Flood emergency management decision support system on the Gold Coast, Australia

Mirfenderesk discusses the effects of climate change on flood risk on the Gold Coast and a system that has been developed to support decision-making in the area.

Abstract

Gold Coast has long been rated as the most vulnerable area subject to flooding in Australia (Smith, Handmer 2002). In recent years there has been a growing concern worldwide about climate change impacts including sea level rise, increased frequency and severity of storms and changes in rainfall patterns. Implications resulting from these changes include increase in the risk of flooding. Therefore, future floods are more likely to overwhelm existing protection measures more frequently, exposing us to more residual risks. Addressing the issue of an increase in residual flood risk, Gold Coast City Council has been developing a flood emergency decision support system as part of a 10 year flooding and drainage plan. This system integrates Council's flood modelling capacity, properties, infrastructure and population data into a single easy-to-use package. Using this system, emergency managers are able to have access to valuable forecasted flood information. The Decision Support System (DSS) is designed mainly to assist in a post-disaster situation; although currently it is being used for pre-disaster flood emergency planning. As a post-disaster measure it can identify vulnerable population and assist in the evacuation of the population at risk. Its availability on the Internet allows it to be potentially used for implementation of flood emergency procedures by vulnerable places such as child and aged-care centres. This paper provides a description of the elements of the system that has been developed or implemented so far, provides a brief description of the elements that are planned to be developed in future, make recommendations on how such systems can be improved and how their improvements can contribute to better flood emergency management.

Introduction

It is not possible to protect everyone, everywhere against flooding eventuality. Extreme or unpredictable events can happen. While physical defences may provide a level of protection they may be breached. Once flooding overwhelms existing mitigation and protection measures, flood emergency management is the main tool for providing safety to the community. An effective flood emergency management needs to be informed by a robust Decision Support System for being effective. Flood emergency Decision Support Systems (DSS) have been used by emergency managers for a long time. In the 1980's and 1990's these systems were usually in the form of hard copy flood maps, graphs, tables and other hard copy documents. With recent advances in computer and communication technologies, these systems have been morphing into more sophisticated forms; providing much needed real time flood information in more detail, in significantly less time-frame and with much higher quantity and quality. These systems are similar in some of the basic principles, such as computerisation of the flood prediction operations and usage of GIS as a platform for interaction with the users. The dissimilarities among these systems come from the fact that the nature and consequence of flooding vary substantially in different locations. Flooding can happen in different forms and, in a sense, it can be categorised into two main groups, namely, regional and flash floods.

1. Regional floods occur when water spills over rivers, creeks, man-made canals, lakes, ocean (in general receiving waters) and result in inundation of surrounding lands. Regional floods can be sub-grouped based on the source of water spillage. Water could spill as a result of:
   - 1.1 heavy rainfall (generally long-duration),
   - 1.2 storm tide (as a result of cyclonic activities),
   - 1.3 sea level rise; and
   - 1.4 Tsunami.

2. Flash floods occur when overland flow (resulting from heavy short-duration rainfalls) cannot be effectively drained (generally through man-made drainage system) into receiving waters (including rivers, creeks, man-make canals, lakes and ocean).

Although, from a resident perspective, there may not be much difference between being flooded by various types of regional or flash floods, there are substantial differences on how the emergency efforts associated with each type of flood should be informed (by a DSS) and what level of sophistication a DSS should possess to be able to address a specific type of flooding. In addition to the nature of a flood, the consequences of potential flooding in an area influence decision making on the sophistication of a DSS.

A review of existing Flood Emergency DSS' in South East Queensland shows that local authorities have chosen different approaches towards the type of DSS that they use for flood emergency management. A common element of the flood emergency DSS in south east Queensland that is shared between all local authorities is the FloodWise (Moris and Galletly, 2007) tool. This system provides users with a range of flood information to take appropriate action during a flood emergency situation. This system is potentially applicable to regional and flash flooding (mainly as a result of rain). The system interrogates existing rainfall and water level measurement stations across the region every 5 minutes (round the clock) and posts the results on the Internet. This system has been enhanced by the Brisbane City Council to provide a range of flood information such as (but not limited to):

- Rainfall summary maps,
- Flood levels,
- Flooded roads and locations, and
- Flooded areas.

This information can be accessed via the Internet. No real time hydrological or hydrodynamic modelling is embedded in this system. The relationship between the measured data and flood information is basically achieved through empirical relations.

Some of the local authorities have developed new elements of DSS for flood emergency management. For instance, Logan City Council has developed a GIS-based DSS that operates on Water Ride (http://www.waterride.net/) software platform. This system converts a predicted peak flood level at a gauge in the catchment into surface showing the likely flood extent. An extensive library of pre-cooked flood map library is used for interpolation of flood surface. This system is very fast but does not contain any real time hydrological or hydraulic modelling element for prediction of water level and routing of flood wave across the floodplain. Moreton Bay Regional Council has extended its DSS to include real time hydrological modelling (Druery et al, 2009). This system is an extension of a system similar to the one that operates at Logan City Council. This system uses a continuous hydrological model to estimate water level at the gauging stations. A shortcoming of the system is that it does not have any embedded real time hydraulic modelling. Hydrological models are reliable on simulating discharge, but for water level prediction and flood wave routing, a hydrodynamic model is superior. Despite this drawback (that in the context of flood emergency management may not be critical at all), this system is an excellent progress in DSS development. All the above mentioned systems are mainly engineered to deal with riverine flooding. A general shortcoming of most of the DSS' employed by various local authorities is that they lack an automated rainfall prediction mechanism embedded in their systems.

The Gold Coast has experienced more than 45 floods since 1925 (Bureau of Meteorology web site). Passing cyclones have triggered many of the floods. Historical records indicate that more than 40 cyclones have passed the Gold Coast region over the last 120 years. The last major flood (1974) was triggered by Cyclone Wanda. This led to the evacuation of 1500 people and in many places homes were swamped with 1.2m to 1.5m of water (Gold Coast Bulletin, Tuesday 29, 1974 p3). More recent localized flooding in June 2005 and January 2008 resulted in the inundation of several hundred houses and the loss of two lives. Comprehensive flood studies on the Gold Coast show that more than 5000 properties would experience over-floor flooding during a 1 in 100 year flood event (Mirfenderesk and Abbs, 2008). The damage bill for the Nerang River catchment (Figure 1) that is the most populated catchment on the Gold Coast would exceed $200,000,000, excluding damage to infrastructure and intangible losses.

It is estimated that more than 15,000 people would be directly affected by a city-wide 1 in 100 year flood event on the Gold Coast. From post-event observations and statistical analysis of previous floods, it is recognized that residents affected by flooding are subjected not only to physical problems, but also to serious and prolonged psychological and sociological problems, such as nervousness, anxiety, irritability and obsessive behaviour. The rise in the level of vulnerability is mainly due to the fact that exposure to flood hazard (as a result of population growth in flood affected areas) has been growing faster than adaptive capacity. This pressure is expected to increase over the next 20 years as a result of climate change impacts (Mirfenderesk, Abbs (2008)). Gold Coast comprises of 7 major catchments. Some of these catchments such as Tallebudgera, Currumbin and Broadwater have time

Figure 1. An overview of main catchments on the Gold Coast.

of concentrations as low as 3 hours, making them highly susceptible to short duration local flooding. Catchments such as Nerang, Coomera and Logan-Albert can have time of concentrations between 3 and 92 hours, making them susceptible to regional scale long duration flooding, in addition to short duration local ones. These facts clearly demonstrate that Gold Coast is prone to long and short duration riverine flooding, and storm tide as well as flush flooding, with significant consequences on the city's community and economy. Addressing such a wide range of flooding types, Gold Coast City Council has been developing a DSS for flood emergency management as part of a 10 year flooding and drainage plan. This DSS comprises of a suite decision support tools, each one of which addressing a specific flooding type (in terms of available response time and source of flooding).

Gold Coast DSS is embedded into a wider strategic approach to address flood risk on the Gold Coast. In this approach, risk is defined in terms of its components, eg hazard, exposure and vulnerability.

Flood risk = hazard x exposure x vulnerability

Exposure to hazard means presence of people/properties in flood risk areas and vulnerability means lack of resistance/preparedness of the community. In this framework, flood emergency management is seen as an important element of reducing community vulnerability to flood risk. With such a mindset, flood emergency management will not be limited to operations only during the flood incidents. It will also cover post flood activities, which are needed, to help the community to recover from the disaster as quickly as possible.

Consequently, the tool set that supports such flood emergency management needs to be able to perform this role in the aftermath of a flood, highlighting the need for a flood recovery DSS. Addressing all types of flooding Gold Coast DSS is planned to be completed in eight stages. Each stage of the system addresses a specific aspect of flooding with different degrees of accuracy and sophistication. This study provides a description of the system with a more detailed explanation of the elements that have been completed.

Decision Support System for Riverine Flood Emergency Management

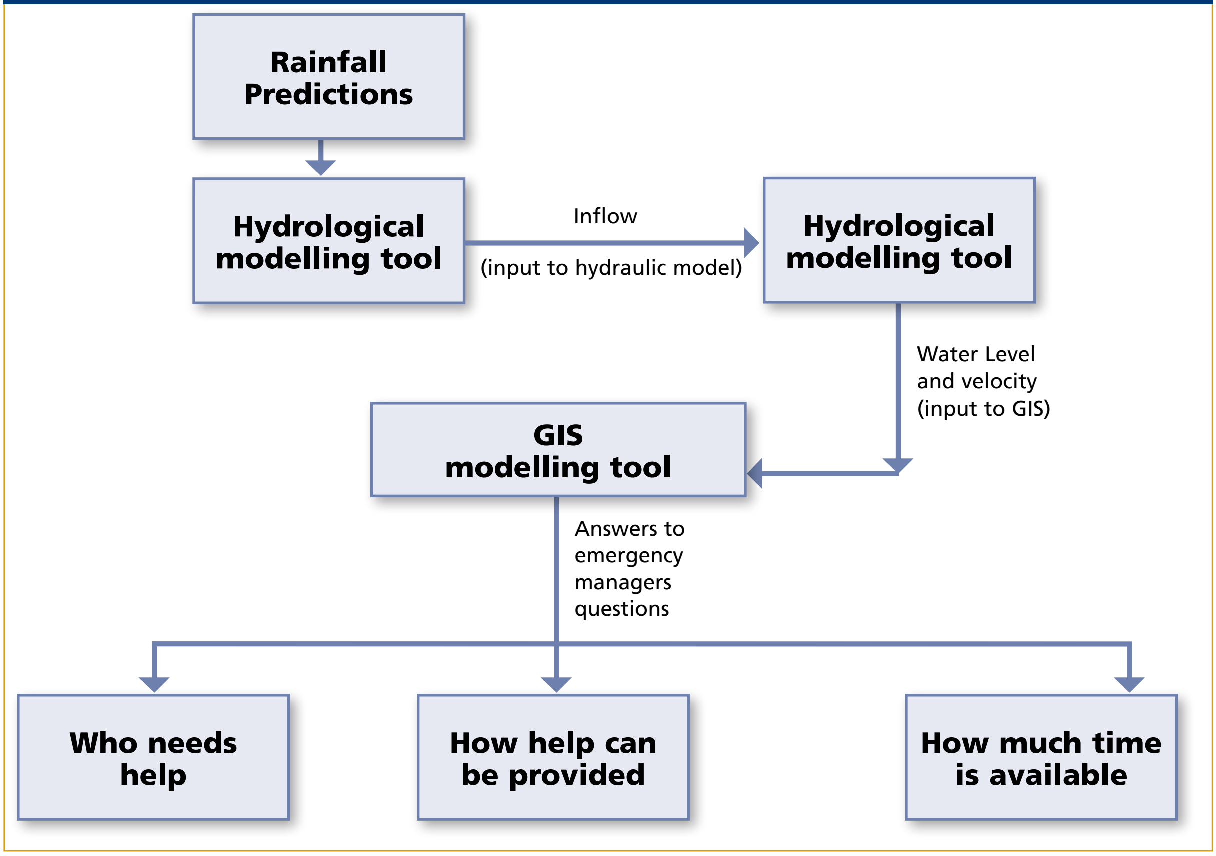
The decision support tools that are embedded in the Gold Coast DSS provide a fully interactive environment where information is presented visually in an easy-to-understand form. Flood affected properties and population can be quickly identified during a flood event. They provide a clear visual presentation of where certain communities may be cut off and isolated, and which evacuation routes may be flooded. The DSS performs real-time flood predictions based on the real-time data provided by the BOM. In general the input to the Decision Support System is predicted BOM river discharges at the input points of the Council's hydraulic models. The Decision Support System runs Council's hydraulic models automatically and produces a multitude of outputs. Figure 2 shows the layout of DSS for riverine flooding emergency management. It comprises of three main elements: Hydrological model, Hydraulic Model and GIS platform.

Hydrological Element – hydrological modelling component of this system is currently undertaken by the Bureau of Meteorology Queensland. The software platform for hydrological modelling is the BoM URBS model. The model uses rainfall predictions as input and generates flow hydrographs that in turn will be used as input to the Council's hydraulic models. These hydrographs are then posted to a webpage so they can be downloaded by the Council's flood emergency officers. These hydrographs are only available for large scale catchments such as Nerang, Coomera and Logan-Albert. For smaller catchments such as Tallebudgera, Currumbin and Broadwater these hydrographs cannot be produced, due to very short response time of these catchments.

GIS Element

Central to the decision support system is a GIS user interface (Patterson & Britton (2007)) based on WaterRide software platform. Input to the GIS tool is flood surface that can be generated in various ways (as explained in the following sections of the paper).

Figure 2. Flood Emergency Decision Support System Layout for Riverine Flooding.



The output of the GIS tool are answers to the flood emergency managers questions, such as who needs help; or what is the best way to access people in need or what is the best evacuation route; or how much time is available for certain actions; etc. To enable these types of questions to be answered, the GIS tool uses Council's data base, simulates flood levels and generates the following information (in the form of map, graph or table) for the forecasted period.

- Flood level map,
- Flood inundation map,
- Evacuation routes map
- Time histories of flood level, flood depth, velocity and hazard at any location
- House-specific flood inundation information (for properties that have been surveyed).
- Hazard and vulnerability maps
- Flood flow velocity maps
- Time histories of flood level, flood depth, velocity and hazard at every location.
- A report containing a list of inundated houses and vulnerable elements (such as age care centres, schools, child care centres, etc).

GIS data that are used for this system are mainly sourced from the Council's data base and 2001 census data for the Gold Coast. Some of the most important elements of this data base are

- A 5 meter digital elevation model of the whole city and its waterways with an accuracy of 100 mm.
- Flood level survey of close to 10,000 properties across the city.
- Location of the important infrastructure and vulnerable elements (such as child & age-care centres).
- Demographic data (obtained) from the 2001 census data.
- Historic flood level information.

Hydrodynamic Element

Hydrodynamic element of the DSS works in two different modes, named DSS1 and DSS2 tools. DHI (http://dhigroup.com) software platform is the main tools for the development of the hydrodynamic element of the Gold Coast DSS.

DSS1 – In this mode the system uses an electronic library of pre-cooked flood maps, which are linked to a number of water level gauges across the city. Based on the predicted water levels at these stations, DSS1 tool interpolates a new flood surface using the above-mentioned library of flood surfaces. This library includes flood maps associated with various storm intensities. The advantage of this system is that it is very fast (less than 5 minutes). In this mode, since there is not any real time hydraulic modelling, velocity and hazard & vulnerability maps cannot be produced.

DSS2 – In this mode a static link is established between the three main elements of the DSS, e.g. hydrological, hydraulic and GIS tools. In this mode the system performs real time hydrological modelling. At this stage the hydrological modelling element of the system is undertaken by the BOM. The results of the hyrological modelling are provided to the flood emergency officers via internet. The input to the system is predicted BOM river discharges at the input points of the Council's hydraulic models. Decision Support System runs the Council's hydraulic models automatically and produces a multitude of outputs through the GIS element of the system (WaterRide softwar). In this mode the outcome of the system is more accurate than the first mode, because it uses real time hydraulic modelling to generate flood information. For this reason and unlike the first mode the system is capable of producing velocity and hazard & vulnerability maps. In this mode the system takes longer to produce flood information. It generally takes up to two hours to complete hydraulic and mapping exercise for a catchment. It is worth mentioning that both the above-mentioned operation modes need to be triggered by Council officers once the Disaster Coordination Centre (DCC) is mobilised. The operation times that have been mentioned (5 minutes for the DSS1 and 2 hours for the DSS2) do not include the required time for the DCC mobilization. Given the fact that mobilization can take several hours, the above mentioned operation modes are generally unsuitable for small catchments and storm conditions with very small warning time.

Internet-Based Decision Support System

DSS3 – This Web-Based Decision Support tool is designed to address the shortcomings of the two above-mentioned operational modes (in relation to warning time) by offering the following features:

- The system is fully automated, creating flood forecasts every two hours, 7 days a week. This allows forecasts without any mobilization of the Disaster Coordination Centre which gives increased warning times. This is particularly important for short duration floods which can be common on the Gold Coast.
- This system includes a feedback mechanism for automatic correction of forecasts. This method uses real time water level observations as feed back and then adjusts flood level predictions so that the predicted and observed levels match each other.

This provides a practical method of reducing the sensitivity of the hydrological model to uncertainties in rainfall data and calibration accuracy.

- The system publishes the forecasts onto the internet which can be viewed from anywhere in the world and at any time. This can result in decentralized decision-making processes which can be critical in the case of local floods.
- The system operation can be modified over the internet if required. This allows GCCC officers to make basic changes to the system configuration remotely which can be useful during emergency situations.

This system is currently in operation for the Nerang River floodplain. The system publishes three-day flood forecasts every two hours at 12 locations across the Nerang floodplain in the Internet. The main elements in the system are as follows:

- **Gauge Stations:** For the Nerang River catchment two water level gauging stations provide real time data to the system for automatic update of MIKE11 forecasts,
- **BOM Server:** This server is maintained by BOM and is used for posting the forecasted flow hydrographs at the input points of the Council's hydraulic models,
- **Environmen PC:** This is a computer located at the Disaster Coordination Centre. The Environmen software on this machine continuously interrogates telemetry stations (including the two above-mentioned gauging stations) across the Gold Coast. The software produces a report every two hours and put it in an ftp site to be downloaded by the system,
- **FTP Server:** The purpose is to make gauge stations data available over the Internet,
- **FLOODWATCH Server:** this server hosts the FLOODWATCH, MIKE11 and Windows Virtual Server. It collects data, runs MIKE11, implements MIKE11 real time updates and posts the flood forecasts across the floodplain on a dedicated Web Server.
- **Web Server:** This server displays flood forecasts on internet.

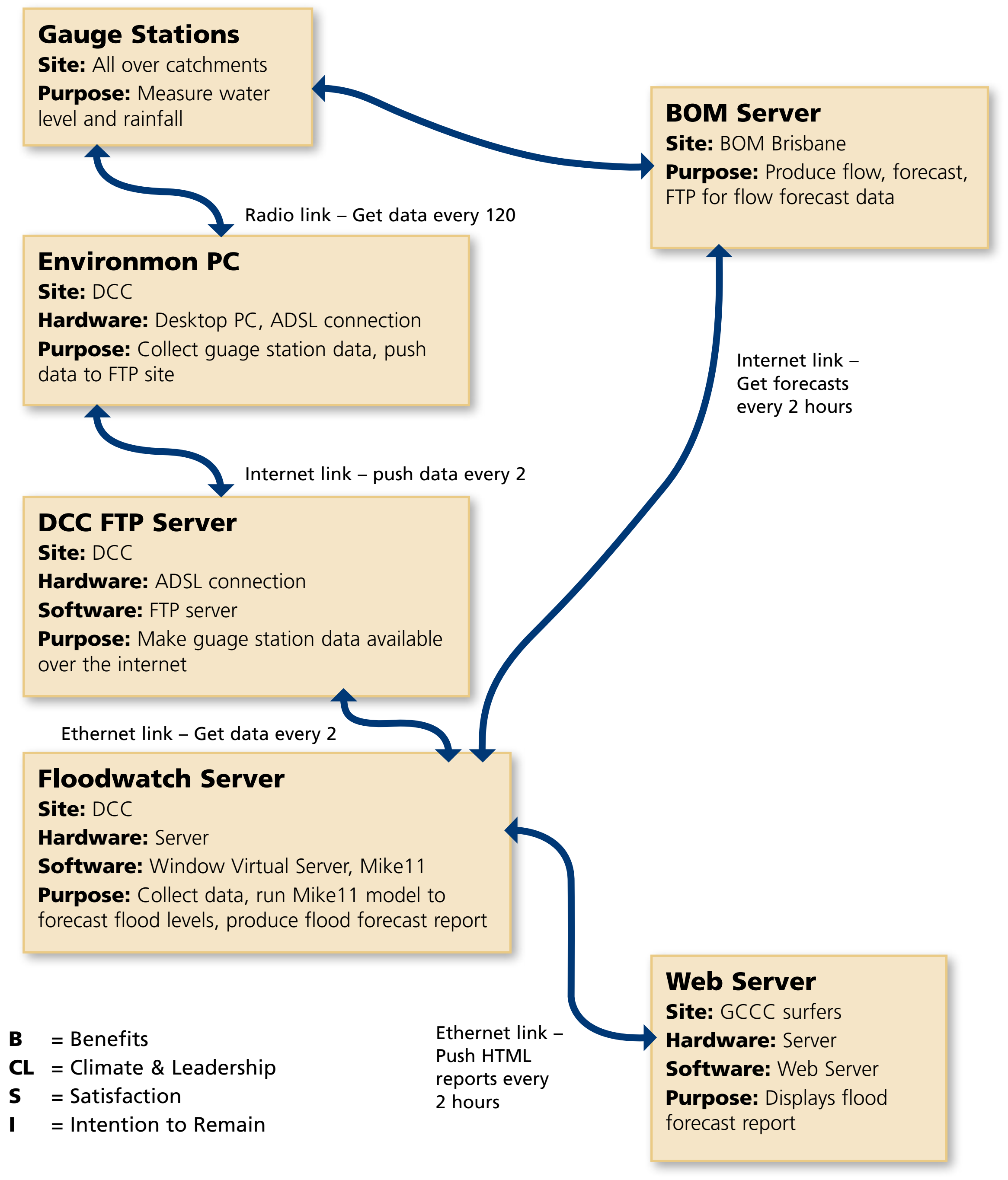
Figure 3 shows how this system works. The system automatically interrogates the BOM website and Enivronmon PC and downloads predicted flow hydrograph and measured water level at the gauging stations. It runs the hydraulic model for the study area and makes a three-day forecast of flood level. The system compares its previous forecast with the measured water level. In the case of a discrepancy it changes the hydraulic model parameters and produces a new prediction, ensuring that predicted water level will be consistent with measured water level for the hind-cast period. Then it publishes the flood levels on a dedicated server. The whole process takes 2 hours and will be repeated round the clock and seven days a week. A shortcoming of this system is that it has to rely on BOM flood forecast as input to the system. These forecasts are generally only available for medium to large size catchments. Therefore this system is only suitable for large scale catchments such as Nerang and Logan Albert.

DSS4 – This tool is designed to address the shortcomings of the Internet-based DSS3 tool. DSS3 is suitable for large catchments such as Nerang, Coomera and Logan-Albert (with relatively long concentration time and therefore long warning time). To apply the concept that has been used in DSS3 to smaller catchments or for short duration floods in large catchments, DSS4 has embedded continuous hydrological modelling within the system. In doing so, it is able to do flood flow forecasting automatically and internally. This forecast system, similar to DSS3 runs automatically and frequently (in the case of Tallebudgera Creek, it is planned to run every 15 minutes), interrogates water level measurement stations periodically and uses them for self correction of its predictions in real time. The results are accessible through the Internet, ensuring that all Council and Emergency response staff can have access to the information even if they are not at the office.

This system is currently being developed for the Tallebudgera Creek catchment with an approximate area of 98km2 and time of concentration of 3 to 9 hours. Input to the system is the rainfall over the catchment. The rainfall is routed through the continuous hydrological model that is embedded in the system. The output of the hydrological model (discharge) is then used as an input to hydraulic model. The hydrodynamic model routs flood wave through the system and provides flood level information as its output. This system has the potential of being extended further by including stormwater drainage system to the hydraulic modelling element. The advantage of this extension is that it can be used for the management of flash flooding. By its very nature, flash flooding occurs quickly. Emergency managers are often caught off guard during a flash flooding situation with little time to implement civil defence measures.

A general shortcoming of this system and indeed all DSS' that are described in this paper or used by various local authorities, is that it does not have an automated rainfall prediction capacity embedded in the system. In general, rainfall prediction is undertaken by the BOM at

Figure 3. Implementation system.



the time of flood. Therefore, reliability of the DSS' heavily depends on robust communication with BOM and the accuracy of predicted rainfall during flood emergency situation. Such predictions basically do not exist for the type of catchments (low concentration time catchments) that are going to be serviced by DSS4, due to short response time of the catchment. As DSS4 does not use BOM rainfall projections, its warning time is therefore limited to the time of concentration of the catchment. On this basis, the warning time for catchments such as Tallebudgera and Currumbin Creeks can be between 3 and 9 hours. This shortcoming is alleviated by automatic publication of flood information on the Internet and therefore saving for the time that would normally be needed to mobilize the Disaster Coordination Centre and to convey flood information to flood managers through the traditional methods. Having said that, this system has the advantage of creating outcomes that are more accurate than the outcome of DSS3 or similar systems (that rely on BOM forecasted rainfall). The reason is that in DSS4 the forecasted flood is based on the measured, and not the forecasted, rainfall.

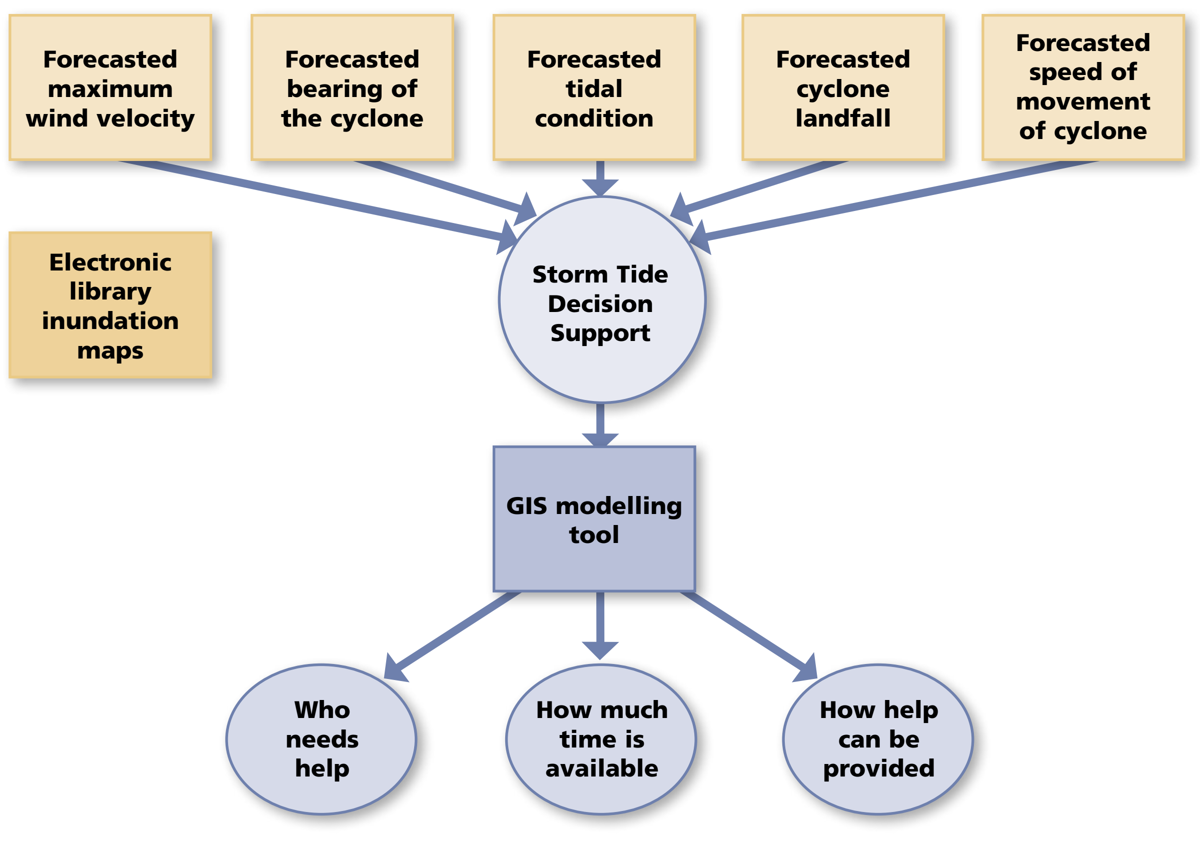
DSS 5 – Flash flooding Decision Support tool (FloodWise)

FloodWise is a DSS tool that allows users to take appropriate action during a flood emergency situation. This system is potentially applicable to regional, local and flash flooding. The system interrogates existing rainfall and water level measurement stations across the region every 5 minutes (round the clock) and provides this information on internet. As the system is fully automated and can be accessed via internet it is effective for flash flooding situations. Once empirical relations between the flooding behaviour of places of interest and surrounding gauging stations established, the system can provide valuable flood information such as the time history of flooding of roads or bridges. This information can be sent to emergency management officers via SMS or similar tools. Through this system the user can gain a synoptic view of flooding in South East Queensland (SEQ), as all the rainfall and water level measurement stations in SEQ can be observed and interrogated in this system. Conversion of the Gold Coast FloodWise tool to a flash flooding DSS tool is currently being undertaken.

Storm Tide Decision Support System (STDSS)

The Storm Tide Decision Support System (STDSS) aims at improving Gold Coast's resilience against likely storm tide conditions. Figure 4 shows a schematic of the STDSS. The system uses five forecasted hydrological parameters, maximum wind velocity, bearing of the cyclone, tidal condition, cyclone landfall and speed of movement as inputs. STDSS interpolates flood surfaces, using an electronic library of flood maps, based on the input parameters. The interpolated map is fed to the GIS modelling tool. Similar to DSS1 and DSS2 the GIS tool can be interrogated to identify those who are at risk and best way to provide help to those who are in need.

Figure 4. Layout of the Storm Tide Decision Support System.



The electronic library that is used in STDSS is a collection of flood maps resulting from the likely storm conditions on the Gold Coast. A storm tide condition is defined as a cyclone with a given maximum wind speed, bearing, tidal condition, landfall and speed of movement. Table 1 provides the range of values that are adopted for the Gold Coast STDSS. A combination of all the values in Table 2 constitutes 108 possible storm tide conditions. These storm tides are simulated by a coupled hydrodynamic-wave model and the resulting flood maps are archived in the electronic library.

Table 2. Selected input parameters for cyclone surge model			
Adopted Maximum Wind Speed (knots)	25	37.5	50
Bearing	N	NE	E
Tide level	Mean Water		High Water
Landfall	North	Centre	South
Speed of movement (km/hour)	8		14

Comparison between Various DSS tools

In this section the above mentioned DSS tools are compared with each other and their advantages and limitations are highlighted in Table 3. The information in table 2 demonstrates that there is no perfect DSS tool that could address all types of flood emergency situations on the Gold Coast alone.

Table 3. Comparison of various DSS tools.

System	Advantage	Limitation
DSS1	The system is very fast. From the time that predicted water levels are available, it takes a few minutes to provide the required flood information.	* There is no real time hydraulic modelling. It relies on BOM for the provision of predicted water levels at the gauging stations. * The system is not accessible via the Internet and therefore there is a need for the officer to go to the Disaster Coordination Centre to perform his duties.
DSS2	The system is far more accurate than DSS1, as flood information comes from real time computer simulation models.	* This system is slower than DSS1. Typically it takes 2 hours to make flood predictions for a typical catchment on the Gold Coast. * The system is not accessible via the Internet. * The system relies on BOM rainfall projections.
DSS3	*…The system provides better accuracy than DSS2, as it has an embedded self calibration mechanism. *…The system is accessible via the Internet. The system is fully automated running round the clock.	* It relies on BOM real time hydrological modelling. If the predicted rainfall is wrong, the system provides erroneous flood information and, as it is fully automated, it is less flexible (compared with DSS2) to be rectified. *… Due to bandwidth limitations the amount of information that can be made available to flood managers via the Internet is substantially less than the amount that can be made available through DSS2.
DSS4	*…It has all the advantages of DSS2 and DSS3, plus it does real time hydrological modelling as well. *…As it uses measured rainfall; its flood predictions are more accurate.	* The system does not use long term rainfall projections, as it uses measured rainfall as input. Therefore warning time for each point within the catchment is as long as the time of concentration at that point.
DSS5	This system can be accessed via the Internet and is very fast; therefore it is potentially suitable for flash flooding situations.	* No real time hydrological or hydraulic modelling is undertaken in this system. *…Flood projections are limited to the time of concentration at each point within the catchment.
STDSS	This system is very fast and in a matter of minutes can provide required flood information.	No real time hydrodynamic modelling is undertaken in this system. Flood information is based on interpolation of an extensive electronic library of cyclone scenarios.

Future Plans

This section of the paper identifies two more elements for the Gold Coast DSS tools that are needed to have all aspects of flooding on the Gold Coast covered. They include Tsunami and flood recovery DSS tools. The below brief descriptions are only an initial assessment of how such tools will look.

Tsunami Decision Support System (TDSS) – The TDSS displays a clear visual presentation of flooding. It shows how a Tsunami-generated tidal wave progresses and evolves across the city. This system is essentially similar to STDSS; the only difference is that a different set of boundary conditions will be used for this system. This set of boundary conditions is the Tsunami-generated tidal wave at 20-meter deep water along the coastline of the Gold Coast. This information is expected to be obtained from BOM global tsunami model for the Australia.

Flood Recovery Decision Support System (FRDSS) – The massive scale of the problems that will be faced in the aftermath of a flood disaster requires a decision support system to help decision makers on time critical issues. Such DSS uses a multi-criteria, risk-ranking approach to allow for careful prioritization and finding a balance between competing needs from a variety of public and private interests. The system focuses on two areas of flood recovery:

- **Debris Removal and Road (waterway) Clearing –** Miscellaneous debris, vessels and cars that are submerged, capsized, or grounded, all create significant transportation, navigation, pollution, health and safety hazards. The FRDSS is aimed at providing a fact-based, participative and rational process for managing this massive effort. The system is designed for a quick evaluation of benefit (risk-reduction) of potential removal alternatives. These alternatives are evaluated in terms of safety, environmental protection, mobility, security, time and efficient equipment usage. In this approach the rational of prioritization of geographic areas and specific targets can be conveyed more effectively to stakeholders, therefore defusing an emotionally charged and highly political environment.
- **Health –** One of the consequences of flood disaster is the possible occurrence of water-borne diseases. This can happen as a result of collection of polluted flood water in low lying areas (in the form of ponds). These ponds may last for a long time until drained and can turn into a suitable habitat for vectors. The real time flood model (as explained in DSS2) will be used to identify the location of flood ponds and the duration of inundation. Based on some basic site measurement the degree of pollution of each pond is estimated and the risk associated with the increase of vector population in each pond is assessed.

  The zone of influence (flight range of vectors) for those ponds that are likely to have an increase in vector population is estimated and population at risk are identified. Such information can be gathered in a short period of time using the FRDSS and proper decisions can be made to protect the population at risk.

Conclusion

A review of the status of flood emergency management shows that this task can benefit significantly from recent advances in computer and communication technologies. Flood management authorities have already started using this technology to develop DSS' that can inform flood emergency operations more effectively. Some of the challenges that existing systems need to overcome in the near future include:

Technical complexity of inclusion of real time hydrological and hydraulic modelling in such systems. Once these technical issues are resolved, these models will be able to replace empirical relationships between measured data and flood information and therefore enhance the accuracy of the existing DSS'.

Development of rainfall forecasting algorithm; and automated rainfall forecasting engines that can be embedded in Decision Support tools.

Making DSS accessible via the Internet to convey flood information faster to flood emergency managers and therefore to increase the available response time (in particular for small catchment).

Continuous enhancement of computing power of computers and the bandwidth of Internet will soon provide an excellent opportunity for the developers of DSS' to meet these challenges at an affordable cost, provided that the technical complexities associated with this exercise have already been resolved thoroughly.

Given the fact that climate change is expected to put more pressure on flood emergency management operations in the future, the recommendation of this study is that flood emergency managers should further support the development of technical knowledge-base for DSS', Building this knowledge base through experimenting with newer DSS' will prepare us ready for the time when fast internet and high computing powers are available at competitive prices.

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About the authors

Hamid Mirfenderesk is the Team leader of the Waterways and Flood Management Section at the Gold Coast City Council and Adjunct Associated Professor at the Griffith University. He can be contacted on hmirfenderesk@goldcoast.qld.gov.au

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Regular contributors should submit letters on varied subjects. Letters by the same author that reiterate opinions previously expressed may not be published. The editor reserves the right to reject or edit any Letter to the Editor.

Conference diary

Full details of local and international conferences relating to emergency management are available from the EMA website. For information, please visit **www.ema.gov.au**.