Australian Government
Geoscience Australia

bushfire&natural HAZARDSCRC

bnhcrc.com.au

BUILT ENVIRONMENT EXPOSURE INFORMATION FRAMEWORK

Nadimpalli K, Mohanty I
Geoscience Australia
Bushfire and Natural Hazards CRC

Version	Release history	Date
1.0	Initial release of document	9/05/2016

Australian Government
Department of Industry, Innovation and Science

Business Cooperative Research Centres Programme

Publisher:
Bushfire and Natural Hazards CRC

May 2016

Citation: Nadimpalli K, Mohanty I (2016), Built environment exposure information framework, Bushfire and Natural Hazards CRC

Cover: Building damage during the Christchurch February 2011 earthquake.
Photo: John McCombe, New Zealand Fire Service.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Krishna Nadimpalli and Itismita Mohanty, *Geoscience Australia, Canberra, ACT*

Bushfire and Natural Hazards are features of the Australian climate and landscape and the threats will continue (COAG, 2011). Disaster management is a collective responsibility of all levels of government, society, businesses and individuals. These hazards can have profound personal, social, economic and environmental impacts.. The impacts of these disasters demand the need to advance the efforts of planning, preparation, response and recovery to improve community resilience. For disaster resilience, emergency management planning should consider risk and risk treatments across the built, economic, social and environment (COAG, 2011). Exposure "what is at risk" information is fundamental for assessing risk from disasters and therefore nationally consistent information is required for evidence based prioritizing and targeting interventions. To address this, consistent methodologies and frameworks are required to enable information sharing and accurate interpretation.

In natural hazards and disasters decision making *Exposure* is the key component and constitutes people, buildings, infrastructure, businesses, hazardous substances, primary and major industries. This report is the outcome of research funded by Bushfire and Natural Hazards CRC to develop "Australian Natural Hazards Exposure Information Framework" (ANHEF). The framework is aimed to support the development of nationally consistent exposure information systems to enable the decision making in disaster management with evidence. This research has reviewed the current literature and information providers; engaged end users and researchers for future requirements; and conducted a gap analysis to make suggestions.

The literature review has helped to understand the relevant practices and future trends at international, national, regional and local levels. In particular, the review highlighted the exposure data requirements to enable researchers to develop models for better impact analysis. The review has considered significant literature including Global Exposure Database, Hazus, Hygo, Sendai and other Australian exposure information frameworks. The review has also contributed to collating the requirements for information needed by decision makers for response and strategic policy initiatives.

The research has conducted an on-line survey for the review of existing exposure information capabilities in Australia to ascertain existing data and information capabilities for disaster response and recovery (DRR). The survey has identified significant gaps in the existing data provisions and translation of information for evidenced based disaster risk response, recovery and reduction decision making. Overall lack of national consistency in existing data and information capabilities is a limiting factor in the decision making.

The research also conducted a Stakeholder Engagement Workshop with an aim to identify the exposure information needs of researchers and end users in Australia. The workshop provided an opportunity for thirty six participants representing decision makers, emergency managers, planners, researchers, asset managers and the insurance sector to outline their future requirements. Mind-maps presented at the workshop enabled us to observe overlapping concepts and data elements in the three exposure components of disaster exposure information. The workshop helped us to understand how this framework aligns with broader framework objectives of the National Emergency Risk Assessment Guidelines. Further the research considered Geoscience Australia's (GA)

previous exposure workshop reports. Stakeholder engagement has also continued with the researchers and subject matter experts. Recommendations were drawn to develop a standardised, nationally consistent and scalable natural hazards exposure information framework for Australia.

The collective views of data managers, researchers and end users have informed the basis for exposure information requirements to develop a consistent, standardised exposure information framework that will support vulnerability assessments for disaster risk reduction and socio-economic impact analysis.

The framework presents the exposure elements required to develop information systems to support various phases of disaster risk reduction from a variety of natural hazards at different levels of governance. The document outlines a generic framework to underpin the above mentioned diverse utilisation and focused on end user requirements. Information on some exposure elements are highly critical for some end users and may not be of interest for others. To reduce the complexity, the framework categorises the information provision into three levels depending on user requirements such as policy and planning; implementation; and research analysis. ANHEF levels and their aims, description and boundaries are outlined in Chapter 2.

There is some fundamental information that underpins the entire exposure framework such as spatial enablement; land use categorization; insurance status and metadata outlined in Chapter 3.

Buildings are vulnerable from the impact of bushfires, natural hazards and malevolent acts. The exposure elements of the buildings considered are usage, type, structure system (foundation, internal frame, external walls, façade, roof, height etc.), number of storeys, size, age, attachments, replacement value and contents value. The end user and researchers building exposure element requirements, existing data sources and suggestions are outlined in the Chapter 4.

Infrastructure is lifeline support for communities, economy and disaster response. The infrastructure assets are vulnerable from the impact of bushfires, natural hazards, malevolent acts and also its failure. The infrastructure sectors considered are transportation, energy, communication, urban water supply, waste management and hazardous substances. The end user and researchers infrastructure sectors exposure element requirements, existing data sources and suggestions are outlined in the Chapter 5.

The information on industries is highly critical for the economy and safety of workers due to natural hazards. Major industries particularly in manufacturing sector are considered for the scope of this exposure component. In Australia, the major manufacturing sectors are mainly Metal products, Building Materials, Automobiles, Timber, Food Processing, Textiles, Pharmaceuticals, Chemical and others. The industry site has many unique elements that are at risk, pose risk and contribute on value chain on the economy. The end user, researchers and insurance industry major industries exposure element requirements, existing data sources and suggestions are outlined in the Chapter 6.

The primary industries sector includes agriculture, fishing, forestry and mining. The types of natural hazards or the climatic conditions that impacts on this sector in Australia includes draught, water security, soil fertility, weeds, global warming and biosecurity. The end user, researchers and insurance industry primary industries exposure element requirements, existing data sources and suggestions are outlined in the Chapter 7.

Australian communities are varied in their composition and in their level of exposure to disaster risk (COAG, 2011). Factors that can influence disaster management and resilience include remoteness, population density, mobility, socio-economic status, age profile and communication skills. The end user and researchers population exposure elements requirements, existing data sources and suggestions are outlined in the Chapter 9.

This milestone report considered buildings, infrastructure and population information to the exposure elements level. Business exposure information requirement are developed by University of Melbourne in a separate milestone report. Attribute requirements, definitions and standard terminology for buildings, infrastructure, businesses and population exposure elements will be included in the final framework report as the next major milestone.

1. INTRODUCTION

Natural disasters in Australia continue to highlight the disasterous mediating impact of the built environment on communities. Built environment exposure is the major component of exposure to natural hazards. However, there is no comprehensive information system available in Australia that provides fundamental and consistent knowledge around the elements of exposure of buildings, infrastructure, population and businesses under different natural hazards and the associated risk. The absence of a robust and quantitative evidence base is impeding the development and implementation of strategies for disaster management policy and planning. This study is to develop a Australian Natural Hazards Exposure Information Framework (ANHEF) that links strongly with *National Strategy for Disaster Resilience* (COAG, 2011). COAG (2011) states that "Disaster resilience is the collective responsibility of all sectors of society, including all levels of government, business, the non-government sector and individuals. If all these sectors work together with a united focus and a shared sense of responsibility to improve disaster resilience, they will be far more effective than the individual efforts of any one sector."

Consistent and reliable information on natural hazard exposure is crucial for disaster risk mitigation and evidence-based decision making. Exposure is referred to as the elements that have been, or could be, subject to the impact of natural hazards within an area (Middelmann et al, 2005, p.1). The elements that are at risk include buildings, assets, population, economic activities, services, utilities and infrastructure (EMA, 2004, p.48). Describing these elements in a nationally consistent exposure information framework will provide a reliable base to inform decision making for natural hazard risk reduction. There are few such capabilities in Australia to provide exposure information such as Geoscience Australia's (GA) National Exposure Information System (NEXIS) and a database developed by Emergency Information Coordination Unit (EICU) in New South Wales. NEXIS was developed with an aim to support GA's risk and impact analysis projects and provision of advice for climate change adaptation policy development through it is not comprehensive enough to underpin the entire spectrum of decision making for disaster risk reduction. To manage the disasters

effectively and efficiently, there is a compelling requirement to develop a nationally consistent framework for collection, collation and provision of expsoure information for researchers and decision makers.

1.1 Scope of the Project

This research project to develop an *Australian Natural Hazards Exposure Information framework* (ANHEF) is funded by Bushfire and Natural Hazards CRC (BNHCRC). The scope of the project is to develop an exposure information framework through review of existing literature/reports and international best practice; in collaboration with researchers, end users and international experts. The project covers the information needs on exposure of the built environment (buildings, infrastructure and residential population) and, business and proposes national standards for exposure database and a reliability assessment framework. The research has reviewed the current literature and information providers; engaged end users and researchers for future requirements; and conducted a gap analysis to make suggestions. The project is not scoped to collect, collate, model, maintain and distribute any exposure data. The key milestones and timelines are shown in the Figure 1.

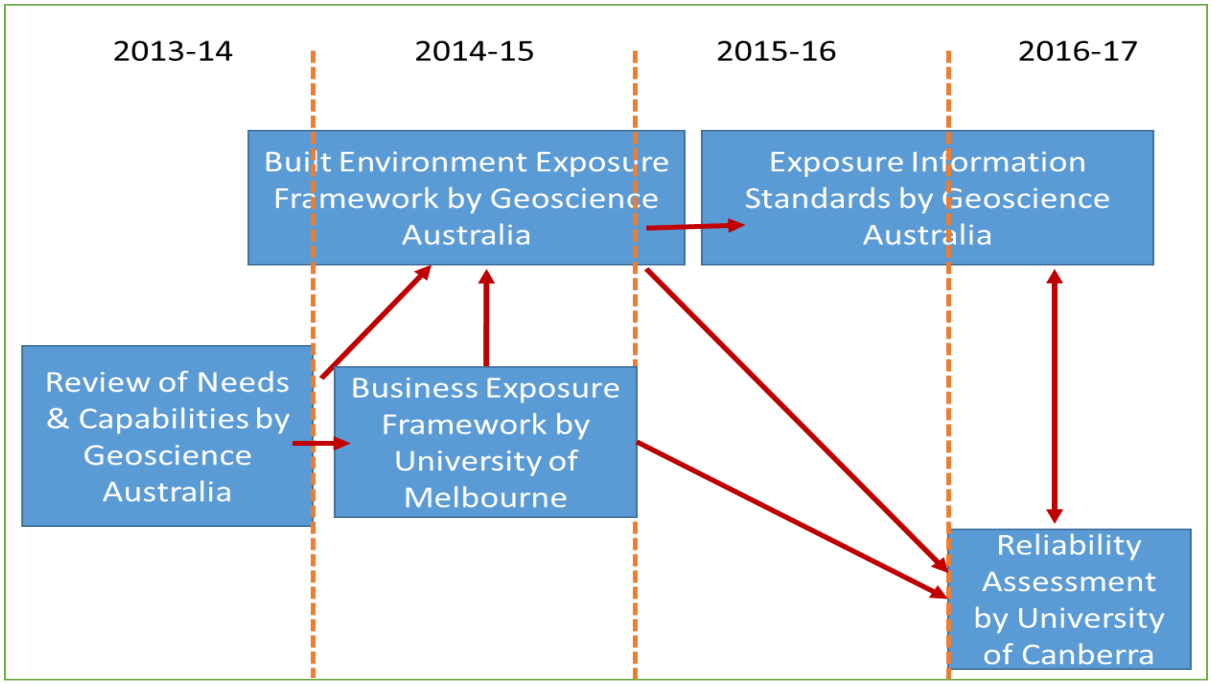


Figure 1. ANHEF project milestones, linkages and timelines

The literature review has helped the authors to understand the relevant practices and future trends at international, national, regional and local levels. In particular, the

review highlighted the exposure data requirements to enable researchers to develop models for better impact analysis. The review has considered significant literature including the Global Exposure Database for the Global Earthquake Model, HAZUS, the Hyogo-, and Sendai Framework for action and other Australian exposure information frameworks (please refer Nadimpalli et al (2014) for a detail literature review). The review has also contributed to collating the requirements for information needed by decision makers for response and strategic policy initiatives.

The research has conducted an on-line survey for the review of existing exposure information capabilities in Australia to ascertain existing data and information capabilities for disaster response and recovery (DRR). The survey has identified significant gaps in the existing data provisions and translation of information for evidence based disaster risk response, recovery and reduction decision making. An overall lack of national consistency in existing data and information capabilities is a limiting factor in the decision making.

The research conducted a Stakeholder Engagement Workshop with an aim to identify the exposure information needs of researchers and end users in Australia. The workshop provided an opportunity for thirty six participants representing decision makers, emergency managers, Urban and regional planners, researchers, infrastructure asset managers and the insurance sector to outline their future requirements. Mind-maps presented at the workshop enabled us to observe overlapping concepts and data elements in the four exposure components of disaster exposure information. The workshop helped the project to understand how this framework aligns with broader framework objectives of the National Emergency Risk Assessment Guidelines (NERAG).

Furthermore, the research reviewed Geoscience Australia's previous exposure workshop reports. Follow up stakeholder engagement has also independently continued with the researchers and subject matter experts. Recommendations were drawn to develop a standardised, nationally consistent and scalable natural hazards exposure information framework for Australia.

The collective views of data managers, researchers and end users have informed the basis for exposure information requirements to develop a consistent, standardised

exposure information framework that will support vulnerability analysis and assessments for disaster risk reduction and socio-economic impact.

The final report on *Australian Natural Hazards Exposure Information Framework* (ANHEF) will provide a structure for development of exposure information systems around four main components: buildings, infrastructure, population and business.. The report would contribute to efforts for addressing the problems identified by COAG (2011) and the BNH CRC under the research priority themes of : Data and Knowledge, Disaster Resilience, Decision Support and Resource Assessment, Emergency Management Practice, and Risk Mitigation Policy and Planning.

The framework is scoped to provide guidance for the development of exposure information systems to support researchers and end users. The framework would also provide a reference for researchers and users investment priorities. The framework will not include any modelling to derive exposure data. Generally, exposure information is not available as an off-the-shelf and it requires rigorous modelling to integrate contribution data and develop extraction, translation and provision tools.

1.2 Scope of the Report

This Milestone Report *Built Environment Exposure Framework* outlines the broad requirements of buildings, infrastructure and population exposure elements only. The Business Exposure Framework is prepared by the University of Melbourne as another milestone report. The attribute requirements, definitions and standard terminology for buildings, infrastructure, businesses and population exposure information will be included in the final framework report as the next major milestone (refer Figure 1).

The *Built Environment Exposure Framework* identifies different aspects of built environment exposure information requirements, existing capabilities and gaps that would improve information for disaster risk mitigation capabilities. The framework includes the end user and researcher requirements, analyses existing information capabilities, highlight the gaps and suggestions. The exposure components identified in the framework has been developed using generic terminology to provide an ability to translate for multi-hazard risk assessment modelling capabilities and also for the non-technical users. Also, the framework presents the exposure elements required to develop information systems to support various phases of disaster risk reduction for a variety of natural hazards. The document outlines a generic framework to underpin

the above mentioned diverse utilisation and focused on end user requirements. Mind maps for buildings, population and infrastructure exposure information requirements are included in the annexure.

The criticality of exposure elements and the level of details required to inform decisions on disaster management at different levels of geographies varies for respective Commonwealth, State and Local governments. For example for the national or state level decision-making the individual asset level information, may not be required as it would result in information overloading. While they require asset level information they require those to be aggregated to their required level of geography such as national and state. On the contrary at the local government level (where the intervention would be undertaken by the end users), they are more likely to need asset level information. To reduce the complexity, the framework categorises the information provision into three ANHEF levels depending on user requirements such as policy and planning; implementation; and research analysis. Theses ANHEF levels and their aims, description and boundaries are outlined in the report.

The next phase of the project will consider the knowledge of subject matter experts and the feedback solicited at a workshop to define the exposure to attribute level for each of the elements and typologies (a combination of exposure elements) for a purpose. The final framework report will provide guidelines and standards on exposure information for the development of information systems to assist all levels of disaster governance.

2. ANHEF END USER REQUIREMENT LEVELS

The framework is a simple and clear way of presenting the exposure elements required to develop information systems to support various phase of disaster risk reduction from a variety of natural hazards at different levels of governance. The document outlines a generic framework to underpin the above mentioned diverse utilisation and focused on end user requirements. Information on some exposure elements are highly critical for some end users and may not be of interest for others. For example, floor height of the buildings is significant piece of information to assess the flood vulnerability and not required for earthquake risk assessment. Researchers may require building floor height information with centimeter accuracy and qualitative information is good enough for others. To reduce the complexity, the framework categorises into three levels depends on user information requirements. The levels are defined with a user perspective and not the input datasets.

2.1 ANHEF Level 1 Data Description

ANHEF Level 1 - recommends the data useful for policy and planning purposes for Commonwealth and State/Territory Governments. The data would be aggregated for a defined geographic area with a combination of the necessary exposure information for buildings, population, business and infrastructure. For example, a combination of building elements such as building type, wall type, roof type and others, together with household income profile of people at a given geographic area would be aggregated and made available.

The exposure information available at this level include derivatives of some of the Australian Statistical Geographic Standard (ASGS) data such as those from Statistical Area 2 (SA2) or larger (SA3 and SA4), State or Territory, Australia, Greater Capital City Statistical Areas (GCCSA), Urban Centre, Section of State, Indigenous Areas, Indigenous Region and Remoteness Areas. Information derived from non-ASGS geographic areas for this level may include Local Government Area (LGA), Postal Areas (POA), Electorate Boundaries, Suburbs and localities, Natural Resource Management Regions, Australian Drainage Divisions and Tourism Regions. Further, the exposure information systems have to be able to aggregate for 5X5 km or larger grid cells. The infrastructure assets

with line geometry for elements such as roads may need to be aggregated in terms of its length or any other relevant units of measurement in a defined area.

The actual numbers in each area will be different, because the same distribution will be modulated according to the residential population of the given area.

2.2 ANHEF Level 2 Data Description

ANHEF Level 2 - recommends the data to be useful for the planning and implementation in both tactical response and strategic perspective by State/Territory and Local Governments, researchers and the insurance sector. The data would be aggregated for a defined geographic area with more detailed exposure classifications from buildings, population, business and infrastructure.

The exposure information available at this level includes some of those found in Australian Statistical Geographic Standard (ASGS) such as Statistical Area 1 (SA1), ABS Meshblocks and Indigenous Location. In the categories of non-ASGS geographic areas, information considered for this level includes Destination Zones, a large building and 1X1 km or smaller grid cells. The infrastructure assets with line geometry such as roads may need to be aggregated in terms of its length or any other relevant units of measurement in a defined area.

The privacy of the available information at this level is critical and needs to be maintained as per the Privacy Commissioner prescribed guidelines. The exposure information systems to be enabled for buildings and population numbers of a given classification for a defined area be aggregated and provide to users. The infrastructure assets with classifications at a more detailed level can be aggregated for a defined area.

2.3 ANHEF Level 3 Data Description

ANHEF Level 3 - recommends the data useful for research and analysis at the asset level or building level, which may be needed to provide more detailed advice for the decision makers. The data sourced for this level must be highly authoritative, reliable and mapped at the asset or single building level. This could include attribution such as structural, occupancy and economic variables. The information available at this level is able to support highly advanced modelling capabilities such as 3D blast and plume models. Further modelling may be required to translate data into 3D Geometry

suitable for analysis of buildings in Central Business Districts (CBDs). Further the data may be able to be augmented to support analysis of the spatio-temporal dynamics of people and business activity.

Privacy of the information at this level, as well as its security classification, may require that its access be restricted for nationally significant projects and emergency response activities.

3. FUNDAMENTAL INFORMATION

3.1 Location

Spatial location is a common reference for the exposure data inventory, analysis and dissemination. It provides “where is” information for the asset is physically located using a spatial referencing system such as geographic coordinates. Location is a fundamental element for exposure data and provides perspective for decision making. Once features are attributed with a location, then the exposure information system will be able to aggregate information of assets within any given geographic area such as disaster footprint or impact zones. Some datasets are available at an aggregated level only (eg. residential population data from the census) and the exposure information system may need to be able to disaggregate and distribute statistical information.

It is now well documented that there is a (UN/ISDR, 2005) need for disaster risk assessments into the space of urban planning and management of disaster-prone human settlements, in particular highly populated areas and rapidly developing urban settlements. The issues of informal or non-permanent housing and the location of housing in high-risk areas were raised as priorities and exposure information systems need to quantify these highly vulnerable elements of the built environment.

There is an identified need to develop building vulnerability models for different housing locations, types (e.g., effect of increased urbanisation) (Stewart and Li, 2009; Henderson and Ginger, 2007) for different wind speed zones, flood categories, earthquake prone areas. It is also identified that a risk analysis for a specific region will require an accurate and detailed probabilistic wind field model capable of considering topographic, terrain roughness and shielding effects.

Geocoded addressing is the primary source of data to provide a location once the asset has an address. Geocoded addressing is the process of associating an address with coordinates such as a latitude and longitude to enable it to be readily mapped and related to other spatial data. There are several administrative boundaries exists for the governance and statistical perspectives to make an informed decision making. There are existing geographic areas such as national, state and local government areas for

governance in Australia. Australian Bureau of Statistics (ABS) has defined Statistical Areas (SA) such as SA1 through to SA 4, Meshblocks etc.

Exposure elements required for exposure data collection, collation and provision to users may include:

1) Latitude (Degree Decimal or Degree-Minutes-Seconds)
2) Longitude (Degree Decimal or Degree-Minutes-Seconds)
3) Address (Unit Number, Street Number, Street Name, Suburb, State and Post Code)
4) Geometry
    a. Point (example - Address)
    b. Line
    c. Polygon (example - building foot print)

Existing Capabilities:

There are several systems enabled to capture and manage the location information for buildings exposure information in Australia.

Public Sector Mapping Agency (PSMA) – the Geocoded National Address File (GNAF) of PSMA is a geocoded address file that locates addresses in a defined geographic coordination system. That means, by having address, GNAF will provide the geographic location (latitude & longitude) and vice-versa.

Geoscience Australia (GA) – GA has developed the National Exposure Information System (NEXIS) that has sourced the GNAF, rural buildings survey database and many other sources to define the buildings location across Australia. GA has also mapped the rural properties location data in collaboration with state jurisdictions and is available for public use.

At the national level there are several spatial and mapping agencies representing State Jurisdictions such as Landgate (WA), DPIPWE (TAS), DEWNR (SA), DNRM (QLD), LPI (NSW) and EICU (NSW) have location information at varied levels. Some of the major local councils have the building locations as points or building footprints data.

Gaps & Suggestions:

Some of the state jurisdictions such as Tasmania, South Australia, ACT and Northern Territory have buildings location captured for most of their building stock. NSW and QLD have no state level buildings location database available. Though there is some limited information that can be drawn from their cadastre system about properties. Some major local governments like Sydney City have authenticated and authoritative

data on location of the assets in their jurisdiction. Some small local governments don't have enough resources to collect and maintain the location information for at asset level.

There is no asset level location information available for researchers and decision makers across the nation.

3.2 Land Use

Land use and land management practices have a profound impact on natural resources (water, soil, nutrients, plants and animals), agricultural production and built environment. The availability of consistent and reliable spatial information regarding land use is critical for sustainable natural resource management at various levels of governments, regional groups, industry groups, community groups and land managers. Australia has well defined land use plans prepared by local governments. The information is useful for agriculture audit, biosecurity, monitoring and evaluation of impacts on natural resources from disasters. This information is also highly required particularly for land degradation, draught and sedimentation from natural hazards. The Australian Land Use and Management (ALUM) Classification system provides a nationally consistent method to collect and present land use information for a wide range of users across Australia. There are some gaps in these classes at a local level. The framework advises to adopt the ALUM classification and more details are available at

http://www.agriculture.gov.au/abares/aclump/Documents/ALUM_Classification_V7_May_2010_summary.pdf

http://www.agriculture.gov.au/abares/aclump/Documents/ALUM_Classification_V7_May_2010_detailed.pdf

Existing Capabilities:

Australia Land Use Map – Land use mapping in Australia is conducted broadly at two scales: national scale and catchment scale. Both land use mapping methods use the ALUM Classification system.

National scale (1:2,500,000) uses a modelling approach to integrate agricultural commodity data, satellite imagery and other land use information. It is relatively inexpensive, statistically rigorous and is amenable to relatively frequent update to enable the assessment of trends.

Catchment scale land use mapping can vary from 1:25,000 (where 1cm on the map = 250m on the ground) for irrigated and peri-urban areas, to 1:100,000 scale (1cm = 1km) for broadacre cropping regions, and 1:250,000 (1cm = 2.5km) for the semi-arid and arid pastoral zone. Catchment scale land use data is produced by combining state cadastre, public land databases, fine-scale satellite data, other land cover and use data, and information collected in the field.

The land use maps and other relevant data can be obtained from http://www.agriculture.gov.au/abares/aclump/Pages/land-use/data-download.aspx

State Land Use Map – The state and local governments prepare and maintain the land use maps.

ACT - http://www.actmapi.act.gov.au/html5.html

Queensland - https://www.qld.gov.au/environment/land/vegetation/mapping/qlump-datasets/

Northern Territory - http://www.lrm.nt.gov.au/soil/landuse

Victoria - http://services.land.vic.gov.au/landchannel/content/productCatalogue

Cadastre – The cadastre spatial data is available from many local and state governments, Public Sector Mapping Agency (PSMA) and through PSMA product distributors.

Gaps & Suggestions:

The land use plans and other information are available for decision makers at ANHEF Level 1. Level 2 requires the data at catchment scale. The cadastre datasets doesn't provide land use information mapped with national classification system but some information of cadastre provides land use indicators to derive exposure information.

3.3 Insurance Status

Disaster affected communities face a humongous task in rebuilding the assets and resilience of people and businesses. Insurance proceeds are significant financial contributors to rebuilding and resilience efforts. Appropriate level of insurance cover will help the people, businesses, asset managers and governments have better resilience after the disaster. In general, people are under insured for their properties and not understanding the fine print conditions.

For example, not many insurance companies give "flood cover" automatically. Essentially, people need to check their policy schedule to see if it indicates that the

policy taken out the flood extension and if so, to what extent (Flood Insurance Guide, 2012).

The National Disaster Relief and Recovery arrangement (NCRRA), State and Territory Governments are required to have adequate capital or insurance to fund the replacement or restoration of essential public infrastructure. Federal Government has announced Natural Disaster Insurance Review (NDIR) in 2011 for the availability and affordability of insurance for floods. A key outcome of this review is the government's support for the homes exposed to high flood risk through a Flood Insurance Pool.

The insurance status covers across buildings, people, business and infrastructure assets exposure, so it considered in the fundamental category. In general, the insurance is available for the following.

1. People
    a) Life Insurance
    b) Income Protection Insurance
    c) Health Insurance
    d) Motor Insurance
    e) Travel Insurance
2. Householders
    a) Buildings Insurance
    b) Contents Insurance
3. Business
    a) Worker's Compensation
    b) Professional Indemnity Insurance
    c) Liability Insurance
4. Government
    a) State Owned Assets
    b) Flood Cover Insurance
    c) Malevolent Cover Insurance
    d) Compulsory Third Party Motor
    e) Public Liability Insurance
5. Insurance Companies
    a) Re-insurance

The information about the status of insurance cover is highly significant for the researchers and decision makers to assess the impacts, resilience and recovery.
For an Exposure Information Framework, the following information at the asset level on insurance status may be useful:

1. Insurance Cover Status
    a) No Insurance
    b) Under Insured
    c) Optimum
    d) Comprehensive

Existing Capabilities:

Insured Value – Many insurance companies have the insurance portfolio data but this is not available in the public domain. The state owned assets are insured by the public owned insurance authorities such as Comcover, Victoria Managed Insurance Authority. These authorities have detailed portfolio insurance details and generally fully insured.

Gaps & Suggestions:

The data on insurance status for people is highly difficult to collate and there is a gap in estimating the impacts of disasters on people.
Comparing the insurance portfolio data and the replacement value of buildings estimates from NEXIS would provide an overview of the assets insurance status for a defined geographic area. Insurance Council of Australia shall take the initiative to collect and provide an aggregated insurance portfolio data for the exposure information capabilities for buildings.
The replacement value estimate of infrastructure assets is not available in the public domain. The asset managers including government organisations have a realistic value of their assets for example, Department of Main Roads have the engineering estimates of the bridges, culverts etc.

3.4 Metadata

Metadata is often called “data about data”. The development of metadata standards improves quality, relevance, consistency and the availability of data. This consists of the data definitions and standards. The purpose of the metadata is to facilitate in data discovery and inform the reliability of data for the purpose.

The exposure framework identifies the following minimum metadata attributes required to understand input data:

1. Keywords
2. Geometry
3. Feature Type
4. Definition
5. Data Source
6. Spatial Accuracy
7. Attribute Reliability
8. Attribute Source
9. Attribute Accuracy
10. Data Currency
11. Maintenance Cycle
12. Revision Date
13. Limitations
14. Restrictions
15. Contacts

Existing Capabilities:

The metadata about buildings, population, business and infrastructure data collected and maintained by various government and non-government organisations for diverse purposes. The standards, definitions and provision of access vary significantly in the type of information. A number of standard classifications exist for industry, business and geographical areas are widely accepted. But there is no standards developed for exposure data elements.

Gaps & Suggestions:

The need for consistency of meaning is vital to facilitate information sharing among primary and secondary users of the data. The exposure data attribute definitions, standards, data dictionaries and reliability assessment framework needs to be developed at a detailed level for the framework utilisation or implementation. Much of the work involved in establishing a data collection is in the development of metadata standards to ensure comparability and consistency. The project would prepare in consultation with data custodians, data providers, standards developers, subject matter experts and end users in the next phase of the project. This will enable the

future exposure information systems to be transparent and consistent. The project is further developing data reliability framework in the next phase and it would provide guidelines for metadata standards.

4. BUILDINGS EXPOSURE

Buildings can be vulnerable to the extreme forces exhibited by natural hazards. The details of the building characteristics including usage, type, structure system (foundation, internal frame, external walls, façade, roof, height etc.), size, age and its value are required to analyse and assess the likely impact and risk from natural hazards. These building characteristics are considered as exposure elements and discussed below with greater details. Further these elements will be defined to attribute level in the final version of framework. The purpose of defining the buildings exposure attributes is to enable the researchers to group them into a set of classes to assess the damage. Damage and loss prediction models can then be developed for all representative building types. The buildings exposure information also underpins disaster mitigation and urban planning.

The building usage information is important for disaster management prevention, preparedness, response and recovery (PPRR) decision making and assesses impacts. This also support to estimate the time-space population exposure to disasters such as day time population and night time population as well as population demographic/disability composition content of the building.

4. 1 Building Usage or Occupancy

Building usage is highly critical to understand the exposure profile in a given location. The buildings are constructed for specific usage or occupancy. The buildings and its attributes such as construction types, building standards, population demographics, replacement value, contents, refurbishment and equipment vary depends on the occupancy. The usage is basically defined as the purpose for which the building is presently in use such as for different residential, commercial, light industrial or institutional categories.

This information is required by the end users for tactical response and planning for all natural hazards. The researchers would need this information for analysis to derive meaningful information for other unknown variables and also for sustainable urban planning.

1) Residential

(a) Single Dwelling,

(b) Multiple Dwelling

(c) Farm House

(d) Mobile Homes

(e) Temporary Lodging/Dormitory

2) Commercial

(a) Business

(b) Retail

(c) Shopping Mall Complex

(d) Restaurants & Cafes

(e) Cinemas

(f) Parking Structures

(g) Automotive Dealerships

(h) Data Centres

(i) Gas station

(j) Hotels

3) Light Industrial

(a) Warehouse

(b) Manufacturing

4) Educational Facilities

(a) Kindergartens

(b) Pre-Schools

(c) Primary Schools

(d) Secondary Schools

(e) Special Schools

(f) Tertiary Institutions

(g) Technical Colleges

(h) Community College

(i) Research Labs

5) Health & Welfare Facilities

(a) Health Centres

(b) Medical Centres

(c) Dental Clinics

(d) Hospitals

(e) Psychiatric Facilities

(f) Dental Hospitals

(g) Respite Centres

(h) Hospices

(i) Nursing Homes

(j) Aged Care facilities

(k) Childcare Centres

(l) Disability Support Services

(m) Veterinary Services

6) Emergency Services

(a) Police Stations

(b) Water Police facilities

(c) Urban Fire Stations

(d) Rural Fire Stations

(e) Marine Fire Stations

(f) State Emergency service Depots

(g) Ambulance Stations

(h) Aviation Rescue & Fire Fighting Stations

(i) Marine Rescue or Coast Guard Stations

(j) Surf Life Saving Clubs

(k) Aero-Medical and Rescue Facilities

7) Government Buildings

(a) Parliament Buildings or Council Chambers

(b) Government Houses – Accommodation

(c) Customer Service Centres

(d) Administration Centres

(e) Law Courts

(f) Field Operations Depots

(g) Scientific and Research Laboratories

(h) Correctional and Detention facilities

(i) Australian Defence Force Barracks, Bases and Facilities

(j) Archive and Storage Facilities

(k) Transport Facilities

8) Community Facilities

(a) Community Centres

(b) Service Clubs

(c) Ethnic Society Clubs

(d) Sporting Clubs

(e) Exhibition Centres

(f) Arts Centres

(g) Places of Worship

(h) Cemeteries or Crematoria

(i) Public Libraries

9) Recreational Facilities

(a) Outdoor Stadiums

(b) Indoor Stadiums

(c) Outdoor Sports Centres

(d) Indoor Sports Centres

(e) Amateur Sports Grounds

(f) Race Tracks

(g) Shooting Ranges

(h) Sporting Clubs

(i) Indoor Sports Centres

(j) Aquatic Sports Centres

(k) Amusement Parks

(l) Parks and Gardens

10) Mixed Use

(a) Primary Use

(b) Secondary Use

(c) Tertiary Use

Existing Capabilities:

NEXIS – Geoscience Australia has sourced building usage information from various sources and built into the exposure information.

Land use- Australian Bureau of Statistics (ABS) ASGS Mesh Blocks are the smallest geographical area and has broad reflection of land use categories such as residential, commercial, education etc. Mesh Blocks are covering the whole of Australia and aligned with other defined statistical areas.

Address Database – PSMA's GNAF has address type and flat type information that provides some details about the usage of buildings or assets. But this information is not complete for entire address records in GNAF.

State Jurisdictions - Some of the states and major local governments have the buildings usage in their property databases. For example, Landgate has complete information for Western Australia; DPIPWE has complete information for Tasmania; SES-NSW has partial information for NSW and EICU-NSW has partial information; DEWNR South Australia has partial information and DNRM Queensland has partial information on building institutional usage such as educational, health, essential services, cultural services and recreation.

Other Data Sources - There are many other relevant data sources like MyHospitals to derive specific building usage information. For example for Health and Welfare facilities building level information can be obtained from

(1) Department of Health and Aging, Commonwealth Department

(2) Australian institute of Health and Welfare, Commonwealth Statutory Authority

(3) Australian Private Hospitals Association, Private Organisation.

Likewise, MySchools is available with relevant departments to derive the education usage information. This provides the location of public education facilities across Australia. The private schools data is available in a limited coverage.

Gaps & Suggestions:

ABS Mesh blocks provide a reasonable level of urban land use information but not comprehensive enough for informing risk and impact analysis for DRR.

NEXIS provides the aggregated building usage information at SA1 level and counts of residential and light industrial buildings. The information in NEXIS is reasonably reliable for buildings in urban areas but, there are few gaps for the information in rural areas of some states and some categories of buildings. Further investment is required to develop exposure database for all buildings.

Tasmania, South Australia and ACT and have buildings usage information captured for most of their building stocks. Northern Territory has good building footprints data and has limited information on their usage. NSW and QLD have no state level buildings usage database available. Though some limited information can be drawn from their cadastre system and properties database on their use. This can be used as a sample and extrapolate this for the entire building stock. *MySchools, MyHospitals and other data sets* provide comprehensive information for public assets but limited information is available for private owned facilities.

Census of Land Use and Employment (CLUE) - CLUE provides comprehensive information about land use, employment available for Melbourne City only and not a national coverage.

There are several gaps in the exposure information available from various sources.

Mixed-use buildings - any urban, suburban or even a single building, that blends a combination of residential, commercial, cultural, institutional, or industrial uses, where those functions are physically and functionally integrated. There is no single source of information to provide nationally about the mixed use of buildings. This gap creates a bias in the existing information systems.

The information at building level is highly critical for tactical planning and response. There is no exposure information system provides reliable information to provide the data at level 3 except Melbourne and Sydney.

4.2 Building Type

Every building is different depends on the functionality, look, size, materials and design. Houses can be built in a large variety of configurations. A basic division is between free-standing or Single-family houses and various types of attached or multi-user dwellings. Both may vary greatly in scale and amount of accommodation provided.

Building type has a major influence on every individual, as it provides the homes in which we live, the places in which most of us work and play, our schools and hospitals that are exposed and vulnerable to natural hazards. There is an identified need of building types information to develop building vulnerability models for different construction techniques (and materials), age profiles, code specifications, compliance and enforcement, changes in exposure categories (e.g., effect of increased

urbanization) (Stewart and Li, 2009; Henderson and Ginger, 2007) for different wind speed zones and flood categories. The demographics of building type are important information for disaster management and will be influenced by the resolution of the probabilistic wind field model (Stewart and Li, 2009), by flood zone types and earth quake intensity. ABS defines only few building types for residential dwellings.

The building type information is required by the end users for tactical response and planning for all natural hazards. The researchers would need this information for analysis to understand the current building stock to derive meaningful information for vulnerability assessment and also for sustainable urban planning.

The framework suggests the following building types to cover all building stock in Australia.

1. Separate house
2. Semi-detached house
3. Apartments
    a) Low Rise
    b) Medium Rise
    c) High Rise
4. Multi Storey Commercial Buildings
5. Shopping Mall Complex
6. Agriculture Sheds – Barn, Cow-shed etc.
7. Building Complex
8. Warehouse
9. Light Industrial Buildings
10. Parking Structures
11. Religious Buildings
12. Monuments/Heritage Buildings
13. Heavy Industrial Structures
14. Multiple Buildings
15. Public Venues

However, the standard commercial or institutional building types could also include the many buildings representing one institution such as the universities, schools, hospitals and sports enclaves or one building containing many institutions such as the

ones we normally find in the city CBD locations where a multi-storey building houses multiple institutions.

Existing Capabilities:

ABS Census of Population Housing contains information at different ASGS spatial levels that need to be extracted and compiled for this purpose. ABS Census provides the information about Separate House, Semi-detached, Apartment Buildings with 2 or 3 or 4+ storeys.

NEXIS provides exposure information for the residential component and to some extent for the commercial buildings. GA has building types data for CBD area at building level sourced from engineering surveys.

At state level DFES-WA and Landgate-WA have complete information on WA; DPIPWE-TAS has complete information on Tasmania and SES-NSW has partial information on NSW.

Gaps & Suggestions:

There is no single data set provides this information across the nation classified by the Australian standard building types above. Though there is some information available with large councils and surveyed by some research projects.

There is significant gap in providing buildings type information at national, state and small area level that can be bridged using ABS Census of Population and Housing.

More information and knowledge about building types can be accessed from https://en.wikipedia.org/wiki/List_of_building_types

4.3 Structural System

Building structure is a combination of several aspects that act as a building. The information about the building structure is significant to assess the structural vulnerability of a building from various hazards. The construction materials, style and type of the buildings depends on the usage such as residential, commercial, light industrial and other buildings.

Generally, the building construction types for the residential buildings include separate houses, semi-detached and apartment buildings. Commercial construction types consist predominately of, load bearing masonry, concrete frame with or without shear wall and steel frame with or without concrete shear core. These construction types also have a combination of, timber, concrete columns or steel beams floors and

unreinforced masonry (and other material) exterior walls. Industrial construction types consist of unreinforced and reinforced masonry walls with supporting steel roof, steel frame with steel clad walls; or unreinforced masonry walls with steel roof, small and large panel precast walls with supporting steel roof, concrete first floor with steel portal above; or unreinforced masonry walls and single storey with concrete basement with steel portal superstructure and precast walls or steel frame and concrete pan basement with steel superstructure.

The structural system of the building will affect its replacement cost. As an example, with other aspects being equal, a building constructed using a braced steel frame will have a different cost to a similar building built using reinforced masonry. It is proposed in the framework that the data supplied for rates reflect this where possible.

To have an understanding about the building structure, building typologies (a combination of various components) are required.

The building structure information is required by the end users for tactical response and planning for all natural hazards. The researchers would need this information for analysis to understand the current building stock to derive meaningful information for vulnerability assessment and also for sustainable urban planning. The standard building structure system or types are listed and will be consulted experts for details to be incorporated into the final framework.

1. Building Foundation
2. Building Internal Frame
3. Building External Wall
4. Building Façade Coverage
5. Building Roof Shape
6. Building Roof Type
7. Building Orientation
8. Building Floor Type
9. Floor Height
10. Number of Storeys/Height
11. Number of Basements
12. Building Connections/Attachments
13. Building Code/Standard

14. Building Emergency Exit
15. Building Energy Utility Source

Existing Capabilities:

Geoscience Australia and Attorney Generals Department have conducted engineering survey of major cities in Australia and collected facade types of the buildings in three heights, lower, middle and upper portion of the buildings. This covers only for the city buildings in major cities and there is no other database maintains Façade data in Australia.

DPIPWE-Tasmania and Landgate-WA - At the state level organizations like DPIPWE-Tasmania and Landgate-WA have complete building structure system information for the respective state.

EICU-NSW and SES-NSW have building structure system information for limited building stock in New South Wales.

4.3.1 Building Foundation

The foundation of the building is part of the structural system and it is critical information for the assessment of earthquake vulnerability assessment. For high rise buildings, the foundation information is much more crucial to understand and may also interfere with underground facilities such as tunnels and utility networks. The building parameters above ground provide some information about the foundation and this information may be submitted to planning authorities. More detailed structural engineering input is required to derive the foundation information for high rise buildings.

The revised GEM Building Taxonomy V 2.0 (2012) has identified information need for *Building Foundation System* in their list of building attributes into GED4GEM risk modelling. Following GEM Building Taxonomy V 2.0 (2012) and HAZUS Inventory Framework provides a significant list of building foundation types. This list will be reviewed further to develop standard building foundation categories for Australia.

1) Shallow foundation, with lateral capacity
2) Shallow foundation, no lateral capacity
3) Deep foundation, with lateral capacity
4) Deep foundation, no lateral capacity
5) Unknown foundation system

Gaps & Suggestions:

There is no centralized database providing this information for researchers even though this may be available with planning approval authorities in local councils. The available data may not be in a proper format to provide. Some of this information can be derived using expert knowledge and the variables may range from building height, year built, size and frame.

4.3.2 Building Internal Frame

The internal frame fits various building components together and gives support and shape to the structure. The frame information enables the engineers to study the vulnerability of the building structure to hazards. The material normally used in the internal frame are usually wood, engineered wood and steel. Building frame is a composite of wall, corners, exterior wall studs, partitions and headers.

GEM Building Taxonomy V 2.0 (2012) and HAZUS Inventory Framework provides a significant list of building internal frame types. This list will be reviewed further to develop standard building framing categories for Australia in the next phase of the project. Building framing is divided into two broad categories:

1. Heavy-frame construction
    a) timber framing
    b) pole building framing,
    c) steel framing
2. Light-frame construction
    a) balloon framing
    b) platform framing
    c) light-steel framing.

Gaps & Suggestions:

There is limited information available in the public domain about the building internal frame and it is highly critical for the vulnerability assessments. Geoscience Australia and Attorney Generals Department have conducted engineering survey of major cities in Australia. That provides the structural system of the buildings in three heights, lower, middle and upper portion of the buildings. Some of this information can be derived using expert knowledge and the variables may be the height, year built, size and location of the building.

4.3.3 Building External Wall

External walls provide a barrier against the outdoors and support roof and any upper storeys. Interior walls might help carry weight from the roof, hide plumbing or wiring, help insulate the building, or simply divide interior space for functionality. As building structure is supported by external walls, the information is highly critical to assess the risk and also to protect the people living in. If the external wall is damaged due to severe winds, then the wind enters into the building that lifts the roof and damages the entire structure. So the external wall information is important for the risk assessment of natural hazards.

NEXIS Framework, GEM Building Taxonomy V 2.0 (2012) and HAZUS Inventory Framework provide a significant list of building external wall types. This list will be reviewed further to develop standard building external wall categories for Australia.

1. Concrete Masonry,
2. Cavity and Solid Masonry,
3. Veneer Masonry,
4. Precast Concrete,
5. Timber,
6. Metal Sheeting,
7. Fibre Cement,
8. Mudbrick or Rammed Earth
9. Synthetic

Gaps & Suggestions:

GA - NEXIS, stores information on number of residential buildings by the above wall types. Consequently, this is considered as required for inclusion into the national exposure information database in Australia. NEXIS has collected the data for some states and generalized for national consistency. For rest of the country, a desktop survey was conducted and applied statistically for the entire building stock in those areas.

At the national level, NEXIS contains information on number of residential buildings by different wall types that can be aggregated at state level and ASGS SA2 and SA1 levels. There are no standard wall types defined in Australia and mapped. The wall type in Australia varies with the location, materials and age of the construction. The building

wall type data is not collected using one standard approach across Australia. Some of the states like Tasmania and South Australia have this data and need to be mapped to a standard wall types.

4.3.4 Building Facade Coverage

Façade is one of the most important exterior elements for building functionality and an elegant component of the building envelope. This is the first line of defense against environmental and physical exposure based on its intrinsic design and location. Façade is a non-load bearing exterior skin that does not contribute stiffness to the building structure. Façade is to provide and maintain air and water integrity in the cladding system; adequate wind, thermal, noise proof and seismic response in addition to provide light transmittance to the interior space. The façade system schemes may be an all-glazed façade (aluminum framed systems, point-supported systems, cable net systems), an opaque façade (such as precast, natural stone and/or metal panels) or a combination of both depending on the building intent.

There are specific guidelines and requirements of Façades prescribed by the standards for its blast, seismic, and thermal loadings. Understanding of the Façade classification is important to assess the impacts from earthquakes, blast and wind-blown debris on the buildings and its operations.

GA's City Buildings Survey Framework provided a significant list of building facade types. This list will be reviewed further to develop standard building façade categories for Australia.

1. Curtain Wall
2. Planar Wall
3. Foyer Wall
4. Shop Front
5. Balcony
6. Sheet
7. Composite
8. Brick Load Bearing
9. Brick Non Load Bearing
10. Block
11. Stone
12. Terracotta

13. Copper
14. Precast Panel Lb
15. Precast Panel Non Lb
16. Insitu Conc

Gaps & Suggestions:

There is no database providing this information on building facade coverage for researchers and end users in Australia.

4.3.5 Building Roof Shape

The climate, environment, availability of building materials and purpose are the key factors in determining the shape of the building roof. The shape considers the pitch (angle it slopes at) and materials used depend on the snow, rainfall and wind it is likely to endure. As building envelope is supported by the roof, the information is highly critical to assess the multi-hazard risk and to protect the people living in. The roof shape plays an important role in maintaining the building envelope. The frame of the roof helps to get the shape and brings strength to the building. The shape of the roof is defined as Gabled, Flat, Hip, Clerestory, Arched, Sawtooth, Curved, Domed, Skillion, Mansard and complex combinations.

Gaps & Suggestions:

There is no information available in the public domain about the building roof shape.

4.3.4 Building Roof Type

Like Building Roof Shape the roof type is also determined by the climate, environment, availability of building materials and purpose of use. Roof type is defined by materials used considering the snow, rainfall and wind it is likely to endure. As building envelope is supported by the roof, the information is highly critical to assess the multi-hazard risk and also to protect the people living in. For example, if some part of roof or wall is damaged during a cyclone and allows more wind into the building, the internal pressure causes to lift roofs and ceilings and pushes outwards. The popular outer roof materials used in Australia are tile, concrete, sheet metal, timber and fibro. The roof type in Australia varies with the location, materials and age of the construction. NEXIS Framework, GEM Building Taxonomy V 2.0 (2012) and HAZUS Inventory Framework provides a significant list of building roof types. This list will be reviewed further to develop standard building roof type categories for Australia.

1. Tile
2. Metal sheeting
3. Concrete
4. Fibre cement
5. Imitation tile,
6. Synthetic

Gaps & Suggestions:

NEXIS contains roof materials information of residential buildings that can be aggregated at national, state and ASGS SA2 and SA1 levels. Some of the states like Tasmania and South Australia have this data and need to be mapped to a standard roof types. This information is not collected using standard approach across Australia. There are no standard roof types defined in Australia and mapped. The roof type data is not captured and maintained in Australia consistently. Using structural engineering knowledge, this information can be derived statistically using the variables of building standards, location, year built and climatic zoning.

4.3.5 Building Orientation

Orientation is the positioning of a building in relation to seasonal variations in the sun light as well as prevailing wind patterns. Sun light is more relevant for energy efficiency but the wind pattern is important input for the wind direction. Australian Wind Loading Standards provide the wind directional multiplier outlining the predominant wind directions across the nation. The building orientation along with a set of other variables such as local climate, temperature ranges, humidity ranges, seasonal extremes, local geographic features, adjacent buildings and existing landscape characteristics influence the impact of natural hazards on buildings. This information enables the researchers to assess the vulnerability assessment more accurately.

Gaps & Suggestions:

There is no centralized database in Australia that collects, maintains and provides building orientation information.

4.3.6 Building Floor Type

The choice of material for floor covering is affected by factors such as cost, endurance, noise insulation, comfort and cleaning effort. Flooring is a non-load bearing interior

skin that does not contribute strength to the building structure. This information is significant in assessing the direct loss from the floods and also other natural hazards. The known floor materials used in Australia are concrete, carpet, timber, vinyl tiles and synthetic tiles. In Australia, in-slab heating is built-in with the flooring.

GA's City Buildings Survey Framework provides a significant list of building floor types. This list will be reviewed further to develop standard building floor type categories for Australia.

1. Post
2. Tensioned
3. Precast
4. Composite
5. Mesh Or Reo
6. Bandbeams
7. Flat Plate Slab
8. Other

Gaps & Suggestions:

There is no centralised database that collects, maintains and provides building floor type data in Australia.

4.3.7 Number of Storeys

The number of floors, levels or storeys is important information to estimate the height of the building, gross built-up area, and replacement cost of the building. Residential buildings commonly have only one or two floors. This information is highly critical for flood risk assessment and response at micro level. Buildings are often classified as low-rise, mid-rise and high-rise according to how many levels they contain, but these categories are not well-defined.

The height of each storey is based on the ceiling height of the rooms plus the thickness of the floors between each level. The height of each storey varies widely depending on its construction style and purpose. Storeys within a building need not be all the same height, often the lobby is more spacious and higher levels may be smaller in height. Council of Tall Buildings and Urban Habitat has developed the height calculator to assist in determining building height using three categories. According to CTBUH, 2015 floor to floor height is 3.9m (office), 3.1m (residential) and 3.5m (mixed-use). Buildings

designed to house special industrial processes require large areas and unusual heights to accommodate crane ways or special machinery and equipment. There will be some exceptions for aircraft hangers etc. when calculating height for number of storeys. Total floor area also varies significantly with the height or number of storeys. Generally the ground floor has the maximum area and the floor on upper part of the building might be less than the floor below.

Gaps & Suggestions:

There is no datasets that provides the number of storeys consistently across the nation in Australia.

ABS Census provides number of buildings with number of storeys for residential buildings information that can be aggregated at national, state, ASGS SA 2 and SA1 geographic areas.

NEXIS maintains the number of storeys collected for some parts and maintains in the reference data at the individual storeys level. This has aggregated into 2, 3 and 4 plus for residential buildings (following ABS Classification), commercial buildings into 1-3, 4-7, 8-35 and 36 plus and the industrial buildings 1 and 2 plus storeys. Institutional building classification has not been defined. It provides number of buildings with number of storeys for residential buildings information aggregated at national, state, ASGS SA 2 and SA1 geographic areas.

Both these datasets derives the information from different sources and processes. Some of the states like Tasmania and South Australia have this information at buildings level and other states have no information on number of storeys.

Geoscience Australia and Attorney Generals Department have conducted engineering survey of major cities in Australia and collected number of storeys for city buildings.

The commercial datasets like *Cityscope* has the number of storeys data covering major city centres and the data is available with commercial licensing conditions.

4.3.8 Number of Basements

Number of basements information and its usage is critical for vulnerability assessment of natural hazards particularly for an earthquake hazard. Generally there are no basements for simple residential buildings in Australia. The high rise buildings have several basement levels and particularly used for car parking.

Gaps & Suggestions:

There is no centralized database providing this information for researchers. *Cityscope* provides this data covering major city centres and it applies commercial licensing conditions on its use. Number of basements data is available with building plan approval authorities in local councils. Some of this information can be derived using expert knowledge and a potential set of variables such as the height, year built and location of the building.

4.3.9 Building Connections/Attachments

There are several building components that are not considered to be the part of building and at the same time they are integral to the building structure. The areas in the building not used for habitation and storage are considered to be part of this category. These attachments are including towers, spires, steeples, balcony and other roof structures. There are some attachments such as solar panels, air-conditioning system, awning, appurten and equipment.

Gaps & Suggestions:

These features are not captured by any dataset to provide for risk and impact analysis from natural hazards.

4.3.10 Building Code/Standards

The Australian Building Codes Board (ABCB) is a Council of Australian Government (COAG) standards writing body that is responsible for the National Construction Code (NCC) which comprises the Building Code of Australia (BCA) and the Plumbing Code of Australia (PCA). The NCC has been developed to incorporate all on-site construction requirements into a single performance-based code. This provides flexibility through the use of the Deemed-to-Satisfy Provisions or the development of Alternative Solutions based on existing or new and innovative building, plumbing and drainage products, systems and designs. This Building Code information is an identified requirement for this framework (ABCB, 2015).

After natural disasters, the ABCB examines the nature of building damage to decide whether the regulations provide enough protection. During Cyclone Tracy in 1974, 70 percent of Darwin's houses suffered severe damage (90 percent in some areas), causing 65 deaths and damage worth of hundreds of millions of dollars. It was obvious that existing building standards were not protecting the community. As a result, the

regulations were changed in the 1980s to improve the construction processes that attach the roof to the rest of the house, making homes more resistant to severe wind damage. Analysis after cyclones Vance (1999), Larry (2006) and Yasi (2011) showed that the updated regulations have resulted in much less building damage and consequent loss of life. During Cyclone Yasi for example 12 percent of older homes suffered severe roof damage, but only 3 percent of newer homes.

End users' require a building code mark by the Australian Building Codes Board (ABCB) that satisfies their building product certification scheme.

Gaps & Suggestions:

There is no capability in Australia that provides ABCB building certification codes or standards consistently across the nation. Based on the location, structural system and year built, the standards implemented can be assumed for the buildings.

4.4 Year Built and Retrofit

Building construction year provides information on building standards, technologies, materials, components, construction practices and style. Year of Construction or Retrofit information has been identified as one attribute for inclusion in Global Earthquake Model. AS1170.2 Wind Loading Standards were adopted as standardisation factor in 1980, so the buildings classified into pre 1980 and post 1981 marks a significant change in building construction standards in Australia. This is to safeguard people from injury, loss of amenity, neighboring properties by structural failures.

The building age information is required by the end users for tactical response and planning for all natural hazards and also to understand the risks to emergency rescue teams. The researchers would need this information for analysis to understand the current building stock to derive meaningful information for vulnerability assessment and also for sustainable urban planning.

1. Built Year
2. Construction Period
3. Retrofit Year
4. Renovation Year

Retrofitting the old buildings to a new standard improves the susceptibility of building to different natural hazards. Structural retrofitting to existing housing is considered as adaptation of building to increased intensity and frequency of natural hazards due to climate change.

The year of construction is captured in the data that will help to derive building standards and other hazardous materials used in the construction. ***Existing Capabilities:***

NEXIS manages actual age at the building level, data is sourced from actual age from local source data, cadastral parcel release date as a surrogate for building age or median suburb age derived from actual age data. *GA* contains information on number of residential buildings built: pre and including 1980, post 1981. There is about 1.5% buildings has no data and declared as unknown. The information can be aggregated at national, state, ASGS SA2 and SA1 levels. NEXIS also contains other age classifications

Gaps & Suggestions:

NEXIS, GA has sourced the built year or period information for the buildings from various sources and also derived the information from various other sources. It is reasonably reliable for ANHEF Level 1 users. This information is available with local planning authorities and can be sourced through a proper data sharing arrangements for more recent years. Exact year of construction may not be available for heritage and old buildings but they can be grouped into a period such as First World War.

4.5 Building Position within a Block

Building Position within a block is important to know particularly for the buildings in rural or regional areas. Usually in the large farms, the address may be pointing to the location of the farm gate or letter box but, not to the building itself. The vegetation coverage of the farm, topography or other localised factors may impact the building vulnerability to various natural hazards. Also, it is equally important to know the exact positon of the building within a block for other planning purposes and the space and height of the buildings for wind multiplier modelling and detailed bushfire spread hazard models. For semi-detached buildings in a block, this information will provide the location of the shared wall on one side in case of the corner buildings and two

sharing walls in case of the building in the middle of row housing. Building footprints data is available for some areas with local governments.

Gaps & Suggestions:

This information is not available in any of the datasets and sometimes the building footprints provide the position more accurately.

4.6 Building Size & Capacity

Building size information is one important requirement to estimate the social aspects, size of the population at a given time, replacement value, contents value and energy consumption of the building. This is particularly required to strengthen disaster preparedness for effective response at all levels of government. Building capacity basically denotes the maximum number of persons in a residential building, student-teacher capacity in a school building, hospital beds-staff capacity in a hospital building and number of seats in a restaurant etc. that the building can accommodate. Some risk assessment projects require highly detailed exposure information inside the building to represent floor space and different usage.

The building size information is required by the end users for tactical response and planning for all natural hazards. The researchers would need this information to estimate the replacement value to derive meaningful information for vulnerability assessment.

Building size basically includes information on

1. Land size
2. Gross Floor Area
3. Building Lettable Area
4. Number of Dwellings
5. Extensions
6. Number of Bedrooms
7. Number of Toilets
8. Number Car Parks
9. Size of Garage
10. Annex buildings

Existing Capabilities:

NEXIS provides aggregated information about the floor area (size of built-up area) for SA1 geographic areas. NEXIS is able to derive the floor area for other combinations in a given area. NEXIS has sourced this information from known sources where available. Where there is no data available, NEXIS modelled to derive using sample area and apply for the entire building stock.

Valuer Generals Office in West Australia has the data at record level for urban areas.

Valuer Generals Office in Victoria provides this information at an aggregated level.

South Australia and Tasmania also has this information for some of their building stock. The information consists of the size of the buildings, number of bedrooms, number of bathrooms etc. in their property databases.

Other Data Sources - There are some commercial datasets like Property Council of Australia provides shopping malls data and Cityscope provides the building size in CBD areas and has commercial licensing restrictions.

Some of the local councils conduct survey of their building stock and their land use regularly that shows the details of the buildings and their internal use. City of Sydney completes the Floor Space and Employment Survey regularly.

Gaps & Suggestions:

There is no single and centralised dataset available for entire Australia. There is no data available for Queensland and NSW at building level. Currency of the data is also an issue as these datasets are not updated regularly. Risk assessment modelling capabilities are highly advanced and able to provide analysis at 3 Dimensional level. Level 3 data is required for Australian Re-insurance Pool Corporation risk assessment projects and the available data resolution is not good enough.

4.7 Building Emergency Exit

Every building is different depends on the functionality, look, size, materials and design. The emergency exit information is highly critical for the people live or works in the buildings for faster evacuation and provides an alternative when regular exits are blocked in emergencies.

It is usually a strategically located (e.g. in a stairwell, hallway, or other likely place) outward opening door with a crash bar on it and with exit signs leading to it. The name is a reference to when they are frequently used, however a fire exit can also be a main

doorway in or out. A fire escape is a special kind of emergency exit, mounted to the outside of a building.

The emergency exit information is required by the end users and particularly highlighted the discussions in stakeholder engagement workshop. This is critical information for building evacuation and tactical response planning for sudden onset of events. In Australia the standard emergency exit include

1. Signage
2. Evacuation Floors
3. Evacuation Lifts
4. Evacuation Stairwells
5. Evacuation Plan
6. Code Regulations

Gaps & Suggestions:

There is no centralised database that provides emergency exit information about the buildings and other facilities such as tunnels and industries. The information is provided by the builders to the planning authorities at building level and may be available in paper format with those agencies. Having this information readily available with exposure information enables emergency response more effective. This information is required for the ANHEIF Level 3.

4.8 Building Utility Services Connections

Location of electricity, gas, water and communication network connections to the buildings and industries is highly important for emergency response. In an emergency, continuing the supply of these utilities would add further risk to the people in it and also affect the rescue operations. These services in multiple occupancy dwellings pose a complex set of challenges. In an emergency, early engagement with Utility Connection Providers (UCP's) is crucial to stop the supplies.

In Electricity industry it is more or less given that meters and associated apparatus will be housed in a recessed cavity box, unless the dwelling is multiple occupancy where a suitable cupboard or dedicated room will be used. Water is fairly straight forward, most meters are housed in the boundary or stop cock box.

The location of utility connection type information is required by the emergency responders to cut the services at the time of the event. This was highlighted by

stakeholders at the workshop. For exposure information purpose, the following information on building utility services connections is considered as important:

1. Location of Gas Meter
2. Location of Electricity Mains
3. Location of Solar Power Mains
4. Location of Water Mains
5. Location of Hydrants

Gaps & Suggestions:

There is no centralised database that provides the location of utility connections or mains at a building and other facility premises. The information is available with utility service providers and the planning authorities at building level. Having this information readily available with exposure information would enable emergency response more effective. This information is required for the ANHEIF Level 3.

4.9 Building Value

4.9.1 Replacement Value

In order to estimate the impact of natural hazards, it is necessary to estimate the building construction rate at the level of individual buildings. The construction rate relates to the building fabric; that is, structure, finishes, walls, building services, etc. (Wehner, 2013). Wehner, 2013 methodology to estimate the construction rate needs to be applied to develop a more detailed exposure database where data on individual buildings are recorded.

Quantity Surveyors would usually break the building down into its constituent components and calculate the cost of each component to calculate an accurate replacement value for a building. Based on the industry knowledge and data derived from past projects, each component would be evaluated, the individual values summed up and add builder's overheads to produce a final replacement value. In Australia, the value of building varies by its geographic location with the lowest in the larger cities (where resources are in close proximity) and values progressively increase with distance from the larger cities. The replacement rate provided by Quantity Surveyors is available per square meter and depends on various parameters. This information can be sourced through consultation.

There are variables that affect the replacement value of a building. It is suggested that many of the variables influencing replacement values are taken into account in the selection of the replacement rate. These variables include the following:

1. Urban and Rural

The replacement value varies by location depending on the urban versus rural. Urban areas have the materials and resources available for building construction better than rural areas. So the distance from the main town centres is an important variable in estimating the construction rates.

2. Usage of building

The usage for which a building is built will affect its replacement value. Thus all other aspects being equal, a building built for residential apartments will have a different value to a similar building built for hospital use. It is proposed that, where possible, the data supplied for rates reflect this.

3. Building structure

The structural system used for a building will affect its replacement value. As an example, all other aspects being equal, a building constructed using a braced steel frame will have a different value to a similar building built using reinforced masonry. It is proposed that, where possible, the data supplied for rates reflect this.

4. Size of building

The size of a building will affect its replacement rate with larger buildings of similar height attracting a lower rate than multiple buildings of smaller size due to economies of scale. Taller buildings of similar footprint will attract higher rates than lower buildings. It is proposed that where possible, the data supplied for rates reflect this.

5. Type of building

Within a given usage, structural system, size of building and the form or nature of a building will affect its replacement rate. For example, a single storey brick veneer slab-on-grade residential building could be a free-standing building, a terrace house, a duplex or a townhouse. Each of these would have slightly different replacement rates. It is proposed that, where possible, the data supplied for rates reflect this.

6. Quality of building

Within a given usage, structural system and size of building, the quality of finish can affect the replacement rate. The difference in residential reconstruction rates can vary by a factor of more than 2 between a basic standard of finish and a prestige standard of finish.

7. Site topography

The local topography will affect the replacement cost of a building. In general it is more expensive to build on a steeply sloping or hilly than a flat terrain. It is proposed that this is reflected in the data in two ways. Firstly, using different rates for different regions will tend to reflect regional differences in topography, and, secondly, providing a range of rates for each building type will reflect variations that may be encountered.

8. Site ground conditions

The local ground conditions will affect the replacement value of a building. In general it is more expensive to build on sites underlain by deep, soft soils than sites with strong materials at shallow depths.

9. Demolition and debris removal costs

In the event of a natural hazard, prior to rebuilding the remaining building the rubble must be removed from the site and disposed of. This is cost to the reconstruction project although, clearly, in a new-build situation the cost does not exist. The demolition and disposal cost should be included.

10. Builder's preliminaries

The charge levied by builders for their overheads and profit is a cost to the reconstruction project and hence to be included in the data provided for the reconstruction rate.

11. Rate variations from the date for which data are available

The cost of reconstruction for a given building in any one location will vary from year to year due to inflation, local demand and other factors. Typically the construction rate will not be able to be revised on a yearly basis. To account for annual variations in rates from the year is proposed that yearly building price indices are prepared.

12. Design, documentation, authority, taxes and legal fees associated with reconstruction

Though it is a small fraction in the replacement value, it is required to consider this variable in estimating the construction rates. It is normal quantity surveyor practice to exclude these fees in their estimate of the building construction rates.

Often after a natural disaster, the demand to repair or reconstruct buildings will exceed the capacity of the local building industry leading to a post-disaster demand surge and higher prices. The magnitude of such a demand surge depends on many factors such as the intensity and geographical extent of damage, people's decisions about whether to rebuild or relocate, the ability of the local building industry to source resources from neighboring regions and government's control on prices. In view of the uncertainty over the magnitude of the post-disaster demand surge, the framework identifies to add another demand multiplier that would be part of further special purpose modelling explicit to the situation and nature/type of the hazard. However, this demand multiplier would not be considered in this more generic exposure framework.

Estimate the Replacement Value

A range of building construction rates needs to be considered to estimate the building replacement value and this is expressed as:

$$RV = A_b \times R$$

Where *RV* is the replacement value of the building, A_b is the total built-up area of the building and *R* is the replacement rate per square meter.

Existing Capabilities:

Geoscience Australia sourced the building construction cost factors for some building types from quantity surveyors. These construction rates are applied to estimate the building replacement values in its NEXIS database. NEXIS provides the replacement value of the buildings aggregated to a known geographic area.

Rawlinson's Construction Cost Guide, 2011, Edition 19 – provides the construction rates for buildings with various factors.

Gaps & Suggestions:

There is no standard process to estimate the contents value of the building due to variations in factors that influence people's spending behaviors and market values. The

contents value data available from insurance companies and underwriters is confidential for their property portfolio and not available in the public domain.

It will be a good strategy to develop some algorithms to estimate building content values using the insurance portfolio data as a sample and applying to the building stock across Australia.

Estimating the building construction rates are not available for all the factors listed above. Estimation of the floor area or total built-up area is statistically driven by NEXIS. There is no data set that provides the size of the building accurately and that leads to low reliability of the data at buildings level.

Heritage buildings reconstruction rate to reinstate original appearance and materials is highly complex. Reconstruction rates are usually variable due to the differing requirements on how faithfully the reconstruction is required to reinstate the original. Hence it is not included in the framework.

Likewise, Iconic or special buildings such as the Sydney Opera House and the like which are unique and do not lend themselves to generalization. So, it is not included in the framework.

4.9.2 Contents Value

The contents in the buildings vary significantly depending on its usage and in case of residential buildings it varies depending on household socio-economic status. The contents in the building include additional fittings, refurbishment, furniture, household goods, cars, equipment, goods in warehouse, memorabilia, outdoor equipment, etc. Contents replacement value is estimated as a percent of structure replacement value and to be applied a multiplier for household wealth or household income category.

CV = f (RV, HI)

Where CV - Contents Value,

RV - Replacement Value

HI – Household Income

Home contents are the most commonly held household asset with almost every household reports items of value for insurance. According to ABS, the average value of a household's home contents (e.g. clothing, jewellery, hobby collections, furniture, appliances, paintings, art works) was $61,000 in 2009-10.

Most households (90%) held some equity in their private vehicles net worth was $18,000, on average in 2009-10.

For large industries and businesses, Insurance Underwriters evaluate the exposure of value of assets/contents.

Existing Capabilities:

NEXIS, GA contains information on Building Contents Value and derived using a statistical approximation using dwelling structure value and household income as variables. Total contents value ($) for all residential buildings aggregated to a defined geographic area. Contents value is calculated as a proportion of the replacement cost and adjusted for the gross income classes.

Insurance Companies - Insurance portfolio of various companies has the information of contents insured. The insurance portfolio provides a reasonable estimate of the contents value but the households are always underinsured.

Underwriters such as *Llyods of London*, *Arch Underwriters* etc. estimates the exposure of contents value in medium to large industries.

Gaps & Suggestions:

There is no database providing this information on building facade coverage for researchers and end users in Australia.

5. INFRASTRUCTURE EXPOSURE FRAMEWORK

The literature review Nadimpalli et al (2014) have identified the need for collecting data describing infrastructure networks, also maintaining and updating of information on attributes required to predict the consequences of infrastructure failures for multi hazard planning and policy modelling for prevention, preparedness, response and recovery. . So this framework identifies the following broad components of the infrastructure sector that are critical exposure risk:

1. Transport Sector
2. Energy Sector
3. Communication Sector
4. Urban Water Supply and Sanitation Sector
5. Waste management Sector
6. Hazardous Substance Sector

5.1 Transport Sector

In recent days natural disasters in form of extreme weather/climatic conditions and earth quakes have observed to have significant and wide ranging impact on Transport sector. Transport sector is the life line of modern day logistics, if fails it can itself lead to hazardous consequences. In US the National Research Council (2008) identified that:

"Climate change will affect transportation primarily through increases in several types of weather and climate extremes, such as very hot days; intense precipitation events; intense hurricanes; drought; and rising sea levels, coupled with storm surges and land subsidence. The impacts will vary by mode of transportation and region of the country, but they will be widespread and costly in both human and economic terms and will require significant changes in the planning, design, construction, operation, and maintenance of transportation systems".

Consequently protecting and managing transport sector during natural hazards is critical for disaster management, response and recovery actions. This compels the need for transport sector information collection, organisation, storage and management describing infrastructure networks. It is also important to maintain and

update the information on different attributes required to predict the consequences of infrastructure failures.

Transportation system is divided into infrastructure, vehicles and operations in the framework in four modes of transport viz; air, rail, road and water. Transport infrastructure consists of the fixed installations including roads, railways, airways, waterways and terminals such as airports, railways stations, bus stations, warehouse, fueling stations and seaports.

There are several facilities linked with the transport system and they are fixed assets or infrastructure such as terminals, toll plazas, parking lots etc. Terminals may be used both for interchange of passengers and cargo and for maintenance. Terminals such as airports, ports and stations, are locations where passengers and freight can be transferred from one vehicle or mode to another. For passenger transport, terminals are integrating different modes to allow riders to interchange to take advantage of each mode's advantages. For instance, airport rail links connect airports to the city centres and suburbs. The terminals for automobiles are parking lots, while buses and coaches can operate from simple stops. For freight, terminals act as trans-shipment points, though some cargo is transported directly from the point of production to the point of use.

5.1.1 Roadway

The road transport system consists of highways, bridges, tunnels and associated road usage. The roads, bridges and tunnels are represented as lines and the terminals are associated facilities such as bus stops and traffic controls etc. are represented as points. Road transport network offers freedom to road users to transfer the vehicle from one road to another as needed.

The most common road vehicle is the automobile; a wheeled passenger vehicle that carries its own motor. Other users of roads include buses, trucks, motorcycles, bicycles and pedestrians.

As of January 2011, the Australian motor vehicle fleet had 16.4 million registered vehicles, with an ownership rate of 730 motor vehicles per 1000 people, up from 696 vehicles per 1000 residents in 2006. The motor vehicle fleet grew 14.5 percent since 2006, for an annual rate of 2.7 percent during this five-year period ("Motor Vehicle

Census, Australia, 31 Jan 2011". Australian Bureau of Statistics. 2011-07-28. Retrieved 2011-08-23)).

Following ANZLIC Metadata Guidelines, NEXIS Framework and HAZUS Inventory Framework provides a significant list of road network types, structure and components that should be included in National Disaster Database in Australia.

Roads information is required by the end users for evacuation during emergency for all natural hazards. The researchers would need this information to estimate the direct and indirect losses which is highly critical for the recovery and community resilience. This list will be reviewed further to develop standard road network system categories for Australia.

1. Name
2. Ownership
3. Type
    a) Freeways/Motorways
    b) Highways
    c) Secondary Roads
    d) Local Collector Roads
    e) Streets
4. Private or Restricted Roads
5. Construction Material
6. Carrying Capacity
7. Capacity Utilization
8. Year Upgraded
9. Lane Width
10. Shoulder Width
11. Grade/Condition
12. Carriageway Division
13. Bicycle Paths/Footpaths
14. Reconstruction Cost

5.1.2 Railway

The rail transport system consists of railway lines and associated infrastructure. There are two modes of rail transport in Australia i.e., trams (light rail) and trains. The light

rail is mainly used as urban public transport system, whereas the train is for public (urban and rural) and goods transport. The railway lines/tracks buckle due to earthquakes and also the heat waves. They washed out due to floods and storm surge. The transport service disruptions and response costs from heatwaves in 2009 in Melbourne were estimated at $800million and disruption of public transport (Steffen et al, 2014).

Railway lines information is required by the end users and researchers to estimate the direct and indirect losses. Different components of the rail transport system include:

1. Ownership
2. Railway Lines
    a) Gauge (broad, meter, light)
    b) Usage (urban/rural/goods)
    c) Control Facilities
    d) Rail Gates/Intersections
    e) Train/Tram
    f) Metropolitan Networks
3. Condition
    a) Elevated/Ground
    b) Sleepers
    c) Electrification
4. Carrying Capacity
5. Capacity Utilization
6. Reconstruction Cost
7. Year Built
8. Year Upgraded

5.1.3 Waterway

Water transport operates by means of a watercraft—such as a boat, ship or ferry—over a body of water, such as a sea, ocean, lake, canal or river. The waterways are significant mode of transport for urban commuters in Sydney and Perth, tourism in Murray River and ferries in the sea.

The waterways in Australia consists of

1. River Channels

a) Width
b) Depth
c) Purpose

2. Harbours / Wharves
3. Sea Ferry networks

5.1.4 Bridges, Culverts & Aqueduct

The bridge is considered as transport infrastructure to overcome on the obstacles and provide passage for road or rail networks. Design of the bridge varies to serve its unique purposes and nature of the terrain.

The culvert is an infrastructure that allows water to flow under a road, railroad, trail, or similar obstruction. Culvert may be made from a pipe, reinforced concrete or other material. Aqueduct structure is to carry water above road.

This information is required by the researchers to develop vulnerability models particularly earthquakes, floods, storm surge and tsunami risk assessment. This is also required to estimate the direct and indirect losses, which is highly critical for the recovery and community resilience. The end users needs it for evacuation during emergency for all natural hazards. Different components of the Bridges, Culverts & Aqueduct structures include:

1. Bridge/Culvert/Aqueduct
2. Ownership
3. Length
4. Width
5. Type
    a) Beam
    b) Truss
    c) Cantilever
    d) Tied Arch
    e) Suspension
    f) Cable Stayed
    g) Double-decked
    h) Movable
    i) Multiple levels

6. Structure Type
    a) Tension
    b) Compression
    c) Bending
    d) Torsion
    e) Shear
7. Design
    a) Conventional
    b) Standards
8. Number of Spans
9. Span Continuity
10. Materials
11. Purpose
    a) road over rail
    b) rail over road
    c) road over water
    d) water over road
    e) Pedestrian bridges
12. Carrying Capacity
13. Capacity Utilization
14. Year built
15. Year upgraded
16. Pier walls
17. Single/multi columns bents
18. Abutment type
19. Reconstruction Cost

5.1.5 Tunnels

A tunnel is an underground or underwater passageway enclosed except for entrance and exit. A tunnel may be for foot or vehicular traffic of road, rail, or canal. The central portions of a rapid transit network are usually in tunnel. Some tunnels are aqueducts to supply water for consumption or for hydroelectric stations or are sewers. Utility tunnels are used for routing steam, chilled water, electrical power or

telecommunication cables, as well as connecting buildings for convenient passage of people and equipment. Secret tunnels are also there for military purposes, or by civilians. Special tunnels, such as wildlife crossings, are built to allow wildlife to cross human-made barriers safely. The impacts of natural hazards on tunnels would vary depending on the types, structure and extent of its use.

The tunnels information is required by the researchers to develop vulnerability models particularly earthquakes and any other sudden onset of events for emergency response. This is also required to estimate the direct and indirect losses, which is highly critical for the recovery and community resilience. The associated equipment information is also required to assess the risk. For exposure information purpose different components of the Tunnels include:

1. Tunnel Ownership
2. Tunnel Usage
3. Tunnel Length
4. Tunnel Width
5. Tunnel Type
    a) Single Level
    b) Multiple levels
6. Structure Type
7. Shape
8. Materials
9. Purpose
10. Equipment
11. Year Built
12. Year Upgraded
13. Carrying Capacity
14. Capacity Utilization
15. Reconstruction Cost

5.1.6 Airport

Airport is a transportation terminal for air travel. Airports often have many associated facilities consisting of landing area and runaway, control tower, aircrafts, helicopters, hangers, maintenance workshops, customs, immigration etc. The impacts of natural

hazards on the airports varies depends on its size and functionality. They are ranging from landing grounds (rural and agriculture purpose), domestic airports and large international airports.

For exposure information purpose different types and components of the airport infrastructure include:

1) Airport Functional Type
    a) Rural Landing Ground
    b) Small Domestic
    c) Large Domestic
    d) International
    e) Civil
    f) Military
    g) Cargo & Freight
    h) Defunct Airports
2) Landing Grounds
    a) Runway Length
    b) Runway Width
    c) Runway Material
3) Air Traffic Control
    a) Tower
    b) Systems
4) Weather Station
5) Air Safety Facility
6) Airport Security
7) Fuel Depo
8) Hotels
9) Lounges
10) Terminals/Gates
    a) Number
    b) Type
11) Customs Office
12) Immigration

13) Hangers

14) Ownership

a) Public

b) Private

c) Partnership

15) Establishment Year

16) Carrying Capacity

17) Capacity Utilization

18) Activity

19) Traffic Pattern

20) Reconstruction Cost

5.1.7 Sea Ports

Seaport is a transportation terminal for maritime travel or a junction of road/rail with water ways. Seaports are used to dock the ships, people and cargo transport operations. Ports need to handle a variety of traffic, storage and support facilities. Ports are economically highly critical and some of them are strategically significant for military operations. So the impact of natural disasters on sea ports carries strategic importance for country and varies by the size and extent of its use.

For exposure information purpose different types and components of the port infrastructure include:

1. Port Name
2. Port Type
    a) Cargo
    b) Cruise
    c) Fishing
3. Berthing structures
    a) Piers
    b) Wharves
    c) Jetties
    d) Bulkheads
    e) Docks
    f) Column or pile

   g) Lamella berth

4. Platform Type
   a) Gravity Wall
   b) Sheet Pile
   c) Relieving Structure
   d) Kerbs
   e) Pavements
5. Protection barriers
   a) Bollards
   b) Handrails/guardrails
   c) Crane rails
   d) Break water
   e) Revetment
   f) Seawalls
6. Port Super structures
   a) Administrative buildings
   b) Warehouses
   c) Storage sheds
   d) Terminals
7. Ownership
   a) Public
   b) Private
   c) Partnership
8. Carrying Capacity
9. Capacity Utilization
10. Year established
11. Year upgraded
12. Replacement cost
13. Depth of water
14. Connections
   a) Road & Rail Infrastructure
15. Corrosion protection

16. Facilities

5.1.8 Public Transport Facilities

Public transport facilities support the transport system and shared passenger services. The facilities consist of bus stations, railway stations, traffic control rooms and signaling system, trucking terminals and terminals. Transport terminals may be used both for interchange of passengers and cargo and for maintenance. Passenger transport may be public, where operators provide scheduled services, or private. So to study the impact of natural disasters on public transport facilities this framework identifies the need to include information on different types and components of the infrastructure.

1. Terminals
2. Interchange/hub
3. Bus stops
4. Railway Station
5. Railway Yards/depots
6. Control rooms
7. Harbours

5.1.9 Multimodal Transport Facilities

Multimodal transport is the transportation performed with a combination of at least two different means of transport (by rail, sea and road). This is an integrated transport chain where the strength of each alternative is utilised. The multimodal transportation has transshipment terminals that allow efficient cargo handling between short and long distance freights. In general, trucks cover short distances from source and recipient of the freight and the long distance haulage is by the rail, air or ship. Freight transport has become focused on containerization, although bulk transport is used for large volumes of durable items. Trailer shipment generally refers to the multimodal transport. Transport plays an important part in economic growth and globalization and the framework suggests the following as exposure elements.

1. Transport Connections
2. Number of Containers
3. Type of Containers

4. Type of Cranes
5. Container Stackers
6. Trucks
7. Barges
8. Ships
9. Planes
10. Control rooms
11. Capacity
12. Value

5.1.10 Transport Vehicles

As we can experience vehicles traveling on different types of transport networks may include automobiles, bicycles, buses, trains, trucks, people, helicopters, watercraft, spacecraft and aircraft. Operations deal with the way the vehicles are operated in respective transport infrastructure varies significantly. In the transport industry, operations and ownership of infrastructure can be either public or private, depending on the mode. The type and number vehicles at a particular location varies depends on the time of the day and events. This needs development of a transport model is required to estimate the vehicles.

The impact of Natural disasters on transport vehicles carries significant importance for disaster management, response and recovery. Number, type and value of the following list of vehicles by different mode of transport suggested to be in the framework.

1. Aircrafts
2. Helicopters
3. Cargo flights
4. Buses
5. Trucks
6. Cars
7. Motor Cycles
8. Trains
9. Cargo Trains
10. Trams

11. Boats
12. Ferry
13. Ships

5.1.11 Transport Functions

Relocation of travelers and cargo are the most common function of transport sector. However, other functions include the strategic and tactical relocation of armed forces during warfare, or the civilian mobility construction or emergency equipment. Natural disasters have significant negative consequences for the transport sector as it is the life line of disaster management, response and recovery process. So, following are some of the broad categories of transport sector functions that are proposed in the framework.

1. Schedule Services
2. Bus/Train Routes
3. Commuting Patterns
4. Logistics/Freight Patterns
5. Dependencies
6. Economic
7. Capacity

In addition to capturing and storing inherent spatial location information (geometry) for each transport infrastructure asset (spatial feature), data tables and attributes should be structured to best represent the above information.

Existing Capabilities

Transportation is one of the critical sector for national economy. It is quite diverse and underpins several value chain activities. There is plenty of segregated data available on transport sector while, the availability depends on the role of authoritative and regulatory organisations across commonwealth, state or local jurisdictions. The sector information is also maintained by private companies. Primary data sources in the public domain include:

Data Source	Data Description	Web Link
ROAD		
Geoscience Australia	National Roads (Creative Commons)	
PSMA	Roads Database (*Commercial Licence)*	http://www.psma.com.au/?product=transport-topography
State Govt	NSW Road (RTA restricted Licence)	http://www.rms.nsw.gov.au/business-industry/heavy-vehicles/index.html
	QLD higher mass limits maps	http://www.tmr.qld.gov.au/business-industry/Heavy-vehicles/Excess-mass-and-dimensions/Higher-mass-limits/Higher-mass-limits-maps.aspx
	SA heavy vehicle access	https://www.sa.gov.au/topics/transport-travel-and-motoring/heavy-vehicles/operating-a-heavy-vehicle/heavy-vehicle-access-framework
	TAS transport	http://www.transport.tas.gov.au/__data/assets/pdf_file/0005/108509/Tasmanian_State_Road_Hierarchy.pdf
	NT road report	http://www.ntlis.nt.gov.au/roadreport/
OSM	Public domain data	http://www.openstreetmap.org
RAIL		
Geoscience Australia	National Rail Network	http://www.ga.gov.au/corporate_data/79566/Railways2014_WEB.pdf
Department of Infrastructure	A wide range of rail information	http://www.infrastructure.gov.au/rail/
BITRE	Rail freight performance indicators	https://bitre.gov.au/publications/2010/files/arfpi_2007_08.pdf
PSMA	Rail Network (*Commercial*	http://www.psma.com.au/?product=transport-topography

	Licence)	
ARTC	Australian Rail Track Corporation	http://www.artc.com.au/Content.aspx?p=37
Interstate freight operators	ARG Bulk Freight Pacific National SCT Logistics Queensland Rail Patrick Rail Freightlink South Spur	http://www.aurizon.com.au/ourservices/bulk-freight http://asciano.com.au/pacific-national http://www.sctlogistics.com.au/http://www.queenslandrail.com.au/ http://asciano.com.au/patrickhttp://www.freightlinks.com.au/http://www.southspurrail.tripod.com/ssr/
Intrastate freight operators	Tasmanian Railway Network Pilbara Rail Company	http://www.railtasmania.com/lines/ http://www.pilbararailways.com.au/
Regional passenger operators	V/Line TransWA Great Southern Railways Country Link	http://www.vline.com.au/ http://www.transwa.wa.gov.au/ http://www.greatsouthernrail.com.au/ http://www.nswtrainlink.info/
Australian Rail Maps	Major railway lines and rail services	http://www.railmaps.com.au/austrail.htm
MPT rail operators	Major metro rail Sydney Melbourne Adelaide Perth	http://www.sydneytrains.info/stations/network_map http://www.transport.nsw.gov.au/railcorp http://ptv.vic.gov.au/getting-around/stations-and-stops/metropolitan-trains/ http://www.adelaidemetro.com.au/Timetables-Maps/ http://www.transperth.wa.gov.au/Timetables

	Brisbane	https://www.queenslandrail.com.au/forcustomers/stationsmaps
OSM	Public domain data source	http://www.openstreetmap.org
STRUCTURES		
Department of Infrastructure	List of Australia's major road corridors and distribution hubs	http://investment.infrastructure.gov.au/publications/reports/
BITRE	Road freight capacity figures	http://bitre.gov.au/publications/publications.aspx?query=s:"freight"&link-search=true
ATS	224 existing tunnels and 47 current projects in Australia	http://www.ats.org.au/index.php/resources/tunnelling-databases
State Govt	Vic Roads height clearance under structures for permit vehicles	*https://www.vicroads.vic.gov.au/.../heavyvehiclesheightclearanceunderstr*
	WA Landgate	http://www.landgate.wa.gov.au/corporate.nsf/web/Topographic+Data
	WA Main Roads	https://www.mainroads.wa.gov.au/UsingRoads/HeavyVehicles/Pages/HeavyVehiclesHome.aspx
	ACT bridge weight limits	http://www.tams.act.gov.au/roads-transport/Road_Infrastucture_and_Maintenance/bridges
MPT operators	Capital city MPT interchanges/d	

	epots: Sydney Melbourne Brisbane Canberra Adelaide Darwin Perth Hobart	 http://www.sydneybuses.info/routes http://www.metlinkmelbourne.com.au/timetables http://translink.com.au/travel-information/network-information/maps http://www.action.act.gov.au/rider_Info/maps https://www.adelaidemetro.com.au/Timetables-Maps/ http://www.transport.nt.gov.au/public/interchanges-and-bicycle-enclosures http://www.transperth.wa.gov.au/Timetables http://www.metrotas.com.au/timetables/
Public sourced	Major Australian bridges with construction information	http://en.wikipedia.org/wiki/List_of_bridges
	Road rail bridges	http://en.wikipedia.org/wiki/List_of_road-rail_bridges
	Low bridges	https://www.gps-data-team.info/poi/australia/safety/Low_Bridges_au.html
MARITIME		
GA	Australian Mines Atlas – list of ports	http://www.australianminesatlas.gov.au/mapping/files/ports.xls
Ports Australia	Map of Australian ports	http://www.portsaustralia.com.au/members_list/map.htm
	Imports and exports	http://www.portsaustralia.com.au/aus-ports-industry/trade-statistics/
BITRE	Shipping information	http://bitre.gov.au/statistics/maritime/index.aspx
ATC	Australian container	https://bitre.gov.au/publications/2014/cr_001.aspx

	ports study	
State Govt	NSW maritime QLD Transport WA Transport Tasmania Ports Victoria Transport NT Lands and Planning SA Transport	http://www.rms.nsw.gov.au/maritime/using-waterways/index.html http://www.tmr.qld.gov.au/business-industry/Transport-sectors/Ports.aspx http://www.transport.wa.gov.au/imarine/sea-freight-and-ports.asp http://www.tasports.com.au/ http://economicdevelopment.vic.gov.au/transport/ports http://www.transport.nt.gov.au/public/mandorah-ferry http://www.sa.gov.au/topics/transport-travel-and-motoring/boating-and-marine
State Port Corporations	Flinders Ports North Queensland Bulk Ports Corporation (NQBP)	http://www.flindersports.com.au/portfacilities1.html http://www.nqbp.com.au/
Major port operators	Gladstone Esperance Eden Brisbane Geelong	Individual Port Authorities generally have very detailed information including detailed maps of their port's infrastructure. http://gpcl.com.au/big6/SitePages/maps.aspx http://www.esperanceport.com.au/map-port.asp http://edenport.com.au/port_facilities_and_services https://www.portbris.com.au/property-planning http://www.geelongport.com.au/generalinfo_pl.html
Major port operators	Sydney Geelong	Individual Port Authorities generally have commodity trade figures. http://www.sydneyports.com.au/trade_services/trade_information http://www.geelongport.com.au/downloads.html
Ferry and shipping	Sydney Ferries	Wharf and terminal information: http://www.transportnsw.info/#ferry-status-updates-item-tab

operators	NSW Maritime Brisbane Melbourne	http://www.rms.nsw.gov.au/maritime/index.html http://translink.com.au/ http://www.williamstownferries.com.au/
	Cruise ships Sydney ferry Darwin ferry	http://bitre.gov.au/publications/publications.aspx?query=s:"maritime"&link-search=true http://www.sydneyferries.info/uploads/library/about/Oct%2010%20patronage.pdf https://www.sealinknt.com.au/
AIR		
Air Services Australia	Control tower and runway information	http://www.airservicesaustralia.com/about/our-facilities/
BITRE	Australian Domestic Aviation Activity Annual Publications	http://bitre.gov.au/publications/ongoing/domestic_airline_activity-annual_publications.aspx
	Air transport service trends in regional Australia	http://bitre.gov.au/publications/2012/files/report_130.pdf
Major airport operators	 Sydney Melbourne Brisbane Perth Adelaide Canberra	Maps, facilities, master plans, capacities and other information for Australian capital city airports: http://www.sydneyairport.com.au/corporate/master-plan/master-plan-downloads.aspx http://www.melbourneairport.com.au/About-Melbourne-Airport/Corporate-Information/Facts-Figures.html http://www.melbourneairport.com.au/About-Melbourne-Airport/Corporate-Information/Annual-Reports.html http://bne.com.au/corporate/current-publications http://www.perthairport.com.au/master-plan.aspx http://www.adelaideairport.com.au/corporate/community/adelaide-airport-master-plan/ http://www.canberraairport.com.au/corporate/planning-environment/masterplan/

	Hobart Darwin	http://hobartairport.com.au/corporate/environment-planning/master-plan/ http://www.ntairports.com.au/media-centre/darwin-international-airport-2010-master-plan-approved
Regional airport operators	Gold Coast Cairns Townsville Newcastle Launceston Mackay Sunshine Coast	Most regional operators have websites containing most required information. http://www.goldcoastairport.com.au/ http://www.cairnsairport.com.au/ http://www.townsvilleairport.com.au/ http://www.newcastleairport.com.au/ http://www.launcestonairport.com.au/ http://www.mackayairport.com.au/ http://www.sunshinecoastairport.com.au/
Air Freight Stats	Airport sponsored air freight data.	http://www.airfreightstats.com/ *(restricted license agreement)*

Gaps & Suggestions:

The data on transport infrastructure like road, rail, airports and sea ports is available in the public domain. Geoscience Australia and state jurisdictions maintain location (only) information about the transport infrastructure and facilities. The data provided by these agencies is not comprehensive enough to make decisions and has limited coverage. GA is able to provide the length of transport infrastructure like various types of roads and number of associated facilities.

Road Transport Authorities of various states maintain the data on transport operations and vehicles. This data is not in the public domain, though these agencies provide the data for research purpose but not consistent across the nation.

BITRE provides data about transport activities such as freight and other value chain information. BITRE maintains the subjective information and knowledge of the transport system and sensitivities to assess the impacts. There is much more raw data collected by BITRE and it will be useful for impact analysis on transport value chain and consequences.

However, there is no centralised database to collect, collate, maintain and disseminate the transport exposure information other than the location of assets for emergency service authorities. The framework advices the agencies holding the data can be engaged to release the data. Further strategies are to be prepared to implement the framework, develop the database and deliver under creative commons licensing agreements. There may be a legislative mandate required for the facilities to disclose the information from the above agencies.

5.2 Energy Sector

Modern society relies heavy on large amounts of fuel, and the energy industry is a crucial part of the infrastructure and economy of the nation. It is identified critical and life line of the nation. The energy infrastructure sector consists of the industries involved in the production and distribution of liquid fuels, gas and electricity.

In recent days the devastating impact of natural disasters on the energy sector has been documented (Bucci et al, 2013, Vivoda, 2011) in the literature. For example damages of natural disasters such as hurricanes Sandy, Katrina, Isabel and Irene in US have led to power outages ranging from hours to weeks before full restoration. It is not only the electricity sector that gets affected; there have been severe damages to the petroleum and gas industry from hurricanes on the Mexican bay and during the 2011 earth quakes in Japan. Therefore, it is important to understand the issues and operational challenges of the energy sector during natural disasters such as severe cyclones, floods and earth quakes and to improve resilience of the energy infrastructure. It is required to identify gaps and areas to improve resilience through plans for preparing, responding and recovering from natural disasters. The primary requirement in these initiatives is to develop information storage and a database of the energy sector that details each components of the sector that would help in natural disaster management and planning.

The energy industry comprises primarily liquid fuels, gas and electricity. The liquid fuels industry includes petroleum wells, exploration, production, refiners, transportation and end-user sales at service stations. The gas industry includes natural gas extraction, and coal seam gas manufacturing, distribution and sales. The electrical industry includes power generation, distribution and sales.

5.2.1 Petroleum Well

Petroleum wells are generally used for exploration and production of crude oil or gas. The exploration is also known as hydrocarbon exploration and it is to collect the information about hydrocarbon deposits beneath the earth surface such as oil and gas. As part of this, the companies drill several exploration wells to estimate the hydrocarbon prospective. These wells are very expensive and will carry high risk operations. Sometimes, these wells blowout and hence, pose huge risks to the communities and environment.

For natural disasters exposure information modelling purpose, the following details of the assets suggested as exposure elements.

1. Location
    a) Onshore
    b) Offshore
2. Ownership
    a) Public
    b) Private
    c) Partnership
3. Well Status
    a) Exploration
    b) Drilling
    c) Production
    d) Abandoned/Dead
4. Depth
5. Storage Capacity
6. Platform
7. Value
    a) 10million
    b) 10-100million
    c) 100million

7. Year Built
8. Year Upgraded

5.2.2 Petroleum Refinery

Petroleum refinery is the manufacturing plant where crude oil is processed and refined into petroleum products as petrol, diesel, kerosene, liquefied natural gas, asphalt base etc. Petroleum refineries are very large industrial complexes. They have extensive pipes running throughout and carrying large volumes of chemical. There are usually crude storage tanks and product storage depots at the refinery.

For exposure information purpose different types and components of the Petroleum Refinery are suggested that include:

1. Products
    a) Light Distillates
    b) Middle Distillates
    c) Heavy Distillates
2. Ownership
    a) Public
    b) Private
    c) Partnership
3. Processing units
4. Processing Capacity
5. Associated Facilities
6. Storage Capacity
    a) Crude
    b) Products
    c) Waste
7. Shipping
8. Air Pollutant Monitors
9. Electricity Power Plants
10. Carrying costs
11. Value
12. Year Built
13. Year Upgraded

5.2.3 Petroleum Terminals

Petroleum terminals or oil depots are industrial facilities for the storage of oil and other petrochemical products that are processed and ready for the transport. This typically has tankage and pumping into mobile tankers and pipelines. The import and export terminals have the facilities to handle the marine cargo tankers. This storage facility is also required to be treated as a hazardous substances storage facility. There are also small terminals used as distribution terminals for urban delivery.

For exposure information purpose different types and components of the Petroleum Terminals are suggested that include:

1. Ownership
    a) Public
    b) Private
    c) Partnership
2. Underground
3. Above ground
4. Vicinity
    a) Refinery
    b) Seaport
    c) Airports
    d) Urban Gateways
5. Substances Stored
6. Auxiliary Facilities
7. Total Capacity
8. Capacity utilization
9. Fuel Turnover
10. Year Built
11. Blending Facility
12. Reconstruction Cost

5.2.4 Petroleum Transmission

Petroleum, liquid fuels or crude oil is transported by road, rail or through pipelines from one place to another between wells, refineries, terminals or other end outlets.

For exposure information purpose different types and components of the petroleum transmission process are suggested that include:

1. Pipe Lines
    a) Type
    b) Size
    c) Construction material
    d) Capacity
    e) Year built
    f) Year upgraded
    g) Replacement cost
    h) Rebuilding timeframe
1. Oil Cargo Ships
    a) Material
    b) Capacity
    c) Vessel Cost
2. Ship-Ship transfer
3. Tanker Truck
4. Rail Tanker

5.2.5 Gas Processing

Liquid Petroleum GAS (LPG), Liquid Natural Gas (LNG), Bio-LPG, Coal Seam Gas (CSG) and industrial Gas are by-products of fossil fuel or available from natural sources. All these products are used essentially the same way for cooking, heating and motor fuel. Their contents and calorific values are different. LPG is mostly transported and sold in cylinders whereas LNG is delivered in pipelines for domestic use in Australia. Industrial gas is a group of materials that are specifically manufactured for use in industry and are also gaseous at ambient temperature and pressure. In the exposure framework, all these products are considered as gas.

Gas is produced during petroleum (crude oil) refining or extracted as natural gas streams as they emerge from the ground. Gas processing is a component in petroleum refinery or extracted directly from the wells.

There are three LNG projects operating in NW Shelf and Pluto from Carnarvon Basin in West Australia and Darwin LNG in Northern Territory from Bonepart Basing. LNG

facility at Curtis Island will turn CSG into LNG to export. The CSG is transported through pipelines from CSG field in Queensland.

For exposure information purpose different types and components of the Gas Processing sector are suggested that include:

1. Ownership
    a) Public
    b) Private
    c) Partnership
2. Products
    a) LPG
    b) LNG
    c) CSG
3. Industrial Gas
4. Processing units
5. Processing Capacity
6. Associated Facilities
7. Storage Capacity
    a) Crude
    b) Products
    c) Waste
8. Liquefaction Plants
9. Shipping Facility
10. Electricity Power Plants
11. Carrying costs
12. Year Built
13. Reconstruction Cost

5.2.6 Gas Transmission

Gas is compressed and transported by road, rail or through pipelines from gas processing facility to the end user. The crude oil or the gas is also transferred through pipelines to the processing plants. For exposure information purpose different types and components of the gas transmission process are suggested that include:

1. Pipe Lines

a) Ownership
b) Type
c) Size
d) Construction material
e) Capacity
f) Year built
g) Year upgraded
h) Replacement cost
i) Rebuilding timeframe

2. Gas Cargo Ships
    a) Ownership
    b) Material
    c) Capacity
    d) Vessel Cost
3. Ship-Ship transfer
4. Tanker Truck
5. Rail Tanker
6. Retail Cylinders

5.2.7 Gas Storage

In a refinery or gas plant, LPG is stored in pressure vessels. These containers are either cylindrical and horizontal or spherical. In order to transport it, LPG needs to be placed under modest pressure to form a liquid. It can then be stored and transported in LPG cylinders.

LNG is transported through pipelines from its source or a refinery to the city gateways. LNG is further distributed through pipelines for domestic use in many urban areas in Australia. LNG terminals are purpose-built ports used exclusively to export or import LNG. For exposure information purpose different types and components of the gar storage process are suggested that include:

1. Ownership
2. Storage Tank
    a) External Wall Type
    b) Internal Wall Type

c) Capacity

d) Compression Ratio

3. Cylinders Storage
    a) Size of Cylinders
    b) Number of Cylinders
    c) Fill Facility
4. Auxiliary Facilities
    a) Reliquefaction Facility
    b) Blending Facility
5. Total Capacity
6. Capacity utilization
7. Fuel Turnover
8. Year Built
9. Reconstruction Cost

5.2.8 Petrol Service Stations

Petroleum service stations are the customer end contact point of the petrol distribution chain and are the retail stores. The facility is to sell fuel and lubricants to automobiles. They have other ancillary business such as selling motor vehicle accessories or parts; food, drinks and other convenience goods; hiring of trailers; servicing or washing of motor vehicles; and installing of motor vehicle accessories or parts.

For exposure information purpose different types and components of the Petrol Service Stations are suggested that include:

1. Ownership
2. Site Category
    a) Super sites
    b) Primary sites
    c) Neighborhood sites
    d) Marginal sites
3. Tank Construction Material
    a) Steel
    b) Fibre Glass

4. Tank Year built/replaced
5. Number of Pumps
6. Auxiliary Facilities
    a) Convenience Store
    b) Fast Food Outlets
    c) Car wash
    d) Workshop
7. Capital Value
8. Fuel Turnover
9. Reconstruction Cost

5.2.9 Electricity Generation

The electricity generation is the process of generating power from coal industry, the nuclear power industry, the renewable energy industry comprising alternative energy including hydroelectric power, wind power, and solar power. Electricity is most often generated at a power station by electromechanical generators, primarily driven by heat engines fueled by chemical combustion or nuclear fission but also by other means such as the kinetic energy of flowing water and wind.

For exposure information purpose different types and components of the electricity generation process are suggested that include

1. Ownership
    a) Public
    b) Private
    c) Partnership

2. Generation Type
    a) Coal Thermal
    b) Gas Thermal
    c) Diesel Engines
    d) Hydro
    e) Nuclear
    f) Wind
    g) Solar

h) Others

3. Storage
    a) Type
    b) Capacity
4. Material Stackers
5. Conveyors
    a) Type
    b) Length
6. Boilers
7. Generators
    a) Type
    b) Number
8. Transformers
9. Cooling towers
    a) Type
    b) Number
    c) Size
    d) Height
10. Chimneys
11. Water Supply
12. Switch Yard
13. Auxiliary Facilities
14. Generation capacity
    a) Base load power
    b) Peaking power
15. Year Built
16. Reconstruction Cost

5.2.10 Electricity Transmission

Electric-power transmission is the bulk transfer of electrical energy, from electricity generation plants to substations located near demand centers. Transmission lines are interconnected and become transmission networks. The combined transmission and distribution network is known as the power grid.

Most transmission lines are high-voltage three-phase or single phase (railway electrification systems). High-voltage direct-current (HVDC) technology is used for greater efficiency at for long distance services, in submarine power cables, and in the interchange of power between grids. HVDC links are also used to stabilize and control problems in large power distribution networks where sudden new loads or blackouts in one part of a network can otherwise result in synchronization problems and cascading failures.

For exposure information purpose different types and components of the electricity transmission process are suggested that include:

1. Ownership
    a) Public
    b) Private
    c) Partnership
2. Transmission Lines
    a) Overhead
    b) Underground
3. Insulation
4. Circuit Breakers
5. Voltage Capacity
    a) High Voltage AC
    b) High voltage DC
    c) Subtransmission
    d) Single Phase
6. Carrying Capacity
7. Year Built
8. Reconstruction Cost

5.2.11 Electricity Transmission Towers

Transmission tower is the main support for the overhead transmission lines. Transmission towers carry the heavy transmission conductor at a sufficient safe height from ground. In addition to that all towers weather and sustain all kinds of natural calamities. So transmission towers are vulnerable to natural hazards and lead to indirect losses on economy and communities.

For exposure information purpose different types and components of the Electricity Transmission towers are suggested that include:

1. Tower Ownership
2. Year Built/Upgraded
3. Tower Foundation
4. Site Topography
5. Height of Tower (Peak)
6. Height of Tower (Cage)
7. Height of Tower (Body)
8. Width of Tower (Cross Arm)
9. Number of Circuits
10. Type of Conductors
11. Tower Types
    (a) Tangent
    (b) Angle
    (c) River Crossing
    (d) Railway Crossing
    (e) Transposition
    (f) Utility Pole
12. Tower Design
13. Tower Materials
14. Dead-end Tower
15. Distribution Network Coverage
16. Reconstruction Cost

5.2.12 Electricity Transmission poles

Transmission poles are the main support for the overhead electricity low voltage distribution lines, transformers, street lights and other cables. For exposure information purpose different types and components of the Electricity Transmission poles are suggested that include:

1. Pole Type
2. Pole Usage
3. Pole Materials
4. Pole Height
5. Power Equipment

6. Dead-end Poles
7. Pole Route
8. Population distribution Coverage
9. Reconstruction Cost

5.2.13 Electricity Substations

Electricity substations are where electricity lines are connected, switched and voltage is changed by transformers for end user usage. They range from the very large to the very small and change the voltage from low to high or the reverse.

For exposure information purpose different types and components of the electricity substations are suggested that include:

1. Ownership
2. Substation Types
    a) Transmission
    b) Distribution
    c) Collector
    d) Converter
    e) Switching
3. Substation Usage
    a) National Grid
    b) Sealing End
    c) Intermediate
    d) Distribution
4. Substation Design
5. Height
6. Equipment
7. Total Capacity
8. Population Distribution Coverage
9. Year Built/Upgraded
10. Reconstruction Cost

Existing Capabilities:

Geoscience Australia provides spatial location of several energy infrastructure assets in Australia. The infrastructure data collected, collated and provided by GA includes

power stations, sub-stations, transmission towers, transmission lines, gas pipelines, refineries, fuel terminals/depots and petrol stations. But these datasets are not comprehensive enough to provide the exposure information.

There are several other organisations or private companies that hold the data and release through reports. The following table provides a comprehensive list of information sources of energy sector.

Data Source	Data Description	Web Link
ELECTRICITY		
Australian Energy Market Operator (AEMO)	Lists power stations and capacities for each National Electricity Market (NEM) state	http://www.aemo.com.au/Electricity/Data
	List of non-scheduled power stations, including energy source and capacity for the NEM	http://www.aemo.com.au/Electricity/Data
	Numerous diagrams of electricity and gas infrastructure	http://www.aemo.com.au/Electricity/Data http://www.aemo.com.au/Gas/Market-Data
Powerlink	North Qld network map	https://www.powerlink.com.au/Network/
	South Qld network map	https://www.powerlink.com.au/Network/
Transgrid	Relevant NSW network maps	https://www.transgrid.com.au/what-we-do/our-network/Pages/default.aspx
NSW State	EICU - Restricted Access	http://www.lpi.nsw.gov.au/about_lpi/eicu
AER	SP AusNet transmission determination	https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/ausnet-services-sp-ausnet-determination-2014-17
ESC	Distribution level data but some links to transmission	http://www.esc.vic.gov.au/Accessibility
Electra-Net	State wide network map (SA)	http://www.electranet.com.au/network/network-maps-and-statistics/
	Metropolitan network map (SA)	http://www.electranet.com.au/network/network-maps-and-statistics/

Western Power	Network map (WA)	http://www.westernpower.com.au/corporate-information-network-data.html
PAWA	Power and Water (NT)	http://www.powerwater.com.au/
Transend	State wide network map	http://www.tasnetworks.com.au/our-network
GAS		
Relevant Information Sources	ACCC AER AEMC IPART ERA	http://www.accc.gov.au/about-us/ Australian Energy Regulator Australian Energy Market Commission Independent Pricing and Regulatory Tribunal of NSW Economic Regulation Authority of WA
State Departments	Federal NSW WA QLD VIC NT SA	www.environment.gov.au www.planning.nsw.gov.au www.energy.wa.gov.au www.coordinatorgeneral.qld.gov.au www.nrw.qld.gov.au www.energy.qld.gov.au www.invest.vic.gov.au www.dse.vic.gov.au www.nt.gov.au www.pir.sa.gov.au http://www.infrastructure.sa.gov.au/
Compressors		https://www.seagas.com.au/portfolio/the-pipeline/ http://www.gasnet.com.au/ http://www.marshallday.com/ http://www.pir.sa.gov.au/ ACCC draft decision NT gas pty ltd proposed access arrangement for the Amadeus Basin to Darwin pipeline system(2 May 2001).pdf Amadeus Basin to Darwin Pipeline Access Arrangement Information (MJM90625NTAAINFO.rtf) http://www.ntgas.com.au/ Pipeline Access Arrangement, Attachment 1 (PipelineMaps) 7 May 1999 Goldfields Gas Pipeline Access Arrangement, Attachment No.1:

		Pipeline Maps, 15 December 1999 Goldfields Gas Transmission Joint Venture, Goldfields Gas Pipeline Estimated Replacement Cost, October 21, 2004 DampiertoBunburyGasTransmissionSystem.pdf http://www.ncc.gov.au/ http://www.marshallday.com/ http://www.ferret.com.au/ http://minister.industry.gov.au/ http://www.atns.net.au/agreement.asp?EntityID=687
Storage	NSW	http://www.elgas.com.au/
PETROLEUM		
Exploration	PEDINGA	Petroleum and Greenhouse Gas Advice Group
Location	Oil and Gas Infrastructure portal	http://www.oilandgasinfrastructure.com/home/oilandgasoceania/australia
Processing		http://www.asicc.com.au/ http://www.abareconomics.com/research/energy/ http://www.conocophillips.co.uk/Pages/default.aspx https://alintaenergy.com.au/home http://www.originenergy.com.au/files/ http://www.arrowenergy.com.au/ http://www.nigc.gov/ http://www.alpga.asn.au/ http://www.santos.com/ http://www.bhpbilliton.com/ http://www.ncc.gov.au/ http://www.chemlink.com.au/ https://www.engineersaustralia.org.au/sites/default/files/shado/Infrastructure%20Report%20Cards/Australian/2010%20Australian%20IRC%20Report.pdf

		http://www.industry.gov.au/Office-of-the-Chief-Economist/Pages/default.aspx https://www.pesa.com.au/technical-library/ http://www.industry.gov.au/resource/upstreampetroleum/Pages/default.aspx http://www.bhpbilliton.com/investors/reports/2015-annual-reporting-suite http://www.lngplants.com/conversiontables.htm http://www.appea.com.au/?s=Industry+information http://www.environment.gov.au/ http://www.pdc.wa.gov.au/ https://www.oilonline.com/news http://www.santos.com/ http://www.awexplore.com/irm/content/home.html http://pipeliner.com.au/
Petrol Stations	GA	https://data.gov.au/dataset/national-petrol-stations-database
Pipelines	GA	National Geographic Information Branch GPInfo Pipelines dataset
	Australia Map	http://pipeliner.com.au/pipeline_map_of_australia/

Gaps & Suggestions:

Some of the energy infrastructure like liquid fuels and electricity assets/facilities locations data is available with Geoscience Australia, spatial data providers from state jurisdictions and the industry. Sometimes the data is release in the form of annual reports. The data provided by these agencies cannot be used to make decisions on disaster risk reduction and often has limited coverage. GA – NEXIS summarises and provides the length of transmission lines, power stations etc. for disaster management authorities.

The exposure information about these facilities and knowledgebase is available with the service providers and private companies. The information is available in their reports and there is no provision to provide the data from these companies. Some of the data is considered as commercial-in-confidence.

There is no centralised database to collect, collate, maintain and disseminate the energy sector exposure information other than the location data for emergency service authorities. This framework identifies that the agencies holding the data can be engaged to release for the development of *the National Disaster Management Database*. Further strategies are to be prepared to implement the framework, develop the database and deliver under creative commons licensing agreements. There may be requirement for a legislative mandate that would facilities to disclose the information from the private companies.

5.3 Communications Sector

The communications infrastructure component considers the services of telephones, mobile services, internet, national broadband network, international submarine cables, broadcasting (mass communication) and postal services. Australia's national security, community safety, economic prosperity and social wellbeing increasingly rely on telecommunications networks. This sector supports the businesses, individuals and public sector to do their business efficiently and is highly critical in response to emergency management. Proper disaster continuity planning is essential to ensure continued delivery of vital messages to community during emergency situation and it is important to have information on the situation of communication assets at a particular location.

5.3.1 Telephone exchanges

The technology of telecommunication sector is changing rapidly from analogue into digital. The telephone exchanges are the hubs to connect the landline telephones through cabling networks. Telephone exchange is located as a central facility, typically a building is used to house the equipment of potentially several telephone exchanges, each serving a certain geographical exchange area. The location of the telephone exchange is highly critical to keep the service live during natural disasters.

Consequently, following are some of the important information requirements on telephone exchanges are suggested that are critical for disaster management.

1. Ownership
2. Area of coverage
3. Capacity
    a) Frequency (Broadband, ADSL 1, ADSL 2)
    b) Switches
    c) Internet
    d) Number of lines
4. Year Built
5. Equipment
    a) Year
    b) Value
6. Rebuilding Timeframe
7. Reconstruction Cost

5.3.2 Telephone Cable Network

The telephone network is a cable connecting all end users with a telephone exchange. The cable may be using a copper or fibre wire and the network is overhead or underground. The cables may be for a direct connection between exchanges. Following are some of the important information requirements on telephone cable network are suggested that are critical for disaster management.

1. Ownership
2. Telephone line
3. Switch nodes
4. Materials (Coper/Fibre)
5. Year Built
6. Rebuilding Timeframe
7. Reconstruction Cost

5.3.3 Communication Towers

Communication tower is the main support for the overhead transmission antenna or lines. Communication towers carry the heavy transmission conductor at a sufficient

safe height from ground. Natural disasters could have significant impact on communication towers and lead to severe impacts on communities and economy. Following are some of the important information requirements on communication towers are suggested that are critical for disaster management.

1. Ownership
2. Tower Foundation
3. Site Topography
4. Tower Purpose
5. Height of Tower (Peak)
6. Tower Design
7. Tower Materials
8. Year Built
9. Rebuilding Timeframe
10. Reconstruction Cost

5.3.4 Submarine Cable

The submarine cable is laid on the sea bed between land based stations to carry telecommunication signals across stretches of ocean. As of 2006, 99 percent of international communication traffic is through submarine cables. The total carrying capacity of these cables is in terabits per second while satellites offer 1GBPS. Construction of these networks is highly expensive and it is vital for national economy. So, it is important to store and manage information on submarine cables for disaster management purpose.

Following are some of the information requirements are suggested that are critical for disaster management.

1. Ownership
2. Submarine Cable Network
3. Cable Landing Station
4. Frequency/Bandwidth
5. Cable Type
6. Cable Capacity
7. Offshore Destination
8. Year Built

9. Rebuilding Timeframe
10. Reconstruction Cost

5.3.5 Broadcasting

Broadcasting is the distribution of audio and/or video content to a wider audience through mass communications media using the electromagnetic spectrum (radio waves). There are several methods used for broadcasting electronic media to the general public, they include radio, television, cable broadcasting, satellite broadcasting, webcasting and datacasting. With the emergence of internet the social media is quite popular in broadcasting the information.

Radio broadcasting is a one-way wireless transmission over radio waves whereas television broadcast using video signals intended to reach a mass audience. Stations can be linked in radio networks to broadcast common formats, either in broadcast syndication or simulcast or both. So, it is important to store and manage information on broadcasting infrastructure for disaster management purpose.

Following are some of the identified information requirements are suggested that are critical for disaster management.

1. Broadcasting Type
2. Ownership
3. Purpose
    a) Community
    b) Commercial
    c) Private (Hospital, Campus)
    d) Digital
    e) Satellite
    f) Internet
    g) SMS Services
4. Site Name
5. TV Station
6. Radio station
7. Studio Facilities
8. Coverage Area
9. Frequency

a) AM

b) FM

10. Equipment
11. Cable Networks
12. Rebuilding Timeframe
13. Reconstruction Cost

5.3.6 Satellite Earth Stations

A ground/earth station is a terrestrial radio station designed for extra planetary telecommunication with spacecraft, or reception of radio waves from an astronomical radio source. Earth stations communicate with spacecraft by transmitting and receiving radio waves in the super high frequency or extremely high frequency bands. When a ground station successfully transmits radio waves to a spacecraft (or vice versa), it establishes a telecommunications link. A principal telecommunications device of the ground station is the parabolic antenna. So, it is important to store and manage information on Satellite Earth Stations for disaster management purpose.

Following are some of the information requirements are suggested as exposure elements for disaster management.

1. Ownership
2. Type of Antenna
3. Number of Antennas
4. Size of Antenna
5. Capacity
6. Equipment
7. Construction Material
8. Year Built
9. Rebuilding Timeframe
10. Reconstruction Cost

5.3.7 Postal / Courier

With the emergence of digital telecommunications, the postal services are less important but, critical for the disaster risk reduction. The courier services will be

delayed and can be resumed once the communities/businesses are back on track. The following facilities are considered as exposure elements in this category.

1. Ownership
2. Mail Sorting Centres
3. Delivery Vehicles

In addition to capturing and storing inherent spatial location information (geometry) for each communication infrastructure asset (spatial feature), data tables and attributes should be structured to best represent the above information.

Existing Capabilities:

Australian Communications and Media Authority (ACMA) provide comprehensive information on communications infrastructure, operations and regulations in Australia. The data needs to be cleaned and customised for the end user purpose. Geoscience Australia has collected the data from ACMA and through other sources and provides spatial location of several infrastructure assets in Australia. But these datasets are not comprehensive enough to provide as exposure information for disaster risk reduction research and response.

There are several other organisations or private companies that hold the data but, it is commercial-in-confidence or restricted due to security reasons. The following table provides a comprehensive list of information sources of communications sector available in public domain.

Data Source	Data Description	Web Link
TELECOMMUNICATIONS		
Telstra	Huge amount of operational information including key site locations and MPLS technology	http://telstrawholesale.com.au/products/product-roadmap/prod-roadmap.htm https://www.telstra.com.au/business-enterprise
Optus	Information about major terrestrial and satellite infrastructure	http://www.optus.com.au
ACMA	Submarine cable protection zones	http://www.acma.gov.au/
Alcatel	Global submarine cable map	https://www.alcatel-lucent.com/solutions/submarine-networks http://submarine-cable-map-2015.telegeography.com/

Operators	Each of the cable operators have annual reports (generally posted on the ASX) that describes their infrastructure	http://www.southerncrosscables.com/home/network/overviewandmap
General	Submarine cables	http://en.wikipedia.org/wiki/List_of_international_submarine_communications_cables
	Global submarine cable landing stations	http://www.kidorf.com/DBLandings.php
	Telephone exchange locations	http://whirlpool.net.au/wiki/Australian_Exchange_Guide
	ADSL2 exchanges	http://www.adsl2exchanges.com.au/
NBNCO	National broadband network information	http://www.nbnco.com.au/learn-about-the-nbn.html
RFNSA	National mobile phone tower information	http://www.rfnsa.com.au/nsa/index.cgi
BROADCAST		
NGIG	GA's Towers Database. RAAF have a vested interest in this database by funding GA to do this work on their behalf	
ACMA	RADCOM database is a register of radiocommunications licences	http://web.acma.gov.au/pls/radcom/register_search.main_page
	List of licensed radio and TV broadcasting transmitters	http://www.acma.gov.au/Citizen/Consumer-info/Broadcasting-in-my-area/Lists-of-broadcasters/licensed-broadcaster-listings-broadcasters-list-i-acma
Operators	ABC lists all broadcast services and their transmission towers	http://www2b.abc.net.au/reception/frequencyfinder/asp/results.asp
	SBS annual report and website list all radio and TV services and transmitters	http://www.sbs.com.au/shows/aboutus/tablistings/detail/i/2/article/4952/Annual-Reports http://www.sbs.com.au/blog/119042/Enjoying-the
	All commercial radio frequencies	http://www.commercialradio.com.au/find-a-station
POSTAL		
Australia Post	Locations of mail sorting and distribution centres	

Gaps & Suggestions:

Some of the communication sector infrastructure assets and facilities location data is available with ACMA and Geoscience Australia. The data provided by these agencies is not comprehensive enough to make decisions on disaster risk reduction and has limited attribute coverage. GA – NEXIS summarises and provide the number of assets aggregated for a given area for disaster management authorities.

The exposure information about these facilities and knowledgebase is available with the service providers and private companies. The information is available in their reports and there is no provision to acquire the data from these companies. Some of the data is considered as commercial-in-confidence and also national security.

There is no centralised database to collect, collate, maintain and disseminate the communication sector exposure information other than the spatial location for emergency service authorities. Further strategies are to be prepared to implement the framework, develop the database and deliver under creative commons licensing agreements. There may be a legislative mandate required for the companies to disclose the information from the above agencies.

5.4 Urban Water Supply & Sanitation Sector

Urban Water supply and sanitation is the provision of water by public utilities and commercial agencies for the domestic and industrial use, usually via a system of pumps and pipes. Irrigation for agriculture is not covered in this section.

Provision of clean water supply with high standards of sanitation is the most important public health concern. Damage and disruption of water supply and sanitation infrastructure following major catastrophes including earthquakes, floods and human threats poses very high risk of public health hazards with escalating epidemics of life threatening waterborne diseases.

Collating, storing and maintaining inherent spatial location information (geometry) for each water infrastructure asset (spatial feature) is an important requirement for disaster management, response and recovery. Also, data tables and attributes should be structured to best represent the required information.

5.4.1 Potable Water Catchment

Water supply systems get water from a variety of sources after appropriate treatment, including surface water (lakes and rivers), the sea through desalination and groundwater (aquifers). The water treatment steps include, in most cases, purification, disinfection through chlorination and sometimes fluoridation. Treated water then either flows by gravity or is pumped to reservoirs, which can be elevated such as water towers or on the ground.

For exposure information purpose different types and components of the portable water catchment process are suggested as exposure elements that include:

1. Catchment (area)
2. Dams
    a) Foundation
    b) Length
    c) Type
    d) Spillway type
    e) Construction Material
    f) Year Built
    g) Replacement Value
    h) Height
    i) Storage Capacity
    j) Rebuilding Timeframe
3. Ground Water Well
    a) Well Depth
    b) Well Type
    c) Well Capacity
    d) Storage Capacity
    e) Year Built
    f) Replacement Value
    g) Rebuilding Timeframe
4. Criticality
5. Equipment
    a) Pumping
    b) Repair Timeframe

6. Storage Tanks/Reservoirs

5.4.2 Potable Water Treatment

Water treatment is the removal of contaminants from water collected from catchments or desalination to produce drinking water that is pure enough for the most critical of its intended uses. Substances that are removed during the process of drinking water treatment include suspended solids, bacteria, algae, viruses, fungi, minerals such as iron, manganese and sulfur, and other chemical pollutants such as fertilizers. Measures taken to ensure water quality not only relate to the treatment of the water, but to its conveyance and distribution after treatment as well.

For exposure information purpose different types and components of the portable water treatment process are suggested as exposure elements that include:

1. Storage Tank
    a) Ownership
    b) Size
    c) Foundation
    d) c) Construction
    e) d) Year Built/Upgrade
    f) e) Rebuilding Timeframe
2. Equipment
    a) Clarification Plant
    b) Filtration Plant
    c) Disinfection Plant
    d) Desalination
    e) SCADA Facilities
    f) Repair Timeframe
3. Reconstruction Cost

5.4.3 Waste Water Treatment Plants

Waste water treatment is the process of removing contaminants from wastewater, primarily from household sewage. It includes physical, chemical, and biological processes to remove these contaminants and produce environmentally safe treated wastewater. A by-product of waste water treatment is usually a semi-solid waste or

slurry, called sewage sludge that has to undergo further treatment before being suitable for disposal or land application. The sewer system will also carry industrial effluent to the waste water treatment plant which has usually received pretreatment at the factories themselves to reduce the pollutant load.

The treated water will be called as grey water or black water and it is permitted to be used for gardening or flushing toilets.

For exposure information purpose different types and components of the waste water treatment plants are suggested as exposure elements that include:

1. Ownership
2. Storage Tank
    a) Size
    b) Foundation
    c) Construction
3. Aeration Tank
    a) Size
    b) Foundation
    c) Construction
4. Sludge Tank
    a) Size
    b) Foundation
    c) Construction
5. Methane Gas Chamber
    a) Size
    b) Construction
6. Equipment
    a) Machinery
    b) Disposal
    c) Energy
    d) Odor
    e) Disinfection
    f) Bio-chemical
    g) Filtration

7. Repair Timeframe
8. Reconstruction Cost

5.4.4 Water Transmission Networks

Water transmission works through pipelines from the dams to a storage reservoir and then continued into the distribution networks. Water supply will be based on gravity or pumping facilities to pressurize the water for high rise buildings.

Once water is used, wastewater is typically discharged in a sewer system and treated in a waste water treatment plant before being discharged into a river, lake or the sea or reused for landscaping, irrigation or industrial use. Waste water can be treated close to where the sewage is created or alternatively, sewage can be collected and transported by a network of pipes and pump stations to a municipal treatment plant.

For exposure information purpose different types and components of the water transmission network are suggested as exposure elements that include:

1. Ownership
2. Reticulation Area
3. Reticulation Type
    a) Potable
    b) Storm Water
    c) Waste Water
    d) Recycled Water
    e) Multiple
4. Pumping Stations
5. Pipes Network
6. Pipes Size/Diameter
7. Pipes Material
8. Filtering
9. Connectors
10. Year Built/Upgraded
11. Repair Timeframe
12. Reconstruction Cost

Existing Capabilities:

Data is available for water supply catchments, dams and natural networks via the Australian Hydrological Geospatial Fabric (the Geofabric) managed by the Bureau of Meteorology with assistance from Geosciences Australia, Australian National University (ANU), CSIRO and the States and Territories. But this data is useful for rural water supply for agriculture or for catchment. This does not cover the urban water infrastructure or supply.

The availability of water sector data in the public domain (on-line) is very limited, if any, relevant urban water sector data readily available in the public domain (reports, websites, etc). However certain data sourced from water services corporations may be available, by agreement, for distribution in the public domain in some processed and/or aggregated form. The custodians of some of the public domain datasets are listed below:

Data Source	Data Description	Web Link
Water		
GA & BOM	Geofabric	http://www.bom.gov.au/water/npr/index.shtml
ANCOLD	Australian National Committee on Large Dams	http://www.ancold.org.au/
ACTEW	Water Supply & Recycle in ACT	
Sydney Water	Spatial Data Dam Capacities Catchment Boundaries Weirs, Filtration, Recycle, desalination Contacts	http://www.waternsw.com.au/water-quality/catchment http://www.waternsw.com.au/supply/dam-levels/greater-sydneys-dam-levels http://www.waternsw.com.au/supply/Greater-Sydney/system http://www.waternsw.com.au/about/contact
Hunter	Dam Capacity, Water	http://www.hunterwater.com.au/Water-and-

Water	Supply, Waste Water Systems, Recycling, Storm Water.	Sewer/Water--Sewer.aspx
NSW Environment	Catchment Management Authority	http://www.hunterwater.com.au/Water-and-Sewer/Water--Sewer.aspx
EICU	Water Utilities	
QLD Urban Utilities	Water Utilities	http://www.urbanutilities.com.au/
SEQ Water	Dam Capacity, Water Supply, Waste Water Systems, Recycling, Storm Water.	http://www.seqwater.com.au/water-supply
SUN Water	Dam Capacity, Water Supply, Waste Water Systems, Recycling, Storm Water.	http://www.sunwater.com.au/
Melbourne Water	Dam Capacity, Water Supply, Waste Water Systems, Recycling, Storm Water.	http://www.melbournewater.com.au/waterdata/Pages/waterdata.aspx
Victoria Councils	Barwon Water Central Highlands Water City West Water Coliban Water East Gippsland Water GWNWater Gippsland Water Goulburn Valley Water Lower Murray Water North East Water South East Water	

	South Gippsland Water Wannon Water Western Water Westernport Water Yarra Valley Water	
Water Corporation of WA	Need to explore	https://www.watercorporation.com.au/water-supply-and-services/rainfall-and-dams
SA Water	Need to explore	https://www.sawater.com.au/community-and-environment/our-water-and-sewerage-systems
TasWater	Need to explore	http://www.taswater.com.au/Community---Environment
Power & Water Corporation	Northern Territory Utilities - Need to explore	https://www.powerwater.com.au/networks_and_infrastructure/water_services

Gaps & Suggestions:

Location of urban water supply and waste water infrastructure data is available with the respective utilities authorities or companies. The jurisdiction authorities provide the standards, regulation and catchments. The data provided by the water supply agencies is not comprehensive enough to make decisions on disaster risk reduction and has limited coverage as there are no centralised databases.

The exposure information about these facilities and knowledgebase is available with the service providers and private companies. The information available on the websites and in the reports is very limited and there is no provision comprehensive exposure data from these companies. Some of the data is considered as commercial-in-confidence.

Strategies are to be prepared to implement the framework, develop the database and deliver under creative commons licensing agreements. A legislative mandate may be required for the private companies to disclose the information.

5.5 Waste Management Sector

The waste management sector consists of collection, transport, treatment and disposal of waste activities. This is also considers prevention of production, reuse and recycling of waste. The waste materials are generated from urban (residential, commercial and institutional), agricultural, healthcare, hazardous waste and sewage.

The waste is considered as exposure to the natural hazards and risk to the communities and environment. When the waste materials are exposed to floods, storm surge or other natural hazards and mixed with the water is highly dangerous to the human health, environment and aesthetics.

The Asbestos Safety and Eradication Agency provides national focus on asbestos issues which goes beyond workplace safety to encompass environmental and public health concerns. The agency aims to ensure asbestos issues receive the attention and focus needed to drive change across all levels of government.

The waste management infrastructure component of the framework categorises assets suggested as follows:

1. Collection Centres
2. Transfer Stations
3. Collection Trucks
4. Incineration Plants
5. Recycling Plants
6. Landfills
7. Waste type
8. Energy Recovery Facility
9. Reconstruction Cost

NB: Water sewerage facilities are covered as part of water sector infrastructure

Existing Capabilities:

A small amount of Waste Management Sector data is publicly available. Each State and Territory government website lists (partially) landfills, waste transfer and reprocessing sites. Most of the specific information, including hazardous waste sites is held at the State or Local Government level or with industry bodies. The following is a list of known sources of waste management information.

Data Source	Data	Web Link

	Description	
SOLID WASTE		
Department of Environment	National Waste Reporting 2013 and other documents	http://www.environment.gov.au/resource/national-waste-reporting-downloads
WMAA	WMAA landfill survey for GA	http://www.impactenviro.com.au/waste2013/wmaa.html
CSIRO	Australian Waste Database including both solid and hazardous waste	http://www.greenfinder.com.au/Recycling-and-Waste/Australian-Waste-Database
State Govt	Environmental Protection Agencies of States and Territories	http://www.tams.act.gov.au http://www.ntepa.nt.gov.au/ http://epa.tas.gov.au/epa/ http://www.epa.vic.gov.au http://www.der.wa.gov.au/
Local Govt	Local Council websites lists their landfill facilities information. example: Swan Hill	http://www.swanhill.vic.gov.au/environment-and-waste/waste-and-recycling/
HAZARDOUS WASTE		
SEWPaC	Hazardous Waste Act and relevant data	https://www.environment.gov.au/protection/hazardous-waste
CSIRO	Australian Waste Database including both solid and hazardous waste	http://www.greenfinder.com.au/Recycling-and-Waste/Australian-Waste-Database
Asbestos Safety and Eradication Agency	National Asbestos Exposure Register	https://asbestossafety.gov.au/national-asbestos-exposure-register

Gaps & Suggestions:

Waste Management Association of Australia (WMAA) is peak waste industry body and has most of the waste management businesses are members of this association. WMAA conducts survey of the landfill facilities and their activities regularly. Geoscience Australia has collected and collated the waste management sites information from WMAA, Environmental Protection Agencies from various jurisdictions and Department of Environment. The exposure elements are required to be added to the existing datasets and provide consistent information.

5.6 Hazardous Substances

Hazardous material facilities contain substances that can pose significant hazards because of their toxicity, radioactivity, flammability, explosiveness or reactivity. Significant casualties or property damage could occur form a small number or even a single hazardous materials release induced by natural hazards. Extremely hazardous substances (EHS) can be released accidentally as a result of chemical spills, industrial explosions, fires, or accidents involving railroad cars and trucks transporting them. Workers and residents in communities surrounding industrial facilities where EHS are manufactured, used, or stored and in communities along the nation's railways and highways are potentially at risk of being exposed to airborne EHS during accidental releases. The consequence can vary greatly according to the type and quantity of substance released, meteorological conditions and timeliness and effectiveness of emergency response.

Example: In the Bhopal disaster of 1984, approximately 2,000 residents living near a chemical plant were killed and 20,000 more suffered irreversible damage to their eyes and lungs following accidental release of methyl isocyanate. The toll was particularly high because the community had little idea what chemicals were being exposed at the plant, how dangerous they might be, or what steps to take in an emergency. This tragedy served to focus international attention on the need for governments to identify hazardous substances and to assist local communities in planning how to deal with emergency exposures.

The information on hazardous substances is highly critical for the safety of emergency workers and managers when respond to disasters/crisis. There may be simple acts can save lives of several people and their future health conditions. For example, in the Bhopal Disaster, the instructions to breathe through a wet cloth and walk opposite

direction to the wind could have saved many lives. Comprehensive information of the substances, impacts and mitigation strategies would enable the authorities to reduce the risk to the communities significantly.

In response to disaster risk reduction, the hazardous substances are considered as elements of risk from natural hazards. The exposure information capabilities need to collect, collate, maintain and provide for disaster management. The following attribute information is critical for disaster risk reduction for all levels of governance and in all phases.

1. Facility location
2. Facility name
3. Facility Structure (see buildings framework)
4. Facility usage
    a. Manufacturing
    b. Storage
    c. Transportation
    d. Emission in air/water/underground.
    e. Treatment plants
    f. Retail
    g. Asbestos Materials
    h. Others
5. List of substances
6. Substance physical characters
7. Substance chemical characters
8. Airborne concentration thresholds
9. Pictogram code
10. Pictogram Image
11. Hazard statement code
12. Hazard statement
13. Hazard character
    a. Explosive
    b. Radioactive
    c. Flammable

d. Oxidising
e. Gases under pressure
f. Corrosive
g. Acute toxicity
h. Health hazard
i. Chronic health hazard
j. Environmental

14. Severity of toxicity
    a. Acute lethal
    b. Non lethal
15. Symptoms when exposed
16. Critical support/suggestions when exposed by humans

Existing Capabilities:

Safe Work Australia has developed "Hazardous Substances Information System (HSIS)" that provides information on hazardous substances and classification. HSIS provides searchable access to two data sets, one for hazardous substances and the other for exposure threshold standards information. HSIS also provides access to consolidated lists of all substances included in the hazardous substances part of the database. HSIS database consists of the information about Chemical substance name, Chemical Abstract Service (CAS) Registry number, United Nations (UN) number, Classification based on atmospheric contamination, labelling on products, Risk and Safety Phrases, Health Hazard Category, Concentration Cut-off Levels and Chemical substance mixture classification.

Regulatory and registration services in various state jurisdictions like Department of Justice collect some of the data about the chemical substances handled by the industry. Some of the chemical substances stored beyond the thresholds quantities also reported to the regulatory authorities.

Department of Environment has developed National Pollutants Inventory (NPI) database to support the environmental planning and management for the government and industry. This also provides up to date information on chemical substance emissions and transfers from industrial facilities to the community to minimise waste, cleaner production and resource efficiencies. Australian industrial facilities are

mandated to disclose defined thresholds for the 93 NPI substances, must estimate and report their emissions and transfers of NPI substances in waste, to their state or territory environment agency. The state and territory environment agencies review all NPI reports for completeness and forward the data to the Australian Government. The data is then maintained and provided through the NPI website.

Insurance underwriters collect and process the chemical substance manufacturing and storage capacities to evaluate the risk and exposure of business or industries. Underwriting involves measuring risk exposure and determining the premium that needs to be charged to insure that risk. Normally the information is in the forms of reports and not released in public.

Gaps & Suggestions:

The National Pollutants Inventory provides the location, airborne emissions and their characteristics data for the environmental protection decision making by the industry and governments.

The *HSIS* provides the subjective information and knowledge of the chemical substances.

Geoscience Australia and other agencies from state jurisdictions maintain location (only) information about the facilities. The data provided by these agencies is not comprehensive enough to make decisions and has limited coverage.

There is no centralised database to collect, collate, maintain and disseminate the hazardous substances data to the emergency service authorities. The framework advices the agencies mentioned above can develop the database and align with the capabilities like National Exposure Information System (NEXIS) at GA. Further strategies are to be prepared to implement the framework, develop the database and deliver under creative commons licensing agreements. There may be a legislative mandate required for the facilities to disclose the information to the above agencies.

6. MAJOR INDUSTRIES

The information on industries is highly critical for the economy and safety of workers due to natural hazards. Major industries particularly in manufacturing sector are considered for the scope of this exposure component. In Australia, the major manufacturing sectors are mainly Metal products, Building Materials, Automobiles, Timber, Food Processing, Textiles, Pharmaceuticals, Chemical and others. The industry site has many unique elements that are at risk, pose risk and contribute on value chain on the economy.

For exposure information purpose there is a need to collect, collates, maintain and provide information on manufacturing industries for disaster management. The following attribute information suggested is critical for disaster risk reduction for all levels of governance and in all phases.

1. Ownership
2. Industry name
3. Industry Structure (see buildings framework)
4. Industry Usage
5. Total Floor Area
6. Number of Buildings
7. List of Facilities
    a. Buildings
    b. Workshops
    c. Engine Rooms
    d. Wharfs
    e. Control Room
    f. Admin Office
    g. Ancillary
8. Year Built
9. Building Materials (see buildings exposure)
    a. Combustible
    b. Non-Combustible

10. Equipment
    a. Maintenance Status
    b. Gas Compressors
    c. Steam Generators
    d. Coolers
    e. Boilers
    f. Power
    g. IT Systems
    h. Mobile Equipment
11. Storage Warehouse
    a. Raw Materials
    b. Processing Materials
    c. Product Materials
    d. Capacity
12. Working Hours
13. Waste Management
14. Liability Issues
    a. Pollution
    b. Internal Hazards
15. Special Hazards
16. Plant Layout
17. Firefighting Capability
    a. Sprinkler system
    b. Emergency Response Team
    c. Evacuation Facilities
18. Security
19. Critical Equipment
20. Interdependency
21. Production Capacity
22. Onsite Parking
23. Reconstruction Cost

Existing Capabilities:

Insurance underwriters collect and process the manufacturing and storage capacities information to evaluate the risk and exposure of business or industries. Underwriting involves measuring risk exposure and determining the premium that needs to be charged to insure that risk. Normally the information is in the forms of reports and not released in public.

Gaps & Suggestions:

There is no centralised database or data processing capabilities to collect, collate, maintain and disseminate the large industry sites exposure to the emergency service authorities. Further strategies are to be prepared to implement the framework, develop the database and deliver under creative commons licensing agreements. There may be a legislative mandate required for the facilities to disclose the information to the data provision agencies.

7. PRIMARY INDUSTRIES SECTOR

The primary industries sector includes agriculture, fishing, forestry and mining. The types of natural hazards or the climatic conditions that impacts on this sector in Australia includes draught, water security, soil fertility, weeds, global warming and biosecurity. The CSIRO, the federal government agency for scientific research in Australia, has forecasted that climate change will cause decreased precipitation over much of Australia and that this will exacerbate existing challenges and quality for agriculture (Preston and Jones, 2006).

Australia produces a large variety of primary industries products for export and domestic consumption and earns $155 billion-a-year for a 12percent share of GDP. Australian farmers and graziers own 135,997 farms, employed over 325,300 and covering 61percent of Australia's landmass (AIEC, 2015). The Australian Bureau of Agricultural and Resource Economics and Sciences forecasts agricultural exports alone to be worth $38bn in 2014-15 that consists of 58 percent Australia's food production. Agriculture sector comprises of crops, horticulture, viticulture, diary, meat, fisheries, wool and seaweed.

Australian commercial fisheries gross value production is 2.4 billion in 2013 (ABARE, 2013). This comprises of a variety of fish products from wild catch (gross value of 1.4 billion) and aquaculture (gross value of 1 billion). Tasmania produces the highest aquaculture products followed by South Australia.

Australia's native forests occur in a broad range of geographic landscapes and climatic environments, and contain a wide array of mostly endemic species combining to form unique and complex ecosystems. Australia's native forests provide a range of wood and non-wood products that are consumed by Australians and used for export. The forests are significant in providing clean water; protect soil; provide opportunities for recreation and tourism, and scientific and educational pursuits; and support cultural, heritage and aesthetic values.

7.1 Agriculture – Crops Farming

Crops refer to harvests from a range of cultivated agricultural plants such as cereals, Pulses, vegetables, fruits, oil seeds, pastures, sugars and fibre. Australia's main crops include wheat, corn, vegetables, fruits, cotton, sugarcane, barley, and canola.

For exposure information purpose different types and components of the crops farming that we need to collate and manage information, include:

1. Farm Size
2. Crop Type
3. Crop Calendar
4. Crop Value
5. Farm house
6. Equipment
7. Storage Size
8. Processing Plant

7.2 Agriculture – Horticulture Farming

Australia's horticulture industry comprises fruits, vegetables, nuts, flowers, turf and nursery products. It comprises mainly small-scale family farms—however, there is a growing trend towards medium to larger scale operations. For an exposure framework perspective, Floriculture (flower farming) and Viticulture (Vineyard) are also considered in this category.

So the different types and components of the horticulture farming that we need to collate and manage information, include:

1. Farm Size
2. Plantation Type
3. Number of Plants
4. Age of Plants
5. Yield Pattern
6. Equipment
7. Storage Size
8. Processing Plant
10. Farm Value

7.3 Agriculture – Dairy Farming

Dairy farming is a class of agriculture for long-term production of milk, which is processed (either on the farm or at a dairy plant) to manufacture dairy products. Australian dairy is a $13 billion farm, manufacturing and export industry (Diary

Australia, 2015). A range of high-quality consumer products, including fresh milks, custards, butter, yogurts, variety of cheese and milk powder are produced in Australia. Australia's 6700 dairy farmers produce around 9.5 billion liters of milk a year. The Australian dairy industry directly employs 43,000 Australians on farms and in factories, while more than 100,000 Australians are indirectly employed in related service industries. The industry is very sensitive to natural hazards such as draught and dependant on other sectors like water supply, energy and fodder supply.

For exposure information purpose different types and components of the dairy farming that we need to collate and manage information, include:

1. Farm Size
2. Animals Type
3. Number of Animals
4. Age Mix of Animals
5. Dominant Breed
6. Sub-dominant Breed
7. Equipment
8. Ancillary Buildings
9. Products
11. Farm Value

7.4 Agriculture – Animal Farming

Animal farming is primarily keeping the livestock of animals such as cows, pigs, lambs, horses and chickens in high densities for meat, eggs and other bi-products. This includes breeding programs in controlled environments with high investments. The animal farming is sensitive to the natural hazards and its consequences of infrastructure utilities failures.

For exposure information purpose different types and components of the animal farming that we need to collate and manage information, include:

1. Farm Size
2. Animals Type
3. Farming Type
    a) Free Range

b) Caged

c) Indoors

4. Number of Animals
5. Age Mix of Animals
6. Dominant Breed
7. Sub-dominant Breed
8. Equipment
9. Ancillary Buildings
10. Products
11. Farm Value

7.5 Fisheries – Wild Catch

Fishing is done commercially in marine, lakes and rivers and considered as wild catch fisheries. Marine fisheries production is largely influenced by bathymetry (sea floor topography), reefs, estuaries, ocean currents, ocean temperature, salinity and habitats. Global warming, acidification, massive runoff of nutrients and sediments are directly impacts the productivity of fishing. Natural hazards such as floods, cyclones, tsunamis and storm surge impacts the fishing industry harvest.

For exposure information purpose different types and components of the fisheries-wild catch that we need to collate and manage information, include:

1. Fishing Zones
2. Fishing Restrictions
3. Endangered Species
4. Port Location
5. Number of Trawlers
6. Size of Nets
7. Total Capacity
8. Storage Capacity
9. Processing Plants

7.6 Agriculture – Aquaculture

Aquaculture involves cultivating freshwater and saltwater populations under controlled conditions, and is contrasted with commercial wild catch fishing. Aquaculture includes the farming of fish, shrimp, oyster, seaweed, and ornamental

fish. The farming of fish is the most common form of aquaculture that involves growing fish commercially in tanks, ponds, or ocean enclosures. Shrimp farming is more sensitive to climate variations, salinity and pollution. Oysters are grown in brackish water estuaries mainly for human consumption and also for pearl production. For exposure information purpose different types and components of the aquaculture that we need to collate and manage information, include:

1. Farm Size
2. Fish Type
3. Fishing Stock
4. Products Pattern
5. Equipment
6. Processing plants
7. Ancillary Buildings
8. Farm Value

7.7 Forestry

Australia has a total of 125 million hectares of forest (16 percent of Australia's land) and 98 percent of this is native forest. Australia has about 3 percent of the world's forest area, and globally is the country with the seventh largest forest area. Native forests are categorised in Australia's National Forest Inventory into eight national forest types named after their key genus or structural form: Acacia, Callitris, Casuarina, Eucalypt, Mangrove, Melaleuca, Rainforest, and Others (ABARE, 2013). Industrial plantations are grown on a commercial scale for wood production, sandalwood plantations for other products and non-commercial planted forests includes agroforestry plantations and plantations within the reserve system.

For exposure information purpose different types and components of the forestry sector that we need to collate and manage information, include:

1. Forest Area
2. Status
3. Forest Structure
4. Dominant Species
5. Sub-dominant Species
6. Ownership

7. Products
    a) Hard wood
    b) Softwood
    c) Veneer Logs
    d) Pulp Logs
    e) Oils

7.7 Mining

Mining is the extraction of valuable minerals or other geological materials from the earth. The process of mining from exploration/prospectivity of an ore body through extraction of minerals and finally returning to the land to its natural state consists of several distinct steps. Mining techniques can be divided into two common excavation types: surface and underground. Modern commercial mining uses heavy equipment to explore, develop sites, remove overburden, excavate, process the ore and carry out reclamation after the mine is closed. The mineral processing is considered as part of heavy industries. Safety has long been a concern in the mining business especially the underground extraction due to natural hazards. Concentration of Methane and other contaminants in underground can be hazardous for the workers.

Mining is a significant primary industry and contributor to the Australian economy. Disruptions in mining activity due to natural hazards will be a major impact on the economy and employment in Australia.

For exposure information purpose different types and components of the mining sector that we need to collate and manage information, include:

1. Mining Area
2. Operating Status
3. Operating Type
    a) Surface
    b) Underground
4. Commodities
5. Ownership
6. Equipment
7. Production Capacity
8. Value

Existing Capabilities:

Agriculture Census - Australian Bureau Statistics (ABS) conducts an Agriculture Census every five years. The Agricultural Census provides a detailed picture of what is happening in the Australian agricultural sector at the regional level. It provides vital information on agricultural production, water and land management practices throughout Australia and provides a detailed understanding of the contribution that agriculture makes to the national economy. The Agricultural Census provides estimates for a range of agricultural commodity items including land use, industry structure, broadacre crops, horticultural production and livestock. The data is presented for the Statistical Area 4, Statistical Division, Statistical Local Area, Murray-Darling Basin and Natural Resource Management (NRM) region geographies. The information gathered through the Agricultural Census can help to influence decisions that will shape the future of Australia.

More information about the census is available at

http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/7101.0main+features2Dec%202012

ABS Agriculture Census is available aggregated to LGA and SA 1.

Farm Surveys – Australian Bureau of Agricultural and Resource Economics (ABARE) conducts farm surveys annually to provide a broad range of information on the current and historical economic performance of farm business units in the rural sector. The main surveys are the Australian agricultural and grazing industries survey (AAGIS) and Australian dairy industry survey (ADIS). These two surveys cover detailed financial, physical and socioeconomic information for the broadacre and dairy sectors that contain around 68 percent of Australian farm business units. Information gathered is presented in the publication Australian farm surveys results as well as in a range of industry publications such as Australian grains, Australian lamb, Australian beef and Australian dairy.

More information about the Surveys is available at

http://www.agriculture.gov.au/abares/surveys

More information about the land use data and data download is available at

http://www.agriculture.gov.au/abares/aclump/Pages/land-use/data-download.aspx

http://data.daff.gov.au/anrdl/metadata_files/pb_luausg9abll20150415_11a.xml

Forest Inventory - Australia's National Forest Inventory (NFI) is represented by state, territory and Australian government agencies involved in forest information management. The NFI performs the collection, compilation, analysis and management of forest data, and the public communication of forest information.

The National Plantation Inventory (NPI) is a program of the NFI. Data on Australia's industrial plantations are collected through an annual survey of growers, grower representatives and state and territory agencies. The survey records the total commercially managed plantation estate each year, and the area of commercially managed plantations newly established on land that had not previously been used for plantations.

More information about the national forest datasets developed for national and international reporting purposes, available for downloading from http://www.agriculture.gov.au/abares/forestsaustralia/forest-data-maps-and-tools/forest-data

Dairy Research - Dairy Australia is the national services body for dairy farmers and the industry to help farmers adapt to a changing operating environment, and achieve a profitable, sustainable dairy industry. Dairy Australia conducts R&D throughout the dairy supply chain, identifying the opportunities that give farmers. There is plenty of research information about the farm and product development but there is no data available. The cows and farms summary statistics are available from their website. http://www.dairyaustralia.com.au/Markets-and-statistics.aspx

Fisheries Research - The Fisheries Research and Development Corporation (FRDC) has a significant responsibility to undertake research to assist in the management of the fisheries and aquaculture resource for ongoing sustainability. This means that a significant proportion of funding is directed at research that has a benefit for the three sectors of the fishing industry: commercial (wild catch and aquaculture), recreational and indigenous. See more at: http://frdc.com.au/Pages/home.aspx http://frdc.com.au/research/Documents/Final_reports/2009-214-DLD.pdf

Mineral Atlas – Geoscience Australia provides the spatial location of mines and potential mining sites.

"Australian Atlas of Mineral Resources, Mines & Processing Centres". Geoscience Australia.

Mineral Council of Australia provides locations of coal, gold and uranium mines and associated infrastructure, http://www.minerals.org.au/

Mining Australia provides location & type of ores, http://www.miningaustralia.com.au/australian-mine-map

Mine Sites - Mining Oil Gas portal website provides data on Mine Sites of Australia (A-Z) which is an easy-to-use, highly informative reference, providing a comprehensive overview of every operating mine site in the country. This includes site history, location details and production performance figures. More information about the mine sites, mine suppliers and oil and gas suppliers is available for downloading from http://www.miningoilgas.com.au/index.php/products

Mines in Australia – A list of all mines and their details in Australia is available from https://en.wikipedia.org/wiki/List_of_mines_in_Australia

State Jurisdictions – The primary industries departments in various state jurisdictions have plenty of information on the sector.

Gaps & Suggestions:

There is plenty of data on primary industries available for exploration, prospectivity, products, business operations etc. However, the information is not prepared as exposure data for analysis and decision making of disaster risk reduction. This framework identifies the need for developing a centralised and consistent database with above defined data items for risk assessment from bushfire, natural hazards and system failures.

8. POPULATION EXPOSURE

Collating and managing information on level of population exposure to natural disasters in Australia is potentially one important aspect of disaster management. In the past, high level of population exposure to natural hazards had not only proved to be disastrous in overpopulated developing countries like Philippines, Japan and during Hurricane Mitch in Honduras and Nicaragua (in 1998) but, also during Hurricane Sandy and Katrina in US. Australian communities are varied in their composition and in their level of exposure to disaster risk. For exposure information purpose the factors that can influence level of population exposure to disaster can broadly be classified as:

1. Remoteness Status
2. Demographic Status
3. Socio-economic Status
4. Labour force Status
5. Health
6. Ambient Population
7. Risk Response
8. Social Capital

8.1 Population Remoteness Status

It is well identified that, Australian population are diverse in their composition and quite dispersed in their spatial distribution and therefore widely vary in their level of exposure to disaster risk (NSDR, 2011). Australia is the world's (apart from Antarctica) driest continent (ABS, 2012). Nearly 20 per cent of the land mass is classified as desert. As well as having a low average annual rainfall, rainfall across Australia is also variable. Most of Australia's population is concentrated in two widely separated coastal regions – the south-east and east, and the south-west. Of the two regions, the south-east and east is by far the largest in area and population. The population within these regions is concentrated in urban centres, particularly the capital cities (ABS, 2012). Remoteness distribution of the population is one significant factor that can influence disaster resilience and disaster management initiatives and policy (NSDR, 2011) because of their level of access to infrastructures and services including the health care and fire brigade. Australia has strong pattern of spatial concentration in

cities and the coastal areas of the east, southeast and southwest. Also, there have been distinctive patterns of population change across the country. In recent years we have observed the fastest growing populations in the major cities. There is a systematic pattern with a decline in rates of population growth with increasing remoteness (Hugo et al, 2013). The proportion of the population living in each of the ASGS classified Remoteness Areas (broad geographical areas sharing common characteristics of remoteness) varied considerably across the states and territories (ABS, 2008).

This framework identifies that population ratios and population distribution at national, state and small area (SA2) level across the ASGS Remoteness Structures would be useful for end users. The Remoteness Structure divides each state and territory into several regions on the basis of their relative access to services. There are six classes of Remoteness Access in the Remoteness Structure: Major Cities of Australia, Inner Regional Australia, Outer Regional Australia, Remote Australia, Very Remote Australia and Migratory.

8.2 Demographic Composition

The changing demographic landscape all around the world and population dynamics such as population growth; age, gender and ethnic composition; distribution; migration and urbanisation are the important factors that have increased population exposure to disasters and have contributed to the devastating impact of natural disasters as observed with Hurricane Katrina (2005) and the Indian Ocean Tsunami (2004) (Donner and Rodriguez, 2008; Martine and Guzman, 2002). More importantly the key role of human behaviour in modelling population exposure to natural hazards should not be undermined. Human risk perception or how individuals process information on hazard risk are heavily constructed by their particular social, cultural (Tierney, 1994) and economic context such as race, income, age and gender. Consequently, demographic composition has been identified as one important component of population exposure, risk assessment and vulnerability modelling for disaster management. Important components of this demographic composition include:

1. Population age profile
2. Population density

3. Gender composition
4. Migration
5. Indigenous and ethnic composition
6. Household composition

8.2.1 Population Age profile

This framework identifies the important need to keep information on population age composition: number of people in different age categories that can broadly be classified as children (0-4, 5-14), working age (15-64) and aged (65 plus); in the *National Disaster Exposure Database*. Australia, like the other OECD partners, is characterised by a rapidly aging population with low birth rate and higher life expectancy. The number of Australians aged 65 years and over is projected to outnumber children aged 0-14 years by 2018. By 2056, nearly one-in-four Australians are projected to be aged 65 years and over (Kinfu et al, 2015). This population ageing presents number of challenges to the society in terms of their long term health and care need as they are more likely to be living with long term health conditions, less mobile, living in single persons or group households. Such occurrences significantly increase the exposure and vulnerability of population to natural disasters. Along with aged, information on infants, babies and children are equally perceived as important for disaster response and recovery purposes.

Information on population age composition: number of people in different age categories that can broadly be classified as children (0-4, 5-14), working age (15-64) and aged (65 plus) at national, state and small area (SA2) level would be useful for end users.

8.2.2 Population Density

It is not only the population size in an area but, the density - number of people living per square meter is an important indicator of population exposure to natural disasters (also see NSDR, 2011). Rising population density primarily in relation to urbanisation and coastal developments pose a particular risk to natural disaster as the very physical structure of urban settings and congestion not only results in exposing greater numbers of individuals to natural disasters but, within an ecological context, also create the conditions conducive for more disasters and for greater exposure. Environmental exploitations such as deforestation, destruction of mangroves or

expanding the coastal zone to areas which were once occupied by water, increase the likelihood of disasters (Donner and Rodriguez, 2008). It is also believed that areas of high population density - particularly urban areas - are more likely to experience changes in meteorological conditions and increasing likelihood of severe storms such as tornadoes (Donner and Rodriguez, 2008; Elsom and Meaden 1982; Snider 1977).

This framework identifies that information on number of people living per square meter along with the absolute population count in an area at national state and small area (SA2) level would be useful for the end users.

8.2.3 Gender Composition

In modelling human behavior into population exposure to natural hazards, gender composition is one important component of population demographics that might influence population evacuation decision. It is important to study the human evacuation responses to disasters as Bateman and Edwards (2002) have observed that, in general, women have greater objective risk and more realistic perceptions of risk. It is concurrently perceived essential for response and recovery to keep information on the number of evacuees by their age and gender to determine the type of support and care need in the immediate aftermath of the disaster. Equally important are the information on pregnant women and women with babies. Biological and physiological differences based on gender are unlikely to explain large-scale gender differences in mortality rates. Social norms and role behaviors, however, provide some explanation, but what is likely to matter most is the everyday socioeconomic status of women. Neumaye and Plumper (2007) using a sample of up to 141 countries over the period 1981 to 2002 find, first, that natural disasters lower the life expectancy of women more than that of men. In other words, natural disasters (and their subsequent impact) on average kill more women than men or kill women at an earlier age than men. Also, the stronger the disaster (as approximated by the number of people killed relative to population size), the stronger this effect on the gender gap in life expectancy. More importantly, it is the socially constructed gender-specific vulnerability of females built into everyday socioeconomic patterns that lead to the relatively higher female disaster mortality rates compared to men (Neumaye and Plumper, 2007).

This framework identifies that information on population gender composition at national, state and small area (SA2) level would be useful for the end users.

8.2.4 Migration

Migration is one important aspect of population dynamics that decide the size, density and distribution of population in an area. While the post disaster impact on in and out migration from an area is well documented and context of ongoing research, following COAG (2011) this framework identifies that it is equally important to document the information on in and out migration in an area even before the disaster strikes. At this stage it is also important to document the pattern of in and out migration from areas affected with natural disasters in the past that can influence to shape the future policy. AEMI (2011) identified that in Australia internal migration due to many varied reasons in recent days increases the pressures on local communities, governments and environments (McLennan & Birch 2005, pp 101–08). It leads to a population that is more dispersed and less well connected to its local community and formal and informal support structures. AEMI (2011) also noted that Indigenous Australians living in rural and remote areas may regularly move between different communities and family groups and may not see themselves as belonging to a geographically defined location.

International immigration patterns and process can also, significantly affect the population response to disasters. Naik et al, (2007) in their study on *Indian Ocean Tsunami* found migrants, both regular and irregular, face increased vulnerability at times of natural disaster. If not planned or documented properly before the disaster strikes, migrants at times of crisis may become increasingly vulnerable. Even though composition of international migration in an area is not as relevant in an Australian context for natural disaster response and recovery, it is important to identify the recent (post 2006) international immigration settlement pattern into regions. As, they may miss out on rescue and recovery assistance and support due to lack of concurrent information and knowledge on Australian practice.

This framework identifies that following information at national state and small area level would be useful for end users.

1) Proportion of Households with one or more residents having different address one year ago
2) Proportion of Households with one or more residents having different address five years ago
3) Residents new to Australia – proportion of population arrived in Australia after 2006

8.2.5 Indigenous and Ethnic Composition

It is now well identified that natural disasters affect people unequally. Apart from inequalities in exposure based on their geographical situation and sensitivity to risk based on age, gender, migrant status and how densely they are distributed over space; inequalities in access to resources, their capabilities, and available opportunities systematically disadvantage certain groups of people and make them more vulnerable to the impact of natural disasters. For that reason it is important to document information on indigenous and ethnic composition of the population in Australia at different ANHEF levels in the *National Disaster Exposure Database*. It is well recognised that in Australia indigenous people are lacking behind the non-indigenous population in almost all indicators of social disadvantage such as education, health, employment and income. Also, it is observed that they are less likely to access the resources and services and harness the opportunities meant for them; faced with disasters they are certainly rendered more vulnerable. Equally important are the information requirements on ethnic composition of the population, for example non-English speaking population or population for which English is the second language. These people are at risk of social exclusion and are more vulnerable to natural disasters due to their restricted communication capabilities.

This framework identifies that following information at national state and small area level would be useful for end users.

1) Proportion of population who do not speak English very well at national, state and small area (SA2) level.
2) Proportion of indigenous population at national, state and small area (SA2) level.

8.2.6 Household Composition

The household composition is an indicator of household exposure and vulnerability to natural disasters. Information such as whether the household is composed of family with dependent children, older people, adults only, single parent, single person or people with disabilities living in supported accommodation arrangements are important information for disaster response, recovery and policy making initiatives. This information can also be a source of strength and resilience to aid recovery as large families and extended families can support each other, pool resources and assist with the very old and young (AEMI, 2011).

This framework identifies that following information at national, state and small area (SA2) level would be useful for end users.

1) Number/proportion of Couple families with children
2) Number/proportion of Couple families with no children
3) Number/proportion of Group household
4) Number/proportion of Other family
5) Number/proportion of Single parent family
6) Number/proportion of Single person household

8.3 Socio-economic status

In recent days natural disasters like Hurricane Katrina (2005) and Indian Ocean Tsunami (2004) have more significantly highlighted the differential impact of disasters on socio-economically backward communities particularly those who do not have enough resources to be resilient to such events (Donner and Rodriguez, 2008; Martine and Guzman, 2002). Masozeraa et al (2007) for Hurricane Katrina in New Orleans found that pre-existing socio-economic conditions play a significant role in the ability for particular economic classes to respond immediately to the disaster and to cope with the aftermath of Hurricane Katrina (also see Nix-Stevenson, 2013) . Fothergill and Peek (2004) in their literature review of a wide range of studies on poverty and disaster in US over a period of 20 years illustrated people of different socioeconomic statuses perceive, prepare for, and respond to natural hazard risks differently. They suggested low-income populations were differentially impacted, both physically and psychologically, and disaster effects vary by social class even during the periods of emergency response, recovery, and reconstruction.

Important indicators of socio-economic status of population include:

1. Household Income
2. Household Dwelling Tenure Status
3. Population Insurance Coverage

8.3.1 Household Income

Consequently this framework identifies that information requirement on different household income classes at different ANHEF geographic levels are important for disaster response, recovery and resilience. In this space NEXIS, GA already contains information on percentage of residential dwellings with low ($1-$599), middle ($600-$1999) or high (greater than $2000) gross household income.

The following information at national, state and small area (SA2) level would be useful for end users.

1. For each dwelling type (in Buildings Section 3), a percentage is required to calculate if that dwelling has a Nil, Low, Medium or High gross household weekly income as a proportion of all dwellings of that type. This low income household is determined by using the OECD definition of half the national median. In 2011 the national median was $1234/week, which gives a low income measure of $617/week. This has been adjusted to $600 because it is the nearest category in the Census data. High income is set to $2000/week, as this category reflects the top deciles nationally.

2. An alternative category, also available with NEXIS, is looking at equivalised household income. This is considered a more realistic approach. It is the total household income adjusted by the application of an equivalence scale to facilitate comparison of income levels between households of differing size and composition, reflecting the requirement of a larger household to have a higher level of income to achieve the same standard of living as a smaller household. Percentage of residential dwellings with nil, low, middle or high equivalised income (ABS, 2006), for each dwelling type (in Buildings Section 3), is required. Equivalised total household income can be viewed as an indicator of the economic resources available to a standardised household.

8.3.2 Household Dwelling Tenure Status

The information on percentage of residential dwellings by tenure: owned, rented privately, rented publicly or other tenure type; has been identified as important for natural disasters response and recovery purposes in Australia (also see Nadimpalli et al, 2007). In the built environment it is identified as an indicator of social vulnerability to natural disasters. It is mostly believed that (Williams et al, 2009; Cutter et al, 2003) people that rent do so because they are either transient or do not have the financial resources for home ownership. They often lack access to information about financial aid during recovery. In the most extreme cases, renters lack sufficient shelter options when lodging becomes uninhabitable or too costly to afford.

The following information at national state and small area level would be useful for end users.

1) Number/proportion of Owner Occupied dwellings –owned outright or owned with a mortgage
2) Number/proportion of Rented dwellings – rented from real estate agent or directly from owner
3) Number/proportion of Rented public housing - Rented from a State/Territory housing authority or rented from a co-operative, community or church group
4) Number/proportion of Other Tenure Type dwellings –Rented from a person not in the same household, occupied rent-free, occupied under a life tenure system and all other tenure types,

8.3.3 Population Insurance Coverage

Fothergill and Peek (2004) found that the poor in the United States are more vulnerable to natural disasters due to their place and type of residence, building construction, and social exclusion. Fussell et al (2010) in their study on return migration to New Orleans after Hurricane Katrina find that black residents, live in areas that experienced greater flooding and hence suffered more severe housing damage, returned to the city at a much slower pace than white residents irrespective of socioeconomic status and demographic characteristics. In line with this thinking population insurance coverage is perceived as an important requirement for this

framework as it can provide the much needed security for building contend and replacement values against natural disaster.

For exposure framework prospective please refer to *Section 3.3* for a detail explanation on user requirements of this component.

8.4 Labour Force Status

Information on labour force status of the population such as employed: full time/part time, unemployed and not in the labour force, in an area is identified as required for disaster preparedness, response and recovery purposes. The potential loss of employment following a disaster exacerbates the number of unemployed workers in a community, contributing to a slower recovery from the disaster. Also, information on labour force status is important as an indicator of social vulnerability (Cutter et al, 2003), like household income, information on employed and unemployed population in an area can be viewed as uneven access to resources and capital, that leave some people more vulnerable than others to natural disasters. On the contrary, for policy perspective this is an important requirement for post disaster economic productivity loss estimation.

The following information at different ANHEF levels would be useful for end users.

1) Proportion employed
2) Proportion unemployed
3) Proportion not in the Labour force.

8.5 Population Health

World Health Organisation (WHO) in their DROUGHT – Technical Hazard Sheet- Natural Disaster Profiles (2015) identified that poor health status of the population before the disaster is an indicator of population vulnerability. Additionally, population health status is an important information requirement for disaster preparedness, response and recovery purposes. It is essential to understand a priori the existing disease pattern in the localities and to identify the risks and vulnerability in the disease pattern in relation to the disasters. In U.S. the Institute of Medicine in (2015) recommended to integrate health considerations into recovery decision making through the National Disaster Recovery Framework (NDRF). While this is increasingly important community resilience information this is also vital for planning to reduce health impacts of

disaster. This puts population health at the forefront of disaster risk management, including prevention preparedness, response and recovery.

Important indicators of population health status include:

1. Physical health status
2. Mental health status
3. Disability status

8.5.1 Physical Health

Health informed decision making through the availability of data is critical for immediate - to intermediate - to long-term response, recovery and preparedness for disasters. IOM (2015) notes that Community Health Needs Assessment (CHNA) has become critical public health preparedness for natural disaster impact assessment and planning in US. This is a process that uses quantitative and qualitative methods to systematically collect and analyses data to understand health within a specific community. An ideal assessment includes information on risk factors, quality of life, mortality, morbidity, community assets, forces of change, social determinants of health and health inequity, and information on how well the public health system provides essential services. Community health assessment data inform all aspects of community decision-making, the prioritization of health problems, and the development, implementation, and evaluation of community health improvement plans. IOM (2015) identified some of very important public health indicators that possibly can provide input to community health improvement and impact assessment planning before and after disasters. These indicators include:

1) Early childhood development;
2) Data analysis, including use of geographic information systems;
3) Social network analysis;
4) Public health and health care economics;
5) Clinical—chronic and acute disease states;
6) Epidemiology;
7) Policy and legislative actions;
8) Health education;
9) Preventive medicine;
10) Public health– and health care–related legal issues;

11) Ethical issues;

12) Lead poisoning;

13) Continuous quality improvement;

14) Oral health;

15) Vital statistics;

16) Immunizations; and

17) Special-needs populations.

So, while it is increasingly recognised that collecting and maintaining baseline data on community health status is an essential component of disaster management, there is no such coordinated systems available to provide information across Australia. So this framework identifies the need to input *Community Health Status* or *Community Health Indicators* into the disaster information systems.

For information on the individual level health status or health profile of the population in Australia it would be ideal to use the scores on the Short Form 36 Questionnaire (SF-36), a widely used multi-dimensional measure of health-related quality of life, The SF-36 is a multi-purpose, short-form health survey with only 36 questions (Mansdotter et al, 2008; Walters, 2004; Ware et al, 2001). It produces an 8-scale profile of functional health and well-being scores as well as psychometrically-based physical and mental health summary measures and a preference-based health utility index. It is a generic measure, as opposed to one that targets a specific age, disease, or treatment group. The SF-36 has proven useful in surveys of general and specific populations, comparing the relative burden of diseases, and have been translated in more than 50 countries as part of the International Quality of Life Assessment (IQOLA) Project; and studies of reliability and validity (Health Survey Update, 2015). Australian data for the SF-36 Health Survey is available from *Household Income and labour Dynamics in Australia Surveys (HILDA).*

However, it is equally important to input information on:

1. Vital Statistics
2. Early Childhood Development
3. Immunization
4. Life expectancy
5. Epidemiology

6. Morbidity
7. Existing Disease pattern in the community
8. Identified Risk and Vulnerabilities in the disease patterns
9. Quality of Life

8.5.2 Mental Health

There is wide ranging literature on associations between respondents' natural disaster experiences and their mental health. Natural disasters cause unprecedented amount of havoc destroying people's life and property, consequently it exerts tremendous impact on their mental and physical wellbeing. On the other hand prevailing mental health status of the population is also an indicator of existing social vulnerability and exposure to risk. World Health Organisation identifies mental well-being as a fundamental component of health. Good mental health enables people to realize their potential, cope with the normal stresses of life, work productively, and contribute to their communities (WHO, 2013) so it is an important indicator of natural disaster vulnerability. Mental disorders frequently lead individuals and families into poverty, homelessness and increase their risk of marginalization and vulnerability. As such, persons with mental disorders often live in vulnerable situations and are excluded and marginalized from society. Therefore, this framework identifies prevailing mental health status of the population as an important information requirement for communities to input into disaster information systems.

Similar to the physical health status of the population, for information on the individual level mental health status or mental health profile of the population it would be ideal to use the scores on the Short Form 36 Questionnaire (SF-36) mental health summary measure or Kessler Psychological Distress Scale (K-10) measures available with HILDA Survey and Australian Bureau of Statistics.

8.5.3 Disability

Along with demographic and socio-economic factors that make people more/less vulnerable even when they are exposed to similar risk from a natural disaster, people with disability are also more vulnerable to such risks. Individuals with disabilities are disproportionately affected in disaster, emergency, and conflict situations due to inaccessible evacuation, response (including shelters, camps, and food distribution),

and recovery efforts. The World Bank Disability and Development Team (2006) established that evaluation and monitoring of the inclusion of vulnerable groups in disaster preparedness should be part of planning. Also, since disasters happen locally, disability inclusive planning process should start locally developing a bottom up approach. The fundamental requirements in disaster planning should ensure: equal access to shelter facilities, equal access to evacuation/ transportation and equal access to disaster clean up (World Bank Disability and Development Team, 2006). The United Nations (2015) post-2015 disaster risk reduction strategy highlights "It is imperative that persons with disabilities are explicitly represented as a group and that their perspectives and concerns are reflected in Hyogo Framework for Action 2 (HFA2)" for post 2015 disaster risk reduction strategy and Sendai Framework for Disaster Risk Reduction 2015-2030 is in agreement with this.

In Australia just under one in five people (4.2 million people or 18.5 percent of Australians) reported having a disability in 2012. For those people with disability, 3.7 million (88 percent) had a specific limitation or restriction that meant they were limited in the core activities of self-care, mobility or communication, or restricted in schooling or employment (ABS, 2012).

The following information at national, state and small area (SA2) level would be useful for the end users.

1. Number/Proportion of population with some kind of disability
2. Number/Proportion of population with Core Activity Need for Assistance

8.6 Ambient Population

8.6.1 Spatiotemporal Population

Another decisive aspect of population vulnerability to natural disasters is the space and time dependence of the population exposure to the hazard. It is identified as critical to model the dynamics of high-resolution time dependence population distribution data for disaster management. The policy decisions are significantly influenced by the number of impacted people which in turn is dependent on time of hazard occurrence (Bhaduri, 2007). Freire et al (2013) in assessing the tsunami risk and in more efficient and effective emergency management have considered the time

dependence of population exposure to hazard in a large urban area. They have modelled population density in high spatial and temporal detail following a top-down approach to disaggregate data from official statistics. The resulting population distribution surfaces are integrated with a tsunami hazard map to estimate potential human exposure. Additionally, the population's speed of evacuation is modelled and analysed in the night-time and day-time periods to investigate whether there are significant differences and what consequences these might have for emergency management.

Bhaduri et al (2007) utilizing the increasing availability of national geospatial data sets including high resolution imagery, the LandScan USA model implemented an innovative spatial data modelling approach. This included integration of multiple high resolution indicator data sets, such as land cover, roads, cultural landmarks, educational institutions, and business activity locations, combined with human intelligence thought analyst intervention that allowed efficient resolution enhancement in both spatial and temporal dimensions. Such development to incorporate activity-based temporal information is needed to design and develop a nationally consistent model not only for night time or residential population distribution, but also the mobility and dynamics of different demographic groups in Australia.

For disaster management purpose it would be ideal to have information on spatiotemporal distribution of population such as day time and night time spatial distribution of population and transit population. To start with ABS Census information on *location of work* and ABS National Regional Profile (NRP) information on *existing business in the area* and the scale would be useful.

8.6.2 Composition of floating and/or tourist population

It is equally important to obtain floating/tourist population census on the tourism focus small islands and coastal cities in Australia for the natural hazard planning, recovery and response. In these cities a significant proportion of population are floating population or tourists. GAR-UNISDR (2013) identified that 6 of the top 10 countries in the world with the greatest proportion of assets at risk to cyclone wind damage are tourist small islands. While tourism investment and planning in such areas come with high levels of disaster risk, it also, bears large potential benefits from

investment in disaster risk management which needs to be factored into exposure information modelling. Therefore, this framework identifies that floating/tourist population census on small islands and coastal cities in Australia as an important information requirement for communities in the *National Disaster Exposure Database*. End users require information on number/proportion of floating/tourist population at national state and small area level.

8.7 Population Access to Transportation

Population accesses to transportation have been identified as an important factor determining pre/post disaster ability to response and evacuate (Cutter et al, 2010; Tierney, 2009). It is also an important determinant of disaster resilience as it can determine people's ability to move and evacuate freely and immediately and come back and resume their normal function without time lag in case of short term displacement. Mode of transportation and establishing transportation standards for evacuation response has been found to be important in case of Hurricane Katrina when people with elderly and disable family members at home and people with pets decided to stay back at home instead of responding to the evacuation requirement (Tierney, 2009). In remote and regional Australia household access to motor vehicles would possibly be the most important transportation option available for immediate disaster response and evacuation requirement.

This framework identifies that information on - population/household access to motor vehicles would be useful for end users for disaster evacuation response and resilience decision making.

8.8 Population Risk Response

As already identified (Nadimpalli et al, 2014) it is important and would certainly facilitate the process of disaster management and planning if we have information on population risk response, risk perception and evacuation speed. Human behavior is an important determinant of population exposure to hazards. So it is required to keep information on people's evacuation response and speed after they hear hazard warnings (Dash and Gladwin, 2007). As Dash and Gladwin (2007) acknowledged accurate and geographically focused predictions of evacuation rates including clearance times, shelter usage, and potential casualty rates are needed for the emergency managers. Information on shadow or spontaneous evacuators are equally

important, such as those not at greatest objective risk but panic and rush to evacuate (Dash and Gladwin, 2007).

The following information at national state and small area level would be useful for end users.

i) Population Evacuation speed after they hear hazard warning;
ii) Geographically focused predictions of evacuation rates, clearance times, shelter usage, and potential casualty rates.

8.9 Social Capital

The important role of social capital in natural disaster management has been well documented (Aldrich, 2012; Tierney, 2014; UNISDR, 2005). Individual and community resilience is an essential component of risk reduction, response and recovery process. Social groups and community participation play significant role in this process (Tierney, 2014; UNISDR, 2005). Hyogo Framework (UNISDR, 2005) identified the significance of community participation in disaster risk reduction and recommended for the adoption of specific policies to promote networking, the strategic management of volunteer resources, the attribution of roles and responsibilities, and the delegation and provision of the necessary authority and resources. It is also identified that in the aftermath of natural disasters it is not only the existing social community institutions and network organisations in that area that play a crucial role to bring together resilient communities also, emerging new social networks and groups create settings for adaptive resilience (Tierney, 2014). Aldrich (2012) in examining the post-disaster responses of four distinct communities—Tokyo following the 1923 earthquake, Kobe after the 1995 earthquake, Tamil Nadu after the 2004 Indian Ocean Tsunami, and New Orleans post-Katrina—finds that those with robust social networks were better able to coordinate recovery. The role of social capital in disaster management and efficient reconstruction is further heightened through timely access to and dissemination of information and financial and physical assistance, communities with an abundance of social capital were able to minimize the migration of people and valuable resources out of the area.

End users require following information at national state and small area level.

i) Existing network organisations, community groups, volunteer groups
ii) Population Internet Access

Existing Capabilities on Population Exposure

Detailed information on existing capabilities in Australia on population exposure to natural disasters has been presented in the following table:

Data Source	Data Description	Web Link
Remoteness Status		
ABS Census of Population and Housing	Population ratios and population distribution at national state and small area- SA2 level across the ASGS Remoteness Structures	ABS Table Builder Software Access at http://www.abs.gov.au/websitedbs/censushome.nsf/home/tablebuilder
Demographic Composition		
ABS Census of Population and Housing	***Population Age profile :*** Number of people in different age categories that can broadly be classified into children (0-15), working age (15-64) and aged (65 plus) at national, state and small area- SA2 level	ABS Table Builder Software Access at http://www.abs.gov.au/websitedbs/censushome.nsf/home/tablebuilder
	Population density: Number of people living per square mile/kilometre at national, state and SA2 level	
	Gender Composition: Population gender composition at national, state and small area- SA2 level	
	Migration: Proportion of Households with one or more residents having different address one year ago Proportion of Households with one or more residents having different address five years ago	

	Residents new to Australia – proportion of population arrived in Australia after 2001	
	Indigenous and Ethnic composition: Proportion of population for who English is a second language at national, state and SA2 level. Proportion of indigenous population at national, state and SA2 level.	
	Household composition: Proportion of families by different family types (Couple family with children, Couple family with no children, Group household, Other family, Single parent family and Single person household) at Australian national, state and SA2 level.	
Socio-economic status		
ABS Census of Population and Housing	***Household Income:*** Proportion of households in each residential dwelling type by different household gross weekly income classes (Nil, Low, Medium or High) at national, state and SA2 level.	ABS Table Builder Software Access at http://www.abs.gov.au/websitedbs/censushome.nsf/home/tablebuilder
National Exposure Information System (NEXIS), Geosciences Australia	Proportion of households in each residential dwelling type by different household equivalised weekly income classes (Nil, Low, Medium or High) at national, state and SA2 level.	http://www.ga.gov.au/metadata-gateway/metadata/record/gcat_82219

	Household Dwelling Tenure Status: Proportion of households in each residential dwelling type by different tenure status (Owner Occupied, Rented, Commercial Lease, and Government Owned) at national, state and SA@ level.	
AURIN: SA2 Income Support	***Income support*** : Proportion of population on different income support payments (age pensions, disability pensions, health care concession cards, single parent support and unemployment support) at national, state and SA2 level. Information on low income families, children and the unemployed by SA2 in 2013.	http://data.aurin.org.au/dataset/ua-phidu-phidu-sa2-incomesupport-sa2
	Population Insurance Coverage	
Labour force Status		
ABS Census of Population and Housing	Proportion of working age population in different employment categories (employed, unemployed and not in the labour force) at national, state and SA2 level.	ABS Table Builder Software Access at http://www.abs.gov.au/websitedbs/censushome.nsf/home/tablebuilder
Population Health		
	Physical Health:	

Australian Bureau of Statistics Life Tables Australian Institute of Health and Welfare (AIHW) Public Health Information Development Unit (PHIDU) at the University of Adelaide	Vital Statistics at National and state level Hospital level mortality data Data on premature deaths across the life course, from infants, to young children (deaths at one to four years of age), youth (deaths at ages 15 to 24 years) and adults (deaths before 75 years of age), in addition to the more recent concept of avoidable mortality	http://www.abs.gov.au/ausstats/abs@.nsf/ViewContent?readform&view=productsbyCatalogue&Action=Expand&Num=3.3 http://www.adelaide.edu.au/phidu/maps-data/data/
Australian Early Development Census (AEDC), held every three years, with the third collection taken place from May to July 2015	Early Childhood Development indicators for children aged 5: I. physical health and wellbeing, II. social competence, III. emotional maturity, IV. language and cognitive skills, V. communication skills and general knowledge	https://www.aedc.gov.au/
Community Indicators Victoria (CIV) provides information at small area level for the state of Victoria only. Public Health Information Development Unit (PHIDU) at the University of Adelaide	Information on immunization status of children in Victoria. Children fully immunised at 1/2/5 year of age in 2014 at national, state and Sa2 level.	http://www.communityindicators.net.au/ http://www.adelaide.edu.au/phidu/maps-data/data/
Australian Bureau of Statistics Life Tables	Life expectancy at national and state level	

Community Indicators Victoria (CIV) provides information at small area level for the state of Victoria only.	Life expectancy at small area level	http://www.communityindicators.net.au/
Public Health Information Development Unit (PHIDU) at the University of Adelaide. Community Indicators Victoria (CIV) provides information at small area level for the state of Victoria only.	Estimated population, aged 18 years and over, who were obese by gender at national, state and Sa2 level between2011-13.	http://www.adelaide.edu.au/phidu/maps-data/data/ http://www.communityindicators.net.au/
Public Health Information Development Unit (PHIDU) at the University of Adelaide. Community Indicators Victoria (CIV) provides information at small area level for the state of Victoria only.	Risk Alcohol Consumption and Smoking Status	http://www.adelaide.edu.au/phidu/maps-data/data/ http://www.communityindicators.net.au/
Different waves of Household Income and Labour Dynamics in Australia (HILDA) Surveys, 2001-2013 and ABS, National Health Survey 2012 Public Health Information	Number/Proportion of population with physical health problem at national and state level based on the scores of the Short Form 36 Questionnaire (SF-36) physical health summary measure Estimates of Australia wide Self-Reported Health at SA2 level and Estimates of long term health conditions.	https://www.melbourneinstitute.com/hilda/ http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/4364.0.55.0012011-12?OpenDocument

Development Unit (PHIDU) at the University of Adelaide. Community Indicators Victoria (CIV) provides information at small area level for the state of Victoria only.	Same as above Self-Reported Health at small area level for Victoria only	 http://www.adelaide.edu.au/phidu/maps-data/data/ http://www.communityindicators.net.au/
AURIN: SA2 Subjective Wellbeing-Modelled Estimate Community Indicators Victoria (CIV) provides information at small area level for the state of Victoria only.	Estimates of Australia wide Subjective wellbeing at SA2 level Estimates of Australia wide Subjective wellbeing at small area level for Victoria	http://data.aurin.org.au/dataset/uc-natsem-natsem-natsem-tb3-lifesat-in-3-groups-geometry-sa2 http://www.communityindicators.net.au/
Australian Institute of Health and Welfare (AIHW)	Hospital level Morbidity information in Australia.	
AURIN: SA2 Chronic Disease - Modelled Estimate	Modelled estimates of chronic diseases including: arthritis, asthma, circulatory system diseases, chronic obstructive pulmonary disease, type 2 diabetes, high cholesterol, hypertension disease, mental and behavioural problems for males and females, musculoskeletal system diseases, respiratory system diseases, and arthritis for 2011-13 by	http://data.aurin.org.au/dataset/ua-phidu-phidu-sa2-chronicdisease-modelledestimate-sa2

Public Health Information Development Unit (PHIDU) at the University of Adelaide.	SA2 Estimates of the prevalence of major chronic diseases and associated risk factors by SA2s	http://www.adelaide.edu.au/phidu/maps-data/data/
Different waves of Household Income and Labour Dynamics in Australia (HILDA) Surveys, 2001-2013 and ABS 4327.0 - National Survey of Mental Health and Wellbeing, 2007	**Mental Health :** Number/Proportion of population with mental health problem at national and state level based on the scores of the Short Form 36 Questionnaire (SF-36) mental health summary measure	https://www.melbourneinstitute.com/hilda/ http://www.abs.gov.au/ausstats/abs@.nsf/Products/4327.0~2007~Main+Features~Survey+products?OpenDocument
ABS, 4430.0 - Disability, Ageing and Carers, Australia Surveys, the latest 2012 Prepared by the Rural and Regional Statistics National Centre, ABS for the Commonwealth Department of Social Services (DSS) AURIN: SA2 Disability	**Disability Status** : Number/Proportion of population with some kind of disability at State and National level Modelled Estimates for number/Proportion of population with some kind of disability at Small Areas, projected for 2015 People with a profound or severe disability, with those living in the community also separately reported for	http://www.abs.gov.au/ausstats/abs@.nsf/mf/4430.0 http://data.aurin.org.au/dataset/ua-phidu-phidu-sa2-disability-sa2

ABS Census of Population and Housing	2011. Number/Proportion of population with Core Activity Need for Assistance at National state and SA2 level	ABS Table Builder Software Access at http://www.abs.gov.au/websitedbs/censushome.nsf/home/tablebuilder
AURIN: SA2 OECD Indicators: MBS and PBS data	**MBS and PBS Beneficiaries:** Number/Proportion of Medical Benefits System (MBS) and Pharmaceutical Benefits System (PBD) recipients for SA2's across. The data was calculated from the 2011 Census for the AURIN Social Indicators project.	http://data.aurin.org.au/dataset/uc-natsem-natsem-natsem-tb5-3-mbs-and-pbs-geometry-sa2
Ambient Population		
ABS Census of Population and Housing	Information on location of work from census	ABS Table Builder Software Access at http://www.abs.gov.au/websitedbs/censushome.nsf/home/tablebuilder
ABS Census of Population and Housing	Number/Proportion of people working nearby or faraway in the city	ABS Table Builder Software Access at http://www.abs.gov.au/websitedbs/censushome.nsf/home/tablebuilder
ABS National Regional Profile (NRP)	Information on existing business in the area and the scale	http://www.abs.gov.au/ausstats/abs@.nsf/mf/1379.0.55.

		001
AURIN: SA2 Industry Atlas 2011 Businesses by Turnover Size and Industry Department of State Development, Business and Innovation, Victorian Government	Number of businesses at Statistical Area level 2 by size of Turnover and the Industry Sector	http://data.aurin.org.au/dataset/vic-govt-dsdbi-dsdbi-sa2-ia-2011-turnover-industry-sa2
City of Melbourne's the Census of Land Use and Employment (CLUE)	Temporal distribution of pedestrians in the city of Melbourne	https://www.melbourne.vic.gov.au/AboutMelbourne/Statistics/CityEconomy/Pages/CLUE.aspx
ABS Census of Population and Housing	Number/proportion of floating/tourist population at national state and small area level	ABS Table Builder Software Access at http://www.abs.gov.au/websitedbs/censushome.nsf/home/tablebuilder
Access to Motor Vehicles		
ABS Census of Population and Housing	Population or Household access to a Motor Vehicle	ABS Table Builder Software Access at http://www.abs.gov.au/websitedbs/censushome.nsf/home/tablebuilder
Social Capital		
AURIN: SA2 OECD Indicators: Volunteering 2011	The number and proportion of people aged 15 years and over engaged in voluntary work for a group or organisation, for the year 2011 by SA2	http://data.aurin.org.au/dataset/uc-natsem-natsem-natsem-tb5-7-social-indicators-volunteering-geometry-sa2
ABS Census of Population and Housing	Population Internet Access	ABS Table Builder Software Access at http://www.abs.gov.au/websitedbs/censushome.nsf/home/tablebuilder

Gaps & Suggestions:

Largely there is no data gap for obtaining information on population remoteness status, demographic composition, socioeconomic status, labour force status, population health and disability in Australia. This information can broadly be sourced and estimated from ABS Census of Population Housing or other ABS publications. However, there are few data gaps like information on population insurance coverage against fire and natural disasters are not openly available. This information can potentially be sourced from the Insurance Council of Australia or other individual insurance companies.

For population physical health status there is significant data gap in Australia. To date there is no integrated and standardised database available for the all of Australia at state and community level to provide information on a comprehensive set of population and public health indicators.

For population mental health status there is no census level information available on the mental health status of population in Australia. The Household Income and Labour Dynamics in Australia (HILDA) surveys and the National Survey of Mental Health and Wellbeing do not contain information at small area (SA2) level. However, potentially microsimulation modelling techniques can be used to obtain SF36 Mental Health Summary Measures at small area level using the Census 2011 and the surveys.

For population disability status, there is no data gap in Australia in obtaining information on people with Core Activity Need for Assistance and it can be estimated from the latest 2011 Census. There is no census level information available on people with disability in general and *Disability, Ageing and Carers, Australia Survey* do not produce information at small area (SA2) level. However, potentially microsimulation modelling techniques can be used to obtain disability estimates at small area level using the Census 2011 and Disability, Ageing and Carers Survey 2012.

There is no database providing information on ambient/spatiotemporal distribution of population to researchers for the whole of Australia or major cities/small towns in Australia. This area needs to be further researched and population temporal dynamics needs to be modelled to generate the data.

Similarly, in obtaining information on population evacuation response and speed human risk perception needs to be modelled and synthetic estimates need to be

generated at small area level with more detail. Human risk perception or how individuals process information on hazard risk are heavily constructed by their particular social, cultural (Tierney, 1994) and economic context such as race, income, age and gender - in general, women have greater objective risk and more realistic perceptions of risk (Bateman and Edwards, 2002); their cognitive ability- do the decision makers have the psychological ability to process the information being presented to them (White, 1994; Kasperson et al. 1988); and previous evacuation experience (Dow and Cutter; 1998).

Likewise, there is a gap in obtaining information on existing network organisations, community groups, and volunteer groups. This has to be compiled from a range of sources including local council registers.

9. SUMMARY AND CONCLUSION

This report is the first major attempt in developing a generic, consistent and standardized *Built Environment Exposure Information Framework* for Australia. The framework provides the collective views of data managers, researchers and end users on exposure information requirements that will support vulnerability assessments for disaster risk reduction and socio-economic impact analysis with a multi-hazard focus at all levels of governance. More importantly the framework identifies the gaps and overlaps in built environment exposure information requirement at different levels of governance and provides suggestions to overcome those deficiencies. One of the key outcomes of this report is to identify a list of exposure elements across different components of the built environment are presented in the following *Tables: Summary of the exposure information elements.* In this respect, findings presented here provide an important first step in understanding and identifying the complexity in exposure information requirement.

The next phase of the project will consider the expert knowledge and a workshop to define the exposure to attribute level for each of the elements and typologies (a combination of exposure elements) for a purpose. Attribute definitions and standard terminology for buildings, infrastructure, businesses and population exposure elements will be included in the final framework report as the next major milestone.

The final framework report will provide guidelines and standards on exposure information for the development of information systems to assist all levels of disaster governance.

TABLES

Summary of the exposure information elements

FUNDAMENTAL INFORMATION			
Location	**Land Use**	**Insurance Status**	**Metadata**
Latitude	ALUM Classification	**PERSONAL**	Keywords
Longitude		Life Insurance	Geometry
Address		Income Protection Insurance	Feature Type
Geometry		Health Insurance	Definition
		Motor Insurance	Data Source
		Travel Insurance	Spatial Accuracy
		HOUSEHOLDS	Attribute Reliability
		Buildings Insurance	Attribute Source
		Contents Insurance	Attribute Accuracy
		BUSINESS	Data Currency
		Worker's Compensation	Maintenance Cycle
		Professional Indemnity Insurance	Revision Date
		Liability Insurance	Limitations
		GOVERNMENT	Restrictions
		State Owned Assets	Contacts
		Flood Cover Insurance	
		Malevolent Cover Insurance	
		Compulsory Third Party Motor	
		Public Liability Insurance	
		INSURANCE COMPANIES	
		Re-insurance	

BUILDINGS							
Usage	**Type**	**Structure System**	**Year Built**	**Size**	**Emergency Exit**	**Utility Connections**	**Replacement Value**
Residential Commercial Light Industrial Educational Health & Welfare Emergency-Services Government Community Recreational Mixed Use	Separate house Semi-detached house Apartment - Low Rise Apartment - Medium Rise Apartment - High Rise Multistorey Commercial Commercial Buildings Shopping Mall Complex Agriculture Sheds Warehouse Light Industrial Buildings Parking Structures Religious Buildings Monuments/Heritage Heavy Industrial Multiple Buildings Public Venues	Foundation Internal Frame External Wall Façade Coverage Roof Shape Roof Type Orientation Floor Type Floor Height # of Storeys # of Basements Attachments Building Standard Emergency Exit Utility Source	Built Year Construction Period Retrofit Year Renovation Year	Land size Gross Floor Area Building Lettable Area Number of Dwellings Extensions # of Bedrooms # of Toilets # of Car Parks Size of Garage Annex buildings	Signage Evacuation Floors Evacuation Lifts Evacuation Stairwells Evacuation Plan Code Regulations Problems	Location of Gas Location of Electricity Location of Water Location of Solar Location of Hydrants	Building Value Contents Value

TRANSPORT INFRASTRUCTURE										
Roadway	**Railway**	**Waterway**	**Bridges Culverts**	**Tunnels**	**Air ports**	**Sea Ports**	**Public Transport**	**Multimodal**	**Vehicles**	**Functions**
Name Ownership Type Construction material Carrying Capacity Capacity Utilization Year upgraded Lane width Shoulder width Grade/Condition Bicycle Paths/Footpaths Reconstruction- Cost	Ownership Type Gauge Usage Control Facilities Rail Gates Train/Tram Condition Electrification Capacity Year built Year Upgraded Reconstruction-Cost	Channel -Width -Depth -Purpose Harbours Wharves Sea Ferry Networks	Ownership Length Width Type Structure Type Design Spans Materials Purpose Capacity Year built Pier walls Abutment Reconstruction-Cost	Ownership Usage Length Width Type Structure Shape Materials Purpose Equipment Year Built Capacity Reconstruction-Cost	Ownership Functional Type LandingGrounds Traffic Control Tower- Systems Weather Station Safety Facility Security Fuel Depo Terminals/Gates Customs Office Immigration Hangers Year Capacity Traffic Pattern Reconstruction- Cost	Ownership Port Name Port Type Berthing structures Platform Type Protection barriers Super-structures Capacity Year Connections Protection Facilities Reconstruction-Cost	Terminals Interchange Bus stops Railway- Station Railway- Yards Control- Rooms Harbours	Connections Containers Cranes Stackers Trucks Barges Ships Planes Control- rooms Capacity Value	Number & Type Aircrafts Helicopter Cargo Buses Trucks Cars Motor Cycles Trains Trams Boats Ferry Ships	Schedules Routes Patterns Dependencies Capacity

ENERGY INFRASTRUCTURE

Petroleum well	Petroleum Refinery	Petroleum Terminals	Petroleum Transmission	Gas Processing	Gas Transmission	Gas Storage	Service Stations	Electricity Generation	Electricity Transmission	Electricity Transmission Towers/Poles	Electricity Substations
Ownership Well Status Depth Capacity Platform Year Built Reconstr.- Cost	Ownership Products Processing- units Capacity Facilities Storage -Crude -Products -Waste Shipping Pollutant Electricity Year Built Reconstr.- Cost	Ownership UnderGround AboveGround Vicinity Refinery Substances Facilities Capacity Turnover Year Built Blending Reconstr.- Cost	Pipe Lines -Type -Size -Material -Capacity -Year built - Reconstr.- Cost Oil Cargo Vessel -Material -Capacity -Value Ship-Ship transfer Tanker Truck Rail Tanker	Ownership Products Processing-units Capacity Facilities Waste Liquefaction Shipping Electricity Value Year Built Reconstr.- Cost	Ownership Pipe Lines -Type -Size -Material Capacity Year built Cargo Ships Capacity Vessel Cost Ship-Ship Tanker Truck Rail Tanker Retail-Cylinders Reconstr.- Cost Rebuild-timeframe	Ownership Storage Tank Cylinders- Storage Facilities -Reliquefaction -Blending Capacity Fuel Turnover Year Built Reconstr.- Cost	Ownership Site Category Tank Material Year Built Pumps Facilities Store Capital Fuel- Turnover Reconstr.- Cost	Ownership Type Storage Material Conveyors Boilers Generators Transformers Cooling-towers Chimneys Water- Supply Switch Yard Facilities Capacity Year Built Reconstr.- Cost	Ownership Lines Type Insulation Circuit Breakers Voltage- Capacity Year Built Reconstr.- Cost	Ownership Year Built Foundation Topography Height (Peak) Height (Cage) Height (Body) Width Circuits conductors Types Design Materials Dead-end Reconstr.- Cost	Ownership Type Usage Design Height Equipment Capacity Year Built Reconstr.- Cost

COMMUNICATION INFRASTRUCTURE						
Telephone Exchanges	**Telephone Cable Networks**	**Communication Towers**	**Submarine Cable**	**Broadcasting**	**Satellite Earth Stations**	**Postal/Courier**
Ownership	Ownership	Ownership	Ownership	Ownership	Ownership	Ownership
Area of coverage	Telephone line	Tower Foundation	Cable Network	Broadcasting Type	Type of Antenna	Mail Sorting Centres
Capacity	Switch nodes	Site Topography	Cable Landing Station	Purpose	# of Antennas	Delivery Vehicles
-Frequency	Materials (Coper/Fibre)	Tower Purpose	Frequency/Bandwidth	Site Name	Size of Antenna	
-Switches	Year Built	Height of Tower (Peak)	Cable Type	TV Station	Capacity	
-Internet	Rebuilding Timeframe	Tower Design	Cable Capacity	Radio station	Equipment	
-# of lines	Reconstr.- Cost	Tower Materials	Offshore Destination	Studio Facilities	Construction	
Year Built		Year Built	Year Built	Coverage Area	Year Built	
Equipment		Rebuilding Timeframe	Rebuilding Timeframe	Frequency	Rebuilding Timeframe	
Rebuilding Timeframe		Reconstr.- Cost	Reconstr.- Cost	Equipment	Reconstr.- Cost	
Reconstr.- Cost				Cable Networks		
				Value		
				Rebuilding Timeframe		
				Reconstr.- Cost		

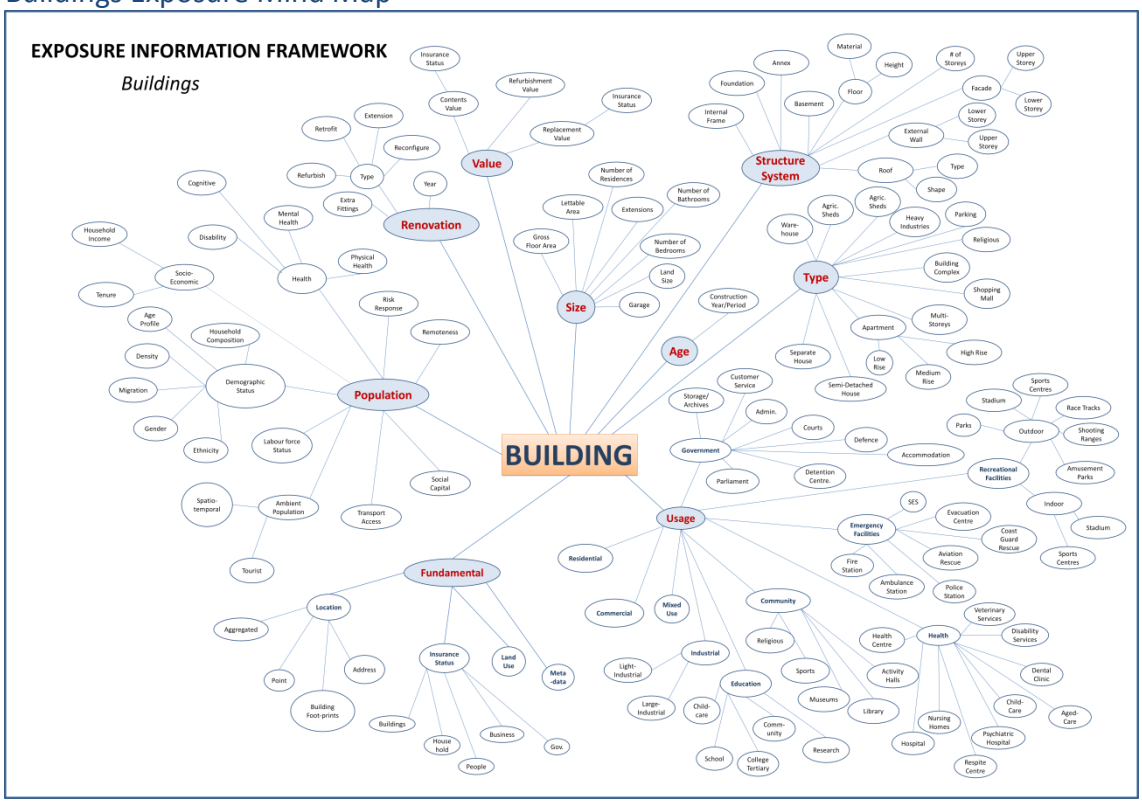
URBAN WATER INFRASTRUCTURE				WASTE MANAGEMENT	HAZARDOUS SUBSTANCES	MAJOR INDUSTRIES
Potable Water Catchment	**Potable Water Treatment**	**Waste Water Treatment**	**Water Transmission Networks**			
Catchment (area)	Ownership	Ownership	Ownership	Collection Centres	Facility usage	Ownership
Dams	Storage Tank	Storage Tank	Reticulation Area	Transfer Stations	List of substances	Industry name
- Foundation	-Size	Aeration Tank	Reticulation Type	Collection Trucks	Physical characters	Industry Structure
- Length	-Foundation	Sludge Tank	Pumping Stations	Incineration Plants	Chemical characters	Industry Usage
- Type	-Construction	Methane Gas- Chamber	Pipes Network	Recycling Plants	Airborne thresholds	Total Floor Area
- Spillway type	-Year Built/Upgrade	Equipment	Pipes Size/Diameter	Landfills	Pictogram	Number of Buildings
- Material	Equipment	-Machinery	Pipes Material	Waste type	Hazard code	List of Facilities
- Year Built	-Clarification Plant	-Disposal	Filtering	Energy Recovery Facility	Hazard character	Year Built
- Reconstruction Cost	-Filtration Plant	-Energy	Connectors	Reconstruction Cost	Severity of toxicity	Building Materials
- Height	-Disinfection Plant	-Odor	Year Built/Upgraded		Symptoms	Equipment
Ground Water Well	-Desalination	-Disinfection	Repair Timeframe		Key suggestions	Storage Warehouse
Criticality	-SCADA Facilities	-Bio-chemical	Reconstruction Cost			Working Hours
Equipment	-Repair Timeframe	-Filtration				Waste Management
Pumping	Reconstruction Cost	Repair Timeframe				Liability Issues
Storage Capacity		Reconstruction Cost				Critical Equipment
Tanks/Reservoirs						Production Capacity
						Reconstruction Cost

PRIMARY INDUSTRIES							
Agriculture- Crops	**Agriculture- Horticulture**	**Agriculture- Diary**	**Agriculture-Animal**	**Fisheries – Wild**	**Fisheries – Aquaculture**	**Forestry**	**Mining**
Farm Size Crop Type Crop Calendar Crop Value Farm house Equipment Storage Size Processing Plant	Farm Size Plantation Type # of Plants Age of Plants Yield Pattern Equipment Storage Size Processing Plant Farm Value	Farm Size Animals Type # of Animals Age Mix of Animals Dominant Breed Sub-dominant Breed Equipment Ancillary Buildings Products Farm Value	Farm Size Animals Type Farming Type # of Animals Age Mix of Animals Dominant Breed Sub-dominant Breed Equipment Ancillary Buildings Products Farm Value	Fishing Zones Fishing Restrictions Endangered Species Port Location Trawlers Nets Total Capacity Storage Capacity Processing Plants	Farm Size Fish Type Fishing Stock Products Pattern Equipment Processing plants Ancillary Buildings Farm Value	Ownership Forest Area Status Forest Structure Dominant Species Sub-dominant Species Products -Hard wood -Softwood -Veneer Logs -Pulp Logs -Oils	Ownership Mining Area Operating Status Operating Type -Surface -Underground Commodities Equipment Production- Capacity Value

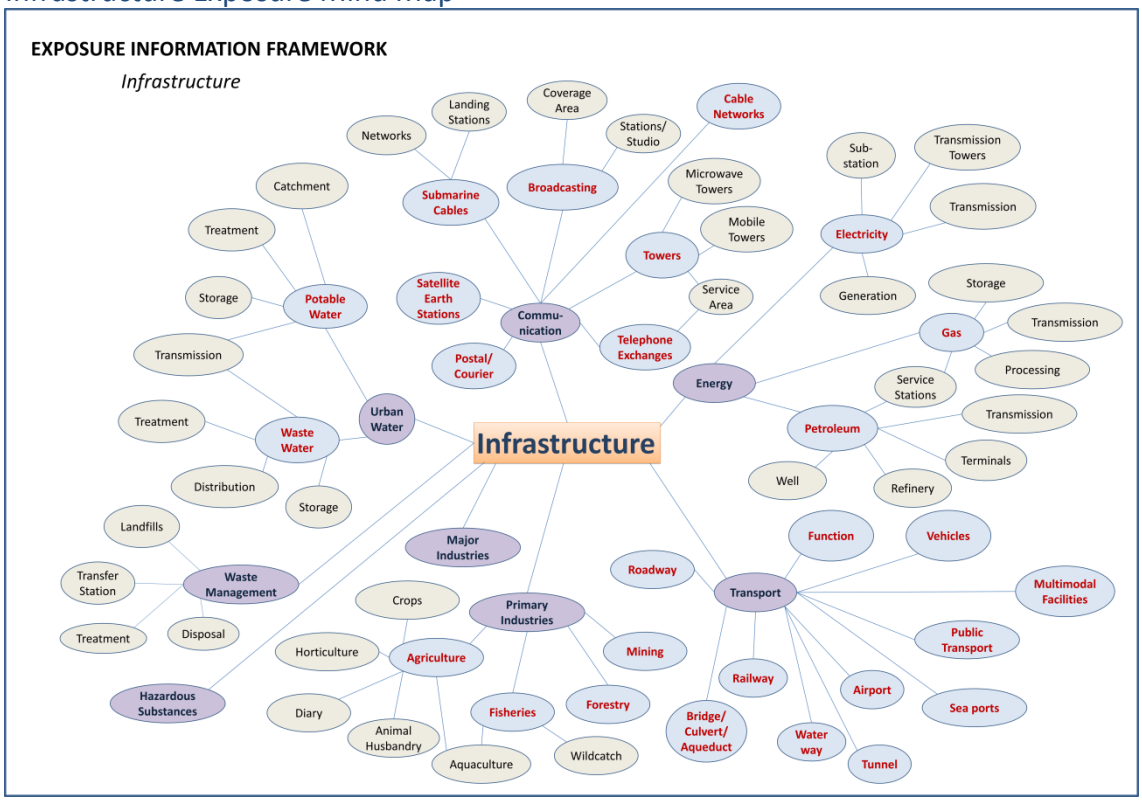
POPULATION						
Remoteness Status	**Demographic Composition**	**Socio-economic Status**	**Population Health**	**Ambient Population**	**Risk Response**	**Social Capital**
	Population age profile Population density Gender composition Migration Indigenous & ethnic-composition Household- composition	Household Income Household Dwelling Tenure Status Insurance Status	Physical health status Mental health status Disability status			

ANNEXURE

Buildings Exposure Mind Map



Infrastructure Exposure Mind Map



NATIONAL EXPOSURE INFORMATION SYSTEM (NEXIS)

BUILDING EXPOSURE
STATISTICAL AREA LEVEL 1 (SA1) AGGREGATED METADATA

1 Population estimate:

d) the average population per occupied private dwelling structure type for each Statistical Area1 (SA1),

e) the proportion of unoccupied dwellings in the total dwelling stock by structure type,

f) the ratio between the 2011 Estimated Resident Population (ERP) and the Census population counts and the number of NEXIS derived residential dwellings. ABS Census 2011.

2 Dwelling Estimates:

d) Number of residential dwellings by type : A dwelling is a structure which is intended to have people live within it i.e. house and flat.

e) Total floor area for each dwelling type: separate and semi-detached houses, and flats or apartments with 2, 3 or 4+ storeys: Sum of the building area (footprint x no. of storeys)

f) Percentage of residential dwellings with low ($1-$599), middle ($600-$1999) or high (greater than $2000) gross household income: For each dwelling type (SH, SD, F0, F3 and F4), a percentage is applied to calculate if that dwelling has a Nil, Low, Medium or High gross household weekly income as a proportion of all dwellings of that type. Dwellings with a negative gross household income are included in the Nil category. The low income household is determined by using the OECD definition of half the national median. In 2011 the national median was $1234/week, which gives a low income measure of $617/week. This has been adjusted to $600 because it is the nearest category in the Census data. High income is set to $2000/week, as this category reflects the top deciles nationally. ABS Census 2011.

g) Percentage of residential dwellings with nil, low, middle or high equivalised[i] income: For each dwelling type (SH, SD, F0, F3 and F4), a percentage is applied to calculate if that dwelling has Nil, Low, Medium, or High equivalised total household income as a proportion of all dwellings of that type. Dwellings with a negative equivalised total household income are included in the Nil category. ABS Census 2011.

h) Percentage of residential dwellings by tenure; owned, rented privately, rented publicly or other tenure[ii]: For each dwelling type (SH, SD, F0, F3 and F4), a percentage is applied to calculate if that dwelling is:

i) Percentage of residential dwellings that DO NOT have access to a motor vehicle: For each dwelling type (SH, SD F0, F3 and F4), a percentage is applied to calculate if the family, lone person or group household in that dwelling does not have access to a registered motor vehicle at or near the dwelling (on Census night) as a proportion of all dwellings of that type. ABS Census 2011

j) Percentage of residential dwellings with one or more persons in the household aged between 0 and 4 years: For each dwelling type (SH,SD F0, F3 and F4) a percentage is applied if that dwelling comprises a family, lone person or group household with one or more persons aged between 0 and 4 years as a proportion of all dwellings of that type. ABS Census 2011

k) Percentage of residential dwellings with ALL persons aged 65 years and over: For each dwelling type (SH,SD F0, F3 and F4) a percentage is applied if that dwelling comprises a family, lone person or group household with ALL persons aged 65 years and over as a proportion of all dwellings of that type. ABS Census 2011.

l) Percentage of residential dwellings with one parent families: For each dwelling type (SH, SD F0, F3 and F4) a percentage is applied if that dwelling comprises a one family household containing a one parent family with children under the age of 15 as a proportion of all dwellings of that type. ABS Census 2011.

m) Percentage of residential dwellings with one or more persons needing assistance with core activities: For each dwelling type (SH,SD F0, F3 and F4) a percentage is applied if that dwelling comprises a family, lone person or group household where one or more persons needs assistance with a core activity as

a proportion of all dwellings of that type. People with a profound or severe disability are defined as those people needing help or assistance in one or more of the three core activity areas of self-care, mobility and communication, because of a disability, long term health condition (lasting six months or more) or old age. ABS Census 2011.

n) Percentage of residential dwellings where ALL persons speak English not well or not at all: For each dwelling type (SH,SD F0, F3 and F4) a percentage is applied if that dwelling comprises a family, lone person or group household where all persons speak English not well or not at all as a proportion of all dwellings of that type. ABS Census 2011.

o) Percentage of residential dwellings where ALL persons highest educational attainment was year 11 or below: For each dwelling type (SH,SD F0, F3 and F4) a percentage is applied if that dwelling comprises a family, lone person or group household where all persons highest educational attainment is year 11 or below as a proportion of all dwellings of that type. Includes households where all persons have no educational attainment. ABS Census 2011.

p) Percentage of residential dwellings where one or more persons undertook voluntary work: For each dwelling type (SH,SD F0, F3 and F4) a percentage is applied if that dwelling comprises a family, lone person or group household where one or more persons undertook voluntary work as a proportion of all dwellings of that type. Comprises people who spent time doing unpaid voluntary work through an organisation or group, in the twelve months prior to Census night. It excludes work done as part of paid employment, if the main reason is to qualify for a Government benefit or if the work was done as part of a family business. ABS Census 2011.

q) Percentage of residential dwellings where all persons in the household moved residential address from 2010 to 2011: For each dwelling type (SH,SD F0, F3 and F4) a percentage is applied if that dwelling comprises a family, lone person or group household where all persons in the household lived in a different SA1 in 2010 to the SA1 they lived in on Census night as a proportion of all dwellings of that type. ABS census 2011.

r) Percentage of residential dwellings where all persons in the household moved residential address from 2006 to 2011: For each dwelling type (SH,SD F0, F3 and F4) a percentage is applied if that dwelling comprises a family, lone person or group household where all persons in the household lived in a different SA1 in 2006 to the SA1 they lived in on Census night as a proportion of all dwellings of that type. ABS census 2011.

3 Building Estimates:

a) Number of residential buildings: A building consisting of one or more dwelling units and the primary use is to house people.
b) Number of residential buildings built: pre and including 1980, post 1981 or unknown: The number of buildings is grouped into pre 1980 and post 1981 as this marks a significant change to building standards in Australia. Other age classifications are available
c) Number of separate houses (SH): A residential house which is separated from other residential dwellings and does not share a common wall
d) Number of semi-detached houses (SD): A residential dwellings sharing a common wall with another dwelling, having their own private grounds with no other dwellings above or below
e) Number of flat or apartment buildings with up to 2 storeys (F0): A residential apartment building up to two (2) storeys
f) Number of flat or apartment buildings with 3 storeys (F3): A residential apartment building with three (3) storeys
g) Number of flat or apartment buildings with 4 or more storeys (F4): A residential apartment building with four (4) or more storeys
h) Number of residential buildings with the wall type: concrete masonry, cavity and solid masonry, veneer masonry, precast concrete, timber, metal sheeting, fibre cement, mudbrick or rammed earth or synthetic: Building counts by NEXIS wall type classifications
i) Number of residential buildings with the roof type: tile, metal sheeting, concrete, fibre cement, imitation tile, synthetic: Building counts by NEXIS roof type classifications

j) Total structure value ($) for all residential buildings (rounded to the nearest million): Replacement cost is the cost to rebuild the existing structure (size and construction material) at current building standards at the current costs. Source: Altus Group Cost Management Pty Ltd, 2010 (UPDATED Sept 2013)

k) Total contents value ($) for all residential buildings (rounded to the nearest million): Contents value is calculated as a proportion of the replacement cost, adjusted for depending on the gross income classification.

l) Total building footprint area for residential buildings (m2): Sum of the building footprints

Source Website: http://www.ga.gov.au/scientific-topics/hazards/risk-impact/nexis

ABS, (2010-11) Agricultural Census Data Release:

7121.0 - Agricultural Commodities, Australia, 2010-11 this publication contains final estimates for the main commodities collected in the 2010-11 Agricultural Census. Includes statistics on land use, industry activity, crop and horticultural area and production, and livestock numbers. Data at national and state level including sub-state geographies such as Statistical Area 4 (SA4) and Statistical Area 2 (SA2) geographical levels are available from November 2012.

The Agricultural Census is conducted once every five years, with the Agricultural and Resource Management Survey (ARMS) and the Agricultural Survey (AS) conducted between Censuses. The main objective of the Agricultural Census is to provide benchmark information on the agriculture sector for small geographic areas. The 2010-11 Agricultural Census provides estimates for a range of agricultural commodity items, including broad acre cropping, horticultural production, livestock and land preparation. Care should be taken when comparing estimates over time as not all categories directly align between years (ABS, 2015)

PSMA Australia

PSMA Australia collates, standardizes and enhances location data from each of the Australian state and territory governments to deliver national aggregate datasets. These datasets deliver essential base location data including geocoded addressing, roads, land parcels and administrative boundaries.

PSMA datasets are distributed by a network of value-added partners (VARs) who resell the raw datasets as well as develop products and services that cater for a wide range of industry, government and community uses for the benefit of the whole of Australia.

PSMA data is foundation data that provides spatial context to business, statistical and crowd-sourced data.

Our datasets may be purchased individually or in combination. We encourage you to talk to our VARs about how PSMA data can be used to meet your specific needs.

The following datasets are available for sale through our value-added resellers.

- Administrative Boundaries
- Features of Interest
- CadLite
- G-NAF (including G-NAF Lite)
- Land Tenure
- Postcode Boundaries
- Transport & Topography

Source Website: http://www.psma.com.au/

Australian Early Development Census (AEDC)

For information on early childhood development the **Australian Early Development Census (AEDC)** can provide important information. It is a Australian Government initiative for nationwide data collection of early childhood development at the time children commence their first year of full-time school. The AEDC highlights what is working well and what needs to be improved or developed to support children and

their families by providing evidence to support health, education and community policy and planning. The AEDC is held every three years, with the third collection taking place from May to July 2015. It looks at five areas of early childhood development: physical health and wellbeing, social competence, emotional maturity, language and cognitive skills, and communication skills and general knowledge.

Community Indicators Victoria (CIV)

At the community level Community Indicators Victoria (CIV) provides a comprehensive framework of community wellbeing measured by local level data. Community indicators are a democratic resource for engaging citizens and communities in informed discussions about shared goals and priorities, a policy resource guiding evidence-based planning and action to address the issues identified as important by communities, and a reporting resource tracking and communicating progress towards agreed goals and outcomes. CIV is a collaborative project within the Place, Health and Liveability Research Program at the McCaughey VicHealth Centre, within the School of Population & Global Health, at the University of Melbourne.

For the state of Victoria at community level along with a set of other wellbeing indicators, CIV provides information on

1. Child Health assessment
2. Immunization
3. Life Expectancy
4. Obesity
5. Risk Alcohol Consumption
6. Self-Reported Health
7. Smoking Status
8. Subjective wellbeing

However, it provides no information on morbidity, epidemiology and existing disease pattern in the community. More importantly it is not a health indicators focused database. While there similar initiatives initiated at other states in Australia such as 1338.1 - NSW State and Regional Indicators, Dec 2010.

Public Health Information Development Unit (PHIDU)

Another important source of information on public health domain in Australia is ***Public Health Information Development Unit (PHIDU) at the University of Adelaide***. Since its establishment in 1999, PHIDU has been providing information on a broad range of health and other determinants across the life course with a particular emphasis on the publication of small area statistics for monitoring inequality in health and wellbeing, and for supporting opportunities for the prevention of, and early intervention in, the development of adverse population health outcomes.

PHIDU offers online access to a comprehensive range of current (and some historic) data at national, jurisdictional, regional and small area levels for Australia at no cost to users. The data describe the demographic characteristics of individuals and families; and provide various measures of socioeconomic status and health status (including estimates of the prevalence of major chronic diseases and associated risk factors), disability, community capacity and strength, early childhood development and learning outcomes and the population's use of health protection, screening and treatment services. Data are also published for premature deaths across the life course, from infants, to young children (deaths at one to four years of age), youth (deaths at ages 15 to 24 years) and adults (deaths before 75 years of age), in addition to the more recent concept of avoidable mortality. Socioeconomic and geographical variations in health are demonstrated through interactive atlases and graphs, which are supported by data tables and metadata; where the data are available, they are analysed by age, sex and Indigenous status. This web-based source of data on health and its determinants is unique in Australia, and has been recognised as an innovative and useful approach internationally, by agencies such as the World Health Organization.

REFERENCES

ABARE (2013), Australia's State of the Forests Report 2013, *ABARE Report*, Department of Agriculture, Available at http://www.agriculture.gov.au/abares/forestsaustralia/Documents/criterion1_web.pdf; Accessed on 21 September 2015

ABARE (2013), Australian fisheries and aquaculture statistics 2013, *ABARE Report*, Available at http://data.daff.gov.au/data/warehouse/9aam/afstad9aamd003/2013/AustFishAquacStats_2013_v1.2.0.pdf); Accessed on 21 September 2015

ABS (2015), Australian Statistical Geography Standard (ASGS), Resource Document, Available at http://abs.gov.au/websitedbs/D3310114.nsf/home/Australian+Statistical+Geography+Standard+(ASGS). Accessed on 10th Jun 2015.

ABS (2012), 'GEOGRAPHIC DISTRIBUTION OF THE POPULATION', *1301.0 - Year Book Australia*, Available at http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/1301.0~2012~Main%20Features~Geographic%20distribution%20of%20the%20population~49, Accessed on 27th August 2015.

ABS (2011), Census of Population and Housing, Available at http://www.abs.gov.au/census, Accessed on 12th September 2015.

ABS (2008), 4102.0 - Australian Social Trends, 2008
Previous ISSUE Released at 11:30 AM (CANBERRA TIME) 23/07/2008

ABS (2006), 2901.0 Census Dictionary Australia 2006(Reissue), Australian Bureau of Statistics, Australian Government.

AIEC (2015), *Australian Agriculture Horticulture Live Stock Wool and Crops*, Australian International Education Centre Europe, Available at http://aiec.hu/en/agriculture-in-australia, Accessed on 17 August 2015

Aldrich, D.P. (2012), *Building Resilience: Social Capital in Post Disaster Recovery*, The University of Chicago Press.

Australian Emergency Management Institute, Attorney-General's Department (2011), 'AUSTRALIAN EMERGENCY MANAGEMENT HANDBOOK SERIES: Community Recovery', Hand Book 2, © Commonwealth of Australia, Third edition: ISBN 978-1-921152-27-6.

Bateman, J. M., and Edwards, B. (2002), 'Gender and evacuation: A closer look at why women are more likely to evacuate for hurricanes', *Nat. Hazards Rev.*, 3(3), 107–117.

Bhaduri, B., Bright, E.,Coleman, P. & Marie L. (2007), 'LandScan USA: a high-resolution geospatial and temporal modeling approach for population distribution and dynamics', *Urban* Published online: 29 September, Springer Science+Business Media B.V.

Bucci, S. P., Inserra, D., Lesser, J., Mayer, M. A., Slattery, B., Spencer, J. and Tubb, K. (2013), 'After Hurricane Sandy: Time to Learn and Implement the Lessons in Preparedness, Response, and Resilience', The Heritage Foundation Emergency Preparedness Working Group, Special Report No. 144, available at http://report.heritage.org/sr144, accessed on 21st Aug 2015.

Council of Australian Governments (2011), *NATIONAL STRATEGY FOR DISASTER RESILIENCE*, Attorney-General's Department, Commonwealth of Australia.

CTBUH, (2015), 'CTBUH Tall Building Height Calculator', Council on Tall Builidngs and Urban Habitat (CTBUH), http://www.ctbuh.org/LinkClick.aspx?fileticket=s4SVxV%2FruCM%3D on 15 September 2015.

Cutter, S. L., C. G. Burton, and C. T. Emrich. (2010), 'Disaster resilience indicators for benchmarking baseline conditions', *Journal of Homeland Security and Emergency Management,* 7 (1): 1–22.

Cutter, S. L., B. J. Boruff, and L. W. Shirley. (2003), Social vulnerability to environmental hazards. *Social Science Quarterly,* 84 (2): 242–61.

Dash, N. and Gladwin, H. (2007), 'Evacuation Decision Making and Behavioral Responses: Individual and Household', *Natural Hazards Review* © ASCE, DOI: 10.1061/(ASCE)1527-6988(2007)8:3(69)

Diary Australia (2015), About Australian dairy industry, http://www.dairyaustralia.com.au/Industry-information/About-the-industry.aspx on 21 September 2015.

Donner, W. and Rodríguez, H. (2008), 'Population Composition, Migration and Inequality: The Influence of Demographic Changes on Disaster Risk and Vulnerability', *Social Forces* , Vol. 87, No. 2 (Dec., 2008) , pp. 1089-1114

EMA (2004), *Emergency Risk Management Applications Guide,* Manual 5, Emergency management Australia, Canberra.

Flood Insurance Guide (2012), 'Flood and Storm Surge', *http://www.jvib.com.au/wp/wp-content/uploads/2015/02/Flood-Insurance-Guide.pdf on 1 October 2015.*

Fothergill, A. and Peek, L. A. (2004), 'Poverty and Disasters in the United States: A Review of Recent Sociological Findings', *Natural Hazards* 32: 89–110.

Freire, S., Aubrecht, C. and Wegscheider, S. (2013), 'Advancing tsunami risk assessment by improving spatio-temporal population exposure and evacuation modeling', *Nat Hazards*, 68:1311–1324 DOI 10.1007/s11069-013-0603-4

Fussell, E., Sastry, N., VanLandingham, M. (2010), **'**Race, socioeconomic status, and return migration to New Orleans after Hurricane Katrina', *Popul Environ*. , 31(1-3): 20–42.; doi:10.1007/s11111-009-0092-2.

Health Survey Report, (2015), validity (SF-36 Health Survey Update, 2015: available from http://www.sf-36.org/tools/sf36.shtml) (SF-36® Health Survey Update, 2015).

Henderson, D.J. and Ginger J.D. (2007), 'Vulnerability Model of an Australian High-Set House Subjected to Cyclonic Wind Loading', *Wind and Structures*, 10(3), 269-285.

Hugo, G., Feist, H. and Tan, G. (2013), POPULATION CHANGE IN REGIONAL AUSTRALIA**,** 2006-11 Australian Population & Migration Research Centre Policy Brief March, 1(3)

IOM (Institute of Medicine) (2015), *Healthy, resilient, and sustainable communities after disasters: Strategies, opportunities, and planning for recovery*, Washington, DC: The National Academies Press.

Kinfu, Y, Mohanty, I, Brown, L, Davey, R. (2015), 'Population ageing and small area need for primary care in Australia', *Report prepared for the Australian Primary Health Care Research Institute*, The Australian National University.

Månsdotter, A., Backhans, M., Hallqvist, J. (2008), 'Health related quality of life measured by SF-36: a population-based study in Shanghai, China', *BMC Public Health*, 8: 292.

Martine, G. and Guzman, J. M. (2002), POPULATION, POVERTY, AND VULNERABILITY: MITIGATING THE EFFECTS OF NATURAL DISASTERS, *ECSP Report* (8), 45-68

Masozeraa, M., Baileyb, M., Kerchnerc, C. (2007), 'Distribution of impacts of natural disasters across income groups: A case study of New Orleans', *Ecological Economics,* 63: 299–306.

Middelmann, M. H., (Editor) (2007), *Natural Hazards in Australia: Identifying Risk Analysis Requirements*, Geoscience Australia, Canberra.

Nadimpalli, K. Mohanty, I. and Kalantari, M. (2014), Natural Hazards Exposure Information Modelling Framework, *Literature Report 2014*. Geoscience Australia, Canberra.

Nadimpalli, K., Edwards, M. and Mullaly, D. (2007), 'National Exposure Information System (NEXIS) For Australia: Risk Assessment Opportunities', In Oxley, L. and Kulasiri, D. (eds) MODSIM 2007 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2007, pp. 1674-1680. ISBN : 978-0-9758400-4-7

Naik, A., Stigter, E. and Laczko, F. (2007), *Migration, Development and Natural Disasters:Insights from the Indian Ocean Tsunami*, Prepared for IOM by International Organization for Migration, Geneva

National Academy of Sciences (2008), *Potential Impacts of CLIMATE CHANGE on U.S. Transportation,* National Research Council, THE NATIONAL ACADEMIES, Transportation Research Board, WASHINGTON, DC , US, available from http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf

Neumayer, E. and Plumperw, T. (2007), 'The Gendered Nature of Natural Disasters: The Impact of Catastrophic Events on the Gender Gap in Life Expectancy, 1981–2002', *Annals of the Association of American Geographers*, 97(3): 551–566. Association of American Geographers. Blackwell Publishing: MA 02148 and Oxford OX4 2DQ, U.K.

Nix-Stevenson, D. (2013), 'Human Response to Natural Disasters', *SAGE Open July-September: 1–12*; DOI: 10.1177/2158244013489684, sgo.sagepub.com.

NPI (2012), *National pollutants inventory guide*, version 5.3, ISBN: 8 642 54690 8

NRC (National Research Council) (2014), *Acute exposure guideline levels for selected airborne chemicals*, volume 17, ISBN 978-0-309-30476-4

Preston, B.L.; Jones, R.N. (2006), 'Climate Change Impacts on Australia and the Benefits of Early Action to Reduce Global Greenhouse Gas Emissions', *A consultancy report for the Australian Business Roundtable on Climate Change*, CSIRO Marine and Atmospheric Research.

Queensland University of Technology (2010), *Impacts and adaptation response of infrastructure and communities to heatwaves: The southern Australian experience of 2009*, National Climate Change Adaptation Research Facility, Gold Coast, 152 pp.

Safe Work Australia (2014), *Global harmonised system – Hazardous chemical information list*, http://hsis.safeworkaustralia.gov.au/GHSInformation/GHS_Hazardous_Chemical_Information_List on 9 September 2014

Safe Work Australia (2009), *Hazardous Substances Information System (HSIS) –* Guidance material for hazard classifications, http://hsis.safeworkaustralia.gov.au/Home/GuidanceMaterialHazardousSubstances on 9 September 2014

Steffen, W., Hughes, L., and Perkins, S. (2014), *Heatwaves: Hotter, Longer, More Often,* Climate Council of Australia Limited, ISBN: 978-0-9924142-2-1).

Stewart, M. G. and Li, Y. (2009), 'Impact and Adaptation Assessment of Cyclone Damage Risks due to Climate Change', ***Research Report No. 276.08.2009***, ISBN No. 9780 9806 0344 6

Tierney , K. J. (2014), *The Social Roots of Risk: Producing Disasters, Promoting Resilience*, Stanford University Press, ISBN: 9780804791397.

Tierney, K. J. (2009), 'Disaster Response: Research Findings and Their Implications for Resilience Measures', *CARRI Research Report 6*. Oak Ridge: Community and Regional Resilience Institute. http://www.resilientus.org/library/Final_Tierney2_dpsbjs_1238179110.pdf

Tierney, K. J. (1994), 'Sociology's unique contributions to the study of risk', *Paper presented at the 13th World Congress of Sociology*, Bielefeld, Germany.

United Nations Inter-Agency Secretariat of the International Strategy for Disaster Reduction (UN/ISDR) (2005), *Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters*, available at http://www.unisdr.org/2005/wcdr/wcdr-index.htm

Vivoda, V. (2011), 'Japan's Energy Security Predicament in the Aftermath of the Fukushima Disaster', *Journal of energy Security*, December.

Walters, SJ. (2004), 'Sample size and power estimation for studies with health related quality of life outcomes: a comparison of four methods using the SF-36', *Health & Quality of Life Outcomes,* 2:26.

Ware, John E. and Kosinski, Mark (2001), 'Interpreting SF&-36 summary health measures: A response', *Quality of Life Research*, 10 (5): 405

Williams, S., Jacobs, K., Newton, P. and Blakely, E. J. (2009), 'Natural disaster preparation and response: a guide for state housing authorities', Australian Housing and Urban Research Institute, *AHURI Positioning Paper No. 113*: ISSN:1834-9250; ISBN:978-1-921610-03-5

World Health Organisation (2015), *Humanitarian Health Action: DROUGHT - Technical Hazard Sheet - Natural Disaster Profiles*, accessed on 16th July, 2015, available at http://www.who.int/hac/techguidance/ems/drought/en/

World Health Organisation (2015), *MENTAL HEALTH ACTION PLAN 2013-2020*, accessed on 16th July 2015, available at http://apps.who.int/iris/bitstream/10665/89966/1/9789241506021_eng.pdf

[i] Equivalised total household income is total income adjusted by the application of an equivalence scale to facilitate comparison of income levels between households of differing size and composition. An 'ABS-modified OECD equivalence scale' is used where 1 point is allocated to the first adult, 0.5 points to every subsequent adult and 0.3 for every child under 15.
Equivalised total household income can be viewed as an indicator of the economic resources available to a standardised household. For a lone person household it is equal to household income. For a household comprising more than one person, it is an indicator of the household income that would be needed by a lone person household to enjoy the same level of economic wellbeing.

[ii] Owned – Owned outright or owned with a mortgage
Rented – Rented from a real estate agent or direct from owner
Rented Public Housing – Rented from a State/Territory housing authority or rented from a co-operative, community or church group
Other Tenure Types –Rented from a person not in the same household, occupied rent-free, occupied under a life tenure system and all other tenure types, as a proportion of all dwellings of that type. ABS Census 2011