Planning for resilience in a changing climate: Integrating spatial analysis and online pollution inventories to manage chemical releases during floods

Michael Howes¹, Jago Dodson², and Deanna Tomerini²

¹ Urban Research Program, Griffith School of Environment (Griffith University), m.howes@griffith.edu.au
² Urban Research Program (Griffith University), j.dodson@griffith.edu.au
³ Urban Research Program, Griffith School of Environment (Griffith University), d.tomerini@griffith.edu.au

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ABSTRACT

Climate change is likely to increase the frequency, duration and intensity of flooding in urban areas around the world, posing a major challenge for planners (IPCC 2012). While scientists are reluctant to attribute individual floods to climate change, there have been indications of the types of challenges that lie ahead with major inundations of urban areas in the USA, UK and Australia over the last two years. When such flooding occurs in industrial zones there is an increased risk that hazardous substances will be released into flood waters posing an added danger to both people and the environment. A well-integrated and coordinated response is required to manage these risks using spatial planning and policy instruments that make the best use of the full range of information available about such hazards. This paper argues that the essential information needed is already available, much of it online, through initiatives such as online pollution inventories that identify the location of sites where hazardous chemicals are used, created or emitted. We demonstrate how such online data can be integrated into a useful spatial risk analysis tool that will assist urban planning, disaster risk management, and climate change adaptation. The paper offers a three-way comparative analysis of the relevant planning and policy instruments already in place in the USA, UK and Australia (Howes 2005). A pilot study of the 2011 Brisbane floods is used as an example of how an integrated spatial risk analysis instrument can be created to provide timely, accessible and valuable information for policy-makers, planners and emergency services.

1 INTRODUCTION

With the level of public debt at record levels around the world, and the increasing pressure being placed on the public purse for action on an ever growing list of issues, governments must find ways to do more with less. One option is to make better use of available resources by integrating hitherto disparate activities into a more coherent whole. We argue that several policy arenas such as land-use planning, pollution reporting, disaster risk management and climate change adaptation provide a prime opportunity for such efficiencies. The idea is to take data that has already been collected by various government agencies and turn it into a spatial analysis tool that can support better decision-making. In particular, this paper will focus on how to use data from land-use planning and national pollution inventories to provide better information about the risk of hazardous substance releases during floods. The paper deals with this topic in several stages. First, the research problem and aims are outlined. Then, some background is given on the governing systems, land-use planning and zoning of hazardous sites in three countries: the USA, UK and Australia. Third, the administration and operation of national pollutant inventories in these countries is reviewed. In the final section,
we demonstrate how all of this can be integrated into a spatial analysis tool using Geographical Information System (GIS) techniques via a case study of the 2011 Brisbane floods in Australia. Overall we argue that these techniques will be beneficial not only for the three countries reviewed in this paper, but for all of the 47 countries that have similar national pollution inventories (Mee 2011).

2 THE RESEARCH PROBLEM & AIDS

Flooding is a natural phenomenon that occurs periodically in many areas of the world and its impacts can range from the local to the international scale. Two factors, however, have increased the risks posed by flooding to both people and the built environment. First is the increasing development of urban settlements in flood-prone areas, particularly along coasts (DCC 2009). Second is climate change that alters rainfall patterns, raises sea-levels and may lead to changes in the frequency, duration and/or intensity of extreme weather events (IPCC 2012, 2007; Royal Society 2010; NOAA 2010; AAS 2010). While climate scientists are reluctant to attribute a particular event to climate change, there is growing evidence that it has been a key influence in major flooding events for both the northern and southern hemispheres (Schiermeier 2011; Climate Commission 2013, 2012).

The risks posed by flooding include: health impacts that range from the immediate threat to life from drowning and the spread of water-borne diseases, to the contamination of drinking water and psychological distress; the physical damage to homes, buildings and essential infrastructure; and, the economic costs associated with repairs to the built environment, providing emergency services, and the loss of production. When flooding occurs in industrial areas, however, there is the additional risk posed by the release of hazardous substances into flood waters. This can have additional health impacts on residents and emergency service workers. It can also complicate the clean-up and recovery efforts after the event.

There has been some research into mapping the physical and biological impacts of flooding (Palmer, et al. 2009; Merz, Thieken and Gocht 2007; Sauer, Schanze and Walz 2007) as well as measuring its health impacts (Du, et al. 2010; Fitzgerald, et al. 2010; Tapsell and Tunstall 2008; Ahern, et al. 2005; Jonkman and Kelman 2005). The effect of chemical contaminants in flood waters (Euripidou and Murray 2004), their mobilisation, dispersal and sedimentation have also been considered to a limited extent (Wolz, et al. 2009; Hilscherova, et al. 2007; Dennis, et al. 2003). Ademollo, et al. (2011) and Shiedek, et al. (2007), for example, draw the link between increased flooding due to climate change and chemical contamination. Despite the advances made by these studies, the release of chemical contaminants from industrial sites during flooding and the increased risk of this happening due to climate change is a problem that remains under-researched. It is this part of the problem that we focus on in our work and planning has a key role to play in managing the risk. We argue that much of the data that is needed has already been collected by various government organisations and the necessary spatial analysis tools are already available. All that is needed is to bring the disparate elements together into a useable resource. The overall aim is to reduce the vulnerability of communities to hazardous substances during floods and increase their resilience to some of the impacts of climate change.

3 BACKGROUND: GOVERNING INSTITUTIONS

The risks summarised in the previous section were graphically illustrated in 2012 by the extensive flooding across the south of the UK and east-coast of the USA, and the 2011 floods in the north-east of Australia. These events occurred in similar but significantly different countries (see table 1) which makes for an interesting comparison. All three are classed as developed countries with high levels of per capita income and a highly urbanised
population. All have long coastlines with many of their largest cities located on coasts and estuaries. On the difference side, there are significant variations in total landmass, climate, population and the size of their economies. For the purposes of this research, however, these differences simply serve to illustrate that the problem we are addressing can occur in a variety of contexts. The most significant differences for our purposes arise from the variations in the governing and planning institutions of these three countries. These will have the most influence on the ability to collect and integrate data on potential pollution hotspots during floods into a useful spatial analysis and planning tool. They are therefore worth briefly summarising before looking at the design and operation of the relevant national pollution inventories.

Table 1: A snapshot of the USA, UK & Australia

<table>
<thead>
<tr>
<th></th>
<th>USA</th>
<th>UK</th>
<th>Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (millions)</td>
<td>316</td>
<td>63</td>
<td>22</td>
</tr>
<tr>
<td>GDP (US$ trillion PPP)</td>
<td>15.65</td>
<td>2.32</td>
<td>0.96</td>
</tr>
<tr>
<td>GDP per capita (US$ PPP)</td>
<td>49,800</td>
<td>36,700</td>
<td>42,400</td>
</tr>
<tr>
<td>Government</td>
<td>Constitutional federal republic</td>
<td>Constitutional monarchy</td>
<td>Federal parliamentary democracy</td>
</tr>
<tr>
<td>Landmass (square km)</td>
<td>9,826,675</td>
<td>243,610</td>
<td>7,741,220</td>
</tr>
<tr>
<td>Coastline (km)</td>
<td>19,924</td>
<td>12,429</td>
<td>25,760</td>
</tr>
<tr>
<td>Climate</td>
<td>Mostly temperate but with some tropical arid and arctic zones</td>
<td>Temperate</td>
<td>Mostly semi-arid centre and west; tropical north; temperate south and east</td>
</tr>
<tr>
<td>Urbanisation (% of population)</td>
<td>82</td>
<td>80</td>
<td>89</td>
</tr>
</tbody>
</table>

(Source: CIA. 2013.)

Of the three countries, the UK has the longest continual development of governing institutions and is classified as a constitutional monarchy. There is no single written document that embodies the constitution, instead there are a series of historical agreements, legislation and conventions that shape the basic institutional architecture of government (CIA 2013). This gives the national government a great deal of freedom to implement change and intervene in local government activities (Dryzek, et al. 2003; Garner 2000). The national parliament is bicameral. The upper chamber is the House of Lords that is not elected and has 788 seats which are filled by 670 life peers, 92 hereditary peers, and 26 representatives of the clergy. The lower chamber, the House of Commons, consists of 650 seats with members elected for a term of up to five years. Government is formed by the party that wins the most seats in the Commons and the Prime Minister and Cabinet are all members of parliament (CIA 2013). The UK encompasses four countries: England, Wales, Scotland and Northern Ireland. Since 1999 there have been elected regional assemblies in Wales, Scotland and Northern Ireland that have limited powers to raise taxes and control expenditure in some public policy areas. The majority of revenue is still raised by national government in Westminster, and it remains the major policy-making body (Bradbury & Mitchell 2001; Garner 2000; Brown 1998). At the local level, England has 152 different local governments that range in size from the City of London to various counties, boroughs, metropolitan districts and local authorities. Northern Ireland has 26 council areas, Scotland has 32, and Wales has 22 local authorities (CIA 2013). In total this makes 232 different local governments across the UK that deliver services to communities. They can raise their own local taxes, but are still heavily dependent on Westminster for funding.
The USA emerged from the rebellion of 13 colonies against British rule in 1776. After the war of independence a written constitution was agreed to in 1787 that came into force two years later. It established the federal government (where each colony became a state) with broad ranging powers, a bicameral Congress, and an independently elected president who leads an executive of appointed secretaries (none of whom are members of the Congress) and serves a term of 4 years\(^1\). The first ten amendments to the constitution formed the Bill of Rights for citizens that placed some restrictions on government power. The Supreme Court plays an important role as it can strike down laws that it deems to contradict the constitution (CIA 2013; Wagman 1995; Anastapolo 1989; Brogan 1985). By the middle of the twentieth century the USA had expanded to include other colonies and territories that now formed 50 states within the federation. Each of the 50 states has their own constitution, governor, legislature and legal system. The national Congress is made up of the House of Representatives with 435 members (elected every 2 years to represent specific constituencies), and a Senate with 100 members (2 for each State) elected for 6 years (one third go to the polls every 2 years with the House) (CIA 2013; Brogan 1985). Legislation must pass both chambers and be signed by the President to become law, a situation that can often lead to deadlock. There are also 89,004 different local governments that range from counties, to municipalities, towns, and districts (US Census Bureau 2012).

Australia is the youngest of the three countries in terms of governing systems. While it is classified as a federal parliamentary democracy, the Monarch of Great Britain remains the symbolic head of state, and so it has also been described as a constitutional monarchy (CIA 2013). The written constitution came into force in 1901, turning the original six colonies into states, with two territories added later. This document outlined specific powers for the federal government, with all residual powers falling to the states. The Australian system of government is a hybrid of the USA and UK systems, and is sometimes referred to as the ‘Washminster mutation’ (Jaensch 1997; Thompson 1980). There is a bicameral national parliament: a House of Representatives with 150 members elected for up to 3 years to represent specific constituencies; and, a Senate with 76 members elected for 6 years (12 from each state and 2 from each territory). The High Court has the power to strike down legislation that it deems to be unconstitutional. The executive is made up of a Prime Minister and Cabinet drawn from the parliament. Each of the six state and two territories have their own parliament and legal system. There are also 562 local councils that range from cities to shires, boroughs and towns (ALGA 2013).

There are three key differences between these governing systems that are pertinent to our research. The first is that the UK’s membership of the European Union (EU) adds an extra tier of governance, with Westminster having to implement EU directives on the one hand, and trying to influence European policy on the other (Dunleavy, et al. 2002; Garner 2000). The second key difference is that the USA has a much more litigious political culture which encourages pressure groups and businesses to challenge government actions in court. The final difference is that the Australian electoral system enables environmental parties to get elected to parliament more easily (at both the state and federal levels), which influences the development of environmental planning and policy (Howes 2005).

4 LAND-USE PLANNING & ZONING FOR HAZARDOUS SITES

The variations between these three governing systems manifest themselves in differences in their land-use planning systems that seeks to manage the impacts of potentially incompatible activities by guiding the location of developments. This imperative is most pronounced in areas where there is close competition for space for activities - as in cities. The policy instruments used by land-use planners have evolved over the last century but often derive

\(^1\) The constitution was later amended to restrict presidents to a maximum of two terms in office.
from early templates involving the use of prescriptive ‘zoning’ of land (Howard 1898; Abercrombie 1913). Local scale zoning policies have been widely applied in many jurisdictions to exclude activities of a particular type from operations within designated areas in order that the impact of undesirable pollutants (such as noise, odour, toxic chemicals) be avoided or mitigated (Pollard 1931; Whitnall 1931; White 1937). The externalities from industrial activity, for example, have been extensively managed by separation of that activity from other land-uses on which it has an adverse impact, particularly residential environments. Heavy industry is often located at sites away from residential or commercial activity, typically via a buffer zone. Arguably, much of the history of modern urban planning has involved managing the distribution of land-uses so as to limit and isolate negative externalities from activities, especially on residential populations.

The application of zoning regulation differs between jurisdictions as a result of constitutional and legal frameworks. In the United Kingdom zoning has been applied under the legal authority of the Crown to regulate development whereas in the USA the application of zoning has been subject to rigorous legal testing against national and state constitutional frameworks. Zoning in the USA typically relies on key cases from the common law. Ambler vs the Village of Euclid (US Supreme Court 1926), for example, affirmed the constitutionality of zoning ‘in the public interest’, while Nectow vs City of Cambridge (US Supreme Court 1928) added the test of ‘reasonableness’ to the application of zoning. Australian urban planning frameworks historically have been heavily influenced by those operating in the UK with legislation-based zoning often being a prominent feature at the state level of government.

Zoning-based land-use planning has often required highly detailed specification of the activities that might be proscribed and those which might be permitted within a given zone. Although it provides a high degree of certainty such prescriptive planning over time often hinders the flexible use of land which in turn is perceived as producing inefficiencies in urban land markets and economic activity. Zoning against use has also been criticised as inadequately addressing the substantive effects of an activity. Some permitted land-uses might nonetheless produce injurious externalities while some presumed offensive activities could apply measures to avoid or mitigate such emissions. Since the early-1970s some jurisdictions in Australia have moved to performance-based modes of land-use planning in which direct prescription of use is avoided in favour of an approach that regulates the quality or impacts of the effects of different uses (Baker, Sipe & Gleeson 2006). Any attempt to understand the combination of pollution, climate change adaptation and disaster events should thus be attentive to the changing modes of regulating land-uses. Whether performance based planning is up to the task of environmental and public protection from pollutant emissions mediated by disaster events is yet to be determined.

An alternative approach has been the use of exclusionary regulation to prevent vulnerable activities from locating at sites where they are then exposed to hazards. The exclusion of residential activity from locations subject to flooding, landslips, erosion and similar climate or geotechnical hazards is one example of this exclusionary regulatory approach. Zoning to prevent the impacts of environmental hazards was applied after its use in the control of hazardous land-uses. White (1937: 58) writing of the US context notes that:

“Most county and city zoning commissions have general authority to prohibit the erection of new structures which would be injurious to other land uses in the same district or adjacent districts, but there are few instances of the jurisdiction having been exercised to prevent flood-plain occupancy.”

The application of zoning for the avoidance of natural hazards has typically operated two ways. In the case of extreme hazards where design measures would be insufficient to adequately protect activities, direct exclusionary measures are typically used. Where the
nature and probability of the hazard occurring is known, performance standards, such as minimum floor heights for dwellings built in areas subject to flooding, are often used.

Australia has a mixed history of flood-based zoning protection among a mixed array of wider flood protection arrangements. Smith and Handmer (1985) have described how flood policy evolved weakly in Australia noting that while zoning powers were provided to local governments from the 1940s onwards these were little used in favour of direct physical protections. Flood protection policy did not develop strong frameworks until the emergence of resource management policy in the 1970s though this was often focused on floodplain management rather than on land-use planning regulation. A common version of a zoning policy mode has been to limit development in locations where the assessed risk of flooding (the annual exceedence probability (AEP)) is greater than 1 in 100 years (Handmer 1996). The literature on the sensitivity of flood risk regulation to land-use type, other than broad categories such as residential or commercial, is sparse. In Queensland, Thomas, et al. (2011) have noted, prior to the introduction in 2003 of State Planning Policy 1/03 there was no planning policy which imposed any restrictions to developments in natural hazard prone areas. Godber, et al. (2006) have identified a desire for flexibility in the application of planning techniques to ensure a close match between protection and community development expectations. The emergence of new forms and scales of flood risk in the recent years in Queensland and elsewhere suggests an important opportunity for innovation in this area of planning policy, especially in the context of the evaluation of existing measures.

In summary, planning policy to manage offensive land-uses has historically used zoning measures applied at the local and sub-regional scale. While some zoning policy has incorporated a natural hazard dimension, including flood protection, this has often been poorly integrated with wider questions of risk management. Policy and research integrating land-use planning with the management of hazardous sites and resilience to major natural hazards such as flooding is underdeveloped. Land-use policy that is sensitive to both natural hazard risk and human activity risk is clearly an area of potential policy innovation and one subject to a growing sense of urgency.

5 POLLUTION INVENTORIES & HAZARDOUS SITES

Each of the three countries being considered has some type of publicly available pollution reporting inventory, although their origins and operation have been very much shaped by the differing systems of government. We seek to demonstrate that all of them can provide a useful source of data in identifying industrial sites that have the potential to release hazardous substances during a climate-related event, such as a flood.

The world’s first pollution inventory, the Toxics Release Inventory, was created in the USA in 1986 and was founded on the principle that communities have a ‘right to know’ about chemical hazards in their locality (US EPA 2013a). The inventory monitors the use of a set of hazardous substances (initially 329, later expanded to over 650) and publishes information about their release annually. Over 20,000 facilities that use, generate or emit more than a threshold amount of these substances have to report their emissions to the Environment Protection Agency (US EPA 2013a). The agency then publishes a report each year identifying what is released, where and by whom (Howes 2005; Howes 2001). The purpose is threefold:

1. To inform the community about potential risks;
2. To put pressure on firms to reduce their emissions; and,
3. To provide government agencies with useful information for decision making about pollution management.
It should be noted that these releases are lawful and the inventory relies only on the power of knowledge, how it might be used by community organisations, and the fears of business of the consequences (i.e. bad publicity, consumer boycotts and law suits).

Since 1986 the idea of using pollution inventories as a policy instrument has spread to 47 countries (Mee 2011). The UK Pollution Inventory, for example, works in a similar fashion to the TRI and is administered by the UK Environment Agency (EA) within the Department of Environment, Food and Rural Affairs (DEFRA). It started as the Chemical Release Inventory in 1990, was restructured in 1997, and has 150 substances on its reporting list (UK EA 2013a). In 2002 the inventory was reorganised again so that it covered England and Wales while a separate inventory was established by the Scottish Environment Protection Agency (SEPA 2013). The UK also reports to the European Union’s air pollutant emission inventory which has a particular focus on trans-boundary air pollutants.

An Australian inventory was proposed by Prime Minister Keating in 1992 and the early development work was undertaken by the Commonwealth Department of Environment. Eventually it was handed over to the joint Commonwealth-State ministerial body the National Environment Protection Council (NEPC). This council was supported by complimentary legislation at both levels of government so that decisions taken on National Environment Protection Measures became enforceable in all jurisdictions. The National Pollutant Inventory (NPI) was the first measure created and was formally launched in 2000. State agencies collect data from reporting sites, the Commonwealth Department of Environment runs the website, and overall administration is undertaken by the NEPC’s supporting organisation. There are currently 93 substances or groups of substances on the reporting list and approximately 4,000 reporting sites around the country (Thorning and Howes 2007; Howes 2005; Howes 2001). The NEPC later became part of the larger Environment Protection and Heritage Council and in 2011 it was merged into the Council of Australian Governments (COAG) Standing Council on Environment and Water.

All three inventories offer a spatial analysis in the form of maps that identify reporting facilities and their emissions. In the USA, the EPA also runs several programs on land-use planning, particularly with regards to climate change and greenhouse gas emission reductions (US EPA 2013b), and there are also some resources for adaptation planning (US EPA 2013c), but both of these run independently of the TRI. In the UK, the Environment Agency offers a range of interactive maps for the public to use on its website that include pollution and flooding, but these are offered separately and are not integrated into a single risk management tool (UK EA 2013b). Another organisation, the UK Health and Safety Executive (HSE) offers advice on land-use planning and public safety that includes information on hazardous substances, but again there is no integration with climate change adaptation or the pollution inventory (UK HSE 2013). In Australia, the division of NPI responsibilities between state and federal organisations, and its separation from both state and local planning authorities, as well as emergency management agencies, leaves little opportunity for integration.

We argue that there is a substantial opportunity to integrate land-use planning and pollution reporting into a tool that could assist with both disaster risk management and climate change adaptation. We have sought to demonstrate such an approach by way of a pilot study of the 2011 Brisbane floods as an example. The outcome of this work is detailed in the next section and the lessons learnt here could apply equally well anywhere in the rest of Australia, the UK or the USA. In fact they would be useful in any of the 47 countries that currently have some form of pollution inventory (Mee 2011).
EXAMPLE: A SPATIAL ANALYSIS OF THE 2011 BRISBANE FLOODS

Research into inventories like the NPI has focussed on their origins, purpose, operations, impacts on business, and responses by community organisations (Thorning 2009; Lloyd-Smith 2009; Thorning and Howes 2007; Howes 2005; Gunningham and Gadenne 2003; Lloyd-Smith 2002; Howes 2001; Pitts 1996). This pool of research raises some questions about their effectiveness in encouraging firms to reduce emissions (Kerret and Gray 2007; Harrison and Antweiler 2003), the accuracy and extent of the reported emission figures (Cowan and Deegan 2011; National Toxics Network 2010; Nelson 2007; Jenkins 2003), and the trends in emissions (IPCC 2007). The use of this data by government has been under-researched, however, particularly with regards to identifying reporting sites as potential hazards during extreme weather events or the implications for climate change adaptation.

A pilot study undertaken by this project team examined how land-use planning and pollutant inventory data could be integrated into the spatial scale of a flood event that occurred in the Brisbane River catchment in January 2011. The pilot study shows how the experiences and other empirical information from this major disaster can be utilised and integrated to inform a ‘framework for action and research’ to improve the prediction and management of risk from toxic pollutants.

Map 1: River Catchments & Local Government Boundaries

In December 2010 and January 2011, Queensland was impacted by historically significant flooding, caused by above-average rainfall associated with the La Nina weather pattern. A comprehensive description of the spatial and temporal extent of these flood events is provided in the Interim Report of the Commission of Inquiry into the Queensland Floods of 2010/2011 (QFCI 2011). The flood event that occurred in January 2011 within the Brisbane
City Council and Ipswich City Council local government areas within the Brisbane River Catchment is our specific study area and is shown in Map 1.

The approach taken for this pilot study was to first identify and describe the relevant management frameworks and spatial data produced by pollution reporting mechanisms, dangerous goods management, disaster risk management and land-use planning processes that occur within the study area. The data sources are considered according to the primary reasons the data is collected; the nature of data they collect, collate or produce; the availability and accessibility of that data for extended use; and the potential for data integration. Second, the pilot study provides some preliminary observations on the potential for integration across the four policy streams to identify, quantify and manage the increased risk of climate change induced impacts on toxic sites and hazardous land-uses.

**Data and risk assessment methods available from pollution reporting**

Queensland’s contribution to the National Pollutant Inventory (NPI) is now managed by the Department of Environment and Heritage Protection. The NPI data includes the location of reporting sites and the substances, destinations and quantities of emissions. In addition, a social and environmental risk assessment methodology and application has been developed and applied to the Queensland NPI data.

**Map 2: Location of NPI Sites within the 2011 Brisbane Flood Lines**

The limitations of using the NPI data for flood risk identification is that the data represents lawful emissions of substances from specified sites and does not currently consider on-site storage of hazardous substances or potential interactions between substances during uncontrolled emissions. An additional limitation is that the NPI reports sites that emit pollutants above a threshold amount and hence, does not capture all possible sites and
emissions. The NPI does however include a methodology to estimate and report on diffuse emissions for some substances.

Spatial data overlay shows there are 16 NPI reporting sites within the Brisbane January 2011 flood-lines. The location of these sites is indicated on Map 2. A future focus of this research will be to investigate which of these sites were actually inundated by floodwaters during the January 2011 flood event, and what was the impact in terms of uncontrolled emissions of pollutants.

Data available from dangerous goods and hazardous substances management
The Queensland Dangerous Goods Safety Management Act 2001 and its management of dangerous goods in relation to their storage, handling and transportation, provides a comprehensive source of data relevant to this research. Industrial premises are categorised according to the quantities of dangerous goods that are stored and handled at the location. There are four classifications: Minor Storage Workplaces, Dangerous Goods Locations (DGLs), Large Dangerous Goods Locations (Large DGLs) and Major Hazard Facilities (MHFs). Large DGLs and MHFs have to be notified to the Department of Emergency Services. The key agencies involved in dangerous goods and hazardous substances management are important stakeholders and source of information for this research.

Map 3: Industrial Land-Use Zones within the 2011 Brisbane Flood Lines

Data available from land-use planning processes
Local Government Authorities play a major role in land-use planning, zoning and management in Queensland. As shown in Map 1, the Brisbane City Council and Ipswich City Council jurisdictions are relevant to the pilot study area, with the Brisbane City Plan 2000
Both Brisbane and Ipswich City Councils responded to the 2011 floods with the development of ‘Temporary Local Planning Instruments’ (TLPIs). The purpose of these TLPIs is to utilise preliminary information about the flood event to achieve an improved level of flood immunity while permanent planning and policy flood immunity responses are considered. The relevant TLPIs are 01/11 – Brisbane Interim Flood Response, TLPI 01/12 – Brisbane Interim Flood Response and Ipswich City Council ‘Temporary Local Planning Instrument 01/2011 – Flooding Regulation.

Disaster risk management
The Queensland State Disaster Management Plan and the State Disaster Management Group provide the existing framework for disaster management and response. This framework integrates key agencies, communication systems, data management and data sharing systems that are relevant to this research project.

Empirical data describing the impact of the Brisbane 2011 floods
The Queensland Reconstruction Authority (QRA) was established by statute following the state-wide natural disaster events of 2010/2011. The QRA has facilitated and coordinated the reconstruction and recovery efforts across the state. It has collected, collated and analysed a vast amount of spatial data, including detailed investigations of the actual natural disaster impact at a cadastre level across large areas of the State. Of interest to this project is the cadastre based attribute data describing and measuring the flood impact in terms of the inundation level of the flood waters. This data could be used to assess the value of NPI data, the dangerous goods/hazardous substances data managed under the Dangerous Goods Safety Management Act 2001 and the local government land-use zoning data to work towards a more complete understanding of the increased risk of toxic sites and hazardous land-uses.

Climate change adaptation research
There is a concerted effort in climate change adaptation research in south-east Queensland, including the area of the Brisbane River catchment. Such research provides a higher resolution local analysis of the broad climate change scenarios, such as those produced by the IPCC. The implementation of climate change adaptation policies at a bioregion scale, such as a river catchment or a climatic region, requires a higher resolution analysis and must deal also with the uncertainties associated with downscaled climate models. The IPCC climate change scenarios provide some guidance on the predicted direction and magnitude of change for various climate change impacts. In comparison, the Brisbane 2011 flood events provide some empirical data that can be used as a benchmark for predicting future local climate change scenarios with greater certainty. For example, flood data may be used to analyse and potentially adjust flood frequency probabilities such as annual exceedence probabilities and flood return periods and magnitudes.

6 CONCLUSIONS
Around the world, a broad range of data is currently being gathered by different agencies at all levels of government. At the same time, governments are being asked to do more with less as the list of urgent policy and planning issues grows, while competition for scarce public resources increases. We argue that one useful strategy for resolving this dilemma is to integrate disparate policy instruments from various agencies into a coherent and practical spatial analysis tool. This would allow for the pooling of resources, a reduction in duplication,
and generate some economies of scale. Further, one of the key requirements of good decision-making is the need for useful information that allows for the effective targeting and prioritisation of actions. This need is even more urgent, given that climate change is likely to increase the impact of extreme weather events and place further stress on a wide range of agencies.

Our research suggests that one example of where this can be done is in bringing together data from land-use planning, flood mapping and pollution reporting inventories using GIS spatial analysis methods to identify sites that have the potential to release hazardous substances during climate related events such as floods. Our pilot study of the 2011 Brisbane floods has already revealed important information that could be useful for disaster risk management, land-use planning and climate change adaptation. In the short term, the results can be used to inform emergency services about the location of potential risks and enable them to develop a better targeted response to hazardous substance releases during a flood. In the medium term, industrial sites that are identified as at risk can be required to invest in defensive engineering that reduces the likelihood of chemical releases during flooding. In the long term, governments can adjust their zoning to encourage the migration of some industries away from flood-prone areas.

This method might be extended to encompass any of the 47 countries that have national pollution inventories. It might also be expanded to provide a more comprehensive analysis that includes other climate-related hazards, such as bushfires, heatwaves, storms and cyclones. These prospects provide promising opportunities and pathways for future research.

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