)	2016	Confluence of Browns River and Whitewater Creek to Derwent Estuary	Flood maps for 2010, 2050 and 2100 with 20%, 5% and 1% AEP showing flood extent, level, depth and flood hazard with coincident 20%, 5% and 1% storm surge
Glenorchy CBD Stormwater System Management Plan (SMEC)	2018	Humphreys Rivulet, Littlejohn Creek and Barossa Creek through Glenorchy to River Derwent Estuary-Bruny	Flood maps for 5%, 1%, 1% CC, PMF showing flood extent for depth and flood hazard.
New Town Rivulet Flood Study (Entura)	2019	New Town Rivulet, Maypole Rivulet, Pottery Creek, Brushy Creek	Flood maps for 1%, 1% CC, showing flood extent for depth and flood hazard.
Snug River Flood Study (Kingborough Council)	2019	Snug River Catchment with flood maps only at Snug township	Flood maps for 2020, 2050 and 2100 with 20%, 5% and 1% AEP showing flood extent, level, depth and flood hazard
Adventure Bay Flood Study (Entura)	2020	Captain Cook Creek Catchment	Flood maps for 2020 1%, 2050 1% and 2100 1% AEP showing flood extent, level, depth and flood hazard
Whitewater Creek Flood Study (WMAwater)	2020	Whitewater Creek Catchment	Flood maps for 5%, 1%, 0.5% showing flood extent for level, depth, velocity, flood hazard and hydraulic categories.
Kingston CBD Catchment Resilience Program (WMAwater)	2020	Kingston CBD area which contains Kingston Rivulet	Flood maps for 5%, 1%, 0.5% showing flood extent for level,

Flood study name	Study year	Study area	Flood extents and layers available
			depth, velocity, flood hazard and hydraulic categories.
Blackmans Bay Catchment Resilience Project (Engeny)	2020	Blackmans Bay area	Flood maps for 5%, 1%, 1% CC and 0.5% showing flood extent for level, depth, velocity, flood hazard and hydraulic categories.
Margate Rivulet Hydraulic Assessment (Cardno)	2021	Whole Margate Rivulet Catchment	Flood maps for 5%, 1%, 1% CC, 0.5% showing flood extent for level, velocity and flood hazard.
Coffee Creek Hydraulic and Erosion Assessment (WMAwater)	2021	Coffee Creek Catchment	Flood maps for 5%, 1%, 0.5% showing flood extent for level, velocity, flood hazard and hydraulic categories.
Various waterways within the municipal of Clarence	Unknown	Whole Clarence City Council Area	Flood extent and depth 1% AEP + Climate Change

2.2. Flow Data

Flood Frequency Analysis (FFA) was performed on annual maximum series (AMS) from some flow gauges within the catchment. The gauges used for FFA are shown in Table 2. The other gauges in the study area were not included in the FFA due to insufficient record length, being highly influenced by upstream dams, inconsistent datasets and/or unreliable rating curves. More detail on the quality of the gauge data is provided in the calibration report (WMAwater, 2022).

A local hydrodynamic model was used to create theoretical rating curves at River Clyde, Tyenna River and Snug River. At River Clyde, this rating was similar to the DNRE rating used for recent mid-size floods. A merged rating was used, using the DNRE ratings for smaller AMS events which were likely within the channel so the DNRE rating is expected to be more accurate, and the revised rating for larger events. This was done across the entire historic period as there seemed to be little evidence in the gauges for significant change in the ratings over time for large events. Similarly, a merged rating was used at the Tyenna River and Snug River gauges using the DNRE ratings for smaller events and the theoretical ratings for larger events.

Florentine above Derwent has a very stable rating, with minimal changes since the site was reinstated in 1951. Information on Water Data Online shows the site is well gauged up to 120 m^3/s with some additional gaugings up to 155 m^3/s, with only 3 historic events peaking above this. This suggests the rating at this site should be very good.

Similarly, Ouse at Ashton also has a long term stable rating with minimal changes in high flows. However, the highest gaugings available (on Water Data Online) are at less than 300 m^3/s with the highest peak on record at over 600 m^3/s so there is significant uncertainty in the highest flows, however calibration showed a good match between observed and modelled rating curves.

Flow data at Derwent below Meadowbank was used as a check on system wide FFAs despite the complications with matching design flows to peaks downstream of the many dams on the River Derwent. The rating at this site should be very good as it is directly downstream of Meadowbank Dam and can therefore be compared to power station and spillway rating curves which are much more predictable.

Table 2: Flow gauges used for Derwent Study Area FFA

Gauge number	Gauge name	River	Period of record	Number of points in AMS
54-1	River Clyde at Bothwell	River Clyde	1979-2020	40
358-1	Ouse River at Ashton	River Ouse	1989-2022	34
40-1	Florentine River U/S Derwent River	Florentine River	1921-1934, 1951-2020	80
499-1	Tyenna River at Newbury	Tyenna River	1965-2020	56
715-1	Derwent River below Meadowbank	River Derwent	1974-2021	48
5202-1	Snug River U/S Snug Tiers Road Bridge	Snug River	1975-2020	46

2.3. Design Inputs

The design inputs used in the study (Intensity Frequency Duration (IFD) depths, losses, pre-burst rainfalls, Areal Reduction Factors (ARFs) and temporal patterns) were obtained through the ARR Data Hub (Babister et al, 2016) and the Bureau of Meteorology website (Bureau of Meteorology, 2019).

2.3.1. Design Rainfall Depths and Spatial Pattern

Intensity Frequency Duration (IFD) information was sourced from the Bureau of Meteorology website (Bureau of Meteorology, 2019). IFD information was sourced for each individual sub-catchment to give a spatial pattern across the study area. Examples of sub-catchment rainfalls are shown in Figure A 1 to Figure A 3 for the Derwent catchment and Figure A 5 to Figure A 7 for Derwent Estuary-Bruny Bruny Island.

2.3.2. Temporal Patterns

ARR 2016 Book 2 Chapter 5 (Ball et. al., 2019) recommends the use of areal temporal patterns for catchments greater than 75 km^2. Therefore, for the flood frequency analysis, the areal temporal patterns relevant to this location were downloaded from the ARR Data Hub. An example of the temporal patterns downloaded from the Data Hub is shown in Figure A 4.

For selection of the final design runs applicable to the entire study area, areal and point temporal patterns were downloaded from the ARR Data Hub. Temporal patterns were filtered for embedded bursts and in some cases patterns with large, embedded bursts causing significant outliers were removed. Embedded bursts were particularly bad in the Derwent-Estuary-Bruny region of the study area as the IFDs in this area are particularly steep. Some patterns had embedded bursts which were up to two time larger than a burst rainfall, with in some cases almost all sub-catchments having embedded bursts of greater than 150% of the shorter burst rainfall. Additional spot checks showed some embedded bursts were in order of 1 in 500 AEP events for a 1% rainfall. Additional to filtering of embedded bursts, highly embedded patterns were censored and removed from the set of patterns available. However it is noted that due to the regional approach adopted for this project with complicated selection of ARF areas and pattern durations, that it is very difficult to systematically remove all embedded bursts, and areas like the Derwent Estuary-Bruny with very high IFD gradients would be better suited to detailed design studies. Examples of the remaining patterns for Derwent Estuary-Bruny are shown in Figure A 8.

When assessing the reference critical flow for each sub-catchment (as described in the Hydrology Methods Report (WMAwater, 2021a)), point temporal patterns were used for sub-catchments with an upstream area of less than 75 km^2 or used to assess shorter storms if the critical duration on a larger catchment was identified as 12 hours (the shortest duration available with areal temporal patterns).

2.3.3. Pre-burst

Pre-burst rainfall depths were taken from the ARR Data Hub as a ratio of the IFD depths. As ILs calibrated to the FFA were greater than 0 there was no need to include sensitivity to adding a pre-burst temporal pattern for this study area, as the pre-burst has effectively been removed from the IL with some IL depth remaining.

2.3.4. Losses

Initial values for sub-catchment initial loss (IL) and continuing loss (CL) were derived from the unpublished Hydrologic Soil Groups of Tasmania data that was provided for use in this project (DPIPWE, 2019).

2.3.5. Baseflow

Baseflow was calculated for each calibration event and was found to be less than 5% of the event peaks. In line with ARR 2016 Book 5 Chapter 4 (Ball et. al., 2019), where baseflows of less than 5% are considered a small component compared to runoff, a simplified approach to baseflow calculations was undertaken. Hydrodynamic modelling of the calibration events showed that large flood events in this study area were peak rather than volume driven. There may be a baseflow in some rivers due to hydropower operations, however this will still be a small component of the hydrograph for the AEPs of interest (2%, 1% and 0.5%). Flood operations rules for the hydropower stations were not modelled in this regional model. Therefore baseflow was not included in the design event modelling, and any baseflows due to power station operation were generally less than 5% of event peaks.

2.3.6. Direct Rainfall

Two hour direct rainfall storms were created using each sub-catchment's IFD depths using the method described in the Hydrodynamic Methods Report (WMAwater, 2021b).

2.3.7. Climate Change

2.3.7.1. Rainfall Factors

Climate change factors for the study area were downloaded from the ARR Data Hub. ARR recommends the use of the RCP4.5 and RCP8.5 values, however the Tasmanian Interim Planning Scheme recommends the use of RCP8.5 and this has been adopted for this project. Using RCP8.5 results for the year 2090, gives a rainfall scaling factor of 16.3% to the IFDs.

2.3.7.2. Boundary Conditions

Sea level rise was included in the climate change scenario and was applied at the downstream boundary of the hydrodynamic model. The rise in water level was taken from the Tasmanian Local Council Sea Level Rise Planning Allowances, which uses sea level rise projections based on RCP 8.5 for 2100. This gave a rise in sea level of 0.85 m for the Hobart Council area.

The levels from this document were deemed most appropriate to be consistent with best practise planning around Tasmanian Councils.

3. OVERVIEW OF METHODOLOGY

The hydrological and hydrodynamic design modelling methodology has been outlined in the Hydrology Methods Report (WMAwater, 2021a) and the Hydrodynamic Methods Report (WMAwater, 2021b). Details on the methods are only included in this report where they deviate from the methods described in these reports or are specific for this catchment.

The modelling method for the design events includes the following steps.

- Data preparation
    - Fitting FFA to suitable flow records
    - Extraction of design data – IFDs, temporal patterns, pre-burst rainfalls from ARR DataHub (automated in the modelling process), derivation of direct rainfall storms
- Hydrologic modelling
    - Identification of flow gauge locations
    - Identification of dam and diversion locations
    - Sub-catchment delineation
    - Include dam storage and spillway ratings where required
    - Event calibration for PERN parameter and event losses, using automated WMAwater RAFTS modelling tool, IDW rainfall surfaces and available flow data.
    - Output event sub-catchment rainfalls, routing parameters and event losses for input to hydraulic model
    - Calibration of design losses to FFA using automated WMAwater RAFTS model
    - Run design events in WMAwater RAFTS modelling tool, with design data, calibrated routing parameters and design losses. Outputs design sub-catchment rainfalls for input to hydrodynamic model.
- Hydrodynamic modelling
    - Run design events and direct rainfall through the calibrated hydrodynamic model with the applicable downstream boundary levels and dam initial conditions.
    - Output design event and direct rainfall results for processing.
- Mapping
    - Convert design event and direct rainfall results to a grid format with a grid resolution of at least 10 m.
    - Envelope design event results to produce the maximum envelope of the inputs.
    - Filter direct rainfall results using a peak flood depth filter of 0.1 m. Clip direct rainfall results to the design event envelope.
    - Map the design event envelope and filtered direct rainfall results.

During the design event selection process, it was discovered that the standard selection process could not select a small number of patterns which were viable across the catchment without the patterns with small ARFs (i.e. higher rainfalls) drowning out all patterns with more appropriate ARF factors in the lower catchment. The selected patterns were therefore forcibly applied to their respective regions through the cropping of the design event results prior to the enveloping. It is acknowledged that the cropping may result in abrupt changes in levels at the boundaries of the selected patterns in the design mapping. Where possible, the boundaries of the selected patterns were located away from human settlement areas and major infrastructure to minimise the impact of the cropping. Discontinuities in the design mapping in isolated areas should still be expected, however this was deemed to be an acceptable compromise in achieving a better representation in the design mapping across the remainder of the study area.

4. CALIBRATION OF DESIGN LOSSES

FFA was undertaken at the gauges identified in Table 2. The results of the FFA are shown in Figure 1 to Figure 7. The fitting method and distribution that provided the best fit to the data at each site is shown in Table 3.

Table 3: Fitting method and distribution used for Derwent Study Area FFA

Gauge number	Gauge name	Fitting method	Distribution
54-1	Clyde River at Bothwell	Bayesian	LP3
358-1	Ouse River at Ashton	Bayesian	LP3
40-1	Florentine River U/S Derwent River	Bayesian	LP3
499-1	Tyenna River at Newbury	Bayesian	LP3
715-1	Derwent River below Meadowbank	Bayesian	LP3
5202-1	Snug River U/S Snug Tiers Road Bridge	Bayesian	LP3

The calibrated external hydrologic model for each study area was run through the solver and the initial and continuing losses that best matched the curve were estimated at each site. As the events of relevance to this study are of 2% AEP or larger, the results were weighted to this end of the FFA curve.

Losses were compared at all sites in the Derwent catchment and a set of losses that minimised errors across all gauges was established. The fit to the local FFAs is variable across the catchment. This is not surprising given the large geographic area, range of land uses and vegetation and soil types. Differences also potentially relate to uncertainties in observed flows. The resulting modelled flows typically fall within the confidence intervals at all gauges investigated. The main exception to this is that flows are significantly overestimated in the Florentine River. As discussed in the calibration report (WMAwater, 2023), the model does a poor job of replicating the double peak which is typically observed in the Florentine and therefore significantly overestimates peak flows; this has also been found in previous studies on the Florentine (Entura, 2015).

Two model runs were done to match the FFA at Derwent below Meadowbank, a run with the initial water level (IWL) for all dams starting at the design levels shown in Table 6 (FFA in Figure 5) and one where most dams were started at the mean level since 2010 (Figure 6). This was done as a very simplified sensitivity test to starting level and showed design levels are sensitive to starting levels in the dams. Therefore, this gauge cannot really be used to calibrate losses as the current methodology does not adequately reflect historic lake levels. However, this gauge has been included as a verification that the flows at the end of the hydro scheme are within the range of expected possibilities.

The losses for the Derwent Estuary-Bruny and Bruny Island were calibrated separately to the Snug River gauge FFA. As discussed in Section 2.3.2 the Derwent Estuary-Bruny Bruny Island region had very severe embedded bursts in the design temporal patterns. Therefore, the set of temporal patterns available for this calibration was significantly reduced, and there is still some potential for embedded bursts to remain.

The percentage differences between the FFAs and the modelled peak flow for the 2%, 1%, and 0.5% AEP events are shown in Table 4 for the Derwent system and Table 5 for Derwent Estuary-Bruny and Bruny Island.

Table 4: FFA and modelled peak flows – Derwent study area

Gauge	AEP	Modelled peak flow (m^3/s)	FFA peak flow (m^3/s)	Peak flow difference (%)
Clyde River at Bothwell	2% AEP	162	224	-28%
	1% AEP	222	287	-23%
	0.5% AEP	300	354	-15%
Ouse River at Ashton	2% AEP	523	523	0%
	1% AEP	636	661	-4%
	0.5% AEP	810	822	-2%
Florentine River U/S Derwent River	2% AEP	354	194	83%
	1% AEP	430	226	91%
	0.5% AEP	538	261	107%
Tyenna River at Newbury	2% AEP	215	166	29%
	1% AEP	255	202	27%
	0.5% AEP	315	243	30%
Derwent River b/l Meadowbank (start FSL)	2% AEP	1,219	1,202	1%
	1% AEP	1,578	1,304	21%
	0.5% AEP	2,143	1,396	53%
Derwent River b/l Meadowbank (start mean)	2% AEP	1,050	1,202	-13%
	1% AEP	1,402	1,304	7%
	0.5% AEP	1,935	1,396	39%

Table 5: FFA and modelled peak flows – Derwent Estuary-Bruny study area

Gauge	AEP	Modelled peak flow (m^3/s)	FFA peak flow (m^3/s)	Peak flow difference (%)
Snug River U/S Snug Tiers Road Bridge	2% AEP	32	36	-11%
	1% AEP	39	39	2%
	0.5% AEP	50	41	22%

The adopted loss values are shown in Table 6 and Table 7.

Table 6: Adopted losses – Derwent study area

Initial Loss (mm)	Continuing Loss (mm/h)			
	Soil Type A	Soil Type B	Soil Type C	Soil Type D
20	3	1.56	0.72	0.36

Table 7: Adopted losses – Derwent Estuary-Bruny study area

Initial Loss (mm)	Continuing Loss (mm/h)			
	Soil Type A	Soil Type B	Soil Type C	Soil Type D
23	6	3.12	1.44	0.72

5. DESIGN EVENT MODELLING

5.1. Design Event Selection

Design inputs were run through the hydrological model across the entire study area with a range of ARFs to select representative ARFs, storm durations and temporal patterns to be run through the hydrodynamic model. The selected storms and the number of sub-catchments best represented by each for the Derwent study area and the Derwent Estuary-Bruny study area are shown in Table 8 and Table 9. The temporal patterns for each selected run for the Derwent study area and the Derwent Estuary-Bruny study area are shown in Figure 8 and Figure 9.

In some parts of the study area, the smaller ARF patterns were drowning out the more appropriate bins. Therefore, in some places the resulting grids were cropped to the appropriate areas, as detailed in Section 3.

Table 8: Selected storms for each AEP with the number of sub-catchments best represented by each set – Derwent study area

AEP	Storm duration (min)	ARF bin	# sub-catchments
2%	720	45	73
2%	1080	75	126
2%	1440	450	148
2%	1440	1800	27
2%	4320	6000	30
2%	5760	800	15
1%	720	45	67
1%	1080	75	131
1%	1440	450	162
1%	1440	1800	13
1%	4320	6000	31
1%	5760	800	15
0.5%	720	45	88
0.5%	1080	75	117
0.5%	1440	450	161
0.5%	1440	1800	15
0.5%	4320	6000	25
0.5%	5760	800	13

Table 9: Selected storms for each AEP with the number of sub-catchments best represented by each set – Derwent Estuary-Bruny study area

AEP	Storm duration (min)	ARF bin	# sub-catchments
2%	540	10	53
2%	720	120	4
2%	1080	45	10
2%	540	10	54
1%	720	120	4
1%	1080	45	9
1%	540	10	56
1%	720	120	4
0.5%	1080	45	7
0.5%	540	10	53
0.5%	720	120	4
0.5%	1080	45	10

Diagram 1 and Diagram 2 shows which ARF-duration-TP set gives representative flows for each sub-catchment for the 1% AEP event for the Derwent study area and the Derwent Estuary-Bruny study area. Headwater sub-catchments where only direct rainfall is applied are also shown. In the headwater catchments, direct rainfall was defined as the dominating event, with the rainfall intensities factored to account for losses via a runoff coefficient. For the Derwent study area, a runoff coefficient of 45% was adopted. For the Derwent Estuary-Bruny study area, a runoff coefficient of 60% was adopted. These runoff coefficients are calculated based on the runoff coefficient of the critical event (from the selected events) for the headwater catchments of each study area. While the hourly CL values are higher for the Derwent Estuary-Bruny study area, this still has a higher runoff coefficient as the events are typically shorter, so the total loss proportion is actually lower than in the Derwent study area. Although direct rainfall is applied to all sub-catchments, the mapping process detailed in Section 3 ensures that primary flow paths are not defined by this event.

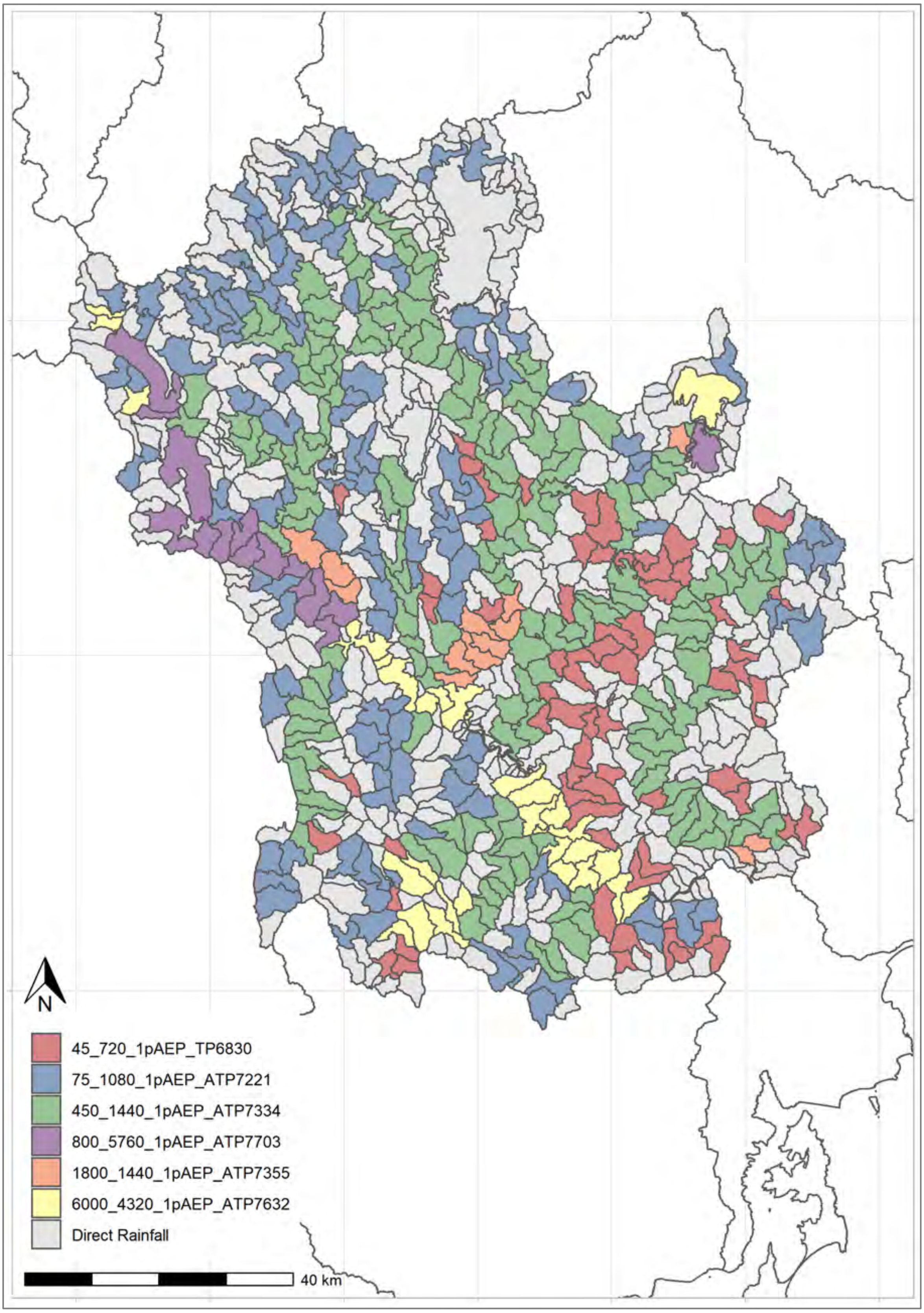

Diagram 1: ARF set relevant for each sub-catchment for the 1% AEP event for the Derwent Study Area

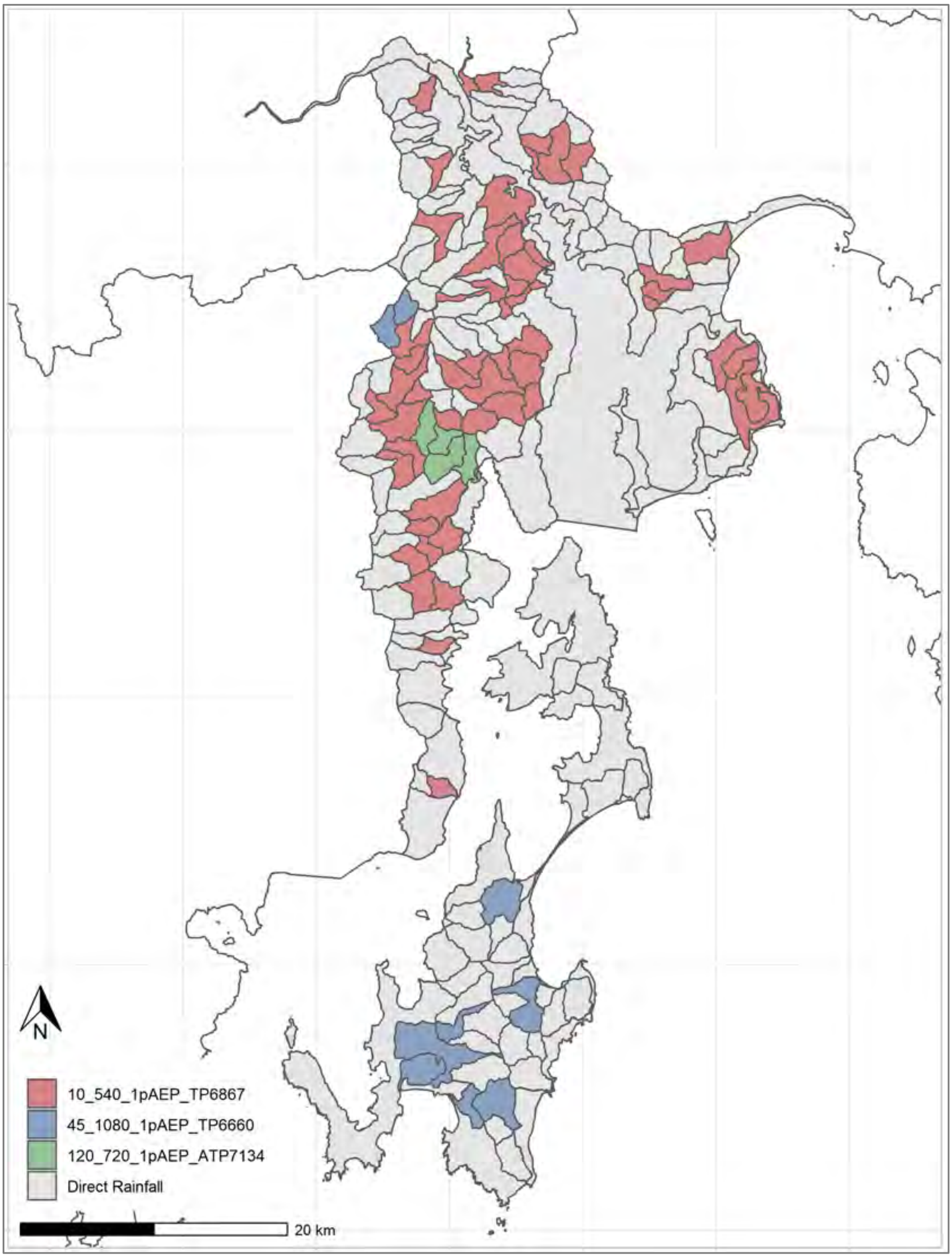

Diagram 2: ARF set relevant for each sub-catchment for the 1% AEP event for the Derwent Estuary-Bruny Study Area

The selection of four and six ARF-duration-TP sets per AEP does introduce errors when compared to running the ideal ARF-duration-TP set through the hydrodynamic model for each sub-catchment, however running thousands of runs of the hydrodynamic model is not computationally feasible. The percentage errors for each sub-catchment are shown in Figure B 1 to Figure B 3 for the Derwent Catchment and Figure B 4 to Figure B 6 for the Derwent Estuary-Bruny Bruny Island study area. A summary of the magnitude of the errors for the Derwent study area and the Derwent Estuary-Bruny study area are shown in Table 10 and Table 11. Each sub-catchment's absolute percentage error is calculated using the following equation:

$SC\_Q\_Peak_{ref}$ = Sub-catchment peak flow run with ARF from that sub-catchment's ARF bin, with critical duration calculated at this gauge, and TP above the mean selected.

$SC\_Q\_Peak_{sel}$ = Sub-catchment peak flow run with ARF, storm duration and TP from the selected pattern as shown in Diagram 1

$$\text{Absolute subcatchment percentage error} = \left|\frac{(\text{SC\_Q\_Peak}_{sel} - \text{SC\_Q\_Peak}_{ref})}{\text{SC\_Q\_Peak}_{ref}}\right| \times 100$$

Table 10: Sub-catchment errors using the ARF-TP-duration sets shown in Table 8 for each AEP for the Derwent catchment

AEP	Absolute sub-catchment error		
	Mean across sub-catchments	**90th %ile across sub-catchments**	**Max of all sub-catchments**
2%	4%	9%	27%
1%	4%	10%	28%
0.5%	4%	9%	30%

Table 11: Sub-catchment errors using the ARF-TP-duration sets shown in Table 8 for each AEP for Derwent Estuary-Bruny Bruny Island

AEP	Absolute sub-catchment error		
	Mean across sub-catchments	**90th %ile across sub-catchments**	**Max of all sub-catchments**
2%	3%	7%	29%
1%	3%	7%	32%
0.5%	4%	7%	42%

The selected storms and direct rainfall were then run through the calibrated hydrodynamic model as documented in the calibration report (WMAwater, 2022). For the design event modelling, the downstream boundary adopts a static tailwater level set to the highest astronomical tide (HAT). This data was provided by the National Tide Centre (NTC) in 5 km² grid cells and was extracted in the Derwent Estuary-Bruny.

Table 12 and Table 13 summarise the downstream boundary levels for the Derwent study area and the Derwent Estuary-Bruny study area. For design modelling most dams were started at FSL as described in the Hydrodynamic Methods Report (WMAwater 2021b), however in some cases this is not a realistic startling level. Therefore, Great Lake, Lake St Clair, Lake King William, Laughing Jack Lagoon and Dee Lagoon were started at their 90% percentile observed level since 2007 as a reasonable, conservative starting level. Lake Crescent and Lake Sorell are also large storages with the potential to capture significant events without spilling, however as less information was known about these storages' operations, they have been assumed to start at FSL. Table 14 and Table 15 show the dam initial conditions for each design event for the Derwent study area and the Derwent Estuary-Bruny study area. As Flagstaff Gully Reservoir and Risdon Brook Reservoir have very small catchment areas they do not have their own sub-catchments inflows and therefore only receive inflow in the direct rainfall models.

Table 12: Downstream boundary levels for each AEP – Derwent study area

AEP	Downstream boundary
2%	HAT (0.78 mAHD)
1%	
0.5%	
1% CC	HAT + sea level rise (1.64 mAHD)

Table 13: Downstream boundary levels for each AEP – Derwent Estuary-Bruny study area

AEP	Downstream boundary
2%	Derwent Estuary HAT - 0.85 mAHD Bruny Island HAT – 0.78 mAHD
1%	
0.5%	
1% CC	Derwent Estuary HAT + sea level rise - 1.71 mAHD Bruny Island HAT + sea level rise – 1.64 mAHD

Table 14: Dam initial conditions – Derwent study area

Storage	FSL (m AHD)	Initial Water Level (IWL) (m AHD)
Augusta Lake	1150.62	1150.62
Great Lake	1039.37	1027.0
Little Pine Lagoon	1007.36	1007.36
Pine Tier Lagoon	670.56	670.56
Laughing Jack Lagoon	761.99	761.44
Echo Lake	846.43	842.27
Dee Lagoon	655.32*	655.32
Bronte Lagoon	655.99	663.56
Tungatinah Lagoons	651.20	650.20
King William Lake	719.94	719.58
Lake St Clair	736.72^	735.55
Liapootah Pond	341.83	341.83
Wayatinah Lagoon	231.03	231.03
Catagunya Lake	169.16	169.16
Repulse Lake	124.96	124.96
Cluny Lagoon	97.84	97.84
Meadowbank Lake	73.15	73.15
Lake Sorell	804.40	804.36
Lake Crescent	803.80	803.80
Shannon Lagoon	1017.66	1017.5
Penstock Lagoon	918.8	918.8
Lake Fenton	1016.50	1016.50
Illa Brook Dam	134.44	134.44

* Dee Lagoon FSL understood to be at tunnel outlet height, not spillway height
^ Lake St Clair is understood to typically be allowed to flow freely into Lake King William with normal operations above FSL.

Table 15: Dam initial conditions – Derwent Estuary-Bruny study area

Storage	IWL = FSL (m AHD)
Flagstaff Gully Reservoir	84.62
Risdon Brook Reservoir	53.56
Lower Reservoir	137.30
Upper Reservoir	154.00
Ridgeway Reservoir	275.84

5.2. Design Event Results

The results of the design event modelling for the River Derwent study area are shown in Figure 10 to Figure 25 in terms of peak flood level, depth, velocity, and hydraulic hazard for the 2%, 1%, 1% CC, and 0.5% AEP design events. The results shown are of the design event envelope and filtered direct rainfall results, as detailed in Section 3. A critical event plot for the 1% AEP design event is provided in Figure 26.

The results of the design event modelling for the Derwent Estuary-Bruny study area are shown in Figure 27 to Figure 42 in terms of peak flood level, depth, velocity, and hydraulic hazard for the 2%, 1%, 1% CC, and 0.5% AEP design events. The results shown are of the design event envelope and filtered direct rainfall results, as detailed in Section 3. A critical event plot for the 1% AEP design event is provided in Figure 43.

As has been discussed throughout this project, this is a regional study which does not take the place of local detailed design flood modelling. This is particularly important in heavily urbanised areas such as Greater Hobart where existing flood studies have been undertaken which included detailed local information such as urban drainage networks and structures. For these detailed studies modelling was targeted specifically at these areas, in particular in regard to choosing critical events, hydrodynamic model extents and grid resolution. Additionally, large areas of Greater Hobart are covered by direct rainfall modelling only in this strategic regional level modelling. Where urban areas have been mapped that are covered by a detailed study (i.e. Greater Hobart) the results of this current modelling are not presented in detail (i.e. no zoomed in figures, or comparisons to previous studies). The results developed in this current study should not be used where detailed flood studies have been undertaken.

For direct rainfall only, in some areas the peak flow for headwater catchments was found to be higher in the hydrodynamic model than in the external hydrologic model. To ensure that the overestimation of these peak flows in the headwater catchments would not impact the design results, the direct rainfall results were clipped to the design event envelope.

The outcomes of the design event modelling have been reviewed against the gauge FFA and previous flood studies. As discussed in Section 4, losses were calibrated across the entire

Derwent catchment, with separate losses for the Derwent Estuary and Bruny Island. Therefore, it is expected that the fits to individual gauges will be variable.

5.2.1. Review of Results at Clyde River at Bothwell

A review of the design flows produced from the hydrodynamic model at Clyde River at Bothwell was undertaken, by comparing to the flows derived from the FFA. The modelled peak flows show a fair match to the FFA peak flows at this location, although peak flows are underestimated (Table 16 and Figure 1) with final ICM flows closer to the FFA, when compared to the at-site external hydrological modelled flows.

Table 16: Design flows at Clyde River at Bothwell

Parameter	2% AEP	1% AEP	1% AEP CC	0.5% AEP
Modelled peak flow (m^3/s)	184	254	363	342
FFA peak flow (m^3/s)	224	287	n/a	354
Peak flow difference (%)	-18%	-11%	n/a	-3%

5.2.2. Review of Results at Ouse River at Ashton

A review of the design flows produced from the hydrodynamic model at Ouse River at Ashton was undertaken, by comparing to the flows derived from the FFA. The modelled peak flows show a fair match to the FFA peak flows at this location (Table 17 and Figure 2), with the model overestimating peak flows.

Table 17: Design flows at Ouse River at Ashton

Parameter	2% AEP	1% AEP	1% AEP CC	0.5% AEP
Modelled peak flow (m^3/s)	598	732	946	928
FFA peak flow (m^3/s)	523	661	n/a	822
Peak flow difference (%)	14%	11%	n/a	13%

5.2.3. Review of Results at Florentine River U/S Derwent River

A review of the design flows produced from the hydrodynamic model at Florentine River U/S Derwent River was undertaken, by comparing to the flows derived from the FFA. The modelled peak flows show a poor match to the FFA peak flows at this location (Table 18 and Figure 3), however, the design ICM flows are significantly improved compared to external hydrology modelling which was performing very poorly (as discussed in Section 4) and results are now within the confidence intervals at this gauge.

Table 18: Design flows at Florentine River U/S Derwent River

Parameter	2% AEP	1% AEP	1% AEP CC	0.5% AEP
Modelled peak flow (m^3/s)	236	293	382	353
FFA peak flow (m^3/s)	194	226	n/a	261
Peak flow difference (%)	22%	30%	n/a	35%

5.2.4. Review of Results at Tyenna River at Newbury

A review of the design flows produced from the hydrodynamic model at Tyenna River at Newbury was undertaken, by comparing to the flows derived from the FFA. The modelled peak flows show a poor match to the FFA peak flows at this location (Table 19 and Figure 4).

Table 19: Design flows at Tyenna River at Newbury

Parameter	2% AEP	1% AEP	1% AEP CC	0.5% AEP
Modelled peak flow (m^3/s)	235	284	353	333
FFA peak flow (m^3/s)	166	202	n/a	243
Peak flow difference (%)	42%	41%	n/a	37%

5.2.5. Review of Results at Derwent River below Meadowbank

A review of the design flows produced from the hydrodynamic model at Derwent River below Meadowbank was undertaken, by comparing to the flows derived from the FFA. As discussed in Section 4 due to the sensitivity of flows at this location to the initial water level (IWL) in the reservoirs upstream it cannot really be used as a like for like comparison, as the IWL for the model run is fixed (as given in Table 6) while this varies for each event in the AMS and therefore the FFA. Therefore, this is presented more as a general sanity check that modelled flows are not completely outside the range of the observed flows which can be seen in Table 20 and Figure 5. As the IWL used in the model are higher compared to long term averages it is not surprising that the modelled flows are overestimated at 1% and 0.5% AEPs.

Table 20: Design flows at Derwent River below Meadowbank

Parameter	2% AEP	1% AEP	1% AEP CC	0.5% AEP
Modelled peak flow (m^3/s)	1,189	1,518	2,064	1,867
FFA peak flow (m^3/s)	1,202	1,304	n/a	1,396
Peak flow difference (%)	-1%	16%	n/a	34%

5.2.6. Review of Results at Snug River U/S Snug Tiers Road Bridge

A review of the design flows produced from the hydrodynamic model at Snug River U/S Snug Tiers Road Bridge was undertaken, by comparing to the flows derived from the FFA. The modelled peak flows show a fair match to the FFA peak flows at this location (Table 21).

Table 21: Design flows at Snug River U/S Snug Tiers Road Bridge

Parameter	2% AEP	1% AEP	1% AEP CC	0.5% AEP
Modelled peak flow (m^3/s)	35	42	56	51
FFA peak flow (m^3/s)	36	39	n/a	41
Peak flow difference (%)	-3%	8%	n/a	25%

5.3. Comparison to Previous Flood Studies

In comparing the results of this regional study to the previous studies, it should be noted that the previous studies discussed in this section were detailed flood studies with models setup to best represent the target areas of interest. This contrasts to the present study, which is a regional study which aims to give plausible flood extents over a large area. The detailed flood studies would have used detailed local survey and river bathymetry and finer details of urban features and modelling of stormwater systems which were not used in the present study. Therefore, flood study comparisons were not made to studies covering any urban areas near Hobart.

5.3.1. River Derwent at New Norfolk

A flood study for the River Derwent around New Norfolk was undertaken by Hydro Electric Commission (HEC) in 1992. As noted in Table 1, the report contains design flood levels at different areas for 5%, 2% and 1% AEP events. Diagram 3 shows a comparison between the 1% AEP flood extents of the 1992 study and the present study at west New Norfolk. The 1992 report used an FFA at a gauge at Derwent at Macquarie Plains. Data at this gauge with data was not provided for this project and is not publicly available so this was not replicated. A significant proportion of this FFA (1921-1930 and 1943-1981) is prior to the conclusion of construction of the Derwent Hydro Power Scheme (Derwent dams largely built in the 1950s-1960s see calibration report for details) with no details provided on how the dams were handled in the previous study. Despite the FFAs at the lower end of the Derwent not being directly comparable between the reports - being a mix of pre and post dam (1992 report) and only post dam (current report), and at Derwent at Macquarie Plains (1992 report) and Derwent below Meadowbank (current report) - it is clear that the 1992 FFA has much higher flows with 1% AEP flows of 2,570 m^3/s compared with 1,300 m^3/s for this report. Therefore, it is expected that the levels found for this study through New Norfolk would be lower than those in the 1992 report.

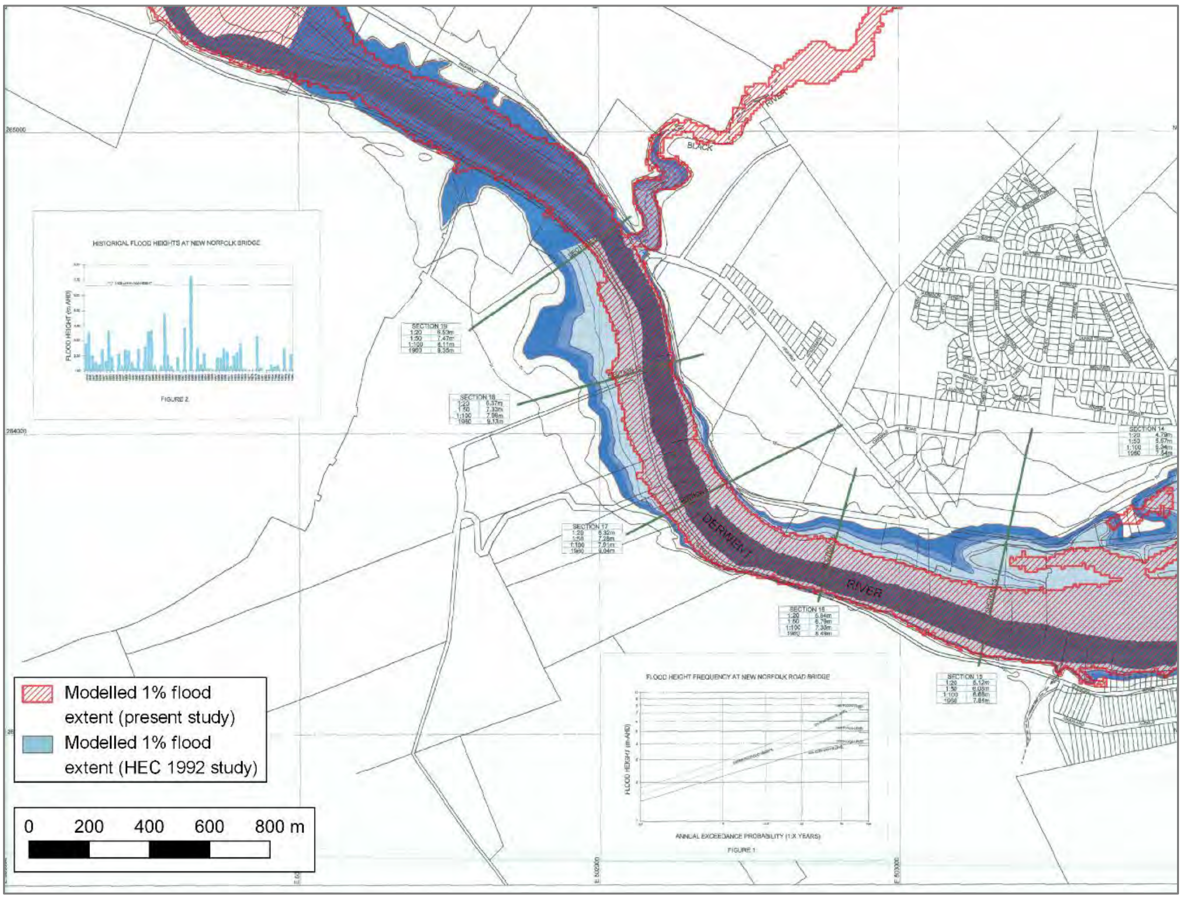

Diagram 3. HEC 1992 study and present study flood extent for the 1% AEP design event and comparison river sections – West New Norfolk

As shown in Diagram 3, the flood extents are closely matched at the top of the figure. As the River Derwent runs east towards New Norfolk, the HEC 1992 study has a slightly wider 1% flood extent, however it is not known what the depth of water is on the edges of the floodplain. No depths were available to compare so these areas could potentially be quite shallow. Given the significant variance in the Derwent FFAs used in the 1992 study and the present study, differences in data availability and modelling methodology, and changes in design methodology and design rainfalls over this timeframe, this level of variability is not surprising. A more detailed flood study that properly considers dam operations and more localised features should be considered for future planning.

5.3.2. River Jordan

A flood study for the Jordan was undertaken by Hydro Electric Commission (HEC) in 1993. As noted in Table 1, the report contains design flood levels at different areas for 5%, 2% and 1% AEP events. Diagram 4 shows a comparison between the flood extents of the 1993 study and the present study for the 1% AEP event at Bagdad Rivulet and River Jordan next to Pontville and Brighton.

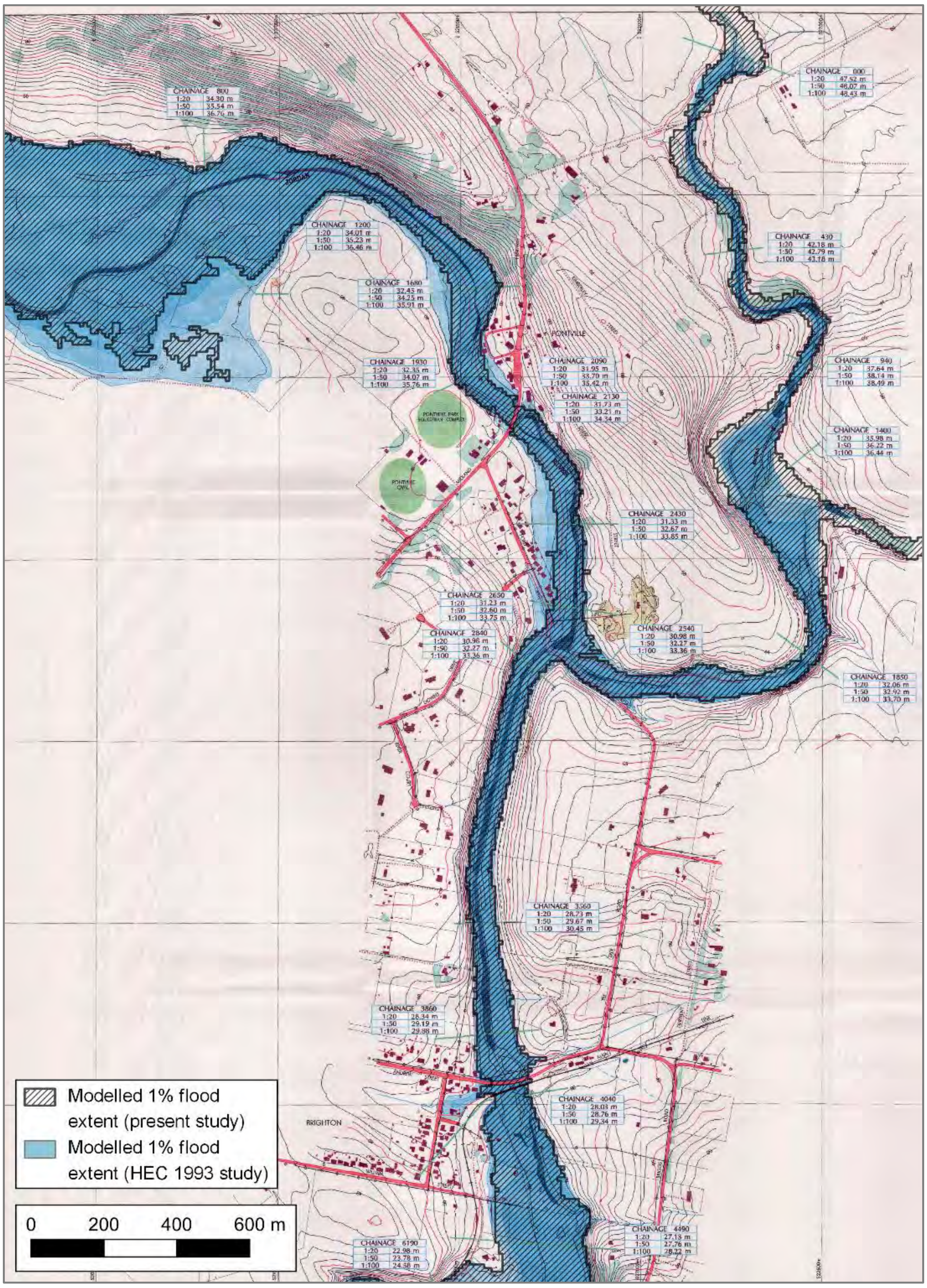

Diagram 4. HEC 1993 study and present study flood extent for the 1% AEP design event – Bagdad Rivulet and River Jordan near Pontville and Brighton

As shown in Diagram 4, the flood extents of River Jordan on the left and Bagdad Rivulet on the top right are closely matched to each other. At the top left there is a floodplain breakout where the present study's flood extent is slightly lower. All other areas of Bagdad Rivulet and River Jordan are in well-defined channels with steep banked slopes which contribute to the contained flood extents that are closely matched to each other.

Diagram 5 shows a comparison between the flood extents of the 1993 HEC study and the present study at River Jordan near Bridgewater.

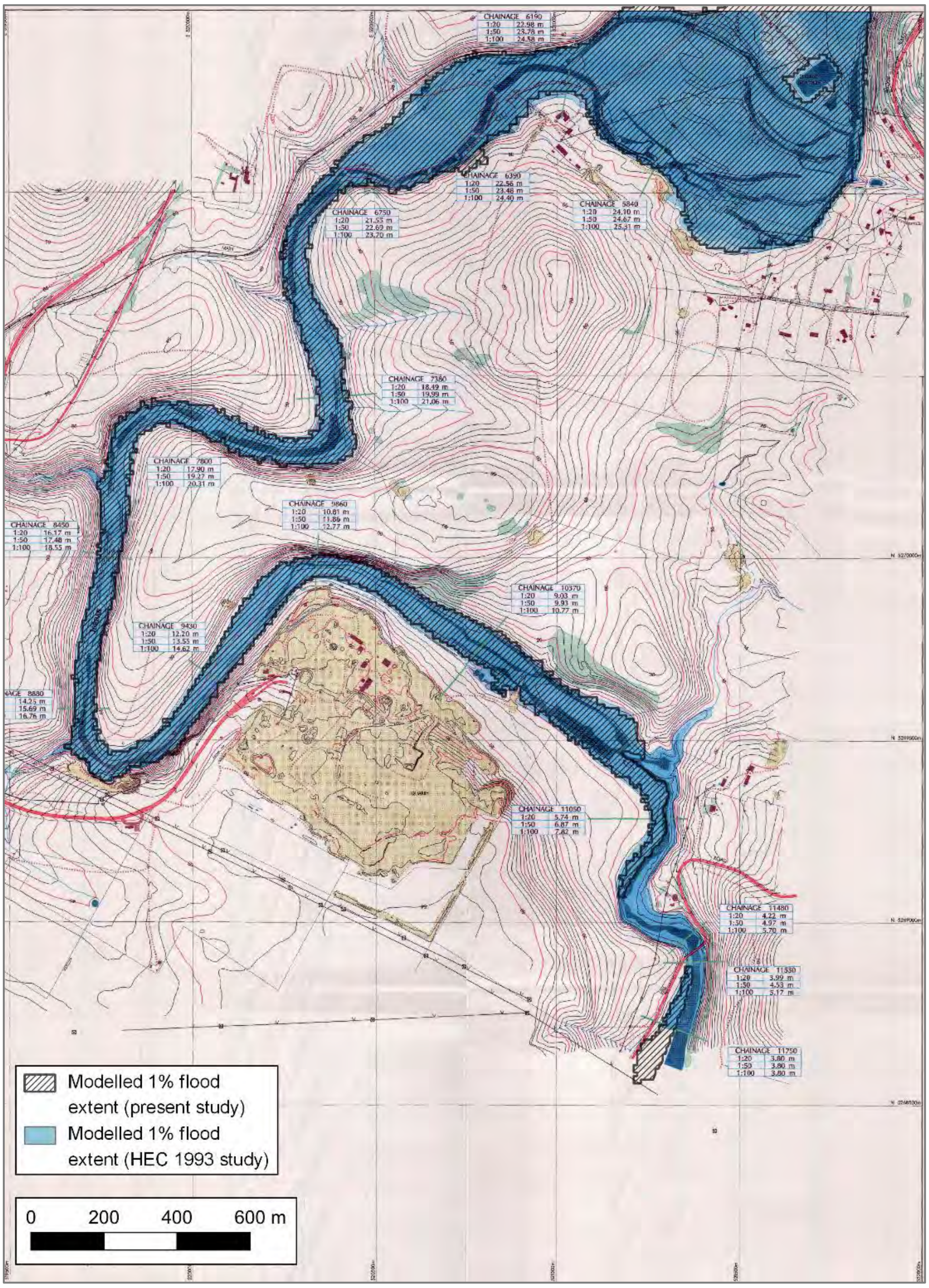

Diagram 5. HEC 1993 study and present study flood extent for the 1% AEP design event – River Jordan near Bridgewater

As shown in Diagram 5, the 1% flood extents of the River Jordan in both studies are closely matched. All areas of the River Jordan are in well-defined channels with steep banked slopes which contribute to the contained flood extents that are closely matched to each other.

5.3.3. Snug River

A flood study for the Snug River was undertaken by Kingborough Council in 2019. Diagram 6 shows a comparison between the flood extents of the 2019 study and the present study for the 1% AEP design event.

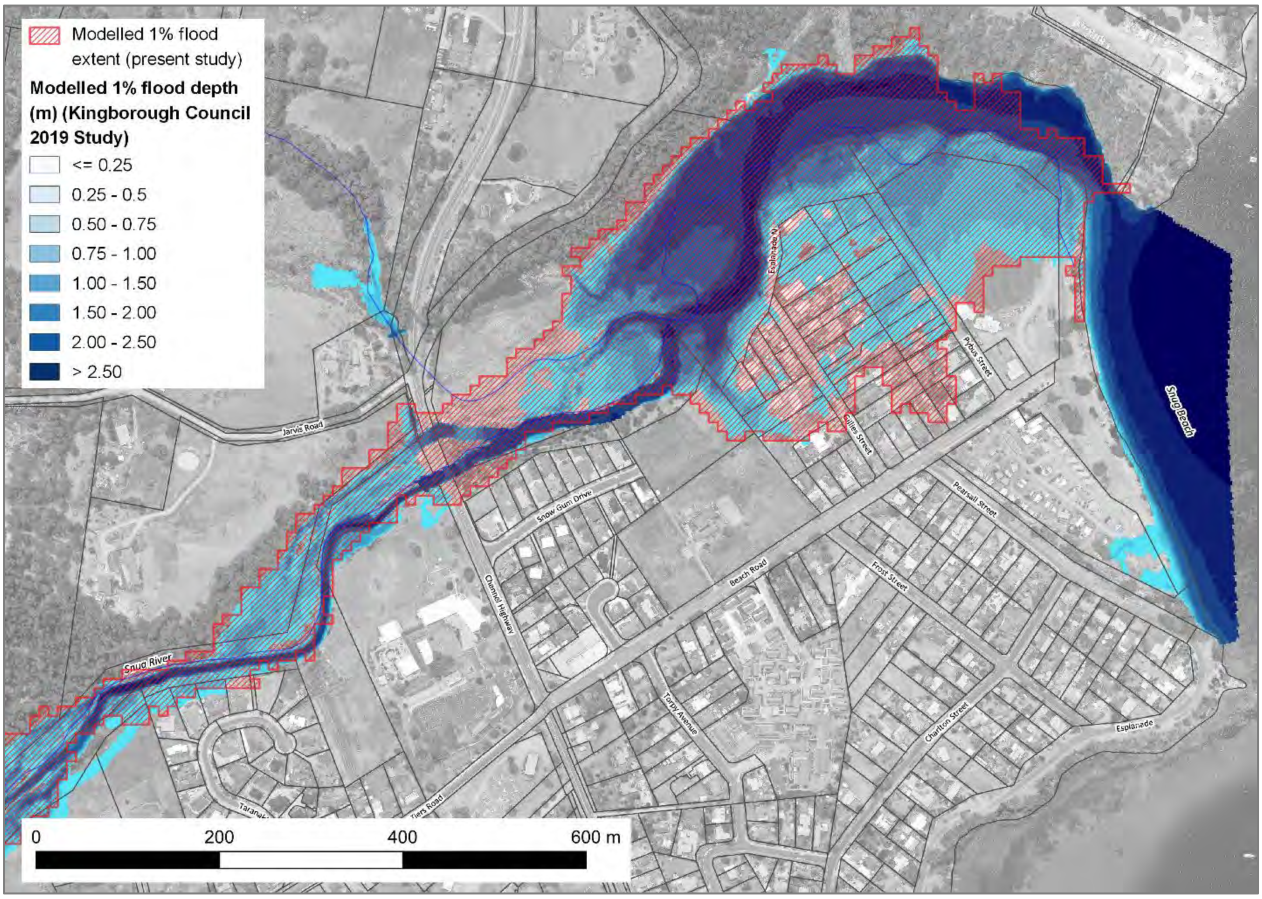

Diagram 6. Kingborough Council 2019 study and present study flood extent for the 1% AEP design event

As shown in Diagram 6, the flood extents between the two studies are a close match over much of the area. At the final bend in the river before entering the ocean, the present study shows a slightly larger 1% flood extent. The Kingborough Council study uses a 5% AEP Tailwater condition whereas the present study uses the Highest Astronomical Tide (HAT). The difference in tailwater conditions is likely to be the cause of the difference in flood extents near the ocean. The present study also does not have bathymetry data within the model for Snug River, which will affect the flood extents with flood storage not captured within the river channel.

5.3.4. Margate Rivulet

A flood study for the Margate Rivulet was undertaken by Cardno in 2020. Diagram 7 shows a comparison between the flood extents of the 2020 study and the present study for the 1% AEP design event zoomed into the town of Margate.

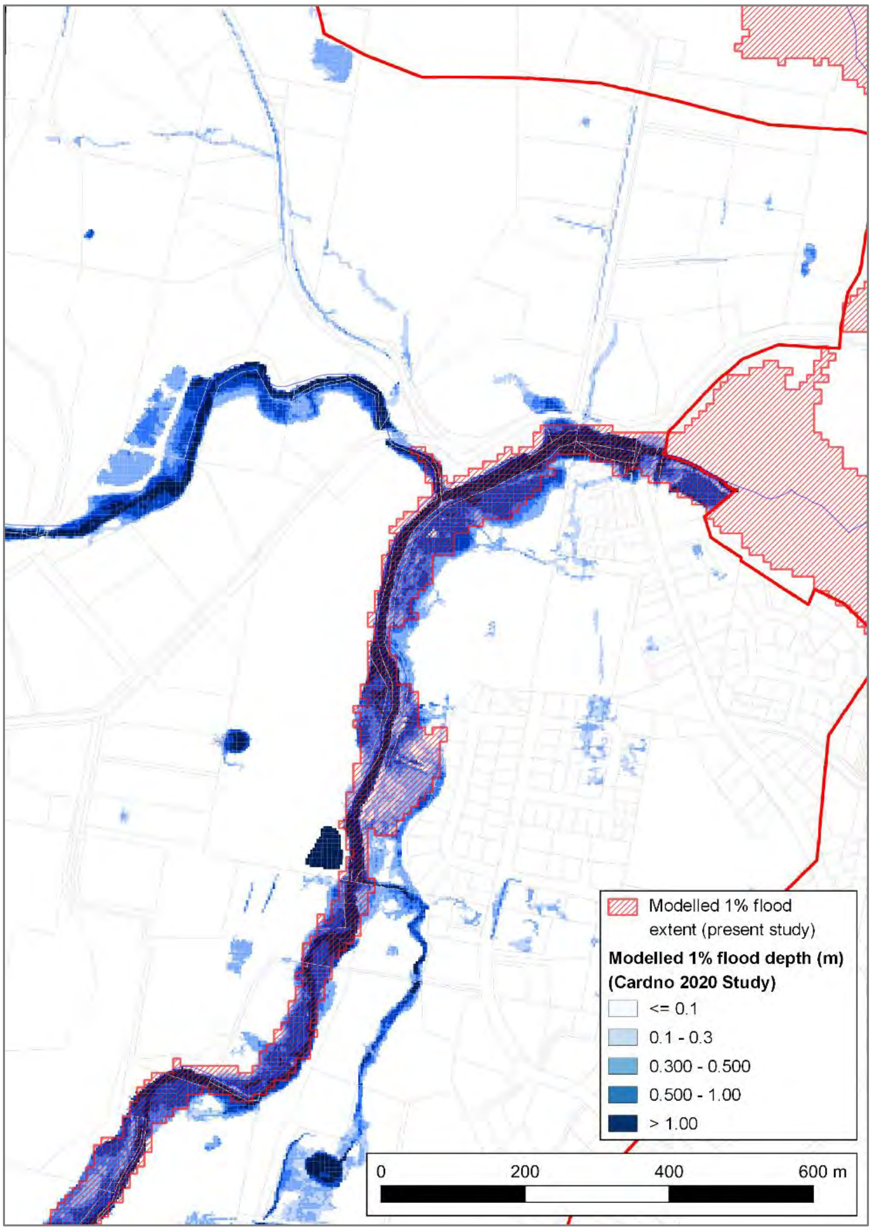

Diagram 7. Cardno 2020 study and present study flood extent for the 1% AEP design event

As shown in Diagram 7, the flood extents between the two studies are a close match throughout the township of Margate. The present study does not have bathymetric data within the model for Margate Rivulet, which will affect the flood extents in some areas with flood storage not captured within the rivulet channel.

5.3.5. Whitewater Creek

A flood study for Whitewater Creek near the township of Kingston was undertaken by WMA Water for Kingborough Council in 2020. Diagram 8 shows a comparison between the flood extents of the 2020 study and the present study for the 1% AEP design event zoomed into the town of Kingston.

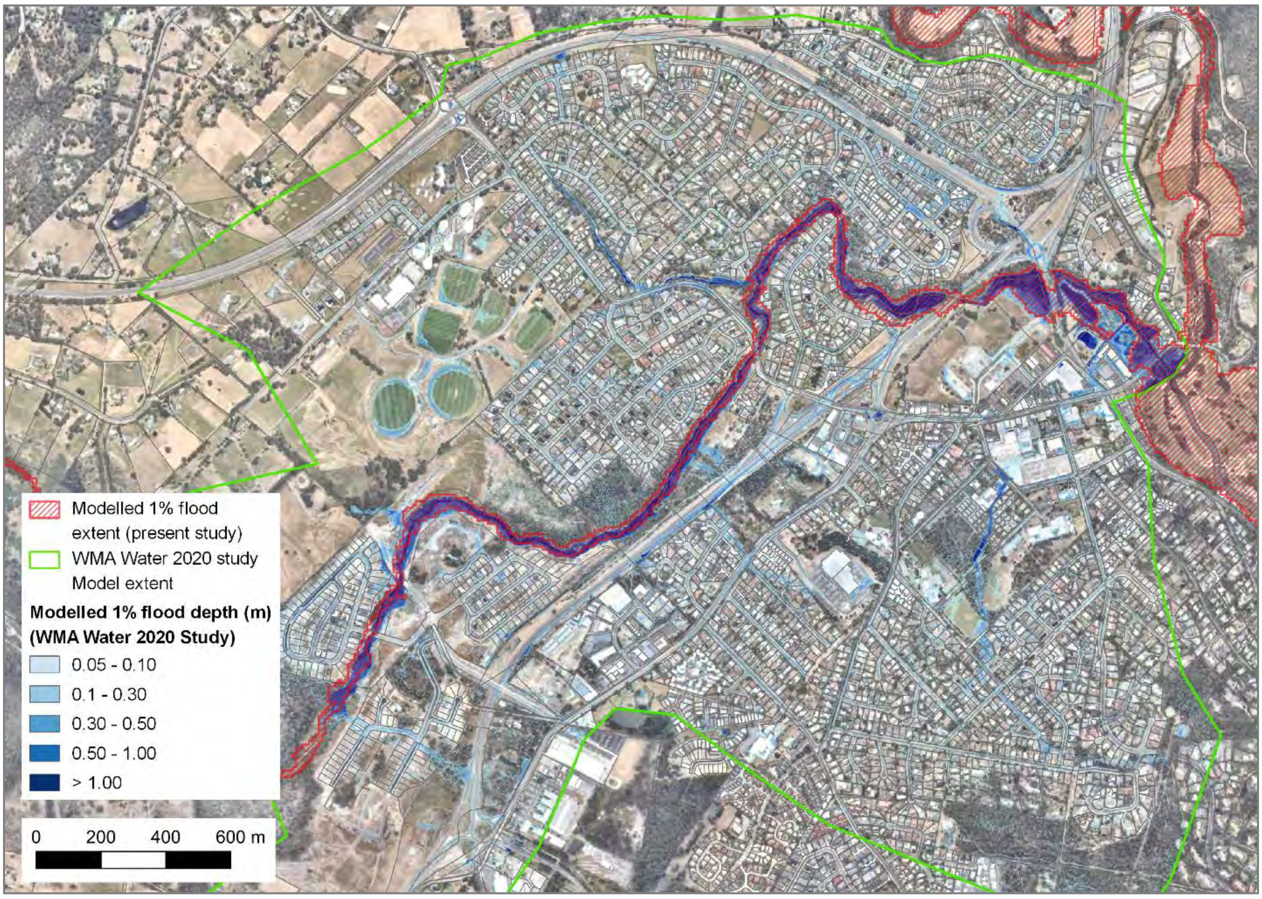

Diagram 8. WMA Water 2020 study and present study flood extent for the 1% AEP design event and comparison points

As shown in Diagram 8, the flood extents of Whitewater Creek between the two studies are a close match as it makes its way through the township of Kingston. It is important to note that the WMA Water 2020 study includes the complexities of the overland flow regimes within the Kingston urban area whereas the present study only captures the main channel flow of Whitewater Creek.

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6. LIMITATIONS

A detailed uncertainty assessment of the data, hydrological calibration and hydrodynamic model is contained in the Derwent Calibration Report (WMAwater, 2023). In line with the calibration report there are some areas where the lack of bathymetry or LiDAR may have impacted the modelled flood levels. If LiDAR or bathymetry were made available this model would benefit from being re-run with this information.

The selection of limited duration-TP-ARF sets introduces some errors across the catchment as described in Section 5.1. This is appropriate for a regional method, however site-specific ARFs, critical durations and TP selection should be used for detailed design modelling at specific locations. This was particularly challenging for such a large catchment area as the Derwent catchment where the range of ARFs, critical durations and temporal patterns which would be selected at site specific design studies for individual parts of the catchment can vary so significantly.

As discussed in Section 5.2 there is some uncertainty introduced by the direct rainfall application on the headwater catchments. While the method used is appropriate for broad scale mapping, a full design event assessment should be undertaken for any future focussed studies in this area.

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Figures

FIGURE 1

Clyde River at Bothwell

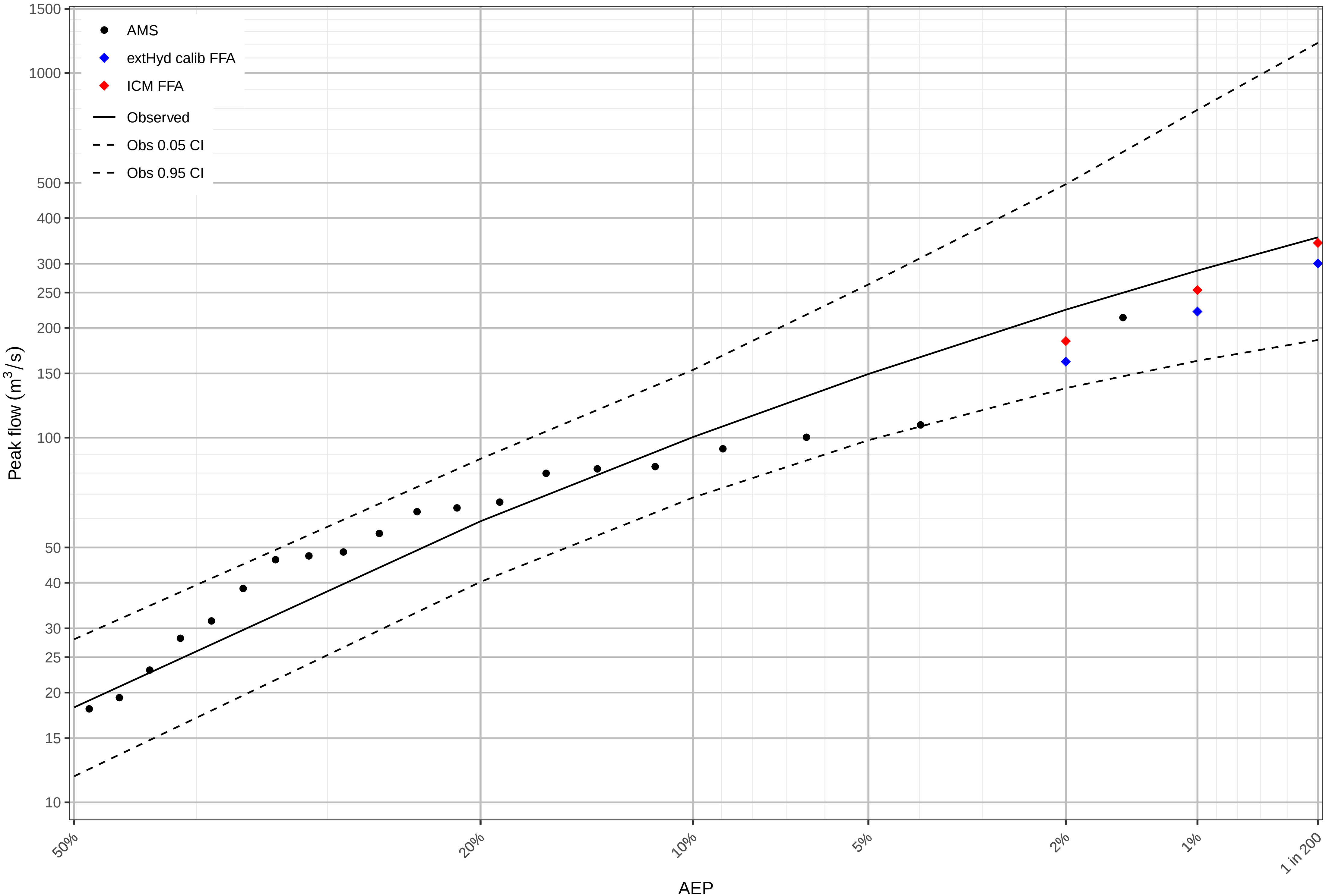

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FIGURE 2

Ouse River @ Ashton

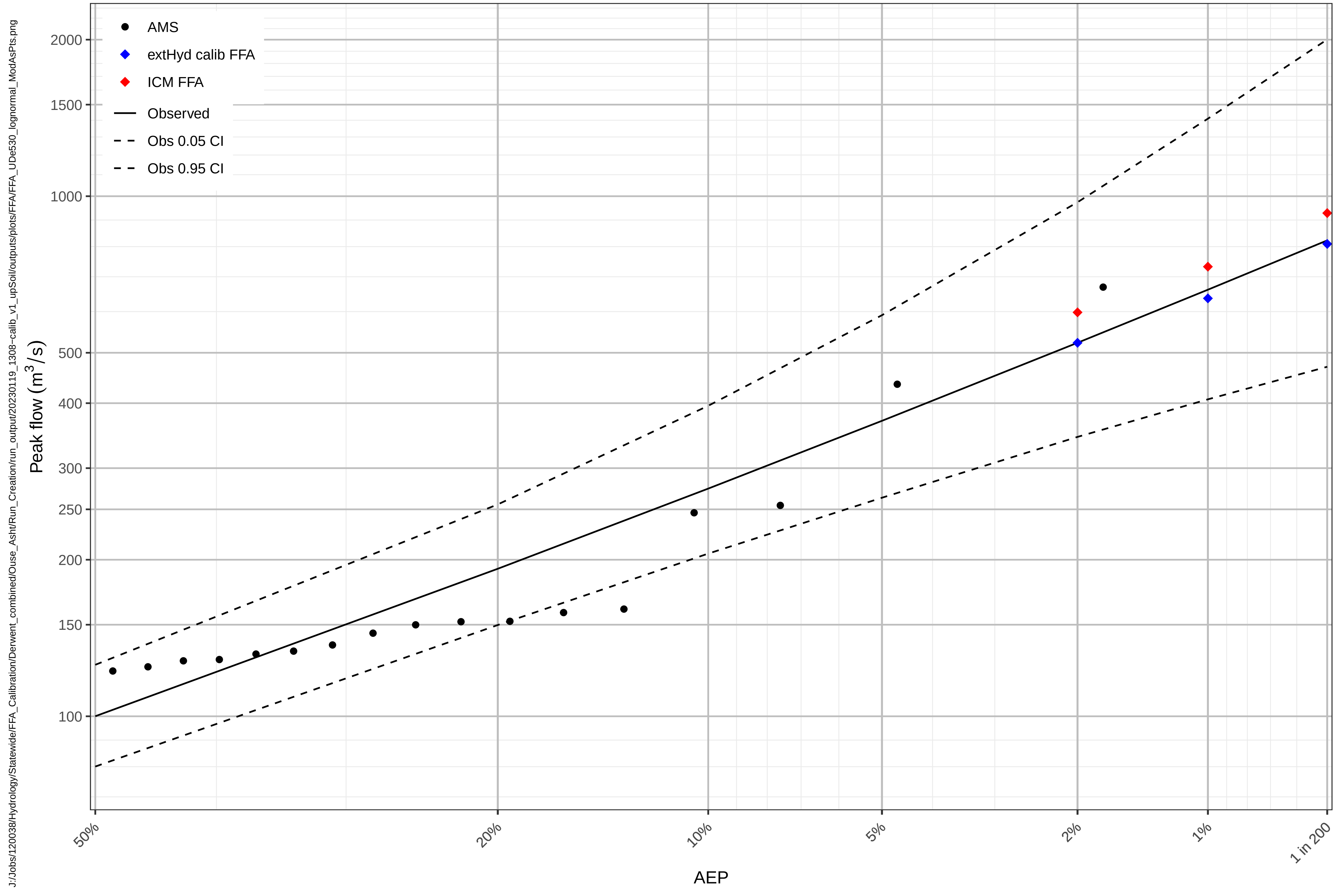

FIGURE 3

Florentine River U/S Derwent Junction

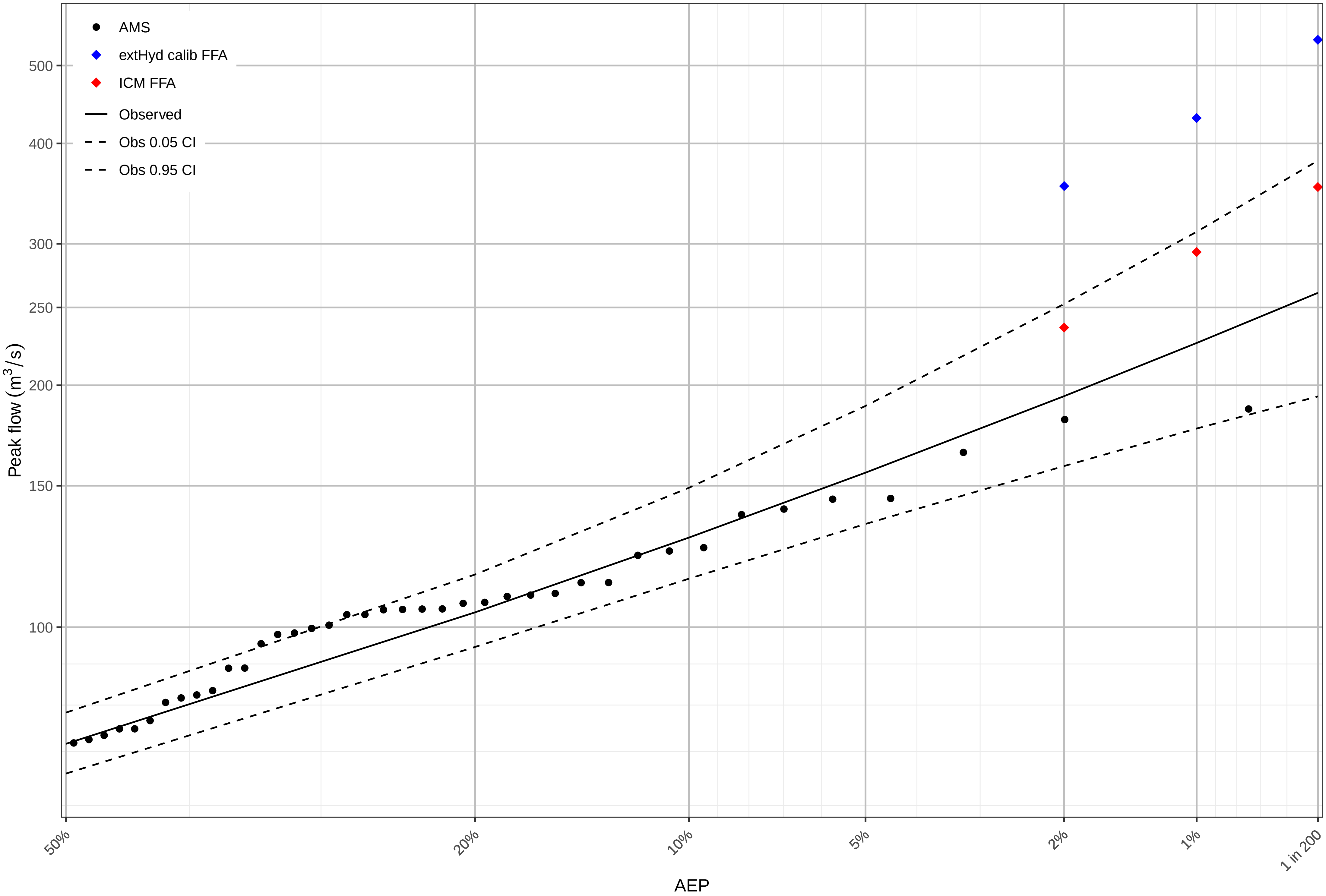

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FIGURE 4

Tyenna River At Newbury

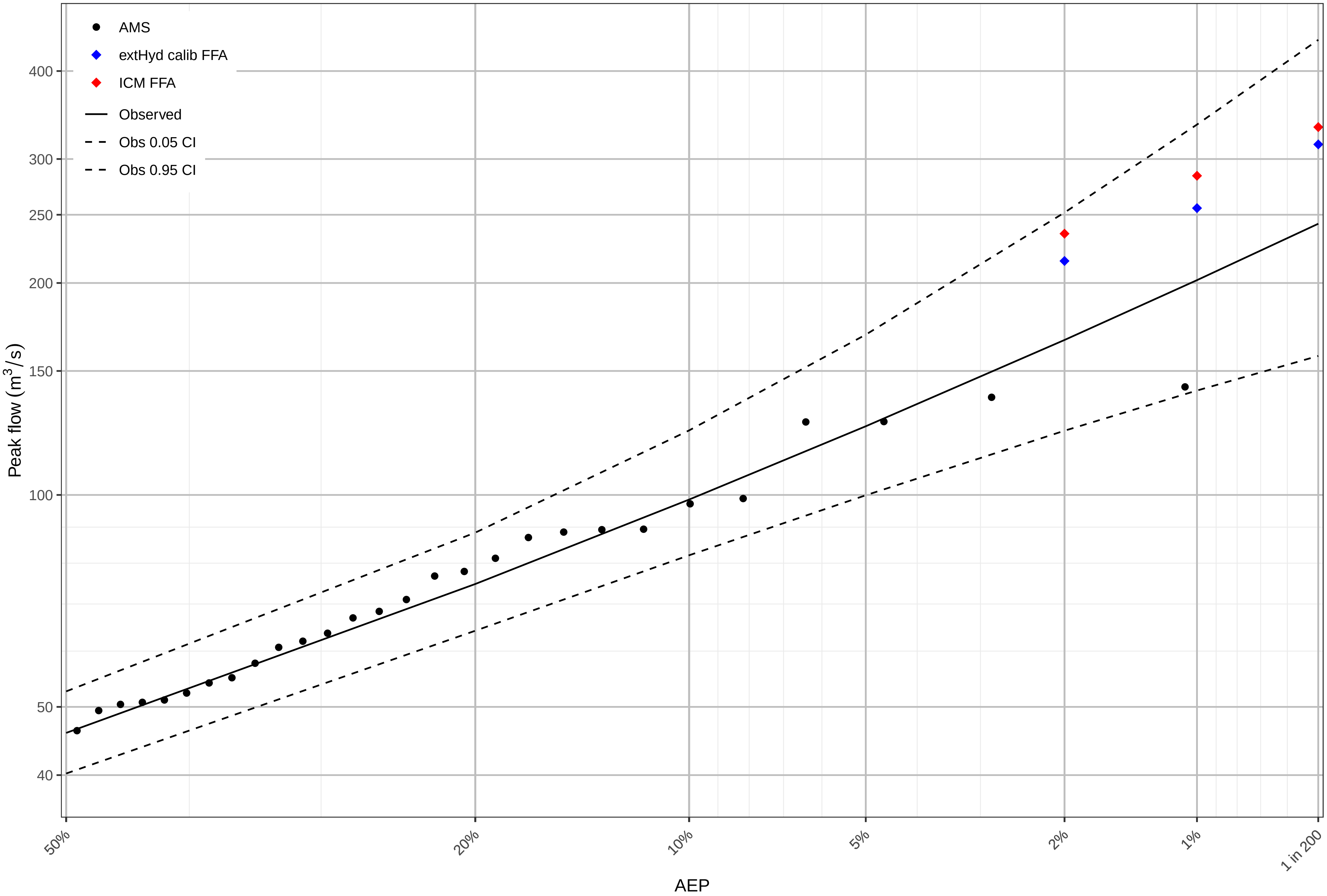

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FIGURE 5

Derwent River B/L Meadowbank: Design IWL

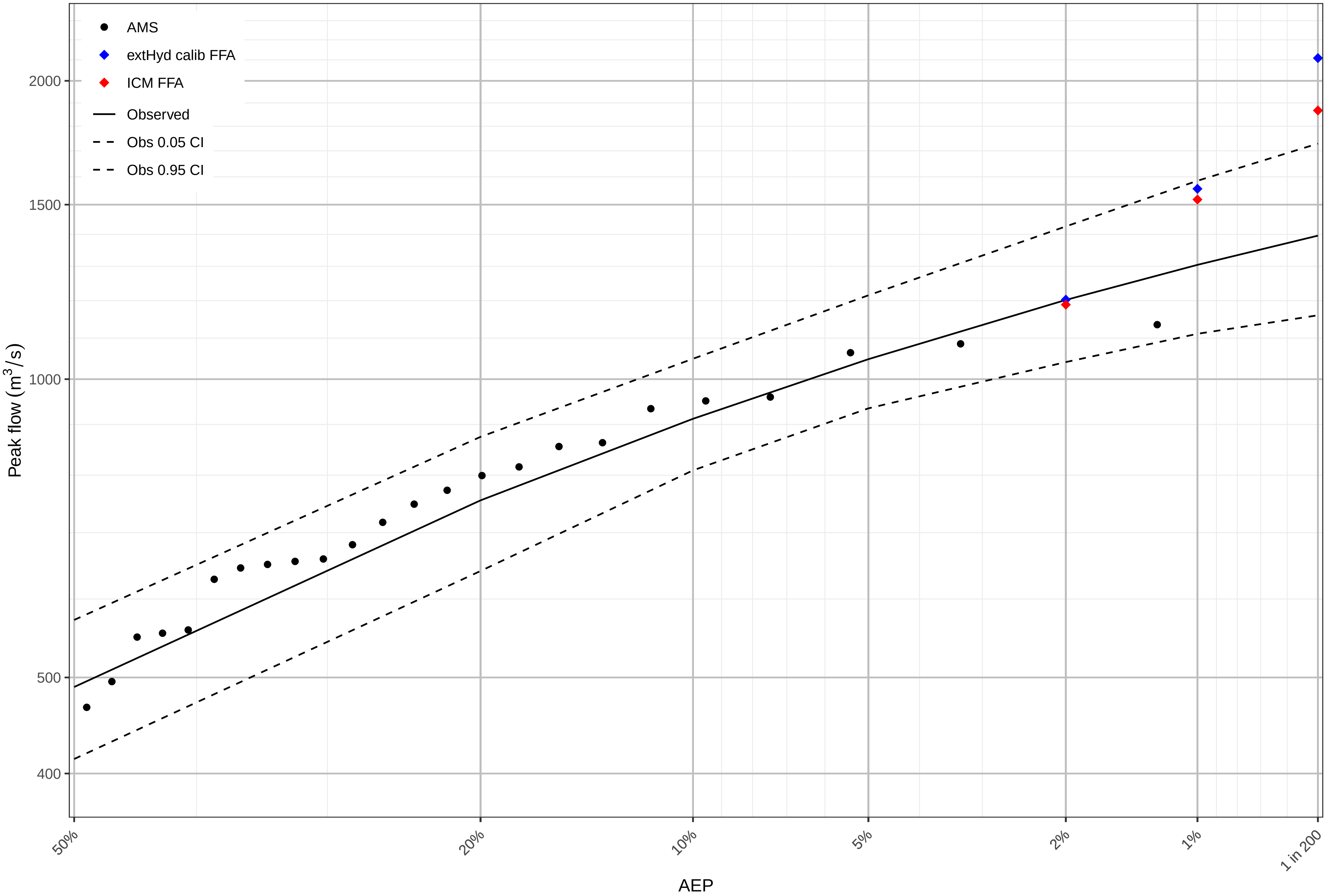

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FIGURE 6

Derwent River B/L Meadowbank: Sensitivity mean IWL

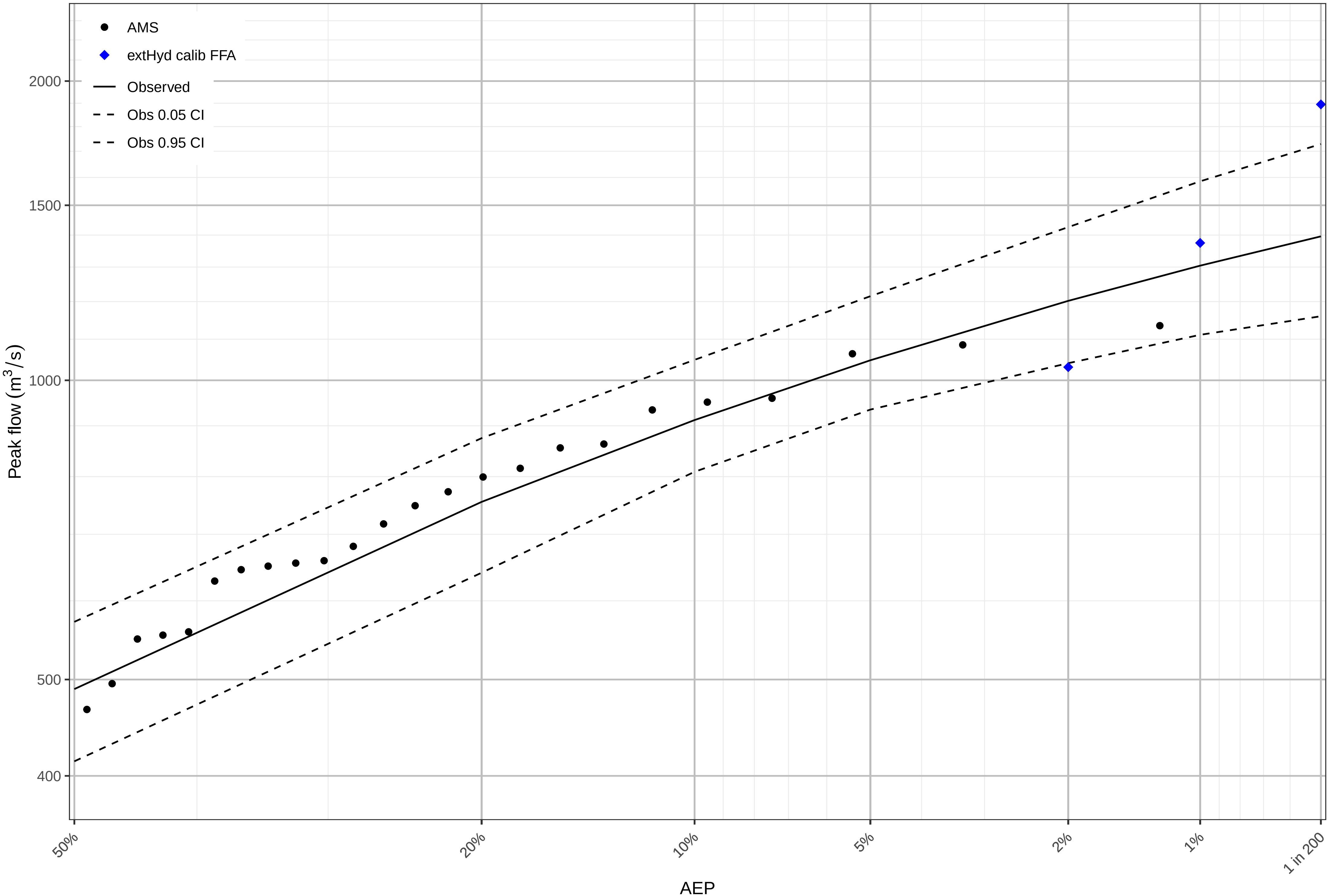

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FIGURE 7

Snug River U/S Snug Tiers Road Bridge

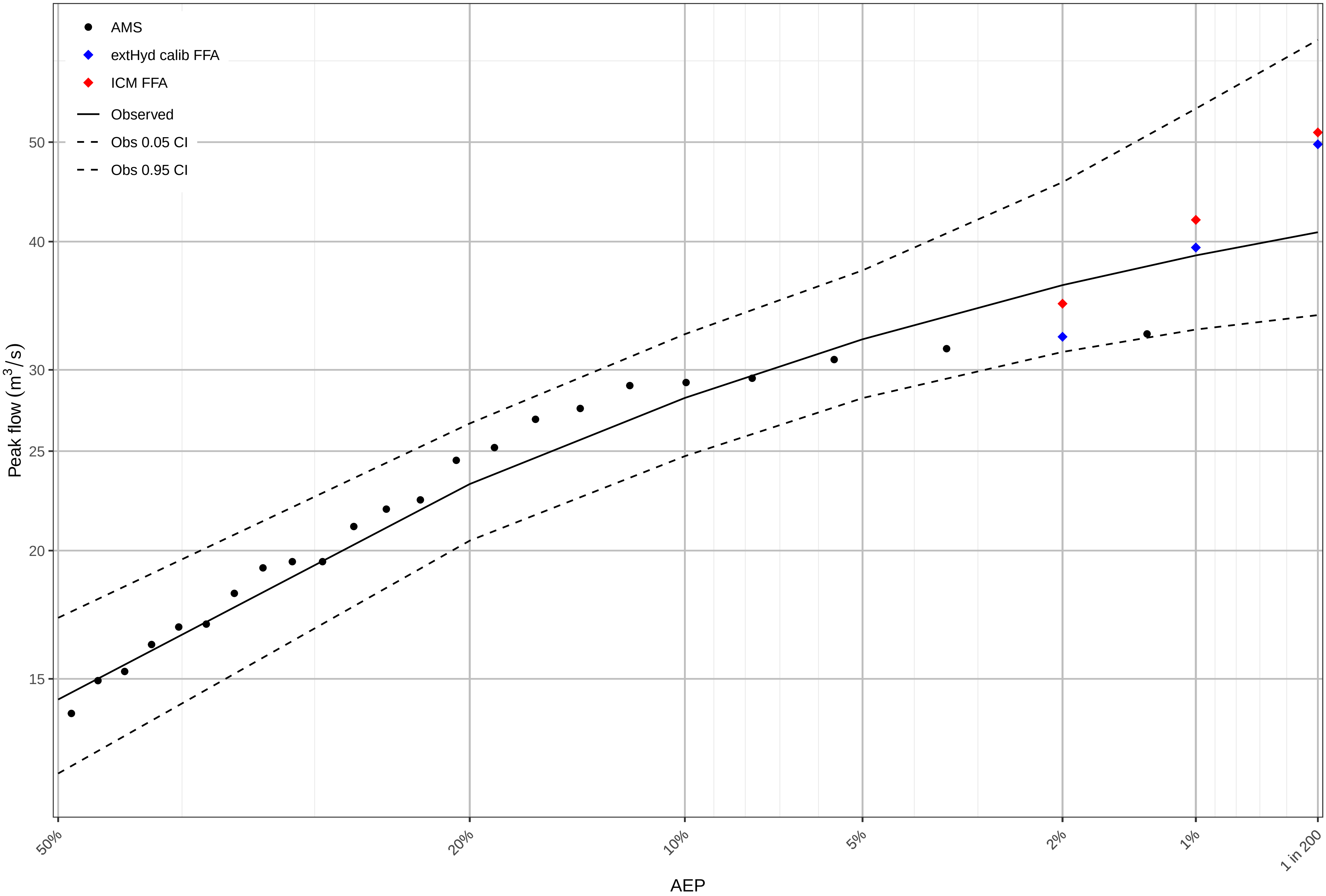


FIGURE 8

SELECTED DESIGN TEMPORAL PATTERNS ALL AEPS BY STORM DURATION AND ARF AREA

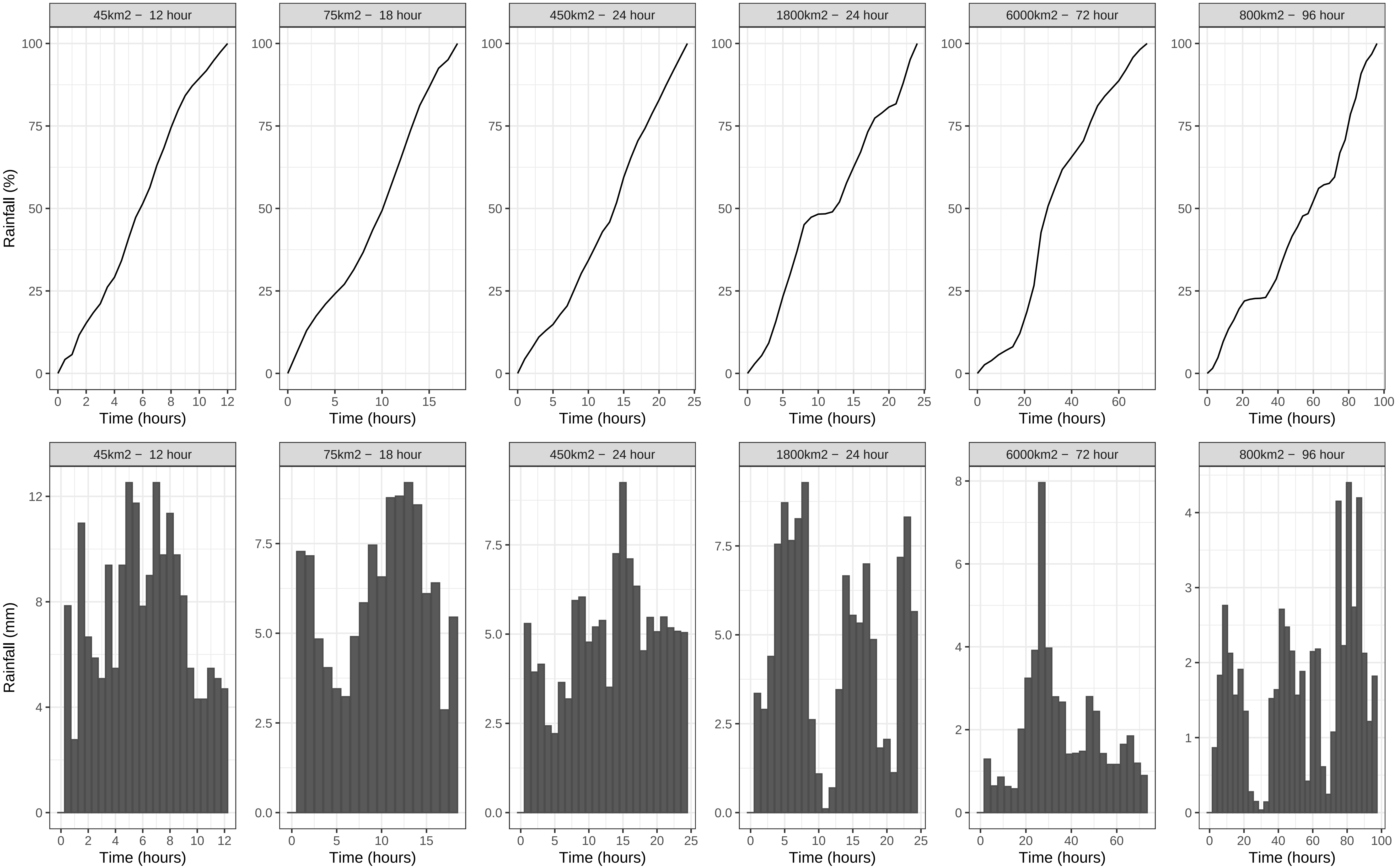
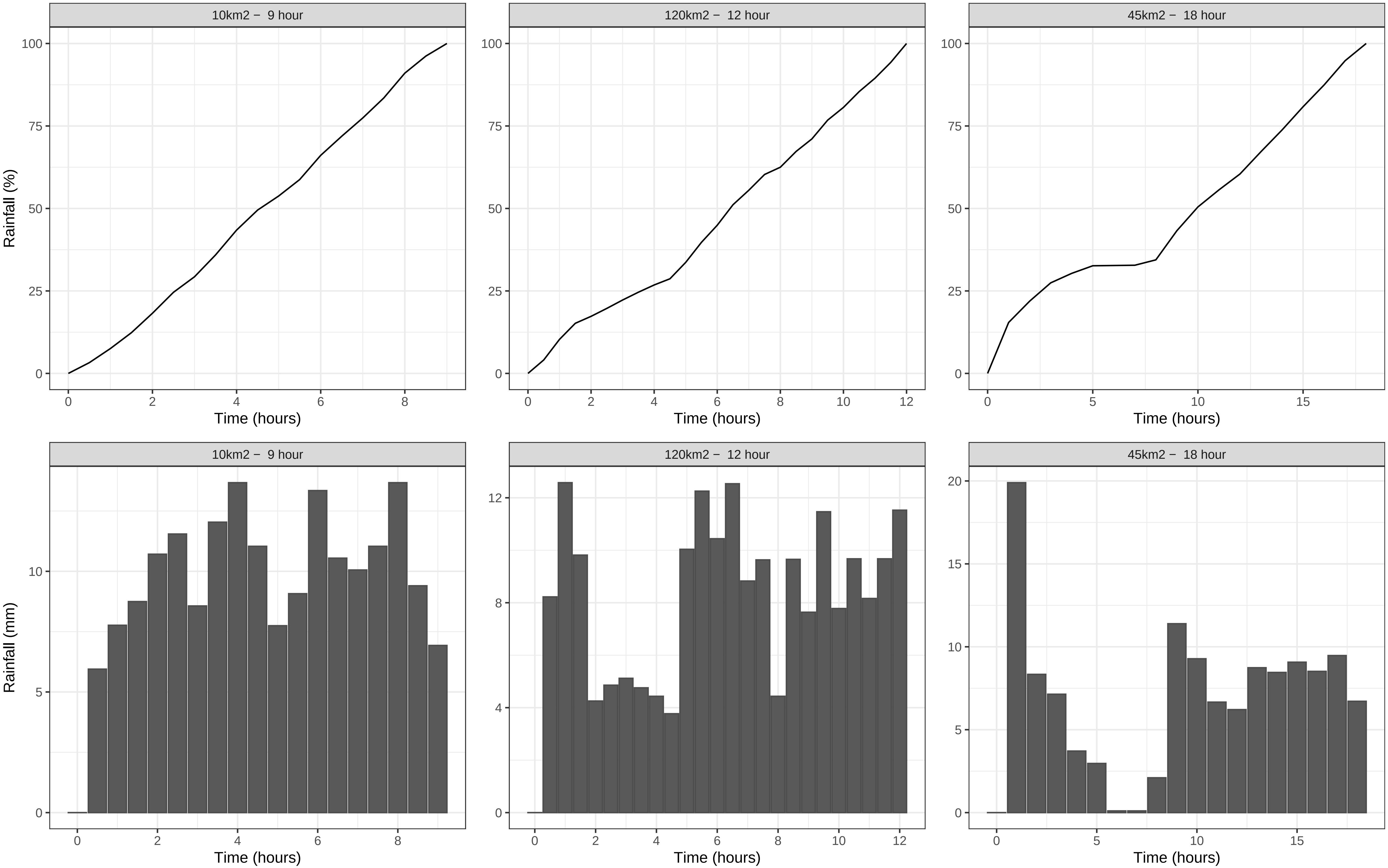
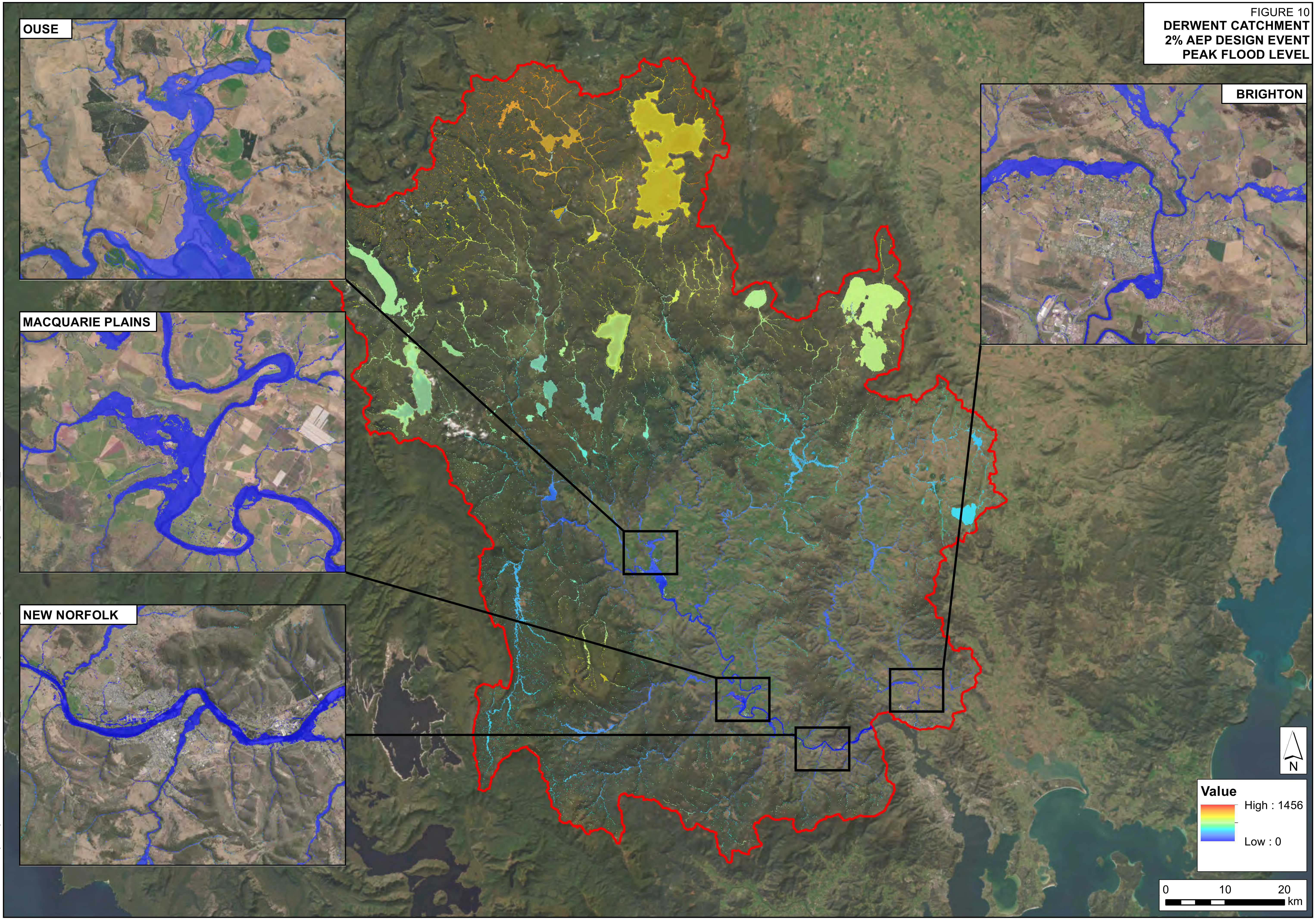


FIGURE 9

SELECTED DESIGN TEMPORAL PATTERNS ALL AEPS BY STORM DURATION AND ARF AREA





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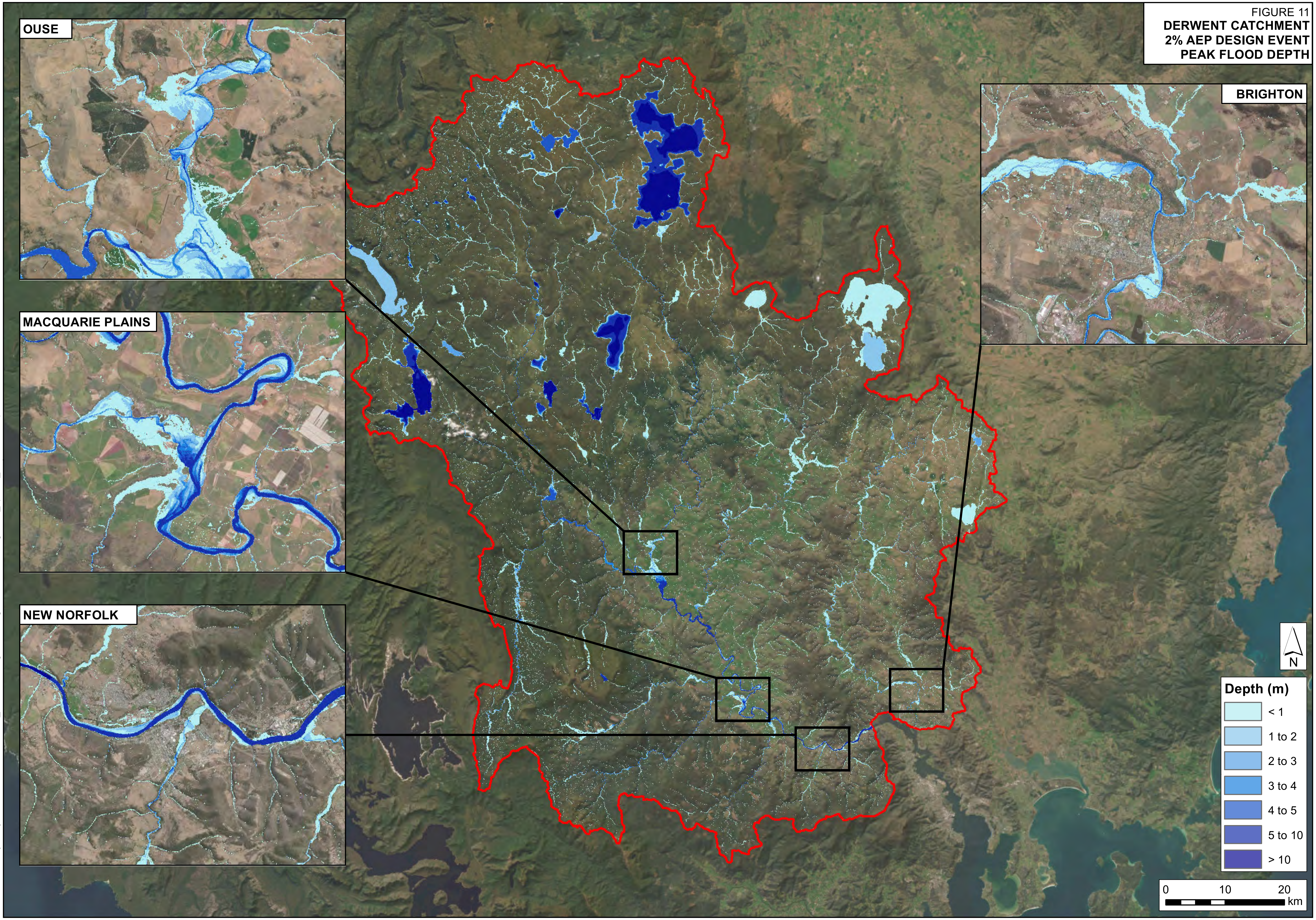

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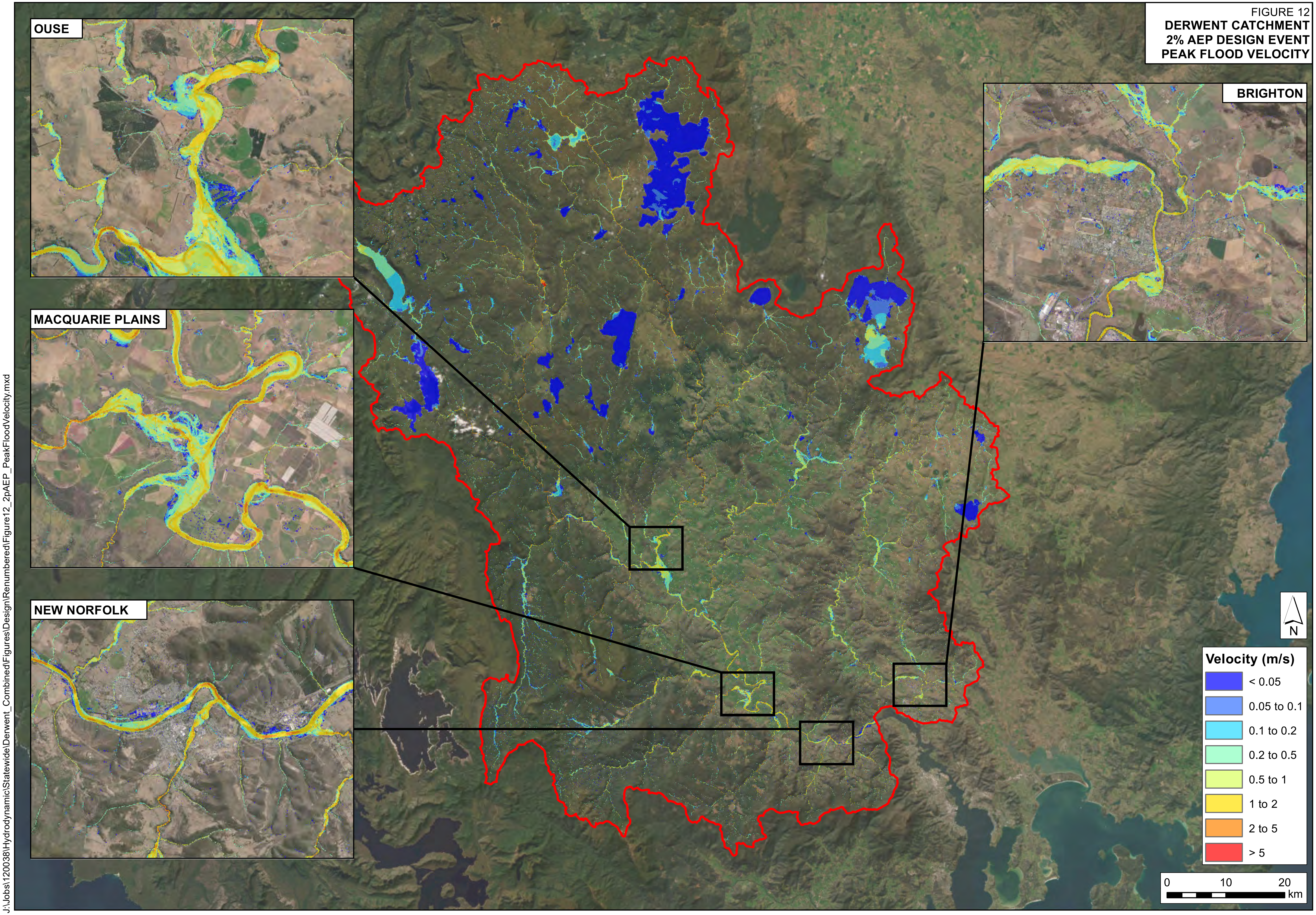
FIGURE 12
DERWENT CATCHMENT
2% AEP DESIGN EVENT
PEAK FLOOD VELOCITY
OUSE
MACQUARIE PLAINS
NEW NORFOLK
BRIGHTON
Velocity (m/s)
< 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.5
0.5 to 1
1 to 2
2 to 5
> 5
N
0
10
20
km
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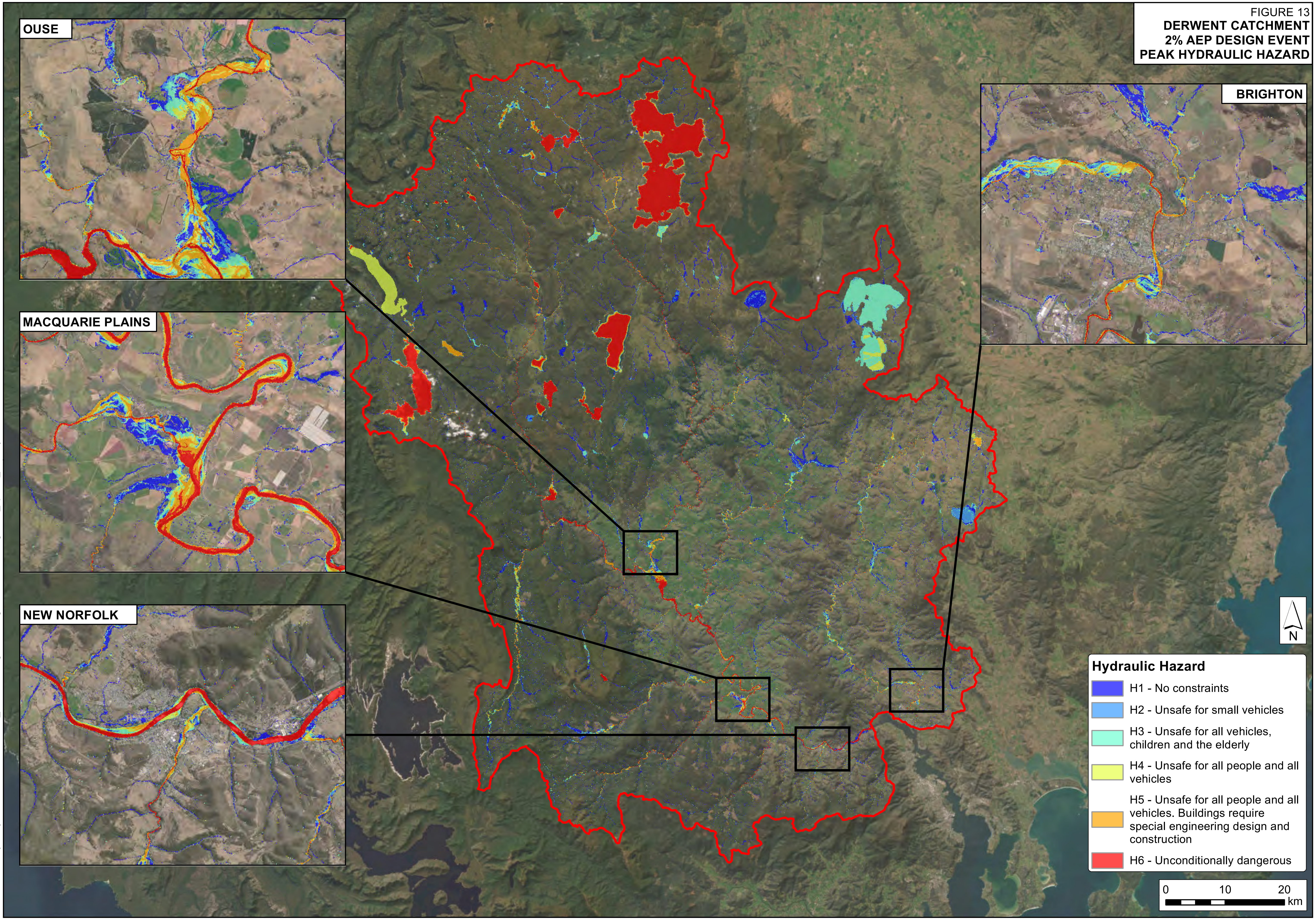

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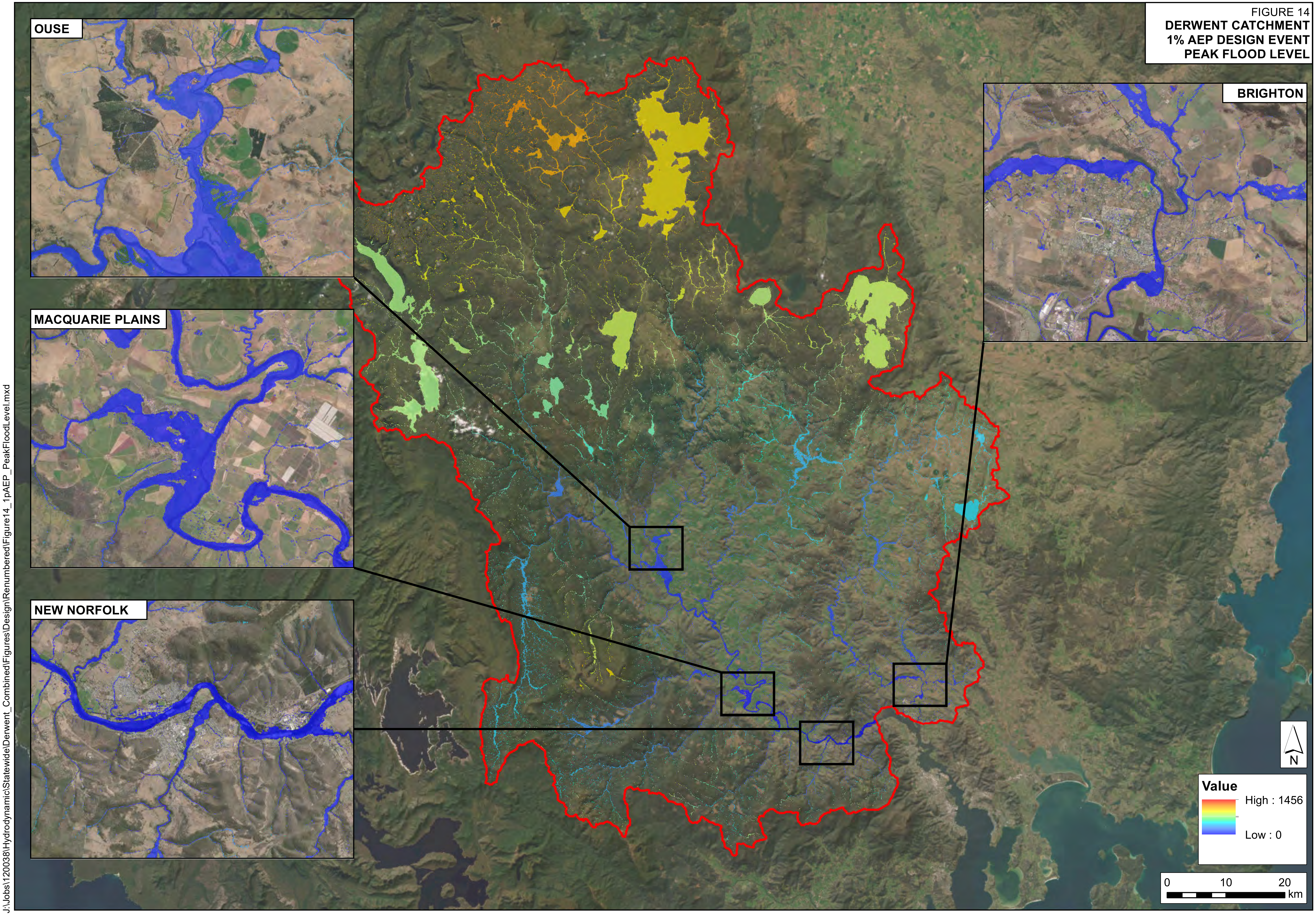
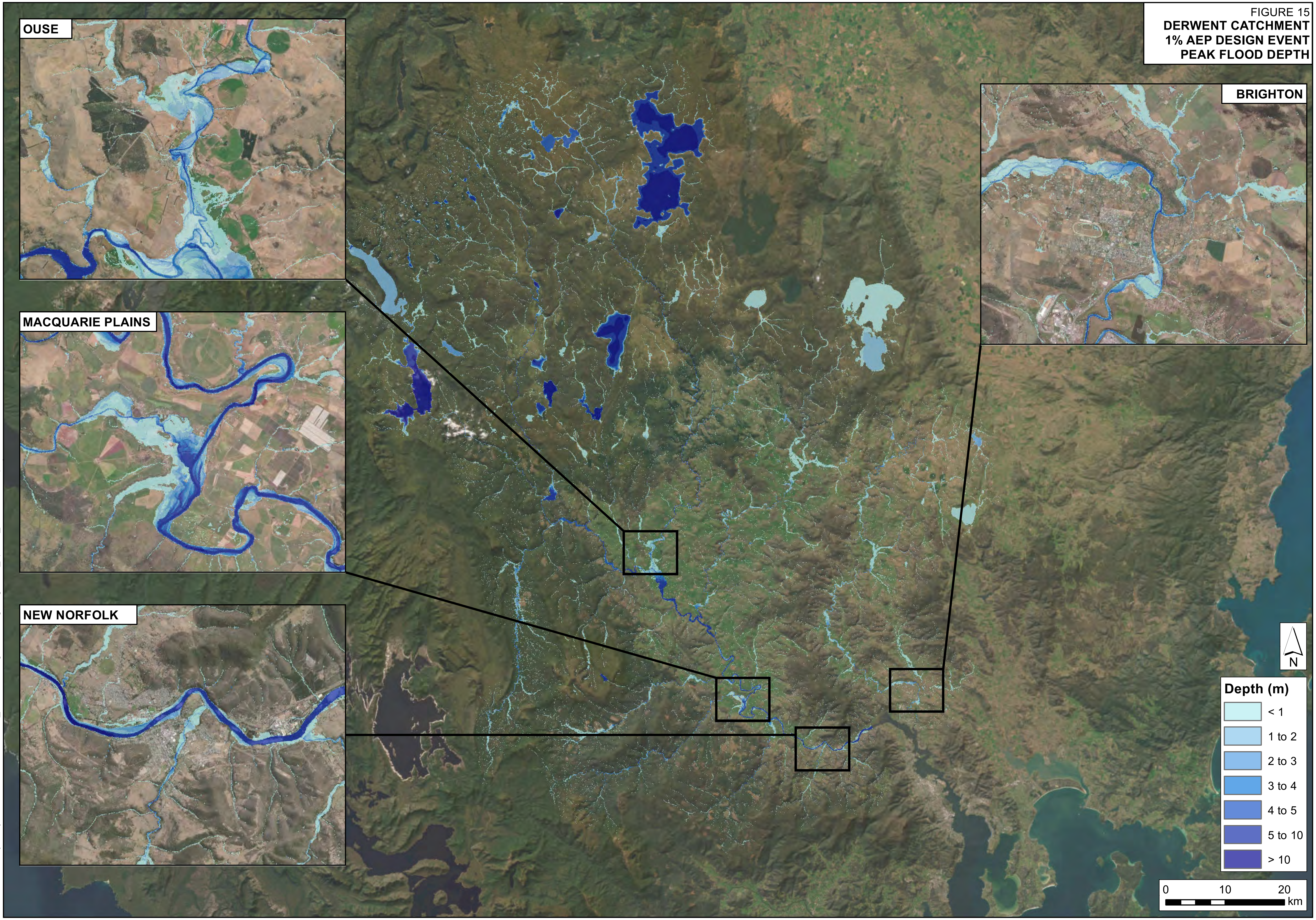
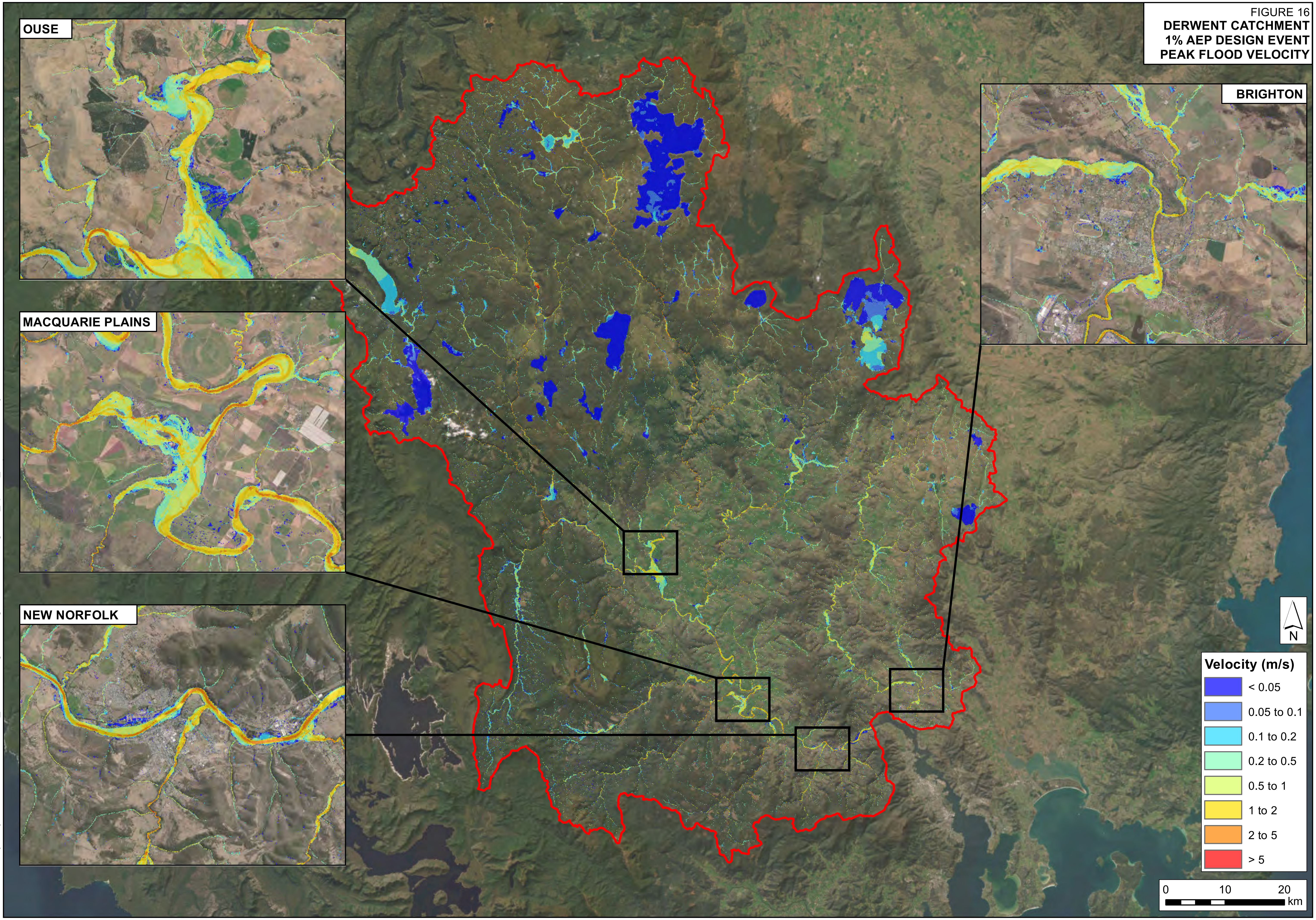


FIGURE 14
DERWENT CATCHMENT
1% AEP DESIGN EVENT
PEAK FLOOD LEVEL
OUSE
MACQUARIE PLAINS
NEW NORFOLK
BRIGHTON
N
Value
High : 1456
Low : 0
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Combined\Figures\Design\Renumbered\Figure14_1pAEP_PeakFloodLevel.mxd



J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Combined\Figures\Design\Figure15_1pAEP_PeakFloodDepth.mxd



J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Combined\Figures\Design\Renumbered\Figure16_1pAEP_PeakFloodVelocity.mxd

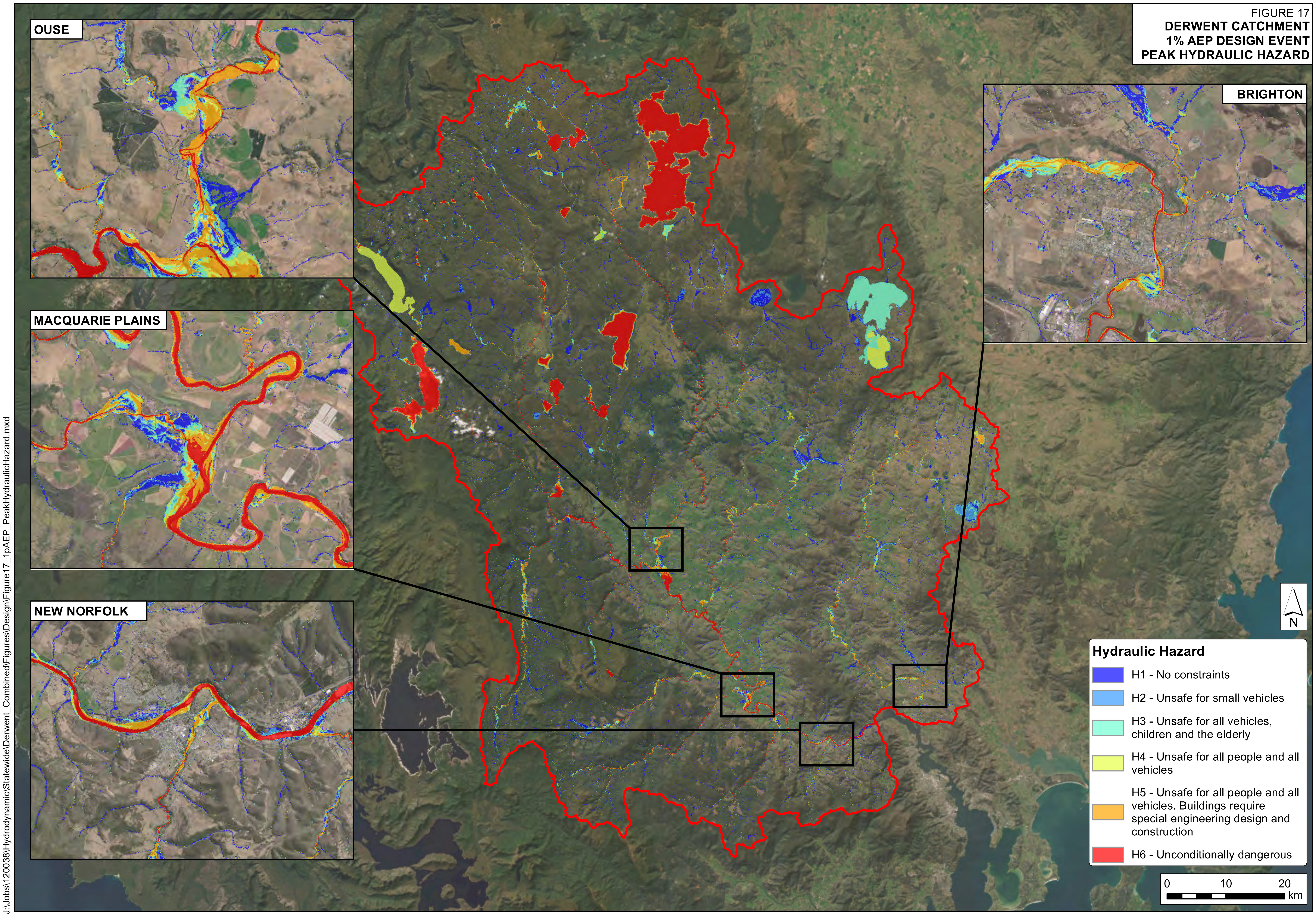


FIGURE 17
DERWENT CATCHMENT
1% AEP DESIGN EVENT
PEAK HYDRAULIC HAZARD
OUSE
MACQUARIE PLAINS
NEW NORFOLK
BRIGHTON
N
Hydraulic Hazard
H1 - No constraints
H2 - Unsafe for small vehicles
H3 - Unsafe for all vehicles, children and the elderly
H4 - Unsafe for all people and all vehicles
H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction
H6 - Unconditionally dangerous
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Combined\Figures\Design\Figure17_1pAEP_PeakHydraulicHazard.mxd

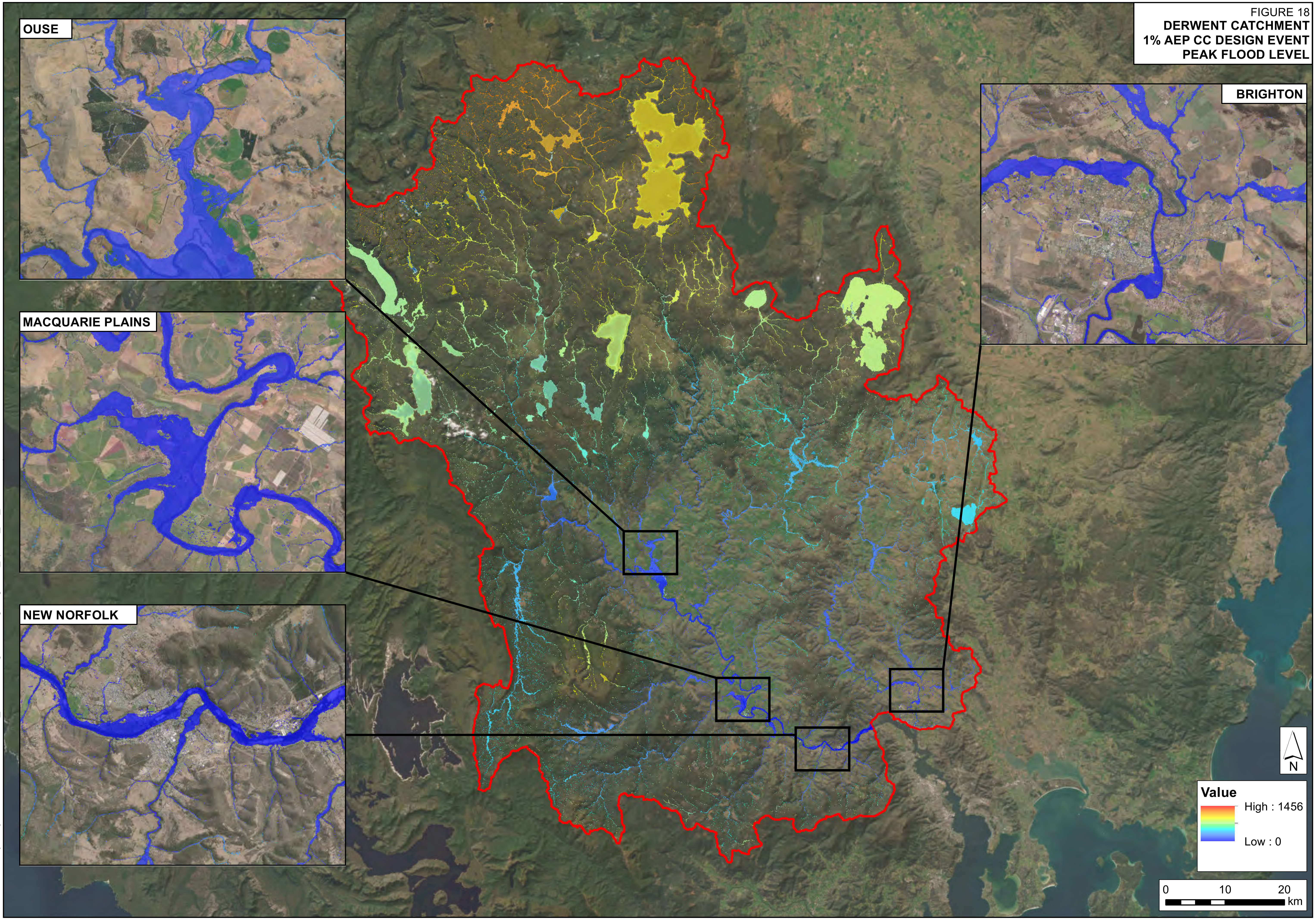


FIGURE 18
DERWENT CATCHMENT
1% AEP CC DESIGN EVENT
PEAK FLOOD LEVEL

J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Combined\Figures\Design\Figure18_1pAEP_CC_PeakFloodLevel.mxd

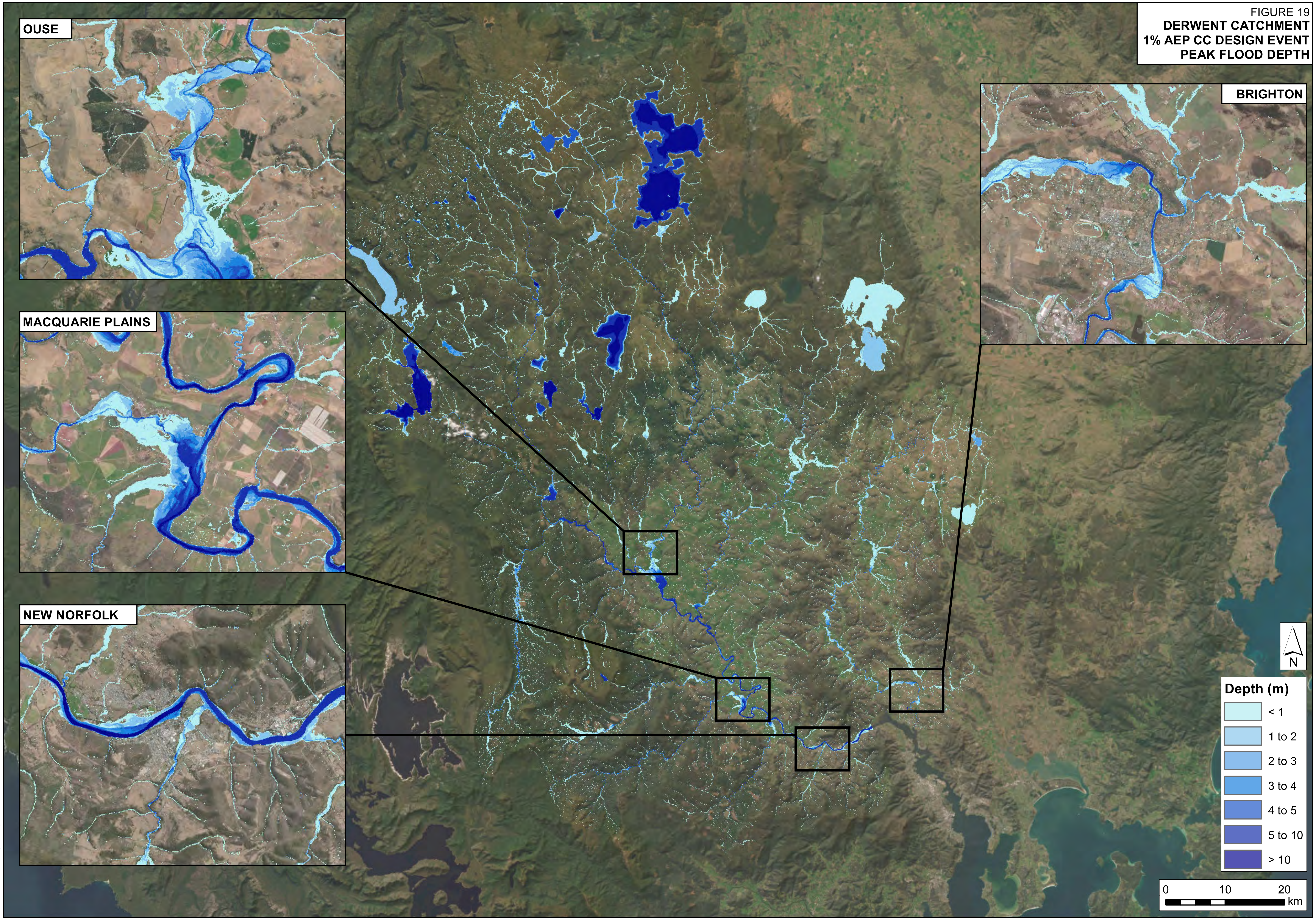


FIGURE 19
DERWENT CATCHMENT
1% AEP CC DESIGN EVENT
PEAK FLOOD DEPTH
OUSE
BRIGHTON
MACQUARIE PLAINS
NEW NORFOLK
N
Depth (m)
< 1
1 to 2
2 to 3
3 to 4
4 to 5
5 to 10
> 10
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Combined\Figures\Design\Renumbered\Figure19_1pAEP_CC_PeakFloodDepth.mxd

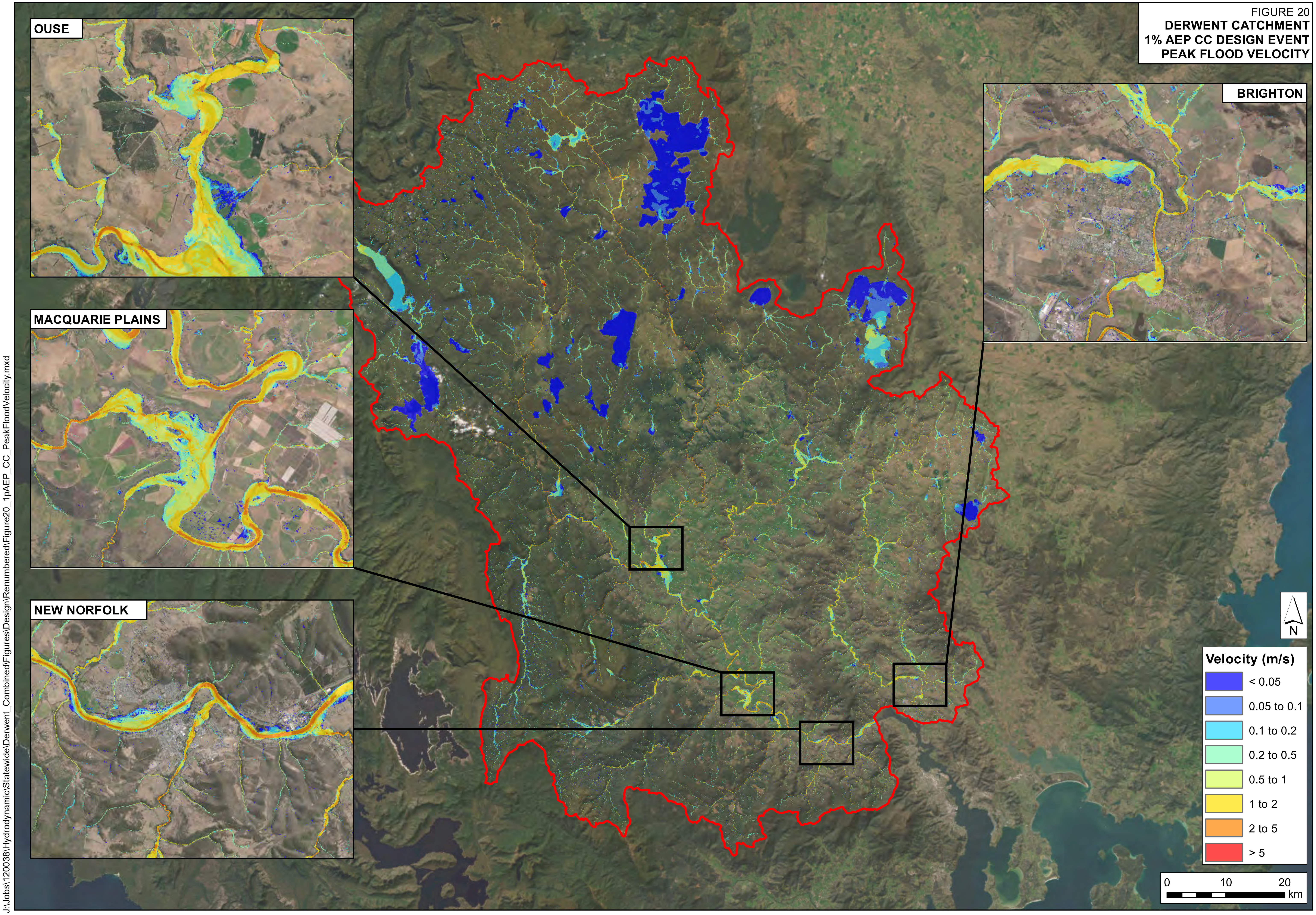


FIGURE 20
DERWENT CATCHMENT
1% AEP CC DESIGN EVENT
PEAK FLOOD VELOCITY
OUSE
MACQUARIE PLAINS
NEW NORFOLK
BRIGHTON
N
Velocity (m/s)
< 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.5
0.5 to 1
1 to 2
2 to 5
> 5
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Combined\Figures\Design\Renumbered\Figure20_1pAEP_CC_PeakFloodVelocity.mxd

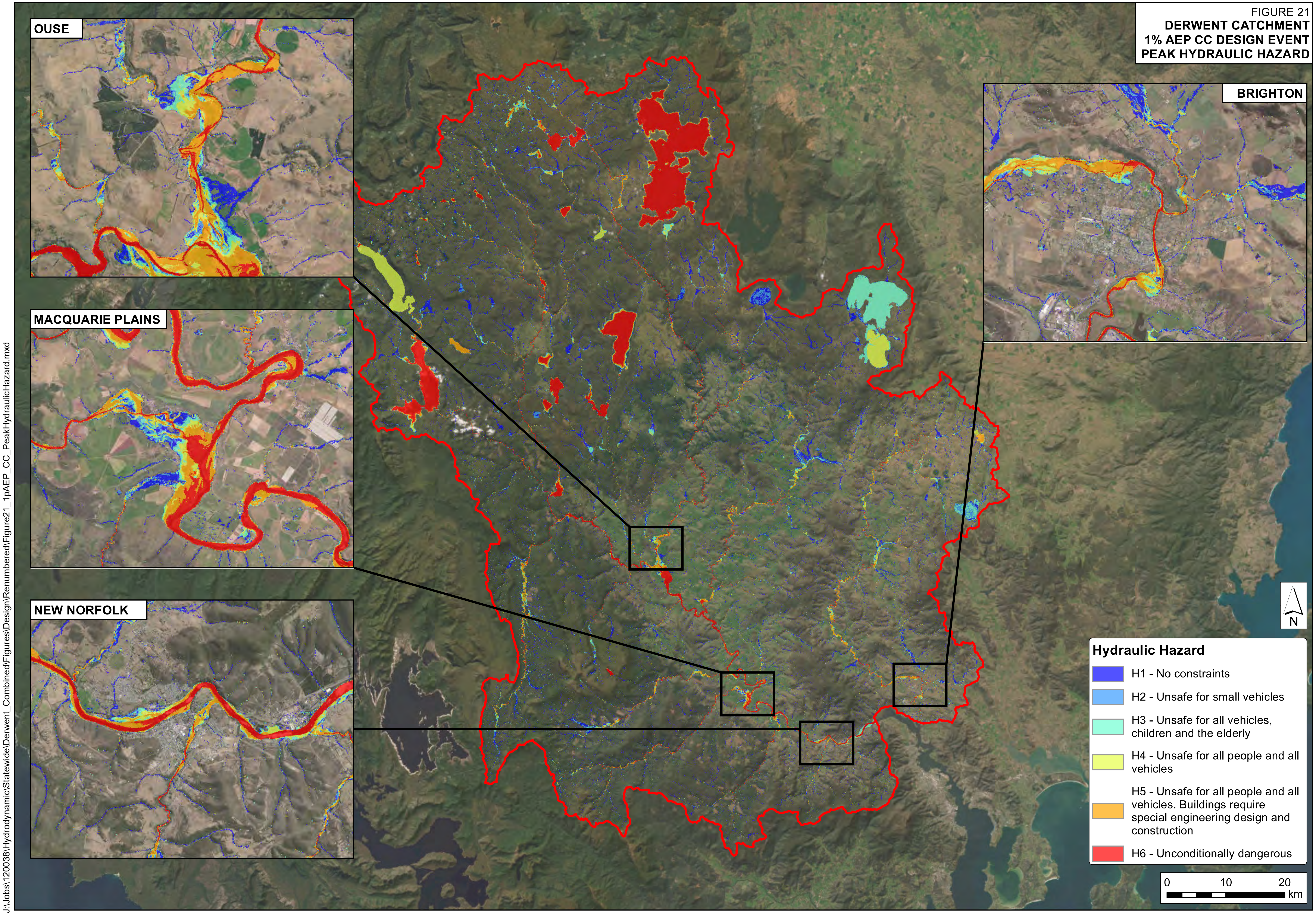


FIGURE 21
DERWENT CATCHMENT
1% AEP CC DESIGN EVENT
PEAK HYDRAULIC HAZARD
OUSE
MACQUARIE PLAINS
NEW NORFOLK
BRIGHTON
N
Hydraulic Hazard
H1 - No constraints
H2 - Unsafe for small vehicles
H3 - Unsafe for all vehicles, children and the elderly
H4 - Unsafe for all people and all vehicles
H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction
H6 - Unconditionally dangerous
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Combined\Figures\Design\Renumbered\Figure21_1pAEP_CC_PeakHydraulicHazard.mxd

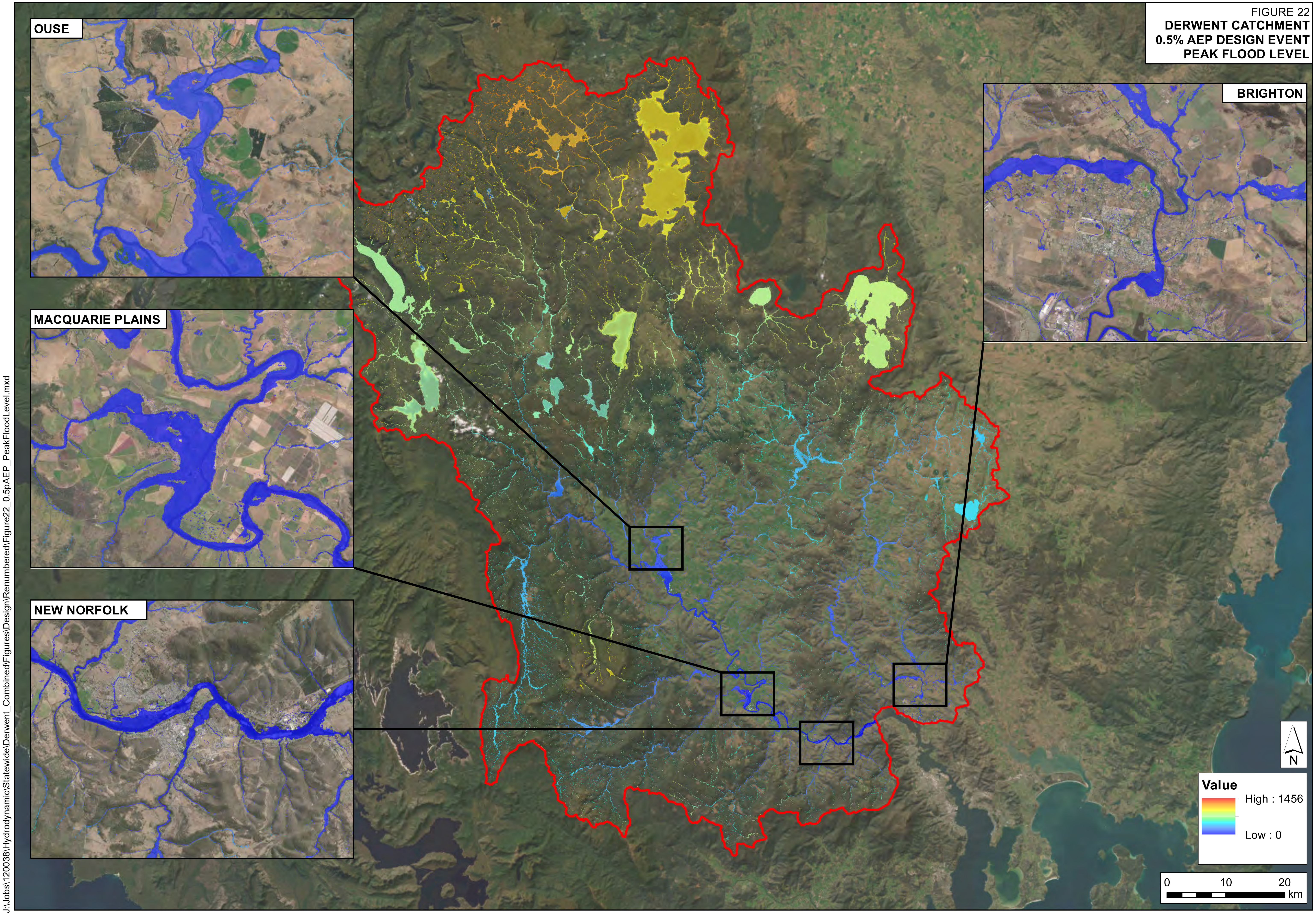
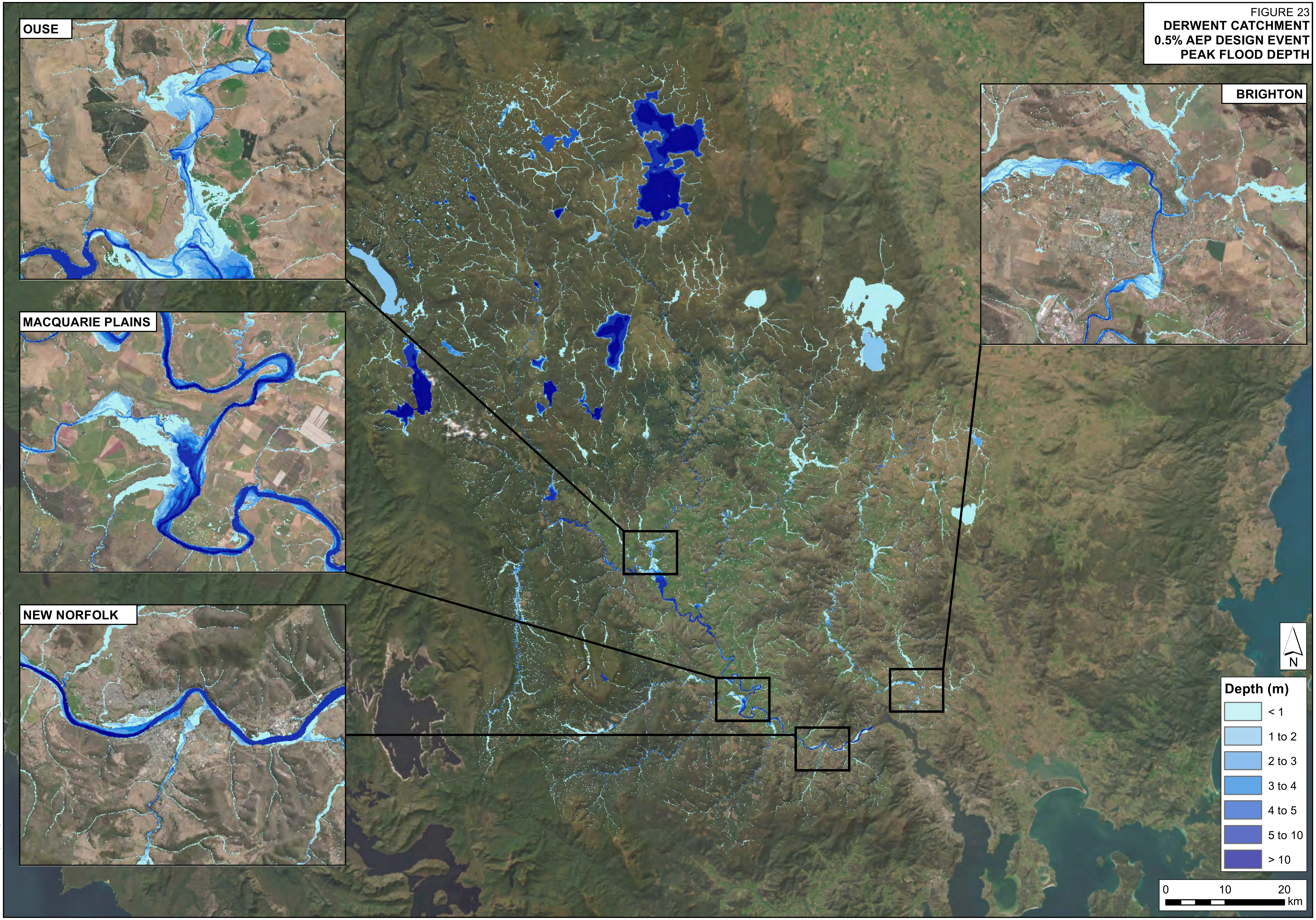


FIGURE 22
DERWENT CATCHMENT
0.5% AEP DESIGN EVENT
PEAK FLOOD LEVEL
OUSE
MACQUARIE PLAINS
NEW NORFOLK
BRIGHTON
N
Value
High : 1456
Low : 0
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Combined\Figures\Design\Renumbered\Figure22_0.5pAEP_PeakFloodLevel.mxd



J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Combined\Figures\Design\Renumbered\Figure23_0.5pAEP_PeakFloodDepth.mxd

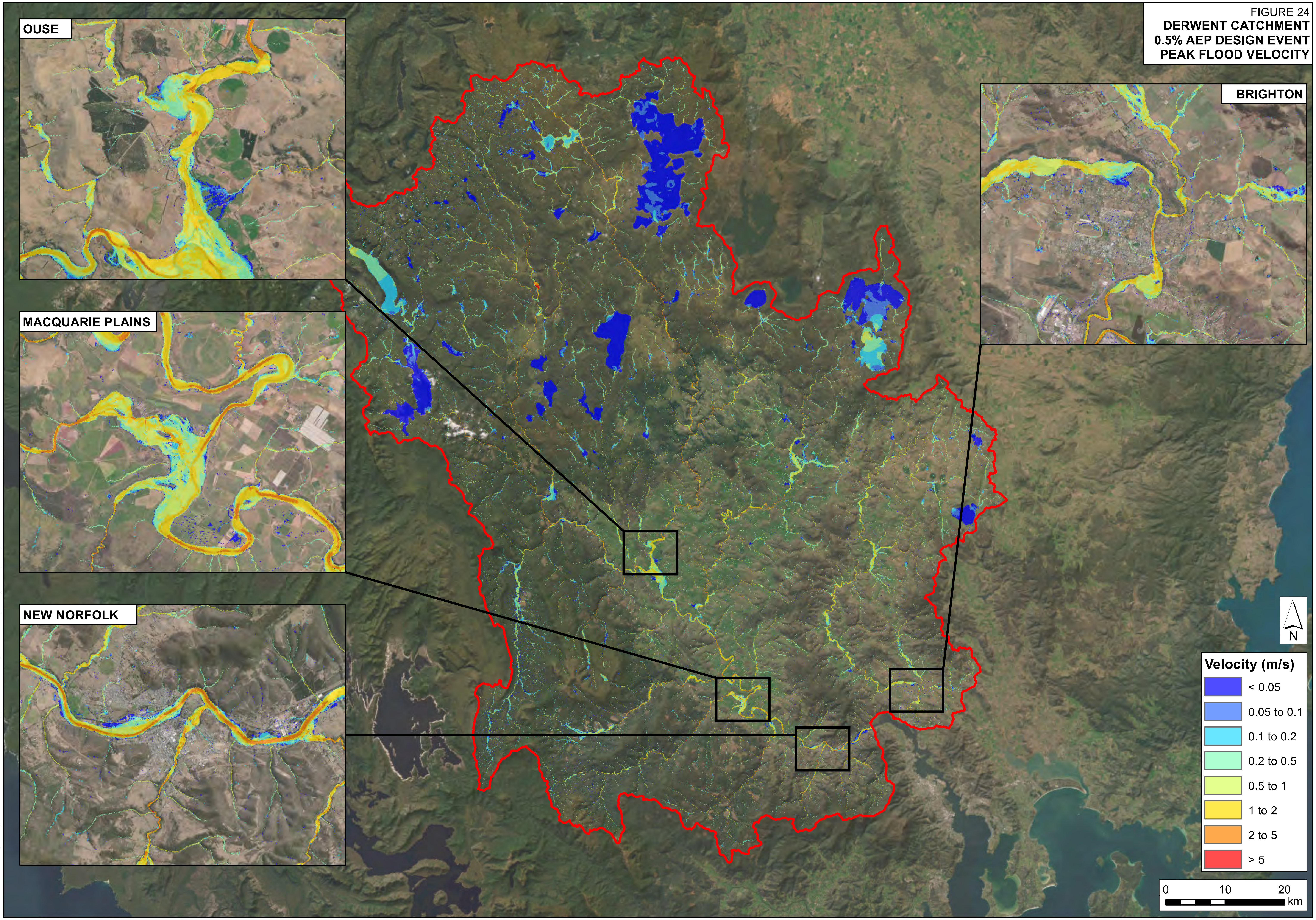


FIGURE 24
DERWENT CATCHMENT
0.5% AEP DESIGN EVENT
PEAK FLOOD VELOCITY
OUSE
MACQUARIE PLAINS
NEW NORFOLK
BRIGHTON
N
Velocity (m/s)
< 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.5
0.5 to 1
1 to 2
2 to 5
> 5
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Combined\Figures\Design\Figure24_0.5pAEP_PeakFloodVelocity.mxd

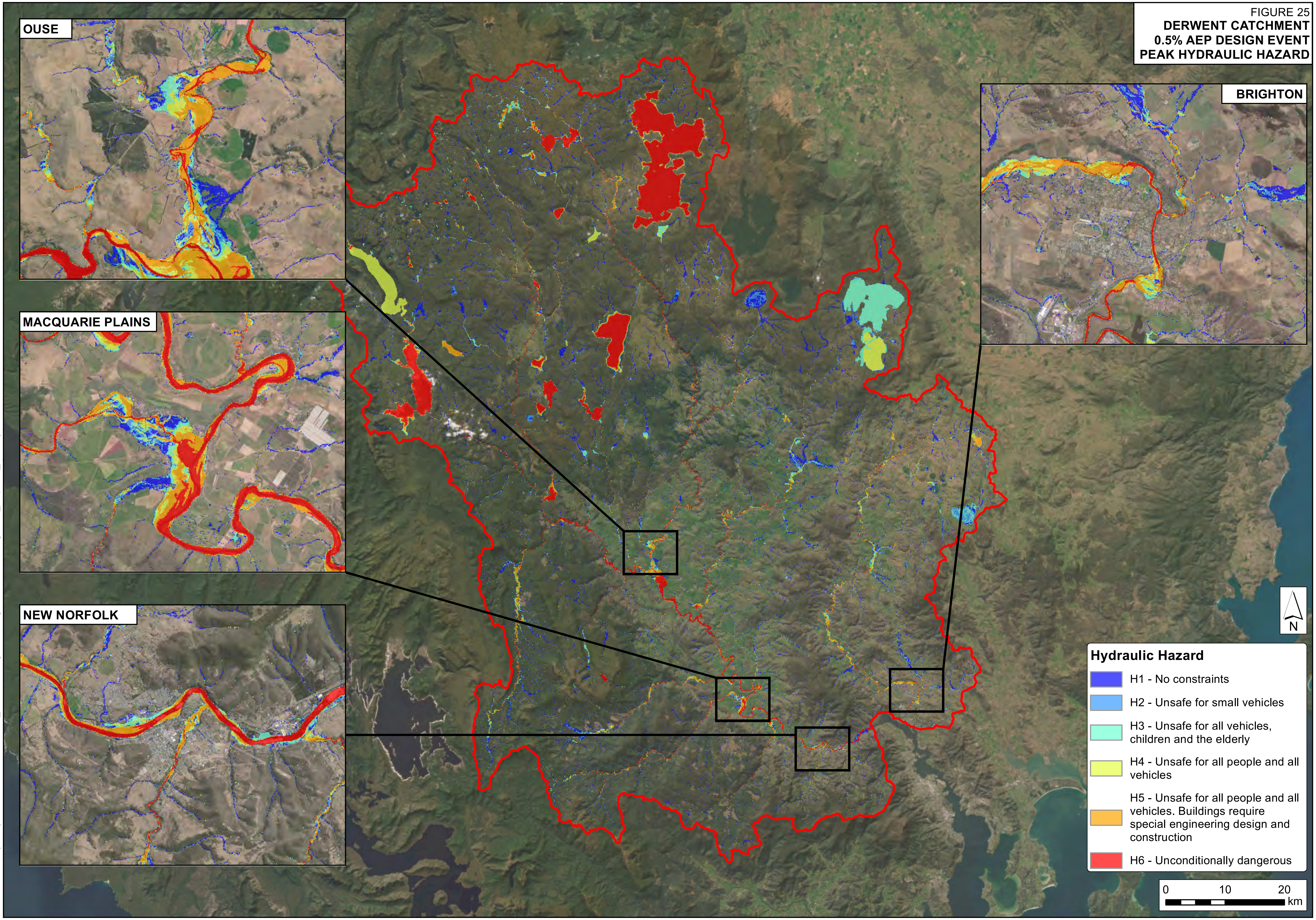


FIGURE 25
DERWENT CATCHMENT
0.5% AEP DESIGN EVENT
PEAK HYDRAULIC HAZARD
OUSE
MACQUARIE PLAINS
NEW NORFOLK
BRIGHTON
N
Hydraulic Hazard
H1 - No constraints
H2 - Unsafe for small vehicles
H3 - Unsafe for all vehicles, children and the elderly
H4 - Unsafe for all people and all vehicles
H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction
H6 - Unconditionally dangerous
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Combined\Figures\Design\Renumbered\Figure25_0.5pAEP_PeakHydraulicHazard.mxd

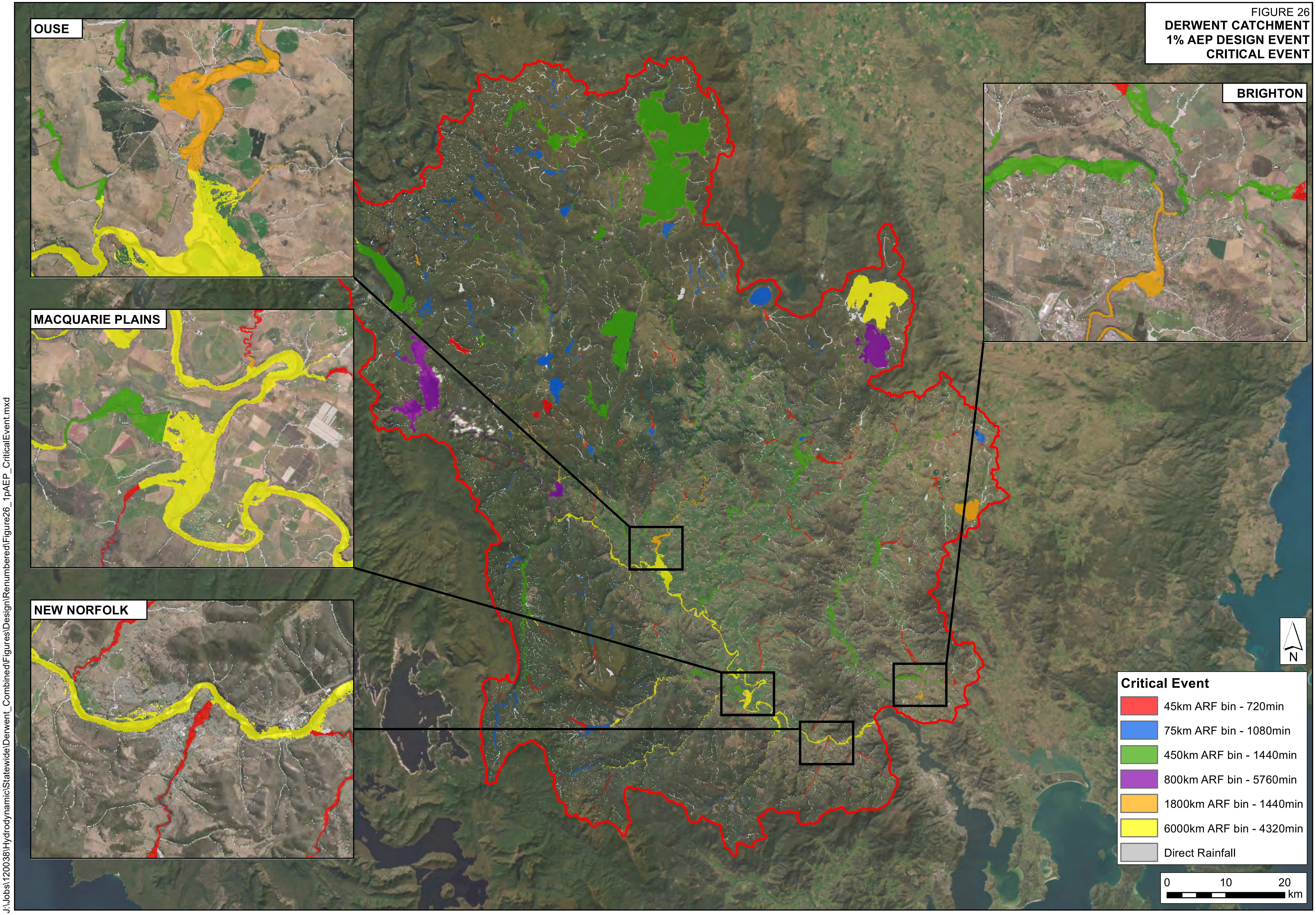


FIGURE 26
DERWENT CATCHMENT
1% AEP DESIGN EVENT
CRITICAL EVENT
OUSE
MACQUARIE PLAINS
NEW NORFOLK
BRIGHTON
N
Critical Event
45km ARF bin - 720min
75km ARF bin - 1080min
450km ARF bin - 1440min
800km ARF bin - 5760min
1800km ARF bin - 1440min
6000km ARF bin - 4320min
Direct Rainfall
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Combined\Figures\Design\Renumbered\Figure26_1pAEP_CriticalEvent.mxd

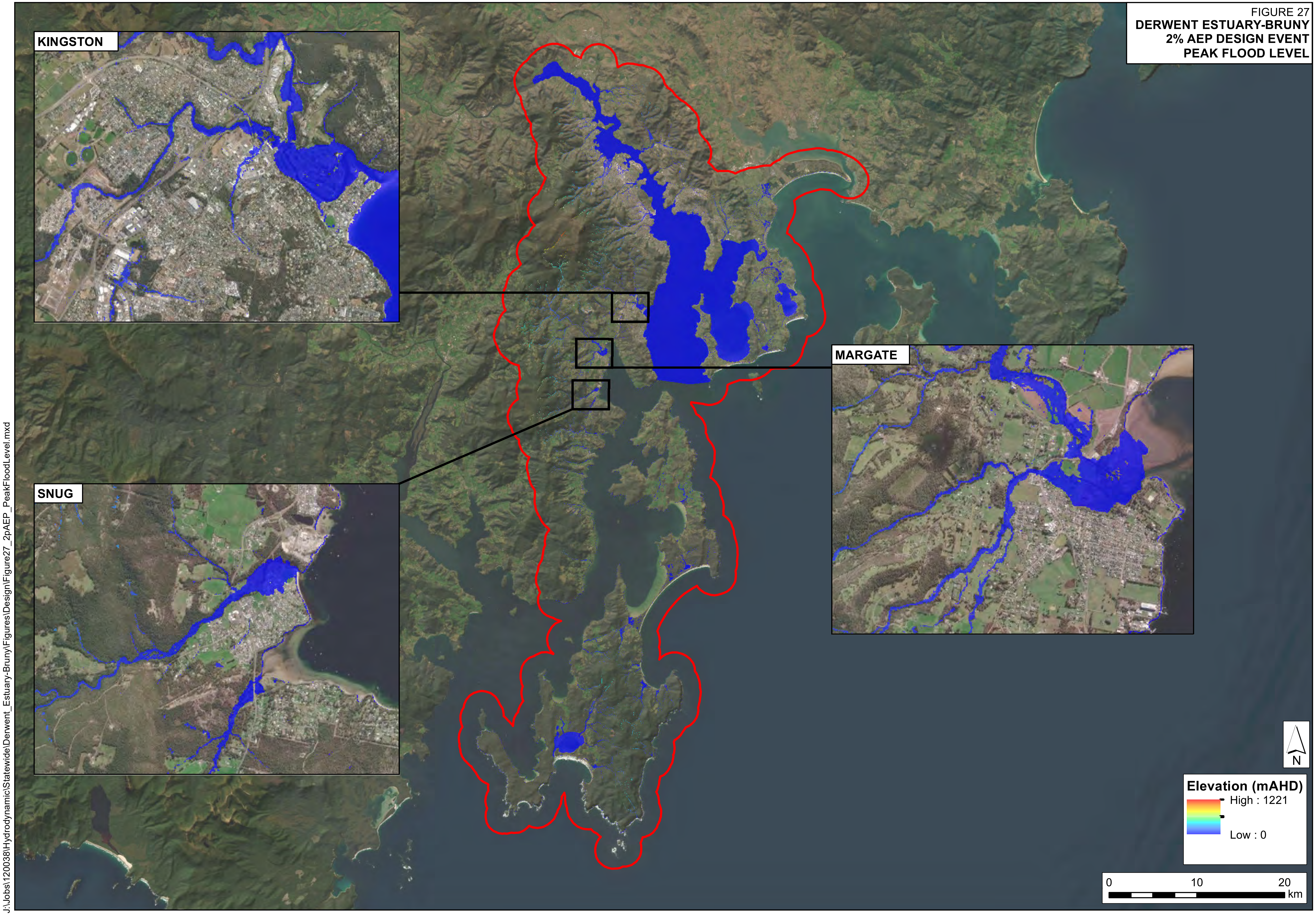


FIGURE 27
DERWENT ESTUARY-BRUNY
2% AEP DESIGN EVENT
PEAK FLOOD LEVEL
KINGSTON
MARGATE
SNUG
N
Elevation (mAHD)
High : 1221
Low : 0
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Estuary-Bruny\Figures\Design\Figure27_2pAEP_PeakFloodLevel.mxd

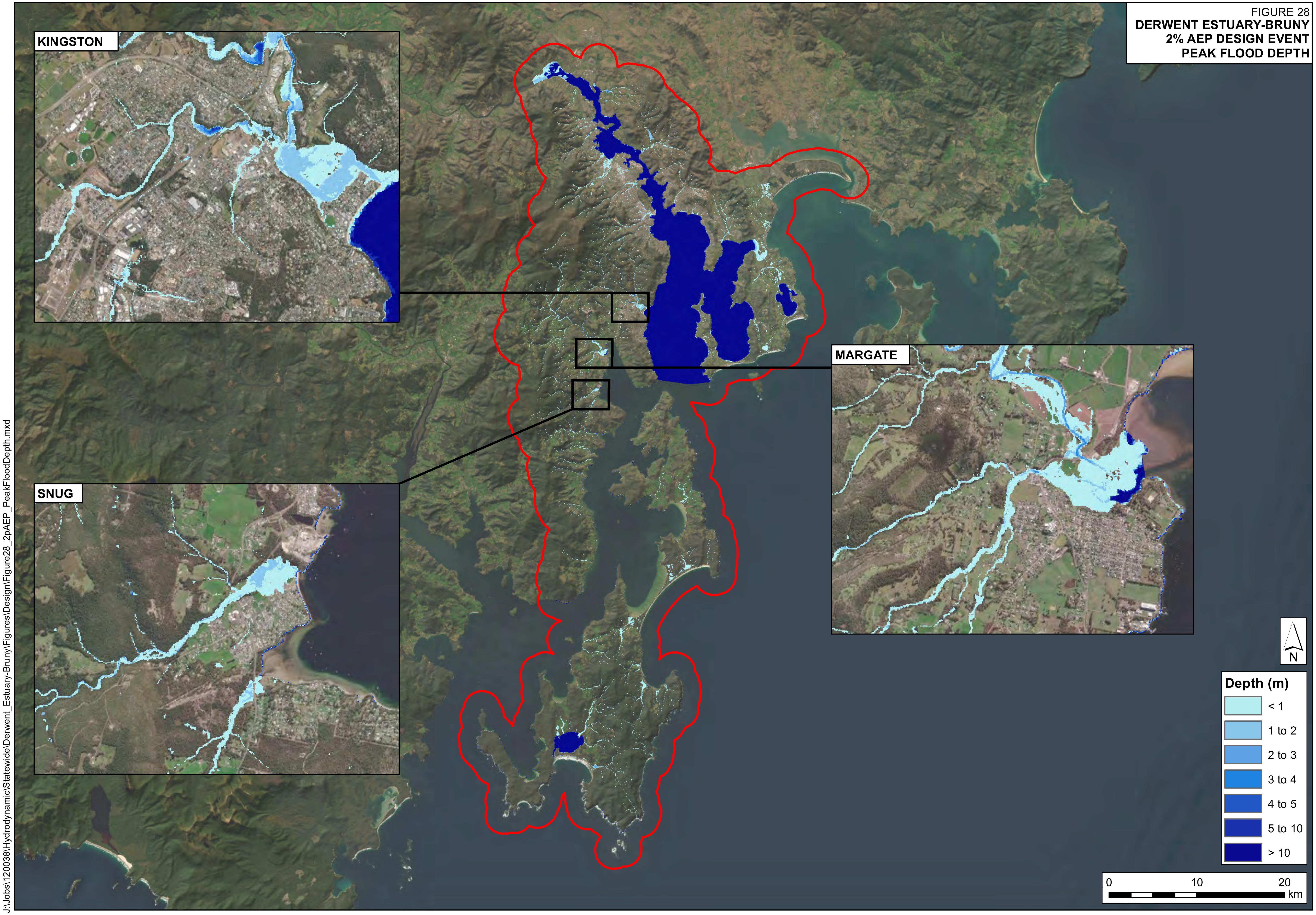


FIGURE 28
DERWENT ESTUARY-BRUNY
2% AEP DESIGN EVENT
PEAK FLOOD DEPTH
KINGSTON
MARGATE
SNUG
N
Depth (m)
< 1
1 to 2
2 to 3
3 to 4
4 to 5
5 to 10
> 10
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Estuary-Bruny\Figures\Design\Figure28_2pAEP_PeakFloodDepth.mxd

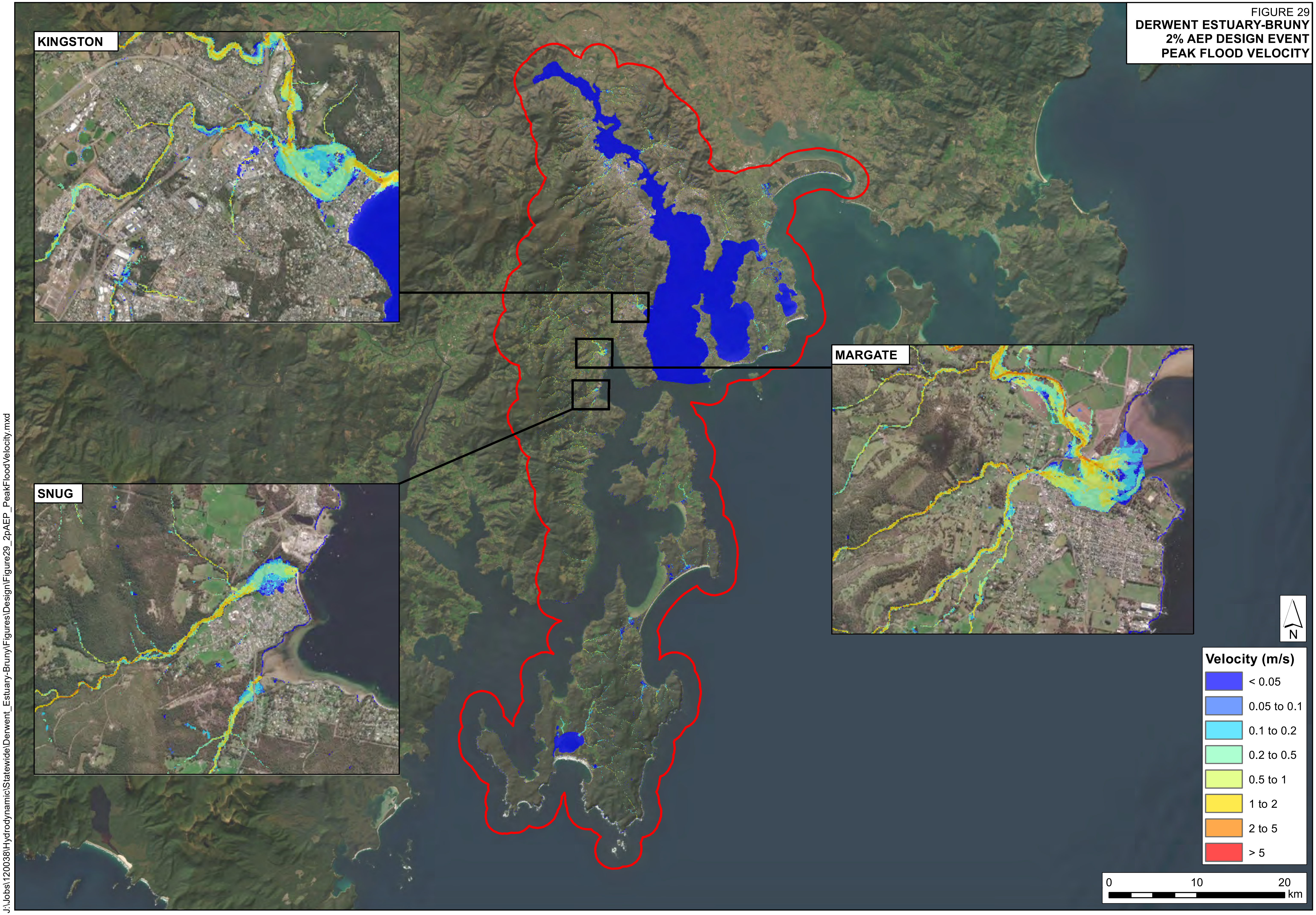
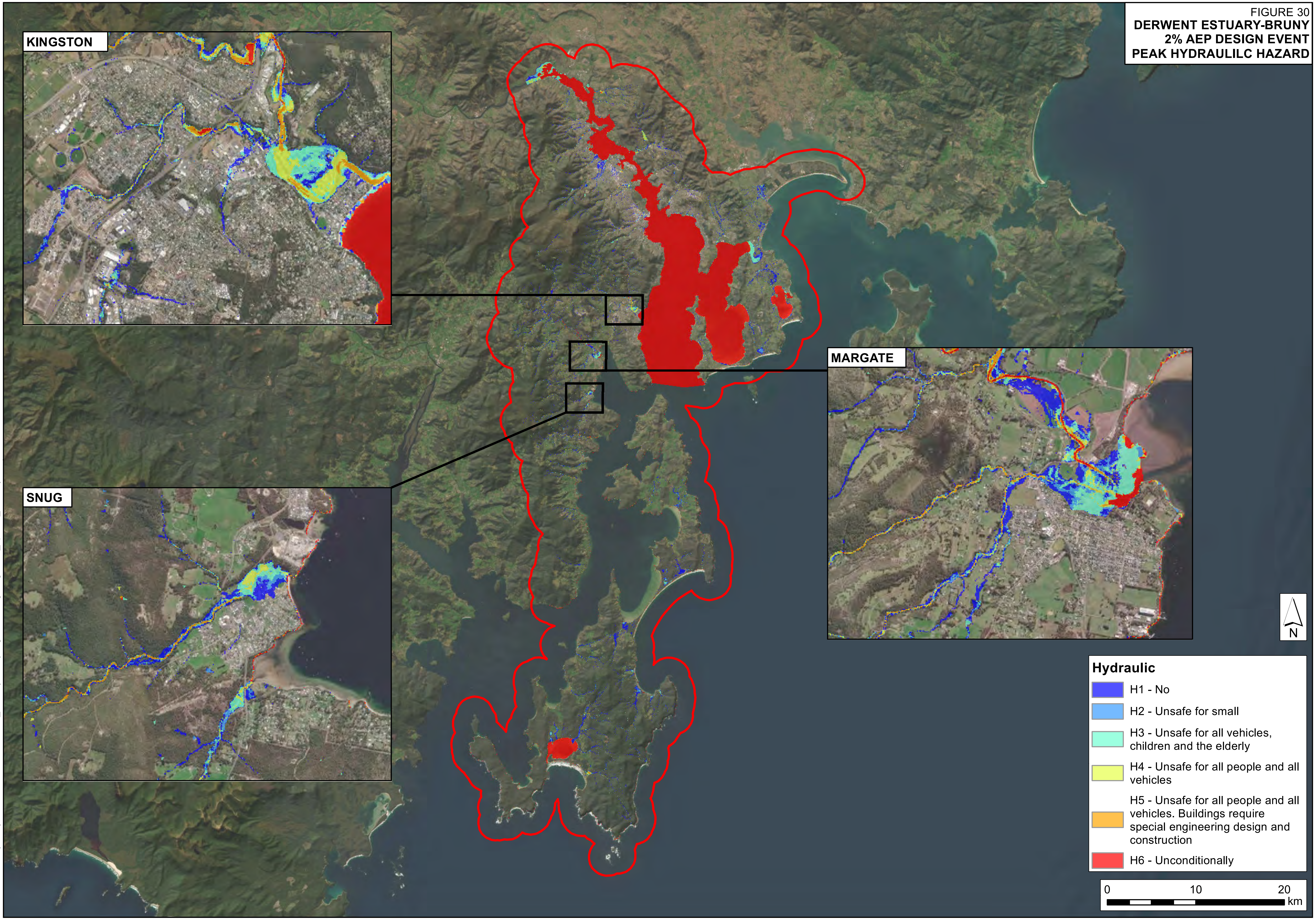


FIGURE 29
DERWENT ESTUARY-BRUNY
2% AEP DESIGN EVENT
PEAK FLOOD VELOCITY
KINGSTON
MARGATE
SNUG
N
Velocity (m/s)
< 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.5
0.5 to 1
1 to 2
2 to 5
> 5
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Estuary-Bruny\Figures\Design\Figure29_2pAEP_PeakFloodVelocity.mxd



J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Estuary-Bruny\Figures\Design\Figure30_2pAEP_PeakHydraulicHazard.mxd

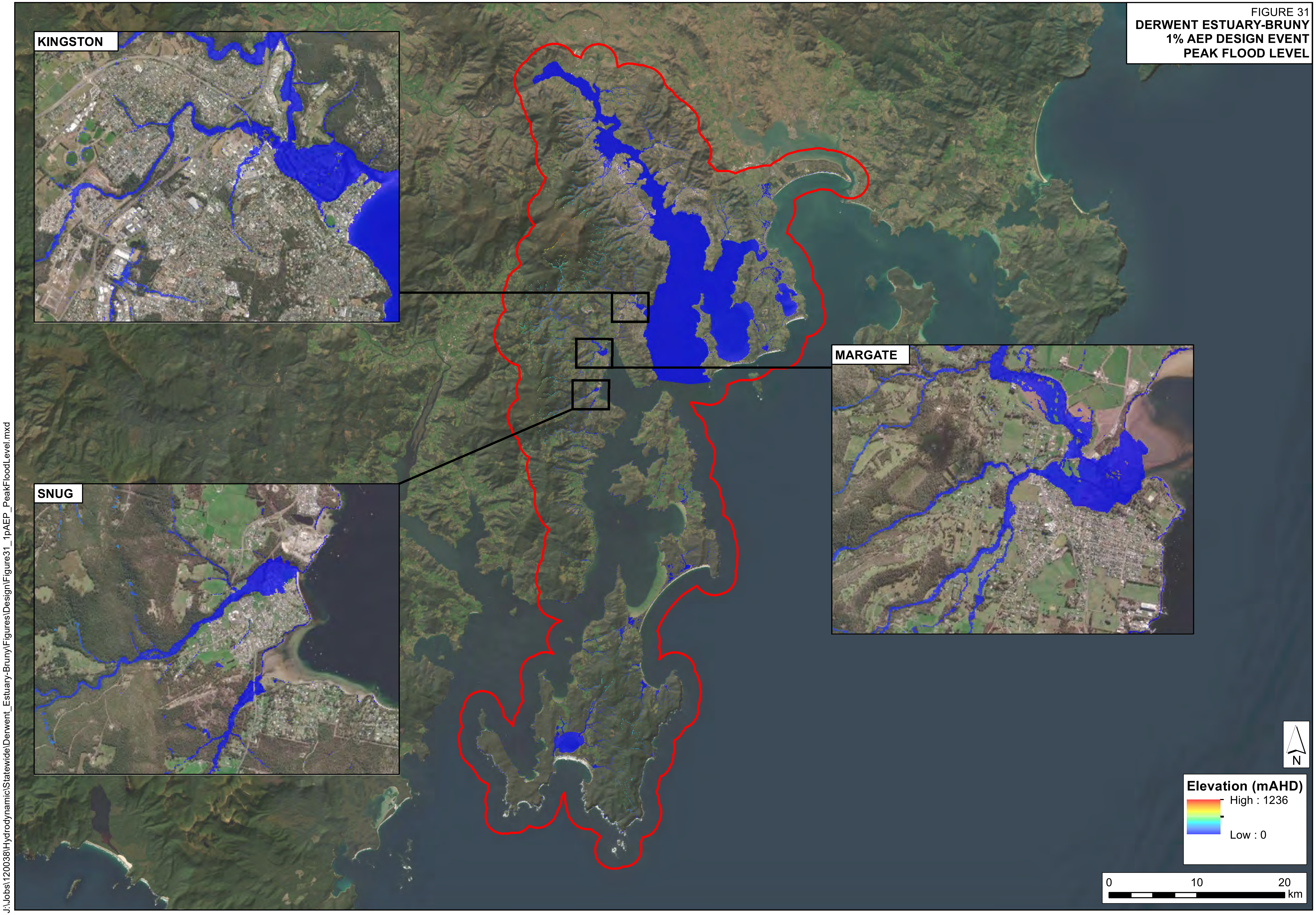


FIGURE 31
DERWENT ESTUARY-BRUNY
1% AEP DESIGN EVENT
PEAK FLOOD LEVEL
KINGSTON
MARGATE
SNUG
N
Elevation (mAHD)
High : 1236
Low : 0
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Estuary-Bruny\Figures\Design\Figure31_1pAEP_PeakFloodLevel.mxd

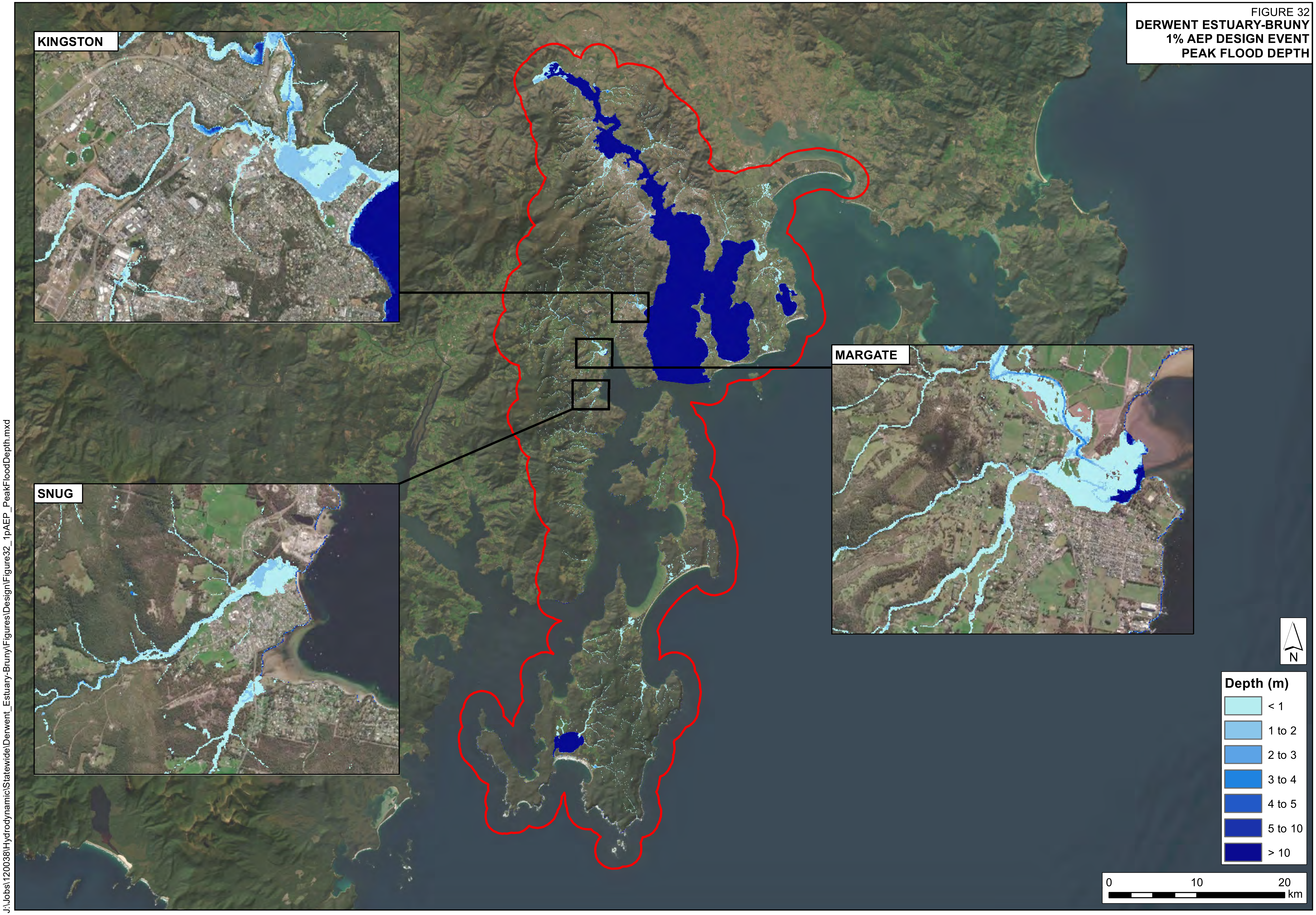


FIGURE 32
DERWENT ESTUARY-BRUNY
1% AEP DESIGN EVENT
PEAK FLOOD DEPTH
KINGSTON
MARGATE
SNUG
N
Depth (m)
< 1
1 to 2
2 to 3
3 to 4
4 to 5
5 to 10
> 10
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Estuary-Bruny\Figures\Design\Figure32_1pAEP_PeakFloodDepth.mxd

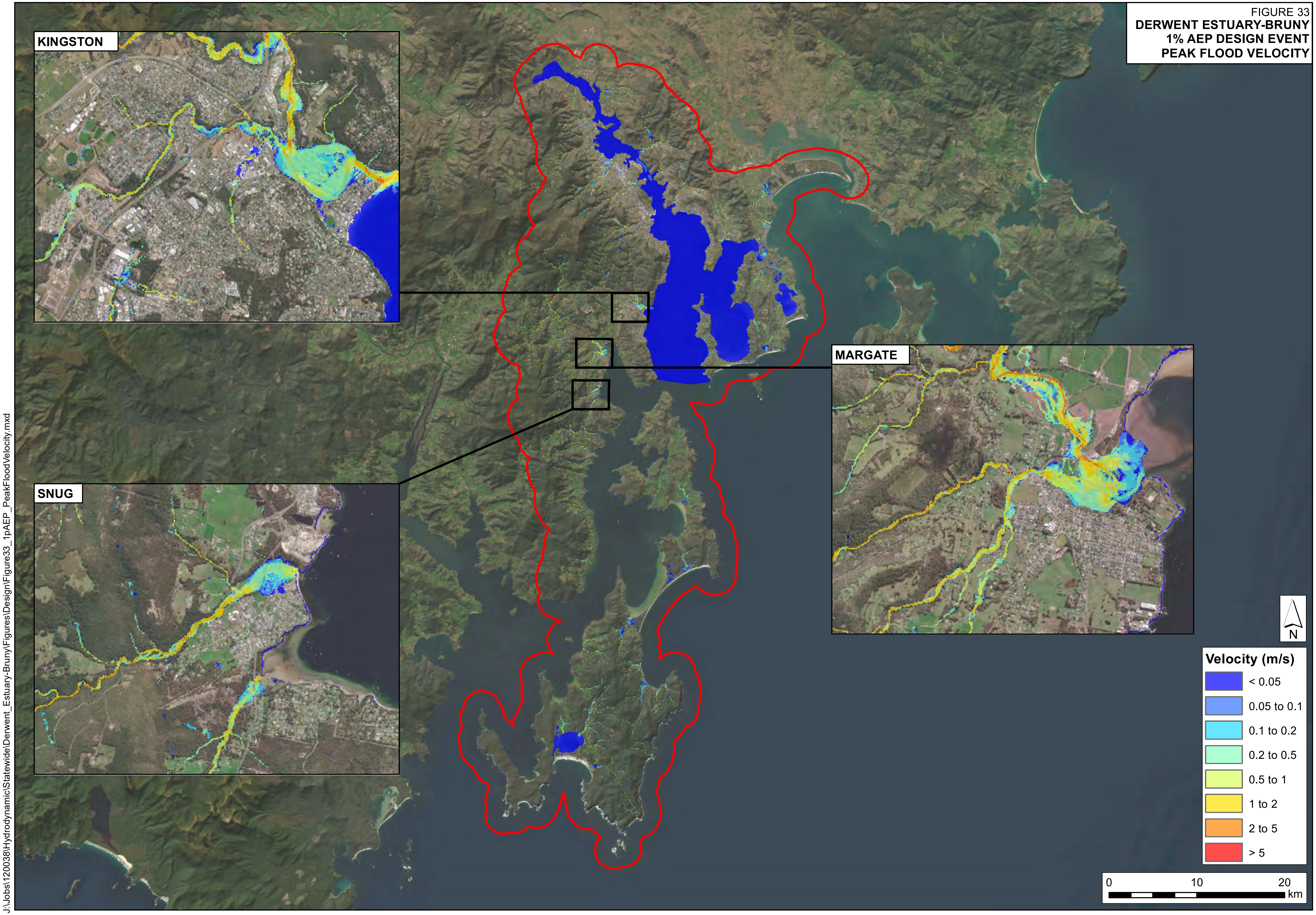


FIGURE 33
DERWENT ESTUARY-BRUNY
1% AEP DESIGN EVENT
PEAK FLOOD VELOCITY
KINGSTON
MARGATE
SNUG
N
Velocity (m/s)
< 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.5
0.5 to 1
1 to 2
2 to 5
> 5
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Estuary-Bruny\Figures\Design\Figure33_1pAEP_PeakFloodVelocity.mxd

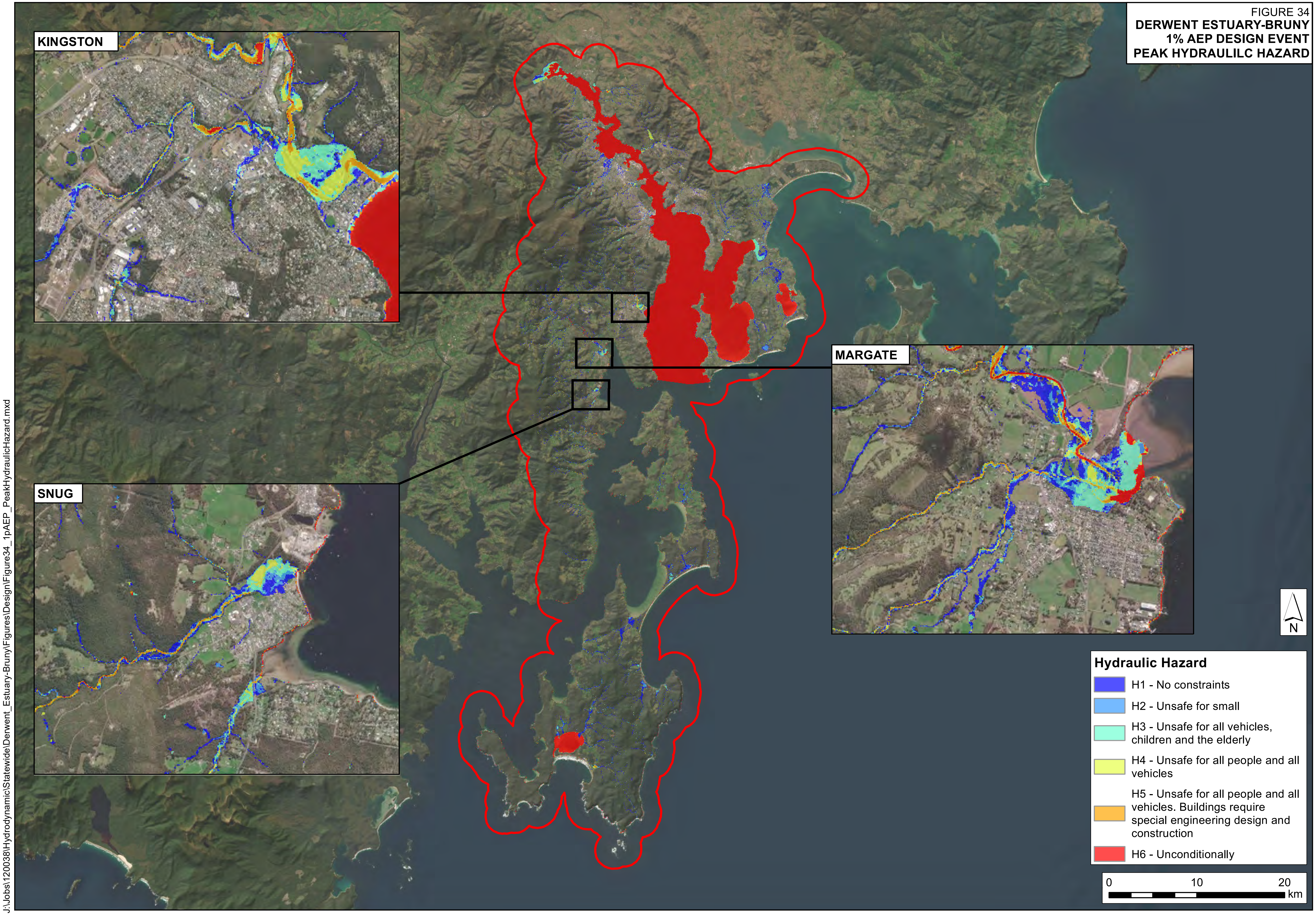


FIGURE 34
DERWENT ESTUARY-BRUNY
1% AEP DESIGN EVENT
PEAK HYDRAULILC HAZARD
KINGSTON
MARGATE
SNUG
N
Hydraulic Hazard
H1 - No constraints
H2 - Unsafe for small
H3 - Unsafe for all vehicles, children and the elderly
H4 - Unsafe for all people and all vehicles
H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction
H6 - Unconditionally
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Estuary-Bruny\Figures\Design\Figure34_1pAEP_PeakHydraulicHazard.mxd

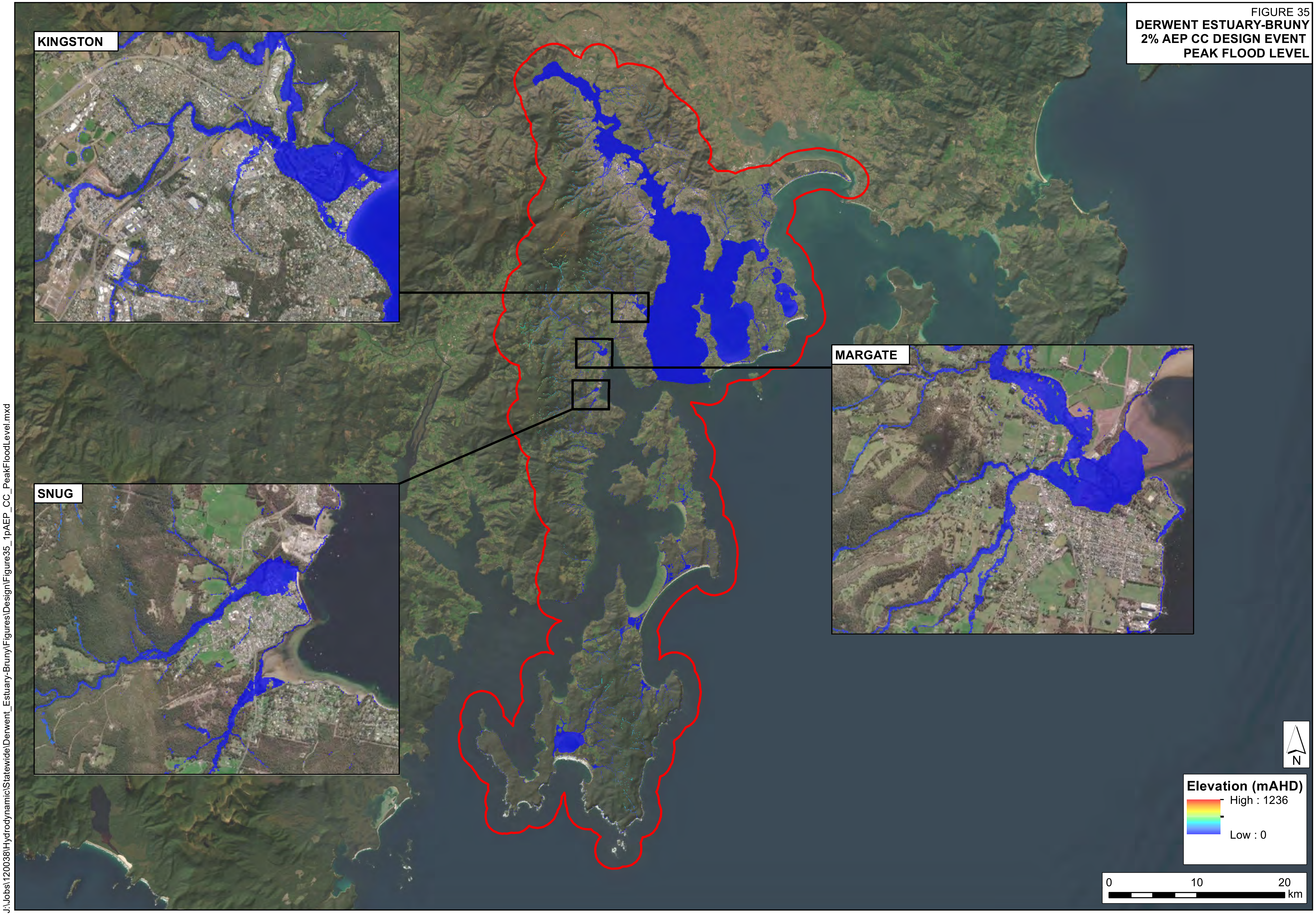


FIGURE 35
DERWENT ESTUARY-BRUNY
2% AEP CC DESIGN EVENT
PEAK FLOOD LEVEL
KINGSTON
MARGATE
SNUG
N
Elevation (mAHD)
High : 1236
Low : 0
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Estuary-Bruny\Figures\Design\Figure35_1pAEP_CC_PeakFloodLevel.mxd

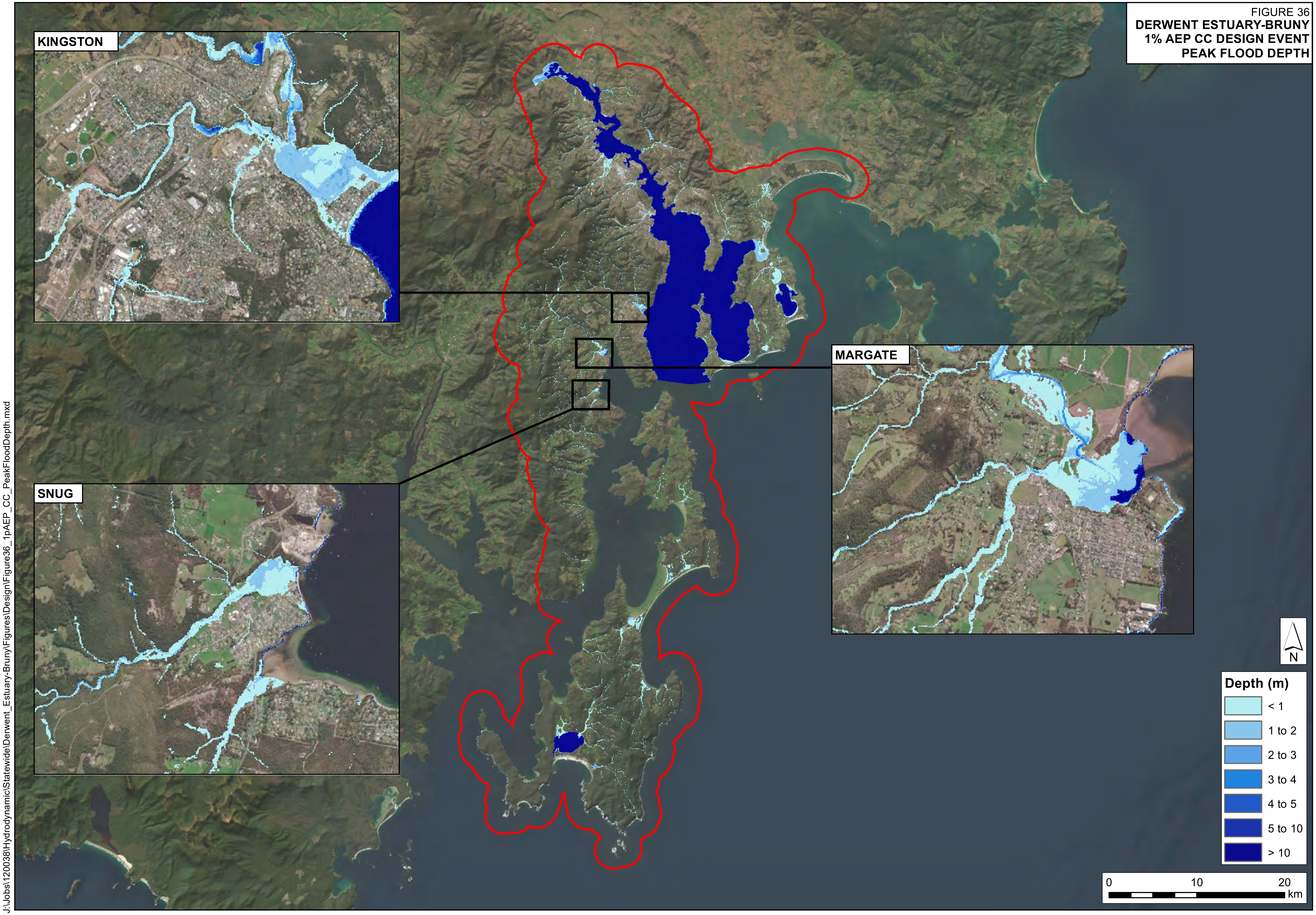


FIGURE 36
DERWENT ESTUARY-BRUNY
1% AEP CC DESIGN EVENT
PEAK FLOOD DEPTH
KINGSTON
MARGATE
SNUG
N
Depth (m)
< 1
1 to 2
2 to 3
3 to 4
4 to 5
5 to 10
> 10
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Estuary-Bruny\Figures\Design\Figure36_1pAEP_CC_PeakFloodDepth.mxd

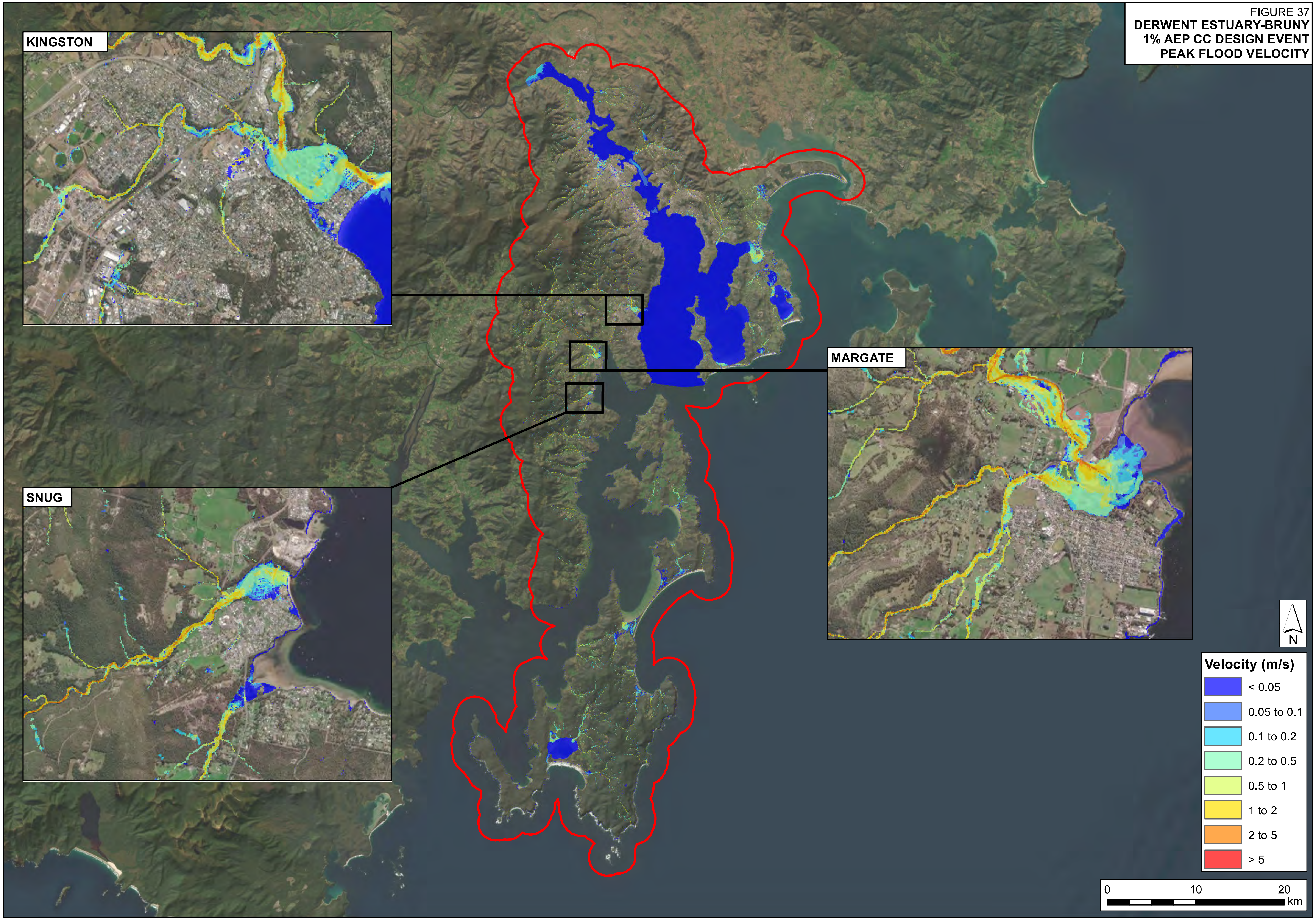


FIGURE 37
DERWENT ESTUARY-BRUNY
1% AEP CC DESIGN EVENT
PEAK FLOOD VELOCITY
KINGSTON
MARGATE
SNUG
Velocity (m/s)
< 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.5
0.5 to 1
1 to 2
2 to 5
> 5
N
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Estuary-Bruny\Figures\Design\Figure37_1pAEP_CC_PeakFloodVelocity.mxd

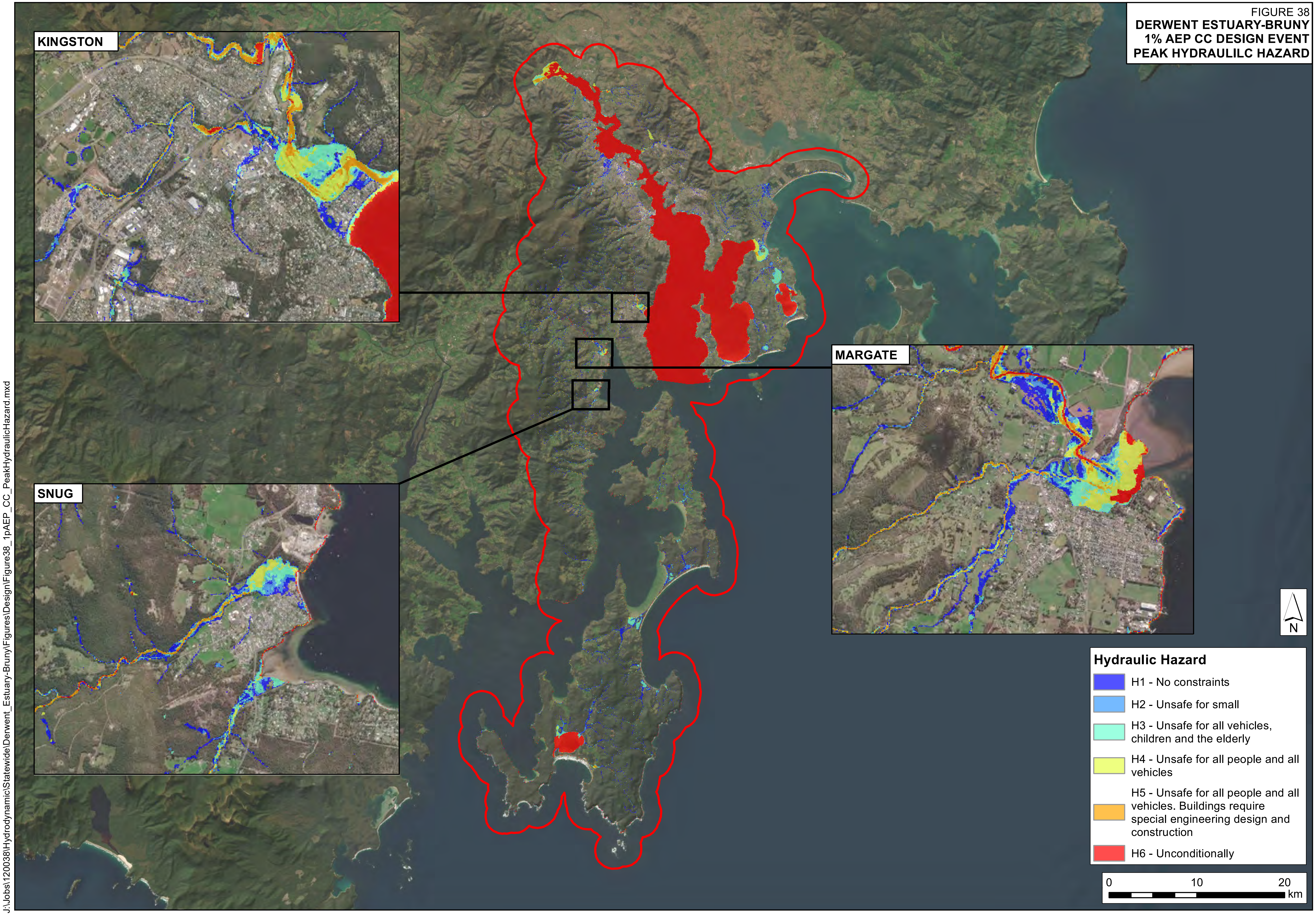


FIGURE 38
DERWENT ESTUARY-BRUNY
1% AEP CC DESIGN EVENT
PEAK HYDRAULILC HAZARD
KINGSTON
MARGATE
SNUG
Hydraulic Hazard
H1 - No constraints
H2 - Unsafe for small
H3 - Unsafe for all vehicles, children and the elderly
H4 - Unsafe for all people and all vehicles
H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction
H6 - Unconditionally
0
10
20
km
N
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Estuary-Bruny\Figures\Design\Figure38_1pAEP_CC_PeakHydraulicHazard.mxd

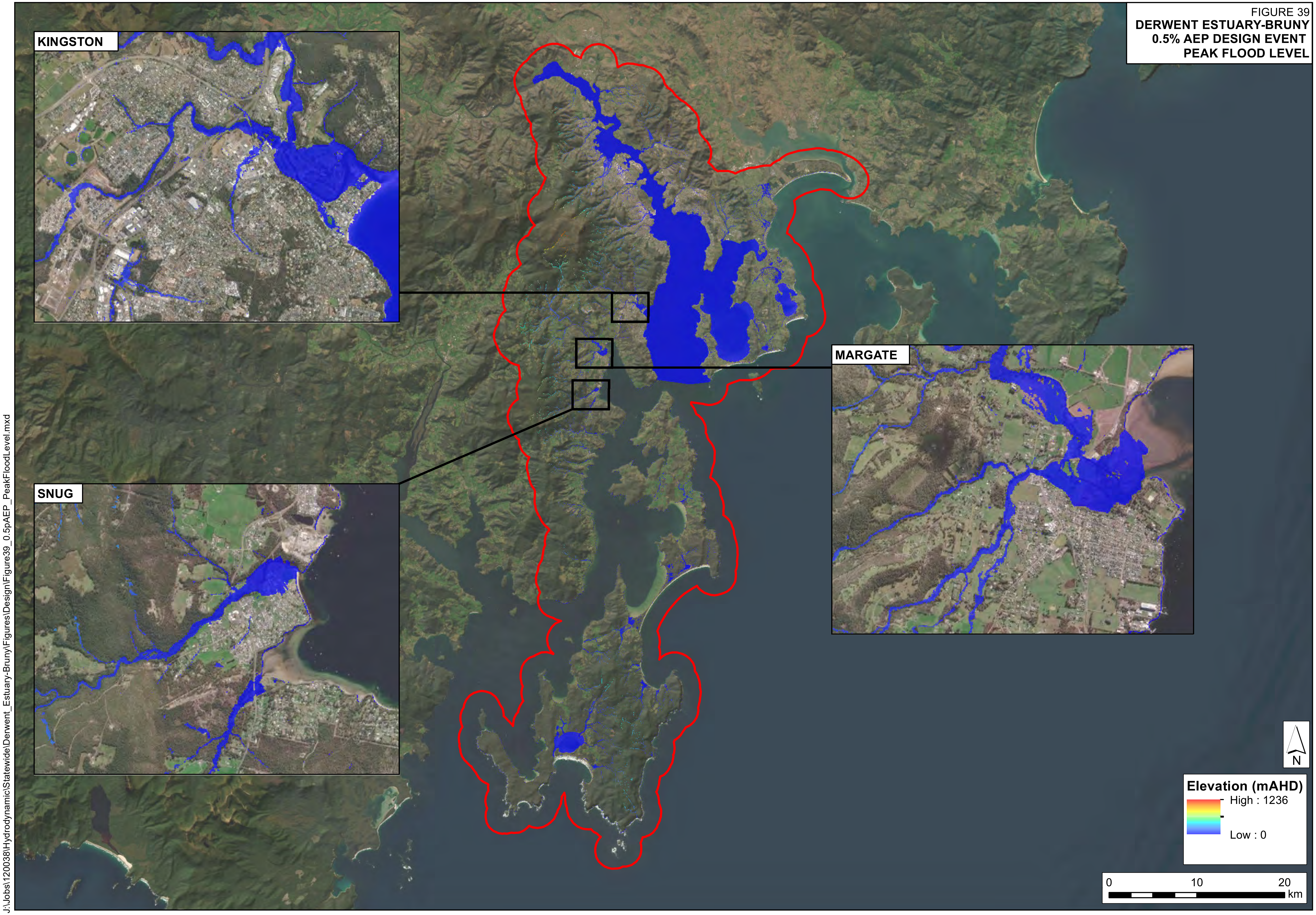
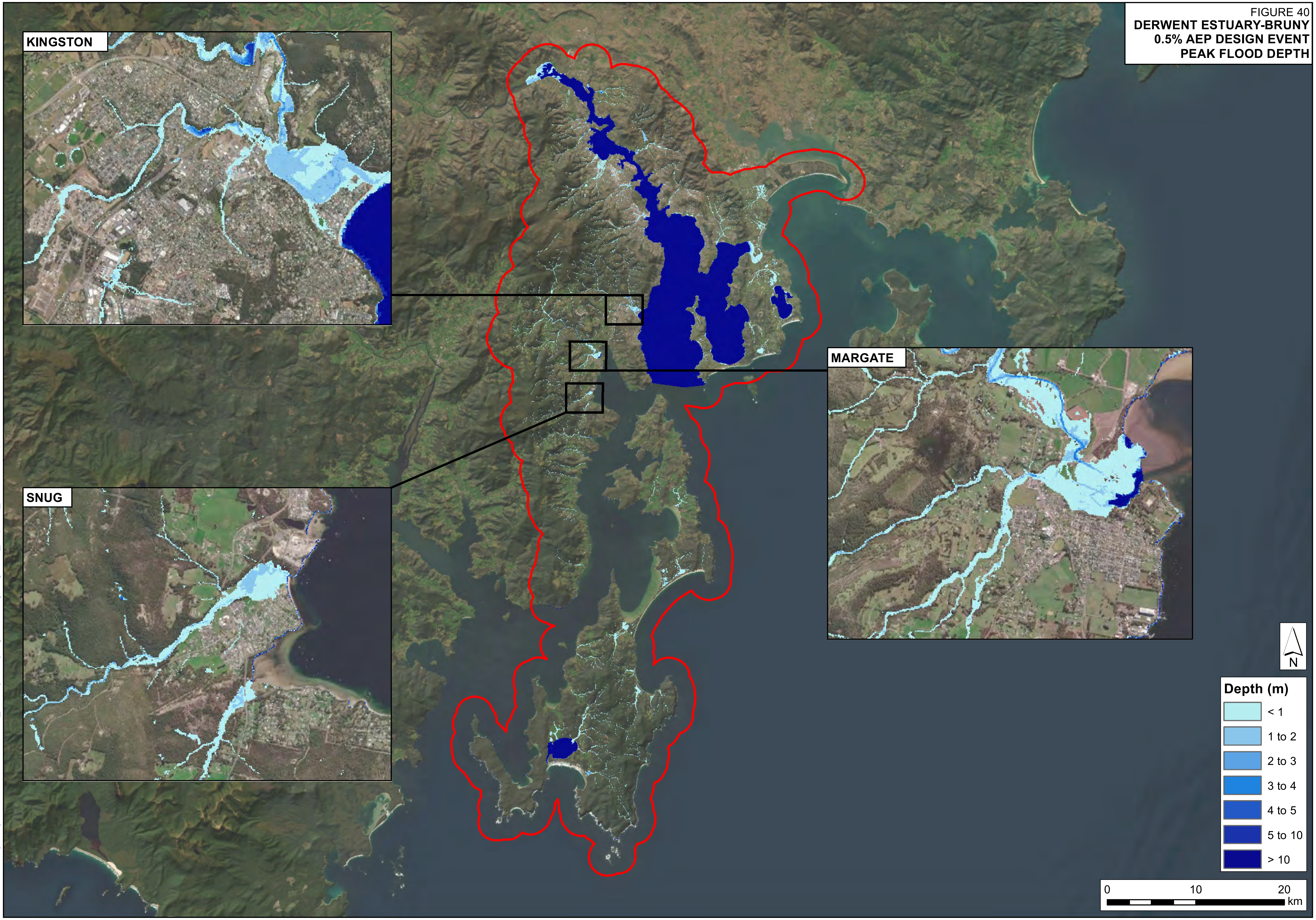


FIGURE 39
DERWENT ESTUARY-BRUNY
0.5% AEP DESIGN EVENT
PEAK FLOOD LEVEL
KINGSTON
MARGATE
SNUG
Elevation (mAHD)
High : 1236
Low : 0
N
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Estuary-Bruny\Figures\Design\Figure39_0.5pAEP_PeakFloodLevel.mxd

FIGURE 40
DERWENT ESTUARY-BRUNY
0.5% AEP DESIGN EVENT
PEAK FLOOD DEPTH



J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Estuary-Bruny\Figures\Design\Figure40_0.5pAEP_PeakFloodDepth.mxd

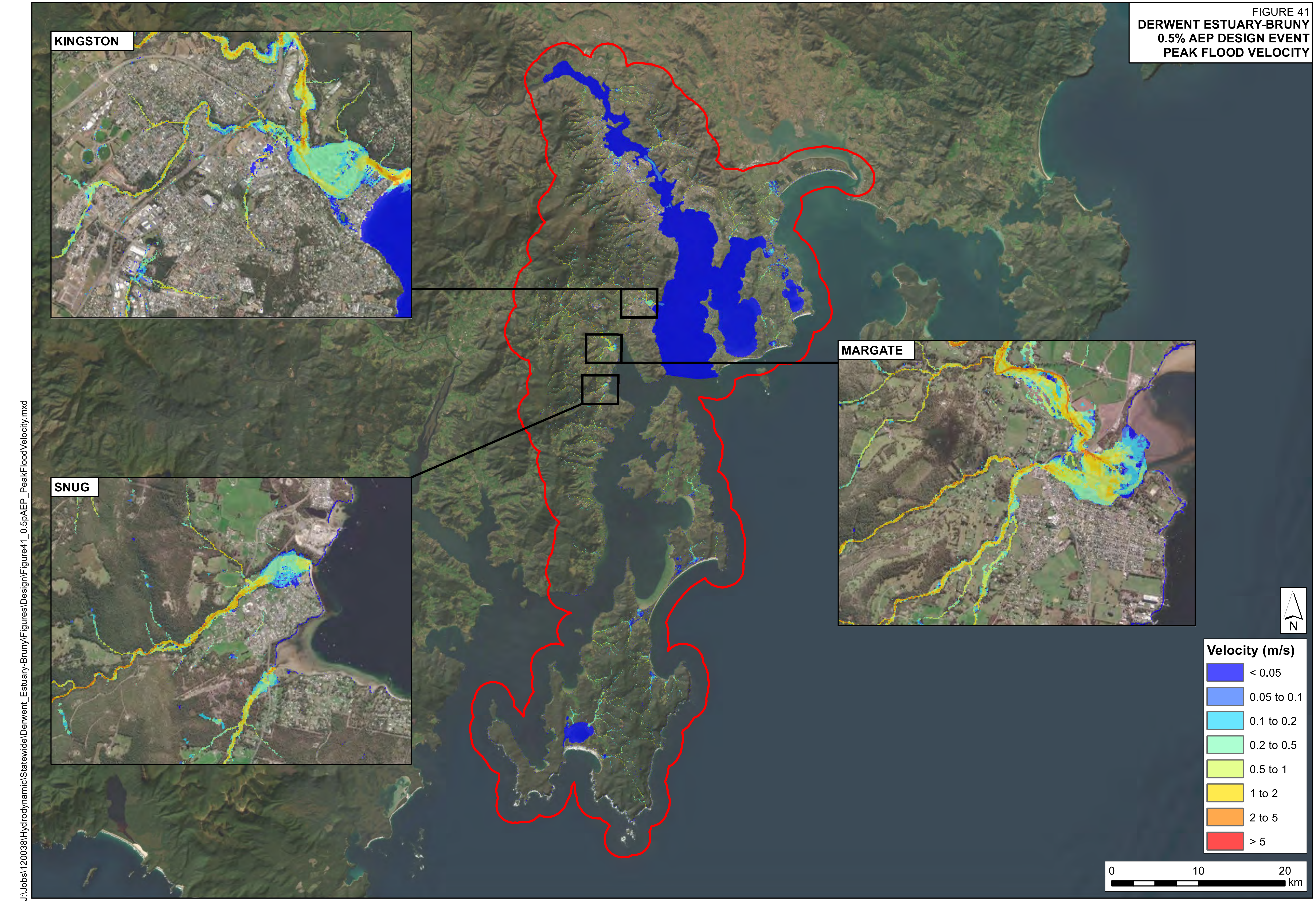
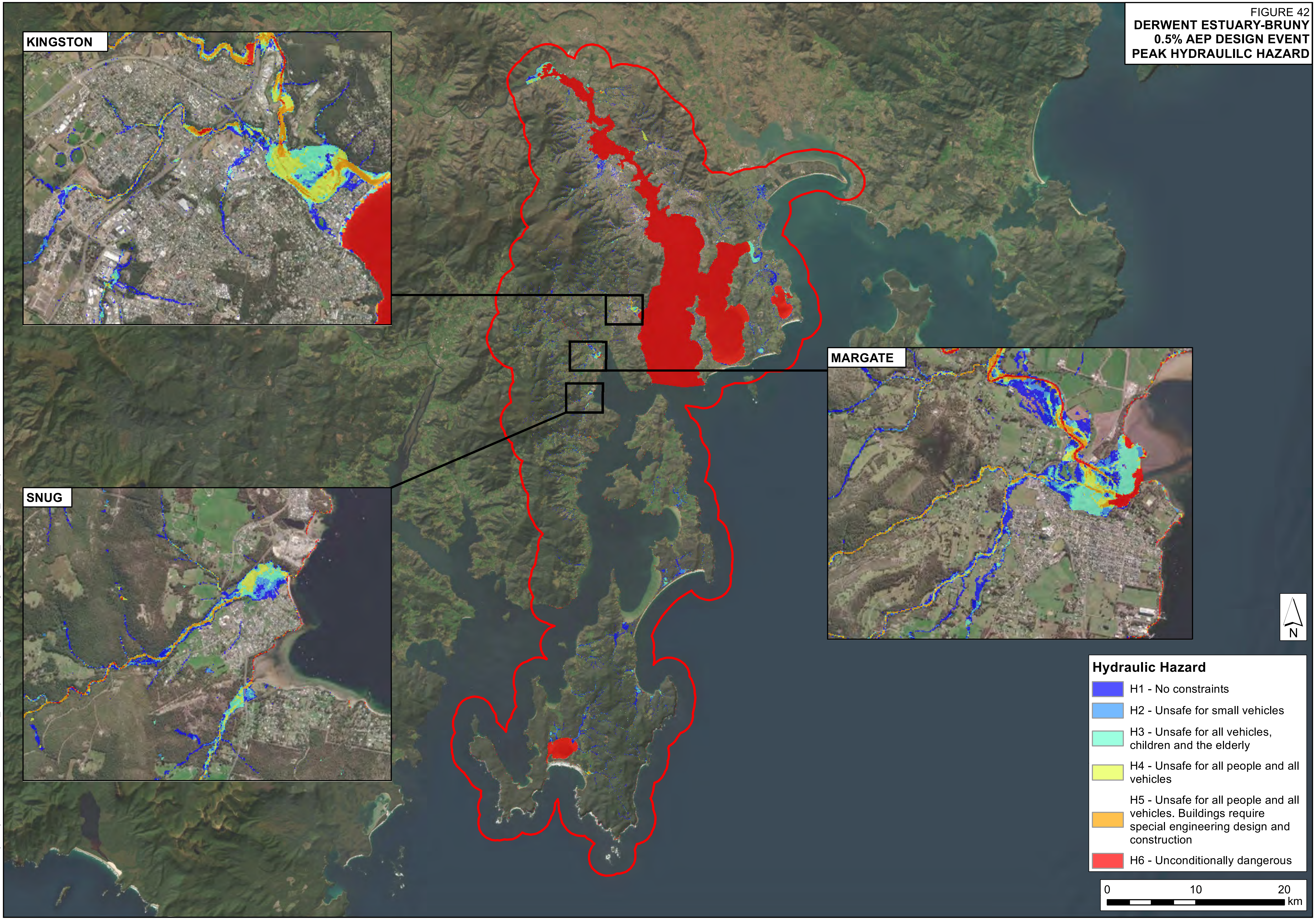


FIGURE 41
DERWENT ESTUARY-BRUNY
0.5% AEP DESIGN EVENT
PEAK FLOOD VELOCITY
KINGSTON
MARGATE
SNUG
N
Velocity (m/s)
< 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.5
0.5 to 1
1 to 2
2 to 5
> 5
0
10
20
km
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Estuary-Bruny\Figures\Design\Figure41_0.5pAEP_PeakFloodVelocity.mxd



J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Estuary-Bruny\Figures\Design\Figure42_0.5pAEP_PeakHydraulicHazard.mxd

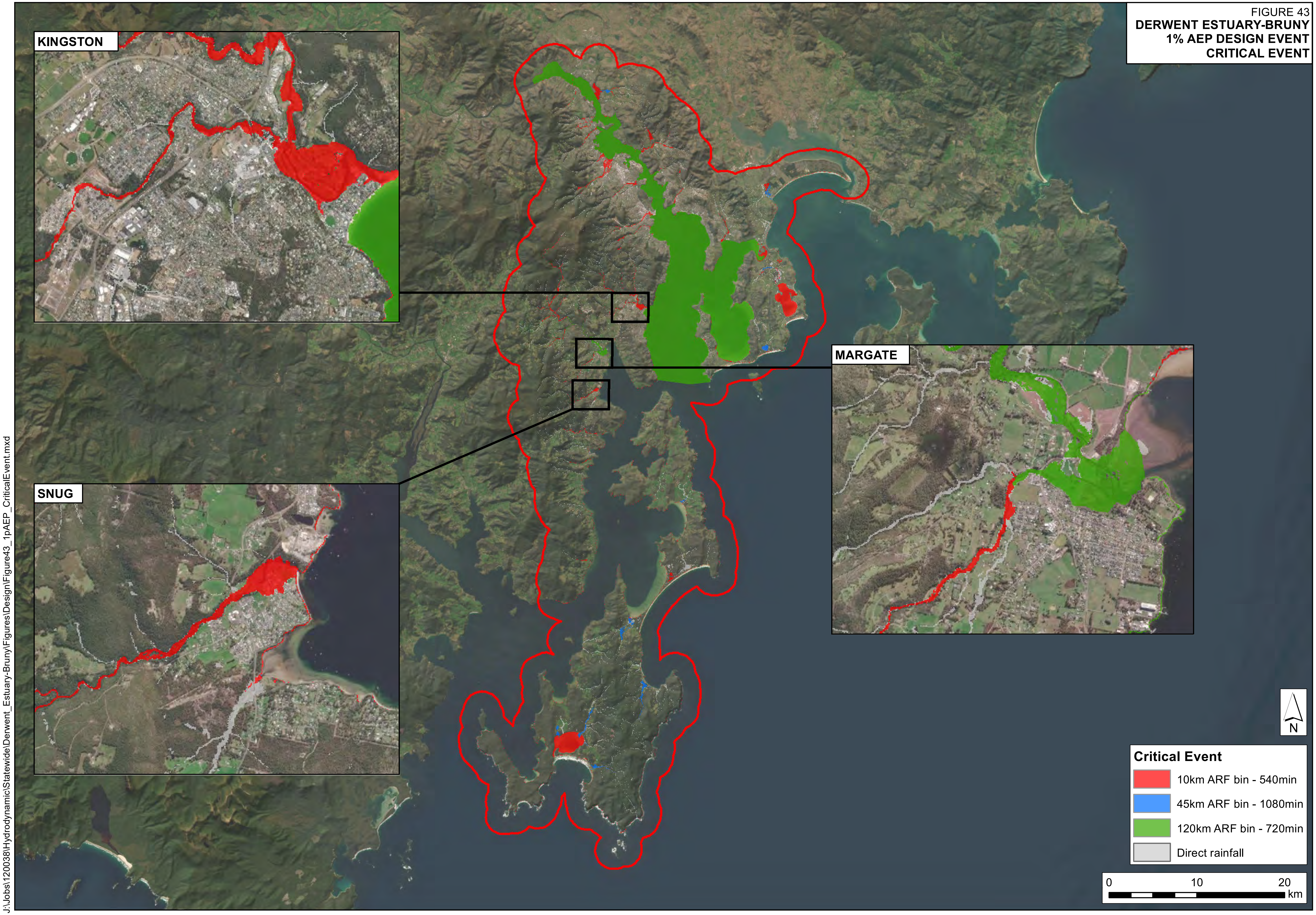


FIGURE 43
DERWENT ESTUARY-BRUNY
1% AEP DESIGN EVENT
CRITICAL EVENT
KINGSTON
MARGATE
SNUG
Critical Event
10km ARF bin - 540min
45km ARF bin - 1080min
120km ARF bin - 720min
Direct rainfall
0
10
20
km
N
J:\Jobs\120038\Hydrodynamic\Statewide\Derwent_Estuary-Bruny\Figures\Design\Figure43_1pAEP_CriticalEvent.mxd

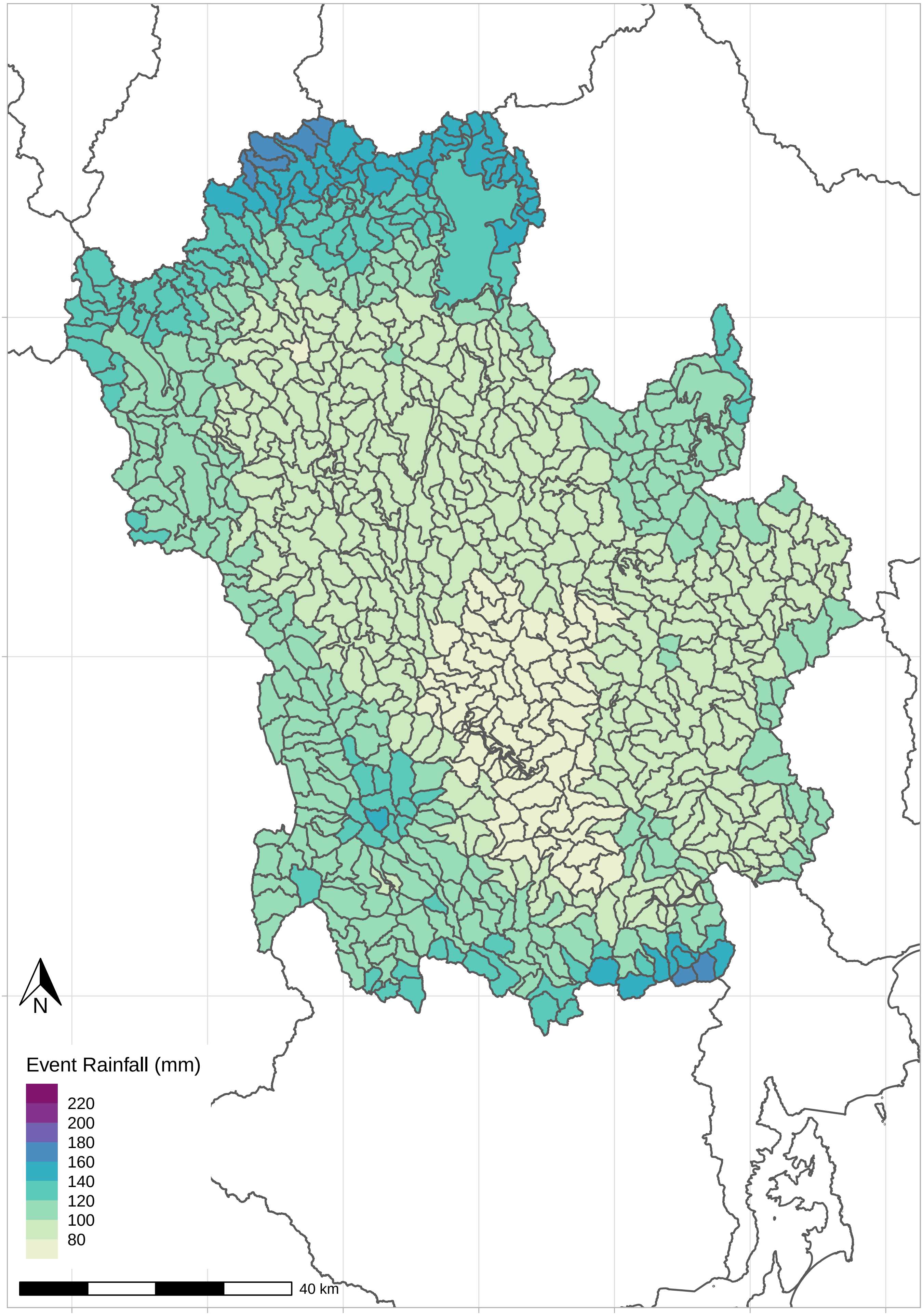
Appendix A

APPENDIX A. DESIGN EVENT DATA

FIGURE A1

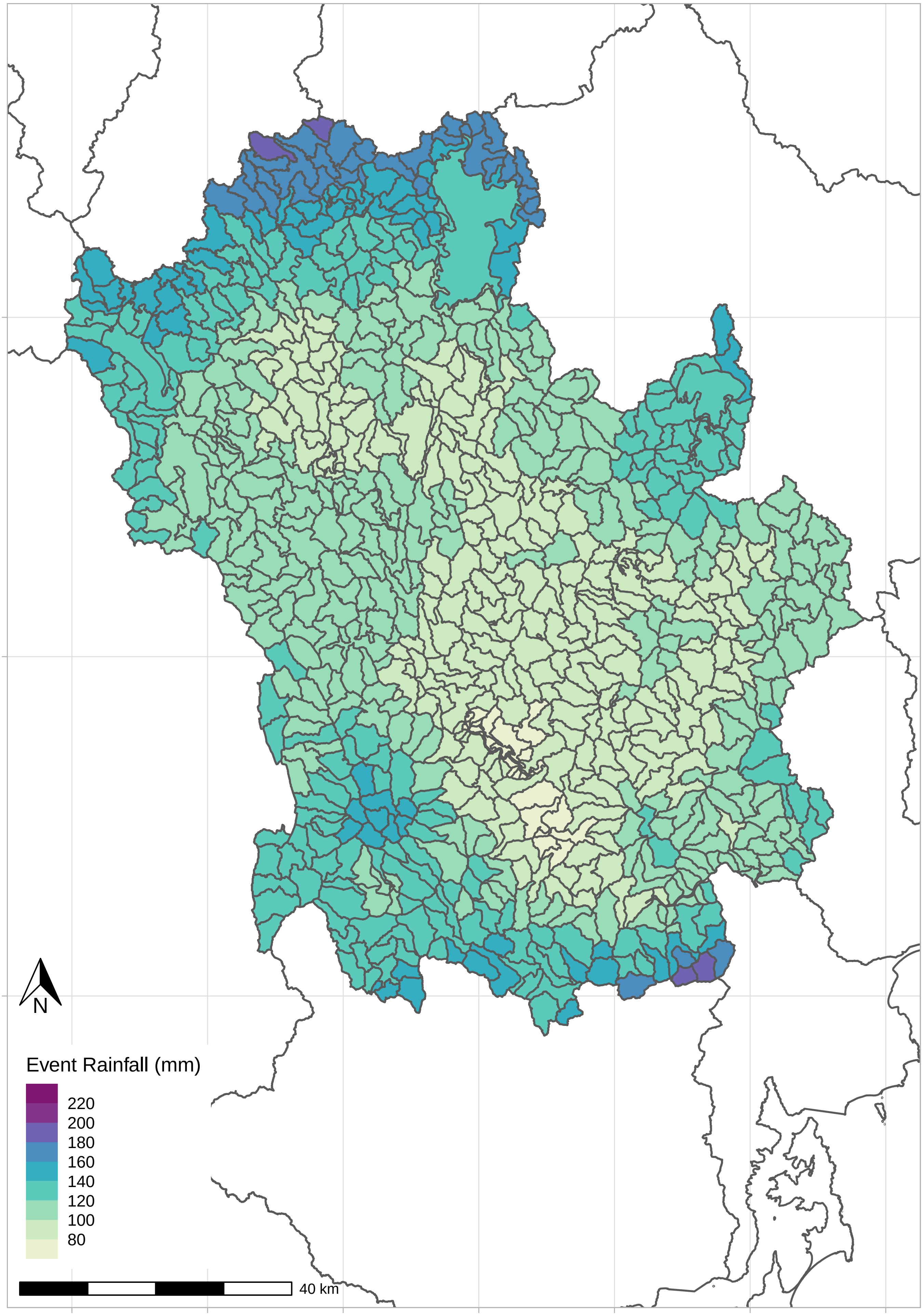
DESIGN RAINFALL DEPTHS

1440MIN 2%AEP



created by J:/Jobs/120038/Hydrology/Statewide/Design_Events/Derwent_combined/7_Derwent_Design_Report_Plots.R
J:/Jobs/120038/Hydrology/Statewide/Design_Events/Derwent_combined/Derwent_combinedv3/Report_Figures/FigureA1_1440_2pAEP_same_scale.pdf

FIGURE A2
DESIGN RAINFALL DEPTHS
1440MIN 1%AEP

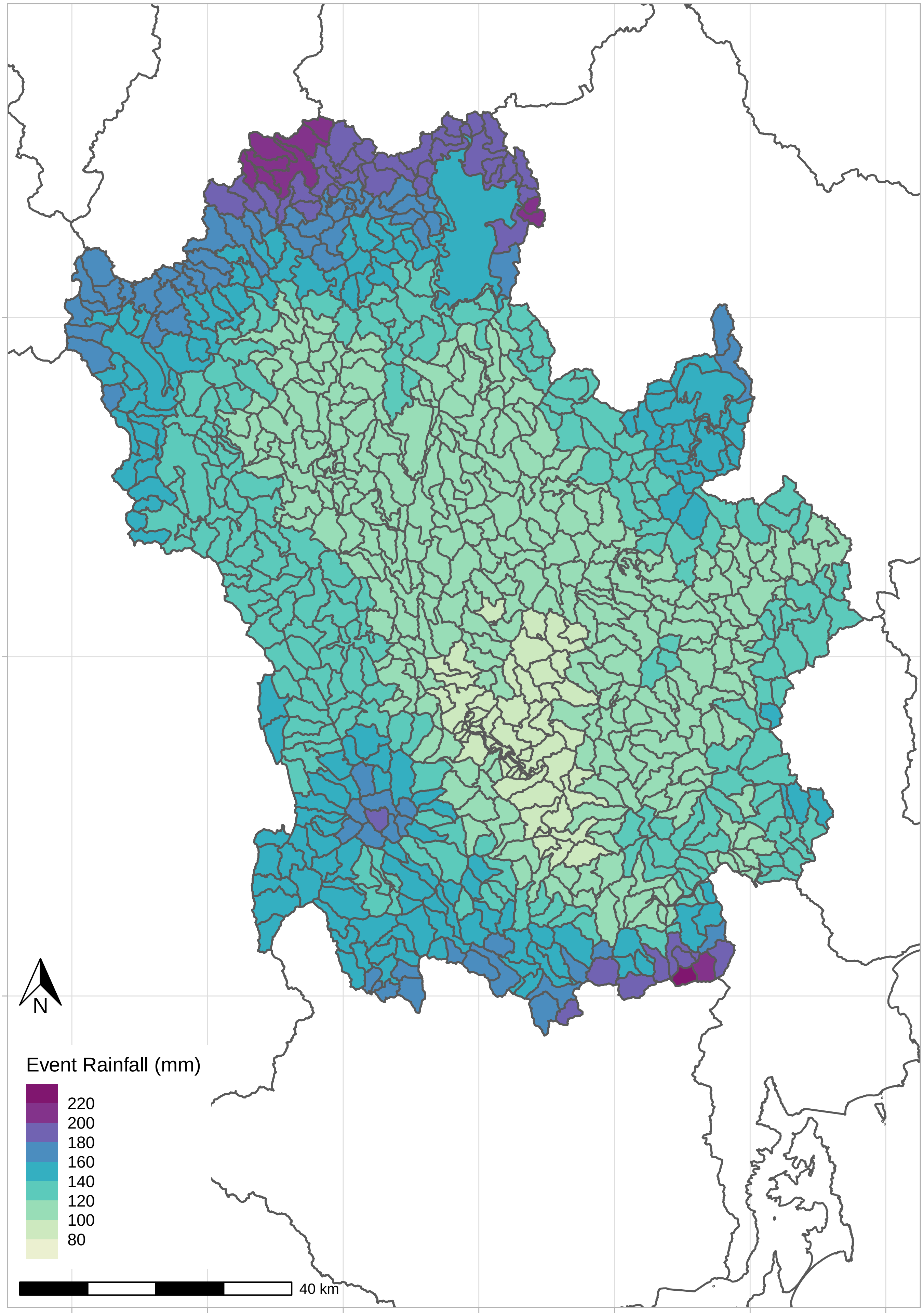


created by J:/Jobs/120038/Hydrology/Statewide/Design_Events/Derwent_combined/7_Derwent_Design_Report_Plots.R
J:/Jobs/120038/Hydrology/Statewide/Design_Events/Derwent_combined/Derwent_combinedv3/Report_Figures/FigureA2_1440_1pAEP_same_scale.pdf

FIGURE A3

DESIGN RAINFALL DEPTHS

1440MIN 0.5%AEP



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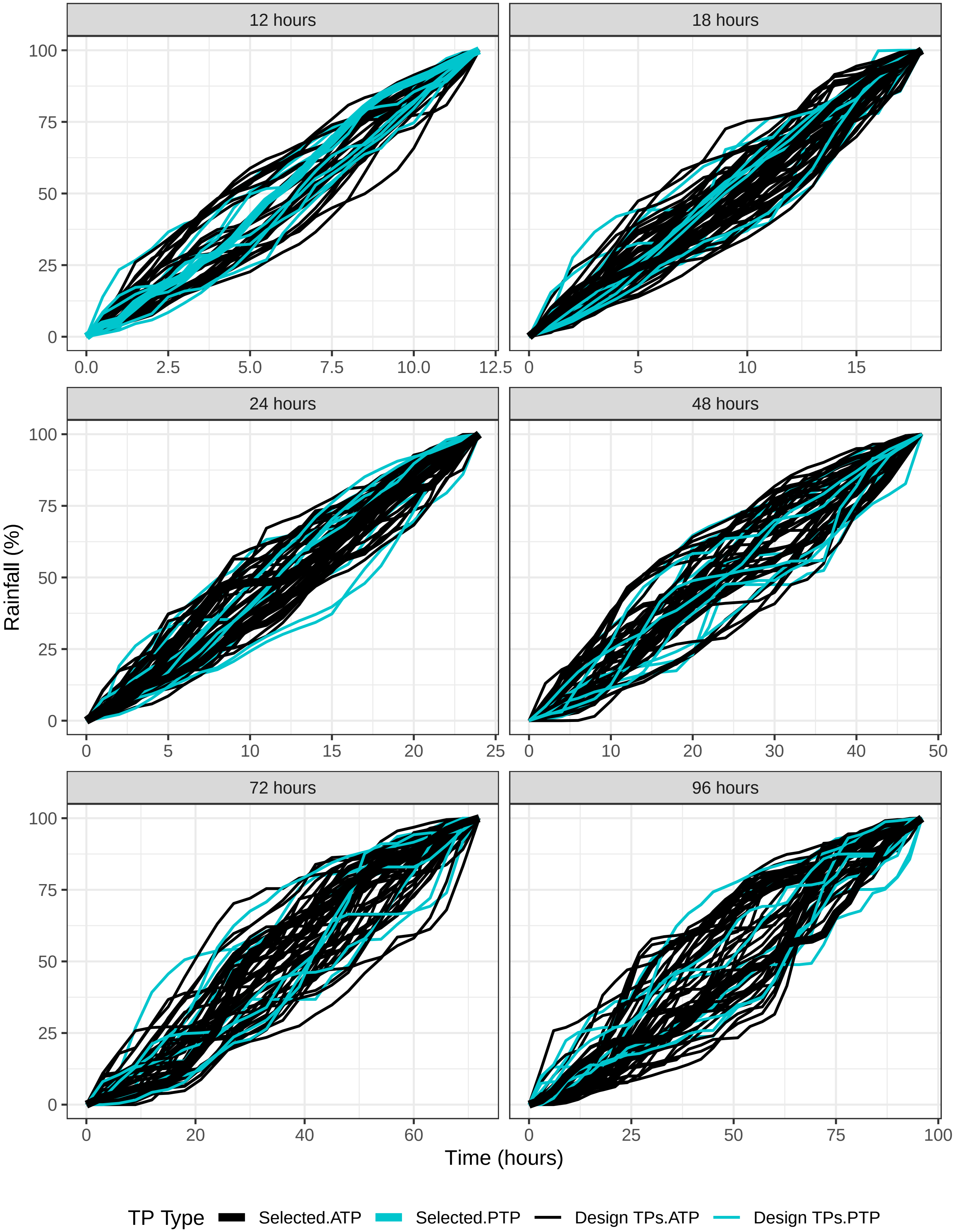
J:/Jobs/120038/Hydrology/Statewide/Design_Events/Derwent_combined/Derwent_combinedv3/Report_Figures/FigureA3_1440_1in200AEP_same_scale.pdf

FIGURE A4

DESIGN TEMPORAL PATTERNS

DURATIONS FROM 12 TO 96 HOURS

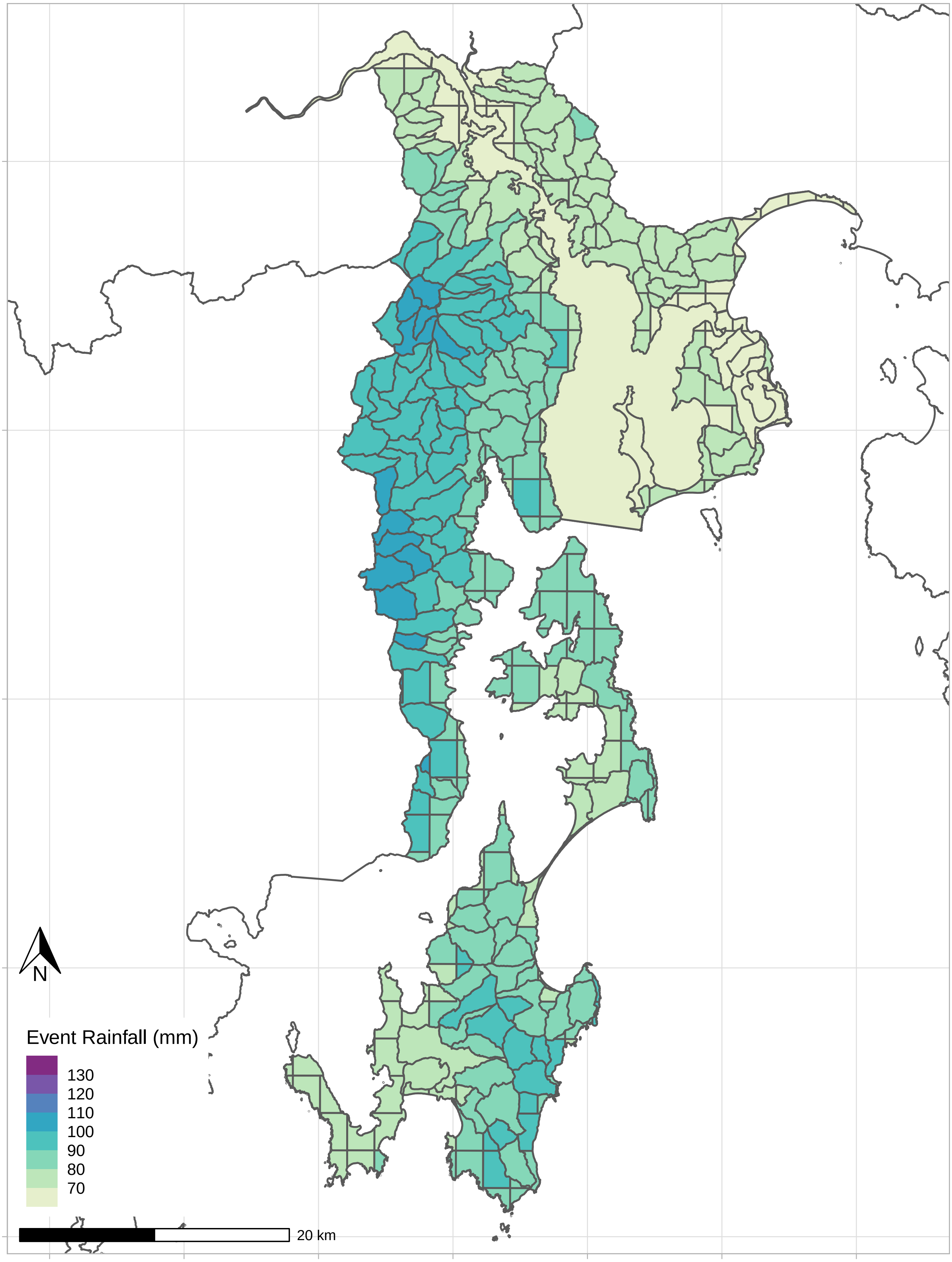


created by J:/Jobs/120038/Hydrology/Statewide/Design_Events/Derwent_combined/7_Derwent_Design_Report_Plots.R

FIGURE A5

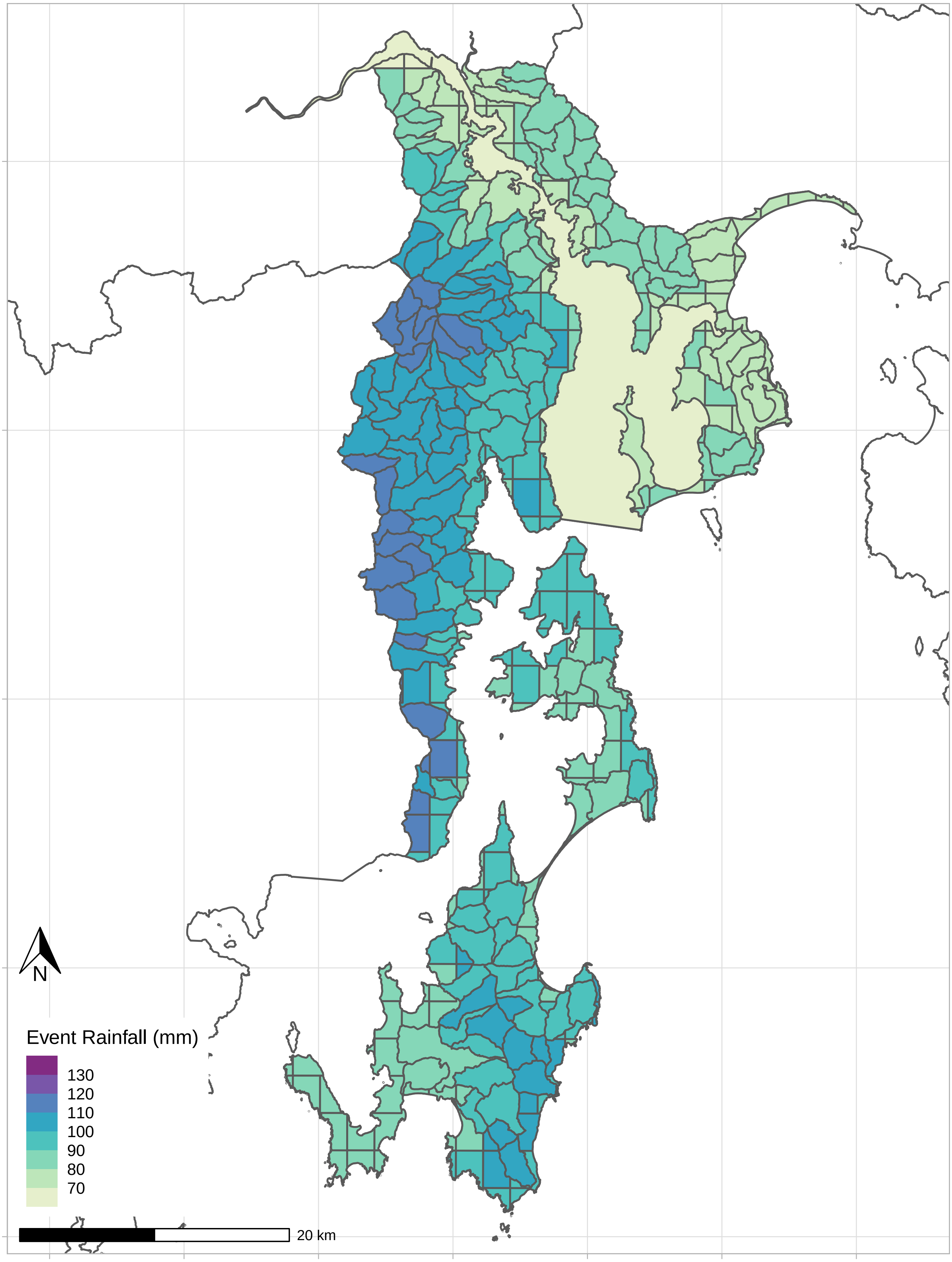
DESIGN RAINFALL DEPTHS

540MIN 2%AEP



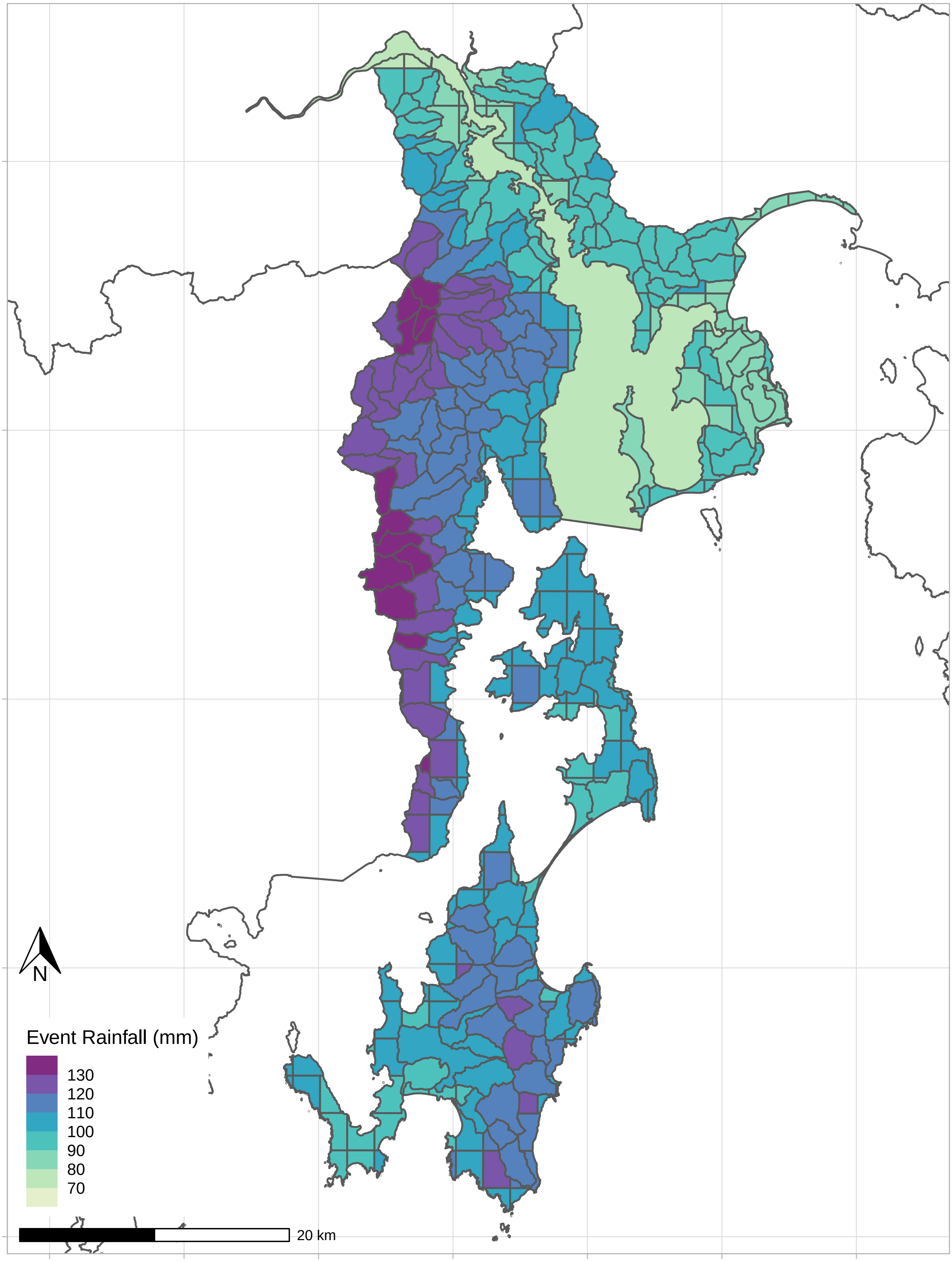
created by J:/Jobs/120038/Hydrology/Statewide/Design_Events/Derwent Estuary-Bruny/7_DEB_Design_Report_Plots.R
J:/Jobs/120038/Hydrology/Statewide/Design_Events/Derwent Estuary-Bruny/Derwent_Estuary_Brunyv2/Report_Figures/FigureA5_540_2pAEP_same_scalewCoast.pdf

FIGURE A6
DESIGN RAINFALL DEPTHS
540MIN 1%AEP



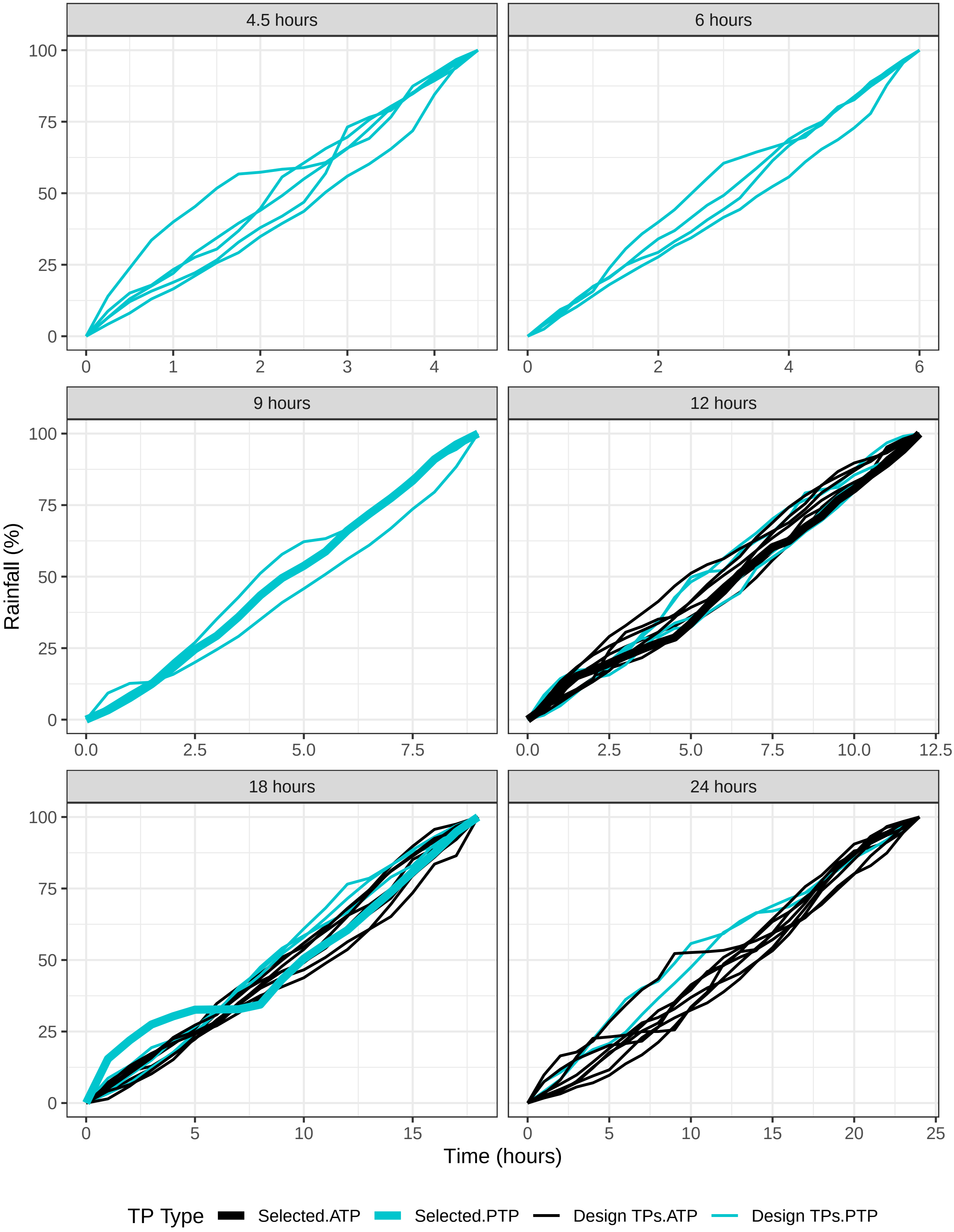
created by J:/Jobs/120038/Hydrology/Statewide/Design_Events/Derwent Estuary−Bruny/7_DEB_Design_Report_Plots.R
J:/Jobs/120038/Hydrology/Statewide/Design_Events/Derwent Estuary−Bruny/Derwent_Estuary_Brunyv2/Report_Figures/FigureA6_540_1pAEP_same_scalewCoast.pdf

FIGURE A7
DESIGN RAINFALL DEPTHS
540MIN 0.5%AEP



created by J:/Jobs/120038/Hydrology/Statewide/Design_Events/Derwent Estuary−Bruny/7_DEB_Design_Report_Plots.R
J:/Jobs/120038/Hydrology/Statewide/Design_Events/Derwent Estuary−Bruny/Derwent_Estuary_Brunyv2/Report_Figures/FigureA7_540_1in200AEP_same_scalewCoast.pdf

FIGURE A8
DESIGN TEMPORAL PATTERNS
DURATIONS FROM 4.5 TO 24 HOURS



created by J:/Jobs/120038/Hydrology/Statewide/Design_Events/Derwent Estuary−Bruny/7_DEB_Design_Report_Plots.R

Appendix B

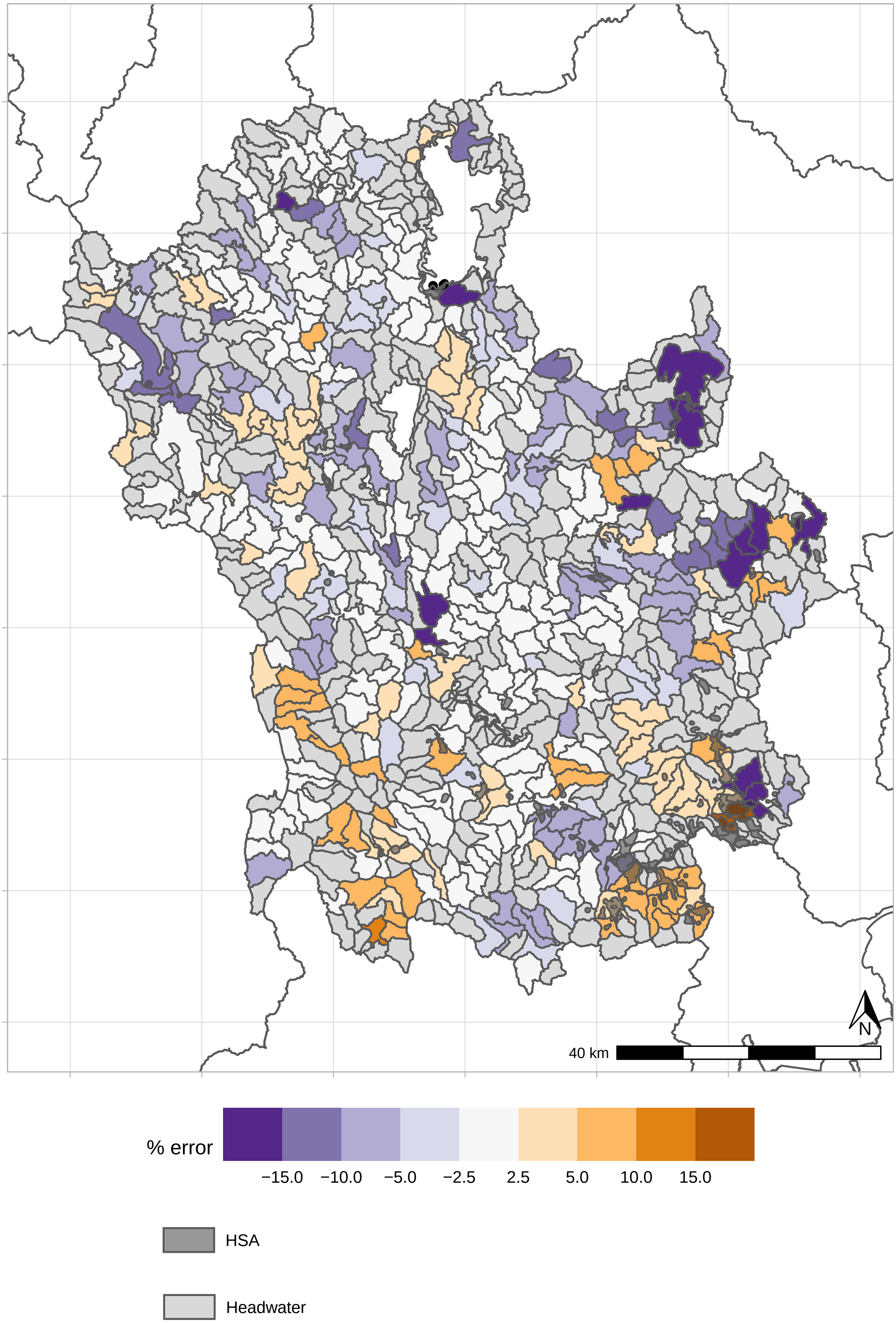
APPENDIX B. DESIGN PEAK ERRORS

Figure B1

Derwent_combined Catchment

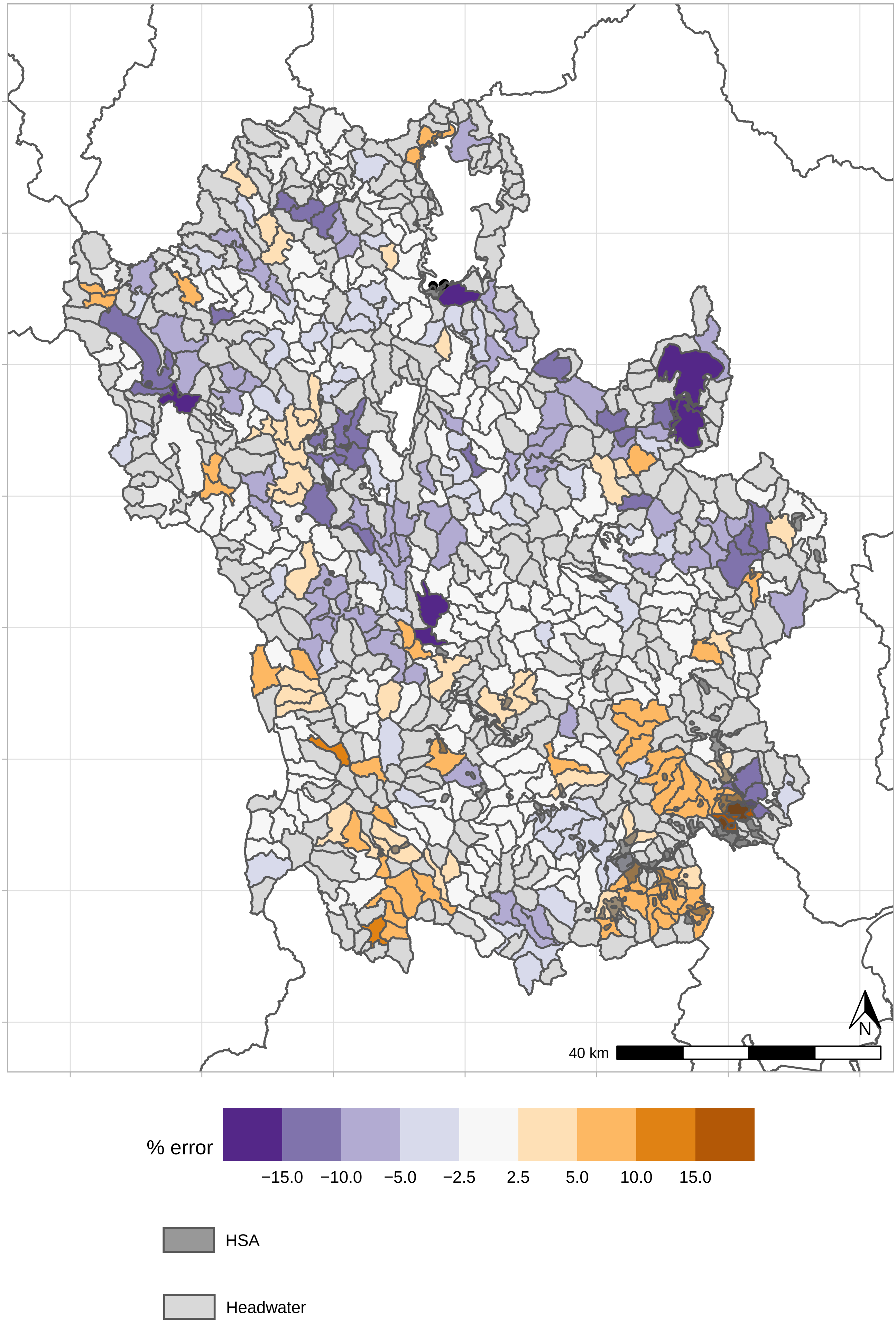
Percentage error in peak flows using selected runs

2%AEP



created by J:/Jobs/120038/Hydrology/Statewide/Design_Events/Derwent_combined/7_Derwent_Design_Report_Plots.R

Figure B2
Derwent_combined Catchment
Percentage error in peak flows using selected runs
1%AEP



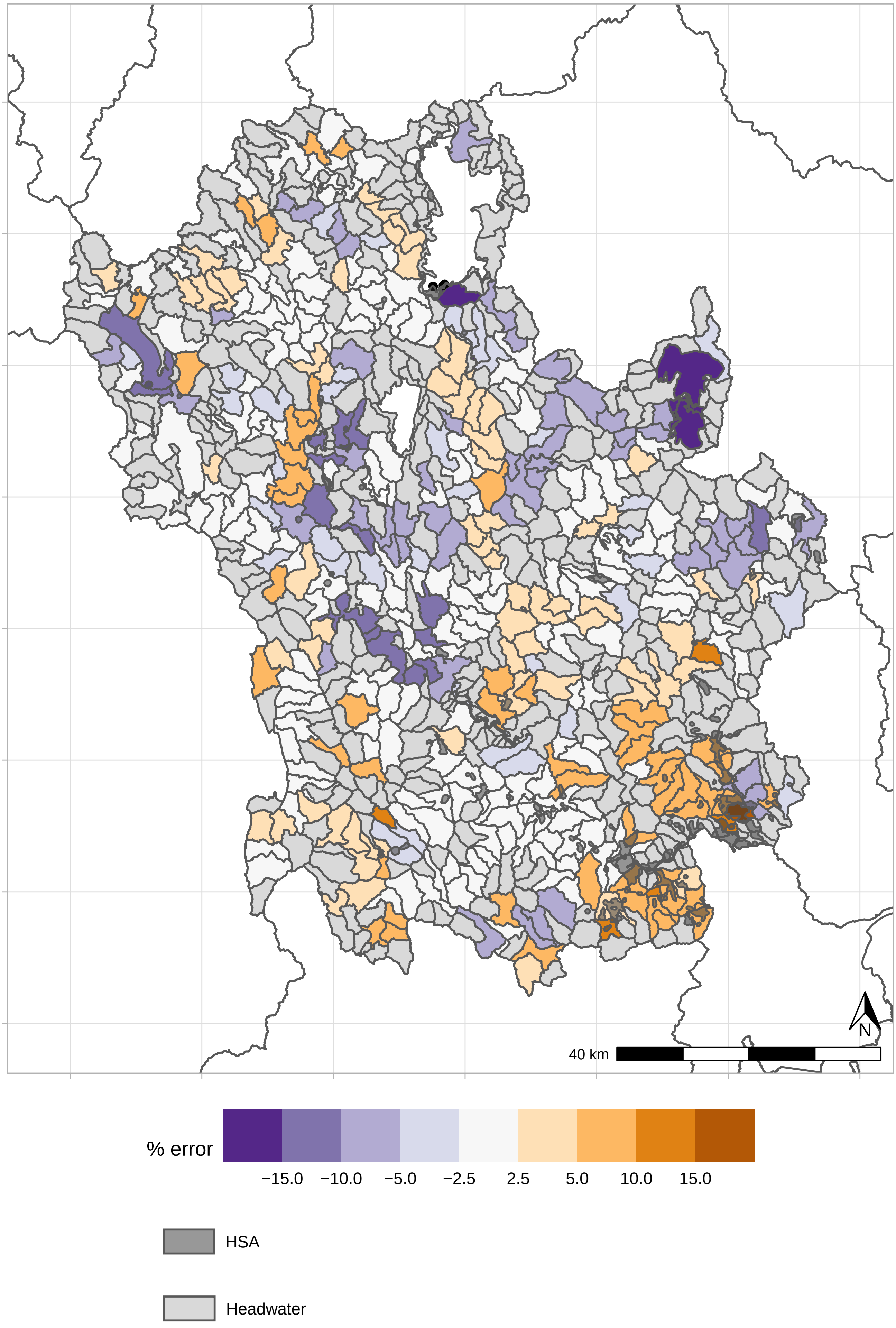
created by J:/Jobs/120038/Hydrology/Statewide/Design_Events/Derwent_combined/7_Derwent_Design_Report_Plots.R

Figure B3

Derwent_combined Catchment

Percentage error in peak flows using selected runs

0.5%AEP



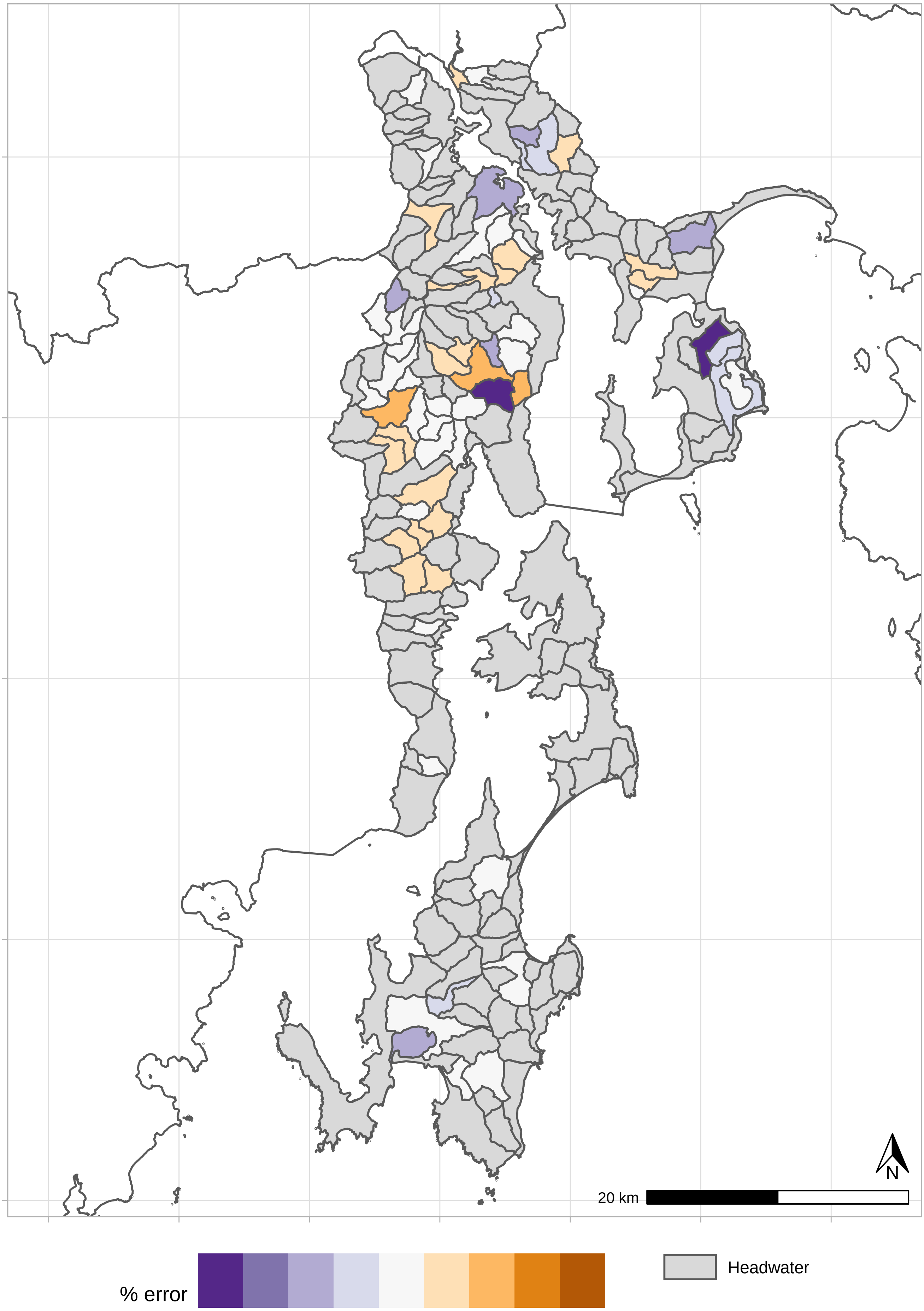
created by J:/Jobs/120038/Hydrology/Statewide/Design_Events/Derwent_combined/7_Derwent_Design_Report_Plots.R

Figure B4

Derwent Estuary−Bruny Catchment

Percentage error in peak flows using selected runs

2%AEP



created by J:/Jobs/120038/Hydrology/Statewide/Design_Events/Derwent Estuary−Bruny/7_DEB_Design_Report_Plots.R

Figure B5

Derwent Estuary−Bruny Catchment

Percentage error in peak flows using selected runs

1%AEP

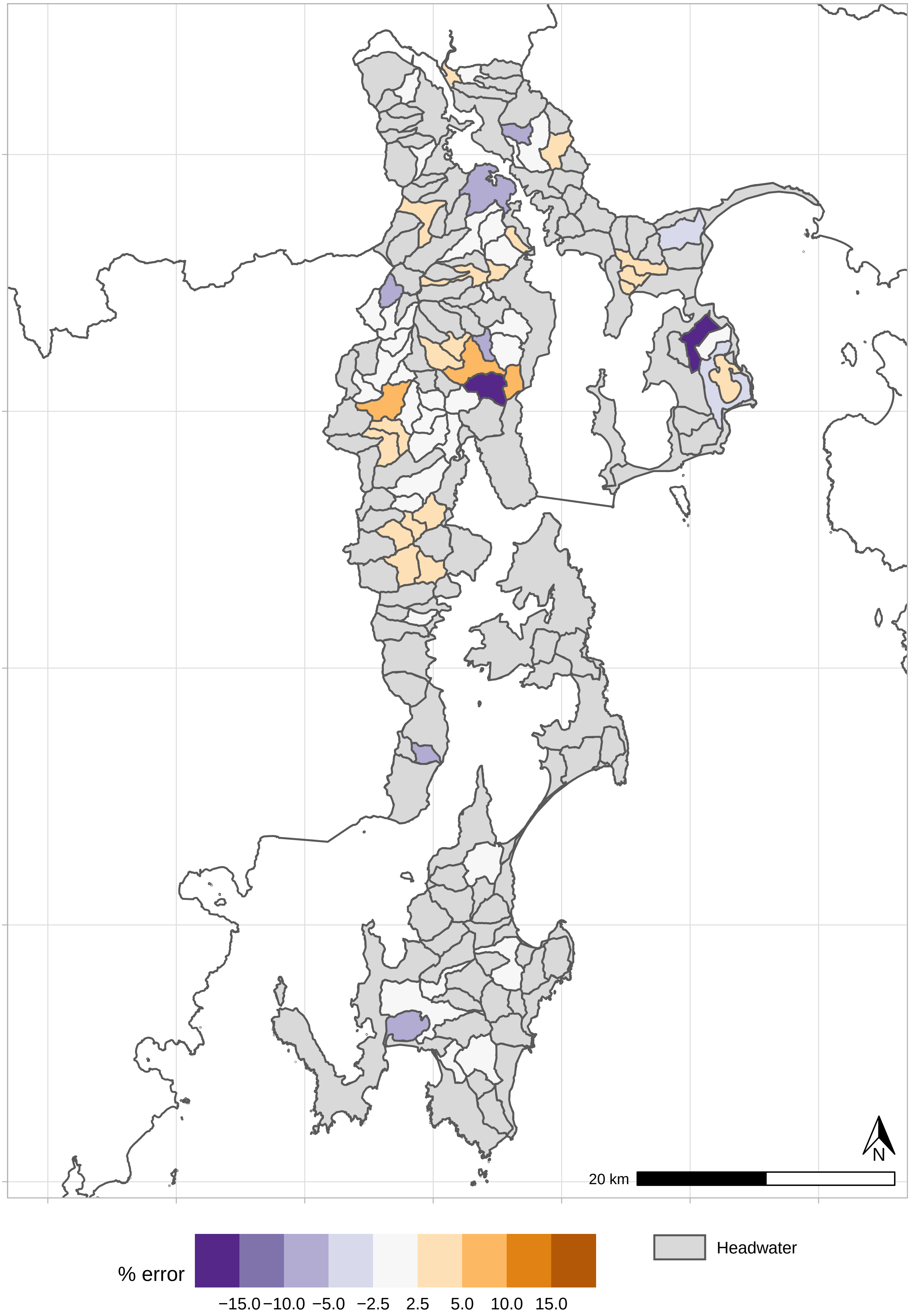


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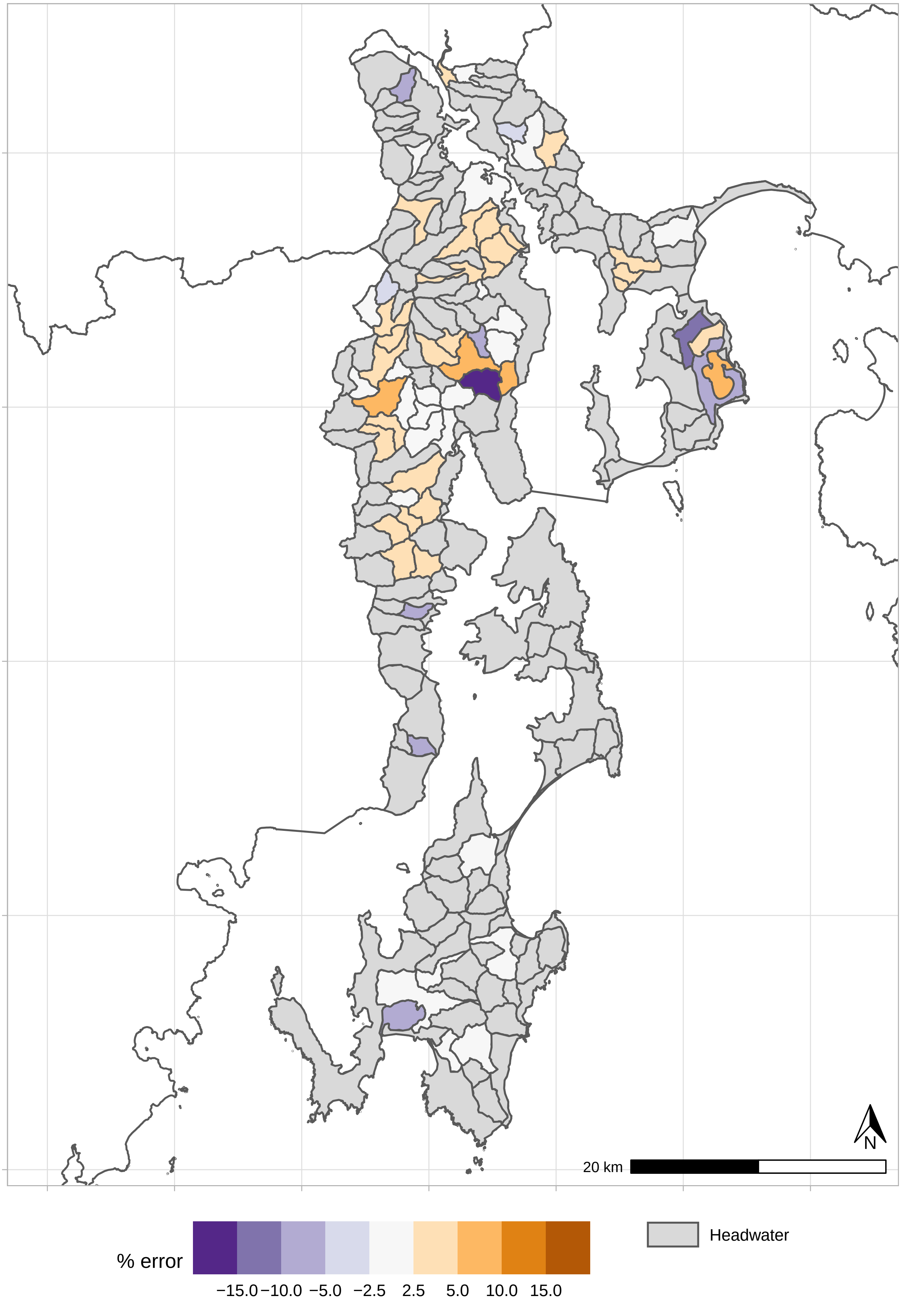
Figure B6

Derwent Estuary−Bruny Catchment

Percentage error in peak flows using selected runs

0.5%AEP



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