FINAL REPORT

Documenting the largest floods in the Wet Tropics catchments using geomorphology, hydrological and archival data

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Barron Falls in flood (1894) (Cairns Historical Society, P00553)

PROJECT SUMMARY

This project combined palaeohydrological approaches and historical documentation to provide a solid basis for understanding extreme floods in the Wet Tropics of Far North Queensland. Importantly, the work has shown that extreme floods, larger than the Flood of Record (FoR), have occurred in the past and are likely to occur again in the future. For the Barron River fan-delta, calculations of palaeoflood discharges using imbricated boulders estimate discharges between 2067 and 16,159 m^3s^{-1}. The largest of the two reconstructed palaeoflood discharges are larger than the FoR recorded at the Barron River Myola river gauge station and larger than the 1% AEP flood discharge measured for the Barron River at the Myola gauging station (6046 m^3s^{-1}). A review of tropical and subtropical rivers in Australia reveals that palaeoflood discharges are generally greater than FoR, indicating that flood frequency using the short modern day gauged record may not adequately capture the larger floods that have occurred in the past. The palaeofloods studied fall within the scope of the Australian Envelope Curve (AEC) with the tropical rivers of Queensland lying on the AEC. It is likely that larger palaeofloods exist but their flood discharges have not been calculated, making these sites important areas for future flood studies. Climate drivers, ENSO and IPO, are important drivers of flooding for the Barron River. This is attested by historical accounts that mention repeated flooding for the period between 1867 and 2009. The accounts of flood inundation depths ranging from slightly >1 metre to >2.5 metres are in line with modelled flood depths from hydraulic models. The historical information reveals that the local communities and government were aware of the flood risks of the fan-delta and adapted accordingly. This information is useful to increase flood awareness and resilience of local communities to future flooding events. An important but not well-studied aspect of this project relates to mass load transport of pollutants, namely sediment and nutrients, to the Great Barrier Reef from extreme floods. Initial estimates indicate that a flood of the magnitude large enough to move the Barron River boulders will likely transport fine sediment, particulate nitrogen and particulate loads of 27.9 kt day^{-1}, 2.23 kt day^{-1} and 10.5 kt day^{-1} respectively. The fine sediment loading from this palaeoflood equates to approximately 18% of the annual load to the GBR, highlighting significant water quality impacts on an already fragile ecosystem should floods of similar or larger magnitude occur in the future. Key areas of future work include investigations into the role climate drivers play in floods in the Wet Tropics, hydraulic modelling of the Barron River fan delta area to assess flood risk given that the recent ex-TC Jasper flood (17 December 2023), improved estimates of mass loads for extreme flood events as well as communicating the results of this work to local communities.

ACKNOWLEDGEMENTS

The project was funded by the Queensland Government, Department of Environment and Science, through Queensland Water Modelling Program.

We acknowledge the involvement and support of Professor Jonathan Nott (JCU), Sioux Campbell (Cairns Regional Council), Paul Hoye, Shane Brumby (Douglas Shire Council), Sarah J Collins, Dave Warren and Jarrah Doran-Smith.

CONTENTS

1. INTRODUCTION

The Wet Tropics region is projected to experience more intense rainfall with climate change, affecting flood magnitude in this region. The gauged record for many rivers in the region spans at most 100 years, which is insufficient to capture the largest floods. This report presents an application of this approach to the Barron River fan delta in Far North Queensland. The Barron River catchment is an important area of agricultural activities, yet it hosts and drains into World Heritage Sites (Wet Tropics Rainforests, Great Barrier Reef, GBR) that are currently under threat due to the multiple pressure of population increase, development and climate change. The fan-delta of the Barron River also experiences frequent flooding that are now presenting increasing risk for the local population as development pressures increases for this fan delta.

This project adopts multiple approaches that includes geomorphological, hydrological and historical knowledge to estimate and evaluate the magnitude and impacts of and responses to past floods of the Barron River fan delta, with the aim of improving flood mitigation and resilience to future floods for this river and other regional rivers.

1.1 Palaeoflood hydrology

Palaeoflood hydrology is the reconstruction of the magnitude and frequency of past floods using evidence from the geosciences (river and lake sediments and speleothems) and tree rings (Baker et al., 2021), not from river gauging. Palaeofloods may not be a result of the most extreme floods because these events probably remove evidence of the smaller palaeofloods. Palaeoflood discharges may not always equate to the Probable Maximum Floods (PMF), although in some cases they appear to be (Saynor et al., 2020) and are therefore a good approximation to extreme floods.

Current engineering practices for design and flood management are based on flood frequency analysis of short, gauged records with a focus on designing events of low return periods, often the 100-year flood, due to the increasing cost of construction to mitigate the impact of rare events. A locally relevant example is provided by the Queensland Reconstruction Authority (2012) who recommend, for planning purposes, estimation and spatial hydraulic modelling of floods with 2%, 1%, 0.5% and 0.2% Annual Exceedance Probabilities (AEP) and the Probable Maximum Flood (PMF) while noting that the 1% AEP flood (Average Return Period, ARI, of 1 in 100 years) is a useful guide for many purposes.

On a broader level of improving flood resilience, the knowledge of palaeofloods is useful as this information can be combined with or compared with gauged extremes to provide flood frequency analyses that are statistically more robust than would be the case if gauged records alone had been used (Lam et al., 2017a). Palaeoflood records can provide estimates of extreme floods where there are no gauged records, or the gauging is for such a short period that estimation of return intervals is suspect (Wasson, 2016). Therefore, palaeofloods can be used to test the veracity of both long return period calculations from gauged records and theoretical PMFs on which many engineering decisions are made as well as stress-testing warnings, evacuation procedures, provision of services such as electricity, levees, and also defined flood events, defined flood levels, and flood hazard areas (Tsionis et al. 2016, Australian Building Codes Board, 2019).

Even though there may be larger floods in the future, palaeofloods offer the best opportunity for stress testing because they are ‘real’, unless gauged Floods of Record (FoR) are larger. By examining the climatic conditions under which palaeofloods and FoRs occur, there may be a way to anticipate future floods by examining climate projections from climate models. This is not a straightforward approach due to the limitations of climate models but is a step towards a better understanding of the climatic drivers on floods, especially in a climate changing world (Shepherd et al., 2018).

1.2 Flood histories/memories as an innovative source of information

Flood histories globally have been used to extend hydrologic records (e.g., Potter, 1978; Bayliss and Reid, 2001; Thorndycraft et al., 2003), identify flood prone areas (Conesa Garcia and Garcia Garcia (2003), and improve risk assessment (Williams and Archer, 2002). With an increasing trend to flood risk management rather than flood control through structural solutions such as levees, local flood histories are likely to provide important information for the development of greater resilience of people at risk of flooding (e.g., Puzyreva and Vries, 2021).

The Australian Institute for Disaster Resilience (2017) recommends the construction of local flood histories as part of flood studies ‘... to provide an understanding of the full range of flood behaviour and consequences.’ (p.4). The type of history to be pursued is not specified by the Institute but from the text it appears to involve quantified flows that can be used in flood frequency analysis and for calibration of hydrologic and hydraulic models. This could include documentary and cartographic information, data from tree rings and flood sediments, the discharge required to move boulders in rivers or scour bedrock, and other information sources (Ballesteros Canovas et al., 2020).

To increase the resilience to future floods, Puzyreva and Vries (2021) make the important point that local flood histories can help to create shared responsibility for flood mitigation between local communities and the disaster management authority. This approach also permits more context-specific understanding and knowledge for mitigation decision-making. Communities therefore become more resilient. And it has been shown in Europe that local flood histories are key factors affecting community engagement with flood management (Bradford et al., 2012; Thaler et al., 2016). Local flood histories also remind people that floods recur, especially if there haven’t been any large floods for decades which is the case for the Barron River. In other words, they create an enduring memory.

1.3 Study Site

The Wet Tropics (WT) NRM region has an approximate catchment area of 21,722 km^2 (~5% of the total GBR catchment area (GBRCA) (423,134 km^2)); the Barron catchment covers 2,188 km^2 (10% of the WT region). Rainfall averages 1,442 mm a year, which results in river discharges to the coast of about 879 GL each year. The WT contributes 32% of the total discharge to the GBR, despite only comprising 5% of the adjacent catchment area (McCloskey et al 2021a). The Barron catchment is located in the central section of the Wet Tropics region and lies largely inland, with only a small coastal fringe. The catchment is divided into two main sections, the upper reaches in the Atherton Tablelands, above the Barron Falls, and the lower reaches in the narrow coastal plain. The Tablelands has a large catchment area comprising numerous sub-catchments that flow into the Barron River and is a major agricultural region. Other major waterways in the Barron catchment include Lake Tinaroo, Lake Morris and

Freshwater Creek, which feeds into the Barron River below the Barron Falls. The lower reaches of the Barron River cross to the coast north of Cairns and consists principally of urban and agricultural (grazing and sugarcane) land use.

The Barron River rises on the Atherton Tableland at about 900 asl and passes over the Barron Falls knickpoint and through a 6km long gorge on the margin of the Tableland before reaching Kamerunga which is the apex of an alluvial fan-delta (Figure 1). The river's catchment area is 2,175km^2, and the fan-delta has an area of about 40km^2.There is one major tributary downstream of the fan apex, Freshwater Creek, which contributes about 10% to the mean annual flow in the Barron River (Department of Harbours and Marine, 1981). A fan-delta is a landform consisting of an alluvial fan built by riverine (fluvial) processes that merges downslope with a body of water where different geomorphic processes prevail (Van Dijk et al., 2012). In the case of the Barron fan-delta, the transition is from riverine processes to marine and coastal processes on beaches (90% of the sand in which comes from the Tableland; Nicolls et al., 20124), dunes, beach ridges, estuaries, mangroves forests, and offshore subaqueous deltas. A geomorphic map is provided by Department of Harbours and Marine, (1981, Figure 2.11) (Figure 2 below).

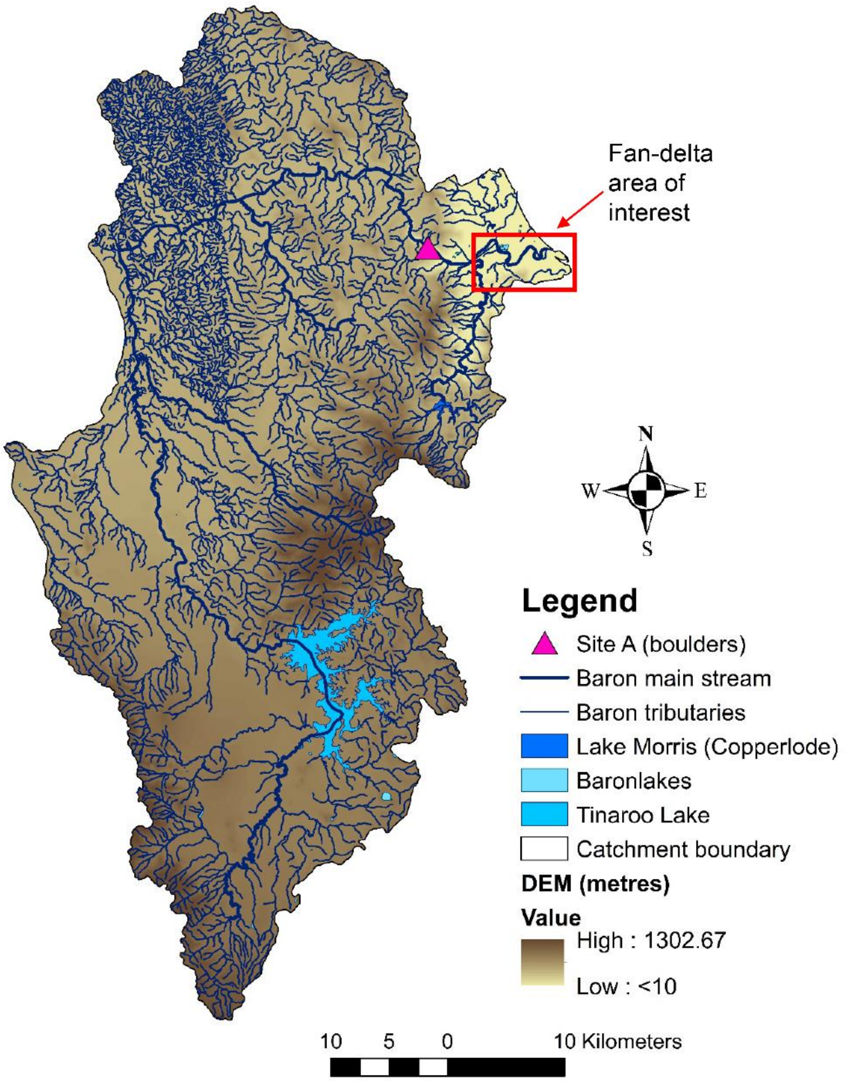


Figure 1: Barron River catchment with boulder sampling site (Site A) and fan-delta area

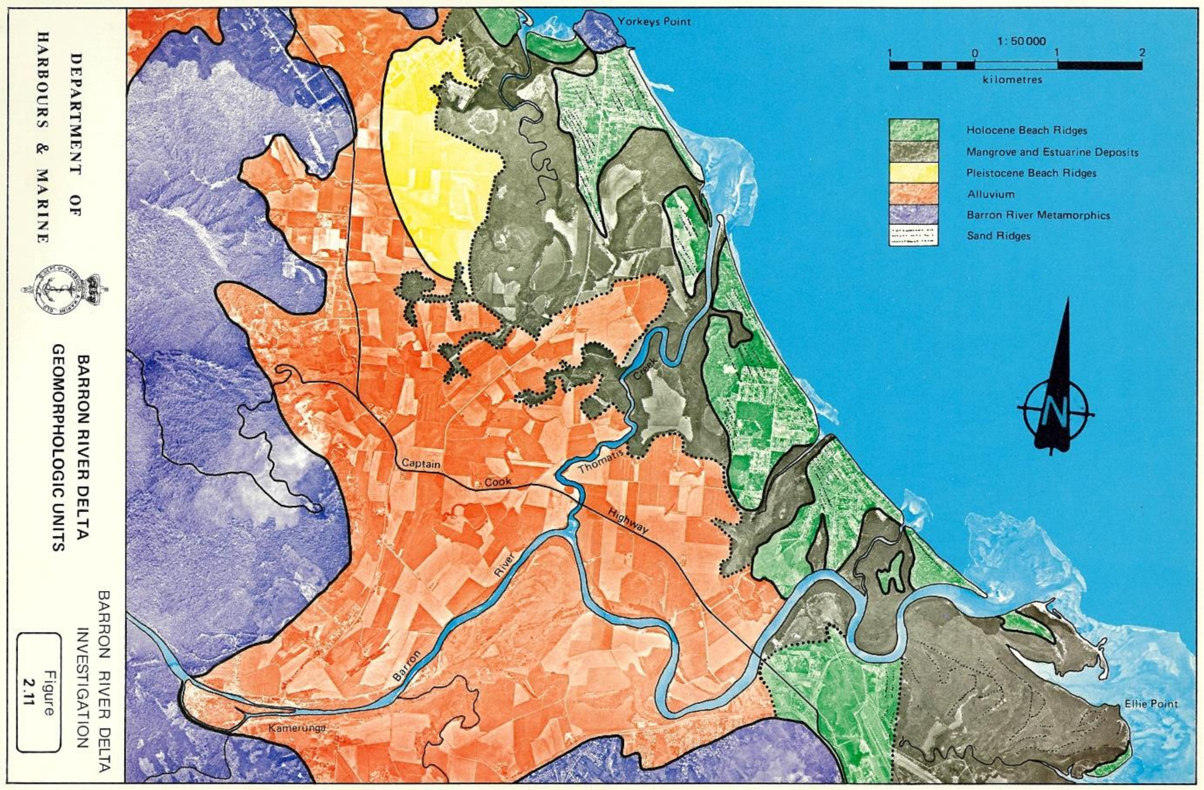


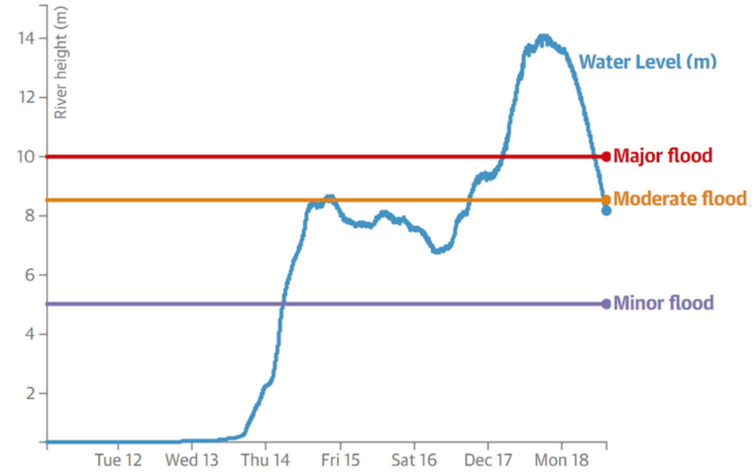
Figure 2: Barron River delta geomorphic landscape units (Source: Department of Harbours and Marine, 1981, Figure 2.11)

The fan was originally dominated by tropical lowland rainforest but from about 1890 was largely cleared and used for agriculture, aquaculture, and some sand and gravel mining. Fluvial processes of sandy and gravelly bedload deposition have occurred in channels and laterally migrating flood plains such as that currently on the right bank of the Barron River where it comes closest to the Cook Highway south of the Kart Hire establishment, as evidenced on Google Earth by scroll bars and swales. The Barron is the major river on the fan with an average depth below the flood plain surface between 2.5m near the mouth and a maximum of 10m adjacent to the old Smithfield township from which it decreases upstream to 5.5m at the Kamerunga Bridge. There is bank erosion on this and other rivers on the fan, a result of both natural channel change and removal of protective riparian vegetation. The surface of the fan consists of fine sediment, deposited from overbank flow from the river channels.

The fan-delta is subject to large floods that are mostly tropical cyclone induced. Orr (2016) found that between 1915 and 2014 50% of annual peak flows greater than an Average Recurrence Interval (ARI) of 2 years were associated with cyclones, and >80% were associated with cyclones for ARIs >20 years. The more recent significant flooding events occurred in 1967 and 1977 with peak discharges between 2500 and 5000 m^3/s. This resulted in extensive overbank flooding of the alluvial part of the fan delta, with inundation depths between 1 and 3 metres. These results are based on ground observations, flow gauging and hydraulic modelling. By comparison, the PMF of the fan delta was estimated to be between 5 and 10 times the 1967 and 1977 flood discharges (Flanagan Consulting Group, 2014). Either way, these estimates suggest significant flooding in response to heavy rainfall.

The available rainfall and flow data for this site extends just over 100 years. Rainfall records include a 125-year rainfall record measured at the Kuranda Railway station (Station 031036) and a shorter 78-year record from the Cairns airport (Station 031011) (Bureau of Meteorology, http://www.bom.gov.au/climate/data/, accessed 17 June 2022). Gauge flow records started around 1915/1916 at Kuranda (110001A) with the gauging stations moving to various locations. The most consistent flowing monitoring site for this part of the Barron River is from the Myola station where data collection started in 1982 and continues to present day (Station 110001D) (Source: https://water-monitoring.information.qld.gov.au/ , accessed 24 June 2022). This gives a total of approximately 108 years of flow record for the Barron River fan-delta area.

The recent 17 December 2023 flood caused by ex-TC Jasper was slightly larger than the 1% AEP flood for the gauging station at Myola. The 1% AEP flood at Myola is approximately 6046 m^3/s (Log-Pearson 3) while the maximum peak discharge and water level for the 17 December 2023 event was 6440 m^3s^{-1} and 14.09 m respectively (Figure 3). Heavy rainfall that fell continuously over a 48-hour period was due to the cyclone stalling inland and creating a stationary convergence zone. This led to the collision of very moist tropical winds, which converged with the northerly winds from the Gulf of Carpentaria and southeast trade winds from the Coral Sea (Turton, 2023). The local mountain range also created extra uplift. The 7-day rainfall totals were over 2000 mm (Redfearn, 2023). The flood resulted in significant flooding and damage in the Lake Placid/Caravonica estate, as well as in the coastal suburbs of Machans and Holloway beaches and area around the Cairns Airport. The Insurance Council of Australia estimates insurance claims up to A$743m of insured losses due to this event (Source: https://www.afr.com/policy/energy-and-climate/cyclone-jasper-s-damage-bill-mounts-as-rain-eases-20231220-p5esq0). Although the 2023 flood adds to the gauge record of floods, the modern-day record collected at the Myola gauging station is unlikely to capture more extreme floods that have occurred in the lower reaches of the Barron River, which highlights the role palaeoflood information have in extending the flow records (Lam, 2017 Baker et al., 2021).



Guardian graphic | Source: Bureau of Meteorology

Figure 3: River height at the Myola gauging station, Barron River due to the ex-TC Jasper cyclone exceeds levels where a major flood event occurs
(Source: Bureau of Meteorology, extracted from https://www.theguardian.com/australia-news/2023/dec/19/cyclone-jasper-how-did-it-cause-so-much-rain-and-could-global-heating-be-to-blame)

2. EXTREME FLOOD MAGNITUDES OF THE BARRON RIVER

To extend the flow records, we adopt a palaeoflood geomorphic/hydrological approach to reconstruct the magnitude and frequency of past floods using evidence left behind in the environment (e.g., river and lake sediments, speleotherms, corals, tree rings, Baker et al., 2021). The method used to reconstruct flood magnitudes in this study relies on the dimensions of boulders moved during floods and the flow velocities that initiated their movement.

2.1 Reconstructing palaeoflood flood magnitudes of the Barron River

A collection of imbricated boulders, stacked against each other, at an angle of approximately 20º exists downstream of the Barron Falls hydropower station (Figure 4). The dimensions, long (d_L), intermediate (d_I) and short (d_s) axes of 16 boulders at this site were measured (Figure 3b). Details of their dimensions are given in Appendix 1. The intermediate axes of the measured boulders ranged between 1.8 and 4.3 m. More than half of the boulders measured were in the size range between 2 to 3 m wide (56%) with the largest two boulders measured over 4 metres across. This size range is similar to the bed material Costa (1983) used to calculate mean flow velocity (0.05 m – 5.18 m).

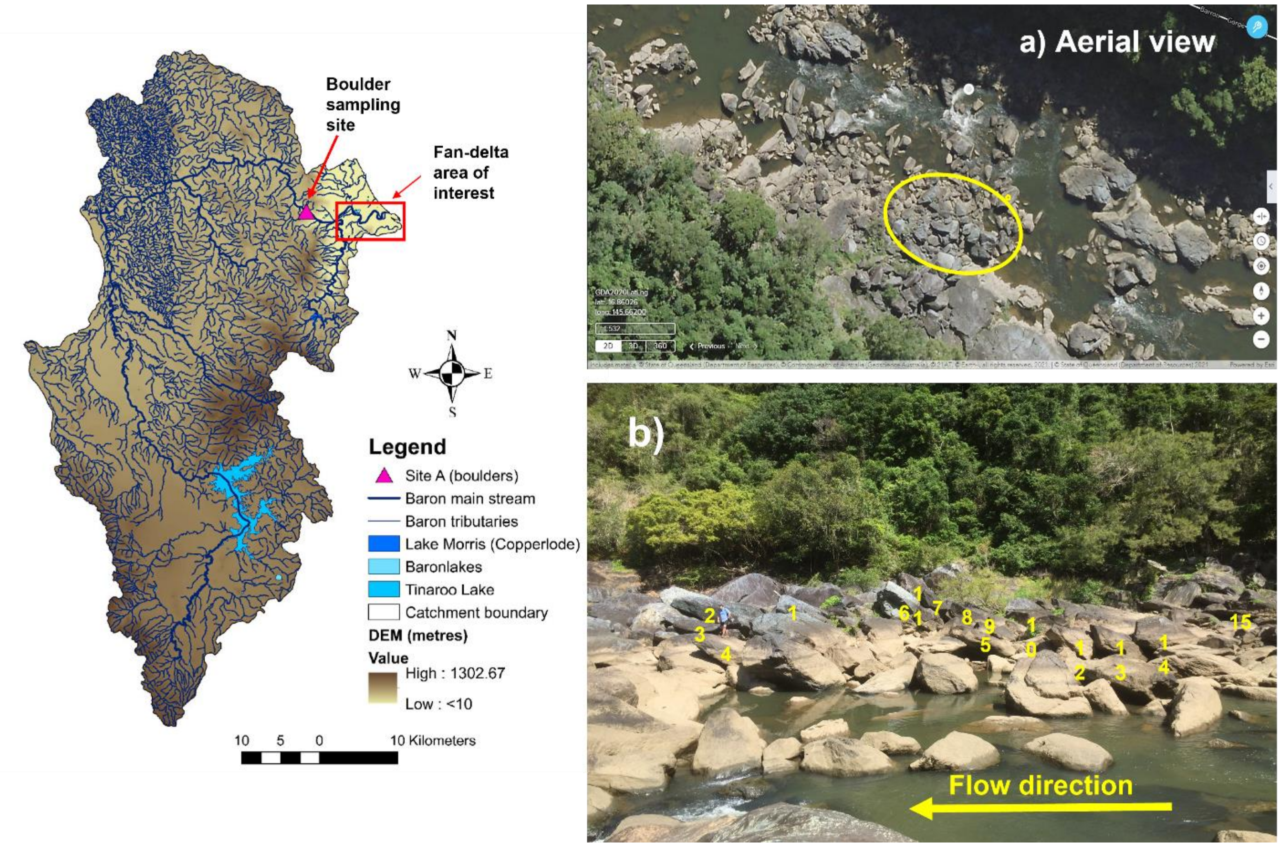


Figure 4: Map on the left shows the location of the boulder sampled, with photos on the right showing a) aerial view of Site A (16.860429051° S, 145.661839478° E) and b) imbricated boulders selected for measurement at Site A (n= 16 boulders).

The mean flow velocity ($\overline{v}$) needed to initiate boulder movement was calculated using both theoretical and empirically-derived equations. These equations have been used to reconstruct flood magnitude from large particles, including those moved by flash floods in both arid and mountainous environments (e.g., Carling, 1986, Kehew et al., 2010, Greenbaum et al., 2020, Huber et al., 2020). The theoretical equations account for the critical forces that initiate (drag, lift) and forces that resist particle movement (weight). Movement occurs when both forces equilibrate. These equations are based on the assumptions such as steady flow conditions, a logarithmic velocity profile and assume that the particles are fully submerged (e.g., Helley, 1969, Bradley & Mears, 1980, Clarke, 1996). In reality, unsteady non-uniform flow can occur during floods, especially when there are sudden changes in velocity between periods of constant flow when flash floods occur. To account for these transient flow conditions, Alexander & Cooker (2016) added an additional force term (*impulsive force*) to their force balance equation. Improvements in theoretical equations will see them addressing conditions that better reflect the complex field conditions when floods occur, such as bed conditions (sorting, packing of material, stable or shifting bed), the way particles are lodged on-site (on the river bed, buried) and the flow conditions (hydraulic characteristics, sediment concentration) during the flood event (Bradley & Mears, 1980, Komar & Li, 1988, Carling & Fan, 2020). Three empirical equations were used to calculate mean flow velocity ($\bar{\boldsymbol{v}}$) (Costa, 1983, Williams, 1983). These equations are outlined in Appendix 1. Table 1 presents the calculated flood depths, average flow velocity and flood depth using the 5 largest boulders.

Table 1: Estimates of flood water depth, average flood flow velocities ($\bar{\boldsymbol{v}}$) and discharge calculated from the 5 largest boulders at Site A, Barron River

Site A	**Water depth (m)**	**Average flow velocity, $\bar{\boldsymbol{v}}$ ($m\ s^{-1}$)**	**Discharge (m^3s^{-1})**
Theoretical equations (critical vs resisting forces):			
Helley (1969)	15	11.9	11,298
Bradley & Mears (1980)	11.1	9.8	6,066
Clarke (1996)	9.6	8.8	4,358
Alexander & Cooker (2016)	9.3	8.7	4,093
Empirical equations:			
Williams (1982)	2.8	3.9	197
Colorado Range (Costa, 1983)	6.9	7.1	2,067
US Bureau of Reclamation* (Costa, 1983)	17.9	13.4	16,159

* The water depth equates to bankfull conditions at Site A.

The calculated minimum extreme flood discharges ranged between 197 m^3/s to 16,159 m^3/s (Table 1). Most of the theoretical equations result in similar $\bar{\boldsymbol{v}}$ to initiate boulder movement (8.7- 9.8 m/s, Table 1, with the Colorado Range velocity slightly lower (7.1 m/s). The highest $\bar{\boldsymbol{v}}$ estimate (13.4 $m\ s^{-1}$) and corresponding flood discharge (16159 m^3s^{-1}) was obtained from the equation by the US Bureau of Reclamation dataset that largely included angular pieces that are not easily dislodged, unlike the boulders at this study site (Costa, 1983). The Helley (1969) equation that considers the forces that turn a boulder give a $\bar{\boldsymbol{v}}$ value of 11.9 ms^{-1}, the highest velocity estimate for the theoretical equations and is of the same order of magnitude as the one obtained using the US Bureau of Reclamation equation (Table 1). Both Clarke (1996) and the Alexander & Cooker (2016) give very similar velocity estimates despite the latter incorporating transient changes in velocity during flash floods. The Williams (1983) equation returns an unusually low velocity (3.9 ms^{-1}) and discharge value (197 m^{3}s^{-1}) compared to the estimates obtained by the other equations. Wohl (1992) also found that the Williams (1983) equation resulted in underestimates of $\bar{v}$ when compared against estimates obtained from HEC-2 modelling for the boulders deposited at the Burdekin River and suggested that this equation is better suited for smaller particle sizes (< 1.5 m). The minimum d_I is 1.8 m for the boulders measured in this study is larger than the size range suited for application of Williams (1983) equation, hence resulting in unusual velocity and discharge estimates for the Barron River boulders.

The $\bar{v}$ and flood discharge values obtained for the Barron River boulders provide a range of minimum velocity required to initiate boulder movement at Site A. Figure 5 provides a range of average velocities that may initiate boulder movement of different sizes measured at the Barron River. This range of $\bar{v}$ values correspond to a zone of potential boulder movement Williams (1983) termed the 'zone of potential movement of boulders'.

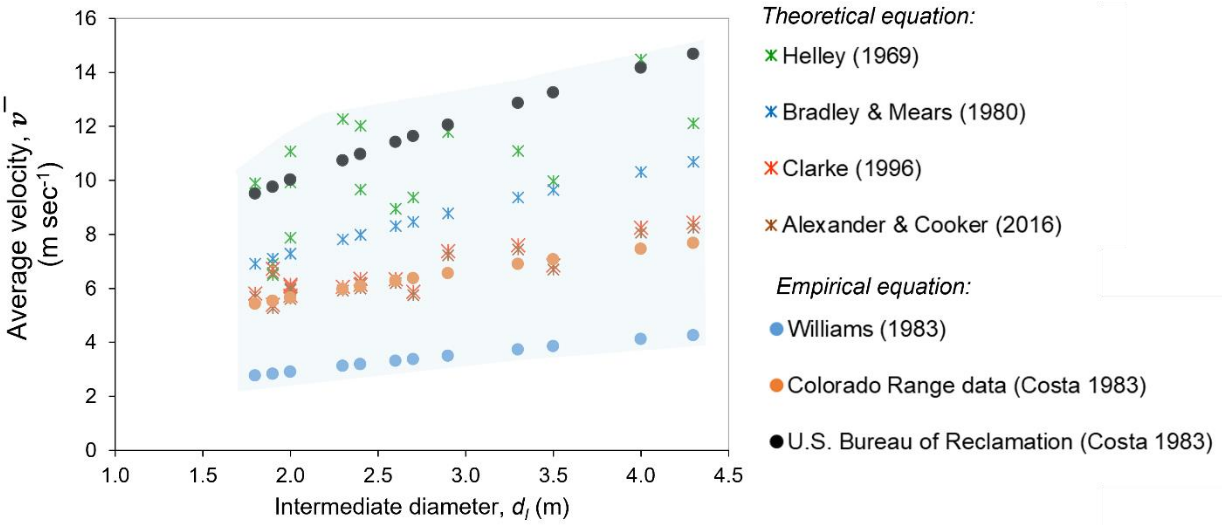


Figure 5: Range of average velocities that initiate boulder movement from various palaeohydrologic equations, theoretical (✱) and empirical (●) for the boulders measured at Site A, Barron River

It is very likely that the actual velocities that moved the boulders are higher, due to fluctuations in the near-bed velocity that can result in tractive forces that can be up to 2 to 4 times greater than the average values calculated by these equations (Graf, 1971, cited in Alexander & Cooker, 2016). The range in velocity and discharge values obtained by these equations represent in a simplistic manner the uncertainty around the estimates of the average flow velocities and need to be compared with values obtained through flow monitoring and hydraulic modelling of the river reach and fan delta.

2.2 Comparing extreme flood discharges of tropical and subtropical Australian rivers

Knowledge about the flood regime and impacts of floods in tropical and subtropical Australian rivers are limited by the sparse gauge network where stations often have short flow records. Palaeoflood studies provide additional information about large floods in the region. A data compilation effort that included the search for palaeoflood magnitudes and the largest flow recorded at the closest gauging station resulted in Table 2. The magnitude of palaeofloods examined for tropical and subtropical rivers in Australia were conveniently summarised in Lam (2017). The maximum gauged flow for each catchment is termed the Flood of Record (FoR). Most of these rivers, where palaeoflood information exists, have gauged records of less than 100 years, with the exception of the Barron River (see Appendix 1). The specific discharge ($m^3s^{-1}km^{-2}$) of the FoR and palaeoflood are also presented in Table 2 and allows a comparison of flood magnitudes for rivers in both climate zones.

The palaeoflood discharge is greater than the FoR for most of the rivers, with the exception of four rivers; East Alligator, Lennard, Mary and Logan (Table 2). Palaeoflood discharges are also lower than the Probable Maximum Flood (PMF) for the rivers where such information exists (Table 2). The magnitude of the reconstructed palaeoflood discharge for the East Alligator River differs quite significantly; 2900 m^3s^{-1} (Wohl et al., 1994a), 60,600 m^3s^{-1} (Saynor et al., 2020), highlighting the uncertainty around palaeoflood discharge reconstruction, associated with factors such as the preservation of flood deposits, dating techniques used and associated uncertainty. Sandercock & Wyroll (2005) also stated that palaeoflood discharges obtained from dating slackwater deposits from the Katherine River provide only a conservative estimate as the elevation of the slackwater deposits they examined were deposited at a lower elevation than where peak flood stage occurred (the reason why this occurred is unclear).

Four rivers stand out in the list where their specific palaeoflood discharges are much higher than the other rivers; E Alligator (25.4 $m^3s^{-1}km^{-2}$, using Saynor et al., 2020 estimate), Barron (8.8 $m^3s^{-1}km^{-2}$), Nerang (8.2 $m^3s^{-1}km^{-2}$) and Logan (6.0 $m^3s^{-1}km^{-2}$). The specific palaeoflood discharge for the East Alligator River decreases to 1.5 $m^3s^{-1}km^{-2}$ if the palaeoflood discharge of Wohl et al. (1994a) is used. For the Barron River boulders, the specific palaeoflood discharge is still high at 6.1 $m^3s^{-1}km^{-2}$ if the second highest estimate is used (i.e., Helley, 1969).

The ratio of the specific discharges, $Q_{SPEC\_PALAEO}/Q_{SPEC\_FoR}$, show three main results. The first is where the ratio is greater than 2, indicating that the specific discharge of the palaeoflood is twice that of the FoR and this is seen for 3 rivers, East Alligator, Barron and Margaret Rivers. The majority of the rivers exhibit ratio values between 1 and 1.6, where values closer to 1 show that the flood specific discharges did not differ significantly between the palaeoflood record and the shorter FoR-derived value (Table 2). Finally, 4 rivers exhibit ratio values less than 1 (East Alligator, Lennard, Mary, Logan) which suggests that the specific palaeoflood discharge was much higher than the peak flood recorded in the modern gauged record (Table 2). These types of comparisons can be problematic given the short nature of the gauged records and uncertainty around palaeoflood discharge estimation, associated with reconstruction techniques and whether the palaeofloods studied fall within the range of larger floods experienced by the catchment, which so far seems to be the case for most of the rivers reported in Table 2.

Another way of evaluating flood magnitude is using graphical methods where the flood magnitude is plotted against catchment area. An envelope Curve (EC) is included in this plot, with the EC defining the upper limit of flood discharges for a region or country (e.g., Wohl et al., 1994a, Saynor et al., 2020). In this study, we plot the palaeoflood discharges against the Australia Envelope Curve (AEC) to examine the flood magnitudes of tropical and subtropical Australian rivers. The AEC used here is an updated version of Lam (2017) derived from peak flows from 91 gauges with at least 30 years of flow records (2669 records of maximum flows

Table 2: Flood of Record (FoR) and palaeoflood discharges for tropical and subtropical rivers in Australia. Values in brackets refer to the Probable Maximum Flood (PMF)

State	**River**	**Area above gauging station (km^2)**	**Q_{FoR} (m^3s^{-1})**	**Area above study site (km^2)**	**Q_{PALAEO} (m^3s^{-1})**	**Specific discharge Q_{SPEC_FoR} ($m^3s^{-1}km^{-2}$)**	**Specific discharge Q_{SPEC_PALAEO} ($m^3s^{-1}km^{-2}$)**	**Ratio, $\frac{QSPEC\_PALAEO}{QSPEC\_FoR}$**	**Source[1]**
TROPICAL RIVERS									
NT	Katherine	6,390	5,168	6390	6,300	0.8	1.0	1.2	Baker et al. (1985), Baker & Pickup (1987)
		8,640	6,998			0.8			
NT	East Alligator	2,384	9,233	2000	2,900	3.9	1.5	0.4	Wohl et al., 1994a)
				2384	60,600		25.4	6.6	Saynor et al. (2020)
NT	Finke (Road Crossing)	7,500	1,668	6000	8,200	0.2	1.4	6.1	Baker et al. (1983), Pickup et al. (1988), Wohl et al. (1994a)
	Finke (Hermannsberg)	3,973	1,116			0.3			
QLD	Barron River	1,779	6,440	1841	16,159[2] (25,200)	3.6	8.8	2.4	This study
QLD	Herbert	5,236	15,336	5500	17,000 (38,000)[3]	2.9	3.1	1.1	Wohl (1992a)
QLD	Burdekin	114,700	19,196	114700	30,000	0.2	0.3	1.6	Wohl (1992b)
WA	Fitzroy	46,133	25,546	35000	30,000 (56,713)[4]	0.6	0.9	1.5	Wohl et al. (1994b)
WA	Margaret	7,646	8,930	7800	20,000	1.2	2.6	2.2	Wohl et al. (1994b)
WA	Lennard	1,050	5,437	1200	2,600	5.2	2.2	0.4	Gillieson et al. (1991)
SUBTROPICAL RIVERS									
QLD	Baramba	5,553	7,594	5556	9,000 (82,080)	1.4	1.6	1.2	Lam (2017), Lam et al. (2017a,b)
QLD	Mary	3,068	8,215	3095	6,750	2.7	2.2	0.8	Lam (2017), Lam et al. (2017a,b)
QLD	Emu Creek	915	2,036	904.5	3000	2.2	3.3	1.5	Lam (2017), Lam et al. (2017a,b)
QLD	Logan	175	1,904	158	950	10.9	6.0	0.6	Lam (2017), Lam et al. (2017a,b)
QLD	Nerang	68	494	79	650	7.3	8.2	1.1	Lam (2017), Lam et al. (2017a,b)

[1] Palaeoflood data obtained from Lam (2017), unless otherwise stated.

[2] This estimate is obtained by the US Bureau of Reclamation method of estimating flow velocity from boulder dimensions. The PMF estimate is obtained from Flay (2001) and Flannagan Consulting Group (2014a,b).

[3] PMF value obtained from Wohl (1992a)

om gauges in 6 climate zones in Australia). Lam (2017)'s equation for the AEC is shown below:

$$f(x) = 10^{\frac{Asym}{\left(1+exp\left(\frac{mid-\log(x)}{scal}\right)\right)}}$$

where x is the catchment area and the model parameters are asymptote (*Asym)*, mid-point (*mid*) and scale (*scal*). The values of *Asym*, *mid* and *scal* are 4.825, 0.749 and 1.431 respectively (Lam, 2017).

Figure 6 only includes palaeoflood discharges and not FoR because the former was generally higher than the FoR for most of the rivers examined in this section of the study. The three rivers where the FoR is greater than the palaeoflood discharge (Lennard, Mary, Logan Rivers) are also plotted in Figure 6. A regional distinction is clear where the tropical rivers of Queensland (QLD) plot on the boundary of the AEC, whereas the tropical rivers of the Northern Territory and subtropical rivers plot below the AEC (Figure 5). The palaeoflood discharge that will initiate movement of the Barron River boulders plots just slightly above the AEC. Interestingly, the palaeoflood estimate obtained by Saynor et al. (2020) for the East Alligator is above the AEC and comparable to the PMF of some of the rivers examined in this study (refer to Table 2).

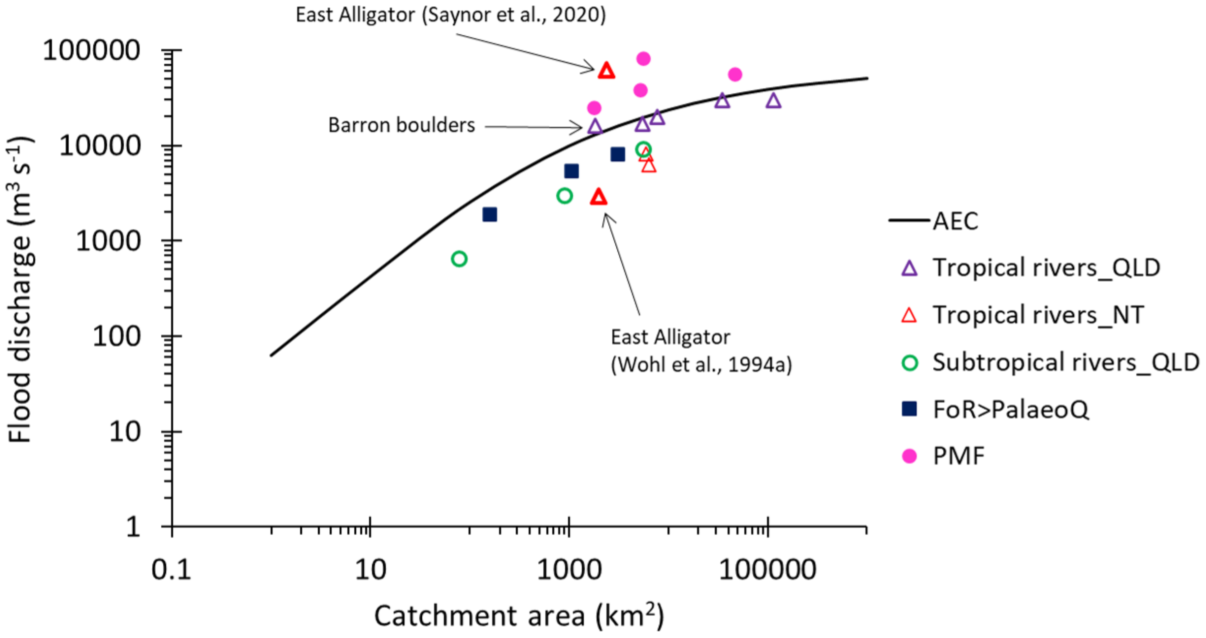


Figure 6: Palaeoflood, Probable Maximum Flood (PMF) and gauged flows where the (FoR is greater than the palaeoflood) plotted against the Australian Envelope Curve (AEC) for tropical and subtropical rivers in Australia.

While Figure 6 shows that the palaeofloods and recent large floods (cases where FoR> palaeofloods) lie on the upper range of the AEC, this analysis is only based on rivers where palaeoflood data exist. Table 2 and Figure 5 do not include the palaeoflood discharges that have resulted in documented cases of floodplain stripping in the Daintree and Mulgrave River catchments (Leonard & Nott, 2015, 2016, Appendix 3). For the floodplain stripping event for the Daintree River, the FoR was 4,150 m^{3}s^{-1} in 2019 (gauging station number 108002A –

Daintree at Bairds) which was the largest flood in 118 years (Callaghan, 2021). But from geomorphic/hydraulic analysis yet to be completed, the 1895 flood was much larger. This claim is made from existing accounts of a flood event reported in the local newspaper in 1895, which washed away a house located in the Upper Daintree, killing six people. Having approximated the location of the house washed away in the 1895 flood, we know that the 2019 flood did not reach this height. Future work to determine the flood magnitude and fluvial processes that result in floodplain stripping and estimation of associated flood magnitudes will focus on the use of landscape evolution models such as CAESAR (https://csdms.colorado.edu/wiki/Model:Caesar) before the information shown in Table 2 and Figure 5 can be updated to improve understanding of floods in tropical and subtropical Australian rivers. These efforts are supplemented by information gathering from historical accounts of floods to improve understanding of the causes, impact and response to floods, a topic covered in the next section of this report.

3. HISTORICAL ACCOUNT OF BARRON RIVER FLOODS

3.1 Context

The Australian Institute for Disaster Resilience (2017) recommends the construction of local flood histories as part of flood studies 'to provide an understanding of the full range of flood behaviour and consequences.' (p.4). The type of history to be pursued is not specified by the Institute but from the text it appears to involve quantified flows that can be used in flood frequency analysis and for calibration of hydrologic and hydraulic models. This could include documentary and cartographic information, data from tree rings and flood sediments, the discharge required to move boulders in rivers or scour bedrock, and other information sources (Ballesteros Canovas et al., 2020). For the purposes of the present contribution, documentary sources will be used.

Flood histories globally have been used to extend hydrologic records (e.g., Potter, 1978; Bayliss and Reid, 2001; Thorndycraft et al., 2003), identify flood prone areas (Conesa Garcia and Garcia Garcia (2003), and improve risk assessment (Williams and Archer, 2002). With an increasing trend to flood risk management rather than flood control through structural solutions such as levees, local flood histories are likely to provide important information for the development of greater resilience of people at risk of flooding (e.g., Puzyreva and Vries, 2021).

For the last of these uses, Puzyreva and Vries (2021) make the important point that local flood histories can help to create shared responsibility for flood mitigation between local communities and a professional disaster management authority. This approach also permits more context-specific understanding and knowledge for mitigation decision-making, making communities more flood resilient. And it has been shown in Europe that local flood histories are key factors affecting community engagement with flood management (Bradford et al., 2012; Thaler et al., 2016). Local flood histories also remind people that floods recur, especially if there haven't been any large floods for decades which is the case for the Barron River. In other words, they create an enduring memory.

This section interprets the historical accounts on the flooding of the coastal Barron River fan delta, where the river emerges from the Macalister Range and Barron Gorge, for a 132-year period from the inception of European settlement in the Cairns region to present day (1876-2009). The information is presented chronologically and has been sourced from newspaper articles, Colonial Secretary correspondence (QSA), land selection documents (QSA), Cairns Historical Society Bulletins, the Cairns Historical Society Photo archive, and secondary sources. References to the historical material is found in Appendix 4. The earliest accounts of flooding related to the Barron River fan delta were in relation to flooding in the Smithfield townships (1876-1879).

3.2 Background of Cairns and Smithfield

Cairns was established in October 1876 as a coastal port to the Hodgkinson goldfield, but within a month, Smithfield township (1876-1879) was established on the northern bank of the Barron River about 15kms from Cairns. Today the township site is in the suburb of Cara Vonica. Smithfield was easily accessed by boat from Cairns and soon became the primary centre of commerce at Trinity Bay. Smithfield's advantages over Cairns were its proximity to the range tracks, Smith's Track and the Douglas track, that first provided overland access from the coast to Thornborough and the other townships of the Hodgkinson goldfield, as well as abundant feed and water for packers' stock in the vicinity of Smithfield. In about March/April 1877, Smithfield township became a township in two parts: Smithfield township, the original township grid of four sections on the Barron River, and West Smithfield (1877-1879) northwest of the township and situated on the Cairns to Thornborough Road (see C199.5). This clarification becomes important to understating the course flood waters may have taken during the flooding events of the late 1870s and 1880s. However, West Smithfield is rarely referred to; making the impacts from flooding to the two different areas harder to distinguish.

The Cairns to Thornborough Road, once it crossed the Barron River to the northern bank in the Smithfield area, followed a natural arc of interspersed lagoons to the east of the road and passed through West Smithfield. The lagoons' proximity to the road provided travellers and their stock, as well as the stores, hotels and private homes established along the road with an accessible water supply. The pre-cut path of the road provided a path for the later telegraph line to follow, telegraphically connecting Smithfield beyond the confines of its tropical location. However, the builders, road and telegraph-makers had possibly not factored in the chain of lagoons' propensity to act as a distributary of the Barron River during severe flooding, when establishing these infrastructures, which so catastrophically impacted West Smithfield in the floods of 1879.

The site for Smithfield township was a considered decision. It was positioned at the head of navigation where the riverbank rose 20 feet (*Queenslander* 30 December 1876:13). Situated on a 20-foot riverbank suggests a consideration of flood risk by the settlers. However, Smithfield's demise is historically linked to severe flooding in 1879. By the 1880s, Smithfield township no longer existed, but the broader landscape had been officially opened for acreage land selection in April 1878 and many of Smithfield's previous inhabitants transitioned to acreage properties in the vicinity of Smithfield township and south of the Barron River in the Freshwater Creek area.

The *Queenslander* (10 February 1877:6) notes that the north bank of the Barron River is a fertile valley where the soil, 'in most places is a rich humus, while the valley itself is intersected with belts of the finest timber, forming at places' dark and dense jungles. While land on the south bank 'is a sandy waste, where the usual forms of the Eucalypti grow' (*Queenslander* 10 February 1877:6). The Barron River carried 'a large stream of water during the driest season of the year' (*Queenslander* 10 February 1877:6).

1877

The first European records of flooding in the Barron River are associated with the January to March 1877 wet season. However, there are conflicting reports as to whether flooding of the Barron River occurred at Smithfield township (e.g., *Brisbane Courier* 12 March 1877:2; *Wee*k 3 March 1877:8) or not (e.g. *Brisbane Courier* 13 March 1877:2; *Telegraph* 3 March 1877:2; *Week* 10 March 1877:18). The articles claiming that flooding occurred state that 'nearly the whole of the site of the township of Smithfield was flooded' and goods in Mr Craig's store, valued at £400, were destroyed (*Week* 3 March 1877:8). Central to the claims that flooding did not occur at Smithfield are the reports quoted from merchant Robert Craig. Craig's public denial of flood waters affecting his stores at Smithfield township may have been made to maintain commercial confidence in his business and the commercial prospects of Smithfield more generally. Craig only concedes that a few kegs of powder were damaged, which were stored about a mile from the township (*Brisbane Courier* 13 March 1877:2). A one-mile arc radius from Smithfield township places the stored powder kegs in the vicinity of the arc of lagoons that the Cairns to Thornborough Road, near Smithfield, followed (see C157.314).

Placing the floods waters back at the Smithfield township site is the *Telegraph* (5 April 1877:3) which notes that 'water has been up to the floors of the storehouses, and there are indications of former flood marks, which show the water to have been fifteen feet higher than the recent fresh'. It is unclear if the storehouses referred to in the above quote were attached to the two landings/wharves at Smithfield or if they were on the allotments closest to the riverbank (see S199.1 and S199.2). The reference to 'former flood marks' highlights that during the first three months of 1877 there were several flooding events associated with a gale and heavy rain as well as several Spring tides (QSA IID 846965 - 77/751; *Telegraph* 5 April 1877:3).

Further mention of flooding at Smithfield, in early 1877, comes from correspondence from Cairns Police Magistrate, Edmund Morey, to the Colonial Secretary dated 25 February 1877, Morey wrote:

> Sir, from a reliable source I learn that the township of Smithfield on the Barron was on Wednesday last all but submerged. The waters rose to within three feet of the highest part of the township, while all the surrounding country was under water. From the same authority I gather that the rain lasted but ninety [?] four hours, and that another day's rain must have covered to some depth every part of Smithfield (QSA IID 846964 -77/750).

Evidence for flooding on the Barron River at Smithfield in early 1877 outweighs the evidence saying that flooding did not occur. Flooding at Cairns during the same period (*Telegraph* 5 April 1877:3) confirms that climatic conditions predisposed the district to flooding. By mid-April, the wet season, that amounted to between 80 and 90 inches of rain, was reported as having passed (*Queenslander* 14 April 1877:6).

Undeterred by the recent wet season, Smithfield's residents proceeded with township allotment purchases at the two Smithfield land sales on 15 February 1877 and 29 May 1877. Several businesses also started establishing West Smithfield (*Week* 26 May 1877:8). These activities suggest that the levels of flooding recently experienced were not a deterrent to the continued progress of the township and West Smithfield. However, in June 1877, questions were raised in a sitting of the Queensland Government concerning Smithfield's flood levels. Pettigrew wished to know whether Smithfield's flood levels had been ascertained prior to the land sales because he had been informed that a large portion of Smithfield would be under water as soon as there was a flood (*Brisbane Courier* 29 June 1877:3). In response, Douglas commented that:

> he had not even heard that any part of the town was under water. The place was in great favour, and there would be another land sale held there shortly. If the hon. Member [Pettigrew] had information that any part of the land proposed to be sold was dangerously below flood-mark, he would be glad to be supplied with it (*Brisbane Courier* 29 June 1877:3).

It is worth noting that Macrossan did not believe that the Government should withhold from selling town lands because they were subject to floods. Rather, he felt that 'it was the duty of the residents to provide against any danger that might arise in such places' (*Brisbane Courier* 29 June 1877:3). Furthermore, Macrossan opined that 'if the Government were prohibited from selling lands that were subject to floods their land sales would come to a sudden stop' (*Maryborough Chronicle, Wide Bay and Burnett Advertiser* 30 June 1877). Douglas' mention of another land sale to be held shortly probably refers to the selling of township allotments in the West Smithfield area (see S199.3 and S199.3b, S199.5), but there is no archival evidence that any of these allotments were sold.

1878

The *Queenslander* (9 February 1878:8) notes that the wet season was late in arriving at Cairns and Cardwell (established 1864): 'the really heavy continuous rain, that is a "sure thing" in Cardwell in the first week of January has not been so late in arriving for the past few years'.

Finally, the Cairns region was hit by a cyclone on 8 March 1878 with cyclonic winds and heavy rain. On Thursday 7 March 1878, the barometer suddenly fell at 10pm from 81 deg. to 68 deg. and a few hours later to 63 deg. A little after 3am on Friday 8 March ‘an extraordinary fall of 34 deg. took place, the register showing 28.90. An hour later the wind attained a hurricane violence, unroofing houses, shaking buildings, breaking branches of trees, and uprooting others and carrying them before it. The road between Cairns and Smithfield was so blocked up with fallen timber that for 5 days after the storm traffic was entirely suspended’ (*Brisbane Courier* 6 April 1878:6).

Impacts from the cyclone included large boulders dislodged from the top of the hills that carved cleared avenues through the dense hillside vegetation, immense trees were uprooted, while the remaining trees were denuded of their leaves. Despite the various reports of destruction to infrastructure at Cairns and Smithfield from the cyclone (e.g., *Australian Town and Country Journal* 30 March 1878; *Evening News* 6 April 1878:5; *Morning Bulletin* 21 March 1878:3) there are no references to the Barron River flooding.

1879

Major flooding of the Barron River occurred in March 1879 that severely impacted the West Smithfield area (*Brisbane Courier* 18 April 1879:2; *Morning Bulletin* 4 April 1879:2; *Morning Bulletin* 14 April 1879:4; *Queenslander* 19 April 1879:487). Of the articles appearing in the newspapers following the March 1879 flooding of the Barron River only the *Queenslander* (19 April 1879:487) specifically states that the flooding was to West Smithfield. The other articles just say Smithfield was flooded (e.g., *Brisbane Courier* 22 February 1879:7). The March 1879 flooding event is cited by twentieth century authors as the reason Smithfield was abandoned because they claim it was ‘washed out to sea’ (e.g., Favell 1976; Griffiths 1959; Hale 1996:5; Hooper 1993:385; Idriess 1958:50; Lack 1971:234; Pike 1956:13).

In January and February 1879, there was heavy rainfall that impacted the roads, and the Barron River experienced several freshes (*Brisbane Courier* 22 February 1879:7; *Queenslander* 15 February 1879:221). From 17-25 March, there was a continual downpour of heavy rain, accompanied by violent wind gusts, that caused severe flooding of the Barron River, as well as flooding at Cairns (*Morning Bulletin* 4 April 1879:2). Other impacts were the dislodgement of boulders from hill tops, and landslips that caused the earth to shake and rumbling noises heard by the Cairns townspeople (*Morning Bulletin* 14 April 1879:4). Various newspaper articles mention the impacts to several Smithfield residents and their properties (e.g., *Brisbane Courier* 18 April 1879:2; *Morning Bulletin* 4 April 1879:2; *Morning Bulletin* 14 April 1879:4). The properties mentioned were all proximal to the arc of lagoons that the Cairns to Thornborough Road followed and were predominantly located at West Smithfield. This correlates with the *Queenslander* (19 April 1879:487), which notes that ‘The river broke over its bank at Bill Smith’s crossing and rushed down on west Smithfield’. It is unclear whether ‘Bill Smith’s crossing’ refers to the upper or lower crossings of the Barron River near Smithfield. Figure 7 shows the locations of the properties mentioned in the newspapers (1-6), which are described below.

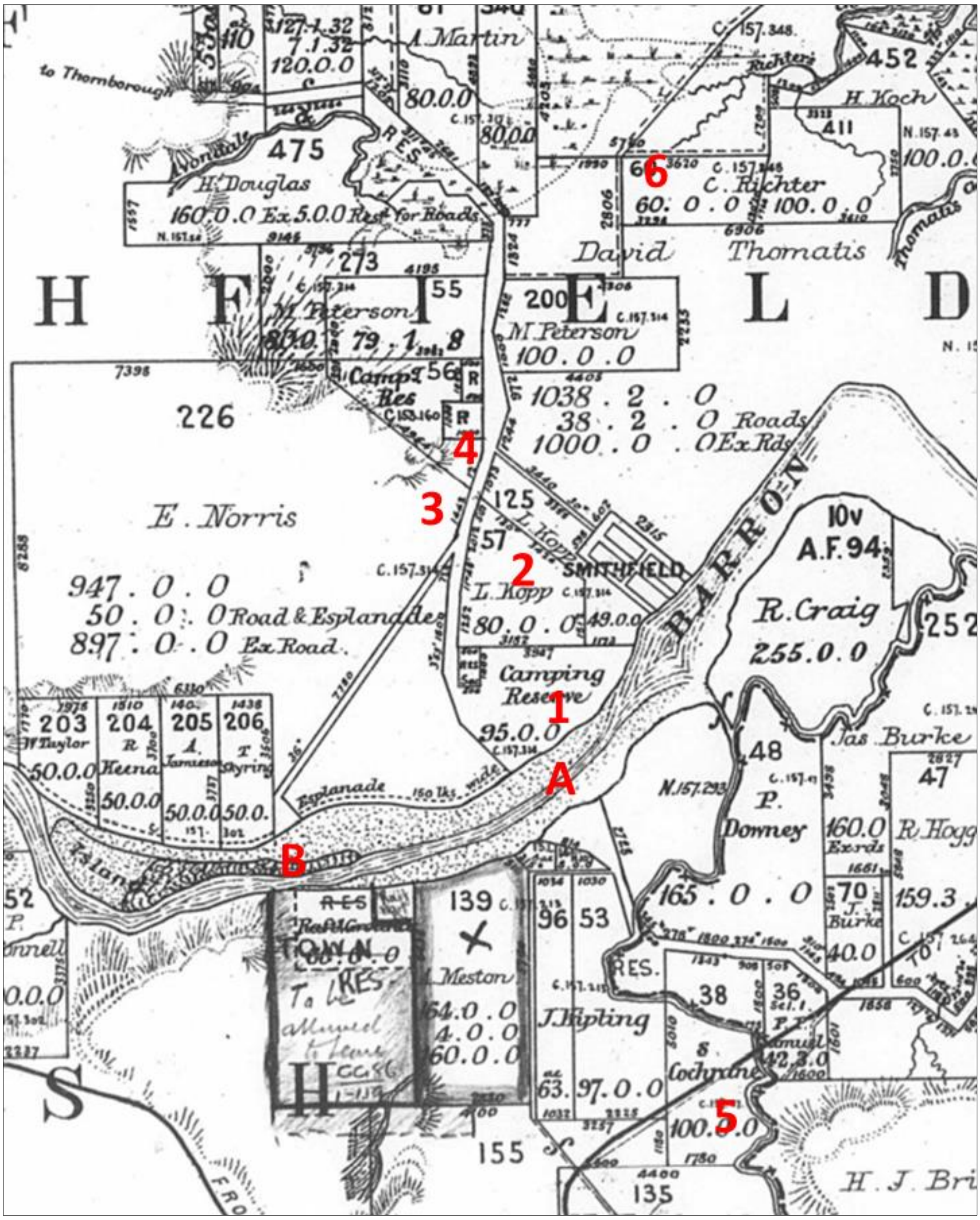


Figure 7: Visualisation of properties mentioned in the 1879 newspapers. Key: 1, Cameron's selection no.59; 2, Kopp's selection no.57; 3, Frith's hotel (estimated location); 4, Clifton & Aplin's store (estimated location); 5, Cochrane's selection no.38; 6, estimated location of where sarsaparilla bottles were found in 1888; A, lower crossing of Barron River; B, upper crossing of Barron River (QSA ID ITM37870).

1. Donald Cameron's house and crop was under water (*Morning Bulletin* 14 April 1879:4). Cameron was the ferryman at the Lower crossing of the Barron River (A; B shows the Upper crossing). The location of Cameron's house is unknown, but it was probably fairly close to the Barron River crossing. Cameron's property, land selection no.59, later became a camping reserve in the early 1880s after Cameron forfeited the selection (see C157.314). Surveyor Horan's 1881 survey of selection no.59 shows a large lagoon on the property (Figure 8), which is not indicated on Surveyor Behan's 1883 survey (see C157.314).

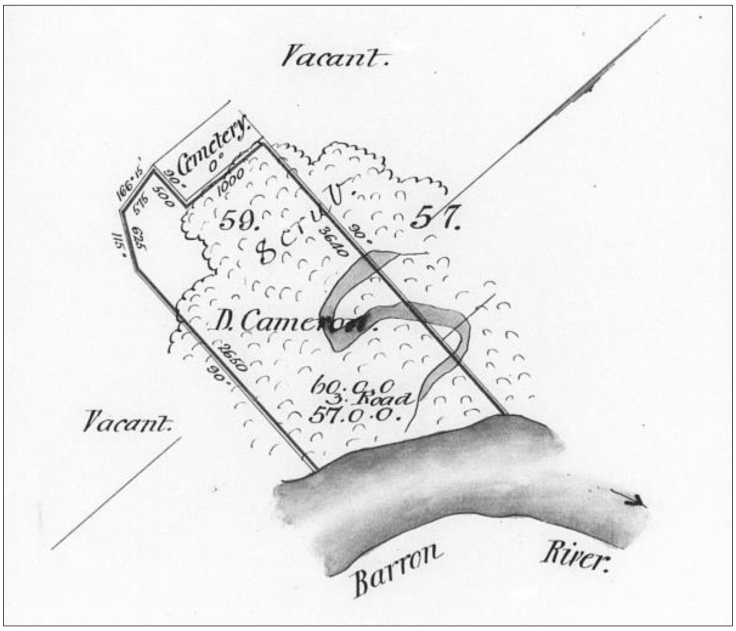


Figure 8: Thomas Horan's survey of Cameron's Selection no.59 dated 12 May 1881, Cat. No.C157.112 (QSA ID ITM37821).

2. Louis Kopp had the neighbouring selection no.57 (Figure 9). His house was close to the largest lagoon in the Smithfield area (see C157.314). The 1879 flooding 'destroyed' the Kopp's farm and Mr and Mrs Kopp were forced to occupy the top rail of the stockyard for 24 hours (*Morning Bulletin* 14 April 1879:4). 'Destroyed' is probably exaggerated because they remained on the property until 1893. According to the 1885 property inspection, Kopp's house was on piles four feet high (QSA ID ITM37819). This seems sensible given the house's proximity to the lagoon, but it is unknown if the house was always on four-foot piles.

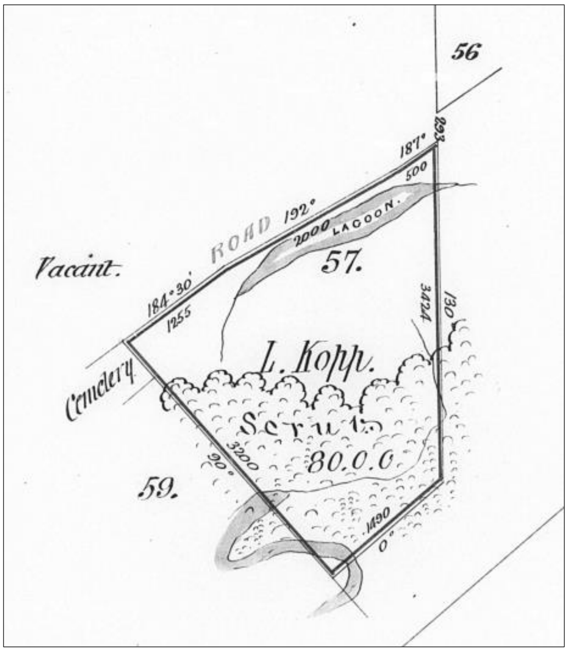


Figure 9: Thomas Horan's survey of Kopp's Homestead Selection No.57 dated 12 May 1881, Cat. No. C157.122 (QSA ID ITM37819).

3. The *Brisbane Courier* (18 April 1879:2) notes that 'Robert Frith's house has also washed away and came in contact with Clifton and Aplin's premises'. 'House' is believed to refer to hotel because Frith was the publican of Frith's hotel on the Cairns to Thornborough Road, but the exact location is unknown (Figure 6).

4. Clifton and Aplin's store (Figure 7), which had a frontage of forty feet by a depth of eighty feet (*Week* 26 May 1877:8), was washed off its stumps and moved thirty yards away (*Brisbane Courier* 18 April 1879:2;). The *Queenslander* (19 April 1879, page 487) says the store was transported 60 yards away. Marks inside the store showed a 5ft high water level before the store was moved, and a mud deposit 6in to 12in deep remained after the flooding (*Brisbane Courier* 18 April 1879:2).

5. Extensive flooding was also reported south of the Barron River in the Freshwater Creek area, an area in 1879 described as Smithfield. Samuel Cochrane's property, land selection no.38 on Freshwater Creek and the Cairns to Thornborough Road, was flood affected (Figure 7). The rooms of Cochrane's house which were on piles nine feet above the ground were flooded. Freshwater creek was flooded to a quarter of a mile to the Cairns side of Cochrane's property (*Brisbane Courier* 18 April 1879:2).

6. In 1888, six intact Dr Townsend sarsaparilla bottles were found at the head of Richter's Creek about one and a half miles from Clifton and Aplin's store at West Smithfield, which is where they were believed to have transported from by the 1879 flood waters (Figure 7) (*Queensland Times, Ipswich Herald and General Advertiser* 17 November 1888:7). The same article adds that 'the flood was about 12 feet deep in the main Street' (*Queensland Times, Ipswich Herald and General Advertiser* 17 November 1888:7). The main street referred to is the main street through West Smithfield which was the Cairns to Thornborough Road.

Given the impacts of the 1879 flooding reported, it is curious that the *Morning Bulletin* (4 April 1879:2) reported that: 'although the rain [in March 1879] has been heavier than upon any known previous occasion, the Barron River is not so high as last year [1878] when the wet season was a very light one'. If flooding of the Barron River was higher in 1878 than in 1879 as the *Morning Bulletin* (4 April 1879:2) contends then one would expect the 1878 newspapers to have reported on it, but the 1878 newspapers do not indicate any flooding of the Barron River.

Research shows that, in 1879, the flooded Barron River broke its banks above Smithfield and followed the natural arc of interspersed lagoons, to the east of the Cairns to Thornborough Road, creating a distributary of the Barron River that flooded West Smithfield to a depth of 12 feet, and with a force capable of shifting buildings in its path (*Brisbane Courier* 18 April 1879:2; *Queenslander* 19 April 1879:487; *Queensland Times, Ipswich Herald and General Advertiser* 17 November 1888:7). The 1879 flood event contributed to the abandonment of township settlement at Smithfield township and West Smithfield, but the land selectors remained.

Smithfield land selectors, which included selectors in the Freshwater Creek area continued to be impacted by flooding of the Barron River and Freshwater Creek in the 1880s. Figure 10 shows the land selections on the south bank of the Barron River in the Freshwater Creek area. The precise date of the map is unknown, but it probably dates to the early 1880s. Note the 'liable to inundation' notations on the properties along Freshwater Creek. The 'clearing' on selection no.38 was probably where Cochrane's house, described in the 1879 floods, was located (QSA ID ITM37867). A sketch map of some of the selections in the Freshwater Creek area also shows ‘flooded land’ (Figure 11).

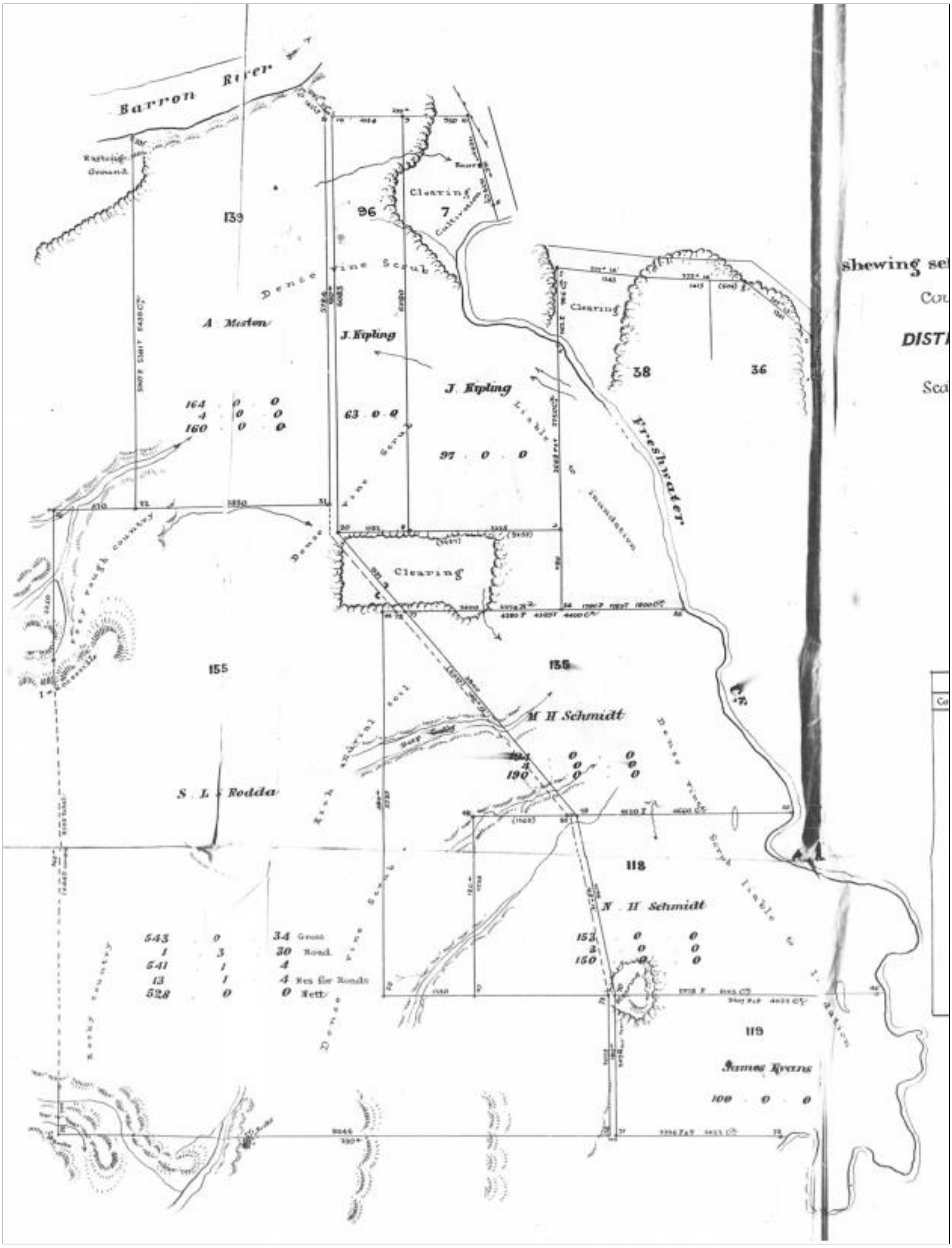


Figure 10: Land selections on the south bank of the Barron River in the Freshwater Creek area. The ‘clearing’ on selection no.38 was probably where Cochrane’s house, described in the 1879 floods, was located (QSA ID ITM37867).

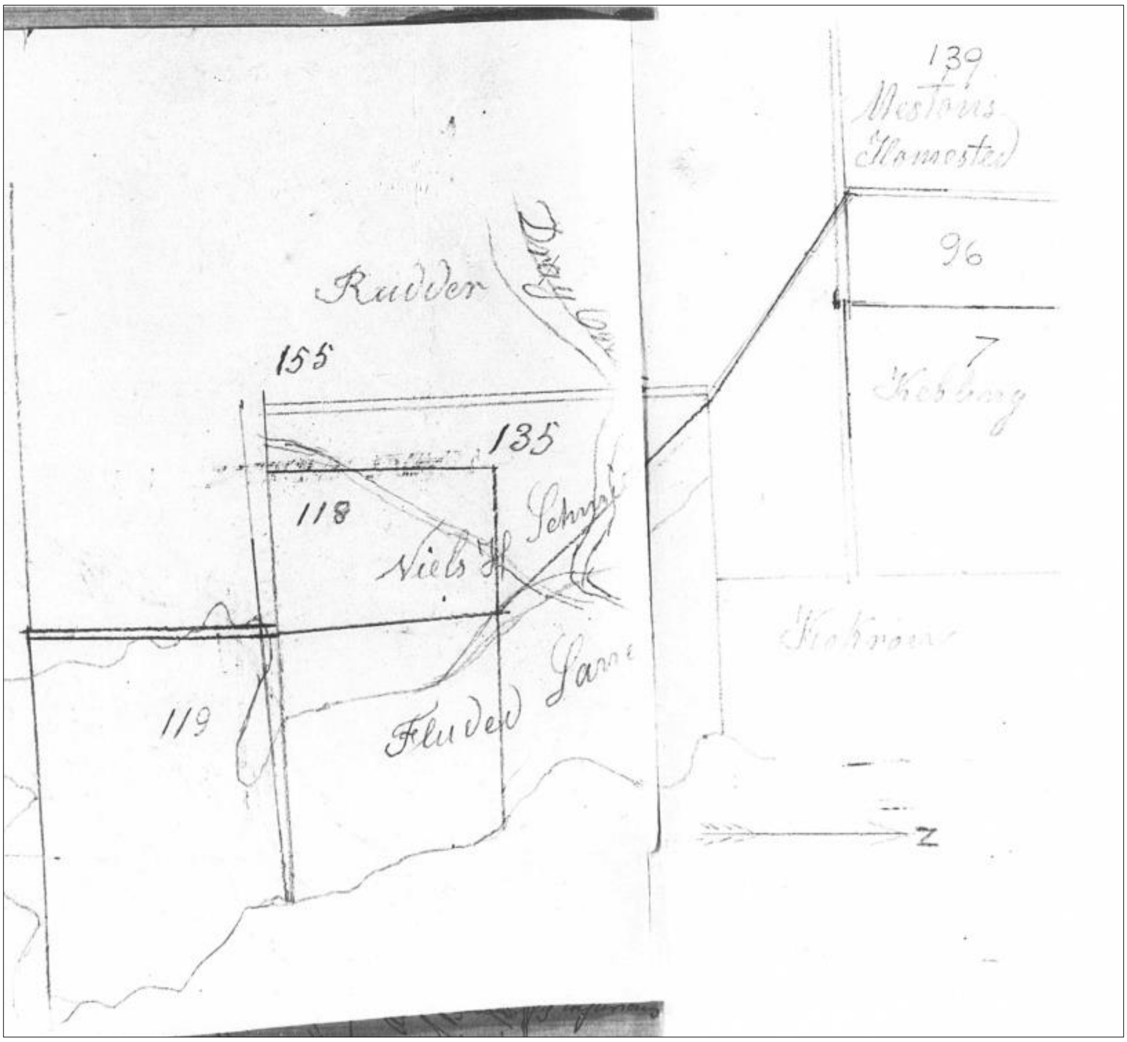


Figure 11: Sketch map showing ‘flooded land’ near Freshwater Creek. ‘Rudder’ refers to Niels Hansen Schmidt’s neighbour, Stephen Rodda, on selection no.155 (QSA ID ITM37867).

1880

The *Morning Bulletin* (9 January 1880:2) reported that ‘Old 1879 was completely washed out without allowing the people to bid it adieu, and young 1880 came into existence undergoing severe ablutions’. Rain began to fall on 30 December 1879 and by 2am Wednesday morning [31 December] ‘one of those lively torrents came pouring down in first-class style and continued with brief intervals till Friday [2 January 1880]’.

The Barron River flooded in 1880 (*Morning Bulletin* 30 January 1880:2). The *Morning Bulletin* (23 January 1880:2) reported that:

> The wet season has set in unusually early…Continual heavy rain has prevailed since the 11th instant [11 Jan], and the tides have been higher than have been seen in Cairns before; nor, in fact, has such stormy and wet weather been experienced in the month of January since the opening of the town [1876]. It is said that more rain has fallen from Sunday [11 Jan] to Wednesday last [14 Jan], than fell in any one week during the past two or three years. On Wednesday, Fresh Water Creek was flooded, and the water reached within a foot of Cochrane’s residence [selection no.38], which is erected on 9ft piles. The Barron and Hodgkinson rivers are also impassable. Telegraphic communication

> has been stopped since Tuesday morning last. The rain is still falling incessantly as we go to press [Advertiser, January 17].

More heavy rain fell in April. The *Week* (1 May 1880:11) reported that the district experienced 'very heavy rainfall from Saturday last [10 April] until Tuesday [13 April] causing the Barron and the Mulgrave rivers to rise several feet'.

1881

The *Queenslander* (9 April 1881:473) reported that there were heavy falls of rain in February and again in March 1881 when rainfall 'submerged the rear of the main street [Abbott Street, Cairns] allotments and the upper part [northern end] of the main street, which is so admirably situated for receiving the surplus waters of the contiguous flats, creeks, and swamps'. The *Queenslander* (9 April 1881:473) stated that the 1881 wet season was worse than the wet season of 1879: 'The few years' experience of Cairns shows that this wet season has, up to now, been the heaviest'.

Samuel Croft, land selector on selection no.56 at West Smithfield, wrote, in March 1882, that he had been subjected to two heavy floods since living in the area (QSA ID ITM37818). These are believed to be the floods of 1879 and 1881.

The February rainy weather caused the Mulgrave River to rise 9 feet (*Telegraph* 28 February 1881:3).

Further reference to flooding in 1881 appeared in the *Cairns Post* (1 November 1926):

> During the 1881 flood the waters reached the foot of the range, all Smithfield being submerged, and the few residents had a very anxious time. Mrs Kopp was three nights and four days in a flattie, and subsisted on a young pig that she caught when swimming past the boat.

This Kopp anecdote is problematic because no other source corroborates its content. Written 45 years after the event, perhaps the author has confused the year, perhaps this event and the Kopps stranded on the top rail of the stockyard in 1879 are recalling the same event.

Broughton (2007:3 Part 2), writing about the floods in 1911, writes that Joseph Kipling, one of the first land selectors in the district (selections no.53 and 96), noted in 1911 that 'about 30 years ago [1881] there was a similar flood in the river but at the time due to there being less cultivation, the current was not so swift, and consequently there was less damage done'. However, two men on reaching Freshwater Creek 'discovered a small sea with a strong current', which swept them away as they tried to cross (*Queenslander* 26 March 1881:391). Furthermore, the *Queenslander* (16 April 1881:501, 23 April 1881:519) reported that the selectors between Cairns and Freshwater Creek had incurred damage and will probably abandon their locations, 'being too poor to fight against floods'.

1883

There are no 1883 newspaper reports of flooding of the Barron River in 1883. However, Alfred Martin's obituary (*Cairns Post* 25 August 1919:4) says that Martin's hotel at Smithfield township (Beehive Hotel) was washed out by the big flood of 1883. Either there was a big flood in 1883, like the 1879 flood, or the writer has mistaken the dates. However, given that Martin's hotel was still standing and survived the fire at Smithfield township in October 1880, the reference to 1883 is possibly correct (*Morning Bulletin* 18 October 1880:2). Flooding in the Daintree River in 1883 might suggest that the Barron River also flooded (see Summary Daintree River) (*Brisbane Courier* 5 May 1883:6).

1884

Early in 1884, rivers rose and a bridge crossing the Barron on the Tablelands was damaged when its planking was swept away. Timber getters used this opportunity to float 3,000 cedar logs down the Barron River (*Week* 15 March 1884). Archibald Meston recorded in the *Brisbane Courier* (9 January 1885:2) that 'tons of fish, killed as they go over the Barron Falls', came down the river in March 1884. Freshwater Creek also rose and became impassable (*Cairns Post* 21 February 1884:2). The Endeavour River at Cooktown also flooded. The Endeavour bridge was damaged (CHS P00585).

1886

The *Week* (4 June 1887:24) described the 1886 and 1887 wet seasons as 'unprecedented heavy rainy seasons'.

Meston, writing in the *Queenslander* (6 February 1886:215) noted that on 1 January 1886 the Barron River rose to within 4 and a half feet of seven years ago [i.e. 1879] 'when Smithfield was submerged, and the surrounding selectors were picturesquely roosting on the roofs of their flood-surrounded houses for two days!' The problem with Meston's account is that he was not in north Queensland in 1879, so his article is not providing a first-hand account of 1879, though he could have been informed by someone who was. However, Meston's *Queenslander* account of the Barron River in January 1886, was made 2 days after 20 inches of rainfall in 24 hours (*Brisbane Courier* 21 December 1887:9).

1887

The *Morning Post* (27 March 1903:5) notes that 1887 was one of four years in 16 years (1887-March 1903) that had annual rainfall exceeding 100 inches: 1887 annual rainfall was 137 inches. Therefore, this information means that annual rainfall did not exceed 100 inches in 1888, 1890, 1892, 1893, 1895, 1896, 1897, 1898, 1899, 1900, 1901, 1902.

Given this finding, further research was undertaken, which revealed the following.

The 'Highest flood in the Barron for 7 years' occurred 1-3 January 1887 (*Sydney Mail and New South Wales Advertiser* 29 January 1887:237). Before tumbling over the Barron Falls the torrent of water was described as '300 yards wide and about 60 feet deep, rushing resistlessly along at the rate of 20 miles an hour' (*Sydney Mail and New South Wales Advertiser* 29 January 1887:237). Flooding of the Barron was also reported in February (*Telegraph* 23 February 1887:5). More rain fell, 17.92 inches, in early March (Thursday 3-Monday 7 March) 1887: 3rd March 1.12 inches; 4th March 2.11 inches; 5th March 4.11 inches; 6th March 9.12 inches; 7th March 1.46 inches (*Cairns Post* 10 March 1887:2). The rain was accompanied by stormy weather with alternate NE and SE winds and high temperatures. The Barron River, little Mulgrave River and Wright's Creek were swollen. On the 5-6 March Freshwater Creek could only be crossed by swimming 'there being a very heavy fresh coming down' (*Cairns Post* 10 March 1887:2). It was dangerous to cross the Barron River at the upper crossing, near Meston's property, because of the 'large body of water' in the river (*Cairns Post* 10 March 1887:2).

A further 7.12 inches fell in 24 hours ending 9am on 18 March, and there were concerns that the swollen Barron River and Freshwater Creek would flood (*Toowoomba Chronicle and Darling Downs General Advertiser* 22 March 1887:1). Days later the Barron River was reported as overflowing its banks with the surrounding country submerged (*Morning Bulletin*

23 March 1887:5). The *Week* (4 June 1887:24) described the 1886 and 1887 wet seasons as ‘unprecedented heavy rainy seasons’.

The *Brisbane Courier* (21 December 1887:9) mentions that there were floods in October 1887 after 5 months of continuous drought.

1888

Cairns received over 20 inches of rain between 7-10 January 1888 making all the rivers and creeks in the district impassable. The Barron River ran a banker (*Sydney Mail and New South Wales Advertiser* 21 January 1888:153). Freshwater Creek was 4-8 feet (1.21 m to 2.43 m) over the railway line (*Brisbane Courier* 23 January 1888:7; *Sydney Mail and New South Wales Advertiser* 21 January 1888:153; *Sydney Morning Herald* Friday 13 January 1888:8). Water over the railway line at Freshwater Creek stopped the running of trains (*Brisbane Courier* 23 January 1888:7).

The flooding of Freshwater Creek caused an ana-branch that surrounded John Parker’s selection (selection no.147) with deep and swift running torrents (*Newcastle Morning Herald and Miners’ Advocate* 26 January 1888:5) (Figure 12). John Nairne, the manager on Shaw’s selection no.137 (QSA ID ITM37868) swam across the flooded Freshwater Creek to check on his neighbours, the Parkers, only to find John Parker dead and his wife, Mary, and their three children cut off by the flooded Creek (Figure 13) (*Cairns Post* 14 January 1888:2. The Mulgrave River also rose higher than it has been for the last three or four years (Telegraph 31 January 1888:3).

More flooding occurred in the Barron River in March 1888. On the 11 and 12 March flooding of the Barron River caused Kamerunga to be cut off and Freshwater Creek to flood. Robert Craig’s selection near Freshwater Creek ‘was entirely submerged, and his bailiff had to leave the house for 24 hours’ (*Cairns Post* 14 March 1888:3). The Chinese hands employed there followed suit (*Cairns Post* 14 March 1888:3).

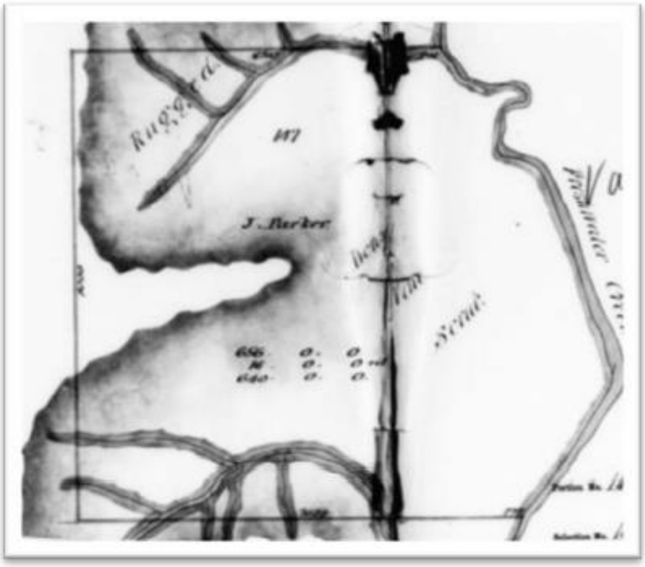


Figure 12: John Parker’s land selection no.147 (QSA ID ITM37877).

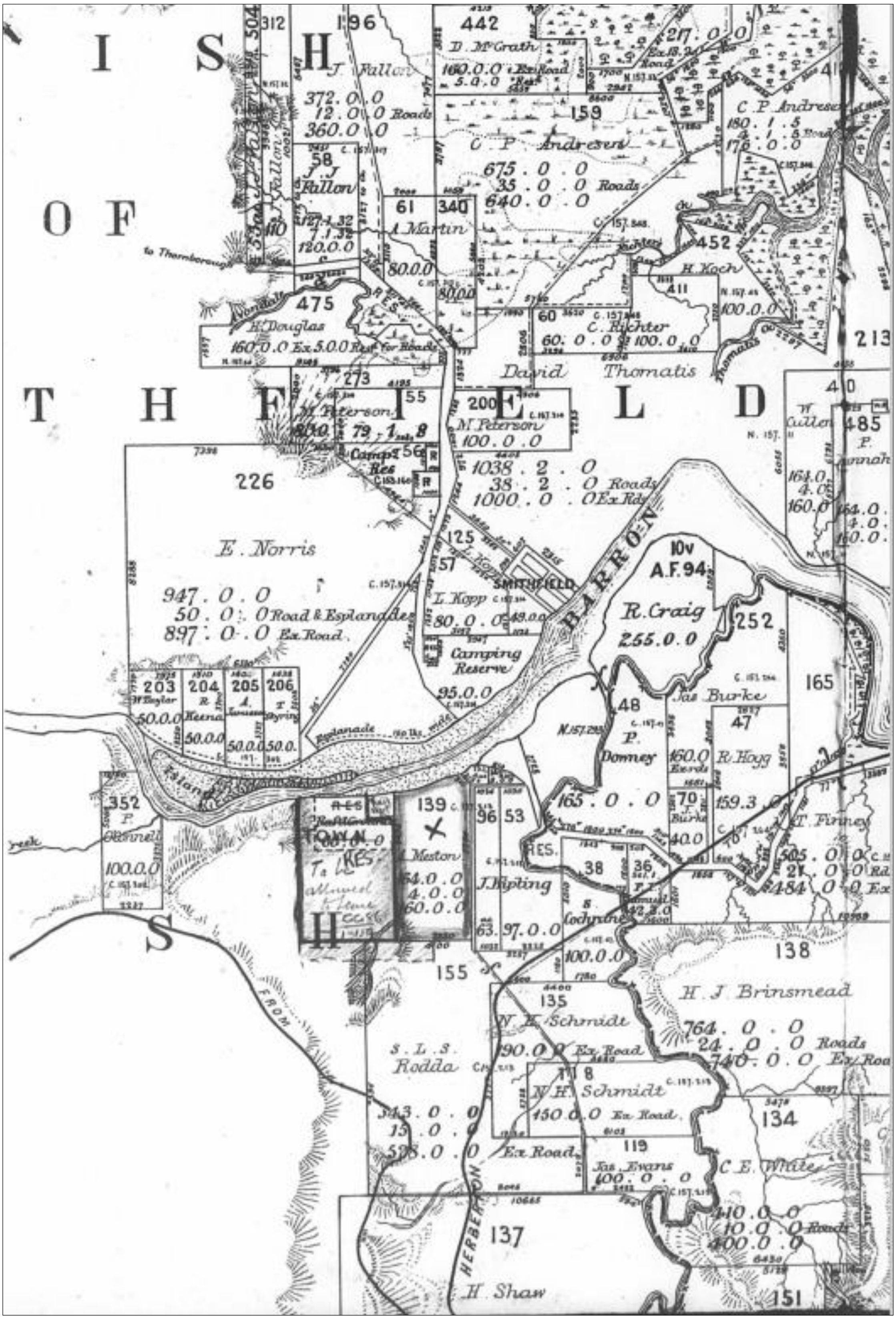


Figure 13: Smithfield land selections referred to in the text include Cochrane's selection no.38; Kipling's selection no.53 and no.96; Croft's selection no.56; Kopp's selection no.57; Cameron's selection no.59; Shaw's selection no.137; Parker's selection no.147 which was beneath Shaw's selection. Mason's selection no.395 and Cochrane's selection no.160 are shown in Figure 14 (QSA ID ITM37870).

1889

The *Morning Post* (27 March 1903:5) notes that 1889 was one of four years in 16 years (1887-March 1903) that had annual rainfall exceeding 100 inches: 1889 annual rainfall was 123 inches. Therefore, this information means that annual rainfall did not exceed 100 inches in 1888, 1890, 1892, 1893, 1895, 1896, 1897, 1898, 1899, 1900, 1901, 1902.

1891

The *Morning Post* (27 March 1903:5) notes that 1891 was one of four years in 16 years (1887-March 1903) that had annual rainfall exceeding 100 inches: 1891 annual rainfall was 134 inches. Therefore, this information means that annual rainfall did not exceed 100 inches in 1888, 1890, 1892, 1893, 1895, 1896, 1897, 1898, 1899, 1900, 1901, 1902. Thirteen inches of rain fell between 18 January to 24 January 1891 and all the rivers were flooded (*Sydney Mail and New South Wales Advertiser* 7 February 1891:286).

The Barron River flooded in February 1891 and the rice crops of Behan's North Queensland Rice Milling Company were washed away (*Week* 20 February 1891:13; *Week* 24 April 1891:16). The flooding of the Barron River inundated the low-lying land on the north side of the river. In the 24 hours to 9am on 10 February, 1.45 inches of rain had fallen at Cairns. During the same period, the Herbert River flooded having received 10 inches of rain, and there was flooding of the Endeavour River where 3.28 Inches of rain fell at Cooktown (*Queensland Times Ipswich Herald and General Advertiser* 11 February 1891:3). In the 24 hours to 9am on 12 February, 6.32 inches of rain had fallen at Cairns (*Gympie Times and Mary River Mining Gazette* 14 February 1891:3). At Kamerunga, the water was within a foot of the office and the population at Kamerunga was told to take precautions against flooding (*Week* 13 February 1891:20). The office referred to is possibly Robb's railway office. Another source says that during the week prior to Monday 16 February, 26 inches fell at Kamerunga and the Chinese estimated that about 500 tons of corn was damaged as well as a vast extent of the banana crop, due to the Barron River flooding (*Northern Miner* 18 February 1891:3). On Sunday night, 22 February, 'a portion of the bank on the first section of the railway, at Stratford, was washed away' by the flooding (*Morning Bulletin* 25 February 1891:5). The Barron River 'rose to a great height' and 'nearly all Smithfield was submerged (*Morning Bulletin* 25 February 1891:5).

Significant flooding occurred on 5-6 April 1891 on the Russell River with flood marks 20 feet high. The 'Mulgrave rose 70 feet above its normal level – yes it says '70' (O'Keefe 2011:1).

The *Morning Post* (27 March 1903:5) notes that 1891 was one of four years in 16 years (1887-March 1903) that had annual rainfall exceeding 100 inches: 1891 annual rainfall was 134 inches. Therefore, this information means that annual rainfall did not exceed 100 inches in 1888, 1890, 1892, 1893, 1895, 1896, 1897, 1898, 1899, 1900, 1901, 1902.

1893

The *Morning Post* (17 March 1903:3) reported that the March 1903 flood of the Barron River was equal to the Barron River flood in 1893. Given this finding, 1893 needed more research, but the only information found was that on 23 February 2.03 inches of rain was registered and that heavy rain had caused the Barron and Mulgrave rivers to rise by 6 feet (*Telegraph* 24 February 1893:3).

1894

The *Morning Post* (27 March 1903:5) notes that 1894 was one of four years in 16 years (1887-March 1903) that had annual rainfall exceeding 100 inches: 1894 annual rainfall was 122 inches. Therefore, this information means that annual rainfall did not exceed 100 inches in 1888, 1890, 1892, 1893, 1895, 1896, 1897, 1898, 1899, 1900, 1901, 1902.

Flooding of the Barron River occurred twice in 1894: first in January (*Telegraph* 17 January 1894:4; *Week* 19 January 1894:14) when the Barron River rose 17 feet at Biboohra (*Week* 19 January 1894:14). The second time was in April when it coincided with a cyclone that impacted a large swath of far north Queensland (Queenslander 21 April 1894:728). On the night of Friday 6 April 1894, a 'terrific gale with heavy rain' struck Cairns, 'all the country below the range appears to be one sea of water' (*Age* 10 April 1894:5). Similarly, the *Queenslander* (21 April 1894:728) reported that 'It is feared that Smithfield has been cleared of horses and cattle, besides great damage being done to the crops', indicating extensive overbank flooding. The *Telegraph* (10 April 1894:2) printed a short article titled 'Gale at Cairns. Barron River flooded' and reported that 14 inches of rain had fallen. The April flooding of the Barron surpassed the 1879 flood level. It was estimated that the Barron River was 5 feet higher than the 1879 flood, 'when Smithfield was almost wiped out' (*Northern Miner* 13 April 1894:3). The total Cairns rainfall for April 1894 was 36 inches (*Week* 4 May 1894:24). Freshwater Creek rose 2 feet 6 inches (0.76 m) over the railway line (*Age* 19 April 1894:6) and the Slater's house on the Barron River at Kamerunga was washed some distance away resulting in the death of Mr Slater's four-year-old child (*Northern Miner* 18 April 1984:3).

There are two photographs of the Barron Falls in flood in 1894, with one of them shown in Figure 14 below (CHS P00553, P00554). The 1894 flooding of the Barron River is used as a comparison in 1911. For instance, at Mareeba, the Barron River rose one foot higher than the 1894 flood (Broughton 2007:2 Part 1). The *Telegraph* (3 April 1911) wrote that from Saturday 1 April to Monday 3 April 1911, 42 inches of rain fell at Kuranda and the Barron River rose to only one foot below the 1894 flood level.

Figure 14: The Barron Falls, 1894 (Cairns Historical Society P00553).

1895

Kamerunga received over 12 inches of rainfall and the Barron River rose to within 3 feet of the highest known floods (*Daily Northern Argus* 9 April 1895). It is presumed that the highest known flood in 1895 was the 1879 flood, or could it be 1894? (see 1911).

The heavy rainfall was in connection with a cyclone. Flood waters threatened W.W. Mason's home, Acacia Bank, on selection no.395, on the north bank of the Barron River opposite Cochrane's former selection no.160 on the south bank (Figure 15) (Broughton 1978:2). For a photograph of Mason's selection within the broader Barron River valley landscape see CHS P28027.

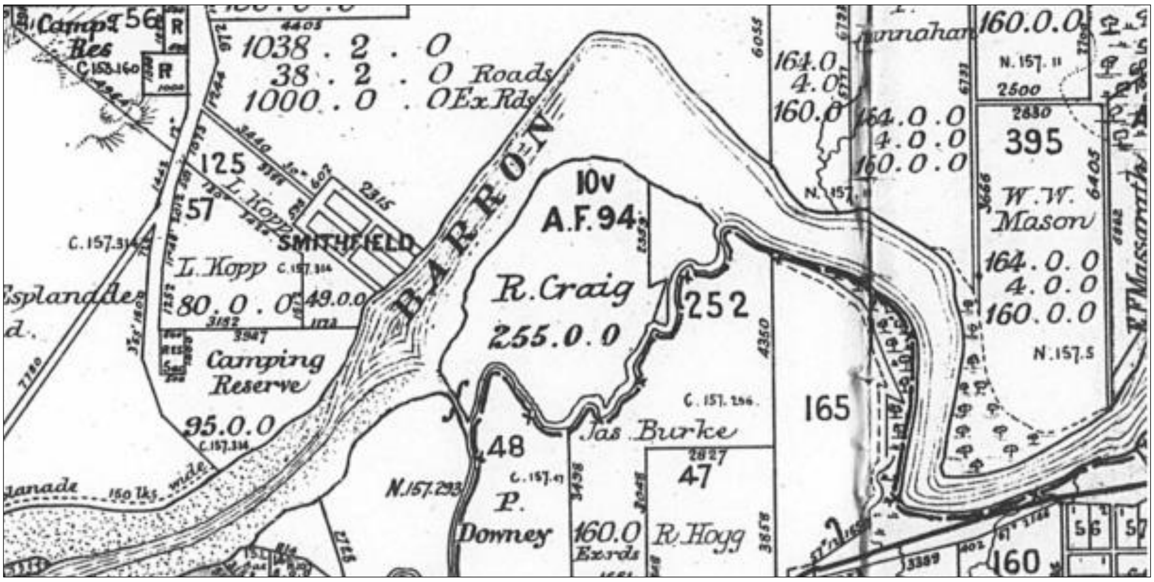


Figure 15: W.W. Mason's selection no.395 on the northern bank of the Barron River opposite today's Stratford (QSA ID ITM37870).

1899

Cyclone Mahina, in March 1899, killed 400 at Bathurst Bay north of Cooktown (Courier Mail 15-16 January 2011:40). The Endeavour and Annan Rivers flooded (*Morning Bulletin* 8 March 1899:5). At Cairns, there was flooding of the Barron and Mulgrave Rivers. The Mulgrave was 25 feet over the tramway bridge, and Behan Creek was a banker (*Daily Times* 7 March 1899:6; *Morning Post* 8 March 1899:5). The total rainfall for the week (prior to 8 March) was 16 inches 15pts. At Kuranda 14 inches 12pts of rain were registered for 24 hours ended Tuesday 7 March. All the low-lying land on either side of the Barron River was inundated. 'Cattle, horses, timber and crops are being swept to sea' (*Morning Post* 8 March 1899:5). The customs boat was sent to the Barron River to rescue settlers from their roofs. (*Telegraph* 8 March 1899:4). W.W. Mason (selection no.395) and several Chinamen were cut off by the water at Stratford 'and were in such danger that a pilot boat from Cairns was sent out by train yesterday morning and two constables rescued the men from their dangerous positions' (*Morning Post* 8 March 1899:5). Flooding of Freshwater Creek made it impassable (*Darling Downs Gazette* 8 March 1899:2).

1900

Heavy rains and flooding were reported in the Cairns district in January 1900, with 41 inches of rain for January reported. The Mulgrave River went 16 feet (4.87 m) over the Mulgrave tramway level and the bridge over Freshwater Creek was several feet under water. In the 24 hours to 25 January 1900, 8 inches of rain fell at Kuranda (*Age* 26 January 1900:6).

1903

The *Morning Post* (27 March 1903:5) notes that in the past 16 years there have been only 4 years when the annual rainfall has exceeded 100 inches. They are 1887, 137 inches; 1889, 123 inches, 1891, 134 inches; and 1894, 122 inches. The *Morning Post* (27 March 1903:5), at the end of March, predicted that 1903 would be another year with an annual rainfall over 100 inches.

There were two flooding events in 1903, one c.9-27 March and the other c.20-24 April (*Brisbane Courier* 25 April 1903:5; *Morning Post* 17 March 1903:3; *Morning Post* 27 March 1903:5; *Morning Post* 31 March 1903:2). In March, there was flooding in the Barron River, a cyclone at Townsville (‘Leonta’ 9 March) and flooding in the Mulgrave River. The *Morning Post* (27 March 1903:5) noted that the Mulgrave River was 13 feet (3.96 m) above the tramway bridge which was a record for the year. A few days later, the *Morning Post* (31 March 1903:2) reported that the Mulgrave River had risen 23 feet (7 m) over the tramway bridge, ‘a record height since the bridge was constructed’. An estimated two-thirds of corn crops in the Mulgrave district were destroyed (*Morning Post* 31 March 1903:2). The Russell River also flooded (*Capricornian* 28 March 1903:24).

Between 9-15 March 15.5 inches of rain fell at Kamerunga (*Morning Post* 17 March 1903:3). On Friday 13 March, Draper managed to get his horses on his selection no.160, formerly Cochrane’s selection, at Stratford (see Figure 9) out of a flooding paddock and to higher ground. From the flood marks at Stratford, Draper believed that the Barron River flood on Friday 13 March was ‘equal to that of 1893 and was 4 feet under that of 1894’ (*Morning Post* 17 March 1903:3). The Barron River was running so strongly that it could not be crossed by boat for several days (c.13 March to 16 March) (*Morning Post* 17 March 1903:3).

During the week of c.20-27 March, there was heavy rain and a gale on Wednesday 25 March that blew from 10pm to 6am the next morning and delivered 5.1 inches of rain at Cairns (recorded at Cairns Meteorological Station), 10 inches at Kuranda and 10 inches at Mareeba. At Mareeba, the Barron River was up by 25 feet. The lowest barometer reading (overnight 25 March) was 29.843 (*Morning Post* 27 March 1903:5). Total rainfall for the month of March up to 9am on 26 March 1903 was 28.50 inches and the total for the year to date, 70.10 inches (*Morning Post* 27 March 1903:5).

The April flooding in the Barron was more severe than in March. In April, c.20-24, ‘the Barron River was in the highest flood since 1894’, and 3 feet higher than one month ago (*Brisbane Courier* 25 April 1903:5). The Barron River rose 28 feet and was still rising, and all the low-lying land was submerged (*Western Star and Roma Advertiser* 22 April 1903:2). During the 24 hours prior to 9am on 21 April, Kuranda had 14 inches of rain (*Western Star and Roma Advertiser* 22 April 1903:2). The Mulgrave River rose 16 feet over the tramway bridge (*Brisbane Courier* 25 April 1903:5). The Herbert River also flooded (*Gympie Times and Mary River Mining Gazette* 28 April 1903:3).

1906

In January 1906, there was a cyclone affecting Cairns and the Broader region. Four and a half inches of rain was recorded and the Barron, Herbert and Johnstone rivers flooded (*Morning Post* 30 January 1906:3). Callaghan (2011) claimed that there was another cyclone at Cairns on the 4 March 1906 but these claims were not supported by any newspaper accounts.

1908

In the 24 hours 9 am on 8 January, 6.40 inches of rain fell at Cairns and 9 inches of rain fell at Redlynch. Water was up to the headstocks of the bridge over Freshwater Creek (*Darling Downs Gazette* 9 January 1908:8). All the creeks in the vicinity of Cairns were in high flood (*Evening News* 9 January 1908:6). The Barron River, Freshwater Creek and Stoney Creek were also in high flood (*Daily Telegraph* 9 January 1908:6). Rainfall at Kuranda was 6.5 inches (*Telegraph* 10 January 1908:2). In March, the Barron River and Stoney Creek falls were at their highest peak since 1884 (*Brisbane Courier* 28 March 1908:7). The total rainfall for March 1908 was over 26 inches (*Northern Miner* 30 March 1908:3).

1909

Cairns experienced strong winds and heavy rainfall 12-14 January 1909 which resulted in flooding to low-lying parts of Cairns (Table 4) (*Cairns Post* 15 January 1908:5; *Northern Miner* 23 January 1909:4). This rain event caused the Barron River to flood and the creeks around Cairns to run rapidly (*Cairns Post* 15 January 1908:5). Up until 23 January the rainfall for the month was 24 inches 95 points (*Northern Miner* 23 January 1909:4). These weather conditions continued to the end of the month with Cairns experiencing a heavy gale on 29 January (*Brisbane Courier* 1 February 1909:5). All the low-lying country was submerged (*Balonne Beacon* 3 February 1909:2). The continued heavy rain caused the Mulgrave River to flood with water several feet over the tram bridge. The Barron River was also in flood. On 31 January, the wind increased to a strong gale with heavy seas and the barometer was at 29.57 (9 am) (*Brisbane Courier* 1 February 1909:5).

1910

Cyclone at Cairns 27-30 January 1910, 19.5 inches of rainfall was measured. The *Brisbane Courier* (28 February 1910:5) reported that ‘the Barron River has risen 29 feet [8.83 m], being 1 foot [0.30 m] lower than the 1902 flood’. Heavy rain again fell from 22-23 March. The Mulgrave River flooded 7 feet (2.13 m) over the bridge (*Northern Miner* 24 March 1910:4). The continuous heavy rain caused the collapse of No. 19 tunnel on the range, which held up traffic for several weeks (*Cairns Post* 24 March 1939:6). Boats along the Cairns Esplanade were swamped (Callaghan 2011).

1911

The 1911 flooding event was that the highest flood level ever recorded in the Barron River (Broughton 2006:1). January-April 1911 was the wettest period in Cairns’ history, approximately 152 inches fell (3801mm), and from 30 March to 3 April the worst flood in Cairns’s history. This was due to three cyclones: one on 11 February, one on 16 March that severely affected Port Douglas, Mossman and Cairns, and another one week later south of Cairns (Broughton 2007:1 Part 1). On the 10 February 1911, 17 inches of rain was recorded at Redlynch (Callaghan 2011). The 1911 total rainfall was 161 inches – the second highest rainfall recorded (Broughton 2007:1 Part 1). At Mareeba, the Barron River rose one foot higher than the 1894 flood (Broughton 2007:2 Part 1). The 1911 flooding event was the highest flood level ever recorded in the Barron River (Broughton 2006:1), and the worst known by the oldest residents (*Northern Miner* 6 April 1911:3).

On the 16 March 1911 at tropical cyclone crossed the coast near Port Douglas a barometer reading by ship at Low Woody was 959.7 hPa (Callaghan 2011). On the 31 March 1911 Kuranda recorded 18 inches rain, Redlynch 11 inches, Cairns 8.3 inches in 24 hours (Broughton 2007:2 Part 1).

From Saturday 1 April to Monday 3 April, 42 inches of rain fell at Kuranda and the Barron River rose to only one foot below the 1894 flood level (*Telegraph* 3 April 1911). The *Sydney Morning Herald* (1 April 1911) reported that the Barron River was 30 feet and rising and that rainfall figures were: Mareeba 1059, Atherton 826 and Thornborough 626. The heavy rainfall was due to a cyclone (*Warwick Examiner and Times* 1 April 1911). Flooding caused damage to the market gardens/farms along the Barron River near Kamerunga (*Cairns Post* 21 January 1998; Broughton (2007:1 Part 2) reports that the Barron River was running at 11 knots [1 April 1911] and that at Kamerunga,

> the river tore away everything in its path. From upstream of the newly opened bridge and for several miles downstream, the southern bank of the river was eroded back for a distance of several chains. A number of outhouses belonging to the Kamerunga State Nursery Overseer's quarters were washed away, creating a bank with a sheer drop of eight feet. Mr Porter's cottage and orchard on Old Smithfield Road between Freshwater Creek and Kamerunga were completely destroyed by the flood.

The *Queensland Times, Ipswich Herald and General Advertiser* (7 April 1911:7) reported that:

> On the Kamerunga side of the river [Barron] the bank was swept away to a depth of almost a couple of chains from a little below the new bridge at the crossing to Freshwater Creek. Outhouses at Kamerunga State Nursery, the overseer's quarters (where Mr Woods, the overseer, and his family resided) were washed clean away. Where there was land there is now a sheer drop of 8 feet [2.43 m], the land being swept clean away by the force of the torrent. The overseer's house now stands only a few feet away from the chasm.

While 'From Koah to Kuranda the [rail] line was washed away by the flood in the Barron River and the bridges over tributary creeks and gullies were damaged. Along the Barron Gorge, sections of railway line were left hanging in the air and No.10 Tunnel fell in' (Tenni 1978:1). Three days of constant rain created a sea of water from Redlynch across to Smithfield: 'In fact you could get into a boat at Redlynch and go straight out to the Pacific Ocean' (Tenni 1978:1). Mason's house, Acacia Bank, on selection no.395 (Figure 9) 'was on 3 feet blocks but the water came over the floorboards' (Broughton 1978:2). Mason's selection was opposite selection no.160, formerly Samuel Cochranes' selection, in today's suburb of Stratford. In 1911 it was owned by Draper. Crops along the Barron River in the Redlynch and Freshwater areas were destroyed. Joseph Kipling, one of the first land selectors in the district (selections no.53 and 96) noted that 'about 30 years ago [1881] there was a similar flood in the river but at the time due to there being less cultivation, the current was not so swift, and consequently there was less damage done' (Broughton 2007:3 Part 2).

Broughton (2007:3 Part 1) notes that 'The Cairns Post Office recorded 40.16 inches of rain from 9.00am Friday [31 March] to 9.00am Sunday [2 April]. Half of this rain (20.16 inches) had fallen during Saturday. The lowest pressure recorded was 29.816 inches (1009.7hPa) at 3.00pm Saturday'. Landslips occurred on the range above Second Beach in the same area where landslides occurred in 1878, and they were heard from Cairns Broughton (2007:3 Part 1).

As the 1911 flood waters subsided, it was discovered that Freshwater Creek had changed its course. The mouth of the creek now joined the Barron River several miles upstream from its previous position and the Freshwater creek flats were covered in sand 2-3 feet deep (Broughton 2007:3 Part 2). Stream gauging commenced in the Barron River catchment in 1916. The Queensland Water Resources Commission records that 'highest recorded flood in the Barron

River delta occurred on 7 March 1977, with a maximum river height at the Myola gauging station of 34.8 feet'. However, 1911 flood measurements taken at the Myola Railway station enable a comparative height of 50.4 feet to be made at the gauging station, which indicates that the 1911 flood was at least 50% greater than the 1977 flood (Broughton 2007:3 Part 2). Broughton (2007:3 Part 2) noted that 'The flood of 1911 has been estimated to have an ARI (average recurrence interval) of between 500 and 1000 years. By contrast, the 1977 flood has been estimated as a one in 50-year event'.

A summary of Cairns' weather in 1911 reported that 1911 was 'one of the driest and wettest experienced in Cairns' (*Cairns Post* 3 January 1912:4) (Table 3). The article goes on to say:

> The total rainfall as recorded on the official gauge at the Cairns Post Office was 170 inches 75 points, but it practically all fell between January and April. The fall in those months was most abnormal, and it is within remembrance of all when 20 inches were recorded in 24 hours, the town being flooded. There were 112 wet days last year. The closing months of 1911 were marked by a series of dry stages, during which bush fires ragged throughout the district (*Cairns Post* 3 January 1912:4).

Table 3: Wet season December 1910 to April 1911 – high rainfall figures (*Cairns Post* 10 April 1942:4).

Month	**Rainfall (inches)**
December 1910	14
January 1911	34
February 1911	27
March 1911	35
April 1911	52

1913

A cyclone originated at Cooktown on 22 January 1913 (Callaghan 2011). Cyclonic winds with heavy rain affected the Cairns region 30-31 January 1913. At Kuranda nearly 32 inches of rain fell in 48 hours, making a total of 47 inches for the month of January (*Barrier Miner* 7 February 1913:4). 'All the country east of the Barron River was isolated by floods (Barrier Miner Friday 7 February 1913:4). On the Smithfield side of the Barron River a Chinese man was rescued from the roof of his humpy which was afloat in the Barron River (*Cairns Post* 3 February 1913:4). Banana plantations were destroyed at Freshwater (Callaghan 2011). The Kamerunga State Nursery was 'severely damaged' by the flood and cyclone with a strip of land washed away by the Barron River (*Daily Standard* 6 February 1913:7).

At Mareeba, John Atherton, a resident of the area since 1877 reported that the flood in the Barron River, near Mareeba, was 6 feet (1.82 m) higher than any previous flood. The river had broken its banks and extended in places over half a mile wide (*Cairns Post* 4 February 1913:5).

The Mulgrave River flooded and the railway bridge was submerged in 15 inches of water (*Daily Mercury* 4 March 1913:5).

1914

There was flooding in the Cairns CBD at the Cairns Drill Ground next door to the School of Arts building in Lake Street (CHS P14188; *Northern Herald* 30 January 1914:27).

1916

The Barron River flooded and Babinda Creek was 8 feet (2.43 m) over the railway bridge. At Behana Creek, the water was 5 feet 6 inches (1.7 m) over the rail line and the water was 9 feet (2.74 m) over the rail line at the Mulgrave River (*Beaudesert Times* 28 January 1916:5). There was flooding in the Cairns CBD at Sheridan Street (CHS P15969) and Grafton Street (CHS P15970) (*Northern Herald* 4 February 1916:26).

1917

Sheppard (2001:2) notes that there was a cyclone in March 1917.

1918

In 1918, a cyclone ‘Flattened’ Babinda and Innisfail while damage at Cairns was not as bad, but ‘Freshwater was hit quite badly and practically every house had some damage’. (Tenni 1978:1). The March 1918 cyclone that hit Innisfail was the most severe cyclone to hit a populated area in Queensland (https://www.slq.qld.gov.au/blog/deadly-cyclone-season-1918).

1920

On 3 February 1920 a tropical cyclone crossed the coast north of Cairns. Barometer reading at Port Douglas was 962 hPa. Port Douglas was almost complexly destroyed. The Barron River rose 10 feet over the bridge crossing the Barron River (Sheppard 2001:2). It is assumed that Sheppard (2001:2) means the Kamerunga bridge. The first Kamerunga bridge was 4ft 6 inches above the normal flow of water (Broughton 2006:1). Therefore, flood waters rose 14 feet 6 inches in the Barron River.

Flooding along the Cairns Esplanade and Cairns CBD (Callaghan 2011). Photographs at the Cairns Historical Society show flooding at Cairns when sea water flooded the Esplanade, Wharf Street and lower Spence Street to Abbott Street (CHS P05482, P05508, P05482). The Cairns Aquatic Club was flooded (CHS P01088).

1922

The Barron River flooded and Glen Boughton, opposite Cairns, had nearly 40 inches of rain during a week in February (*Bowen Independent* 21 February 1922:2).

1923

Cairns had 13 and a half inches of rain 27-28 March which made crossing Freshwater Creek and the Barron River difficult (*Northern Miner* 28 March 1923:6). Parts of Cairns were flooded and all the small creeks in the area were flooded (*Northern Miner* 28 March 1923:17).

1925

Cairns experienced a cyclone on 26 February 1925 which crossed the coast between Cooktown and Cairns (*Cairns Post* 26 February 1935:7; *Telegraph* 1 January 1926:6). Heavy rain in March 1925 caused the Mulgrave River and Tully River to flood. (*Catholic Press* 19 March 1925:42).

1927

Tropical cyclone Willis struck Cairns on Wednesday 9 February 1927 and brought destructive winds and rain (Table 4). Winds were 125mph (Tenni 1978:1). The lowest barometric reading was 971 hPa (Callaghan 2011). The cyclone weakened into a disastrous rain depression resulting in serious flooding at Cairns, Halifax, Ingham, and Tully (*Courier Mail* 15-16 January

2011:40). The Burdekin River reached a record height of 65 feet at Charters Towers (Gallogly 1959).

Table 4: Cairns Post Office rainfall figures 9-13 February 1927 taken at the 24 hours ended at 9 am each morning (*Cairns Post* 14 February 1927:4).

Date (February)	**Rainfall (mm)**	**Comment**
9 February (Wednesday)	23	Cyclone Willis hits Cairns
10 February (Thursday)	148	
11 February (Friday)	31	
12 February (Saturday)	60	All 60 mm of rainfall were registered in 2 hours, 6.30-8.30 pm Friday night
13 February (Sunday)	283	246 mm of rainfall fell between 7.15 pm and 12.30 am which means that for the 5 hour period rain fell at the rate of 47 mm/hr.
TOTAL	**546**	

On Saturday afternoon (12 February), the Barron River had 'resumed its normal channel and the spans of the Stratford bridge were 6 feet above water level' and it was possible to go by car as far as the Barron River crossing at Kamerunga. It was noted that the high-water mark was 3 feet (0.9 m) lower than the remembered flood marks of 1911. However, this all changed following the heavy rain on Saturday night which caused 2 feet (0.6 m) of water to rise over the Freshwater railway bridge. On Sunday afternoon, the Barron River again washed over the Stratford bridge and flooded the neighbouring countryside (*Cairns Post* 14 February 1927:4). Freshwater Creek was over the road bridge to such an extent that traffic could not proceed further than the turn off to Brinsmead's gap. The country in the Freshwater Creek area was one vast sheet of water covering crops and homes. The high tide on Sunday night, 13 February, 'made it impossible for the Barron River to pour its swollen flood water into the sea' (*Cairns Post* 14 February 1927:4). The result was that the water was 'forced back by a semblance of a tidal bore, to overrun the countryside, and to add to the already heavy overcharges of Freshwater Creek' (*Cairns Post* 14 February 1927:4). Water was 18 inches to 2 feet (o.6 m) deep across the road between Cairns and the Four Mile. I think the Four Mile reference refers to a point in the Stratford/ Freshwater Creek bridge area four miles from Cairns.

The country between Redlynch and Cairns was flooded. At the height of the flooding the 'cane paddocks along the Barron and Freshwater flats were submerged by water that rose well above the tops of the cane plants' (Tenni 1878:2). Freshwater Creek 'rose to two feet over the railway bridge', and all the houses at Freshwater Creek were damaged. Uprooted trees washed down the creek and piled up against the railway bridge (Tenni 1978:2). Tenni (1978:2) notes that 'up in Freshwater valley over three acres of standing scrub on the creek was torn out, taking away with it the main water pipeline carrying the Cairns water supply from Freshwater Intake to the Reservoir'.

Sections of the first Stratford Barron River Bridge were washed away in the 1927 floods (Broughton 2006:2; CHS P04370). Flooding also occurred in the Cairns CBD; for instance, in Lake Street near Hides Hotel (CHS P05476), and the wharf end of Abbott Street (CHS P00845). The flooding caused logs from the wharf to break free and hit against the Samuel Allen building, Cairns (CHS P10979).

After the 1927 cyclone, the hillsides that were previously densely covered rainforest were denuded of vegetation. Tree branches torn off and leaves stripped from trees, a few months later the dried out broken timber burned when fires swept through which marked a changed from tree covered slopes to grass covered slopes (Tenni 1978:2). More research is needed in relation to the floods for this year through a more detailed search of contemporary newspaper accounts.

1929

The Barron River was also in high flood (*Northern Miner* 27 February 1929:4), with water well over the banks and a ‘terrific volume of water is flowing seawards’ (*Townsville Daily Bulletin* 28 February 1929:6). From 24-27 February, 1,936 points (387 mm, 1 point is approximately 0.2 mm) of rain was recorded at Cairns. Most of that rain fell between 25-27 February (*Townsville Daily Bulletin* 28 February 1929:6).

1930

A tropical cyclone crossed the coast near Mossman on 20 January 1930. At Cairns the barometer read 1000 hPa and the rivers between Cairns and Ingham flooded. Low lying areas of Cairns were flooded (Callaghan 2011).

1931

A tropical cyclone near Cooktown affected north Queensland between 1-8 February 1931. Flooding occurred between Cairns and Ingham (Callaghan 2011). The Barron River at Stratford was lapping the bridge and Freshwater Creek was 3 feet (0.9 m) over the Cairn to Redlynch Road (*Telegraph* 8 January 1930:2). Water was over the Mulgrave River railway bridge (Figures 30-31) (*Brisbane Courier* 7 January 1930:13). Another tropical cyclone crossed the coast near Mossman on 20 January 1930.

1932

In December 1932, a flood damaged the trestle bridge and air pipeline installed across Barron River near Kuranda during construction of the Barron Falls Hydro-Electricity Project (Veivers 1996:3).

In January, Cairns experienced four days of ‘phenomenal’ rain from 15 to 18 January and a cyclonic storm on 18 January 1932 (*Cairns Post* 25 January 1932:10). In two days, 15-17 January, 12 inches of rain fell. Intensified rain during the afternoon of the 17 January registered 15 inches 30 points and caused rivers and creeks to flood. The Freshwater Creek railway bridge was submerged in 3 feet (0.9 m) of water, which was noted as a record for this place (*Cairns Post* 20 January 1932:5). The *Cairns Post* (20 January 1932:5) wrote that:

> Though the flood at Freshwater was stated to be a record, the Barron has been higher at Stratford. The difference is accounted for by the fact that Rechter’s [Richter’s] Creek last year joined the Barron, and the same thing happened on this occasion, enabling a large portion of the flood waters of the Freshwater Creek and Barron to be diverted into another channel in their rush towards the sea.

> With each successive flood the Barron seems to be carving out for itself a readier access to Rechter's [Richter's] Creek and then to the sea. The process of evolution may eventually reach the stage when the Barron and Rechter's [Richter's] Creek will permanently join up, giving the Barron a double mouth on the seafront.

Flood waters filled the low-lying country in the Stratford area. The Barron River rose over the Stratford bridge by about 6 feet (1.82 m) and extended up to a mile wide at some points. At its height, portions of the Barron valley 'were a great inland sea' (*Cairns Post* 20 January 1932:5). A large section of the northern end of the Stratford bridge was swept away and piled against the trees on the bank (Figure 37) (*Cairns Post* 20 January 1932:5). The Barron River also went over the Kamerunga bridge (*Cairns Post* 22 January 1932:4). The northern end of the Barron River bridge at Stratford was damaged by flood in 1932 (Figure 16) (CHS P18037).

Figure 16: The Stratford bridge over the Barron River, damaged in the 1932 flood (Cairns Historical Society P18037).

Another tropical downpour hit Cairns between 29 February–1 March 1932 which in conjunction with a cyclone warning (*Cairns Post* 1 March 1932:4). The rainfall resulted in flooding of the Barron River and Freshwater Creek. The total Cairns rainfall for January and February combined was 3 feet 4.81 inches (c.1 m) (*Cairns Post* 2 March 1932:4).

In December 1932, a flood damaged the trestle bridge and air pipeline installed across Barron River near Kuranda during construction of the Barron Falls Hydro-Electricity Project (Veivers 1996:3).

1933

Over four days, 3-6 February, 25 inches of rain fell at Cairns (*Cairns Post* 6 February 1933:7). The Barron River and Freshwater Creek flooded. Water went over the Freshwater Creek traffic bridge on the Cairns to Redlynch Road (*Cairns Post* 4 February 1933:9). At Stratford, the Barron River was level with the Stratford bridge having been over the bridge during the night. Flooding in the Barron River and Freshwater Creek resulted in the residents in the Smithfield area being completely cut off from the city on 4 February. Low-lying areas of cane land in the

Smithfield, Stratford and Freshwater areas went under water (*Cairns Post* 6 February 1933:7). On 4 February, Norman Park 'looked more suited for the holding of a skiff championship than the cricket' (*Cairns Post* 6 February 1933:7).

In February 1933, flood waters again damaged the bridge and pipeline across the Barron River, at the Falls near Kuranda, which was erected during construction of the Barron Falls Hydro-Electricity Project (CHS P06058; Veivers 1996:3). At Kuranda, the Barron River was 23 feet (7 m) above normal level. During the night of 3 February, 150 feet (45.72 m) of the 600 feet (182.88 m) trestle foot bridge was swept away (*Cairns Post* 6 February 1933:7).

1934

In January 1934, a cyclone formed over the Coral Sea and a storm warning was issued on 19 January (*Cairns Post* 24 January 1934:7). The road between Cairns and Port Douglas (Cook Highway) was impassable due to flooded creeks and landslides (*Cairns Post* 2 February 1934:6). Rail traffic was interrupted by water rising more than a foot over the railway bridge over the Mulgrave River (*Cairns Post* 3 February 1934:7).

On 20 February, flood waters in the Barron River rose 23 feet 6 inches (7.16 m) and demolished the trestle bridge. The original bridge, a lighter structure, had been swept away the year before on 3 February 1933, when the river reached 24 feet (7.31 m) (*Cairns Post* 27 February 1934:9). The footbridge across the Barron Falls was erected to assist construction of the Barron Falls Hydro Electric scheme (see images CHS P07540, P07541, P07542, P07543, P07544). The flooded state of the Barron River at Kuranda caused a suspension of work on the hydroelectric power scheme (*Daily Mercury* 23 February 1934). On 13 March, the Barron River rose 35 feet 3 inches (10.74 m) above its summer level and 18 feet (5.48 m) over the traffic bridge, which was regarded as a record flood at Kuranda for the last 20 years (*Cairns Post* 15 March 1934:8; Cairns Post 12 February 1936:3; *Tweed Daily* 14 March 1934). In one hour, there was a rise in river level of 2.5 feet (0.76 m) (Figure 17) (*Tweed Daily* 13 March 1934).

Figure 17: The Barron Falls in flood, 1930s (CHS P05986).

Freshwater Creek flooded and caused damage to the Cairns water supply (*Cairns Post* 14 March 1934:7). At Stratford, the Stratford Barron River bridge was damaged by flood waters (CHS P07937).

Rainfall totals taken at the top gate on the Range Road were 28.35 inches for January 1934, and 29.75 inches for February 1934 (*Cairns Post* 2 March 1934:8). By 14 March, the total rainfall for March was 24 inches and 32 points at Cairns (*Cairns Post* 15 March 1934:8).

On 12 March, a cyclone crossed the coast near the Daintree River and brought heavy rain to the water catchments of the Barron and Mulgrave rivers (*Cairns Post* 14 March 1934:7; Roberts 1987). Comparisons were made between this weather event and conditions in 1911 (*Cairns Post* 14 March 1934:7).

1935

A low in the Coral Sea brought heavy rain to Cairns on Wednesday 26 February 1935 (*Cairns Post* 26 February 1935:7). During Wednesday's downpour, over 9 inches of rain was recorded at Cairns (*Cairns Post* 2 March 1935:7). From the night of 27 February to 9 am on 2 March, Cairns had a further 932 points of rain and a cyclone warning was given: cyclone between Cooktown and Willis Island (*Cairns Post* 3 March 1935:9). A total of nearly 19 inches of rain fell in a little over 2 days. The total February rainfall was just over 20 inches (2,011 points) (*Cairns Post* 2 March 1935:7). Table 5 compares the rainfall figures for January and February 1935.

On 28 February 1935, the Barron River rose to 10 feet 8 inches (3.25 m) and continued to rise reaching 21 feet 8 inches (6.6 m) on 3 March (*Cairns Post* 12 February 1936:3).

On 2 March, Freshwater Creek broke its banks and flooded the road making the road impassable with, at one stage, 5 feet (1.52 m) of water over the road. The Mulgrave River rose 5 feet 6 inches (1.7 m) over the bridge. Babinda Creek and Behana Creek rose 2 feet 6 inches (0.76 m) over the railway line (*Cairns Post* 3 March 1935:9).

Table 5: Rainfall figure comparisons (in points) between February 1934 and 1935, and the combined January and February 1935 totals (*Cairns Post* 5 March 1935:5).

Place	**1934**	**1935**	**January and February 1935**
Cairns	2,606	2,011	2,675
Redlynch	2,494	2,046	2,847
Kuranda	2,675	2,100	3,140
Mareeba	1,353	650	914
Yungaburra	2,277	1,358	2,864
Malanda	2,637	1,530	2,047
Millaa Millaa	3,842	2,459	3,421
Atherton	2,367	1,197	1,695
Herberton	1,983	808	1,406
Ravenshoe	2,652	1,324	1,512
Gordonvale	3,039	1,700	2,600
Deeral	4,402	3,206	4,420
Babinda	4,546	3,178	4,115
Dimbulah	1,022	488	927
Mt Mulligan	1,451	455	770
Almaden	1,196	714	1,205
Chillagoe	931	208	943
Mungana	922	333	827

1936

Torrential rains fell at Cairns 15-16 February with almost 6 inches of rainfall during the night of 15 February. The rainfall was in connection with a cyclonic depression located midway between Cairns and Willis Island (*Cairns Post* 17 February 1926:6). More rain fell at Cairns during the following week with 605 points registered on 19 February: rivers and creeks in the region rose. The Mulgrave River, Babinda Creek and Behana Creek rose over the rail line. The

Barron River also rose 14-16 feet (4.26-4.87 m) at Kuranda. Kuranda experienced exceptionally heavy rain during the night of 18 February with 140 mm of rainfall registered in the 24 hours ended 9 am 19 February. Kuranda had almost three times more rain in January and February 1936 than during the same period last year (1935) (*Cairns Post* 20 February 1936:7). After nine days of rainy weather, Cairns had recorded 30 inches of rain (*Cairns Post* 22 February 1936:7).

1938

Heavy rain fell at Cairns on 27 January and continued for several days. Freshwater Creek broke its banks at the crossing and covered the road which held up traffic to Redlynch (*Cairns Post* 29 January 1938:6). A cyclone warning for the region accompanied the wet weather (*Cairns Post* 31 January 1938:8).

1939

Heavy rain fell continuously over 6-8 January at Cairns, Innisfail, Babinda and other places (*Cairns Post* 9 January 1939:7). The Barron River, at 9 am on 7 February was 13 feet 6 inches (4.11 m) above normal and 'was rising at the rate of one foot an hour' (*Cairns Post* 8 February 1939:6). The lowlands of the Barron River coastal plain were flooded (*Cairns Post* 13 February 1939:6). Freshwater Creek almost reached its 1927 level.

1940

The Barron River gauge at 5pm on 2 April 1940 measured 9 feet 1 inch (*Cairns Post* 13 April 1940 – CHS D05551).

1941

On 5 February, Cairns had its second cyclone warning in six days, and heavy rain fell at Cairns during that period (*Cairns Post* 6 February 1941:4). Rain continued to fall with particularly 254 mm of rain were recorded. Freshwater Creek was in high flood. Floodwaters from Freshwater Creek were 4 feet (1.21 m) over the Freshwater traffic bridge which stopped access to Redlynch (*Cairns Post* 1 March 1941:4). Wet weather continued throughout March and into April with 4 inches of rain recorded on 3 April that caused Freshwater Creek to flood (*Cairns Post* 13 March 1941:4; *Cairns Post* 4 April 1941:4).

1942

There was no flooding in 1942.

1943

There was no flooding in 1943.

1945

0n 1 February 1945, 810 points of rain caused the Barron River to rise 8 feet over the traffic bridge at Mareeba, the highest level reached in nine years (*Cairns Post* 6 February 1945).

Strong winds of cyclonic character and torrential rain fell at Cairns over the weekend of 17-18 March. The Mulgrave River and Behana Creek were in high flood with water 5 feet (1.52 m) and 8 feet (2.43 m) over the respective railway bridges. The Little Mulgrave River was 4 to 5 feet (1.21 to 1.52 m) over the Gillies Highway and the flooded Barron River was 4 to 5 feet (1.21 to 1.52 m) over the Cook Highway at Smithfield, on the southern side of the Barron River.

1946

The Harold Collins bridge at Kuranda was submerged by the flooded Barron River (*Cairns Post* 16 February 1946:4). A 'cyclonic disturbance' was experienced in the Cairns region on 2-3 March with continual rain that caused the coastal streams to rise (*Cairns Post* 2 March 1946:1; *Cairns Post* 5 March 1946:3). There were extensive landslides on the red bluff section of the Cairns Range (*Cairns Post* 5 January 1949:3). The total Cairns rainfall for the year up to 1 April 1946 was only 41.18 inches: 12.81 inches in January, 20.61 inches in February, and 7.37 inches in March (*Cairns Post* 2 April 1946:5). The *Cairns Post* (5 January 1949:3) described 1946 as 'one of the most perverse of wet seasons' experienced in north Queensland:

> From the time of the [March] cyclone until very late in 1946 little or no rain fell in North Queensland, Stock died in thousands, Crops suffered severely because of this dryness. On the Atherton Tableland dairying and maize growing were hard hot, Cane harvesting on the coast was curtailed and the outlook for the next season looked gloomy.

1948

Very heavy rain fell at Kuranda 11-12 January which caused the Barron River to rise and submerge the Harold Collins bridge at Kuranda, so there might have been significant falls at Cairns as well (*Cairns Post* 13 January 1948:1).

1949

In 1949, Cyclones were recorded at Gladstone and Rockhampton (*Courier Mail* 15-16 January 2011:40) and at Cooktown (*Courier Mail* 15-16 January 2011:41). The Barron River, at Fairyland, Kuranda, reached 28 feet 9 inches (8.76 m) at the height of the flood which was the highest recorded level there for several years (*Cairns Post* 25 February 1949:4).

1950

The Barron River flooded in January 1950 following four days (11th-15th Jan) of heavy rain. River described a 'raging torrent'. Collins Bridge at Kuranda was several feet under water. 925 points fell from 9am 14 January to 9am 15 January. Total points since Friday 13 January to 9am 15 January was 1,535 points (*Cairns Post* 16 January 1950). The *Cairns Post* (11 March 1950) again reports flooding in the Barron River and the Harold Collins bridge under several feet of water. The flood waters isolated farmers in the Myola and Mantaka areas. Over the week circa 1-7 March, 677 points of rain recorded with nearly 50 inches of rain recorded since the beginning of 1950 (*Cairns Post* 11 March 1950).

The *Cairns Post* (11 March 1950:4) again reports flooding in the Barron River and the Harold Collins bridge under several feet of water. The flood waters isolated farmers in the Myola and Mantaka areas. Over the week circa 1-7 March, 135 mm of rain were recorded with nearly 50 inches of rain recorded since the beginning of 1950 at Kuranda (*Cairns Post* 11 March 1950:4).

On the 8 December 1950 the Barron River was again a raging torrent with flood waters submerging Collins bridge at Kuranda in about six feet of water, 24 mm of rain fell in 24 hours (*Cairns Post* 9 December 1950). The *Townsville Daily Bulletin* (22 December 1950) reported that from about 18-21 December 36.8 mm of rain was recorded at Mareeba making a total for December 1950 of 145 mm and for the year a total of 48 inches, 'which is approximately 14 inches above the average rainfall' (*Townsville Daily Bulletin* 22 December 1950). Note that the 48 inches figure contradicts the 50 inches reported to have fallen for the year from January to March 1950 (see *Cairns Post* 11 March 1950). There was also flooding in the Cairns CBD (CHS P03159).

1952

Freshwater Creek flooded over the low bridge below Redlynch and all streams between Cairns and Edmonton rose considerably.

1953

On 13 February, the Barron River at Kuranda was in flood and the Collins bridge was submerged (*Cairns Post* 14 February 1953:1, 16 February 1953:3). The Kuranda barracks' reclaimed area was flooded and the roadway to the Strand Hotel from the city baths on the Esplanade was covered in a foot of water. The roadways near Smith's Creek were also affected.

NOTE: Trove only includes entries from the *Cairns Post* newspaper up to 1954. Therefore, from 1955 onwards the level of detail about flooding events at Cairns dops significantly. This also explains why there are gaps in the chronology. The solution would be to access the hardcopies/microfilms of the *Cairns Post* from the Cairns Historical Society.

1956

The 1956 cyclone (Cyclone Agnes) was 'a dry blow', cyclonic winds rather than rain (Tenni 1978:2). However, there are CHS photographs showing flooding at Cairns, but this flooding might be related to storm/tidal surges (CHS P15790, P01555).

1958

Areas of the Cairns CBD were flooded in 1958. For instance, near the Grand Hotel (CHS P04641). There was also flooding of the Barron River at Kamerunga (CHS P25171).

1966

In 1966, a King tide flooded the lower end of Abbott Street near the Barrier Reef Hotel (CHS P15049).

1967

In 1967, the Barron River rose to its highest point in 30 years [since 1927]. From Saturday morning on 11 March until Sunday morning on 12 March, 16 inches of rain fell. The Barron River was 16 feet over the spillway above the Barron Falls. Landslides and washouts were recorded and the Kuranda range was closed (*Cairns Post* 13 March 1967:1). The Barron River rose to its highest point in 30 years [since 1927]. At Kamerunga, the Barron River rose 22 feet (6.7 m) above the level of Kamerunga bridge (Broughton, P. 2006:3). The Leonadari cane property at Smithfield was cut off by flood waters and the people had to be rescued by boat (*Canberra Times* 14 March 1967:1). The Cairns Airport was flooded because the Barron River levee bank broke (CHS P28350-P28352). The Stratford Barron River bridge was flooded in 1967.

There was severe flooding at Ingham, the Mulgrave River and on the Tablelands (*Cairns Post* 15 March 1967:1). The Mossman River also flooded (CHS J06089). The *Cairns Post* (15 March 2017:13) called the 1967 flood a once in a century flood.

1971

Cyclone Althea hit north of Townsville on Christmas Eve, and Magnetic Island was almost completely destroyed' (*Courier Mail* 15-16 January 2011:41). There was flooding in the Mossman River (CHS J06089).

1972

Rain, in the aftermath of cyclone Bronwyn, caused widespread flooding along the 300 mile stretch of coast from Mackay to Ingham. The rain was reported as some of the heaviest rain on record in north Queensland. Cardwell recorded 25 inches of rain between 6-9 March and Innisfail recorded 19 inches for the same period. At Ingham, 'at least 60% of the 1,000 square mile Herbert River Valley was covered by water up to 2 feet [0.6 m] deep' (*Canberra Times* 10 January 1972:1). The impacts of this rain event on Cairns are unknown without further investigation of the Cairns Post newspapers.

1973

Rain, in the aftermath of cyclone Madge (third cyclone of the year), caused widespread flooding along the 300 mile stretch of coast from Cooktown to Ingham, on 5 March, with falls of over 12 inches in 2 days. During the 48 hours to 9 am on 6 March, Cairns recorded 801 points of rain. Mossman recorded 1,678 points, Port Douglas recorded 1,193 points and Cape Tribulation recorded 1,052 points of rain (*Canberra Times* 6 March 1973:3). The impacts of this rain event on Cairns are unknown without further investigation of the Cairns Post newspapers.

1976

There was flooding at the corner of Oleander and Canna Streets, Holloways Beach (CHS P15495).

1977

Cyclone Otto, 6-10 March 1977, caused extensive flooding in the Cairns region. The wave station at Double Island Point recorded 3.8m wave height, and 1200m of Machans Beach Esplanade was destroyed by heavy seas (*Sun* 9 March 1977:1). The Barron River flooded. Aerial photographs show the flooded junction of the Barron River and Thomatis Creek (CHS P02493, P02494). The old crossing of the Barron River at Kamerunga also flooded (CHS P02491). Machan's Beach was a major disaster area in the 1977 floods (CHS D16191). There was also flooding in McLeod Street, Cairns (CHS P12012).

The Queensland Water Resources Commission records that 'highest recorded flood in the Barron River delta occurred on 7 March 1977, with a maximum river height at the Myola gauging station of 34.8 feet' (Broughton 2007:3 Part 2). However, 1911 flood measurements taken at the Myola Railway station enable a comparative height of 50.4 feet to be made at the gauging station, which indicates that the 1911 flood was at least 50% greater than the 1977 flood (Broughton 2007:3 Part 2). Broughton (2007:3 Part 2) noted that 'The flood of 1911 has been estimated to have an ARI (average recurrence interval) of between 500 and 1000 years. By contrast, the 1977 flood has been estimated as a one in 50-year event'. Others have obtained rather different estimates of the ARI for the 1977 floods which include a 40-year event (Connell Wagner Pty Ltd, 2004) and 165-year event (Orr, 2016). These differences in estimated ARI values are a result of different methods used in flood frequency analysis.

1979

There was record rainfall with serious flooding due to cyclone Peter (1-2 Jan) between Tully and Cooktown, especially at Cairns (Callaghan 2011). Flooding of the Mossman River in 1979 was highest flood on record (CHS J06089).

1981

Cyclone Freda (26 February) caused flooding in the Barron, Herbert, Tully and Johnstone Rivers (Callaghan 2011). Severe flooding at Babinda impacted cane farmers (*North Queensland Register* 17 January 1981).

1986

Cyclone Winifred (January) caused record floods in the Herbert and Tully Rivers (Callaghan 2011).

1997

Justine II crossed the coast near Cairns on 22 March 1997 (Justin I, 9 March) (Callaghan 2011). Callaghan (2011) notes flooding in the Johnstone, Herbert and Tully Rivers but does not mention the Barron River.

1998

Ex Tropical cyclone Sid, 10-11 January, severe monsoon low that mostly affected Townsville (Callaghan 2011). There was flooding of the Mulgrave River (*Cairns Post* 9 January 1998:1).

1999

Cyclone Rona, 11 February, crossed the coast north of Cow Bay near the mouth of the Daintree River causing major flooding between Townsville and Cairns that resulted in major crop damage. At Port Douglas (low tide) there was a 1 metre storm surge. At the mouth of the Mossman River a 1.4 m storm surge was recorded (Callaghan 2011). Significant flooding of the Barron River led to the evacuation of Lake Placid residents (Connell and Wagner Pty Ltd 2004). This was the ‘First time local disaster management authorities put an emergency action plan for Lake Placid and Caravonica in place’ (Cairns Regional Council 2014). A month after cyclone Rona there was more flooding described as the ‘biggest wet in 22 years [since 1977]’ affecting Cooktown to Tully (*Cairns Post* 17 March 1999:1). Rainfall totals between Thursday 11 March and 9am Tuesday 16 March 1999 were Babinda, 1239mm; Cairns airport, 458mm; Kuranda, 428mm; Cairns City (Showgrounds), 667mm; and Port Douglas, 528mm (*Cairns Post* 17 March 1999:3).

2000

Cyclone Steve crossed the coast at Cairns Northern Beaches. Flooding occurred in the Cairns district. At Cairns, a 1 m storm surge (King tide) was recorded exacerbating flooding, and 237mm of rain was recorded in 24 hours to 26 February at the Cairns airport (*Cairns Post* 9 February 2000:1; Callaghan 2011). One month of rain fell in one week. Lake Placid recorded 377 mm of rain and the roundabout at Freshwater Creek was flooded (*Cairns Post* 9 February 2000:1).

Heavy rainfall was experienced in the Barron River catchment with 256mm recorded in 12 hours to 6.25am on 28 February at Emerald Crest, causing major flooding at Mareeba. The Mareeba flood level reached 12.4 m, a record. The railway bridge was washed away and 90 people were evacuated, 20 by helicopter. The heavy rainfall caused the range roads to be closed and severe damage to crops (Callaghan 2011).

2004

Due to cyclone Fritz, 11 February, 173 mm rain was recorded at Saddle Mountain near Cairns (Callaghan 2011). Between 19-24 March, cyclone Grace caused widespread flooding and damage to property and roads between Cairns and Cooktown. Over 72 hours to 11pm on 20 March, 759mm of rain was recorded at Topaz. The highest 24-hour total during these 3 days was 372mm. There was flooding at Cairns and Cairns' northern beaches suburbs which closed all roads leading into Cairns. Landslides on the Captain Cook Highway north of Cairns with 'boulders the size of cars' caused closure of the Cairns to Port Douglas Road (Callaghan 2011).

2006

Cyclone Larry (18-24 March), a category 5 cyclone, crossed the coast north of Innisfail on 20 March 2006 and caused structural and crop damage estimated at 0.5 billion AUD (Callaghan 2011).

2008

The Barron River burst its banks (*Cairns Post* 6 March 2008:2; *Weekend Post* 5 April 2008:9). Avondale Creek threatened to flood the Captain Cook Highway and Thomatis Creek spilled over the Captain Cook Highway (*Cairns Post* 6 March 2008:3). Rainfall from Sunday 2 March to 9am Wednesday 5 March 2008 was 425mm at Kuranda and 301mm at Cairns (*Weekend Post* 5 April 2008:24).

2009

Cyclone Charlotte 11-12 January 2009. *Weekend Post* (Cairns Post) (4-5 April 2009:7) article includes a photo from elevated/aerial position of Normanton's Burns Philip building surrounded by flood waters.

As of 21 June 2022, further research is required for years 1927, 1931, and 1977 and years 1977-2009 require more research from the local papers which are not available on Trove.

3.3 Summary

The 132-year historical account of the Barron River floods reveals many aspects of flooding events and its impact on Smithfield Village. While historical accounts are not always accurate for many reasons including memory loss and conflicting records, accounts of flood damage suggests that we can rank the floods in the following order of decreasing magnitude: 1911, 1894, 1881, 1879 for the pre-gauging period (Barron River streamflow gauging commenced 1916).

The close relationship between climate (monsoon rainfall, tropical cyclones) and flooding is clear, with a wide range of damages, including loss of life and vegetation (forest cleared), destruction of crops (e.g., sugar, rice), infrastructure damage (loss of railway line and bridge in the 1911 flood) and riverbank erosion. Changes to the Barron riverbank at the Smithfield township site are highlighted in Figure 18, which shows the alignment of the Barron riverbank in 1876 with the alignment of the Barron riverbank in 2022. The difference in alignment represents an approximately 30 metre loss of riverbank and highlights the volatility of this river and its potential to cause significant damage to our current developed landscape. Indeed, the recent flood caused by ex-TC Jasper (17 December 2023) washed away vegetation and significantly broadened the Barron River, especially around the Caravonica, Lake Placid area (Figure 19).

Figure 18: Georeferenced map S119.1 (Warner’s survey of Smithfield township sections 1 and 2) overlaying the modern Open Street Map highlights the changes to the Barron River alignment since 1876 due to bank erosion

Figure 19: Changes to the Barron River at Caravonica/Kamerunga due to the 17 December 2023 ex-TC Jasper flood, a) the Barron River before and after the flood (photo source: Facebook user upload) and widening of the Barron River b) upstream and c) downstream of the Kamerunga Bridge. The yellow arrow shows the direction of river flow.

While most of the historical accounts document river flooding, there are accounts of riverbank erosion which hints at the possibility of the Barron and other floodplain rivers avulsing during significant floods. For instance, the 1911 floods caused Freshwater Creek to change its course. The mouth of the creek now joined the Barron River several miles upstream from its previous position and the Freshwater creek flats were covered in sand 2-3 feet deep (Broughton 2007:3 Part 2). Observations that the Barron River gradually shifts its course with each flood were also noted in the Cairns Post article (20 January 1932:5); with 'each successive flood the Barron seems to be carving out for itself a readier access to Rechter's [Richter's] Creek and then to the sea. The process of evolution may eventually reach the stage when the Barron and Rechter's [Richter's] Creek will permanently join up, giving the Barron a double mouth on the seafront'.

The historical accounts show that the overbank flooding, riverbank erosion, loss of property and infrastructure experienced due to the 17 December 2023 ex-TC Jasper flood has repeatedly occurred in the past. Yet, the settlement and development of the Barron River fan delta continues to this day. It is wise to remember that even though the Smithfield Township was located on a riverbank about 20 feet above the river, it was still flooded to the point that the settlement was abandoned after the 1879 floods. Section 5 considers the role historical knowledge plays in increasing flood resilience of both community and ecological resilience.

4. EXTREME FLOODS AND MASS LOAD TRANSPORT TO THE GREAT BARRIER REEF

Apart from loss of lives and infrastructure, floodwaters can also have significant impacts on downstream ecosystems, via the transport significant amounts of pollutants, in this case, to the coast where the GBR is located. Current estimates of pollutant mass fluxes to the GBR are calculated using the gauged river flow data and modelling which often does not include extreme flood magnitudes due to the relatively short nature of the modern gauged record. To estimate potential mass load to the GBR due to extreme flooding, we applied the Barron River palaeoflood magnitudes to current day pollutant concentration values. This simple experiment provides a first step into an analysis of mass load transport to the GBR due to extreme flood events, which are likely to occur due to climate change.

4.1 Estimating mass load using extreme flood discharges

There is a wide body of literature regarding the impacts of changing land use and urban settlement in the GBRCA on water quality discharging to the GBR lagoon (Brodie, et al 2003, Brodie et al, 2013, McCloskey et al 2021a, b; and others). Of particular concern are excess fine sediments, dissolved inorganic nitrogen (DIN), particulate nutrients, and pesticides. To address these issues, water quality targets have been set for catchments that drain to the GBR, including the Barron River. The fine sediment target for the Barron River basin is to ‘maintain current load’, implying that fine sediment loads from this basin are not a major priority for management (particularly when compared to the large grazing basins such as the Burdekin, Fitzroy, Herbert and Mary River). It is estimated, through the eWater Source-GBR Dynamic SedNet model that 138 kt yr^{-1} of fine sediment is exported from the Barron River basin, along with 135 t yr^{-1} and 507 t yr^{-1} of particulate phosphorus and nitrogen, respectively on average each year (McCloskey et al 2021a). The Barron River basin does have a 60% reduction target for DIN but given the origin of this pollutant (predominantly cropping land uses such as sugarcane and bananas), we do not consider DIN further.

To provide a coarse estimate of fine sediment, PP and PN loads during an extreme flood event, we have applied a simple calculation, using a concentration x flow approach. This approach will produce a very conservative estimate of loads because of the peak discharge, determined above from boulder sampling, multiplied by an appropriate concentration value for each of fine sediment, PP and PN, as determined from long-term monitoring data Table 6. The estimated pollutant loads for extreme palaeoflood events are summarised in Table 7.

Table 6: Concentration value applied for each constituent based on long-term monitoring data of the Barron River

	Concentration (mg L^{-1})
Fine sediment	20
Particulate phosphorus (PP)	0.16
Particulate nitrogen (PN)	0.75

Table 7: Load of fine sediment, particulate phosphorus (PP) and particulate nitrogen (PN) exported by the Barron River for a palaeoflood that will move 5 of the largest boulders measured at Site A.

Site A	**Palaeoflood discharge ($m^3 s^{-1}$)**	**Flow (ML day^{-1})**	**Fine sediment (kt day^{-1})**	**PP (t day^{-1})**	**PN (t day^{-1})**
Helley (1969)	11298	976147	19.5	1.56	7.32
Bradley & Mears (1980)	6066	524102	10.5	0.84	3.93
Clarke (1996)	4358	376531	7.53	0.60	2.82
Alexander & Cooker (2016)	4093	353635	7.07	0.57	2.65
Williams (1983)	197	17021	0.34	0.03	0.13
Colorado Range (Costa 1983)	2067	178589	3.57	0.29	1.34
US Bureau of Reclamation (Costa 1983)	16159	1396138	27.9	2.23	10.5
Range (excluding the values obtained by the Williams, 1983 method)	2,067-16,159	178,589 – 1,396,138	3.57 – 27.9	0.29 – 2.23	1.34 – 10.5

Considering the maximum discharge (calculated herein) required to move the instream boulders (16,159 m^3/s), the palaeoflood that is able to move the 5 largest boulders produced a maximum fine sediment load of 151.3 kt day^{-1}, approximately 18% of the annual load. The estimates provided in Table 7 are considered extremely conservative, for a number of reasons. The concentration value applied is calculated from long-term monitoring data collected as part of the Paddock to Reef Catchment Monitoring Program. This data has been collected since 2006, and while it does capture high and low flow events, it has not captured a severe flooding event of the magnitudes determined herein. Thus, the concentration data will not have captured the impact of mass-failure events (such as floodplain stripping and landslides) that are likely to occur during these events. Additionally, the long-term monitoring data captures information about contemporary water quality data; that is, current range of land uses and any infrastructure that might impact flow and pollutant transports, such as dams and weirs. Depending on where the rain falls during an event will also impact water quality data, particularly if there is a proportion upstream of Tinaroo Dam which acts as a sink for pollutants to drop out, or the weir at the top of the Barron Gorge. Further, this simple calculation converts peak discharge (m^3s^{-1}) into ML day^{-1}, and a load calculated using this flow. Of course, we know nothing about the duration of this event, only the peak discharge required to move the boulder in the first instance. Thus, if the flood occurred over several days, then the estimate provide here is only a minimum, with additional pollutant loads coming from flow either side of the ‘day’ for which we have determined the load. The results presented are very preliminary estimates of pollutant loads discharged to the GBR by large flood events. Improved estimates of pollutant loads will be explored as part of a future research program.

5. LESSONS LEARNT

5.1 Drivers of flooding

The estimates of palaeoflood discharges for the Barron River (Section 2) allow us to compare extreme flood discharges with FoR (Table 2) but do not tell us when the events occurred. Dating the imbricated boulders at Site A of the Barron River is the subject of future work. However, research for other tropical and sub-tropical rivers in Queensland provide information of both peak discharges and approximate time of occurrence, extending the palaeoflood information for the region to the past 100 years. This allows an examination of the role hydroclimate shifts have on flooding for the rivers summarised in Table 2.

Using Yan et al. (2015)'s classification system, the past millennium was divided into 3 major climatic periods that include the Medieval Climate Anomaly (MCA), Little Ice Age (LIA) and the Current Warm Period (CWP). A relative wetness index was calculated for the MCA, LIA and last 150 years of the Australian monsoon tropics (Yan et al., 2015). The results suggest that in the tropics, the MCA was slightly wetter than the LIA and drier than the CWP. These conclusions are consistent with the findings of Mann et al. (2009) (see also Henke et al., 2015, Porter et al., 2021). Therefore, the relative wetness index is ranked in the following order with the CWP>MCA>LIA in decreasing order of relative wetness.

The consolidated account of palaeofloods for coastal Queensland rivers, shown in Table 8, reflects this change in relative wetness for the 3 climate periods described above. The frequency of palaeoflood occurrence in both regions during the CWP is clearly much higher than either the MCA or the LIA periods. Wet season streamflow to the Great Barrier Reef from the Burdekin River has increased in the latter half of the nineteenth century in a record that begins in 1648CE (Lough et al., 2015). Gallego et al. (2017) have demonstrated a steady increase in the Australian monsoon over the past 200 years while Higgins et al. (2022) have shown that streamflow in northern Australia has increased from the 1800s with the past 40 years being unprecedented in the last 600 years. These records accord with the palaeoflood record of Table 2.

Table 8: Frequency of palaeofloods for different combinations of rivers. Numbers out of brackets are raw scores and those in brackets are number of floods/year

Climatic Period (Age Range, CE)	Tropical (Burd+Herb)	Sub-tropical (Burn+Lock)	All (Burd+Herb+ Burn+Lock)	All (without Burnett River) *
MCA (1000-1400CE)	3 (0.008)	13 (0.03)	16 (0.04)	15 (0.04)
LIA (1400-1700CE)	2 (0.007)	15 (0.05)	17 (0.06)	16 (0.05)
CWP (1700-2000CE)	6 (0.02)	35 (0.12)	41 (0.14)	37 (0.12)

Burd – Burdekin. Herb – Herbert. Burn – Burnett. Lock – Lockyer (refer to Appendix 3 for palaeoflood details for each river)

*Data from the Burnett River from Lam et al. (2017a) are excluded due to the possibility that the radiocarbon dates for this river are too old.

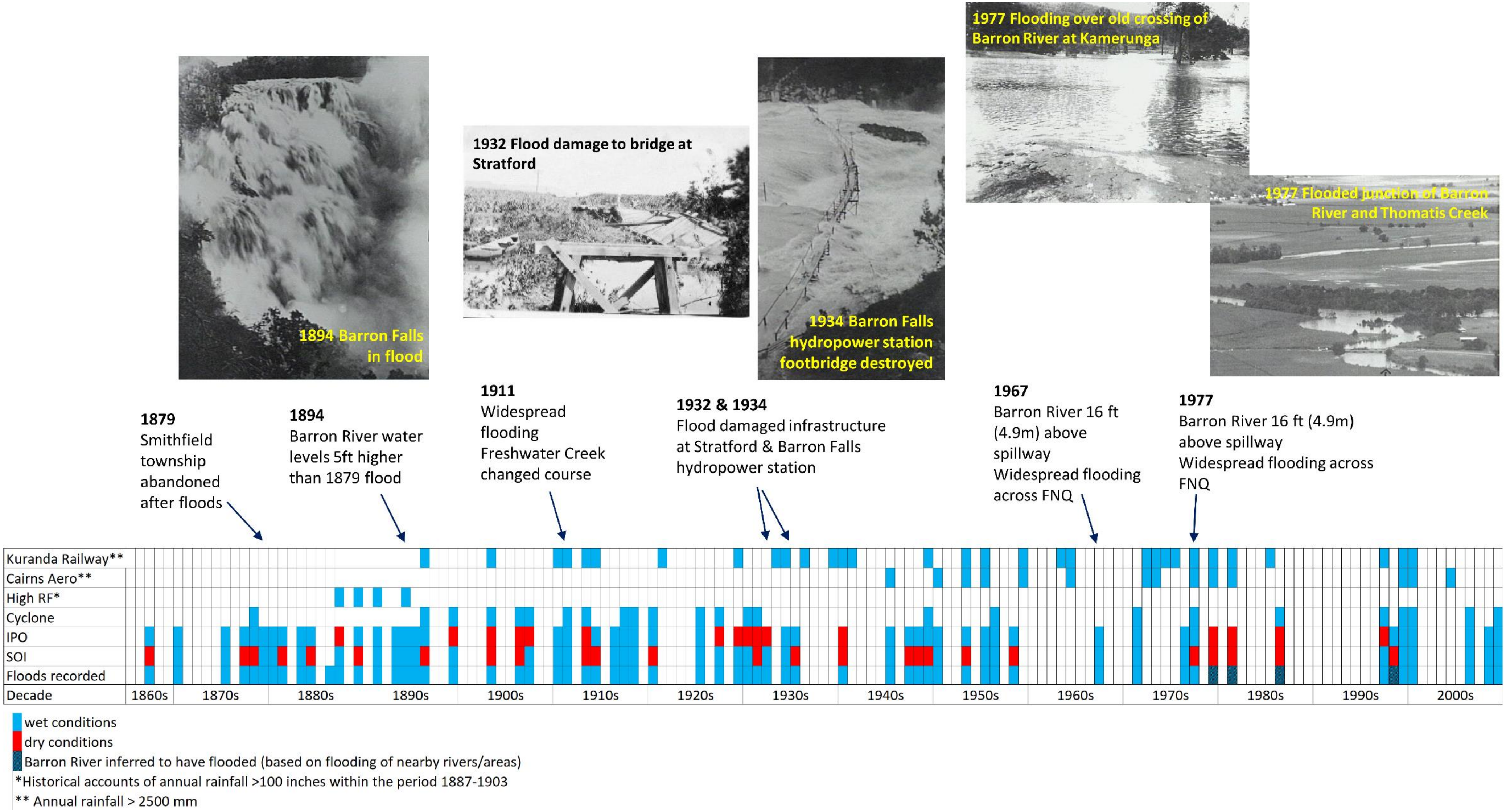
The El Ninδ Southern Oscillation (ENSO) phenomenon, Inter-Decadal Pacific Oscillation (IPO) and the Indian Ocean Dipole (IOD) are known large scale climatic drivers that affect Australian rainfall (Pui, 2011, 2012, Vance et al., 2022). Other climate factors play a role, including the Madden-Julian Oscillation, trade winds, extra-tropical blocking systems, extra-tropical cyclones, and tropical cyclones, and their interactions with ENSO and the IPO (Klingaman, 2012). Research into the relationship between palaeoflood discharge estimates and climate drivers have revealed the important role and interactions between the ENSO and IPO climate phenomenon. Lam et al. (2017a) compared fifteen palaeoflood discharge estimates from south-eastern Queensland with the same climate phases used by Yan et al. (2015) but with slightly different time periods and found the following distribution of flood occurrence; 6% in the MCA, 33% during the LIA, and 61% in the CWP. Most palaeofloods occurred when the IPO was negative with a cluster occurring during a period of peak tropical cyclone activity in the early eighteenth-century CE (Haig et al., 2014). The cyclone frequency record shows an increase from about 1600 CE to about 1800 CE, then a decline to values seen in the early LIA and the CWP. But the frequency of palaeofloods continues to increase into the period of lower cyclone frequency, so cyclones were not the only cause of these floods. Further evidence of the close relationship between palaeoflood frequency and the IPO is seen for the Lockyer Creek, a tributary of the sub-tropical Brisbane River in south-eastern Queensland, where higher flood frequency coincided with negative phases of the IPO (using the IPO reconstruction by Vance et al., 2015). Heinrich et al. (2009) used a combined tree ring record from northern NSW, Brisbane rainfall, and coral luminescence records from the Great Barrier Reef beginning in 1854 CE to show interdecadal modulation of precipitation by the IPO, supporting the conclusions of Croke et al. (2016). Palaeofloods were notably absent during periods of mega-droughts when the IPO is positive (Croke et al., 2016, Table 5). Broadly, the higher flood frequency observed for the CWP, especially in the last 150 years, is attributed to negative phase of the IPO which has the effect of enhancing La Niña's and rainfall in the study area (Verdon et al., 2004) along with a peak in tropical cyclone frequency early in this period (Lam et al., 2017a, Croke et al., 2016).

The historical account of the Barron River floods, which is within the last 150 years of the CWP, corroborates this close relationship between climate (monsoon rainfall, tropical cyclones) and flood magnitude. Appendix 5 provides a listing of floods recorded in historical documents and the corresponding ENSO, IPO states and tropical cyclones that were recorded. This information is summarised in a timeline of flooding produced by combining information from historical documents, large-scale climate phenomenon and modern rainfall data (Figure 18). There is a general pattern of floods occurring in years when the Southern Oscillation Index (positive SOI, proxy used to indicate ENSO state) and IPO (negative IPO) states favour wet conditions with high rainfall and resulting flooding (e.g. 1896, 1911, 1934, 1967, 1977, Figure 18). Cyclones also create flooding with resultant damages due to strong winds in addition to heavy rainfall. As such, both the palaeoflood evidence and historical accounts point to the important role of large-scale climate phenomenon in driving floods in the fan-delta, especially extreme floods. Pui et al. (2011) note that the IPO modulates the intensity of ENSO events (also see Weir et al., 2021) but argue that for flood analysis the IPO is most important. However, the relative importance of each or both phenomenon in flood generation is likely to be different on an annual basis, depending on more local scale drivers such as catchment wetness conditions (see below).

Apart from large-scale climatic influence, catchment conditions also affect the magnitude of floods, notably in the form of catchment wetness. For the instrumental period between 1920 and 2002CE, Pui et al. (2011) show that it is antecedent catchment soil moisture conditions prior to annual maximum floods that are dependent upon the state of the IPO, not the maximum precipitation. The combination of wet years, which amplify more modest rainfalls subsequently through soil moisture, can produce floods in a catchment. This likely occurred in the 1970s where high rainfall (>2500mm) occurred in consecutive years from 1972 to 1975, creating wet catchment conditions that favour flooding when a heavy rainfall occurred in 1977 (Figure 18).

The rapid land-use land cover (LULC) change that have occurred in the recent past may have also played a secondary role in increasing runoff rates from land cleared of its native vegetation; impervious urban surfaces, loss of floodplains, river training and river shallowing from increased sedimentation have roles to play in the flooding problem. Blöschl et al. (2007) conclude that because LULC is local its effects will decrease as catchment size increases, while climate effects are regional and should have similar effects in catchments of many sizes, reflected in the general trend of increasing palaeoflood frequency for wetter periods (CWP) for many rivers across coastal Queensland (Table 3).

So far, a long period of negative IPO, more intense La Niña's appear to have combined and interacted to produce an increased frequency of large floods during the CWP, mainly during the second half of this period. The wet period in the 1970s was due largely to a negative IPO and repeated occurrences of La Niña events that resulted in significant flooding in 1977. Given the nearly planet-wide global warming during the CWP (Neukom et al., 2019), and the operation of the Clausius-Clapeyron relationship and the Super Clausius-Clapeyron relationship (Lenderink et al., 2017), it is likely that anthropogenic climate change is also involved which may have made La Niña's more extreme (Gergis and Fowler, 2009). The future of the IPO and ENSO is therefore critical to anticipate wet periods and future flood magnitudes, information critical for increasing infrastructure and community resilience to these events.



1879
Smithfield township abandoned after floods

1894
Barron River water levels 5ft higher than 1879 flood

1911
Widespread flooding
Freshwater Creek changed course

1932 & 1934
Flood damaged infrastructure at Stratford & Barron Falls hydropower station

1967
Barron River 16 ft (4.9m) above spillway
Widespread flooding across FNQ

1977
Barron River 16 ft (4.9m) above spillway
Widespread flooding across FNQ

🟦 wet conditions
🟥 dry conditions
▨ Barron River inferred to have flooded (based on flooding of nearby rivers/areas)
*Historical accounts of annual rainfall >100 inches within the period 1887-1903
** Annual rainfall > 2500 mm

Figure 20: Flooding events and associated climate conditions for the Barron River, 1865-2009. Significant flood events are highlighted with additional text and historical photographs sourced from the Cairns Historical Society

5.2 Building resilience to future floods

5.2.1 Flood depths

Because the imbricated boulders measured in this study are yet to be dated, we only have the palaeoflood discharges and not the time when these floods occurred. Hence, flood frequency analysis with the palaeoflood discharges included with the modern gauge record is not possible. However, the historical accounts provide important information related to the extent of flooding and flood inundation depths and other associated impacts. Figures 21-24 highlight land selections around the Barron River fan delta that were flooded, based on historical accounts, mainly for the floods of 1879, 1903 and 1911 (Figure 21). For the 1879 flood that caused the abandonment of Smithfield Township, one land selection (56) recorded flooding depths of less than 1 metre but there are accounts of two land selections where flood depths was > 2.5 metres (38, 60) (Figure 22). Figure 23 shows flood inundation for land selections for flood events where there are reports of inundation depths. These figures show the spatial extent of flooding for land selections where flood depths were reported but it is likely that neighbouring areas were also flooded although their inundation depths were not reported in the historical documents.

What is interesting to note is that these patchy historical accounts of flood depths correspond well with the modelled flood depth of the 100-year flood event, where the area of the Smithfield Township likely experiences flood depths of around 1 metre or less (Figure 24). Areas southeast of Smithfield Township experience deeper flood depths, up to 3 metres, broadly similar to the general spatial patterns reported in the historical accounts (Figures 21-24). The peak discharges at Kamerunga for the floods of 1967 and 1977 were between 2500 and 5000 $m^3 s^{-1}$ with inundation depths of 1-3m and flow velocities across the fan < 1m s^{-1}. These floods had an Annual Exceedance Probability (AEP) of 20 and 3% respectively according to Department of Harbours and Marine (1981), although Connell Wagner (2004) calculated an ARI of 26 years (an AEP of 3.9%) for the 1967 flood and an ARI of 41 years (an AEP of 2.4%) for the 1977 flood. The ARIs for these floods are 22 and 165 years respectively according to Orr (2016). The difference in the estimated ARIs for the 1977 flood probably results from the application of different methods. The 17 December 2023 flood caused by ex-TC Jasper is slightly greater than the 1% AEP event. This flood caused significant flooding at the suburbs of Caravonica/Kamerunga, Machans and Holloways Beach. Rough estimates of flood depths at Caravonica are in the range of between 1 to 2 metres shown in Figure 24. However, further work in surveying flood debris will provide more updated information about flood depths due to this recent event.

Attempts to estimate the flood inundation depths of events greater than the 100-year event suggest that an ‘extreme’ flood could result in flood depths across the fan delta between 1 and 1.5 metre higher than the 100-year event (Connell Wager, 2004). At Caravonica and Kamerunga the flood depth would be 2 to 3 metres greater and almost 4 metres greater, a distance 500 metres upstream of Kamerunga. This will mean extensive flooding around the suburbs of Kamerunga, Caravonica and Freshwater, where there is currently significant suburban housing and agricultural activities. Updated hydraulic flood modelling using the field data from the 17 December 2023 flood will provide more insight into the impacts of floods, larger than the 1% AEP event, for the Barron River fan delta.

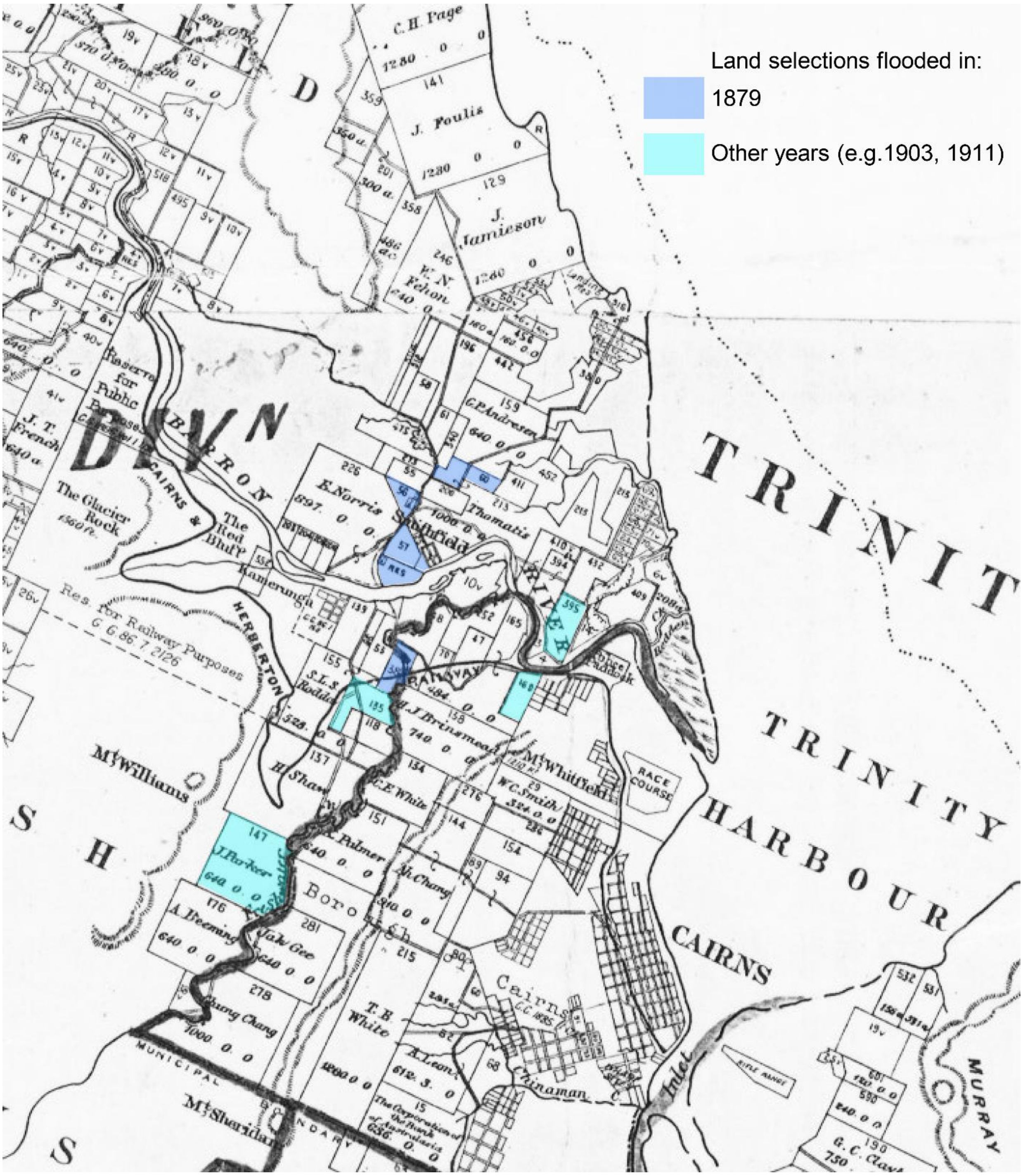


Figure 21: Land selections reported to be flooded in historical accounts (*Source: Queensland Historical Cadastral Maps. Cook District 1890-1917. Cook District 1894)*

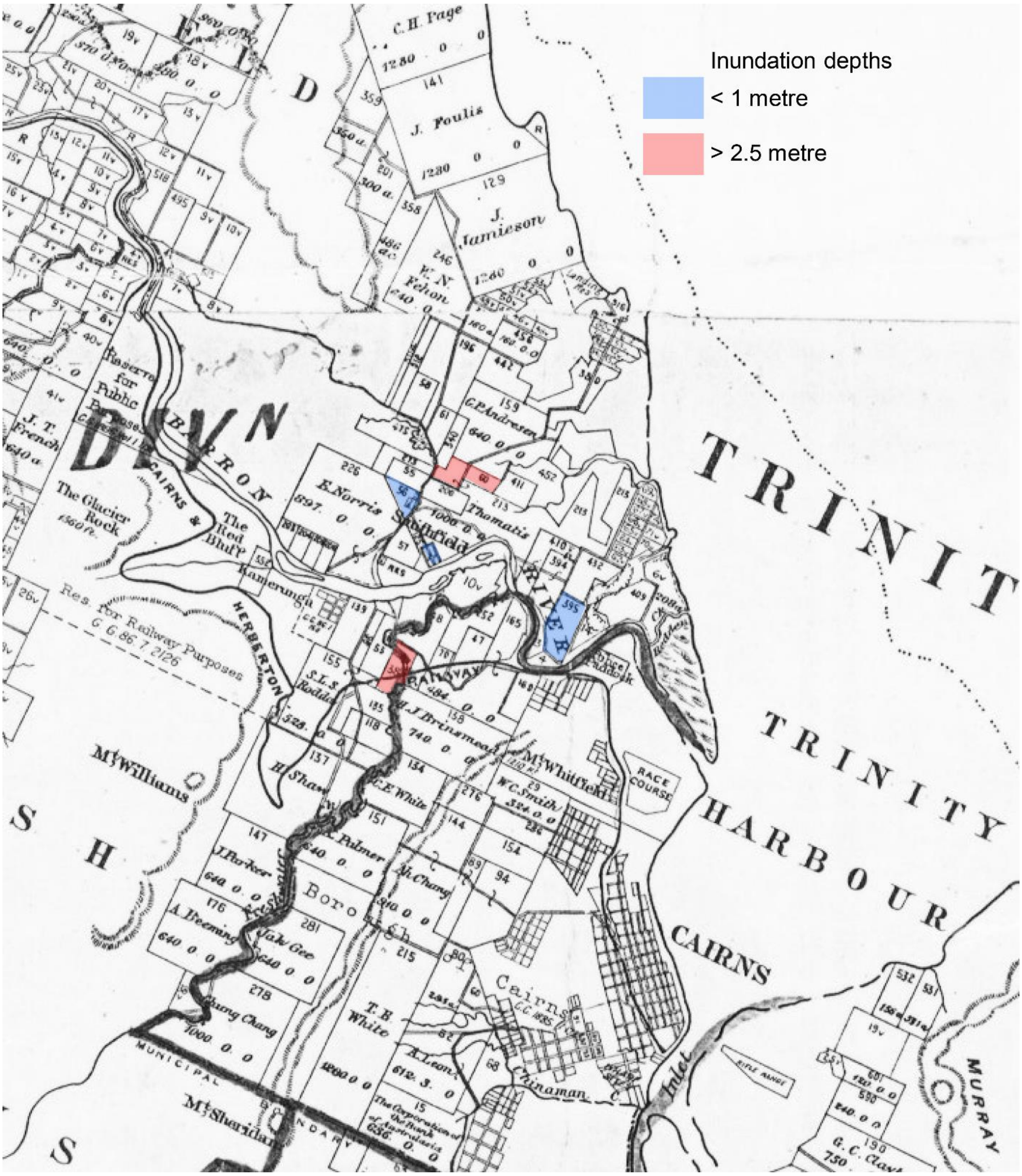


Figure 22: Flood inundation depths reported in historical accounts (*Source: Queensland Historical Cadastral Maps. Cook District 1890-1917. Cook District 1894)*

Figure 23: Flood inundation depths reported in historical accounts for the 1879 floods that cause the abandonment of Smithfield Township (*Source: Queensland Historical Cadastral Maps. Cook District 1890-1917. Cook District 1894)*

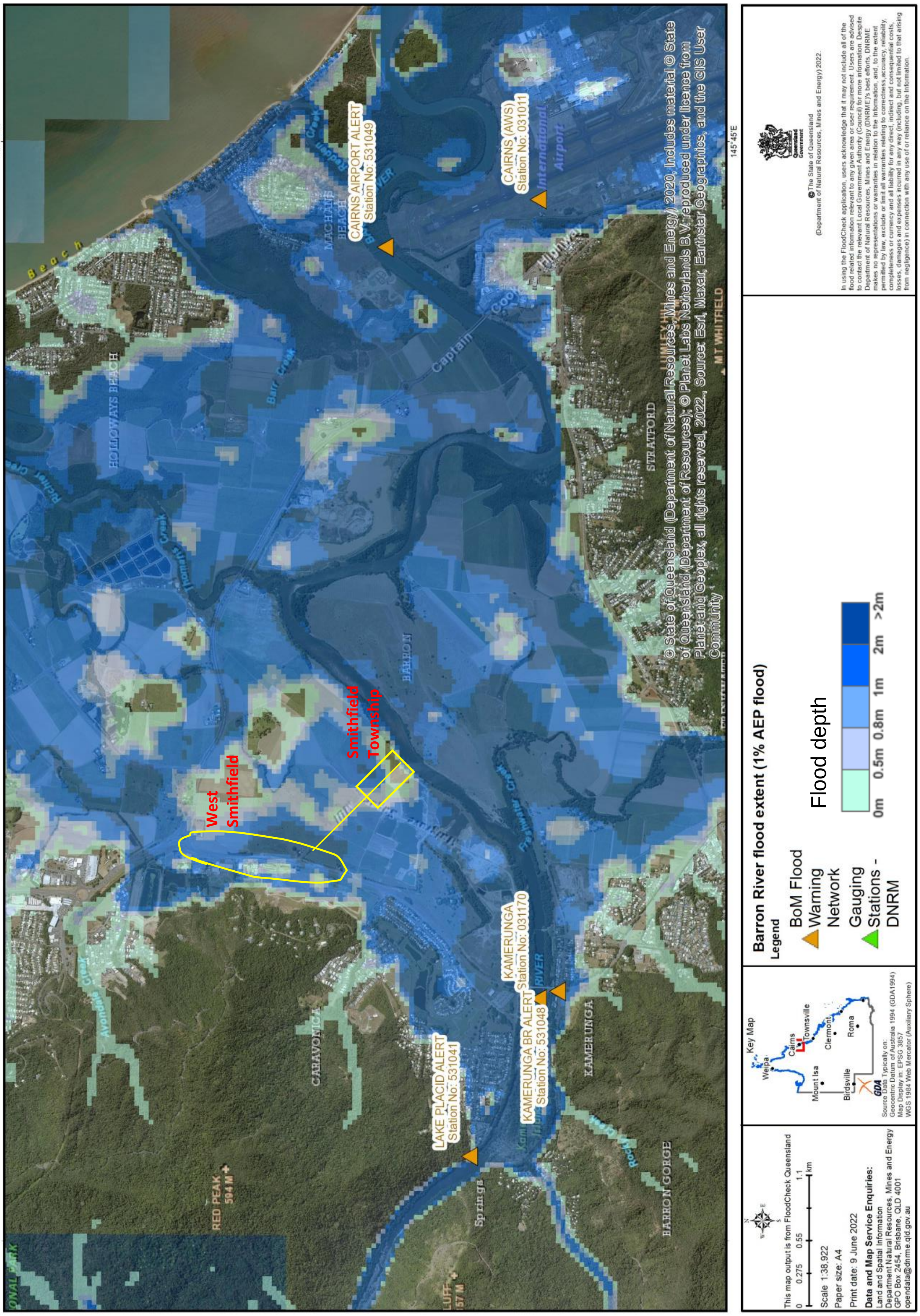


Figure 24: Flood inundation extent for a modelled 1-100 year flood event. Approximate locations of Smithfield Township and West Smithfield are included for reference (Source: https://floodcheck.information.qld.gov.au/)

5.2.2 Knowledge of flood risk

It is evident from the historical documents dating from the late 19th Century that flooding occurs regularly, resulting in significant damages to local businesses and communities. From the perspective of a landowner, it is also clear that the communities in the late 19th Century were aware of flood risk around the Smithfield township area. The siting of Smithfield Township was a considered decision, on a riverbank 20 feet above possibly average water levels. The local community accepted that risk and adapted accordingly to a point where it was probably not feasible (economically etc) to continue activities in the Smithfield Township area, which was abandoned after the 1879 floods.

It was also clear that government officials at that time knew the locations of land selections at high risk of flooding as these areas were marked on the historical maps (Figures 10 and 11). The flood issue was also considered in relation to land sales around the Smithfield Township and surrounds. The historical accounts of 1877 clearly highlight deliberations between government officials about the issue of land sales that were at risk of flooding. In fact, Macrossan felt that it was the duty of the landowners/residents to provide against any danger that might arise from flooding, pushing the responsibility of flood management to the community (refer to 1877 notes, Section 3.2).

Flood histories globally have been used to extend hydrologic records (e.g., Potter, 1978; Bayliss and Reid, 2001; Thorndycraft et al., 2003), identify flood prone areas (Conesa Garcia and Garcia Garcia (2003), and improve risk assessment (Williams and Archer, 2002). In the Barron River fan-delta context, the reminder of flood magnitudes and its associated damages may be a tool to increase flood awareness and for the community to discuss mitigation actions should similar floods occur in the future. Community knowledge of past flood events affects their ability to cope with, adapt to and recover from the adverse impacts of future flooding events. The call for attention to extreme/unprecedented floods is even more pertinent given the 2022 Southern Queensland and Lismore floods, whereby increasing community resilience to future floods is part of an integrated flood management approach (Gissing, 2022, Thomas, 2022). Efforts in this direction may include education about severe floods that have not happened in the recent past, encouraging community leadership specially to design their own flood management strategies (Gissing, 2002). Future work in this respect involves Council-led community events where information about historical floods is presented to the local community of the Barron River fan-delta.

6. CONCLUSIONS AND RECOMMENDATIONS

This project used a combined approach that included geomorphology, hydrology and history to provide a solid basis for understanding extreme floods in the Wet Tropics of Far North Queensland. The work is by far complete, especially with the occurrence of the 17 December 2023 ex-TC Jasper flood. Importantly, the work has shown that extreme floods, larger than FoR, have occurred in the past and are likely to occur again in the future, both for the Barron River fan-delta as well as other tropical and subtropical rivers in Australia. The work has also shown the important climate drivers of flooding in this region, which include ENSO and IPO, which can indirectly affect cyclone activity. A negative IPO climate state is likely going to result in increased flooding, especially when it persists for several years. Further efforts into understanding the relationships between the IPO and ENSO and floods is critical to anticipate future wet periods and associated flood magnitudes. The historical accounts not only support the close relationship between flooding and climate drivers, they show that flooding depths are in line with modelled flood depths using hydraulic models and can be an additional dataset by which to validate modelling outputs.

The historical accounts also highlight the fact that local residents and government were aware of the flood risk associated with the fan-delta area and adapted accordingly to floods that occurred in the late 19th Century. The Smithfield Township was abandoned when flood risks exceeded the benefits of living close to a major waterway of that time. These historical accounts provide a good basis to build flood awareness in the local communities and encourage the design of locally adaptable flood management strategies that build community resilience.

The project also provides very preliminary estimates of pollutant mass loads that are transported to the GBR should extreme floods occur in the future. The extreme floods that moved the boulders at the Barron River can result in sediment mass loads of approximately 18% of the modern-day annual sediment load to the GBR from the Barron River. This simple thought experiment provides the basis for further work on the role extreme floods play in mass load transport into an already fragile ecosystem, allowing managers to develop management and conservation options that take into account these extreme events which are projected to increase in the future with climate change.

6.1 Recommendations for future work

The most direct outcomes of this project include two to three academic papers, all of which are currently under development. Discussions with Cairns Regional Council are underway for a community event to present the historical floods to the local community and interested stakeholders.

However, the short length of this project (4 months) means that there is scope for further work on many aspects of the results presented in this report. These include the search for additional funds to conduct the following activities:

1. Sampling imbricated boulders for dating

The imbricated boulders will be sampled for Optically Stimulated Luminescence (OSL) exposure dating to determine when they last moved. This provides an approximate date that against the palaeoflood discharges that allows us to conduct flood frequency analysis with the palaeoflood data and the modern gauged record. This work was planned as part of this QWMN project, however environmental conditions and a changed risk profile made it unviable. The Cairns region experience a very late burst of wet seasonal rainfall and flooding activity which have made it impossible to safely sample the boulders. Our current permit to sample the boulders in a National Park ends in December 2022. Re-applying for approval to sample in the Barron Gorge National Park, undertaking the sampling, processing, and analysis are the next steps to be undertaken as part of this research. The sampling is required to be repeated approximately one year apart (to determine the base rate) of exposure.

2. Continued archival research for the Barron River and also the Daintree River

The 133-year historical account of Barron River floods still require a more in-depth search of local newspapers for information about past floods from 1954 till present day (as the TROVE system does not have the local newspaper available online from 1954 onwards). At the same time, more effort is required for the old maps, particularly those presented in Figures 7-19 and 21 to 24 to georeferenced them to modern maps to identify the flood prone areas identified in the historical account.

While documenting the historical evidence of palaeofloods for the Barron River, the project team also conducted initial data collection on floods for the Daintree River, believed to have experienced a floodplain stripping event in 1895 (Leonard & Nott, 2015). The project team have already had discussions with hydrographers from the region about undertaking a drone cross-section survey of the estimated peak flood site and relating this to the upstream gauging station site to determine velocity and discharge. This is the next step in this research, and ideally will be undertaken very late in the dry season before the onset of the wet (when the river is shallow). This work will provide us with additional information about the largest floods in the Wet Tropics and put this event in context with other recorded events (the 2019 flood event being the largest in the gauged record for the Daintree River). There is scope to apply the landscape evolution model, CEASAR, to simulate the flood magnitudes required to strip the Daintree floodplain. Additionally, the project team will need to contact the Disaster team from Douglas Shire Council to obtain documents related to recent floods and community events, in an attempt to better understand the response and management of recent floods.

3. Updated flood modelling of the Barron River fan-delta

This study did not include hydraulic flood modelling of the Barron River fan-delta which needs an updated modelling effort since the previous flood modelling efforts are more than 20 years old. Significant changes have occurred in the delta since then, particularly with increased development around the floodplain and coastal areas around the Barron River mouth. To do this requires cross-section surveys of the river downstream of the hydropower station and to the floodplain for input into hydraulic models such as TUFLOW or HEC-RAS. The updated flood modelling results will be followed by an in-depth assessment of flood risk, which will also include information from the historical account and local community.

The recent 17 December 2023 floods provided flood depths and other accounts of flooding for an event which is close to what is considered a 1% AEP flood. The field information is useful for validating hydraulic model predictions of the 1% AEP flood. Current work is underway mapping changes in the Barron River due to the flood using drones and on the ground surveying. There is also a call for flood photographs to identify flood depths and other information such as flow velocity, debris, sediment concentration, for as many locations as possible. Some of these locations are already surveyed by the local Council whilst other sites will be surveyed at a later period.

4. Improved estimation of extreme mass loading to the GBR

The load estimate provided here is a coarse approximation using a simple concentration x flow calculation. There are a number of ways this estimate could be improved in future. For example, a 100-year concentration model (applying an EMC/DWC model at a monthly time-step) could be used to estimate annual (indeed, monthly) loads using the eWater Source-GBR Dynamic SedNet models as the basis. This is currently being trialled in the Burdekin basin and could potentially be expanded to the Wet Tropics. Another avenue for future research is using climate forecast predictions to model future flood events, and again this is being trialled in other parts of the GBRCA by other researchers. Finally, we could look to using alternative models which simulate mass-failure events (e.g., floodplain stripping events and landslides) to better estimate fine sediment and particulate nutrient loads during extreme flooding events.

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APPENDICES

APPENDIX 1: ESTIMATING PEAK FLOWS FROM IMBRICATED BOULDERS

Methods

To obtain the palaeoflood magnitudes, we conducted the following measurements and calculations:

Step 1: Identify imbricated boulders along the Barron River downstream of the hydropower station
Step 2: Measure dimensions of imbricated boulders (long, short, intermediate axes).
Step 3: Calculate the minimum velocity needed to initiate boulder movement.
Step 4: Calculate water depth associated with minimum velocity for boulder initiation.
Step 5: Calculate minimum flood magnitude from river cross-section.

We identified a boulder field along the riverbank with imbricated boulders that were suitable for measurement. The angle of imbrication (approximately 20º) highlighted that they were transported by previous floodwaters and deposited stacked against each other. We found 16 such boulders and measured their long, short and intermediate axes (Figure A1.1). Boulder dimensions are given in Table A1.1. The boulders are derived from the meta-basalt and meta-andesite rocks of the Hodgkinson Formation (*Jonathan Nott, pers. comm*).

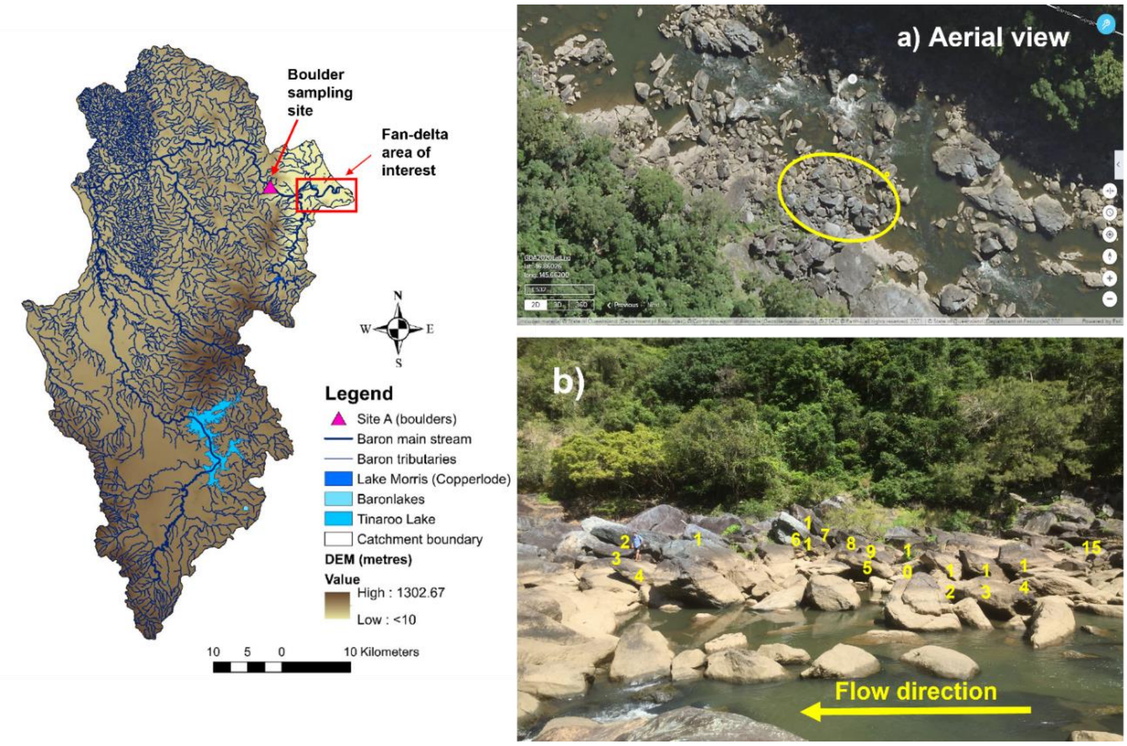

Figure A1.1 (similar to Figure 3 in the report): Map on the left shows the location of the boulder sampled, with photos on the right showing a) aerial view of Site A (16.860429051° S, 145.661839478° E) and b) imbricated boulders selected for measurement at Site A (n= 16 boulders).

Table A1.1: Dimensions of the boulders downstream of the Barron Falls, Barron River

Boulder no.	Long axis, d_L (m)	Intermediate axis, d_I (m)	Short axis, d_s (m)	Nominal axis, D_n $(d_L{*}d_I{*}d_s)^{1/3}$ (m)
1	5.1	4.3	2.6	3.8
2	5.5	1.9	1.4	2.4
3	2.9	1.9	0.7	1.6
4	3	2.7	0.8	1.9
5	3.9	2.4	0.9	2.0
6	4.9	2.9	1.8	2.9
7	3.1	2.4	1.4	2.2
8	3.1	1.8	1.1	1.8
9	2.5	2	1.6	2.0
10	3.6	3.5	1.3	2.5
11	5.4	4	2.3	3.7
12	2.6	2.3	1.3	2.0
13	3	2	1.4	2.0
14	4.4	3.3	2.1	3.1
15	4	2	0.7	1.8
16	3.8	2.6	1.04	2.2
Average of 5 largest boulders	4.7	3.6	2.0	3.2

The minimum flow velocity required to initiate boulder movement were calculated using both theoretical and empirical equations. The theoretical equations balanced forces (lift, drag) that initiate boulder movement and forces of resistance (friction, particle weight) and considered both characteristics of the fluid and boulders (e.g., Helley, 1969, Bradley & Mears, 1980, Clarke, 1996, Alexander & Cooker, 2016) and used by other researchers to estimate flood discharges (e.g., Carling, 1986, Greenbaum et al., 2020, Huber et al., 2020). Empirical equations are also used here to provide comparison estimates of flood discharges to those obtained from the theoretical equations. Two empirical equations obtained from Costa (1983) were used and based on; Colorado Range dataset and the U.S. Bureau of Reclamation derived equation. Both theoretical and empirical equations are summarized in Table A1.2. The equations that provided estimate of bed velocity for the initiation of boulder movement (v_b) were multiplied by a value of 1.2 to obtain average flow velocity, $\bar{v}$, for the water column. Values between 1.2 and 1.43 have been used to convert v_b to $\bar{v}$ and a value of 1.2 was used in this study because it was likely turbulent flows in the Barron River resulted in bed velocities that were close to the mean velocity of the flood (Baker, 1973, cited in Costa, 1983). With the measurements of boulder dimensions, we calculated the minimum flow velocity required to initiate boulder movement using four equations outlined in Costa (1983), shown in Table A1.2. These equations provide estimates of bed velocity for boulder initiation (v_b) which is then converted into average flow velocity for the water column ($\bar{v}$).

Table A1.2: Equations used to convert boulder dimensions into bed velocity to initiate boulder movement and average flow velocity.

Source	**Equation for bed velocity (v_b) and average velocity ($\bar{v}$) for incipient motion of large particles (m/s)**	**Parameters**
Theoretical equations		
Helley (1969)[1]	$v_b = 3.276\left[\frac{(\gamma_s - 1)d_L(d_s + d_l)^2 MR_L}{C_{D'}d_s d_L(MR_D) + 0.178 d_l d_L(MR_L)}\right]^{0.5}$ where, $MR_L = \left(\frac{d_I}{4}\right)\cos\theta + \left(\sqrt{\frac{3}{16{d_s}^2}}\right)\sin\theta$ $MR_D = 0.1 d_s\cos\theta + \left[\left(\sqrt{\frac{3}{16{d_s}^2}}\right)\cos\theta - \left(\frac{d_I}{4}\right)\sin\theta\right]$	A_B – cross-section area of boulder (m^2). Calculated as D_n^2 after Huber et al. (2020) where D_n is nominal diameter. C_D – drag coefficient C_L – lift coefficient $C_{D'}$ - adjusted drag coefficient d_s – short axes (m) d_I – intermediate axes (m) d_L – long axes (m) D_n – nominal axis (m) $D_n = (d_L * d_I * d_s)^{1/3}$ F_C – critical force (Newtons) F_D- drag force (Newtons) F_R – resisting force (Newtons) M_B – boulder mass (kg) MR_L – turning moment for lift MR_D- turning moment for drag θ - imbrication angle (degrees) β- bed slope (radians) g- gravitational acceleration μ – coefficient of friction between particle and riverbed ρ - fluid density (kg/m^3) σ - boulder density (kg/m^3) γ_s – specific weight of particle (N/m^3) γ_f – specific weight of fluid (N/m^3)
Bradley & Mears (1980)	$v_b = \left[\frac{2(\gamma_s - \gamma_f)d_l g\mu}{\gamma_f(C_L + C_{D'})}\right]^{0.5}$	
Clarke (1996)	$v_b = \left[\frac{2\frac{\left(\frac{F_D}{C_D}\right)}{\rho}}{A_B}\right]^{0.5}$ where, $F_D = \frac{(C_D F_R)}{(C_L + C_D)}$ $F_R = M_B\left[\frac{(\sigma - \rho)}{\sigma}\right]g\{((\cos\beta)\mu) - (\sin\beta)\}$	
Alexander & Cooker (2016)	$\bar{v} = \left[2Lg\left\{\lambda_{max}\left(\frac{\rho_s}{\rho_f} - 1\right) - k\frac{a}{g}\right\}\right]^{0.5}$	
Empirical equations		
Williams (1982)	$\bar{v} = 0.065{d_I}^{0.5}$ (for 0.01 m $\leq d_I \leq$ 1.5 m)	
Colorado Range data (Costa, 1983)[2]	$\bar{v} = 0.27{d_I}^{0.4}$	
U.S. Bureau of Reclamation (Costa, 1983)	$v_b = 5.9{d_I}^{0.5}$ $\bar{v} = 1.2 v_b$	

[1] $\bar{v}$ is in ft/s and is converted to m/s by division with 3.2808

[2] The coefficient of 0.27 and 0.40 were used because the boulders were larger than 500mm (Costa,1983)

Using the average flow velocity through the water column, the flood depth was calculated using the equation below (Costa, 1983):

$$D = \left[\frac{\bar{v}n}{\sqrt{S}}\right]^{1.5}$$

where,
D – depth of water
$\bar{v}$ – average flow velocity (metres per second)
n – roughness coefficient (Manning's n)
S – stream gradient

A roughness, n, value of 0.085 was used, with a stream gradient of 0.0278 was used for the calculation. A cross-sectional area of flow of 1271.8 m^2 was obtained from field measurements approximately 20 m upstream of the boulder field site (Figure A1.2). Flood discharge was calculated using the equation below:

$$Flood\ discharge = \text{cross-section area } \times \bar{v}$$

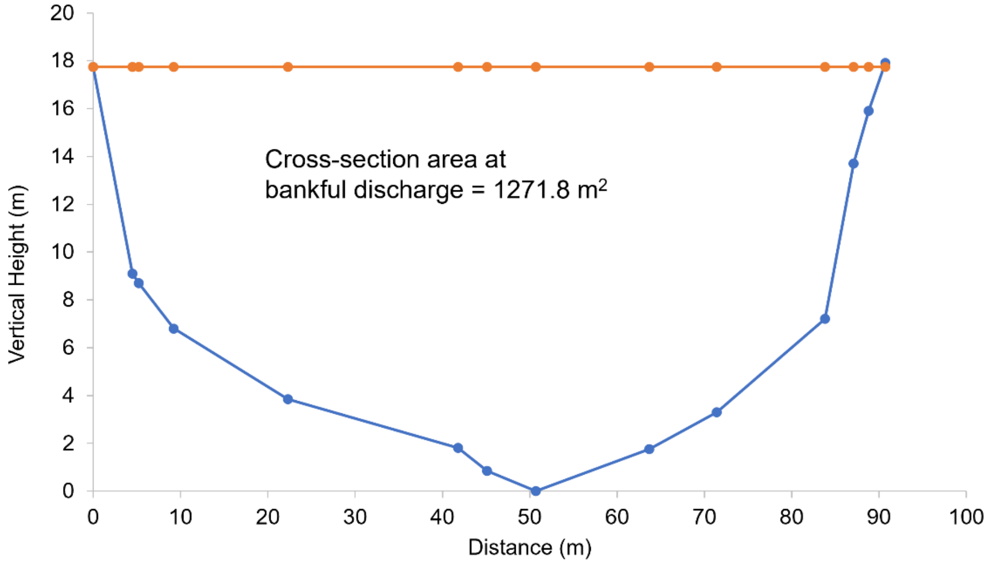

Figure A1.2: Cross-section profile 20 metres upstream of Site A where the imbricated boulders are located.

Table A.1.3 List of gauge stations close to sites where palaeoflood studies were conducted

	River	**Area above gauging station (km^2)**	**Q_{FoR} (m^{3}s^{-1})**	**Station code (start date)**
Tropics				
NT	Katherine	6390	5168	G8140019 - Katherine Gorge (upstream of gorge) (started 1954-1987)
		8640	6998	G8140001 Katherine @ railway bridge (started 1957)
NT	E Alligator	2384	9233	G8210010 (started 1971 - 2006)
NT	Finke S Road Crossing	7500	1668	G0050116 (started 2004)
NT	Finke Hermannsberg	3973	1116	G0050139 (started 1973)
QLD	Barron Gorge	1779	6440	Station 110001D Myola (started 1982)
QLD	Herbert	5236	15336	Station 116004C @ Glen Eagle (started 1959)
QLD	Burdekin	114700	19196	Station 120302B Cape River @ Taemans (started 1968)
WA	Fitzroy	46133	25546	Station 802055 Fitzroy @ S Crossing 802055 (started 1956)
WA	Margaret	7645.6	8930	Station 802198 Me No Saavy (started 1965)
WA	Lennard	1049.8	5437	Station 803001 Mt Joseph (started 1966)
Subtropical				
QLD	Baramba	5553	7594	station 136207 Burnett at Ban Ban (started 1966)
QLD	Mary	3068	8215	station 1380007A Fisherman Pocket (started 1968)
QLD	Emu Creek	915	2036	Station 143010B Boat mountain at Emu Creek (started 1976)
QLD	Logan	158	1904	Station 145003B Logan River @ Forest Home, started 1953)
QLD	Nerang	68	494	Station 146015A Nerang River @ Numinbah (started 2007)

APPENDIX 2: THE BARRON RIVER FAN DELTA

Geomorphic Development

The Barron River rises on the Atherton Tableland at about 900 asl and passes over the Barron Falls knickpoint and through a 6km long gorge on the margin of the Tableland before reaching Kamerunga which is the apex of an alluvial fan-delta. The river's catchment area is 2,175km^2, and the fan-delta has an area of about 40km^2 There is one major tributary downstream of the fan apex, Freshwater Creek, which contributes about 10% to the mean annual flow in the Barron River (Department of Harbours and Marine, 1981).

A fan-delta is a landform consisting of an alluvial fan built by riverine (fluvial) processes that merges downslope with a body of water where different geomorphic processes prevail (Van Dijk et al., 2012). In the case of the Barron fan-delta, the transition is from riverine processes to marine and coastal processes on beaches (90% of the sand in which comes from the Tableland; Nicolls et al., 20124), dunes, beach ridges, estuaries, mangroves forests, and offshore subaqueous deltas. A geomorphic map is provided by Department of Harbours and Marine, 1981, Figure 2.11).

The fan was originally dominated by tropical lowland rainforest but from about 1890 was largely cleared and used for agriculture, aquaculture, and some sand and gravel mining. Fluvial processes of sandy and gravelly bedload deposition have occurred in channels and laterally migrating flood plains such as that currently on the right bank of the Barron River where it comes closest to the Cook Highway south of the Kart Hire establishment, as evidenced on Google Earth by scroll bars and swales. The Barron is the major river on the fan with an average depth below the flood plain surface between 2.5m near the mouth and a maximum of 10m adjacent to the old Smithfield township from which it decreases upstream to 5.5m at the Kamerunga bridge. There is bank erosion on this and other rivers on the fan, a result of both natural channel change and removal of protective riparian vegetation. The surface of the fan consists of fine sediment, deposited from overbank flow from the river channels.

The fan-delta is underlain at the modern coast by about 100m of unconsolidated sediment, with up to 94m of interbedded sand, clay, clayey sand, and gravel overlying Palaeozoic metasediments at the AQUIS Resort Site in the northeast of the fan (Flanagan Consulting Group, 2014a) suggesting that much of it has accumulated since the last low stand of sea level about 20,000 years ago during the Last Glacial Maximum. When sea level reached its current position about 6,000 years ago (or possibly 1.5-1.8m higher than the present: Nakada and Lambeck, 1989), the modern landforms began to form. Traces of palaeochannels on the fan surface show that deposition was by mildly sinuous anastomosing and anabranching rivers that probably moved mostly by avulsion during large floods and by slow lateral migration across floodplains as already noted for the modern Barron River.

One of the preferred flow paths for overbank flows is from the left bank of the Barron River through Caravonica, as shown by ground observations and hydraulic modelling (Connell Wagner, 2004) and by a line of elongate lagoons that mark a palaeochannel. In a sand pit adjacent to this palaeochannel there is about 10m of fluvial cross-stratified sand and gravel overlain by 2m of overbank clay and silt that thins towards the palaeochannel. This sequence overlies what appears to be clay deposited in a mangrove forest (from information provided by Barry Warne of Pioneer North Queensland) about 6m below modern sea level, suggesting that an active channel developed over the mangroves from about 10,000 years ago according to the regional sea level curve of Lambeck and Nakada (1990). The information upon which this tentative conclusion is based needs more thorough investigation.

During the period of European presence, several changes to the rivers have been documented and certainly the indigenous people of the area have similar accounts, such as the formation of Lake Placid by a flood (according to an information board at the lake) upstream of the head of the fan. The most significant documented local change after European arrival occurred during the flood of 1932 when the Barron River broke into Thomatis Creek which to that time was a tributary of Richter’s Creek, was partially tidal, and routed overbank flows to the coast as currently happens in Redden Creek, Barr Creek, Yorkey’s Creek, and Half-Moon Creek. Thomatis Creek and the Barron River downstream of the junction are now distributary channels with different outlets to the ocean, each with a subsea delta. It is claimed by Department of Harbours and Marine (1981) that the breakthrough was instigated by cultivation that caused a washaway between the two channels, enlarged by the floods of 1911 and 1913 until the 1932 flood completed the connection. The mouth of the Barron River has also shifted (probably by avulsion) from south of Casuarina Point about 10km along the coast to the northwest (Marrie, 2021). Other smaller channel changes are reported by Department of Harbours and Marine (1981).

Floods

The fan-delta is subject to large floods, that are mostly tropical cyclone induced. Orr (206) found that between 1915 and 2014 50% of annual peak flows greater than an Average Recurrence Interval (ARI; see Notes) of 2 years were associated with cyclones, and >80% were associated with cyclones for ARIs >20 years. That the entire alluvial part of the fan is subject to overbank flooding, with an additional direct rainfall (pluvial) component, is shown by the maps in Department of Harbours and Marine (1981) and Flanagan Consulting Group (2014b) for the floods of 1967 and February and March of 1977, from ground observations, gauging and modelling. Both floods were associated with cyclones.

The peak discharges at Kamerunga for the floods of 1967 and 1977 were between 2500 and 5000 $m^3 s^{-1}$ with inundation depths of 1-3m and flow velocities across the fan < 1m s^{-1}. These floods had an Annual Exceedance Probability (AEP) of 20 and 3% respectively according to Department of Harbours and Marine (1981), although Connell Wagner (2004) calculated an ARI of 26 years (an AEP of 3.9%) for the 1967 flood and an ARI of 41 years (an AEP of 2.4%) for the 1977 flood. The ARIs for these floods are 22 and 165 years respectively according to Orr (2016). The difference in the estimated ARIs for the 1977 flood probably results from the application of different methods, although Wasson (2016) and Stuart et al., (2016) raise fundamental issues with such calculations. Both floods flowed along the preferred pathway though Caravonica, and elsewhere.

Flanagan Consulting Group (2014) calculated the theoretical Probable Maximum Flood (PMF) of 25,255 $m^3 s^{-1}$ which at the proposed AQUIS Resort Site on the north-eastern part of the fan would produce inundation depths up to 5.5m. This peak discharge is between 5 and 10 times the 1967 and 1977 flood discharges. Roy & Associates (1976), cited in Connell Wagner (2014), suggest a PMF of only 8,900 $m^3 s^{-1}$ a value that Connell Wagner (2004) imply is too low.

Connell Wagner (2004) doubled the calculated 100-year ARI flood to estimate the impact of an ‘extreme’ flood indicating that flood depths across the fan would be 1 to 1.5m higher than the 100-year event. At Caravonica and Kamerunga the flood depth would be 2 to 3m greater and almost 4m greater 500 upstream of Kamerunga, a depth greater by at least a metre at Placid Lake (as marked on a tree) for the 1999 flood of about 1760 $m^3 s^{-1}$ (G. McCloskey, pers. comm.) The ‘extreme’ flood would be 12,600 $m^3 s^{-1}$, with an ARI of 1,500 years, and is about half of the PMF. Orr (2016) shows that there has only been one 100-year flood between 1951 and 2002, although very large floods occurred in 1911 and 1913, estimated to have had peak discharges of 7220 $m^3 s^{-1}$ and 6570 $m^3 s^{-1}$ respectively. However, the accuracy of these values is questionable (Connell Wagner, 2004). If accurate, the 1911 peak flow would be the Flood of Record for the Barron River. Earlier but ungauged large floods have been reported on the fan-delta from the late nineteenth century.

Sedimentation

The change of land use with the arrival of the Europeans and Chinese probably increased erosion rates in the Barron River’s catchment, which may have increased sedimentation rates on the fan thereby possibly exacerbating floods. There is no direct sedimentary evidence for this possibility and the results of Nicholls et al. (2014) mysteriously suggest no change in the sediment yield from pre to post land use change. However, the identification of the pre-land use change sediment yield used by these authors is highly uncertain with 8 estimates ranging from <1 to 6.5mm/1000 years, excluding that of the Department of Harbours and Marine (1981). From first principles, there must have been an increase in erosion rates following land use change, some of the products of which is stored in the catchment on the Tableland for future release, as suggested by Nicholls et al, (2014) but surely not all. If so, there was probably an increase in sedimentation rate on the fan within the last century or. A more secure analysis by Mariotti et al. (2021) show an increase of erosion rate after land use change by a factor of three and, unless there is extremely efficient sediment storage on the Tableland, much of this increased erosion should have added to the fan; but by an amount that cannot be known without analysis of sedimentation rates on the fan and therefore if it has exacerbated floods.

Note on AEP and ARI

The AEP is the risk of at least one exceedance in the next n years and is given by

$R_n = 100\ (1-p^n)$

where,

R_n is the risk of exceedance for a period of n years in percent.

$p = (1-1/T)$ is the probability that the flood discharge with ARI of T years will not be exceeded in any one year. Hence p^n is the probability of no exceedance in n years.

An AEP of 1% = an ARI of 100 years and AEP of 50% = an ARI of 2 years.

For an AEP of 1% there is a 63% chance of exceedance over a 100-year period.

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APPENDIX 3: META ANALYSIS OF PALAEOFLOODS

This appendix is a meta-analysis of extreme flooding events that occurred for major rivers along coastal Queensland that represent the Wet, Wet/Dry Tropics and Sub-tropical climate zones based on palaeoflood evidence. The analysis is based on published data, with commentary on the accuracy of peak flows and ages of palaeofloods and estimates from boulder deposits with some new information from Barron River boulder deposits.

Daintree River

Using a morpho-stratigraphic approach supported by Optically Stimulated Luminescence (OSL) dating, Leonard and Nott (2015) concluded that over the past 6,000 years there have been six large floods or clusters of large floods, probably induced by cyclones that stripped the floodplain of this river and flushed much of the dislodged sediment to the Great Barrier Reef lagoon. Between stripping events the floodplain has been rebuilt by vertical accretion for which flood couplets in one reach are clear evidence (also see Wasson et al., 2021, for a global perspective on such rivers). The periods of stripping were between 2500 and 400 BCE, 1020 and 1680 CE, 1580 and 1920 CE, and in 1895 CE (https://www.douglashistory.org.au/timelines/daintree.html; http://www.bom.gov.au/qld/flood/brochures/daintree/daintree.shtml; both accessed 2 April 2022). The FoR was 4,150 $m^3 s^{-1}$ in 2019 (gauging station number 108002A – Daintree at Bairds) which was the largest flood in 118 years (Callaghan, 2021). But from geomorphic/hydraulic analysis yet to be completed, the 1895 flood was much larger. This claim is made from existing accounts of a flood event reported in the local newspaper in 1895, which washed away a house located in the Upper Daintree, killing six people. Having approximated the location of the house washed away in the 1895 flood, we know that the 2019 flood did not reach this height. It was reported at the time (in 1985), that the flood rose 8 feet (2.4 m) higher than ever before (REF). From currently available information the FoR is the extreme flood that could be used for stress testing. Interestingly the beginnings of clearing for agriculture of the lowland rainforest by European settlers were in the 1870s and 1880s. The first four floodplain stripping events were therefore when the valley floor and riverbanks were ‘wooded’ and thickly vegetated by ‘luxuriant jungles’ according to Dalrymple (1874). The same was probably partially the case for the 1895 event. This implies remarkable stream power to remove both the vegetation and the floodplain, the analysis of which would require a landscape evolution model such as Caesar (https://csdms.colorado.edu/wiki/Model:Caesar) to model fluvial processes that will strip floodplains and their associated flood magnitudes.

Mulgrave River

A similar analysis was performed for the Mulgrave River (Leonard and Nott, 2016) where it was found that the last major phase of sediment removal was between about 820 and 1770 CE during a period of heightened cyclone activity. Unlike in the Daintree catchment, where there were periods of coeval accumulation and stripping of alluvium, one or more floods in the Mulgrave River were sufficient to remove all the alluvial valley fill and its overlying lowland rainforest (see Dalrymple, 1874, for a description of the vegetation). The FoR for the Mulgrave was 3,354 $m^3 s^{-1}$in 1977 (gauging station number 111007A – Mulgrave River at Peets Bridge), but this gauged value is likely to be substantially smaller than any of the floods that stripped the floodplain and valley fill.

Barron River

There are no palaeoflood records based on slackwater deposits for this catchment, but there is a range of estimates of peak discharges from analysis of imbricated boulders in the gorge a short way upstream from the apex of the fan-delta that forms the floodplain at the lower end of the catchment. These are minima as they are estimates of the velocity and discharge needed to move the boulders, not necessarily the actual flow. Flay (2001) employed the methods provided by Costa (1983) to estimate a peak discharge of 16,970 $m^3 s^{-1}$ for six boulders. Also, four equations from Costa (1983) for 16 boulders (to be reported elsewhere) gave a range of peak discharges from 2,690 to 17,500 $m^3 s^{-1}$ with a reliable range from 7,400 to 17,500 $m^3 s^{-1}$. The FoR for this river is 7,220 $m^3 s^{-1}$ and was estimated at Myola upstream of the boulders for 2011. At the boulder site it is likely to have been 10% larger (Flay, 2001) at 7,940 $m^3 s^{-1}$. The Probable Maximum Flood (PMF) is estimated at 25,220 $m^3 s^{-1}$ (Department of Harbours and Marine, 1981). From these limited results the maximum peak discharge is $\geq$ 16,970 to 17,500 $m^3 s^{-1}$, which are likely to be identical given uncertainties.

The most reliable extreme is the FoR but for stress testing it would be prudent to use the average of the two extreme discharges from the boulder analysis, 17,240 $m^3 s^{-1}$, a more credible extreme than the PMF which has enormous uncertainties. For example, McMahon (2012) estimated the 95% confidence limits of 8,000 to 300,000 $m^3 s^{-1}$ for the Wivenhoe Dam PMF on the Brisbane River in Southeast Queensland. For the Herbert River (see below) the range for the PMF is 11,000 to 52,000 $m^3 s^{-1}$ (WBM Oceanics Australia, 2003).

Herbert River

The pioneering work by Wohl (1992a) focused on the palaeoflood slackwater deposits, dated by radiocarbon, and boulders in the Herbert River. It has not been updated by using OSL dating, for example, that is likely to provide a more accurate chronology. This is because charcoal, which was used for dating by Wohl, can have a finite residence time (an inherited age) in a catchment before being incorporated in a slackwater deposit (Frueh and Lancaster, 2014; Lam et al., 2017a) and therefore does not provide an age for the deposit. OSL dating, by contrast, but not without limitations, provides ages for the deposition of the sediment or more accurately the age of burial beyond the zeroing effect of sunlight.

The estimates of peak discharges however are likely to be as reliable as other estimates to be reported later because essentially the same methods have been used. These estimates are also minima because the top of each flood deposit is taken to be the depth of water above the channel bed for each flood. This is the only available method because the actual depth of water is unknown, although it can be several metres above the deposit top (Saynor et al., 2020).

The results from Wohl (1992a) and Wohl et al. (1994) are presented in Table . The most probable ages are presented based on the radiocarbon counting statistics. For the 1850-1950 range of ages from seven samples, the youngest is used because the older samples must have inherited ages.

Table *A3.1:* Most probable ages and peak discharges for the Herbert River (from Wohl, 1992a).

Most Probable Age (years CE)	Minimum Peak Discharge Range (10^3 m^3 s^{-1})
1060	11.5-12
1580	14.5-16.5
1700	15.5-17.0
1805	14.0-16.0
1950*	13.0-14.0
Post-1950 (1967)	13.0-15.0

*the youngest estimated age from a range of 1850-1950 (Wohl et al., 1994) is likely to be the most accurate.

The highest discharge is 17,000 m^3 s^{-1} compared with the FoR of 11,920 m^3 s^{-1} in 1967 (gauging station 116001D – Herbert River at Ingham) which Wohl (1992) equated with the youngest slackwater deposit for which she had four radiocarbon analyses, and the PMF of 38,000 m^3 s^{-1} (WBM Oceanics Australia, 2003). In this case the highest flow from the palaeoflood record should be used for stress testing because of the large error associated with the PMF, as described above.

Burdekin River

Wohl (1992b) also analysed slackwater deposits and palaeostage indicators along with boulder deposits in the Burdekin gorge. Dating of the slackwater deposits was by radiocarbon and evidence was found for seven large floods over the past 1,200 years (Table A3.2). The caveats described for the Herbert River results apply to these Burdekin results.

Table *A3.2:* Burdekin results from Wohl et al. (1994).

Most Probable Age (years CE)	Minimum Peak Discharge Range (10^3 m^3 s^{-1})
770	23.5-26
1260	27.5-28
1500	11-15
1725	28-30
1950*	17-20
1960#	21-25
1980@	22.5-25

* the youngest age from a range of dates from 1850 to 1950.
# the approximate youngest age from two dates.
@the approximate youngest age from two dates.

To move the largest boulders in the Burdekin gorge a discharge of 30,000 m^3 s^{-1} is required, and to achieve cavitation in the bedrock benches of the river, to form small scale erosional features, between 15,000 and 30,000 m^3 s^{-1} is required. From these results, the worst-case flood has a discharge of at least 30,000 m^3 s^{-1}compared with the FoR in 1991 of 19,195 m3s-1 (gauging station 120015A – Burdekin River at Hydro) (The Centre for Catchment and Flood Management, 2018; Jordan et al., 2021).

More recent work that used OSL dating and hydraulic calculations similar to those of Wohl (years) has produced results presented in Table A3.3 (The Centre for Catchment and Flood

Management, 2018). Each “Identified Flood” is a result of grouping of analyses of up to three slackwater deposits for different locations for each flood.

Table *A3.1:* Most probable ages and peak discharges for Burdekin palaeofloods over the past 1,000 years (from The Centre for Catchment and Flood Management, 2018).

Identified Flood	Most probable Age (CE)	Peak Discharge ($m^3 s^{-1}$)
A	1910	24,000
B	1847	27,800
C	1684	27,700
D	1380	27,500
E	1069	27,200

The largest peak flows are no different between the two sets of data (Table A3.2 and Table A3.3), given the likely uncertainties, with a maximum of about 30,000 $m^3 s^{-1}$. But an upper bound peak flood discharge is 55,800 $m^3 s^{-1}$, beyond which there is no evidence of a flood exceeding this value (Jordan et al., 2021). Therefore, the peak discharges lie between 30,000 and 55,800 $m^3 s^{-1}$, given that the peak discharges calculated from the slackwater deposits are minimum values. In this case the lower value is probably the best to be used for stress testing as the upper bound has more uncertainties attached to it and it is unlikely that it has been exceeded in the past 1,000 years. A PMF is not publicly available.

Burnett River

Lam et al. (2017a) provided three palaeoflood peak discharge estimates for the sub-tropical Burnett River (Figure 3) at Barambah of between 6,800 and 9,000 $m^3 s^{-1}$, over the past 3,400 years, which are about the same as the FoR of 7,590 $m^3 s^{-1}$ in 2013 (gauging station 136207A – Barambah at Ban Ban) A more detailed palaeoflood study was performed downstream of the Paradise Dam on the Burnett River, producing evidence for nine large floods over the past 1,000 years (Sunwater, 2021). Both studies on this river used essentially the same methods as those used for the most recent Burdekin study. The results from Sunwater (2021) are in Table A3.4.

Table *A3.4:* Summary of palaeoflood-based peak discharges and their ages for the Burnett River. From Sunwater (2021).

Flood ID	Age and range (CE)	Peak Discharge ($m^3 s^{-1}$)
A	1942	21,292
B	1893	21,132
B1	1890	20,866
C	1864	15,931
D	1737-1769	13,980
E	1643-1683	17,180
F	1507-1575	13,664
G	1307-1377	18,660
H	1088-1145	18,261

The FoR is 8, 060 $m^3 s^{-1}$ (1954 at gauging station 136003A – Burnett River at Gayndah) and the PMF is 76,140 $m^3 s^{-1}$ at Gayndah or 83,980 $m^3 s^{-1}$at Walla, and the adopted design PMF is 82,080 m^3s^{-1} (https://www.northburnett.qld.gov.au/wp-content/uploads/2016/09/3-Gayndah-Flood-Study-Vol-1.pdf). Unlike the earlier study of the Burnett, the magnitudes of these palaeofloods are considerably more than the FoR.

Brisbane, Mary, Logan-Albert, South Coast rivers

Lam et al. (2017a) calculated palaeoflood discharges at four other sites in Southeast Queensland. There are insufficient data for a thorough analysis, so only a summary is provided in Table A3.5*:* and the sites are not located on **Error! Reference source not found.**.

Table *A3.5:* Palaeoflood discharge estimates for the Mary (a Brisbane River tributary), Logan-Albert and South Coast rivers

River	Reach	Number of estimates	Palaeoflood range ($m^3 s^{-1}$)	Age and age range
Mary	Mary	2	3,600-6,750	1935 CE-480 BCE
Brisbane	Emu	3	650-3,000	1907 CE-1550 BCE
Logan-Albert	Logan	1	900-950	1720-57 CE
South Coast	Nerang	1	580-650	1830 CE

Of the latest destructive floods in the Brisbane River catchment, the youngest OSL date for a slackwater deposit on the tributary Emu Creek of 110±25 years ago is likely to be for the 1893 CE flood (Cook, 2019). There is no sedimentary record of the 1974 and 2011 CE floods at Emu Creek and there are no data from the main river.

The FoRs for the Mary and Logan-Albert rivers are higher than the maximum palaeoflood discharges, by 8% and 100% respectively. For the South Coast the FoR is smaller by 9% than the palaeoflood.

APPENDIX 4: REFERENCES FOR HISTORICAL ACCOUNTS OF BARRON RIVER FLOODS

The references are listed by introduction, maps and the year they apply to.

Introduction

Queenslander Saturday 30 December 1876:13
Queenslander Saturday 10 February 1877:6
Maps
S199.1, S199.2, S199.3a, S199.3b, S199.4, S199.5, C157.314
1877
QSA IID 846964 -77/750
QSA IID 846965 - 77/751
Brisbane Courier, Monday 12 March 1877:2
Brisbane Courier, Tuesday 13 March 1877:2
Brisbane Courier, Friday 29 June 1877:3
Maryborough Chronicle, Wide Bay and Burnett Advertiser, Saturday 30 June 1877
Queenslander, Saturday 14 April 1877:6
Telegraph, Saturday 3 March 1877:2
Telegraph, Thursday 5 April 1877:3
Week, Saturday 10 March 1877:18
Week, Saturday 3 March 1877:8
Week, Saturday 26 May 1877:8
1878
Australian Town & Country Journal, Saturday 30 March 1878
Brisbane Courier, Saturday 6 April 1878:6
Evening News, Saturday 6 April 1878:5
Morning Bulletin, Thursday 21 March 1878:3
Queenslander, Saturday 9 February 1878:8
1879
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QSA ID ITM37819
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QSA ID ITM37867
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Brisbane Courier, Friday 18 April 1879:2
Morning Bulletin, Friday 4 April 1879:2
Morning Bulletin, Monday 14 April 1879:4
Queenslander, Saturday 15 February 1879:221
Queenslander, Saturday 19 April 1879:487
Queensland Times, Ipswich Herald and General Advertiser, Saturday 17 November 1888:7
Week Saturday 26 May 1877:8
1880
Morning Bulletin, Friday 9 January 1880:2
Morning Bulletin, Friday 23 January 1880:2
Week, Saturday 1 May 1880:11
1881
QSA ID ITM37818
Cairns Post,1 November 1926
Queenslander, Saturday 9 April 1881:473
Telegraph, Monday 28 February 1881:3
Telegraph, Monday 28 February 1881:3
1883
Brisbane Courier, Saturday 5 May 1883:6
Cairns Post, Monday 25 August 1919:4
Morning Bulletin, Monday 18 October 1880:2
1884
CHS P00585
Week, Saturday 15 March 1884
1886
Brisbane Courier, Wednesday 21 December 1887:9
Queenslander, Saturday 6 February 1886:215
Week, Saturday 4 June 1887:24
1887
Brisbane Courier, Wednesday 21 December 1887:9
Cairns Post, 10 March 1887:2
Morning Bulletin, Wednesday 23 March 1887:5
Morning Post, Friday 27 March 1903:5
Sydney Mail and New South Wales Advertiser, Saturday 29 January 1887:237
Telegraph, Wednesday 23 February 1887:5
Toowoomba Chronicle and Darling Downs General Advertiser, Tuesday 22 March 1887:1
Week, Saturday 4 June 1887:24
1888
QSA ID ITM37868
QSA ID ITM37870
QSA ID ITM37877
Cairns Post, Saturday 14 January 1888:2

1889
Morning Post, Friday 27 March 1903:5
1891
O'Keefe, P. 2011 Russell River Floods of 5th and 6th April, 1891. *Cairns Historical Society Bulletin* No.588.
Gympie Times and Mary River Mining Gazette, Saturday 14 February 1891:3
Morning Bulletin, Wednesday 25 February 1891:5
Morning Post, Friday 27 March 1903:5
Northern Miner, Wednesday 18 February 1891:3
Queensland Times Ipswich Herald and General Advertiser, Wednesday 11 February 1891:3
Week Friday 13 February 1891:20
Week, Friday 20 February 1891:13
Week, Friday 24 April 1891:16
1893
Morning Post, Friday 27 March 1903:5
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1894
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Age, Tuesday 10 April 1894:5
Morning Post, Friday 27 March 1903:5
Northern Miner, Friday 13 April 1894:3
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Telegraph, Wednesday 17 January 1894:4
Telegraph, Monday 3 April 1911
Telegraph, Tuesday 10 April 1894:2
Week, Friday 19 January 1894:14
Week, Friday 4 May 1894:24
1895
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Daily Northern Argus Tuesday 9 April 1895
1899
Courier Mail, 15-16 January 2011:40
Daily Times, Tuesday 7 March 1899:6
Darling Downs Gazette, Wednesday 8 March 1899:2
Morning Bulletin, Wednesday 8 March 1899:5
Morning Post, Wednesday 8 March 1899:5
Telegraph, Wednesday 8 March 1899:4
1903
Brisbane Courier, Saturday 25 April 1903:5
Capricornian, Saturday 28 March 1903:24
Gympie Times and Mary River Mining Gazette, Tuesday 28 April 1903:3

Morning Post, Tuesday 17 March 1903:3
Morning Post, Friday 27 March 1903:5
Morning Post, Tuesday 31 March 1903:2
Western Star and Roma Advertiser, Wednesday 22 April 1903:2

1906

Morning Post, Tuesday 30 January 1906:3
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1910

Week, Friday 4 February 1910
Harden Up Qld - https://hardenup.org/umbraco/customContent/media/1150_EastCoastImpactsofTropicalCyclones_1858-2008.pdf

1911

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Telegraph, Monday 3 April 1911
Warwick Examiner and Times, Saturday 1 April 1911
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1913

Barrier Miner, Friday 7 February 1913:4
Harden Up Qld - https://hardenup.org/umbraco/customContent/media/1150_EastCoastImpactsofTropicalCyclones_1858-2008.pdf

1914

CHS P14188
Northern Herald, 30 January 1914:27

1916

CHS P15969, P15970
Northern Herald, Friday 4 February 1916:26

1917

Sheppard, R. 2001 Douglas Pitt 1877-1925: Cyclone survivor. *Cairns Historical Society Bulletin* No.479.

1918

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1920

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1927

CHS P00845

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CHS P04370, P05476, P10979,

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1929

Daily Mercury, Tuesday 22 January 1929

1930

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1931

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1932

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Veivers, C. 1996 The First Barron Falls Hydro-Electricity Project. *Cairns Historical Society Bulletin* No.423.

1933

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1934

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1940

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1945

Cairns Post, Tuesday 6 February 1945

Cairns Post, Saturday 31 Mar 1945

1947

CHS P07942

1948

CHS P10831

1949

Cairns Post, Wednesday 30 March 1949

Courier Mail, 15-16 January 2011:40

CHS P01813, P02913, P03159

1950

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Cairns Post, Saturday 11 March 1950

Cairns Post, Saturday 9 December 1950

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1955

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1956

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1958

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1966

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1967

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1971

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1979

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1981

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1986

Callaghan, J. 2011 East Coast Impacts of Tropical Cyclones 1858-2008. Harden Up Queensland. Green Cross Australia.

1997

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1998

Cairns Post Friday 9 January 1998:1

Callaghan, J. 2011 East Coast Impacts of Tropical Cyclones 1858-2008. Harden Up Queensland. Green Cross Australia.

1999

Cairns Post Wednesday 17 March 1999:1

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2000

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2006

Callaghan 2011

2008

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Cairns Post Thursday 6 March 2008:2

Cairns Post Thursday 6 March 2008:3

Weekend Post Saturday 5 April 2008:9

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2009

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<u>Other newspapers sourced:</u>

Brisbane Courier, Friday 15 February 1878:3

Brisbane Courier, Saturday 9 March 1878:7

Brisbane Courier, Thursday 21 March 1878:5

Brisbane Courier, Saturday 30 March 1878:7

Brisbane Courier, Saturday 29 June 1878:7
Capricornian, Saturday 8 December 1877:15
Morning Bulletin, Thursday 14 February 1878:2
Queenslander, Saturday 10 February 1877:6
Queenslander, Saturday 12 January 1878:34
Queenslander, Saturday 18 May 1878:199
Rockhampton Bulletin, Friday 7 December 1877:2
Telegraph, Friday 26 April 1878:3

APPENDIX 5: HISTORICAL FLOODS (OVERBANK FLOODING) AND CLIMATE DRIVERS (ENSO, IPO)

Date	**Overbank flooding**	**Location**	**ENSO Phase SOI**	**IPO (NOAA ERSST v5)**	**Cyclone**	**Photos/References**
1867 (Mar Townsville & Cardwell)			-ve	-ve		CHS F1141
1870 (Feb Townsville & Cardwell)			+ve	-ve		CHS F1141
1875 (Cooktown)			+ve	-ve		CHS D22694
1877 Feb-Mar		S T	-ve	-ve		
1878			-ve	-ve	Cyclone (Mar)	Sim 2014-CHS Bulletin 624 & 625;
1879 Jan, Feb, Mar (Barron)	Yes (end of Smithfield village)	W S	+ve La Niña – middle of a three year La Niña (Allan and D'Arrigo, 1999, Table 1b)	-ve		BC 22 Feb 1879:7
1880 23rd Jan. 1880 30th Jan. 1880 12th March 1880 April	Possibly Possibly Possibly		+ve Neutral or La Niña (according to Allan and D'Arrigo, 1999, Table 1b)	-ve		MB 9 Jan 1880:2; W 1 May 1880:11
1881 Feb, Mar (Barron, Mulgrave)	Yes	W S	-ve La Niña	-ve		QSA ID ITM37818; Qlder 9 Ap 1881:473; T 28 Feb 1881:3
1883	Yes		+ve La Niña	-ve		
1884 15th March 1884 29th March 1884 (Cooktown)	Probably Probably		-ve La Niña ditto	-ve		11 CHS P00585 & P38796
1886 Jan (Barron)						BC 21 Dec 1887:9; Qlder 6 Feb 1886:215; W 4 Jun 1887:24

1887* Jan, Feb, March, Oct (Barron, Mulgrave)	*137 inches annual RF		+ve	+ve		CP 10 Mar 1887:2; BC 21 Dec 1887:9; MB 23 Mar 1887:5; SMNSWA 29 Jan 1887:237; T 23 Feb1887:5; TCDDGA 22 Mar 1887:1; W 4 Jun 1887:24
1889 *	123 inches annual RF		-ve	-ve		MP 27 Mar 1903:5; No 1889 newspaper accounts
1891 * Feb, April (Barron, Cooktown, Herbert Valley,	134 inches		+ve	-ve		GTMRMG 14 Feb 1891:3; MB 25 Feb 1891:5; MP 27 Mar 1903:5; NM 18 Feb 1891:3; QTIHGA 11 Feb 1891:3; W 20 Feb 1891:13; W 24 Ap 1891:16
1893 Feb (Barron, Stratford)	yes		+ve	-ve		MP 17 March 1903:3; T 24 Feb 1893:3
1894 10th April (Cairns)* Ingham	122 inches annual rainfall Possibly (likely flooding worse than 1879)		+ve Neutral	-ve		CHS F02299
1895 9th April	Yes		+ve Neutral	-ve		
1896 Feb (Cooktown) 1896 26 Jan (Townsville)			-ve	-ve	Cyclone Sigma	CHS P04951
1899 5 Mar (Cooktown, Barron, Mulgrave, Bathurst Bay)			+ve	+ve	Cyclone Mahina	CM 15-16 Jan 2011:40; DT 7 Mar 1899:6; MB 8 Mar 1899:5; MP 8 Mar 1899:5; T 8 Mar 1899:4; DDG 8 Mar 1899:2
1903 c.9-27 Mar (Barron,			-ve	+ve	N.B. Cyclone	MP 31 March 1903:2; BC 25 April

Mulgrave, Russell) c.20-24 April (Barron, Mulgrave. Herbert)					Leonta at Townsville 9 Mar	1903:5; MP 27 Mar 1903:5; MP 17 March 1903:3; C 28 Mar 1913:24 (needs further research in the future)
1906 Jan (Barron, Herbert, Johnstone 1906 4 Mar (Cairns)			-ve	+ve	cyclone cyclone?	MP 30 Jan 1906:3 Callaghan 2011
1907 19 Jan (Cooktown)			+ve	+ve	cyclone	Callaghan 2011
1910 27-30 Jan (Cairns) 1910 4th February	Possibly		+ve	-ve		Callaghan 2011 W 4 Feb 1910
1911 11 Jan (Cairns) 1911 Feb & Mar-April (Barron) 1911 1st and 3rd April	Yes		+ve El Niño	-ve	Cyclone and landslides Cyclone	Harden Up Qld CP 21 Jan 1998 - [D07714]; T 3 April 1911; WET Sat 1 April 1911; CP 21 Jan 1998 - D07714; SMH Sat 1 April 1911; Tenni 1978:1; Broughton 1978:2; Broughton 2006:1; Broughton 2007:1,2; CHS P01085, P01555 CHS P01085
1913 30-31 Jan (Cairns)			-ve	+ve	cyclone	Sheppard 2001 – CHS Bulletin 479; BM 7 Feb 1913:4; Harden Up Qld;
1914 (Cairns)			-ve	-ve		CHS P14188; NH 30 Jan 1914:27;
1916 (Walsh River) 1916 (Cairns)			+ve	-ve		CHS P02107, P02108

						CHS P15969, P15970; NH 4 Feb 1916:26;
1917 Mar (Cairns)			+ve	-ve	cyclone	Sheppard 2001 – CHS Bulletin 479
1918 10 Mar (Innisfail - Cairns)			+ve	-ve	cyclone	CHS Bulletin 539; CM 15-16 Jan 2011:40; Callaghan 2011
1920 3 Feb (Cairns) 1920 Feb (Barron at Stratford)			-ve	-ve	cyclone	CHS P01088, P05508, P05482; Callaghan 2011; CHS P02193
1925 26 Feb			+ve	-ve	Cyclone btw Cooktown & Cairns	Callaghan 2011
1927 Feb (Barron at Stratford)			+ve	+ve	Cyclone and severe rain	CHS P04370, P04372
1927 9 Feb (Cairns, Halifax, Ingham, Tully, Innisfail)			+ve	+ve		CHS P05476, P10979; CM 15-16 Jan 2011:40; Callaghan 2011
1929 21st January	Possibly		+ve Neutral	+ve		
1930 20 Jan (Cairns to Ingham)			+ve	+ve	cyclone	Callaghan 2011
1931 1-8 Feb (Cairns to Ingham)			-ve	+ve	cyclone	Callaghan 2011
1932 Dec (Barron at Stratford)			+ve	+ve		CHS P18037
1934 23rd February (Kuranda) 1934 (Barron at Stratford)	Probably – damage at hydro station		+ve Neutral	-ve		CHS P07540, P07541, P07542, P07543, P07544 CHS P07937
1935 (Cairns Lily & Arthur Streets)			-ve	-ve		CHS P06642

1940 Apr (Barron)	Yes (gauge 9ft 1in)		-ve	+ve		CP 13 April 1940 – [CHS D05551]
1945 1 Feb & end Mar (Mareeba)			+ve	-ve		CP 31 Mar 1945; CP 6 Feb 1945
1947 (Cairns)			-ve	-ve		CHS P07942
1948 (Cairns)			-ve	-ve		CHS P10831
1949 Mar (Cairns) Gladstone Rockhampton Cooktown			-ve	-ve	cyclone	CHS P01813, P02913, P03159; CP 30 Mar 1949; CM 15-16 Jan 2011:40
1950 11-15 January (Kuranda) 1950 1-7 March (Kuranda) 1950 8th December 1950 18-21 December	Probably Probably Probably Probably		+ve La Niña	-ve		CP 16 Jan 1950 CP 11 Mar 1950 CP 9 Dec 1950 TDB 22 Dec 1950 CHS P03159
1953 (Cairns) ?			-ve	-ve		CHS P04642 [photo possibly incorrectly dated]
1955 (Cairns)			+ve	-ve		CHS P05507
1956 (Cairns)			+ve	-ve	cyclone	CHS P15790, P01555, Tenni 1978:2
1958 (Cairns) 1958 (Barron at Kamerunga)			-ve	-ve		CHS P04641 CHS P25171 (colour)
1967 Mar (Cairns, Barron) Ingham, Tablelands, Mulgrave Mossman River			+ve Barron highest since 1927	-ve		CHS P19387; CP 13 Mar 1967:1 CP 15 Mar 1967:1 Noli, PD Bulletin 41--[CHS J06089];
1971 Dec (Townsville)			+ve	-ve	Cyclone Althea	CM 15-16 Jan 2011:41

Mossman River						Noli, PD Bulletin 41--[CHS J06089];
1976 (Holloways Beach)			+ve	-ve		CHS P15495
1977 6-10 Mar (Barron at Kamerunga) Barron Thomatis Ck junction – aerial Kamerunga Machans Beach Cairns			-ve	-ve	Cyclone Otto	CHS P02491; Sun 9 March 1977:1; CHS P02493, P02494; CHS P02491 CHS D16191 CHS P12012
1979 (Mossman River)			-ve	+ve		Noli, PD Bulletin 41-[CHS J06089]; Callaghan 2011; CHS J06068
1981 Jan (Barron, Herbert, Tully, Johnstone, Babinda)			-ve	+ve		NQR 17 Jan 1981; Callaghan 2011
1986 Jan (Nth Qld)			-ve	+ve	Cyclone Winifred	CM 15-16 Jan 2011:41; Callaghan 2011
1997 (March, Cairns)			+ve	+ve	Cyclone Justine	O'Donoghue 1997; Callaghan 2011
1998 Jan (Gordonvale)			-ve	-ve		CP 9 Jan 1998:1; Callaghan 2011
1999 (Feb & Mar) Barron, Cairns Cooktown-Tully	Biggest flooding since 1977		+ve	-ve	Cyclone Rona As above	'Living with Water' 2014; CHS D09537; Connell Wagner 2004:v; Callaghan 2011 CP 17 March 1999:1
2000 Jan (Barron, Cairns)			+ve	-ve	Cyclone Steve	CM 15-16 Jan 2011:41; CP 9 Feb 2000:1; Callaghan 2011
2004 Feb, 19-24 Mar (Barron)			+ve	-ve	Cyclone Grace	Callaghan 2011
2006 18-24 Mar (Cairns)			+ve	-ve	Cyclone Larry	CM 15-16 Jan 2011:41; Callaghan 2011

2008 Mar (Barron)			+ve	-ve		CP 6 March 2008:2,3; WP 5 Apr 2008:9, 24
2009 Jan (Cairns)			+ve	-ve	Cyclone Charlotte	WP 4-5 April 2009:7-[CHS D19890];

ST: Smithfield township
WS: West Smithfield
Text in red: Barron River floods from newspaper accounts. Estimate of overbank flooding based on Smithfield being submerged or the possibility it was submerged.
Text in black- information about floods collected from newspapers, Cairns Historical society photos (e.g., P numbers) and CHS Bulletins. 'ST' means Smithfield township, 'WS' means West Smithfield.
Phase of ENSO from https://www.longpaddock.qld.gov.au/rainfall-poster/enso-year-classification/.
Unless from Allan & D'Arrigo (1999) (Table 1b).
Positive SOI values – wet conditions associated with La Niña, Negative SOIL values – dry conditions associated with El Ninδ
Positive IPO values – often results in lower rainfall in Eastern Australia,
Negative IPO values – often results in higher rainfall in eastern Australia (Vance et al., 2022)
Information about the Interdecadal Pacific Oscillation (IPO) from: https://psl.noaa.gov/data/timeseries/IPOTPI/
Asterisk * = the 4 years (1887, 1889, 1891, 1894) in 16 years (1887- Mar 1903) with annual rainfall over 100 inches at Cairns (Morning Post Friday 27 March 1903:5).

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List of Abbreviations

AEC- Australian Envelope Curve
BM – Barrier Miner
C - Capricornian
CHS – Cairns Historical Society
CM – Courier Mail
CP – Cairns Post
EC- Envelope Curve
ENSO – El Niño Southern Oscillation
FoR – Flood of Record
GTMRMG – Gympie Times and Mary River Mining Gazette
IPO – Inter-Decadal Pacific Oscillation
NH – Northern Herald
NM – Northern Miner
NQR - The North Queensland Register Saturday 17 January 1981
P – Photo
PMF – Probable Maximum Flood
QTIHGA – Queensland Times Ipswich Herald and General Advertiser
SMH - Sydney Morning Herald
SMNSWA – Sydney Mail and New South Wales Advertiser
ST: Smithfield township
T – Telegraph
TCDDGA – Toowoomba Chronicle and Darling Downs Advertiser
TDB – Townsville Daily Bulletin
W – Week
WET - Warwick Examiner and Times
WP – Weekend Post (Cairns Post)
WS: West Smithfield