The Katherine-Daly flood disaster 1998

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The Katherine-Daly region (area 22,500km^2) is located approximately 300 kilometres south of Darwin, in Australia's Northern Territory. Katherine (pop. 10,809), the regional centre and hub for government services and industry, is located on the Stuart Highway, and is the only substantial township and service centre. There are several Aboriginal communities (e.g. Beswick, Barunga, Nauiui Nambiyu, Peppimenarti and Ngukurr), and a selection of agricultural and pastoral properties (Florina, Manbulloo, Willeroo, Dry River and Delamere). Nitmiluk (Katherine Gorge) National Park is a major tourist attraction.

Other settlements within the Katherine District are the RAAF Tindal Base (15 km south-east of Katherine), Nitmiluk–Katherine Gorge (28 km north-east), the Katherine–Edith Farms development (20 km west) and the Katherine Rural College (17 km north-west). The population of the entire flood-impacted Katherine-Daly region would be in excess of 12,000 people.

The general topography of the district comprises the rugged terrain of the Arnhemland escarpment and low-lying river flats or floodplains. Vegetation ranges from densely-wooded, inaccessible areas common to the escarpment, to sparsely vegetated grazing and agricultural land. The Katherine district is characterised by the number of rivers and creeks that feed into each other, draining the catchment during the wet season. *Figure 1* shows the Katherine River catchment and flood forecasting station sites. Some stations were not robust enough to cope with the flood. Similar remote telemetric river level gauge stations are located along the Daly River. Professional analysis of river level data takes place at Palmerston, near Darwin.

The main watercourses are the Katherine, Edith, Flora and King Rivers, all of which feed into the Daly and the Victoria Rivers, which flow south-west. Water within the catchment also contributes to smaller watercourses to the south-east of Katherine which eventually feed into the Roper River, which passes to the east of the district and ultimately into the Gulf of Carpentaria.

The region's climate is monsoonal, and therefore, experiences a distinct 'Wet' and 'Dry' season. The Wet season typically extends from November through to May. The average rainfall experienced throughout the District is approximately 950 mm per annum. Localised flooding is experienced within the Katherine District from monsoonal rains and decaying tropical depressions that pass over and delugethe Katherine River catchment.

Unique January 1998 Katherine features

There are a number of distinctive factors in Katherine that markedly influenced the flood response. Katherine is a regional centre whose functionality is vital to a number of smaller communities. It is a north-south and east-west electronic and transportation crossroads and node of critical commercial, government, military and community significance. For the effective functioning of the Darwin region (pop. 100,000) to the north, Mataranka in the south, Borroloola in the east and Kununurra in the west, Katherine's infrastructure and resources are essential.

Just 15km south of Katherine is RAAF Tindal, a major strategic airforce base. Tindal Creek, which crosses the Stuart Highway 10km south of Katherine, is susceptible to flooding and may thus cut off the base from the town, as happened in the 1998 flood. Normally, Katherine and its

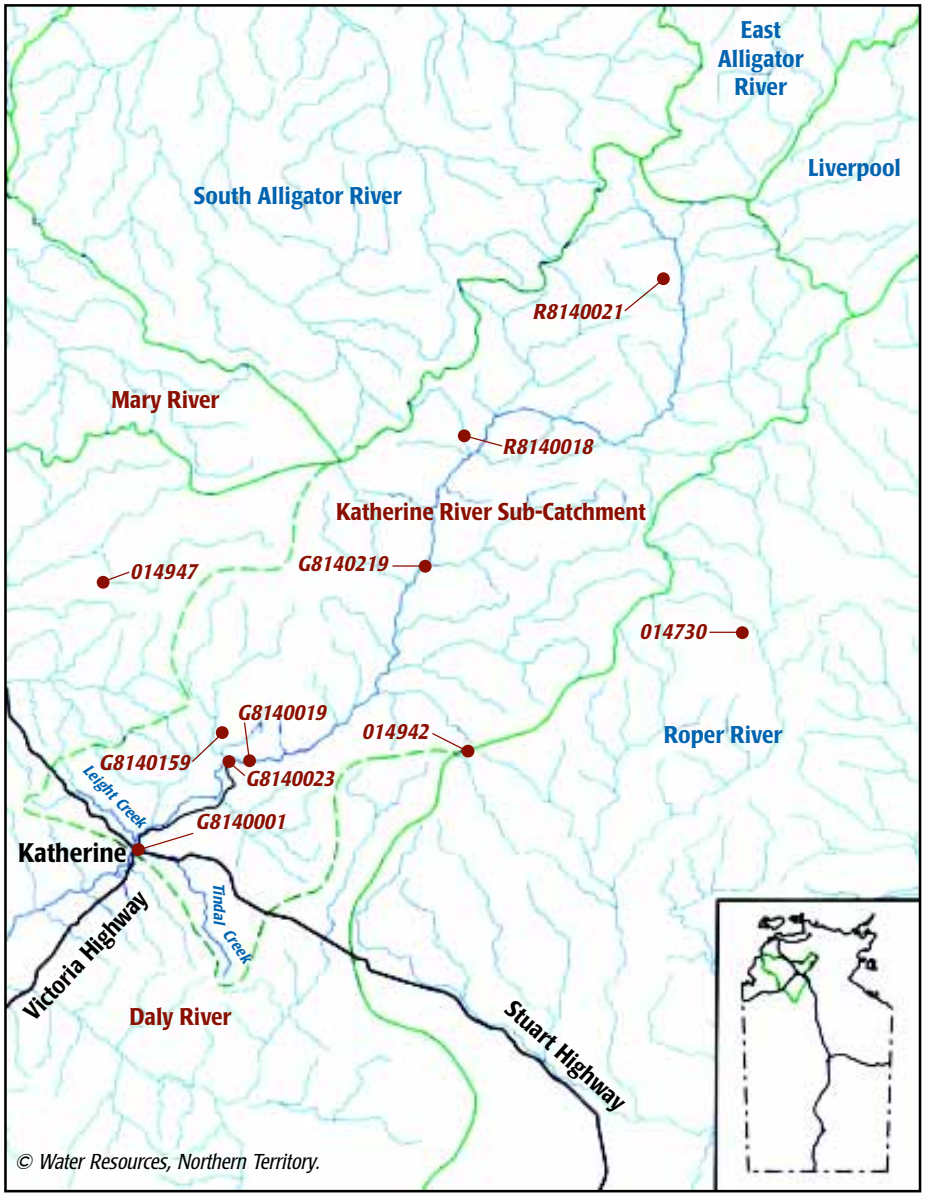

Figure 1: Katherine River catchment flood forecasting sites.

resources, services and amenities add invaluably to Tindal's capabilities. There is reciprocal synergistic support between each entity. Maintaining RAAF Tindal at the highest possible levels of operational efficiency, at optimal costs, depends on a robust Katherine. The quick offer of many of RAAF Tindal's human and other resources at the time of the 1998 flood was a major component of Katherine's immediately effective emergency management interventions.

The adventitious presence in Katherine of two outstanding RAAF CO's added their capabilities to those of an experienced Regional Police Chief and Emergency Services management team, joined early on by a top Darwin bureaucrat. This group was backed up by technocrats, and provided, *in situ*, a 'world-best practice' emergency management team.

Katherine also possessed, as their local member of the Northern Territory Parliament, the Honorable Mike Reed, Deputy Chief Minister, Minister for Police, Fire and Emergency Services and Treasurer. Minister Reed expedited ready access to powerful politicians, bureaucrats and the counter-disaster capabilities of both the Northern Territory and Australian Governments.

The disastrous 1998 flood

In January 1998, the Katherine-Daly River region experienced a devastating flood disaster of unprecedented proportions. Total disruption to life and property was experienced in urban, rural and isolated settlements within the region in the aftermath of tropical Cyclone Les (Bureau of Meteorology, 1998). Cyclone Les was one of the worst recorded rain-bearing depressions to impact the Northern Territory.

Extensive flooding of the Katherine and Daly Rivers during late January and early February 1998 occurred as a result of a record rainfall in the catchments in the 48 hour period up to 0900 CST on January 27. Cyclone Les developed in the central Gulf of Carpentaria on the morning of January 24 1998. As it moved across the Top End of the Northern Territory, Cyclone Les weakened from a Category 2 cyclone into a tropical low which produced between 300-400 mm of rainfall both, in the Katherine and upper Roper River catchments, and in Katherine itself, during January 25 and 26. *Figure 2* depicts the track of Cyclone Les (Bureau of Meteorology, 1998). *Table 1* depicts daily rainfall for a number of locations on 26 and 27 of January 1998.

The water level in the Katherine Basin commenced to rise on 25 January in the Katherine Gorge, and moved downstream to Katherine township by 27 January and

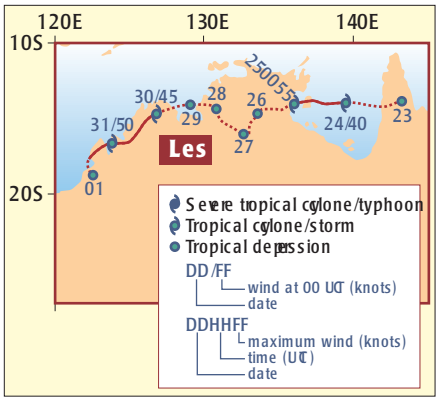

Figure 2: Operational track of Cyclone Les, Jan 1998

Station	26 January	27 January	2-day total
Katherine	221	153	374
Tindal	147	239	386
Sleisbeck	171	112	283
Eva Valley	149	282	431
Upper Ferguson	176	218	394

Table 1: Daily rainfall records Katherine and catchments.

subsequently onto the Daly River. The upper reaches of the Roper and Waterhouse Rivers were also substantially flooded, affecting the communities of Beswick, Mataranka and Ngukurr (Roper River).

The Katherine River continued to rise above its 'normal planning peak' flood level of 16.0 metres (recorded at the Katherine Railway Bridge) and remained high between 26 and 31 January. The Katherine River reached its maximum level of 20.4 metres at 1630 CST January 27, exceeding the previous 1957 maximum recorded level by 1.1 metres. On January 28, the Daly River rose above its 'normal planning peak' flood level of 11.5 metres at the Daly River Police Station, with runoff from further rainfall between January 27 and 30 in the Daly region contributing to the flood-waters. The Daly River reached its maximum level of 16.8 metres on 3 February. The water remained near this level until 6 February.

Figure 3 depicts rainfall and river levels during the 1998 flood. Notable is the rapidity of the rises in river levels.

The lowest curve (2) depicts the river level at the Katherine Gorge, which was used as an advance flood warning for Katherine. The premature 'false peak' on January 26, as the Katherine River at the Gorge temporarily fell a little, is clear. Curve (3) beginning at the lower left of the figure at 3.5 metres on January 25, and rising to 20.4 metres on January 27–28, depicts the river level at the Katherine Railway Bridge, the fiducial flood level benchmark. The river level at Katherine Gorge provided a 12 hour advance warning of potential flooding in Katherine. Recently installed gauges in the Gorge increase Katherine flood warnings to 24 hours. A more sophisticated warning system is currently being devised. The other curves (4,5) depict flood water level profiles around Katherine after the river banks were breached. The scales for these water level profiles differ.

As a result of the extensive flooding of the Katherine and Daly River Systems, and flooding in the Upper reaches of the Roper River and Waterhouse River, around 5000 residents in the Katherine–Daly region district (including Katherine township and the Mataranka, Daly River and Beswick communities) had to be evacuated. Important lifelines were severed—notably, the

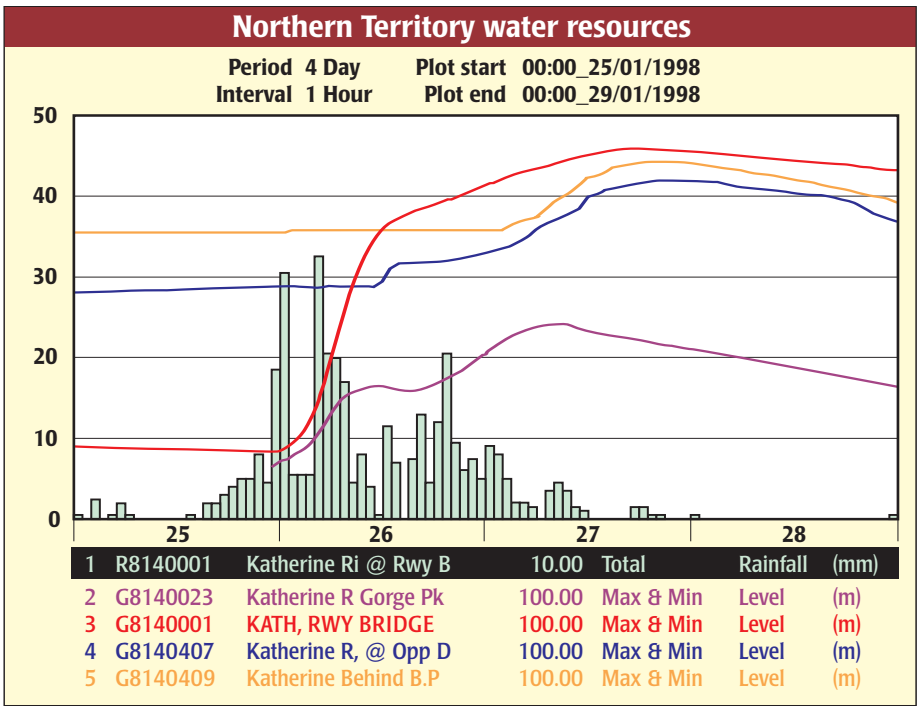

Figure 3: Katherine rainfall and river levels.

Stuart (both north and south of Katherine), Victoria (west) and Arnhem (east) Highways were impassable, power and water supplies, communications and community functions were severely disrupted and there were three known deaths by drowning.

Immediate impacts and responses

There were a number of key bodies involved in managing the flood and its aftermath. The following report is a view from the overseeing body, the Counter Disaster Council, followed by some general impressions from the field in Katherine. Equally traumatic stories from other essential utilities and service bodies are not included.

View from Counter Disaster Council

After careful consideration of the weather charts and field reports on 23 January the Emergency Operations Centre of Northern Territory Police, Fire and Emergency Services, Berrimah, was raised to a high state of readiness. The emergency responses to flooding in Beswick and the rising Katherine River levels, were well in hand by the morning of Monday 27 January, a day on which the CDC met, and continued meeting until February 19. Traumatic flood and inundation situations progressively unfolded. The essence of the flood is captured (Bates, 1998) by the CDC thus:

Monday 26 January 1998

CDC were briefed that flood levels were predicted to reach 18.9–19.0 metres at Katherine and the bridge had been closed as a precautionary measure. The Stuart Highway was cut both north and south of Katherine and roadblocks established to prevent other than legitimate travellers to proceed. Evacuations had begun early on Monday morning 26 January 1998. Support was being provided by Police, Fire and Emergency Service personnel and volunteers and arrangements for further support were underway. Katherine Hospital had been evacuated, an accident and emergency centre established within the Katherine Police Station, and major power installations had been sandbagged. CDC were advised that the community of Beswick was under threat and the Daly River region could expect significant flooding in a week or so. The community may have to be evacuated. Main damage could be expected to Katherine CBD and damage to sewage treatment works expected. Military assistance will continue to be provided. Health and evacuation requirements were discussed. CDC decided that in the event that a declaration of a State of Emergency may become appropriate relevant documentation was to be prepared for the Minister's signature.

Tuesday 27 January 1998

The Minister for Police, Fire and Emergency Services, The Hon Mike Reed MLA, signed a declaration of a State of Emergency at 6 a.m. Briefings were provided on rainfall to date and the forecast. At 9 a.m. the Katherine River level was reported at 19.74 metres and rising 10 cm hourly, with an expected peak at 20 metres. The Daly River will be affected in 7-10 days. The previous Katherine flood level has been broken and Council was briefed on water flow and height, the extent of the flooding and subsequent isolation of Katherine by road. Council was also briefed on evacuations, the status of medical, sewage, welfare, water, food, fuel, power, and communications issues. Status reports on Beswick indicated that 350 people were isolated and would require supplies and may require evacuation. There did not appear to be any problems at Barunga or Timber Creek at this stage.

CDC members were again provided with an out-of-session Situation Reports on the Katherine flooding, which included the deployment of a RAAF Hercules aircraft with equipment to depart at 6 p.m. and floods updates on food and equipment supplies, power and communications, radio transmissions, sewerage, evacuation centres, health supplies, road conditions, road blocks and stranded motorists, the status of the Daly River community, and weather forecasts. Minister Reed had requested that Mr Fuller be on the ground in Katherine on the morning of 28th January as the senior public servant to coordinate damage assessment and related processes.

Thursday 29 January 1998

Chairman Bates briefed Council on his visit to Katherine with the Chief Minister and Brigadier Roberts. The minutes recorded previous briefings by the Chairman and the recommendation of Council to Government which resulted in a State of Disaster being declared at 4 p.m. Wednesday 28 January 1998. The assistance of the RAAF was acknowledged and Group Captain Benjamin offered the services of additional personnel and aircraft. The remaining briefings covered food drops and evacuations; flooding and the weather situation in the Katherine and Daly River areas; reports on Barunga, Beswick Wooliana; and a flood update on Tropical Cyclone Les.

A briefing on Departmental reports including government services re-opening in Katherine was provided; the establishment of an insurance hotline; damage to some primary industries; and health, media and communications, road and public building damage, and power and sewage systems. Commander Burke, police and Emergency Service Regional Commander, Katherine, and Mr Col Fuller (top NTG bureaucrat) to be tasked to undertake a survey of available accommodation and advise the CDC. Police roadblocks to remain in place and the CDC recommended a press release and radio bulletins to educate would-be travellers to Katherine. The Prime Ministers visit to Katherine on following day was discussed.

Monday 2 February 1998

CDC briefed that Katherine is moving from an emergency to a reconstruction stage; and police are accounting for all residents. CDC were advised the Reconstruction Office team, headed by Mr Fuller had been established in Katherine.It was further briefed on clean up procedures, the restoration of power, sewage, the Katherine Hospital and other government, commercial and banking services; water levels and flow for Katherine the Daly Rivers; and access to the Daly River area. CDC was also advised the Emergency Operations Centre has been downgraded to operating during daylight hours only and that approximately 4000 calls had been received on the public information lines.

CDC were also briefed on public information and media arrangements, Daly River flood clean-up problems and concerns by residents in relation to flood relief; evacuation arrangements for Daly River residents; and discussions with Daly River people on a location for the township. Discussion also took place around easing the focus on Katherine and moving to the Daly River region. The Administrator of the Northern Territory, Dr Neil Conn, to visit Katherine Tuesday 3 February.

Wednesday 4 February 1998

A reconstruction officer is to be appointed for the Douglas–Daly region. Executive Officer to provide advice to the ADF as to when support can cease with cleanup and cooking resources. CDC recommended to Government that the State of Disaster for Katherine be extended until 4 p.m. Sunday 8 February 1998, and also recommended a separate instrument to extend the State of Disaster for the Douglas–Daly region for 14 days, ceasing 4 p.m. Wednesday 18 February 1998.

Thursday 19 February 1998

The Chairman opened the meeting and welcomed Brigadier Alan Hodges, Director General of Emergency Management Australia. He advised that he had been kept fully informed of events as they progressed. Superintendent Van Heythuysen, who

coordinated the volunteer response, and Superintendent Gary Smith, who coordinated the response at Daly River, presented briefings and written situation reports. Further reports were received from the Department of the Chief Minister, that Katherine had returned to normal operations, and Transport and Works, that with the departure of Mr Fuller, a Transport and Works team to be located in Katherine to assess damage and reconstruction costs. Territory Health Services CDC recommended the cessation of the State of Disaster for the Douglas–Daly region from 4 p.m. Saturday 21 February 1998. Executive Council to meet 20 February. Lt Col. Douch, ADF, advised that the ADF were currently reviewing operations and post-activity analysis following the flood. He suggested that all emergency services be given an opportunity to familiarise themselves with ADF capabilities and resources.

The Chairman, Commissioner Bates, advised Council that Council should undertake a debriefing process. A special final meeting is to be held once the State of Disaster has ceased. Chairman thanked CDC members for their work in relation to formal meetings and informal meetings when business of Council was dealt with by phone. He noted that most business premises in the main street were flooded to a depth of over two meters with damage running into many tens of millions of dollars. A number of surrounding settlements were also severely flooded as far north as Adelaide River, 200 km from Katherine, and also those well to the east (Beswick) and west (Daly River). The Stuart Highway was impassable in a number of places, cutting off the vital land transport link to and from Darwin and the south. The torrential rains had continued westward towards Western Australia causing further extensive local flooding.

Council formally recorded thanks to agencies, groups and individuals involved in Katherine–Daly floods. The most-able Executive Officer of the Counter Disaster Council, Iain Rae, remarked that 'this was the most complex operation in which he had ever been engaged'.

The small group of full time Northern Territory Emergency Service staffers, directed by Mike Bowman, performed in an exemplary manner. Emergency Service personnel know-how and capabilities, and those of the Northern Territory Police and Fire divisions, were functionally outstanding. A notable feature of the operation was the extraordinary *ad hoc* capacity to handle such a unique, complex, and fast-changing, traumatic flood disaster, extending over a remote area of around 50,000 km^2.

View from Katherine

Upon a request for assistance with immediate evacuation from the Katherine hospital, RAAF Base Tindal had responded immediately with manpower and helicopter transportation. This was the first time that CO RAAF Tindal became aware of the level of flood-proneness at his base. Very soon after the complete hospital evacuation, many other key RAAF resources were being utilised to ameliorate the progressively desperate similar situations in which many other people wholly unexpectedly found themselves. Homes and businesses by the hundreds were being inundated and normal modes of communication, movement and life were rapidly curtailed. Simultaneously, Police Fire and Emergency Service workers, politicians, public and civic servants, volunteers and members of the public, undertook heroic emergency management duties in the service of many communities. Regional police HQ at Katherine, under Regional Commander, Maurie Burke, accommodated feverish activity. Sergeant Ron Millar and Constable John Bowen, 'camp overnight in an Aboriginal community under a tarpaulin between two cars with camp dogs crawling in from the rain for company' (Munday, 1998).

Within the township of Katherine, when the extent of the floods became apparent, the Deputy Chief Minister and Police, Fire and Emergency Services Minister, Mike Reed, who a little later declared a 'State of Emergency', said he was satisfied all resources had been made available. He said manpower had been sent in from Darwin to help local emergency workers, Government employees and RAAF Tindal defence personnel. 'The immediate need is to make sure people themselves are safe and after that to attend to people's property. Morale in the town is good and people were co-operating with police and emergency services' (Northern Territory News 27–30 Jan. 1998). Northern Territory Chief Minister, Shane Stone, Prime Minister of Australia, John Howard, Defence Minister, Ian McLachlan and Australian Defence Forces Chief, General John Baker, all visited the town for on-the-spot assessments.

Initially the magnitude of the flood kept increasing by the hour and the traumatic turn of events was experienced individually in so many ways. At one stage, when the water level appeared to plateau, a 'false peak' level of near 16 metres was communicated. This indication was spurious and hopes of an early easing of the flood were dashed. The Katherine River level increased rapidly to an unanticipated 4.04 metres (1.1 metres above the supposed record flood level of 1957) with, consequently, water up to several metres deep in the main street and central business district.

On January 28, 1998, upon the recommendation of the Chief Minister of the Northern Territory, Shane Stone, a 'State of Disaster' was declared by the Administrator Dr Conn, for Katherine and surrounding flood affected areas, the Northern Territory Police, Fire and Emergency Services assumed state of disaster powers and continued, with direct participation from Northern Territory Government personnel, Royal Australian Air Force (RAAF) officers and other ADF personnel, and citizens generally, an expeditious evacuation of over 5000 people whose homes had been flooded.

The extent of the flooding around Katherine town centre is shown in *Figure 4*. The darkest shading indicates the extent of the flood beyond normal 1-in-100 planning levels. Some 1170 flats and houses, 500 businesses and every government office and business in the CBD was inundated. Around 5000 people, half of Katherine's population, were evacuated.

As the flood receded, communication links were being re-established; public buildings and business premises, which were initially abortively sand-bagged, were cleaned; and the community made as safe and secure as possible. Medical centres were progressively staffed, and essential supplies and food were distributed, with some 10,000 meals being supplied twice daily at the height of the disaster. A comprehensive audit of the emergency situation and precautionary planning and actions to restore the *status quo* to Katherine and other, already, or prospectively, seriously water-affected and water-damaged places, was undertaken. Relief measures were swift and effective. Both the Army and the Royal Australian Navy were ultimately involved in the cleanup procedures.

Throughout the immediate emergency responses and well into the recovery stage those concerned with managing and reconstructing the physical fabric and vital systems of the towns and settlements did a fine job (Munday, 1998). All essential services and utilities were kept operating to the maximum capabilities available. The following services and utilities are recognised as handling their difficulties with distinction: Police, Fire and Emergency Services, Telstra, PAWA, Medical and Health, Transport and Works and other core government agencies (DTW, 1998). The Northern Territory Government responded with alacrity requesting or commissioning many studies (e.g. Kinhill, 1998). Private organisations and corporations and volunteers all played further recovery roles (Skertchly, 1998).

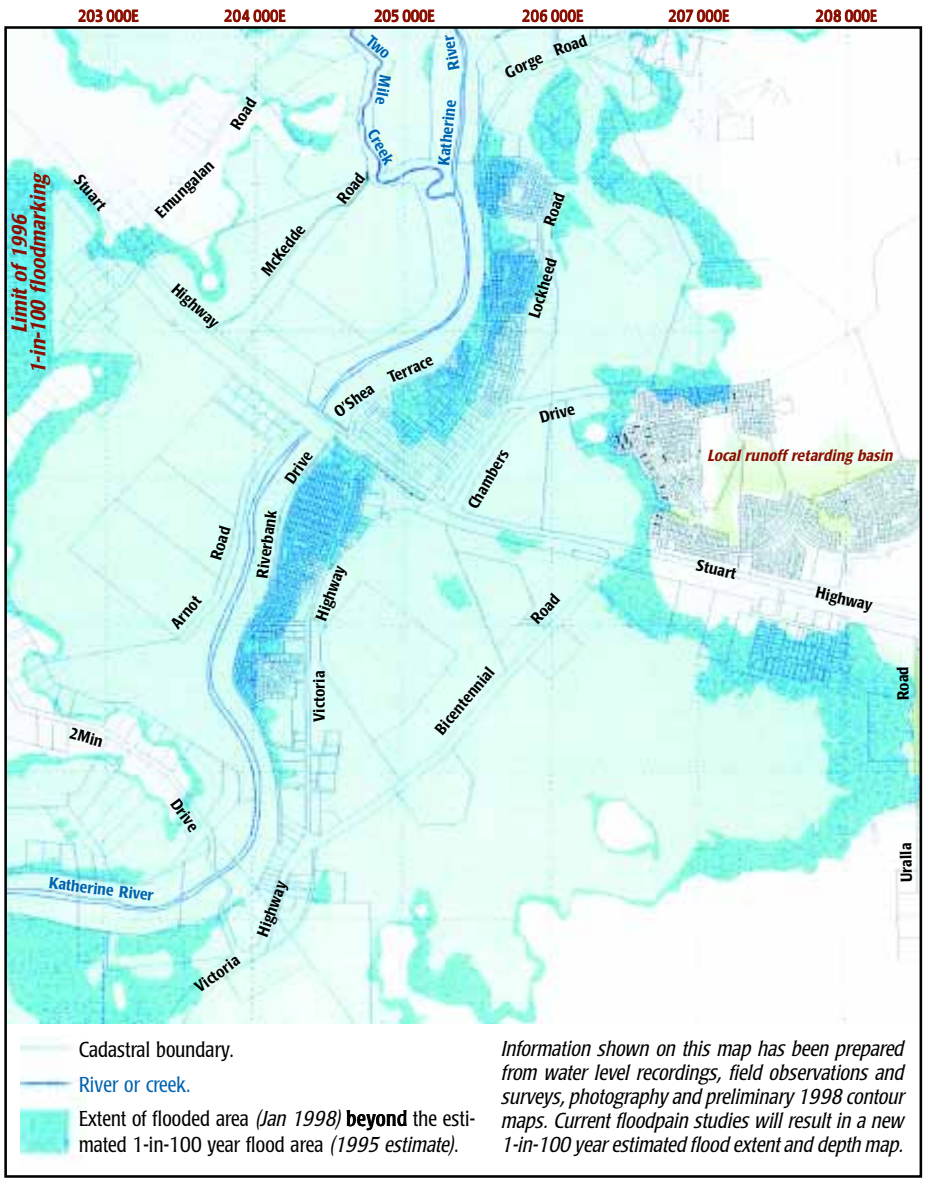

Figure 4: Extent of 1998 flood and inundation — town centre, Katherine (DLPE, 1998).

Many people took on responsibilities well beyond their normal fields when others were simply not available. Largely through high technical skills, sometimes aided by a little good fortune, those responsible for such effective, highly collaborative, contingency crisis management of a largely unexpected situation deserve the highest commendations. All those centrally concerned coped very well. Much of the credit for this lies in the high quality of the multi-faceted, multi-skilled and highly experienced, human power available *in situ* and the resources that they could access or utilise, or acquire. Many people released and exploited dormant talents.

Eva Cox's statement 'When we have a natural disaster we remember we are a community' (Cox, 1997) was substantiated by the behaviour of the majority of Katherine-Daly residents faced with the flood. Businessman Lee Hunt's statement published in the Age newspaper sums up the general feeling of the Katherine residents:

> 'You actually felt pretty good, you know. All these blokes I'd known since I'd lived in this town, off we'd go looking for people. The guys coming into the boats weren't victims and we weren't heroes. It brought everyone back to the same level'.

The sense of camaraderie amongst residents was generally high during the flood experience within the Katherine–Daly region.

State of flood awareness

To an overwhelming extent inhabitants, including emergency management personnel, were completely caught by surprise by the severity of the 1998 flood. Notably, it substantially exceeded the 1-in-100 year flooding event and subsequently damage and inundation due to the flood impact was, as we have seen, unexpected and considerable. The 1998 Katherine Flood has been estimated as between a 1-in-200 and a 1-in-500 year event (Kinhill, 1998).

However, awareness by some professional and other persons of the potential of the Katherine River to extremely severe flooding is indicated by the documentation of several earlier investigations into the possibility of beyond 1-in-100 flooding and the impact such events (on a variety of scales) could have on the township of Katherine.

Katherine has been seriously and adversely inundated at least six times in the past 100 years (and much higher than these levels prior to 1788). The highest recorded level, prior to the 1998 event, occurred in 1957 where the Katherine River reached a level of 19.25 metres. Subsequently, models of flood contours emerged from research since this time (KRCDPC, 1997).

In response to a request from the Northern Territory Town Planning Board in 1969, the Water Resources Section of the Mines and Water Resources Branch (NT) conducted an investigation into flooding of the Katherine River and its potential impact upon the township. The report, released in 1970, was confined to areas over which contours were available. In addition to the ten year and twenty year flood return periods which were examined, investigation also focussed on the potential for more extensive flooding in rarer events and the effects that such events may have on flooding in the area (MWRB, 1970).

Notably, the study concluded that a severe flood (of the order of 500,000 cubic feet per second corresponding to a level of RL 360 at the bridge), as a rare event, could be expected. It was predicted that a flood of this magnitude would be 'above the 1957 flood level for about three days and well above it for two' (MWRB, 1970). These investigations, and others, had a significant degree of foresight, but did not raise much interest outside an elite group of technocrats. The 1995 land-use report (DLP, 1995) continued to use average recurrence interval (ARI) 1-in-100 floodlines.

Further, there is now available scientific data confirming much higher Katherine region flood levels (by metres) than those experienced in the aftermath of Cyclone Les have occurred outside the modern river level data observation period (Nott, 1998).

The immediate emergency response for the Katherine-Daly Region 1998 flood was an outstanding success. Overwhelmingly, the immediate response's effectiveness was close to 100%. Economic, cost-beneficial efficiency would be significantly less. With refined planning, improved flood warning, better deployment of rescue resources, a more aware citizenry and enhanced flood mitigation in place, the total adverse financial and other impacts of a flood of similar magnitude could perhaps be halved. Immediately after the flood an urgent hydrological appraisel was commissioned (Kinhill, 1998) and this lead to a substantial

project of geomorphological modelling of Katherine River and its catchments. This, and a number of other much-needed initiatives, will hopefully contribute to better Katherine-Daly flood preparedness and remediation in the future.

If the 'Precautionary Principle' had been clearly manifested in planning and government administration of human settlements in the Northern Territory, the question as to whether the 1998 Katherine-Daly Flood was 'The flood we had to have?' (Collins, 1998) would probably never have arisen.

Social issues and concerns

People living in isolated and remote settlements generally display high levels of self-reliance. The Katherine District is a good case in point. Although very largely reliant upon government utilities and resources for ultimate survival, often the directives from authority figures as to actions to be taken are not taken kindly by local inhabitants. When these impersonal power figures even suggest, let alone direct you to leave your home, a high level of command 'insubordination' is in evidence in the civilian population. The natural resistance to such radical change, coupled with sheer disbelief as to the severity of the pending flood threat resulted in the first 'door-knock', advising people to prepare for evacuation, to be all but ignored. Until the water was seen to be visibly rising into houses and direct evidence conveyed the actual seriousness of the situation, many people did not take the evacuation advice seriously. This resulted in many unnecessary losses of household goods, vehicles, and artefacts etc, and slower, more dangerous and more expensive, boat and airborne rescues. The people of Katherine and Daly River Regions have much to be grateful for, due to the fact of the many rescuers who were available, able and willing to help, and who had access to the resources necessary to affect so many successful rescues and evacuations. The ultimate need, in the face of clear danger, to secure their own safety and survival provided the motivation for most, (with the exception of three people), to, ultimately, respond positively directives.

Great variability exists in Aboriginal communities with regard to effective day-to-day administration. When a community lacks cohesion, or ignores the advice of expert others, this seriously and adversely affects its capacity to respond and cope efficiently when exposed to potentially damaging natural hazard risks. In the case of the flooding of Beswick community, the total responsibility for safeguarding and evacuating the community rested on the shoulders of the OIC Maranboy, who coped with all the many demands placed upon him in an outstanding manner. At the time of the flood the Beswick community on its own could not have coped. A Beswick adviser, upon returning to the community on 29 January acted 'inept and devious'. Waipiri people reacted at a late stage and they had to walk out of the community in waist deep rising waters.

At least one community, Ngukurr (Roper River), anticipated and coped with the worst of the floods on their own. This community, under the highly commendable leadership of their local Police and Emergency OIC brought in extra supplies at an early stage and were therefore relatively self-sufficient. Other communities, such as Daly River, which are also well administered, were simply overwhelmed by the magnitude of the flood, and had to be totally air-evacuated to Batchelor using official external emergency transportation. The Daly River community was dislocated for a month before they could return, but apart from some social tensions during confinement at Batchelor, coped well.

For many persons, the impacts and losses experienced in such events as the Katherine Region Flood 1998 will have lasting personal repercussions. Research confirms that up to 15% of populations so impacted may be affected adversely for longer than a year, some for life. Once the immediate reconstruction phase is over, it is important not to forget that hundreds of people may require sustained advice and counselling to help with their post-flood lives. Providing such support in the diverse, scattered and remote communities of the Katherine District over many years to come is a challenge to the providers.

The central role of volunteers in Australian emergencies is well known and highly regarded. In the Katherine–Daly floods, many volunteers again performed beyond normal expectations. Apart from official organisational volunteers, there were thousands of individuals. The fatigue and motivation of such hard-pressed volunteers is another important issue (Skertchly, 1998). We need to examine the roles, resources, and recognition and rewards, that should be accorded to such quintessential people working in vital emergency management domains, and ensure they may optimally used and always esteemed.

Future research

There are many future possibilities for research and development. This outline of the circumstances of the Katherine-Daly flood confirms on-going areas worthy of early research attention as indicated below, highlights flood research possibilities:

- hazard warnings and human responses for culturally diverse communities
- far-out hazard incidence modeling beyond 1-in-100 year: EVT-extreme value theory
- applications of military command and response systems in civil emergencies
- modern emergency mobile and fixed command centres
- optimal civilian-military co-operation
- life-line vulnerabilities
- selection and training of emergency management leaders
- Emergency management in remote communities
- robust broad-band data communications under extreme environmental conditions
- robust narrow-band message AM short wave or homing pigeons under EEC
- maintaining the motivation and viability of the emergency volunteer force
- appropriate forms of remedial aid and reconstruction
- costs and benefits for attainable flood mitigation measures
- action-effective contingency emergency management.

Some recommendations

The flood stimulated a number of new initiatives by many key people, groups and organisations. Flood studies were undertaken (Kinhill,1998). New flood level gauges, more advanced flood warning, telemetry and town sirens systems, are now in place. The 1998 flood levels are incorporated in new maps of Katherine. New land-use policies and practices have been promulgated for Katherine township. A comprehensive contemporary hydrological and geomorphological study of the Katherine water catchment area has been commissioned, and the Katherine Region Counter Disaster Plan has been updated (NTES, 1998). The ADF has instituted a natural hazard mitigation plan for RAAF Tindal. And there are more such initiatives completed or initiated. But there remains much to do still, particularly in flood preparedness and hazard mitigation in the smaller communities and amongst the widely dispersed remote people. The Emergency Management Australia commissioned 1998 Katherine–Daly Region Flood Study included the following recommendations:

- Australian Government needs to assess vulnerability to natural hazards of all strategic military installations and their 'life-lines'.
- The Northern Territory Government needs to accommodate better, through precautionary thinking and acts, realistic natural hazard risks *. . . (cont. page 50)*

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Author's note

The PrE theory as outlined in this and other manuscripts is the joint and collaborative work of the author and T. Shelley Duval.

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The Katherine–Daly flood disaster 1998

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- The Katherine flood map (13/2/98) be immediately mandated as the interim land usage flood areas and levels benchmark.
- Government bureaucracies enabling acts need to accommodate expedited functioning during periods of emergencies and disasters—'administrative realism'.
- Regional, urban and remote communities should be planned and administered to standards in line with their natural environments.
- Northern Territory Emergency Service needs augmentation, so that their immediately available operational resources and capabilities are matched to their demanding tasks of ensuring the survival and well-being of all, anytime.
- Appropriate flood gauging and telemetry systems, non-vulnerable, 'dedicated' communications systems, robust, accessible local physical resources and necessary external resources, and secure, adequate emergency operations control centres are required.
- The NTES needs to audit all current counter disaster plans and actionable resources to accommodate realistically, extreme levels of environmental hazards.
- Key emergency leaders and workers need continuing state-of-the-art selection, training and experience of simulations to become expert in complex, uncertain, emergency situations.
- Innovative extreme hazard contingency management training programs should be developed and offered by Emergency Management Australia
- Katherine-Daly region flood 1998 experiences and lessons should be carefully studied and incorporated for similar future emergency capabilities elswhere.
- Australian and Northern Territory Governments need to 'contemporise' their emergency operations procedures taking into account the many glitches and uncertainties of the 1998 Katherine-Daly flood.
- *Status quo* disaster restoration policies should be given close scrutiny, with a view to improving and increasing individual and community restoration.
- The whole issue of flood and counter-disaster mitigation measures, appropriate land use planning and building standards needs to be taken up at the highest Government levels. A National Hazard Mitigation Program is vital.
- Research needs to be undertaken on human behaviour of people and communities facing and coping with hazards.
- Effective communications to diverse people and groups is required.
- Overall, the 'Precautionary Principle'—anticipating and preventing potential hazards of all kinds, should be taken seriously and become integrated into all aspects of Australian (and elsewhere) human settlement planning, design, administration and management.

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