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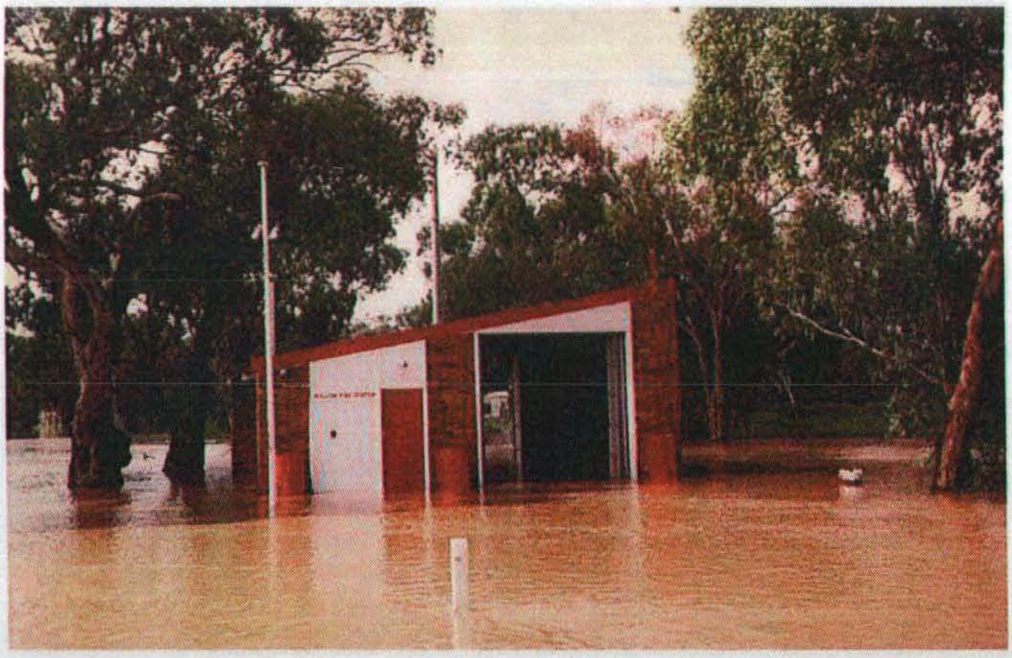
BALONNE SHIRE DISASTER RISK MANAGEMENT STUDY

FINAL REPORT



May 2004

For the People
Balonne Shire Council

LANDMARC

FINAL REPORT

FOR THE

Natural Disaster Risk Management Strategy Study

Prepared for:

Balonne Shire Council

Prepared by:

Landmarc Pty Ltd,
the land and disaster management resource centre of
Coffey International Limited

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PREFACE

This report has been prepared for Balonne Shire Council by LANDMARC Pty Ltd, land and disaster risk management consultants. The report details the outcomes of the Natural Disaster Risk Management Study undertaken for Council by LANDMARC under the Natural Disaster Risk Management Studies Program. The study follows the methods for disaster risk assessment contained in the Australian & New Zealand Risk Management Standard (AS/NZS 4360-1999) and guidelines prepared by the Department of Emergency Services (Zamecka and Buchanan, 1999).

It is presented in a narrative form supported by tables and figures, rather than in the proforma style suggested in the Department of Emergency Services publication *Natural disaster risk management: guidelines for reporting*. The risk evaluation criteria (DES Form A5) are developed and described in Chapter 1. The hazards are described (Form A6) in Chapter 2, the elements of the community and the environment exposed to the hazards (Form A7) and community vulnerability (Form A8) are all described and analysed in Chapter 3. The risks are analysed in Chapter 4, which also contain the risk register (Form A9) and risk evaluation (Form A10). Identification and evaluation of risk treatment options (Form A11), risk treatment action and monitoring schedule (Form A12) and the mitigation plan (Form A13) are all addressed in Chapter 5.

The study was undertaken by Mr Ken Granger, LANDMARC's senior disaster risk scientist, with editorial and administrative support provided by Mr Tony Batten, LANDMARC's business development manager.

Considerable assistance and support was provided by Councillors and officials of Balonne Shire Council together with external members of the Study Advisory Group (SAG). The SAG was chaired by Dr John Stone, Mayor of Balonne Shire.

The assistance and support of all those involved is greatly appreciated.

Ken Granger
Disaster Risk Scientist
LANDMARC Pty Ltd

SUMMARY

This Summary is a condensed version of the full report and was produced for public consultation purposes. This report is the result of an extensive study of natural disaster risk in Balonne Shire. The report:

- outlines the factors that impact on the management of natural disaster risks in the Shire;
- describes and analyses the range of **hazards**, the **exposure** of elements of the community to the hazards, and the **vulnerability** of the exposed community; and
- discusses the key issues involved in risk reduction and **suggests risk reduction strategies that could be applied.**

THE STUDY CONTEXT

Overview

The area administered by Balonne Shire Council (BSC) extends over approximately 31,120 square kilometres and its centre is about 500 km west of Brisbane. The Shire lies entirely within the Murray-Darling Basin and is surrounded by Paroo, Booringa, Warroo and Waggamba Shires in Queensland and Moree Plains, Walgett and Brewarrina Shires in NSW.

At the national census held in September 2001, Balonne Shire had a population of 5,420, a moderate growth from the 1996 census total of 4,805. Population is distributed unevenly throughout the Shire. Around 70% of the population is located within the Shire's six urban centres of St George (2,453 or 51% of the Shire total), Dirranbandi (401), Bollon (155), Mungindi (97), Thallon (96) and Hebel (>50). Mungindi is unique in that the one town straddles the Queensland – NSW border.

The Shire has a generally mild and moderately dry sub-tropical continental climate. It can, none-the-less be subject to extremes of both temperature and rainfall. Land use in Balonne Shire is dominated by agriculture. The largest areas are used for dry-land grazing (sheep and cattle) and grain production (wheat, barley). Cotton and field crops such as grapes are important on irrigated land. The Shire has a history of hazard impacts, particularly floods, severe storms, bushfires and earthquakes. Some of these events have produced wide spread damage and economic loss, though loss of life appears to have been a rare event.

Land Management

Balonne Shire contains a wide range of both discrete and overlapping land management jurisdictions. The nature of these jurisdictions has an important bearing on the management of a number of hazards, especially bushfire.

Council is directly responsible for 38.39 sq km of land. This area is made up of parks and reserves including recreation reserves, town commons and the St George showground. By far the largest portion of the Shire is held under freehold title and controlled by private entities and a range of public authorities. It totals 21,268.09 sq km. Several areas of Balonne Shire are the subject of claims under Native Title legislation. Successful claims under this legislation do not remove any responsibilities for use and management that may have an impact on community safety both on that land and beyond, for example bushfire fuel management.

Legislation

A range of Queensland legislation and national standards have an influence on disaster risk management within Balonne Shire. Relevant sections of this legislation and standards have been taken into account in the development of the bushfire management strategies contained in this report.

The most significant area of evolving policy In relation to natural disaster risk management is the State Planning Policy 1/03 (SPP) for Natural Disaster Mitigation published by the Departments of Emergency Services and Local Government and Planning in 2003.

Evaluation Criteria

The current level of risk posed by natural hazards within Balonne Shire, and the effectiveness of the risk reduction strategies suggested in this study, are measured against the following criteria, in priority order:

1. reduce, to an acceptable level, the risk of death or injury to emergency workers engaged in responding to any hazard impact;
2. reduce, to an acceptable level, the risk of death or injury to the general population;
3. reduce, to an acceptable level, the risk of destruction or damage to public infrastructure and facilities;
4. reduce, to an acceptable level, the risk of destruction or damage to private property;
5. manage the impact of hazards on the environment to the extent that the biodiversity of both flora and fauna is maintained;
6. minimise the long-term impact on the local economy.

It is likely that conflicting views will emerge between the priority that should be given to the protection of life and property, access to flood waters by water harvesters and the priority given to environmental protection and the maintenance of biodiversity.

THE HAZARDS

A range of natural hazards have a history of serious impact within Balonne Shire.

Floods

Floods are *water where and when it is not wanted*. This multi-dimensional view is particularly relevant in Balonne Shire where floods are something of a Jekyll-and-Hyde hazard. Whilst they pose a regular, and at times serious, threat to both public and private property, they are also essential to the agricultural industries that sustain the Shire's economy

However, floods account for the largest amount of loss caused by natural hazards in Australia. Between 1967 and 1999 the annual average loss caused by floods across Australia is estimated to be $314.0 million of which Queensland contributes $111.7 million (BTE, 2001).

The Shire contains a small portion of one, and substantial portions of two, major catchments. About 305 sq km of the Macintyre-Weir catchment's total area of 44,000 sq km is contained within Balonne Shire, namely, the area around Mungindi. The highest floods at Mungindi on record were those of 1976 and 1996. Mungindi is protected to approximately the level of the 1976 flood by a levee. This levee does not provide protection to the Mungindi Hospital which stands on a higher point on the river bank and has its own levee. The town levee was extended in 2001 (Lawson and Treloar, 2000).

Around 5,270 sq km of the Moonie River's 14,050 sq km catchment lies with the Shire. The highest flood on record in the Moonie occurred in February 1976 when waters reached a stage height of 4.15 m at Nindigully and 5.43 at Thallon (i.e. on each locality's respective flood gauge). This flood is one of the few reported to have entered houses in both settlements. Such major flooding inundates many thousands of hectares of low-lying country, isolates numerous properties and closes roads, including the Carnarvon Highway. Records indicate that major flooding occurs at Thallon, on average, every four years.

The Condamine-Balonne system occupies about 80% of the Shire. It is one of the major tributaries of the Murray-Darling system and is one of the most important river systems in Queensland in terms of agriculture. The headwaters of the Condamine-Balonne rise in the Border Ranges upstream of Killarney and flow for approximately 1200 kilometres through Queensland before entering NSW, whilst the Maranoa River, which joins the Balonne just upstream from St George, rises in the Carnarvon National Park area of the Great Dividing Range and Chesterton Range. Also included in this catchment are the Nebine, Mungallala and Wallam Creeks which drain the Chesterton and Brunel Ranges to the north. In flood, the waters of these creeks join the Culgoa – Balonne system in NSW.

The most significant effects of flooding along the Balonne River are the widespread inundation of agricultural land, cutting of roads, the isolation of rural homes and properties and the loss and damages suffered in these areas. Damage to fencing, pumping equipment, machinery and loss of stock through drowning result in significant losses during major floods. Records of large floods along the Balonne River extend back to the 1860s at St George with extensive records at several other locations on the main stream. Over the past 100 years major floods occur, on average, every 2 years.

The worst flooding occurred in 1864, 1890, 1942, 1950, 1956, 1975, 1976, 1983 (twice), 1988, 1990 and 1996. Major floods generally occur in the first half of the year, although records indicate that they may also occur in late spring. Figure 1 provides the flood history of the Balonne River at St George. The modern flood of record at St George was that of April 1990 with a stage height of 12.24 m, however the flood of 1890 had an equivalent stage height of at least 13.1 m. It is also clear that there is a significant gap in the records between 1900 and 1920.

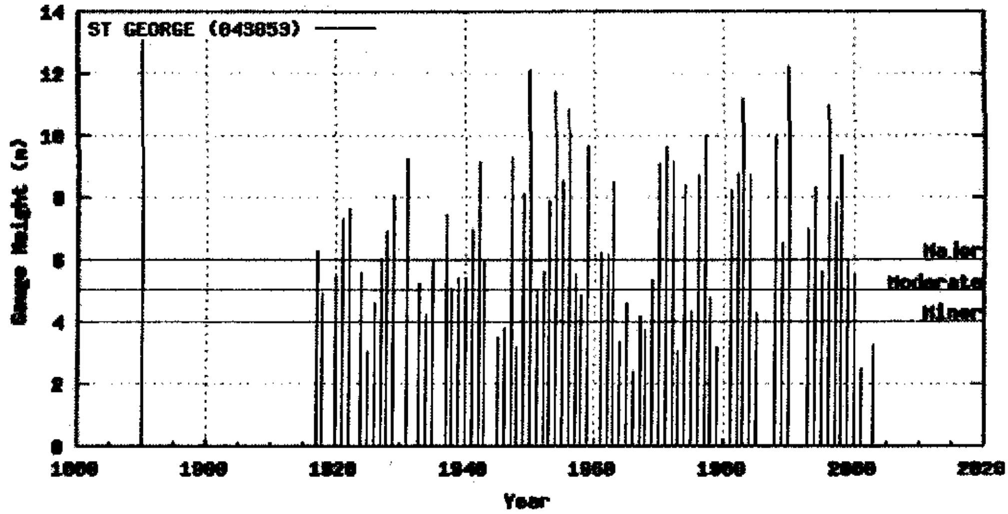

Figure 1: Balonne River highest annual flood peak at St George (source BoM, 2003c)

It is not widely known that St George itself has been subject to severe flooding. The following account from a publication celebrating the centenary of St George published in 1946 relates to the 1890 flood and is an important reminder that the Shire centre is not immune from floods.

> *At the height of St George's famous Ninety Flood, the site of the town was completely submerged. The Balonne for miles had overflowed its banks, spreading a brown sea through houses, along streets, until many inhabitants were forced to evacuate and seek higher ground.*
>
> *Their main camp was located on the sandy ridge southeast of the present bridge, where, during the flood, diphtheria broke out, but no deaths occurred.*
>
> *The only safe route to the hospital was via the rear of the town and it seems fantastic today to record that the entire journey was made by boat.*
>
> *In those days, when regattas were popular, St George claimed numerous boats and these proved invaluable during the anxious days of the flood. The old, bark-constructed Q.N. Bank served as a temporary hospital and as a depot from which the late James Tosh (then bank manager) directed rescue work and the distribution of supplies.*
>
> *Flour was scarce. But goats, pumpkins and the fowls which had taken refuge on roof tops, enabled the inhabitants to survive until the late Will Digger and others brought flour from Dalby.*
>
> ***During the 14 days when the water remained stationary the streets were submerged to a depth of four feet and more.***
>
> *On one occasion a boat from St George was rowed the entire six miles to Boombah, through the orchard at Riverston where a load of oranges was picked from half submerged trees and taken to the station.*
>
> *Deep holes remained in the streets twelve months after the water had passed and a hollow in the Church of England sand hill today marks the pit from which sand for repairs was taken.*

> St George in the first half century of its existence recorded some memorable floods but none so prolonged or destructive as the famous '90. (emphasis added)

In the absence of other investigations, it may be safe to assume that the 1990 flood level (a stage height of 12.4 m) represents a flood with an average recurrence interval (ARI) of approximately 100 years. The stage height for the flood of 1890 (at least 13.1 m) may then represent an ARI of 150 to 200 years, whilst the 1864 flood (stage height assumed to be about 15.5 m) may represent a flood with an ARI of 250 to 500 years.

A flood of the magnitude of the 1890 event would directly expose, or indirectly affect through isolation, at least 3850 people. That figure includes the population of St George, which has no structural defences against flood. Dirranbandi is afforded some flood protection by a series of levees along the eastern, southern and western sides of the town.

Tropical Cyclones and Severe Thunderstorms

Tropical cyclones and severe thunderstorms each bring with them potentially destructive winds and intense rainfall. Thunderstorms also bring with them potential for damaging hail and lightning strike. Both forms of severe weather have had damaging impacts within Balonne Shire.

At least five tropical cyclones have come within 200 km of St George. The first recorded was in February 1928. These have caused major flooding and, on occasions, damage to property. The most recent, and most damaging, system was TC *Audrey* in January 1964. Known locally as 'Little Audrey' after the comic-strip character, *Audrey* formed in the Gulf of Carpentaria around 7 January and tracked south until it hit St George at 8 am on 14 January. At least 52 houses lost all or part of their roofs and 22 of the business houses were badly damaged. Other towns in the region, including Goondiwindi and Boggabilla suffered damage. The tracks of the five tropical cyclones to have had a direct impact on the Shire are shown in Figure 2.

The record of severe storm impacts is not as comprehensive as that for cyclones, however, the recent experience of storms indicates that they pose a serious risk. A possible tornado on 30 January 1999, for example, uprooted trees, unroofed buildings and almost demolished the town of Hebel. Associated hail has killed sheep and caused damage to sheds, vehicles and crops.

No part of the Shire is immune from severe wind damage, hail or lightning.

The approach of cyclones is well tracked for several days before they are within destructive range so warnings are good. Modern weather radar systems are proving invaluable for detecting and tracking severe thunderstorms. There are instances, however, when storms form very rapidly and practical warnings are not possible. This can be the case in the Balonne Shire which is not completely covered by the BoM weather radar network - there is a gap over the Shire between the coverage provided by the Charleville and Moree radars.

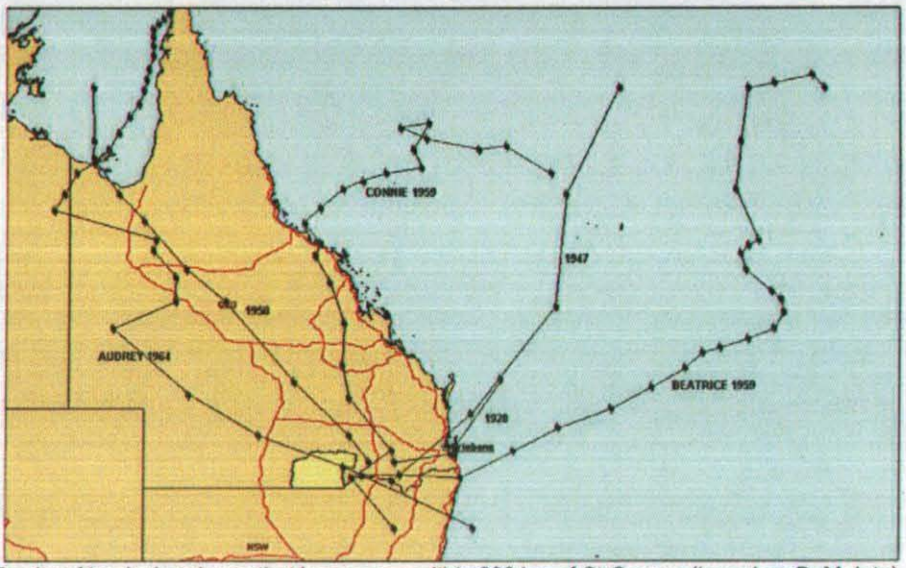

Figure 2: Tracks of tropical cyclones that have come within 200 km of St George (based on BoM data)

Bushfires

Bushfires are defined in SPP 1/03 as:

> *an uncontrolled fire burning in forest, scrub or grassland vegetation, also referred to as wildfire.* (DLGP/DES, 2003, p 10)

From 1967 to 1999 bushfires cost the Australian community an average $77.2 million annually, whilst Queensland's annual loss was only $0.4 million.

For a bushfire to start and to be sustained, three basic elements are needed:

- there must be fuel available to burn;
- there must be sufficient heat to cause and maintain ignition, and;
- there must be sufficient oxygen to sustain combustion.

If any one of these is absent, or inadequate, the fire will either not start or will not spread.

In Balonne Shire, fire has long been used as a major land management tool and bushfires are, consequently, a common feature. Losses from bushfires, whether started naturally by lightning or deliberately started, have typically been small and confined to assets such as fencing, pasture, crops and livestock. The earliest anecdotal report of bushfires in the Shire indicates that a major fire burnt 'from the border to the Carnarvon Range' in 1910. The earliest records of significant bushfires in the Shire held by the QFRS Rural Fire Service are for fires in September 1941 when fires around St George were amongst numerous outbreaks across the south-west of the State. In 1943 fires burnt some 45,000 ha near Dirranbandi. Another major fire episode started on 10 October 1951 and burnt from Dirranbandi to St George. Many sheep were reported killed in this fire.

The incidence and severity of fire is most closely linked to episodes of 'fire weather' – days, or sequences of days, with low humidity (below 25%), high temperatures (above 30°C) and sustained winds of more than 25 km/hr (measured at 3.00 pm). The most extreme episode of fire weather in the past 50 years was probably from 1 to 6 November 1965 when four of the six days met the criteria. The three consecutive days from 6 to 8 January 1994 was also a significant episode. A further eight episodes of two consecutive days of fire weather were recorded.

Mapping produced by the QFRS shows that a total of 6,474.4 sq km (or 20%) of the Shire is classified as having a potentially medium fire hazard. The remaining 80% of the Shire has either a low or negligible hazard potential. This mapping is shown in Figure 3.

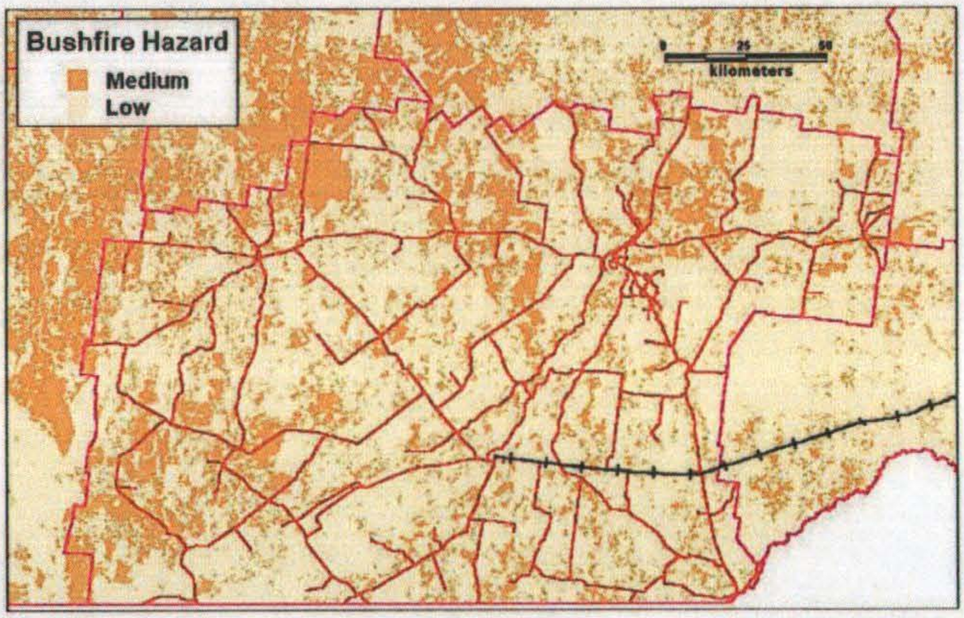

Figure 3: Balonne Shire bushfire hazard (source QFRS, 2003)

Historically, the most common source of bushfire ignition has been lightning strike. In more recent years, unfortunately, these natural sources of ignition have been joined by non-natural sources including:

- power line failure (e.g. caused by power lines coming in contact with vegetation or being brought down by high winds or falling vegetation);
- human carelessness (e.g. a poorly supervised burn-off); stupidity (e.g. a discarded cigarette butt, or fires lit by bored and unsupervised children); or,
- criminality (e.g. by outright arson, or by car thieves disposing of stolen cars by setting them alight in bushland).

Within Balonne Shire, these causes are less significant than they have become in more closely settled areas.

Fire suppression responsibilities are divided between the rural and auxiliary elements of the QFRS, the QPWS and individual landholders. There are 33 rural fire brigades. The towns of St George, Bollon and Dirranbandi are covered by three auxiliary brigades, whilst Thallon is protected by a rural brigade.

St George and Dirranbandi have reticulated water supplies and consequently hydrants to supply fire fighting water. All other areas must rely on their own water resources. The availability of water with which to fight fires during drought is a major concern.

Earthquakes

Earthquakes occur when stresses in the Earth exceed the rock's strength to resist, thus causing the sudden rupture of rocks and displacement along a fault. The fault may already have existed or may be newly created by the earthquake rupture. Nearly all damaging earthquake effects are caused by the energy from the fault rupture which is transmitted as seismic waves.

Within a square, the sides of which are approximately 500 km from St George, the National Earthquake Database maintained by Geoscience Australia contains records of some 650 earthquakes, the earliest of which was on 27 January 1841, a Richter magnitude(ML) 4.9 event located in the New England area of NSW, whilst the largest on record was the ML 6.0 event of 6 June 1918 located off Bundaberg.

The most significant earthquake event in the Shire was that of 19 September 1954. This M_L 5.4 event had its epicentre close to Thallon at a relatively shallow depth of 10 km. It was felt as far away as Roma and Mitchell to the north and Moree and Brewarrina to the south. It was felt in St George with a Modified Mercalli Intensity (MM) of IV to V (i.e. clearly felt by people and some minor damage to contents such as crockery falling off shelves, etc).

The historical experience of earthquake in the Shire suggests an increasing level of threat the further east one goes. That said, however, the earthquake hazard is low across the Shire by both global and national standards. On the basis of the historic record (not withstanding the uncertainty that exists in the knowledge of earthquake mechanisms in the region), it seems safe to assume that the risk of damage to buildings, and death or injury to people, throughout the Shire, is very low.

Climate Change

Whilst there remains considerable uncertainty relating to the nature of climate change over the next 50 or so years, there appears to be a degree of consensus by the scientists responsible for the 2001 Intergovernmental Panel on Climate Change (IPCC) report who argue (as reported by Hennessy and Walsh, 2003) that it will lead to:

- *Higher maximum temperatures and more hot days over nearly all land areas;*
- *Higher minimum temperatures, fewer cold days and frost days over nearly all land areas;*
- *Reduced diurnal temperature range over most land areas;*
- *Increased heat index over land areas;*
- *More intense precipitation events;*
- *Increased summer continental drying and associated risk of drought;*
- *Increased tropical cyclone peak wind velocities;*
- *Increased tropical cyclone mean and peak precipitation intensities.*

For Balonne Shire climate change would thus lead to hotter and dryer conditions overall but with intense rainfall episodes likely to lead to flooding increasing in frequency. Some authors have suggested that the increased frequency in intense precipitation will see the stage height for a flood with a current ARI of 100 years being achieved with an ARI of 25 or 30 years.

Other Hazards

This study is formally confined to consideration of those natural hazards for which Council may claim relief under the Natural Disaster Relief Arrangements (NDRA).

NDRA funding does not include all natural hazards that may have an impact on the Shire and its community. Drought, for example, was excluded from NDRA coverage in April 1989, whilst hazards such as salinity, reactive soils and heatwave have never been covered. Such hazards should, none-the-less be considered by Council in their disaster planning process and general community governance.

ELEMENTS AT RISK AND THEIR VULNERABILITY

The study describes and analyses the community elements that may be exposed to the impact of one or more of the identified hazards and their vulnerability to such an exposure. Five main groups of element are considered here: people, buildings, lifeline infrastructure, economic activity and the environment.

Exposure of Community Elements

The exposure of community elements varies depending on the hazard involved and its severity. Exposure may be direct, i.e. covered by flood waters, or indirect, i.e. affected by the loss of power supply.

Exposure to Floods: No flood extent information for various event ARI are available to this study, consequently, it has not been possible to produce statistics relating to different flood scenarios. The anecdotal evidence suggests that very few people are directly exposed to floods in Balonne Shire, given that their onset is generally slow and preceded by adequate warnings. Flood deaths can generally be attributed to inappropriate action by inexperienced or foolhardy people trying to negotiate flooded roads.

Virtually all people in the Shire can be *indirectly exposed* to flood impact, given the widespread dislocation of roads throughout the area. This indirect exposure can extend for many weeks and if people in flood-isolated areas are not adequately prepared with stocks of food or essential medicines, emergency relief will be required.

Rescue resources are available should a medical or other emergency occur during a flood.

Few residential buildings appear to be directly exposed to flood given that most are either sited in low hazard areas and/or have been constructed with floor levels elevated 0.8 m or more above ground level.

The key infrastructures exposed to flood are the roads of the Shire. Anecdotal information provided by Balonne Shire Council staff indicate that road segments totalling around 500 km of the Shire's 2940 km of roads are subject to varying degrees of inundation. The most flood prone roads are those in the Balonne valley. As many as 750 people would be directly affected in that area. Isolation of the properties in the western creek catchments would affect about 130 people. In a major flood of 1890 proportions, however, it is likely that the entire population of the Shire would be isolated for two weeks or more.

Rail infrastructure is said to be generally not flood-prone. The Shire's key airfields at St George, Dirranbandi and Bollon are largely flood free, however only the St George and Dirranbandi airfields have sealed runways that are unaffected by rainfall.

Power supply can be disrupted by flood. Poles may be brought down by flood waters or flood-transported debris and supply will also be cut off by Ergon Energy when they assess that the power lines could come within 1 m of the flood waters.

Key services, including fuel and food supply are unlikely to be directly exposed, however, indirect exposure is highly likely as food and fuel supplies are transported by road.

<u>Exposure to tropical cyclones and severe thunderstorms:</u> It can be assumed that all above-ground facilities are potentially exposed to the severe wind, hail and lightning associated with tropical cyclones and severe thunderstorms

Exposure of people to severe winds associated with tropical cyclones is likely to be lower than that for severe storms due to advance warning. Thunderstorms, by contrast, have a more rapid onset and limited warnings. Consequently, it is much more likely for people to be caught out-of-doors during thunderstorms.

All buildings in the Shire are potentially exposed to severe winds and wind-blown debris.

Roads may be blocked by fallen trees and other wind-blown debris, signalling and associated equipment is potentially exposed to both wind and lightning damage and all airfields are likely to be closed (albeit temporarily) during severe wind episodes. Power supply is highly exposed to wind, debris and lightning damage and telecommunications and SCADA (supervisory control and data acquisition) infrastructure could be damaged or taken out of service.

<u>Exposure to bushfires</u>: The harm-causing components of bushfires include flames, radiant heat, embers, smoke and fire-generated severe winds. Exposure to bushfires is, therefore, largely dependant upon proximity to the fire front. There is generally adequate warning of an approaching fire for steps to be taken to reduce exposure.

Fire fighters are generally the people who have the greatest exposure to bushfire harm because their activities place them close to the fire front. Exposure of the rest of the population should be limited, however, inadvertent exposure, e.g. travellers unaware of the fire, can have lethal consequences.

Except under the more severe fire conditions, buildings that are separated from the heavy fuel (woodland, scrub, etc) by more than 100 m should have only limited direct exposure. From observation, there appear to be very few buildings in either rural or urban areas located closer than several hundred metres from bush.

Roads may be closed temporarily by dense smoke or by trees brought down by the fire. Rail infrastructure, especially wooden sleepers and wooden bridges, can be damaged. Airfields may be closed by smoke.

Power supply infrastructure is highly exposed. Wooden poles can be destroyed; cables, substations and control equipment can be affected by heat; high voltage transmission lines can arc to the ground in dense smoke.

Exposure to earthquakes: It is widely acknowledged that earthquakes do not kill people – poorly constructed buildings that fall down in earthquakes kill people. Fortunately, the vast majority of buildings in the Shire have timber frames which perform reasonably well under earthquake loads. Exposure of people to earthquakes depends largely on the time of day and day of the week at which it occurs, and consequently, the nature and quality of the building in which people are located at the time – i,e, whether they are at home, school or work.

Underground utilities, including water supply pipes, sewerage pipes and telecommunications cables are probably the most exposed to earthquake damage of all community elements.

People and Their Vulnerabilities

Regardless of the hazard phenomenon involved, a disaster is something that happens to people. People are, consequently, the principal consideration in disaster risk management. In this study 'vulnerability' is defined as:

> *The degree of susceptibility and resilience of the community and environment to hazards.*
> (EMA, 1998)

Many of the attributes that make communities more or less susceptible to hazard impact, such as social attitudes, values, behaviour, perceptions and social networks, are unquantifiable. There are, however, a number of demographic and socio-economic measures that are available from the National Census that provide some useful insights.

The study examines 13 census variables including:

- population density, people aged under 5 years and people 65 and over;
- households with low income, living in rented accommodation and people unemployed;
- households without access to a car, families with single parents and large families;

- people of less than 5 years residence, people with limited education, people with no English and people who do not use the Internet.

By combining the values for the various indicator measures in each of the four categories an index is dev eloped that 'measures' the relative degree of vulnerability that exists between the 17 Census Collectors' Districts (CCD) in the Shire. It is clear that the urban communities are significantly and consistently more vulnerable than are the rural communities.

Buildings and Their Vulnerabilities

The buildings in which the community live, work, are educated, are cared for, and play, represent the second most significant component in understanding community risk. They, and their contents, represent the most significant economic (and possibly also emotional) dimension to disaster. The physical vulnerability of buildings, and consequently their functional vulnerability, is dictated to a large degree by the engineering codes that prevailed at the time of their construction and by the standard of maintenance they subsequently receive.

Engineering codes: Standards that set design and construction parameters for severe wind and earthquake loads and bushfire-prone areas have been published and legislated. However, there are no comparable standards for construction in flood-prone areas. A wide range of other engineering standards also apply to the construction and design of infrastructure elements such as drainage, water supply, sewerage and so on. These standards are applied within the Shire.

Residential buildings: Whilst no specific data on the residential structural characteristics of Balonne Shire dwellings were available, observations indicate that the great majority of dwellings have:

- timber frame construction;
- timber, asbestos cement (AC) or similar sheeting;
- high pitched hip metal roof;
- pole or pier foundations – typically 0.8 m or more above ground level.

Most dwellings constructed in the past decade are slab-on-ground brick veneer over a timber frame. All of these designs are well suited to the region's climate and hazard environment.

Critical Facilities: A wide range of facilities exist throughout the Shire that are important to community safety and wellbeing before, during and after any emergency. The loss or dislocation of these critical facilities would greatly exacerbate the impact on the community. These include emergency services, medical, transport and repair facilities.

The older brick buildings may be susceptible to the earthquake loads that could be experienced in the Shire, however, most critical facilities appear to have been constructed to current engineering standards and sited to minimise flood damage, if not isolation.

Sensitive facilities: A further range of facilities exist at which people, especially children or the elderly, may congregate or be concentrated at different times. Some of these sensitive facilities are of older brick construction and are consequently susceptible to failure under earthquake loads. The remainder are typically of timber fame construction to standards similar to the dwellings detailed above.

Economic and logistic facilities: A wide range of facilities support the community through the provision of services and supplies together with industrial processes. These are largely concentrated in, or close to St George and Dirranbandi. Most of the facilities in this group are of steel frame and steel clad construction that is largely resilient to all hazards.

Infrastructures and Their Vulnerability

The loss of, or damage to, lifeline infrastructures can have a significant impact on the community.

Roads: There are seven highways in the Shire that are the responsibility of the Department of Main Roads and three main roads that are the responsibility of the BSC. The remaining 2000 km of roads in the Shire are made up of the urban street networks of St George (approximately 47 km mostly sealed), Dirranbandi (14 km mostly sealed) and the other small towns as well as an extensive network of unsealed rural roads.

Sealed roads are generally resilient to damage, though after flood episodes their bitumen seal may need repair and their foundations are likely to take some time to dry out, making them susceptible to damage by heavy vehicles.

All natural surface roads can become quickly impassable to most vehicles after rain because of their slippery clay nature. They are particularly susceptible to damage by any traffic until they have dried out sufficiently following floods. The approaches to stream crossings are likely to require repair.

Rail: It is believed that the rail line is essentially flood-free. It could be susceptible to damage by a significant earthquake that produced surface ruptures or distortions and some of the bridges are of timber construction and would be susceptible to bushfire damage.

Power supply: No details of the power reticulation network were available to this study. However, Ergon Energy state that they have established procedures that are aimed at restoring power throughout the network within two weeks of a major flood.

Water supply: Reticulated water supply is provided in St George, Dirranbandi, Bollon, Thallon, Mungindi and Hebel. The water sources include both bore field and stream catchment. Reticulation pressure is, in most instances, provided by pumps with water towers for control. The in-ground pipe network in all centres with the exception of Hebel contains significant amounts of older AC pipe that is susceptible to rupture under relatively low earthquake loads. Water supply could also be threatened by earthquake if the water towers were damaged or even toppled. Apart from earthquake damage, the main vulnerability of the water supply systems across the Shire is the interruption of power supply for an extended period. All systems rely on electric pumps for both treating and reticulating supply.

Sewer: Reticulated sewerage is provided only in St George, Dirranbandi and Bollon. As with the water supply network the main susceptibility is in the AC pipes that again make up significant proportions of the network

Economic Vulnerabilities

The Shire's economy is firmly based on agricultural industries, with cotton, wool, grain crops, beef, and wild game being the main enterprises. The agricultural industries are highly susceptible to the impact of floods, severe weather and bushfires. Drought, however, remains the most significant threat to the entire agricultural sector of the Shire.

Environmental Vulnerabilities

The native flora and fauna of the Shire has evolved to cope with the impact of natural hazards such as flood, severe storms and bushfire. The development of agriculture and the introduction of exotic animals have had far greater impact than any natural hazard event is ever likely to have.

RISK REGISTER

The following tables summarise the risks posed by the key hazards considered in this study.

Table 1: Balonne Shire catchments flood likelihood, consequences and risk levels

LIKELIHOOD	CONSEQUENCES	RISK LEVEL
Almost certain (ARI ~2-5 years)	Minor to moderate flood levels reached. Roads cut and a few tens of rural properties isolated for days. Stock losses possible. Minimal risk to urban communities.	Insignificant to Minor
Likely (ARI ~10 years)	Major flood levels reached. Roads cut, perhaps as many as 100 rural properties isolated for up to a few weeks. Power cuts and stock losses likely. Minimal urban properties.	Insignificant to Minor
Unlikely (ARI ~ 50-100 years)	Major flood levels reached. Roads cut for weeks and damaged. Power cuts certain and damage to infrastructure likely. At least 150 rural properties isolated for several weeks; building and equipment damage likely. Some evacuations likely. Potentially extensive stock losses. Damage to irrigation infrastructure possible. A few tens of low-lying urban properties likely to be flooded.	Moderate
Rare (ARI ~200 years or greater)	Widespread road and infrastructure damage. Rural properties and urban communities isolated for several weeks with virtually the entire population of the Shire directly or indirectly affected. Evacuations will be required. Extensive stock losses. Major irrigation infrastructure damage likely. Significant inundation of urban properties including St George and Dirranbandi. Major economic losses. Loss of life possible.	Major to Catastrophic

Table 2: Balonne Shire destructive wind and hail likelihood, consequences and risk levels

LIKELIHOOD	CONSEQUENCES	RISK LEVEL
Almost certain (ARI ~2-5 years)	Minor to moderate levels of wind and hail damage reached in small areas – a few tens of buildings damaged. Roads and power supply may be affected for a short time by fallen trees. Power supply may also be affected by lightning strike.	Insignificant to Minor
Likely (ARI ~10 years)	Major levels of wind and hail damage reached in small areas – a few buildings destroyed and up to 100 buildings with significant damage. Roads, power supply and telecommunications infrastructure may be affected for up to a day by fallen trees, blown debris and/or lightning strike. Crop losses from hail likely. Vehicles in the open likely to suffer hail damage. Some older buildings may lose their roofs. Injuries likely.	Moderate
Unlikely (ARI ~50 years)	Major levels of wind and hail damage reached in extended areas – tens of buildings destroyed and more than 100 severely damaged. Roads, power supply and telecommunications infrastructure will be affected for more than a day by fallen trees and blown debris. Crop and stock losses from hail almost certain. In areas where hail is experienced, vehicles and equipment in the open will suffer damage. Some buildings likely to lose roofs or suffer debris damage. Serious economic impact. Numerous injuries likely and loss of life possible.	Major
Rare (ARI ~100 years or greater)	Severe wind damage over extensive areas, hail damage over smaller areas. Many tens of buildings destroyed and a few hundred more severely damaged. Roads, power supply and telecommunications infrastructure will be affected for up to a week by fallen trees and blown debris. Widespread crop and stock losses. In areas where hail is experienced, all vehicles and equipment in the open will suffer damage. Major economic losses. Many injuries and some loss of life likely.	Catastrophic

Table 3: : Balonne Shire bushfire likelihood, consequences and risk levels

LIKELIHOOD	CONSEQUENCES	RISK LEVEL
Almost certain (ARI ~2-5 years)	Small intensity fires with some spread potential. Limited property threat. Easily controlled.	Insignificant
Likely (ARI ~10 years)	Medium intensity fires with some spread potential. Property such as fencing likely to be damaged. Easily controlled.	Insignificant
Unlikely (ARI ~50 years)	Severe intensity fires with significant spread potential. Property loss, especially standing crops and stock, possible. Injuries to fire fighters possible. Manageable by conventional methods.	Minor
Rare (ARI ~100 years or greater)	Extreme fire intensity with major spread potential. Property loss, especially standing crops, stock and some buildings, likely. Injury to fire fighters likely and fatalities possible. Difficult to manage by conventional methods.	Major

Table 4: Balonne Shire earthquake likelihood, consequences and risk levels

LIKELIHOOD	CONSEQUENCES	RISK LEVEL
Almost certain (ARI ~0-50 years)	Small intensity shaking to MM IV. Little if any damage.	Insignificant
Likely (ARI ~100 years)	Small intensity shaking to MM V. Little if any damage.	Insignificant
Unlikely (ARI ~500 years)	Moderate intensity shaking to MM VI. Minor damage to poorly constructed buildings possible. Injuries unlikely. Some damage to the more fragile in-ground infrastructure possible.	Minor
Rare (ARI ~1000 years or greater)	Moderate intensity shaking to MM VI to VII. Damage to older masonry and poorly constructed buildings likely. Some serious injuries possible but fatalities unlikely. Some dislocation of in-ground infrastructure likely.	Moderate

The two largest towns in the Shire, St George and Dirranbandi, carry the greatest levels of risk, simply because they contain more people and assets that are potentially exposed to hazard impacts. They also contain the more susceptible communities.

The next highest levels of risk are carried by the smaller villages – Mungindi, Thallon, Bollon and Hebel – again because of the relative concentration of people and economic assets and the fact that they provide services (albeit limited) to an extended hinterland. Mungindi is a special case given that the bulk of the population and assets of this centre are located on the NSW side of the border. The hospital, located on the Queensland side, is a key facility for populations in both NSW and Queensland and is thus of critical importance.

The high-value crops and major engineering investments associated with the St George and Dirranbandi irrigation areas are exposed to considerable risk, primarily from flood and destructive winds. The risks posed to people are minor, because their populations are small and widely spread.

In the dry-land areas the economic risks are much greater than the threat to people, though major floods will isolate people for extended periods. Floods pose a significant threat to stock which may need to be sustained by fodder drops by helicopter. Fencing and pastures will also be damaged, however, the value of replenished soil moisture and surface storage will offset these losses to some extent. Destructive winds and hail pose a significant threat to crops such as wheat and barley. Most grain growers, however, are able to insure their crops against such impacts. Bushfires pose a significant threat to both pasture and standing crops, as well as to livestock and fencing.

MITIGATING THE RISK

The study identifies and discusses a range of strategies that would help to reduce or eliminate disaster risks across Balonne Shire. It is focused primarily, but not exclusively, on those strategies that might be adopted by Balonne Shire Council. Where they address issues that are the responsibility of either State or Commonwealth agencies, or individual property owners, they are expressed in terms of what Council might do to influence the adoption of those strategies by those who have the primary responsibility.

The strategies that relate to specific hazards are dealt with first and are followed by more general strategies that are applicable to all hazards. Regardless of which strategies are adopted, it is important for risk managers to see disaster risk reduction activity as being **an investment rather than a cost.**

Treating Flood Risks

It is not within the capacity of modern science and technology to have an impact on the flood hazard component. Flood risk reduction must, therefore, be achieved by affecting exposure and/or vulnerability. Reducing exposure is the approach most commonly adopted, particularly focussing on structural defences, the planning process, building siting and design, warning systems and evacuations. Flood insurance is one of the few strategies available for reducing vulnerability to flood impact.

Structural defences: The most common response to a known or perceived flood threat has been to build defences such as levees, drainage works or detention basins. These defences are normally designed to provide flood immunity to a stated historic or modelled level of event that represents an 'accepted' level of risk.

While effective at reducing risks these defences can engender a false sense of security based on the attitude that because there is a levee, then all flood risks have been eliminated. This false sense of security can magnify residual risks if the levee is overtopped or if it fails. It is essential that 'escape' strategies also be considered such as identifying flood-free localities to which people could be evacuated before the levee fails.

The planning process: It is not possible to understand, let alone effectively treat, the flood risk posed to both present and future development without a clear understanding of the hazard and its likely impact across a range of scenarios. Such information is largely lacking for Balonne Shire, other than (perhaps) for Mungindi.

Given the continuing growth and economic importance of both St George and Dirranbandi, and the implementation of State Planning Policy 1/03 (SPP 1/03) with its provisions for setting 'defined flood event (DFE)' levels for future development planning, it would be appropriate for detailed hydrological and hydraulic studies of the flood hazard at those localities to be undertaken. This modelling could be extended at a lower resolution to the whole of the lower Balonne and Moonie catchments to provide a clearer appreciation of flood risks in the smaller settlements and the wider countryside.

This modelling would need to be supported and contributed to by Commonwealth and State Government agencies (including Sunwater), as well as the private sector (including members of Smartrivers) and **should not be seen as solely the responsibility of Balonne Shire Council.**

Given the scale and likely cost of this 'top end' strategy, information on historic flood events can be used in the interim. Satellite imagery of major floods such as those of 1988, 1990, and 1996 are available and could be used to map, within a few tens of metres, the extent of inundation. A program of collecting oral histories from residents who experienced these and earlier events and relating that material with attributes such as flood depth and duration of inundation, would also greatly enhance subsequent modelling.

Should a major flood event occur before a program of modelling and high resolution mapping is undertaken, every opportunity should be taken to gather accurate information on the behaviour of the flood.

Building siting and design: In planning schemes, exposure reduction is typically achieved through establishing minimum ground height and floor height levels above the DFE level. Most of the houses constructed in the Shire before the mid-to-late 1980s were constructed with floor levels generally 0.8 m or more above ground level. More modern houses, however, have adopted slab-on-ground forms of construction which provides minimal immunity if sited in flood-prone areas.

Warning systems: Flood warning is an integral component of counter disaster arrangements for a community at risk from flooding. To be effective warnings must be delivered in a timely and effective manner and property owners and residents must have confidence in the warning and take appropriate action in advance of being flooded.

There are both formal and informal warning systems operating in the Shire and these should be sustained, if not enhanced.

Evacuation and rescue: Most roads in the Shire are susceptible to closure by flood waters. Evacuation over natural surface roads with up to 1.0 m of water over them (and with minimal velocity) should only be attempted as a last resort and then using heavy, high-set vehicles such as graders, large tractors or trucks. Such depths of water would normally require evacuation by boat, or helicopter.

People who are more vulnerable because of isolation or medical conditions should be identified and their details maintained by local emergency managers.

Navigation of helicopters to a rescue location during floods can be a problem unless accurate coordinates of the destination are available. Recording coordinates for all occupied buildings in rural areas using GPS technology and maintaining these in a database managed by Council would overcome this problem. Taroom Shire has developed such a system and it would be an ideal model for Balonne Shire to follow.

Treating Severe Thunderstorm and Cyclone Risk

As with flood, there is nothing that can be done to reduce thunderstorm or cyclone hazards, and given the generally flat terrain of Balonne Shire, there is little that can be done to reduce exposure. Reducing the risks posed by thunderstorms, therefore, must rely largely on reducing vulnerability. The use of appropriate building design/construction standards and warning systems are the most effective strategies available.

Advances made in severe wind resistant construction since the 1970s have resulted in improved building performance under wind loads. Houses built since 1980, or those that have had their roofing systems upgraded to the new standards, should perform well under severe wind loads. Older buildings, that have not been upgraded, and/or those that have been exposed to past severe wind episodes, will be more susceptible to damage.

Council could consider adopting regulations that make upgrade to modern standards mandatory for their own building assets and when any major renovation, alteration, addition or change of use is undertaken to private buildings.

Treating Bushfire Risk

Unlike the other hazards dealt with in this report, there are strategies available by which to reduce the hazard (if there is no fuel there is no fire), as well as strategies to reduce both exposure and vulnerability.

Managing the hazard: The objective of fuel management is to mitigate fire risk by reducing fire intensity and spread. Its objective is not, and can not be, to eliminate fire. Whilst the priority in risk reduction is the protection of life and property, the management of fuel, particularly by prescribed burning, should be done in such a way as to have a minimal negative impact on biodiversity.

There are two recognised forms of fire management to preserve biodiversity - prescribed burning on a rotational basis and site-specific mechanical control. Where the preservation of biodiversity is less of a concern, grazing and 'green fire breaks' can also be employed.

It is the responsibility of the land owner and/or land controller to manage the fire hazard on their land in a 'responsible manner'. Section 69 of the *Fire and Rescue Service Act* 1990 requires land owners to take measures to reduce the risk of fire.

The bushfire hazard can also be reduced by minimising the incidence of ignition. Whilst there is nothing that can be done to prevent lightning strike starting fires, there are strategies available to reduce the incidence of human-produced causes.

Managing the fire: The fire hazard can also be reduced by an effective response to a fire once it has started. Early detection and a prompt and appropriate response are the keys. In Balonne Shire the detection of fire and its reporting to fire authorities depends largely on the vigilance and awareness of members of the public. An aware and informed public is, therefore, the best defence available.

A critical element in a rapid response is knowing where the fire is and how to get to it. BSC is in the process of implementing rural road addressing that conforms to the National standard for addressing. However, an address is worthless unless the road names and property addresses are adequately displayed, preferably in a standard form. Many roads in the Shire are not signposted and the display of property numbers, in both rural and urban areas, is far from universal. This poses a significant problem for responding emergency services, especially those coming from out-of-area.

The application of water to both saturate and cool the fuel and to deny the fire oxygen is still the most effective means of fighting fire. The urban areas of the Shire are served with hydrants on the reticulated water supply mains. As long as there is water in the mains, these hydrants are available to be used directly for fire fighting or as a source to replenish the tanks of fire units. In rural areas, however, natural sources such as rivers and creeks, or developed sources such as dams, bores and irrigation channels are relied on for fire water.

Managing exposure: Balonne Shire is not included in the list of local government areas to which SPP 1/03 applies with respect to bushfire. Managing exposure to bushfire is, therefore, essentially the responsibility of individual land owners and is best achieved by employing the fuel management strategies discussed above.

Reducing vulnerability: The resilience of buildings and other structures constructed within fire-prone areas can be maximised by following the design guidelines contained in Australian Standard AS 3959-1999 *Building in bushfire prone areas* (Standards Australia, 1999). It is essential that buildings and their surrounds in bushfire-prone areas be well maintained if the fire resistance afforded by these standards is not to be compromised.

The ultimate responsibility for reducing vulnerability to bushfire rests with the property owner or occupier, consequently the development of an individual fire plan is essential. There are several publications available that provide advice on property fire planning.

It is important that individual property fire plans be lodged with Council and the local rural brigade so that they can be reviewed by fire management specialists and so that the information they contain, such as that relating to water supply and access, can be entered into the Council and brigade's information bases.

Treating Earthquake Risk

There is nothing that can be done to influence earthquake hazards. Given that earthquakes are a regional hazard there is also nothing that can realistically be done to reduce exposure. That leaves vulnerability as the only effective risk element that can influence earthquake risk.

Building design and construction: The Building Code of Australia (BCA) earthquake loading code aims to provide buildings that will not suffer catastrophic failure under design levels of earthquake load. The philosophy is essentially one which aims for buildings to fail safely (thus reducing the risk of injury to occupants) rather than them to be immune from failure. The vast majority of buildings in the Shire are of timber frame construction which has a good degree of inherent resilience. Many older buildings, however, are probably not in optimum condition, and their performance could be poor, particularly if they are not tied to their stumps or if their stumps are not cross-braced.

It would be appropriate for Council to seek structural engineering advice regarding their buildings, especially the Council offices.

Lifeline vulnerability: A significant amount of brittle material, especially unlined asbestos cement (AC) pipe has been used in the both St George and Dirranbandi water supply reticulation networks. Rupture of significant segments of the pipe network could reduce the availability of potable water to the community and fire fighting water to the emergency services.

As water and sewerage systems are progressively upgraded such brittle material should be replaced or lined with PVC to improve their resilience.

Risk Reduction Strategies

A wide range of potential risk reduction strategies have been identified as being capable of improving community safety in Balonne Shire. Some of these are very simple, can be implemented immediately and carry little if any cost while others will undoubtedly need to be progressively implemented over time as funds can be made available. While most are the responsibility of Balonne Shire Council to implement, some can only be implemented with the active collaboration of other levels of government or industry sectors. There are some strategies that lie completely outside the capacity of Council, but they are included in the report to provide a more holistic approach.

Conclusion

The overall risks posed to the population of Balonne Shire are relatively small and infrequent. Floods represent the most significant threat, though they also represent a significant positive for rural communities.

By adopting the strategies outlined in the report Balonne Shire Council will go a long way to eliminating the risks posed by all hazards throughout the Shire in all but the most extreme events. Their adoption will also make Balonne Shire a safer and more sustainable community.

CHAPTER 1: THE CONTEXT

This chapter outlines the factors that impact on the management of natural disaster risks in Balonne Shire.

1.1 THE STUDY AREA

This study covers the entire area administered by Balonne Shire Council (BSC). It extends over approximately 31,120 square kilometres and its centre is about 500 km west of Brisbane. The Shire lies entirely within the Murray-Darling Basin and is surrounded by Paroo, Booringa, Warroo and Waggamba Shires in Queensland and Moree Plains, Walgett and Brewarrina Shires in NSW. The study area is shown in Figure 1.1.

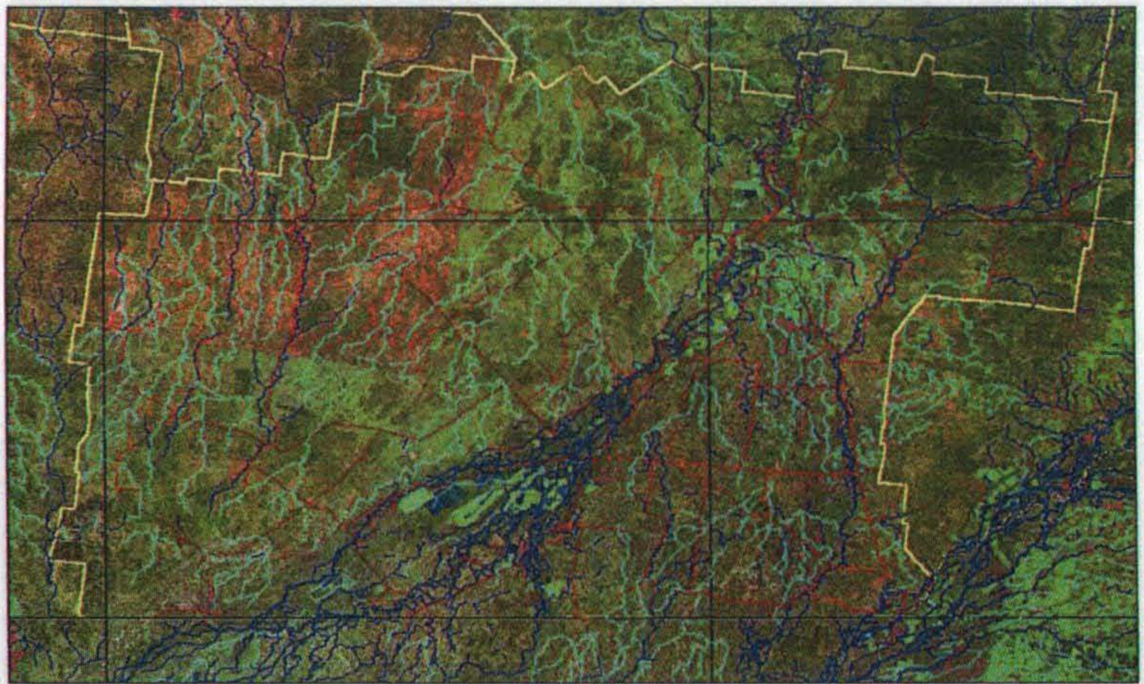

Figure 1.1: Balonne Shire (background Landsat image from GA, 2003)

1.1.1 Population and Settlement: At the national census held in September 2001, Balonne Shire had a population of 5,420. This represented a moderate growth, from the 1996 census total of 4,805. Of the total enumerated on census night, 596 were visitors to the Shire, giving a resident population of around 4,817. The two main groups of visitors were probably itinerant workers employed in the cotton and horticulture industries, and tourists. Anecdotal evidence indicates that the total population may have declined over the two years since the census as a direct result of the drought and its impact on the availability of work for itinerants. The Department of Local Government and Planning has projected an ongoing increase in the resident population which is expected to reach a total of around 5,500 by 2021 (OESR, 2003).

Population is distributed unevenly throughout the Shire. Around 70% of the population is located within the Shire's six urban centres of St George (2,453 or 51% of the Shire total), Dirranbandi (401), Bollon (155), Mungindi (97), Thallon (96) and Hebel (>50). The small communities of Nundigully, Boolba and Alton are essentially meeting places for the surrounding rural populations.

Mungindi is unique in that it straddles the Queensland – NSW border. Service agreements exist between the two states so that the provision of services such as ambulance, fire service and hospital is shared.

1.1.2 Climate: The Shire has a generally mild and moderately dry sub-tropical continental climate. It can, none-the-less be subject to extremes of both temperature and rainfall. Table 1.1 summarises the climatic statistics recorded at St George Post Office. Rainfall statistics are from 116 years of records and temperature statistics are from 35 years of records.

Table 1.1: St George Post Office selected climate statistics (source Bureau of Meteorology)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Mean max (ºC)	34.5	33.4	31.4	27.6	22.9	19.6	19.0	21.0	25.0	28.7	31.9	34.3	27.5
Highest max (ºC)	45.0	43.0	40.5	37.2	32.6	27.8	28.8	34.4	36.2	40.7	43.3	44.0	45.0
Mean min (ºC)	21.5	21.1	18.5	14.1	10.0	6.7	5.4	6.9	10.2	14.6	17.6	20.2	13.9
Lowest min (ºC)	12.8	12.2	7.8	3.3	0.5	-2.2	-1.7	-1.0	1.5	4.9	8.3	11.1	-2.2
Mean rain (mm)	74.7	61.3	54.4	32.7	39.0	33.3	33.1	25.3	26.7	38.8	45.8	51.8	516.8
9am humidity (%)	51	57	56	58	67	73	69	60	51	47	44	46	57
3pm humidity (%)	35	37	36	37	45	46	42	36	31	30	29	30	36
Highest rain (mm)	415.7	292.7	360.2	203.8	310.0	151.7	261.2	136.9	128.2	156.8	181.8	172.7	
Lowest rain (mm)	0	0	0	0	0	0	0	0	0	0	0	0	

1.1.3 Land use: Balonne Shire is dominated by agricultural land uses. The largest areas are used for dry-land grazing (sheep and cattle) and grain production (wheat, barley). Irrigation has become an important addition, with cotton and horticultural crops (grapes, vegetables) now accounting for the greatest proportion of the value of the Shire's production.

1.1.4 Disaster History: The Shire has a history of hazard impacts, particularly floods, severe storms, bushfires and earthquakes. Some of these events have produced wide spread damage and economic loss, though loss of life appears to have been a rare event.

1.2 LAND MANAGEMENT

Balonne Shire contains a wide range of both discrete and overlapping land management jurisdictions. The nature of these jurisdictions has an important bearing on the management of a number of hazards, especially bushfire.

1.2.1 BSC: Council is directly responsible for 38.39 sq km of land. This area is made up of parks and reserves including recreation reserves, town commons and the St George showground.

1.2.2 State Forests and National Parks: There are 49.28 sq km of State Forest and 552.06 sq km of National Parks within the Shire. State Forests and National Parks come under the management of the Environment Protection Authority.

1.2.3 Road, travelling stock, rail, power and drainage reserves: A variety of public authorities are responsible for road, travelling stock, rail, drainage and power supply reserves throughout the area.

They total 1,386.76 sq km in area and include land used for schools and hospitals, roads and water courses.

1.2.4 Freehold: By far the largest portion of the Shire is held under freehold title and controlled by private entities and a range of public authorities. It totals 21,268.09 sq km. There are three parcels that are more than 150 sq km in area. The area under Lake Kajarabi (Beardmore Dam), for example, is freehold land.

1.2.5 Leasehold: Crown land made available for use under lease totals 7,624.07 sq km. The majority of this land is under agricultural lease. A further 144.70 sq km is held under special lease, 139.8 sq km, or 96.6%, of special lease land is contained in two parcels on the western border of the Shire in the Narcoola area.

1.2.6 Native title and culturally sensitive sites: Several areas of Balonne Shire are the subject of claims under Native Title legislation. Successful claims under this legislation do not remove any responsibilities for use and management that may have an impact on community safety both on that land and beyond, for example bushfire fuel management.

The existence of certain sites of cultural sensitivity, such as burial sites, may, inhibit the willingness of site custodians to agree to access by emergency workers under some circumstances.

Table 1.2 details the areas and numbers of parcels in the Shire under each major form of tenure.

Table 1.2: Balonne Shire land tenure

TENURE	PARCELS	AREA (km²)	PERCENT
Council freehold	57	0.32	0.01
Council reserves	43	38.07	0.12
National Parks	11	552.06	1.77
State Forest	4	49.28	0.16
Road, travelling stock & drainage reserves	2487	1228.02	3.95
Other reserves	212	158.74	0.51
Freehold	3458	21,268.09	68.34
Leasehold	398	7624.07	24.50
Special leases	175	144.70	0.46
Other tenures	150	55.65	0.18
Totals	**6995**	**31,119.00**	

1.3 OTHER SPECIAL INTERESTS

There are, in addition to the land management interests identified above, a range of other groups that have a role in influencing the management of disaster risk in Balonne Shire. These include:

1.3.1 Murray-Darling Basin Ministerial Council and Commission: The purpose of the *Murray-Darling Basin Agreement*, signed in 1992, is to "*promote and co-ordinate effective planning and management for the equitable, efficient and sustainable use of the water, land and other environmental resources of the Murray-Darling Basin.*" The agreement establishes institutions at the political, bureaucratic and community levels, namely the Ministerial Council, Commission and Community Advisory Committee respectively.

1.3.2 Department of Natural Resources and Mines: The Department of Natural Resources and Mines (DNRM) is responsible for ensuring the sustainable development of the State's land, water, vegetation, mineral and petroleum resources. As such it has a significant role in administration, regulation, research and risk monitoring. DNRM is responsible for administering water allocations to irrigators. They are also responsible for administering dam safety regulations.

1.3.3 SunWater: Established in 1994 in response to the introduction of the Council of Australian Government (COAG) water resources policy, SunWater is responsible for managing and developing water supply for irrigation. It is a State Government enterprise (the former State Water Projects Division of the Department of Natural Resources) which operates the major irrigation infrastructure throughout Queensland. Within Balonne Shire SunWater operate the E J Beardmore Dam and Jack Taylor Weir together with their associated channels.

1.3.4 Smartrivers: A number of decisions taken in the late 1990s by both Commonwealth and State governments have had an impact on the allocation of water for irrigation. These include:

- COAG water resources policies
- National Competition Policy (NCP) agreements
- Murray-Darling Basin Agreement
- Inter-Governmental Agreement on the Environment
- National Principles on the Provision of Water for Ecosystems.

In mid 2001 these policies and agreements were translated by the State Government into a Draft Water Allocation and Management Plan (WAP) for the Condamine-Balonne Basin aimed at reducing water allocations in order to allow a greater flow of water to the environment. The draft WAP was seen by a group of St George water harvesters and Dirranbandi channel irrigators as posing a serious threat to their industry. They formed Smartrivers, a pressure group, in late 2002 to "*protect their communities from the devastating economic and social effects*" of the proposed changes in water allocation.

1.4 LEGISLATION AND STANDARDS

A range of Queensland legislation and national standards have an influence on disaster risk management within Balonne Shire. The key pieces of legislation, standards and guidelines are:

1.4.1 Emergency Services and Risk Management

Commonwealth *Meteorology Act 1955*
State Counter-Disaster Organisation Act 1975
Public Safety Preservation Act 1986
Fire and Rescue Service Act 1990
AS/NZS4360-1999 Risk management
Natural Disaster Relief Arrangements (NDRA) *Guidelines*

1.4.2 Land and Water Management

Forestry Act 1959
Nature Conservation Act 1992
Nature Conservation (Forest Reserves) Regulations 2000
Water Act 2000
Queensland Dam Safety Management Guidelines 2002

1.4.3 Planning and Construction

Integrated Planning Act 1997
State Planning Policy 1/03 Mitigating the effects of flood, bushfire and landslide
Local Government Act 1993
Building Act 1975
Building Regulation 1991
Building Standard Regulation 1993
AS 1170.2-1989 SAA Loading Code Part 2: Wind loads
AS 1170.4-1993 Minimum design loads on structures Part 4: Earthquake loads
AS3959-1999 Building in bushfire prone areas
AS3826-1998 Strengthening existing buildings for earthquake
SAA HB132.1 Structural upgrading of older houses part 1: non-cyclone areas.

1.4.4 Local Laws and Regulations

Shire of Balonne Planning Scheme (1995) and Strategic Plan
Assistance to bush fire brigades policy (1996)

1.4.5 Interstate agreements

In 1992 a mutual aid agreement between Walgett Shire Council (NSW) and Balonne Shire Council concerning the use of plant and equipment during emergencies was developed. This agreement forms part of the respective disaster plans for the two councils.

1.5 PREVIOUS STUDIES & MITIGATION ACTIVITY

No previous disaster risk management studies of Balonne Shire have been undertaken. Studies of specific issues including flood studies and a dam failure study of Beardmore Dam have been undertaken. Those that have been sighted in this study include:

- *Lower Balonne River system – floodplain management plan*, Phase 1 Study, Connell Wagner Pty Ltd, April 1994.
- *Border Rivers floodplain hydraulic analysis*, Lawson and Treloar Pty Ltd, October 1998.
- *Assessment of flood impacts – Mungindi town levee upgrade*, Lawson and Treloar Pty Ltd, January 2000.
- *Emergency action plan – E.J. Beardmore Dam*, Water Resources Commission, Department of Primary Industry, 2001.

Some flood mitigation works have been constructed to protect Mungindi, Dirranbandi and Thallon. Much of the water harvesting infrastructure is likely to have a flood reduction capability under most circumstances.

The Balonne Shire Counter Disaster Plan was produced in 1997 and is currently under review.

1.6 RISK MANAGEMENT METHODOLOGY

The risk management Standard AS/NZS 4360-1999 (SA/SNZ, 1999) defines 'risk' as:

> *the chance of something happening that will have an impact upon objectives. It is measured in terms of consequences and likelihood.*

Department of Emergency Services provide a similar definition of risk, namely:

> *A concept used to describe the likelihood of harmful consequences arising from the interaction of hazards, community and the environment.* (Zamecka and Buchanan, 1999)

The 'likelihood' component is derived largely from consideration of the hazard phenomena involved and the assessed probability of events of differing magnitude or severity occurring. It can also include measures of the 'likelihood' that those elements exposed to the hazard will be harmed, i.e. their degree of vulnerability. 'Consequences' are usually measured in terms of lives lost, people injured, damage to property and disruption to economic activity. Risk can thus be assessed in terms of the interaction between three key elements – the hazard, the community elements exposed to that hazard and their vulnerability. The relationship between these three elements is shown in Figure 1.2.

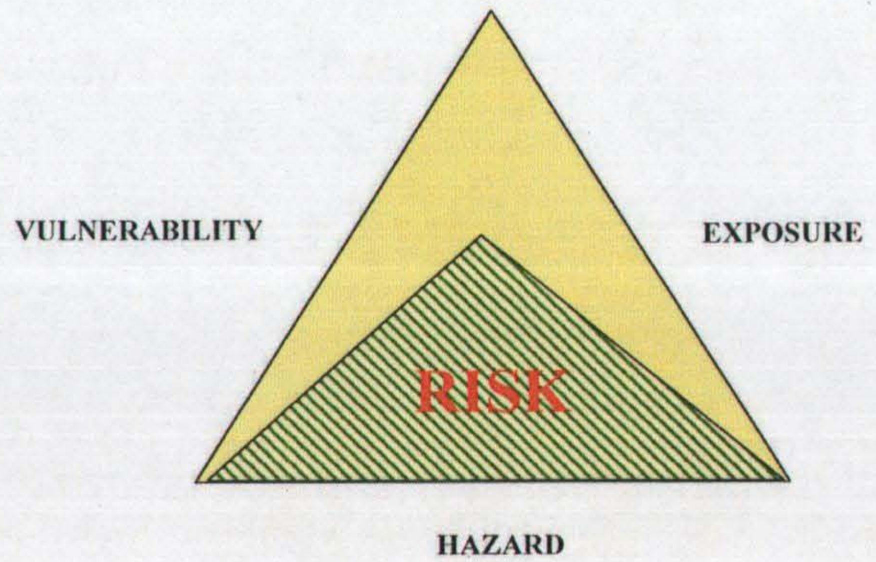

Figure 1.2: The risk-hazard-exposure-vulnerability relationship (based on Crichton, 1999 & Granger, 2001)

In the figure, the larger (yellow) triangle portrays each of the variables as being equal and risk being represented by the area of the triangle. The amount of total risk may be diminished by reducing the size of any one or more of the three contributing variables. In the smaller (green hachure) triangle the total risk has been reduced by mitigating the exposure and the vulnerability[1]. The reduction of any of the factors to zero would consequently eliminate the risk. Conversely, an increase in any one of the elements (e.g. an increase in development in areas with a recognised flood hazard) will increase the risk.

In this study, the risk assessment and risk treatment options are developed in terms of these three components.

1.7 UNDERSTANDING PROBABILITY

The allocation of event probabilities is an area of particular uncertainty and a potential source of confusion. For example, a common description of event probability is the so-called 'return period' of a particular phenomenon, typically given in a form such as 'a one-in-one hundred year flood'. Not only are such figures typically based on less than 100 years of record, it has been widely reported that such an expression of probability is prone to be misinterpreted and misused. Description of an event as a '1:100 year event' is frequently taken (wrongly) to indicate that there will not be another such event for another 100 years.

Disaster management professionals prefer to use the terms 'average recurrence interval' (ARI) and 'annual exceedence probability' (AEP) which are less ambiguous. Table 1.3 is provided to illustrate probabilities related to the chance of one or more events of a given magnitude occurring in a given time frame. In this table, an event with a given ARI occurring in a specific time frame is compared with the betting odds (given in parenthesis) that most punters are familiar with.

Table 1.3: Probability of one or more events in a specific period (from Granger, 2001)

Period in which event might occur (years)	50 year ARI (2.0% AEP)	100 year ARI (1.0% AEP)	200 year ARI (0.5% AEP)	500 year ARI (0.2% AEP)	1000 year ARI (0.01% AEP)
5	10% (10 to 1)	5% (20 to 1)	2% (50 to 1)	1% (100 to 1)	0.5% (200 to 1)
10	18% (5 to 1)	10% (10 to 1)	5% (20 to 1)	2% (50 to 1)	1% (100 to 1)
25	39% (2 to 1)	22% (5 to 1)	12% (10 to 1)	5% (20 to 1)	2% (50 to 1)
50	63% (2 to 1 on)	39% (2 to 1)	22% (5 to 1)	10% (10 to 1)	5% (20 to 1)
100	86% (7 to 1 on)	63% (2 to 1 on)	39% (2 to 1)	18% (5 to 1)	10% (10 to 1)
200	98% (near certain)	86% (7 to 1 on)	63% (2 to 1 on)	33% (3 to 1)	18% (5 to 1)
500	99.999% (certain)	99% (near certain)	92% (near certain)	63% (2 to 1 on)	39% (2 to 1)

[1] It should be noted that bushfire is the only natural hazard of significance in the Shire that can be influenced directly by human intervention. Indeed, by eliminating the available fuel, the bushfire hazard itself can be eliminated.

1.8 EVALUATION CRITERIA

The current level of risk posed by natural hazards within Balonne Shire, and the effectiveness of the risk reduction strategies suggested in this study, will be measured against the following criteria, in priority order:

1. reduce, to an acceptable level, the risk of death or injury to emergency workers engaged in responding to any hazard impact;
2. reduce, to an acceptable level, the risk of death or injury to the general population;
3. reduce, to an acceptable level, the risk of destruction or damage to public infrastructure and facilities;
4. reduce, to an acceptable level, the risk of destruction or damage to private property;
5. manage the impact of hazards on the environment to the extent that the biodiversity of both flora and fauna is maintained;
6. minimise the long-term impact on the local economy.

It is likely that conflicting views will emerge between the priority that should be given to the protection of life and property, access to flood waters by water harvesters and the priority given to environmental protection and the maintenance of biodiversity.

CHAPTER 2: THE HAZARDS

This chapter describes and analyses the hazards that have a history of serious impact within Balonne Shire.

2.1 FLOODS

Flood is defined in State Planning Policy 1/03 (DLGP/DES, 2003a, p11) as:

> *A temporary inundation of land by expanses of water that overtop the natural or artificial banks of a watercourse i.e. a stream, creek, river, estuary, lake or dam.*

To put it a bit more simply, floods are *water where and when it is not wanted.*

This multi-dimensional view is particularly relevant in Balonne Shire where floods are something of a Jekyll-and-Hyde hazard. Whilst they pose a regular, and at times serious, threat to both public and private property, they are also essential to the agricultural industries that sustain the Shire's economy. At the time of writing (November, 2003), people in the Shire are hoping for floods to replenish soil moisture and to provide water for cotton irrigation following an extensive drought.

Floods account for the largest amount of loss caused by natural hazards in Australia. Between 1967 and 1999 the annual average loss caused by floods across Australia is estimated to be $314.0 million of which Queensland contributes $111.7 million (BTE, 2001).

The Shire contains a small portion of one, and substantial portions of two, major catchments.

2.1.1 Macintyre – Weir system: Only 305 sq km of the total Macintyre-Weir catchment's total area of 44,000 sq km is contained within Balonne Shire, namely, the area around Mungindi. The total catchment is shown in Figure 2.1.

No details of the flood history at Mungindi were available to this study, however, records of floods at Goondiwindi, 150 km upstream, indicate that at least 38 major floods have occurred since records began in 1916 – that is a major flood, on average, every two years. The highest floods at Mungindi were those of 1976 and 1996.

Mungindi is protected to approximately the level of the 1976 flood by a levee. This levee does not provide protection to the Mungindi Hospital which stands on a higher point on the river bank and has its own levee. The town levee was extended in 2001 (Lawson and Treloar, 2000). The Mungindi levees are shown in Plate 1. If heavy local rain over the town coincides with a flood then pumping from inside the levee is required.

Flood warnings for the Barwon River at Mungindi are issued by the Bureau of Meteorology's Flood Warning Centre in Sydney rather than their Brisbane centre.

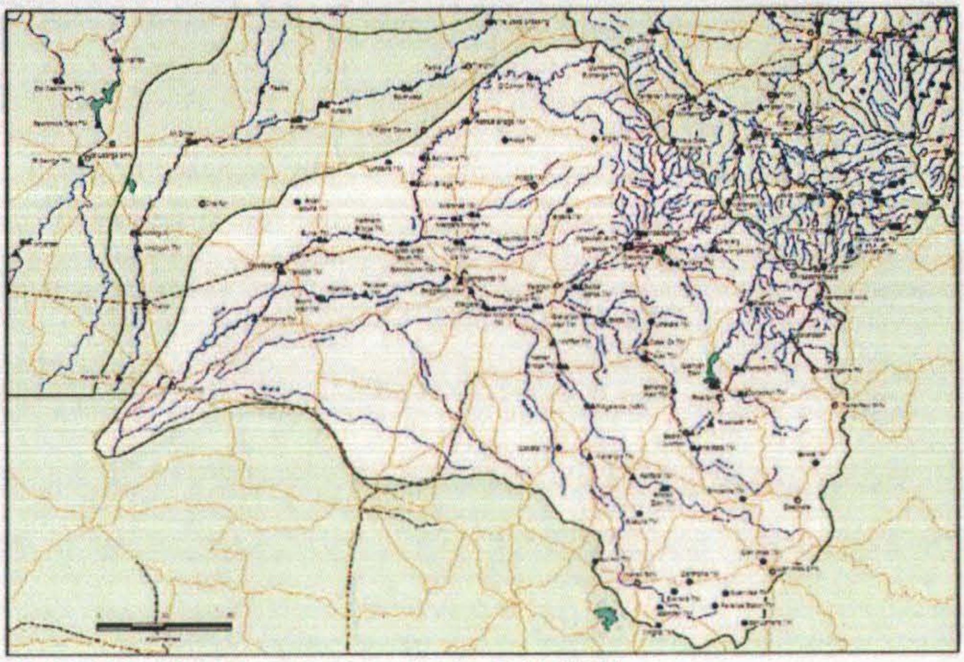

Figure 2.1: Macintyre and Weir Rivers' catchment (source BoM, 2003a)

2.1.2 Moonie River: Around 5,270 sq km of the Moonie River's 14,050 sq km catchment lies with the Shire. The whole of the catchment within Queensland is shown in Figure 2.2.

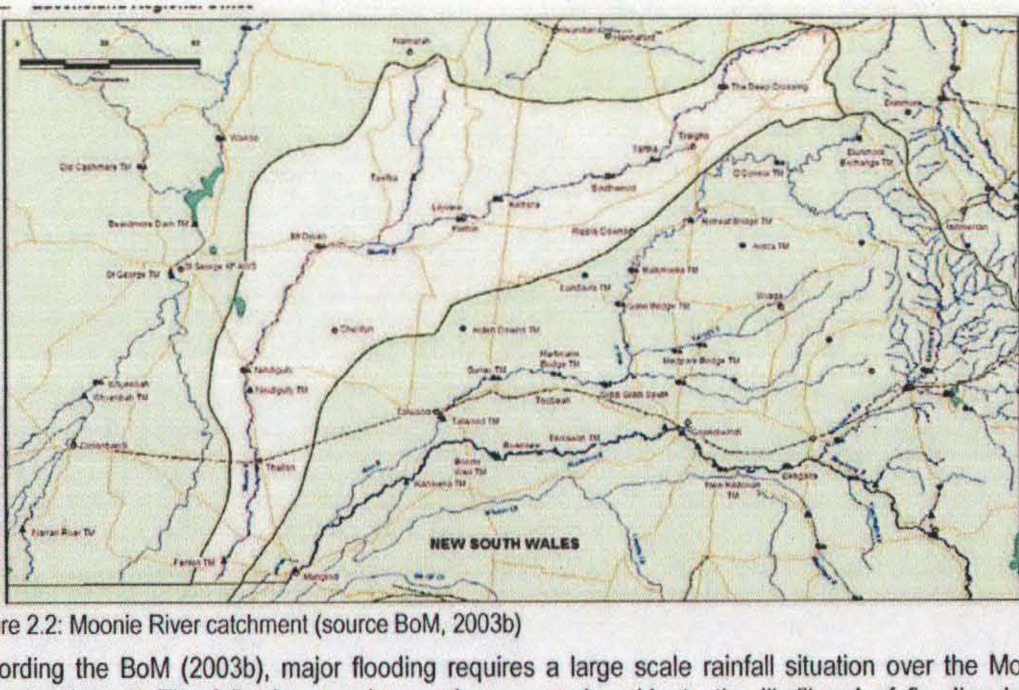

Figure 2.2: Moonie River catchment (source BoM, 2003b)

According the BoM (2003b), major flooding requires a large scale rainfall situation over the Moonie River catchment. The following can be used as a rough guide to the likelihood of flooding in the catchment:

50mm in 24 hours over isolated areas, with lesser rains of 25mm over more extensive areas will cause stream rises and the possibility of minor flooding. If lesser rainfalls have been recorded in the previous 24 to 72 hrs, then moderate to major flooding may develop.

50mm in 24 hours will cause isolated flooding in the immediate area of the heavy rain.

General 50mm or heavier falls in 24 hours over a wide area will most likely cause major flooding, particularly in the middle to lower reaches between Tartha and Mt Driven extending downstream to Nindigully, Fenton and the New South Wales and Queensland border.

(BoM, 2003b)

The highest flood on record occurred in February 1976 when waters reached a stage height of 4.15 m at Nindigully and 5.43 at Thallon (i.e. on each locality's respective flood gauge). This flood is one of the few reported to have come close to entering houses in both settlements. Such major flooding inundates many thousands of hectares of low-lying country, isolates numerous properties and closes roads, including the Carnarvon Highway. Figure 2.3 shows the flood record for Thallon since 1950. These records indicate that major flooding occurs at Thallon, on average, every four years.

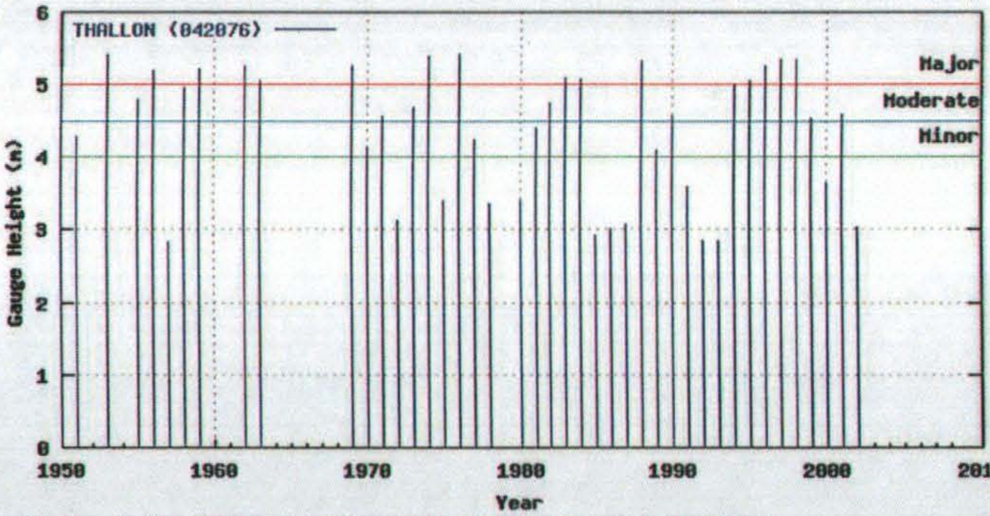

Figure 2.3: Moonie River highest annual flood peak at Thallon (source BoM, 2003b)

Stage heights for the highest known flood and recent significant floods in the Moonie River are shown in Table 2.1.

Table 2.1: Balonne Shire – significant floods in the Moonie River (source BoM, 2003b)

River height station	Highest recorded flood (in metres)		Apr 1988	Jan 1996	May 1996	Feb 1997	Sept 1998
Nindigully	Feb 1976	4.15	3.88	3.39	3.14	3.83	3.93
Thallon	Feb 1976	5.43	5.33	5.25	5.12	5.36	5.36
Fenton	Jan 1974	5.90	5.11	4.73	4.45	4.91	5.03

These flood heights may be compared with the relevant stage height thresholds at which key impacts, such as roads being cut, agricultural land inundated and town buildings being inundated. These are shown in Table 2.2.

Table 2.2: Balonne Shire – threshold stage heights for the Moonie River (source BoM, 2003b)

River Height Station	First Report Height	Crossing Height	Minor Flood Level	Crops & Grazing	Moderate Flood Level	Towns and Houses	Major Flood Level
Nindigully	2.0	3.5 (A)	2.2	2.8	3.0	4.5	4.0
Thallon	3.0	4.9 (B)	4.0	5.0	4.5	5.3	5.0
Fenton			3.5		4.3		5.0

(A) = approaches (B) = bridge

No mapping of the horizontal extent of inundation, for either historic flood events or modelled events, in the Moonie River has been available to this study. Given the low-lying nature of the Moonie River floodplain topography, however, it is likely that the depth of inundation (i.e. stage height) will increase by perhaps only 1 m between that for an event with an annual exceedence probability (AEP) of 1.0% (i.e. an average recurrence interval – ARI – of 100 years) and the probable maximum flood (PMF) event. The horizontal extent, however, could be significantly greater.

Such flooding can last many weeks. In the 1956 flood in the Moonie River, for example, it is said that some properties were isolated for six weeks (Dr John Stone, personal communication, 2003). On at least one occasion in recorded history (1864) flood waters from the Moonie merged with those from the Balonne system.

Flood protection measures at Thallon are shown in Plate 2. A levee to protect the eastern side of the settlement has recently been constructed (solid line) and the existing railway embankments (dotted line) also provide a degree of protection. No hydrological investigation was used to design these levees.

Flood warnings for the Moonie River are issued by the BoM Brisbane Flood Warning Centre.

2.1.3 Balonne – Maranoa catchment: The Condamine-Balonne river system occupies about 80% of the Shire. It is one of the major tributaries of the Murray-Darling river system and is one of the most important river systems in Queensland in terms of agriculture. The headwaters of the Condamine-Balonne rise in the Border Ranges upstream of Killarney and flow for approximately 1200 kilometres through Queensland before entering NSW, whilst the Maranoa River, which joins the Balonne in just upstream of the Beardmore Dam, rises in the Carnarvon National Park area of the Great Dividing Range and Chesterton Range.

Also included in this catchment are the Nebine, Mungallala and Wallam Creeks which drain the Chesterton and Brunel Ranges to the north. In flood, the waters of these creeks join the Culgoa – Balonne system in NSW.

Figure 2.4 shows the extent of the Balonne – Maranoa section of the catchment.

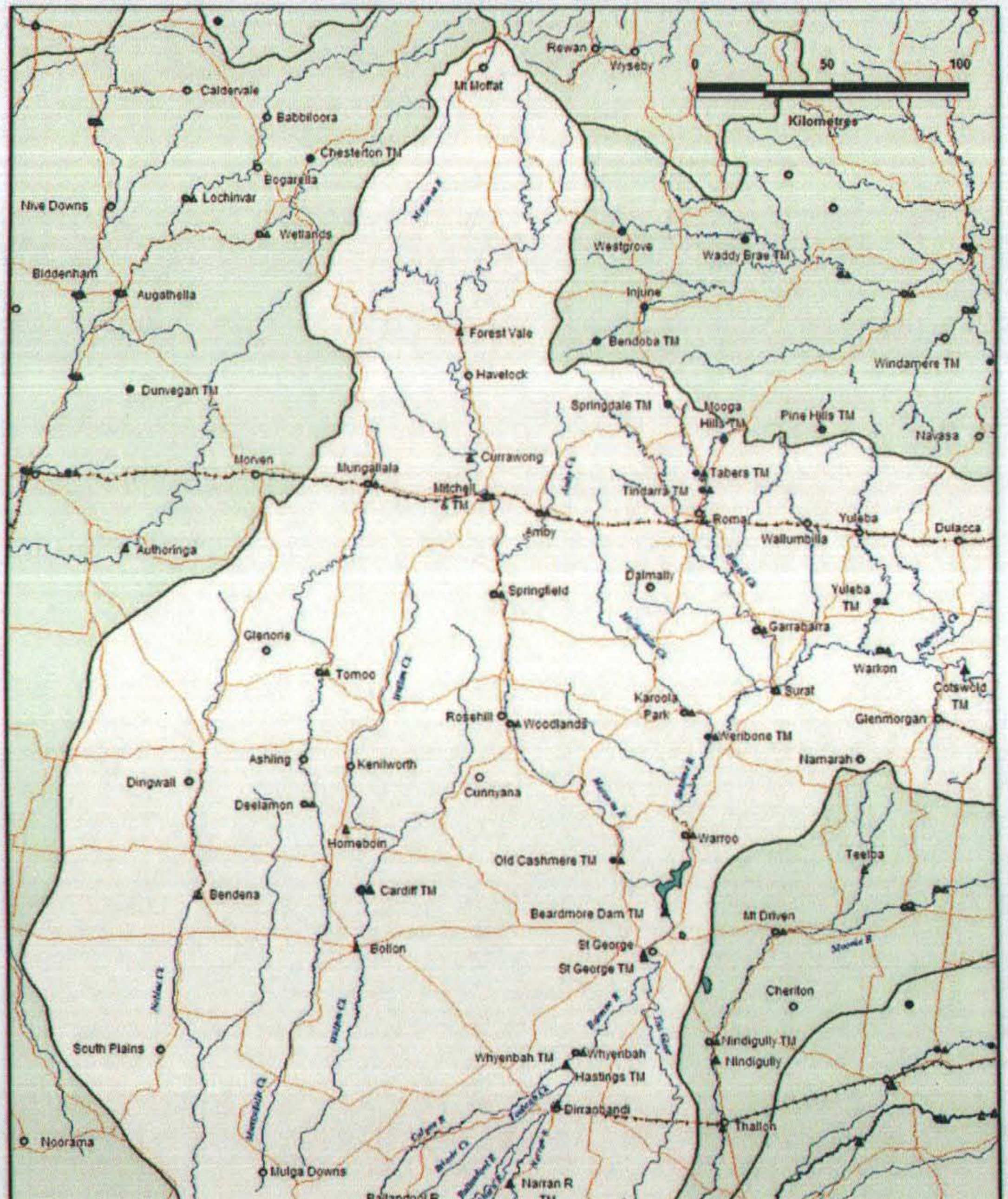

Figure 2.4: Balonne-Maranoa catchment (source BoM, 2003c)

Major floods do not necessarily develop in the headwater areas of the catchment but can result from heavy rainfall in any of the large tributaries which enter the main Balonne River. In 1990, for example, the Maranoa River experienced a major flood which extended to the NSW border. There was no significant flooding, however, in the main Balonne system.

The most significant effects of flooding along the Balonne River are the widespread inundation of agricultural land, the cutting of roads, the isolation of rural homes and properties and the loss and damages suffered in these areas. Damage to fencing, pumping equipment, machinery and loss of stock through drowning, results in significant losses during major floods.

According to the BoM (2003c) major flooding in the Condamine - Balonne River catchment downstream of Cotswold requires a large scale rainfall situation. The following can be used as a rough guide to the likelihood of flooding in the catchment:

> *Average catchment rainfalls in excess 25mm, with isolated 50mm falls, in 24 hours may result in stream rises and the possibility of minor flooding and local traffic disabilities and extending downstream.*
>
> *Average catchment rainfalls in excess of 50mm, with isolated 75 to 100mm falls, in 24 hours may result in significant stream rises with the possibility of moderate to major flooding developing with local traffic disabilities and extending downstream.*

Records of large floods along the Balonne River extend back to the 1860s at St George with extensive records at several other locations on the main stream. In the past 100 years major floods have occurred, on average, every 2 years.

The worst flooding occurred in 1864, 1890, 1942, 1950, 1956, 1975, 1976, 1983 (twice), 1988, 1990 and 1996. Details of recorded floods in the Balonne at St George are given in Appendix A and stage heights for recent significant floods are shown in Table 2.3.

Table 2.3: Balonne Shire – significant floods in the Balonne River (source BoM, 2003c)

River height station	Highest recorded flood		Feb 1942	Jan/Feb 1956	May 1983	Apr 1988	Jan 1996
St George	Apr 1990	12.24	9.14*	10.80*	11.17	9.90	10.98
Whyenbah	Aug 1950	8.18		7.82	7.97	7.81	8.0
Dirranbandi	Jan 1922	5.26	5.08	5.16	5.14	5.10	5.12
Hebel	May 1983	2.30			2.30	2.10	2.25

*These readings were taken at old flood gauges which cannot be related to the current gauge heights.

Major floods generally occur in the first half of the year, although records indicate that they may also occur in late spring. Figure 2.5 provides the flood history at St George. The modern flood of record at St George was that of April 1990 with a stage height of 12.24 m, however the flood of 1890 had an equivalent stage height of at least 13.1 m. It is also clear that there is a significant gap in the records between 1900 and 1920.

These flood heights may be compared with the relevant stage height thresholds at which key impacts, such as roads being cut, agricultural land inundated and town buildings being inundated. These are shown in Table 2.4.

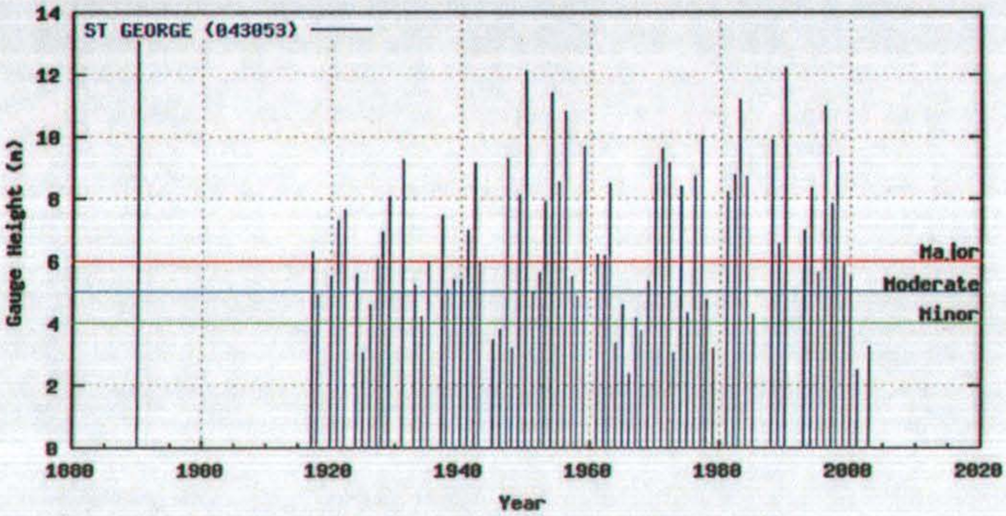

Figure 2.5: Balonne River highest annual flood peak at St George (source BoM, 2003c)

Table 2.4: Balonne Shire – threshold stage heights for the Balonne River (source BoM, 2003c)

River Height Station	First Report Height	Crossing Height	Minor Flood Level	Crops & Grazing	Moderate Flood Level	Towns and Houses	Major Flood Level
St George	2.0	10.7 (B)	4.0	11.0	5.0	12.1	6.0
Whyenbah	3.0	5.3 (B)	4.0		6.0		7.0
Dirranbandi	2.0	5.2 (B)	4.0	4.0	4.3		4.8
Hebel	1.0		1.0		1.5		2.0

(B) = bridge

The 1990 flood did not enter homes in St George but did affect a few town properties on lower ground down stream of the Jack Taylor Weir.

The only mapping of the horizontal extent of inundation for either historic flood events or modelled events for the Balonne River, or the creeks to the west, available for this study is the modelling undertaken by Connell Wagner for the Department of Primary Industry in 1994 (Connell Wagner, 1994). That study does not contain any indication of the event probability used in that modelling but it is assumed to be a 100 year ARI event. St George township is not included in the modelled 'floodplain'[2].

The following accounts of floods in the 1860s, 70s and 90s, including the 1890 flood, clearly show that St George is in the floodplain. Both accounts were included in the *St George Centenary Souvenir 1846-1946*. The first was attributed to "Coolibah" and taken from the *Australian Pastoralist* 1917 and reprinted from *Beacon* files:

> *Looking back over my weather notes I am reminded of some the floods that came over this country of rivers from Surat to Mungindi; and the lower Narran. There were heavy floods in July 1862 and in*

[2] 'Floodplain' is formally define in *SPP 1/03* as: 'an area of land adjacent to a creek, river, estuary, lake, dam or artificial channel, which is subject to inundation by the Probable Maximum Flood (PMF)'.

> *February 1863. Coincident with heavy gales and floods on the coast there were floods in the S.W. country which caused great loss of stock, especially around Surat where further floods occurred in October of the same year. 1864 was noted for its February floods. There were 13 days rain from the 26th of that month, while heavy rain fell in March and April. Generally speaking it was an awful year for rain and floods.* ***The Moonie and Balonne Rivers joined and made a sheet of water over 25 miles wide.*** *Tooth's Merivale station was swept away; Mr Browne of Southwood lost 1500 out of 1800 sheep; Beck of Canmaroo lost 250 rams; and* ***Sam Hyland's store on the Balonne was swept away, the water rising 12 feet over the banks – a rushing torrent of water.*** *There were heavy rains in 1865 and floods in '66. This latter year was also noted for the severe cold winter. The cattle became so poor and impoverished by starvation and cold that they were unable to travel, and the south-western townships were put to great straits. There was no butter, milk etc obtainable and the people were compelled to live on flour and water. On August 25th there was ice half an inch thick on any standing water. Heavy frosts were common in 1872.*
>
> *1868 was another wet year, floods succeeding floods. In April the country was in places like a sea. 1870 was another wet year. There were heavy rains and floods in March and August. 1875 was another bad year. There were floods in March which on the upper Maranoa and Dawson were records. In this month 45 persons were on a punt at Laurel Bank on the Dawson for several days and only after strenuous efforts were they rescued. In December 1873 there were great floods on the Condamine and Balonne and late in January 1877 Surat, St George and Cunnamulla were surrounded by waters. 1878 was a flood year, while in July and August the heavy rains caused the four rivers to almost meet between the junction of the Coogoon. In 1883 the floods were heavy but Goondiwindi suffered most, the residents there were busy night and day damming back the Barwon waters which threatened to sweep away the township at any moment.* ***In 1886 there was a famine at St George owing to the non receipt of supplies through the floods.*** *1890 was a flood year. On March 30th the Balonne at St George rose 40 feet above the normal level. In 1891 there was a fall of 16 inches in January, a record fall. In 1893 heavy floods visited the district in June while 1907 and 1908 were bad years in this regard. In between whiles we had droughts, some bad, others worse and some awful; when the whole country was a realm of bleached bones and broken hearts of pioneers. South-west Queensland has been kind in spots and unkind in lumps.* (emphasis added)

The store referred to as having been swept away in the 1864 flood is said to have been located on the site now occupied by the Australian Hotel (Ken Murchison, personal communication, 2003). The second account provides details of the 1980 flood.

> *At the height of St George's famous Ninety Flood, the site of the town was completely submerged. The Balonne for miles had overflowed its banks, spreading a brown sea through houses, along streets, until many inhabitants were forced to evacuate and seek higher ground.*
>
> *Their main camp was located on the sandy ridge southeast of the present bridge, where, during the flood, diphtheria broke out, but no deaths occurred.*
>
> *The only safe route to the hospital was via the rear of the town and it seems fantastic today to record that the entire journey was made by boat.*
>
> *In those days, when regattas were popular, St George claimed numerous boats and these proved invaluable during the anxious days of the flood. The old, bark-constructed Q.N. Bank served as a temporary hospital and as a depot from which the late James Tosh (then bank manager) directed rescue work and the distribution of supplies.*

Flour was scarce. But goats, pumpkins and the fowls which had taken refuge on roof tops, enabled the inhabitants to survive until the late Will Digger and others brought flour from Dalby.

During the 14 days when the water remained stationary the streets were submerged to a depth of four feet and more.

On one occasion a boat from St George was rowed the entire six miles to Boombah, through the orchard at Riverston where a load of oranges was picked from half submerged trees and taken to the station.

Deep holes remained in the streets twelve months after the water had passed and a hollow in the Church of England sand hill today marks the pit from which sand for repairs was taken.

St George in the first half century of its existence recorded some memorable floods but none so prolonged or destructive as the famous '90. (emphasis added)

In the absence of other investigations, it may be safe to assume that the 1990 flood level (a stage height of 12.4 m) represents a flood with an ARI of approximately 100 years. The stage height for the flood of 1890 (at least 13.1 m) may then represent an ARI of 150 to 200 years, whilst the 1864 flood (stage height assumed to be about 15.5 m) may represent a flood with an ARI of 250 to 500 years.

The Connell Wagner 'floodplain' covers 3570 sq km of country below St George (Connell Wagner, 1994, p19). This includes the township of Dirranbandi and all of the properties that lie between the Culgoa and Narran Rivers. Approximately 930 people live in this area.

A visual inspection of Landsat imagery of the 1990 flood (Plate 3) confirms the general pattern and extent of inundation indicated by the Connell Wagner study. A digital analysis of that imagery would enable a more detailed analysis of flood extent to be undertaken.

A flood of the magnitude of the 1890 event would directly expose, or indirectly affect through isolation, at least 3850 people. That figure includes the population of St George, which has no structural defences against flood.

Dirranbandi is afforded some flood protection by a series of levees along the eastern and southern and western sides of the town. The natural river levee provides some protection along the northern side of the town. These are shown in Plate 4.

No hydrological study was undertaken to determine an appropriate height for these levees. It would be prudent, however, to assume that they will <u>not</u> provide protection from a 100 year ARI event. If heavy local rain coincides with a flood then pumping from inside the levee is required.

Hebel is located on higher ground and is not affected by river flooding (Plate 5).

Floods in the western creek systems also pose a threat to rural properties and to the township of Bollon. Extensive floods were experienced in these catchments in May 1983, April 1990 and February 1997.

The flood record for Wallam Creek is shown in Figure 2.6 and flooding during the 1997 event is shown in plates 6, 7 and 8.

A program of vegetation management along Wallam Creek down stream of Bollon has been implemented in an attempt to reduce flood levels.

Flood warnings for the Balonne River-Maranoa system are issued by the Brisbane Flood Warning Centre.

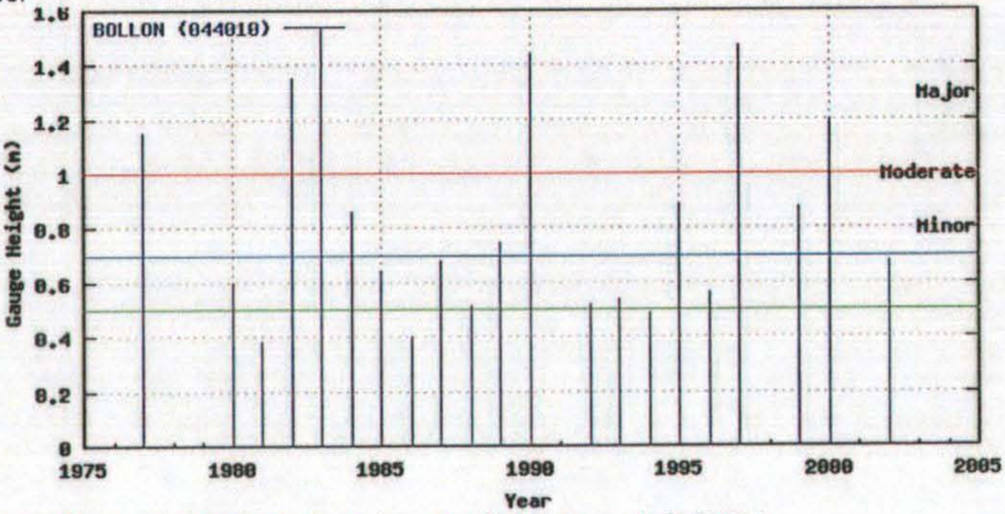

Figure 2.6: Wallam Creek highest annual flood peak at Bollon (source BoM, 2003d)

In all catchments, flood peaks can last for several days or weeks as evident from the accounts of the 1890 flood, where water remained at its peak in St George for 14 days.

2.1.4 Dam failure: Flooding would occur in the lower Balonne River were the E.J. Beardmore Dam to fail, either as result of structural failure, serious overtopping during a flood or as result of a significant earthquake. The emergency action plan for this dam (DPI, 2001) provides three dam failure scenarios:

- 'sunny day failure' breach in the main embankment;
- 'sunny day failure' caused by the sudden removal of the flood gate;
- fifty-four hour probable maximum flood (PMF)[3] event with no dam failure.

The consequences of such events are analysed and details provided for St George, however, areas further south are not addressed.

Under the first two scenarios, the only consequence of significance would be the closure of the Balonne Highway which crosses the Jack Taylor Weir (Plate 9). This would occur approximately two hours after the start of the breach forming. The road would be inundated to a depth of approximately 3m for at least 150 hours in both instances.

[3] 'Probable Maximum Flood' is defined as a flood resulting from the probable maximum precipitation (PMP) coupled with the worst flood producing catchment conditions that can be realistically expected in the prevailing meteorological conditions. 'Probable Maximum precipitation' is the theoretical greatest depth of precipitation for a given duration that is physically possible over a particular drainage system. (DPI, 2001)

Under the third scenario, flooding of truly biblical proportions would be experienced. The dam wall would be overtopped for a period of 118 hours commencing 26 hours after the arrival of the first inflow. The junction of the Carnarvon and Moonie Highways would be inundated to a depth of 5 m for almost 10 days (222.4 hours) beginning 36 hours after the first inflow. In St George township, the flood waters would reach a depth of 6.75 m above the Balonne River bank for 265 hours commencing 42.4 hours after initial inflow, whilst the Balonne Highway across the Jack Taylor Weir would be inundated to a depth of 10.69 m for 356.8 hours. No assessment of the potential impact of such an event is provided for areas downstream of St George.

The probability of such an event happening, however, is extremely small (an ARI of probably more than 150,000 years).

No information was available on dam safety relating to the numerous irrigation ring dams, some of which have walls of 5 m or more in height.

2.1.5 <u>Flood mitigation works</u>: Other than the levees at Mungindi, Dirranbandi and Thallon, no major flood mitigation works have been constructed on any of the streams in the Shire. The Beardmore Dam at the junction of the Maranoa and Balonne Rivers provides a minimal flood detention capability, whilst the water harvesting infrastructure developed within the Moonie and Balonne catchments will have some influence on flood height downstream of those works.

2.1.6 <u>Warnings</u>: The BoM flood warning network is extensive and efficient, as are informal warning systems run by rural communities. With the exception of Wallum Creek at Bollon, floods in all of the catchments in the Shire rise relatively slowly and flood warnings are usually measured in days rather than hours. Floods can rise at Bollon in a matter of hours. The Shire communities are also relatively familiar with coping with flood and are adept at translating forecast stage heights to their own localities.

2.2 TROPICAL CYCLONES AND SEVERE THUNDERSTORMS

Tropical cyclones and severe thunderstorms each bring with them potentially destructive winds and intense rainfall. Thunderstorms also bring with them potential for damaging hail and lightning strike. Both forms of severe weather have had damaging impacts within Balonne Shire. In this section, only the severe wind, hail and lightning threat will be addressed. Intense rainfall leading to flooding has been addressed in section 2.1 FLOODS above.

<u>Tropical cyclones</u> are defined by the World Meteorological Organisation (WMO, 1997) as:

> *A non-frontal cyclone of synoptic scale developing over tropical waters and having a definite organized wind circulation with average wind of 34 knots (63 km/h) or more surrounding the centre.*

These are very large-scale and intense tropical low pressure weather systems that form over warm tropical seas, generally during the warmer months between November and April. Typically, they degenerate rapidly into rain depressions once they cross the coast, however, at least five, systems have come within 200 km of St George whilst still classified as cyclones.

Thunderstorms are, by comparison, a relatively small scale convective process which can occur when the atmosphere is moist and unstable. Many thunderstorms are typically short-lived (up to an hour) and limited in size (up to 10 km in diameter) but can traverse large distances during that time and are capable of inflicting significant damage (Kessler, 1983). Individual storm impacts can vary significantly both in space and time. In Australia, a *severe thunderstorm* is defined as a thunderstorm which causes one or more of the following phenomena (BoM, 1995a):

- *a tornado;*
- *wind gusts of 90 km/h or more at 10 m above the ground;*
- *hail with diameter of 20 mm or more at the ground;*
- *an hourly rainfall intensity in excess of the 10 year ARI for a region (about 70 mm/h or greater, dependent on the location and previous rainfall).*

Interestingly, lightning is not used as a discriminator of thunderstorm intensity. Almost all convective storms will exhibit some lightning and hence some thunder and there is no established link between lightning display and overall storm intensity.

Between 1967 and 1999 severe storms were the cause of the second largest losses (after flood) caused by all natural hazards in Australia. It has been estimated that nationally, severe storms caused on average $284.4 million damage each year, of which Queensland contributed an average $37.3 million (BTE, 2001). Cyclones accounted for a national average annual loss of $266.2 million, of which Queensland incurred an average $89.8 million annually.

2.2.1 Impact history: The following notes on cyclone impacts are based on material compiled by Mr Jeff Callaghan of the Severe Weather Section of BoM Queensland Regional Office in Brisbane. At least five tropical cyclones have come within 200 km of St George. The first was in February 1928. This unnamed cyclone formed in the southern Coral Sea and crossed the coast at Brisbane on 14 February. It did extensive damage in coastal areas and brought very heavy rain to inland areas. Killarney received 240 mm of rain in one hour, leading to a rise of more than 5 m in the Condamine River in 40 minutes – and subsequent flooding at St George.

The second was in January 1950. This unnamed cyclone formed in the Gulf of Carpentaria on 16 January and tracked generally south-south-east, approaching to the east of St George on 18 January as a Category 1 system before reaching the Sydney area on 19 January. This cyclone caused considerable damage in coastal areas around Brisbane and 7 lives were lost in NSW. The extent of damage in Balonne Shire is not recorded.

In 1959 two cyclones approached the area. The first, TC *Beatrice*, formed in the Coral Sea on 21 January and crossed the coast near Lismore NSW and tracked west to the Balonne area. It is reported to have caused widespread flooding. The second, TC *Connie*, formed in the northern Coral Sea on 11 February and crossed the coast at Bowen on 16 February as a Category 3 system before tracking south until it passed to the east of St George on 17 February. It produced extensive flooding across Queensland and northern NSW.

The fifth, and most damaging, system was TC *Audrey* in January 1964. Known locally as 'Little Audrey' after the comic-strip character, *Audrey* formed in the Gulf of Carpentaria around 7 January and tracked south until it hit St George at 8 am on 14 January. At least 52 houses lost all or part of their roofs and

22 of the business houses were badly damaged. Other towns in the region, including Goondiwindi and Boggabilla suffered damage. *Audrey* finally petered out in the Coffs Harbour area.

Figure 2.7 shows the approximate tracks of these five cyclones based on BoM 'best track' data.

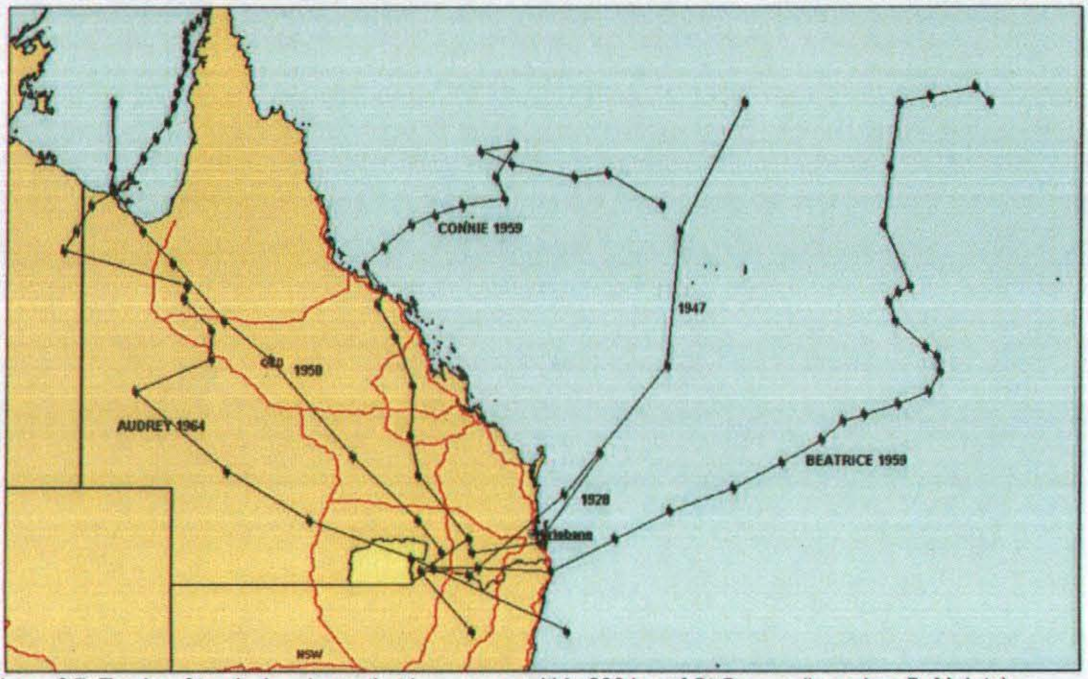

Figure 2.7: Tracks of tropical cyclones that have come within 200 km of St George (based on BoM data)

The record of severe storm impacts is not as comprehensive as that for cyclones, however, six recent storms illustrate the reality of severe thunderstorm impacts. The following information is based on records provided by Mr Tony Webb, also of the Severe Weather Section of BoM Queensland Regional Office.

1 January 1995: A severe storm affected Bollon. A newspaper report described "high winds snapping gum trees like toothpicks."

4 December 1995: A house in St George was completely unroofed by a storm.

30 January 1999: Hebel was all but flattened by a severe hailstorm (possibly a tornado) which struck about 7pm with wind gusts estimated at 160-180 km/h with the following results:

- 15 of the town's 20 houses were unroofed;
- large hail smashed windows. A store owner described hail the size of cigarette packets (estimated 7.5cm) being blown horizontally through the front of his store to strike the back wall 44 feet away
- the town hall was described as being "close to a write off" and the local sporting complex had only one wall left standing
- caravans were blown up to 40m

- sheets of galvanized iron were later found up to 5km from the town
- the town was declared a disaster area.

Dirranbandi also sustained damage from a severe storm earlier in the day (about 4:30pm). Two homes on the property 'Beverley' were damaged by 4cm hail. An eye witness described a "swirling motion" in a lowering from the cloud base associated with the storm.

26 February 1999: St George was struck by a severe thunderstorm at about 9:30am. Numerous trees were brought down by wind gusts. One hotel lost part of its roof. The Bureau of Meteorology automatic weather station recorded wind gusts up to 55 knots (100 km/h). 83mm of rainfall was recorded in half an hour and there was some flash flooding.

27 October 2002: Seven sheep were killed by hail near Moonie. Hail damage to sheds, vehicles, and wheat crops was also incurred.

15 May 2003: A severe hailstorm struck Surat (outside the Shire to the north) at about 12:30pm. Golf ball sized hail fell for 15 minutes. Many windows in the town were smashed. The mail utility was dented and its windscreen smashed. Several trees were uprooted and one house unroofed by wind gusts.

2.2.2 Severe wind: Most of the damage done by cyclones is caused by their strong winds. The most severe winds, however, are associated with the tornadoes that may be spawned by a super-cell thunderstorm. Peak wind speeds in these storms are estimated to approach 450 km/h in the largest tornadoes, although actual measurements are sparse. Their spatial extent, however, is small, ranging from just a few tens of metres up to a few kilometres. Track lengths typically vary from as little as 1 km and can extend for over 100 km, if conditions are 'favourable'.

Wind damage tends to increase disproportionately to the wind speed. According to Meyer (1997), winds of 70 m/sec (250 km/h) cause, on average, 70 times the damage of winds of 35 m/sec (125 km/h). Damage tends to start where sustained wind speeds begin to exceed 20 m/sec (about 75 km/h). In addition to the high wind speeds, the turbulence of the winds caused by terrain features and large buildings is also a decisive factor.

Thankfully, the strength of severe winds from thunderstorms is inversely related to the area they impact. For example, very severe downdrafts (or microbursts) can attain speeds of more than 200 km/h and affect areas up to 1 km wide, while severe tornadoes might have winds in excess of 400 km/h but are typically restricted to widths of less than 100 m (Fujita, 1981).

Severe winds can destroy buildings, flatten standing crops, bring down power lines and block roads with fallen vegetation. People are most at risk of injury or death from wind driven projectiles such as roofing iron and tree branches.

No part of the Shire is immune from severe wind damage.

2.2.3 Hail: BoM records suggest that approximately 30% of all severe thunderstorms produce damaging hail, with actual sizes varying depending on the strength of the recirculating updrafts in the storm system. Hail is thought to grow by the accumulation of super-cooled water droplets as the hail nucleus is supported by the strong updrafts. Eventually, the mass of ice particles cannot be maintained and the hailstones typically fall in intermittent 'shafts', which form damage swaths at ground level due to the forward movement of the storm. These swaths vary from a few kilometres in width and up to 10 kilometres in length. However, the formation of hail (and lightning) is not completely understood.

Hail can destroy standing crops such as wheat and cotton, kill livestock, do extensive damage to buildings and vehicles in the open, damage power supply and telecommunications infrastructure and block roads. Under the more extreme conditions hail can kill or seriously injure people.

No area in the Shire is immune from hail impact.

2.2.4 Lightning: Almost all storms produce some lightning and associated thunder. An average thunderstorm produces a few lightning flashes each minute and generates several hundred megawatts of electrical power during its lifetime.

Specific lightning protection is required for commercial and industrial buildings and structures to provide isolation for electrical, telecommunications and computer equipment and personnel who operate such systems. As well as the immediate impact of the peak current from a lightning strike, earth potential rise (EPR) is a common cause of extensive damage to underground cables and is the most common form of injury through the use of telephones during an electrical storm (Quelch and Byrne, 1992). Telephone subscribers are warned against the possibility of lightning-induced electrical or acoustic shock if the handset is used during thunderstorms. Lightning strike can also start wildfires.

Fatalities from lightning strike are relatively rare, however during the period 1803 – 1991 some 650 people were killed by lightning strike in Australia. These fatalities are especially seasonal and gender/age-based. Over 85% of all outdoor lightning strike victims have been males between the ages of 15 and 19 struck between midday and 6pm in the summer months of November to February. Historically, most outdoor fatalities involved those working on the land, however, urbanization and the rise in outdoor recreation, especially water related sports, golf and cricket, is changing this statistic (Coates and others, 1993).

No area of the Shire is immune from lightning strike.

2.2.5 Warnings: The approach of cyclones is well tracked for several days before they are within destructive range so warnings are good.

Modern weather radar systems are proving invaluable for detecting and tracking severe thunderstorms. This information is used to provide as long a warning time as possible. There are instances, however, when storms form very rapidly and practical warnings are not possible. This can be the case in the Balonne Shire which is not completely covered by the BoM weather radar network - there is a gap between the coverage provided by the Charleville and Moree radars.

2.3 BUSHFIRES

Bushfires are defined in SPP 1/03 as:

> *an uncontrolled fire burning in forest, scrub or grassland vegetation, also referred to as wildfire.*
> (DLGP/DES, 2003, p 10)

From 1967 to 1999 bushfires cost the Australian community an average $77.2 million annually, whilst Queensland's annual loss was only $0.4 million.

Most of the native vegetation types encountered in Balonne Shire are fire tolerant or fire climax forms. This provides a clear indication that fire has played a major part in the evolution of the area's landscape over many millennia.

For a bushfire to start and to be sustained, three things are needed:

- there must be fuel available to burn;
- there must be sufficient heat to cause and maintain ignition, and;
- there must be sufficient oxygen to sustain combustion.

If any one of these is absent, or inadequate, the fire will either not start in the first place, or will not spread.

2.3.1 <u>Bushfire history</u>: In Balonne Shire, fire has long been used as a major land management tool. Bushfires are, consequently, a common feature in the Shire. Losses from bushfires, whether started naturally by lightning or deliberately started, have typically been small and confined to assets such as fencing, pasture, crops and livestock. Records of bushfires are, however, sketchy at best. The earliest records of significant bushfires in the Shire held by the QFRS Rural Fire Service are for fires in September 1941 when fires around St George were amongst numerous outbreaks across the south-west of the State. In 1943 fires burnt some 45,000 ha near Dirranbandi. One anecdotal local report indicates that a major fire impacted the area in 1910. This is said to have burnt 'from the border to the Carnarvon Range'. A second major fire episode started on 10 October 1951 and burnt from Dirranbandi to St George. Many sheep were reported killed in this fire (Ken Murchison, personal communication, 2003). More recently, a bushfire is said to have threatened Thallon in 2000.

Episodes of drought certainly contribute to heightened fire hazard in forest and scrub areas, with deep curing of heavier fuels and an increase in leaf and bark drop, especially from eucalypts and cypress pines. Drought also significantly reduces the availability of fire-fighting water in streams, dams and tanks. In grasslands and pasture areas, by contrast, drought can virtually eliminate the fire hazard because there is little fuel to burn. The 1910 and 1951 fires were said to have been preceded by major droughts (1902 and 1946) which were in turn followed by several 'good seasons' that gave rise to the build up of fuels, especially grasses.

2.3.2 <u>Fire weather</u>: The incidence and severity of fire is most closely linked to the occurrence of episodes of 'fire weather' – days, or sequences of days, with low humidity (below 25%), high temperatures (above 30°C) and sustained winds of more than 25 km/hr (measured at 3.00 pm). BoM data from St George since January 1962 were analysed for occurrences of such conditions. There were

113 days over the 41 years that met the 'fire weather' criteria, i.e. approximately three days a year on average. There were 11 years in which no days of fire weather occurred, and nine years in which five or more days were recorded (i.e. roughly one year in four will have 'bad' fire weather conditions). The most days in any one year was 12 in both 1965 and 1970. Such conditions in Balonne Shire tend to occur during the spring and summer period (October to February) as shown in Figure 2.8.

This record of fire weather shows that wind direction on those days has been predominantly from a south-westerly direction (32.5% of all records), followed by south-east and west, 15.7% each, and south with 14.5%.

The most extreme episode of fire weather was probably from 1 to 6 November 1965 when four of the six days met the criteria. The three consecutive days from 6 to 8 January 1994 was also a significant episode. A further eight episodes of two consecutive days of fire weather were recorded.

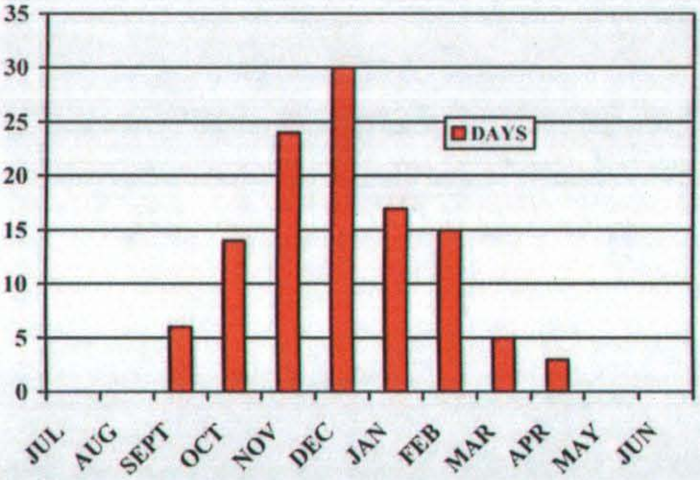

Figure 2.8: Monthly incidence of fire weather days at St George 1962 to 2001 (BoM data)

2.3.3 The bushfire hazard: The intensity of a bushfire, and thus its destructive potential, is determined by three factors. The **heat yield** of most vegetation types in Balonne Shire is high. The eucalypt, cypress and wattle trees of the forests, scrub and woodlands of the Shire all produce naturally volatile substances. These fuels invariably produce more intense fires and yield more heat than do grasses, pasture or crops such as wheat. The greater heat energy released by scrub and forest fires makes it potentially more damaging to houses and other buildings than that from grass fires. The heavier fuels also produce airborne embers and firebrands which can start spot fires well ahead of the fire front. Grass fires, by comparison, consume the available fuel much more quickly and produce few embers.

The second factor is the **rate of spread**. In Balonne Shire this is most influenced by weather. Rising temperatures and wind velocities, and decreasing humidity, directly contribute to an increase in both the rate of fire spread and its intensity. As fuels dry out, ignition becomes easier and the rate of spread increases. Winds can also assist the spread of fire by constantly replenishing the oxygen supply and by carrying heat and burning embers to new fuels (causing spot fires ahead of the fire front) or by bending the flames closer to unburned fuels ahead of the fire. Doubling the wind speed will quadruple the rate of spread of the fire. Hot and dry air can lower the moisture content of forest and grassland fuels to around 5% (and in extreme cases to 2-3%,) greatly increasing the spread of fire.

The third factor is the amount and nature of the **fuel** available. This can be influenced by the nature of the preceding growth season(s) – a wet summer will give rise to much more growth than will a dry summer; the length of time since the area was last burnt (either by a previous bushfire or by fuel reduction burning); and by other land management practices such as cultivation, grazing, slashing, irrigation and so on. Vegetation clearing practices are also influential here. In areas in which vegetation or regrowth has been 'pulled' and windrows not burnt, the fallen timber can provide significant quantities of fuel. This can be greatly exacerbated by subsequent regrowth.

2.3.4 Hazard mapping: The potential bushfire hazard can be analysed by integrating mapping of the vegetation type (to account for intensity and fuel), the terrain slope (rate of spread) and the aspect of the slope (also influential in the rate of spread). The most recently published QFRS Rural Fire Service bushfire hazard mapping methodology is provided in Appendix 3 of the Guidelines to SPP 1/03 (DLGP/DES, 2003b).

It must be emphasised that this methodology has been designed to map bushfire hazard potential as a guide for land use planning and development into the future. It is not designed as a tool for fire management, though the elements included may be employed for that end use.

Under this methodology (designed to provide relative bushfire hazard across Queensland) the bulk of the remaining tall natural and regrowth vegetation in the Shire ('grassy eucalypt forest and cypress pine forest') carries a weight of 6 (out of 10). The other broad vegetation categories which include 'native grassland (un-grazed) and open woodland' (score of 5) and grazed grassland (score of 2), even when at their most lush, produce a very limited hazard.

The vast majority of slopes in the Shire are under 5% (hazard score of 1) and aspect is largely omnidirectional (because it is flat - hazard score 0.5).

On this basis the maximum hazard score for any area in the Shire would probably be (at most) 7.5. Table 2.5 reproduces the bushfire hazard score contained in DLGP/DES (2003b).

Table 2.5: Fire hazard potential scores (source DLGP/DES, 2003b)

TOTAL SCORE	SEVERITY RATING
13 or greater	High
6 to 12.5	Medium
1 to 5.5	Low

It is clear that the highest **relative** bushfire potential in the shire is medium.

Mapping of Balonne Shire conducted by the GIS and Risk Management staff of the QFRS Rural Fire Service employing the methodology detailed in DLGP/DES (2003b) is provided as Figure 2.9.

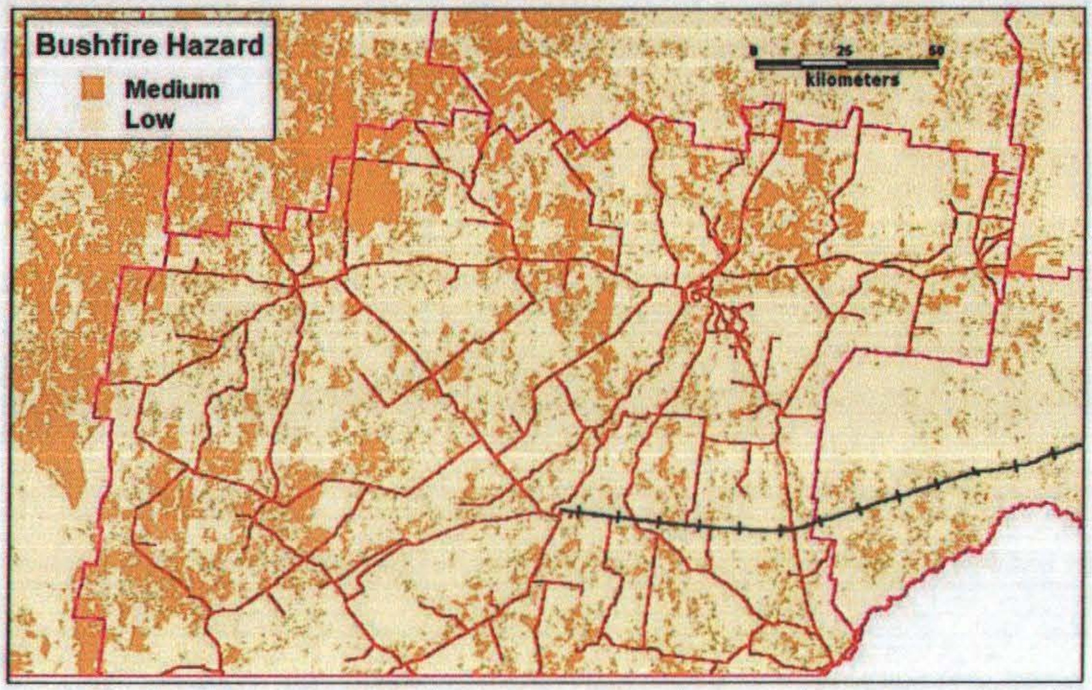

Figure 2.9: Balonne Shire bushfire hazard (source QFRS, 2003)

It should be recognised that the vegetation component of this analysis is highly variable, particularly in response to land use practices and weather. Where land is converted from scrub to pasture or cropland, the inherent bushfire hazard will be reduce; conversely where land is allowed to regenerate to its natural forest or woodland form, the inherent hazard will be increased.

Using the QFRS mapping, a total of 6,474.4 sq km (or 20%) of the Shire are classified as having a potentially medium fire hazard. The remaining 80% of the Shire has either a low or negligible hazard potential.

2.3.5 Ignition sources: Prior to European settlement the most common form of bushfire ignition in the taller vegetation types was lightning strike or the intrusion of fires set by Aboriginal people as part of their 'firestick farming' subsistence methods. Statistically, no point in the Shire is immune from lightning strike. Since European settlement, fire has become a key tool in land management, particularly by graziers. Section 65 of the *Fire and Rescue Service Act* establishes a system of 'permits to burn'. Under this section, a landholder wanting to light a fire greater than two metres on a side must apply either orally or in writing to their local fire warden. In making application the following information must be provided to the fire warden:

- the land on which the fire will be lit;
- the names of all neighbouring landholders;
- the steps taken to notify every occupier of adjoining land of the intention to light the fire; and
- whether any of those adjacent occupiers has objected to the lighting of fire and the reasons for that objection.

The 'permits to burn' system is aimed at managing the responsible use of fires as a land management tool in rural areas. Its successful application relies heavily on the experience and knowledge of the local fire warden.

In more recent years, unfortunately, these natural and managed sources of ignition have been joined by non-natural sources including:

- power line failure (e.g. caused by power lines coming in contact with vegetation or being brought down by high winds or falling vegetation);
- human carelessness (e.g. a poorly supervised burn-off); stupidity (e.g. a discarded cigarette butt, or fires lit by bored and unsupervised children); or
- criminality (e.g. by outright arson, or by car thieves disposing of stolen cars by setting them alight in bushland).

Within Balonne Shire, these causes are noticeably less significant than they have become in more closely settled areas.

2.3.6 Fire suppression resources: Fire suppression responsibilities are divided between the rural and auxiliary elements of the QFRS, the QPWS and individual landholders. There are 33 rural fire brigades. The four towns are covered by three auxiliary brigades - St George, Bollon and Dirranbandi - and the Thallon rural brigade. Figure 2.10 shows the boundaries of the brigades, each labelled with their respective brigade identification number. Table 2.6 lists their ID numbers, names and areas as a key to the figure.

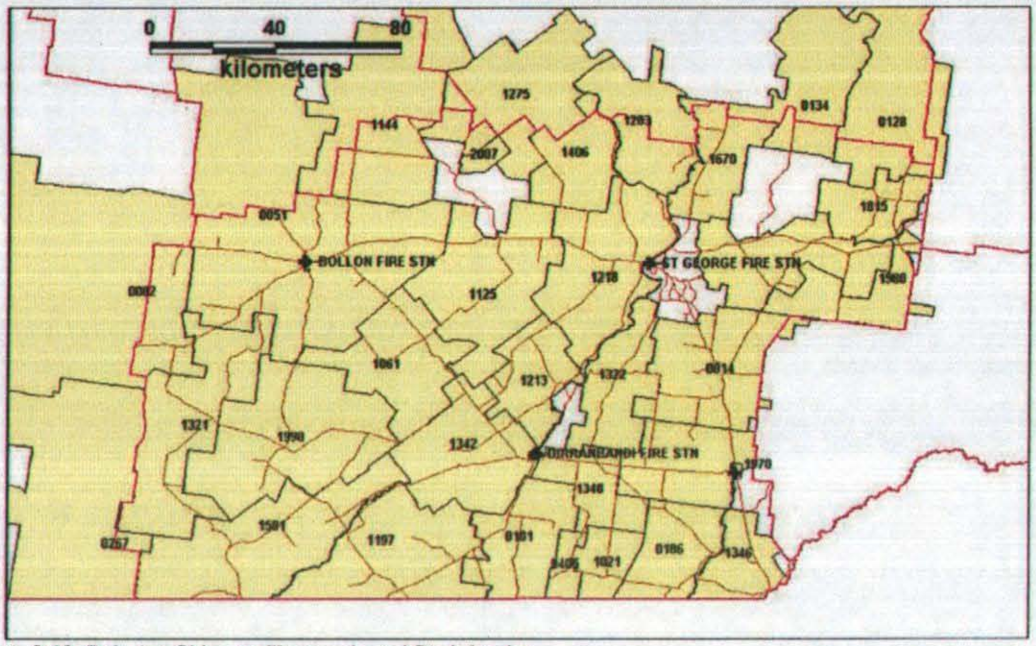

Figure 2.10: Balonne Shire auxiliary and rural fire brigades

Table 2.6: Balonne Shire rural fire brigades

ID	BRIGADE	AREA	ID	BRIGADE	AREA
0014	Nindigully Rural	1338.5	0051	Bollon Rural	4744.2
0082	Nebine Rural	4941.4	0101	Dirranbandi Rural	899.0
0128	Teelba Rural	1673.8	0134	Kyeen Rural	1231.7
0186	Moonie River Rural	720.7	0267	Lowe Widgee & Nebine	2771.1
0405	Narine Rural	175.3	1021	Pooloomoodool Rural	364.5
1061	Bogong Rural	1157.6	1125	Boolba Rural	1591.4
1137	Bullamon Rural	901.4	1197	Noogilla Rural	2288.1
1197	Hebel Rural	1465.0	1213	Whyenbah Rural	713.2
1218	Gulnarbar Rural	1523.1	1275	Ivanhoe Rural	1568.2
1283	Chesterfield Rural	1005.7	1321	South Bollon Rural	1652.7
1322	Noondoo Rural	827.6	1342	Cubbie Rural	1256.3
1346	Weir Rural	525.9	1348	Bookalong Rural	574.8
1406	Yarara Rural	717.5	1581	Culgoa Rural	1796.2
1670	Bindle Rural	702.1	1738	Bullholes Rural	1130.4
1815	Rocky Crossing Rural	568.2	1970	Thallon Town Rural	14.7
1988	East Balonne Rural	678.3	1998	Kulki Rural	2047.8
2007	Cypress Tank Rural	98.9			

St George, Dirranbandi, Mungindi, Hebel, Thallon, and Bollon all have reticulated water supplies and consequently hydrants to supply fire fighting water. All other areas must rely on their own water resources. The availability of water with which to fight fires during drought is a major concern.

2.3.7 Warnings: There are no formal systems in place to provide warnings of approaching bushfire. The informal 'bush telegraph' however, tends to be very effective.

2.4 EARTHQUAKES

Earthquakes occur when stresses in the Earth exceed the rock's strength to resist, thus causing the sudden rupture of rocks and displacement along a fault. The fault may already have existed or may be newly created by the earthquake rupture. Nearly all damaging earthquake effects are caused by the energy from the fault rupture which is transmitted as seismic waves.

The size of an earthquake is often expressed in terms of Richter (or local) magnitude, denoted by M_L. The energy released by earthquakes varies enormously and so the Richter scale is logarithmic. An increase in magnitude of one unit is equivalent to an increase in energy released of about 33 times. For example, an earthquake with Richter magnitude M_L 6 releases about 33 times the energy of an earthquake with magnitude of M_L 5, and about 1000 times the energy of an earthquake with magnitude of M_L 4.

Descriptions of the severity of an earthquake at any place may be given using intensity scales such as the Modified Mercalli Intensity scale. The Modified Mercalli (MM) scale describes the strength of shaking by categorising the <u>effects</u> of an earthquake through damage to buildings, the disruption of ground conditions, and the reactions of people and animals. A full description of the Modified Mercalli Intensity scale is provided in Appendix B. It should be noted that MM intensities are always shown in roman numerals.

Although damaging earthquakes are relatively rare in Australia, the high impact of individual events on the community has made them a costly natural hazard. Earthquakes account for around $144.5 million of the $1.14 billion annual average loss caused by natural hazards in Australia (BTE, 2001). This amount was greatly influenced, however, by the 1989 Newcastle earthquake which produced an insurance loss of around $1 billion and a total loss of around $4 billion.

2.4.1 <u>Earthquake history</u>: Earthquakes are regional events. Their effect is not influenced or constrained by topography in the way that floods, for example are contained in a floodplain. It is therefore necessary to look at a wide region when considering the earthquake risk to Balonne Shire. Within a square, the boundaries of which are approximately 500 km from St George, the *National Earthquake Database* maintained by Geoscience Australia contains records of some 650 earthquakes, the earliest of which was on 27 January 1841, a M_L 4.9 event located in the New England area of NSW, whilst the largest on record was the M_L 6.0 event of 6 June 1918 located off Bundaberg. The epicentre locations are shown in Figure 2.11.

The area immediately to the east of St George appears to have a concentration of relatively frequent but low magnitude earthquake activity. The mechanisms that control this activity are currently not understood.

The most significant earthquake event in the Shire was that of 19 September 1954. This M_L 5.4 event had its epicentre close to Thallon at a relatively shallow depth of 10 km. It was felt as far away as Roma and Mitchell to the north and Moree and Brewarrina to the south. It was felt in St George with an intensity of MM IV to V. Figure 2.12 shows the way in which this earthquake was felt across the Shire.

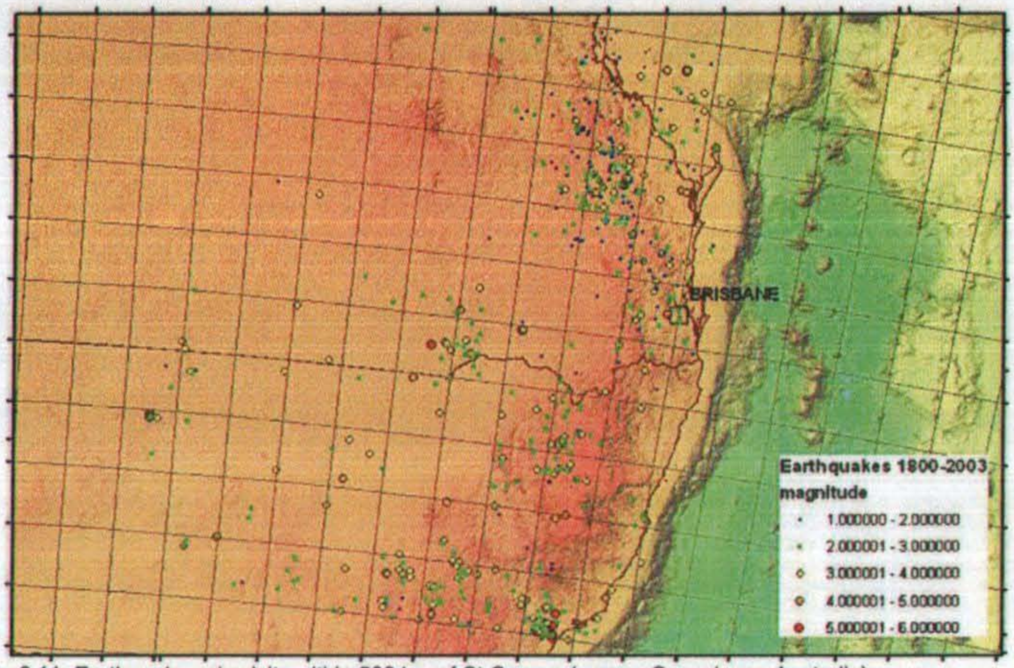

Figure 2.11: Earthquake seismicity within 500 km of St George (source Geoscience Australia)

On 24 September 1991 a M_L 4.1 earthquake with its epicentre about 30 km east of St George and a depth of 8 km was felt over a relatively small area. It was felt in St George with an intensity of MM II. It was followed on 28 September 1991 by a M_L 3.6 aftershock. The aftershock appears not to have been felt in St George. Figure 2.13 shows the isoseismal map of those two events.

The *National Earthquake Database* does not report any damage being caused in St George or any other part of the Shire by any earthquake to date. The full list of recorded earthquakes within 500 km of St George is contained in Appendix C.

2.4.2 <u>The Earthquake Threat</u>: The historical experience of earthquake in the Shire suggests an increasing level of threat the further east one goes. That said, however, the earthquake hazard is low across the Shire by both global and national standards. On the basis of the historic record (not withstanding the uncertainty that exists in the knowledge of earthquake mechanisms in the region), it seems safe to assume that the risk of damage to buildings, and death or injury to people, throughout the Shire, is very low.

Table 2.7 provides an estimate of the expected Modified Mercalli intensity level likely to be experienced in St George over a range of ARI.

Table 2.7: Approximate Modified Mercalli intensity levels at St George by ARI

ARI (years)	APPROXIMATE MM LEVEL
100	IV-V
200	V
500	V-VI
1000	VI
2500	VI-VII

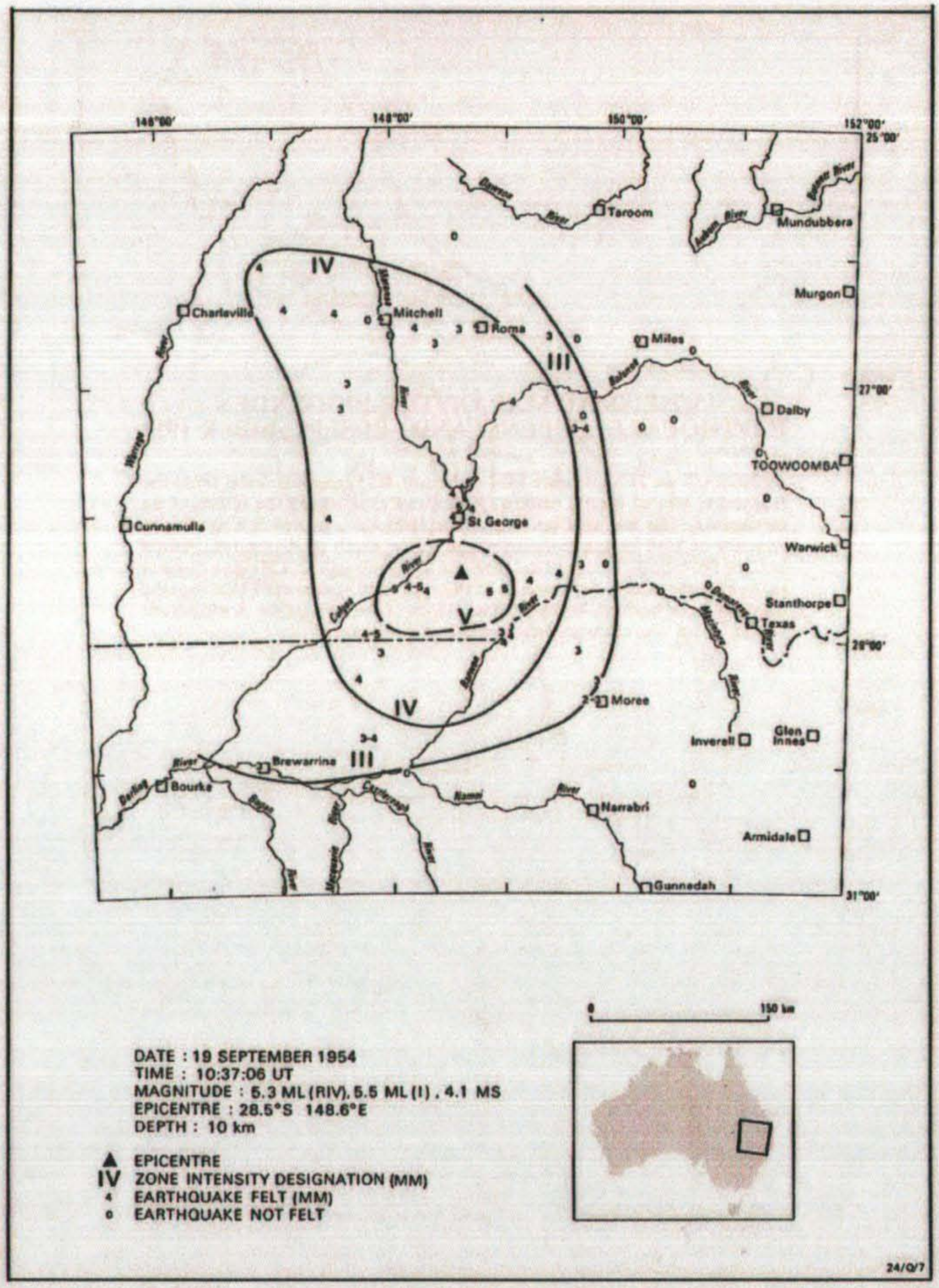

Figure 2.12: Isoseismal map of the September 1954 St George earthquake (xxxxxx, 19nn)

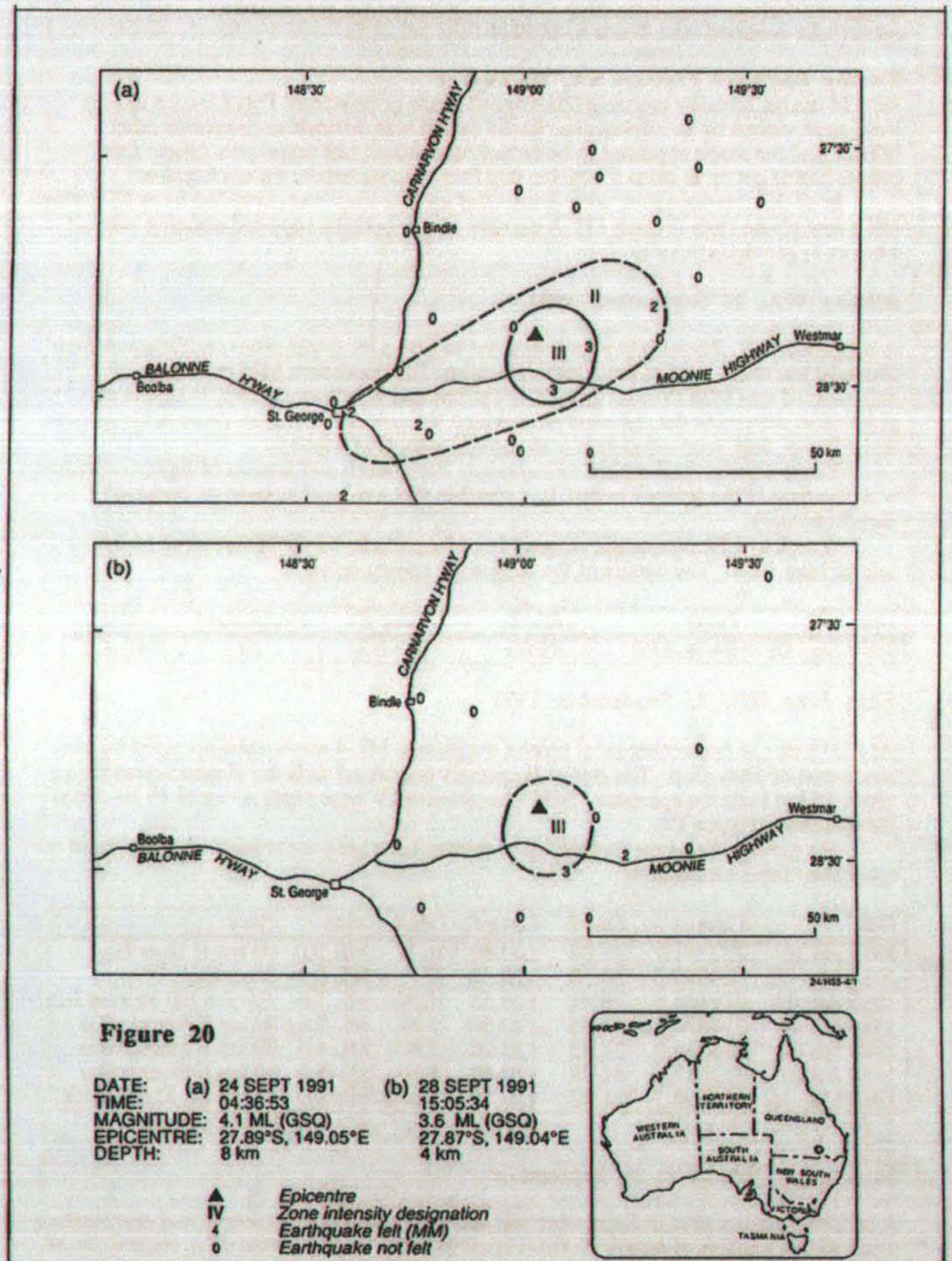

Figure 2.13: Isoseismal map of the September 1991 St George earthquake (xxxxx, 1999)

2.5 CLIMATE CHANGE

Whilst there remains considerable uncertainty and debate relating to the nature of climate change over the next 50 or so years, there appears to be a degree of consensus by the scientists responsible for the 2001 Intergovernmental Panel on Climate Change (IPCC) report who argue (as reported by Hennessy and Walsh, 2003) that it will lead to:

- *Higher maximum temperatures and more hot days over nearly all land areas;*
- *Higher minimum temperatures, fewer cold days and frost days over nearly all land areas;*
- *Reduced diurnal temperature range over most land areas;*
- *Increased heat index over land areas;*
- *More intense precipitation events;*
- *Increased summer continental drying and associated risk of drought;*
- *Increased tropical cyclone peak wind velocities;*
- *Increased tropical cyclone mean and peak precipitation intensities.*

For Balonne Shire, climate change would thus lead to hotter and dryer conditions overall but with intense rainfall episodes, likely to lead to flooding, increasing in frequency. Some authors have suggested that the increased frequency in intense precipitation will see the stage height for a flood with a current ARI of 100 years being achieved with an ARI of 25 or 30 years.

2.6 OTHER HAZARDS

This study is formally confined to consideration of those natural hazards for which Council may claim relief under the Natural Disaster Relief Arrangements (NDRA). Landslide losses are covered by NDRA funding, however, they do represent a threat within Balonne Shire, largely because of the Shire's generally flat terrain.

NDRA funding clearly does not include all natural hazards that may have an impact on the Shire and its community. Those additional hazards that Council may need to consider in their disaster planning process and general community governance are addressed briefly below.

2.6.1 Heatwave: In terms of the threat to life, heatwave is the most serious of all natural hazards in Australia. Over the last 100 years more people have died as a direct result of heatwave than have died as a result of all other natural hazards combined – and the evidence suggests the death toll is rising.

There has been a significant shift in the demographics of heatwave fatalities over the past 50 or so years. In the past, most deaths were males engaged in manual labour in the outdoors. With changes in workplace health and safety regulations and the increased use of (air conditioned) machinery the incidence of deaths amongst this group has declined significantly. Such work, however, remains important in Balonne Shire with groups such as railway fettlers and seasonal workers in the grape and horticultural industries still a significant group at risk. In urban centres, those now considered to be at greatest risk are the elderly, especially women, living alone.

As well as significant loss of life, heat waves can also cause significant economic losses through livestock/crop losses and damage to roads, railways, bridges, power reticulation infrastructure, electrical equipment, and so on (EMA, 1998). Heat wave conditions also lead directly to significant increases in demand for electricity to power domestic air conditioners. This demand can exceed the available capacity of the generating system, leading to load shedding – which in turn exacerbates the heat wave impact on people.

2.6.2 <u>Drought</u>: Undoubtedly the most significant hazard from an economic and social perspective is drought. It has not been included under the NDRA for more than a decade because drought has been deemed to be 'part of the natural seasonal variability' and relief arrangements are managed under different legislation.

2.6.3 <u>Salinity</u>: There is a significant risk of soil salinity becoming a major threat to the economy of the Shire.

CHAPTER 3: THE ELEMENTS AT RISK AND THEIR VULNERABILITY

This chapter describes and analyses the community elements that may be exposed to the impact of one or more of the hazards described in Chapter 2, and their vulnerability to such an exposure. Five main groups of element will be considered here: people, buildings, lifeline infrastructure, economic activity and the environment.

3.1 EXPOSURE OF COMMUNITY ELEMENTS

The exposure of community elements varies depending on the hazard involved and its severity. Exposure may be direct, i.e. covered by flood waters, or indirect, i.e. affected by the loss of power supply.

In assessing indirect exposure, it is important to take account of the interdependence of lifeline utilities and key services. Table 3.1 indicates the nature of this interdependence. In this table, the loss of the lifeline in the left-hand column will have an impact on the lifelines across the row to a significant (**S**), moderate (**M**) or minor (blank) degree.

Table 3.1: Interdependence of lifeline assets (after Granger, 1997)

	POWER	WATER	SEWER	COMMS	ROAD	RAIL	AFLD	FUEL	FOOD
POWER		S	S	S	M	S	S	S	S
WATER	M		S						S
SEWER		S							M
COMMS	S	S	S		M	S	S	M	M
ROAD	M	M	M	M		M		S	S
RAIL					M			S	M
AFLD									M
FUEL	S	M		M	S	S	S		M
FOOD									

3.1.1 Exposure to floods: Direct exposure to flood is dependent on the magnitude of the event. Indirect exposure to flood is also significant given that people and properties can be isolation for extended periods. No flood extent information for various event ARI are available to this study, consequently, it has not been possible to produce statistics relating to different flood scenarios.

3.1.1.1 People: The anecdotal evidence suggests that very few people are directly exposed to floods in Balonne Shire, given that their onset is generally slow and preceded by adequate warnings. Flood deaths can generally be attributed to inappropriate action by the inexperienced or foolhardy, for example, people trying to negotiate flooded roads.

Virtually all people in the Shire can be indirectly exposed to flood impact, given the widespread dislocation of roads throughout the area. This indirect exposure can extend for many weeks and if people in flood-isolated areas are not adequately prepared with stocks of food, emergency relief will be required.

Rescue resources are available should a medical or other emergency occur during a flood. SES flood boats, Council graders and other large tractors are immediately available. Rescue-equipped helicopters would need to be positioned from Brisbane and operate from St George (St George is too far from Brisbane for helicopters to operate without refuelling).

3.1.1.2 Buildings: Few residential buildings appear to be directly exposed to flood given that most are either sited in low hazard areas and/or have been constructed with floor levels elevated 0.8 m or more above ground level. Many commercial, farm and industrial buildings are, by comparison, generally more exposed because they have floor levels at, or less than, 0.3 m above ground level.

3.1.1.3 Infrastructure: The key infrastructures exposed to flood are the roads of the Shire. Anecdotal information provided by Balonne Shire Council staff indicate that road segments totalling around 500 km of the Shire's 2940 km of roads are subject to inundation. Figure 3.1 shows the distribution of these flood-prone road segments.

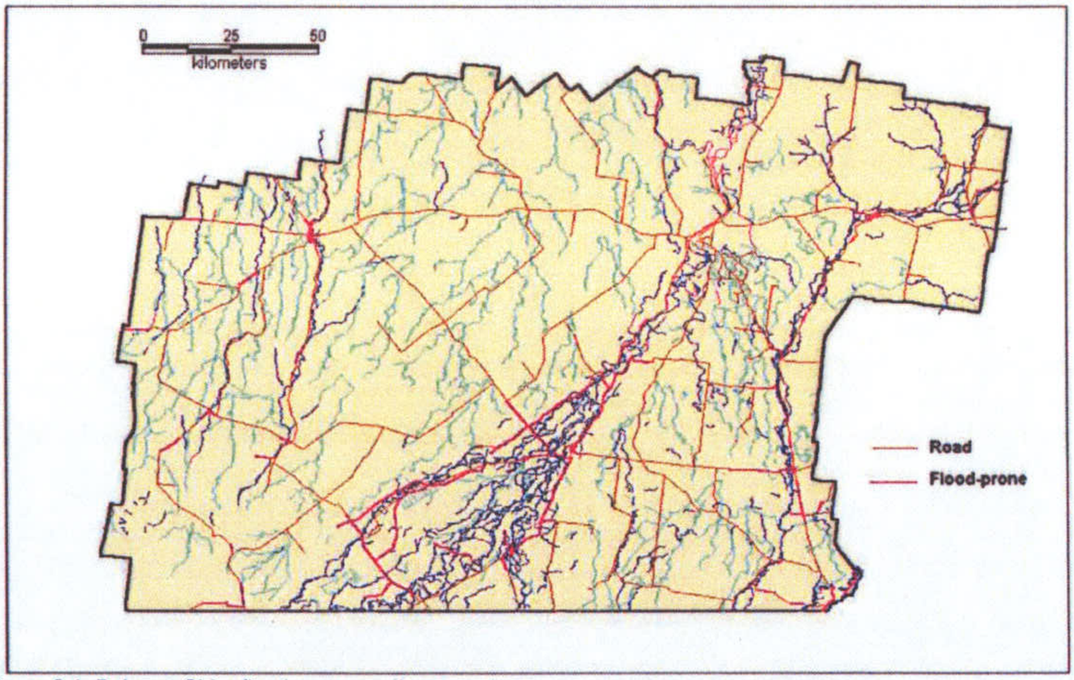

Figure 3.1: Balonne Shire flood-prone road segments

The length of time each segment remains closed will vary depending on the nature and severity of each individual flood event. Anecdotal evidence suggests that main roads can be closed for periods from a few days to a few weeks, whilst other roads, especially natural surface roads can be closed for somewhat longer.

The most flood prone road areas are those in the Balonne valley. As many as 750 people would be directly affected in that area. Isolation of the properties in the western creek catchments would affect about 130 people. In a major flood of 1890 proportions, however, it is likely that the entire population of the Shire would be isolated for two weeks or more.

Rail infrastructure is said to be generally not flood-prone.

The Shire's key airfields at St George, Dirranbandi and Bollon are largely flood free, however only the St George and Dirranbandi airfields have sealed runways that are unaffected by rainfall, St George airfield, however, has a much greater load capacity than does Dirranbandi. Many rural properties also have their own airstrips. There is also a gravel-surface airfield on the NSW side of the border at Mungindi, whilst Hebel and Thallon have small natural-surface airstrips. Many of these will be flood-prone and/or easily closed by rainfall.

Power supply can be disrupted by flood. Poles may be brought down by flood waters or flood-transported debris. Supply will also be cut off by Ergon Energy when they assess that the power lines could come within 1 m of the flood waters.

Underground utilities such as water supply, sewerage and telecommunications cabling are perhaps less directly exposed, however, they have significant indirect exposure as a direct result of the potential failure of power supply. Above-ground facilities, such as treatment plants and pump stations, however, can be affected, as shown in Plate 7 of the 1997 flood at Bollon.

Failure of telecommunications will also have flow-on impacts on other utilities and the community at large. Most utilities are controlled by microwave-based SCADA (supervisory control and data acquisition) which may not function without power supply.

Key services, including fuel and food supply are unlikely to be directly exposed, however, indirect exposure is highly likely. Fuel supply (petrol and diesel) to the Shire is brought in by road, either directly from Brisbane (Mobil, BP, Shell) or Goondiwindi (Ampol, Caltex), whilst aviation fuel is trucked in from Moree. (See Plate 10 for the Mobile depot in St George). Virtually all food supplies are also brought in from external centres by road. One of the three supermarkets in St George, for example, brings in 100,000 kg of foodstuffs each week (Dr John Stone, personal communication, 2003) so the task of keeping that level of supply going during flood could be very difficult.

3.1.2 <u>Exposure to tropical cyclones and severe thunderstorms</u>: It can be assumed that all above-ground facilities are potentially exposed to the severe wind, hail and lightning associated with tropical cyclones and severe thunder storms.

3.1.2.1 People: Exposure of people to severe winds associated with tropical cyclones is likely to be lower than that for severe storms given that they are tracked for several days before they come within range of the Shire and warnings are widely disseminated. Exposure to severe thunderstorms, by contrast, can be greater because of their more rapid onset and limited warnings. Consequently, it is much more likely for people to be caught out-of-doors during thunderstorms.

3.1.2.2 Buildings: All buildings in the Shire are potentially exposed to severe winds and wind-blown debris.

3.1.2.3 Infrastructure: Roads may be blocked by fallen trees and other wind-blown debris. The rail permanent way is less exposed than roads, however, signalling and associated equipment is potentially exposed to both wind and lightning damage. All airfields are likely to be closed (albeit temporarily) during severe wind episodes.

Power supply is highly exposed to wind, debris and lightning damage. Underground infrastructures are, however, not directly exposed.

Telecommunications and SCADA infrastructure could be damaged or taken out through the misalignment of microwave dishes, for example.

3.1.3 Exposure to bushfires: The harm-causing components of bushfires include flames, radiant heat, embers, smoke and fire-generated severe winds. Exposure to bushfires is, therefore, largely dependant upon proximity to the fire front. There is generally adequate warning of an approaching fire for steps to be taken to reduce exposure by implementing appropriate fire protection practices.

3.1.3.1 People: Fire fighters are generally the people who have the greatest exposure to bushfire harm because their activities place them close to the fire front. Exposure of the rest of the population should be limited, however, inadvertent exposure, e.g. travellers unaware of the fire, can have lethal consequences.

3.1.3.2 Buildings: Except under the more severe fire conditions, buildings that are separated from the heavy fuel (woodland, scrub, etc) by more than 100 m should have only limited direct exposure. From observation, there appear to be very few buildings in either rural or urban areas located closer than several hundred metres from bush. The possible exceptions are Bollon and possibly Thallon, where dense scrub appears to come close to some buildings in the settlement. The vegetation close to Bollon is shown in Plate 11.

3.1.3.3 Infrastructure: Roads may be closed temporarily by dense smoke or by trees brought down by the fire. Two wooden bridges remain (one on the Castlereagh Highway over the Narran River and the other on the Carnarvon Highway at Mungindi over the Barwon River. These could be burnt out in a serious fire. Rail infrastructure, especially wooden sleepers and wooden bridges, can be damaged. Airfields may be closed by smoke.

Power supply infrastructure is highly exposed. Wooden poles can be destroyed; cables, substations and control equipment can be affected by heat; high voltage transmission lines can arc to the ground in dense smoke.

Underground utilities are unlikely to be exposed.

3.1.4 Exposure to earthquakes: The historic evidence suggests that areas to the east of a line through St George and Dirranbandi have experienced more earthquake shaking than areas to the west – though the differences are relatively small and the historic record very limited. Earthquakes have a sudden onset and no warning is possible.

3.1.4.1 People: It is widely acknowledged that earthquakes do not kill people – poorly constructed buildings that fall down in earthquakes kill people. Exposure of people to earthquake thus depends largely on the time of day and day of the week at which it occurs, and consequently the nature and quality of the building in which people are located at the time.

3.1.4.2 Buildings: For the purposes of this study it can be assumed that all buildings in the Shire have an equal level of exposure to earthquake vibrations.

3.1.4.3 Infrastructure: *It would take a significant earthquake in which ground rupture* is experienced to expose road, rail and airfield infrastructure to risk.

Power supply facilities such as transformers, large insulators and some control equipment could be damaged if exposed to shaking of greater than MM VII. Similarly, some telecommunications links could be broken if shaking causes microwave and satellite dishes to become misaligned.

Underground utilities, including water supply pipes, sewerage pipes and telecommunications cables are probably the most exposed to earthquake damage of all community elements.

3.1.5 Overall exposure: Apart from exposure to severe winds, direct exposure to hazards throughout the Shire is relatively low. All people, buildings and infrastructure, however, have potentially significant indirect exposures to all hazards.

3.2 PEOPLE AND THEIR VULNERABILITIES

Regardless of the hazard phenomenon involved, a disaster is something that happens to people. People are, consequently, the principal consideration in disaster risk management.

At the 2001 National Census Balonne Shire had a total population of 5420, (2927 males and 2493 females) of whom 3676 resided in the urban centres. The Shire's main centre, St George (Plate 12), had a population of 2781, followed by Dirranbandi with 526, Bollon with 173, Thallon with 103 and Mungindi with 93. The indigenous population of the Shire totalled 724, or 13.3% of the total, making them a very significant minority. Almost 93% of the indigenous community live in the urban centres - the *largest numbers residing in St George* (459) and Dirranbandi (128).

The Australian Bureau of Statistics (ABS) has divided the Shire into 17 census collectors districts (CCD). For ease of reference in this study, each CCD have been given names as shown in Figure 3.2. Their basic population statistics are summarized in Table 3.1.

In this study 'vulnerability' is defined as:

> *The degree of susceptibility and resilience of the community and environment to hazards.*
> (EMA, 1998)

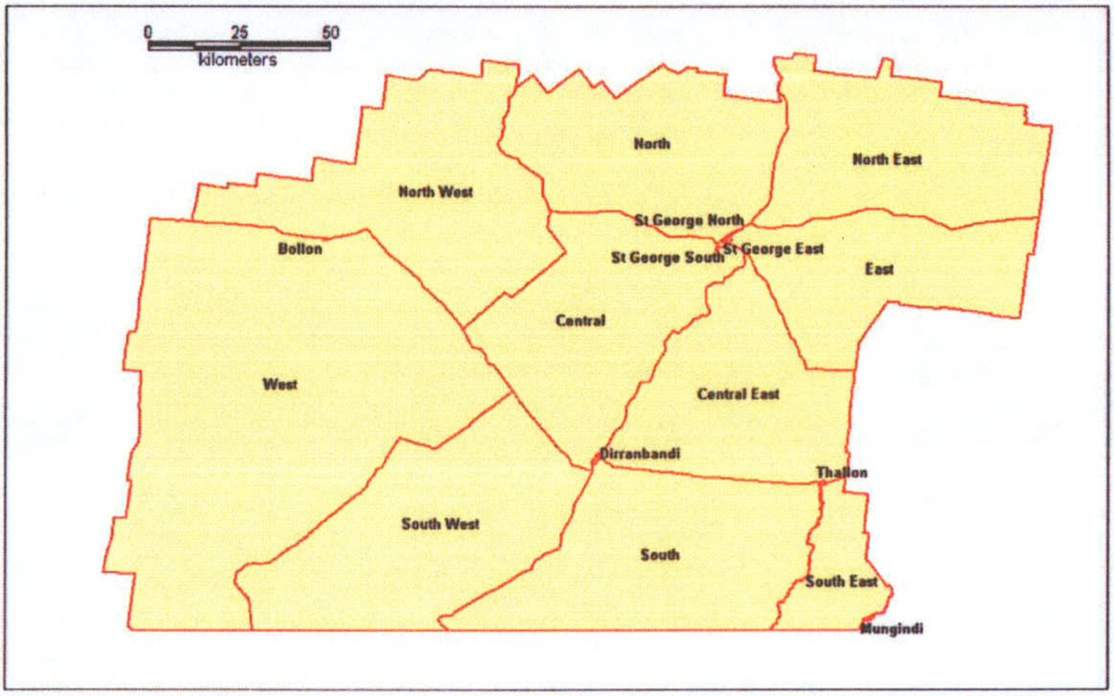

Figure 3.2: Balonne Shire CCD

Table 3.2: Balonne Shire population summary (source ABS, 2003a)

CCD	MALES	FEMALES	TOTAL POPULATION	INDIGENOUS POPULATION
Bollon	99	74	173	40
Central	120	85	204	19
Central East	126	92	218	7
Dirranbandi	267	259	526	128
East	156	125	281	3
Mungindi	48	45	93	16
North	114	93	207	8
North East	98	67	165	11
North West	59	35	94	3
South	80	51	131	3
South East	67	38	105	0
South West	132	74	206	3
St George East	393	404	797	144
St George North	481	443	924	97
St George South	552	508	1060	218
Thallon	50	53	103	28
West	85	47	132	5
Shire Totals	2927	2493	5420	724

There is no single measure of the human or community vulnerability. Many of the attributes that make communities more or less susceptible to hazard impact, such as social attitudes, values, behaviour, perceptions and social networks, are unquantifiable. There are, however, a number of demographic and socio-economic measures that are available from the National Census that provide some useful insights. They can be grouped into four categories: physical vulnerability, social and economic vulnerability, mobility vulnerability and awareness vulnerability. In this analysis, data are presented at the census collector's district (CCD) level.

3.2.1 Physical vulnerability: The greater the concentration of people, the greater will be their exposure to hazard impact and, consequently, their vulnerability. Population density across the Shire averaged less than 0.2 people per sq km. The average population density across the five urban communities is 223.5 people per sq km. The remaining 1744 people were spread across the rural areas at an average population density of 0.06 people per sq km.

Physically, the most susceptible people in the community are those who are ill, disabled or have a psychological condition that impairs their ability to cope with the stress of disaster. Unfortunately we do not have data on those attributes. However, it may be assumed that as much as 10% of the population will fall into one or more of those categories at any one time.

The next most physically susceptible groups are probably the very young and the elderly. In 2001 there were 505 (or 9.3% of the population) children under 5 years of age. The percentages ranged from highs of 19.1% in North West CCD and 13.6% in South West CCD to lows of 2.9% in Central CCD and 3.2% in Mungindi. The very young tend to be well cared for by parents or other carers.

The elderly (i.e. traditionally considered to be those 65 years of age and over) make up 6.1% of the total population. Their distribution is much more concentrated than the young, with the largest percentages in the urban centres (Mungindi with 12.9%, St George North with 11.8% and St George South with 11.7%). These concentrations probably reflect the presence of institutions such as hospitals, aged care facilities or retirement villages. Concentrations of elderly in rural areas were generally low to very low. In the Central East CCD there were no people over 65 at the 2001 census and in East CCD they made up only 2.5% of the total. While the elderly may have greater resilience based on experience and awareness of disaster survival, they can be more susceptible because of increasing physical frailty and social isolation.

Some studies also suggest that the degree of masculinity of the population is also a factor, with greater numbers of females suggested to be more susceptible than greater numbers of males, though this is far from universally agreed. Certainly the population of Balonne Shire is significantly more masculine than the national or State populations, with an average of only 85 females to every 100 males.

The physical vulnerability statistics for all 17 CCD are summarised in Table 3.3.

Table 3.3: Balonne Shire physical vulnerability indicators (source ABS, 2003a)

CCD	DENSITY (people/sq km)	UNDER 5 YEARS (%)	65 YEARS + (%)
Bollon	282.87	9.8	7.5
Central	0.07	2.9	5.9
Central East	0.09	6.9	0
Dirranbandi	177.03	10.3	6.1
East	0.13	9.3	2.5
Mungindi	33.85	3.2	12.9
North	0.08	7.7	8.7
North East	0.06	5.5	6.1
North West	0.03	19.1	7.4
South	0.04	9.9	3.8
South East	0.14	11.4	7.6
South West	0.06	13.6	7.8
St George East	429.97	11.2	7.5
St George North	299.94	7.6	11.8
St George South	308.05	10.5	11.7
Thallon	59.08	8.7	8.7
West	0.02	6.8	7.6
Shire Totals	0.17	9.3	8.3

3.2.2 Social and economic vulnerability: The capacity to recover from the impact of any disaster is closely related to socio-economic well being. Less advantaged households will tend to be in rented accommodation; have low disposable incomes; have no, or inadequate, insurance; and have difficulty replacing any losses. They will also be more susceptible to unemployment should the businesses in which they work be impacted by the event.

Households with low income (i.e. less than $400 per week) are significantly disadvantaged when confronted with disaster and would probably need to rely on welfare or charity support for an extended period if they suffered the impact of disasters. Across the Shire around 16.6% of all households fell into this category. Percentages ranged from 25.0% in South West CCD and 23.8% in Bollon to 5.8% in South CCD and zero in South East CCD.

Households who are renting their accommodation are also seen as being more susceptible to disaster impact. Across the Shire, 28.7% of households were living in rented accommodation. This ranged from 55.2% in Mungindi to only 5.9% in West CCD. In a rural community, such as that in Balonne Shire, where many workers are transient and thus renting their accommodation, the importance of high levels of rentals is perhaps not as significant an indicator of susceptibility as it is in urban communities.

At the 2001 census Mungindi (with 17.8%) and Thallon (with 11.8%) had the highest levels of unemployment. Four of the rural CCD (North, South East, South and North West) registered no unemployment.

Table 3.4 summarises the social and economic indicators.

Table 3.4: Balonne Shire social and economic vulnerability indicators (source ABS, 2003a)

CCD	% LOW INCOME	% RENTING	% UNEMPLOYED
Bollon	23.8	26.7	4.3
Central	18.5	26.0	2.4
Central East	10.2	13.0	2.3
Dirranbandi	21.2	34.6	3.2
East	18.1	14.7	3.9
Mungindi	20.7	55.2	17.8
North	9.9	14.1	0
North East	18.2	15.5	3.2
North West	19.4	7.7	0
South	5.8	21.2	0
South East	0	8.1	0
South West	25.0	10.9	2.7
St George East	11.8	37.9	4.8
St George North	15.2	30.5	3.3
St George South	21.0	38.6	4.8
Thallon	13.6	36.6	11.8
West	17.6	5.9	3.4
Shire Totals	16.6	28.7	4.0

3.2.3 Mobility vulnerability: In situations where evacuations may be required in the face of a rapidly evolving flood or severe bushfire situation, the capacity to quickly and easily evacuate can be paramount. People who do not have independent means of transport, or where there are several dependant children per adult, for example, are at a significant disadvantage.

Households that do not have access to a vehicle are particularly disadvantaged in centres where there is no public transport. The overall mean percentage of households without access to a private vehicle across the Shire was 6.4%. Mungindi, with 13.8% of households was the most disadvantaged, whilst seven of the ten rural CCD had no households without private transport.

Single parent households are also seen as being more susceptible when it comes to evacuation or relocation because there is only one adult available to assist and organise their dependant children. In the Shire, 9.5% of all families have a single parent. Single parent families were most evident in the urban CCD, with the highest figures being in Thallon (20.7%) and Mungindi (15.0%). Six of the ten rural CCD had no single parent families.

Large families, i.e. those with three or more dependant children, are also seen as being more susceptible to hazard impact because of greater stresses created by the responsibilities associated with coping in emergency situations. Across the Shire, 18.3% of all families had three or more children in 2001. The highest percentage was in Mungindi (30.0%), whilst Thallon and South East CCD had no large families.

The statistics for the mobility vulnerability variables are summarised in Table 3.5.

Table 3.5: Balonne Shire mobility vulnerability indicators (source ABS, 2003a)

CCD	% HOUSEHOLDS WITH NO CAR	% SINGLE PARENT FAMILIES	% LARGE FAMILIES
Bollon	4.8	12.8	14.9
Central	7.4	0	21.6
Central East	3.4	9.5	23.8
Dirranbandi	10.9	9.6	19.2
East	0	0	15.7
Mungindi	13.8	15.0	30.0
North	0	6.1	24.5
North East	0	6.5	19.6
North West	0	0	25.0
South	0	0	8.1
South East	0	10.7	0
South West	0	0	26.3
St George East	6.4	9.6	17.4
St George North	7.4	14.8	20.1
St George South	10.6	13.0	17.4
Thallon	6.8	20.7	0
West	5.9	0	24.0
Shire Totals	6.4	9.5	18.3

3.2.4 Awareness vulnerability: A lack of awareness of the threats posed by natural hazards, and how to cope with such an emergency, places people at greater risk than those who have a good level of knowledge and awareness - to cite the emergency services slogan, **'an aware community is a prepared community'.**

People who are new to the area tend to have a lower level of awareness than those who have lived there for a long time. Balonne Shire clearly has a mobile population, with 43.9% of the population living elsewhere at the previous census five years previously. Mungindi, with 53.8% new residents was the most mobile community, whilst even the lowest percentage (31.9% in North West CCD) is relatively high.

An understanding of public education material and an ability to understand warnings and other emergency messages is clearly important. According to the 2001 census figures only 44 people in the

Shire stated that they had never attended school. Familiarity with the English language is also a strong indicator. Across the Shire 72 people indicated that they only spoke languages other than English. Both of these measures coincide with communities in which there was a high proportion of indigenous residents, such as St George South, St George East and St George North.

The Internet has become a key medium for communication and information gathering, especially in the more remote parts of the country. Agencies such as the BoM use the Internet extensively to provide warnings and forecasts of severe weather, for example. The 2001 census was the first to record Internet usage. Across the Shire and average of 21.2% of the total population said that they accessed the Internet. This ranged from 29.0% in South CCD to 11.7% in North West CCD.

The statistics for the mobility vulnerability variables are summarised in Table 3.6.

Table 3.6: Balonne Shire awareness vulnerablity indicators (source ABS, 2003a)

CCD	% NEW RESIDENTS	NO SCHOOL	NO ENGLISH	% INTERNET USE
Bollon	43.9	3	0	13.3
Central	45.4	3	0	22.0
Central East	44.0	0	0	28.4
Dirranbandi	46.0	7	3	20.5
East	47.3	0	6	25.6
Mungindi	53.8	0	0	19.4
North	48.3	3	3	26.6
North East	48.5	0	3	18.2
North West	31.9	0	0	11.7
South	41.2	0	0	29.0
South East	33.3	0	3	20.0
South West	46.1	3	6	24.3
St George East	40.4	8	11	19.3
St George North	44.2	6	17	25.6
St George South	45.9	11	20	18.1
Thallon	32.0	0	0	21.4
West	32.6	0	0	25.8
Shire Totals	43.9	44	72	21.2

3.2.5 Community vulnerability: By combining the values for the 13 indicator measures described above it is possible to develop an index that 'measures' the relative degree of vulnerability that exists between the 17 CCD in the Shire. It is clear that the urban communities are significantly and consistently more vulnerable than are the rural communities. The index values are detailed in Table 3.7. The maximum possible index score is 13.

Table 3.7: Balonne Shire community vulnerability index

CCD	VULNERABILITY INDEX	CCD	VULNERABILITY INDEX
St George South	9.44	Mungindi	8.47
St George North	8.38	St George East	7.79
Dirranbandi	7.32	Bollon	6.44
Thallon	5.96	South West	5.81
Central	5.08	North	5.08
West	4.67	North East	4.59
East	4.47	Central East	4.44
North West	4.32	South	3.47
South East	3.31		

3.2.6 Vulnerability intangibles: There are numerous intangible factors that can influence a community's relative vulnerability. Observations by experienced disaster managers, such as Silberbauer (2003), for example, suggest that a potentially critical factor is community cohesion. Whilst there are many potential cleavages within communities, such as religion, ethnicity, social standing, employment, occupation and so on, communities in which these cleavages fail to divide are much more resilient than those in which they do divide. Community participation in sporting clubs, school groups such as P&C, service clubs (Rotary, Apex, CWA, etc), cultural groups (choirs, dramatic societies, historical societies, etc) and volunteer organisations such as SES, is a strong indicator of community cohesion. Commitments to welfare activities such as Meals on Wheels, Red Cross, St Vincent de Paul and Lifeline are also important. Whilst this study does not have direct knowledge of the levels of support given to such community strengthening activities, the impression gained is that the Balonne community is strongly coherent.

Disasters and emergencies have a nasty habit of catching people unprepared. It is probably inevitable that many families will be caught out with vehicles with near-empty fuel tanks, stocks of food and other essentials enough for only a few days and essential medicines close to exhaustion. This situation is no longer confined to urban centres where the convenience of the ready access to a local service station, supermarket and pharmacy has developed significant complacency. It has also become common in rural areas. This can be attributed to factors including better roads and vehicles which make it a lot easier to 'pop into town'. This 'convenience store complacency' can erode community preparedness and self reliance.

There is also strong anecdotal evidence that the self reliance and independence that has traditionally been attributed to rural communities appears, at least in some areas, to be giving way to an increasing dependence on outside assistance during emergencies. Again, anecdotal evidence from recent disasters in Balonne Shire and other rural areas of Queensland indicate that there is an increasing expectation (if not demand) that emergency food drops and other assistance will be provided by disaster workers when needed, rather than people taking a greater degree of responsibility for their own welfare and sustenance. Such attitudes, if they become entrenched, can only reduce community resilience.

3.3 BUILDINGS AND THEIR VULNERABILITIES

The buildings in which the community live, work, are educated, are cared for, and play represent the second most significant component in understanding community risk. They, and their contents, represent the most significant economic (and possibly also emotional) dimension to disaster.

The vulnerability of the community is, to a large degree, determined by the functions that structures perform. Their physical vulnerability, and consequently their functional vulnerability, is dictated to a large degree by the engineering codes that prevailed at the time of their construction and by the standard of maintenance they subsequently receive.

3.3.1 Engineering codes: The Building Code of Australia is based on a number of standards designed to maximise the structural integrity of all buildings. Of particular significance are the standards that set design and construction parameters for severe wind and earthquake loads. A standard for construction in bushfire-prone areas has also been published (Standards Australia, 1991). There are no areas within the Shire, however, that would be classed as 'bushfire-prone' under this code. There are no comparable standards for construction in flood-prone areas.

Wind loading standards in Australia were first implemented by structural engineers in 1952. It was not until the experience of the severe destruction wrought by TC Althea (Townsville) in 1971 and TC Tracy (Darwin) in 1974 that efforts were made to strengthen building standards in Queensland and elsewhere in Australia, especially for domestic structures. Standard AS1170.2 Minimum design loads on structures: Part 2 – Wind loads was first published in 1973 and was subsequently revised in 1975, 1981 and 1983. The current (5th) edition was published in 1989 (Standards Australia, 1989). This Standard was first adopted under the Queensland Building Act in 1981, and had already become widely applied for domestic structures in Queensland by that time. AS1170.2 is now encompassed by the Building Code of Australia. The wind loading code is based on a design event for which there is a 5% probability of exceedence in any 50 year period (i.e. a notional 1000 year ARI). In Balonne Shire, this wind velocity is deemed to be 32 m/s. Standards Australia and the Insurance Council of Australia have also published standards for the upgrade of older buildings in both cyclone and non-cyclone-prone areas (Standards Australia & ICA, 1999a and 1999b).

Similar loading codes have been developed for earthquake loads over a similar time frame. The current codes are *AS1170.4-1993 Minimum design loads on structures Part 4: Earthquake loads* (Standards Australia, 1993) and its replacement, the draft ANZS DR 00902 (Standards Australia, 2001). Earthquake loads are expressed as a 'acceleration coefficient' which relates to a 10% probability of exceedence in 50 years at 'rock' or 'firm' sites. This probability corresponds to an AEP of approximately 0.02%, or an ARI of approximately 500 years. Under the standard, the eastern half of Balonne Shire has an acceleration coefficient of between 0.03 and 0.05 g. This value is equivalent to a peak horizontal ground acceleration (PGA) of between 0.03 and 0.05 g, where 'g' is the acceleration experienced at the earth's surface under gravity. The western half of the Shire has an acceleration coefficient of less than

0.03 g. Following the 1989 Newcastle earthquake a standard designed to upgrade older buildings to modern earthquake-resistant standards was developed (Standards Australia, 1998).

A wide range of other engineering standards also apply to the construction and design of infrastructure elements such as drainage, water supply, sewerage and so on. These standards are applied within the Shire.

3.3.2 Residential buildings: No data were available to this study that provides details of the buildings of the Shire. In terms of residential shelter, however, the 2001 census indicates that there were 1844 individual dwelling units, made up of 1613 separate dwellings, 84 flats and 147 caravans. These probably represent 75-80% of all buildings in the Shire. Their distribution is proportional to the population distribution.

3.3.2.1 Functional vulnerability: Residential buildings provide shelter to the population for significant proportions of the day.

3.3.2.2 Physical vulnerability: The structural characteristics of buildings, such as design, size, age and materials, largely determine their susceptibility to the impact of any hazard. Whilst no specific data on the residential structural characteristics of Balonne Shire dwellings were available, observations indicate that the great majority of dwellings have:

- timber frame construction;
- timber or asbestos cement (AC) or similar sheeting;
- high pitched hip metal roof;
- pole or pier foundations – typically 0.8 m or more above ground level.

Most dwellings constructed in the past decade are slab-on-ground brick veneer over a timber frame. All of these designs are well suited to the region's climate and hazard environment. Timber frame buildings behave in a ductile manner in earthquakes and can undergo relatively large displacements because of their non-rigid construction. Many dwelling in the Shire have roof-mounted air conditioning units which could be dislodged under earthquake loads because of the large displacement allowed by the timber frame.

Timber and 'fibro' cladding is resilient to inundation damage. High pitched metal roofs are the most resilient to severe winds and hail damage (though fibro walls are highly susceptible to hail damage). The high-set foundations raise the more susceptible parts of the dwellings (such as plaster board, particle board and electrical wiring) above the 'design' flood level.

3.3.3 Critical Facilities: A wide range of facilities exist throughout the Shire that are important to community safety and wellbeing before, during and after any emergency. The loss or dislocation of these critical facilities would greatly exacerbate the impact on the community.

3.3.3.1 Functional vulnerability: Based on field work undertaken as part of this study several facilities potentially critical to the wellbeing of the community were identified in the Shire. The most important of these are grouped as follows.

Emergency services: The Shire is well serviced by emergency services with the following facilities:

- Police stations at St George, Dirranbandi, Thallon, Mungindi and Bollon;
- Auxiliary fire stations at St George and Dirranbandi; rural brigades in Thallon, Hebel and Bollon; the fire service in Mungindi is provided from the NSW side of the border;
- Ambulance stations at St George and Dirranbandi (Mungindi and Thallon are serviced by the NSW Ambulance service);
- SES sheds at St George, Dirranbandi, Thallon and Bollon.

When activated, the local disaster control centre is located in the Shire Council building in St George (Plate 13). The disaster district centre is located in Roma.

Medical: The Shire is also well serviced by health facilities with:

- Hospitals at St George (Plate 14), Dirranbandi and Mungindi;
- Bush Nurses Clinic at Bollon;
- Warrawee Community Nursing Service in St George.

The three hospitals provide a range of emergency and medical services together with related services such as surgical, podiatry, optometry, psychiatry and so on through a range of visiting specialist clinics. More serious cases are generally transferred to hospitals in Brisbane.

There are, in addition to these public facilities, private medical, dental, chiropractic, pharmacy and physiotherapy services available in St George with visiting services provided to the smaller centres. A good range of private medical services are also located in the NSW section of Mungindi.

Transport: The most significant transport facility is the St George airfield. This facility is capable of taking aircraft up to C-130 transport size under most conditions and has a sealed runway of 1640 m length. The Council-run airfields at Dirranbandi and Bollon have a smaller capacity.

A local general aviation and aerial agriculture provider, Jones Air, maintains three airfields (Trafalgar – near Dirranbandi, Zagzig and Kia-Ora - both in the St George district). Many rural properties also have their own natural surface airstrips used for communication and aerial agricultural uses.

Rail freight facilities, mostly related to the handling of bulk grain, are established at Dirranbandi, Thallon and Noondoo (see Plate 15 for the Dirranbandi facility.

Road freight operators are established in all centres.

Repair facilities: Council operates works depots in St George, Dirranbandi and Mungindi. These provide repair and maintenance services across the Shire under both normal and emergency situations.

3.3.3.2 Physical vulnerability: Many of the buildings that have critical functions are of either brick and concrete construction (the hospitals, Shire Office, etc), of steel frame construction (airport facilities, works depots, etc), reinforced concrete (rail facilities), or are of similar construction to the dwellings described above (police stations, medical centres, etc).

The older brick buildings may be susceptible to the earthquake loads that could be experienced in the Shire, however, most critical facilities appear to have been constructed to current engineering standards and sited to minimise flood damage, if not isolation.

3.3.4 <u>Sensitive facilities:</u> A further range of facilities exist at which people, especially children or the elderly, may congregate or be concentrated at different times.

3.3.4.1 Functional vulnerability: Facilities that cater for large numbers of people can be both a concern in the case of quick onset hazards, and an asset in terms of accommodating people who have been evacuated or relocated during or following a disaster. They include:

Educational facilities: There are nine schools in the Shire. They are:

- St George State High School
- St George State School
- St Josephs School St George
- Dirranbandi State School (P to 10)
- Bollon State School
- Thallon State School
- Hebel State School
- Rocky Crossing State School

The schools that service the Mungindi community are located in the NSW section of the town. Distance education services are also provided for children in the more remote parts of the Shire.

In 2003 these schools had an enrolment of approximately 920 students with 68 full time teachers (BSC, 2003).

There are also six preschools, child care and kindergarten facilities spread across the urban centres. A Rural Childs Centre associated with the Bollon State School provides hostel accommodation for children from more isolated properties.

Aged care facilities: In addition to services provided at the three hospitals, the Warrawee Nursing Centre in St George and small 'retirement villages' in both St George and Dirranbandi provide domiciliary accommodation for the elderly.

Community facilities: Communities in each urban community have established facilities such as churches, community halls, libraries, Scout and Guide huts, CWA centres, memorial clubs, theatres, visitors' centres and so on to provide for their social, cultural and spiritual wellbeing.

Commercial accommodation: There are at least 22 centres that provide commercial accommodation. These include hotels, motels and caravan parks. St George has the greatest numbers with nine hotels/motels and three caravan parks. Dirranbandi has three hotel/motels and a caravan park. Even little Hebel has a hotel and a caravan park.

Recreational facilities: A wide range of facilities have been established to accommodate the sporting and recreational interests of the Shire's community. The majority of these are located in St George, however, many rural communities also have their local tennis courts or sporting field. These facilitate sports including golf, bowls, horse racing, rodeo, cricket, netball, basketball, football (league and union), squash, tennis, swimming and so on.

3.3.4.2 Physical vulnerability: Some of these sensitive facilities are of older brick construction and are consequently susceptible to failure under earthquake loads. The remainder are typically of timber fame construction to standards similar to the dwellings detailed above.

3.3.5 Economic and logistic facilities: A wide range of facilities support the community through the provision of services and supplies together with industrial processes. These are largely concentrated in, or close to St George and Dirranbandi. They can be grouped as follows.

3.3.5.1 Functional vulnerability: The facilities in this group tend to underpin community and economic activities. Some represent hazards in their own rights, though these hazards lie outside the scope of this study.

Industrial facilities: Queensland Cotton operate three cotton ginneries (one south of Dirranbandi, one south-east of St George and the other north of St George). These are the largest of the industrial facilities in the Shire. They process cotton from March to July each year. A pet meat abattoir north of St George is also a significant employer. In addition to these larger facilities there are several service facilities providing engineering, repair and construction services. The smaller centres each have similar small scale facilities, including game chiller depots.

Commercial facilities: Each centre has its local stores to provide basic groceries, hardware and the like. St George and Dirranbandi have a wider range of stores, including more specialised stores such as clothing, household goods, agricultural supplies and machinery parts. The NSW section of Mungindi also has a range of higher order commercial facilities.

Service industries: St George and Dirranbandi have a range of service facilities including banks, insurance, accounting, legal and government services. Some of these services may also be provided in the smaller centres on a periodic visiting basis.

Logistic facilities: Bulk fuel depots are established in St George, Dirranbandi and Thallon. There are at least seven retail fuel outlets across the Shire. Most rural properties have bulk fuel storages, some of which can be quite large. Fuel is also available from outlets on the NSW side of Mungindi.

Bulk storages for agricultural chemical have also been established. The Incitec anhydrous ammonia storage a few kilometres south of St George is perhaps the largest. Some of the larger cotton holdings may also hold significant stocks of agricultural chemicals and fertilisers.

Bulk grain handling facilities are operated by Grainco at Thallon and Noondoo.

Rural properties: Most rural properties have a range of buildings that facilitate the operation and production of the holding. These range from sheering sheds and shearers accommodation to bulk grain storage facilities.

3.3.5.2 Physical vulnerability: Most of the facilities in this group are of steel frame and steel clad construction that is largely resilient to all hazards. Severe winds may be a problem in some of the older facilities, especially those that have already experienced significant wind loads. Exposure to severe winds, even if the structure does not appear to be damaged, will probably have undergone sufficient stress to cause it to fail at much lower levels of wind load in the future.

The commercial and service facilities are typically of masonry construction and should be resilient to most hazard events.

It is assumed that hazardous materials storage facilities, including bulk fuel and agricultural chemicals have been constructed to the appropriate national standards set for such facilities.

3.4 INFRASTRUCTURES AND THEIR VULNERABILITY

As discussed at the beginning of this chapter the loss of or damage to lifeline infrastructures can have a significant impact on the community. Given that the functions of each form of infrastructure are self evident, only their physical vulnerabilities will be dealt with here.

3.4.1 Roads: The following roads in the Shire are the responsibility of the Department of Main Roads, the regional headquarters for which are located in Warwick (road lengths relate only to the roads within the Shire):

- Carnarvon Highway – 174 km of sealed two-lane highway linking St George with Surat to the north and Mungindi in the south;
- Moonie Highway – 81 km of sealed two-lane highway that links St George to Dalby;
- Castlereagh Highway – 157 km of sealed two-lane highway linking St George with Dirranbandi, Hebel and the NSW border;
- Balonne Highway – 151 km of sealed two-lane highway linking St George with Bollon and on to Cunnamulla;
- Barwon Highway – 112 km of sealed two-lane highway linking Nindigully with Goondiwindi;
- Collarenebri Road – 5 km of unsealed road linking Mungindi to Collarenebri;
- St George – Mitchell Road – 54 km of sealed road linking St George and Mitchell.

A further three main roads within the Shire are the responsibility of the Shire. They are:

- Thallon – Noondoo Road – 64 km (of which 20 km is sealed) linking Thallon and Dirranbandi;
- Bollon – Mitchell Road – 20 km of unsealed road;
- Dirranbandi – Bollon Road – 107 km (of which 67 km is sealed) linking Dirranbandi and Bollon.

The remaining 2000 km of roads in the Shire are made up of the urban street networks of St George (approximately 47 km mostly sealed), Dirranbandi (14 km mostly sealed) and the other small towns as well as an extensive network of unsealed rural roads.

There are approximately 16 bridges on the roads throughout the Shire. Other stream crossings are typically by culvert, ford or floodway (many of which are sealed even on the unsealed road segments). This makes them all susceptible to closure during periods of rain.

Sealed roads are generally resilient to damage, though after flood episodes their bitumen seal may need repair and their foundations are likely to take some time to dry out, making them susceptible to damage by heavy vehicles.

All natural surface roads can become quickly impassable to most vehicles after rain because of their slippery clay nature. They are particularly susceptible to damage by any traffic until they have dried out sufficiently following floods. The approaches to stream crossings are likely to require repair.

The Police Service maintains the *Crossroads* information system to log road closures. This information is passed on to agencies including Council and RACQ who pass the details on to the public.

3.4.2 Rail: There are 66 km of Queensland Rail's South Western Railway within the Shire. There are sidings at Thallon, Dirranbandi, Dunwinnie, Noondale, Hawkston and Noondoo. It is believed that this line is essentially flood free, however, it could be susceptible to damage by a significant earthquake that produced surface ruptures or distortions. Some of the bridges on this line are of timber construction and would be susceptible to bushfire damage.

3.4.3 Power supply: No details of the power reticulation network were available to this study. It is, however, connected to the State grid with the main feed coming from Roma. The Dirranbandi substation was said to be the only part of the network that was potentially susceptible to flood. The bulk of the reticulation network is carried on wooden poles which are susceptible to bushfire damage. The power lines themselves may also be damaged by the radiant heat from bushfires. Lines can also be brought down by wind blown debris and, on smaller rural supply lines, by falling vegetation.

Ergon Energy have established procedures that are aimed at restoring power throughout the network within two weeks of a major flood. This includes charter of helicopters to reconnoitre damage and to position some equipment and crews. This is largely driven by the business reality that their major consumers are the water harvesters who use electric pumps to secure their allocation of flood waters. Repair times will always, however, be dictated by the length of time it takes to get repair crews in on the ground.

Power supply into Mungindi, and as far north as Moonie, is provided by NSW-based Country Energy.

Some supply facilities such as transformers, large insulators and control equipment may be susceptible to earthquake damage.

3.4.4 Water supply: Reticulated water supply is provided in St George, Dirranbandi, Bollon, Thallon, Mungindi and Hebel. The water sources include both bore field and stream catchment. Reticulation pressure is, in most instances, provided by pumps with water towers for control.

The in-ground pipe network in all centres with the exception of Hebel contains significant amounts of older AC pipe that is susceptible to rupture under relatively low earthquake loads. Table 3.8 lists the numbers of segments in each supply system that are of AC material. The figures suggest that a significant earthquake could have a major impact on urban water supplies across the Shire.

Table 3.8 Balonne Shire water supply material makeup (based on Council data)

NETWORK	TOTAL SEGMENTS	AC SEGMENTS	% AC
St George (bore field)	228	84	36.8
St George (river)	245	120	49.0
Dirranbandi	86	29	33.7
Bollon	50	23	46.0
Thallon	35	20	55.6
Hebel	16	0	0
Mungindi	23	10	43.4

Water supply could also be threatened by earthquake if the water towers were damaged or even toppled. They are inherently susceptible structures under earthquake loads given the significant mass sitting on top of a tall concrete structure.

Apart from earthquake damage, the main vulnerability of the water supply systems across the Shire is the dislocation of power supply for an extended period. All systems rely on electric pumps for both treating and reticulating supply.

The public and private irrigation infrastructure across the Shire represents a major investment. The major element in the public infrastructure of the St George Irrigation Project is the Beardmore Dam. It has a storage capacity of 81,700 mega litres (ML) and is of earth fill construction. It may be susceptible to both flood overtopping and earthquake. Associated with the Beardmore Dam is the Jack Taylor Weir (at St George) which is of concrete construction. It has a storage capacity of 10,100 ML and may not be susceptible to hazard impacts within the range considered in this study.

Private irrigation infrastructure is also significant. Cubbie Station, the largest privately owned cotton property in Queensland, has a storage capacity of 440,000 ML. This storage is fed by diversions of the Culgoa and Balonne Minor Rivers. Much of these works are earthen banks that may be susceptible to damage under major flood events, especially if the storages are already full.

3.4.5 Sewer; Reticulated sewerage is provided only in St George, Dirranbandi and Bollon. As with the water supply network the main susceptibility is in the AC pipes that again make up significant proportions of the network as shown in Table 3.9. The St George network in particular appears to very susceptible.

Table 3.9: Balonne Shire sewerage network material makeup (based on Council data)

NETWORK	TOTAL SEGMENTS	AC SEGMENTS	% AC
St George	309	271	87.7
Dirranbandi	116	34	29.3
Bollon	40	13	32.5

As with the water supply, the sewerage system is also dependant on power to run the electric pumps involved in reticulation and treatment.

3.4.6 Waste disposal: All urban centres have dedicated waste dumps. These should be adequate for most post-disaster putrescible waste.

3.4.7 Telecommunications: Broadcast radio and television is provided throughout the Shire. The radio services are provided by ABC Toowoomba (ABC 710), 4ZR Roma, 2WEB (Bourke NSW) and Rebel FM. A radio broadcast transmission facility, operated by the Australian Transmission Authority, is located near the junction of the Moonie and Carnarvon Highways north of St George.

Free-to-air TV coverage is provided by the Council by rebroadcast satellite transmissions of ABC, Imparja (based in Alice Springs, NT), Channel 7 Central and SBS in St George, Dirranbandi and Bollon, whilst Queensland Rail operate a similar service in Thallon. In St George, the retransmission facility is located next to the Shire office with the antennae mounted on the adjacent water tower (Plate 16). Smaller centres and rural properties across the Shire also access both free-to-air and pay-TV via satellite.

Whilst each of these broadcast systems are fairly resilient (as long as there is power), a significant concern is that none of them have local input through which to broadcast warning or community information messages.

Telephone, fax and data communications services operate through telephone exchanges in St George, Dirranbandi, Bollon, Thallon and Hebel. Telephone services in Mungindi are provided from the exchange located in the NSW section (see Plate 17 for the Dirranbandi exchange).

An east-west network of microwave towers is evident along the Moonie and Balonne Highways. Many rural properties appear to have telephone services that feed from this microwave backbone. Presence of appropriate satellite dishes indicates that satellite-based telecommunications services are being used by many rural properties. Telstra has also recently completed a fibre-optic link from Goondiwindi to St George and on to Roma. This provides a redundant ring which minimises the risk of telecommunications outage.

GSM mobile phone coverage is confined to within around 10 km from St George whereas there is extensive CDMA coverage (with car aerial) across the Shire.

Reliance on microwave and satellite systems makes the telecommunications network potentially susceptible to temporary disruption by severe wind damage (disturbing the alignment of antennae) and lightning.

The key to the telecommunications system, however, remains the exchanges. If they, and particularly the St George exchange, are taken out of service through hazard impact then the network, including the mobile network, is compromised – regardless of what service provider is used.

The emergency services and Council, as well as several private sector enterprises maintain mobile radio communications (UHF) throughout the area. Satellite phones are also used in the more remote areas. Both systems are susceptible to atmospheric disturbances such as severe thunderstorms.

3.5 ECONOMIC VULNERABILITIES

The Shire's economy is firmly based on agricultural industries, with cotton, wool, grain crops, beef, and wild game being the main enterprises. Horticultural crops, including table grapes, cucurbits and vegetables also important – indeed table grapes are now the second highest earning crop after cotton (BSC, 2003). The trend towards horticulture is likely to continue as the economies of water use make inefficient water using crops such as cotton less profitable.

The agricultural industries are highly susceptible to the impact of floods, severe weather and bushfires. Any wide-spread event, such as a major flood, could have a very significant impact on the Shire and State economies, given that Balonne Shire in 2000-20001 produced around $210 million of agricultural produce or around 3% of the State's agricultural output. Cotton contributed $124.3 million (30% of the State total), wool $15.8 million (8.1% of the State total); grapes $6.4 million (34.9% of the State total); and $40.3 million worth of beef slaughtered (13.6% of the State total). Drought, however, remains the most significant threat to the entire agricultural sector of the Shire (ABS, 2003b).

The significance of each industry to the Shire's economy can be gauged from the level of employment in each sector. Agriculture, with 37.9% of the workforce is clearly the dominant industry. It is followed by retailing (11.0%). The service industries of health services (6.6%) and education (6.3%) are the next largest employers. The 2001 statistics are summarised in Table 3.10.

Table 3.10: Balonne Shire employment by industry sector 2001 (source ABS, 2003a)

INDUSTRY SECTOR	PEOPLE EMPLOYED	% OF TOTAL
Agriculture, forestry & fisheries	1060	37.9
Mining	12	0.4
Manufacturing	104	3.7
Electricity, gas & water	35	1.3
Construction	159	5.7
Wholesale trade	127	4.5
Retail trade	309	11.0
Accommodation, cafes, etc	125	4.5
Transport & storage	81	2.9
Communications services	42	1.5
Finance and insurance	28	1.0
Property & business services	85	3.0
Government & defence	121	4.3
Education	175	6.3
Health & community services	184	6.6
Cultural & recreation services	9	0.3
Personal & other services	81	2.9
Unclassified	15	0.5
Not stated	45	1.6
Total	2798	

3.6 ENVIRONMENTAL VULNERABILITIES

The native flora and fauna of the Shire has evolved to cope with the impact of natural hazards such as flood, severe storms and bushfire. The development of agriculture and the introduction of exotic animals have had far greater impact than any natural hazard event is ever likely to.

Riverine and riparian ecosystems in the area have evolved to rely on periodic and frequent flooding. The impact on these ecosystems of the reduction of the frequency and extent of flooding by water harvesting and flood mitigation works has been identified as a concern by environmentalists.

3.7 FUTURE EXPOSURE AND VULNERABILITIES

The various issues of exposure and vulnerability detailed above relate to what the situation currently is in Balonne Shire. The demography, economy and built environment of the Shire will not, however, remain static. In much the same way as climate change must be considered, so too should the other likely temporal changes in the other constituents of the disaster risk environment be considered.

As mentioned in Chapter 1, the Department of Local Government and Planning has projected an ongoing increase in the Shire's resident population to reach a total of around 5,500 by 2021, an increase of approximately 700 people over the 2001 total. We assume that this growth will be concentrated in St George and Dirranbandi and that it is likely to be based largely on in-migration for employment within the Shire, rather than on natural growth in the existing population. Such population growth will increase the level of risk in the Shire simply because there will be more people, buildings and infrastructure potentially exposed to hazard impacts. It is not possible, however, to translate those population projections into forecasts of changes in demographic, social or economic make-up of the community into the future (see Glavac, Hastings and Childs, 2003).

Many of the changes that will influence community safety in Balonne Shire into the future (either for good or bad) will be triggered by outside influences and events, rather than by decisions taken within the community. Issues such as the globalized economy, changes in public policy (at international, national and state levels) and technical innovation will all have an impact comparable to those anticipated to be brought about by global warming and consequent climate change.

The degree to which levels of risk become an issue in Balonne Shire will largely depend on the implementation of appropriate planning policies and community governance by Council. If such activities continue to recognise the importance of safe and sustainable communities, then that growth, and other changes, are unlikely to produce unacceptable levels of risk.

CHAPTER 4: THE RISKS ANALYSED

In this Chapter the risks are analysed by drawing together the information on the hazard phenomena, the elements in the community exposed to those hazards and the vulnerability of those elements to such exposure. A risk register, in which the identified risks are prioritised, is developed.

4.1 SPECIFIC RISKS

This section summarises the specific risks posed by each of the hazards considered.

4.1.1 Floods: Floods are the most frequently occurring hazard in Balonne Shire with the effects of flooding increase from north to south. Fortunately, the more frequently occurring levels of flood produce inconvenience rather than disaster. Their impact is more pronounced in the rural communities than they are in the urban communities. The inconveniences and losses brought by flooding are, to a large extent, offset in most rural communities, especially those in the dry-land grazing and cropping areas, by their replenishment of soil moisture and surface water. They are also welcomed by water harvesters in the irrigation areas as the opportunity to replenish their irrigation storages.

Council's greatest exposure to most floods is with the roads for which they are responsible. These will inevitably suffer some damage, either from the flood waters themselves or from them being used by heavy vehicles before they have adequately dried out. The likelihood, consequences and risk levels for flood in all of the Shire's river catchments are summarised in Table 4.1.

Table 4.1 Balonne Shire catchments flood likelihood, consequences and risk levels

LIKELIHOOD	CONSEQUENCES	RISK LEVEL
Almost certain (ARI ~2-5 years)	Minor to moderate flood levels reached. Roads cut and a few tens of rural properties isolated for days. Stock losses possible. Minimal risk to urban communities.	Insignificant to Minor
Likely (ARI ~10 years)	Major flood levels reached. Roads cut, perhaps as many as 100 rural properties isolated for up to a few weeks. Power cuts and stock losses likely. Minimal urban properties.	Insignificant to Minor
Unlikely (ARI ~ 50-100 years)	Major flood levels reached. Roads cut for weeks and damaged. Power cuts certain and damage to infrastructure likely. At least 150 rural properties isolated for several weeks; building and equipment damage likely. Some evacuations likely. Potentially extensive stock losses. Damage to irrigation infrastructure possible. A few tens of low-lying urban properties likely to be flooded.	Moderate
Rare (ARI ~200 years or greater)	Widespread road and infrastructure damage. Rural properties and urban communities isolated for several weeks with virtually the entire population of the Shire directly or indirectly affected. Evacuations will be required. Extensive stock losses. Major irrigation infrastructure damage likely. Significant inundation of urban properties including St George and Dirranbandi. Major economic losses. Loss of life possible.	Major to Catastrophic

Floods approaching PMF levels will be devastating and lead to heavy loss of life and virtually total property loss. They could, in fact, change the whole landscape.

4.1.2 Tropical cyclones and severe thunderstorms: The widest exposure of all hazards is to the severe winds brought by both tropical cyclones and severe thunderstorms. No area of the Shire is immune. In addition to destructive winds, severe thunderstorms also bring hail and lightning. Any given storm, however, produces a relatively small footprint. Given their much greater area of exposure, rural areas are more likely to suffer the impact of severe winds and hail than are urban centres. When a severe storm does hit an urban centre, however, damage and economic losses can be considerable, with injury and even fatalities a possibility.

Council's exposure to destructive wind losses is relatively small with the greatest risk being posed to their buildings and vehicles.

The likelihood, consequences and risk levels posed by the destructive winds and hail associated with tropical cyclone and severe thunderstorm hazards are summarised in Table 4.2.

Table 4.2: Balonne Shire destructive wind and hail likelihood, consequences and risk levels

LIKELIHOOD	CONSEQUENCES	RISK LEVEL
Almost certain (ARI ~2-5 years)	Minor to moderate levels of wind and hail damage reached in small areas – a few tens of buildings damaged. Roads and power supply may be affected for a short time by fallen trees. Power supply may also be affected by lightning strike.	Insignificant to Minor
Likely (ARI ~10 years)	Major levels of wind and hail damage reached in small areas – a few buildings destroyed and up to 100 buildings with significant damage. Roads, power supply and telecommunications infrastructure may be affected for up to a day by fallen trees, blown debris and/or lightning strike. Crop losses from hail likely. Vehicles in the open likely to suffer hail damage. Some older buildings may lose their roofs. Injuries likely.	Moderate
Unlikely (ARI ~50 years)	Major levels of wind and hail damage reached in extended areas – tens of buildings destroyed and more than 100 severely damaged. Roads, power supply and telecommunications infrastructure will be affected for more than a day by fallen trees and blown debris. Crop and stock losses from hail almost certain. In areas where hail is experienced, vehicles and equipment in the open will suffer damage. Some buildings likely to lose roofs or suffer debris damage. Serious economic impact. Numerous injuries likely and loss of life possible.	Major
Rare (ARI ~100 years or greater)	Severe wind damage over extensive areas, hail damage over smaller areas. Many tens of buildings destroyed and a few hundred more severely damaged. Roads, power supply and telecommunications infrastructure will be affected for up to a week by fallen trees and blown debris. Widespread crop and stock losses. In areas where hail is experienced, all vehicles and equipment in the open will suffer damage. Major economic losses. Many injuries and some loss of life likely.	Catastrophic

4.1.3 Bushfires: The principal ingredient for bushfires is the availability of ample fuel. This is only found in quantities in the dry-land farming areas of the Shire. In those areas, however, fire is commonly used as a land management tool and communities in those areas are very familiar with the hazard and how to manage it. There is some risk posed to standing crops and stock losses could be significant in more severe and rapidly developing fires. There is very little threat to urban communities and to irrigation areas. Fire fighters are the most likely people to be injured or killed by bushfire.

Bushfires pose a low level of risk to Council. Their greatest exposure is probably that associated with claims for compensation should a damaging fire originate on Council-controlled land. The likelihood, consequences and risk levels posed by bushfire hazards are summarised in Table 4.3.

Table 4.3: Balonne Shire bushfire likelihood, consequences and risk levels

LIKELIHOOD	CONSEQUENCES	RISK LEVEL
Almost certain (ARI ~2-5 years)	Small intensity fires with some spread potential. Limited property threat. Easily controlled.	Insignificant
Likely (ARI ~10 years)	Medium intensity fires with some spread potential. Property such as fencing likely to be damaged. Easily controlled.	Insignificant
Unlikely (ARI ~50 years)	Severe intensity fires with significant spread potential. Property loss, especially standing crops and stock, possible. Injuries to fire fighters possible. Manageable by conventional methods.	Minor
Rare (ARI ~100 years or greater)	Extreme fire intensity with major spread potential. Property loss, especially standing crops, stock and some buildings, likely. Injury to fire fighters likely and fatalities possible. Difficult to manage by conventional methods.	Major

4.1.4 Earthquakes: The historical evidence suggests that whilst earthquakes may be experienced in all parts of the Shire, they are more likely to achieve damaging intensities in the eastern half of the area. They pose a relatively low level of risk overall.

Council's exposure to earthquake loss is probably confined to possible damage to water and sewerage infrastructure. Older buildings, including the Council Offices could also be at risk of damage given their age and construction. The likelihood, consequences and risk levels posed by earthquake hazards are summarised in Table 4.4.

Table 4.4: Balonne Shire earthquake likelihood, consequences and risk levels

LIKELIHOOD	CONSEQUENCES	RISK LEVEL
Almost certain (ARI ~0-50 years)	Small intensity shaking to MM IV. Little if any damage.	Insignificant
Likely (ARI ~100 years)	Small intensity shaking to MM V. Little if any damage.	Insignificant
Unlikely (ARI ~500 years)	Moderate intensity shaking to MM VI. Minor damage to poorly constructed buildings possible. Injuries unlikely. Some damage to the more fragile in-ground infrastructure possible.	Minor
Rare (ARI ~1000 years or greater)	Moderate intensity shaking to MM VI to VII. Damage to older masonry and poorly constructed buildings likely. Some serious injuries possible but fatalities unlikely. Some dislocation of in-ground infrastructure likely.	Moderate

4.2 REGISTER OF TOTAL RISKS

In order to guide and prioritise the development of risk treatment options the following assessment of total risk across the various communities that make up the wider Shire community is provided.

4.2.1 The towns: The two largest towns in the Shire, St George and Dirranbandi, carry the greatest levels of risk, simply because they contain more people and assets that are potentially exposed to hazard impacts. They also contain the more susceptible communities. The data available to this study, especially that relating to flood, does not permit a detailed quantification of exposure and consequently potential economic impacts of a range of disaster scenarios. The fact that some structural mitigation works have been developed to 'protect' Dirranbandi indicates that there has been a demonstrated need to reduce exposure and consequently risks.

The levels of community awareness and preparedness is difficult to measure, however, given the highly mobile nature of the population of both centres, and the relatively long period since the last major flood impact, it is likely to be low. Populations in both towns are very much dependant on the ready availability of food, fuel, power and water supplies.

These towns also contain the most significant critical facilities that support the whole of the Shire including hospitals and other medical services; emergency services and disaster relief control; key transport infrastructures (e.g. airfields); telecommunications nodes; and logistic support services (food, fuel, etc). Any impact on these towns, or their isolation, will flow on to the wider community.

Flood is clearly the hazard with the greatest risk potential. Even if a flood event does not enter these towns they will be isolated from the hinterlands they service. They can also be cut off, other than by air, from sources of resupply.

Severe thunderstorm and tropical cyclone winds pose the next greatest threat. These hazards have caused significant damage to buildings and infrastructure in the recent past.

Earthquake poses the next most significant threat to both centres. The chief concern is the apparent susceptibility of their water supply and sewerage systems to earthquake shaking. Some older un-reinforced masonry buildings are also susceptible to damage.

Bushfires pose only a minor threat to the towns.

4.2.2 The villages: The next highest levels of risk are carried by the smaller villages – Mungindi, Thallon, Bollon and Hebel – again because of the relative concentration of people and economic assets and the fact that they provide services (albeit limited) to an extended hinterland. Mungindi is a special case given that the bulk of the population and assets of this centre are located on the NSW side of the border. The hospital, located on the Queensland side, is a key facility for populations in both NSW and Queensland and is thus of critical importance.

Flood again is the hazard which poses the greatest level of risk, especially given the extended length of time that these villages could be isolated by flood waters. Mungindi and Thallon both have some level of protection provided by levees, however, it is unlikely that they would afford protection to other than events with a relatively frequent ARI.

Destructive winds are probably the second greatest risk. As with the towns, each of the villages has experienced significant damage from sever thunderstorms – Hebel was almost completely demolished in one recent storm.

Bushfire is probably the next greatest threat, especially to Bollon and possibly Thallon.

Earthquakes pose a relatively limited threat, though Thallon and Mungindi would have a slightly greater risk than the more western centres.

4.2.3 <u>The irrigated lands</u>: The high-value crops and major engineering investments associated with the St George and Dirranbandi irrigation areas are exposed to considerable risk, primarily from flood and destructive winds. The risks posed to people are minor, because their populations are small and widely spread. People in these areas could, however, be isolated for many weeks during floods and require either evacuation or regular re-supply by helicopter or flood boat. The economic risks, by contrast, are considerable. A major flood or severe storm could wipe out many millions of dollars worth of agricultural production and cause significant damage to irrigation infrastructure.

Earthquake and bushfire are not considered to be significant threats, though an extreme earthquake event could destroy or damage infrastructure such as the Beardmore Dam. The likelihood of such an event, however, is considered to be remote.

4.2.4 <u>The dry-land areas</u>: Here again, the economic risks are much greater than the threat to people, though major floods will isolate people for extended periods. Floods pose a significant threat to stock which may need to be sustained by fodder drops by helicopter. Fencing and pastures will also be damaged, however, the value of replenished soil moisture and surface storage will offset these losses to some extent.

Destructive winds and hail pose a significant threat to crops such as wheat and barley. Most grain growers, however, are able to insure their crops against such impacts.

Bushfires pose a significant threat to both pasture and standing crops, as well as to livestock and fencing.

Earthquakes pose an insignificant risk in this area.

CHAPTER 5: TREATING THE RISKS

In this chapter, strategies that would help to reduce or eliminate disaster risks across Balonne Shire are identified and discussed. It is focused primarily, but not exclusively, on those strategies that might be adopted by Balonne Shire Council. Where they address issues that are the responsibility of either State or Commonwealth agencies, or individual property owners, they are expressed in terms of what Council might do to influence the adoption of treatment strategies by those who have the primary responsibility.

5.1 OVERVIEW

There is no single point of responsibility for disaster risk mitigation – it is a total community responsibility. Acceptance of that fact, especially after a tragic event, is far from universal. It is an unfortunate, but understandable, feature of disasters such as floods and bushfires that after the event, victims feel the need to allocate blame. Typically, that blame is directed towards the public sector – 'why did Council permit that development on the floodplain in the first place?'; 'if the National Parks people had managed their fuel, the fire would not have been so bad'; 'why didn't the SES get a tarpaulin on my damaged roof quicker?', and so on. The media reporting of the January 2003 fires in Canberra, for example, are full of such expressions.

The risk management standard *AS/NZS 4360-1999* identifies four options for risk treatment:

- eliminate the risk – whilst this is the theoretical ideal, this option is very difficult to achieve in practice because it would require one or more of the risk elements (hazard, exposure, vulnerability) to be reduced to zero;
- reduce the risk – this is typically the most practical option, however, it inevitably involves setting thresholds beyond which risk reduction is deemed to be either impractical or uneconomic. This involves the difficult and often contentious task of establishing what the community considers to be a level of 'acceptable' or 'tolerable' risk;
- transfer the risk – administratively, this is frequently done by a higher level of government passing responsibility to the next level down the line, or governments passing responsibility to individual property owners. When available, insurance is the most common strategy employed to transfer financial risk;
- accept the risk – where it is not possible to eliminate, reduce further, or fully transfer the risk, the residual risk is simply accepted or tolerated. Acceptance typically relates to those risks that are either relatively common, but their impact is more of an inconvenience than a significant threat (i.e. not worth worrying about); or those that may have a devastating impact but their occurrence is extremely rare (i.e. impossible to control or manage).

The strategies that relate to specific hazards are dealt with first and are followed by more general strategies that are applicable to all hazards. Regardless of which strategies are adopted, it is important for risk managers to see disaster risk reduction activity as being **an investment rather than a cost**.

5.2 TREATING FLOOD RISKS

It is not within the capacity of modern science and technology to have an impact on the flood hazard component. Flood risk reduction must, therefore, be achieved by affecting exposure and/or vulnerability. Reducing exposure is the approach most commonly adopted, with the planning process, building siting and design, warning systems and evacuations are the principal mediums used. Flood insurance is one of the few strategies available for reducing vulnerability to flood impact.

5.2.1 The planning process: Preventing inappropriate development in a floodplain is a very effective strategy by which to prevent the growth of future risks. In most circumstances, however, it can by itself have only limited impact on established development. Reducing exposure of existing development typically requires construction of works such as levees, detention basins, drainage systems and vegetation management, and/or the modification or relocation of existing structures.

It is not possible to understand, let alone effectively treat, the flood risk posed to both present and future development without a clear understanding of the hazard and its likely impact across a range of scenarios. Such information is largely lacking for Balonne Shire, other than (perhaps) for Mungindi. This situation is probably the result of two factors:

- first, the emphasis in the floodplain management studies of the Moonie and Balonne systems undertaken to date has been on their irrigation potential rather than on flood control issues; and,
- second, the fact that over the past 100 years or so, floods have had only a limited impact on the population centres of the Shire, whilst their impact on dispersed rural communities has more often been a blessing than a curse.

Given the continuing growth and economic importance of both St George and Dirranbandi, and the forecast changes in flood regimes under the most widely accepted climate change scenario, it would be appropriate for detailed hydrological and hydraulic studies of the flood hazard at those localities to be undertaken. It would also be appropriate for such modelling to be extended, albeit at a lower resolution, to the whole of the lower Balonne and Moonie catchments to provide a clearer appreciation of flood risks in the smaller settlements and the wider countryside. Developments in these areas over the past decade, especially irrigation and water harvesting infrastructure, is likely to have introduced significant complexities into the region's hydrology that has not been taken into account in the existing modelling. Modern mapping and modelling techniques can also greatly reduce the uncertainties and inaccuracies that existed in earlier work.

Given the wide range of stakeholders involved, such modelling would need to be supported and contributed to by Commonwealth and State Government agencies (including Sunwater), as well as the private sector (including members of Smartrivers). It may also be appropriate for agencies such as the Murray-Darling Basin Commission and NSW Government agencies to also participate and/or contribute. **This modelling should not be seen as a responsibility for Balonne Shire Council alone.**

Such studies are recommended by State Planning Policy 1/03 (SPP 1/03) (DLGP/DES, 2003a) to meet the requirements of local governments to establish 'natural hazard management area (flood)' for a

'Defined Flood Event'[3] (DFE) in their planning schemes under the *Integrated Planning Act*. Paragraph A3.2 of Annex 3 (p16) of SPP 1/03 states:

> *The Queensland Government's position is that, generally, the appropriate flood event for determining a natural hazard management area (flood) is the 1% Annual Exceedance Probability (AEP) flood. However, it may be appropriate to adopt a different DFE depending on the circumstances of individual localities. This is a matter that should be reviewed when preparing or undertaking relevant amendments to a planning scheme. Local governments proposing to adopt a lower DFE in their planning schemes to determine a natural hazard management area (flood) for a particular locality will be expected to demonstrate to the satisfaction of the Department of Emergency Services (DES) and the Department of Natural Resources and Mines (NR&M) that the proposed DFE is appropriate to the circumstances of the locality.*

A footnote to this paragraph amplifies its advice as follows:

> *Local Governments are encouraged to adopt a DFE and identify natural hazard management areas (flood) in a planning scheme as soon as possible to enable the application of the SPP to development in flood prone areas.*

Appendix 2 of the Guidelines to SPP 1/03 (DLGP/DES, 2003b) provides guidance on the key issues to be considered when determining an appropriate DFE, including taking into account climate change. It is important to note that these guidelines recommend that modelling be undertaken to identify the risks posed by events beyond the level of that selected for the DFE up to and including the PMF level. Dam failure issues should also be included in that modelling, not only for major structures such as the Beardmore Dam and Jack Taylor Weir, but also for the many irrigation storage ring dams (both registered and unregistered), the failure of which could greatly exacerbate local risk levels during a flood.

In addition to providing appropriate information on which Council can establish appropriate planning constraints for flood in urban areas, it would also provide an assessment of the adequacy, or otherwise, of the levee system developed at Dirranbandi and Thallon. It would also provide a basis on which to assess the benefits and costs of developing further structural mitigation works such as raising the level of flood-prone road segments.

Such a modelling project would need to be underpinned by a greatly improved map base at an appropriate scale, especially the development of a DEM with a vertical accuracy of at least 10 cm or better and the mapping of all works developed in the floodplain such as irrigation channels, drains, ring dams and so on. Given the importance of the drainage networks that flow through the Shire to both the Queensland and national economies and environment, **such mapping should be seen as a strategic investment in the national interest**.

Given the scale and likely cost of this 'top end' strategy, information on historic flood events can be used in the interim. Satellite imagery of major floods such as those of 1988, 1990, and 1996 are available and could be used to map, within a few tens of metres, the extent of inundation. Such

[3] Defined in SPP 1/03 as: 'the flood event adopted by a local government for the management of development in a particular locality. The DFE is generally not the full extent of flood-prone land.'

mapping would also provide valuable calibration for the essential modelling. A program of collecting oral histories from residents who experienced these and earlier events and relating that material with attributes such as flood depth and duration of inundation, would also greatly enhance subsequent modelling.

Should a major flood event occur before a program of modelling and high resolution mapping is undertaken, every opportunity should be taken to gather accurate information on the behaviour of the flood. Sequential coverage by satellite imagery, using both radar and multi-spectral sensors, could be used to map both the extent of inundation and its behaviour over time as the peak works its way through the catchment. GPS measurements on the ground would also provide the level of control that would provide accuracies of a few metres, if not better. Implementation of such a data capture and analysis effort would, however, need to have been planned and resources identified well in advance. Again, such an effort would require the support and commitment at all levels of government and the public, as well as input from technical agencies such as Geoscience Australia, CSIRO, DNRM and relevant academic bodies.

5.2.2 Structural defences: For many years the most common response to a known or perceived flood threat has been to build defences such as levees, drainage works or detention basins. These defences are normally designed to provide flood immunity to a stated historic or modelled level of event that represents an 'accepted' level of risk. The levees that protect Mungindi, for example were designed to the level of the flood of record (1976). Levees constructed at Dirranbandi and Thallon, however, appear to have been simply built to an 'agreed' level.

Structural defences are very effective at reducing risks posed by the more common levels of flood inundation. They can, however, engender a false sense of security. It is not uncommon for communities to adopt the attitude that because there is a levee, then all flood risks, regardless of stage height, have been eliminated. This can produce a false sense of security that will magnify residual risks if the levee is overtopped or if it fails, as happened in the NSW town of Nyngan in 1996.

When considering structural defences it is also essential that 'escape' strategies also be considered such as identifying flood-free localities to which people could be evacuated before the levee fails. A flood-free escape route for St George, for example, could significantly reduce the residual risk posed by an event similar to that of 1890.

5.2.3 Building siting and design: In planning schemes that have established 'natural hazard management areas (flood)', exposure reduction is achieved through establishing minimum ground height and floor height levels above the DFE level. In areas not covered by a planning scheme it is left to the building owner to incorporate strategies to minimise flood inundation by either siting their buildings on land that is thought to be flood-free (based on local knowledge of flood history), by constructing buildings on elevated mounds and/or constructing buildings on piles that elevate floor levels. In areas where flood velocities may pose an additional problem, building designs typically leave the ground level components open so that flood waters can flow through under the house with minimal resistance.

Most of the houses constructed in the Shire before the mid-to-late 1980s were constructed with floor levels generally 0.8 m or more above ground level. More modern houses, however, have adopted slab-on-ground forms of construction which provides minimal immunity if sited in flood-prone areas.

Older houses tend to be less susceptible to damage if inundated because of the materials used. Homes in this category tend to have both external and internal walls, as well as fittings such as kitchen cupboards, of solid timber. Such material is quite resilient to inundation. More modern homes, by contrast, have plaster board internal walls and cupboards of chipboard, both of which materials suffer significant damage if inundated, especially if inundation lasts for more than a day.

5.2.4 Warning systems: 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, that is, by reducing the level of their exposure to the hazard. 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. Figure 5.1 shows how experience and effective warnings can greatly reduce flood damage.

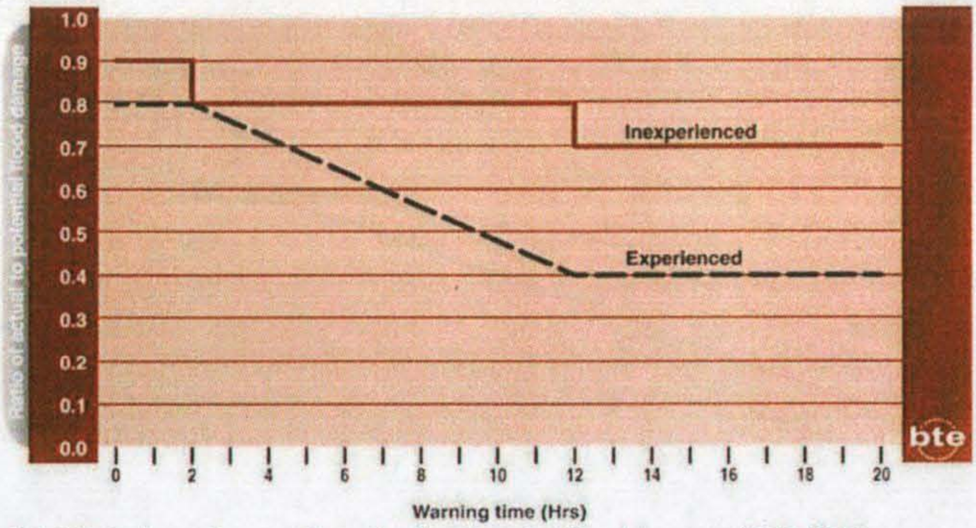

Figure 5.1: Affect of experience and warning time on actual flood damages (BTE, 2001).

The responsibility for flood forecasting and warning services in Australia rests with the 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 roles and relationships of the various agencies involved are outlined in Figure 5.2.

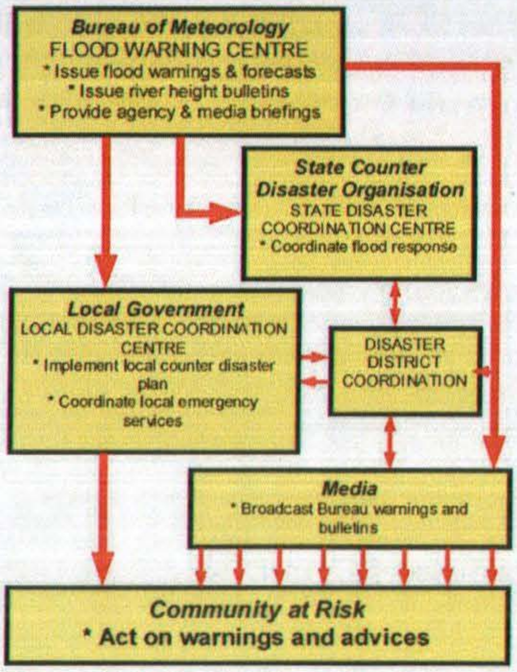

Figure 5.2: Roles and responsibilities within the flood warning system (Granger and Hayne, 2001, Fig 9.19)

These flood warning services provide:

- river height bulletins which contain the latest observed river heights at selected locations within a catchment and are issued up to six times daily;
- flood warnings, which provide a summary of existing conditions within a catchment and predictions of river heights at key locations (towns, bridges, rural centres).
- professional advice and assessments of flood conditions to emergency agencies and local government officials;
- media briefings of radio, television and newspaper news services.

The formal flood warning system relies on data from automatic weather recording stations and stream gauges, and reports from observers in the field. These data are incorporated into hydrological and hydraulic models of river behaviour to produce the forecasts included in the bulletins and warnings. Warnings are given as estimated stage heights likely to be reached within a given time frame. Effective use of this information, however, requires community members to be able to translate stage heights to flood heights on their own properties. In rural areas at least, most residents are experienced in making those translations and act accordingly. It is unlikely that urban dwellers have the same knowledge and scope exists for Council to incorporate such information in their community education work.

An informal warning network also operates with property holders along the rivers keeping their neighbours, police and Council officers informed of actual flood behaviour and its impact (e.g. by reporting road closures). Both formal and informal systems contribute greatly to reducing exposure to flood impact and both should be sustained, if not enhanced.

5.2.5 Evacuation and rescue: Most roads in the Shire are susceptible to closure by flood waters. This will impose difficulties if people in isolated areas need to be evacuated, either for medical or other emergency reasons, or because their extended isolation poses an unacceptable risk. Though inundated, some roads 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, and then only on roads with a bitumen surface. Larger, higher and heavier cars can only drive safely though water less than about 0.4 m deep (ARMCANZ, 2000). Evacuation over natural surface roads with up to 1.0 m of water over them (and with minimal velocity) should only be attempted as a last resort and then using heavy high-set vehicles such as graders, large tractors or trucks. Such depths of water would normally require evacuation by boat, or helicopter.

Where it can be anticipated that people in isolated areas will probably require evacuation in the event of a flood, for example, ladies at an advanced stage of pregnancy or people who rely on medical support such as home dialysis, precautionary evacuation before roads begin to go under water is preferable. Such vulnerable people should be identified and their details maintained by emergency managers with the assistance of local medical practitioners.

Should an emergency evacuation be required from a property that is isolated by flood water, because of an injury sustained in an accident or because of snake bight, for example, helicopter rescue resources will probably be required. Navigation of helicopters to a rescue location during floods can be a problem unless accurate coordinates of the destination are available. Roads and watercourses that would normally be used for visual navigation disappear in a flood and the location of homesteads or outstation buildings are rarely accurately recorded. A concerted effort is required to record coordinates for all occupied buildings in rural areas using GPS technology and maintained in a database managed by Council to overcome this problem.

Taroom Shire Council, in conjunction with their SES unit, established such a system in 2001 to complement the introduction of their rural addressing scheme. SES volunteers have visited every property and recorded GPS coordinates for every homestead, cattle yard and so on. Each locality is given a unique identification number and a brass tag with that ID number and the relevant coordinates are fixed at each site and a similar tag is placed beside the telephone at the homestead (see www.loc-gov-focus.aus.net/2001/june/sesgps.htm for details). The Taroom system would be an ideal model for Balonne Shire to follow.

5.2.6 Flood insurance: Until recently, flood insurance was available only for commercial premises and rural industries. It was not readily available for residential properties. This situation is changing due in part by public and political pressure on the insurance industry (see, for example, the papers contained in Smith and Handmer, 2002). Major insurers operating in Queensland now offer domestic flood insurance, typically as an option that attracts an additional premium. Suncorp Metway Ltd, for example, offers such an option, but it is not available in areas where '*accurate, historical flood risk information is not available*' or where '*the risk of flooding is so high that we are not prepared to offer flood cover as an option*' (Suncorp, 2003).

5.2.7 Funding sources: The Commonwealth Department of Transport and Regional Services (DOTARS) administers the Regional Flood Mitigation Programme (RFMP) '*a Federal Government initiative working in partnership with State, Territory and Local Governments in the implementation of* *priority, cost effective flood mitigation works and measures in rural, regional and outer metropolitan Australia... Projects funded by the Regional Flood Mitigation Programme are those which address flooding issues as part of regional floodplain management.'* (see www.dotars.gov.au/regional/rfmp/ for details and project guidelines).

Other sources of funding may also be available for minor mitigation efforts. The Taroom GPS project, for example, was funded through a grant from the Jupiter's Casino Community Benefit Fund.

5.3 TREATING SEVERE THUNDERSTORM AND CYCLONE RISK

As with flood, there is nothing that can be done to reduce thunderstorm or cyclone hazards, and given the generally flat terrain of Balonne Shire, there is little that can be done to reduce exposure. Reducing the risks posed by thunderstorms, therefore, must rely largely on reducing vulnerability. The use of appropriate building design/construction standards and warning systems are the most effective strategies available.

5.3.1 Building design and construction: Advances made in severe wind resistant construction since the 1970s have resulted in improved building performance under wind loads. Houses built since 1980, or those that have had their roofing systems upgraded to the new standards, should perform well under severe wind loads. Older buildings that have not been upgraded, and/or those that have been exposed to past severe wind episodes, will be more susceptible to damage. The following quote from Harper, Granger and Hall (2001) provides a background on wind loading codes:

> *Wind loading standards in Australia were first implemented by structural engineers in 1952 and have been variously updated over time. After the experience of the severe destruction wrought by TC* Althea *(Townsville) in 1971 and TC* Tracy *(Darwin) in 1974, special efforts were made to strengthen building standards in Queensland and elsewhere in Australia, especially for domestic structures. Standard* AS1170.2 Minimum design loads on structures: Part 2 – Wind loads *was first published in 1973 and was subsequently revised in 1975, 1981 and 1983. The current (5th) edition was published in 1989 (Standards Australia, 1989). This Standard was first adopted under the* Queensland Building Act *in 1975. Before this, each local authority had its own building regulations, and many authorities would have referred to the wind code. However, housing was not explicitly addressed in the* Act *until Appendix 4 was included in the 1981 publication of the* Act. *Implementation of the 1981 publication did not occur until 1 July 1982 (George Walker, Aon Group Australia Ltd, written communication, 2001).* AS1170.2 *is now encompassed by the* Building Code of Australia. *The wind loading code is based on a design event for which there is a 5% probability of exceedance in any 50 year period (i.e. a notional 1000 year ARI or 0.1% AEP).*

In their oversight of construction standards, Balonne Shire Council applies to the *Building Act* and the *Building Code of Australia*, however, the vast majority of buildings in the Shire (perhaps more than 80%) were constructed before implementation of the wind loading code. Guidelines are available, however, for the retrofit of pre-code buildings to bring them up to modern wind resistant standards. Council could consider adopting these as regulations that make upgrade to modern standards mandatory for their own building assets and when any major renovation, alteration, addition or change of use is undertaken to private buildings. *SAA HB132.1* and *SAA HB132.2* (Standards Australia & ICA, 1999a and 1999b) contain recommendations for structural upgrade of dwellings for severe wind.

Harper, Granger and Hall also provide the following advice regarding hail damage:

> *Damage to housing and infrastructure due to hail is a progressive failure, dependent upon the hail size and to some extent on the angle of attack. Windows are normally the first affected and will break at around the 30 to 40 mm hail size (SEA, 1999). Aluminium awnings, external shades and vinyl sidings are also susceptible to hail damage at about this size. Roofs and guttering are normally next to fail, especially aged AC sheeting, brittle tiles and aged corrugated iron. There were several reports from the 1995 storm impact on the Brisbane suburb of Bellbowrie of hail penetrating both roof tiles and the plaster board of the ceiling before damaging furniture inside the building.*
>
> *When roof integrity is lost, significant rainwater entry occurs and contents damage rapidly rises. As has been witnessed with the 1999 Sydney hail storm, delays in roofing repair can severely exacerbate the consequential losses. In past events in South-East Queensland involving hail sizes in the order of 80 mm, some insurance losses have reached 25% of the insured value of the property (SEA, 1999). Similar levels of loss can be expected in* (Balonne Shire). *Motor vehicle damage can also be very extensive when hail sizes exceed 40 mm. It should also be remembered that large hail is a significant personal hazard and serious injuries can be sustained by people (or animals) unable to gain shelter.*

There is probably little that can be economically done to reduce vulnerability to hail damage of existing buildings and infrastructure. Choice of hail resistant materials, such as toughened concrete tiles, in new buildings should, however, prevent the risks from growing further. Council might consider providing advice on such material to local builders, and to people making applications for building permits.

5.3.2 Lifeline vulnerability: Above-ground infrastructure is clearly exposed to thunderstorm hazards including wind, lightning and hail. There is little that can economically done to reduce this exposure or to improve on its resilience. Service providers should, however, take account of these risks when planning and equipping to undertake emergency repairs.

5.3.3 Warning systems: Some reduction to the overall losses from severe thunderstorms, especially hail damage to vehicles, could be achieved if warnings of approaching storms could be provided in a timely fashion. Unfortunately the effectiveness of storm tracking by radar over Balonne Shire is diminished because of the gap in coverage over the Shire between the Charleville and Moree radars. Even if this gap did not exist, the lack of a local radio broadcast station tends to limit the dissemination of warnings to the public.

5.4 TREATING BUSHFIRE RISK

Unlike the other hazards dealt with in this report, there are strategies available by which to reduce the hazard (if there is no fuel there is no fire), as well as strategies to reduce both exposure and vulnerability.

5.4.1 Managing the hazard: The objective of fuel management is to mitigate fire risk by reducing fire intensity and spread. Its objective is not, and can not be, to eliminate fire. Whilst the priority in risk reduction is the protection of life and property, the management of fuel, particularly by prescribed burning, should be done in such a way as to have a minimal negative impact on biodiversity. There are two recognised forms of fire management to preserve biodiversity, namely:

- prescribed burning on a rotational basis to reduce fuel loads to an acceptable level, that is, burning carried out under selected conditions such that the fire will burn a predetermined amount of vegetation within predetermined boundaries. This method is generally used to reduce fuel throughout large areas; and,
- site-specific mechanical control such as slashing, hand removal of fuel and/or use of herbicides to remove growth. This technique is only viable in smaller sites, generally to establish fire-lines, or along roads and tracks.

In areas in which the preservation of biodiversity is less of a concern, two additional forms of fuel management can also be employed:

- grazing by stock in appropriate numbers to keep vegetation at a desired level. This can be effective across wide areas; and,
- the planting of fire retardant species to protect built structures and fire sensitive vegetation types by creating a barrier to catch sparks and embers, and to shield them from radiant heat (so-called 'green fire breaks').

It is the responsibility of the land owner and/or land controller to manage the fire hazard on their land in a 'responsible manner'. Section 69 of the *Fire and Rescue Service Act* 1990 requires land owners to take measures to reduce the risk of fire and, in the event of a fire, the danger to persons, property and the environment through, *inter alia*:

- the maintenance or making of firebreaks;
- the removal of vegetation;
- the obtaining of fire fighting equipment;
- the provision of an adequate water supply;
- the suspension of operations.

The objective of fuel management should be to prevent any fire that may start on their land to spread beyond their boundaries.

The bushfire hazard can also be reduced by minimising the incidence of ignition. Whilst there is nothing that can be done to prevent lightning strike starting fires, there are strategies available to reduce the incidence of human-produced causes.

Fire weather warnings: When fire weather conditions become extreme (i.e. a combination of existing and forecast weather conditions, and estimates of fuel loads), under the Commonwealth *Meteorology Act*, the Severe Weather Section of the Bureau of Meteorology's Regional Office in Brisbane is required to issue a public Fire Weather Warning. Where such a warning is issued, it is usual practice for a local fire ban to be declared over the areas likely to be affected.

Fire bans and states of fire emergency: Part 8 of the *Fire and Rescue Service Act 1990* provides the legislative base for the declaration of local fire bans (Division 1) and states of fire emergency (Division 2). Fire bans may be imposed by the Fire and Rescue Service Commissioner over an entire local government area, or part thereof, and will prohibit the lighting of all, or only certain types of fires. The duration of a local fire ban may not exceed 14 days and may be cancelled at any time after its declaration by the Commissioner. The declaration of a local fire ban revokes the authority of fire wardens and other authorities to issue permits to light fires.

A declaration of a state of fire emergency may be made by the Commissioner, with the approval of the Minister for Emergency Services, across the whole State or part thereof. It can impose restrictions on the lighting of fires similar to those in a local ban, but gives the Commissioner more flexibility in their application. The most important power given under a state of fire emergency is that the Commissioner may *"...requisition premises, plant, equipment, materials or substances for fire fighting or fire prevention."*

These legal provisions impose criminal sanctions to the lighting of fires during periods of significant and identified high fire threat. These usually relate to periods when episodes of fire weather are forecast or when unusual fuel conditions exist, e.g. after a cyclone has brought down large volumes of fuel.

Permits to burn: Section 65 of the *Fire and Rescue Service Act* establishes a system of 'permits to burn'. Under this section, a landholder wanting to light a fire greater than two metres on a side must apply either orally or in writing to their local fire warden. In making application information on: the land on which the fire will be lit; the names of all neighbouring landholders; the steps taken to notify every occupier of adjoining land of the intention to light the fire; and whether any of those adjacent occupiers has objected to the lighting of fire and the reasons for that objection, must be provided to the fire warden.

The 'permits to burn' system is aimed at managing the responsible use of fires as a land management tool in rural areas. Its successful application relies heavily on the experience and knowledge of the local fire warden.

Criminal sanctions: The *Fire and Rescue Service Act* (Sections 62 and 149) provides for fines or imprisonment for a range of offences, especially related to the lighting of fires without a permit. It also makes provision for offenders to be made responsible for costs associated with any fire that was lit without a permit. Arson is a crime under the Queensland *Criminal Code Act* and can carry a penalty of life imprisonment if it involves the destruction of a building or structure and 14 years if only involving vegetation.

Common law sanctions: Wright and Plumpton (1997) observe that '*the common law provides a number of courses of action in tort to persons who have suffered loss or damage as a result of bushfire*'. The common law claims most likely to arise in the context of bushfire are those relating to negligence or nuisance. A negligence action arises where there is a breach of duty of care, for example, to ensure that a fire lit on Council controlled land does not escape onto neighbouring land. Council is also responsible for preventing damage to lands under its control.

A nuisance action arises where the use of the land *'causes an unreasonable and substantial interference with a person's use or enjoyment of the land (private nuisance) or the right of the public at* *large to health, safety, property and equality of environment (public nuisance)* (Wright and Plumpton, 1997). Allowing the build up of flammable material and smoke from a fire may be considered as nuisance, if the person responsible has not taken reasonable steps to avoid or minimise the interference.

5.4.2 Managing the fire: The fire hazard can also be reduced by an effective response to a fire once it has started.

Detection and reporting: Experience has shown that the early detection of fire is essential if its spread, and impact, is to be minimised. In Balonne Shire, the detection of fire and its reporting to fire authorities depends largely on the vigilance and awareness of members of the public. An aware and informed public is, therefore, the best defence available. Awareness of the significance of fire smoke is greatest in rural areas. It is likely, however, that awareness is not as great amongst people living in urban areas; tourists are even less likely to be aware of the importance of reporting fires.

A critical element in a rapid response is knowing where the fire is and how to get to it. This requires the availability of up-to-date and accurate maps, together with a spatial referencing system that is universally understood. Street, or rural road, address is by far the most widely used and understood form of spatial referencing available. BSC is in the process of implementing a rural road addressing process that conforms to the National standard for addressing. Allocating an address, however, is worthless unless the roads names and property addresses are adequately displayed, again, preferably in a standard form. Many roads in the Shire are not signposted and the display of property number, in both rural and urban areas, is far from universal. This poses a significant problem for responding emergency services, especially those coming from out-of-area.

Fire Water: The application of water to both saturate and cool the fuel and to deny the fire oxygen is still the most effective means of fighting fire. Ready access to water is, therefore, essential for effective fire fighting. The urban areas of the Shire are served with hydrants on the reticulated water supply mains. As long as there is water in the mains, these hydrants are available to be used directly for fire fighting or as a source to replenish the tanks of fire units. Hydrants can service up to 10 fire appliances at the one time. In rural areas, however, natural sources such as rivers and creeks, or developed sources such as dams, bores and irrigation channels are relied on for fire water.

Under extended periods of dry weather or drought, the availability of water in dams and domestic tanks for fire fighting in areas not serviced by the reticulated water supply will inevitably be less than optimal. Landholders understandably will give priority to their own domestic requirements and their stock's need for water ahead of maintaining reserves for possible fire fighting.

5.4.3 Managing exposure: Whilst SPP 1/03 aims at mitigating the adverse impacts of bushfire, in addition to flood, Balonne Shire is not included in the list of local government areas to which the SPP applies (Annex 2 Table A2.1 in DLGP/DES, 2003a). Managing exposure to bushfire is, therefore, essentially the responsibility of individual land owners and is best achieved by employing the fuel management strategies discussed above.

Where a severe fire is likely to threaten life, evacuation may be an appropriate strategy. This practice is, however, somewhat controversial and, if not properly managed, could place evacuees at greater risk than if they were permitted to remain and protect their properties.

Section 8(d) of the *Public Safety Preservation Act* (PSPA) states that the police 'incident coordinator', following the declaration of an 'emergency situation', may:

(d) *direct the evacuation and exclusion of any person or persons from any premises and for this purpose may remove or cause to be removed (using such force as is necessary for the purpose) any person who does not comply with a direction to evacuate or any person who enters, attempts to enter or is found in or on any premises in respect of which a direction for the evacuation of persons has been given;*

(e) *close or cause to be closed to traffic and pedestrians, any road, street, motorway, private road, private way, service lane, footway, right of way, access way or other way or close any place to which members of the public have access whether on payment of a fee or otherwise.*

These are very sweeping powers indeed and may be enforced without reference to any other authority. In practice, however, close liaison is maintained between the QFRS (as the combat authority) and the police during a bushfire-based 'emergency situation' and police tend to act on the advice of the QFRS on-site commander. Where that advice is not available, however, it is standard operational procedure for the police to put the protection of life ahead of the protection of property regardless of the individual circumstances. This can, and has, led to serious conflict, between police and landholders in the area affected, including the arrest of landholders who have demanded to be allowed to defend their own property.

Warning of the need to evacuate, or to take shelter, needs to be given as soon as possible. The experience of the residents of Canberra during the fire storm event there on 18 January 2003 provides a salutary example of inadequate warning, whilst the Sydney fires in early December 2002 provide a stark contrast. In Canberra there was little media coverage of the rapidly approaching fire threat other than over the local ABC station. On the day of the fire (a Saturday), TV coverage was concentrated on the Australian Open Tennis and other sporting events, however, no messages about the fire were provided via the 'crawler' message system used to intrude local messages without breaking into a program controlled from Sydney or Melbourne. Many people, especially elderly folk, had closed themselves into their houses to avoid the heat and smoke. Those who watched the TV were completely unaware of the approaching fire until warned by a police door-knock or by neighbours. The disruption of power supply, that accompanied the fire, cut off the excellent support provided by ABC local radio in the many households that did not have a battery-powered radio. Some people even resorted to using their car radios to keep themselves informed. Canberra was a demonstrably unprepared community.

During the Sydney fires in December 2002, by contrast, the media kept the community extremely well informed of the progress of the fires and their impact on the transport network. Talk-back radio proved to be an excellent forum for people to provide up-to-date first-hand reporting on fire outbreaks, road closures and so on. This intelligence greatly enhanced that being acquired by fire authorities and added significantly to the generally successful fire fighting effort. Given their experience of severe fires in the previous Christmas period, the Sydney community was a very aware community and the Sydney media very much attuned to fulfilling their community information role.

Balonne Shire does not have the luxury of a locally based radio or TV station to provide appropriate, timely and locally-relevant public information during such an emergency.

5.4.4 Reducing vulnerability: To re-state the emergency services adage – *an aware community is a prepared community.* A clear understanding of the risks being faced, and strategies by which to minimise their affect on individuals, families and households, has been demonstrated many time over to add greatly to community safety. Given that bushfire in Balonne Shire is a relatively unusual event, maintaining an appropriate level of awareness is clearly a challenge.

A significant number of avoidable injuries are incurred by untrained and inexperienced people defending their own properties from bushfire attack. These injuries can be reduced by following simple guidelines, for example, wearing cover-all clothing of natural fibres (wool or cotton) and wearing eye, breathing and head protection. Working from exposed positions such as roof tops and under trees or power lines should also be avoided.

The media, especially the electronic media, have an important role to play in both supporting community awareness programs, in addition to their role of providing essential information during a bushfire disaster as discussed above.

Design and siting of buildings: The resilience of buildings and other structures constructed within fire-prone areas can be maximised by following the design guidelines contained in Australian Standard AS 3959-1999 *Building in bushfire prone areas* (Standards Australia, 1999). This Standard applies only to residential buildings (Classes 1, 2 and 3 of the Building Code of Australia). The fire-resisting construction measures of AS 3959 only lessen the risk of property damage and hence the risk to life, and then only if there is an adequate separation distance from a potential fire front. (NOTE: AS 3959 is currently under review and significant changes have been anticipated.)

Construction to AS 3959 standards is a significant improvement over some construction methods and designs employed before its introduction. There are certainly homes built in areas of high bushfire hazard that fall well below current standards of fire-resistance. It is clearly in the interests of owners and occupiers of such buildings to bring them up to current standards.

A detailed explanation of the construction and siting principles was produced jointly by CSIRO and Standards Australia to accompany the publication of the first edition of AS 3959 in 1993. This advisory publication (CSIRO/SA, 1993) should be referred to by everyone who has a responsibility for the development, siting and construction of residential properties in bushfire-prone areas. If these principles and standards are conformed with, then buildings constructed in bushfire prone land will be significantly more resilient to bushfire attack than will buildings that do not follow these principles.

Building and site maintenance: It is essential that buildings and their surrounds in bushfire-prone areas be well maintained. If simple housekeeping practices, such as keeping gutters clear of litter, are not followed, any fire-resistant properties afforded by construction to AS 3959 standards will be greatly compromised. Similarly, leaving a garden to become overgrown, especially with native plans, will compromise siting principles designed to provide a protection buffer between the building and the potential fire front.

Individual fire planning: The ultimate responsibility for reducing vulnerability to bushfire rests with the property owner or occupier, consequently the development of an individual fire plan is essential. There are several publications available that provide advice on property fire planning, for example, the FABC-produced *Individual property fire management planning kit* (FABC, 2002) and the various publications produced by the QFRS.

It is important that individual property fire plans be lodged with Council and the local rural brigade so that they can be reviewed by fire management specialists and so that the information they contain, such as that relating to water supply and access, can be entered into the Council and brigade's information bases.

Insurance: Most properties carry some form of insurance against a wide range of risks ranging from accidental damage and theft to earthquake. Fire risk is a standard inclusion in most policies. Experience in fire disasters elsewhere, however, suggests that a small, but significant, number of property owners do not carry insurance or carry an inadequate amount of cover.

5.5 TREATING EARTHQUAKE RISK

As with the other hazards with the exception of bushfires, there is nothing that can be done to influence earthquake hazards. Given that earthquakes are a regional hazard there is also nothing that can realistically be done to reduce exposure. That leaves vulnerability as the only effective risk element that can influence earthquake risk.

5.5.1 Building design and construction: Construction type and earthquake vulnerability in Australia appears to be closely correlated with building age. In part, this reflects the introduction of, and upgrades to, the Building Code of Australia (BCA) to address both wind and earthquake loads in the 1970s and 1980s. The BCA earthquake loading code aims to provide buildings that will not suffer catastrophic failure under design levels of earthquake load. For domestic construction that level of shaking equates to the level that would be experienced with an ARI of 500 years, whist public buildings have a design level of ARI of 3000 years. The philosophy is essentially one which aims for buildings to fail safely (thus reducing the risk of injury to occupants) rather than them to be immune from failure.

Even where buildings are constructed to BCA standards (or above) it is possible for some building components to fail and cause harm. For example, evaporative coolers mounted on the roofs of buildings may be dislodged.

The vast majority of buildings in the Shire are of timber frame construction that has a good degree of inherent resilience because under earthquake loads they behave in a ductile manner and can undergo relatively large displacements because of their non-rigid construction. Many older buildings, however, are probably not in optimum condition, and their performance could be poor, particularly if they are not tied to their stumps or if their stumps are not cross-braced.

It would be appropriate for Council to seek structural engineering advice regarding their buildings, especially the Council offices. It may also be appropriate for Council to advise owners of other critical and sensitive facilities (especially schools and hospitals) of the findings of this study.

5.5.2 Lifeline vulnerability: Water supply in particular, and sewer systems to a lesser degree, are vital to community well being. Brittle material, especially unlined asbestos cement (AC), may be particularly susceptible to fracture. A significant amount of such pipe has been used in the both St George and Dirranbandi water supply reticulation networks. Rupture of significant segments of the pipe network could reduce the availability of potable water to the community and fire fighting water to the emergency services. Widespread damage would take a considerable time for supply to be fully restored. As water and sewerage systems are progressively upgraded such brittle material should be replaced or lined with PVC to improve their resilience.

A key susceptibility for all utilities is in the resilience of their SCADA systems. They may fail initially because of the misalignment of their numerous antennae but such disruption should be quickly rectified.

5.6 GENERIC RISK REDUCTION STRATEGIES

In addition to the hazard-specific recommendations described above the following general observations relating to risk treatment are drawn from Chapter 13 of Granger and Hayne (2001).

5.6.1: Risk management culture:

At a philosophical level at least, one of the most potent forms of risk mitigation is the development and nurturing of a strong risk management culture across the community. It has, for example, been frequently observed that emergency risk management is most effective where it is an integral part of overall community risk management. Similarly, disaster planning is most effective where it is managed as an integral part of total community planning. In the vast majority of cases, however, these processes and activities tend to be divorced from the mainstream of community governance, even within organisations that are clearly committed to public safety, as is the Balonne Shire *Council. The compartmentation and isolation of emergency risk management from the mainstream of community governance can best be attributed to the lack of a broad culture of risk management.*

A mature risk management culture will see the decisions made by the executive, administrative, public health, planning, environmental, engineering, fiscal, legal and emergency management elements become more integrated, consistent and coordinated. The outcome would see the interdependencies of strategic decisions in each of those areas acknowledged and their consequences taken into account in a more transparent and seamless process. Such an approach would also tend to widen the planning timeframe from the current two or three year, electorally-constrained horizon to one of 10, 20 or even 50 years.

5.6.2 Disaster information:

For a comprehensive risk management culture to flourish, it is necessary for it to be underpinned by a strong and effective information infrastructure. We see the development of such an infrastructure as being the most fundamental of all risk mitigation strategies. It is also one of the most cost effective strategies, given that most of the information required is already collected, maintained and used by Balonne Shire *Council and the other authorities that have a role in community risk management..*

Whilst much of the basic information required for risk management (such as street layout, property information, land use and demographic aspects) is already available, there are several themes that we have found to be poorly addressed. Three themes stand out:

- *historical information: whilst the Bureau of Meteorology,* Geoscience Australia *maintain their own information on hazard history and other bodies in the community such as the* 'Balonne Beacon' *each maintain* *collections on the community experience of disaster, there is no consolidated index or coordination of information about the* Balonne Shire's *history of disasters and the impact on the community;*

- *modern event experience:* Balonne Shire *has not experienced any significant disaster impacts for several years, so there has been little need for post-event research to be conducted .... Much of this post-event information, such as the recording of earthquake aftershocks,* and flood levels *is highly perishable – if it is not collected during the event it will be lost forever. Without such detail of real events it is not possible to reduce the uncertainty that exists in our models and input data. The requirement to collect key event information needs to be entrenched in the doctrine of disaster response, with appropriate resources identified in disaster plans and made available to undertake the collection and management of that information;...*

There has been significant public investment in the development of systems to monitor hazard phenomena and to provide warnings of an impending impact. This important investment has not, however, been matched by the level of investment in information that enables the warnings or risk forecasts to be translated into information of relevance to members of the community. There is clearly a need for a greater level of investment in risk information.

Comment: It has been observed (not without some truth) that one of the most common activities in disaster management is 'information-free decision making' (Granger and Johnson, 1994). This is largely because the key information is not available or is out of date or is in a form that is hard to use. There is also a significant reliance by disaster managers on personal local knowledge. Whilst local knowledge is important, it is not easily shared and is instantly perishable if the person who has it becomes a victim!

Council operates a *MapInfo* GIS in which a good range of data are maintained. It is also used routinely by a wide range of Council officers in their routine work. The GIS can provide an excellent base on which to build a strong disaster management information infrastructure along the lines described by Granger (1998 and 1999). Such an information infrastructure can facilitate the integration of a wide range of disaster-related information from DCDB and topographic data to census and local knowledge. Data collected in a Taroom-style property location project, for example, can be integrated with mapping derived from flood modelling. At the time of writing, data in the Balonne Shire Council's GIS used the AGD84 projection. This projection has now been superseded by the earth-centred projection GDA94 which better supports GPS data collection. Most data provided from providers such as Geoscience Australia and DNRM now come automatically in GDA94 projection.

Other supporting data could also be introduced to the GIS, such as data on the location and availability of resources such as tractors and pumps on rural properties that could be called on in times of emergency. Such a collection had been developed a few years ago but it needs to be updated and upgraded and resources allocated to keeping it current. Given that disaster management ideally functions as a seamless part of overall community governance, it is important that the information systems used to underpin community governance are also suitable for and available to disaster managers.

5.6.3 Monitoring and warning systems:

For all of the hazards considered in this study, with the exception of earthquake, warnings of impending impact are already provided in one form or another. A report produced by the Institution of Engineers, Australia (Institution of Engineers, 1993) provides a useful hypothetical example of the benefits of this approach in the following terms:

> Flood warning systems now feature real time data collection networks linked to computer based flood models. These systems not only identify and track floods down a river but also enable emergency services to quickly assess the impact of various scenarios of increased or decreased rainfall, changing tidal conditions in the lower reaches of the river and varying tailwater effects at the river mouth due to storm surge and wave setup. Based on these scenarios, authorities can take more effective action to save lives and minimise damage to property. Even in a catchment with only one thousand flood prone homes, accurate advanced information on flood levels which enables residents to move contents and motor vehicles to locations above flood waters can result in a saving of $10 000 per household. **This $10M savings is a direct benefit to the community every time such a flood occurs.**
>
> *(emphasis in original)*

The coverage and sophistication of most of the monitoring and surveillance systems is constantly improving. There are plans, for example, to introduce Doppler radar to measure wind speed in storms and cyclones and thus improve both warnings and our knowledge of extreme wind speeds. There is also significant scope to improve on the existing seismic monitoring network in the ... Queensland region so that instrumental recording of the smaller and more frequent events can help build up our knowledge of the region's seismic environment.

Nonetheless, warning systems will be much more effective if the community is aware of their existence and of the implications of warnings. Whilst there is some scope to improve the timeliness and accuracy of warnings, their value will only be increased when individuals are able to relate warning information to their own circumstances and translate that information into risk reduction action. To achieve this it is necessary to increase public awareness by combining appropriate risk information and warning information.

5.6.4 Community awareness:

An effective strategy of risk communication is essential. For example, a typical public flood warning will be expressed in terms of a height on the reference flood gauge. Few people in urban areas can translate that level, with any certainty, to their own property in terms of how high the water would reach. The value of the warning is consequently diminished because few individuals know what action they should take in response.

A considerable literature on risk communication has emerged over the past decade or so (see, for example, the review by Marra, 1998). One of the most coherent examples we have encountered is that promoted by the US Environmental Protection Agency (EPA). Their approach devolves from the basic tenet that, in a democracy, people and communities have a right to participate in decisions that affect their lives, their property, and the things they value. The EPA approach is based on the following 'seven cardinal rules' (word in italics are quoted from EPA, 1988):

> Rule 1 – accept and involve the public as a legitimate partner: the goal of risk communication in a democracy should be to produce an informed public that is involved, interested, reasonable, thoughtful, solution-oriented, and collaborative; it should not be to diffuse public concerns or replace action.
>
> Rule 2 – plan carefully and evaluate your efforts: there is no such entity as "the public"; instead, there are many publics, each with its own interests, needs, concerns, priorities, preferences, and organisations.

Rule 3 – listen to the public's specific concerns: people in the community are often more concerned about such issues as trust, credibility, competence, control, voluntariness, fairness, caring, and compassion than about mortality statistics and the details of quantitative risk assessment.

Rule 4 – be honest, frank and open: trust and credibility are difficult to obtain. Once lost they are almost impossible to regain completely.

Rule 5 – coordinate and collaborate with other credible sources: few things make risk communication more difficult than conflicts or public disagreements with other credible sources.

Rule 6 – meet the needs of the media: the media are frequently more interested in politics than in risk; more interested in simplicity than in complexity; more interested in danger than in safety.

Rule 7 – speak clearly and with compassion: tell people what you cannot do; promise only what you can do, and be sure to do what you promise.

Governments, at any level, can only hope to reduce risk if their risk reduction strategies are accepted and supported by the community. Risk communication is the most democratic way of achieving that support.

Efforts to inform the community about risks are not always viewed with the same passion and altruistic values as those held by risk communicators. They are often met with opposition from small, but influential, sectors. The most common negative reactions relate to the belief that such information will have a negative impact on real estate values, and/or, will 'scare away' tourists or investment. Whilst there has been only limited research into the overall economic impact of risk communication, the anecdotal information that we have seen indicates that such negative beliefs are wrong. They do, nevertheless, excite levels of passion and political 'outrage' that typically leads to the dilution, if not termination, of public awareness efforts.

Comment: Further research has been published since completion of the GA studies, most notably that by Yeo (2003). He draws attention to the work of Tobin and Montz (1994) who observe that residential property values '*reflect a complex interaction of spatial, temporal, economic, sociological and hydrologic variables*'. The public outrage recently directed at Brisbane City Council over their refusal to release flood modelling done in 1998 was based largely on (largely irrational) fears about property values.

It is also important for community awareness programs to be sustained so that new residents, transients and tourists are also covered. Programs should be designed and resourced to cover these populations.

5.6.5 Emergency management:

The emergency management process has been based on consideration of the prevention, preparedness, response and recovery phases of disasters (known as PPRR). Under the adaptation of AS/NZS 4360:1999 to emergency risk management, these traditional components of emergency management can be seen as risk treatment options. The emphasis is on the treatment of residual risks (i.e. the risks that can not be eliminated or reduced by other means), especially in the preparedness, response and recovery phases. Most risk reduction options, however, clearly focus on prevention.

The preparedness phase emphasises disaster planning, community awareness, training and exercising and the provision of appropriate resources such as communications equipment. It is important, therefore, for emergency planning to be based on sound risk assessments and realistic risk scenarios, otherwise plans may be inappropriate, awareness will be inadequate, training and exercises will not be based on realistic scenarios and resources may not be appropriate. Evacuation planning provides a good example. If such plans are based on an assessment that badly underestimates the numbers of people at risk and the timing for an evacuation, many people could be placed in serious jeopardy by reacting too late and with too few resources. Conversely, if the estimates are too conservative, large numbers of people who did not need to be evacuated could easily overwhelm evacuation resources and shelters.

The detailed information and decision support tools provided to Balonne Shire Council *as a result of this study can be used to produce threat-specific plans on which to base all aspects of the preparedness phase. They enable, for example, the development of disaster response and recovery plans for specific levels of cyclone or flood risk, well in advance of any event, and to use the scenarios on which they are based to run realistic exercises and training serials.*

The risk scenarios also provide a capacity to model and forecast impact consequences so that the response phase can be managed more effectively. In Cairns in 1999, for example, the data developed under the Cities Project's Cairns multi-hazard risk assessment was used by the local counter disaster staff together with the Cairns City Council's own flood model data to forecast the likely impact of the flood that was developing in the Barron River following the passage of Cyclone Rona. *The information derived from this scenario modelling was then used to successfully plan and carry out the evacuation of more than 1500 people, assessed as being at risk, <u>before</u> the flood peak was reached. That evacuation was conducted at 2.00 am!*

The same modelling is also appropriate for rehearsing and planning for the recovery phase. There are examples in the literature of GIS being used to model the impact of a damaging earthquake and to forecast the requirements for short term and long term post-event shelter. Similarly it is possible to model the physical impact on lifelines and the consequences of their loss on the community.

Use of the scenario analysis technique develops 'future memory', i.e. disaster responders develop an understanding of what will happen when such an eventuality occurs so that their actions are based on 'experience' when it eventually does happen. This process could be reinforced by the development of role-play simulation 'games', such as SimCity, designed around real ... urban centres.

5.6.6 <u>Critical facility protection</u>:

The loss or isolation of critical facilities such as hospitals, airports, cold stores, fuel depots and emergency service facilities, will greatly magnify the impact of disaster on the community. Whilst such facilities remain exposed to disaster impact, plans to protect them are called for. Such protection may be as simple as ensuring the priority allocation of sandbags to the facility. It may be as routine as ensuring that the facility has an adequate uninterruptible power supply (UPS) or a stand-by generator with adequate fuel to cover the loss of reticulated power supply. Or it may embrace costly structural defences such as the construction of permanent protective berms or levees and the development of redundant capacity at other facilities to cope with the potential loss of one component in a critical system.

Comment: The greater attention being given at National and State levels to critical infrastructure protection as a result of the perceived threat of terrorism should be exploited by those whose focus is on the far greater threat from natural hazards.

5.7 RECOMMENDED RISK REDUCTION STRATEGIES

A wide range of potential risk reduction strategies can be identified as being capable of improving community safety in Balonne Shire. Some of these are very simple, can be implemented immediately and carry little if any cost while others will undoubtedly need to be progressively implemented over time as funds can be made available. While most are the responsibility of Balonne Shire Council to implement some can only be implemented with the active collaboration of other levels of government or industry sectors. There are some strategies that lie completely outside the capacity of Council, but they are included here to provide a more holistic approach.

5.7.1 Council policy, principles and practice: There are several actions that Council could consider taking that would have the affect of publicly confirming its commitment to a policy of disaster risk reduction.

> **Strategy 1:** Formally adopt, as Council policy, a commitment to the principles and practice of disaster risk reduction.
>
> **Strategy 2:** Formally adopt, as Council policy, the principle that the community has the right to know about the risks posed by the hazards that they face.

5.7.2 Implement SPP 1/03 requirements: It is clear that floods pose the greatest risks across the Shire, especially in the urban centres of St George and Dirranbandi because of their concentration of population and community infrastructure. It is important that Council implement the provisions of SPP 1/03 as a matter of priority. That step, however, does not come without potentially significant costs and inter-jurisdictional negotiation.

> **Strategy 3:** Council commit to implementing a *natural hazard management area (flood)* zone in their planning scheme covering St George and Dirranbandi and adopt, as Council policy, the performance criteria established in SPP 1/03 for development in those zones as their principal strategy to minimise the future growth of flood risk in the Shire.
>
> **Strategy 4:** Council develop, in consultation with DNRM and other relevant stakeholders, a program of hydrological and hydraulic modelling, supported by a high resolution DEM, to establish an appropriate Defined Flood Event (DFE) level for St George and Dirranbandi on which to base a *natural hazard management area (flood)*. This program should also extend, at an appropriate scale and resolution, to cover all of the Balonne and Moonie catchments. DES should be consulted to determine the potential availability of funding from sources including the Natural Disaster Reduction Studies Program and the Regional Flood Mitigation Programme. This research should take account of the effects on flood of forecast climate change and of irrigation and water harvesting regimes.

Strategy 5: As an interim measure until the major modelling effort outlined in Strategy 4 becomes available, again in consultation with DNRM and other stakeholders, commission mapping of flood inundation in the Moonie and Balonne catchments based on satellite imagery of the 1988, 1990, 1996 and 1998 floods to determine an interim DFE level.

5.7.3 Empirical flood data collection: To underpin work that would be undertaken under Strategies 3, 4 and 5, and to keep it adequately calibrated into the future.

Strategy 6: Council initiate, as a local studies program in Shire libraries and schools, the collection and analysis of oral histories and other material relating to historic floods.

Strategy 7: Council initiate, in consultation with DNRM and other technical experts, a program aimed at capturing and analysing satellite imagery (using both radar and multi-spectral sensors) of future major floods, as they occur, supported by the capture of appropriate GPS control data.

5.7.4 Engineering standards: Increasing the resilience of buildings and other structures will greatly reduce the consequences severe wind, bushfire and earthquake impacts. Whilst Council complies with the provisions of the *Building Act*, the *Building Code of Australia* and other engineering standards, much of the construction in the Shire pre-dates the implementation of those codes.

Strategy 8: Council undertake a survey of their built assets to determine their susceptibility to damage by severe wind, earthquake loads or bushfires against the design criteria established in current engineering standards. Where assets are identified that are below standard, take remedial action to bring them up to standard. Council should also encourage owners or occupiers of critical and sensitive facilities (e.g. schools and hospitals) to undertake comparable surveys of their assets in the Shire.

5.7.5 Structural defences: Exposure to flood and bushfire, at least to a considered (design) level, may be reduced by construction and maintenance of appropriately designed defences such as levees and fire breaks.

Strategy 9: Once Council is in a position to establish a DFE for flood, it should review the level of protection afforded by existing levees at Mungindi, Dirranbandi and Thallon. If they provide protection that is significantly less than the DFE then those levees should be upgraded accordingly.

Strategy 10: Once appropriate modelling becomes available, Council, in consultation with Department of Main Roads and DES, review the capacity of the Carnarvon Highway to provide a flood-free escape and resupply route for the St George community and, if appropriate, seek funding to enhance that route's flood-free status.

Strategy 11: Council establish and maintain fire breaks, where necessary, around Bollon and Thallon.

5.7.6 Disaster management information: Effective emergency management requires effective information management.

Strategy 12: Council convert their GIS data to the GDA94 projection as a matter of priority so that it can be integrated with data from sources such as GPS, satellite imagery and mapping agencies with complete accuracy.

Strategy 13: Council initiate, as a matter of priority, a program of data capture modelled on that established by Taroom Shire Council to accurately locate every rural homestead and other significant features. This program should be run in conjunction with Council's introduction of rural addressing.

Strategy 14: *Council update and* upgrade information collections, such as lists giving the location of assets, such as tractors and pumps, that could be used in the event of a disaster and integrate them into their GIS. Resources need to be identified to keep such collections current.

5.7.7 Disaster planning: It is important that disaster plans be current and appropriate to the risks likely to eventuate.

Strategy 15: The Balonne Shire local disaster plan be updated to reflect the findings of this study.

Strategy 16: Particular attention needs to be given to evacuation planning, not only to cope with events within 'normal' levels, but also to address evacuation requirements to cope with residual risks such as an ARI of 200 to 500 years.

5.7.8 Community awareness: A comprehensive disaster plan can not be effective unless the community that it is designed to protect is not aware of the risks and prepared to develop and implement their own household disaster plans. That requires an effective and sustained program of community awareness to be conducted.

Strategy 17: Council, in conjunction with DES, develop a program of community awareness based on the findings of this study. An important aim of this program is to encourage and equip individual households to develop their own disaster plans. Providing the basics to school children is an effective way of introducing the concepts to each family.

Strategy 18: Include disaster-related material in welcome packs provided to new residents and also make appropriate material available at motels and caravan parks in the Shire.

5.8 CONCLUSIONS

The overall risks posed to the population of Balonne Shire are relatively small and infrequent. Floods represent the most significant threat, though they also represent a significant positive for rural communities.

By adopting the strategies outlined above Balonne Shire Council will go a long way to eliminating the risks posed by all hazards throughout the Shire in all but the most extreme events. Their adoption will also make Balonne Shire a safer and more sustainable community.

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APPENDIX A: HISTORIC FLOOD HEIGHTS AT ST GEORGE

(Bureau of Meteorology data)

Station : ST GEORGE CBM No : 043053
Stream : BALONNE RIVER AWRC No : 422943
Flood Classifications: MINOR 4.0 MODERATE 5.0 MAJOR 6.0

Date	Time	Gauge Height (metres)	Site	Data Source	Data Type	Obs Site[i]
1890		13.10	A	REGISTER	MANUAL OBS	A
29/09/1917	1600	6.25	A	REGISTER	MANUAL OBS	A
25/11/1917	0900	4.95	A	REGISTER	MANUAL OBS	A
16/12/1917	0900	3.20	A	REGISTER	MANUAL OBS	A
05/02/1918	1600	4.93	A	REGISTER	MANUAL OBS	A
09/02/1920	1700	5.54	A	REGISTER	MANUAL OBS	A
04/07/1921	1600	6.86	A	REGISTER	MANUAL OBS	A
26/07/1921	1600	7.32	A	REGISTER	MANUAL OBS	A
08/08/1921	1000	3.35	A	REGISTER	MANUAL OBS	A
30/12/1921		6.25	A	REGISTER	MANUAL OBS	A
14/01/1922	0900	7.62	A	REGISTER	MANUAL OBS	A
23/12/1922	0900	3.35	A	REGISTER	MANUAL OBS	A
19/02/1924	1700	5.13	A	REGISTER	MANUAL OBS	A
27/02/1924	0900	4.06	A	REGISTER	MANUAL OBS	A
11/03/1924	0900	5.56	A	REGISTER	MANUAL OBS	A
02/09/1924	1800	3.28	A	REGISTER	MANUAL OBS	A
12/11/1924		3.73	A	REGISTER	MANUAL OBS	A
17/11/1924		5.59	A	REGISTER	MANUAL OBS	A
28/11/1924		5.59	A	REGISTER	MANUAL OBS	A
16/01/1925	0900	3.00	A	REGISTER	MANUAL OBS	A
11/01/1926		4.62	A	REGISTER	MANUAL OBS	A
22/05/1926	0900	3.51	A	REGISTER	MANUAL OBS	A
01/01/1927	0900	3.28	A	REGISTER	MANUAL OBS	A
16/02/1927	0900	6.07	A	REGISTER	MANUAL OBS	A
20/12/1927	0900	3.28	A	REGISTER	MANUAL OBS	A
19/02/1928	0900	4.57	A	REGISTER	MANUAL OBS	A
08/03/1928	0900	4.72	A	REGISTER	MANUAL OBS	A
27/04/1928	0800	6.93	A	REGISTER	MANUAL OBS	A
07/04/1929	1000	8.03	A	REGISTER	MANUAL OBS	A
18/02/1931	0900	3.96	A	REGISTER	MANUAL OBS	A
10/12/1931	1630	9.22	A	REGISTER	MANUAL OBS	A
04/02/1933	0900	3.40	A	REGISTER	MANUAL OBS	A
10/10/1933	1000	3.16	A	REGISTER	MANUAL OBS	A

13/11/1933		5.23	A	REGISTER	MANUAL OBS	A
20/01/1934		3.05	A	REGISTER	MANUAL OBS	A
03/12/1934	0900	4.22	A	REGISTER	MANUAL OBS	A
03/01/1935	0900	6.02	A	REGISTER	MANUAL OBS	A
27/01/1935	0900	3.61	A	REGISTER	MANUAL OBS	A
15/02/1937	0900	5.18	A	REGISTER	MANUAL OBS	A
22/03/1937	0900	7.44	A	REGISTER	MANUAL OBS	A
02/06/1938	0900	5.08	A	REGISTER	MANUAL OBS	A
18/11/1938	0900	3.10	A	REGISTER	MANUAL OBS	A
01/02/1939	0000	5.41	A	REGISTER	MANUAL OBS	A
26/03/1939	0900	4.11	A	REGISTER	MANUAL OBS	A
11/02/1940	0900	3.99	A	REGISTER	MANUAL OBS	A
05/03/1940	1700	4.88	A	REGISTER	MANUAL OBS	A
25/03/1940	0900	5.39	A	REGISTER	MANUAL OBS	A
10/01/1941		6.48	A	REGISTER	MANUAL OBS	A
27/01/1941	1700	6.07	A	REGISTER	MANUAL OBS	A
02/04/1941	1300	6.99	A	REGISTER	MANUAL OBS	A
23/02/1942	0900	9.14	A	REGISTER	MANUAL OBS	A
16/12/1942	0900	3.20	A	REGISTER	MANUAL OBS	A
13/01/1943	0900	5.97	A	REGISTER	MANUAL OBS	A
30/11/1943	1200	3.10	A	REGISTER	MANUAL OBS	A
05/03/1945	0900	3.48	A	REGISTER	MANUAL OBS	A
27/06/1945	0600	3.05	A	REGISTER	MANUAL OBS	A
28/01/1946	0900	3.66	A	REGISTER	MANUAL OBS	A
09/02/1946	0900	3.81	A	REGISTER	MANUAL OBS	A
19/02/1947		5.92	A	REGISTER	MANUAL OBS	A
04/03/1947	0900	9.30	A	REGISTER	MANUAL OBS	A
11/04/1947	0900	3.51	A	REGISTER	MANUAL OBS	A
18/12/1947	0900	5.05	A	REGISTER	MANUAL OBS	A
02/07/1948	0900	3.18	A	REGISTER	MANUAL OBS	A
31/03/1949	0900	4.57	B	REGISTER	MANUAL OBS	B
20/10/1949	0900	8.13	B	REGISTER	MANUAL OBS	B
01/03/1950	0900	6.96	B	REGISTER	MANUAL OBS	B
14/04/1950	0900	3.81	B	REGISTER	MANUAL OBS	B
12/07/1950	1300	6.91	B	REGISTER	MANUAL OBS	B
31/07/1950	1700	12.12	B	REGISTER	MANUAL OBS	B
27/10/1950	0900	4.47	B	REGISTER	MANUAL OBS	B
29/11/1950	1700	10.92	B	REGISTER	MANUAL OBS	B
19/02/1951	0900	5.03	B	REGISTER	MANUAL OBS	B
25/03/1952	0900	4.90	B	REGISTER	MANUAL OBS	B
15/04/1952	0900	5.08	B	REGISTER	MANUAL OBS	B
28/06/1952	0900	5.13	B	REGISTER	MANUAL OBS	B
18/10/1952	0900	5.61	C	REGISTER	MANUAL OBS	C

26/02/1953	1300	7.87	C	REGISTER	MANUAL OBS	C
22/01/1954	1600	5.72	C	REGISTER	MANUAL OBS	C
28/01/1954	1700	5.79	C	REGISTER	MANUAL OBS	C
19/02/1954	0900	11.43	C	REGISTER	MANUAL OBS	C
22/07/1954	1200	10.19	C	REGISTER	MANUAL OBS	C
22/10/1954	0900	9.14	C	REGISTER	MANUAL OBS	C
03/11/1954	0900	4.57	C	REGISTER	MANUAL OBS	C
26/01/1955	0900	3.20	C	REGISTER	MANUAL OBS	C
28/02/1955	0900	5.43	C	REGISTER	MANUAL OBS	C
15/03/1955	1700	3.51	C	REGISTER	MANUAL OBS	C
04/05/1955	2100	3.43	C	REGISTER	MANUAL OBS	C
31/05/1955	1600	8.56	C	REGISTER	MANUAL OBS	C
03/02/1956	0900	10.67	C	REGISTER	MANUAL OBS	C
13/02/1956	1600	10.06	C	REGISTER	MANUAL OBS	C
22/02/1956	1600	10.26	C	REGISTER	MANUAL OBS	C
05/04/1956		10.80	C	REGISTER	MANUAL OBS	C
19/05/1956	1600	5.33	C	REGISTER	MANUAL OBS	C
30/06/1956	0900	8.23	C	REGISTER	MANUAL OBS	C
12/07/1956	1200	7.52	C	REGISTER	MANUAL OBS	C
04/01/1957	1600	5.54	C	REGISTER	MANUAL OBS	C
20/06/1958	0900	4.88	C	REGISTER	MANUAL OBS	C
03/01/1959	0900	4.19	C	REGISTER	MANUAL OBS	C
24/02/1959	0900	9.70	C	REGISTER	MANUAL OBS	C
24/11/1959	0900	4.11	C	REGISTER	MANUAL OBS	C
24/02/1961	0900	4.42	C	REGISTER	MANUAL OBS	C
10/03/1961	0900	3.66	C	REGISTER	MANUAL OBS	C
20/12/1961	0900	6.22	C	REGISTER	MANUAL OBS	C
22/01/1962	0900	6.17	C	REGISTER	MANUAL OBS	C
18/03/1962	1600	5.49	C	REGISTER	MANUAL OBS	C
19/04/1962	0900	3.03	C	REGISTER	MANUAL OBS	C
21/01/1963	0900	6.78	C	REGISTER	MANUAL OBS	C
30/03/1963	0900	7.16	C	REGISTER	MANUAL OBS	C
03/04/1963	1300	8.48	C	REGISTER	MANUAL OBS	C
24/03/1964	0900	3.35	C	REGISTER	MANUAL OBS	C
03/08/1965	1200	2.82	C	REGISTER	MANUAL OBS	C
21/12/1965	0700	4.57	C	REGISTER	MANUAL OBS	C
12/02/1966	0900	2.36	C	REGISTER	MANUAL OBS	C
10/07/1967	0900	4.14	C	REGISTER	MANUAL OBS	C
18/01/1968	0900	3.71	D	REGISTER	MANUAL OBS	D
29/01/1968	0900	3.40	D	REGISTER	MANUAL OBS	D
30/05/1969	0230	4.52	D	REGISTER	MANUAL OBS	D
21/10/1969	0900	5.33	D	REGISTER	MANUAL OBS	D
16/11/1969	0900	4.75	D	REGISTER	MANUAL OBS	D
04/02/1970	0900	4.44	D	REGISTER	MANUAL OBS	D
13/12/1970	2100	7.11	D	REGISTER	MANUAL OBS	D

21/12/1970	2100	9.07	D	REGISTER	MANUAL OBS	D
07/01/1971	0000	6.17	D	REGISTER	MANUAL OBS	D
05/02/1971		7.21	D	REGISTER	MANUAL OBS	D
23/02/1971	1400	9.60	D	REGISTER	MANUAL OBS	D
07/03/1971	2100	6.40	D	REGISTER	MANUAL OBS	D
01/01/1972	0300	9.14	D	REGISTER	MANUAL OBS	D
26/02/1972	0900	2.77	D	REGISTER	MANUAL OBS	D
14/11/1972	1700	6.50	D	REGISTER	MANUAL OBS	D
25/11/1972	0900	4.18	D	REGISTER	MANUAL OBS	D
25/01/1973	0900	3.00	D	REGISTER	MANUAL OBS	D
19/02/1973	0900	3.04	D	REGISTER	MANUAL OBS	D
23/02/1973	0900	3.02	D	REGISTER	MANUAL OBS	D
09/01/1974	0900	5.03	D	REGISTER	MANUAL OBS	D
02/02/1974	2100	8.00	D	REGISTER	MANUAL OBS	D
13/02/1974	0900	8.36	D	REGISTER	MANUAL OBS	D
13/03/1975	0900	3.83	D	REGISTER	MANUAL OBS	D
30/03/1975	0900	3.00	D	REGISTER	MANUAL OBS	D
17/05/1975		4.32	D	REGISTER	MANUAL OBS	D
10/01/1976	0900	8.24	D	REGISTER	MANUAL OBS	D
29/01/1976	0900	5.55	D	REGISTER	MANUAL OBS	D
11/02/1976	1400	5.04	D	REGISTER	MANUAL OBS	D
01/03/1976	1600	8.72	D	REGISTER	MANUAL OBS	D
15/11/1976	0900	3.38	D	REGISTER	MANUAL OBS	D
29/11/1976	0900	3.03	D	REGISTER	MANUAL OBS	D
16/03/1977	0900	9.99	D	REGISTER	MANUAL OBS	D
24/05/1977	0900	3.96	D	REGISTER	MANUAL OBS	D
15/07/1978	0900	4.74	D	REGISTER	MANUAL OBS	D
18/09/1978	0900	4.32	D	REGISTER	MANUAL OBS	D
06/11/1978	0900	3.75	D	REGISTER	MANUAL OBS	D
12/03/1979	0900	3.19	D	REGISTER	MANUAL OBS	D
22/02/1981	1100	8.21	D	REGISTER	MANUAL OBS	D
14/04/1981	1700	3.50	D	REGISTER	MANUAL OBS	D
06/06/1981	1200	7.12	D	REGISTER	MANUAL OBS	D
17/12/1981	0700	3.05	D	REGISTER	MANUAL OBS	D
1982	0900	5.67	D	REGISTER	MANUAL OBS	D
05/01/1982	0600	2.87	D	REGISTER	MANUAL OBS	D
26/01/1982	0600	4.41	D	REGISTER	MANUAL OBS	D
07/03/1982	0600	8.75	D	REGISTER	MANUAL OBS	D
12/01/1983	0900	3.25	D	REGISTER	MANUAL OBS	D
15/05/1983	0600	11.17	D	REGISTER	MANUAL OBS	D
28/05/1983	0600	11.07	D	REGISTER	MANUAL OBS	D
26/06/1983	2100	9.23	D	REGISTER	MANUAL OBS	D
06/07/1983	2300	9.61	D	REGISTER	MANUAL OBS	D
10/08/1983	2000	3.18	D	REGISTER	MANUAL OBS	D
03/12/1983	0200	9.95	D	REGISTER	MANUAL OBS	D
07/01/1984	1200	4.21	D	REGISTER	MANUAL OBS	D
05/02/1984	0900	2.98	D	REGISTER	MANUAL OBS	D

26/02/1984	0900	2.98	D	REGISTER	MANUAL OBS	D
21/04/1984	0900	2.95	D	REGISTER	MANUAL OBS	D
04/05/1984	0900	3.05	D	REGISTER	MANUAL OBS	D
12/08/1984	0800	8.72	D	REGISTER	MANUAL OBS	D
06/11/1984	0900	3.26	D	REGISTER	MANUAL OBS	D
07/11/1985	0900	4.25	D	REGISTER	MANUAL OBS	D
04/03/1988	0900	8.21	D	REGISTER	MANUAL OBS	D
09/04/1988	0600	6.22	D	REGISTER	MANUAL OBS	D
20/04/1988	0600	9.90	D	REGISTER	MANUAL OBS	D
19/07/1988	1500	4.70	D	REGISTER	MANUAL OBS	D
05/04/1989	0900	4.26	D	REGISTER	MANUAL OBS	D
02/05/1989	0600	6.53	D	REGISTER	MANUAL OBS	D
12/06/1989	0600	5.12	D	REGISTER	MANUAL OBS	D
11/11/1989	0600	5.72	D	F521	MANUAL OBS	D
15/04/1990	0900	7.80	D	F521	MANUAL OBS	D
23/04/1990	1500	12.24	D	F521	MANUAL OBS	D
30/05/1990	0900	4.00	D	LOG SHEET	MANUAL OBS	D
13/12/1993	2230	6.95	D	F521	MANUAL OBS	D
14/02/1994	1500	4.25	D	F521	MANUAL OBS	D
07/03/1994	2300	4.88	D	F521	MANUAL OBS	D
14/03/1994	1800	8.31	D	F521	MANUAL OBS	D
06/12/1995	2100	5.63	D	F521	MANUAL OBS	D
23/12/1995	0900	4.32	D	F521	MANUAL OBS	D
19/01/1996	2100	10.98	D	F521	MANUAL OBS	D
20/05/1996	2100	10.11	D	F521	MANUAL OBS	D
08/02/1997	0900	5.91	D	F521	MANUAL OBS	D
19/02/1997	1130	7.82	D	F521	MANUAL OBS	D
12/03/1997	0600	6.38	D	F521	MANUAL OBS	D
15/02/1998	2300	6.61	D	F521	MANUAL OBS	D
14/05/1998	0600	4.32	D	F521	MANUAL OBS	D
06/09/1998	0900	9.35	D	F521	MANUAL OBS	D
25/09/1998	0900	6.77	D	F521	MANUAL OBS	D
11/02/1999	0900	5.66	D	F521	MANUAL OBS	D
14/02/1999	0900	5.55	D	F521	MANUAL OBS	D
14/03/1999	0600	5.72	D	F521	MANUAL OBS	D
20/03/1999	0900	5.95	D	F521	MANUAL OBS	D
19/02/2000	2100	4.25	D	LOG SHEET	MANUAL OBS	D
20/11/2000	1500	4.72	D	LOG SHEET	INSTRUMENT	D
25/11/2000	0600	5.52	D	LOG SHEET	MANUAL OBS	D
17/02/2001	1000	2.46	D	LOG SHEET	MANUAL OBS	D
23/04/2003	0900	3.22	D	LOG SHEET	MANUAL OBS	D

[1] The location of the recording station has been changed four times, hence the four observation sites (A, B, C and D). Whilst the stage heights are not strictly comparable between each site they are close enough for the purposes of this study.

APPENDIX B: MODIFIED MERCALLI (MM) SCALE OF EARTHQUAKE INTENSITY (after Dowrick, 1996)

MM I

People: Not felt except by a very few people under exceptionally favourable circumstances.

MM II

People: Felt by persons at rest, on upper floors or favourably placed.

MM III

People: Felt indoors; hanging objects may swing, vibrations may be similar to passing of light trucks, duration may be estimated, may not be recognised as an earthquake.

MM IV

People: Generally noticed indoors but not outside. Light sleepers may be awakened. Vibration may likened to the passing of heavy traffic, or to the jolt of a heavy object falling or striking the building.

Fittings: *Doors and windows rattle. Glassware and crockery rattle. Liquids in open vessels may be slightly disturbed. Standing motorcars may rock.*

Structures: *Walls and frame of building are heard to creak, and partitions and suspended ceilings in commercial buildings may be heard to creak.*

MM V

People: Generally felt outside, and by almost everyone indoors. Most sleepers awakened. A few people alarmed.

Fittings: *Small unstable objects are displaced or upset. Some glassware and crockery may be broken. Hanging pictures knock against the wall. Open doors may swing. Cupboard doors secured by magnetic catches may open. Pendulum clocks stop, start, or change rate.*

Structures: *Some windows Type I cracked. A few earthenware toilet fixtures cracked.*

MM VI

People: Felt by all. People and animals alarmed. Many run outside. Difficulty experienced in walking steadily.

Fittings: *Objects fall from shelves. Pictures fall from walls. Some furniture moved on smooth floors, some unsecured free-standing fireplaces moved. Glassware and crockery broken. Very unstable furniture overturned. Small church and school bells ring. Appliances move on bench or table tops. Filing cabinets or "easy glide" drawers may open (or shut).*

Structures: Slight damage to Buildings Type I. Some stucco or cement plaster falls. Windows Type I broken. Damage to a few weak domestic chimneys, some may fall.

Environment: Trees and bushes shake, or are heard to rustle. Loose material may be dislodged from sloping ground, e.g. existing slides, talus slopes, shingle slides.

MM VII

People: General alarm. Difficulty experienced in standing. Noticed by drivers of motorcars who may stop.

Fittings: Large bells ring. Furniture moves on smooth floors, may move on carpeted floors. Substantial damage to fragile contents of buildings.

Structures: Unreinforced stone and brick walls cracked. Buildings Type I cracked with some minor masonry falls. A few instances of damage to Buildings Type II. Unbraced parapets, unbraced brick gables, and architectural ornaments fall. Roofing tiles, especially ridge tiles, may be dislodged. Many unreinforced chimneys damaged, often falling from roof-line. Water tanks Type I burst. A few instances of damage to brick veneers and plaster or cement-based linings. Unrestrained water cylinders (Water Tanks Type II) may move and leak. Some windows Type II cracked. Suspended ceilings damaged.

Environment: Water made turbid by stirred up mud. Small slides such as falls of sand and gravel banks, and small rock-falls from steep slopes and cuttings. Instances of settlement of unconsolidated or wet, or weak soils. Some fine cracks appear in sloping ground. A few instances of liquefaction (i.e. small water and sand ejections).

MM VIII

People: Alarm may approach panic. Steering of motor cars greatly affected.

Structures: Buildings Type I, heavily damaged, some collapse. Buildings Type II damaged, some with partial collapse. Buildings Type III damaged in some cases. A few instances of damage to Structures Type IV. Monuments and pre-1976 elevated tanks and factory stacks twisted or brought down. Some pre-1965 infill masonry panels damaged. A few post-1980 brick veneers damaged. Decayed timber piles of houses damaged. Houses not secured to foundation may move. Most unreinforced domestic chimneys damaged, some below roof-line, many brought down.

Environment: Cracks appear on steep slopes and in wet ground. Small to moderate slides in roadside cuttings and unsupported excavations. Small water and sand ejections and localised lateral spreading adjacent to streams, canals, lakes, etc.

MM IX

Structures: Many buildings Type I destroyed. Buildings Type II heavily damaged, some collapse. Buildings Type III damaged, some with partial collapse. Structures Type IV damaged in some cases, some with flexible frames seriously damaged. Damage or permanent distortion to some Structures Type V. Houses not secured to foundations shifted off. Brick veneers fall and expose frames.

Environment: Cracking of the ground conspicuous. Landsliding general on steep slopes. Liquefaction effects intensified and more widespread, with large lateral spreading and flow sliding adjacent to streams, canals, lakes, etc.

MM X

Structures: Most Buildings Type I destroyed. Many Buildings Type II destroyed. Buildings Type III heavily damaged, some collapse. Structures Type IV damaged, some with partial collapse. Structures Type V moderately damaged, but few partial collapses. A few instances of damage to Structures Type VI. Some well-built timber buildings moderately damaged (excluding damage from falling chimneys). Dams, dykes, and embankments seriously damaged. Railway lines slightly bent. Cement and asphalt roads and pavements badly cracked or thrown into waves.

Environment: Landsliding very widespread in susceptible terrain, with very large rock masses displaced on steep slopes. Landslide dams may be formed. Liquefaction effects widespread and severe.

MM XI

Structures: Most Buildings Type II destroyed. Many Buildings Type III destroyed. Structures Type IV heavily damaged, some collapse. Structures Type V damaged, some with partial collapse. Structures Type VI suffer minor damage, a few moderately damaged.

MM XII

Structures: Most Buildings Type III destroyed. Many Structures Type IV destroyed. Structures Type V heavily damaged, some with partial collapse. Structures Type VI moderately damaged.

Construction types

Buildings Type I: Buildings with low standard of workmanship, poor mortar, or constructed of weak materials like mud brick or rammed earth. Soft storey structures (e.g. shops) made of masonry, weak reinforced concrete, or composite materials (e.g. some walls timber, some brick) not well tied together. Masonry buildings otherwise conforming to Buildings Type I–III, but also having heavy unreinforced masonry towers. (Buildings constructed entirely of timber must be of extremely low quality to be Type I).

Buildings Type II: Buildings of ordinary workmanship, with mortar of average quality. No extreme weakness, such as inadequate bonding of the corners, but neither designed nor reinforced to resist lateral forces. Such buildings not having heavy unreinforced masonry towers.

Buildings Type III: Reinforced masonry or concrete buildings of good workmanship and with sound mortar, but not formally designed in detail to resist earthquake forces.

Structures Type IV: Buildings and bridges designed and built to resist earthquakes to normal use standards, i.e. no special collapse or damage limiting measures taken (mid 1930s to c. 1970 for concrete and to c. 1980 for other materials).

Structures Type V: Buildings and bridges designed and built to resist earthquakes to normal use standards, i.e. no special damage limiting measures taken, other than code requirements, dating from since c. 1970 for concrete and c. 1980 for other materials.

Structures Type VI: Structures dating from c. 1980 with well defined foundation behaviour, which have been especially designed for minimal damage, e.g. seismically isolated emergency facilities, some structures with dangerous or high (value) contents, or new generation low damage structures.

Windows
Type I – Large display windows, especially shop windows.
Type II – Ordinary sash or casement windows.

Water tanks

Type I – External, stand mounted, corrugated iron water tanks.
Type II – Domestic hot-water cylinders unrestrained except by supply and delivery pipes.

APPENDIX C: RECORDED EARTHQUAKES WITHIN 500 KM OF ST GEORGE

Extract from the Geoscience Australia National Earthquake Database

Date			Time (UTC)			Lat	Lon	Depth	Magnitude
d	m	y	h	m	s	deg	deg	km	
27	01	1841	21	55	0.0	-32.800	151.600	10	4.9
27	10	1842	19	30	0.0	-32.600	151.600	10	5.3
18	06	1868	14	00	0.0	-32.800	151.600	10	5.3
12	08	1872	12	00	0.0	-26.750	152.000	10	3.0
16	09	1875	20	00	0.0	-27.500	152.300	10	2.2
24	11	1875	11	00	0.0	-28.100	152.000	10	3.9
26	02	1877	21	45	0.0	-27.500	152.800	30	4.3
03	03	1878	02	45	0.0	-24.700	153.200	10	4.3
10	08	1880	19	00	0.0	-28.900	151.900	25	3.6
28	08	1883	16	55	0.0	-25.500	151.670	20	5.6
28	08	1883	18	20	0.0	-25.500	151.670	20	5.0
28	07	1887	06	55	0.0	-31.300	147.000	0	4.0
22	08	1888	15	00	0.0	-29.000	149.000	10	3.2
05	01	1891	03	00	0.0	-25.400	151.100	10	2.2
05	01	1891	03	34	0.0	-25.400	151.100	10	3.8
05	01	1891	03	40	0.0	-25.400	151.100	10	2.2
29	01	1894	00	00	0.0	-25.200	151.600	10	2.2
15	06	1897	19	00	0.0	-24.900	151.100	0	4.0
24	11	1910	22	52	42.0	-25.700	151.200	10	4.7
06	12	1912	17	00	0.0	-23.900	151.200	0	3.5
01	05	1913	16	20	0.0	-27.000	152.500	0	4.0
14	04	1916	06	45	0.0	-24.600	152.100	0	4.0
10	06	1916	00	17	51.0	-32.250	152.500	0	4.6
05	06	1918	18	15	0.0	-23.500	152.500	10	5.1
06	06	1918	18	14	24.0	-23.500	152.500	15	6.0
06	06	1918	18	23	0.0	-23.500	152.500	0	5.5
06	06	1918	19	00	0.0	-23.500	152.500	10	5.1
06	06	1918	19	20	0.0	-23.500	152.500	0	5.7
06	06	1918	19	45	0.0	-23.500	152.500	10	5.1
06	06	1918	20	15	0.0	-23.500	152.500	10	5.1
07	03	1922	16	54	50.0	-23.500	152.500	10	4.5
09	07	1923	08	30	0.0	-27.200	152.800	0	2.5
18	12	1925	10	47	10.0	-33.000	151.600	10	5.3
22	05	1932	10	46	28.0	-32.300	148.300	30	4.5
07	06	1932	09	59	36.0	-32.300	148.300	0	3.5
12	04	1935	01	32	24.0	-25.500	151.670	10	5.5
01	06	1935	12	12	0.0	-25.500	151.670	13	4.0
18	07	1935	19	30	0.0	-25.500	151.670	20	3.5
19	04	1936	06	30	0.0	-25.450	151.750	10	2.2
03	06	1936	05	00	0.0	-24.700	153.200	10	2.2
20	01	1937	19	00	0.0	-26.600	153.000	10	3.2
07	10	1937	01	20	0.0	-25.500	151.670	10	3.3
27	06	1938	22	38	47.0	-30.400	151.800	33	3.9
12	02	1940	05	37	0.0	-25.500	151.670	10	3.2
13	02	1940	11	23	0.0	-25.500	151.670	10	2.2

13 02 1940	14	30	0.0	-25.500	151.670	10	2.2
30 07 1942	01	30	0.0	-26.900	153.100	10	2.2
02 08 1942	06	00	0.0	-27.500	153.050	10	2.2
11 06 1947	10	03	13.0	-25.480	152.700	25	4.3
29 07 1947	17	50	0.0	-27.900	153.200	10	2.2
29 07 1947	18	10	0.0	-27.900	153.200	10	2.2
30 12 1951	20	34	3.0	-25.900	151.000	10	4.0
30 12 1951	20	38	0.0	-25.800	151.000	10	2.1
30 12 1951	21	40	29.0	-25.900	151.000	0	3.0
30 12 1951	21	41	42.0	-25.800	151.000	10	2.2
24 06 1952	01	44	4.0	-25.500	152.800	20	4.8
06 02 1953	17	49	31.0	-24.700	150.700	10	3.3
03 12 1953	15	42	49.0	-24.500	151.400	25	4.0
03 12 1953	15	58	0.0	-24.600	151.600	10	2.4
19 09 1954	10	37	6.0	-28.500	148.600	10	5.3
21 09 1954	20	29	22.0	-25.300	152.000	15	3.2
01 02 1955	11	09	30.0	-26.150	151.800	15	3.0
10 04 1955	22	36	36.0	-26.700	152.200	0	3.2
10 09 1955	06	12	54.0	-25.500	151.600	10	3.0
01 12 1955	05	33	51.0	-25.100	151.700	10	3.2
01 12 1955	05	33	51.2	-25.100	151.700	10	3.2
29 01 1956	03	48	35.5	-25.800	151.500	10	2.8
24 03 1956	15	58	0.0	-26.700	152.700	10	3.2
01 04 1957	15	49	54.3	-25.500	151.000	10	2.7
29 04 1957	16	47	54.3	-25.200	151.700	0	3.5
12 10 1959	21	23	40.0	-31.000	151.500	0	4.7
27 04 1960	19	26	13.0	-33.000	148.500	0	2.5
17 11 1960	05	00	17.0	-27.330	152.850	10	4.4
29 01 1961	05	54	0.0	-33.000	147.500	0	4.0
20 02 1961	14	34	0.0	-33.000	151.000	0	2.0
08 03 1961	10	57	0.0	-32.700	150.300	0	2.3
09 03 1961	05	17	0.0	-32.700	149.300	0	2.8
16 05 1961	06	52	47.7	-30.850	147.270	0	4.8
23 11 1961	01	17	21.0	-33.000	149.000	0	4.0
16 01 1962	06	16	52.0	-31.980	149.620	0	4.0
09 03 1962	14	52	0.0	-32.330	150.750	0	2.3
31 03 1962	15	34	0.0	-32.600	150.300	0	2.3
17 04 1962	17	03	0.0	-32.200	149.700	0	3.3
24 07 1962	22	11	39.0	-25.500	151.200	10	3.1
28 07 1962	05	34	39.4	-25.500	151.200	0	3.0
28 07 1962	14	54	54.0	-25.600	151.500	10	2.6
11 02 1963	07	13	31.8	-25.000	151.200	10	2.4
13 02 1963	07	07	25.7	-25.500	151.200	10	2.4
14 05 1963	07	59	45.1	-24.700	150.700	10	3.0
21 05 1963	07	43	46.5	-25.500	151.000	10	2.5
23 05 1963	05	22	9.5	-25.700	151.700	10	2.4
25 05 1963	03	23	9.8	-25.500	151.200	10	2.5
18 06 1963	06	55	29.0	-25.000	151.500	10	2.8
09 07 1963	12	40	0.0	-26.200	152.000	0	3.0
29 09 1963	16	59	8.0	-27.700	152.700	0	2.5
28 10 1963	08	23	28.0	-32.470	149.180	0	3.0
28 10 1963	08	31	0.0	-32.470	149.180	0	2.8
02 02 1964	07	59	0.0	-32.100	149.800	0	2.8
03 03 1964	06	13	35.0	-25.400	151.700	0	4.5
25 03 1964	06	14	37.9	-25.300	151.400	8	3.9
02 06 1965	12	30	0.0	-28.080	150.220	10	2.2
03 06 1965	21	45	0.0	-28.080	150.220	10	2.2
03 06 1965	21	59	56.9	-28.080	150.220	28	5.1

03	06	1965	23	00	0.0	-28.080	150.220	10	3.2
05	10	1965	15	43	15.0	-28.470	152.550	10	3.6
14	01	1967	11	32	58.0	-29.190	145.950	47	3.8
18	07	1967	07	48	4.1	-25.600	151.300	25	3.7
18	07	1967	07	57	50.8	-25.500	151.700	10	2.5
18	08	1967	19	03	44.5	-32.250	149.630	26	3.3
31	12	1968	16	08	33.1	-31.040	149.260	0	5.0
04	01	1969	06	23	39.0	-32.750	148.250	0	3.5
09	04	1969	02	10	5.0	-32.050	149.580	5	4.0
09	03	1970	12	16	17.0	-32.800	152.420	0	3.0
16	03	1970	07	17	36.0	-32.730	151.670	0	2.7
18	03	1970	00	14	6.7	-32.730	151.450	11	2.6
21	03	1970	01	05	12.0	-32.550	151.770	0	2.3
08	08	1970	16	05	53.0	-29.080	148.350	0	4.8
21	03	1972	03	13	18.0	-32.730	149.230	0	3.2
26	03	1972	05	21	15.0	-32.670	149.120	0	2.6
30	04	1972	17	11	23.9	-31.010	150.150	0	3.9
11	05	1972	01	09	3.0	-32.420	149.120	0	3.1
02	06	1972	07	37	46.0	-32.220	148.730	0	3.1
07	01	1973	23	29	42.6	-32.280	148.580	6	3.4
14	02	1973	07	36	20.0	-32.220	148.520	0	3.4
09	03	1973	00	47	1.0	-32.320	148.730	0	3.5
05	02	1974	01	04	0.0	-28.200	152.000	0	3.0
10	04	1974	23	16	36.4	-31.900	151.180	0	2.5
20	09	1974	20	09	2.0	-31.670	149.290	0	3.5
21	09	1974	06	16	15.0	-31.980	148.480	0	3.9
22	12	1974	11	23	52.9	-30.400	147.700	0	3.6
15	09	1975	18	34	15.3	-30.200	147.300	32	3.5
12	11	1975	10	29	39.0	-25.600	151.900	0	3.2
12	11	1975	10	54	53.0	-25.500	151.700	0	3.0
12	11	1975	18	45	44.0	-25.600	151.900	0	3.0
12	11	1975	20	48	34.0	-25.600	151.900	0	2.5
21	11	1976	09	42	16.0	-32.600	151.280	0	2.3
15	12	1976	16	03	34.0	-32.800	151.030	0	2.6
13	03	1977	13	25	42.3	-32.700	151.340	28	2.5
23	03	1977	17	46	1.7	-32.940	151.480	11	2.5
04	07	1977	09	03	5.0	-26.430	152.620	0	2.1
06	01	1978	13	39	16.1	-27.208	152.862	10	2.3
07	01	1978	16	43	33.4	-26.110	152.000	13	1.6
22	08	1978	10	37	32.3	-32.870	151.420	20	3.4
28	11	1978	17	33	39.0	-23.550	152.140	12	4.8
12	01	1979	14	21	35.0	-26.360	153.400	0	2.9
04	02	1979	13	26	4.1	-33.000	151.400	29	3.2
28	02	1979	15	02	53.0	-24.900	151.500	0	3.1
02	03	1979	18	05	12.2	-32.990	151.410	13	3.0
19	03	1979	12	16	14.0	-32.900	151.400	0	2.5
13	04	1979	15	24	14.5	-32.990	149.850	7	3.0
06	05	1979	13	09	22.0	-32.100	149.830	0	3.3
04	07	1979	13	34	3.0	-24.370	152.080	8	2.3
06	09	1979	13	07	58.8	-30.870	152.980	10	3.1
01	10	1979	08	22	30.0	-32.830	151.420	0	2.8
16	10	1979	11	43	33.0	-25.120	152.390	9	2.4
13	01	1980	17	37	10.0	-28.820	151.070	0	2.1
01	05	1980	21	10	1.6	-32.900	149.680	13	3.7
24	08	1980	15	08	43.0	-29.200	151.490	0	2.1
04	09	1980	21	05	44.9	-29.126	150.937	1	3.7
02	12	1980	00	52	7.0	-28.370	149.210	9	3.6
15	12	1980	15	06	14.1	-32.760	151.410	16	3.4

01	01	1981	09	00	20.0	-32.420	149.200	0	3.2
03	01	1981	18	49	5.4	-25.913	151.240	10	3.0
30	01	1981	11	49	21.8	-26.253	151.989	3	2.0
22	02	1981	13	12	33.5	-32.980	150.510	10	3.4
25	02	1981	05	29	2.3	-32.780	151.460	21	3.6
24	03	1981	18	34	16.0	-27.670	152.240	10	3.1
07	09	1981	02	45	14.0	-32.460	150.990	19	4.2
11	10	1981	09	26	34.8	-29.640	151.750	10	3.0
15	01	1982	10	31	33.7	-25.276	151.690	1	2.2
15	01	1982	11	40	55.0	-25.300	151.700	0	1.5
25	01	1982	11	26	8.0	-28.470	149.200	0	3.0
04	03	1982	10	02	43.4	-29.820	151.200	20	4.3
18	03	1982	06	30	12.7	-29.180	151.150	0	2.8
24	03	1982	18	34	8.9	-27.660	152.200	10	2.0
29	03	1982	08	05	18.0	-29.810	151.430	0	3.0
29	03	1982	20	03	18.0	-29.870	151.040	0	3.1
31	03	1982	04	24	3.2	-25.990	151.920	6	1.5
01	04	1982	15	48	37.8	-26.114	151.817	5	2.1
22	04	1982	06	53	15.5	-27.411	152.607	10	1.7
08	06	1982	03	13	23.7	-29.660	151.490	0	2.5
09	06	1982	04	32	47.0	-29.660	151.570	2	3.6
10	06	1982	10	54	0.0	-29.600	151.500	0	1.1
26	06	1982	06	49	17.0	-32.450	149.750	0	2.8
05	07	1982	09	02	29.0	-29.670	151.530	10	1.8
14	07	1982	16	13	32.9	-27.824	152.034	10	1.6
01	09	1982	08	12	6.1	-25.666	151.047	1	2.4
13	11	1982	08	22	26.4	-26.022	151.446	1	2.3
25	12	1982	16	48	40.0	-33.000	151.900	0	3.5
30	01	1983	21	18	49.0	-25.910	151.360	0	3.4
06	02	1983	23	13	51.5	-31.080	151.330	25	4.6
19	03	1983	05	00	7.0	-32.880	149.240	0	4.1
06	04	1983	02	06	43.0	-28.160	152.640	0	2.2
15	04	1983	07	47	34.0	-25.050	151.250	4	2.0
29	04	1983	16	51	4.8	-32.560	151.390	10	3.6
17	06	1983	02	59	40.3	-32.440	150.920	20	3.5
12	08	1983	07	42	22.0	-32.300	147.500	0	3.3
05	10	1983	23	49	30.4	-30.360	151.190	0	4.0
18	02	1984	19	55	11.6	-27.206	152.059	4	1.3
04	03	1984	07	12	58.2	-26.942	151.794	4	2.2
05	04	1984	00	00	7.5	-27.379	151.492	10	1.0
14	04	1984	16	38	42.0	-32.800	151.400	0	2.7
20	07	1984	21	56	20.2	-32.520	151.370	21	3.9
24	09	1984	11	30	5.0	-25.150	150.790	6	2.0
30	10	1984	06	29	48.0	-26.310	151.960	6	4.2
03	11	1984	02	09	38.0	-26.320	151.940	8	2.1
24	11	1984	22	48	1.8	-24.698	150.703	30	3.7
24	11	1984	22	50	19.3	-24.569	150.665	18	3.5
24	11	1984	22	51	35.0	-24.700	150.700	0	2.0
24	11	1984	22	53	9.0	-24.700	150.700	0	2.2
02	01	1985	09	20	33.3	-30.039	150.764	0	2.5
20	01	1985	12	14	55.1	-25.073	150.675	19	1.7
27	01	1985	02	59	7.4	-24.438	152.347	30	1.6
27	01	1985	03	16	37.8	-24.579	152.306	0	2.3
27	01	1985	03	22	7.3	-24.564	152.319	0	2.4
27	01	1985	04	03	25.0	-24.560	152.210	10	2.1
27	01	1985	04	03	46.4	-24.462	152.389	26	3.1
04	02	1985	11	54	34.0	-24.720	150.720	0	2.5
05	06	1985	21	07	3.1	-28.450	148.810	0	3.9

07	06	1985	17	55	36.0	-27.710	148.810	0	2.8
16	07	1985	08	07	52.0	-25.070	151.400	0	2.1
28	07	1985	03	13	25.6	-24.350	151.700	8	3.0
28	07	1985	21	41	45.0	-24.330	151.760	2	2.5
12	08	1985	07	02	9.4	-28.589	149.330	0	4.5
22	08	1985	14	16	18.0	-32.600	152.400	0	3.1
28	08	1985	02	14	47.0	-28.230	149.460	5	2.2
27	09	1985	10	17	43.0	-25.210	151.000	6	2.0
14	10	1985	07	46	30.2	-28.550	148.950	0	3.5
02	12	1985	06	19	0.9	-25.390	151.730	10	3.2
08	01	1986	09	55	57.0	-27.150	152.500	0	3.2
09	01	1986	18	15	27.7	-27.110	152.515	7	1.0
22	01	1986	12	19	38.5	-32.710	148.370	6	2.3
05	02	1986	12	58	47.0	-26.147	151.620	11	2.3
03	03	1986	14	36	55.5	-26.842	152.361	9	1.3
16	04	1986	08	55	5.0	-32.800	148.350	0	1.8
10	05	1986	19	27	52.1	-30.112	151.180	8	2.7
12	05	1986	06	22	4.4	-27.822	149.432	5	2.5
12	05	1986	21	33	6.2	-29.901	151.318	10	2.6
13	05	1986	06	08	10.9	-29.897	151.336	10	2.7
13	05	1986	19	54	11.1	-28.363	149.414	10	2.3
19	05	1986	00	46	28.5	-27.276	152.816	11	2.6
07	06	1986	17	51	31.4	-29.910	151.188	10	2.7
21	06	1986	10	26	31.3	-26.735	152.090	10	1.4
29	06	1986	20	55	59.8	-25.763	151.279	0	1.6
30	06	1986	05	16	34.8	-28.473	150.643	1	1.7
07	07	1986	06	27	42.3	-29.910	151.190	0	3.1
22	07	1986	17	23	56.8	-27.537	153.421	9	1.4
18	08	1986	11	33	0.0	-26.112	151.444	0	1.3
26	08	1986	19	51	15.8	-27.252	152.803	8	1.1
31	08	1986	17	53	56.4	-30.260	151.240	9	3.3
31	08	1986	19	06	38.0	-30.324	151.184	10	2.6
28	09	1986	20	01	39.0	-26.683	152.210	10	2.2
16	10	1986	10	53	27.0	-33.000	147.370	0	2.8
05	12	1986	14	10	20.0	-32.060	148.200	0	2.9
25	01	1987	11	10	39.0	-32.670	148.650	0	2.0
08	02	1987	00	48	59.2	-29.100	152.600	10	3.1
12	03	1987	16	53	5.0	-32.780	147.750	0	2.4
09	04	1987	10	38	38.9	-29.720	151.260	0	3.3
05	08	1987	06	37	57.9	-32.271	149.674	0	2.6
26	08	1987	01	38	33.9	-32.732	151.168	0	3.3
04	09	1987	07	15	35.9	-32.090	152.580	0	3.4
28	09	1987	19	37	36.9	-29.360	150.670	0	3.4
31	10	1987	06	02	50.0	-23.830	152.840	10	3.5
31	10	1987	13	48	25.0	-24.430	152.800	9	2.4
15	01	1988	10	25	7.2	-29.610	148.890	0	3.9
23	02	1988	21	56	42.5	-31.472	145.605	8	2.9
21	05	1988	02	23	19.8	-23.700	151.690	9	3.4
14	08	1988	23	23	57.1	-27.560	152.330	10	4.0
13	05	1989	02	17	2.2	-30.360	147.000	15	3.0
23	05	1989	12	08	56.3	-28.843	143.978	5	4.0
27	12	1989	23	26	57.0	-32.946	151.607	11	5.6
29	12	1989	09	08	9.6	-32.957	151.627	14	2.3
01	01	1990	22	20	31.5	-25.016	151.288	9	1.6
04	01	1990	03	12	2.8	-28.547	149.478	1	2.2
04	01	1990	10	57	1.4	-29.768	151.965	0	2.3
05	01	1990	19	45	55.1	-25.006	151.502	10	1.3
23	01	1990	07	31	30.0	-24.676	152.613	8	2.8

29	01	1990	01	46	2.2	-26.384	152.305	1	1.4
23	02	1990	12	43	13.1	-32.938	151.503	14	2.9
05	03	1990	01	09	36.2	-27.534	152.843	19	1.0
11	03	1990	22	16	57.2	-24.207	151.622	7	2.0
27	04	1990	16	02	13.2	-27.499	147.247	10	3.0
28	04	1990	14	50	52.7	-25.452	151.402	5	1.7
22	05	1990	06	39	28.0	-32.026	150.332	10	3.4
22	05	1990	13	33	13.5	-25.198	151.386	8	1.8
28	05	1990	03	36	35.8	-25.670	152.350	5	3.4
09	06	1990	04	06	10.3	-23.364	147.822	19	2.9
23	06	1990	08	13	58.9	-25.805	150.861	15	2.3
28	06	1990	02	48	30.6	-26.132	151.474	10	2.0
05	07	1990	11	33	27.4	-26.228	152.122	8	1.1
07	07	1990	13	28	41.0	-24.192	150.776	8	1.4
07	07	1990	16	29	51.4	-24.237	150.857	5	1.5
03	08	1990	01	26	29.7	-26.848	151.989	0	1.4
03	08	1990	12	06	18.5	-28.580	149.262	10	2.8
03	08	1990	12	06	20.4	-26.250	146.240	0	3.1
13	09	1990	19	28	22.8	-32.850	148.290	0	3.3
27	09	1990	05	24	40.2	-25.285	151.036	8	1.0
30	09	1990	19	19	0.0	-32.650	149.370	0	2.6
30	09	1990	19	32	0.0	-32.660	149.330	0	2.8
03	11	1990	19	49	7.1	-23.402	149.160	8	2.7
14	11	1990	18	56	45.0	-30.330	150.840	6	3.1
20	11	1990	12	30	22.1	-28.765	149.416	10	2.2
08	12	1990	13	41	58.2	-26.381	150.724	8	2.5
11	12	1990	16	10	29.6	-23.610	150.619	6	2.3
12	12	1990	22	41	34.4	-25.317	151.394	8	1.1
13	12	1990	02	50	29.4	-25.310	151.535	10	1.5
04	01	1991	02	47	43.9	-28.930	146.732	10	3.6
14	01	1991	14	43	53.9	-30.828	151.846	8	2.9
23	01	1991	03	20	0.0	-24.300	150.500	0	2.6
23	01	1991	23	36	0.0	-24.300	150.500	0	2.4
07	02	1991	11	40	17.3	-26.030	150.526	8	1.6
26	02	1991	10	33	0.0	-23.500	150.700	0	1.3
15	03	1991	04	29	0.6	-23.816	152.378	8	2.4
16	04	1991	20	40	5.3	-25.455	151.793	10	1.4
17	04	1991	01	34	26.7	-25.403	151.786	10	1.4
21	05	1991	03	24	30.8	-30.183	151.431	3	2.7
22	05	1991	07	02	0.0	-24.780	151.316	0	1.1
22	05	1991	07	07	0.0	-24.780	151.316	0	1.3
24	05	1991	04	10	21.5	-26.882	152.647	0	1.3
26	05	1991	06	32	30.5	-23.613	150.667	10	1.6
26	05	1991	12	04	0.0	-23.613	150.667	10	1.3
03	06	1991	14	55	15.2	-25.357	150.622	6	2.1
10	06	1991	12	00	23.2	-23.609	150.658	0	2.9
10	06	1991	13	00	44.0	-23.607	150.644	10	2.9
10	06	1991	13	05	6.1	-23.597	150.627	5	1.7
10	06	1991	20	48	0.0	-23.596	150.632	9	1.2
24	06	1991	12	12	10.5	-25.260	151.390	8	1.3
11	07	1991	07	02	0.0	-26.112	151.440	0	1.2
13	07	1991	19	35	0.8	-25.622	151.307	4	2.3
17	07	1991	02	34	11.1	-32.540	150.900	3	3.2
26	07	1991	04	59	16.9	-25.207	151.460	10	2.1
27	08	1991	02	43	43.0	-32.500	151.500	0	2.9
07	09	1991	06	36	25.0	-26.705	152.203	11	1.9
08	09	1991	21	39	21.3	-23.977	152.722	10	2.6
13	09	1991	13	37	28.5	-25.104	152.878	5	1.8

18	09	1991	21	26	0.0	-24.000	152.700	0	1.9
24	09	1991	04	36	52.7	-27.890	149.051	8	4.1
24	09	1991	09	01	38.8	-27.710	148.331	8	2.6
24	09	1991	15	05	10.8	-28.071	149.283	8	2.5
27	09	1991	08	02	6.8	-28.675	151.322	10	1.5
28	09	1991	15	05	34.2	-27.479	149.330	8	3.6
01	10	1991	03	33	2.2	-25.702	150.543	10	2.6
21	11	1991	01	04	0.0	-24.780	151.316	0	1.1
22	11	1991	17	39	14.6	-26.127	151.698	3	2.9
22	11	1991	18	37	0.0	-26.073	151.725	0	1.2
27	11	1991	05	25	0.0	-26.073	151.725	0	1.1
01	12	1991	18	13	47.5	-26.527	152.502	2	3.6
04	12	1991	10	48	10.2	-26.509	152.589	0	1.4
13	12	1991	19	30	2.3	-26.119	151.654	10	2.1
21	12	1991	14	11	41.1	-26.483	151.442	3	1.4
11	01	1992	03	08	21.0	-25.406	151.133	2	1.3
11	01	1992	21	31	22.6	-26.047	151.717	7	2.4
12	01	1992	12	49	0.0	-26.047	151.717	7	1.0
22	01	1992	12	25	16.6	-27.927	149.001	4	2.3
23	01	1992	09	18	16.1	-27.930	148.966	10	2.4
29	01	1992	03	22	0.0	-24.780	151.316	0	2.6
02	02	1992	12	28	0.0	-26.112	151.444	0	1.0
03	03	1992	03	35	20.9	-26.290	152.400	10	2.3
05	03	1992	13	45	3.9	-29.640	150.940	10	2.4
11	03	1992	00	35	50.3	-25.941	151.092	3	2.4
21	03	1992	22	37	53.2	-26.609	150.895	1	1.8
24	03	1992	21	08	40.4	-26.503	150.944	0	1.6
29	03	1992	00	32	6.0	-26.526	151.024	7	1.4
29	03	1992	08	38	15.7	-26.497	150.974	10	1.1
31	03	1992	01	16	45.7	-25.382	150.429	8	1.9
31	03	1992	01	21	0.0	-26.112	151.444	0	1.5
04	04	1992	14	46	21.2	-24.963	151.371	8	1.6
06	04	1992	17	30	28.3	-26.505	151.093	5	1.1
24	04	1992	12	52	32.1	-24.654	150.798	9	1.7
28	04	1992	05	46	34.4	-24.205	150.989	8	1.2
19	05	1992	12	00	28.6	-25.037	151.203	10	1.5
19	05	1992	12	08	10.1	-25.014	151.375	9	1.5
19	05	1992	13	25	29.4	-25.020	151.375	7	1.1
19	05	1992	17	42	28.6	-25.037	151.203	10	1.1
04	06	1992	03	23	23.0	-25.039	152.756	0	1.9
15	06	1992	13	59	49.3	-25.073	151.378	8	1.1
08	07	1992	23	12	45.2	-25.038	152.448	0	1.7
09	07	1992	08	54	0.0	-26.112	151.444	0	1.3
14	07	1992	07	17	0.0	-26.112	151.444	0	2.1
15	07	1992	15	49	2.8	-24.437	151.103	5	1.9
15	07	1992	15	52	7.2	-32.753	151.397	5	1.3
16	07	1992	03	54	8.1	-24.522	149.778	8	1.7
17	07	1992	12	10	4.0	-26.481	151.942	10	1.7
24	07	1992	02	04	0.0	-32.145	149.702	2	2.6
03	08	1992	00	44	0.0	-26.112	151.444	0	1.0
03	08	1992	05	28	0.0	-26.112	151.444	0	1.0
08	08	1992	08	20	0.0	-26.112	151.444	0	2.0
10	08	1992	06	11	0.0	-27.600	152.600	0	1.8
11	08	1992	01	51	0.0	-24.400	150.600	0	1.3
19	08	1992	11	18	16.5	-30.162	151.457	0	3.3
24	08	1992	12	01	31.9	-32.646	149.376	10	2.4
26	08	1992	01	08	29.1	-26.592	152.744	0	1.0
02	09	1992	04	39	55.4	-32.095	150.594	10	2.7

08	09	1992	07	30	8.7	-23.447	151.276	0	1.0
18	09	1992	03	54	0.0	-26.112	151.444	0	1.0
21	09	1992	08	33	5.5	-25.855	151.868	8	1.5
25	09	1992	05	01	45.1	-25.565	152.021	8	1.5
25	09	1992	07	12	41.1	-25.602	151.895	8	1.1
25	09	1992	07	56	23.8	-25.557	151.899	8	1.3
25	09	1992	15	58	10.1	-25.478	151.700	8	1.9
25	09	1992	15	59	0.0	-25.478	151.700	8	1.3
27	09	1992	07	02	30.8	-25.744	151.287	0	1.6
01	10	1992	01	33	0.0	-24.780	151.316	0	1.7
03	10	1992	07	40	57.5	-25.793	151.808	0	1.0
04	10	1992	03	01	53.5	-26.714	151.810	8	1.3
12	10	1992	12	55	30.0	-24.525	150.244	8	1.7
23	10	1992	03	05	0.0	-26.112	151.444	0	1.2
27	10	1992	02	54	0.0	-26.112	151.444	0	1.5
30	10	1992	04	57	50.0	-25.703	151.688	10	1.5
14	11	1992	08	18	0.0	-26.112	151.444	0	1.0
14	11	1992	16	37	28.1	-24.195	152.133	1	1.8
17	11	1992	05	24	0.0	-24.780	151.316	0	1.9
18	11	1992	03	53	23.8	-25.803	151.694	0	1.4
23	11	1992	06	42	8.0	-23.321	149.814	8	2.6
25	11	1992	21	27	26.0	-25.707	151.563	1	2.6
30	11	1992	03	36	36.3	-30.261	151.408	8	3.2
02	12	1992	01	06	18.9	-24.026	151.268	8	1.3
10	12	1992	02	04	0.0	-26.112	151.444	0	1.3
14	12	1992	08	10	38.9	-25.765	151.300	8	1.6
21	12	1992	22	18	56.0	-30.264	151.436	8	3.0
31	12	1992	08	44	0.0	-26.112	151.444	0	1.4
01	01	1993	20	03	3.3	-23.331	152.904	8	1.8
03	01	1993	08	51	59.5	-26.932	152.426	5	1.6
08	01	1993	15	27	43.5	-26.516	151.020	0	1.5
08	01	1993	21	59	51.9	-24.648	149.697	9	1.7
19	01	1993	07	24	32.8	-24.765	150.902	6	1.4
22	01	1993	04	42	26.5	-24.525	150.624	0	1.5
25	01	1993	04	41	50.7	-28.410	152.055	0	1.2
09	02	1993	16	15	21.2	-24.711	150.903	8	1.3
17	02	1993	09	49	0.0	-26.112	151.444	0	1.0
10	03	1993	07	59	15.9	-27.825	152.327	6	1.1
13	03	1993	12	27	1.5	-25.082	151.404	0	1.0
17	03	1993	16	26	0.0	-26.112	151.444	0	1.0
20	03	1993	16	37	10.0	-24.918	151.369	8	1.8
21	03	1993	07	03	0.0	-30.420	151.628	0	2.6
21	03	1993	07	03	21.9	-29.870	150.670	0	2.8
21	03	1993	07	04	0.0	-30.420	151.628	0	2.4
21	03	1993	07	04	35.7	-29.870	150.670	0	2.6
02	04	1993	02	45	34.9	-24.971	151.372	8	1.1
05	05	1993	00	03	38.4	-29.276	143.747	5	2.0
17	05	1993	10	02	1.6	-26.349	151.930	7	1.3
22	05	1993	09	34	0.0	-26.112	145.484	0	1.2
31	05	1993	04	55	0.0	-27.115	152.550	0	1.2
03	06	1993	11	46	8.7	-26.283	151.329	12	1.8
21	07	1993	06	41	3.8	-26.179	151.449	2	1.7
24	07	1993	14	17	0.0	-24.780	151.316	0	1.5
04	08	1993	05	55	0.0	-26.112	151.444	0	1.2
06	08	1993	10	06	0.0	-26.112	151.444	0	1.1
07	08	1993	14	02	57.4	-24.284	152.794	8	1.6
22	08	1993	09	56	23.1	-26.548	152.500	8	2.0
06	09	1993	16	03	36.2	-23.241	152.549	8	2.3

30	09	1993	17	20	36.5	-28.086	153.390	10	1.2
03	10	1993	02	28	50.5	-26.057	151.828	7	1.7
06	10	1993	01	42	41.9	-25.784	150.588	5	1.9
15	10	1993	21	51	16.4	-25.193	151.475	7	2.2
16	10	1993	04	49	0.0	-26.112	151.444	0	1.0
19	10	1993	15	51	40.0	-30.552	150.516	0	2.9
19	10	1993	17	37	15.5	-30.665	150.345	0	2.5
23	10	1993	12	32	41.5	-32.914	151.299	7	3.0
04	11	1993	03	56	2.3	-32.669	149.404	4	2.9
13	11	1993	19	36	0.0	-24.780	151.316	0	1.9
15	11	1993	20	14	23.9	-26.275	153.441	8	1.6
25	11	1993	04	06	41.0	-23.922	152.632	2	3.7
07	12	1993	09	27	0.0	-24.780	151.316	0	1.2
08	12	1993	08	32	0.0	-24.780	151.316	0	1.6
11	12	1993	20	32	6.5	-25.767	151.152	8	1.4
13	12	1993	18	49	0.0	-26.112	151.444	0	1.0
16	12	1993	16	05	40.3	-25.710	151.071	9	1.5
27	12	1993	03	13	0.0	-26.112	151.444	0	1.0
30	01	1994	15	11	59.8	-24.768	150.728	8	1.4
01	02	1994	16	31	23.5	-25.946	151.246	0	2.2
08	02	1994	11	23	20.3	-25.328	150.176	0	2.5
14	02	1994	22	30	0.0	-26.112	151.444	0	1.4
19	02	1994	21	00	49.5	-25.247	151.389	10	1.7
26	02	1994	02	57	0.0	-26.112	151.444	0	1.0
04	03	1994	07	25	0.0	-26.112	151.444	0	2.2
06	03	1994	07	36	15.6	-28.605	149.236	7	2.6
06	03	1994	07	53	0.0	-26.112	151.444	0	1.1
09	03	1994	13	30	46.8	-25.303	150.334	8	1.4
27	03	1994	01	30	0.0	-24.524	149.587	8	2.8
29	03	1994	11	24	50.0	-24.715	150.807	0	1.2
29	03	1994	11	25	23.8	-24.715	150.807	0	1.2
31	03	1994	05	08	12.0	-28.896	149.547	5	2.3
05	04	1994	05	38	0.0	-26.112	151.444	0	1.1
14	04	1994	03	16	9.7	-27.004	152.913	0	1.3
21	04	1994	03	57	39.1	-24.552	149.918	8	2.6
28	04	1994	07	29	7.5	-23.869	152.452	8	1.8
30	04	1994	06	55	9.7	-24.546	151.008	0	1.2
05	05	1994	15	35	0.0	-26.112	151.444	0	2.4
14	05	1994	16	08	57.8	-26.257	150.878	0	2.3
09	07	1994	14	30	55.7	-31.990	144.990	10	4.2
17	07	1994	11	35	31.2	-29.992	151.444	8	3.0
02	08	1994	09	54	17.6	-32.881	151.299	0	2.3
03	08	1994	03	54	36.8	-32.856	151.288	0	2.5
06	08	1994	11	03	51.6	-32.924	151.288	2	5.3
10	08	1994	11	45	2.3	-26.656	149.392	8	1.6
12	08	1994	20	40	58.7	-24.192	150.179	8	1.8
01	09	1994	23	13	22.9	-24.968	151.372	8	1.8
06	09	1994	14	30	12.6	-24.967	151.367	8	2.3
14	09	1994	08	06	45.2	-29.632	150.911	7	2.7
23	09	1994	16	31	15.5	-29.449	150.923	9	2.3
20	10	1994	12	13	51.5	-23.018	151.161	10	1.9
24	10	1994	10	31	1.7	-32.868	151.330	2	2.3
30	10	1994	16	30	16.4	-32.874	151.305	2	2.3
31	10	1994	23	37	18.8	-25.627	151.024	8	1.7
03	11	1994	16	33	12.9	-32.886	151.313	0	2.3
09	11	1994	17	10	48.1	-32.877	151.324	0	2.3
11	11	1994	16	30	48.9	-32.900	151.323	1	2.2
13	11	1994	01	30	15.7	-26.536	152.575	0	1.6

14	11	1994	01	55	42.1	-32.881	151.281	0	2.3
17	11	1994	10	24	9.2	-32.893	151.289	0	2.1
18	11	1994	03	44	44.7	-24.841	151.364	8	1.4
21	11	1994	22	31	22.9	-32.879	151.294	0	2.2
22	11	1994	10	38	0.0	-26.112	151.444	0	1.2
24	11	1994	19	38	59.1	-32.870	151.299	0	2.2
01	12	1994	00	33	10.5	-32.851	151.267	0	2.3
01	12	1994	08	08	55.5	-32.866	151.292	0	2.6
03	12	1994	05	41	32.3	-32.895	151.284	0	2.2
26	12	1994	12	44	35.2	-25.480	150.643	8	2.0
09	01	1995	08	45	50.1	-32.870	151.324	0	2.3
12	01	1995	12	50	44.0	-30.288	151.087	9	2.6
14	01	1995	02	23	24.5	-30.815	145.980	10	3.6
18	01	1995	03	06	30.9	-30.336	151.058	10	2.3
18	01	1995	18	24	16.4	-30.339	150.970	10	2.2
25	01	1995	09	33	15.2	-32.853	151.290	3	2.3
21	02	1995	00	20	37.4	-32.858	151.313	2	2.5
01	03	1995	17	10	43.9	-31.830	149.507	0	2.4
27	03	1995	15	51	47.9	-29.412	151.238	1	2.3
28	05	1995	20	36	12.9	-32.547	151.428	7	2.2
28	05	1995	23	12	58.4	-32.518	151.408	4	3.5
25	06	1995	15	02	56.0	-32.408	149.378	0	2.2
03	07	1995	03	48	50.2	-32.828	151.318	6	2.4
05	07	1995	14	52	59.5	-32.979	151.197	0	2.2
07	07	1995	06	53	24.5	-32.928	151.318	1	3.2
20	07	1995	16	33	12.2	-32.855	151.208	10	2.1
05	08	1995	07	13	40.6	-29.294	151.275	3	2.5
12	08	1995	06	48	30.6	-32.983	149.997	1	2.2
06	09	1995	07	16	39.7	-32.859	151.325	0	2.3
03	11	1995	15	37	11.4	-32.880	151.341	1	2.2
17	11	1995	16	52	33.9	-32.682	145.572	0	2.0
21	11	1995	17	02	14.1	-32.884	151.269	2	3.1
10	12	1995	18	29	14.0	-32.735	145.415	5	2.2
06	01	1996	01	44	29.2	-25.983	150.967	10	2.1
12	01	1996	12	17	42.6	-32.861	151.255	0	2.2
12	01	1996	12	29	8.5	-32.866	151.258	0	2.4
01	03	1996	01	00	3.1	-32.105	148.588	4	3.0
12	05	1996	18	43	27.9	-32.825	151.285	3	2.2
04	06	1996	08	27	22.3	-28.972	144.063	0	3.4
18	07	1996	05	40	16.2	-27.588	153.041	10	2.9
13	08	1996	04	30	10.7	-30.080	143.519	2	5.1
13	08	1996	05	44	32.1	-30.098	143.550	5	3.0
14	08	1996	03	16	51.6	-30.153	143.501	5	3.6
14	08	1996	09	29	7.4	-30.121	143.538	5	4.4
14	08	1996	10	32	36.3	-30.136	143.647	5	3.7
19	08	1996	20	16	5.3	-30.118	143.533	7	2.3
20	08	1996	00	48	29.2	-30.114	143.534	7	2.1
20	08	1996	18	03	49.2	-30.116	143.542	7	2.3
21	08	1996	12	35	20.6	-30.119	143.531	7	2.5
22	08	1996	15	25	14.9	-30.123	143.535	6	2.7
12	09	1996	14	53	29.9	-28.095	146.033	10	3.8
26	11	1996	07	32	39.1	-29.611	143.868	5	2.7
11	12	1996	00	43	30.9	-30.701	150.083	12	2.8
27	12	1996	16	20	24.6	-29.805	151.247	0	3.2
27	12	1996	16	28	21.8	-29.864	151.180	0	3.5
02	01	1997	07	11	11.0	-28.450	148.850	0	3.1
18	03	1997	15	15	3.4	-32.346	151.396	10	2.4
29	03	1997	20	57	27.8	-30.713	143.628	0	2.9

08	04	1997	01	57	49.5	-32.993	151.579	5	2.5
19	04	1997	21	32	52.5	-28.750	152.840	5	2.0
28	05	1997	17	55	45.0	-23.909	153.339	10	3.5
06	07	1997	23	22	4.7	-32.420	148.620	10	2.1
08	07	1997	10	01	22.4	-31.594	153.060	10	3.7
05	10	1997	21	57	45.3	-28.962	151.213	10	2.4
12	10	1997	14	50	59.9	-31.970	149.490	0	3.2
13	02	1998	23	20	51.5	-25.700	150.620	0	4.0
09	03	1998	12	40	42.9	-32.143	150.003	3	3.1
24	03	1998	22	10	26.4	-31.139	150.278	10	1.8
28	03	1998	09	02	8.7	-32.853	152.225	16	2.6
12	05	1998	15	46	8.9	-31.693	152.652	10	2.8
19	06	1998	22	06	3.2	-32.330	151.377	6	2.3
11	08	1998	18	25	28.8	-32.178	144.355	0	3.8
13	08	1998	02	54	54.5	-32.178	144.384	10	2.9
14	08	1998	08	27	38.0	-28.230	151.162	10	2.4
17	08	1998	00	58	25.8	-32.087	144.417	0	3.0
10	04	1999	02	42	16.1	-32.557	149.839	0	2.1
26	04	1999	21	14	36.7	-29.823	151.266	0	3.3
26	04	1999	21	26	56.5	-29.803	151.256	0	3.2
25	05	1999	00	44	21.4	-30.210	150.175	0	3.1
25	05	1999	07	31	1.4	-30.252	150.212	0	2.7
23	06	1999	17	10	12.7	-26.126	151.392	0	2.5
08	07	1999	08	15	8.0	-30.500	151.120	0	1.5
08	07	1999	16	02	45.0	-30.500	151.120	0	1.9
08	07	1999	22	52	53.0	-30.500	151.120	0	1.4
12	08	1999	12	20	25.1	-32.849	151.528	0	1.6
12	08	1999	16	38	36.7	-27.963	150.202	0	1.8
26	09	1999	05	30	22.4	-27.985	144.141	0	2.7
23	01	2000	08	51	20.2	-30.830	152.966	0	2.6
18	02	2000	01	02	18.6	-30.690	150.126	0	2.8
10	03	2000	18	38	57.0	-29.300	144.300	0	2.0
12	03	2000	10	03	7.0	-25.570	152.000	10	2.6
01	04	2000	10	59	15.2	-31.713	149.275	10	2.2
02	04	2000	15	08	32.3	-32.000	151.330	0	1.9
25	04	2000	12	41	48.3	-31.608	150.889	15	1.9
11	06	2000	19	06	25.5	-29.510	150.046	0	3.5
03	07	2000	10	54	24.6	-30.407	151.631	0	2.2
05	07	2000	06	45	23.0	-31.900	151.400	0	1.5
29	08	2000	15	00	8.0	-25.619	151.944	0	2.5
18	09	2000	22	50	51.5	-31.001	152.841	0	2.1
28	09	2000	05	46	57.4	-30.000	150.100	0	2.6
14	12	2000	22	38	48.8	-29.776	151.289	3	2.8
20	12	2000	04	26	42.5	-32.448	149.278	0	2.3
23	02	2001	07	15	57.1	-29.123	150.191	10	2.6
24	02	2001	04	13	1.7	-30.583	152.730	0	2.7
24	02	2001	06	40	16.9	-30.583	152.730	0	2.7
18	03	2001	06	52	47.9	-32.854	148.620	0	2.0
11	05	2001	12	32	49.5	-26.511	150.208	31	2.2
20	05	2001	10	09	27.9	-32.230	146.560	1	2.8
20	05	2001	11	47	32.1	-32.190	146.500	10	2.9
25	05	2001	07	05	42.2	-32.954	149.971	11	1.9
03	08	2001	22	51	50.0	-30.400	151.600	0	1.0
07	08	2001	20	50	21.7	-27.866	147.805	0	2.4
12	10	2001	00	05	53.3	-24.119	152.883	3	4.0
24	10	2001	08	55	54.9	-32.745	146.255	5	2.4
27	10	2001	18	56	0.5	-32.425	146.409	3	2.7
01	11	2001	16	11	10.5	-30.140	144.220	5	2.8

09	11	2001	18	26	46.2	-32.840	152.100	0	2.6
11	11	2001	11	58	31.6	-29.320	144.180	6	3.2
11	11	2001	13	00	57.2	-29.360	144.250	17	2.5
27	11	2001	15	24	22.7	-32.590	146.550	3	2.2
27	11	2001	15	29	53.5	-32.540	146.620	3	2.8
06	12	2001	20	10	11.5	-28.709	148.822	0	2.9
02	05	2002	21	48	35.5	-25.413	150.975	5	3.0
07	05	2002	22	44	47.9	-28.598	149.405	7	2.4
02	07	2002	03	19	14.9	-31.820	151.396	1	2.0
23	07	2002	18	38	55.4	-31.633	145.586	5	2.7
22	08	2002	06	58	47.5	-28.443	149.069	0	3.0
03	10	2002	17	00	54.5	-29.164	147.352	5	2.5
11	10	2002	13	02	26.2	-32.178	149.804	0	2.1
16	10	2002	18	57	51.6	-32.138	149.767	2	2.3
14	12	2002	13	38	31.4	-27.384	152.983	5	2.8
26	12	2002	21	07	41.1	-30.258	151.288	3	3.0
08	01	2003	16	41	14.3	-24.767	152.382	0	2.4
03	02	2003	15	54	11.3	-29.144	148.770	0	2.3
09	02	2003	17	53	25.8	-30.608	147.998	12	2.4
24	06	2003	16	07	32.3	-27.458	152.133	2	2.7
24	06	2003	16	27	20.4	-32.131	149.741	2	2.6
28	06	2003	02	20	46.1	-25.653	151.511	5	3.2

Total number of Earthquakes = 647

Search criteria:

Latitude between -23.000 and -33.000 degrees
Longitude between 143.500 and 153.500 degrees
Magnitudes restricted between 0.0 and 9.99

PLATES

Plate 1: Mungindi levees (BSC photo – 10 October 1999)

This plate shows the Queensland part of Mungindi as it was in October 1999. Note that the levee has been modified since this photo was taken.

Plate 2: Thallon levee and railway embankments (BSC photo – 19 September 1999)

Note the large grain terminal that is largely protected by the elevated rail embankment. The houses south of the railway embankment are provided with no levee protection.

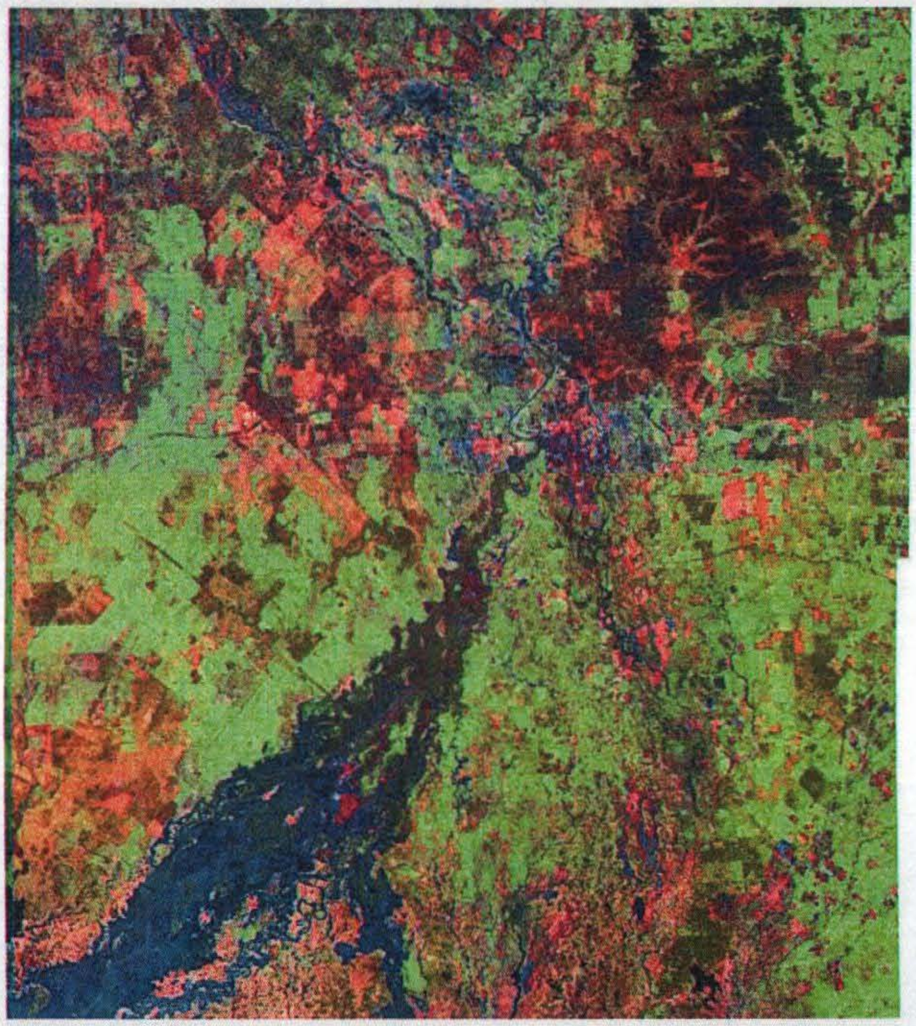

Plate 3: Landsat images of flooding in the Balonne River on 3 May 1990 (Landsat quicklook courtesy of Agrecon Pty Ltd)

Plate 4: Dirranbandi and its levees

Plate 5: Hebel township (BSC photo 19 August 1999)

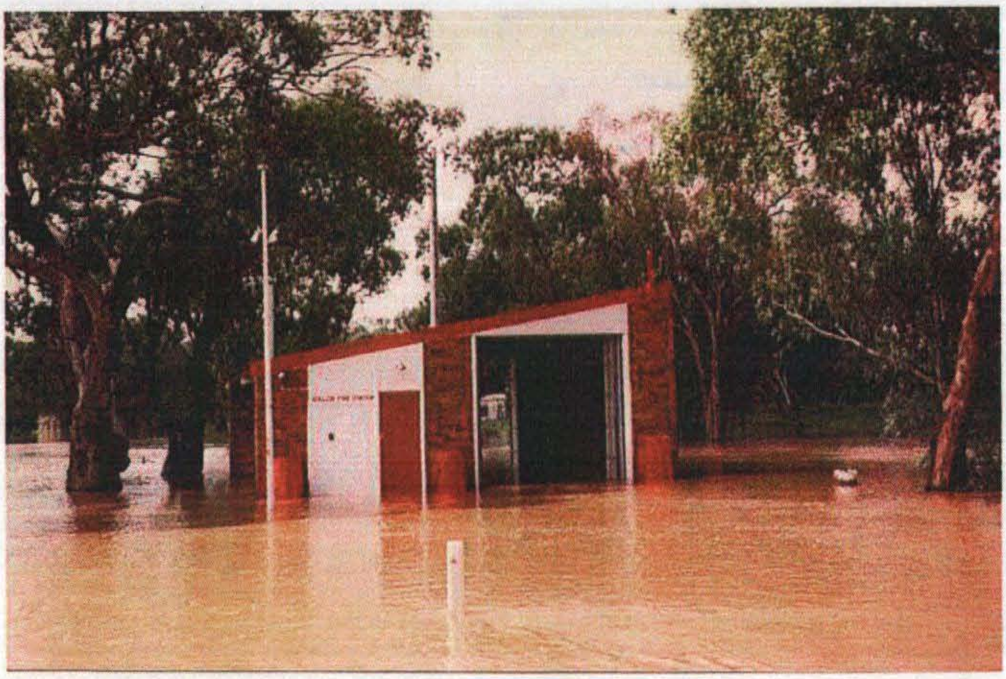

Plate 6: Bollon fire station during the 1997 flood (Max Henderson photo)

Plate 7: Bollon water treatment plant during 1997flood (Max Henderson photo)

Plate 8: Balonne Highway flooded at Wallam Creek in 1997 (Max Henderson photo)

Plate 9: Jack Taylor Weir and the Balonne Highway at St George

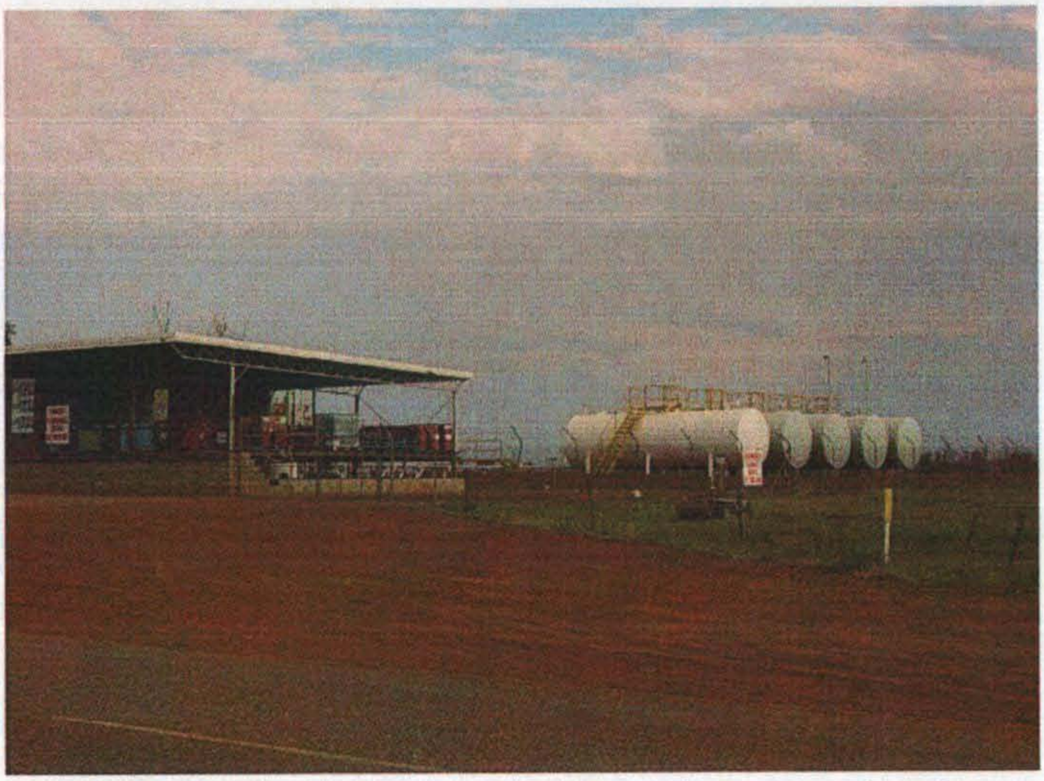

Plate 10: Mobil fuel depot St George

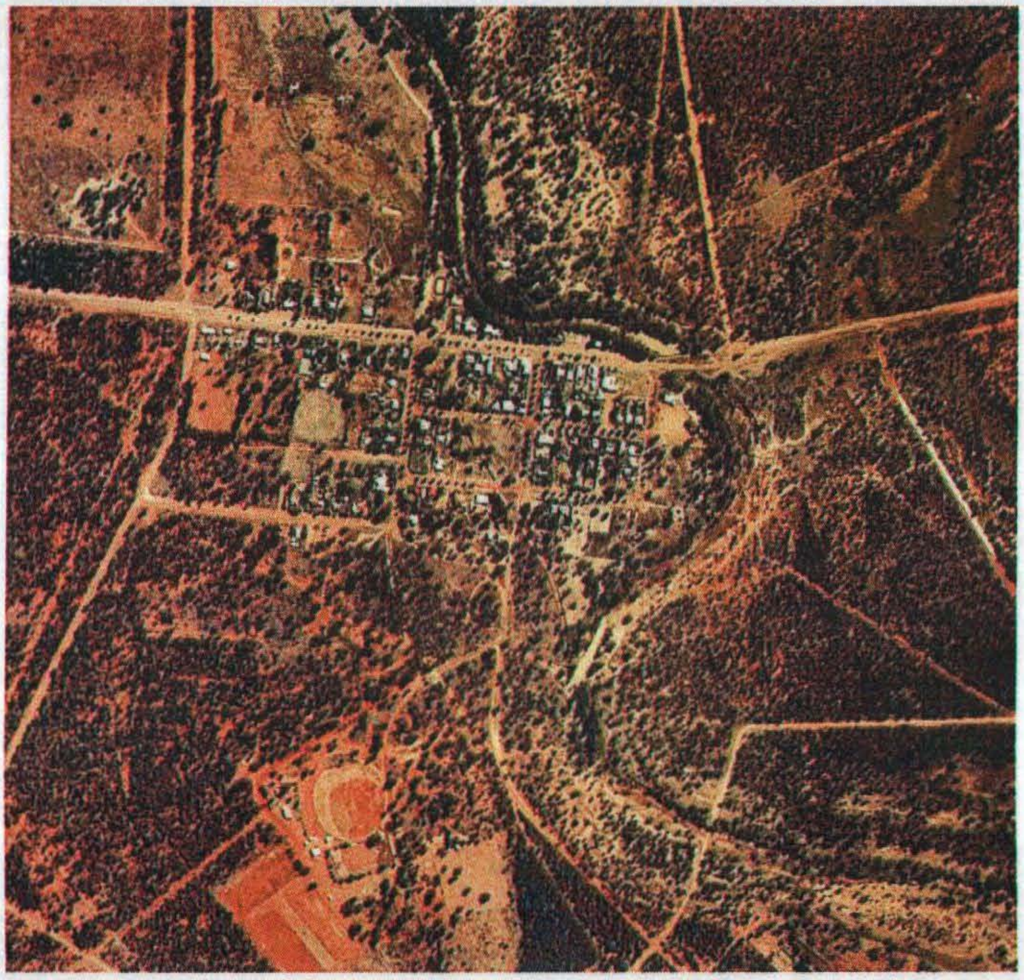

Plate 11: Bollon showing the proximity of dense vegetation (BSC photo – 19 August 1999)

Plate 12: St George (BSC photo 18 August 1999)

Plate 13: Balonne Shire Council offices at St George

Plate 14: St George hospital

Plate 15: Rail freight facility at Dirranbandi

Plate 16: Free-to-air rebroadcast TV down link at St George

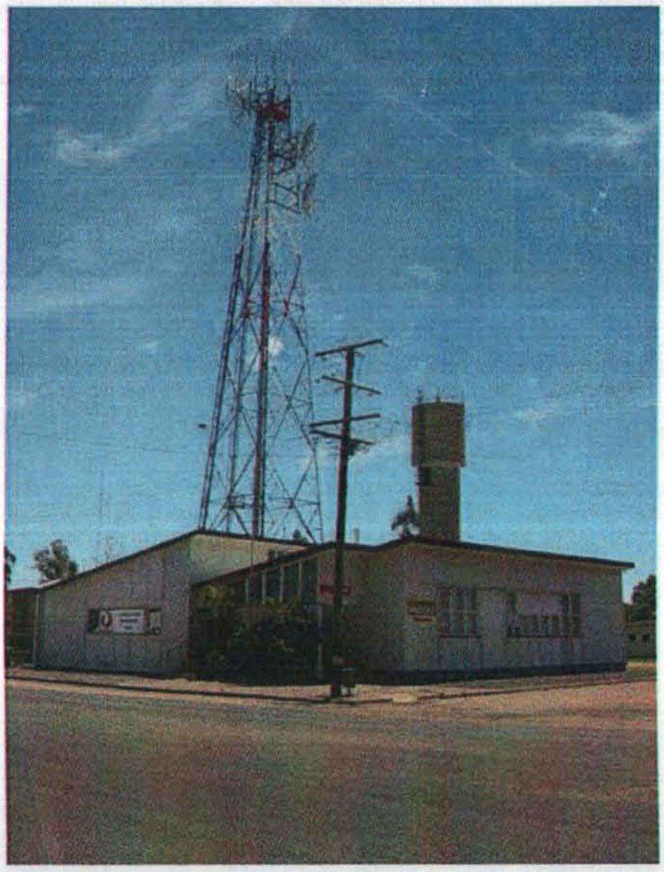

Plate 17: Dirranbandi telephone exchange and post office