STATE EMERGENCY SERVICE

TASMANIAN STRATEGIC FLOOD MAP

KING-HENTY STUDY AREA DESIGN FLOOD MODELLING

ADDENDUM TO CALIBRATION REPORT

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DECEMBER 2022

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Project Tasmanian Strategic Flood Map King-Henty Study Area Design Flood Modelling	**Project Number** **120038**
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Project Manager Fiona Ling	

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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
DPIPWE	Department of Primary Industries, Water and Environment
DNRE	Department of Natural Resources and Environment Tasmania (formerly DPIPWE)
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 King-Henty Study Area Calibration Report (WMAwater, 2022). The study area, available data, model calibration, limitations and uncertainty statements are provided in the calibration report.

Due to the quality of the DTM available across this study area, it was determined at the calibration stage that acceptable flood mapping could not be produced using the regional flood methodology agreed for this project. Therefore, this report outlines the data, methodology and the results of running the external hydrological modelling for the design flood events for the King-Henty Study Area. If a better quality DTM becomes available, the inputs described in this report can be used for future hydrodynamic modelling. No hydrodynamic design models have been run for this study area.

2. DATA

2.1. Previous Flood Studies

There were no previous flood studies provided to WMAwater as part of the project data library.

2.2. Flow Data

Flood Frequency Analysis (FFA) was performed on annual maximum series (AMS) from flow gauges within the catchment. The gauges used for FFA are shown in Table 1. Due to the level of remoteness and high degree of regulation of the study area there are limited natural flow gauges available to conduct FFA. Prior to the construction of Mackintosh and Murchison Dams, there were flow gauges in the area now covered by Mackintosh reservoir. Therefore, FFA has been undertaken at these gauges using a model without these dams present. Flow is also available at the Whyte River. More detail on the quality of the gauge data is provided in the calibration report (WMAwater, 2022).

Table 1: Flow gauges used for FFA

Gauge number	Gauge name	River	Period of record	Number of points in AMS
148.1	Murchison River above Sterling	Murchison	1955-1982	27
149.1	Mackintosh River below Sophia River	Mackintosh	1954-1980	25
350.1	Whyte River above Rocky River	Whyte	1961-1990	26

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.

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. 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

As the FFA was conducted at different gauges to the calibration, the baseflows for the largest events on record were estimated, showing most events had baseflows of 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. Baseflows are therefore assumed to be a small component of the hydrograph for the AEPs of interest (2%, 1% and 0.5%) and so baseflow was not included in the design events.

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.

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.

Due to the poor quality DTM available across this study area it was determined at the calibration modelling stage, that acceptable flood mapping could not be produced for this area using the regional flood methodology agreed for this project. Therefore, this report outlines the data, methodology and the results of running the external hydrological modelling for the design flood events for the king-Henty Study Area. If a better quality DTM becomes available all the inputs can be used for further modelling. No hydrodynamic design models have been run for this study area.

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
    - Not undertaken
- Mapping
    - Not undertaken

4. CALIBRATION OF DESIGN LOSSES

FFA was undertaken at the gauges identified in Table 1. The results of the FFA are shown in Figure 1, Figure 2 and Figure 3. The fitting method and distribution that provided the best fit to the data at each site is shown in Table 2. As the Murchison and Mackintosh River gauges are now in locations inundated Lake Mackintosh, the FFA calibration at these gauges was conducted using a model with Mackintosh or Murchison Dams removed. These gauges were removed prior to construction of the dams, so this is consistent with the catchment at the time.

Table 2: Fitting method and distribution used for FFA

Gauge number	Gauge name	Fitting method	Distribution
148-1	Murchison River above Sterling	Bayesian	Log Pearson III
149-1	Mackintosh River below Sophia	Bayesian	Log Pearson III
350-1	Whyte River above Rocky River	Bayesian	Log Pearson III

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. 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. The catchment-average continuing loss was distributed across the study area using the hydrological soil group final infiltration rates.

A consistent set of losses was chosen over the study area that gave the best overall fit at the three sites. As different gauges had differing losses a combined set of losses was created which resulted in the modelled design event results being overestimated at some sites and underestimated at others.

The percentage differences between the FFA and the modelled peak flow for the 2% and 1% AEP events are shown in Table 3. The modelled data provided a variable fit to the FFA 1% and 2% AEP peak flows, as the gauges have different periods of record, and no information is available about the quality of the ratings the variability in fit was considered acceptable.

Table 3: FFA and modelled peak flows

Gauge name	AEP	AEP peak flow (m3/s)	Modelled AEP peak flow (m3/s)	FFA AEP peak flow (m3/s)
Murchison River Above Sterling	0.5%	1364	1651	21%
	1%	1284	1414	10%
	2%	1202	1279	6%
Mackintosh River Below Sophia River	0.5%	1124	1081	-4%
	1%	1000	883	-12%
	2%	881	772	-12%
Whyte River Ab Rocky River	0.5%	405	488	21%
	1%	378	397	5%
	2%	351	337	-4%

The adopted loss values are shown in Table 4, and comparisons to site FFAs are shown in Figure 1.

Table 4: Adopted losses

Initial Loss (mm)		Continuing Loss (mm/h)		
	Soil Type A	Soil Type B	Soil Type C	Soil Type D
22	2.5	1.3	0.6	0.3

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. Unlike in the FFA calibration, this model included all the dams in the catchment, starting at Full Supply Level (FSL). The selected storms and the number of sub-catchments best represented by each are shown in Table 5. The temporal patterns for each selected run are shown in Figure 4.

Storms with smaller ARF bins are not valid for the main river with large accumulated upstream areas, as rainfalls have not been adjusted down by an appropriate ARF. Therefore, pattern selection was forced to the most relevant pattern along the Pieman downstream of Reece Dam, and the King downstream of Lake Burbury. As Lake Burbury causes extreme attenuation in flows (with spill peaks approximately 10% of inflow peaks), the sub-catchments downstream were given a weighting while calculating their ARF bin, with only 10% of the area upstream of Lake Burbury assigned (and all the subsequent area downstream).

Table 5: Selected storms for each AEP with the number of sub-catchments best represented by each set

AEP	Storm duration (min)	ARF bin	# sub-catchments
2%	540	45	102
2%	720	250	119
2%	2160	800	21
2%	5760	3600	9
1%	540	45	100
1%	720	250	116
1%	2160	800	26
1%	5760	3600	9
0.5%	540	45	111
0.5%	720	250	122
0.5%	2160	800	9
0.5%	5760	3600	9

Diagram 1 shows which ARF-duration-TP set gives representative flows for each sub-catchment.

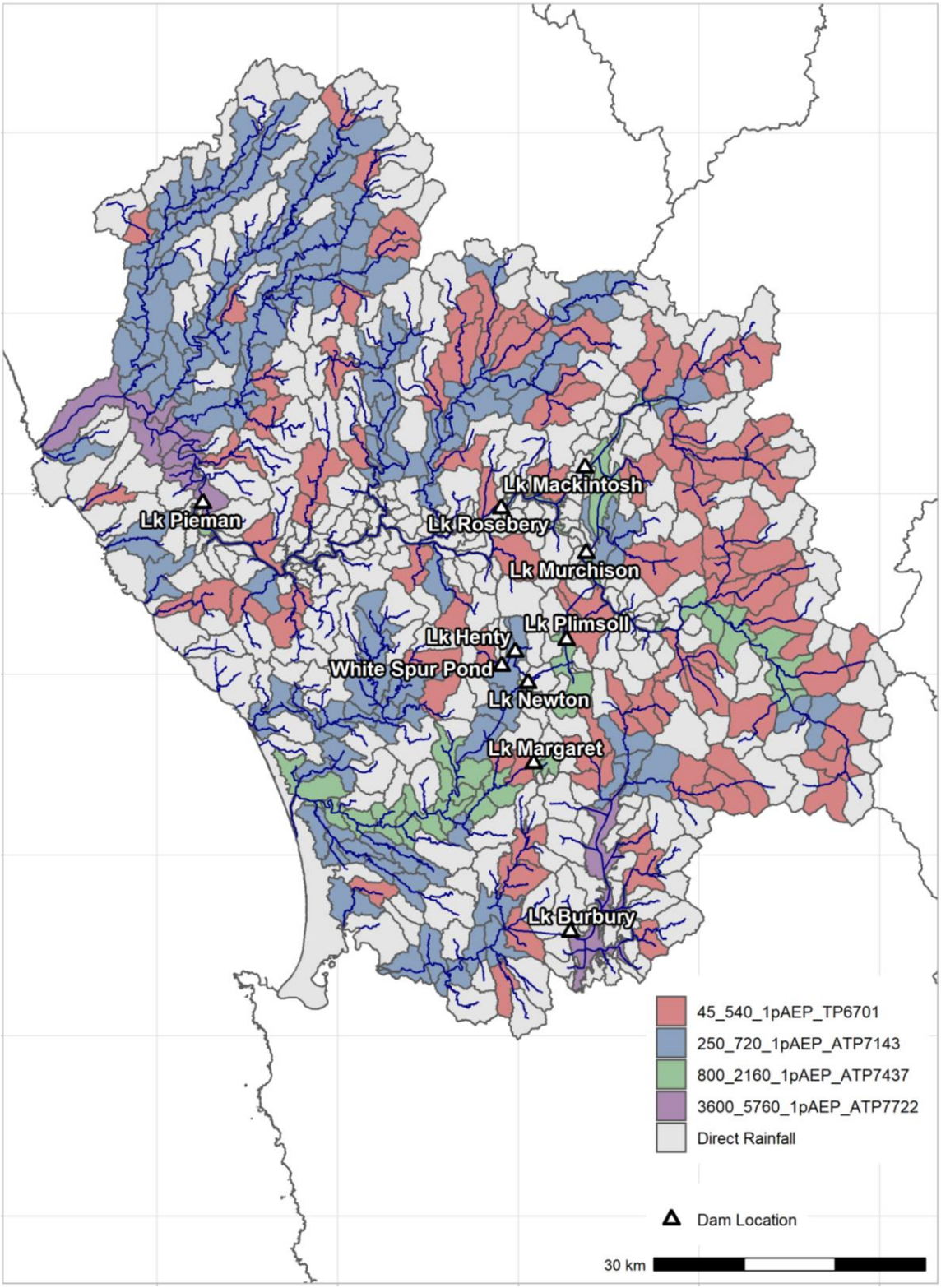

Diagram 1: ARF set relevant for each sub-catchment for the 1% AEP event

The selection of four ARF-duration-TP sets per AEP does introduce errors when compared to running the ideal ARF-duration-TP sets for each sub-catchment, however running thousands of runs of the hydrodynamic model is not computationally feasible, even once a better DTM is available. The percentage errors for each sub-catchment are shown in Figure B 1 to Figure B 3 and a summary of the magnitude of the errors is shown in Table 6. 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 6: Sub-catchment errors using the ARF-TP-duration sets shown in Table 5 for each AEP

AEP	Absolute sub-catchment error		
	Mean across sub-catchments	90th %ile across sub-catchments	Max of all sub-catchments
2%	4.0 %	9%	18%
1%	4.0 %	8%	17%
0.5%	4.2%	9%	21%

5.2. Design Event Results

As discussed in the calibration report (WMAwater, 2022) and the methodology (Section 3), the quality of the DEM results in unrealistic ponding and incorrect flow paths throughout the catchment. Therefore, flood maps have not been produced for this study area.

6. LIMITATIONS

A detailed uncertainty assessment of the data, hydrological calibration and hydrodynamic model is contained in the King-Henty Calibration Report (WMAwater, 2022)

Due to the quality of the DTM, design flood mapping has not been able to be undertaken across this study area.

7. REFERENCES

Babister, M., Trim, A., Testoni, I. & Retallick, M (2016): The Australian Rainfall & Runoff Datahub 37th Hydrology and Water Resources Symposium Queenstown NZ, 2016 available at http://data.arr-software.org/

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WMAwater (2021a): Tasmanian Strategic Flood Map Hydrology Methods Report, August 2021. Report for State Emergency Service, Tasmania.

WMAwater (2021b): Tasmanian Strategic Flood Map Hydrodynamic Methods Report, August 2021. Report for State Emergency Service, Tasmania.

WMAwater (2022): Tasmanian Strategic Flood Map King-Henty Catchment Model Calibration Report, December 2021. Report for State Emergency Service, Tasmania.

Figures

FIGURE 1

Murchison River Above Sterling − Pre Dam

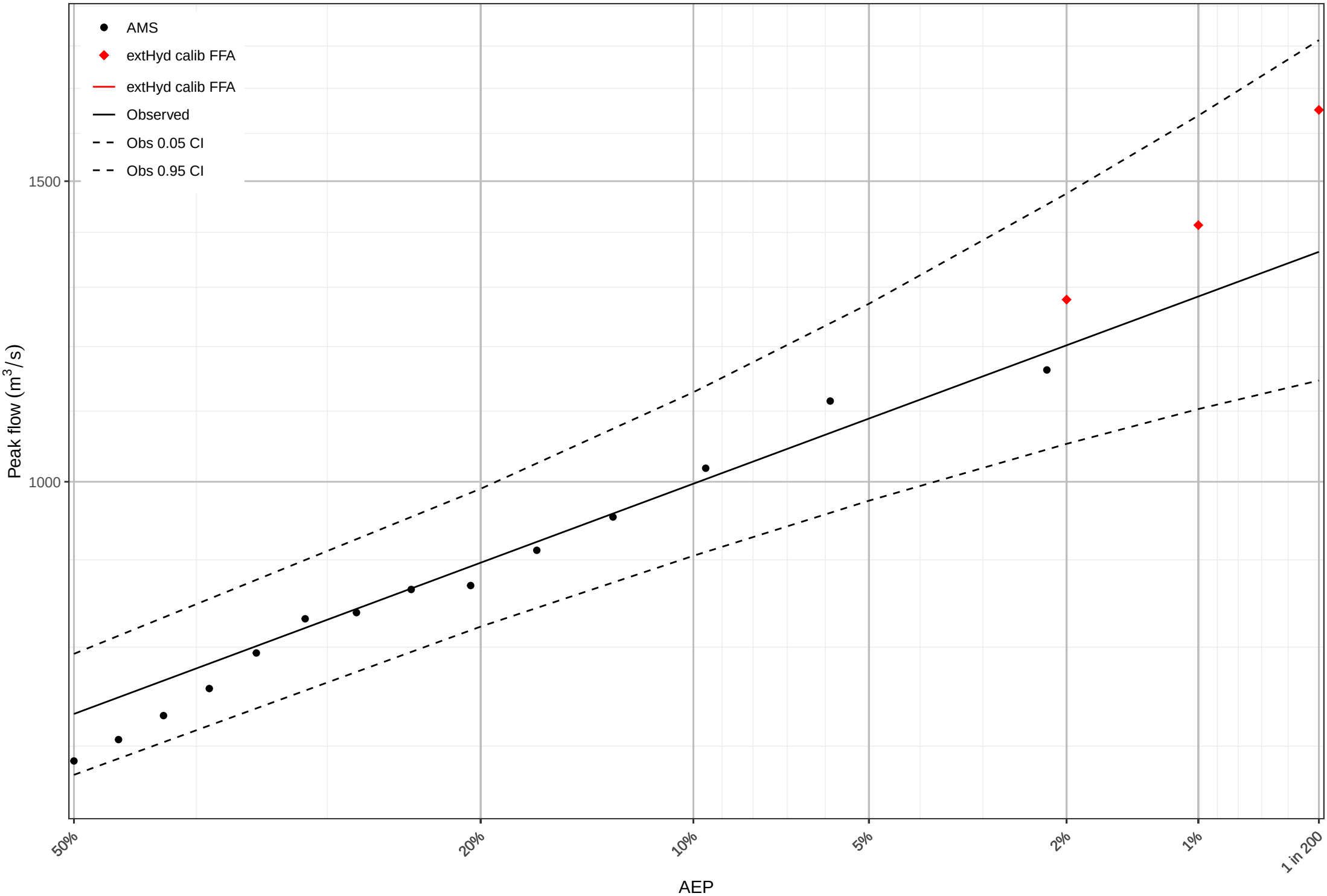

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FIGURE 2

Mackintosh River Below Sophia River − Pre Dam

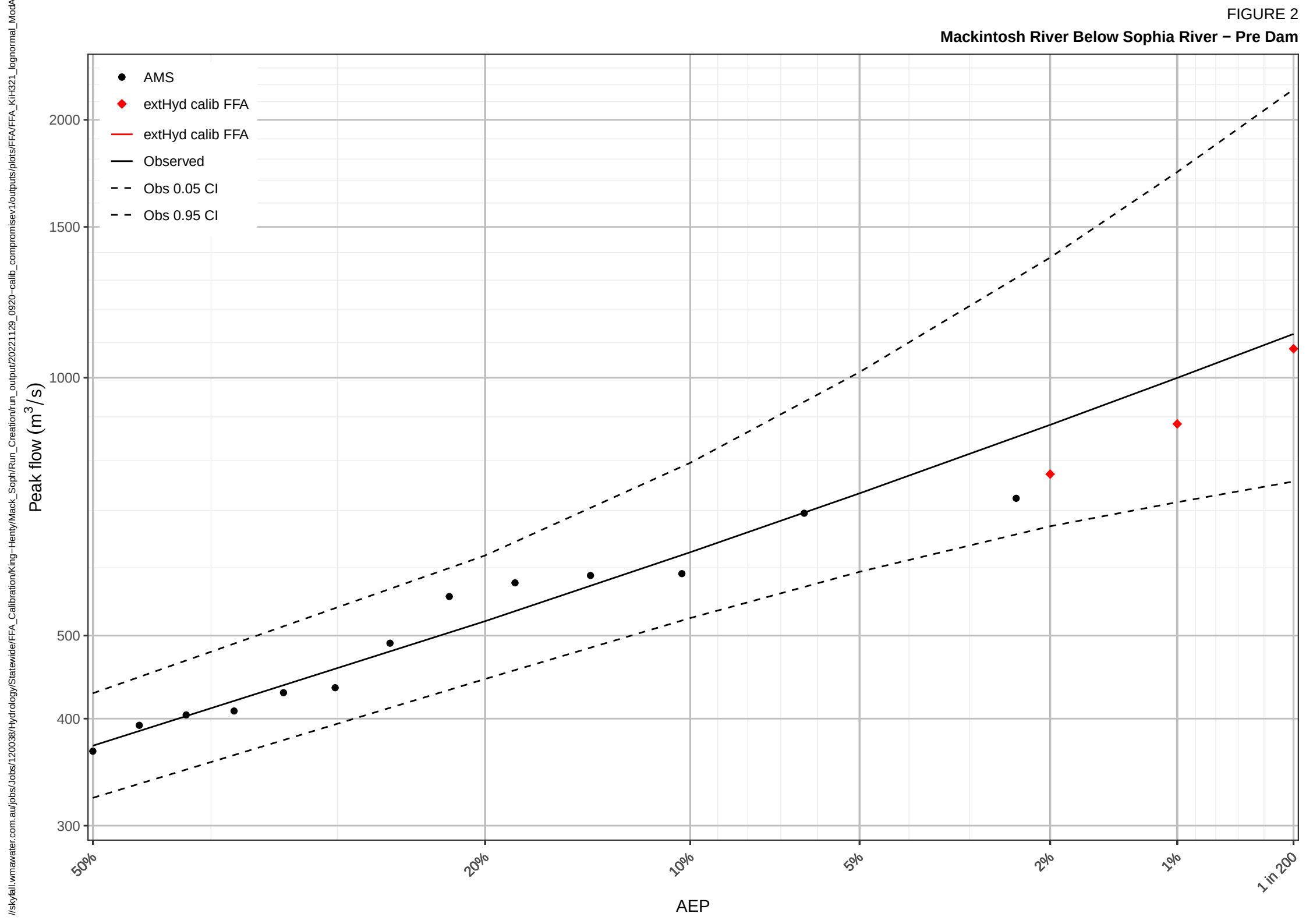

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FIGURE 3

Whyte River Ab Rocky River

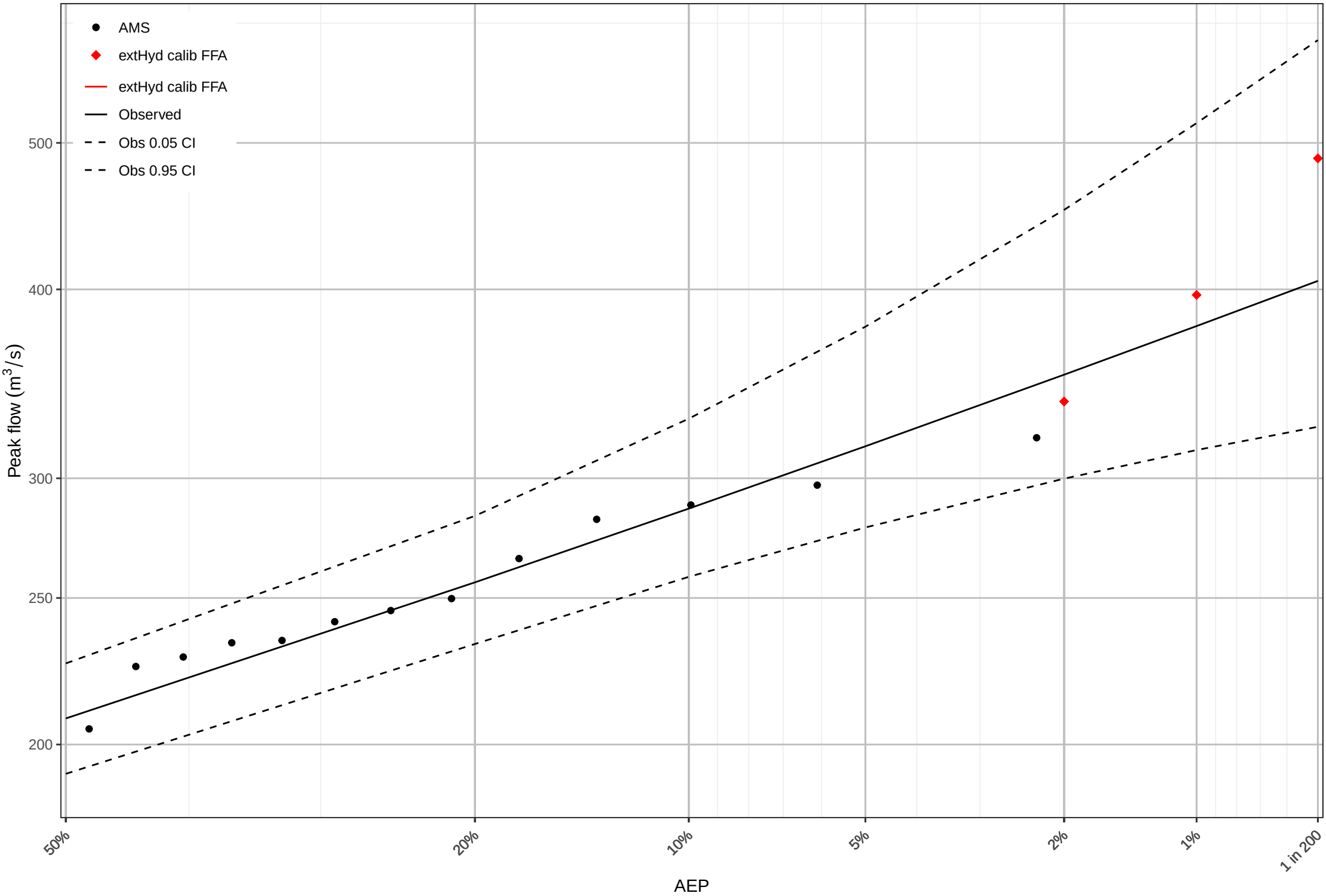

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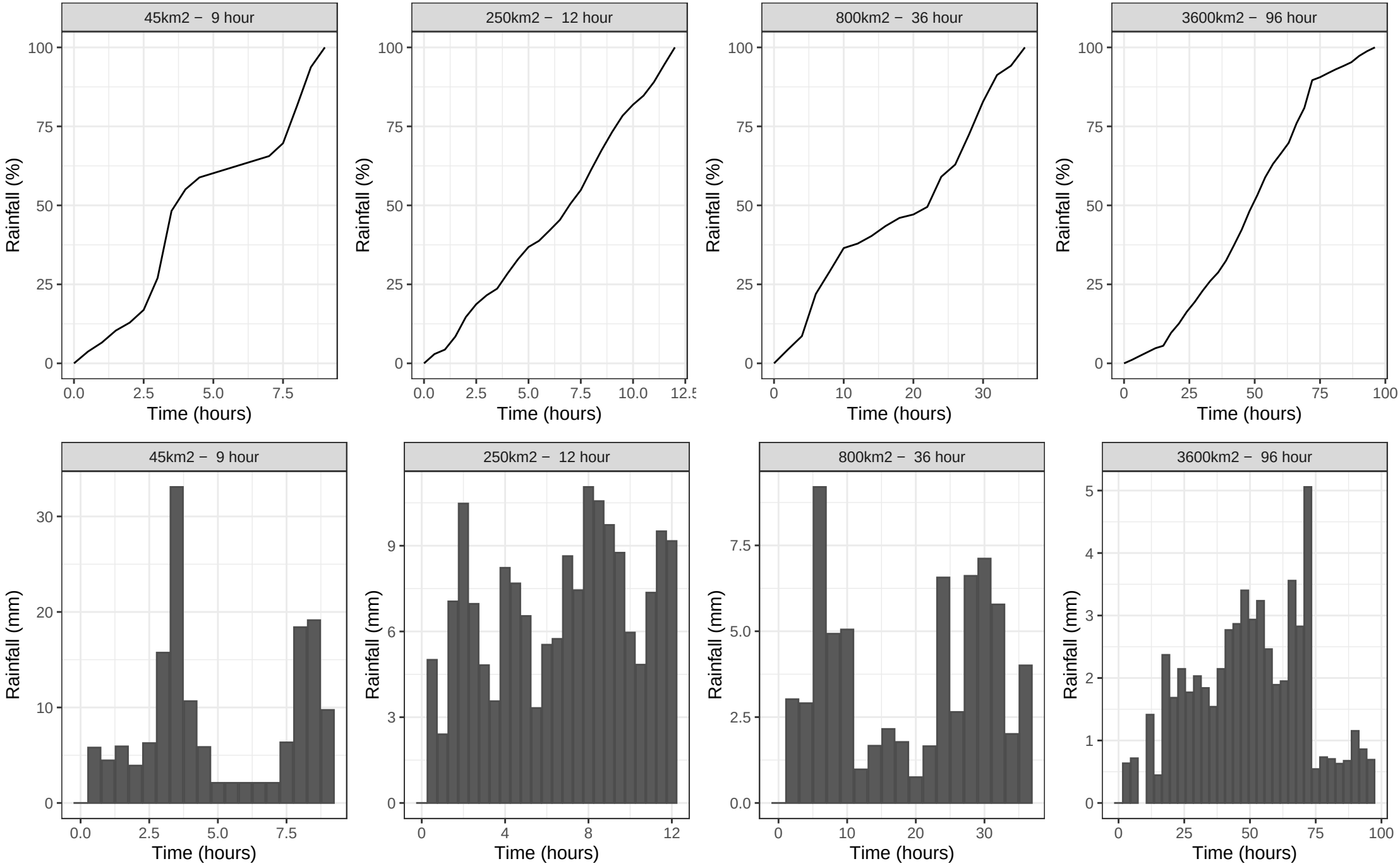
FIGURE 4

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



Appendix A

APPENDIX A. DESIGN EVENT DATA

FIGURE A1

DESIGN RAINFALL DEPTHS

2160MIN 2%AEP

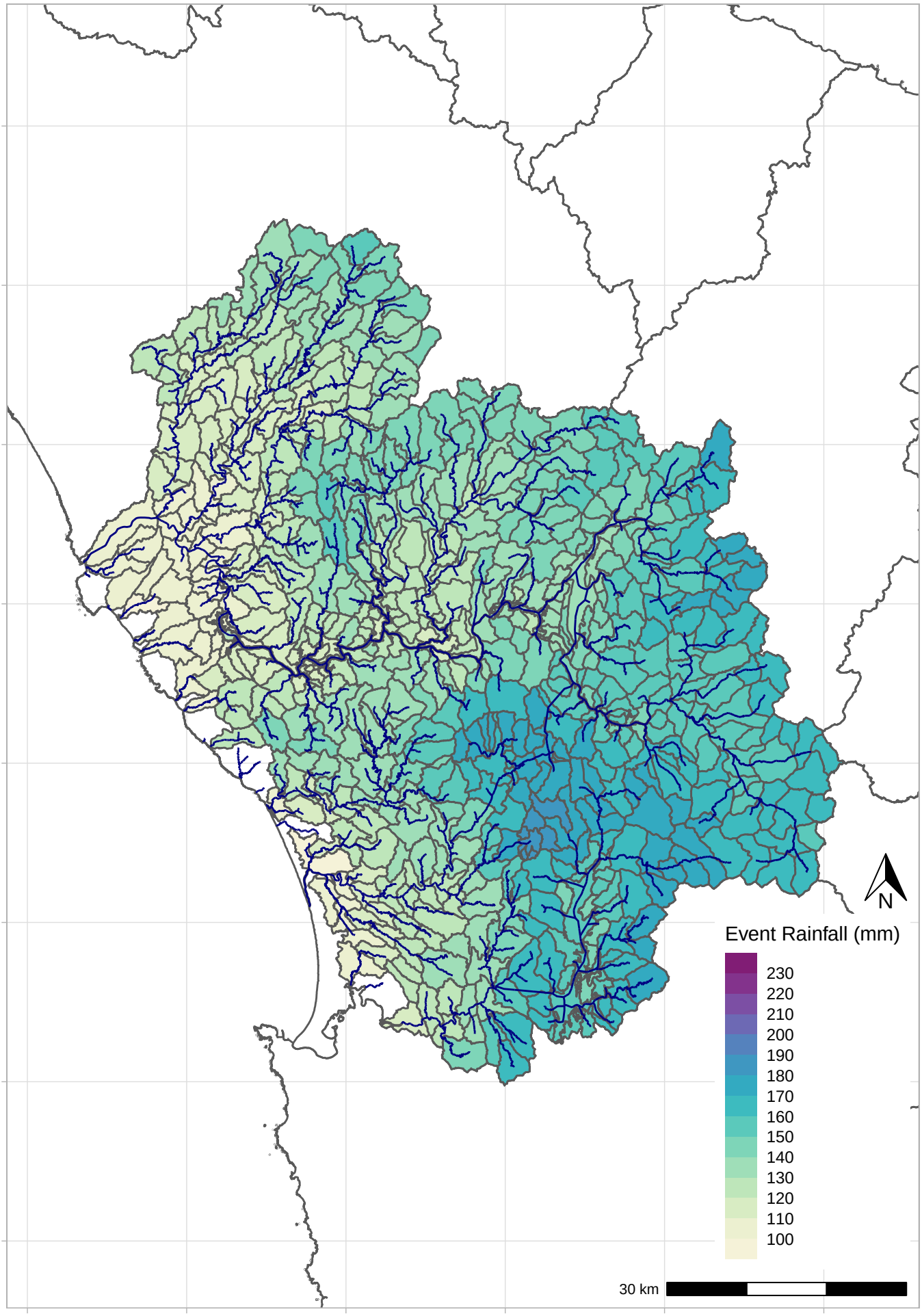


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FIGURE A2

DESIGN RAINFALL DEPTHS

2160MIN 1%AEP

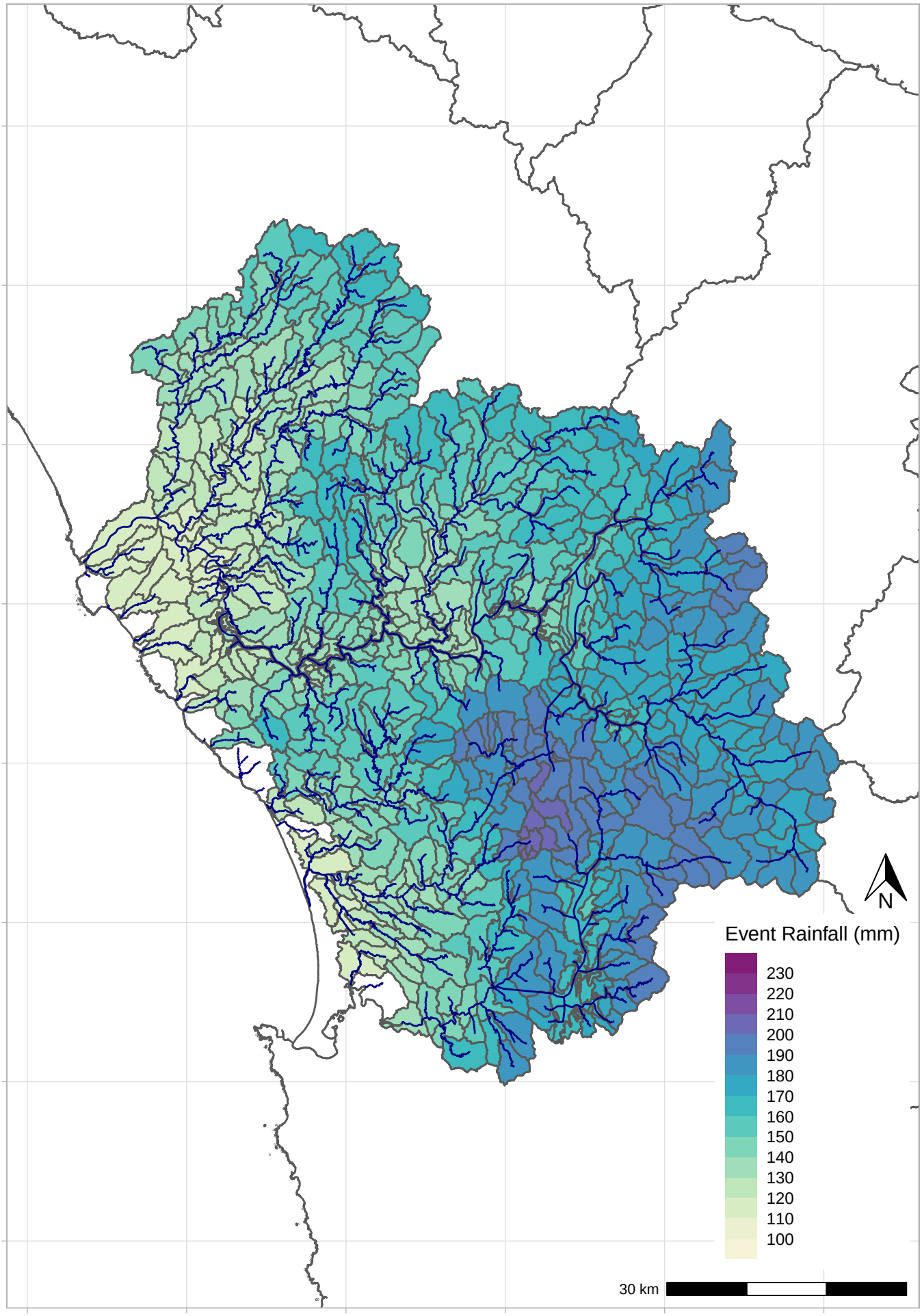

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FIGURE A3

DESIGN RAINFALL DEPTHS

2160MIN 0.5%AEP

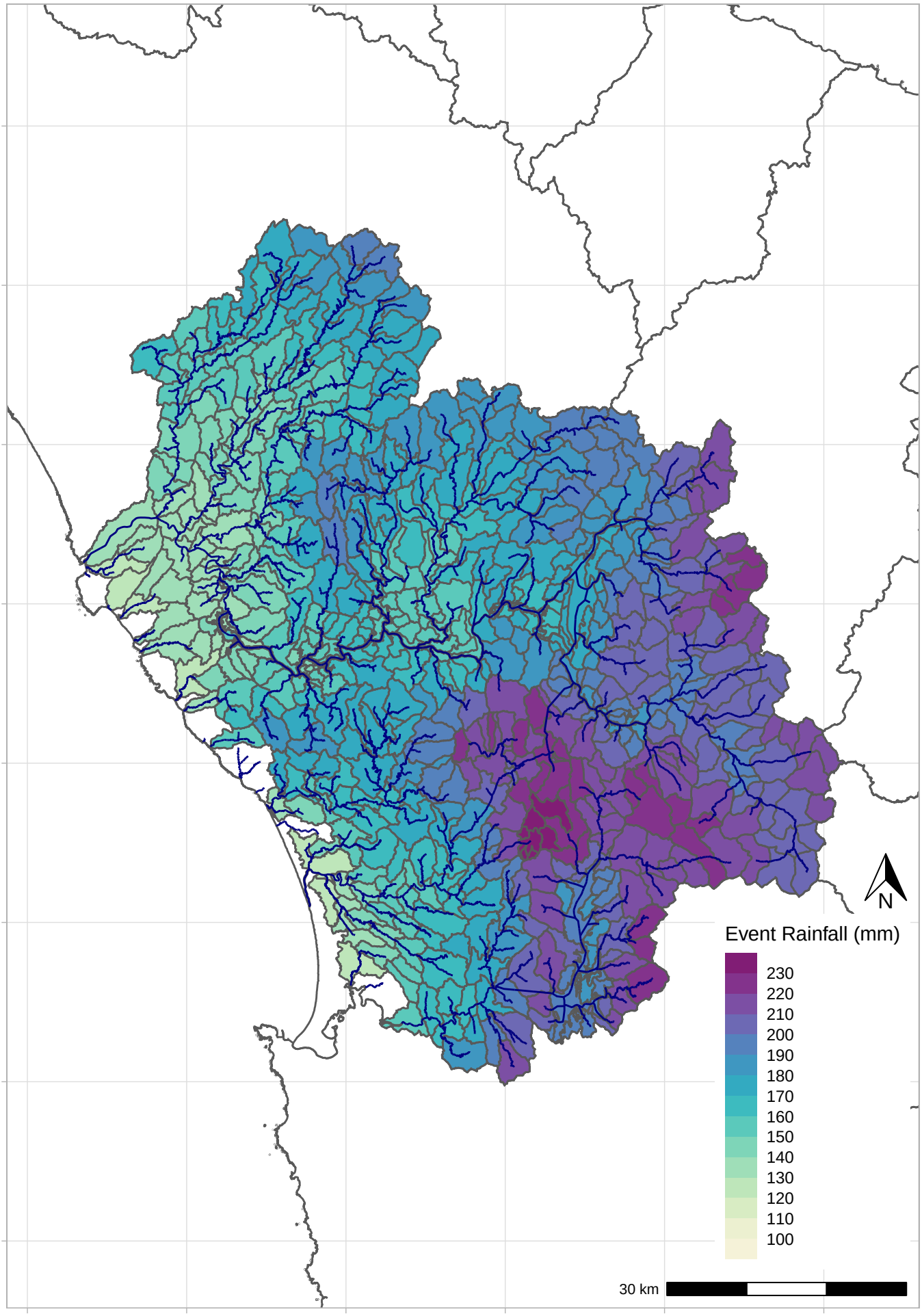

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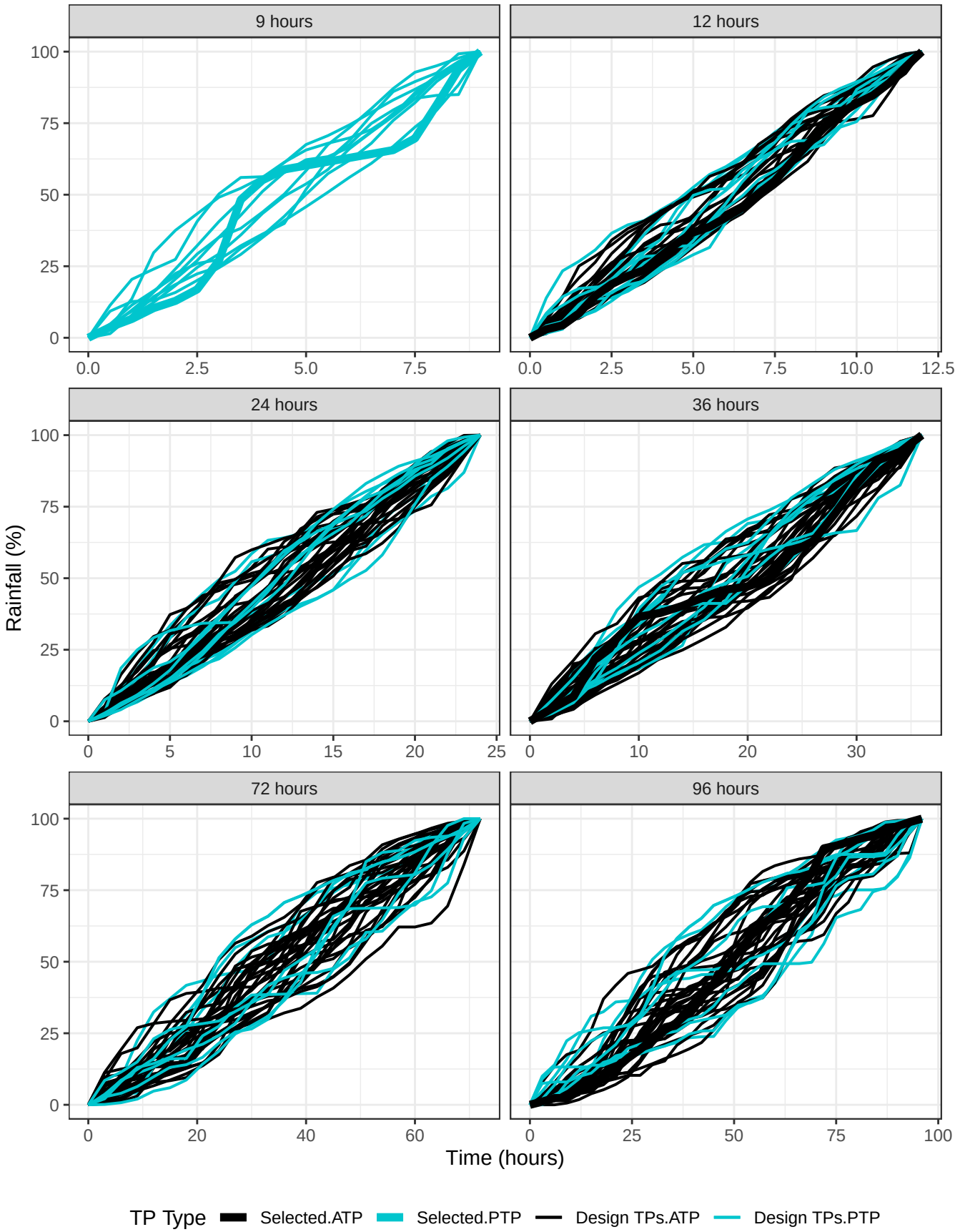
FIGURE A4

DESIGN TEMPORAL PATTERNS

DURATIONS FROM 9 TO 96 HOURS



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Appendix B

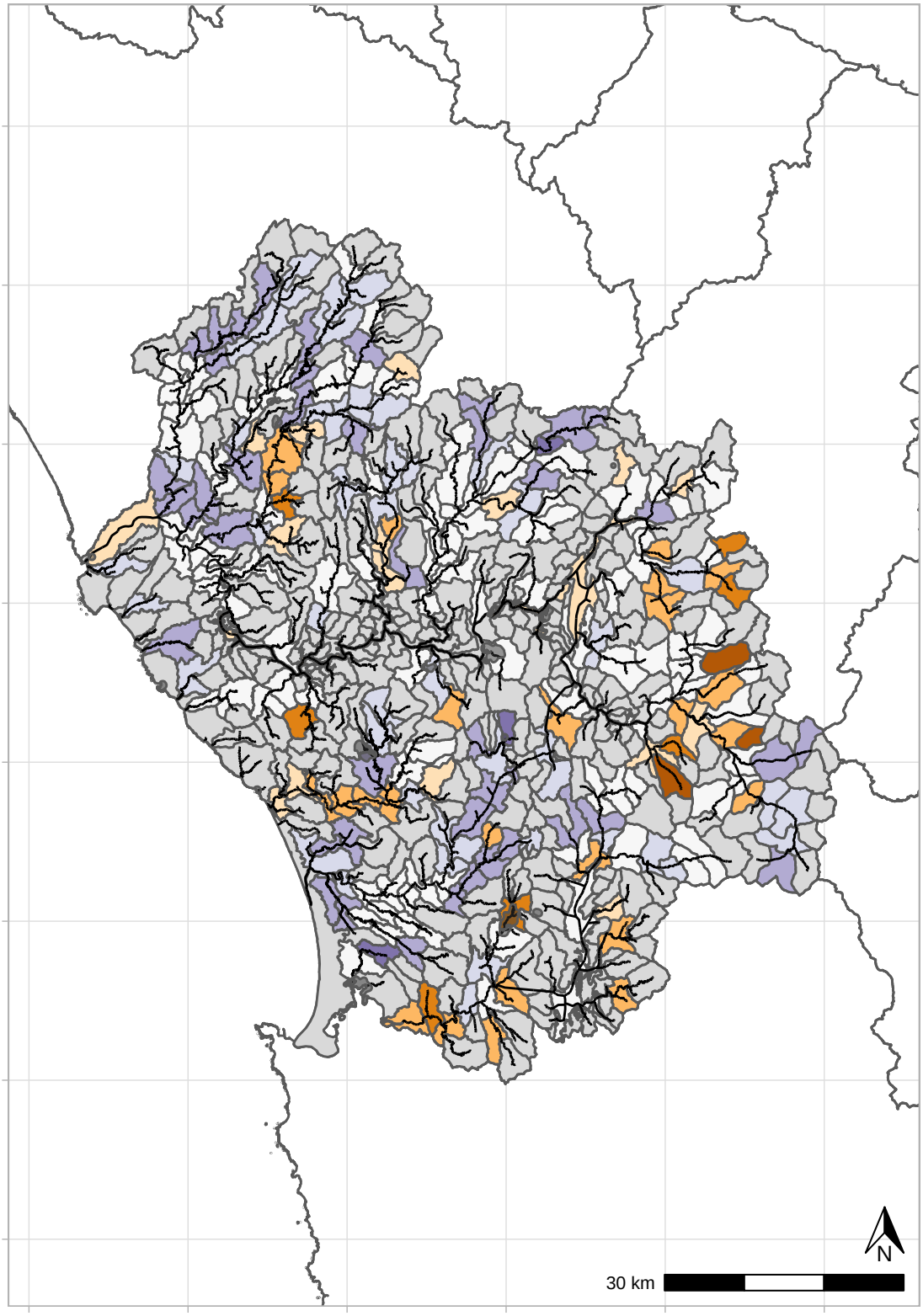
APPENDIX B. DESIGN PEAK ERRORS

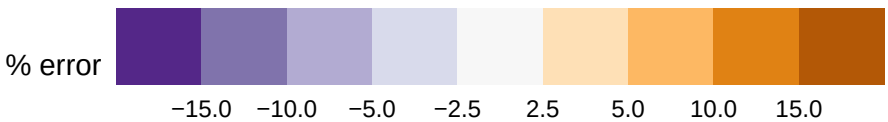
Figure B1

King−Henty Catchment

Percentage error in peak flows using selected runs

2%AEP





HSA

Headwater

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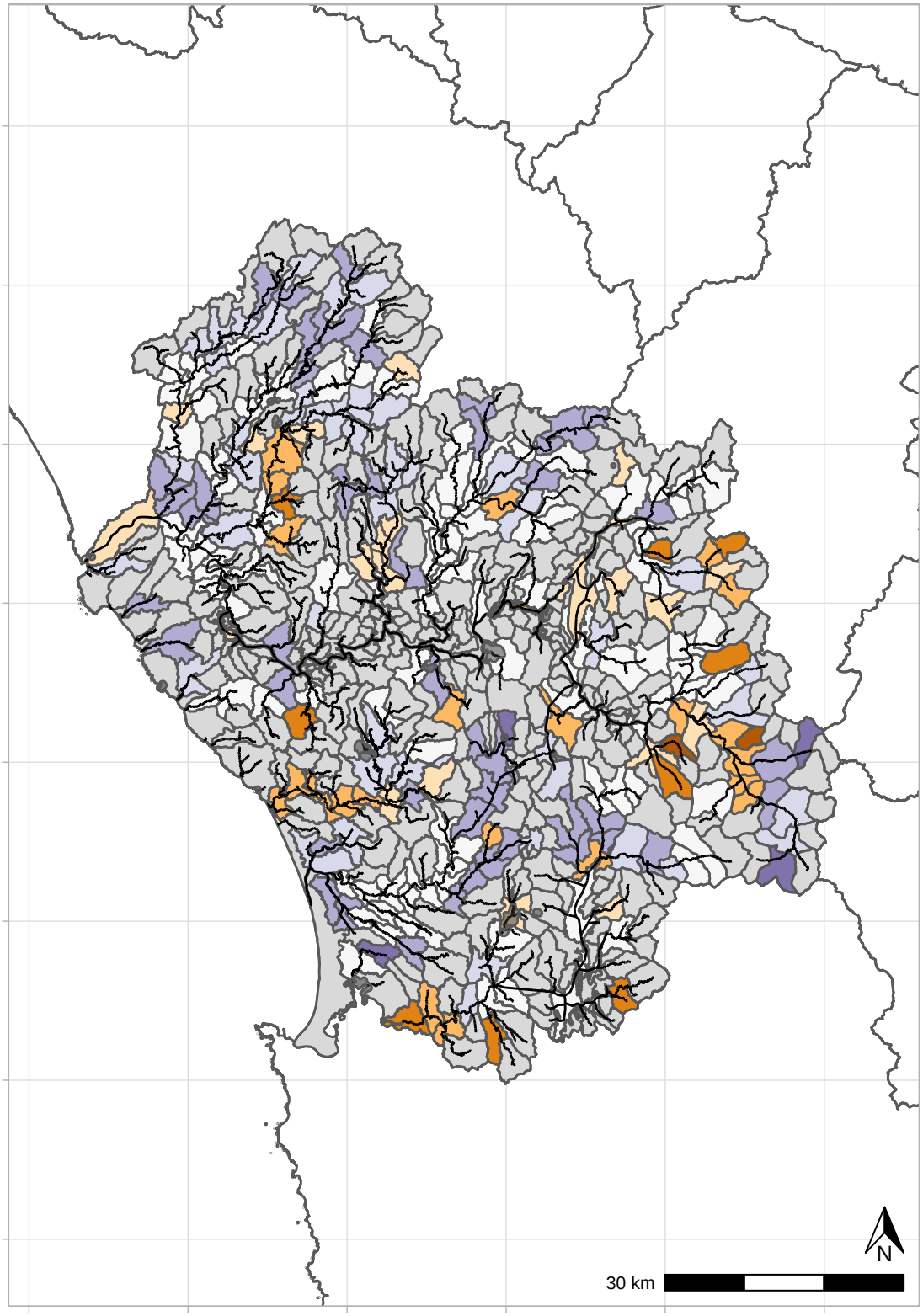
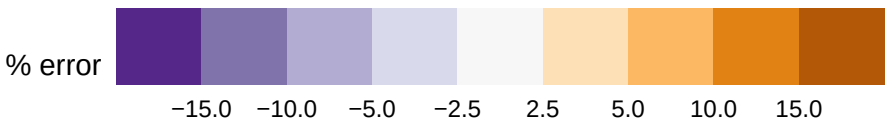
Figure B2

King−Henty Catchment

Percentage error in peak flows using selected runs

1%AEP





HSA

Headwater

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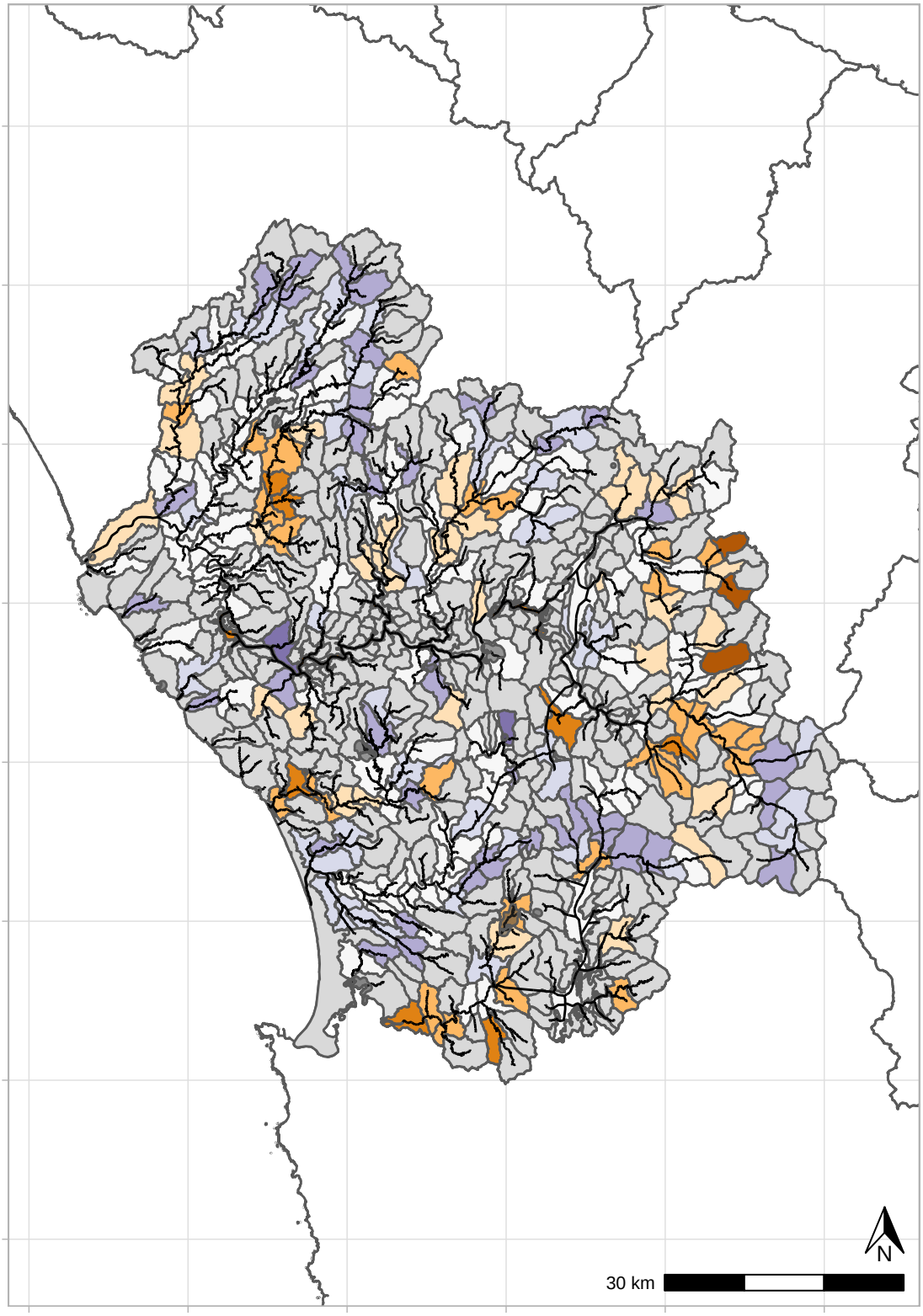
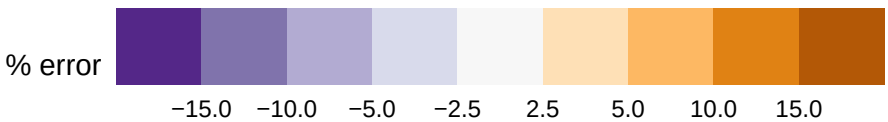
Figure B3

King−Henty Catchment

Percentage error in peak flows using selected runs

0.5%AEP





HSA

Headwater

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