5 THE ELEMENTS AT RISK IN NEWCASTLE AND LAKE MACQUARIE (J. STEHLE, N. CORBY, D. STEWART AND I. HARTIG)

A comprehensive survey of buildings was carried out in Newcastle. This Chapter outlines some of the main results of that survey. The inventory of buildings also in an important input to the risk simulation model in Chapter 6.

5.1 The Urban Setting

5.1.1 The Development of Newcastle and Lake Macquarie

Newcastle, on the Hunter River, was settled from early in the 19th Century as both a centre for coal extraction and export, initially to Sydney. It was also the seaport for trade between the growing agricultural economy in the Hunter Valley, served by river ports at Morpeth and Clarence Town, and by the expanding bullock track and then rail system into the valley and nearby coastal areas. Though a convict penal settlement was established in 1792 the first land grants in the valley, around Newcastle, were in 1823 marking the beginnings of current European style communities. Early occupation was concerned with coal mining, agricultural support, maritime exports and administration. The original settlement was able to draw on resources of this government and commercial investment and from the late 1800s significant building work was carried out in brick and masonry. These structures were for administration, commercial headquarters, warehouses and homes for the wealthy. There was also considerable timber building, much of it for worker housing in the outlying mining settlements spread across the Newcastle Basin.

Lake Macquarie was also first settled early in the 19th century, on both the eastern sand peninsular and the relatively low-lying, south-western shore. The rate of settlement was slow, driven by small scale agriculture rather than by coal extraction. Suburban expansion only commenced with coal mining at Belmont and around Teralba and Toronto late in the 19th century, following train services linking to Newcastle and the new Sydney-Newcastle railway. No major commercial centre was established before 1900, so the type and scale of building in Lake Macquarie settlements is 20th century, and much of it is of timber because of the abundant forests in the hills west of the lake.

These expressions of building form have a bearing on the vulnerability of existing building stock, and the whole community, to earthquake hazard.

5.1.2 Geographical Setting

The geological setting of the municipalities of Newcastle and Lake Macquarie is described in Appendix D. The importance of this to present communities is discussed in the following Sections. The more heavily populated suburbs of both cities sit on an area of Permian sedimentary rocks of the Newcastle and Tomago Coal Measures, which are part of the Hunter Valley Dome Belt and which are characterised by low-relief folded hills and a complex of north-west to south-east trending faults. The towns and suburbs of Lake Macquarie south of Toronto and Swansea are on the northern extremity of the younger Narrabeen/Hawkesbury sandstones of the Hornsby Plateau and are characterised by relatively higher relief but less sharply folded and less frequently faulted strata. These Narrabeen sandstones extend as a north finger along the Mount Vincent ridge to Mount Sugarloaf and also appear locally south-west of Teralba.

The surface of these sedimentary rocks is both weakened by weathering and eroded by recent wash into gullies and creeks. The terrain on which urban structures are built therefore generally comprises up to thirty-metre thickness of soils weathered from the sedimentary rock or washed from adjacent slopes. There is very little exposed competent sound rock to provide foundation for large structures at the surface.

The topographical units, which describe differences in the setting of urban settlements, are:

1) The Newcastle city foreshore and the hill suburbs backing it, The Hill;
2) The Newcastle basin, being that flat terrain on Quaternary sedimentary soils comprising suburbs from Cooks Hill and Merewether through Hamilton, Lambton and Mayfield;
3) The delta areas of Stockton peninsula, Carrington, Kooragang and Hexham which sit on low sand/silt/clay beds which also include areas of fill material human-placed to form land;

4) The hill suburbs on sedimentary rocks of the coal measures (sandstone, siltstone, conglomerates, tuff and coal) from Merewether Heights/Redhead west to Beresfield/Minmi/West Wallsend/Awaba and round the north of the lake to Toronto/Warners Bay/Belmont North;
5) The lakeside townships on Quaternary sediments in widening creek valleys as they enter the lake. These are typified by Dora Creek, Toronto, Swansea and Warners Bay and are much smaller segments of urbanisation than found in the Newcastle Basin;
6) The Belmont to Swansea coastal barrier sand strip;
7) The southern lake suburbs on Narrabeen sandstones and conglomerates from Caves Beach and Cams Wharf across to Morisset, Cooranbong and Wangi Wangi.

These topographical units describe the suburbs and townships and have had some bearing on the development of western settlement in the study area. Topography permitted access, or inhibited it to early transport systems. Water supply and streams, coal seams and soils provided the economic opportunity and spirited development of the settlements.

5.1.3 Significant Features

5.1.3.1 *The Historical City*

The core of the old city of Newcastle contains a mixture of small and medium sized buildings with many dating from the late 19th century, and with a wide variety and a complex mix of urban uses – administrative, commercial, retail, cultural, residential, industrial and transport. Many of these old buildings still operate with their original function. All this is set between a beach and headland at the east, the busy operating Port of Newcastle at its north and a steep cathedral topped hill behind it on the south. This city of old buildings embodies a mixture of construction types; of brick, timber, concrete, some stone and iron. Threaded through this fabric of old is a scatter of buildings of all periods of the 20th century.

In a half moon around this core lies the remainder of the original city, from Merewether to the suburbs of Lambton and Mayfield. These suburbs lie in the basin sitting on sedimentary material as described in Chapter 4. Beyond these are the hill suburbs extending out to Lake Macquarie suburbs in the south and Maitland in the west.

5.1.3.2 *Social & Cultural*

Major structures within the city are:

- City Hall
- Catholic and Anglican Cathedrals and major other churches
- Library and Museum
- Conservatorium of Music.

5.1.3.3 *Community Service*

- Police headquarters
- Royal Newcastle Hospital
- Police, Fire & Ambulance stations
- Regional Court House
- Newcastle City offices and works depot.

5.1.3.4 *Educational*

- Primary and secondary schools
- Pre-school centres
- TAFE College campus
- University campus.

5.1.3.5 Public Utility Infrastructure

- Telephone exchanges
- Water pump and storage facilities.

5.1.3.6 Environmentally Sensitive

- Sewage treatment works
- Oil storage tank farm.

5.1.3.7 Economic

- Newcastle CBD
- Newcastle port facilities
- Major industrial establishments.

An assessment of vulnerability requires consideration of the elements at risk. Broadly, these elements can be grouped into three categories: buildings, societal elements and lifelines.

5.2 Elements at Risk - Buildings

5.2.1 Distribution of Buildings

Building type can be inferred by various attributes such as wall type and number of storeys, which can be determined from a ‘footpath survey’. The survey regime consisted of approximately a 1 in 10 sample for inner Newcastle, with coarser survey rates being adopted for outer Newcastle and Lake Macquarie regions. The survey methodology is discussed in detail in Appendix G. The information was used for the categorisation of buildings according to a “HAZUS” (National Institute of Building Sciences, 1999) structural type and a “HAZUS” usage type. These types are defined below. The categorisation approach is explained in more detail in Appendix G.

Building details often increase the vulnerability of individual buildings compared to the average performance expected for a generic building class. These building details include brick chimneys and parapets, brick gable roof ends, suspended awnings, structural irregularities (including soft-storeys and brick pier foundations) and tile roofs (which are heavy). A particular type of unreinforced masonry house, built before the 1930s, has also been identified as being particularly vulnerable. This type has its heavy tile roof supported by a single exterior skin of brickwork, and can be identified by a lack of soffit lining (see Figure 5.1). The support of the roof on an internal brick skin is considered less vulnerable since interior walls brace the internal skin.

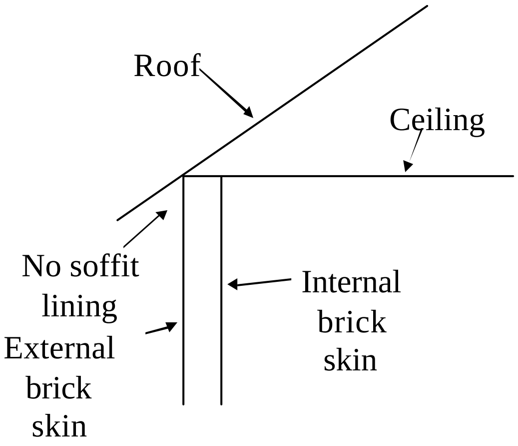

Figure 5.1: Illustration of a vulnerable unreinforced masonry building detail whereby the roof is solely supported on the external brick skin

The variation of building stock over time should be considered in a more rigorous study. In particular, the growth of a city should be considered. For example, in 1999, Lake Macquarie City Council anticipated that

19,000 new homes would be required by 2020. Such growth could increase the overall community vulnerability if the growth consists of the construction of vulnerable building types (such as unreinforced masonry structures) and if the capacity of emergency response facilities is not increased to cope with the increased population. On the other hand, Newcastle has undergone a lot of redevelopment, including some retrofitting. This often involved the replacement or structural upgrading of older (and vulnerable) unreinforced masonry structures. Hence, vulnerability can also reduce over time.

An example of the spatial distribution of some of buildings according to external wall type is shown in Figure 5.2.

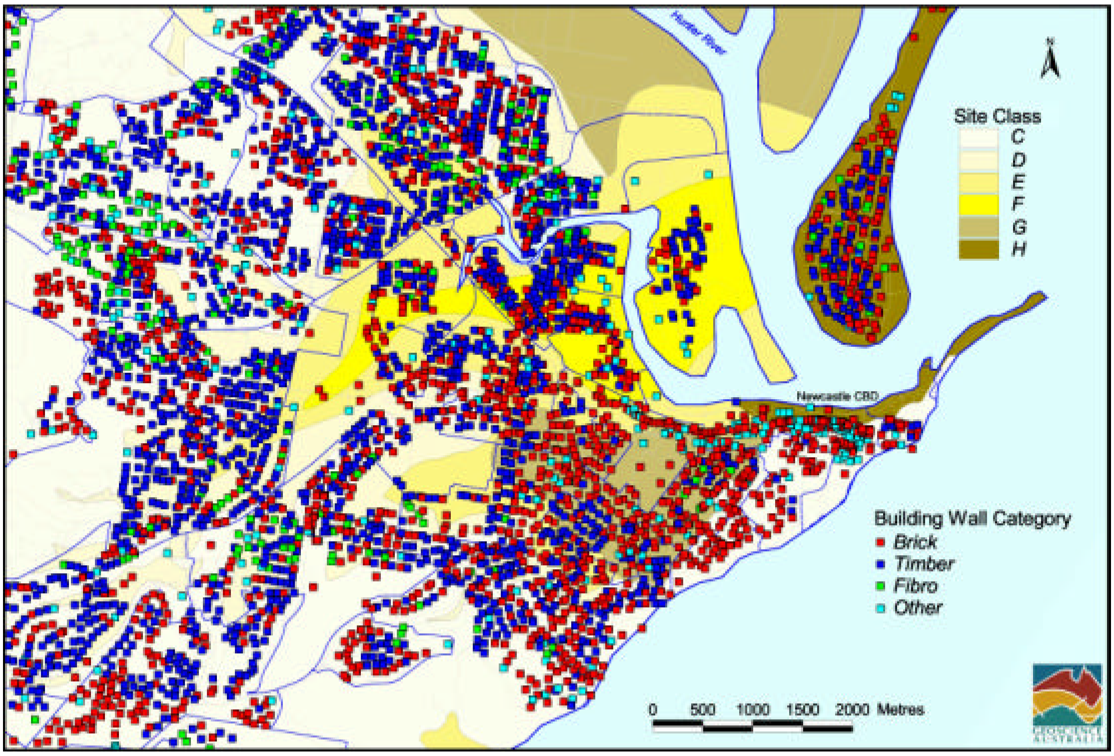

Figure 5.2: Distribution of buildings according to external wall type in the Newcastle area

5.2.2 HAZUS Construction Types

For the risk simulation modelling (see Chapter 6) buildings are classified into subgroups of building construction types. The classifications have been adopted by the methodology used by HAZUS (National Institute of Building Sciences 1999).

The main HAZUS construction types are listed in Table 5-1. There are 36 types in total, although not all types are present in Newcastle. Some of the types are further subdivided into height classes: low-, mid- and high-rise. For a full list of the HAZUS construction types see Chapter 5 of the HAZUS Technical Manual (National Institute of Building Sciences 1999). The most common construction types in Newcastle are timber frame, followed by unreinforced masonry.

Table 5-1: HAZUS classifications for building construction type, found in Newcastle

HAZUS Types	HAZUS type codes
Unreinforced masonry	URML, URMM
Timber frame	W1, W2
Reinforced and pre-stressed concrete buildings	C1L, C1M, C1H, C2L, C2M, C2H, PC1
Steel framed buildings	S1L, S1M, S1H, S2L, S2M, S2H

An example of the spatial distribution of buildings according to the HAZUS structural type is shown in Figure 5.3 (for more information see Appendix G). A more detailed description of some of the key building construction types is given below.

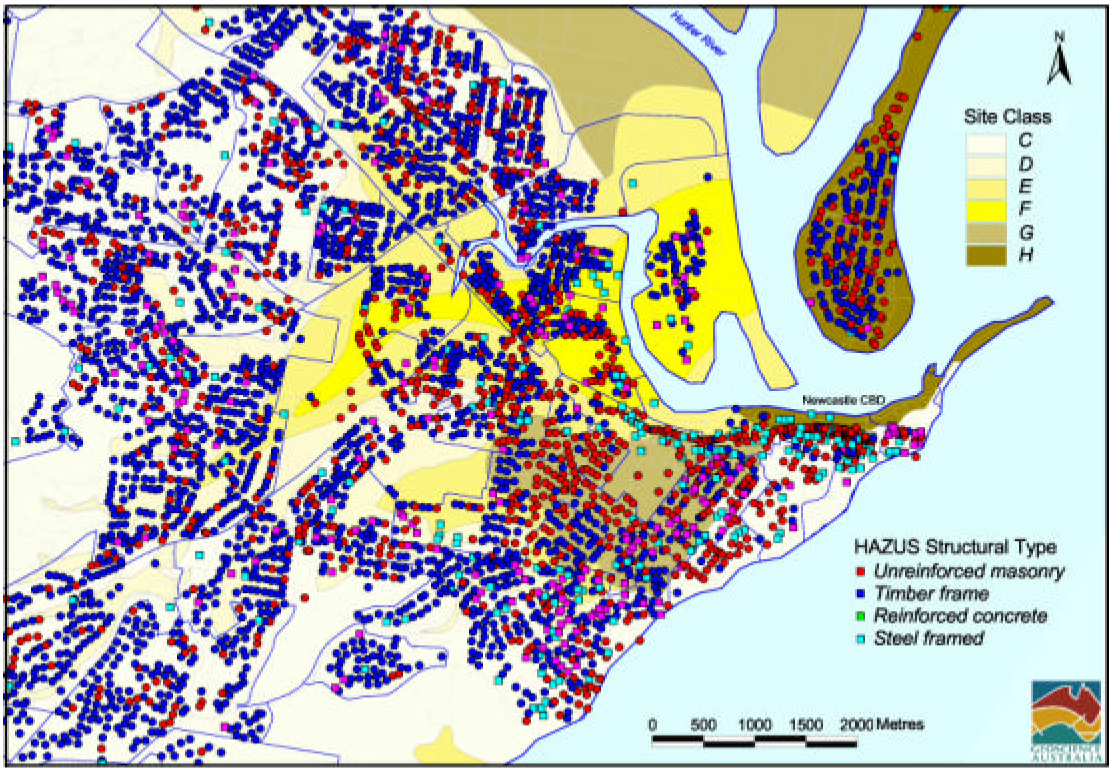

Figure 5.3: Distribution of HAZUS building structural type in the Newcastle area

5.2.2.1 Unreinforced masonry buildings

These types of buildings are very common in Newcastle, particularly for construction up until the 1960s. Older parts of Lake Macquarie also have this type of construction, though it is generally not as common. A wide range of buildings including houses, terraced houses, shops, schools, churches and hospitals are constructed of unreinforced masonry. Infill walls in reinforced concrete framed buildings are also commonly constructed of unreinforced masonry, however this is considered in Section 5.2.2.3.

Unreinforced masonry buildings have historically performed poorly in earthquakes, as witnessed in the 1989 Newcastle earthquake (Melchers, 1990). While these types of structures can perform well if designed and constructed according to current building standards, buildings which are old, decayed of poor design or construction may perform poorly during an earthquake.

A common deficiency in this type of construction is a lack of ties between the two leaves of double-brick cavity wall construction. This deficiency may be a result of corrosion or simply the lack of, or incorrect placement of, ties. Soft and eroded lime mortar joints also contribute to structural weakness and to widespread corner failures in the Newcastle 1989 earthquake (Melchers, 1990). These deficiencies commonly manifest themselves in the failure of parapets, gable roof ends, corners, chimneys and the transverse failure of walls. Cracking due to racking is another common type of damage, although this result is less dependent on construction quality.

Continuity of the structure and ductile behaviour are keys to good seismic performance. The latest Australian standard for masonry structures, AS3700, 2nd edition (AS3700, 1998) was released in 1998 and gives recommendations for design, including requirements for seismic effects to achieve adequate performance levels. This standard replaced the first edition which was issued in 1988, and paid little or no regard to seismic effects. In general, Australian Standards for buildings are enacted by Federal parliament into the Building Code of Australia. The latest version of AS3700 is referenced by way of BCA Amendment 3, and came into effect on the 1st of July, 1998.

5.2.2.2 Timber frame buildings

In Newcastle and Lake Macquarie, timber frame housing is often identified by brick veneer, timber and sometimes fibreboard cladding. Brick veneers, which can easily be confused with unreinforced masonry buildings, are more common for construction dating from the 1960s onwards. The method used for distinguishing brick veneers is presented in Appendix G. Timber frames are most common in smaller buildings such as houses.

Timber frame buildings generally perform very well in earthquakes, although nonstructural and contents damage can be significant. Brick veneer cladding, brick chimneys, plasterboard linings and cornices are commonly damaged by earthquake shaking. However, serious structural damage is perhaps most likely in the foundations, particularly where brick pier or “soft/weak storey” type foundations are used or if there is a lack of continuity.

Timber frame housing must be designed according to AS1720.1 (AS1720.1, 1997) or AS1684.1-4 (AS1684.4, 1999; AS1684.3, 1999; AS1684.2, 1999; AS1684.1, 1999), with consideration of lateral loading predominated by discussion of wind loading in these documents. The consideration of seismic effects has had practically no effect on the construction practices for this category of structure. Despite non-structural and contents components of these building types being more vulnerable than the structural components, little attention is paid to improving their performance, and this is reflected by a lack of requirements in Australian Standards.

5.2.2.3 Reinforced and pre-stressed concrete buildings

Concrete buildings form a significant percentage of large buildings in Newcastle and Lake Macquarie. These buildings are used for a wide range of purposes, including commercial, car parking, industrial, residential, education and government purposes. These concrete buildings may be normally reinforced and/or prestressed, cast *in situ* and/or precast, and consisting of slabs, moment frames and/or shear walls.

Concrete construction performs well when detailed to ensure continuity and ductility and if structural irregularities are avoided. A vertical structural irregularity, often called a ‘soft’ or ‘weak’ storey is particularly susceptible to collapse. These soft/weak storeys are common where car parking or large open spaces are located on the ground floor of a multi-storey building. Irregularities in building plan are equally undesirable since torsional effects can amplify the response for torsionally eccentric components. Soft storey construction can also be an issue for types of construction other than concrete.

The presence of unreinforced masonry infill walls in multi-storey frame buildings can inadvertently cause structural irregularities. Also, the failure or cracking of such walls in racking or out-of-plane response can be costly in terms of repair and also in terms of the hazard they present as falling debris. Falling debris from other failed non-structural components, such as glass windows, can be equally as hazardous.

“Tilt-up” forms of pre-cast concrete construction have become more popular in recent decades. However, this construction method has not been well tested by real earthquake events in Australia.

The current Australian Standard for concrete structures, AS3600, issued in 2001 (AS3600, 2001), requires special seismic design and detailing only in special cases. This version has not been modified from the 1994 version with regard to seismic detailing. Previous versions had no such requirements. In general, however, requirements for seismic effects have had practically no influence on construction practice. Non-structural and contents components are expected to be more vulnerable, although, as previously mentioned, few requirements exist in Australian Standards for these components.

5.2.2.4 Steel framed buildings

Steel framed buildings make up a significant proportion of large buildings in Newcastle and Lake Macquarie. These buildings are mainly used for industrial and recreation purposes, consisting of large shed structures.

Although steel is a ductile material, the connections between steel members can be brittle, particularly when poorly designed and/or constructed welds are used. Structural irregularities, and non-structural elements and contents are the sources for the greatest concern, as they are for concrete buildings.

Both editions of the Australian Standard for steel structures, AS4100, first published in 1990 and revised in 1998 (AS4100, 1998), contain requirements for seismic effects, whereas previous versions lacked them. In general, however, requirements for seismic effects have had practically no influence on construction practice. Non-structural and contents components are expected to be more vulnerable, although, as previously mentioned few requirements exist in Australian Standards for these components.

5.2.3 Key Facilities

Hospitals, police, fire and ambulance stations and similar facilities are extremely important for post-disaster operations. Other key facilities, such as education institutions, nursing homes, and buildings of historical and cultural importance also form critical elements of the community.

The distribution of key facilities is shown in Figure 5.4 and Figure 5.5. While an attempt has been made to capture all key facilities by field survey, some have been missed. Further work is required for a more thorough and detailed risk evaluation.

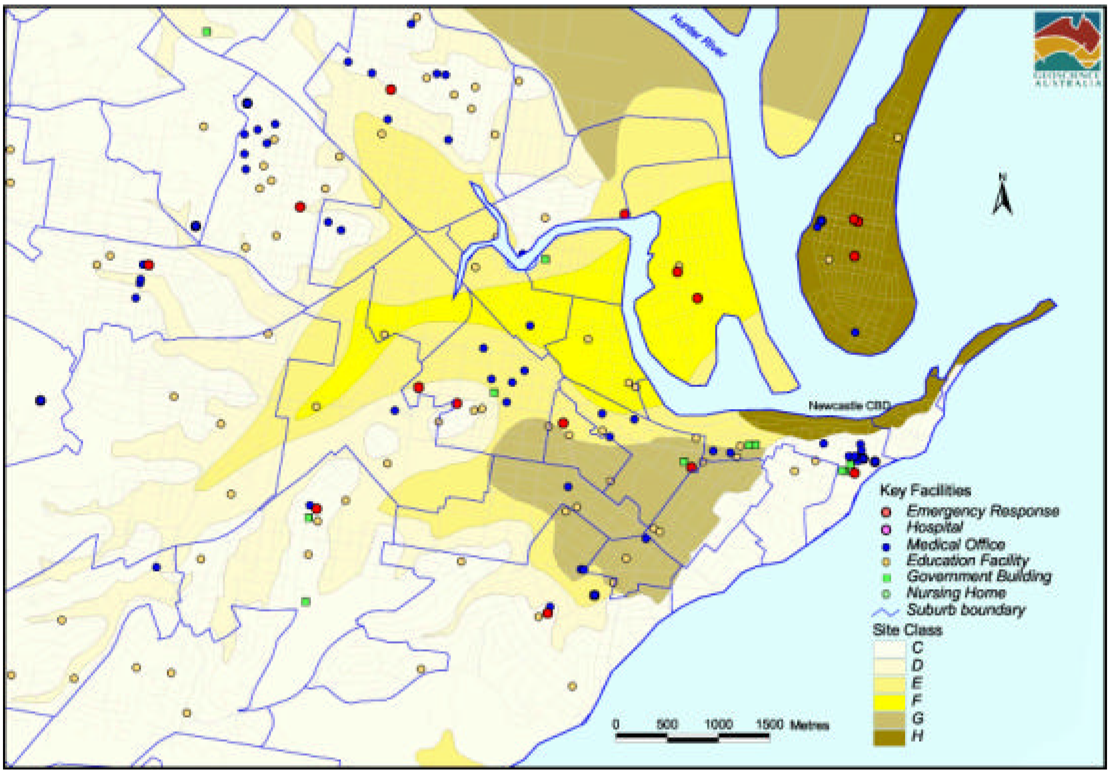

Figure 5.4: Distribution of emergency response and key facilities in the Newcastle area

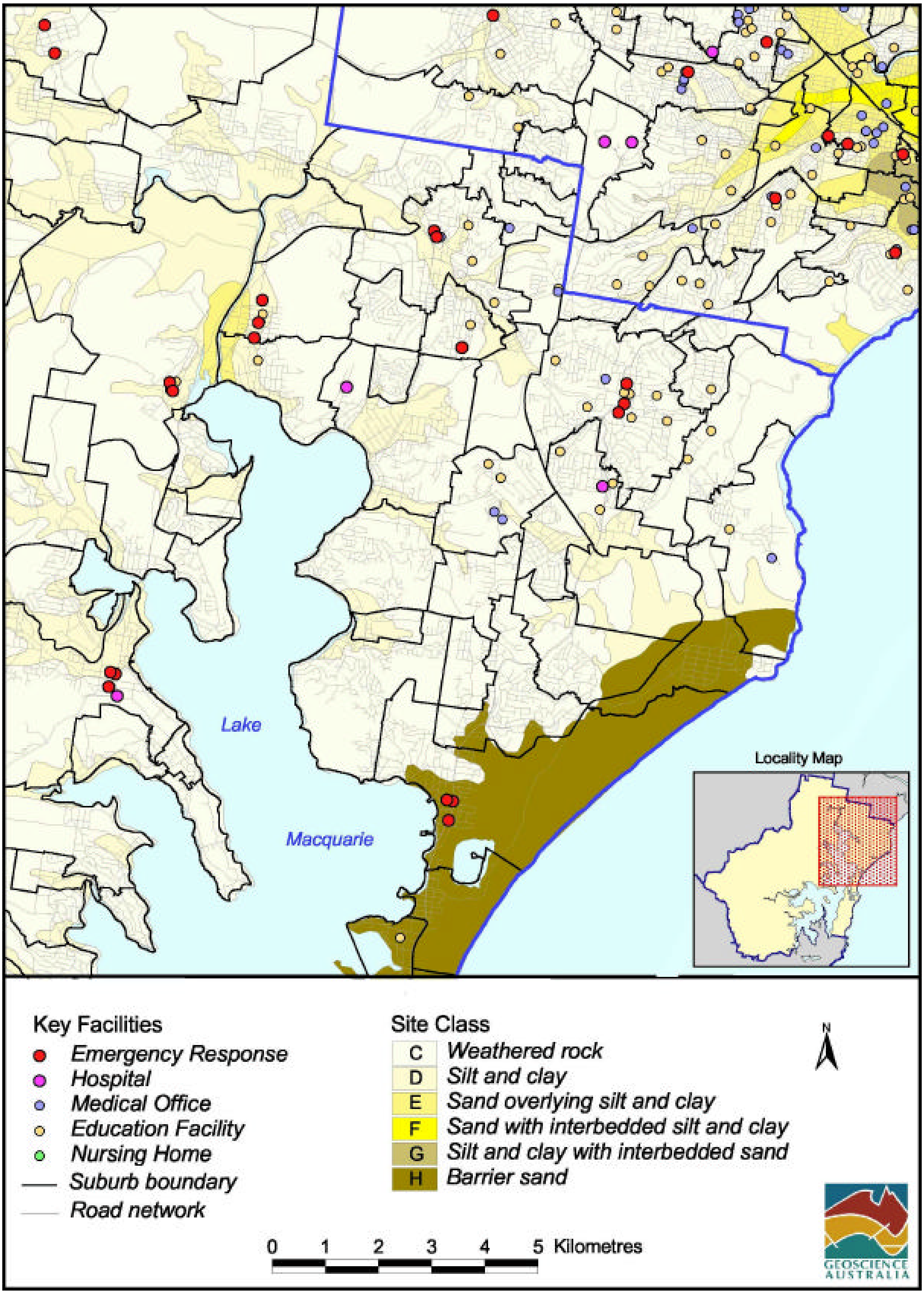

Figure 5.5: Distribution of emergency response and key facilities in the Lake Macquarie area

5.3 Elements at Risk - Societal

The social impact of an earthquake is multi-dimensional and can be measured in a number of ways. Some of the important indicators are discussed here.

5.3.1 Economic

The economic cost of an earthquake is a very important quantity, because decisions can be made for mitigation planning in a financial/risk framework. Economic cost includes the cost of direct damage as well as indirect cost, such as from lost business. The economic cost may not always be a loss for a community, but rather a gain, since economic activity may be spurned by the need to rebuild, often with an external supply of funding from governments, insurance companies and charity. However, for this study, only the economic cost of direct damage to buildings and their contents has been quantified.

5.3.2 Casualty

This includes the number of fatalities as well as the number of non-fatal casualties of varying degree, from serious to non-hospitalisation. In this study, only casualties due to building damage are determined. A key determining factor for vulnerability to injuries of deaths due to earthquakes is the population distribution.

Casualty rates depend on population distribution at the time of the earthquake. The population distribution in the study area, according to place of residence and by suburb, is shown in Figure 5.6. This plot is based on 1996 census demographic data, which are shown in Figure 5.7. Where suburb boundaries and census collection districts (CCDs) are not compatible, a judgment has been made of the division of the population (see Appendix G).

In 1999, the Lake Macquarie City Council estimated a population growth in the range of 0.48% to 0.99% per annum until the year 2020. The continual decrease in the average number of people per dwelling, falling from 3.22 to 2.36 from 1971 to 1996 (ABS, 1998), should see the shift of people from older unreinforced masonry to less vulnerable, newer, construction types.

However, the most important factor in relation to casualty risk is the location of people throughout the day. Since people spend at least one third of their lives at home, and nearly as much at work or school, the relative risk of such environments plays an important role. Further work is required to account for all of these factors.

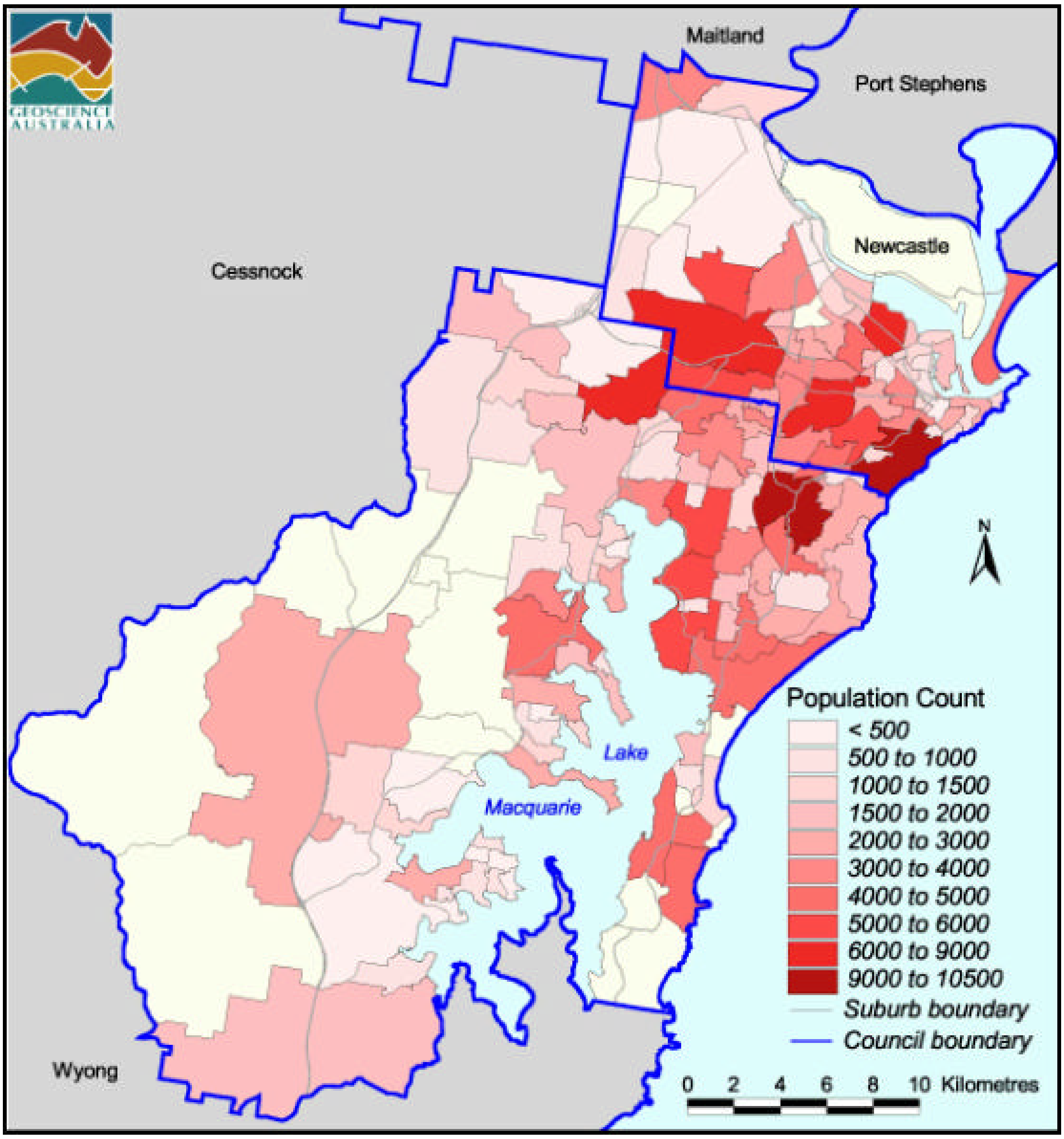

Figure 5.6: Population distribution by suburb

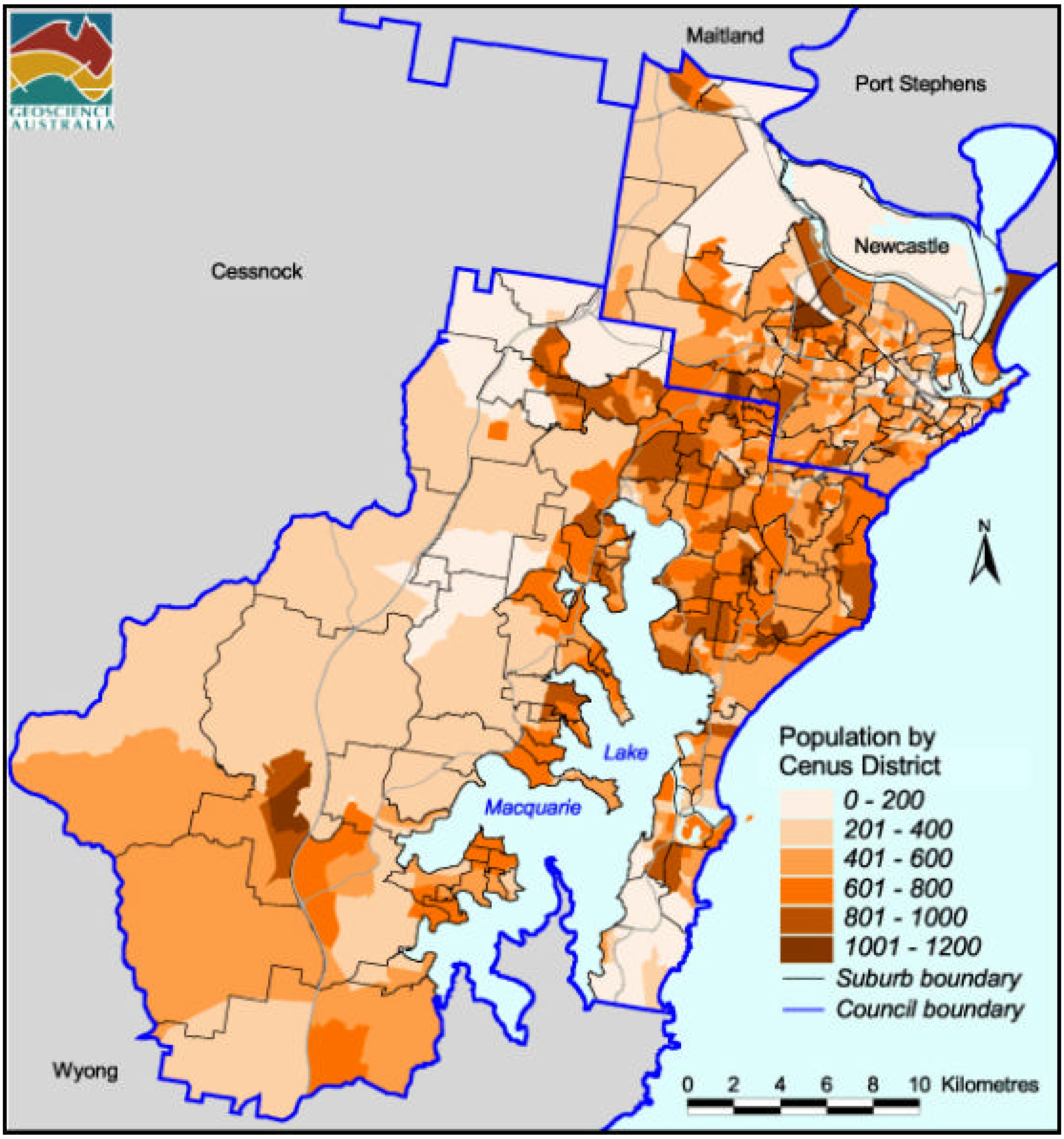

Figure 5.7: Population distribution by census collection district (CCD)

5.3.3 Shelter

The loss of shelter due to building damage is an important consideration. The resilience of the community requires consideration, as does the level of assistance that is socially acceptable and available. Age, economic status, level of insurance, physical capacity, ethnicity and culture may be important factors. However, no analysis of this aspect has been conducted in this study.

5.3.4 Trauma

It is difficult to quantify the trauma caused by an earthquake, with few studies having been performed. The psychological effects can be serious, especially if family and/or friends are killed or maimed. However, no analysis of this aspect has been conducted in this study.

5.3.5 Social Indices

A number of social vulnerability indices are of interest in terms of the ability of the community to recover from an earthquake. These indices account for population age, community support and wealth. While these indices have not been incorporated into any analysis, the distribution of index values as compared to economic risk results is of interest. Factors which have been considered include the distribution of people aged over 65 (Figure 5.8) and under 5 (Figure 5.9), the Index of Socio-Economic Disadvantage (Figure 5.10) and the Index of Economic Resources (Figure 5.11), as defined by the Australian Bureau of Statistics.

The Index of Socio-Economic Disadvantage is a combination of some 20 census statistics including personal income, educational attainment level, unemployment and jobs skill level. The Index has a mean of 1,000 across Australia, and a standard deviation of 100, with lower values indicating greater disadvantage.

The Index of Economic Resources is a combination of some 22 census statistics which reflect the income and expenditure of families, including measures of income, rent and home ownership. This index also has a mean of 1,000 across Australia, and a standard deviation of 100, with lower values indicating lesser economic resource.

Other vulnerability indices may be important in terms of earthquake risk for the community. These may include ethnicity profiles, car ownership levels and levels of unemployment. Considerable further study is required in this area and is an area of active, current research at Geoscience Australia.

It is not clear how social vulnerability indices should be considered in an overall risk assessment, since it depends on the point of view adopted. For example, more vulnerable families and individuals may initially handle a natural disaster with greater difficulty. However, these people may benefit most from the economic activity following the event caused by the influx of money through aid and insurance pay-outs. Another example is, if a person rents rather than owns their house, they do not suffer the financial cost of damage repair to the building, however, they might have to pay for contents damage. The use of vulnerability indices such as these is being activly investigated at Geoscience Australia, however they have not been addressed explicitly in this work.

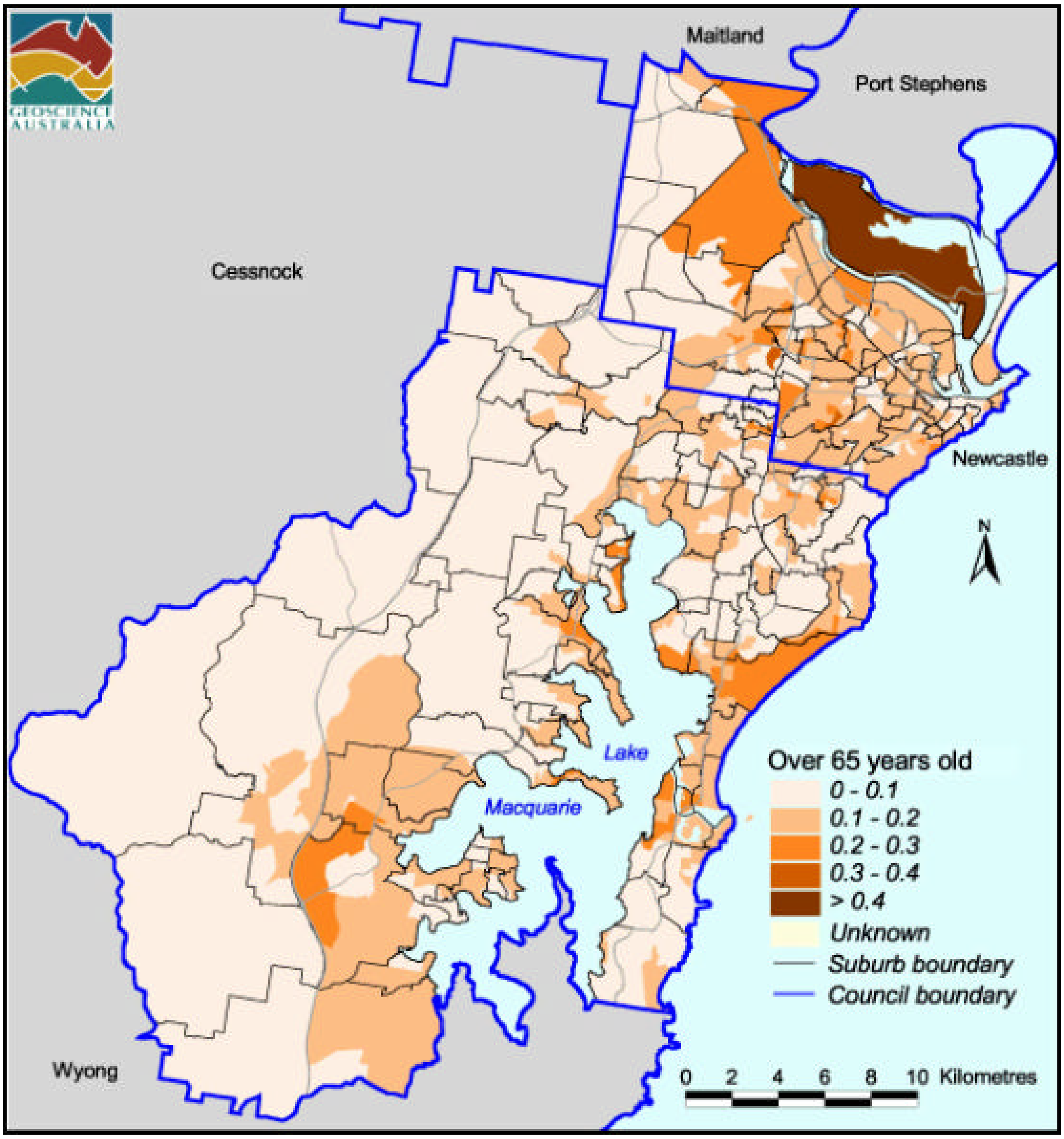

Figure 5.8: Proportion of population over 65 years old by CCD

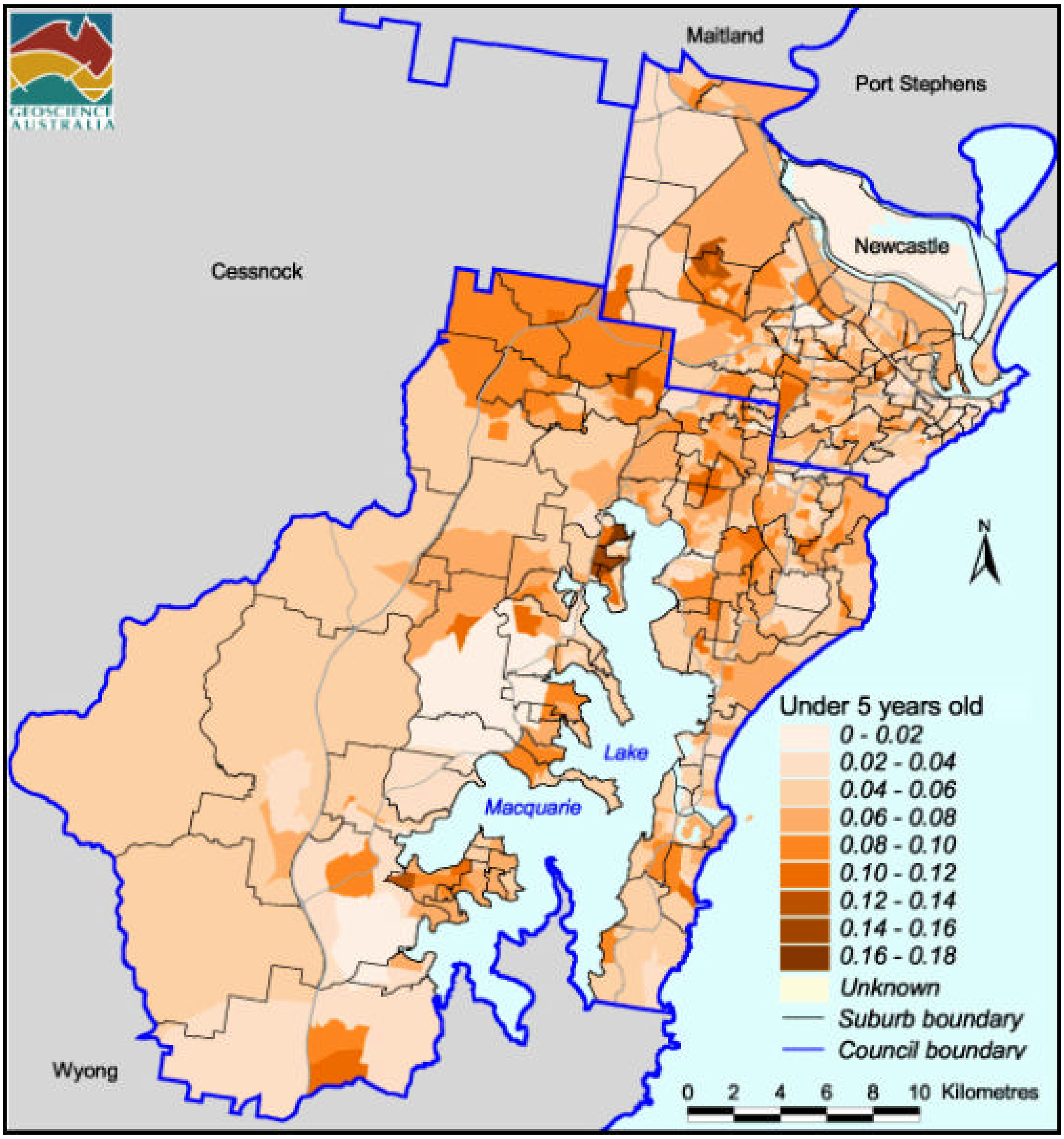

Figure 5.9: Proportion of population under 5 years old by CCD

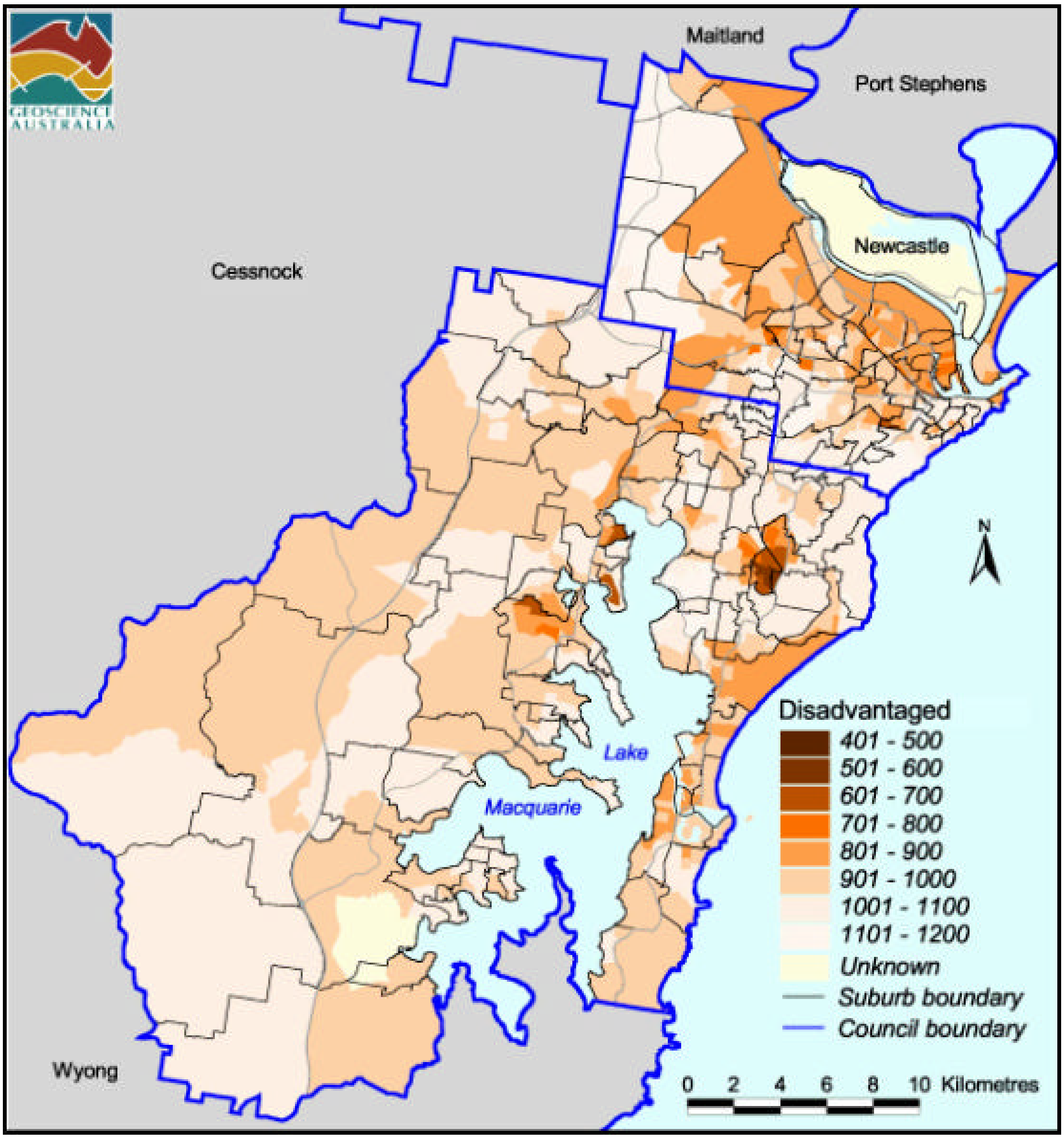

Figure 5.10: The SEIFA (ABS) Index of Socio-Economic Disadvantage

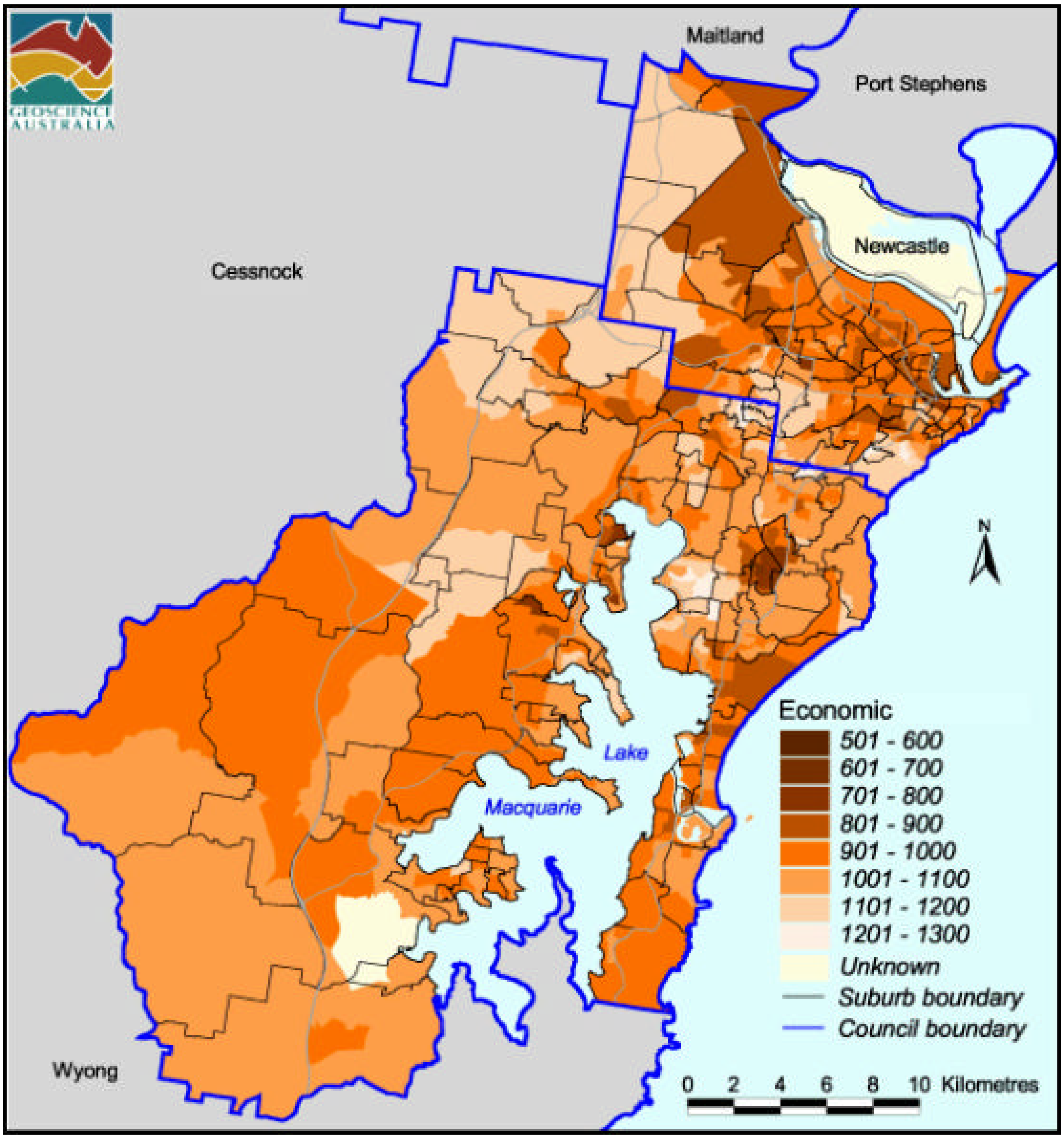

Figure 5.11: The SEIFA (ABS) Index of Economic Resources

5.4 Elements at Risk - Lifelines

Lifelines are networks that allow a community to function. An alternative definition could be "infrastructure". Lifelines include transportation and utility networks. The vulnerability of some of the more important ones are discussed here. However, no analysis of the impact on lifelines has been conducted in this study. In Chapter 3, it is mentioned that lifelines experienced minimal disruption for the 1989 Newcastle earthquake. However, it is also noted that many lifelines were on the verge of serious disruption, which could have had a dramatic impact on the region.

5.4.1 Roads

Bridges and elevated sections of road are the most vulnerable components of road networks. Weak supporting piers and bridge abutments are commonly damaged. Road on the ground surface is generally unaffected, except close to earthquake fault surface ruptures, on slopes susceptible to earthquake triggered landslides or on soils subject to liquefaction and densification. Tunnels have historically performed well during earthquakes.

The Newcastle and Lake Macquarie region has numerous bridges which are critical for local and interstate transport. Other than these bridges, the road network is fairly redundant, as can be seen in Figure 5.12. The risk of death from bridge failure is considered to be low.

5.4.2 Rail

Railway lines are generally affected in a similar manner to roads, although rail operation is far more vulnerable to misalignment of tracks. Newcastle has an important rail connection to Sydney, which if damaged could cause significant disruption. The rail network is shown in Figure 5.12.

5.4.3 Sea Transport

Ports are particularly vulnerable if located on ground which is prone to liquefaction and lateral ground spreading. Damage to port facilities such as loading cranes may render the port inoperable. Ports in Newcastle service some heavy industrial facilities and hence their disruption could cause significant financial losses.

5.4.4 Air Transport

Generally air transport lifelines are unaffected unless runways are susceptible to damage, which is not likely unless close to a fault. Airport buildings and particularly the control tower may be susceptible to damage and so can affect the operational capacity. The study area is serviced by airports which actually lie outside the bounds of the study region. Airport disruption is considered to be a low risk.

5.4.5 Electricity

Electricity is perhaps the most important lifeline since nearly all other lifelines are dependent upon it. A particularly vulnerable component of the electricity distribution network is electricity substations. Ceramic insulators, which are important in substation operation, are very brittle and highly vulnerable to earthquakes. Only limited data on the location of buildings forming part of the electricity distribution network has been collected for this study, as shown in Figure 5.15.

5.4.6 Water and Sewerage

Dams, reservoirs and tanks have the potential for serious damage; however, historically they have performed well in earthquakes. Pipes are susceptible to damage, particularly if close to the earthquake fault and constructed of brittle material. The water and sewerage networks for Newcastle and Lake Macquarie are shown in Figure 5.13 and Figure 5.14 respectively. These figures demonstrate that the networks have a greater level of redundancy in the inner Newcastle area than in Lake Macquarie and outer-lying suburbs and townships.

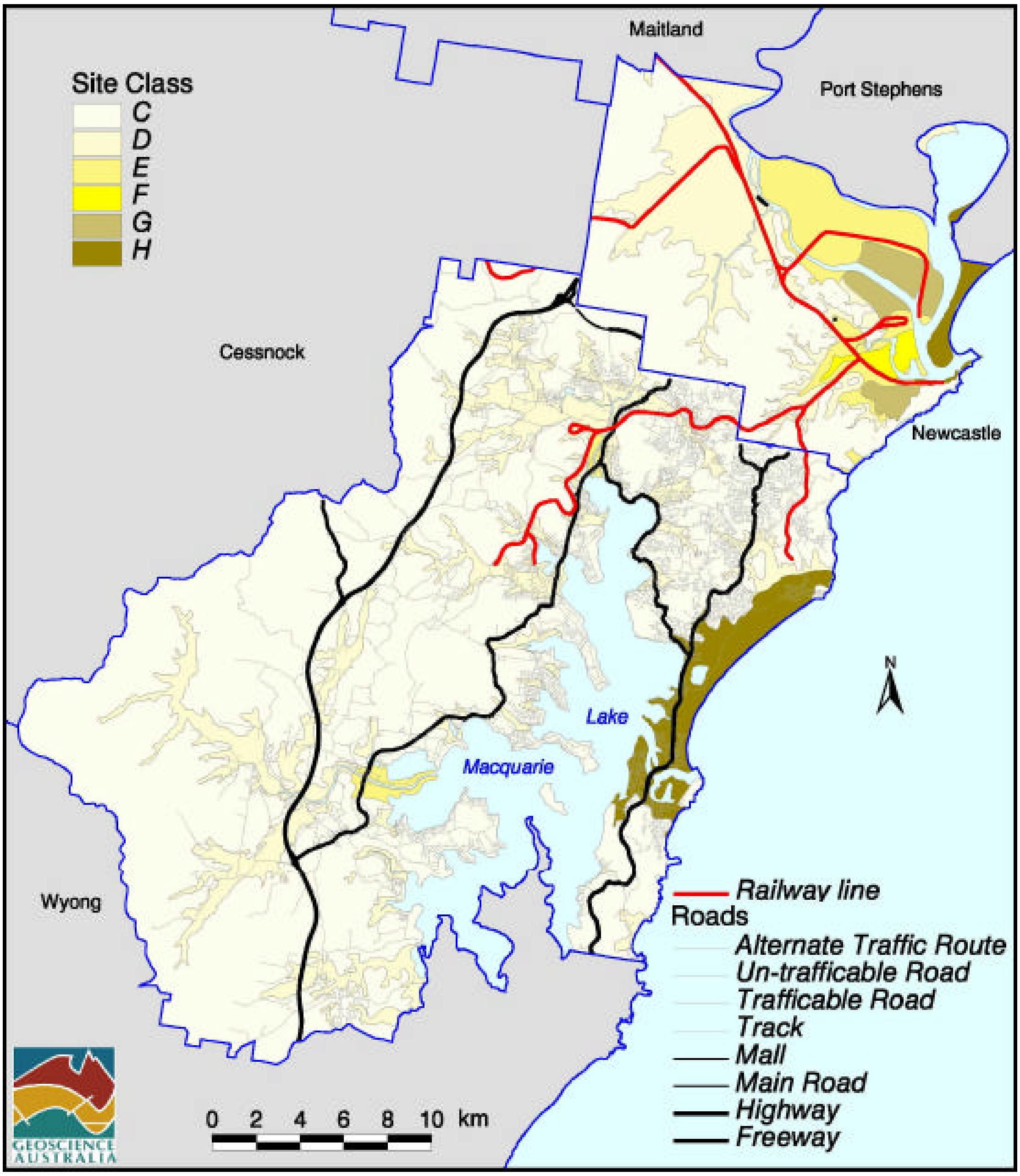

Figure 5.12: Road and rail networks for Newcastle and Lake Macquarie

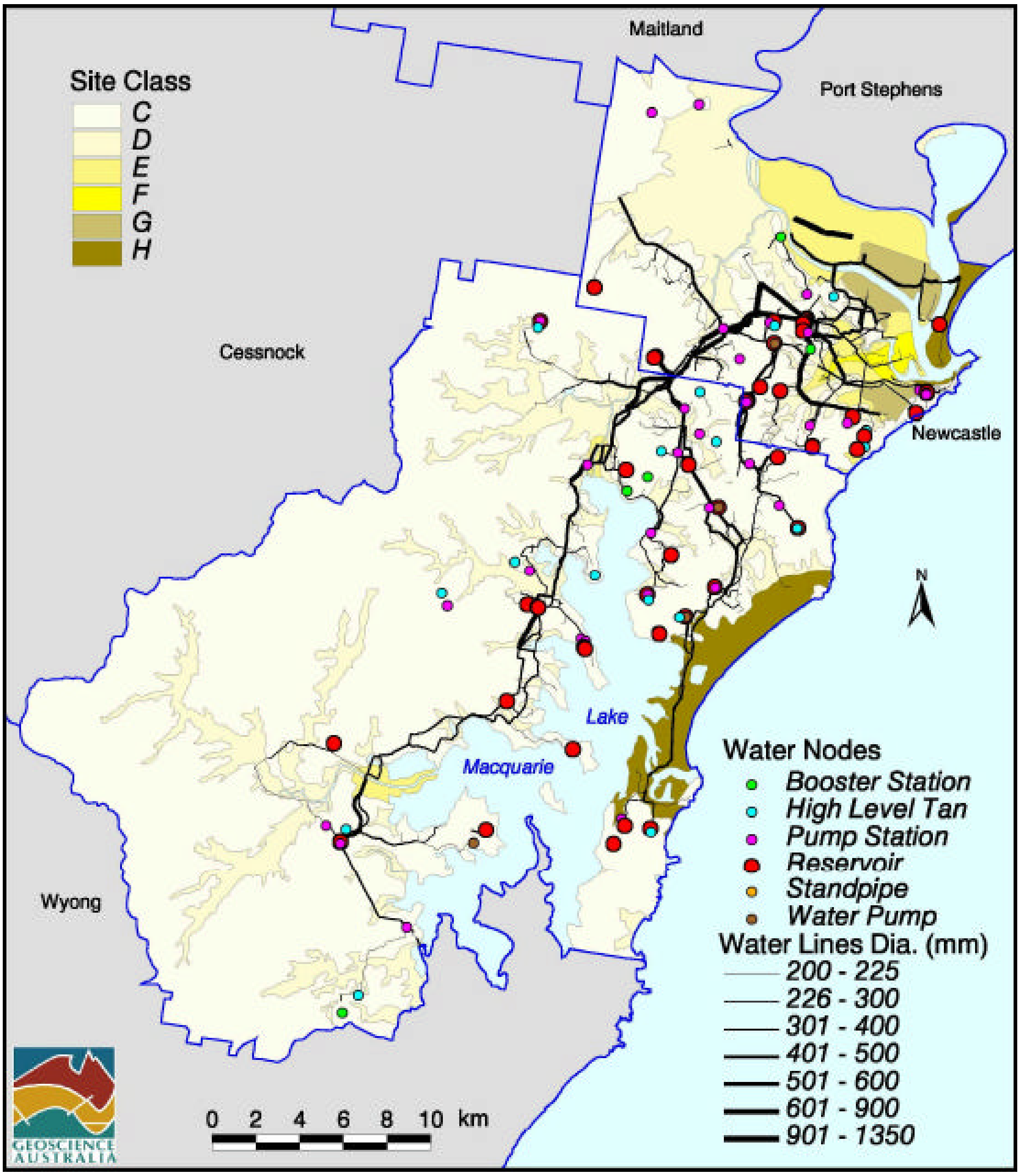

Figure 5.13: Water network for Newcastle and Lake Macquarie

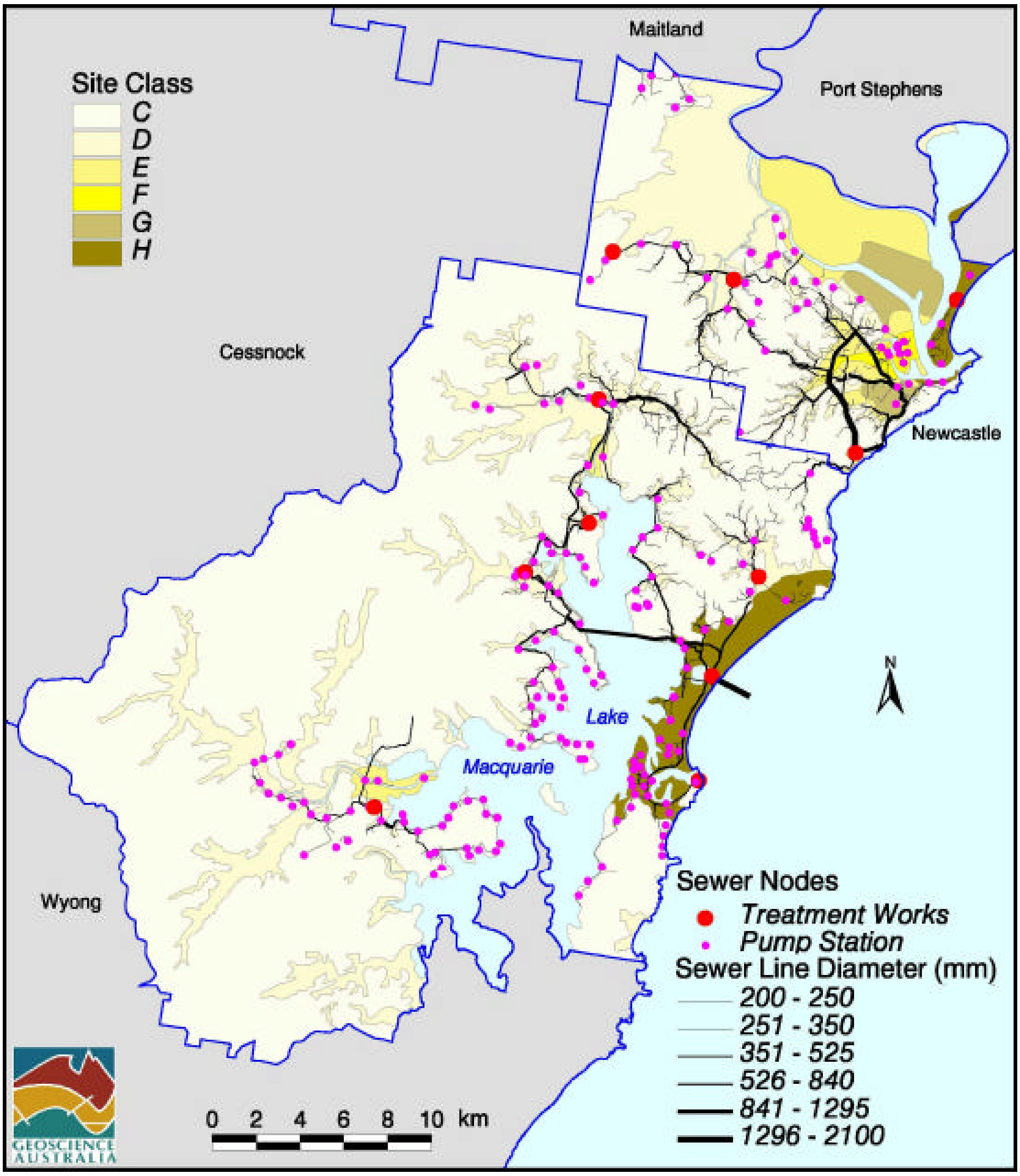

Figure 5.14: Sewerage network in Newcastle and Lake Macquarie

5.4.7 Gas and Other Fuels

Pipeline damage from earthquakes is generally less likely for these lifelines as they are usually constructed of ductile materials. However, any type of pipe which crosses a fault is likely to rupture, and in this case the consequences can be explosive and harmful to the environment. Gas pipelines and fuel facilities are expected to only present local risks of low probability. Only limited data on the location of buildings forming part of the gas distribution network has been collected for this study, as shown in Figure 5.15.

5.4.8 Communication

Communication lifelines are susceptible to damage generally only if the buildings which house telephone exchanges, or support mobile telephone transceivers or satellite dishes, etc. are susceptible to damage. These types of networks are often highly redundant as they are in the study region. Only limited data on the location of buildings forming part of the telecommunication network has been collected for this study, as shown in Figure 5.15.

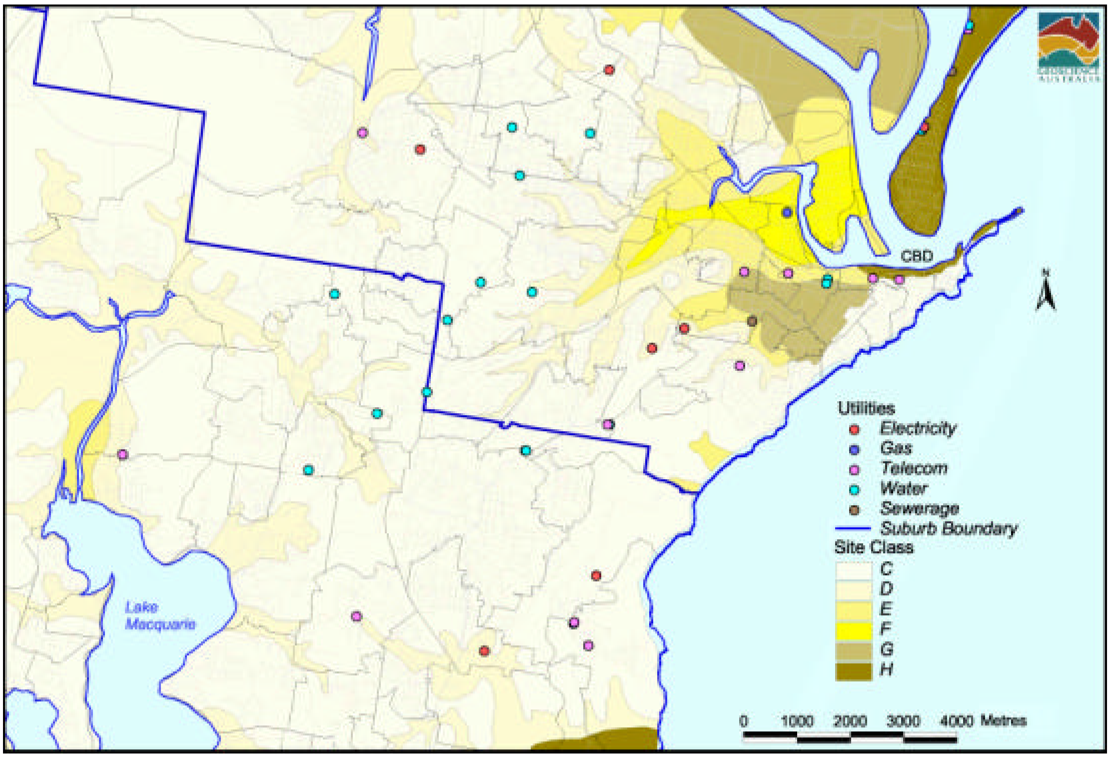

Figure 5.15: Surveyed lifelines in Newcastle and Lake Macquarie

5.5 Collected Statistics

Some statistics have been compiled for road, rail, water and sewerage networks.

5.5.1 Roads

Statistics of the road network are given in Table 5-2. It is clear that for both council areas, a significant amount of road lies upon significant amounts of regolith (site classes E, F, and G). This is the case, irrespective of the road function. While roads may be susceptible to damage from earthquake fault surface rupturing, liquefaction, densification and earthquake induced landslide the risk is not expected to be significant. However, critical bottlenecks in the network, such as bridges, warrant further detailed investigation for the risk to the road network to be properly addressed.

Table 5-2: Road network statistics

Road length (m)		Site Class						
Network[17]	ROAD TYPE	C	D	E	F	G	H	Undefined[18]
NEWCASTLE	Alternate Traffic Route	67,021	22,727	17,240	5,102	6,283	8,466	0
	Freeway	29635	0	0	0	0	0	0
	Highway	76,431	28,431	10,195	4,864	8,046	657	0
	Main Road	377	0	0	0	0	0	0
	Mall	222	0	123	0	7	175	0
	Track	17,185	5,700	2,414	319	0	1,688	0
	Trafficable Road	44,7843	97,075	68,044	31,151	55,381	32,781	0
	Un-trafficable Road	7,228	1,419	803	538	0	3	0
LAKE MACQUARIE	Undefined	158,401	10,753	0	0	0		0
	Alternate Traffic Route	183,338	50,842	0	0	0	9,947	0
	Freeway	77,273	11,397	0	0	0	0	0
	Highway	80,154	148,75	3,255	0	0	18,171	0
	Main Road	4,906	0	0	0	0	0	0
	Mall	266	0	0	0	0	0	0
	Track	7,643	2,031	597	0	0	1,784	0
	Trafficable Road	840,778	158,829	14,458	0	0	84,272	492
	Un-trafficable Road	65,141	13,440	74	0	0	5,204	54

5.5.2 Rail

Rail network statistics are given in Table 5-3. It appears that tunnelling only occurs in less hazardous soil types. Bridges are located on soils of medium hazard, and considering that these are engineered structures should pose little risk. Further risk assessment is recommended if the governing bodies are concerned about possible impacts.

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[17] *Network statistics are determined on a council area basis, since jurisdiction of the roads is generally upon this basis.*

[18] *Undefined site classes are generally for pipes located on foreshore areas, particularly in the Lake Macquarie area, and for underwater pipes. Such areas have not been given a site class.*

Table 5-3: Rail network statistics

Rail length (m)		Site Class						
Network	ROAD TYPE	C	D	E	F	G	H	Undefined
Newcastle and Lake Macquarie	Railway	34,567	29,387	13,946	1,483	2,049	1,125	0
	Bridge	0	0	119	0	0	0	0
	Tunnel	1,306	0	0	0	0	0	0

5.5.3 Sea Transport

Lifeline has not been evaluated at this stage due to a lack of information.

5.5.4 Air Transport

Lifeline has not been evaluated at this stage due to a lack of information.

5.5.5 Electricity

Lifeline has not been evaluated at this stage due to a lack of information.

5.5.6 Water and Sewerage

Statistics for the sewerage and water networks, of the number and type of nodal facilities, and the size and length of pipes, according to the site class they are located on and in are presented in Table 5-4 to Table 5-6. It is expected that site classes D, E, F, G and H will be generally more hazardous locations than for site classes C. It appears that a significant number of sewerage nodes and pipes are located on the more hazardous site classes. For the water network, few node facilities are located on the hazardous site classes, although a significant proportion of pipes are located on these hazardous site classes. Critical elements of the networks; reservoirs and treatment plants are generally located on the least hazardous site class – type C. However, there are a few exceptions, and it is perhaps these exceptions which require a prompt and more thorough assessment. Risk is difficult to quantify without information on construction type and quality. Hence, further work is required.

5.5.7 Gas and Other Fuels

Lifeline has not been evaluated at this stage due to a lack of information.

5.5.8 Communication

Lifeline has not been evaluated at this stage due to a lack of information

Table 5-4: Water and sewerage network node statistics

Number of facilities		Site Class						
Network	**Node type**	**C**	**D**	**E**	**F**	**G**	**H**	**Undefined[19]**
Sewerage	Pump stations	102	43	7	8	2	33	0
	Treatment works	7	2	0	0	0	2	0
Water	Pump stations	43	2	0	0	0	1	0
	Water Pumps	30	0	0	0	0	0	0
	Booster stations	6	0	0	0	0	0	0
	Standpipes	0	0	0	0	0	0	0
	High level tanks	20	0	0	0	0	0	0
	Reservoirs	50	0	0	0	0	1	0

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[19] *Undefined site classes are generally for nodes located on foreshore areas, particularly in the Lake Macquarie area. Such areas have not been given a site class.*

Table 5-5: Water and sewerage network pipe statistics

Length of pipe (m)		Site Class						
Network	Pipe diameter (mm)	C	D	E	F	G	H	Undefined
Sewerage	200	17,298	5,101	2,228	453	649	1,433	0
	225	118,420	57,535	0	6,143	3,062	20,141	0
	250	13,307	4,810	11,185	32	0	5,573	0
	280	41	0	0	0	0	42	0
	300	52,666	39,482	4,305	1,685	967	10,125	0
	325	5	0	0	0	0	0	0
	350	0	0	0	0	0	0	0
	375	25,528	18,602	2,488	0	0	11,125	17
	400	6,144	8,714	895	100	415	2,827	0
	450	14,821	12,778	3,511	184	319	1,169	0
	500	8,411	7,380	979	0	0	879	652
	525	2,255	7,642	830	268	0	159	0
	600	12,025	16,336	1,239	254	294	3,888	0
	675	790	785	970	0	0	0	0
	700	497	728	22	0	0	0	0
	735	0	0	72	0	303	0	0
	750	12,235	11,704	1,692	0	0	11,738	269
	810	0	0	0	0	0	542	0
	840	65	0	255	0	280	0	0
	900	3,133	1,782	0	0	0	1,608	0
	990	0	345	0	0	0	0	0
	1,050	1,360	1,849	1,778	0	320	0	0
	1,065	185	0	1,006	1,580	0	0	0
	1,140	0	0	304	0	0	0	0
	1,145	0	0	121	52	0	0	0
	1,200	0	360	106	822	2,048	0	0
	1,220	91	0	0	0	0	0	0
	1,295	1,207	0	0	0	0	0	0
	1,450	0	0	292	0	156	0	0
	1,650	0	211	248	148	0	219	0
	1,830	1,823	1,139	291	0	0	0	0
	2,100	63	0	252	0	0	0	0
	9,999	20	0	0	0	0	0	0

Table 5-6: Water and sewerage network pipe statistics (continued)

Length of pipe (m)		Site Class						
Network	Pipe diameter (mm)	C	D	E	F	G	H	Undefined[20]
Water	200	117,366	31,854	5,754	4,894	2,823	11,496	0
	225	93	0	0	0	0	0	0
	250	42,630	9,525	4,534	1,641	1,383	5,217	0
	280	0	0	33	0	0	0	0
	300	38,815	12,775	2,058	823	3,162	1,819	0
	375	71,,927	14,986	8,585	943	5,291	11,667	492
	400	53	0	0	0	0	0	0
	450	1636	560	67	0	5	0	0
	500	45,548	23,742	7,904	0	5,684	92	0
	600	13,631	2,601	2,459	518	401	198	0
	750	12,153	4,232	168	0	0	0	0
	900	6,458	205	15	0	0	0	0
	1050	909	340	2,848	0	0	0	0
	1200	2,563	0	0	0	0	0	0
	1350	3,120	185	0	0	0	0	0

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[20] *Undefined site classes are generally for pipes located on foreshore areas, particularly in the Lake Macquarie area, and for underwater pipes. Such areas have not been given a site class.*