Flood prediction for planning purposes differs from flood warnings in respect of the need to estimate the long-term probability of flood impacts so that appropriate planning decisions can be made to minimise the impact. In many other respects, however, the same basic tools are required, namely:

1. historical rainfall and runoff data across a catchment;
2. historical river height and discharge information;
3. catchment topography and land use;
4. surveys of river and floodplain levels and cross sections;
5. models of the hydrologic processes (rainfall, runoff, infiltration, concentration etc);
6. models of the hydraulic processes (propagation, attenuation etc).

Typically, such analyses are undertaken by hydrologists and specialist civil engineers skilled in the physical understanding of rainfall patterns and the fluid mechanics of flood propagation. The results of such studies are often required to set design clearances for public works such as roads, bridges or the height of levee systems.

Items (1) and (2) are essential for describing the statistical nature of the flood hazard. Such data then permits the calibration and verification of the various models derived in (3), (4), (5) and (6) which, depending on the application, may be numerical (mathematical) or physical scale-models. Using statistical analyses of the historical rainfall data, a well-calibrated model is then capable of predicting the impact of floods that are beyond the present limit of experience or even the present or future extent of community development on the floodplain. They can also be used to estimate the ARIs of past and future floods, and to test potential flood mitigation strategies, such as the clearing of choked channels, constructing new channels, levees, detention basins or dams. They can also be used to delineate planning zones where regulations might be made to the minimum property height or floor level allowed, or to limit the amount of infilling in a floodplain to prevent the raising of flood levels. Such models are increasingly being used to manage environmental assets dependent on flooding, such as wetlands.

The above data collection and modelling process leads to a statistical description of flooding for a specific community. It remains then to adopt planning regulations that seek to limit the impact of flooding on that community in an effective manner (socially, environmentally and economically). As the impacts may differ considerably between communities, even on the same floodplain, it is logical that regulations might vary in response to that impact. However, it is usual for a specific ARI flood level to be proclaimed, or in its absence the historical flood-of-record, as the limit for planning purposes. This is then termed the 'designated flood' level for planning purposes. A small freeboard allowance is then applied above the designated level to provide a measure of safety and to allow for vessel wash effects. The most common designated flood level adopted in South-East Queensland is the 100 year ARI or 1% AEP level (Smith 1998).

In the following sections the approach taken by individual LGAs in the study region to manage the community flooding problem is briefly summarised. Indicative AEP flood levels are provided for selected locations in Table 9.9. Information has been drawn from Smith (1998) or has been specially made available to this study by the LGA concerned. Councils provide information on the likelihood of flooding within the area in which an individual property is located upon enquiry.

<u>Caboolture River and Burpengary Creek system</u>

Flood studies have been carried out for the Caboolture River system (CSC 1994a), Burpengary Creek (CSC 1990), Little Burpengary Creek (CSC 1994b), Gympie Creek (CSC 1994c), Six

Mile Creek (CSC 1994d) and Wararba Creek (CSC 1995 & 1999) which provide estimates of the 10, 50 and 100 year ARI flood levels. No estimate of the PMF is currently available. The models have been calibrated using the February 1972, April 1989 and December 1991 floods. The designated flood for planning purposes is the 100 year ARI with a 0.1 m freeboard and there are controls placed on filling in the floodplain.

The region has extensive low lying coastal lands and these are impacted by storm surge, which is discussed in Chapter 4, especially in regard to Beachmere. Estimates of the coastal storm surge levels have been included in the various flood studies because of their influence on the lower floodplain tailwater during a flood. However, this impact is limited to the lower 5 to 6 km of the river for most ARI scenarios. Likewise, the effect of possible sea level rise due to enhanced-Greenhouse has also been investigated in the model studies and found to only influence the lower reaches near the mouth.

A selection of predicted flood level ARIs is given in Table 9.9. For any particular flood event, studies show how the different parts of the floodplain can have significantly different responses depending on the rainfall distribution. For example, the 1972 flood severity in the Caboolture River generally increased travelling down the floodplain. In the upper reaches it represented a 20 yr ARI, the middle reaches a 40 yr ARI, and a 50 yr ARI in the lower floodplain. At the mouth however, the levels were only a 10 yr ARI. Similar behaviour is predicted in the tributary streams King John and Lagoon Creeks.

The flood studies have also considered the potential impact of (presently planned) future urbanisation of Caboolture Shire, which is likely to increase surface runoff over time. The results show that although impacts on the major watercourses are expected to be negligible up to the 100 yr ARI, some local stormwater systems may be significantly affected and their capacities may need to be reassessed.

Burpengary Creek studies have focussed on the residential flooding problems in Dale St and Springfield Dr which have been of regular concern to affected residents. A number of mitigation options were identified for consideration by Council (CSC 1990).

Redcliffe City

There are no major river or creek systems in the Redcliffe City area. Some localised storm water surcharge can occur in specific areas during very heavy rain episodes. Council is currently updating its information base in this regard. Storm surge threats are addressed in Chapter 4.

Pine Rivers system

Numerous flood studies have been undertaken for Pine Rivers and are held by the Pine Rivers Shire Council. The modelling studies are used for setting development conditions and in road network planning. Selected predicted flood levels for various locations are shown in Table 9.9.

The flood studies take into account the ultimate development of the catchment and development conditions have been set according to the flood level results of the studies. Pine Rivers Shire Council will not allow development filling in land inundated by a 50 year ARI creek flood, a 100 year ARI river flood or a 100 year ARI tidal surge. Park contributions cannot include land below the 20 year ARI flood line calculated assuming revegetation of the waterway. Catchment Management Plans are being prepared so to enable revegetation of waterways without adversely affecting flood levels (Peter Stonadge, written communication, 2001). Due to the relatively late development of Pine Rivers Shire, the impact of floods on developed properties is small because of the early development controls put in place. Creek and river flooding, however, cause a number of road closures.

Predicted flood levels for Sandy Creek are currently being reassessed following recent mitigation. New catchment management plans are being prepared for Four Mile Creek and the South Pine River. Predicted levels for the North Pine River, South Pine River and Kendron Brook are available from the Brisbane River and Pine River (Dam Burst Study), South-East Queensland Water Board, DNR and the Brisbane City Council Flood Study.

Brisbane - Bremer River system

Numerous flood studies have been done on the Brisbane creeks (Breakfast, Bulimba, Cabbage Tree, Cubberla, Kedron Brook, Lota, Moggill, Norman, Nundah, Oxley, Pullen Pullen, Wolston and Wynnum creeks). Each flood study has been calibrated against several historical flood events. Further information on these studies (completed between 1992 and 2000) and earlier studies can be obtained from Brisbane City Council. Recent modelling for the Brisbane River undertaken by Brisbane City Council in conjunction with Sinclair Knight Merz is still under investigation and so was not available for use in this report. The modelling used in this report is based on historical river flooding levels and modelling of 1% AEP flood levels for the Brisbane creeks, based on a 1984 study.

Ipswich City Council in conjunction with Sinclair Knight Merz has recently completed a comprehensive flood study which covers the urbanised areas of Ipswich City (IRIT, 2000), the flood modelling of which is used in this study. The study encompasses the Bremer River (from Warrill Creek to the Brisbane River), its major tributaries (Bundamba, Purga, Deebing, Ironpot, Mihi and Sandy Creeks), the Brisbane River (from Woogaroo Creek to Kholo Creek) and its major tributaries (Six Mile, Goodna, Woogaroo, and Sandy/Camira Creeks). The flood models have been calibrated against the January 1974, June 1983, April 1989, December 1991 and May 1996 events and take account of actual water release operations at Somerset Dam and, post-1985, Wivenhoe Dam. The analyses provide estimates of the 2 year, 5 year, 10 year, 20 year, 50 year, 100 year, 200 year, and 500 year ARI events and the PMF, for both existing and future urbanisation of the catchment. A number of flood mitigation options have also been assessed in detail, including use of detention basins, changes to dam operations and construction of levee banks.

The studies confirm that a range of storm scenarios may cause flooding in the area, namely

Local tributary storm: localised short duration (two to six hour), producing fast flow velocities and high flood levels in the upper reaches.

Bremer River storm: more widespread longer duration, producing high discharges at the lower end and backwater effects in local tributaries.

Brisbane River storm: regional extent and long duration (30 hour), producing high peak discharges at the junction of the Bremer River and with tributary backwater effects.

These various storm scenarios were combined and their predicted flood profiles overlapped to determine the maximum envelope of flood levels in the area. The study shows that the Brisbane River flooding scenario predominantly influences flooding in both the Brisbane River and Bremer River tributaries. Flooding in the upper reaches of the tributaries was generally found to be due to local catchment flooding effects.

The Brisbane River is tidally affected as far as the Bremer River with a range of 2.8 m at Ipswich. The model studies also considered the influence of tide and storm surge levels on predicted flood levels. Combining the 100 year ARI flood and 100 year storm surge tailwater condition with an enhanced greenhouse allowance of 300 mm for sea level rise produced a maximum increase of 80 mm in flood heights near Ipswich.

The degree of future urbanisation was determined from the Ipswich City Council Strategic Plan and its effects were tested against the 20 year and 100 year ARI floods. Principal impacts were estimated to be localised to the Deebing, Ironpot, Mihi, Six Mile and Goodna Creek areas. In the larger tributaries the effect of urbanisation is predicted to actually reduce flood levels slightly due to reductions in the time of concentration of the runoff. The effects of floodplain infilling have not yet been determined in detail.

Present planning regulations specify the 20 year ARI flood level for existing development, which applies for the established central city region. For new developments, the 100 year ARI level is used to provide increased protection for the future growth of the city. A 300 mm freeboard is also applied in all cases. A selection of predicted ARI flood levels is provided in Table 9.9. These are based on the present catchment conditions and assume a tailwater at the mouth of the Brisbane River of MHWS (ie. without storm surge allowance).

Logan–Albert River system

The northern side of the Logan River (Logan City) falls within the jurisdiction of Logan City Council. The southern side of the Logan River (Albert River - Beenleigh area) falls within the northern part of Gold Coast City Council (refer to Figure 9.10).

The Logan City area is affected by flooding in the Logan River and its main tributaries of Scrubby/Slacks Creek and the smaller Native Dog Creek further to the east near Redland. A comprehensive flood modelling study of these areas has been undertaken in association with the other regional councils affected by the Logan – Albert River System (SROC 1994). Logan City has implemented comprehensive flood planning practices and approvals based on the results of that study. This culminated in the gazettal of Logan's Local Law No 6 (Floodplain Management) in 1998 which controls building, filling and excavation within the floodplain based on a hazard and risk classification. Prior to 1998 and the SROC study of 1994 the Council implemented a policy in relation to 'rezoning, subdivision and building in areas liable to flood'.

The urban centres of Logan began to expand rapidly during the early 1970s, just prior to the disastrous flooding of January 1974, which swept away several houses in the floodplain. This flood has served as a benchmark event for local government controls on development since that time. Consequently, only a very small proportion of the existing urban development is severely affected by flooding. However, there is a significant accumulation of urban development around the fringes of the main floodplain which is based at, or only just above, the 1974 flood level. There are also some significant areas which are at, or just above the 50 year ARI and 100 ARI flood levels that have been designated as the flood planning criteria in those areas.

The 1994 study extends earlier investigations dating back to 1982 and represents a base case condition for all future proposals for floodplain development. The model has been calibrated on the basis of the 1974, 1976, 1990 and 1991 floods, for which streamflow and river height data was available. The river is also tidally affected from Moreton Bay and the design flood events for the 10, 20, 50 and 100 year ARI have been estimated coincident with the peak of a typical spring tide event. The model has also been used to estimate the impact of flooding across the future planned fully developed urban areas and to set limits on the infilling to be allowed in certain areas. Extensive application of the model is used to ensure that the cumulative impacts of filling and excavation are controlled. This is to ensure that floodplain storage and the conveyance of floodwaters is maintained and that flood levels determined and set as part of the 1994 study are not compromised. In addition to the design event levels, the January 1974 flood has been specially remodelled for the floodplain in this ultimate developed condition. The relativity in levels between the ultimate catchment January 1974 flood levels and the design 100 year ARI levels in the main Logan River vary slightly but the 1974 flood is higher than the 100 year ARI by as much as 0.5 m. This places the levels of the ultimate 1974 flood somewhere near to the 125 year ARI level.

Table 9.9 presents a selection of predicted ARI flood levels throughout Logan City and some selected design levels for the Albert River. The Logan and Albert designated flood levels are derived from a repeat of 1974 rainfall on a fully developed catchment in accordance with the respective LAs' strategic plans being run through a cumulative development hydraulic model. Unlike Logan City, there are no areas of urban development significantly affected by flooding of the Albert River at lower ARI levels.

Redland Shire Council

There are no major river or creek systems in the Redland Shire other than Tingalpa Creek. It is impounded by the Leslie Harrison Dam within a few kilometres of its mouth in Moreton Bay to form the Tingalpa Reservoir. Flooding impacts are, therefore, limited to localised storm water surcharge in smaller watercourses and storm water systems. Storm surge threats were addressed in Chapter 4.

Gold Coast

Gold Coast City is the largest provincial city in Australia and has undergone very significant urban development across the coastal plains between Southport and the NSW border over the past 40 years. Some of its river floodplains were extensively developed when the general appreciation of flood risk, hazard and flood damage was less sophisticated than it is today (GCCC 1999a). There are significant pressures still to utilise the undeveloped flood prone areas that now provide for the storage of significant volumes of floodwaters during major flood events.

Gold Coast City Council has acted proactively to address the flooding hazards over many years and a significant number of individual flood studies have been undertaken, with more underway or planned. A three fold strategy has been adopted which involves extensive community consultation, as follows:

1. Flooding prevention through town planning revisions, leading to the development of a comprehensive planning scheme (consistent with the *Integrated Planning Act*)

2. Physical flood mitigation options in consultation with the community to reduce specific hazards

3. Counter disaster measures to provide warnings, inundation maps and procedures

Gold Coast City Council City Council received a National Commendation from Emergency Management Australia in the Safer Communities Awards for the Council's Nerang River Flood Mitigation project in 2000. The project is designed to address the increasing population of people living in flood affected areas and the serious potential for overfloor flooding. Council has addressed these issues through strategies such as the introduction of stricter land use controls and risk communication.

The extent of the Gold Coast flood problem is summarised in Figure 9.10 which lists the various river catchments affecting the region and the many issues and impacts for the community.

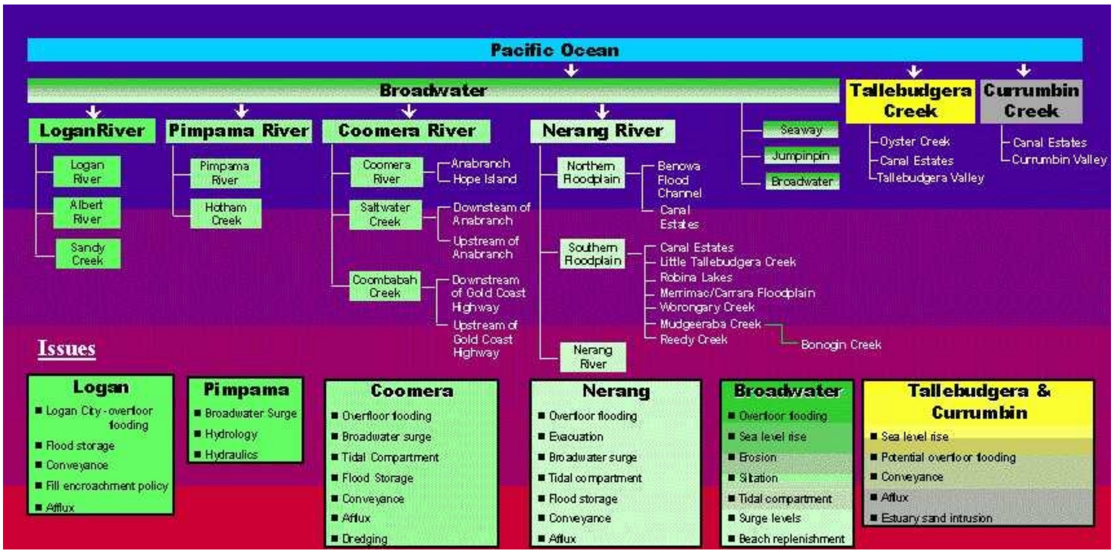

Figure 9. 10 Flooding issues for Gold Coast City catchments (GCCC 1999a)

Pimpama River:

This area is relatively undeveloped and has not been studied in detail at this time. Much of the land east of the Pacific Highway is below 2.5 m AHD and some areas are likely to be surge and flood affected (1999ab). The flood paths are not well defined and detailed two-dimensional modelling may be required.

Coomera River:

Guidelines for development in the Coomera River system date from 1987 and were designed to ensure that proposed developments should allow for the passage of a range of floods without any resultant impact on flood levels for existing properties or facilities (1999ab). This has resulted in residential development minimum floor levels being set to what at that time was deemed to be the 100 yr ARI and a number of other flood sensitive design requirements were imposed. In spite of these requirements, the peak flood levels derived from a series of model studies over the past ten years (e.g. GCCC 1997b) shows that there is an upward trend due to cumulative development effects. There are concerns also that the potential rainfall rate within the catchment may be presently underestimated. Accordingly, increasingly more stringent development requirements are being proposed for this complex network of waterways which continues to be favoured by developers. The major resort developments presently contained within the floodplain include Sanctuary Cove, Hope Island Resort, Monterey Keys and Oyster Cove. The current flood planning level is taken to be the higher of a repeat of the January 1974 flood flow or the 100 yr ARI. The greatest differences between these levels are generally in Saltwater Creek where the 1974 level would be about 0.3 m higher. Table 9.9 provides a selection of predicted flood levels for the area.

The Nerang River:

This river system represents the single greatest flood threat to the local community because of its central role in servicing a myriad of manmade and natural waterways that epitomise the Gold Coast lifestyle and environment. The river has been much studied, the first comprehensive numerical model being developed in 1988. Many studies have been done since that time in response to technical advances and the rapidly changing characteristics of the developing floodplain.

During a major flood, high flows in the river overtop the northern bank at Ashmore and the southern bank at Carrara, and flow onto the Carrara floodplain. Inflows from Mudgeeraba and Worongary Creeks flow onto the floodplain. The Nerang River then breaks its banks at Carrara. These two floodplains then meet if the flood is sufficiently high and force their way east through the tidal canal estates which now occupy what was also a part of the original river floodplain. Ultimately the river discharges into the lower part of The Broadwater and then into the ocean via the Gold Coast Seaway. As well as the canals, there are complex weir and lake systems which provide some flood storage during major events. To the north of the river, the Ashmore and Benowa flood channels and the Sorrento canal system provide an alternative path for floodwaters to The Broadwater and help to reduce levels further south near Carrara.

Gold Coast City has undertaken extensive community damage assessments (GCCC 1997c) and it is accepted that development in the Nerang River floodplain must not increase peak flood levels because of the already high level of potential damage. The Merrimac / Carrara Floodplain Advisory Committee was established in 1996 to advise Council on the planning, development and management of the floodplain and has produced the Guragunbah Hydraulic Master Plan (GCCC 1997a) for this purpose. One of the many requirements of this plan is that the flooding impacts of any future developments must be tested to ensure that the development, either singly or cumulatively, does not cause, or has the potential to cause, 'real damage'. For the Nerang River and some other major rivers in Gold Coast City this means that development should not cause afflux that would worsen flooding or create new flooding.

The designated flood for planning purposes is the 100 yr ARI. Table 9.9 presents a selection of predicted flood levels across the Nerang River floodplain.

Tallebudgera and Currumbin Creeks:

Hydrologic and hydraulic investigations of these creek systems have also been undertaken (GCCC 1997d, 1999a) although the recent reappraisal of rainfall estimates may have altered some of the original flowrates and a future update may be done. The lower reaches of both creeks are heavily developed with a number of canal estates.

Flood velocities in Tallebudgera Creek are quite high upstream of Lakewoods Estate due to the steep bed gradient and narrow stream width. Further downstream at Elanora, the creek meanders and increased friction results in an increase in flood levels upstream. Velocities at the mouth can also be high during major flood events. Most of the floodplain areas which have been developed do not become inundated up to the 100 year ARI event. Regions behind Palm Beach are the most affected and some properties will experience overfloor flooding at the 100 yr ARI level. Currumbin Creek exhibits similar behaviour, with higher velocities in the upper reaches and at the mouth. Table 9.9 presents selected flood levels from hydraulic studies.

Ocean Water Levels:

All of the above studies rely on estimates of the effects of tide and storm surge on the river tailwater during a flood event. Additional studies have considered these effects, together with the potential impact of rising sea level due to the enhanced greenhouse effect (ie. global warming).

Floodplain Management:

A range of individual initiatives across the region is now being amalgamated into a comprehensive floodplain management framework (GCCC 1999a). The key approaches include:

- Designated flood events for each specific land use, i.e. residential, commercial, industrial
- Allowable degrees of hazard for access to development, i.e. depth of water, velocity
- A risk management strategy for each land use to establish building platform and floor levels
- Special consideration for non-habitable spaces, on-site stormwater detention and redevelopment issues

Flood Mitigation:

A number of options have been investigated for reducing the impact of floods across the region. These include conveyance improvements to channels, bridges, weirs, amendments to road infrastructure and the possible raising of Hinze Dam. Recent development applications have incorporated synergies with the Council's physical works flood mitigation strategy for the Nerang River. For example, the raising of the Hinze Dam, in 1989, is predicted to have lowered flood levels by between 200 mm and 650 mm across the Nerang River floodplain for a repeat of the January 1974 rainfall. There remains further scope to raise the dam and to gain further protection from major floods. An artificial outlet to the sea has also been explored as an option for the Nerang River flooding problem.

Table 9.9 Summary of predicted flood levels in South-East Queensland

Local Authority	**River or Creek System**	**Location**	**Predicted Flood Levels (m AHD)**				
			10% AEP	**2% AEP**	**1% AEP**	**0.2% AEP**	**PMF**
Caboolture Shire	Caboolture R	River Mouth	1.87	2.18	2.30	-	-
		Riversleigh	2.80	3.17	3.32	-	-
		Bruce Hwy (u/s)	5.77	7.31	7.88	-	-
		Morayfield Rd	7.58	9.02	9.62	-	-
	King John Ck	Beachmere Pd	2.33	2.94	3.20	-	-
		Caboolture Rd	4.08	4.55	4.68	-	-
		Bruce Hwy	6.29	7.06	7.39	-	-
		Pumicestone Rd	8.14	8.72	9.03	-	-
		Beerburrum Rd	11.91	12.49	12.52	-	-
	Lagoon Ck	Bruce Hwy (u/s)	6.50	7.59	7.80	-	-
		Railway Crossing	10.61	11.59	11.89	-	-
	Burpengary Ck	Oakey Flat Rd	-	-	28.60	-	-
		Rowley Rd	-	-	14.38	-	-
		Dale St area	-	-	11.75	-	-
		Bruce Hwy (south)	-	-	7.98	-	-
	Little Burpengary Ck	New Settlement Rd	20.16	20.35	20.42	-	-
		Ruatoka Ct	14.62	14.74	14.79	-	-
		Philips St	13.66	14.11	14.25	-	-
		Old Bay Rd	4.89	4.97	5.01	-	-

Local Authority	River or Creek System	Location	Predicted Flood Levels (m AHD)				
			10% AEP	2% AEP	1% AEP	0.2% AEP	PMF
		Blue Pacific Rd	2.94	3.07	3.13	-	-
	Six Mile Ck	Beerburrum Rd	21.49	22.70	23.03	-	-
		Bruce Hwy	15.11	16.37	16.83	-	-
	Gympie Ck	Railway Bridge	14.79	15.38	15.62	-	-
		Bruce Hwy	5.32	6.18	6.50	-	-
	Wararba Ck	Bellmere Rd	9.30	11.30	12.08	-	-
		Richards Court	14.43	14.49	14.98	-	-
Pine River Shire	Conflagration Ck	South Pine Rd U/S	-	9.6	-	-	-
	Cabbage Tree Ck	Francis Rd	55.4	56.0	56.2	-	-
	Freshwater Ck North	Anzac Ave	6.2	-	6.6	-	-
	Freshwater Ck	Brays Rd	6.6	-	7.2	-	-
	Albany Ck	Albany Creek Rd U/S	-	16.5	16.6	-	-
	Colthards Ck	Gympie Road U/S	6.9	8.0	-	-	-
	Saltwater Ck	U/S Bruce Highway	17.0	17.7	18.3	-	-
	Yebri Ck	Anzac Ave U/S	-	12.3	-	-	-
	Terrors Ck (Dayboro)	William St. west	-	52.9	-	-	-
Brisbane City	Brisbane R	Mt Crosby Weir	18.65#	21.7*	23.6	-	-
NB: # Indicates 25 year ARI.		Moggill	11.35#	14.40*	16.20	-	-
		Jindalee UQ Vet Farm	7.30#	9.85*	11.50	-	-
		Port Office	2.10#	3.15*	3.85	-	-
*Indicates 55 year ARI	Breakfast Ck	Kelvin Grove Rd	5.84	6.96	7.77	-	-
		Opp Mann Park	2.60	3.41	4.00	-	-
		Opp Newstead House	1.09	1.13	1.17	-	-
	Oxley Ck	Mouth of Oxley Ck	1.26	1.60	3.50	-	-
		Corinda High School	4.27	5.71	6.71	-	-
		Beatty Rd	7.37	9.56	10.22	-	-
	Bulimba Ck	Greenwood St	22.52	23.03	23.39	-	-
		Merion Pl	11.24	12.11	12.37	-	-
		Old Cleveland Rd	6.65	7.42	7.98	-	-
		Doughboy Pde	2.35	2.83	3.02	-	-
		Aquarium Ave	1.72	2.04	2.00	-	-
	Norman Ck	Caswell St	3.02	3.61	3.97	-	-
	Moggill Ck	Fortrose St	9.88	11.02	11.48	-	-
	Kedron Brook	Osbourne Rd	33.00	33.81	34.25	-	-
		Hayward St	20.16	21.10	21.61		
		Kedron Park	9.86	10.52	10.88	-	-
	Cabbage Tree Ck	Old Northern Rd	43.28	43.53	43.84	-	-
		Pineapple St	13.07	13.78	14.43	-	-
		Braun St	2.46	3.40	3.76	-	-
Ipswich City	Brisbane R	Kholo Bridge	18.45	29.04	31.42	32.68	44.64
		Mt Crosby Weir	14.65	24.78	27.11	28.58	41.10
		Moggill Gauge	7.14	16.19	18.26	20.61	33.27
	Bremer R	Hancock Bridge	15.69	20.49	22.05	24.67	36.27
		David Trumpy Bridge	12.41	16.94	18.60	20.79	33.39
		Warrego Hwy Bridge	9.88	16.23	18.30	20.72	33.34
	Six Mile Ck	Redbank Plains Rd	32.80	33.04	33.19	33.46	34.60
		Ipswich Rd	6.82	15.80	17.87	20.22	32.81
	Goodna Ck	Kruger Pde	15.23	15.60	17.14	19.44	31.84
		Brisbane Tce	7.56	15.11	17.14	19.44	31.84

Local Authority	River or Creek System	Location	Predicted Flood Levels (m AHD)				
			10% AEP	2% AEP	1% AEP	0.2% AEP	PMF
	Bundamba Ck	Swanbank Rd	31.10	31.55	31.73	32.35	35.11
		Cunningham Hwy	25.61	26.05	26.24	26.79	33.36
		Brisbane Rd	16.10	16.78	18.30	20.73	33.36
Logan City	Scrubby Ck	Princess St Marsden	11.56	12.08	12.29	-	-
		Logan Mway Xing	8.94	9.70	10.15	-	-
		Railway Bridge	7.46	9.38	10.15	-	-
		Slacks Ck Junction	7.46	9.37	10.15	-	-
	Logan R	Chapmans Flat	10.39	13.09	13.8	-	-
		Waterford Bridge	9.18	11.77	12.64	-	-
		Railway Bridge	7.80	9.99	10.72	-	-
		Slacks Ck Junction	7.46	9.37	10.15	-	-
		Edens Landing	6.73	8.57	9.33	-	-
		Pacific Highway	5.47	6.86	7.46	-	-
		Albert R Junction	3.24	4.56	5.11	-	-
		Native Dog Ck Junc	2.15	3.55	4.18	-	-
Gold Coast City NB: *indicates 20 yr ARI	Albert R	Stanmore Rd	9.65	12.18	13.18	-	-
		Windaroo Ck	7.68	9.67	10.43	-	-
		Pacific Hwy	6.40	8.08	8.71	-	-
		Beenleigh	5.23	6.83	7.47	-	-
	Coomera R	Pacific Hwy (d/s)	3.81*	4.06	4.32	-	-
		Hope Island Resort	2.77*	3.02	3.25	-	-
		Oyster Cove	2.06*	2.3	2.45	-	-
		Sanctuary Cove	2.03*	2.38	2.49	-	-
		Paradise Point	1.56*	1.88	2.14	-	-
		Coombabah Lake	1.78*	2.09	2.34	-	-
	Nerang R	Nerang	5.00*	5.73	6.28	-	-
		Royal Pines Resort	3.59*	4.19	4.67	-	-
		Sun Lakelands	3.25*	3.87	4.41	-	-
		Sorrento	2.97*	3.47	3.97	-	-
		Clear Island Waters	3.27*	3.90	4.40	-	-
		Bond University	3.02*	3.65	4.11	-	-
		Mermaid Waters	3.00*	3.58	4.07	-	-
		Broadbeach Waters	2.66*	3.22	3.69	-	-
		Isle of Capri	2.19*	2.71	3.19	-	-
		Paradise Waters	1.64*	2.05	2.49	-	-
	Tallebudgera Ck	Gold Coast Hwy	1.54	1.98	2.21	-	-
		Pacific Hwy	1.79	2.32	2.57	-	-
		Tallebudgera Connection Rd	3.32	3.77	3.94	-	-
	Currumbin Ck	Gold Coast Hwy	1.53	1.96	2.15	-	-
		Thrower Drive	1.57	30.20	2.21	-	-
		Pacific Hwy	1.61	2.03	2.25	-	-
		Pine Lakes Entrance	1.65	2.10	2.31	-	-

Flood damage

Flooding affects all people, buildings and infrastructure which fall within the zone of inundation, as well as those which fall outside the zone of inundation but which either directly or indirectly use the affected facilities, whether it be roads, a hospital or a fuel refinery. Figure 9.11 summarises the various categories of urban flood damage. Flood damage at the most basic level can be divided into tangible (i.e. financial), or intangible (i.e. social) terms (ARMCANZ, 2000). Direct economic costs are easy to estimate from loss of contents, structural damage and external damage. Indirect costs (such as loss of opportunity [e.g. closure to schools], financial [e.g. loss of production] and clean up costs) are harder to express in dollar terms. Intangible or social costs (e.g. emotional trauma) are even harder to estimate, though the impact of flooding on a person may last long after the tangible costs have ceased to be significant. Appendix H describes the outcomes of flooding in South-East Queensland and some of the impacts. The appendix is limited, and may be enhance in future dedicated projects.

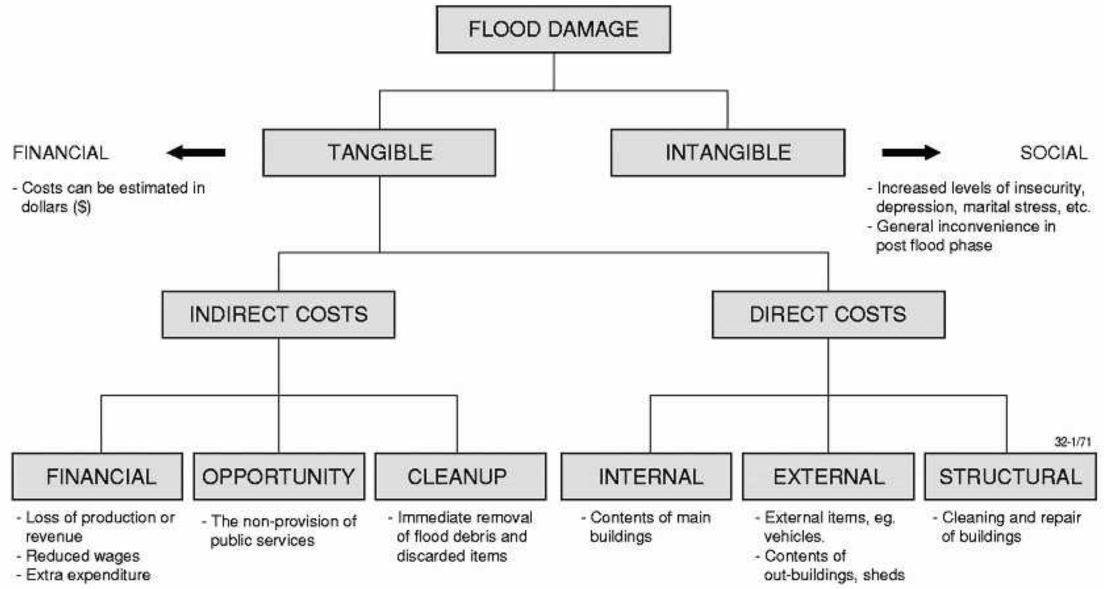

Figure 9.11: Categories of urban flood damage (ARMCANZ, 2000)

In this study, residential building flood damage only is estimated. Flood damage to buildings can be separated into contents and structure damage. The greatest increase in damage to single storey residential buildings for both structure and contents occurs within the first half metre of overfloor flooding. Almost all damage to contents occurs within the first metre of overfloor flooding. Damage to structure, however, increases almost linearly (after a sharp increase in about the first half metre of overfloor flooding) and damage can still be increasing at 3 m (Blong 2001). Due to the large scatter common with flood damage, stage damage curves are not accurate for determining the damage costs to individual buildings. They are, however, valuable in estimating total damage.

Prior to overfloor flooding, damage is restricted to the external building, gardens and fences; and tools, lawnmowers and other items stored below floor level. As soon as overfloor flooding occurs, there is a large increase in flood losses with damage to floors, built-ins, plasterwork, plumbing and electrical, internal decoration and contents. As water depth overfloor increases, so does the risk of extensive damage and structural failure. Blong (2001), for example, showed that where overfloor flooding reached a depth of about 1 m in single storey residential houses, damage to the building (ie excluding contents) ranged 9-25% of the building value, depending on the duration of inundation. Where overfloor flooding reached a depth of about 3 m, damage increased to 34-52%.

Velocity is also a major factor in determining percent damage, with high velocities capable of causing building collapse even in relatively shallow waters. Black (1975), for example, showed that building failure of weatherboard houses could occur when water over the floor is more than one metre and water velocities are more than about 2 m/sec. At lower velocities and greater depths, and at higher velocities and lower depths, building failure may also occur. Building construction/materials are also factors which influence susceptibility to structural failure. Typically, brick veneer residential buildings can withstand higher velocities and depths than single storey weatherboard residential buildings before building failure occurs (Black, 1975). Building age can play a contributing factor to the amount of flood losses, as age can indicate the condition of the building and materials used in construction.

Duration of inundation and amount of sediment also influence the amount of flood damage. For contents loss, factors such as the elevation/location of contents, warning time and awareness also play a major role in the resultant flood damage. A warning time of twelve hours, for example, can provide sufficient time for people to save much of their contents as long as **they are aware and prepared.**

Damage assessments for commercial/industrial buildings are more difficult to determine, though the dollar loss resulting from these greatly exceeds that for residential buildings. The potential mean annual flood damage for industrial buildings (Rand 0.94 m) in Vereeniging, South Africa, for example, far exceeded mean annual damage for residential buildings (Rand 124 000) for the same area (Booysen and Viljoen 1996 in Booysen, Viljoen and de Villiers 1999).

Modelling of flood damage assumes that the buildings have not already been damaged extensively prior to flooding from other hazards. This, however, is not always the case as demonstrated for example in Mackay, Central Queensland. In 1918, severe wind and storm tide preceded landbased flooding, so that the damage caused by riverine flooding in Mackay was minor compared to the damage already inflicted by wind and storm tide.

Limitations and uncertainties - Flood scenarios

Before examing flood risk in the South-East Queensland region it must be pointed out that significant uncertainties are associated with the estimates of damage losses presented here. Sources of uncertainty include, but are not confined to:

Uncertainty in the hazard models:

Uncertainties originate from the inherent variability of floods, inaccuracies in the individual hazard models used, and variations in the modelling within and between catchments. Edge effects were also created when modelling flood depths using the digital elevation model (DEM). Some of the variation between modelled scenarios for each catchment is mentioned below:

1. Caboolture River and Burpengary Creek:
    - 2% and 1% AEP scenarios available.

2. Pine Rivers:
    - 2% and 1% AEP scenarios available but insufficient data to model flood depth.

3. Brisbane-Bremer River:
    - Brisbane River - mapping based on historical flood levels;
    - Major Brisbane Creeks - modelled 1% AEP scenario; and,

- Ipswich 2% and 1% AEP scenarios available.

4. Logan-Albert River:
   - Logan LGA – designated flood scenario available. This varies between applying a 50 year ARI in the upper reaches of Scrubby/Slacks and Native Dog Creeks and a 125 year ARI in the lower reaches and the main Logan River; and,
   - Gold Coast LGA – 2% and 1% AEP scenarios available.
5. Pimpama, Coomera, Nerang, Tallebudgera and Currumbin River/Creeks:
   - 2% and 1% AEP scenarios available, but include a storm surge component along the Broadwater and at Paradise Point.

The uncertainties are, however, building specific and generally affect only part of the study area within a catchment. As loss is shown as a percent damage per building (i.e. it is an average across residential buildings affected **and** unaffected by flooding), it is unlikely that these uncertainties affect damage loss estimates.

Uncertainty in the digital elevation model (DEM):

A DEM was developed for each catchment with a 10 m grid size. Though, a finer resolution grid size would improve the accuracy of the flood damage modelling, particularly when interpolating in the canal estates, the elevation model was developed for a broad-scale study and hence will contain inaccuracies at the individual parcel level.

Uncertainties and incompleteness of the property inventory:

Uncertainties and incompleteness of the property inventory for information such as feature description (particularly relevant for identifying the more critical facilities) and floor height. The key values of floor height and ground height were taken from the detailed property database described in Chapter 3. Floor heights have been estimated on the basis of building age rather than field survey, as was done by the *Cities Project* in Cairns, Mackay and Gladstone. A broad generalisation has been adopted where houses built up to and including 1980 will have a suspended floor at least 0.8 m above ground level and houses built after 1980 will be on a slab (0.3 m above ground level). No allowance has been made for the high-set 'Queenslander' style house so common in northern Queensland. Observation of high set houses in coastal areas of South-East Queensland indicates that where such houses exist the under-house areas have almost all been enclosed, thus making them two story houses with floor heights at 0.3 m. Again these are perhaps conservative assumptions. Non-residential buildings are all assumed to have a floor height of 0.3 m above ground level. Though the floor height inventory may not be accurate at the individual property level, it has been used to provide a good indication of relative flood damage losses.

Uncertainty in the flood loss curve:

The damage (% sum insured) provides a good estimate of residential building flood losses, though it may not be accurate at the individual property level. The assumptions made when applying the loss curves in this context will be discussed later.

The analysis of flood losses does not consider non-residential structures such as commercial, industrial and infrastructure facilities. As stated earlier, damage to these types of facilities can be very costly to the community, both in the tangible and intangible effects they cause. Nor does the assessment consider direct or indirect economic or social losses, or casualties. Hence, potential damage is an underestimate and further analysis is required to develop a more comprehensive understanding of how the community could be affected. In the following analysis, direct dollar losses for residential buildings are not calculated because of the additional uncertainties and complexities involved.

Considering the uncertainties and on-going refinements to the modelling, the data may alter as a result of regular updating. The information provided here is, however, a best estimate using the best available data at the time.

Comparative flood risk

The modelled impact of flooding is presented for the urban centres as shown in Table 9.10. The results are shown by river system/catchment.

Table 9.10: Urban centres in the study area

River Systems/catchment	Urban centres
Caboolture River and Burpengary Creek	Caboolture
Pine Rivers	Pine Rivers
Brisbane – Bremer River	Brisbane and Ipswich
Logan – Albert River	Logan City and Beenleigh
Pimpama, Coomera, Nerang, Tallebudgera & Currumbin R/Cks	Gold Coast City

Two modelled flood scenarios (2% AEP or 50 year ARI, and 1% AEP or 100 year ARI) are presented for each catchment, the limitations of which were stated earlier. The hazard mapping used in this study is that currently in use for floodplain management in the respective local government area (LGA). Where two local governments fall within one catchment (i.e. Brisbane and Ipswich), then the flood mapping adopted by both Councils was combined to assess flood risk across the river system. The Logan-Albert was also modelled as one river system, though Logan (to the north of the Logan River) falls within the Logan City Council LGA and Beenleigh falls within the jurisdiction of Gold Coast City Council.

Typically, a polygon showing only the extent of inundation was available from local Councils. Therefore, a ten metre DEM was used to model flood depths based on the flood mapping available for each catchment. Ideally, flood damage for the more extreme events (e.g. 0.2% AEP and PMF) should be modelled, however, hazard modelling for the more extreme events was unavailable except for Ipswich. The modelling identifies the:

- number of developed properties inundated by catchment;
- number of developed properties by catchment with overfloor flooding;
- percent of buildings with overfloor flooding of each feature type for the region;
- percent inundated residential properties by catchment;
- damage (% sum insured) for residential buildings, by CCD, catchment and region; and,
- number of the more critical facilities affected.

<u>Flood risk to developed properties</u>

Table 9.11 shows the modelled flood risk on developed properties during the 2% and 1% AEP scenarios. Across the region more than 47 400 developed properties are affected by flooding, of which more than half are affected by overfloor inundation. In both the 2% and 1% AEP scenarios, the greatest number of developed properties at risk from flooding fall within the

Brisbane-Bremer catchment followed by the Pimpama-Coomera-Nerang-Tallebudgera-Currumbin river system. The percentage of developed properties having at least some water on the property in the Gold Coast area (20% during a 1% AEP flood event) is, however, much higher than in the Brisbane and Ipswich areas (10% in 1% AEP event). Of those properties inundated, the Brisbane-Bremer catchment has a higher percentage of buildings with overfloor flooding (65% in Brisbane-Bremer compared with 40% in the Gold Coast in a 1% AEP event). The number of buildings (and depth) of overfloor flooding is important when estimating flood damage as shown later.

Table 9.11: Flood risk to developed properties during the 2% and 1% AEP scenarios

River/creek systems	Total number of developed properties	Percent inundated of catchment		Properties inundated (any depth)		Overfloor inundation	
		2% AEP	1% AEP	2% AEP	1% AEP	2% AEP	1% AEP
Caboolture R and Burpengary Ck	37 254	1%	2%	524	824	255	428
Pine Rivers	38 390	0.4%	0.5%	156	203	No data	No data
Brisbane–Bremer R[1]	366 625	5.1%	5.9%	18 877	21 777	12 812	14 070
Logan–Albert R[2]	68 881	6.5%	6.7%	3636	3738	2729	2796
Pimpama, Coomera, Nerang, Tallebudgera & Currumbin [3]	106 881	10.5 %	19.6%	11 201	20 945	3376	8365
Total	**618 031**	**5.6%**	**7.7%**	**34 394**	**47 487**	**19 172**	**25 659**

1. For the Brisbane River only historical flood levels were available. For the major Brisbane Creeks only the 1% AEP scenario was available.
2. The designated planning scenario was used for the northern side of the Logan River. This varies between a 50 year ARI in the upper reaches of Scrubby/Slacks and Native Dog Creeks and a 125 year ARI in the lower reaches and the main Logan River. For the southern side of the Logan the 50 and 100 year ARI scenarios used.
3. Includes a storm surge component along the Broadwater and at Paradise Point.

Ipswich contributes only about 16% of the buildings affected in the Brisbane-Bremer river system during a 1% AEP event, with Brisbane alone having more than 18 300 developed properties affected by flooding. The number of buildings affected by a 1% AEP flood in Brisbane is likely to be an underestimate for a least two reasons. First, the hazard modelling of the Brisbane River is based on historical data, of which most of the flood levels are for recurrence intervals less than a 100 year ARI. Second, modelling of the major Brisbane creeks is based on 1983 data. Though the creek modelling for Brisbane was completed prior to the completion of Wivenhoe Dam in 1985, the size of the dam, and hence the mitigating effect of the dam on flooding in Brisbane was incorporated into the hazard model. Hence, an increase in the number of buildings on the floodplain in the intervening seventeen year period mean that the number of buildings affected by major creek flooding is likely also to be an underestimate.

Several thousand additional developed properties could be isolated by the floodwaters across the region, particularly in the Gold Coast and Brisbane areas. These properties could either be completely isolated by floodwaters or cut off by flooded access roads, though escape by foot (for able-bodied people) on dry land may be possible. **It is recommended to consider 'potentially inundated' those areas likely to be isolated and to evacuate people.** This allows a factor of safety in the event that the resolution used in the modelling is not sufficient to define accurately the boundary of inundation. Furthermore, localised stormwater flooding, in addition to riverine/creek flooding will increase the area affected by inundation and/or the numbers of properties isolated.

The area covered by a floodplain can be much larger than the area inundated during a 1% AEP flood. That is, the area up to, and including the PMF forms the floodplain though the 100 year ARI flood levels (1% AEP) are those commonly used as the designated planning scenario. As mentioned earlier, the PMF is rare and there are few rivers in Australia for which the PMF has been modelled. Depending on the topography of a river system, the number of buildings affected during a PMF (and/or other extreme scenarios) may increase significantly over the 1% AEP scenario. In Ipswich, for example, where the topography is quite hilly, the increase in number of buildings affected by flooding is five fold. Where the topography is flat, however, the increase may be marginal.

Properties affected by overfloor flooding

Properties affected by overfloor inundation (of any depth), as a percent of function, is shown in Table 9.12. Logistics, transport and storage facilities have the greatest percent of buildings affected by overfloor flooding (16%), followed by business and industry, and community facilities. This is similar to storm tide; however, the percent of function affected by riverine flooding is much greater than that affected by storm water inundation at the same recurrence intervals. For example, four times more logistic, transport and storage facilities are affected by riverine flooding than by storm surge inundated.

Table 9.12: Properties affected by overfloor inundation, as a percent of function, across the South-East Queensland study area

Function	Percent (%) overfloor inundation of feature type	
	2% AEP	1% AEP
Houses	2.4	3.1
Flats	3.3	5.7
Commercial accommodation	4.2	6.8
Business & industry	8.9	10.2
Logistic, transport & storage	16.0	16.4
Public safety & health	3.7	4.9
Community, education & sport	7.7	8.4
Utilities	5.2	5.9

Note: The total number of buildings in Redcliffe, Pine Rivers and Redland are included in the number of buildings in the study area though no inundation numbers are included for these areas in the statistics.

Residential properties by catchment

Table 9.13 shows residential properties as a percent of inundated developed properties and as a percent of all residential properties.

Table 9.13: Percent inundated residential properties by river system

River/creek systems	INUNDATED RESIDENTIAL PROPERTIES			
	% of properties inundated		% of all residential properties	
	2% AEP	1% AEP	2% AEP	1% AEP
Caboolture R & Burpengary Ck	95.6	94.9	1.4	2.2

Pine Rivers	79.5	81.8	0.3	0.5
Brisbane – Bremer R.	81.6	82.7	4.5	5.2
Logan – Albert R	92.4	92.5	5.1	5.3
Pimpama, Coomera, Nerang, Tallebudgera & Currumbin	95.9	96.1	10.7	20.1

Residential properties (houses and flats) are the overwhelming majority (about 89%) of inundated properties, though only between 5% (2% AEP scenario) and 7% (1% AEP scenario) of residential properties in the region are affected. Though a large percentage of affected buildings are residential, only a small amount of residential properties are actually affected - less than 6% for all river systems with the exception of the Gold Coast area where 20% of residential properties are affected in a 1% AEP scenario.

Damage (percent of sum insured) for residential buildings

Damage (percent sum insured) has been derived using a combined structure and contents loss curve for single storey residential buildings based on that in Blong (2001), which has been designed for the insurance industry. The curve is preliminary and needs to be tested against large amounts of insurance data, however, it provides a good estimate of flood damage. Though the curve provides larger losses than older Australian loss curves, it probably underestimates potential flood damage for single storey residential buildings, because many people are underinsured and because factors such as structural collapse and velocity were not considered specifically. Available data sets suggest that the ratio of building to contents vary. Here, a content to building ratio of 0.3 was deemed the most suitable.

The framework used for modelling damage for residential buildings is shown in Table 9.14. This has been developed from the loss curve shown in Figure 9.12. Residential buildings were divided into six categories, including i) not inundated, ii) inundated but not overfloor, and into iii-vi) four categories of overfloor flooding as shown in Table 9.14. The median was taken of each of the four categories of overfloor flooding to calculate percent damage. Where water depth overfloor exceeded 2 m, than percent damage for 2.5 m water depth overfloor was used, to reflect that the curves were designed for single storey residential buildings which typically have a height of about 3 m.

Percent damage by CCD was derived by multiplying percent damage at water depth A with the number of residential buildings affected at depth A. This was repeated for depths B through F within the CCD. The product (of percent damage multiplied by the number of residential buildings) at depths A through F were then summed and divided by the total number of residential buildings in the CCD. This was repeated for each CCD. Percent damage by catchment and region (see Table 9.15) was derived in a similar manner.

Table 9.14: Framework used for modelling damage for residential buildings

Water depth		**Damage (% sum insured)**
Range	**Median used for calculating % damage**	
A. Not inundated	Not inundated	0
B. Inundated but not overfloor	-0.3 m	0.9
C. Overfloor >0 – 0.5 m	Overfloor 0.25 m	16
D. Overfloor >0.5 – 1.0 m	Overfloor 0.75 m	28
E. Overfloor >1.0 – 2.0 m	Overfloor 1.5 m	38.6
F. Overfloor >2.0 m	Overfloor 2.5 m	49.2

Though the best loss curve currently available, the loss curve has some obvious limitations when applied in this context, as summarised, but not confined to, those listed below:

- constructed for single storey residential buildings, but used here for all residential buildings;
- does not take into account high set homes, though many have been converted to habitable space, whether legally or illegally;
- damage to commercial/industrial buildings and other critical facilities are unknown and yet will contribute a large amount to damage losses;
- does not take into account buildings which may suffer 100% damage through structural failure, or suffer from ‘domino effects’ (e.g. collapse of one building causing greater damage to another building through its impact on it);
- median percent damage used to represent a range of inundation depths (e.g. for residential buildings with overfloor flooding up to 0.5 m, percent damage was derived from the median water depth, i.e. 0.25 m and a damage of 16% damage was applied, see Table 9.14);
- potential damage estimated – assumes nothing has been done to minimise damage (e.g. removal of contents);
- contents/building ratio varies. The loss curve used a contents/building ratio of 0.3 m;
- does not take into account other site specific factors which influence degree of damage other than water depth, of which velocity is the most important excluded factor. Building type is another important exclusion.

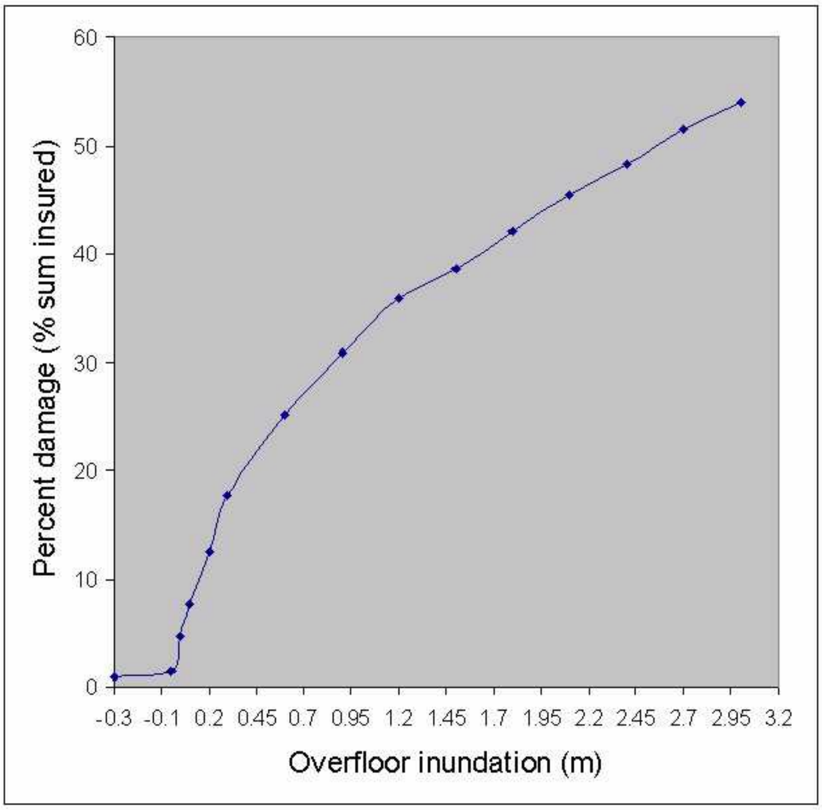

Figure 9.12: Structure and contents combined loss curve (From Blong 2001)

Percent damage for <u>residential buildings</u> by catchment and for the South-East Queensland study area is shown in Table 9.15. Damage is shown as a percent of sum insured. Damage for Pine

Rivers could not be calculated because a suitable DEM (or contours from which to derive a DEM) was unavailable to model flood depths. Damage at Pine Rivers is expected to be low, particularly when compared with the other catchments.

Table 9.15 shows that every building in the South-East Queensland study area will suffer, on average, 1.09% damage during a 1% AEP flood event. The Brisbane-Bremer river system contributes more than half of the total flood damage to the region and double the amount of flood damage contributed by the Pimpama-Coomera-Nerang-Tallebudgera-Currumbin River system. The Pimpama-Coomera-Nerang-Tallebudgera-Currumbin River system, contributes about double the flood damage of the Logan-Albert River system during an event with a 1% AEP. Flood damage in Caboolture is small when compared with the rest of the region.

Table 9.15: Damage (% sum insured) per building

River/creek system	Number of residential properties	% damage (% sum insured)		% of total damage 1% AEP
		2% AEP	1% AEP	
Caboolture R. – Burpengary Ck.	36 128	0.19	0.34	1.8
Brisbane-Bremer R.	345 648	1.04	1.18	58.3
Logan-Albert R.	65 578	1.38	1.43	13.4
Pimpama, Coomera, Nerang, Tallebudgera & Currumbin R/Cks.	100 637	0.87	1.84	26.6
Total of riverine flood affected catchments	547 991[1]	1.00	1.28	100
Total South-East Queensland study area	**644 686[2]**	**0.85**	**1.09**	**100**

1. This includes the Caboolture, Brisbane, Ipswich, Logan and Gold Coast study areas.
2. The number of residential properties includes the Caboolture, Redcliffe, Pine Rivers, Brisbane, Ipswich, Logan, Redland and Gold Coast study areas.

The South-East Queensland region has the largest number of buildings affected in a 1% AEP flood event than any other region in Australia. This is partly because a single event (e.g. a cyclone), can cause rainfall across the region resulting in the flooding of several rivers, each flanked by urban development. However, each of the rivers in the region are unlikely to all suffer exactly a 1% AEP flood during the same episode of flooding. For example, the January 1974 flood in the Brisbane River was estimated to have had an ARI of about 75 years. However, in the Nerang River the flood of January 1974 had an ARI of 65-70 years, whilst in the Coomera and the Logan-Albert rivers an ARI of greater than 100 years has been estimated.

Damage for residential buildings by CCD (remembering the uncertainties mentioned earlier) is shown as an average percent damage per building for the region during 2% AEP (Figure 9.13) and 1% AEP (Figure 9.14) scenarios and by catchment for the 1% AEP scenarios in Figures 9.15-9.18. Using this method, the high damage sustained by some buildings in a CCD is diluted by the number of buildings not affected by flooding.

Damage from flooding is localised along the watercourses across the region and constrained by topography. The geographical extent of the CCDs varies greatly across the region. Typically, those CCDs located in the inner city are small, while those located on the rural/urban fringe are geographically large. However, the number of residential buildings located in a large rural CCD (e.g. Kholo, Ipswich) may be less than in a much smaller inner city CCD. Where residential buildings cover only a small portion of the CCD, the whole CCD will reflect the damage as affected by those few buildings. Therefore, though a CCD located at the rural/urban fringe may have a high percent residential building damage, fewer buildings may be affected by flooding than in the small urban CCD even though the damage in the rural CCD is depicted as covering a large area.

Residential building damage by CCDs varies across the region by 45%. Damage is greatest in the Brisbane-Bremer catchment, with the highest damage in any one CCD estimated at 45%. The CCDs with the greatest damage, falling in the suburbs of Fairfield (Plate 9.23), Rocklea, Chelmer, Saint Lucia (Plate 9.23), Toowong and Graceville (all with residential damage >30%) are areas which suffered substantially in the flood of January 1974. The largest damage for any one CCD in the Logan-Albert area is 24% and falls in the suburb of Waterford West (Plate 9.32). The largest residential building damage for any one CCD in the Pimpama-Coomera-Nerang-Tallebudgera-Currumbin catchment is 23% and in the Caboolture-Burpengary catchment a low 10%.

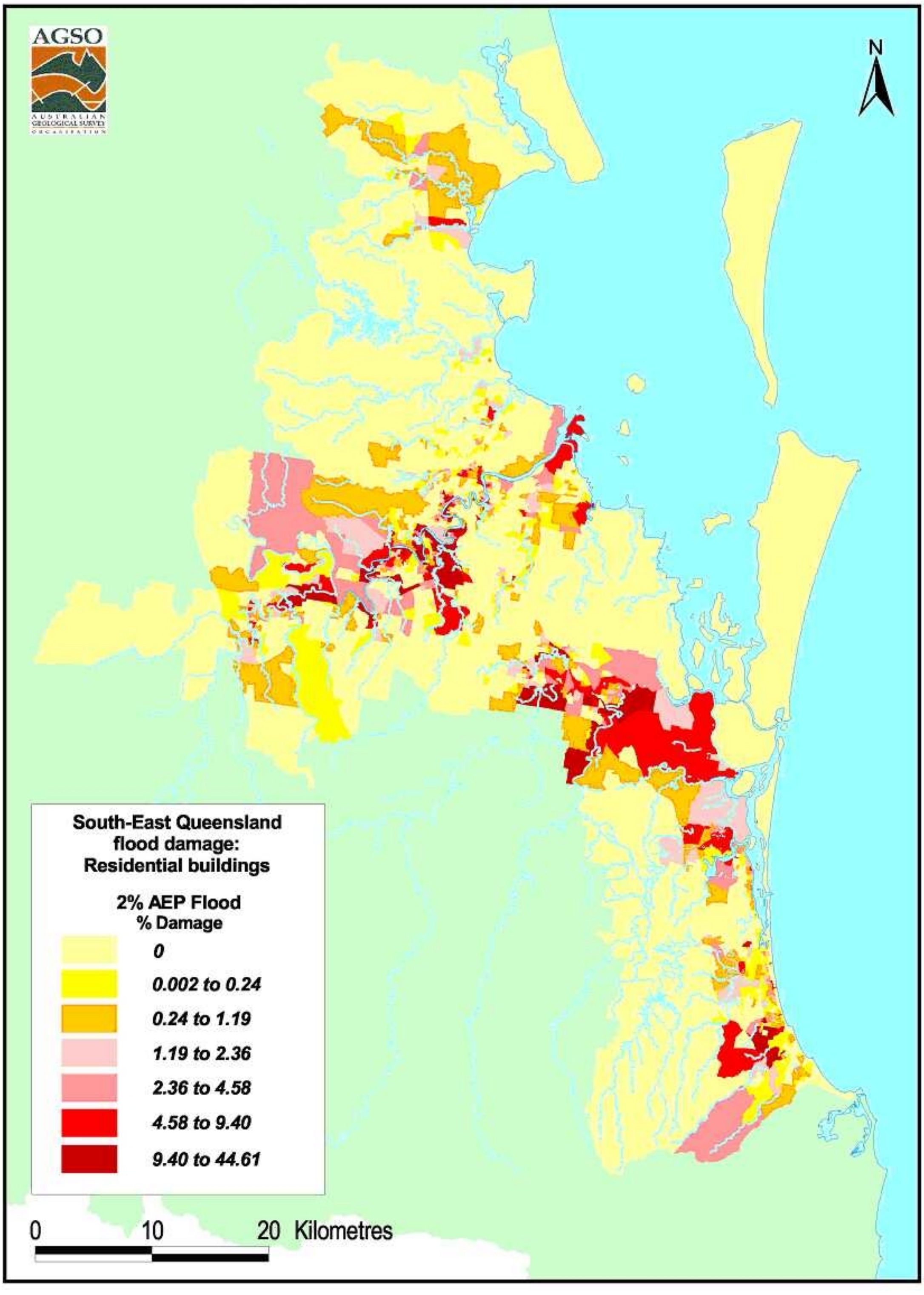

Figure 9.13: Damage (% sum insured) by CCD for residential buildings, 2% AEP, South-East Queensland region

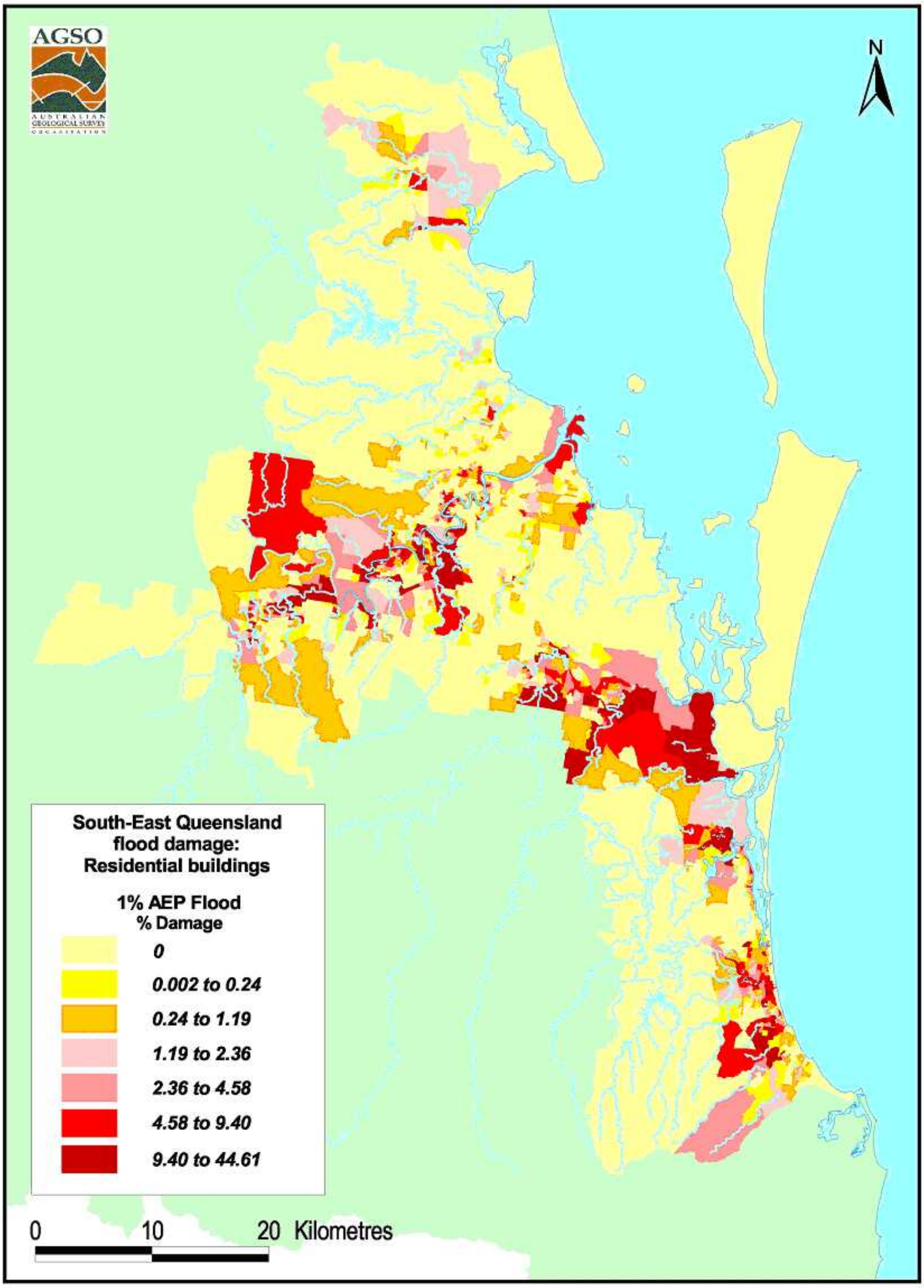

Figure 9.14: Damage (% sum insured) by CCD for residential buildings, 1% AEP, South-East Queensland region

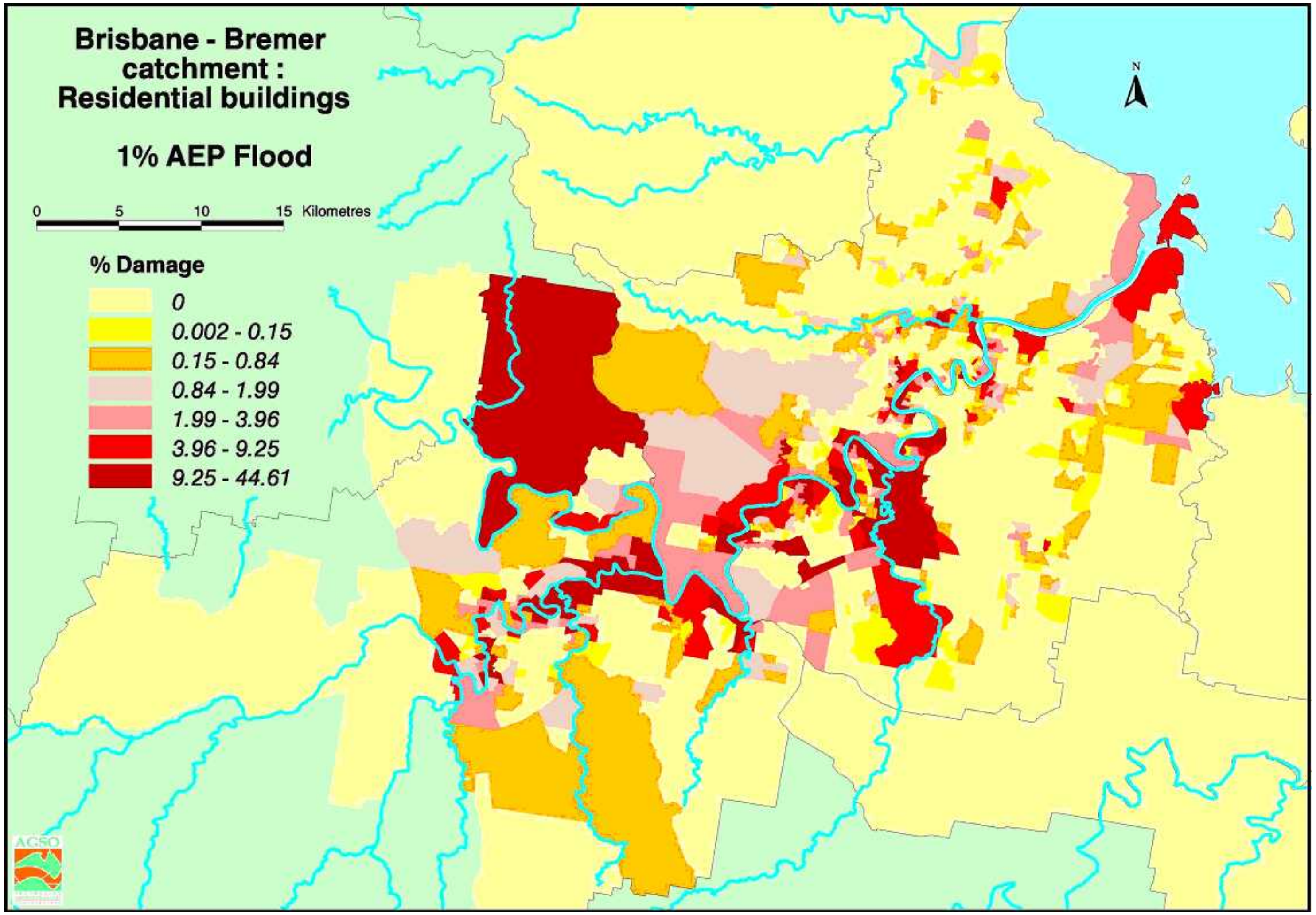

Figure 9.15: Damage (% sum insured) by CCD for residential buildings, 1% AEP, Brisbane-Bremer River catchment

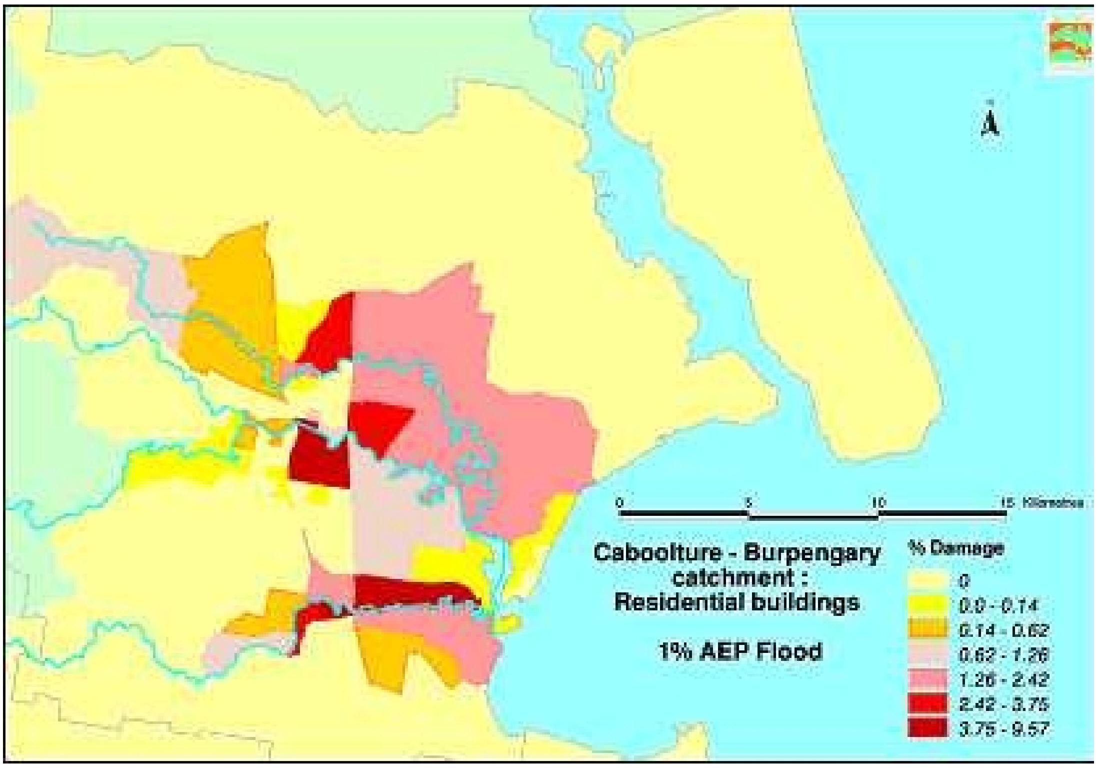

Figure 9.16: Damage (% sum insured) by CCD for residential buildings, 1% AEP, Caboolture River – Burpengary Creek catchment

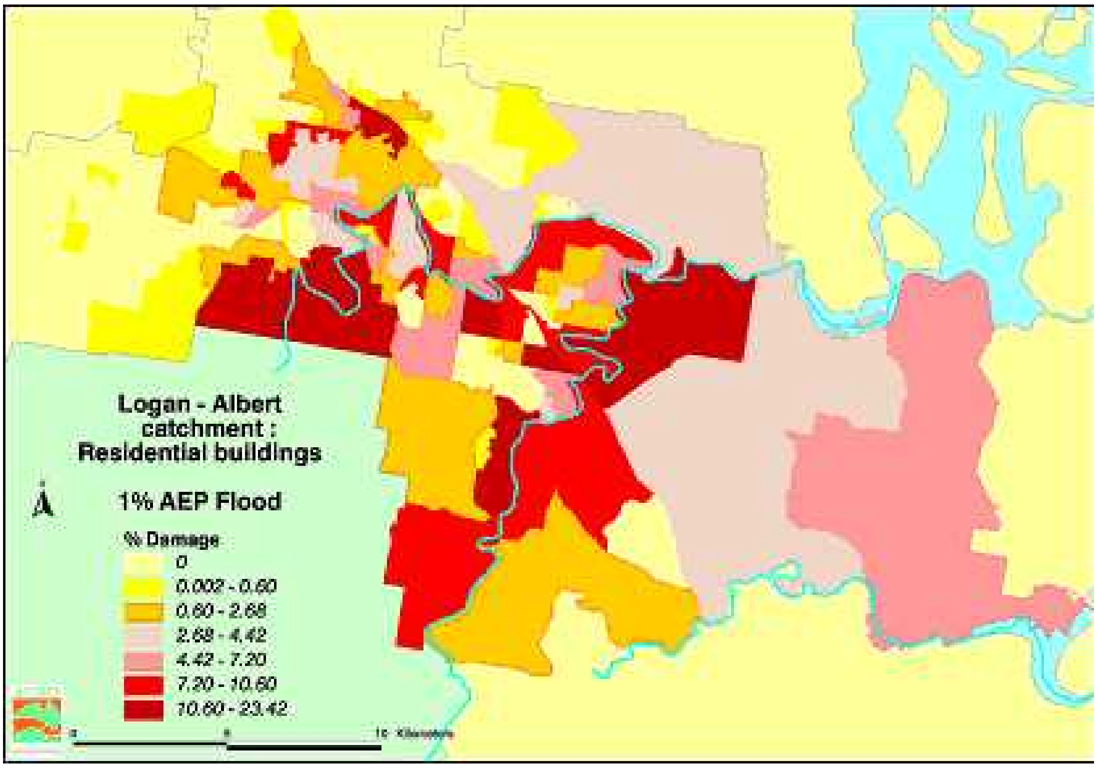

Figure 9.17: Damage (% sum insured) by CCD for residential buildings, 1% AEP, Logan-Albert River catchment

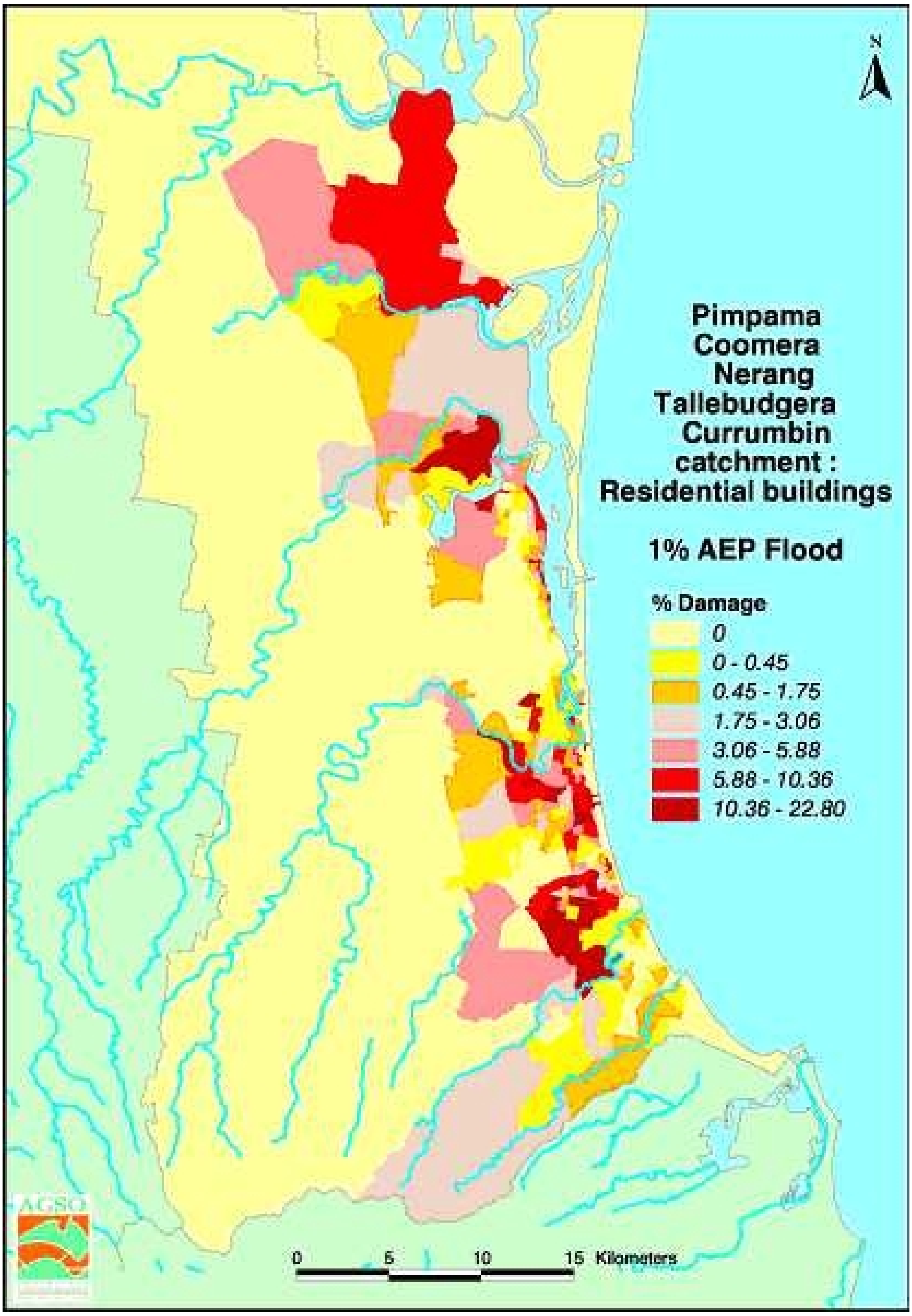

Figure 9.18: Damage (% sum insured) by CCD for residential buildings, 1% AEP, Pimpama-Coomera-Nerang-Tallebudgera-Currumbin catchment

Critical facilities

The greatest number of critical facilities affected by flooding are located in the Brisbane – Ipswich area followed by the Gold Coast area. Keeping in mind the uncertainties mentioned earlier, the particularly sensitive facilities likely to be affected by flooding during a 1% AEP event across the region are detailed as follows:

- two ambulance stations, one each in Caboolture and Brisbane;
- five fire stations, one each in Caboolture and Gold Coast, and three in Brisbane;
- a police station in Brisbane;
- the emergency services operations centre in Beenleigh;
- the air sea rescue, rescue helicopter base and Australian volunteer coastguard, all in the Gold Coast;
- a private hospital in Brisbane;
- nine telephone exchanges, of which six are in the Gold Coast, two are in Brisbane and one in Ipswich;
- thirteen substations, of which eight are in Brisbane, one in Ipswich, one in Beenleigh, and three in Gold Coast;
- a power station in Brisbane;
- three sewage treatment plants, one each in Caboolture, Gold Coast and Ipswich;
- six oil/fuel depots, of which one is in Logan, two in Ipswich and three in Brisbane;
- four railway stations, one each in Logan and Ipswich, and two in Brisbane;
- an airforce base in Ipswich and army barracks in Brisbane; and,
- an aerodrome and aircraft maintenance hanger, both in Brisbane.

Roads

Several hundred kilometres of road would be inundated across the region. A further few hundred kilometres of road could be isolated or cut off by the floodwater though evacuation by foot on dry land may be possible. Though inundated, some of the road may still be passable by vehicles. Evacuation by vehicle becomes increasing difficult and dangerous as water depths rise and velocities increase. Typically, small, low and light cars can only drive safely through water where depths are less than 0.3 m. Larger, higher and heavier cars can only drive safely though water less than about 0.4 m deep (ARMCANZ 2000).

Percent residential building damage and the community vulnerability index

Figure 9.19 shows the product of percent residential building flood damage by CCD and the community vulnerability index by CCD for the 1% AEP flood scenario. The higher the number, the greater the degree of overall risk during a 1% AEP event. The CCDs with the highest value fall in the suburbs of Chelmer, Fairfield, Saint Lucia, Toowong and Rocklea (value >17). These are the same CCDs which are worst affected when only damage is considered. Consideration of vulnerability, however, changes the ranking of CCDs. For example, two of the CCDs which fall in the suburb of Rocklea have a high percent damage but lower community vulnerability (relative to the other CCDs), therefore their overall rank falls somewhere inbetween.

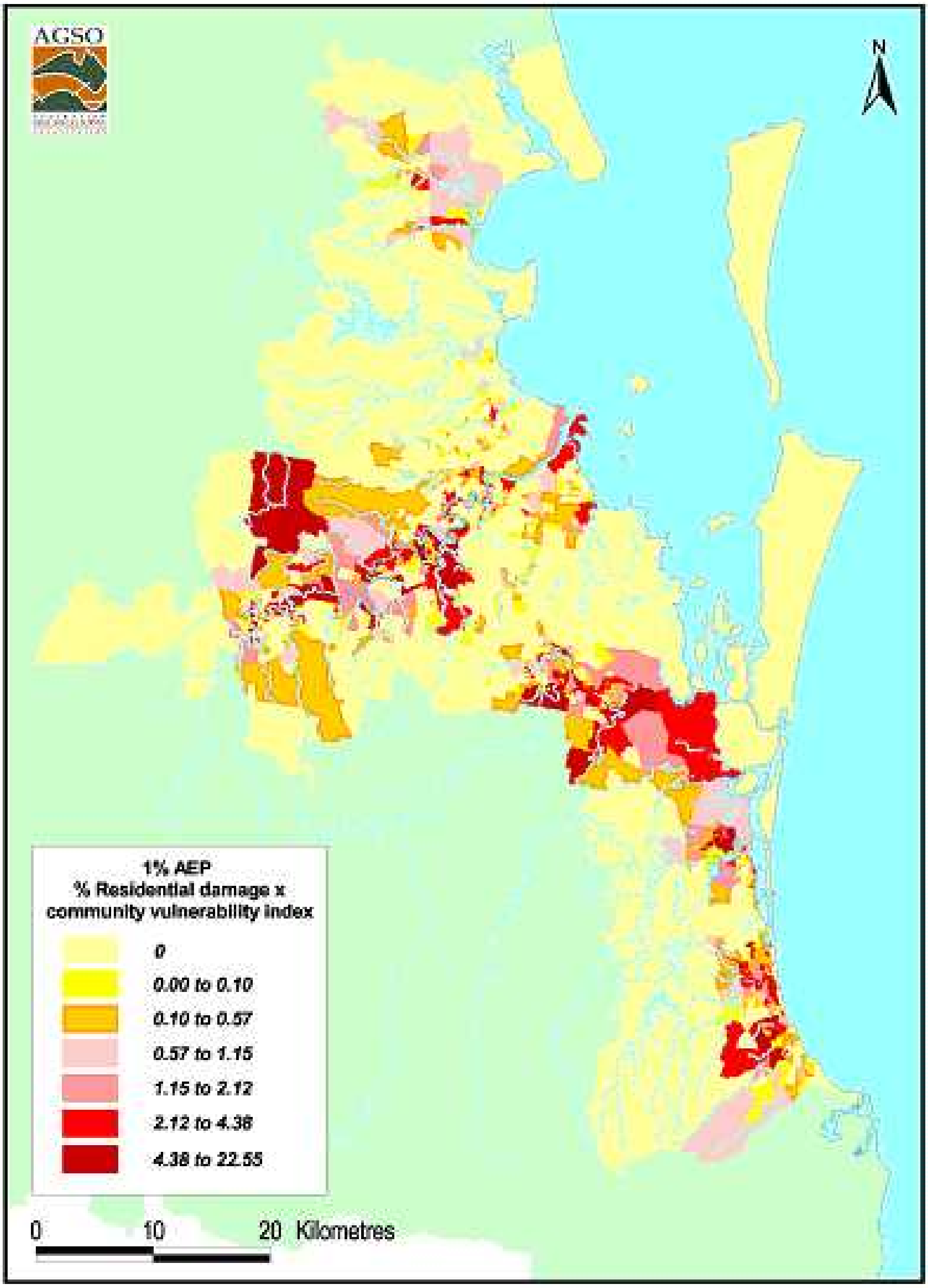

Figure 9.19: Percent residential building damage by CCD multiplied by the community vulnerability index by CCD for the South-East Queensland study area

Community Awareness

Community awareness for flooding is generally poor. Some common examples of misled perceptions are:

- a '1 in 100 year' (100 year ARI) flood occurred twenty years ago, therefore another flood of that magnitude won't occur for another 80 years;
- buildings which fall within the '1 in 100 year' flood line are at risk of flooding. Those buildings which fall outside the '1 in 100 year' line will never be flooded;
- because it hasn't happened before it can't happen;
- a belief in immunity from hazards; and,
- construction of a levee has made the area behind it flood free.

There is also frequently confusion as to how flood levels affect individuals and their properties, and a poor understanding by the media of the forecasts and flood warnings, often resulting in misinterpreted information reaching the general public.

Some of these issues are slowly being addressed. Logan City Council, for example, has established a pilot project whereby some 275 houses affected by flooding from Scrubby Creek were notified of their respective building floor height expressed as a height relative to the flood gauge. This personalising of the flood risk raises awareness amongst at risk households, thereby giving them the opportunity to reduce flood losses to their individual homes in the event of a flood. The Nerang River Flood Mitigation Community Consultation Project also aims to raise awareness of flood risk in the local area. Furthermore, it aims through community consultation, to develop a preferred list of treatment options to reduce flood hazard and risk.

Figure 9.20 shows how experience can greatly reduce flood damage (compared to inexperience) with increased warning time of up to about twelve hours. Experience could easily be substituted with awareness and inexperience with lack of awareness. **Therefore, an aware community is likely to be a less vulnerable community because of its ability to prepare for an event.**

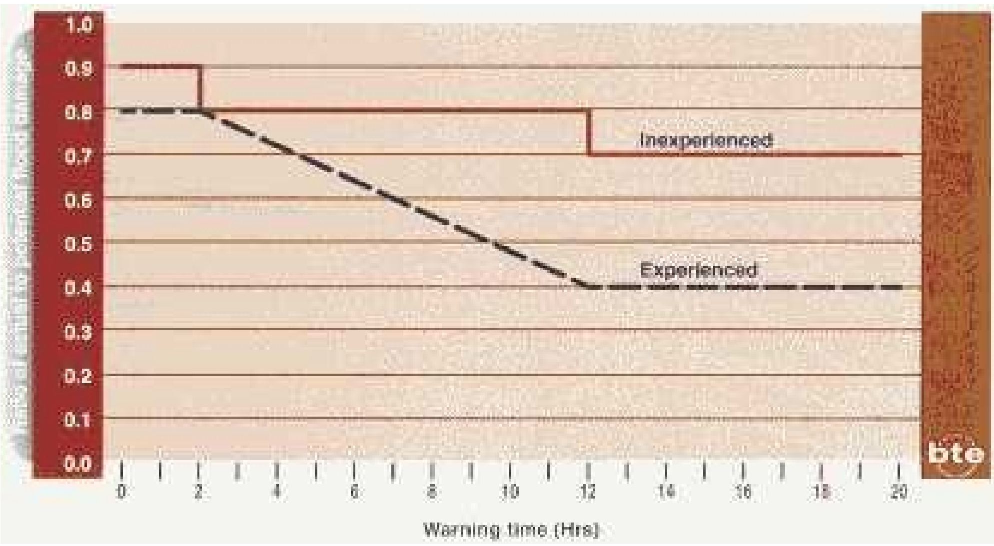

Figure 9.20: Affect of experience and warning time on actual flood damage (Bureau of Transport Economics 2001).

Interpretation

Historical records show that the South-East Queensland region has a long record of moderate to major floods. In the last century, the Australia Day floods of January 1974 resulted in the most widespread damage across the region and represent the most severe example of urban flooding to date in Australia. Each river system in South-East Queensland can flood independently, however, as the 1974 flood showed, each of the rivers in the region can flood within days of each other, causing widespread and prolonged disruptions and damage across the South-East Queensland region.

In the Brisbane River system approximately 13 000 buildings were affected in the January 1974 flood. In the Bremer River subcatchment, approximately 2000 properties in Ipswich were affected by the same flooding episode, 41 houses swept away and 600 houses fully submerged (Smith, 1998). A reoccurence of the 1974 flood today, would result in approximately 4700 developed properties being affected in Ipswich alone. The more than double increase in the number of developed properties affected in Ipswich is the result of the increase in urbanisation on the floodplain over the intervening 26 year period.

In the Gold Coast region, the January 1974 floods directly affected approximately 1000 residential dwellings. Although there has been a large increase in population in the Gold Coast and widespread residential development has occurred within the 1974 inundation zone, if a repeat of the 1974 rainfall were to recur, peak flood levels could be lower because of the floodplain mitigation works that have been undertaken. The strong floodplain planning strategy adopted by Council and advances in its flood emergency planning and response are important risk mitigation strategies adopted by Council.

Flooding of the Logan-Albert Rivers in January 1974 resulted in the destruction of several houses. As urban expansion in Logan began only in the early 1970s, just prior to the 1974 flood, the 1974 flood has since served as a benchmark event for local government controls on development. Flooding also occurred in the Caboolture River - Burpengary Creek and Pine Rivers catchments during the January 1974 floods, though the impact was much less than further south.

Contemporary reports of flooding since records have been kept indicate the immeasurable economic and social cost of flooding, for example, through building and contents damage, damage to infrastructure, agriculture losses, disruption of normal services (e.g. mail and rail) and loss of life. However, despite the historical evidence of the impact of flooding in the South-East Queensland region, occupation of flood prone land continues and the number of people who will be affected by flooding has not diminished.

Early evacuation of people from homes in flood affected areas minimises the risk of drowning especially in areas where water depth exceeds about half a metre (depending on velocity) and buildings are likely to have water overfloor. The movement of smaller items onto tables, shelves and into roof cavities (where the water level is not expected to exceed this level), or the movement of house contents and/or the family car to higher ground away from the flooding, are all methods of reducing the economic and social cost of flooding. As indicated earlier, the expected damage from flooding is directly proportional to the amount of awareness, with an improvement in awareness and preparedness resulting in a sharp decline in damage.

An effective flood warning system (as operated by the Bureau of Meteorology in conjunction with local government - described in more detail later) is therefore crucial to the provision of an adequate warning period for flood preparations and/or evacuation in flood prone areas. Given the limited warning period available for the rivers and creeks in South-East Queensland (some rivers have less than twelve hours), local government needs to give considerable attention to detailed counter disaster planning and risk communication. To be fully effective, this requires the involvement of the communities at risk.

Local governments across the region have been faced with three choices regarding further development of its floodplains:

1. Prohibit development;
2. Permit some development with rigorous conditions; and,
3. Permit development on land already zoned.

The decision made, for example, to permit some development with rigorous conditions in flood-prone land in the Gold Coast area was one made carefully after considering the alternatives. That is, that to prohibit development was virtually impossible without compensation/injurious affection; and to permit development on land already zoned would have increased flood damage and worsened the existing situation.

Forecasting and Warnings

Flood warning is an integral component of counter disaster arrangements for a community at risk from flooding. The aim of a warning system is to minimise loss of life and property damage by warning people of the likelihood and size of a flood so that they can evacuate, shift property or stock to higher ground, or implement other temporary flood loss reduction measures. Warnings are of limited value unless they are delivered in a timely and effective manner and property owners and residents in the flood-threatened area have trust in the warning and take appropriate action in advance of being flooded.

The responsibility for flood forecasting and warning services in Australia rests with the Commonwealth Bureau of Meteorology. In Queensland, the effectiveness of the flood warning system depends on the cooperative involvement of the Bureau of Meteorology, State Government agencies and Local Government working with flood-threatened communities. The Queensland Flood Warning Consultative Committee (FWCC) is a joint Commonwealth, State and Local Government Committee which coordinates the development and operation of flood warning services in Queensland. The roles of the primary agencies involved in the flood warning system, as recommended by the FWCC, are outlined in Figure 9.21.

The development and provision of flood warning services in Queensland is the role of the Bureau's Flood Warning Centre (FWC) in Brisbane. The FWC operates up to 24 hours per day depending on the severity and extent of flooding. The basic components of the flood forecasting system are:

(a) Data collection & transmission

Rainfall and river height data are collected from over 1000 sites throughout Queensland via radio and telephone telemetry from automatic stations and via telephone-computer links from volunteer observers.

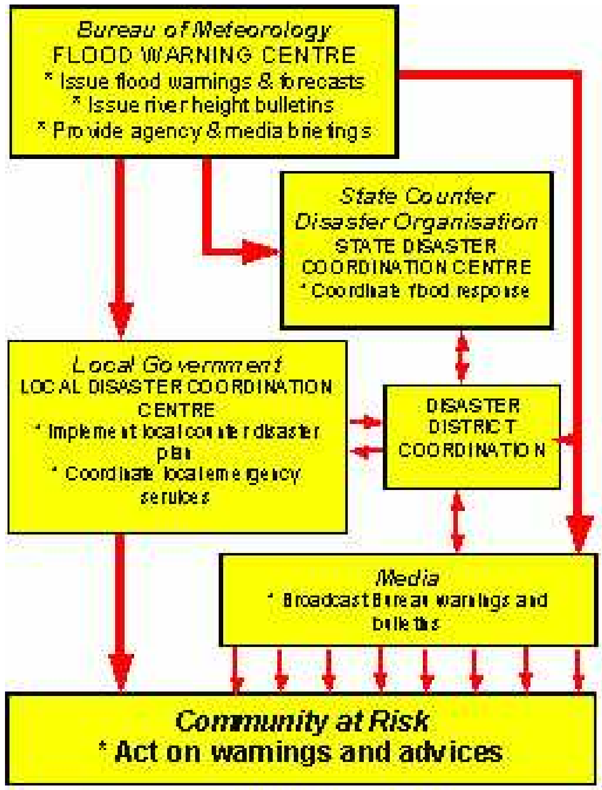

Figure 9.21 Roles and responsibilities within the flood warning system

(b) Meteorological & hydrological forecasting

The collated data is analysed using a range of techniques including simple empirical relationships and complex computer catchment simulation models to predict the likely timing and severity of flooding. The impact of forecast weather and rainfall conditions is also assessed.

(c) Flood warning services

River height bulletins:	These contain the latest observed river heights at selected locations within a river basin and are issued up to six times daily.
Flood warnings:	Provide a summary of existing conditions within a river basin and predictions of river heights at key locations (towns, bridges, rural centres).
Professional advice:	FWC staff provide direct assessments of flood conditions to emergency agencies and Local Government officers.
Media briefings:	Extensive briefing of radio, television and newspaper news services are provided as requested.

The FWC operations are summarised in Figure 9.22 and a typical ALERT flood warning installation is shown in Figure 9.23. Table 9.16 lists the number of rainfall and stream gauging stations in the South-East Queensland region which provide data to the warning system either via telephone or VHF radio. In recent years a number of radio-based rainfall and river height stations have been installed under joint Bureau, State and Local Government funding arrangements. The VHF radio ALERT systems are primarily used in small catchments with short warning times and automatically report either a 1 mm increment in rainfall, or a rise or fall in water depth of a pre-determined amount (say 5 cm). Local Authorities with their own computerised base stations can receive the ALERT data in 'real time', and are then able to assess current flood conditions in a most expedient way.

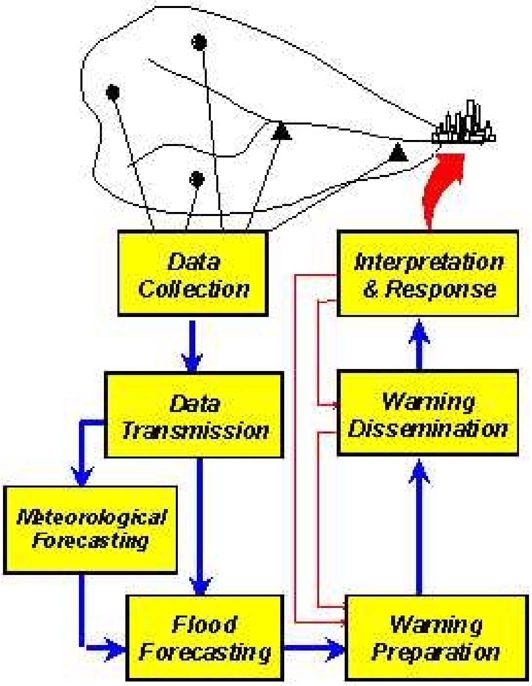

Figure 9. 22 Flood Warning Centre operations

Figure 9. 23 A typical ALERT installation

Table 9. 16 Summary of rainfall and river height gauging stations in South-East Queensland.

River System	Telephone Telemetry	Radio ALERT Systems	
	No. Stations	No. Stations	Cooperating Authority
Pine River	1	29	SEQWCo
Brisbane Valley, incl Brisbane and Ipswich Creeks	31	126	SEQWCo Brisbane City Ipswich City
Logan – Albert	21	13	Logan City
Nerang - Coomera	6	16	Gold Coast City
TOTAL	**59**	**184**	

The Bureau of Meteorology is able to provide summary brochures to the public which describe the flood warning procedures for particular river systems and give guidance on interpreting gauge forecasts.

During floods, Councils work closely with the Bureau of Meteorology in the provision of information to flood-threatened communities.

Further Information

More detailed information on the level of flood risk of individual neighbourhoods or properties should be referred to the respective local government council.