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The need for and appropriate application of spatial data for disaster management and strengthening community resilience

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Abstract

It is only in recent years that the critical role that spatial data can play in disaster management and strengthening community resilience has been recognised. The recognition of this importance is singularly evident from the fact that in Australia spatial data is considered as soft infrastructure. In the aftermath of every disaster this importance is being increasingly strengthened with state agencies paying greater attention to ensuring the availability of accurate spatial data based on the lessons learnt. For example, the major flooding in Queensland during the summer of 2011 resulted in a comprehensive review of responsibilities and accountability for the provision of spatial information during such natural disasters. A high level commission of enquiry completed a comprehensive investigation of the 2011 Brisbane flood inundation event and made specific recommendations concerning the collection of and accessibility to spatial information for disaster management and for strengthening community resilience during and after a natural disaster. The lessons learnt and processes implemented were subsequently tested by natural disasters during subsequent years.

This paper provides an overview of the practical implementation of the recommendations of the commission of enquiry. It focuses particularly on the measures adopted by the state agencies with the primary role for managing spatial data and the evolution of this role in Queensland State, Australia. The paper concludes with a review of the development of the role and the increasing importance of spatial data as an infrastructure for disaster planning and management which promotes the strengthening of community resilience.

Key Words : community resilience, spatial data, disaster management, Queensland floods

1. Background

A case study approach is undertaken based on the most recent flood events in Queensland State, Australia, namely, in 2011 and 2013 to highlight the importance of spatial data for disaster management and strengthening community resilience. A study undertaken by Hayes and Goonetilleke (2012) reviewed lessons learnt concerning the usage and limitations of spatial information as an infrastructure during and in the aftermath of the major Queensland flood event in 2011 and its role as a driver for building community resilience. It highlighted the importance of the creation of an authoritative spatial record of the event as 'point-of-truth' for supporting coordinated, equitable and timely decision-making. The spatial record should preferably include: timely and high-resolution imagery for floodplain mapping, catchment modelling and future inundation predictions; high resolution imagery and elevation data for the determination of the floodline and inundation extent and depth; floor heights for determining the eligibility of flood affected properties for the receipt of emergency assistance and for verification and settlement of insurance claims.

However, what was most paramount in the study undertaken by Hayes and Goonetilleke (2012) was that in an evolving disaster situation: to make information available, publish early whilst still accepting feedback to facilitate dynamic updates and enchancements and to ensure access to information being more important than completeness of information. It was concluded that the strengthening of community resilience will occur if the general public is able to unambiguously assess the disaster risk to their own property. Futhermore, engaging the public should be encouraged and the desired outcome and consequence of the appropriate implementation of lessons learnt will drive the strengthening of community resilience based on access to specific contextual spatial information during a major disaster event such as the 2011 Brisbane flood (Hayes and Goonetilleke, 2012). This paper reviews recent progress in Queensland towards improving the quality and accessibility of spatial data and the potential of such improvement to improve all phases of disaster management and community resilience.

2. Context

The series of natural disasters that struck Queensland between November 2010 and April 2011 (referred to as the 2011 event in the manuscript) which included a major flood event and a very severe tropical cyclone resulted in all of the state being declared a disaster area consequential to the destruction over extensive areas. The Queensland Government assented to the *Queensland Reconstruction Authority Act* 2011 on February 21, 2011. The main purpose of the *Act* is to provide for appropriate measures to ensure Queensland and its communities effectively and efficiently recover from the impacts of disasters. The purpose of the *Act* was primarily achieved: by the establishment of the Queensland Reconstruction Authority (QRA) to coordinate and manage the rebuilding and recovery of affected communities, including the repair and rebuilding of community infrastructure and other property; by the establishment of the Queensland Reconstruction Board (QRB) to oversee the operations of the authority; by providing for the following to facilitate flood mitigation for affected communities, or the protection, rebuilding and recovery of affected communities - the declaration of declared projects and reconstruction areas, and the making of development schemes for declared projects and reconstruction areas (Queensland Government, 2011).

Queensland again experienced flood events in 2012 and particularly in 2013 following heavy rainfall from ex-Tropical Cyclone (TC) Oswald. These events, although not as widespread as that during the 2011 event, impacted on extensive eastern and western tracts of the state with many local government areas being declared eligible for disaster recovery assistance. The role of QRA has been subsequently extended to address all historical and continuing disaster events (Queensland Reconstruction Authority, 2013a). The *Act* was updated in 2013: to amend the main purpose of the Act being to ensure Queensland and its communities effectively and efficiently recover from the impacts of disasters and to improve the resilience of communities to disasters; the definition of a disaster by the inclusion of the terms, storms, tornadoes and floods caused by ex-TC Oswald and associated events; and the expiry date of the Act to June 30, 2015 (Queensland Government, 2013a). It is significant that the amendment specifically identifies that the purpose is to improve the resilience of communities to potential disasters. Other disasters, besides the more recent flood events, within the meaning of the *Disaster Management Act* 2003, are within the jurisdiction of QRA. A disaster event means any of the following: natural phenomena such as cyclone, earthquake, flood, storm, storm tide, tornado, tsunami, volcanic eruption; an explosion or fire, a chemical, fuel or oil spill, or a gas leak; an infestation, plague or epidemic; a failure of, or disruption to, an essential service or infrastructure; an attack against the State (Queensland Government, 2003).

The Queensland Reconstruction Authority website was created in 2011 and has served as a point of authority for matters related to the jurisdictional responsibilities of the Authority. Particular relevance to this study and its focus on the improvement of community resilience, is the website's facility to provide access to metadata concerning spatial datasets that are being created or improved as a result of the implementation of key recommendations of the *Queensland Floods Commission of Inquiry Final Report* (Queensland Government, 2012a: p.635). The recommendations included: that government should ensure the existence and maintenance of a repository of flood related data; councils should develop maps and maintain flood flow maps and have a flood overlay map in their planning schemes; councils should ensure that residents and businesses can clearly understand the impact of predicted flood levels and that the maps be interpretable by the public; a 'real time' flood mapping product be made available to the public; flood maps or data needed takes into account sea level rise or storm surge impacts. The QRA website provides access to spatial products including: an interactive flood-check map; aerial imaging and mapping; floodplain maps; and current disaster activations in place under the Natural Disaster Relief and Recovery Arrangements (NDRRA) (Queensland Government, 2013b).

3. Improvement in the versatility of spatial datasets

QRA has published a series of guides focused on its mission of rebuilding a stronger, more resilient Queensland. One such guide has identified that a key success factor in recovery and rebuilding from natural disasters is comprehensive baseline damage information - damage identification and assessment information - ideally in the first 24 to 72 hours before cleanup and removal activities commence (Queensland Reconstruction Authority, 2012a). The collection of early and accurate information: enables quick activation of response agencies; provides the basis for better co-ordination and targeting of efforts; assists in commencing reconstruction as early as possible after a disaster event; and assists in monitoring of progress of reconstruction.

Introduced as a pilot in April 2011, QRA has conducted damage assessments in the 2011 and 2013 flood event impacted areas using the Damage Assessment and Reconstruction Monitoring system (DARMsys™) to monitor Queensland's re-building progress. Real time data is collected by assessors travelling street-by-street and house-by-house through disaster-affected communities and data is sent via wi-fi to provide map based damage information to identify where the greatest needs exist. QRA has collaborated with key government agencies and local government authorities to improve the system (Queensland Reconstruction Authority, 2012b).

The Department of Natural Resources and Mines (DNRM) had supplied spatial data products during and in the immediate aftermath of the 2011 natural disaster events. The products were produced from the best available datasets available at that time. No corporate information was readily available from the most recent previous major flood event in 1974. The spatial data products were developed on-the-fly in response to and as the extent and range of the disaster evolved. The products, especially those required for decision support for emergency response activities such as the evacuation of townships or hydrologic modelling were not fit-for-purpose. These were based, particularly in inland areas of relatively flat terrain west of the Great Dividing Range, on elevation models created from five metre contours produced from traditional photogrammetric technologies.

However, in the immediate aftermath of the event, DRNM was able to co-ordinate the capture of high resolution aerial photography and satellite imagery over the cyclone and flood damage areas in conjunction with the Department of Community Services (DCS) (within which Emergency Management Queensland (EMQ) is based), QRA and Local Authorities. DNRM (Spatial Data and Mapping Division) commenced work immediately on the production of floodline mapping for the worst affected areas as a decision support tool on which to assess the allocation of financial assistance to individuals and businesses. The delay in the finalisation of insurance and flood assistance claims severly tested the resilience of the community (Hayes and Goonetilleke, 2012).

The Queensland Floods Commission of Enquiry (QFCE) reported on the 2011 floods (Queensland Government, 2012a). The Commission was set up with terms of reference to enquire into a broad and daunting range of subject matter including: preparation and planning for the floods by government, agencies and the community; the adequacy of the response to the floods; management of essential services; the adequacy of forecasts and early warning systems; insurers' discharge of their responsibilities; the operation of flood control dams; and land use planning with the objective to provide recommendations to minimise future flood impacts. A total of 22 recommendations were made, most of which highlighted the immediate need for signficant improvement in the collation and creation of high quality and comprehensive spatial datasets including: rainfall data together with historical and design data and radar; stream flow data; tide levels; inundation levels and extents; river channel and floodplain characteristics encompassing topography, bathymetry and survey data.

The recommendations particularly referred to the urgent requirement for hydrologic models to accurately reproduce: observed hydrograph attenuation; probability distributions of observed values for flood volume and peak flow; timing of major tributary flows; and observed flood behaviour. The recommendation also referred to a requirement for hydraulic models for spatial analysis that are able to: determine flood heights, extents of inundation, velocities, rate of rise and duration of inundation for floods of different probabilities; deal with movement of sediment and changes in river beds during floods; assess historical changes to river bathymetry; be run in a short time to allow detailed calibration and assessment work; characterise the backwater effect at the confluence of rivers as appropriate (Queensland Government, 2012a). The creation of such models require extensive spatial datasets consisting of appropriate spatial resolution. Undertaking hydrologic modelling based on digital elevation models (DEM) derived from the extant five metre contour data would not be fit-for-purpose, particularly in western areas of the state which consist of relatively flat terrain.

DNRM pre-empted the recommendations of QFCE by creating floodline mapping for areas affected by the 2011 events, having initiated two projects that would lead to an improvement in the quality of the Queensland's fundamental datasets. The projects were also initiated in full recognition of the imminent approach of the 2011/12 wet season and the likelihood of natural disaster events. The first project built on the spatial datasets captured by Lidar geospatial technology commencing with data capture for inland towns during the 2010 summer, and extended to other areas during and in the aftermath of the 2011 events. The data capture was progressively extended to include areas and towns with a historical susceptibility to natural disasters such as flooding.

The Lidar capture project is ongoing with over 170 towns and regional areas now included in the coverage. The detailed processing of Lidar datasets facilitated the production of DEMs and contours at a spatial resolution of 0.25m, which is a significant improvement on the extant readily available dataset at a spatial resolution of 5m. DEMs created from the Lidar datasets would be of a suitable spatial and temporal resolution and at an accuracy fit-for-the-purpose for deriving and application of the outcomes from hydrologic and hydraulic analysis recommended by the QFCE Final Report.

The second project, also pre-empting the recommendations of QFCE was the mapping of floodplains over the whole of the Queensland state. This project was completed by the end of January 2012 and the floodplain maps made available to all local government authorities for utilisation in the revision of planning and development documents. DNRM is now able to produce predictive flood mapping on demand based on mathematical modeling of the spatial tools produced from the Lidar datasets. This mapping is used by DCS for community evacuation purposes in the event of potential disasters. It can be concluded that the improvement in the fit-for-purpose and high spatial and temporal resolution of the spatial data, the accompanying geospatial tools built on Lidar data such as floodline mapping, floodplain mapping and predictive flood mapping will strengthen building and development control and approval processes which in turn will promote a complementary enhancement in community resilience.

4. Natural disaster event 2013 and aftermath

In January 2013, Queensland State experienced another significant flood event. Tropical Cyclone (TC) Oswald developed in the Gulf of Carpentaria on Thursday 17 January 2013 and crossed the western coast of Cape York Peninsula as a weak Category 1 system. Ex-TC Oswald further weakened to a low pressure system and moved south as shown in Fig. 1, producing extremely heavy rainfall and damaging winds in the region between the towns of Rockhampton and Bundaberg, and in the ranges along the southern border with New South Wales State.

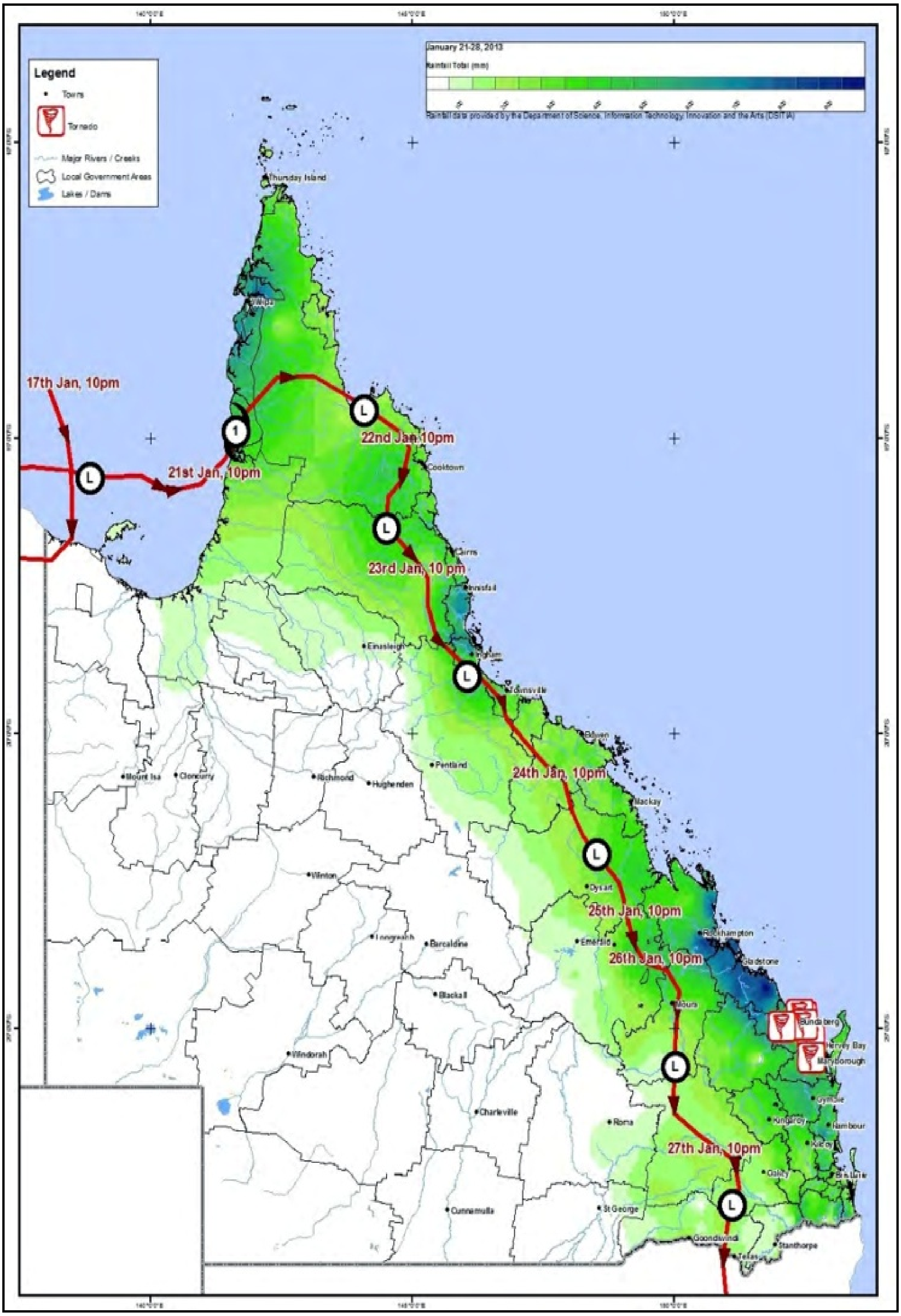

Fig.1 Approximate path of TC Oswald 2013 (Source: QRA & DSITIA)

Gladstone Town received 819.8 mm of rain in four days, which exceeded the amount of rain that fell during of 2011 or 2012. The average area rainfall of 204.1 mm for the Burnett catchment on January 27 exceeded the previous record by more than 80 mm. One day catchment rainfall records were set in the southern regions of the State and for the Mary, Logan, Albert, Kolan and Burrum River catchments. The average rainfall for the Brisbane River catchment was similar to that of the 2011 flood event and for the Bremer River it was above the 2011 figure (Bureau of Meterology, 2013). The extent of known damage included: over 2,000 homes assessed as uninhabitable; more than 390,000 homes and businesses lost power; 5,845 kms of State roads and 2,800 kms (39%) of State rail network closed; natural gas supply disrupted; lost coal production estimated at 3.5 million tonnes and insurance losses of $187 million as at 30 January 2013 (Queensland Government, 2013c).

On this occasion, decisions were made with a greater degree of confidence being based on spatial tools that had been developed and tested as a result of the natural events that occurred during the previous two wet seasons. The DEMs produced from Lidar facilitated the creation of predictive flood models. Although no action could prevent the devastation and damage that occurred, the reliability of the spatial data products promoted a heightened degree of confidence among all stakeholders during the initial disaster response stage and follow-up recovery stage. The efficacy of the DARMsys system was proven in Bundaberg, the major town most adversely affected by the flooding (Fig. 2). Consequently, the majority of insurance and flood assistance claims were processed and affirmed in a considerably reduced time span when compared with the 2011 flood event as decisions could now be made using spatial datasets that were not available during the earlier flood events. The datasets included: accurate floodlines for the areas of inundation, floodplain mapping, and a more comprehensive set of real-time data collected by the assessors. The spatial and aspatial data set collected by DARMsys had been expanded to include 21 items compared with a basic set of six items included in the pilot (Irwin, 2013).

Fig. 2 Aerial views of the flood inundation of Bundaberg during the 2013 natural disaster
(A: http://resources0.news.com.au/images/2013/01/28/1226563/655252-aerials-of-bundaberg-floods.jpg
B: http://www.abc.net.au/news/linkableblob/4488468/data/aerial-of-flooding-in-bundaberg-data.jpg)

In the aftermath of the 2013 floods, the Queensland Government released a flood recovery plan to provide strategic guidance for the coordination and management of recovery, reconstruction and community resilience activities undertaken by government agencies and non-government partners and stakeholders. Central to the recovery plan was the requirement that the public be regularly informed of recovery progress - a central component of improving community resilience. As the recovery period of the program is long term, and functional recovery groups will employ broad communications strategies to engage with local councils, businesses, industries and other stakeholders. The Department of Local Government, Community Recovery and Resilience will assume responsibility for the central coordination and strategic oversight of communication activities, ensuring regular public reporting of recovery progress and resilience improvement initiatives (Queensland Government, 2013c).

In this context, an important issue that decision-makers have grappled with is the definition of community resilience and how can an improvement in it be measured in response to various measures impletement. It is a term being utilised with increasing frequency, especially in the context of disaster management. There is no common definition of what resilience is and even less research around effectively measuring it. In terms of the focus of this paper, community resilience can be described as the *adaptive capacity of a community to anticipate disaster, absorb and recover from the impact, and be innovative and creative in its response* (QCOSS, 2012). It is hypothesised that access to spatial data with ever-evolving improvement of its quality as being ‘fit-for-purpose’, its ready accessibility to the public and its consequential utilisation at each phase of the disaster management cycle will result in a resultant improvement in the adaptive capacity of the community.

5. Interactive mapping for disaster management and strengthening community resilience

Prior to the 2011 major flood event in Queensland, state departments were making steady and gradual progress towards opening up and sharing their spatial datasets for access, both internally and externally facilitated by a growing confidence in the internet and mapping web servers. However, there was only limited public access and inevitably on a viewing only basis. A number of local government organisations provided a facility for the public to create a map themed on a combination of spatial and aspatial datasets deemed to be open access. There also existed a number of interactive mapping systems that were in a prototype stage and were primarily built for accessing and displaying of departmental data collected and managed to meet jurisdictional and statutory obligations. Only a portion of these datasets were available for public access. The natural disaster events of recent years have facilitated, in conjunction with parallel technical and jurisdictional developments, a rapid evolution of these systems in terms of the sharing of data, the mash-up of that data and its progressive access to the public. Such a development is also in accord, although related specifically to flood mapping, with QFCE Final Report recommendations: ‘Flood maps, and property specific flooding information intended for use by the general public, should be readily interpretable and should, where necessary, be accompanied by a comprehensible explanatory note’ (Queensland Government, 2012b). The major initiatives undertaken by key state organisations are briefly discussed below.

Department Main Roads and Transport – Interactive Mapping System

The Department of Transport and Main Roads (DTMR) have developed an interactive mapping system based on an earlier prototype created by Queensland Fire and Rescue Service (QFRS) (which sits within Department of Community Safety (DCS)) to display hazards data. DTMR has recognised the potential of interactive maps to access corporate knowledge. The goal is to consolidate relevant information to support rapid decision-making during disaster events.

Previously, DTMR held an abundance of data of limited format and storage structure and no ready process to display or present the data to staff or to share with other organisations in disaster situations. The corporate knowledge and experience to manage flood events did not exist. The 2011 flood event precipitated a rapid bringing into operation the prototype application system. Output from DTMR system can be shared across the internet with other participants in response to an evolving disaster or emergency event.

Queensland Reconstruction Authority – Website

QRA, in keeping with its statutory obligations, provides support for strengthening community resilience by providing public access via its website to floodcheck maps and access to Natural Disaster Relief and Recovery Arrangements (NDRRA). The former provides an interactive interface that allows the public to: search for a location by address or bounding area; view the floodline or imagery pertaining to that location; and view and compile a report for download. The NDRRA Map as shown in Fig. 3 allows the public to search by local government area for the level and type of financial and other assistance available for NDRRA events during the original 2011 flood event and the recent 2013 event. The ability to access the site to determine eligibility for and type of assistance and to download the appropriate application documentation strengthens community resilience during the initial response and the ongoing recovery phases of the disaster management cycle.

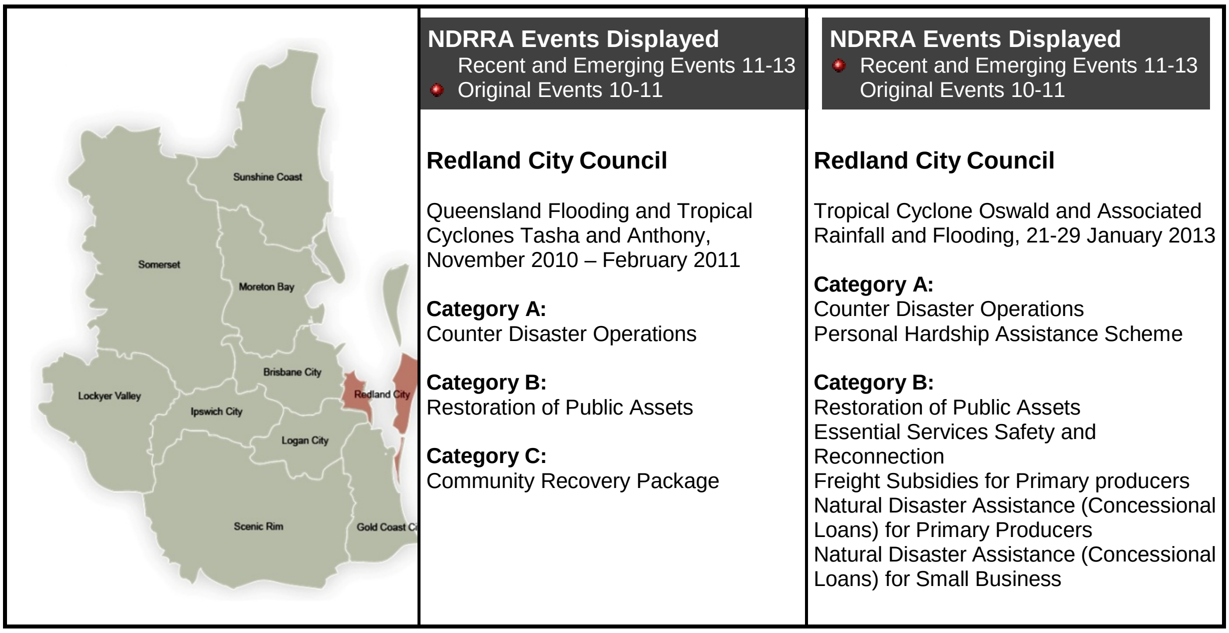

Fig. 3 NDRRA Interactive Map

Department Natural Resources and Mines – Queensland Spatial Portal and Queensland Globe

DNRM provides two interactive mapping sites to facilitate access to spatial datasets: the Queensland Spatial website (Queensland Spatial Portal), and Queensland Globe. The former is the gateway to the geographic information of the Queensland government and provides an interactive interface that allows the public to: browse and search a catalogue to discover government spatial data and services; search government services by location, address or bounding area to locate, order and download spatial datasets for immediate utilisation in geographic information system software; search the Queensland Atlas for property details using lot number or street address (Queensland Government, 2012c).

The Queensland Globe is a free plug-in which allows viewing a wide range of spatial data through Google Earth, including: addresses, localities and boundaries; road and rail networks; land parcels and tenure; areas affected by flood; topographical maps. The imagery included is most current and best available for public access and consists of a single layer of either satellite imagery or aerial photography, with higher resolutions over built-up areas. The system provides display and access via an interactive interface to over 200 spatial datasets (Queensland Government, 2012d). The Queensland Globe is a component of the Queensland's Open Data initiative to share government data to encourage the community, private sector organisations, researchers and non-government organisations to develop innovative solutions to Queensland's issues and to help make government more transparent. The initiative enables government data to be available for open use under flexible licences (Queensland Government, 2012e).

6. Conclusions

Geospatial technologies and the spatial data captured, processed and displayed for decision support have a complementary, but central role in creating and strengthening the resilience of a community at all phases in the cycle of disaster management. During the recent natural disaster events in Queensland, decision-makers and the community have progressively gained access to spatial data products that have progressively evolved as regards being fit-for-purpose. As the next wet season approaches, managers of any consequential disaster event will be able to access and utilise geospatial based tools such as interactive websites maintained by state agencies to inform the public and to provide a point-of-truth, particularly during the response and recovery phases, for certainty as to their personal and property safety thus improving community resilience. The disaster event managers will also have improved access to spatial datasets with progressively improving spatial and temporal resolutions through geospatial portals.

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