CHAPTER 6: FLOOD RISKS

The Flood Threat

Floods occur when the water entering the catchment, usually as a result of rainfall, is too much to be contained within the banks of the drainage network and spills out over the floodplain. Such events can range from very localised and short-term events, such as a flash flood in a suburban storm water system, to major flooding lasting several days or more across an extensive river catchment. The key determinants of whether floods occur or not include:

- the overall amount of rain that falls in the catchment;
- how much and what parts of the catchment receive the rain;
- the intensity of that rainfall; and
- the state of the catchment before the rainfall episode commenced.

A long period of steady rain over a portion of a catchment may eventually produce flooding, however, a large volume of rain falling over a short period (say over 12 to 24 hours) over just a portion of a catchment that is already saturated from earlier rainfall, will almost certainly produce a flood. No two flood events, therefore, are identical and it is difficult to define, with any degree of certainty, an 'average' flood.

The normal benchmark used to overcome this problem is to describe floods in terms of an average recurrence interval (ARI) or, preferably, an annual exceedence probability (AEP). AEP is the probability of a given flood discharge magnitude occurring, or being exceeded, in any one year period.

Cairns has a rather peculiar flood hydrology. The delta on which the bulk of the city stands has not been fed by a river for perhaps many tens of thousands of years. It does not, therefore, have the level of threat from major riverine flooding experienced in other coastal Queensland cities, such as Brisbane, Bundaberg, Mackay, Rockhampton or Townsville, which grew around their river ports.

The only river that poses a significant flood threat within the study area is the Barron River (**Photo 6-1**), which separates the city from its northern beachside suburbs, though smaller catchments can cause serious localised flooding throughout the area. The trauma of major flooding of the Barron River in the early days of the Trinity Inlet settlements has probably minimised the risk to the present-day Cairns community - the lessons of its flood potential were learned at an early stage. Floods in successive years in 1877, 1878 and 1879 sped the abandoning of the original Smithfield settlement on the Barron (sited in the area of present-day Stewart Road, Barron), reinforcing the choice of the shores of Trinity Inlet as the preferred site for the port and settlement.

The Barron River catchment covers about 2 300 square kilometres. The river rises on the Atherton Tableland near Atherton and flows north through Mareeba before turning east to enter the lowland delta through the spectacular Barron Gorge below Kuranda. It is fed by several major tributaries on the Tableland, the largest of which are Granite Creek and the Clohesy River, whilst Freshwater Creek, joins the Barron below the Gorge. The delta covers about 45 sq km with Thomatis Creek - Richards Creek providing a distributary channel at the mouth. Freshwater Creek is the most significant of the tributaries as far as flood in the Cairns suburban areas of Redlynch and Freshwater are concerned - see **Chapter 5** (Landslide Risks). The Barron River catchment is shown in **Figure 6.1**.

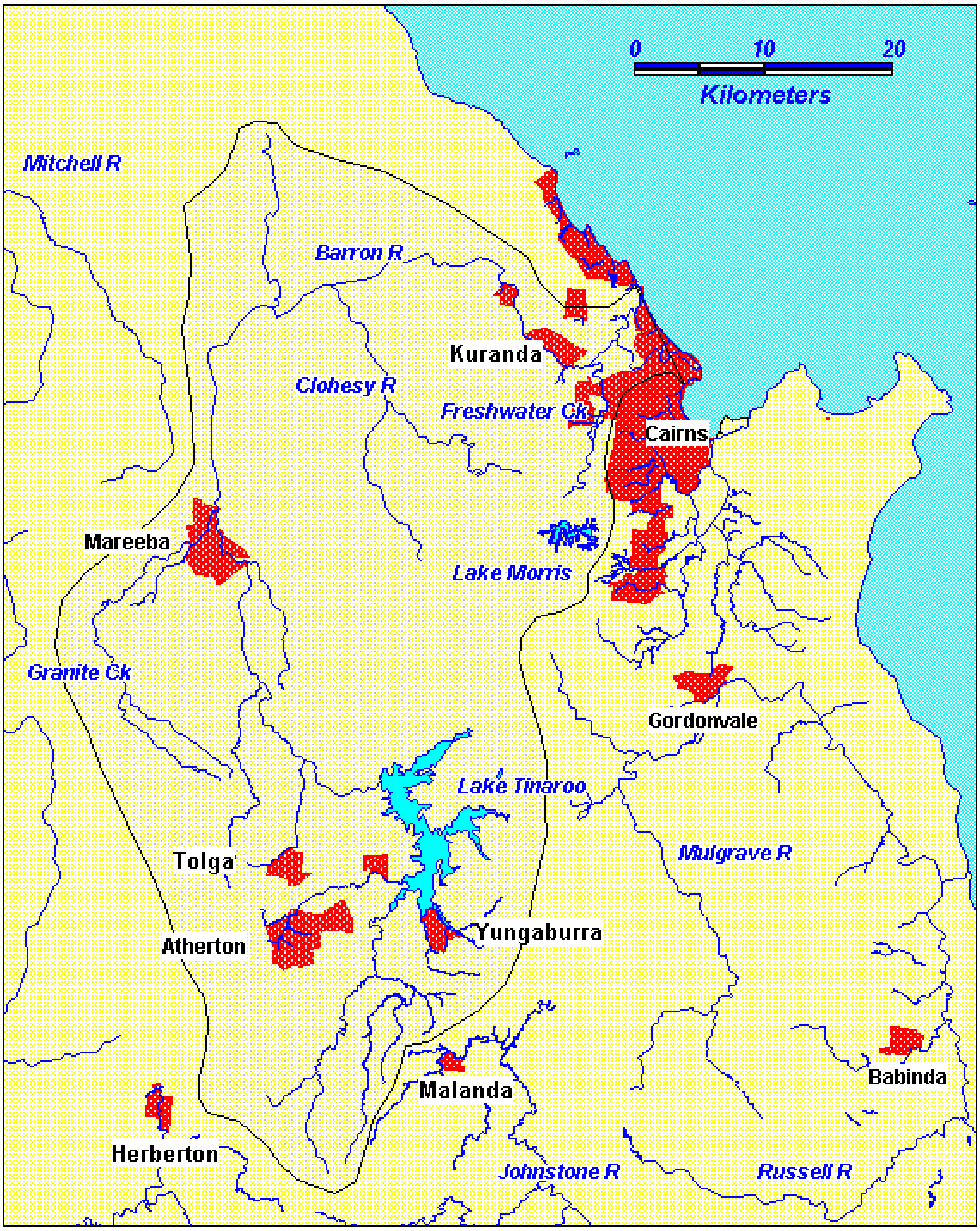

Figure 6.1: Barron River catchment

The study area contains a further four catchments: the MacAlister Range catchment; the Trinity Inlet catchment; the Mulgrave/Russell Rivers catchment; and the Yarrabah valley catchment. Several small creeks that flow off the escarpment of the MacAlister Range dissects the strip occupied by the northern beach suburbs north of Yorkeys Knob. They include (from north to south) Sweet Creek, Delanys Creek, Deadmans Gully, Deep Creek, Moores Gully and Moon River. These water courses are susceptible to flash flooding, though this tends to be localised and of short duration.

The Trinity Inlet catchment receives runoff from Mount Whitfield in the north, the Whitfield Range in the west and the north-western escarpment of the Thompson Range in the east. The main streams that drain the urban area are Saltwater Creek, Lily Creek, Moodys Creek, Chinamans Creek, Clarkes Creek, Gordon Creek, Skeleton Creek and Blackfellows Creek.. These creeks have been augmented or modified by large concrete drains that flow either into Saltwater Creek or the Inlet. The flood threat in this catchment comes mainly from flash flooding or local storm water discharge during an intense rainfall episode, especially if it coincides with a very high tide. Extreme rainfall events in the Cairns area can dump more than 700 mm of rain in less than 12 hours. Most flooding of this 'urban drainage surcharge' kind, however, is of relatively short duration. It can, none-the-less, be very damaging and lead to loss of life.

The Mulgrave and Russell Rivers drain the mountain country dominated by Bellenden Ker and Bartle Frere, Queensland's highest mountains and the highest rainfall area in Australia. Only the Mulgrave River arm is of interest in this study. Gordonvale is the only urban area threatened by flooding in the Mulgrave, however, considerable areas of sugar and other crops that occupy the floodplain can be at risk. Flooding in the Mulgrave River can also cut the Bruce Highway and the main rail link to the south.

The Yarrabah valley receives runoff from the eastern slopes of the Thompson Range and the western slopes of the low range of hills that separate Yarrabah from Cape Grafton. There is no well defined drainage in the valley though there are fairly large areas of wetland. The main threat is from flash flooding in creeks that flow off the high country. There appears to be only a limited threat of flooding on the valley floor itself.

There are three dams in the Barron catchment: the Tinaroo Falls Dam, completed in 1958; the Barron Gorge Weir, close to Kuranda, built in 1935 to provide storage for the Barron Falls hydro-electric power station; and the Copperlode Falls Dam (Lake Morris) on Freshwater Creek completed in March 1976. None of these dams was constructed to provide a flood mitigation capacity. Given the configuration of the catchment and the location of these dams, they have little influence on reducing a flood.

An extensive network of rainfall and river height gauging stations monitors the Barron River. A flood warning ALERT network was established jointly by the Bureau of Meteorology, the then Mulgrave Shire Council and the Cairns Port Authority in 1995. Stations in the network are linked by VHF radio to a base station computer in Cairns. The data produced by these instruments are provided to hydrological models to produce river height predictions on which flood warnings are based. Quantitative river height predictions are given for Kamerunga, which is the reference gauge for flooding on the delta.

Floods are classified in three levels of severity in warnings issued by the Bureau of Meteorology. These are defined generically in a Bureau pamphlet (BoM, 1997a) as follows:

> ***Minor flooding:*** *This causes inconvenience such as closing minor roads and submerging low level bridges…*
>
> ***Moderate flooding:*** *This causes the inundation of low lying areas requiring the removal of stock and/or the evacuation of some houses. Main traffic bridges may be closed by floodwaters.*
>
> ***Major flooding:*** *This causes inundation of large areas, isolating towns and cities. Major disruptions occur to road and rail links. Evacuation of many houses and business premises may be required. In rural areas widespread flooding of farmland is likely.*

The Cairns Flood Experience

The reference gauge for flood levels in the Barron River, with the longest record, is at Myola, a few kilometres upstream from Kuranda. This site has been used to measure river heights in the Barron since 1915, though earlier gauges in the same vicinity give us reasonably equivalent data for major floods back to at least 1910. A level of 7 m or more on the current Myola gauge constitutes a flood; with levels below 8.5 m, flooding is relatively minor; whilst levels above 10 m are considered major floods. **Figure 6.2** shows the annual flood peak measured on the Myola gauge from 1916 to 1999, with the major floods of 1911 and 1913 also included. The gauge at Kamerunga, on the lowland, provides more direct measures for the delta. For this gauge, a minor flood commences at 6 m, a moderate flood is over 8 m and a major flood is above 9 m.

It is clear from the river gauging record that the flood of late March to early April 1911 is the greatest flood on record. That flood was recorded at 15.37 m on the Myola gauge, although this may not be directly comparable with heights at the current gauge. It was caused by widespread rain across the catchment between 31 March and 2 April 1911, including falls of 617 and 732 mm recorded at Kuranda on the last two successive days. This rain fell onto a catchment that had already been saturated by rain brought by a cyclone that crossed the coast near Port Douglas on 16 March. According to figures quoted in a study of flooding on the delta published in 1981 (Harbours and Marine, 1981) this record flood had a discharge of 7 221 cubic metres per second (cumecs) which was estimated to be around 70% of the estimated probable maximum discharge. This makes it an extreme and fairly rare event, with an AEP of between 0.2% and 0.1% (an ARI of between 500 and 1 000 years). There appears, however, to have been little damage, given that there was little development other than some agriculture, at that time, on the Barron River delta.

The second greatest flood on record came two years later and was caused by a cyclone that crossed the coast about 70 km north of Cairns on the night of 29-30 January 1913. A flood peak of 14.76 m on the Myola gauge was recorded on 31 January. The discharge recorded in this flood was 6 569 cumecs, putting it in the region of a 0.5% AEP event. Again, there appears to have been little damage reported, other than to crops, on the floodplain.

Further 'major' floods, measured on the Myola gauge, occurred in 1934, 1967, 1977, 1979 and 1999. The greatest of these was made up by the events of 5 to 11 March 1977. As with the 1911 flood, this event was produced by a period of heavy rain and minor flooding in the catchment being followed within a few weeks by a second heavy rainfall episode. This flood reached a peak of 12.62 m on the Myola gauge (with a discharge of 4 556 cumecs) and 9.5 m on the Kamerunga gauge. The Myola discharge rate would make this a 1:50 year flood on the basis of the most recent revisions of rainfall. The meteorological sequence is described in the Barron River delta flood study (Harbours & Marine, *ibid*) as follows:

> *The start of the wet season* (in February 1977) *was marked by the development of tropical lows in the Gulf of Carpentaria and off the east coast. There was some easting of the weather on the 9th as these lows* (in the monsoonal trough) *moved away from the coast. Tropical cyclones "Lily" and "Miles" developed north and east, respectively, of Willis Island, whilst the low in the Gulf moved onto the coast on the 10th and 11th, bringing further heavy rain on those days. Tropical cyclones "Lily" and "Miles" were not particularly active, and moved generally east to southeast before degenerating without directly affecting Queensland's coastline. However, tropical cyclone "Nancy" developed comparatively close to the coast on the 12th, and maintained cyclonic strength for about 9 hours before crossing the coast near Bloomfield River Mission* (Wujal Wujal) *as a rain depression in the early hours of the 13th.*

As a result of these weather patterns, the northern half of the State received heavy to flood rains during the first half of the month. During this period stations at Babinda and Innisfail recorded their highest monthly totals since records commenced. In the Barron River catchment, high monthly totals (above 600 mm) were recorded on the coast and in inland areas, including most of the Tableland.....

Overbank flow from the Barron River and Thomatis Creek during the flood submerged the Captain Cook Highway and Yorkeys Knob road pavements, linking these floodwaters with the runoff from Avondale Creek catchment. However, there was no flow across the Brinsmead-Kamerunga Road north of the Barron, nor any overland flow west of this road into Avondale Creek. Although large tracts of cane land were inundated, there was no evidence of scouring.

The flood peak in the Barron River passed Lake Placid at 7.00 a.m., and reached B14 gauge at Machans Beach at 9.30 a.m. on February 11, 1977.

A similar weather pattern to February emerged in early March with a high pressure system in the Tasman Sea extending a ridge up to the monsoonal trough. This situation, which continued for much of the first half of the month, caused continuous showers and thunderstorms in the vicinity of the trough.

Again, tropical low pressure systems became active in the trough, developing in the Gulf and off the east coast. The low in the Gulf eventually developed into tropical cyclone "Otto" on the 7th. Tropical cyclone "Otto" traversed Cape York peninsula and moved down the east coast before recrossing it on the 8th and dissipating inland near Townsville.

Tropical Cyclone "Otto" brought particularly heavy flood rains to most areas of the Barron catchment on the 6th and 7th, and subsequent heavy falls on the coast west to the range on the 8th and 9th as it degenerated.

The heavy falls which occurred overnight on the 6th resulted in the highest flood level measured at Myola since systematic recording began (12.62 metres with a corresponding estimated discharge of 4556 cubic metres per second).

The flood rose very steeply, at one time at a rate of 0.75 metres per hour, and the flood peak was almost coincident with the high tide which occurred around midday. The peak occurred at 9.00 a.m. at the Lake Placid Kiosk, and at 11.30 a.m. on the Yorkeys Knob road....

In addition, significant flooding occurred in the built-up areas of Yorkeys Knob, Holloways Beach and Machans Beach. Most of the Delta, consisting mainly of cane land and non-urban areas, was submerged during the flood. The records show that just in excess of 100 houses, mainly located at Machans Beach, were evacuated during the flood. Scouring was evident in the cane fields and on river banks, particularly on the river bend adjacent to the end of the Cairns Airport main runway.

Figure 6.3 shows the extent of the March 1977 flooding which covered approximately 43.5 sq km. It should be noted that the airport layout shown in the figure is the current (1999) airport. In 1977 there were no protective levees and the main runway was under water for a day or so.

The other four major floods, for which measurements are available, were those of March 1934 (10.5 m), March 1967 (11.62 m at Myola, 9.5 m at Kamerunga), January 1979 (10.7 m at Myola, 9.4 m at Kamerunga) and February 1999 (11.4 m at Myola and 8.65 m at Kamerunga). Again the Barron River delta flood study provides an excellent description of the weather systems that produced the 1979 flood and the response of the river to those events.

In all there were six main flood events between 1 January and 6 March 1979. Two (1-9 January and 25-27 January) were well over the bank and inundated large sections of the delta. The other four peaked at, or close to, bank-full discharge. The largest two floods are described here:

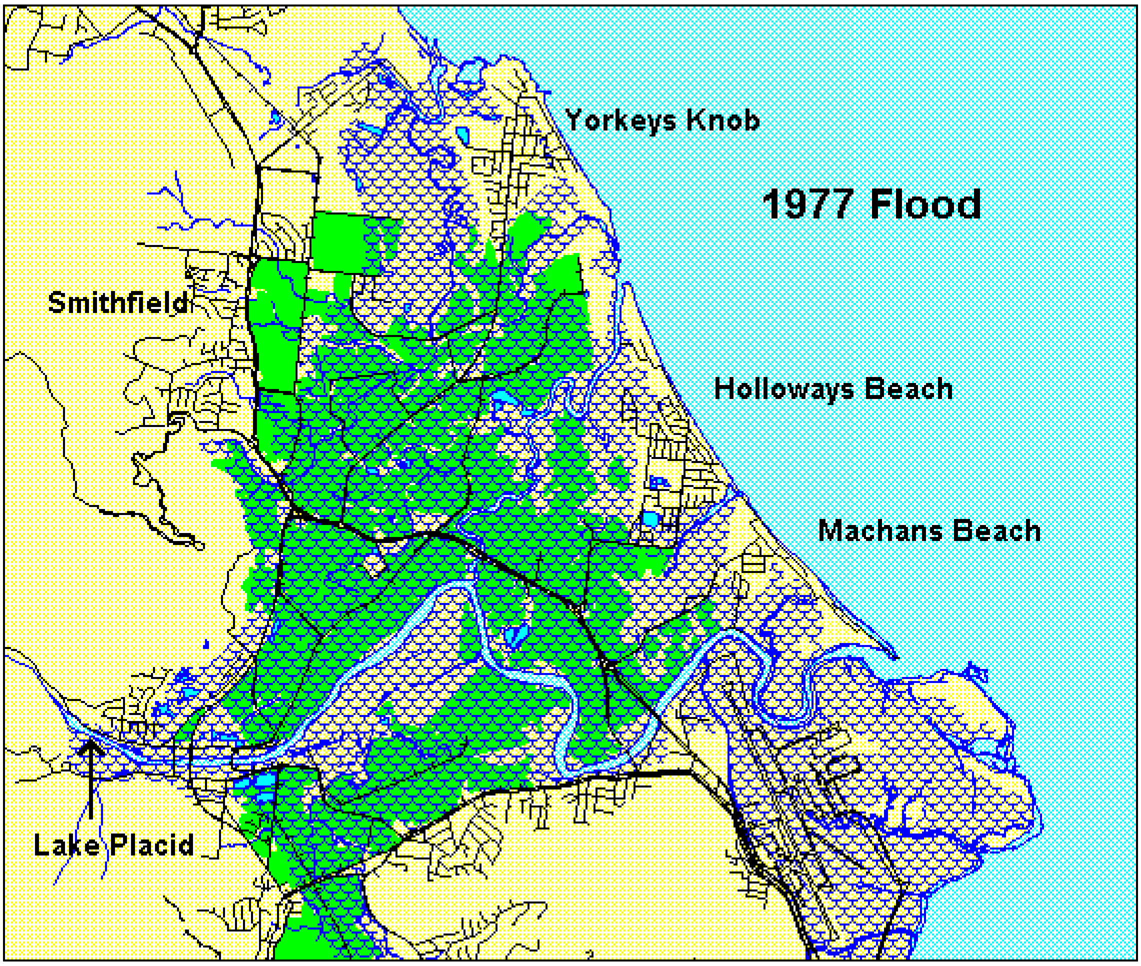

Figure 6.3: Barron River inundation in the flood of March 1977 (after Harbours & Marine, 1981, Figure 4-36)

> *The main feature of the first flood were the concentration of rainfall on the eastern side of the catchment, the particularly high rainfalls at Kuranda and the continuity of rain which maintained the flood peak heights for three days. Tinaroo Falls Dam did not commence spilling until water levels from the first flood began to fall.*
>
> *The first flood was associated with Cyclone "Peter" which crossed from the Gulf and was located over Cape York Peninsula as the month began. Meanwhile, the southern half of the State was being influenced by a ridge extending along the coast from a high in the Tasman Sea to the active monsoonal trough lying across the Cape. "Peter" subsequently moved onto the east coast and weakened into a rain depression centred on the coast to the north of Cairns.*

This situation caused flood rains in the Barron catchment, resulting in prolonged and extensive flooding of the Delta. As this flood receded, the monsoonal trough was still active. A second cyclone named "Greta" crossed the Cape on a similar path to "Peter" and, like "Peter", weakened into a rain depression in the monsoonal trough. However, unlike "Peter", "Greta" moved inland and did not cause any overbank flooding on the Barron Delta. In the middle of the month, the ridge along the coast weakened and rainfall eased on the Barron catchment.

However, later in the month as the coastal ridge strengthened again, a low developed in the Gulf, moved onto the Peninsula on January 25 and caused the flood of January 25-27.

The peak of this flood occurred overnight on the 25th reaching 10.03 metres at Myola. This flood rose very sharply from 4 metres to 10 metres in about 6 hours (an average of 1 metre per hour with a peak rate of rise of 2 metres per hour at 11.00 p.m.). This gives a clear indication of the severity of the storm which produced it, and reflects the completely saturated state of the catchment from the earlier heavy falls. Peak flood levels measured on the Delta were within 0.5 metres of the first January flood peak.

The flood which occurred early in January had a peak which lasted at least three days. Although the peak of this flood was below the March 1977 flood, its total discharge was much greater. Measurements taken on the Delta also indicated that, compared with the 1977 flood, the first January 1979 flood had a greater contribution from watercourses downstream from Myola….

The beach areas of Yorkeys Knob, Holloways Beach, and Machans Beach were isolated during the flood and just in excess of 100 houses had to be evacuated….

The flood had a number of peaks, the highest of which passed Lake Placid at 5.30 a.m., and reached Machans Beach at 8.00 a.m., on January 5, 1979.

The inundation map for the 1-9 January 1979 flood is provided as **Figure 6.4**. The extent of inundation for the 1979 flood, which covered about 40.0 sq km, is very similar to that for the 1967 and 1977 floods. Indeed, the stage heights on the Kamerunga gauge (at the head of the delta) vary only 0.4 m between the three events.

A survey of the extent of inundation caused by the February 1999 flood had been commenced at the time of writing.

One or more of the trio of floods in 1877, 1878 and 1879 may well have reached 'major' levels. Unfortunately no measurements of these floods appear to exist though Broughton (1984b) describes these floods in the following terms:

Even at the height of its (Smithfield's) *glory, the seeds of disaster were quickening when, in February 1877, the Police Magistrate in Cairns, Edmund Morey, reported that "the township of Smithfield was, on Wednesday last, all but submerged." The siting of the town on the banks of the Barron had not been a wise choice as was evident in the wet season of 1877, and even more so in 1878 when the wet season ushered in a cyclone - but what was left of any enthusiasm or optimism seemed to have completely disappeared by the wet season of 1879 when a tremendous flood completed the destruction already begun by time and termites.*

In the early 1970s evidence emerged that the lower course of the river was in the process of change. Of particular concern was erosion at the junction of the main channel and Thomatis Creek that indicated that the latter could become the main channel of the river. Erosion on the major loops of the river immediately to the west and east of the airport runway also indicated that the course of the river was in the process of change. These changes led to the Harbours and Marine study of the Barron River delta in 1979-80 and some bank protection work.

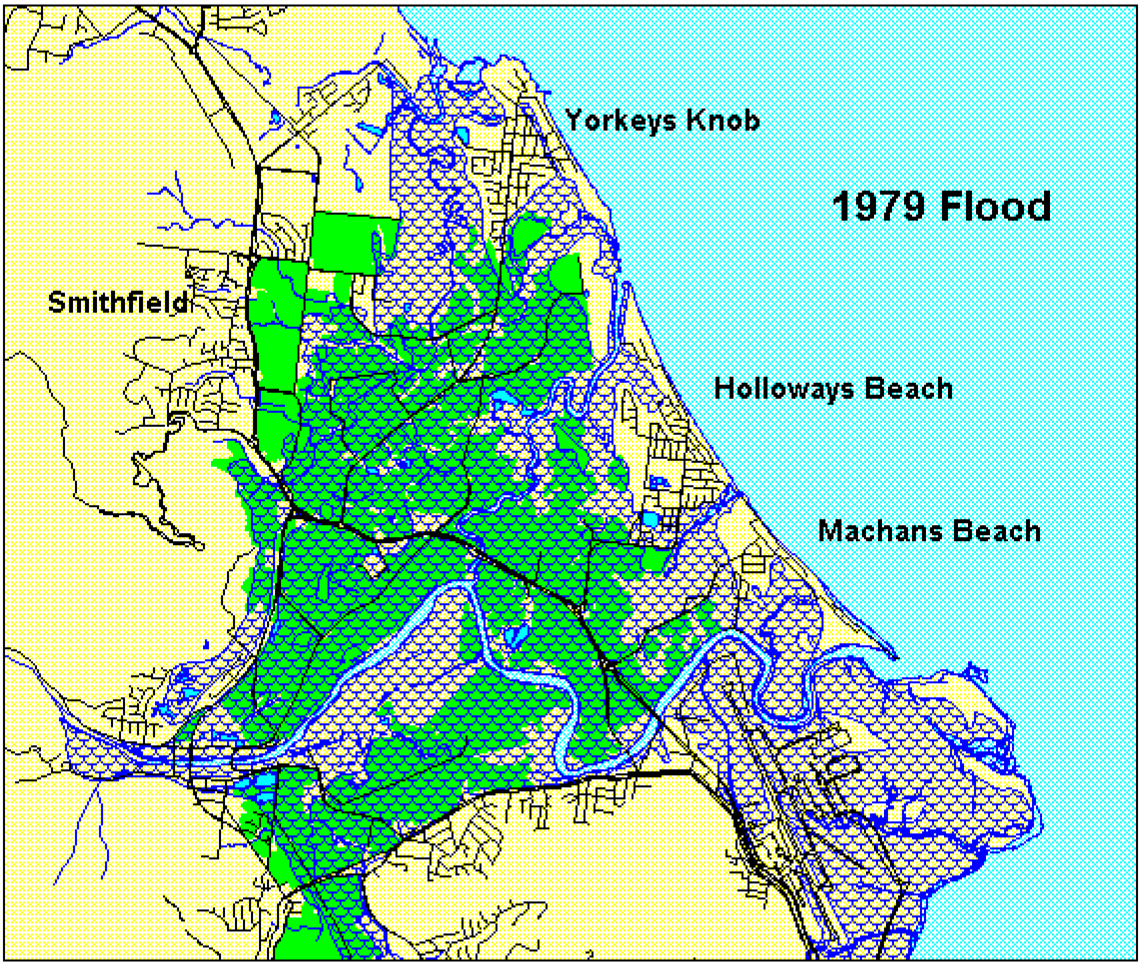

Figure 6.4: Barron River inundation in the flood of January 1979 (after Harbours & Marine, 1981, Figure 4-37)

The Barron River delta has been the subject of several detailed hydrological studies other than the Harbours and Marine study already quoted. In 1981 a study by consultants Cameron McNamara recommended the construction of levees to protect Holloways Beach and Machans Beach. Macdonald Wagner conducted a further study in 1988 for the Cairns Port Authority and the then Mulgrave Shire Council. That study included investigation of the effect on flood levels of cutting a channel across the neck of the loop to the east of the airport and the construction of levees to protect the extensions of the airport's main runway that were about to commence (Macdonald Wagner, 1988). This study was also based on the updated rainfall recurrence values published by the Bureau of Meteorology in 1987. The 1988 flood study was updated in 1994 by Connell Wagner (successor to Macdonald Wagner) and provides the basis for the current Q100 flood model employed by Cairns City Council for planning and regulatory purposes (Connell Wagner, 1994).

Apart from the airport levees, none of these other mitigation works were undertaken. A change in the lower course of the river in a major flood remains a potential threat to the delta suburbs of Holloways Beach and Machans Beach in particular, and Yorkeys Knob to a lesser extent.

Barron River Flood Risk Scenarios

In developing appropriate flood scenarios, the ideal would be to have four-dimensional models (the horizontal extent dimensions, depth over ground level and velocity or discharge rates) for flood events ranging from the 10% AEP (10 year ARI) up to, and including, the probable maximum flood (PMF). PMF is generally taken to have an AEP of between 0.001% and 0.0001% (an ARI of between 100 000 and one million years). Apart from the experience of the more recent historic events that have already been described, the only scenario model that we have available is the so-called 'Q100' model used by Cairns City Council for urban planning purposes. This is the modelled 1% AEP flood. Neither the 1% AEP model, nor the historic record, provides us with sufficient three-dimensional data with which to undertake a detailed risk assessment. They do, however, provide sufficient two-dimensional data to at least provide an indicator of the likely impact.

The two-dimensional data only tells us what land was, or would be, inundated. It tells us nothing about the depth of water at any given point **so we can not identify, with certainty, the buildings that would have water over floor level**, for example, rather than water simply on the property. Likewise we can only identify the road segments and cane fields that would be under water, but not how deep that inundation would be. The lack of velocity information also precludes making estimates of the number or location of buildings that might fail because of the combined effect of water depth and velocity.

Table 6.1 provides the comparative stage height figures for the Myola and Kamerunga gauges. There are difficulties with the Kamerunga data, however, because of the relocation of the gauge. The figures given have been adjusted to the estimated equivalent on the current gauge. It should also be noted that whilst the current Myola gauge is in a slightly different locality to that for which these figures are provided, the relative values remain relevant.

Table 6.1: Barron River gauge height comparisons (Source: BoM, 1999)

GAUGE	MARCH 1967	MARCH 1977	JANUARY 1979	FEBRUARY 1999
Myola	11.12 m	12.29 m	10.42 m	11.4 m
Kamerunga	9.5 m	9.8 m	9.4 m	8.64 m

There is also a significant degree of uncertainty, or at least divergence, in calculations of the recurrence intervals of floods of various magnitudes in the Barron River. The key differences appear to come from the statistical treatment of data from the various Myola gauges and whether the data for the 1911 and 1913 floods are included or not. Based on the discharge, the ARI estimate for the 1977 flood, for example, varies from around 200 years from the 1981 Harbours and Marine study and current modelling by the Department of Natural Resources in Mareeba, to around 40 to 50 years from the 1988 Macdonald Wagner study. **Table 6.2** provides a comparison of AEP estimates.

Because the Connell Wagner figures are those used by Cairns City Council for planning purposes we have chosen to base our analysis on their more conservative estimates. These are shown, with equivalent stage heights and representative historic floods in **Table 6.3**.

The 4% AEP flood scenario: The flood of January 1979 is probably close to a 4% AEP (25 year ARI) flood and has already been described in detail. Were that flood to occur again, some 375 buildings, 35.84 km of roads and 15 800 ha of cane lands would be affected. The distribution of these effects, by suburb, is given in **Table 6.4**.

The northern suburbs would be isolated from the rest of the city because both crossings of the Barron River and extensive lengths of the Captain Cook Highway would be inundated (sections of the Captain Cook Highway can be inundated in a 20% AEP, i.e. 5 year ARI, flood). The suburbs of Holloways Beach, Machans Beach and Yorkeys Knob would be further isolated because their single access roads would also be inundated. Of the 375 buildings that could be affected by flooding, almost 90% would be either houses or blocks of flats. Up to 6 350 people could be isolated for a few days of whom up to 800 may need to be relocated temporarily.

Table 6.2: Comparison of AEP estimates for flood discharge (in cumecs) at Myola

SOURCE	**100%**	**50%**	**20%**	**10%**	**4%**	**2%**	**1%**	**0.5%**	**0.1%**
Harbours & Marine A	81	953	1769	2329	3020	3511	3975		
Harbours & Marine B	91	973	1979	2783	3919	4833	5786	6785	
Connell Wagner					3517	4600	5400	6400	
Natural Resources A	83	852	1602	2139	2626	3332	3826	4305	5379
Natural Resources B	430	972	1511	1969	2686	3332	4088	4972	7647

NOTES:

Harbours & Marine A = recorded floods from 1916 to 1978 only used from Table 4.6 Harbours & Marine (1981)
Harbours & Marine B = as for A plus values for 1911 and 1913 from Table 4.6 Harbours & Marine (1981)
Connell Wagner =
Natural Resources A = annual peaks for all 83 years 1916-1998 (Neile Searle, DNR, personal communication)
Natural Resources B = highest 83 discharges over the period 1916-1998 (Neile Searle, DNR, personal communication)

Table 6.3: AEP for historic flood levels at Myola

AEP (%)	**DISCHARGE** (cumecs)	**STAGE HEIGHT** (m)	**INDICATIVE FLOOD** (year)
100	80	2.0	
50	950	6.4	
20	1820	8.5	1932,1949, 1964, 1968, 1974, 1990
10	2600	10.0	1927, 1934, 1956, 1972
4	3517	11.3	1967, 1979, 1999
2	4600	12.7	1977
1	5400	13.6	
0.5	6400	14.6	1913
0.2-0.1?	7200	15.4	1911

Table 6.4: Indicative impact on Barron River delta suburbs of a 4% AEP flood

SUBURB	**BUILDINGS**	**ROADS** (km)	**CANE LAND** (ha)
Aeroglen	19	0.62	
Barron	8	9.13	6426
Caravonica	80	1.18	138
Freshwater	6	0.97	296
Holloways Beach	90	4.06	1928
Kamerunga	27	4.67	902
Machans Beach	80	3.86	505

Smithfield	6	0.87	1810
Stratford	2		
Yorkeys Knob	36	9.89	4290
TOTALS	371	35.84	15810

Key facilities that could be isolated, if not at risk, would include the FNQEB Kamerunga Bulk Supply Substation, the approach radar for the airport and the sewerage treatment plant at the northern end of the airport.

The 2% AEP flood scenario: The 1977 flood is now considered to be around a 2% AEP (50 year ARI) event. Using the extent of that flood as our model, but excluding the buildings that are now protected by the airport levees, the impact would see 755 buildings, 50.10 km of road and 16 526 ha of cane land affected. It is likely that the numbers of buildings and length of road in Machans Beach could be more than indicated because the construction of the levees to protect the airport in 1988 would increase flood levels in that area by about 120 mm in a flood of this magnitude (Macdonald Wagner, 1988). **Table 6.5** provides the suburban breakdown.

Table 6.5: Indicative impact on Barron River delta suburbs of a 2% AEP flood

SUBURB	**BUILDINGS**	**ROADS** (km)	**CANE LAND** (ha)
Aeroglen	22	0.5	
Barron	8	9.74	6530
Caravonica	297	4.73	191
Freshwater	2	0.97	296
Holloways Beach	209	5.90	1943
Kamerunga	56	5.75	951
Machans Beach	82	3.87	505
Smithfield	16	3.85	1594
Stratford	10	1.34	
Yorkeys Knob	44	10.10	4349
Redlynch	3		167
Trinity Park	17	0.72	
TOTALS	766	50.10	16526

The northern suburbs would be isolated from the rest of the city because both crossings of the Barron River and extensive lengths of the Captain Cook Highway and the alternative Brinsmead-Kamerunga Road route would be flooded. The suburbs of Holloways Beach, Machans Beach and Yorkeys Knob would be further isolated because their single access roads would also be inundated. Of the 755 buildings that could be affected by flooding, 702, or 93% would be either houses or blocks of flats. Up to 6 350 people could be isolated for a few days, of whom up to 2 000 may need to be relocated temporarily.

A flood of this magnitude poses an interesting emergency management challenge - should the population of the beachside suburbs be completely evacuated before the flood reaches its forecast peak or should they be left isolated, but safe, in their homes? The concern is, however, that should the flood become more severe than forecast, the people left isolated on their suburban islands could become overwhelmed, thus posing a far more difficult evacuation problem, with a greatly increased risk of fatalities and material loss.

Key facilities that could be at risk would include the FNQEB Kamerunga Bulk Supply Substation, the approach radar for the airport and both the Aeroglen and Smithfield sewerage treatment plants.

The 1% AEP flood scenario: The modelled 'design' flood used by Cairns City Council and developed by Connell Wagner in 1994 is shown in **Figure 6.5**. A flood of this magnitude would result in about 1 730 buildings, almost 80 km of roads and 17 500 ha of cane lands being affected. The key statistics for each affected suburb are given in **Table 6.6**.

This model indicates that approximately 5.7 km of the Captain Cook Highway would be inundated and Brinsmead-Kamerunga Road, the alternate north-south link, would also be impassable. Extensive sections of the pavement of both roads would probably be destroyed or seriously damaged, delaying their return to trafficability once the floodwaters recede. Such flooding would isolate the city's northern suburbs and towns to the north (Port Douglas, Mossman and beyond) and west (Kuranda, Mareeba and beyond). The impact on cane land would also be significant, with floodwater velocity, scouring and siltation likely to destroy or damage standing cane on as much as 17 500 ha (about 10% of the total area served by the Mulgrave Central Mill).

Table 6.6: Indicative impact on Barron River delta suburbs of a 1% AEP flood

SUBURB	**BUILDINGS**	**ROADS** (km)	**CANE LAND** (ha)
Aeroglen	21	2.65	
Barron	8	9.94	6530
Caravonica	417	6.80	138
Freshwater	8	1.40	6
Holloways Beach	669	17.33	2054
Kamerunga	49	6.22	868
Machans Beach	342	10.15	505
Smithfield	16	4.18	1576
Stratford	36	3.06	
Yorkeys Knob	147	13.00	4681
Redlynch	3		863
Trinity Park	17	0.86	
TOTALS	1733	79.32	17514

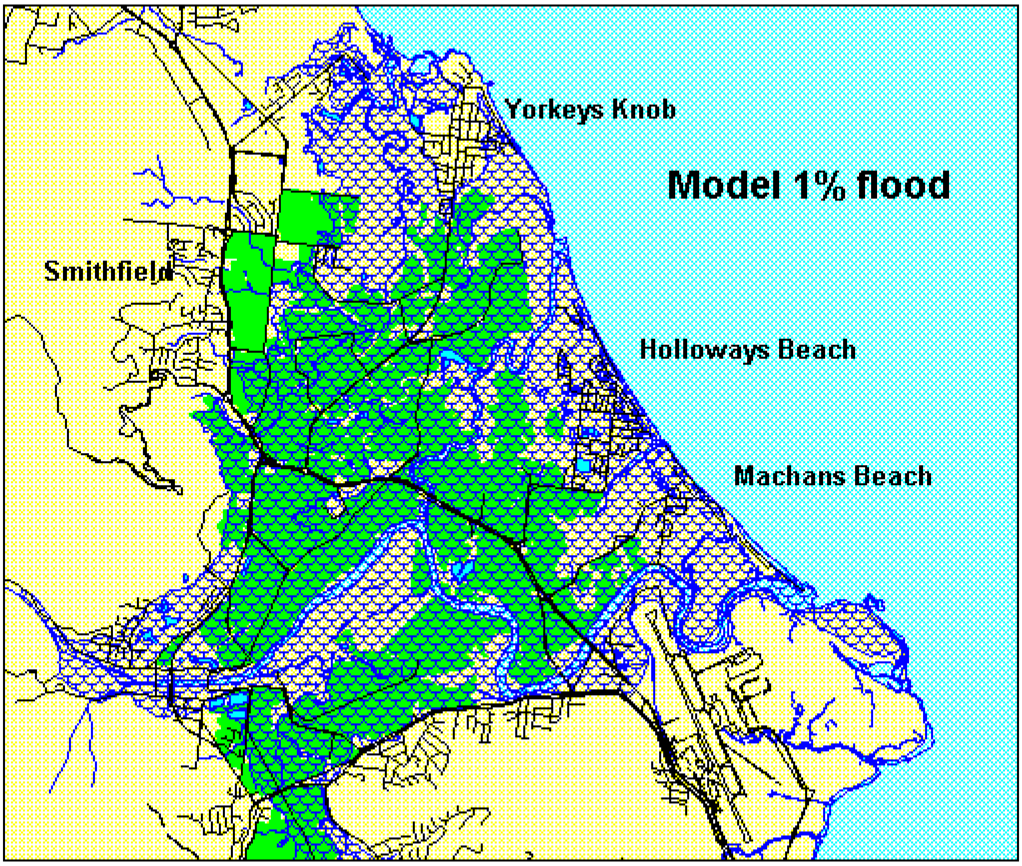

Figure 6.5: Cairns City Council Q100 (1% AEP) flood zone

About 1 640 houses and blocks of flats would be affected. This equates to about 4 600 people overall. Given the isolation and potential threat to the beachside suburbs in particular, a total evacuation of their 6 350 inhabitants, ahead of the flood peak, is probably indicated. There is also an increased likelihood of buildings being destroyed in a flood of this magnitude, especially in low-lying areas of Caravonica and the three beachside suburbs, given the greater depth of inundation and the greater velocity of the flood. This threat could be further increased if, as a result of the flood, the course of the river near its mouth were to change.

Key facilities that would be inundated include the FNQEB Kamerunga Bulk Supply Substation, the approach radar for the airport, the Aeroglen and Smithfield sewerage treatment plants and the Holloways Beach Telephone Exchange. Loss of the major power substation, either by damage or by the cutting of power as a safety procedure, would have widespread impact on all of Cairns. Were the airport levees to be breached or overtopped by this level of flooding, the damage to and dislocation of the Cairns economy would be even more significant. Two state schools (Caravonica and Machans Beach) would also be affected by at least water in the grounds.

The 0.2% AEP to PMF flood scenarios: No estimates of the extent and character of flood events in the 0.2% AEP (ARI of 500 years) to PMF range, such as the 1911 flood, are available to us. There is little doubt, however, that their impact would be substantial, with the likelihood of many buildings being destroyed in the suburbs of Aeroglen (including the airport), Caravonica, Holloways Beach, Machans Beach, Stratford and Yorkeys Knob - at least. As many 3 000 buildings could be at risk, with perhaps 10 000 people directly affected by a PMF-level event in Cairns.

Until hydraulic modelling of these low probability, but high impact, events is undertaken, however, it will not be possible to provide more definitive estimates of flood risk.

The risk coefficient for suburbs exposed to flooding in the Barron River (excluding Freshwater Creek) has been calculated by simply summing the total number of houses, length of road and area of cane land likely to be affected. Given the significant economic impact on the cane industry of serious flooding, the inclusion of cane lands was considered to be relevant in this calculation. The 1% AEP model was used as the reference scenario. **Table 6.7** shows the coefficient value and the risk exposure rank of the suburbs involved, whilst **Figure 6.6** shows the spatial distribution.

Table 6.7: Risk exposure of suburbs to Barron River delta flooding

SUBURB	RANK	COEFFICIENT	SUBURB	RANK	COEFFICIENT
Aeroglen	10	23.65	Machans Beach	6	857.15
Barron	1	6545.94	Redlynch	5	865.00
Caravonica	7	561.80	Smithfield	3	1596.18
Freshwater	11	15.4	Stratford	9	39.06
Holloways Beach	8	274.00	Trinity Park	12	13.86
Kamerunga	4	923.22	Yorkeys Knob	2	4841.00

Freshwater Creek Flood Risk Scenarios

Freshwater Creek, the main tributary of the Barron River below the Gorge, has a catchment of 44 sq km above the Copperlode Falls Dam and 60 sq km below the dam. Whilst it has a history of flooding, the area affected is typically confined to the agricultural land on the floodplain and to low-lying areas and roads in Barron, Brinsmead, Freshwater, Kamerunga, and Redlynch. Communities in these suburbs can be isolated for periods of a day or so during such floods, especially if they coincide with flood peaks in the Barron River itself. Under most flood scenarios involving the whole Barron River catchment, the flood peak in Freshwater Creek is likely to precede the peak in the main channel by several hours.

We are unable to estimate the likely impact of flood in Freshwater Creek in this study because we have not had access to information on the extent of historic flood episodes in Freshwater Creek or modelled floods. Anecdotal evidence, however, suggests that suburban developments in Redlynch at least have a relatively low risk of inundation.

Dam Failure

Community recognition of dam failure as a realistic public safety issue is not widespread in Australia, largely because we have fortunately never suffered a major dam failure disaster like the Buffalo Creek Dam tragedy in West Virginia (USA) in 1972. The failure of that coal sludge dam killed 125 people, injured over 1 000 others and left 4 000 homeless. In the USA, some 9 200 regulated dams have been classified as being 'high-hazard'. Lin (1998) makes the comment that:

> *If we* (dam engineers) *mandate the design of a dam for a theoretical "spillway design flood", for instance, then we should not be surprised if the dam fails in a larger flood. If we design a dam without taking into account all the development that later springs up upstream and downstream, then we should not be surprised if regulators later determine the dam is no longer safe for increased runoff and hazards. Management of dam safety is complex business, because of changes in the dam itself, its watershed and downstream conditions.*

There are two significant dams on the Barron River, the Tinaroo Falls Dam and the Copperlode Falls Dam. The failure of either would pose a considerable threat to communities on the Barron River delta and Freshwater Creek.

The Tinaroo Falls Dam is now 40 years old. It is a mass concrete dam operated by the Department of Natural Resources. The spillway capacity of 1 160 cumecs was determined by an empirical maximum rainfall/area relationship in use at the time of design and construction. That capacity is currently equivalent to a 0.5% AEP (200 year ARI) flood. The dam can be safely overtopped provided that its foundations do not erode. Such an event is considered by the Department to be extremely unlikely since the dam is founded on massive granite rock. The Department of Natural Resources has a dam safety program in place which ensures that the dam is under constant surveillance and action plans exist to cope with any emergencies.

A dam failure alert system has been established for Tinaroo Falls Dam. It is designed to provide warning to communities downstream from the wall in the event of a threatened or actual failure. The major concern with such a possibility is for the population of Mareeba given the relatively short warning time that would be possible. Potential inundation extents have been modelled and mapped for the Barron River as far as the Barron Falls and modelling of the likely impact on the delta is being undertaken at the time of writing. Given the massive volume of water released in a short period it is likely that flood levels would be greater than the 1911 and 1913 floods and perhaps close to PMF levels. The scouring of existing creeks on the delta and the possible break out of the flood from the main channel through Thomatis Creek, is a distinct possibility under such a scenario.

Copperlode Falls Dam, which is operated by the Cairns – Mulgrave Water Board, is a rock and earth fill dam that is now 23 years old. The dam has also undergone a safety review which resulted in minor raising so that it can safely withstand PMF-level flooding. A dam break flood study of Copperlode Falls Dam was undertaken in 1991 by Guttridge Haskins and Davey and areas of possible inundation identified, however, details were not available for this study.

Apart from the likely damage to development in the Freshwater valley and the potential break out of the flood through Thomatis Creek, failure of Copperlode Falls Dam would eliminate the main source of water supply for the Cairns community.

Urban Drainage Surcharge

There are some 17 100 properties at risk from the overflow of the urban storm water system between Saltwater Creek and Chinamans Creek, i.e. in the suburbs of Cairns North, City, Bayview Heights, Earlville, Edge Hill, Kanimbla, Manoora, Manunda, Mooroobool, Parramatta Park, Portsmith, Westcourt and Whitfield. This number is several orders of magnitude greater than the number at risk from flood on the Barron River delta. The main risk here is associated with intense rainfall over a relatively short period (say 6 to 12 hours) directly over the urban area.

Rainfall episodes that would give rise to significant urban drainage surcharge have occurred in the Cairns area. For example, on 2 April 1911, 778 mm of rain were recorded at Yarrabah in 24 hours and on 12 January 1951, 760 mm were recorded in the Ellis Beach area in eight hours. Such falls are comparable to those experienced in Townsville in January 1998 and in Wollongong (NSW) in August 1998. Both of those episodes caused widespread urban drainage inundation and many landslides, including a large and potentially lethal debris flow on Magnetic Island off Townsville. In Cairns, storm water inundation on the coastal plain will be exacerbated by high tides. Very few of the storm water outlets that discharge into the Inlet have one-way tide valves.

Cairns City Council has recently had modelling of this problem undertaken, however, the results have not been available to this study.

Interpretation

Whilst flooding causes inconvenience and some dislocation in Cairns on average about once every 12 years, it poses a relatively limited threat to urban areas and people because urban development has largely been excluded from the most flood-prone areas of the Barron River delta. The loss of sugar cane and damage to roads and other infrastructure on the delta, however, carries with it a significant economic loss. The most significant inconvenience caused by Barron River flooding is the isolation of the northern beachside suburbs from downtown Cairns, with its critical facilities such as hospitals and airport.

The flood warning system for the Barron River operated by the Bureau of Meteorology is very effective and provides residents in flood-prone areas with adequate time to prepare for flood and/or to evacuate if that is indicated. The Bureau of Meteorology hydrologists who are responsible for the ALERT system point out, however, that the behaviour of floods in the lower Barron River is close to that of a 'flash flood' and that only six to nine hours warning can be given. Such a level of warning was sufficient to safely evacuate around 2 000 people from the Lake Placid area of Caravonica as a result of the flooding brought on by Cyclone *Rona* in February 1999.

Flash flooding in the other catchments, especially the streams that flow into Trinity Inlet, is a potentially significant problem. Not only are there significantly more properties exposed to urban drainage surcharge, the risk to life is significant because of its rapid onset the propensity for careless or foolish behaviour by some people in and around floodwaters.

Limitations and Uncertainties

The absence or unavailability of key information significantly limits the assessment of flood risk in Cairns provided here. Many of these shortcomings have been recognised by Cairns City Council and others. Work is already under way to model urban drainage surcharge risks in the low-lying areas of the city and work has commenced on modelling the potential impact of dam failure on the delta, especially for Tinaroo Falls Dam.

Perhaps the most significant limitation, however, is the lack of flood depth data associated with records of historic flood events and with the modelled 1% AEP flood. The lack of these data precludes the assessment of the magnitude of over-floor flooding. Such data is essential input to models of building loss and contents damage, as well as models of road network dislocation.

Further research, probably of an economic nature, is required to determine the relative significance of buildings, roads and cane lands in establishing the risk coefficient for each suburb on the Barron River delta. The approach used here of simply summing the values for each element assumes an the loss for one house is equal to the loss for one hectare of cane land and one kilometre of road. Whilst this is clearly a dubious assumption, we are reasonably confident that the coefficients used (regardless of their absolute quantum) produce a reasonably accurate relative ranking of each suburb's flood risk.