Cyclone surge and community preparedness

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Natural hazards with lead times

This paper considers community flood and cyclone surge preparedness. In relative terms, cyclone surges have a warning time of wavering probability likely to extend over some days, with the erratic behaviour of cyclones (Commonwealth of Australia 1997) making final course and severity difficult to judge until about 12 hours before landfall. Last minute evacuation is likely to be compromised by road flooding. Although likely cyclone strikes provide clear warning, issues of timely evacuation are complicated by infrequent surge strikes in Australian centres, high population turnover in many tropical towns and cities, and the rapid growth of coastal populations and infrastructure.

For these reasons, this paper looks at community-wide involvement in preparation for a precautionary response to a cyclone surge threat. Recent post-flood social research in North Queensland is synthesised with Cairns transport network and elevation modelling as case studies to consider details of community preparedness, as required by the Commonwealth (EMA 1993). To help achieve preparedness, it is necessary to be clear about allocation of responsibility.

State and territory governments carry responsibility for the '... protection and preservation of the lives and property of their citizens' (EMA 1993), with Queensland Department of Emergency Services as state coordinators. Because it is already established that emergency management includes prevention, preparedness (Cronan 1998), response and recovery (EMA 1993), post-flood research indicated a need to strengthen community involvement in preparedness. For instance, SES was on full alert before the floods struck Cloncurry, but the community was poorly prepared, informed or warned. To help understand underlying physical and social issues connected to flood threats, the Centre for Disaster Studies at JCU, North Queensland has developed a research approach.

Flood threat research approach

After establishing the nature of the potential hazard, including the likely maximum flood or surge height, public vulnerability and awareness is surveyed. The great restrictions to evacuation caused by land based flooding is fully factored in to the detail of preferred evacuation timing and destination of the vulnerable. Preferred movement sequence of the vulnerable is developed in discussion with emergency managers, and how the preferred movement can be implemented. Finally, we take the stance that effective implementation of recommendations is all that matters. This approach was used in the synthesis of the following three case studies, considering the event, the response and the lessons learned, leading to recommendations to increase commitment for community preparedness.

Cloncurry, March 1997

Because of the steep, unmonitored upper catchment and the confluence of two major atmospheric depressions (including ex-cyclone Justin), waters in Cloncurry rose 2m higher than any flood in a hundred years, explaining the general inertia against precautionary response. Although there was official preparedness, people 'knew' how high the floodwaters would peak. Research showed overwhelming levels of disbelief during and after the event (King and Goudie 1998). Along with disbelief, research found that support from neighbours was rapid and selfless. A better warning systems was widely called for, and that there was a clear need for more public awareness and involvement.

Townsville, January 1998

There was major flooding in the Townsville area in January 1998 (associated with ex-cyclone Sid). Along with a 1,000 household telephone survey within days of the event, two researchers conducted interviews and local observation on Magnetic Island, a suburb of Townsville, 8 kilometres from the mainland. Those geographers set out to establish impacts of the flooding on the local community and infrastructure, and assess planning issues of evacuation when that level of flooding precedes a significant cyclone surge. They interviewed 24 flood affected householders and business proprietors. Police and the local SES leader were also interviewed at length.

Magnetic Island flood impacts

The four settlements on Magnetic Island (pop. 3000, ABS 1996) are connected by a narrow sealed road, vulnerable to landslides at each intervening headland. The January 1998 deluge caused landslides that obstructed the main road between Picnic and Nelly Bay, Nelly Bay and Arcadia, and Arcadia and Horseshoe Bay (see *Map 1*). The main road network was also severed temporarily in five places by stream flows in three of the settlements. These upslope drainage lines were all temporarily impassable, and will present severe restrictions to any needed evacuation ahead of a cyclone surge. The Townsville and Magnetic Island floods of January 10 clarify the dangers created by swollen off-slope 'mini catchment' streams cutting crucial routes to shelters (see *Photos 1, 2* and *Map 1*).

From interviews and observation it became clear that the official response was brave and swift, but it was also clear that, like Cloncurry, many residents were unaware of the danger. This core issue: lack of community preparedness or knowledge is made stark by results of the 1000 household survey conducted in Townsville, which showed the reality predicted by the extensive research carried out in Cairns by the Tropical Cyclone Coastal Impact Program (TCCIP). The TCCIP included development of the Granger Digital Elevation Model. Extensive mapping with this and other existing databases was used to predict what might happen to Cairns in the event of various storm surge scenarios. *Table 1* summarises Cairns City Council data and identifies the buildings that would be affected by a 3 metre storm surge. This is defined as the height above Australian Height Datum (AHD). Granger used AHD as the basis for the ground height data of each building. Cairns tide tables indicate that AHD is approximately a metre below the highest tide level. Granger states that Cairns AHD is 1.78 metres below the Highest Astronomical Tide (HAT). The following table shows the vulnerability of many building types in Cairns to a moderate storm surge of about 1.2 metres above HAT.

Table 1 predicts the impact from a moderate storm surge that would completely

Type of building	Number of buildings	Number of buildings below 3 metres and above ADH	Percentage of buildings below 3 metres and above ADH *
Accommodation —motels, hotels etc	267	162	61
Houses —private Dwellings	28 041	5093	18
Flats, townhouses and apartments	2488	1071	43
Sub total housing	*30 796*	*6326*	*20*
Business and commercial premises	1533	1259	82
Industry —factories etc	79	68	86
Sheds and warehouses	76	43	57
Miscellaneous —business related	19	19	100
Sub total business and industry	*1707*	*1389*	*81*
Recreational facilities	87	41	47
Community facilities —churches, halls, libraries etc.	210	111	53
Sub total community buildings	*297*	*152*	*51*
Emergency services—police, fire, SES, defence etc.	40	25	62
Logistics - bulk gas, fuel, storage and transport	395	322	82
Health Services	151	98	65
Power Utilities	25	22	88
Water supply	34	11	32
Telecommunications	32	14	44
Educational Facilities	219	113	52
Government Facilities & depots	54	37	69
Sub total service facilities	*950*	*642*	*68*
Total all buildings	**33 750**	**8509**	**25**

Source: Queensland Department of Emergency Services/ Cairns City Council; 1995 survey by Granger et al. AHD —Australian Height Datum (mean sea level: at Cairns this is approximately 1 metre below the highest tide level such that 3 metres above AHD is only 2 metres above the high tide level. The Highest Astronomical Tide is 1.78 metres above AHD).

Table 1: Cairns buildings and flood vulnerability.

cripple the city and probably wipe out its economic base. Of course, considerable wind damage will have occurred in conjunction with the extensive flooding. While only 20% of the residential housing stock will be inside such a flood zone, 81% of all business and industry will be inundated and 68% of all service facilities. It is this latter impact that will cause the greatest problems during and immediately after the event. The emergency services will probably be crippled with 62% of facilities flooded, and health services at 65% will be inaccessible and probably out of action for a considerable time. Power utilities will probably sustain major long term damage aside from the extensive wind damage to power poles and lines.

In comparison, the actual impact of the January 1998 floods in Townsville shows a similar kind of scenario. A far greater impact fell on the emergency services and infrastructure than on residential buildings. While table 2 records the impact on a whole range of services, the ambulance, police and fire stations experienced a much higher rate of disruption, with 75% probably unable to respond during the height of the floods. Although only 15% of households were inundated, this may represent 7,500 households. In fact 6,955 insurance claims had been lodged by domestic householders by the end of April. The size of the disaster, coupled with the intensified impact on services and infrastructure, meant that most of the impacted people were on their own. This is probably the most critical issue in a natural hazard. The whole population has to understand precisely what to do in a disaster situation because the services and infrastructure of the community will inevitably be overwhelmed.

Because the Centre for Disaster Studies is conducting long term, outcome oriented research, the actual state of residents prior to and during an extreme weather event in Townsville sets the scene for the large amount of work needed to inform and involve the public in precautionary evacuation in highly vulnerable centres like Cairns.

Cairns cyclone surge and the road network

A three year study in Cairns set out to define the role and implications of the road network weak points ahead of a cyclone surge, aiming to produce recommendations to minimise loss of life. This scoping study is near completion.

Findings

There are many flood points in the Cairns road network (*Map 2* and *3*), including twelve that are likely to block major evacuation routes, and at least six areas in the main Cairns floodplain. Along with likely landslides on exit routes to the relative safety of the interior Tablelands, these low points in the road network are the most obvious weakness in the Cairns road network.

This paper next considers these issues of road network flooding in some detail, then explores strategies to help achieve an early and precautionary evacuation. These strategies, as detailed below, include local inundation maps, definition of a maximum total flood contour, billet brokers, flood spotters and mobile sirens.

General outcomes from TCCIP road network research in Cairns since 1995

Following meetings with road engineers from Cairns City Council and Department of Main Roads, it became clear that the road network will impose severe restrictions on last minute evacuations. Flood

Statement of Inundation Impact	Yes affected %	No not affected %	Not applicable %
Inaccessible all or part Saturday to Monday	54	46	0
Operations were disrupted	59	41	0
Disruption from water inside building	35	60	5
Disruption from water around buildings	35	54	11
Disruption from dependency on other disrupted facilities	49	46	5
Staff unable to reach premises or leave	57	35	8
Customers/users unable to reach or leave premises or service – Saturday night	41	19	40
Loss of stock, equipment and plant	35	65	0
Damage and loss to storage capacity	22	70	8
Restoration of normal operations delayed	57	41	3

Source: Centre for Disaster Studies Survey of Business and Infrastructure

Table 2 (left): Townsville Flood 1998, impact on Ambulance, Police and Fire Stations, Infrastructure, Government, Council and Transport and Medical Facilities

Table 3 (below): Townsville Floods 1998, summary statistics of inundation levels and utility loss

Summary of inundation levels	Number affected	% affected	Mean depth – mm or % covered
Water inside house	149	15	239.0 mm
Flood water on property	609	60	76.0 %
Depth of water on property	609	60	314.0 mm
Depth of water on road	679	67	453.0 mm
Loss of Utilities			**Mean time —hours**
Loss of water supply	168	17	14.7
Loss of power supply	476	48	11.4

Source: Survey of 1000 households

waters may cut evacuation routes long before a cyclone strike (see *Photo 3*). An evacuation to safe local shelter spread over many hours will minimise traffic congestion if there is increasing probability of an impacting surge. Also, reflection showed that vehicles accumulating on the 'threatened' side of floodwaters will make transferring to 'high-clearance' vehicles increasingly chaotic. Hence the need for early departures, and marshalling points on highest ground within the vulnerable communities.

Also, because the evacuation procedures developed will form the basis of response for many years to come, planning needs to include the likelihood that the enhanced greenhouse effect will increase the frequency and severity of cyclones (Minnery and Smith 1994). Further, sustainable urban development should include explicit cyclone preparation, including vegetation buffering, response infrastructure and strategies in all areas of ongoing urban growth.

The magnitude of the problem

Prior to a surge, about 6,000 vehicles and 25,000 people (ABS 1991 census) will be located in the main Cairns floodplain. Under ordinary road conditions at 60kph, one road lane can carry about 800 cars per hour (Turton 1992). Although not yet confirmed, it is reasonable that vehicles travelling at about 15kph through flood water of less than 250 mm, with double the distance between vehicles (observation during Townsville floods), each flooded lane could only move 100-200 vehicles per hour. Moving traffic through flood waters is very slow, barring breakdowns. Further, about 2,000 households in the main flood plain do not own cars. Transport planning will be successful if no-one is trapped and drowned. Transport planning is fully dependant on an informed public undertaking early and voluntary responses. Map two shows that the only exit routes from Machans Beach, Yorkeys Knob, Holloways Beach and Trinity Beach may be cut days before the cyclone path is clear. The following *Map 3* shows how constricted vehicle movement is likely to be in the main flood plain of central Cairns, with essentially only three exit routes servicing about 6,000 vehicles, evacuating at perhaps 600 per hour, barring any failures.

Map 3 has three 'time' layers.

- *Local land-based flood areas.* The stars in Map 3 show the local flood areas in central Cairns. This flooding may occur days before the cyclone and surge.
- *The three 'dry' exit routes.* The dark continuous lines show the three 'dry' exit routes around the flooded areas (traffic lights will be adjusted to help exit flow).
- *Approximate temporary coast line levels at 1, 2 and 5m.* After flooding and evacuation, the heavy dotted lines show the 'temporary coast line' at 1, 2 and 5m surge above HAT.

The temporary coast lines and the following information are all based on a digital elevation model (DEM) developed by the Granger team, with a general accuracy of about 250mm for elevations for every building in Cairns. The methods developed through this Tropical Cyclone Coastal Impact Program process have relied heavily on the Granger DEM. This accurate elevation data has allowed mapping of ground contours at half-metre intervals. The closeness of some Cairns real estate to the level of the HAT is emphasised by photograph 4, showing floor levels in Central Cairns just centimetres above a calm 'king' tide.

Three evacuation layers

Part of the initial TCCIP brief was to identify three logical layers of inundation, for planning and public education. Generation and study of hundreds of elevation maps shows three 'natural' levels of sea flooding at 1, 2 and 5m (extreme surge height, see *Map 3*). There is a highly vulnerable coastal edge and low points to 1m, then the broad coastal plain of inner Cairns and lowest parts of each northern beach suburb, including Trinity Park from 1–2 metres. A third layer, likely to need mobilising only ahead of the most severe cyclones, occurs above the 2m surge (over HAT). This layer contains progressively more of the beach suburbs, and a relatively narrow upper edge at the beginning of the mountainous base of the Cairns flood plain (from 2 to 5m).

Further specialised hydrological studies are needed to factor in funnelling of surge waters into narrowing valleys, and the additional temporary flooding as the depth of surge combines with the depth of land-based flood waters. This is particularly relevant for the Barron Delta area.

There are three response layers: the obvious and known 'coast-edge' low points to 1 metre; a general surge to 2 metres; and an 'upper edge' from 2–5 metre surge.

'Folding over' from low to higher shelter

An evacuation to minimise loss prior to or during a significant surge should necessarily begin with early and widespread precautionary 'self evacuation' to relatively safe public or domestic shelter on higher ground. Precautionary evacuation is recommended because cyclones have erratic paths (Loudness 1977), and their effects are not fully predictable (Trollope 1972).

Exit roads are likely to be blocked by land-based floodwaters or landslides. The primary objective is for vulnerable people to 'fold over' from low, threatened areas to designated shelters, friends, relatives or networked contacts living on higher ground. Destination shelter would ideally be strong, and away from large trees and major debris sources, with socially similar households. Hosts will be providing a great service to the evacuees in their care. It would be preferable if the hosts felt comfortable with the kind of people sharing their home, especially in the extremes of this natural disaster.

The bulk of the community should be involved in surge preparation. Early public involvement will help clarify community needs and encourage co-operative behaviour. This will minimise direct and formal demands on the disaster response when the next major cyclone threatens Cairns.

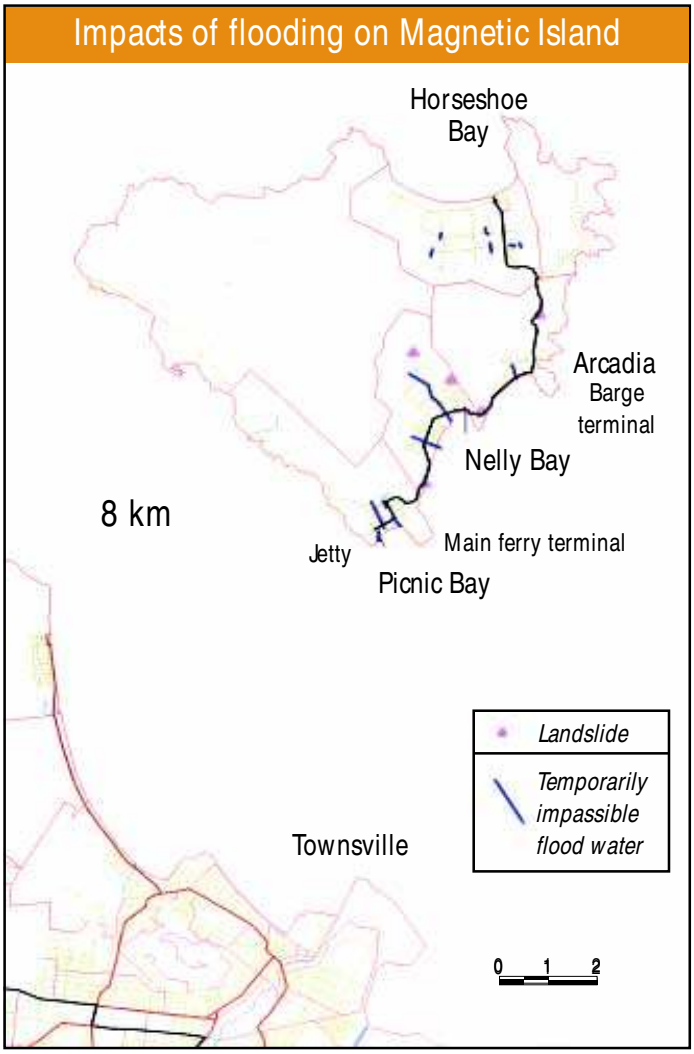
Maximising successful pre-surge road use

Goal: to minimise loss of life and portable valuables through early movement.

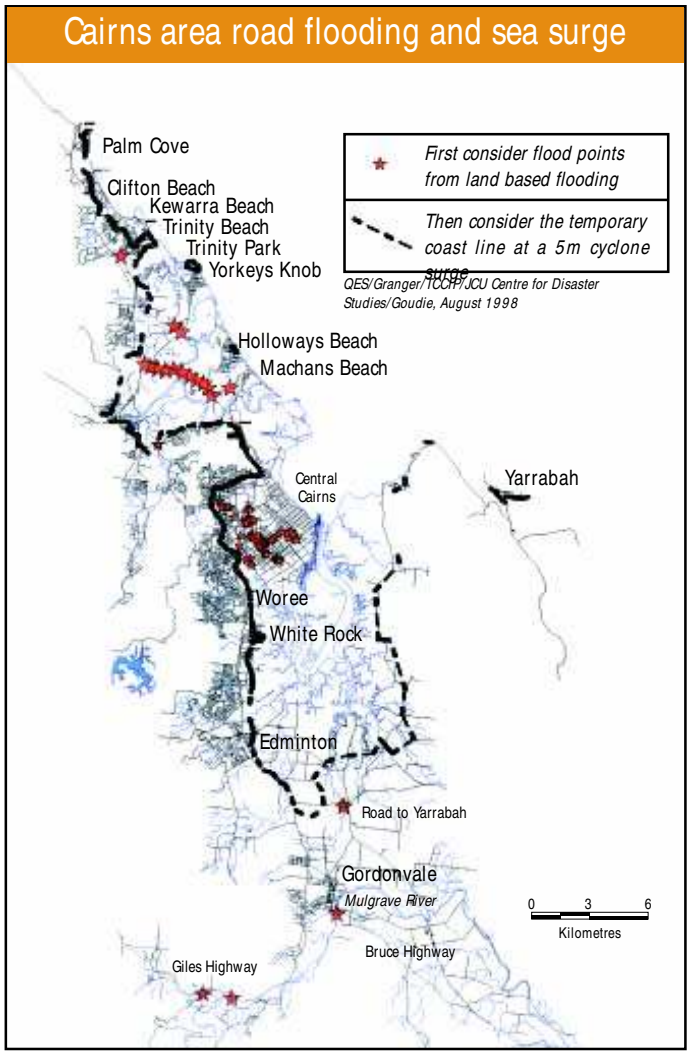
Political support and community preparation can be combined with a commitment to precautionary evacuation. By knowing the flood areas in the road network, and ensuring that evacuation zones are well known, there is the potential for deep community involvement to ensure the vulnerable 'fold over' to fully pre-arranged private billets ('lodgings').

Along with work being done by the Cairns Counter Disaster Committee, the goal may be achieved with clear, strong political support (personalised publicity and generous staffing and funding), public education and involvement, a clear on-ground indication of the extreme edge of flooding vulnerability and local sponsorship. Providing local storm surge maps at 1, 2 and 5 metres in local shops and mail-outs will inform people with the localised information they need for their future safety. The tourism industry can develop detailed plans to relocate all vulnerable tourists booked in to formal accommodation.

A further problem exists for people without contacts on higher ground to arrange safe shelter in the home of a suitable and obliging household. There is need to provide links between vulnerable people without social networks and residents on higher ground who wish to offer pre-arranged shelter. These linking agents are referred to as 'billet brokers' (a 'billet' is a private, usually unpaid temporary lodging).



Map 1: Magnetic Island, 19°S — January 10, 1998 floods



Map 2: Main flood points in the Cairns road network

Finally, use of emergency service and police sirens should ensure everyone knows there is an imminent, locally destructive hazard developing or about to impact.

Developing planning consensus

The strategies of early, *ad hoc* evacuation and much greater political involvement were clearly supported when put to about 50 TCCIP conference members in November 1996 (CDS 1996). During 1997 and 1998, the early *ad hoc* evacuation approach was further developed in consultation with Cairns authorities, and combined with on-ground experiences with flood victims in Cloncurry and Townsville. This led to the development of eight primary recommendations, which were put to a national workshop of experts in planning, natural disasters and emergency management.

The workshop, held in Townsville in July 1998, was convened by the Australian Geological Survey Organisation. The AGSO *Cities Project* applies research to mitigate geohazard impacts on urban Australia. To date, AGSO research has focused on Cairns, Mackay and Gladstone, representing urban centres faced with increased geohazard risks. Of the eight recommendations discussed at this national workshop to achieve early, *ad hoc* precautionary evacuation ahead of a possible cyclone surge, three were strongly supported by the group as a whole, three were supported in principle, and two caused prolonged discussion.

Recommendations for a 'safe' surge

There was clear and near unanimous support for the key recommendation:

- Strong political support for public education.
- Seasonal use of maximum urban flood contour signs was actively supported. Modelling of a Category 5 surge of 5 metres, with funnelling (McDonald Wagner 1988), wave reach and added flood height from land-based flooding should be used to define a 'local contour of safety'— the local maximum flood height, which could be prominently indicated where it crosses major roads. We can then encourage people to negotiate their own billets with friends, relatives, work-mates or other contacts above that line, but within their own general urban sector, minimising cross-town and last minute movements.
- Local 'spotters' placed at known flood points to report as waters rise. When a large cyclone is in the vicinity, radio or mobile phone information from spotters should trigger evacuations before routes are severed as a severe cyclone approaches (see *Photo 4*).

Photo 1: Base of major landslide, Gustav Creek, Magnetic Island, January 1998

Photo 2: Barton St. bridge, breached by flood waters, Nelly Bay.

- Sponsorship and public involvement were clearly accepted by the workshop.
- Local inundation maps in retail outlets was tentatively accepted by the group, but it was asked if people would take any notice of local flood maps. It is essentially an issue of personal, family and 'portable property' survival, so it is likely to be studied with interest each year from October to March, while people are shopping at their local convenience store or mall. Organised by sponsors, larger displays and maps can be established in each shopping complex in the Cairns area. These detailed maps will be specific to the usual 'catchment' of each store.

It was suggested during workshop discussions that mailouts could be prepared for each vulnerable area and sent out to all relevant households and organisations at the first cyclone watch. Legal and liability issues appear to need strengthening in favour of precautionary evacuation. In the context of a 'right to know', there is perhaps also a duty of care involved.

There was *support in principle* for self-organisation in the tourism industry for their staff and guests. This needs more discussion and development. All accommodation providers in the tourism industry are best placed to know of individual tourists in the district, and most likely to know where most of them are during their Cairns stay. Logically, the tourism industry should take full responsibility for the safe relocation of their own staff and guests under Emergency Services direction (Drabek 1994). The industry has many buses, 'adequate' up-slope shelters, and an accurate record of visitors in the area at any given time. It was suggested that a representative of the peak tourism body be drafted onto Counter disaster committees.

There was much energetic discussion over 'local billet brokers' and local siren warnings. These recommendations are discussed in detail below.

'Billet brokers'

For the many low-lying residents in Cairns who do not have their own informal networks to arrange overnight billeting, there is a clear need to have 'billet brokers' (Goudie 1996). This role could be fulfilled by interested and active members of various community groups in Cairns.

To clear the Central Cairns flood plain, about 25,000 people will need relatively safe shelter. Many of these people have not developed social networks in Cairns because many people have not lived in Cairns for long. Developing effective procedures to link the vulnerable with like households on higher ground is crucial to early evacuation efforts, and may be relatively easily achieved by involving community service groups to develop a 'billet link' phone service and data base.

Photo: Kris Kristenson

Photo 3: Machans Road, the only exit from one of the vulnerable North Cairns beach suburbs, soon after Category 2 Cyclone Justin, March 1997

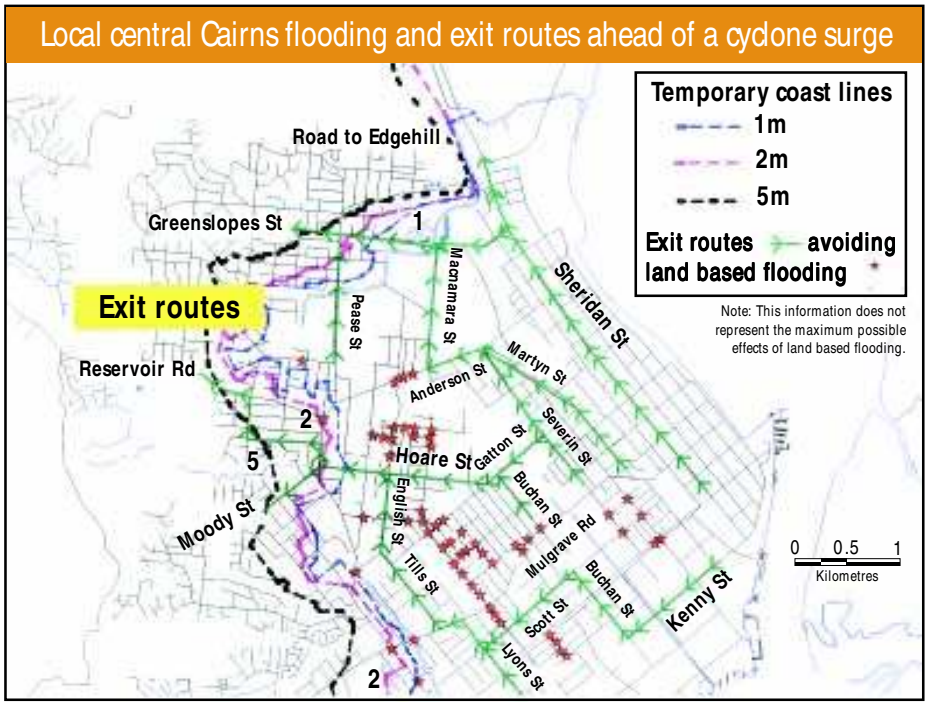
Such activities would need seeding funds to set up the data base framework, and to cover phone, newsletter printing and mailing costs, plus, perhaps, a little support for the parent groups involved. In this way, people in the vulnerable, low-lying areas would be facilitated to form a contact with a welcoming household on higher ground, well before land-based flooding or gale-force winds prevent safe passage from lower to higher ground. A major cyclone threat would trigger an early, ad hoc response, engendering an attitude of a 'practice', an overnight 'picnic', rather than a 'false alarm'.

Mobile sirens

Research in Cloncurry and Magnetic Island found that not enough people listen to the radio, and the TV information is just not localised or specific enough. Development and implementation of an effective siren based public warning system is recommended to avoid ignorance of life-threatening danger. It was luck alone that four people on Magnetic Island did not drown. The use of a mobile siren system could be piloted in a small population like north central Cairns, and developed for all areas of Queensland which are flood or fire prone.

The workshop group was told that a siren warning would be given by the Bureau of Meteorology for severe storms, similar to cyclone warnings. Unfortunately, these warnings are not out in the street, a need indicated by recently studied flood experiences. In the study of the Cloncurry floods of March 1997 it was found that about 70% of the 40 flood or near-flood affected households gained 'no warning at all', a further 15% had 'very little warning'. Seventy percent of interviewees got their flood information from their 'own observation' or 'no-one'.

It may be attractive to assume that people are glued to the electronic media ahead of a major cyclone and surge, but research



Map 3: Detail of temporary coast lines and 'dry' inner Cairns exit routes.

following extreme weather events carried out by the Centre for Disaster studies indicate otherwise. More recently, 53% in a 1000-household Townsville survey (King 1998) did not stay tuned to radio or TV during the Townsville 1998 flood, 53% had heard no warning, and many stated that they wanted a better warning system. This study of 1000 randomly selected households highlights the actual need for on-ground warning systems. The 'unique' floods of Cloncurry and Townsville showed how reliance on the media does not work effectively. Because of the trial nature of this recommendation, it is perhaps best funded through TCCIP, and first tested by a local council at a small scale of about two hundred households.

For sirens to be effective, there would need to be widespread information about the signals, their meaning, and what individual responses should be. Radio and local talks, along with local letter drops, political, SES and police public involvement would help prepare residents and managers for the practice runs. It is suggested that the siren signals (see below) are sounded at 11 a.m. on the first Sundays of October, November and December, to familiarise people with the sound, and the preferred response. Further, *mobile sirens already exist in the community* on police and emergency vehicles. Thus the infrastructure costs should be modest.

The sirens could have three alarm levels:

- *danger looming*, stand by, or respond in a precautionary way (perhaps three short blasts, repeated periodically)
- *respond to danger* (equivalent to an order to evacuate, perhaps one short and two long blasts)
- *danger imminent*, prepare for impact (perhaps three long blasts).

A fourth signal, 'all clear', may also be useful (perhaps short, well spaced blasts).

A pilot to refine understanding

To properly achieve *ad hoc* early self-evacuation, the recommendations detailed above have been developed during the 3-year TCCIP study, discussed and modified to the level documented here. These recommendations address core issues implicit in road network restrictions. If evacuation is delayed until a surge is almost certain, land-based flooding is likely to causes panic, especially in the northern beach suburbs. The recommendations (or others addressing identified problems) should be refined, publicly tested and implemented.

For a pilot test of the recommendations to be worthwhile, the primary requirement of active, funded, near-aggressive and public political support is needed. This view was vigorously supported by the July 1998 AGSO-convened group — strong, active political support is mandatory for widespread precautionary responses. This means effective full time staff, adequate funding and maybe sponsorship, and clear messages from the political arena that each level of government acknowledges the danger and are properly funding likely ways to minimise loss of life through drowning.

Photo 4: Water front central Cairns on a calm Highest Astronomical Tide, January 1997

Secondary recommendations

Seeding funds should be provided to form and support the operations of Community Surge Groups and Billet Brokers.

Staggered evacuation procedures should be developed for all vulnerable people requiring an ambulance. Various health authorities could provide a mapped (Mapinfo or Latitude) database of people in their care who may need special attention (updated each October). If they live in the low areas of beach suburbs, they will need to be moved before exit routes are compromised.

Most vulnerable people (elderly, infirm, disabled, tourists and those without cars or rides with friends or neighbours in the lowest areas) should be moved first.

A strong police anti-looting presence may reassure people to leave sooner rather than later.

A signal that a residence is vacated. As people evacuate a building, they could tie a pillow case near their front door, so emergency workers know the residence was unoccupied.

Evacuees without use of cars should board evacuation buses at specified marshalling points within vulnerable communities as soon as a *recommendation to evacuate* is given.

Signs to identify 'dry' routes should be developed to help guide people from low to high ground, avoiding areas likely to be flooded.

Vertical evacuation (sound high-rise commercial buildings) could be designated as 'shelters of last resort' for people trapped in the inner city area (Smith 1995).

Other recommendations

There is a need for effective communications for SES personnel. Many had difficulty contacting each other on Magnetic Island to co-ordinate effective responses.

More detailed public education should be provided about the dynamics of flooding specific to each 'mini' catchment, and off-slope flooding across roads leading from low to high shelter.

In line with current government policy (ESD 1992, IPA 1997), the community in 'urban segments' should be fully involved to ensure 'safe' upslope shelter. For example, what extra items are needed? Who will help the infirm?

In Cairns, there is an agreed procedure in place between Council and the Main Roads Department to achieve best removal of debris and repair of weak points in the road network immediately after any cyclone flooding, aiming to allow the maximum number of people to return to their properties as soon as possible.

Community Service TV announcements and footage of Cairns road flood-points may help encourage early self-evacuation of the vulnerable to 'safe' shelters.

Use the roads early

A committed combination of political support to the approaches outlined, education, public involvement, billet brokers, mobile sirens and *ad hoc* precautionary evacuation is likely to minimise the social impacts of major cyclone surges in vulnerable coastal centres. This paper has shown that a geography research method that combines computer modelling, interviews, a planning team, literature search and principles of sustainability is useful in disaster impact minimisation. If the above is agreed to, the next step is pilot implementation in one of the vulnerable areas, perhaps in the north of central Cairns.

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