Disaster management

Flirting with (natural) disaster – Recent floods highlight need for adequate forecasting

The trip home from work turned into a frightening ordeal for scores of commuters in the eastern parts of the Greater Johannesburg Area on 9 November, when flash flooding following a thunderstorm changed major roads into raging torrents. Some cars were washed off embankments or completely submerged, prompting heroic behaviour and human-chain rescue efforts by members of the public. The Jukskei River burst its banks in Alexander, destroying shacks in an informal settlement and sweeping away their owners' meagre belongings, while underground parking areas at OR Tambo International Airport were inundated with water, causing severe damage to some cars. At least seven people died as a result of the natural disaster.

The South African Weather Service (SAWS) had issued a watch for severe thunderstorms at 14:15 for the southern parts of Gauteng, and at 16:33 this was escalated to a warning for heavy downpours and small hail for the Midvaal area. Less than an hour later, at 17:23, this warning was extended to the City of Johannesburg and Ekurhuleni too, but by the time the general public would have been alerted – via radio broadcasts, social media or weather app notifications – the flooding was probably already being experienced.

SAWS does make use of an early warning system for conditions likely to result in flash floods, known as the South African Flash Flood Guidance system. Updated on an hourly basis, it uses rainfall estimates from weather radars and satellites, together with rain-gauge data collected over the past 24 hours and hydrological modelling of soil moisture conditions, to calculate how much rain would likely result in flooding for 5366 small catchments averaging 50 – 100 km^2 in the country's main metropolitan areas, as well as the coastal strip between Cape Town and Port Elizabeth.
Unfortunately, the calculations assume natural stream channels, so they are less accurate for the concrete canals and highly

modified river sections typical of urban environments. Besides, much of the flooding on 9 November was caused by the deluge of water being funnelled down roads and trapped by high embankments and barrier walls.

The day after the flooding, the national roads agency, SANRAL, issued a press release noting that the Gauteng freeway network had been designed to withstand one in 20-year floods when it was constructed 40 years ago, but the landscape had changed considerably since then. The reduced infiltration – and hence increased runoff – associated with the hardened surfaces of built-up areas, combined with inadequate or possibly blocked stormwater systems in some places, meant that roads in low-lying areas were prone to flooding. The following day, SAWS tweeted that OR Tambo International Airport had measured 79.4 mm of rain over one hour during the storm, making it a one in 200-year event. Until then, the highest rainfall in the long-term record for this site had been 65 mm, and that was over a 24-hour period!

The South African Flash Flood Guidance (SAFFG) system was first implemented by SAWS in 2010, and in 2015 a Water Research Commission (WRC) funded project to improve certain aspects of it was completed (Poolman et al., **WRC Report No. 2068/1/15**). During the project, some calibration errors in the soil-moisture modelling component were detected that resulted in underestimation of potential flooding in Gauteng, but these were subsequently addressed with the developers of the system – the Hydrologic Research Centre in San Diego, USA.

Another aspect that was resolved within the project was the system's poor performance in simulating flash floods in the Western Cape. Most of the province's rain falls in winter from stratiform clouds, which are low-level horizontal clouds covering a large area, as opposed to the towering thermal columns of convective clouds, typically associated with thunderstorms. Since rainfall estimates from satellites rely heavily on cloud-top temperature measurement, however, they tend to be more accurate for clouds with high tops. The Western Cape's stratiform rainfall was being seriously underestimated, so a new algorithm was developed, which entailed combining satellite convective rainfall estimates with stratiform rainfall forecasts from the UK Met Office Unified Model operated by SAWS. This succeeded in producing more realistic simulations of flash flood potential in the province.

Likewise, rainfall for the area surrounding Port Elizabeth was found to be significantly underestimated, but in this case the problem was due to estimates from radar rather than satellites. Weather radar systems are useful for tracking thunderstorms and tornadoes, so SAWS upgraded the network between 2009 and 2012 with the purchase of 10 new S-band radars (using a 10 cm wavelength), as well as two X-band radars (3 cm wavelength), which are more sensitive but have a limited range, for use at the OR Tambo and Cape Town international airports. Some of the old C-band radars (5 cm wavelength) are still in operation too, but these are prone to interference from radio local area networks (RLAN) being operated in the vicinity. In Port Elizabeth, filters had been deployed to reduce this interference, but had resulted in such inaccurate rainfall estimates that their use in the SAFFG system had to be discontinued.

As part of the project, a procedure was also developed to increase the predictive capability of the SAFFG system beyond the current 1 – 6 hour nowcast to a 12 – 18 hour forecast, allowing for more response time. In addition, workshops were organised with municipal and provincial disaster management officials so that their needs in terms of flash flood warnings could be identified.

The learning that took place during the WRC project has benefited areas within South Africa that fall outside the domain of the SAFFG system, as well as our SADC partners. This is because a similar system – the Southern African Regional Flash Flood Guidance (SARFFG) system – has been implemented by the World Meteorological Organisation in accordance with a resolution taken at its 15th WMO Congress in 2007 to develop a flash flood guidance system with global coverage. In February 2009, the WMO signed a Memorandum of Understanding with USAID's Office of Foreign Disaster Assistance (OFDA), the National Ocean and Atmospheric Administration (NOAA), which operates the US Weather Service, and the Hydrologic Research Centre to turn the resolution into reality. There are now a dozen FFG systems up and running or in the process of implementation, covering 52 countries around the world.

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On 9 November 2016, commuters in the afternoon rush hour were caught off-guard by flash flooding following a thunderstorm.

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In contrast to the SAFFG, the SARFFG covers the whole of South Africa plus eight other countries, and only updates every six hours for catchments of approximately 200 km^2, using rainfall estimates derived from satellites but not radars, which the other countries generally lack. The SAWS head office in Pretoria, designated by the WHO as the Regional Specialised Meteorological Centre (RSMC-Pretoria), is responsible for running the SARFFG modelling system on its computers, and hosts the web interface that makes the products available to weather forecasters throughout the region.

Before the SARFFG was operational, however, RSMC-Pretoria was playing a leading role in another WMO initiative – the Severe Weather Forecast Demonstration Project (SWFDP). This global project actually originated in Southern Africa in 2006, but there are now also SWFDPs for Eastern Africa, Southeast Asia, Central Asia, the Bay of Bengal and the South Pacific. The aim is to improve the ability of developing countries' national meteorological services to forecast severe weather events and coordinate with disaster management agencies and the media for enhanced delivery of early warnings.

The Southern African SWFDP began with the participation of only five countries – Botswana, Madagascar, Mozambique, Tanzania and Zimbabwe – but with RSMC-Pretoria acting as the principal regional centre and RSMC-La Reunion providing support on tropical cyclone forecasting. Based on the successful one-year demonstration phase, however, the Meteorological Association of Southern Africa requested that the SWFDP be rolled out to the entire region, so it was subsequently expanded to include the 15 SADC member countries and Comoros.

Most of these countries do not have the capacity or resources to run weather forecast models, so the SWFDP relies on a 'Cascading Forecast Process'. A number of global centres, namely the UK Met Office, NOAA's National Centres for Environmental Prediction (NCEP), and the European Centre for Medium-Range

Weather Forecasts (ECMWF), provide specialised forecast products to RSMC-Pretoria, which in turn disseminates them to the national meteorological services via a dedicated link on the SAWS website. In addition, RSMC-Pretoria provides products from its satellite nowcasting system and from the Unified Models run by SAWS over the SADC domain, as well as daily interpretation and guidance on severe weather for the next five days, focussing on heavy rains, strong winds, rough seas and extreme temperatures. The various national meteorological services assess the information and issue country-specific warnings as necessary.

Recognising that SARFFG and SWFDP have many common features and objectives, a USAID-funded twinning project has been underway since 2015 to link the two early warning systems. The intention is to integrate them into an enhanced, more streamlined system that will improve the accuracy, lead time, communication and dissemination of early warnings about extreme hydrometeorological hazards to communities.

The project has a strong capacity-building component, consolidating the frequent training activities for forecasters that have been hosted by RSMC-Pretoria for the SARFFG and SWFDP. It also strives to ensure that disaster management agencies and NGOs in the emergency preparedness and response arena receive appropriate information and training, based on needs clearly defined by them. And a particular emphasis is being placed on 'reaching the last mile' – making sure accurate warnings reach the affected population with sufficient lead time, in a format that can be easily understood and acted upon.

The nine participating countries are each expected to prepare a 'Roadmap' document detailing how the project objectives will be met and outlining deliverables, work plans, timelines and organisational structures. They must also compile a Concept of Operations document that spells out everything necessary for a fully functional end-to-end system covering all components of the forecast-warning-response chain.

In an overview of the project published in the international journal ***Water*** in June 2016, the authors – Robert Jubach of the Hydrologic Research Centre and Sezin Tokar of USAID-OFDA – point out that failure of one component will lead to failure of the entire system.

"State-of-the-art technology and a perfect forecast will not save lives if the populations at risk are not informed in a timely manner, or do not have plans and policies in place in advance to reduce impacts," they write. "Well-prepared communities remain vulnerable to these hazards if they do not have access to and understand information that provides the lead time needed to take necessary actions."

"In addition, close coordination must occur between all sectors and between national and local governments for systems to function properly, with clear lines of roles and responsibilities, to avoid confusion and chaos during disasters."