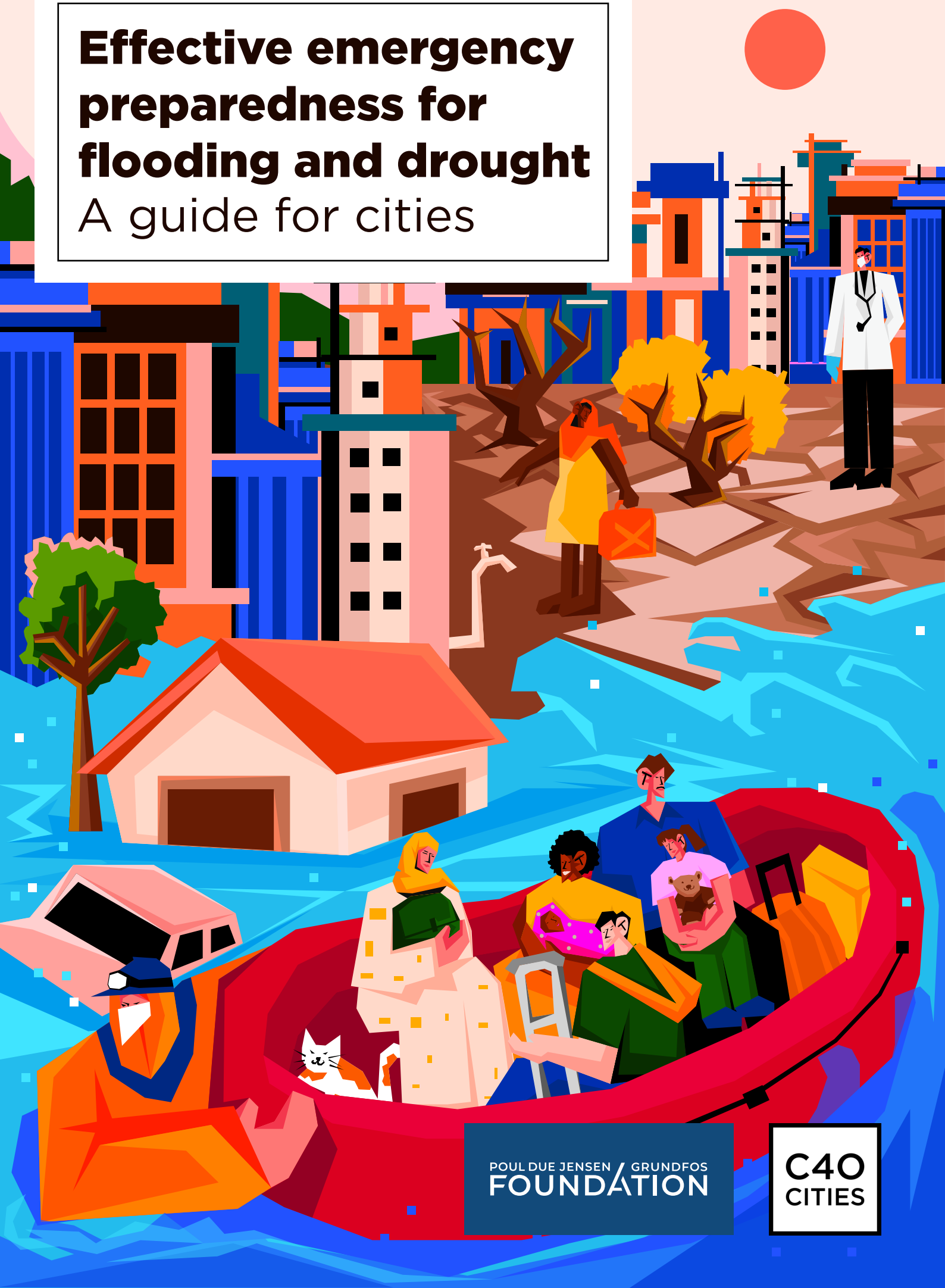
Effective emergency preparedness for flooding and drought

A guide for cities



POUL DUE JENSEN / GRUNDFOS FOUNDATION

C40 CITIES

Author

Euan Crispin

Contributors

Snigdha Garg
Jennifer Wells
Pedro Ribeiro
Lykke Leonardsen
Thulani Mlilwana
Alejandro Henao Mejia
Amanda Ikert
Madeline Forster
Daniel Firth
Sachin Bhoite

Acknowledgements

Expert advisors

Dr Mark Pelling (University College London)
Dr Mirianna Budimir (Practical Action)
Sunayana Sen (Resurgence)

Cities

Freetown: Haja Binta Jalloh, Abdulai Sesay, Sallieu Thaimu Kanu, Davephine Tholley
Quito: Fausto Alarcon, Jessica Patricia Carrillo Chimbo, Byron Paul Yachimba Quinchuela, Monica Abril
Tshwane: Dr Tanja Terblanche, Lesego Lekubu, Kgomotso Rabalao, Mabu Sebola

Editorial and design

Inkwell Communications & Design Studio
Cover illustration by Erin Dwia

C40 CITIES

POUL DUE JENSEN GRUNDFOS FOUNDATION

CONTENTS

EXECUTIVE SUMMARY

Climate-related hazards are growing in intensity and frequency, causing significant loss and damage in cities around the world. Successful emergency preparedness, including the use of early warning systems, is critical to enabling cities and communities to act ahead of extreme events – and thereby to reduce their impact, including climate-related loss and damage.

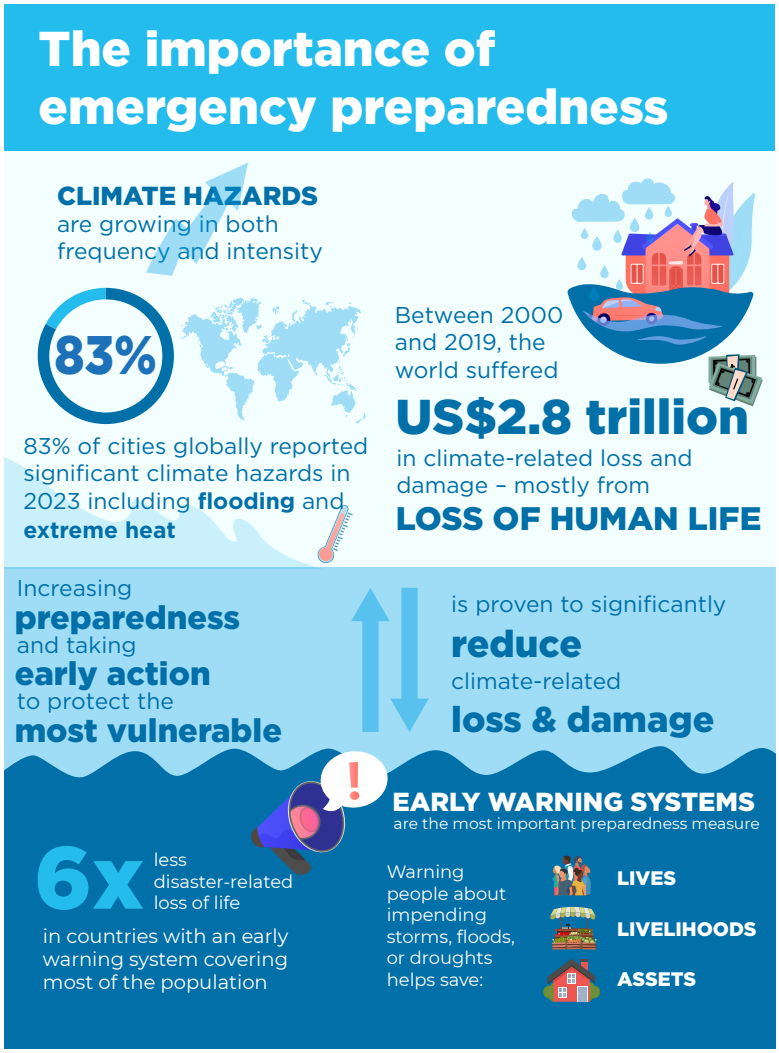


Figure 1: Importance of emergency preparedness.
Data from: CDP (2024); Newman & Noy (2023); and UNDRR & WMO (2023).

The impact of climate disasters is greatest at the local level, and cities are uniquely placed to lead their own emergency preparedness efforts, in collaboration and coordination with regional and national governments, communities, and the private sector. While adaptation and prevention measures – such as flood barriers, spatial planning, and nature-based solutions – remain essential to reducing the number of people at risk, effective preparedness measures can help lessen the residual risk and prevent hazards from turning into disasters.

In 2022, the United Nations Secretary-General formed the **Early Warnings for All initiative**, calling for a global effort to ensure that early warning systems protect everyone on Earth by 2027. A growing number of C40 cities are leading the way in responding to this call as signatories of the **Water Safe Cities Accelerator**.

This includes mayoral commitments to **establish early warning systems and emergency responses**, in order to protect the most vulnerable urban communities at high risk of flooding and drought by 2027.

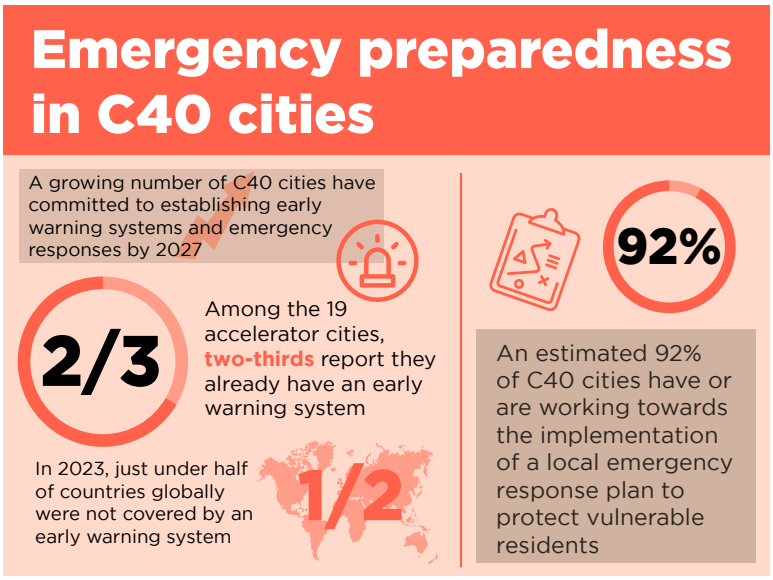


Figure 2: Emergency preparedness in C40 cities.

This guide outlines five key components for effective emergency preparedness. It sets out practical steps that cities can take to help protect vulnerable communities from flooding and drought, and shares relevant case studies from cities around the world. At the end of the guide, a **self-assessment checklist** helps cities to evaluate their current progress and identify areas for improvement and further action.

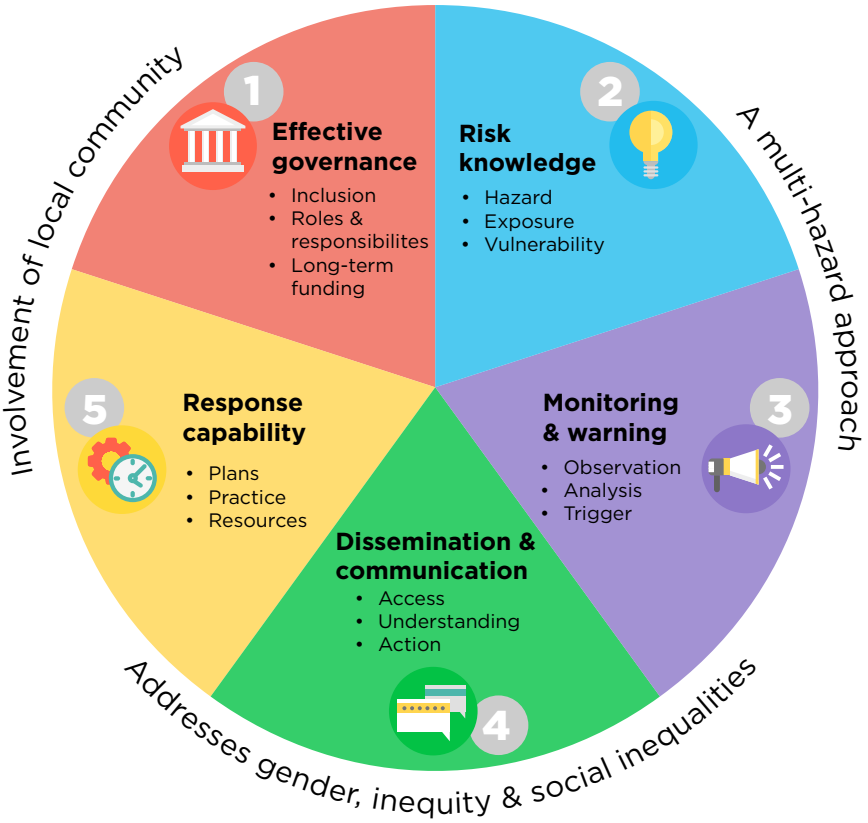


Figure 3: The five key components for effective emergency preparedness.
Adapted from: Practical Action (2023).

ACRONYMS

AI	Artificial intelligence
CBO	Community-based organisation
CDMC	Community disaster management committees
CSO	Civil society organisation
DRM	Disaster risk management
GIS	Geographic information system
NGO	Non-governmental organisation

Photo by Mufid Majnun

INTRODUCTION:
What is emergency preparedness and why is it important for cities?

Climate-related hazards are growing in intensity and frequency, causing significant loss and damage in cities around the world. **In 2023, 83% of cities globally experienced significant climate hazards**, especially from flooding and extreme heat.[1] Between 2000 and 2019, the world suffered at least US$ 2.8 trillion in loss and damage from climate change – mostly from human loss of life.[2]

Increasing preparedness and taking early action to protect the most vulnerable is proven to significantly reduce climate-related loss and damage. Early warning systems, as one of the most important preparedness measures, warn people of impending storms, floods, or droughts. They are a cost-effective tool and save lives, livelihoods, and assets. Countries that have a comprehensive early warning system covering most of the population have nearly six times less disaster-related loss of life than those with only limited coverage.[3]

It is estimated that investing just US$ 1 billion per year in early warning systems globally will reduce losses from disasters (including to income and consumption levels) by US$ 35 billion per year.[4]

KEY DEFINITIONS

Preparedness refers to the knowledge and capacities developed by governments, response and recovery organisations, communities, and individuals to effectively anticipate, respond to, and recover from the impacts of likely, imminent, or current disasters.[5]

Early warning systems are made up of integrated systems and processes related to hazard monitoring, forecasting and prediction, disaster risk assessment, and communication and preparedness activities. These systems and processes collectively enable individuals, communities, governments, and businesses to reduce disaster risks in advance of hazardous events.[6]

"Most vulnerable" refers to people who are socially, economically, culturally, politically, institutionally, or otherwise marginalised. This includes women, children and young people, people living in poverty, residents of informal settlements, people with disabilities, elderly people, migrants, marginalised-language speakers, and the LGBTQ+ population, among others.[7] These groups have typically been excluded from decision-making processes on issues such as emergency preparedness and early warning, meaning their needs are less likely to be considered in their design and implementation.

The impact of disasters is greatest at the local level. The high concentration of people and assets located in urban areas increases and intensifies risks in cities that are already prone to climate hazards, including flooding and drought. Given their size and built-up area, cities often feature microclimates or weather conditions that vary from one neighbourhood to another, producing more localised hazards that are not easily accounted for in national- or regional-level early warning systems. For these reasons, **cities are uniquely placed to lead their own emergency preparedness efforts, in collaboration and coordination with regional and national governments, communities, and the private sector**. While adaptation and prevention measures such as flood barriers, spatial planning, and nature-based solutions remain essential to reducing the number of people at risk, preparedness measures can help lessen the residual risk and prevent hazards from turning into disasters.

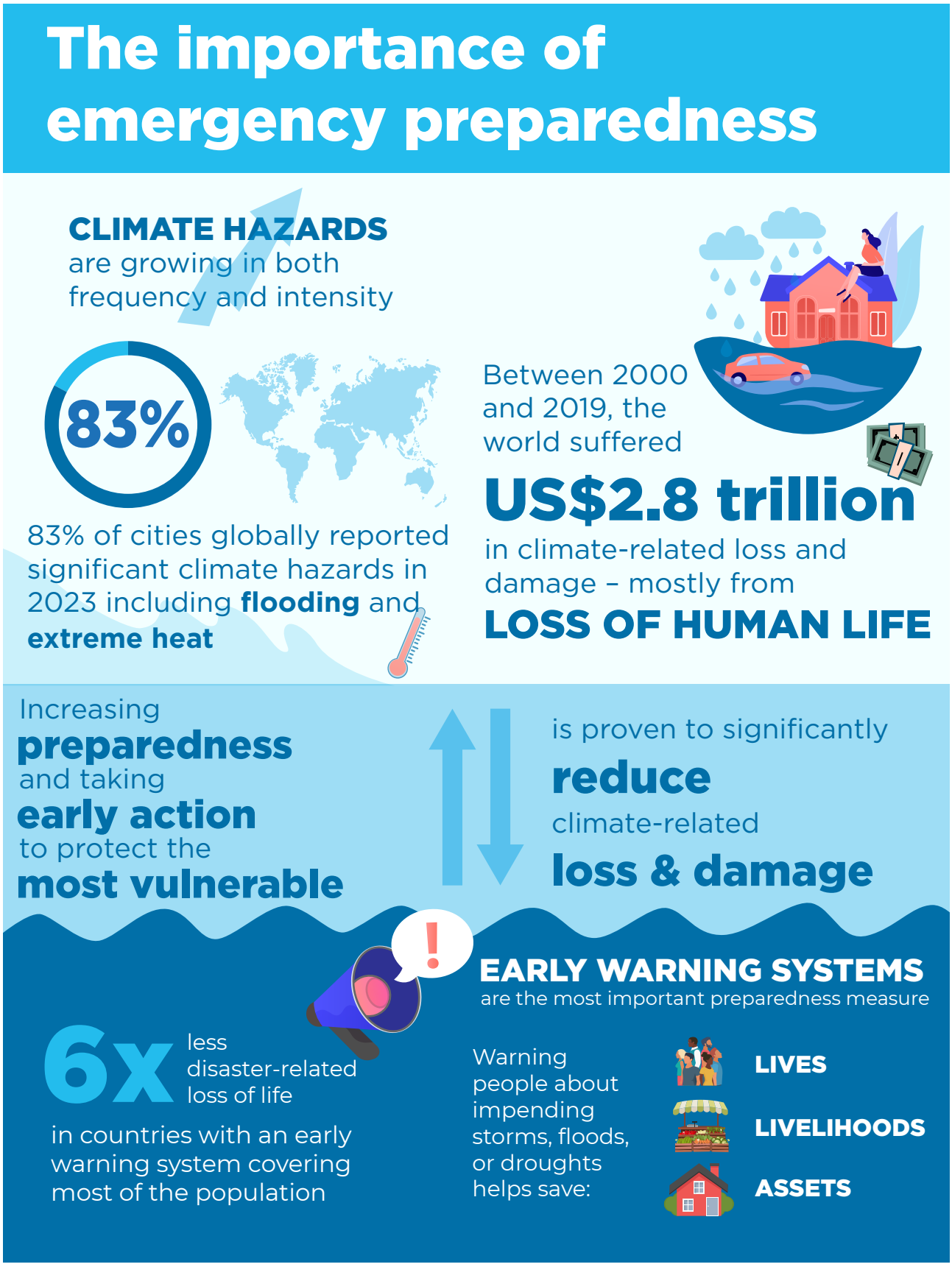


Figure 1: Importance of emergency preparedness.
Data from: CDP (2024); Newman & Noy (2023); and UNDRR & WMO (2023).

AMBITION:
How are C40 cities progressing towards emergency preparedness for all?

> The facts are clear. Early warnings save lives and deliver vast financial benefits. I urge all governments, financial institutions and civil society to support this effort.[8]
>
> **UN Secretary-General António Guterres**

In 2022, the United Nations (UN) Secretary-General António Guterres called for a global effort to ensure that early warning systems protect everyone on Earth by 2027. The **Early Warnings for All initiative** brings together the broader UN system, governments, civil society, and development partners across the public and private sectors to enhance collaboration and accelerate action to address gaps and deliver people-centred, end-to-end, multi-hazard early warning systems.[9]

A growing number of C40 cities are leading the way in responding to this call as signatories of the **Water Safe Cities Accelerator**. This includes mayoral commitments to establish early warning systems and emergency responses, in order to protect the most vulnerable urban communities at high risk of flooding and drought by 2027. **Among the 19 accelerator cities, approximately two-thirds report that they already have an operational early warning system**, with the other third making progress towards establishing one with C40's support. Across the C40 network of 97 cities, an estimated 92% have or are working towards the implementation of a local emergency response plan to protect vulnerable residents from extreme weather events. **This compares favourably to the national level globally, where just under half of countries are not covered by an early warning system**.[10]

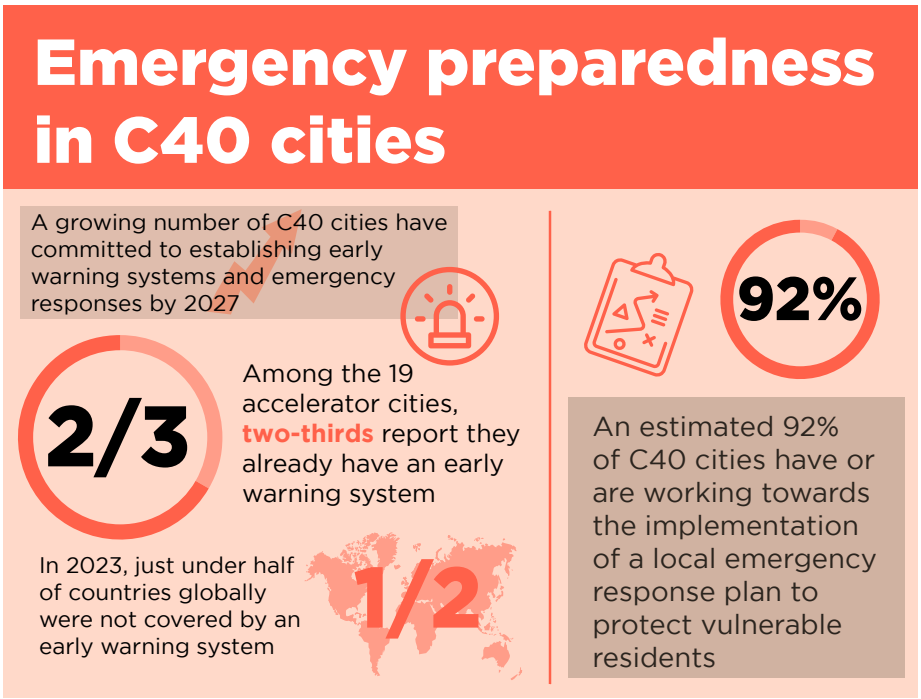


Figure 2: Emergency preparedness in C40 cities.

Across various contexts, cities are taking action to enhance their preparedness for flooding and drought. **Quito** in Ecuador is piloting an early warning system in a low-income neighbourhood along the city's Caupicho river, which alerts community members to emergencies via WhatsApp groups and sirens, and allows for residents to feed their own observations into the system. In **Freetown**, Sierra Leone, the city council is engaging with the national meteorological agency to disseminate weather forecasts to Community Disaster Management Committees (CDMCs), who then work with local volunteers on preparative actions – such as clearing waterways before floods, and harvesting rainwater ahead of the dry season.

Meanwhile, in **Tshwane**, South Africa, monthly awareness campaigns, run in collaboration with community leaders, advise residents on how to better prepare for emergencies. The city also trains Community Response Teams to support evacuation in the event of flooding. **Further information on each of these cities can be found in the city profiles at the end of this guide**. Other case studies of how cities are progressing towards emergency preparedness for all are shared throughout the roadmap section of this guide.

Although cities are making progress, there are several challenges and barriers to implementation. These often reflect the complexity of urban areas. As mentioned in the Introduction, cities can feature multiple microclimates that are not accounted for in national-level forecasts and warnings, which cover a much wider area. This renders such forecasts irrelevant for many residents. In addition, sudden-onset events, such as flash flooding, are much more common in cities due to their high density, mostly impermeable surfaces, and limited or poorly operating infrastructure for flood management, which greatly reduces the warning time residents receive. Meanwhile, the mobility of people in urban settings and their highly diverse backgrounds, past experiences, and prior knowledge of hazards also affects responses to warnings and preparedness measures.

Given these challenges, among others, all the cities consulted during the development of this guide requested support for:

1. **Improved monitoring of rivers and/or dam levels**, to provide more accurate, real-time information and extend warning times.
2. **Lower-cost options and accessible financing mechanisms**, to support emergency preparedness, operations, and maintenance.
3. **Ensuring that alerts effectively reach all people of different social groups** and that they are motivated to act before emergencies occur, not just after the event.

This guide aims to support cities in solving these challenges and sets out practical steps for how to implement early warning systems and emergency responses for all.

The following roadmap introduces a series of actions for cities with different starting points and contexts, together with case studies demonstrating best practices and lessons learned. At the end of the guide, a **self-assessment checklist** is provided to help cities understand their current progress and identify gaps.

Although the primary focus is on flooding and drought, several of the actions can be applied to multiple urban hazards.

Likewise, while this guide is mainly aimed at **city officials and technical experts working in the field of emergency management and/or disaster risk reduction**, many of the steps are also relevant to other stakeholders, **including at-risk communities and the private sector**. This reflects the fact that successful emergency preparedness is a whole-of-society effort.

ROADMAP:
How can cities achieve emergency preparedness for all?

The following roadmap provides step-by-step guidance on the key actions cities can take to achieve emergency preparedness for all. It is structured around five components, adapted from those used by the Early Warnings for All initiative and related international agreements such as the Sendai Framework for Disaster Risk Reduction. These components are visually represented in Figure 3.

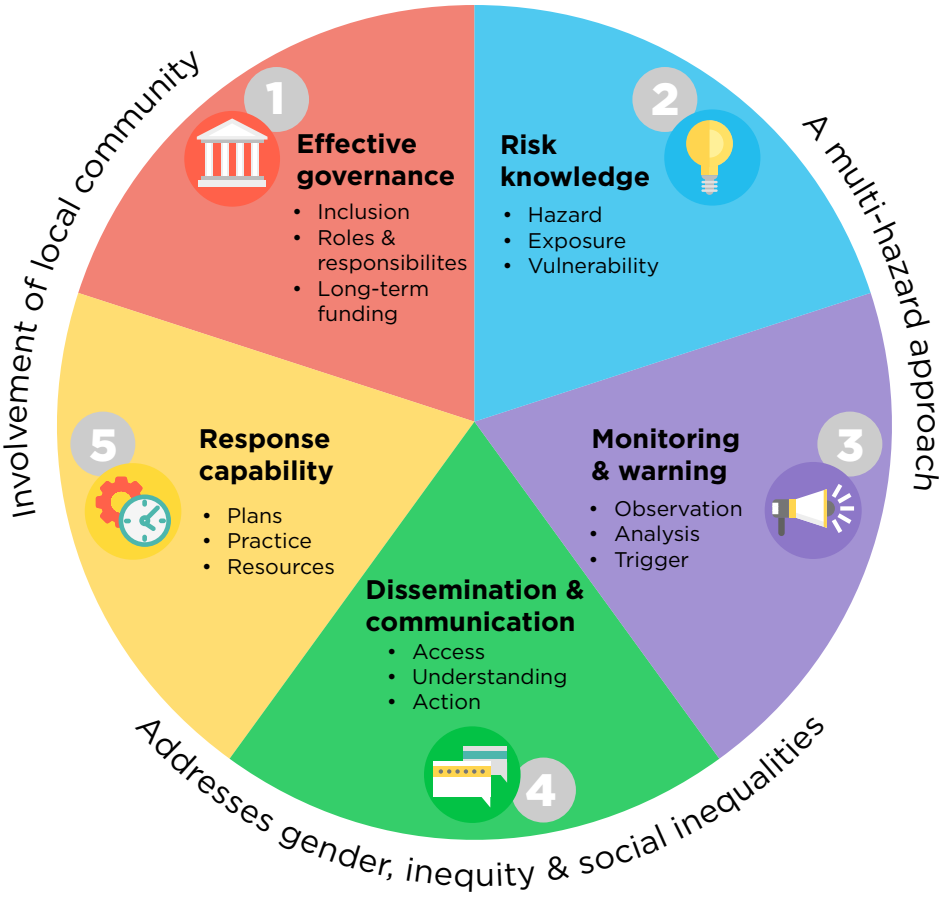


Figure 3: The five key components for effective emergency preparedness. Adapted from: Practical Action (2023).

It is important to note that each component is highly interrelated and a failure in one can result in a failure of others. For example, if a city does not understand the areas that are more exposed to hazards (risk knowledge), then it cannot effectively plan responses, including the location of evacuation sites (response capability).

Depending on a city's individual context and current baseline, not all steps will be relevant. The checklist at the end of this guide will help cities to determine the best starting point for their context.

Throughout the roadmap section of this guide, you can navigate between any of the five components by clicking on the coloured icons at the bottom of the page.

1. Effective governance, resources, and capacities

Emergency preparedness is not the responsibility of one city department or office alone. It is the outcome of successful collaboration and coordination across government, civil society, and the private sector, among other stakeholders.

Effective governance relies upon defining **clear roles and responsibilities** to help prevent duplication of efforts, encourage alignment towards common objectives, and optimise the use of scarce resources. Ensuring that the **most vulnerable and at-risk communities are prioritised** and included from the outset is essential. These residents often know best what information, knowledge, resources, and skills are needed to protect themselves from hazards. **Long-term funding** is required to ensure that preparedness actions are sustained and continually improved over time, while **education and capacity building** around climate hazards is important for all stakeholders, to build common understanding and commitment.

ACTIONS

1. Use tools such as stakeholder influence mapping and information ecosystem mapping (see the DARAJA case study further on in this guide) to identify:

    a. **People who require early warnings and need to be prepared**. This includes those facing disproportionate risks, such as women, children and young people, people living in poverty, residents of informal settlements, persons with disabilities, elderly people, migrants and refugees, people whose livelihoods depend on climate-sensitive natural resources, micro- and small-to-medium-size enterprises, and local private sector businesses working in at-risk contexts or sectors.[11]

    b. **Institutions and other actors that help residents to access warnings and take the necessary response actions**. This includes:

        i. Relevant city departments and agencies (including emergency services such as local police and firefighters) that are involved in forecasting hazards, issuing warning messages, disseminating warnings, and organising and supporting response actions.

        ii. Non-state actors, such as representatives of international non-governmental organisations (NGOs) (e.g. the International Federation of Red Cross and Red Crescent Societies or National Red Cross and Red Crescent Societies); civil society organisations (CSOs) and youth groups; the local private sector (including communication, forecasting, and monitoring companies); community leaders; neighbourhood committees; media institutions; faith-based organisations; and religious leaders.

    c. **People and institutions that are not currently involved in early warning and preparedness but have the potential capacity to add value and strengthen the system**.[12] This may include other cities and regional actors or bodies, which are particularly important where cities rely on shared water resources in transboundary river basins and aquifers.

2. The mapping can then be used to inform the establishment of:

    a. **A municipal task force or unit**, consisting of the relevant city departments and agencies identified to help spearhead the development of an early warning system and emergency responses. The task force should ideally:

        i. Report to the mayor's office, to equip it with the political will and vision necessary for sustained implementation.

ii. Include a direct link or partnership with national meteorological, hydrological, and disaster-management agencies.

iii. Appoint at least one full-time focal point responsible for managing the task force, to ensure smooth coordination and planning.

See the example of the Santa Fe Disaster Risk Management Office.

b. A stakeholder group or platform, consisting of non-state actors and groups that can co-develop the early warning system and emergency responses. This should be linked to the municipal task force. Where there is already a coordination mechanism or platform in place (such as the Disaster Management Advisory Forum in Tshwane), this step may be a case of adding to or strengthening it. In all cases, cities should make sure to include NGOs and community groups or leaders representing vulnerable populations, including those in informal settlements.

Unless otherwise stated, the actions in the remainder of the roadmap should be implemented by members of the task force, with close involvement of the stakeholder group.

3. The initial meeting of the municipal task force and the stakeholder group should focus on **co-defining the roles of each main actor in relation to the different components of this roadmap, and ensuring that everyone is aligned around a common goal or objective**. It must start with genuine commitment to strong, ongoing relationships, which take time and investment to build – especially where there has been a prior breakdown in trust. Tools that can help this process include theory of change, and participatory impact pathways analysis or outcome mapping.[i] Some basic training on key concepts and terminology related to emergency preparedness and hazards may be required to ensure that the city task force and the stakeholder group share a common understanding and speak the same language.

4. The municipal task force will need to develop a transparent and accountable funding structure for the early warning system and emergency responses. It must also ensure sufficient resource allocation, especially for ongoing maintenance and improvement.

The city may already have a dedicated budget for disaster risk management, but it is likely to be insufficient for this purpose. National and/or regional government departments may be able to provide additional funding.

International organisations, multilateral funds, and development banks may also be able to bridge the gap, through funding mechanisms such as the Climate Risk and Early Warning Systems initiative for least-developed countries and small island developing states, and the Systematic Observations Financing Facility for basic weather and climate observations.

Partnerships with the private sector may also be possible for certain aspects of the system, including risk mapping and the provision of monitoring and communication equipment. Mobile network operators and telecommunications companies, and insurance firms are often the most willing to engage, while the big technology companies are increasingly developing forecasting and monitoring services using artificial intelligence (AI) models. However, it is important to ensure that emergency preparedness is supported in an equitable and sustainable manner – especially in scenarios where businesses decide to withdraw their support for financial reasons, and where issues might arise related to data ownership.[13]

i See '02 Vision Setting' module of the C40 Inclusive Community Engagement Playbook

CASE STUDY: Santa Fe, Argentina

The city of Santa Fe in Argentina faced major successive floods in 2003 and 2007, exposing critical infrastructure and preparedness policy failings. Following the 2007 floods, a new administration was elected and **declared a hydrological emergency**, introducing a range of measures to strengthen preparedness and capacity for anticipating and responding to floods.

These measures included **replacing the Department of Civil Protection with a Disaster Risk Management Office, reporting directly to the mayor**, who also serves as a member. The office was given the rank of Secretariat, conferring a higher degree of authority to facilitate rapid decision-making in times of crisis, and enabling direct communication with the mayor. This also facilitated a more **cross-sectional and integrated approach**, involving a range of municipal functions including public works, urban planning, social development, environment, education, culture, and communication.

The active participation and expertise of the mayor and other high-ranking officials, including their direct involvement in neighbourhood meetings and workshops with civil society, has been a key success factor, along with **strong cooperation of technical groups and universities**.

Source: De Majo, V. (2022). Institutional conditions for building proactive flood management: Lessons from Santa Fe in Argentina. *International Journal of Disaster Risk Reduction*, 81, p.103251

CASE STUDY: Tshwane, South Africa

In line with the national Policy Framework for Disaster Risk Management in South Africa, the city has placed a strong emphasis on strengthening and institutionalising disaster risk governance. This includes:

1. A quarterly **Municipal Disaster Management Advisory Forum**, involving public and private stakeholders and NGOs.
2. A **Disaster Risk Management Framework**, integrating the results of a comprehensive disaster risk and vulnerability assessment – identifying priority risks and higher-risk groups, households, and communities – to ensure that appropriate risk reduction measures can be implemented prior to an event.
3. **Critical Infrastructure Contingency Planning**, which compels "owners" of mission-critical municipal services and infrastructure to conduct proper impact and capability assessments as part of emergency preparedness and budget planning.
4. **A Community Emergency Response Team**, to educate volunteers in different regions of the city about preparedness for the hazards that may impact their community, and train them in basic response skills.

The city's Disaster Management Plan is fully incorporated into its main **Integrated Development Plan**, the five-year plan used to outline social and economic development goals and strategies, including the city budget. This ensures better coordination and integration with different departments, projects, and plans across the municipality. The owners of these plans regularly practise and conduct drills to ensure they are better prepared for flooding and drought incidents.

Source: City interview, June 2024.

2. Risk knowledge

Risk is an outcome of **hazard** (including where it is likely to occur, its magnitude, frequency, and probability), **exposure** (including the location of people, assets, and critical infrastructure such as roads and hospitals), and **vulnerability** (who will be more impacted). An up-to-date understanding of risk is essential for determining what hazards to monitor, where is safe and unsafe, and who might be at risk from or more vulnerable to the impacts of these hazards. Out of over 800 cities surveyed by the Carbon Disclosure Project (CDP) and ICLEI in 2020, **over 40% had not carried out any climate risk and/or vulnerability assessment**,[14] making this a crucial exercise for many cities globally.

ACTIONS

1. **Assess existing documentation of climate risks, hazards, hotspots, and vulnerabilities**, including whether the city has an up-to-date and comprehensive climate risk assessment. This should identify areas prone to hazard both now and in the future, based on different climate scenarios and the location of vulnerable groups and critical infrastructure. Resources such as C40's Climate Change Risk Assessment Guide, The World Bank's Urban Flood Risk Handbook, and CDP's Climate Risk and Vulnerability Assessment Training Guide for Cities provide more detailed information on the process of conducting climate risk assessments. New technologies – including the examples in the next case study – can provide more cost- and time-effective solutions where data is scarce. These should always be supplemented by primary and secondary data collection to understand inherent vulnerabilities.[15]

2. **Work with the stakeholder group, including local residents and academic institutions, to understand whether any community maps and data have already been collected** – for example, through initiatives like **Know Your City** and **Humanitarian OpenStreetMap (HOT)** – that might complement and be integrated into city-level assessments. There is often a wealth of knowledge available at the community level, particularly around vulnerability, that may be useful for risk assessment. Accessing this is critical for integrating contextual, local, and Indigenous knowledge, data, and experiences, especially around past events.

3. When conducting a risk assessment, **consider multiple and secondary hazards that may affect an area**. For example, in the Rio de Janeiro case study, the link between intense rainfall and landslides was analysed by looking at steeper slopes and higher catchment areas.

4. **Consider working with other cities and communities at a water basin or watershed level** to share data on risk. This can also help enhance existing assessments by accounting for inflows from outside the city and shared dams or reservoirs.

5. **Create or use an existing mechanism to store and enable access to information on hazards and vulnerabilities** – such as a central repository or geographic information systems (GIS) database – to ensure different city departments and other stakeholders can access, update, and work with the same information. One such example is the Gauteng City-Region Observatory in South Africa, a partnership between the University of Johannesburg, the University of Witwatersrand, Johannesburg, and the Gauteng Provincial Government. This provides a central GIS database for the entire city-region, encompassing the cities of Tshwane, Johannesburg, and Ekurhuleni.

6. **Establish a process to maintain, regularly review, and update risk data**, including information on any new or emerging vulnerabilities and hazards (e.g. due to urban expansion or the establishment of new settlements) and potential changes to particular hazards (e.g. due to shifts in land use).

CASE STUDY: Improved technology and data sources for risk assessments

Cities are increasingly making use of new technology and data sources for climate risk assessment, particularly those in data-poor environments experiencing rapid urbanisation. **Earth observation and satellite imagery can provide good information about changing land use**, including the location of recently developed informal settlements. This data enables estimates of the number of people, buildings, and settlements that are exposed to a given hazard.

Drones or Unmanned Aerial Vehicles can be used to go one step further, providing detailed imagery for mapping individual settlements and infrastructures, as well as during and after hazard events to visualise the areas most affected. **Flying Labs** is one example of a global network of independent knowledge hubs that convene local experts in professional drone, data, robotics, and AI services for mapping and recovery efforts, as well as training young people to operate them. They have worked in several cities, including Johannesburg, to create a high-resolution map and **Digital Elevation Model** of an informal settlement as a basis for disaster preparedness and planning. This includes identifying areas prone to flooding and those that could be used as assembly points. They can also be used following a disaster to conduct damage and needs assessments.

Source: South Africa Flying Labs. (2022). *The Use of Drones in Disaster Preparedness, Mitigation and Response.*

CASE STUDY: Cape Town, South Africa

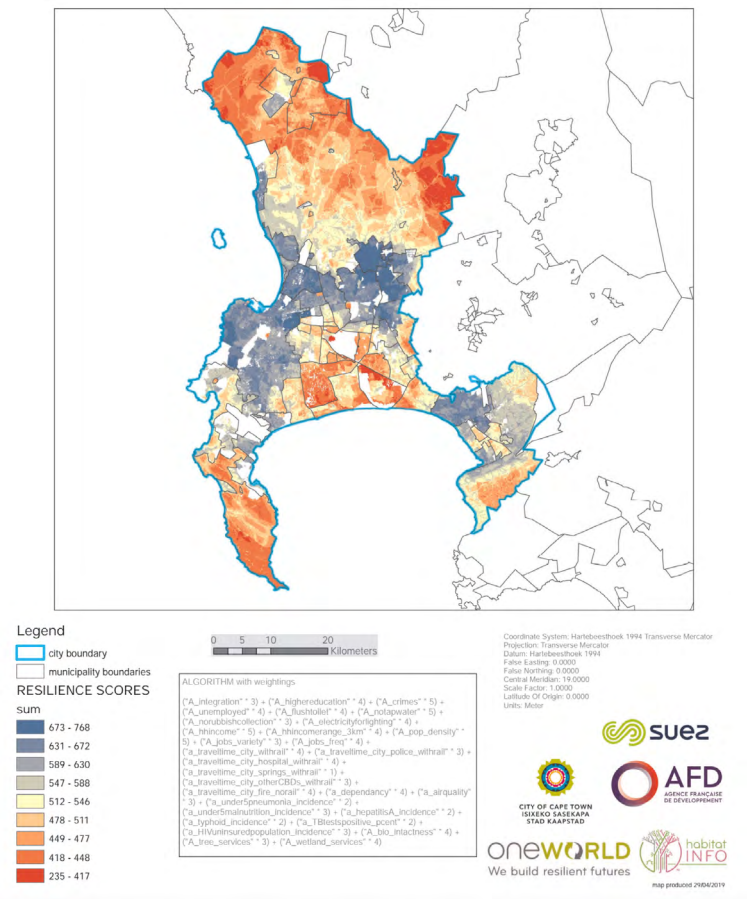


Figure 4: Cape Town resilience summary map.

To assess the extent and nature of climate hazards over time in the city of Cape Town, a team of consultants used a **regional climate model**, downscaled to an 8km resolution over South Africa. Metrics included: average, maximum, and minimum temperature; very hot days; heat wave days; rainfall; and extreme rainfall. Changes were projected for the time periods 2021–2050 (mid-future) and 2070–2099 (far-future), relative to the baseline period 1961–2000, under a low mitigation scenario (RCP8.5).

The assessment of climate change risk and vulnerability builds from the hazard assessment, with **indicators for exposure and resilience** given different weightings using data related to quality of life, such as type of dwelling, access to services like clean water, and household income.

This found that the climate-related hazard posing the greatest risk is **drought followed by fire and heatwaves**. The team also explored different thematic areas of impact, including livelihoods, poverty and inequality, the built environment, and disaster risk.

Source: OneWorld. (2019). *Elaboration of a "Climate Change Hazard, Vulnerability and Risk Assessment" Study to the benefit of the City of Cape Town. Vulnerability and Hazard Assessment Report.*

CASE STUDY: Rio de Janeiro, Brazil

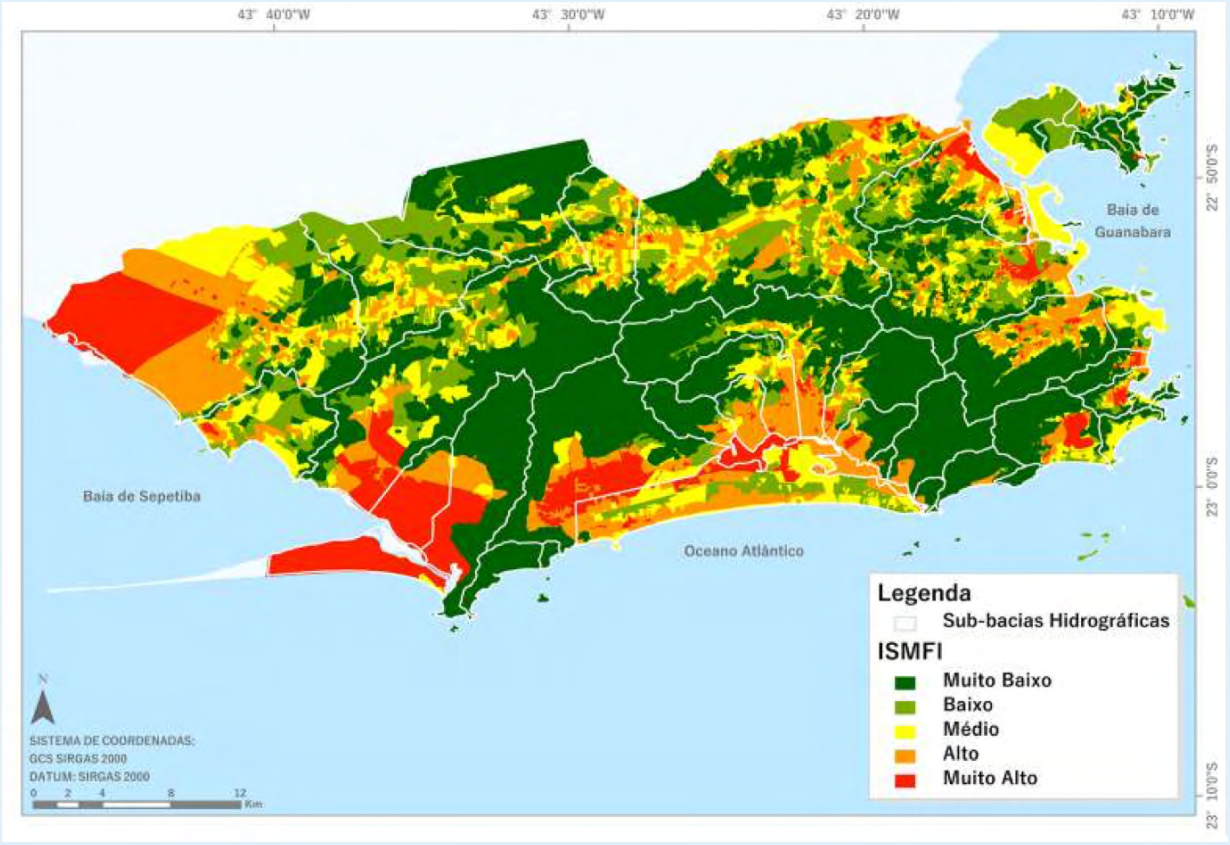


Figure 5: Index of Susceptibility to Floods of the Physical Environment.

To assess hazards related to flood exposure, Rio de Janeiro produced an **Índice de Suscetibilidade do Meio Físico a Inundações (index of susceptibility to floods of the physical environment)** by analysing geography, proximity to water bodies, and permeability, leaving aside rainfall and flood runoff. Figure 5 shows an extract of the mapping, with red areas being those at highest risk of flooding. This can be overlaid with information about vulnerable population groups and assets as part of a more comprehensive flood risk assessment.

Alongside flooding, **landslides are a significant hazard facing the city** – particularly along hillsides, which are home to many informal settlements. As part of the Alerta Rio system, the geotechnical institute of the municipality developed a **Landslide Susceptibility Map**, identifying communities at risk based on a series of factors including land occupation (including types of buildings and density), slope gradient, composition and depth of soil, geomorphology, and previous disasters in the area. This was incorporated into a Google Earth platform, with monthly updates accounting for any land-use changes. **Supplementary mapping of people with disabilities** living within identified areas of risk was also conducted, using local health assistants to collect essential details, including the location of the shelter to which these residents should be taken in times of alert. When the alert is sounded and these areas are evacuated, social services call each of the identified residents, along with the people responsible for assisting them with evacuation. Should anyone be unaccounted for at the emergency shelters, the Civil Defence Team makes house visits.

Generally, the system has performed well, leading to **significantly fewer fatalities and less displacement during rainfall events** since it was implemented following the devastating landslides in 2011. However, community leaders have noted fears around evacuation due to concerns about theft, dangerous routes, or houses being removed by the government after people leave. The quality and safety of identified shelters is also a concern, with many choosing their own safe space instead. This indicates a need to **better understand residents' perceptions**, and the importance of their continued involvement in early warning and preparedness activities.

Sources:

1. City of Rio de Janeiro. (2016). *Climate Change Adaptation Strategy for the City of Rio de Janeiro.*
2. Heffer, C. O. (2013). ELLA Policy Brief: Rio de Janeiro City's Early Warning System for Heavy Rain. *ELLA, Practical Action Consulting.*
3. Bandeira, R.A.d.M, de Britto, R.M., Fontainha, T.C., Melo, P.d., Leiras, A. (2017). Evaluation of community leaders' perception regarding Alerta Rio, the warning system for landslides caused by heavy rains in Rio de Janeiro. *Nat Hazards* 89, 1343–1368.
4. C40 (n.d.). *How to reduce flood risk in your city.*

3. Monitoring and warning

For residents to be warned and take preparedness measures as far as possible in advance of an event, **reliable and accurate forecasting** is essential, and must also include continuous monitoring of the different parameters and precursors that give rise to a hazard. Given the presence of different microclimates and conditions within cities, it is important to connect local observations with those at the city level, as well as from the national to the city level. Using **flood and drought models** combined with real-time observational and historical data can help pinpoint specific areas at risk and increase the lead time for warnings to be issued. Even with the best technology it is not always possible to forecast an event significantly ahead of time – so maintaining a general state of preparedness is essential. This is covered further in the section on response capability.

ACTIONS

1. **Identify existing weather forecasts available at the national or regional level**. Consider their detail and relevance for the different microclimates of the city, and whether they are impact-based (i.e. describing what the weather will do, not just what it will be).

2. **Establish data-sharing protocols for weather and forecast information** with national-level agencies, research institutions, and other cities in the same watershed or basin. This will help ensure information can be accessed in a timely manner, facilitate effective dissemination to communities, and support early action. See the Buenos Aires case study for an example of this.

3. Where national-level forecasts are insufficient or irrelevant, consider supplementing them with a **monitoring network of sensors and river gauges**. Explore lower-cost and -tech options that use **residents as observers**, to complement and fill gaps in knowledge while increasing overall engagement and trust. NGOs, CSOs, or community members may already be active in the collection of such data, which can be fed into the overall system. The Peru and Brazil case studies provide good examples of how this can be integrated into existing networks and actively involve young people.

4. **For drought, the use of remote sensing can complement climate and hydrological data** derived from dam and stream measurements, and can be a good alternative where meteorological and hydrological data are scarce. It can also be used to develop a composite index, which can be regularly updated with indicators such as land surface temperature, vegetation index, and soil moisture.[16]

5. **Deliver training** to personnel responsible for the operation and maintenance of technical equipment, and to residents on how they can contribute to community observation and data collection.

6. **Regularly test and calibrate sensors and technical equipment**, to ensure the data they collect is accurate and reliable.

7. **Collaborating with the private sector** may also be useful, as many companies – including energy utilities and the aviation industry – collect and monitor environmental data to inform their own planning.[17]

8. Ensure that the monitoring system is able to **combine with and benefit from new technology over time**. Quezon City's iRiseUP system shows how multiple data sources can be combined into one unified platform accessible by different city departments and residents.

9. **To increase the lead time for warnings and provide more accurate assessments of risk, consider using hydrological and hydraulic models**. These combine historical measurements, real-time monitoring data from gauges and sensors, and meteorological data from forecasts to predict a time series of flows and water levels in a river system. More advanced, two-dimensional models can also be used to calculate flood inundation in flood-prone areas.

10. Together with the stakeholder group, **define the impact levels/thresholds at which a warning will be issued, accounting for varied users' different lead-time needs**. The data identified in the risk assessment around different vulnerabilities can be particularly useful for this step.

For example, people with disabilities and those with children may require longer lead times in order to evacuate safely or make more than one evacuation. The time of day or year can also influence the lead times needed for taking actions safely – for example, during daylight hours versus at nighttime, or taking into account periods where major shifts in population dynamics or movements are expected, such as festivals.[18]

The indicators that are to be monitored in the early warning system require predictability, timeliness, sensitivity, and reliability in order to detect divergences from normal trends and trigger warnings early. To identify thresholds, consider historical data to understand how the indicators behave, and use observations to determine what constitutes a "normal" and "atypical" or "extreme" period for each indicator.[19]

CASE STUDY: Buenos Aires, Argentina

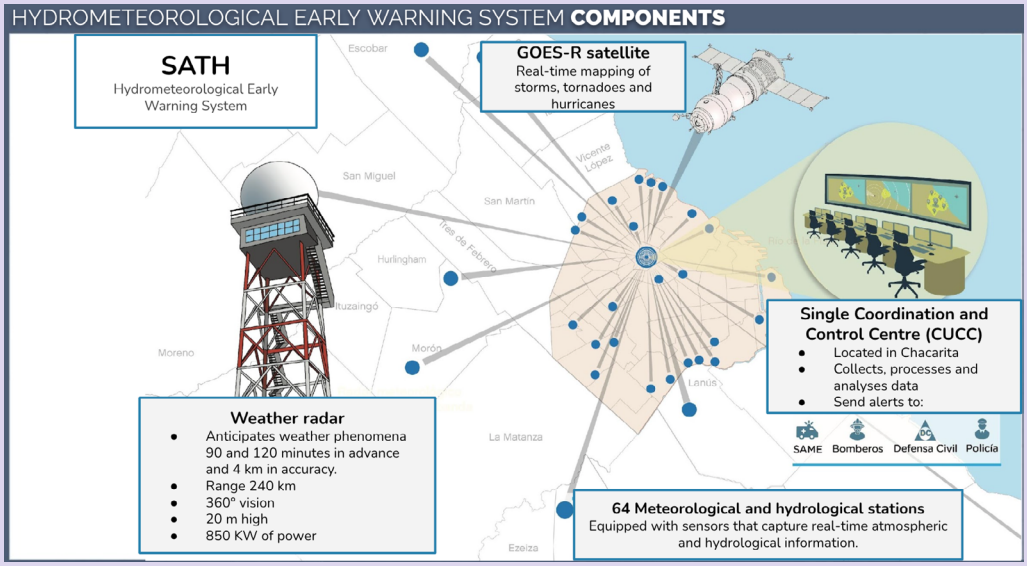


Figure 6: Components of the BA Hydrometeorological early warning system.

In response to frequent flooding events, the city of Buenos Aires commissioned an early warning system to provide real-time information to anticipate storms. The system is composed of a **satellite** (providing real-time mapping of storms, tornadoes, and hurricanes) and **weather radar** (which anticipates weather phenomena 90 and 120 minutes in advance, with 4km accuracy). Within the city there are **64 meteorological and hydrological stations** to measure rainfall, wind, and temperature. A **Single Coordination and Control Centre** receives all the information from the various sensors and radar systems, processes and analyses the data, and sends alerts to different agencies, with rainfall classified according to severity.

A collaboration with the **National Meteorological Service (SMN)** ensures the monitoring of hydrometeorological phenomena and the generation of 36-hour forecasts (every 12 hours) and 7-day forecasts (every 24 hours). The SMN is responsible for providing warnings and alerts for severe storms, which are detailed by neighbourhood or community. This data is shared with civil defence and other agencies for improved emergency management and response.

So far, the system uses a **one-dimensional hydrodynamic model** provided by DHI that uses the information from the monitoring network to determine flood spots. The city is currently working with the SMN to increase the accuracy of the model to 1x1 km and optimising it to reduce simulation times.

Source: Presentation by the city of Buenos Aires, May 2024.

CASE STUDY: Quezon City, Philippines

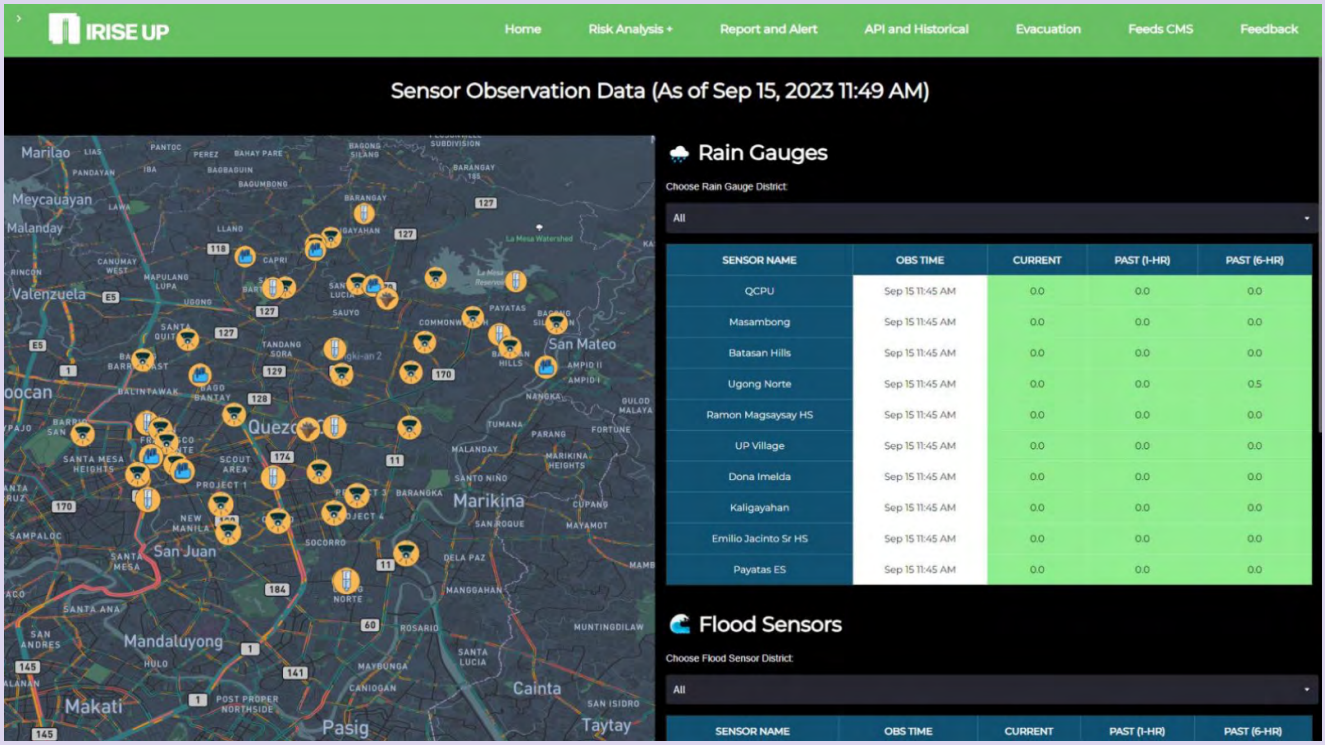


Figure 7: Screenshot of the iRISE UP multi-hazard early warning system.

iRise UP (Intelligent, Resilient and Integrated Systems for the Urban Population) is an initiative by the Quezon City Disaster Risk Reduction and Management Office to provide a localised, multi-hazard early warning system. The initiative employs a system-driven approach, converging multiple data and city government systems into a unified platform including real-time monitoring of sensors, accessible historical and live data, localised hazard and risk maps, impact-based weather forecasting, and the integration of digital and traditional instruments. Data parameters that are analysed and displayed in the system include rain, wind and temperature, water levels, low-pressure areas, and tropical cyclones. Data and analysis can be provided for different time periods – **historical** (past 24 hrs and up to 10 years ago), **observations** (real-time), **nowcast** (1 hr to 6 hrs), and **forecast** (1 day to 15 days).

iRISE UP has facilitated the generation of over 1,000 maps, enabling a comprehensive understanding of hazard-prone areas and informing pre-emptive actions such as localised evacuations. Alongside the training of over 17,000 individuals in disaster response, this has substantially reduced the number of casualties, with **zero recorded since the implementation of iRISE UP in 2020**.

The importance of redundancy has been emphasised with the use of backup communication methods and uninterruptible power supply systems. **Ongoing community engagement and education** are critical for sustaining the programme's effectiveness. Continuous efforts are made to reinforce community understanding, along with regular maintenance and upgrading of technology, infrastructure, and communication equipment to ensure reliability during emergencies.

Sources:

1. iRISE UP. (2023). *User Guide*.

2. Development Academy of the Philippines. (2023). *Rising Above Challenges: How iRISE UP is Transforming Quezon City's Disaster Management and Resilience*.

CASE STUDY: “Citizen science” and community-based methods in Peru and Brazil

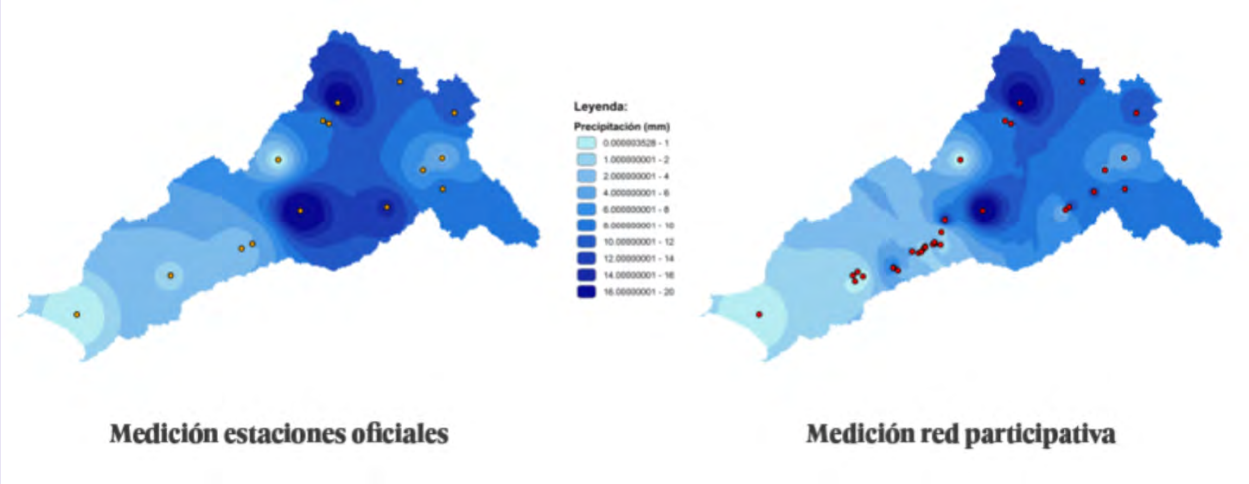


Figure 8: Comparison of official rainfall monitoring stations (left) and those of the MOP Rímac Network volunteers (right) during a heavy rainfall event.

The **Participatory Rainfall Monitoring Network in the Rímac River Watershed (MOP Rímac Network) in Peru** uses trained community volunteers to collect and communicate data captured with **standardised manual rain gauges**. It was established to complement and strengthen the surveillance that the Peruvian National Service of Meteorology and Hydrology (SENAMHI) provide for the Rímac early warning system. Information generated by this network is shared and contrasted with the SENAMHI and existing monitoring networks. Results so far suggest the validity of capturing this type of information through participatory approaches, as shown by the comparison maps in Figure 8, providing a more complete and detailed understanding of the behaviour of rainfall in a particular area.

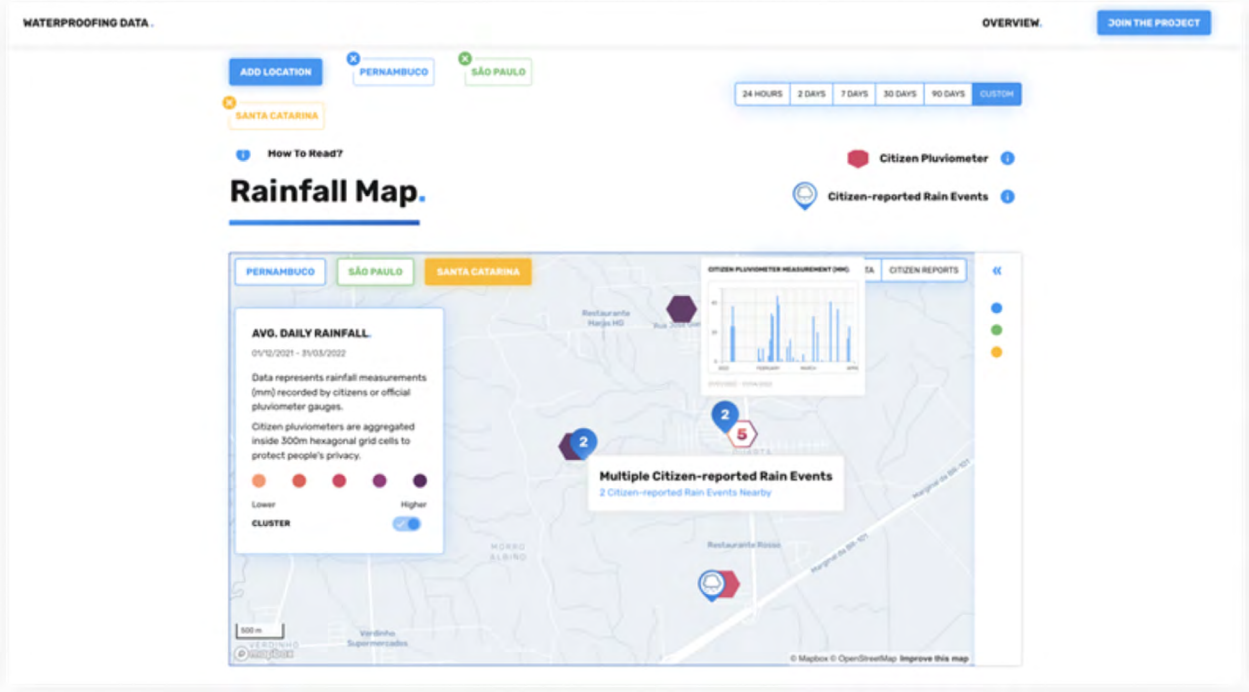


Figure 9: Rainfall map from the Waterproofing Data dashboard showing locations of rainfall pluviometers and volunteer-generated rainfall events.

In Brazil, the Waterproofing Data app, Dados à Prova D'Água, has been tested by teachers, students, civil defence agents, and residents in more than 20 local municipalities. In schools, students learn about flooding risk, vulnerability, and resilience and act as **"citizen scientists"**, generating and analysing data from their own neighbourhoods. Using the dedicated app, they send rainfall measurements and flooding events to Brazil's national agency for early flood warning, CEMADEN. The scheme has informed the policy and practice of CEMADEN, which uses these community-generated data streams to develop better flood models, incorporating lessons from past rainfall and flood events, along with up-to-the-minute, resident-supplied data to improve early warning systems.

Sources:

1. Arestegui, M. and Madueño, G. (2020). How can participatory monitoring help us better understand rainfall? *Flood Resilience Portal.*
2. University of Glasgow. (2022). *DATA-DRIVEN CITIZEN SCIENCE CHANGES THE WAY COMMUNITIES DEAL WITH FLOODING*.
3. Urban Big Data Centre. (2024). *Waterproofing Data Project - Full report and resources.*
4. Urban Big Data Centre (n.d.). *Introducing the Waterproofing Data dashboard.*

Photo by Abhinav Chitikela

4. Dissemination and communication

Even warnings that are provided in good time before an event occurs will not necessarily be received and understood by those who need to act. **Dissemination methods** (i.e. how the warnings reach the end-users), should be tailored to the needs of different groups – including the most vulnerable and marginalised, who may not trust official channels or be able to read. **Communications** (i.e. the content of the warnings), should be easy to understand and interpret for different groups, focussing on the impacts of the hazard as well as any actions they can take.

ACTIONS

1. Work with the stakeholder group to understand **how communities and vulnerable groups perceive risks; which communication channels they use; and what motivates them to act**. Use this information to ensure that dissemination and communication systems are tailored to the needs of these groups. The DARAJA case study describes an example methodology for this action.

2. **Build on existing formal and informal dissemination channels**, incorporating redundancies wherever possible in the system through multiple simultaneous channels (both digital and analogue), such as sirens, radio, TV, mobile phones, and social media. This also provides the ability to verify the information, helping to reinforce trust in the system.

   Access to technology is influenced by socioeconomic status, with lower-income residents, older people, migrants, and those recently affected by disaster typically having fewer opportunities for digital communication.[20] **Individuals – particularly stigmatised groups such as migrants – may not trust official channels**, so it is important to consider alternative and non-traditional channels, including working through community leaders and groups. NGOs, CSOs, and CBOs often have strong contextual knowledge and existing relationships, which can ensure messages reach communities in a timely, understandable, and actionable way.[21]

3. **Ensure that any equipment is maintained and upgraded**, and utilise new technologies (when appropriate) to ensure interoperability, with backup systems and processes in place in case of failure.

4. **Develop standard operating procedures for early warning communications**, agreeing in advance how information will be phrased; how probability will be described; how weather and flood risk will be conveyed; and what language, visuals, and terminology will be used.[22]

   The **Common Alerting Protocol** is an international standard format for emergency alerting and public warning that allows alerts to be sent out with consistent messaging through multiple channels and in multiple formats.[23] It should be noted that while the Common Alerting Protocol does facilitate multilingual messaging, this is only possible for languages that have a written form. The accessibility of written alerts also depends on residents' ability to read.

   Using both written instruction and pictograms or icons can help to accommodate various languages, as well as differing levels of literacy and capacity for understanding symbols. Colour, imagery, and tone of voice can be used to convey urgency better than technical or text-heavy information.[24]

5. **For slower-onset disasters, such as drought, messaging and responses have to maintain significance over time**. Cape Town's messaging around "Day Zero" was very successful in helping drive a long-term water-saving culture.

6. **Pre-test the language and content of messages with the stakeholder group (including majority and minority audiences)** to establish how well the information is understood, and how well it meets people's information needs. The messages should be simple and easily understood by

all members of the community, regardless of their literacy level or spoken language,[25] and provide clear guidance to trigger reactions such as evacuation.

7. **Where possible, consider sharing hyperlocal information and provide more targeted risk communications** by comparing expected weather impacts with known high-risk zones (see the section on risk knowledge). Cities can work with mobile network operators to utilise cell broadcast technology, enabling the delivery of alerts to narrower geographic areas and allowing for more targeted messaging.[26]

CASE STUDY: Developing Risk Awareness through Joint Action (DARAJA)

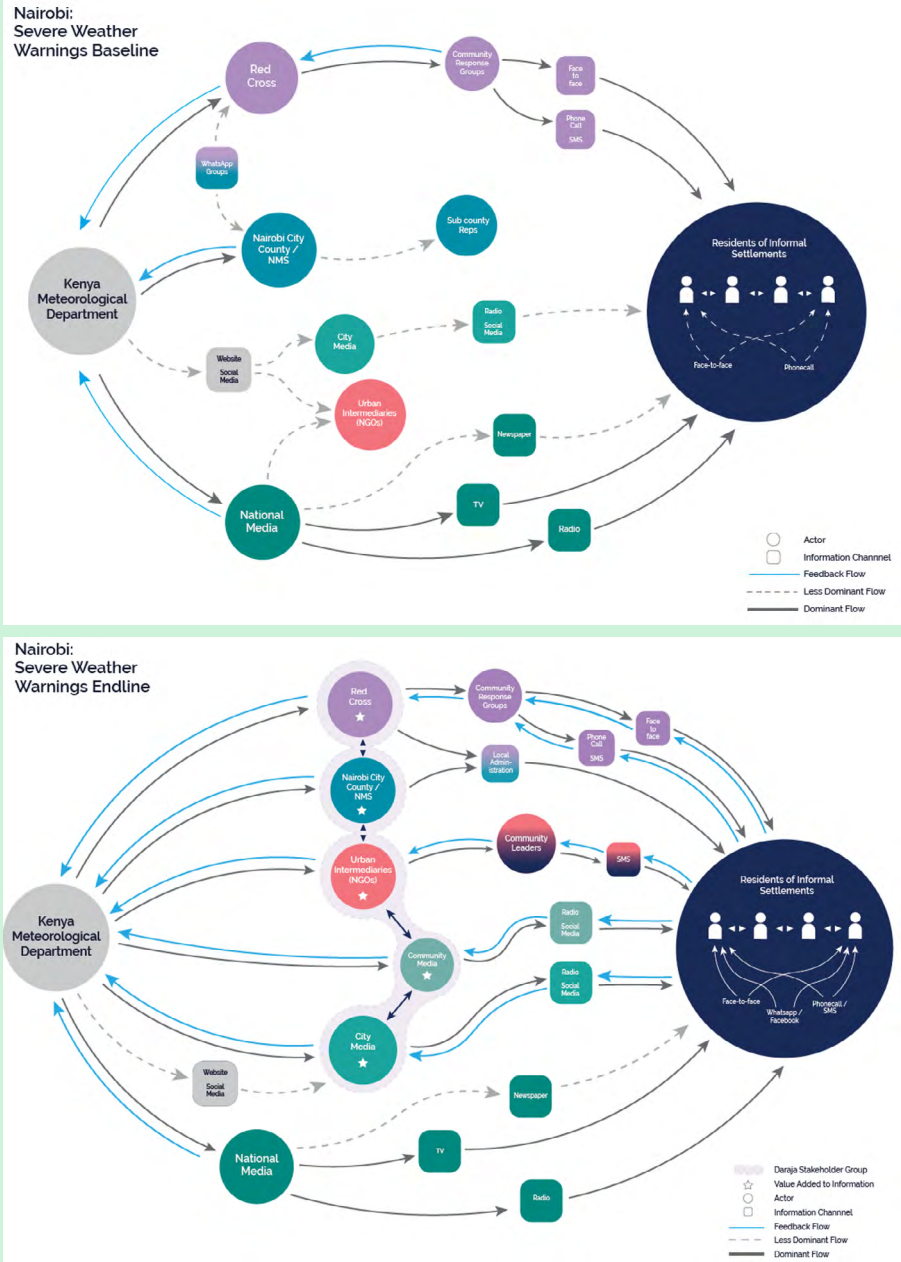


Figure 10: Information ecosystem map of the Nairobi Severe Weather Warnings system at the start (baseline) and end (endline) of the project.

DARAJA is a co-designed programme that aims to improve the climate resilience of vulnerable populations living in informal settlements by improving their access to actionable weather, climate, and early warning information. It has been successfully piloted in Nairobi, Kenya, and Dar es Salaam, Tanzania, with ongoing work on a second phase in Kampala, Uganda, and Addis Ababa, Ethiopia.

Adopting a **systems-wide approach**, it aims to build "bridges" and operational partnerships between the actors critical to the co-design of the products, dissemination channels, and feedback loops for weather forecasts and extreme weather alerts. These actors include:

1. **Vulnerable urban residents**, including residents of informal settlements.
2. **National weather agencies** that provide residents with climate information.
3. **Civil protection and disaster management agencies** that keep people safe.
4. **Infrastructure operators** that serve residents.
5. **Media houses, telecommunications companies, and schools**, which are all key in dissemination to residents.

The programme design was based on qualitative and quantitative research, including household surveys, key informant interviews, community focus groups, information ecosystem mapping, and mass media tracking to understand how people access weather information and what could be improved.

Figure 10 shows the **information ecosystem mapping**, which helped understand how information flows from different points, with the starting point being the national meteorological service and the end point being residents. This provided a baseline of who is involved, how, and at what point information changes shape. At the end of the project, it was possible to see the evolution of the map with greater two-way communication flows, including feedback from residents on the accuracy and usability of the forecasts.

Community feedback helped the team develop easy-to-understand icons in local languages. Information is tailored according to local needs and ranges from daily weather broadcasts on radio and television, to a "community communication system". This involves trained community leaders sharing weekly updates and severe weather warnings through text messages, phone calls, and word of mouth. The project also encourages people to actively protect themselves from adverse weather conditions, for example, by repairing their homes/roofs, moving possessions to a safe place, and cleaning drains.

Key to the success of the project has been the **involvement of local NGOs as intermediaries embedded within the community, alongside the Red Cross**, which is already present in emergency situations. Training on the terminology of weather forecasts and how to communicate these concepts better to a wide range of audiences and listeners meant that more people received and understood the forecasts.

In the Kenya pilot, at the end of the project, **93% of residents accessed or received weather and climate information** compared to 56% at baseline, with **98% using the information to take preparatory action**, compared to 76% at baseline.

Sources:

1. Interview with Sunayana Sen, DARAJA Programme Manager, June 2024.
2. Resurgence. (2024). *DARAJA: The Inclusive City-Community Forecasting and Early Warning Service*.
3. Yore, R., Fearnley, C., Fordham, M., and Kelman, I. (2023). Designing Inclusive, Accessible Early Warning Systems: Good Practices and Entry Points. *Global Facility for Disaster Reduction and Recovery (GFDRR) and UCL Warning Research Centre.*
4. World Habitat. (2024). *DARAJA: The Inclusive City-Community Forecasting and Early Warning Service.*

CASE STUDY: Cape Town, South Africa

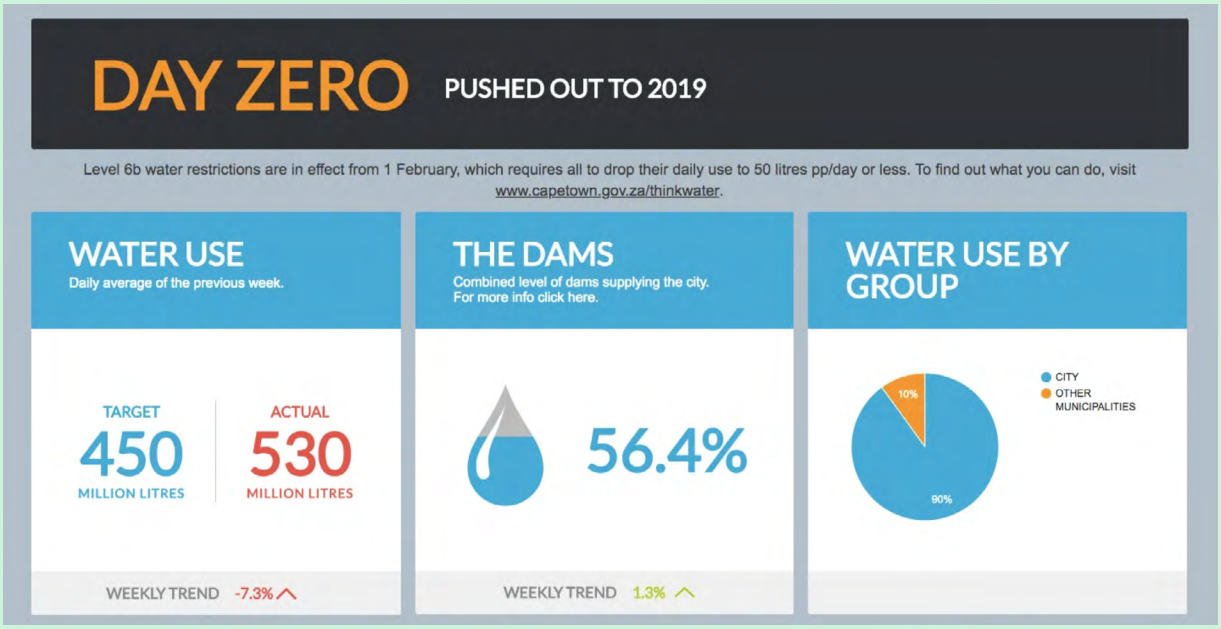


Figure 11: The Day Zero dashboard.

The city of Cape Town, South Africa's second largest metropolitan area, experienced its most severe drought on record from 2015 to 2018. **Dam levels dropped to extremely low levels (20% in mid-2017)** and the city implemented strict policies to reduce demand and avert **"Day Zero"** – the term used to signal when the water supply to many areas of the city would have to be turned off to ensure sufficient daily water rations could be distributed.

The messaging around "Day Zero" allowed for the needed visibility of the crisis to drive responses by both officials and the public before absolute water shortages were experienced, providing a reference point for people's sense of risk. The publication of a **weekly water dashboard** and online residential water map led to significant media coverage and promoted a sense of individual responsibility and accountability to use less water.

Sources:

1. Cole, H.D., Cole, M.J., Simpson, K.J., Simpson, N.P., Ziervogel, G. and New, M.G. (2021). Managing city-scale slow-onset disasters: Learning from Cape Town's 2015–2018 drought disaster planning. *International Journal of Disaster Risk Reduction*, 63, p.102459.

2. Williams, C. (2018). Cape Town Day Zero. Was it rules or community spirit that reduced water use. *Medium.*

5. Response capability

Upon receiving a warning, people and institutions need to know what to do and how to respond. This requires **early action well before an event** occurs to build knowledge and skills; agree and assign roles; and develop, practise, and test emergency responses. **During an event**, these responses will need to be activated in a timely manner to provide immediate relief for at-risk residents and ensure the protection of critical infrastructure, thereby reducing adverse impacts. **After the event**, essential services and infrastructure will need to be restored and rebuilt. There will also be important opportunities to learn from the effectiveness of the responses to ensure continual improvement.

ACTIONS

Before an event

1. **Co-develop the emergency management or response plan with the stakeholder group**. This is a detailed document containing sub-plans that address preparedness for and implementation of response actions to be taken depending on the severity of the hazard. It should clearly identify the roles and responsibilities of different government agencies, including disaster or emergency management, health, transport, communicatios, and emergency services, alongside relevant NGOs, CSOs, and CBOs that undertake emergency responses at the local level. The plan may detail:[ii]

   - the risk analysis, including the nature of the hazard and the areas that could be affected;
   - roles and responsibilities of government agencies before, during, and after an event;
   - early actions or preparedness activities;
   - trigger conditions for plan activation;
   - liaison and communication arrangements; and
   - arrangements for public education and awareness; warning, dissemination and communication to communities; evacuation, rescue, registration, and welfare of evacuees; and initial recovery.

   Drought management plans should account for the longer stress period, with strategies to maintain preparedness for longer return-periods and cascading hazard events. It is important to note that a drought plan is not interchangeable with a water conservation plan; the former focuses on shorter-term efforts and extreme shortage situations.

   Specific actions to aid the development of the plan include:

   a. **Work with the stakeholder group to identify barriers that prevent people acting in advance, and take measures to address these in the planning stages**. People make decisions based on their perception of multiple risks (not just the hazard risk), their capacities, and other cultural, social, cognitive, and psychological factors.[27] For example, some individuals with additional needs may want to be the first evacuated, whereas others, for whom long stays in basic emergency shelters are least comfortable or tolerable, may prefer later evacuation.[28] Crime and security risks may also limit the actions people are willing to take, leading them to prioritise the protection of property over evacuation. People often face more immediate concerns, such as food security and employment, which make it difficult to prioritise acting in advance, even with timely warnings.[29]

ii For more information see: Associated Programme on Flood Management. (2011). Integrated Flood Management Tools Series. Flood Emergency Planning. *World Meteorological Organization*.

b. **Select early actions or preparedness activities to help mitigate impacts, using stakeholder consultations and leveraging the experiences of other cities**. These should be linked to the provision of funding to support them and may vary from the individual to the city level.

   For flooding, actions may include:

   - Communities and local authorities clearing drainage infrastructure to prevent clogging.
   - Communities and local authorities reinforcing riverbanks and housing.
   - Local authorities filling and pre-positioning sandbags to enable swift distribution during a disaster.
   - Local authorities and aid agencies distributing water, sanitation, and hygiene kits and shelter items including soap, a bucket, jerry can, chlorine tablets, sanitary pads, medicines, blankets, etc.
   - Individuals preparing an evacuation bag and first aid kit ready for use.

   For drought, actions may include:

   - Water restrictions and water rationing – restricting certain uses of water, for example irrigation of lawns, car washing, filling swimming pools, or hosing down pavement areas. Water rationing affects all water users and entails a temporary suspension of water supply or a reduction of water pressure to below the level required for adequate supply under normal conditions.[30]
   - Prioritisation of different water uses according to socioeconomic and environmental factors, such as impacts on drinking water supply, industrial uses, power production, agriculture, etc.
   - Raising public awareness about water use and efficiency, as well as voluntary and mandatory requirements.

c. **Ensure there are clear preparedness actions for supporting socially marginalised groups** with additional needs, who are at risk of being left behind without targeted support and resources (e.g. migrants and people who are homeless).[31] See the earlier case study of Rio de Janeiro for an example of supporting people with disabilities during a disaster.

d. **Use the multi-hazard risk assessment to develop and design evacuation strategies, including evacuation routes, demarcation of safe areas, and the location of temporary shelters**. Ensure people understand where they can evacuate to, and what their safest evacuation route will be (with consideration of what this route will be like under different rainfall or flood conditions).[32] Emergency evacuation points and shelters should be designed in accordance with universal accessibility principles such as step-free access, accessible toilet and sanitation facilities, and clear signage and information. They also need to account for fluctuating population numbers in cities. **For drought**, such assessments can be used to determine the locations of mobile water points and supply restrictions, as shown in the Cape Town case study.

2. **Undertake regular exercises, simulations, or drills to test and optimise** the effectiveness of the dissemination processes, preparedness, and response to warnings and actual events.

3. **Conduct ongoing public awareness and education campaigns**, tailored to the needs of vulnerable groups, to promote understanding of hazards, and knowledge of how to reduce disaster impacts and better prepare. NGOs, CSOs, and CBOs can also be involved and may have existing resources and methods. The Santa Fe case study demonstrates the importance of working with city communications departments, the education system, and young people to embed awareness from the bottom-up and link preparedness processes to residents' everyday practices.

During an event

1. **Activate the emergency management or response plan** and conduct a rapid assessment of immediate needs in coordination with responsible government agencies, local communities, and NGOs.
2. **Ensure critical infrastructure is protected**, including the strengthening and rehabilitation of existing structures and flood-proofing measures such as flood barriers, dikes, levees, and retention basins.
3. Depending on the severity of the hazard, coordinate with emergency services, NGOs, and CSOs to help **evacuate people in high-risk areas and activate local search and rescue teams**.
4. **Together with NGOs and CSOs, provide immediate shelter and welfare for those affected**, using the evacuation strategies or plans developed before the event.
5. **Provide residents with regular and consistent updates on the status of the event and response**; utilise different channels, including radio, TV, text message, and social media, while accounting for the considerations outlined in the dissemination and communication section. Updates should provide clear guidance on what support is available, what residents should do for themselves, and how they can help others.

After an event

1. **Work to repair and restore essential services and infrastructure** that may have been damaged during the event – such as water and electricity supply, health and education facilities, and damaged homes – as soon as possible. Local governments can work as a collective of cities affected by a single disaster, to pool resources and leverage national recovery funding.[33]
2. **Use the recovery period as a chance to "build back better"**. Harness opportunities for long-term planning for more inclusive and accessible infrastructure, services, and buildings that are more resilient to climate impacts. After a drought, this may include using the experience to embed longer-term behavioural changes in water use and investments in improving water security.
3. **Together with the stakeholder group, continually review the effectiveness of the response and any challenges experienced during emergencies. Use this information to adapt and update plans and risk assessments**, paying particular attention to the experiences of vulnerable groups. Focus groups, interviews, and questionnaires can provide valuable insights into how well warnings were received, perceived, and ultimately acted upon. **Developing a Monitoring, Evaluation, Accountability and Learning framework** can help measure success across all elements and inform refinements as a continuous process.[34]

Photo by wiredsmart

CASE STUDY: Cape Town, South Africa

In response to drought, the city of Cape Town needed to rapidly develop and operationalise a **Critical Water Shortages Disaster Plan**, with no comparable best practice to base it on.

Disaster planning began in May 2017, when dam levels dropped to 20%, with the creation of the Water Resilience Task Team. The Disaster Risk Management (DRM) department had several hazard plans for localised, rapid-onset events, but none that dealt with city-wide, slow-onset events. The department alone did not have all the skills necessary to develop the plan, so the city's strategy team and the portfolio project management team was tasked to support, alongside the water engineering department and the communications department, which had been working on the drought response since early 2016. This created an effective cross-functional team, led by a drought crisis coordinator.

The disaster plan set out the emergency procedures to be implemented in the event of disaster, including roles and responsibilities, disaster response and relief, emergency procurement of goods and services, and strategic communication and dissemination of information. It had three phases:

1. **Preservation restrictions** – in the first phase, the city implemented water restrictions, water pressure reduction, communication campaigns, and punitive tariffs to drive down total water consumption to 500 million litres per day.
2. **Disaster restrictions** – when water supply dropped to a certain level, the city would enforce a daily water allowance of 25 litres per person to ensure sufficient water supply for basic needs until the onset of the rainy season. This would involve turning off the water supply to residents' homes and workplaces via the water reticulation grid, while critical infrastructure and facilities and vulnerable residential areas would remain connected. Points of distribution (PODs) across the city would be established for greater control over the amount of water being used per person. A pre-agreed trigger point was established at 13.5% of the average dam level.
3. **Full-scale disaster implementation** – if Phases 1 and 2 failed, the city would implement emergency water distribution from reservoirs and boreholes, and commence evacuation protocols.

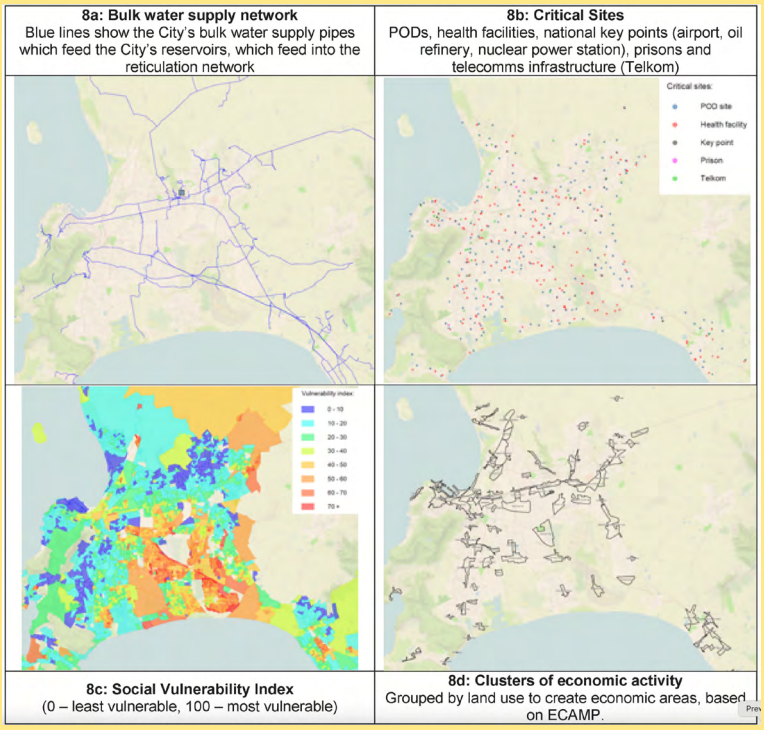


Figure 12: Maps used to determine the Points of Distribution for water collection during Phase 2 of the disaster plan.

For each phase, the disaster plan considered how water users would likely be affected and provided direction for engaging in mitigation measures. To determine locations for the PODs and the sequence for cutting off water supply, a **Social Vulnerability Index (SVI) and an Economic Nodes Index (ENI)** were developed. The SVI used six indicators, weighted to reflect their relevance for assessing vulnerability across three themes – socioeconomic status, household composition and disability, and housing and transport. This was calculated as an index and plotted as a map across the city. The ENI was measured using three weighted indicators for economic importance, including the average number of people employed, and a single indicator for vulnerability to water supply reductions, the percentage of water-vulnerable businesses (e.g. agriculture, beverages, and healthcare). The two component scores were combined to produce an ENI for each node, which were then ranked and grouped into four categories from the first to the last to be cut off from the water supply (see the maps in Figure 12).

Fortunately, the city never needed to implement Phase 2 restrictions, thanks to such a huge effort to reduce water consumption. Lessons learnt during the development of the plan include:

1. **Ensuring the mix of skills necessary for city-wide disaster planning**. This requires investment over time and links with strategic planning functions.
2. **Ensuring that integrated, up-to-date, scale-appropriate data** is available for designing disaster responses.
3. **Ensuring that plans are tested; that regular communication with internal and external stakeholders is established; and that interventions and procurement can be costed rapidly**, to avoid a situation where a city chooses a response option only to find it is financially unworkable.

Source: Cole, H.D., Cole, M.J., Simpson, K.J., Simpson, N.P., Ziervogel, G. and New, M.G. (2021). Managing city-scale slow-onset disasters: Learning from Cape Town's 2015–2018 drought disaster planning. *International Journal of Disaster Risk Reduction*, 63, p.102459

CASE STUDY: Santa Fe, Argentina

8/ EDICIÓN ESPECIAL

¿CÓMO SE ORGANIZA LA EVACUACION?

Cuando llueve mucho o caen grandes chaparrones en poco tiempo, en algunos sectores de la ciudad el agua se vuelve un problema. Por eso, es necesario que las familias radicadas en zonas bajas, dejen sus hogares para estar a salvo. Esta situación se agrava si los ríos están altos, afectando a otras zonas de la ciudad.

El Municipio dispone la evacuación preventiva cuando se detectan riesgos para la salud y seguridad de la población afectada. Para ello, se disponen tres pasos: el aviso, los puntos de encuentro y el traslado a los refugios.

PUNTO DE ENCUENTRO
PLAN DE CONTINGENCIA
SANTA FE

SI TENÉS QUE DEJAR TU CASA...

¿QUIÉN NOS AVISA?
El Gobierno de la Ciudad nos informa a través del personal municipal del Distrito. Las organizaciones comunitarias de la zona colaboran con el aviso boca a boca y también se informa a través de las radios.

¿DÓNDE NOS ENCONTRAMOS?
En caso de tener que dejar la casa, nos dirigimos al Punto de Encuentro acordado para nuestro barrio. Desde este lugar se organiza la atención o el traslado de manera ordenada hacia el refugio asignado.

¿CUÁNDO ABREN LOS REFUGIOS?
El Municipio habilita los refugios según la zona y el tipo de emergencia. En cada uno hay un responsable que organiza la atención a las familias afectadas para brindar abrigo, comida y asistencia sanitaria hasta que finalice la emergencia.

Y NO TE OLVIDES DE...

APOYO
Tener siempre a mano velas, linterna, radio con pilas y botiquín de primeros auxilios.

SEGURIDAD
Desconectar el gas y la electricidad para evitar cortocircuitos.

OBJETOS PERSONALES
Llevar documentos personales y de la casa. Ropa seca y los medicamentos que estén tomando.

PUNTO DE ENCUENTRO
Es el lugar al que deben concurrir las personas que han recibido el aviso de evacuación. Allí se registra cada familia y se organiza la atención o el traslado al refugio asignado.
Es además un centro de información que permite localizar a cada familia recibida.

REFUGIO
Es el espacio físico temporalmente habilitado por el Municipio para recibir y atender a las personas evacuadas hasta que cese la emergencia y puedan regresar a sus viviendas. Se trata de edificios de instituciones que funcionan cerca de cada zona vulnerable y que son habilitados por el Municipio.

MI CIUDAD /9

PUNTOS DE ENCUENTRO
DISTRITO NOROESTE

PUNTOS DE ENCUENTRO

1. Polideportivo La Tablada	Teniente Loza 6970
2. Vecinal Ceferino Namuncurá	12 de Octubre 9501
3. Vecinal Santa Marta	Chubut 6291
4. Polideportivo Acería	Caffarata y Beruti
5. Vecinal Sarmiento	Vieytes 5047

Figure 13: Extract of printed communication materials (My City magazine) showing meeting points and shelters.

Following the 2007 floods, the Santa Fe Disaster Risk Management (DRM) Office developed a set of contingency plans and emergency protocols for heavy rains and river overflows. The contingency plans define how the municipality should be organised, both for **"everyday" management and during an emergency**, and specify how collaboration with other institutions should take place. This ensures their regular application beyond extraordinary events. The protocols are simple and concise and everyone, including the mayor, must know their contents thoroughly. **Participatory evacuation plans** were also prepared, including the selection of meeting points and temporary shelters at neighbourhood and district levels, aligning with existing evacuation plans wherever possible. For all these, the DRM office has maintained an earmarked annual budget and engages with representatives of neighbourhood organisations, who have become effective intermediaries between residents and the municipal government.

The strong cross-cutting role of the DRM office has further helped ensure the mainstreaming of responses in other sectors of the municipal government, including a strong link with the Department of Communications, which has played a key role in embedding the approach internally and externally. A **risk communication programme** was developed, with a special section on the city's website and YouTube channel containing specific information about the root causes of risks and what to do in an emergency, with graphic representations of evacuation routes and meeting points. This extends to primary, secondary, and higher education, with training materials and courses. At the community level, preventative actions are translated into specific everyday practices, such as correct waste management to prevent blockages in the drainage system.

Independent evaluations are undertaken post-incidents by the municipal auditor, who assesses the performance of all actors involved, ensuring an ongoing culture of transparency, accountability, and learning. The city is now expanding its focus to other shocks and stresses, and increasingly recognises the importance of working with other cities and areas beyond the municipality at the river basin scale. This is not without challenges – strong political commitments and engagement are needed from leaders representing diverse political views and interests, which has so far prevented improved coordination with neighbouring municipalities.

Sources:

1. De Majo, V. (2022). Institutional conditions for building proactive flood management: Lessons from santa Fe in Argentina. *International Journal of Disaster Risk Reduction*, 81, p.103251.
2. Valsanga, A. and Evangelina Filippi, M. (2019). Case Study 8. Santa Fe (Argentina) Reflections on a 10-year urban DRM process. In: United Nations Office for Disaster Risk Reduction. (2019). *Local Disaster Risk Reduction and Resilience Strategies*.
3. Santa Fe Ciudad. (2017). *MI CIUDAD - Edición Especial, ABR 2017.*

Photo by Kenny Eliason

SELF-ASSESSMENT CHECKLIST

The following checklist is designed to help cities assess their current progress and identify gaps in emergency preparedness for flooding and drought. Use the drop-down boxes for action status and text boxes to type the name of the city department(s) or agency responsible for each action.

Action	Status	Responsible city department(s) or agency
EFFECTIVE GOVERNANCE, RESOURCES, AND CAPACITIES		
Identify stakeholders across all emergency preparedness components		
Establish a municipal taskforce or unit with those engaged in forecasting hazards; issuing warning messages; disseminating warnings; and organising and supporting response actions		
Establish a stakeholder group or platform involving representatives of international NGOs, civil society organisations, local private sector, community leaders, social workers, neighbourhood committees, local development councils, media institutions, faith-based organisations and religious leaders, women's groups, etc.		
Co-define roles and responsibilities for each actor and determine common goals or objectives		
Develop a transparent and accountable funding structure with sufficient resource allocation, especially for ongoing maintenance and improvement		
RISK KNOWLEDGE		
Assess existing documentation of climate risks, hazards, hotspots, and vulnerabilities, including whether the city has an up-to-date and comprehensive climate risk assessment		
Work with the stakeholder group, including local communities and academic institutions, to understand what maps and data they might have already collected		
Where this is found to be insufficient, ensure the characteristics of key hazards (e.g. geographical extent, magnitude, intensity, frequency, probability) – including the possibility of cascading hazardous events – are analysed, historical data is evaluated, and potential future risks assessed		
Assess and quantify exposed people, services (e.g. hospitals) and critical infrastructure (e.g. electricity and water works) and map for relevant hazards, as well as for any compounding risks		
Ensure that vulnerability factors such as gender, disability, access to infrastructure, economic diversity, societal inequalities, and environmental sensitivities are considered		

Create or use an existing mechanism to store and enable access to information on hazards and vulnerabilities, such as a central repository or GIS database		
Establish a process to maintain, regularly review, and update risk data, including information on any new or emerging vulnerabilities and hazards and potential changes to existing hazards		
MONITORING AND WARNING		
Identify existing forecasts available at the national or regional level and consider their detail and relevance for the different microclimates of the city		
Establish data-sharing protocols for weather and forecast information with national-level agencies and other cities in the same watershed or basin		
Where national-level forecasts are insufficient or not relevant, establish a monitoring network of sensors and river gauges, exploring lower-cost and -tech options that utilise residents as observers		
Provide training for personnel responsible for the operation and maintenance of technical equipment, and for residents on how they can contribute to community surveillance and data collection		
Regularly test and calibrate sensors and technical equipment to ensure the data they collect is accurate and reliable		
Ensure that the monitoring system can combine with and benefit from new technology over time		
Together with the stakeholder group, define the impact levels/thresholds where a warning will be issued, accounting for varied users' different lead-time needs		
DISSEMINATION AND COMMUNICATION		
Work with the stakeholder group to understand how communities and vulnerable groups perceive risks, which communication channels they use, and what motivates them to act		
Ensure warnings reach the entire population – including lower-income residents, older people, and migrants – via multiple simultaneous communication channels, including working through community leaders, NGOs, CSOs, and CBOs		
Ensure any equipment is maintained and upgraded, and utilise new technologies (when appropriate) to ensure interoperability, with backup systems and processes in place in case of failure		
Develop standard operating procedures for early warning communications, agreeing in advance how information will be phrased, how probability will be described, how weather and flood risk will be conveyed, and what language, visuals, and terminology will be used		

Pre-test the language and content of these messages with the stakeholder group (incl. majority and minority audiences) to establish how well the information is understood, and how well it meets people's information needs, ensuring that it provides clear guidance to trigger reactions		
Develop agreements and work with the private sector where appropriate (e.g. mobile network operators, satellite, television, radio broadcasting, amateur radio, social media) to disseminate more targeted or hyper-local warnings		
RESPONSE CAPABILITY		
Co-develop the emergency management or response plan together with the stakeholder group		
Work with the stakeholder group to identify barriers that prevent people from acting in advance, and take measures to address these in the planning stages		
Select early actions or preparedness activities to help mitigate impacts, leveraging stakeholder consultations and the experiences of other cities		
Ensure there are clear actions for supporting socially marginalised groups with additional needs, who are at risk of being left behind without targeted support and resources		
Use the multi-hazard risk assessment to develop and design evacuation strategies for flooding (evacuation routes, demarcation of safe areas, and location of temporary shelters)		
Undertake regular exercises or drills to test and optimise the effectiveness of early warning dissemination processes, preparedness, and response to warnings		
Conduct ongoing public awareness and education campaigns to promote understanding of hazards, and knowledge of how to reduce disaster impacts and better prepare, particularly for those most at risk		
Together with the stakeholder group, continually review the effectiveness of the response and any challenges experienced during disasters, using this information to adapt and update plans and risk assessments		

USEFUL RESOURCES

Associated Programme on Flood Management. (2011). Integrated Flood Management Tools Series. Flood Emergency Planning. *World Meteorological Organisation*.

C40 Cities. (2019). *Inclusive Community Engagement Playbook*.

C40 Cities. (2023). *Disability inclusion in disaster risk management policy paper*.

Climate Risk Early Warnings Systems (CREWS). (2023). *Guidance Document on People-Centered Risk-Informed Early Warning Systems*.

Ferguson, S., Van Ledden, M., Rubinyi, S., Campos, A., Doeffinger, T. (2023). Urban Flood Risk Handbook: Assessing Risk and Identifying Interventions. *World Bank*.

Practical Action. (2023). *Guide to Early Warning Systems.*

Practical Action Consulting and Ramboll. (2021). Policy and Practice Recommendations: Towards a Gender Transformative Flood Early Warning System in Baguio City. *Asian Development Bank (ADB)*.

United Nations Children's Fund (UNICEF). (2021). *Urban Water Scarcity Guidance Note: Preventing Day Zero*.

United Nations Office for Disaster Risk Reduction. (2023). *Inclusive early warning early action: checklist and implementation guide*.

Vahlberg, M., Khan, R., Heinrich, D., Jjemba, E., (2022). Early Warning Early Action (EWEA) in Secondary Cities in South Asia. Guidance Note. *Red Cross Red Crescent Climate Centre*.

World Meteorological Organization. (2018). *Multi-hazard early warning systems: a checklist*.

Yore, R., Fearnley, C., Fordham, M., and Kelman, I. (2023). Designing Inclusive, Accessible Early Warning Systems: Good Practices and Entry Points. *Global Facility for Disaster Reduction and Recovery (GFDRR) and UCL Warning Research Centre*.

CITY PROFILES

This guide is directly informed by the needs of cities. The following city profiles provide a snapshot of current progress and challenges identified by three signatories to the Water Safe Cities Accelerator, as they work towards establishing early warning systems and emergency responses.

FLOOD DROUGHT

FREETOWN, SIERRA LEONE

CONTEXT

Freetown is located on a mountainous peninsula and, with a population of 1.2 million, is among West Africa's most densely populated cities. Deforestation of the water catchment areas has contributed to slope destabilisation, water shortages, landslides, and floods. Successive flash floods and mudslides over recent years have destroyed many lives and properties.

PROGRESS

Freetown's city council and disaster management department worked with researchers from the University of Bournemouth's Disaster Management Centre and local ward councillors from hazard-prone areas across the city to understand which communities are more vulnerable to flooding (the biggest risk) and identify flash flood points. The city is engaging with the national government and meteorological agency to obtain weather forecasts, which it disseminates to communities through an existing structure of Community Disaster Management Committees (CDMCs) and ward councillors. Each year, before the flooding/wet season, city officials and CDMCs engage community volunteers to clear waterways, culverts, bridges, and illegal dumping sites; identify safe spots for evacuation; and encourage people to move to safe spaces. During the dry season, the council collaborates with various agencies, including Guma Valley Water, to provide water trucking and rainwater harvesting. In addition, it is undertaking important efforts to plant more trees around the catchment to capture more water and stabilise slopes. Finally, with the support of the United Nations Peacebuilding Fund and the Swiss Development Agency, 65 water kiosks will be constructed across the city to expand access to safe, affordable water. This initiative will incorporate community and commercial management mechanisms, including training women to manage the kiosks' operations and finances.

CHALLENGES

The city does not have a fully operational early warning system with monitoring equipment. The weather forecasts it receives from the national meteorological agency cover a wide area, are not always accurate, and are only issued once a week. Officials are keen to extend warning times by incorporating greater use of technology, including sensors for rainfall and temperature. The council has a budget line for disaster risk management; however, due to the city's limited revenue generation, the support of NGOs is critical for the implementation of activities – underscoring the need for greater capacity development and funding to meet the increasing scale of disasters. The city has expressed interest in lower-cost early warning system options and associated financial mechanisms; as well as support to map the drainage system, together with the Sierra Leone Roads Authority (which manages drainage construction and road maintenance), to see where improvements are needed.

POTENTIAL SOLUTIONS

Potential solutions to these challenges can be found in relevant sections of this guide, including the sections on effective governance, to identify partners and other institutions that might have greater resources and funding available, and monitoring and warning, with examples of lower-cost "citizen science" approaches.

FLOOD DROUGHT

TSHWANE, SOUTH AFRICA

CONTEXT

The city of Tshwane is one of three metropolitan municipalities in Gauteng province and the administrative capital of South Africa. It is crossed by approximately 6,000km of natural watercourses, including 19 river types, with the most affected flood regions being the more densely populated areas with a higher informal settlement population. Although the rivers overrun in the winter and cause flooding, during the summer months (from Oct/Nov through to late May), there is vulnerability to water demand outstripping supply, with the city relying on imported water from outside local river catchments. This particularly affects areas where there are limited or no other water sources, including in informal settlements.

PROGRESS

The municipality has completed a comprehensive risk and vulnerability assessment identifying known priority risks and high-risk groups, areas, households, communities, and developments. Preparedness and contingency plans for both flooding and drought are also in place from the city to the community level. The city does not have its own early warning system but receives weather reports and associated warnings daily from the national South African Weather Service (SAWS). These are disseminated to communities via local radio broadcasts by the Emergency Services Department liaison officer, who provides guidance on what to do in the event of a warning being issued. Social media channels and WhatsApp groups are also utilised depending on the magnitude of the risk. The SAWS also provides warnings directly to the public on its own channels. Each month, awareness campaigns are held in different regions of the city, with regional managers working directly with community leaders and structures to provide advice and encourage better preparation for emergencies. Trained Community Response Teams can support evacuation in instances of flooding.

CHALLENGES

Key issues include the encroachment of settlements into floodplains and wetland areas and the maintenance of stormwater drainage and pollution. Although the Emergency Services Department has the relevant resources and experience, the team is overstretched, with each region of the city being too large for one manager to cover.

The city requested support for:

- improved methods to disseminate community alerts and notifications to reach all people;
- a monitoring and evaluation method to measure the effectiveness of information and communications;
- a means to integrate information and incident data between various players within the city and beyond its borders; and
- ways to monitor river and dam levels that could lead to flooding in low-lying areas or drought conditions.

POTENTIAL SOLUTIONS

Potential solutions to these challenges can be found in relevant sections of this guide, including the sections on dissemination and communication (particularly the DARAJA case study), and monitoring and warning, where case studies from Buenos Aires and Quezon City demonstrate how a successful monitoring and communications network can be established and integrated.

FLOOD

QUITO, ECUADOR

CONTEXT

The Metropolitan District of Quito has experienced rapid urban growth, particularly along highly exposed areas such as hillsides and stream banks, creating significant risks for populations and infrastructure. In recent decades, the city has suffered from multiple events, including major flash flooding and landslides in 2022 resulting in loss of life and property. Droughts are also common, and have impacted the production of hydroelectricity from the country's reservoirs, leading to power cuts in April 2024.

PROGRESS

The city has conducted studies on its exposure to landslides and flooding, but not a fully developed risk analysis including the location of vulnerable groups. A pilot early warning system project is in place for one creek in the Caupicho river system, incorporating a meteorological station, several video surveillance cameras, and hydrometric scales. The data received from these sources is fed into a management platform by the Metropolitan Emergency Operations Center; alert categories are established at three different levels based on the volume of rainfall, with response procedures in place for each level. Alerts are communicated through community WhatsApp groups, with residents then responsible for activating community sirens and alerting the surrounding population. Residents are also able to issue alerts and share local observations through the groups. At the national level, the Institute of Meteorology and Hydrology provides forecasts and has established three levels of emergency alert for major events. The Quito Responds Plan (El Plan Responde Quito), regulates the response to multiple events in the city and defines the functions and responsibilities of the various institutions involved in the Metropolitan Risk Management System.

CHALLENGES

Despite active community engagement, ensuring that all citizens are motivated to participate in preparedness processes in advance of an event is one of the city's greatest challenges. Other areas where further support is needed include:

- understanding impact and risk scenarios;
- identifying instruments and sensors that can provide more accurate measurements and more real-time information on where flooding is expected; and
- addressing the challenges of equipment maintenance and operation, including funding and capacity building.

POTENTIAL SOLUTIONS

Potential solutions to these challenges can be found in relevant sections of this guide, including the sections on risk knowledge, on the role of remote sensing and community mapping, and dissemination and communication, on how to ensure that different social groups are involved and that messaging is tailored to suit their needs.

REFERENCES

1 CDP. (2024). *83% of world's cities report significant climate hazards.*

2 Newman, R. and Noy, I. (2023). The global costs of extreme weather that are attributable to climate change. *Nature Communications*. 14, Article number: 6103

3 United Nations Office for Disaster Risk Reduction and World Meteorological Organization. (2023). *Global Status of Multi-Hazard Early Warning Systems.*

4 Hallegatte, S., Vogt-Schilb, A., Bangalore M., and Rozenberg, J. (2017). Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters. *World Bank*.

5 United Nations Office for Disaster Risk Reduction. (no date). *Sendai Framework Terminology on Disaster Risk Reduction - Preparedness.*

6 United Nations Office for Disaster Risk Reduction. (no date). *Sendai Framework Terminology on Disaster Risk Reduction - Early warning system.*

7 United Nations. (no date). *Vulnerable Groups.*

8 United Nations. (no date). *Early Warnings For All.*

9 World Meteorological Organization. (no date). *Early Warnings for All.*

10 United Nations Office for Disaster Risk Reduction and World Meteorological Organization. (2023). *Global Status of Multi-Hazard Early Warning Systems*.

11 Climate Risk Early Warnings Systems (CREWS). (2023). *Guidance Document on People-Centered Risk-Informed Early Warning Systems.*

12 Climate Risk Early Warnings Systems (CREWS). (2023). *Guidance Document on People-Centered Risk-Informed Early Warning Systems.*

13 Budimir, M., White, G. and Youds, L. (2024). The Roles of State and Non-State Actors in Early Warning and Early Action. *Risk-informed Early Action Partnership (REAP)*.

14 CDP (2021). *Cities on the route to 2030: Building a zero emissions, resilient planet for all.*

15 Jjemba, E., Khan, R., Heinrich, D., Kruczkiewicz, A., Smarczyk, T. (2023). Urban FbF guidance note for Red Cross Red Crescent National Societies. Guidance Note. *Red Cross Red Crescent Climate Centre*.

16 Heymans, C., Kattan, C., López Pérez, M., and Takeuchi, K. (2022). Urban Drought Risk Management Toolkit for Task Team Leaders in the Southern African Development Community. *World Bank*.

17 Budimir, M., White, G. and Youds, L. (2024). The Roles of State and Non-State Actors in Early Warning and Early Action. *Risk-informed Early Action Partnership (REAP)*.

18 Grant, C. et al. (2021). Baguio City Gender and Inclusion Study. Findings and Solutions to Inform the Baguio City Smart Flood Early Warning System. *Asian Development Bank (ADB)*.

19 Vahlberg, M., Khan, R., Heinrich, D., Jjemba, E., (2022). Early Warning Early Action (EWEA) in Secondary Cities in South Asia. Guidance Note. *Red Cross Red Crescent Climate Centre*.

20 Acland, S., Hollick, S., and Tappendorf, T. (2024). Enhancing inclusion in mobile-enabled risk communications: Lessons from South Africa. *GSMA*.

21 Budimir, M., White, G. and Youds, L. (2024). The Roles of State and Non-State Actors in Early Warning and Early Action. *Risk-informed Early Action Partnership (REAP)*.

22 Practical Action Consulting and Ramboll. (2021). Policy and Practice Recommendations: Towards a Gender Transformative Flood Early Warning System in Baguio City. *Asian Development Bank (ADB)*.

23 Global Disaster Preparedness Center. (2022). *Common Alerting Protocol Implementation*.

24 Acland, S., Hollick, S., and Tappendorf, T. (2024). Enhancing inclusion in mobile-enabled risk communications: Lessons from South Africa. *GSMA*.

25 Budimir, M., White, G. and Youds, L. (2024). The Roles of State and Non-State Actors in Early Warning and Early Action. *Risk-informed Early Action Partnership (REAP)*.

26 Acland, S., Hollick, S., and Tappendorf, T. (2024). Enhancing inclusion in mobile-enabled risk communications: Lessons from South Africa. *GSMA*.

27 Global Facility for Disaster Risk Reduction (GFDRR). (2018). Design for Impact Framework: Integrating Open Data and Risk Communication for Decision-Making. *World Bank Group*.

28 Practical Action Consulting and Ramboll. (2021). Policy and Practice Recommendations: Towards a Gender Transformative Flood Early Warning System in Baguio City. *Asian Development Bank (ADB)*.

29 Acland, S., Hollick, S., and Tappendorf, T. (2024). Enhancing inclusion in mobile-enabled risk communications: Lessons from South Africa. *GSMA*.

30 Climate-ADAPT. (2023). *Water restrictions and water rationing*.

31 Practical Action Consulting and Ramboll. (2021). Policy and Practice Recommendations: Towards a Gender Transformative Flood Early Warning System in Baguio City. *Asian Development Bank (ADB)*.

32 Practical Action Consulting and Ramboll. (2021). Policy and Practice Recommendations: Towards a Gender Transformative Flood Early Warning System in Baguio City. *Asian Development Bank (ADB)*.

33 C40 Cities. (2023). *Disability inclusion in disaster risk management policy paper*.

34 Budimir, M., White, G. and Youds, L. (2024). The Roles of State and Non-State Actors in Early Warning and Early Action. *Risk-informed Early Action Partnership (REAP)*.

C40
CITIES

c40.org