Chapter 4

Disaster risk prevention and mitigation

This chapter analyses disaster risk prevention and mitigation activities, including structural measures (such as dams and levees) and non-structural measures (such as land-use planning, building codes, population relocation, building public awareness of risks and early warning systems). These measures are considered in terms of their importance to achieve Mexico's civil protection goal of reducing disaster damages over the long term. It examines underlying governance challenges to the effective implementation of key disaster risk reduction measures, and the need to base risk prevention policies upon accurate and regularly updated risk identification and risk assessment.

This chapter analyses disaster risk prevention and mitigation activities. This includes structural measures (such as dams and levees) and non-structural measures (such as land-use planning, building codes, relocation, raising public awareness of risks and alerting the population and emergency responders through early warning systems) designed to impede interactions between hazards and the built environment or reduce the intensity-frequency and/or impacts of hazards. The aim is not to analyse the cost-effectiveness of these initiatives, but rather to consider whether an effective mix of federal government support and incentives for individuals to self-protect are in place, and to evaluate their coherence with the roles and objectives SINAPROC sets for itself. The chapter also analyses the linkages between prevention programmes and different phases of the disaster risk management cycle, such as risk identification and risk assessment.

Risk prevention: A SINAPROC priority

Investments in structural measures to prevent or mitigate disaster damages often do not pay-off in the short term. In many countries, both developing and industrialised, there is evidence of under-investment in disaster risk prevention due to competing demands on public resources such as education, health and defence. Investments to protect or reduce the effects of extreme events often fail to garner support over immediate concerns or continuous financing through several electoral cycles.

In Mexico, several policy documents and legal instruments indicate strategic vision, commitment and leadership – the institutional qualities it takes to pursue projects with pay-offs over the long term. While the primary aim of the 2000 General Law on Civil Protection (GLCP) was to establish a legal framework for harmonising civil protection from the national to local levels (see Chapter 2), it also reflected disaster prevention as a key component of Mexico's overall civil protection strategy. In particular, the 2000 General Law:

- raised the need to promote public awareness about natural and man-made risks;
- established the legal basis for what would become FOPREDEN – a specific fund managed by the federal government to finance disaster prevention projects implemented by federal, state and municipal government stakeholders;
- asked the Ministry of Interior (*Secretaría de Gobernación,* SEGOB) to develop and update the National Risk Atlas (see Chapter 3).

The 2001-06 National Programme for Civil Protection placed emphasis on strengthening SINAPROC's role in disaster prevention. It included a Special Programme on Disaster Risk Prevention and Mitigation comprising a list of 60 prevention-oriented projects developed by the National Centre for Prevention of Disasters (*Centro Nacional de Prevención de Desastres*, CENAPRED) from the development of risk atlases to early warning systems (EWSs) and from developing public awareness to the reduction of vulnerability. Although the implementation of this programme was stronger in some areas than others – with for instance only 3 of the 32 projects related to seismic risks implemented due to a lack of financial resources (ECLAC, 2006) – the development of risk atlases, as well as the creation of FOPREDEN, were significant first steps laying the foundation for future disaster prevention.

The *SINAPROC Manual*, published in 2006, re-emphasised the need to address all aspects of the risk management cycle, including not only emergency preparedness, response and reconstruction, but also prevention (see Annex E). The 2008-2012 National

Programme for Civil Protection placed an even heavier focus on disaster prevention in SINAPROC and clearly states it as the new paradigm for integrated risk management, aligned with the National Development Plan. Its specific strategies related to civil protection, territorial development and climate change all insist on the need to reduce the vulnerability of the Mexican territory through prevention measures, such as land-use policies and adaptation to climate change. Finally, the new 2012 General Law states that risk atlases at the national, state and municipal levels will be the legal basis for disaster risk prevention, as well as for land use and building permits.

Reducing physical exposure and vulnerability

Risk prevention policies aim to reduce one of a risk's core components: exposure to hazards and/or vulnerability. Reducing exposure to natural hazards may seek to diminish the frequency or intensity of such phenomena and/or avoid their coincidence in time and space with an asset of value. Depending on the hazard in question, this is more or less feasible and costly. For example, control measures can be put in place to change the width, depth, flow rate and direction of a watercourse, whereas seismic waves may be resisted, but not channelled.

Reducing the vulnerability of assets of value is essentially a matter of enhancing the internal capacity to resist or adapt when exposure is unavoidable. Policies designed to reduce the vulnerability of populations are rather more complex than for material assets, as the underlying variables relate to socio-economic characteristics such as: initial well-being, self-protection, livelihood resilience and social capital, which together characterise a continuum of susceptibility to resilience.

In the course of this review, stakeholders presented several examples of measures to reduce physical exposure to natural hazards. Among the structural measures to reduce flood and tropical cyclone hazards are rainfall storage dams to diminish the peak flows of rivers and dikes to channel water flows to act on the hazard itself. Non-structural measures, such as land use and urban planning or building codes, can reduce exposure and vulnerability.

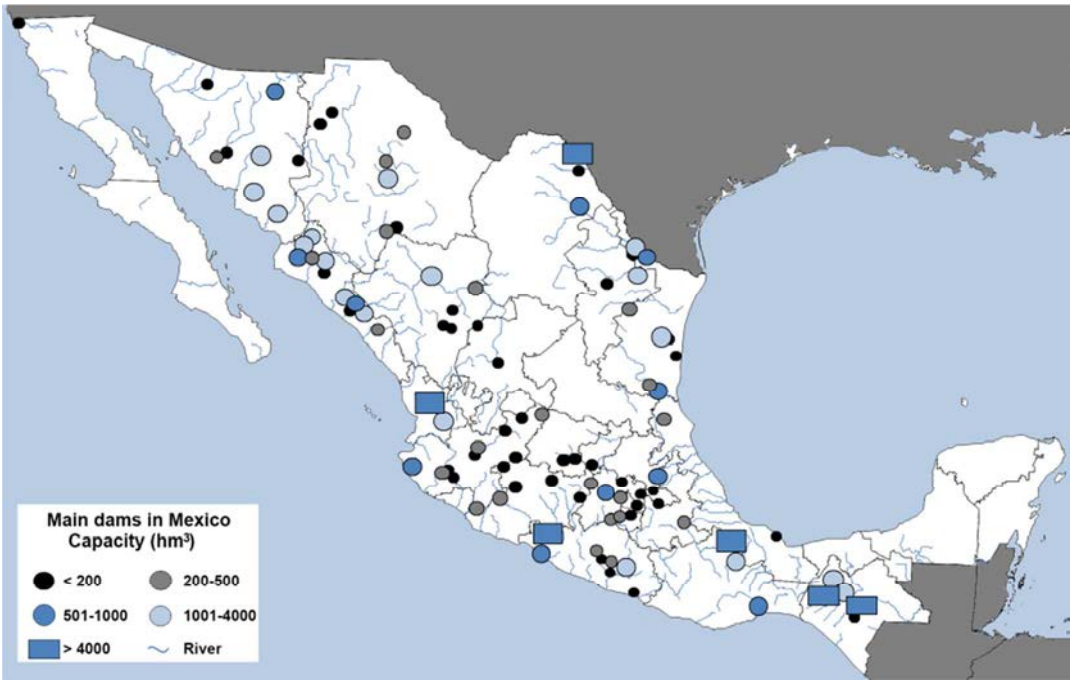
Structural measures to reduce disaster risk

Most of the hydraulic infrastructure in Mexico has been developed by the National Water Commission (*Comisión Nacional del Agua*, CONAGUA), which leads efforts to mitigate hydrometeorological risks such as flooding and tropical cyclones. Mexico has developed a large hydraulic infrastructure network to store water: approximately 4 000 dams, of which 667 are large ones (CONAGUA, 2010a). The purpose of the dams is principally for irrigation, but some also serve to produce electricity, supply drinking water and regulate water flow for flood control.

CONAGUA is also currently implementing two major projects in large flood-prone areas in the country: the Integrated Hydraulic Plan of Tabasco (*Plan Hidrico Integral de Tabasco*, PHIT) and the Hydraulic Sustainability Programme of the Mexico Valley. The PHIT was initiated after the devastating flood in 2007 in the state of Tabasco with the aim to protect all of the state's population centres with the construction of embankments, dikes and protection walls; river drainage; flood control infrastructures and other structural work. It has cost MXN 9.4 billion over the past five years, with the technical support of the National Autonomous University of Mexico (*Universidad Nacional Autónoma de México,* UNAM). Still, this remains a challenging task. According to an

ongoing audit of the Federal Superior Auditor, the plan was not sufficiently detailed technically, the expected objectives were lacking, the cost-benefit analysis was limited and the consultation with UNAM insufficient (Federal Superior Auditor, 2011).

Figure 4.1. **Major dams in Mexico**



Source: CONAGUA (2010), *Atlas digital del agua México 2010* (Mexico 2010 Digital Water Atlas), CONAGUA, Mexico City, *www.conagua.gob.mx/atlas/#.*

CONAGUA also administers an important flood protection project in the Valley of Mexico. The Hydraulic Sustainability Programme of the Mexico Valley (*Programa de Sustentabilidad Hídrica del Valle de México*) is a major hydraulic project integrating all water-related issues, from water supply to wastewater treatment and groundwater over-exploitation. One of its objectives is to reduce the flood risk in Mexico City. As the city was built on an ancient lake, there is no natural way to drain water out of the valley. In the 19th century, a drainage system was built and has been expanded over the years. The current project involves the construction of a tunnel 62 kilometres long and 7 metres wide that would add a new drainage branch to the existing hydraulic system of the Mexico Valley for an estimated cost of MXN 13 billion (CONAGUA, 2010b). It also plans to reduce subsidence in the Mexico Valley, which is a major cause of increased vulnerability of buildings to earthquakes, through the reduction of the overexploited aquifer.

Implementation and maintenance of flood risk infrastructure is a challenge. Such major projects entail environmental costs – for example, ecosystem degradation and erosion – as well as governance challenges related to relocation and the impact on human activities, and may require specific provisions to ensure integrity in the disbursement of public funds. Non-structural measures, such as land-use restrictions and urban development plans to reduce the exposure and vulnerability of human settlements, in conjunction with enhanced risk awareness and better emergency preparedness, may offer a cost-effective alternative. In addition, poorly maintained hydraulic infrastructures have

led to emergencies that require the intervention of civil protection services. These options should be taken into consideration when planning such major investments.

Box 4.1. **Assessing the risk of flood defence failures in the United States**

In periods of extremely high precipitation, the flood scenarios that pose the greatest level of risk to populations and economic activity involve a failure of flood control assets, such as dikes, levies and floodwalls. Risk analysis (hazard, exposure and vulnerability) should therefore take into account the possibility of such failures, but modelling failure requires accurate information about the condition and maintenance of flood defence assets. Most countries, however, do not keep complete and accurate inventories of these assets, much less databases that provide up-to-date and publicly available information about their condition and maintenance. Countries such as the United States (National Levee Database), France (BARDIGUES), and the United Kingdom have made progress in this direction.

In the United States, the Army Corps of Engineers launched the National Levee Database in 2011. It currently includes information on 92% of federal levee systems and plans are to expand the database to include other flood protection systems and to reflect new inspections as reports become available. In addition to physical data points such as location and length of the system, the public can view when the last inspection was performed and a qualitative rating such as acceptable, minimally acceptable and unacceptable, which could help decision makers target limited resources for maintenance. Among the database's impressive features is a mapping tool, which uses Google Earth to enable users to see component parts of a levee system and overlay federal data sets for flood insurance rate maps, data from the U.S. Geological Survey, real-time weather conditions and forecast water levels. In addition to facilitating risk assessments, these tools link activities, such as flood risk communication, levee system evaluation for the NFIP, and flood plain management. Among the parties that could benefit from these features are flood plain managers; levee and drainage district officials; private users, such as property owners protected by a levee; and purchasers or lessees performing real estate due diligence.

Lessons learnt from this experience include a need for building and continuously updating and improving databases of flood defences and their condition to help target investment more precisely to where it is most needed. Currently, significant variability exists between countries with regard to the completeness of such databases, their openness to the public and transparency about the evaluations conducted of the protective assets covered. One challenge to building and maintaining these data sets is cost, but the benefit would be to motivate exposed communities to support their continuance.

Source: National Levee Database website, *http://nld.usace.army.mil/egis/f?p=471:1:1983829781918781*.

In this respect, the development of CONAGUA's 2030 National Water Agenda published in 2011 might indicate a shift in CONAGUA's approach to flood risk reduction. On the one hand, one of the four challenges it identified relates to reducing flood disaster risk, and all of the identified initiatives are non-structural with a strong focus on land use and territorial planning (Table 4.1). On the other hand, an investment programme of MXN 107 billion is targeted at drainage and river control (SEMARNAT, 2011). In the recent OECD Study on Water: *Making Water Reform Happen in Mexico* (2013), it was recommended that Mexico should pay more attention to the cost-effectiveness of water-related spending and decisions (Box 4.2).

Table 4.1. **Initiatives related to flood risk reduction in the CONAGUA 2030 Water Agenda**

CONAGUA: Water Agenda 2030 – initiatives and actions for the development of safe settlements for catastrophic floods	
Initiative 1	Create a Ministry of Territorial Development for the establishment of a long-term urban development policy.
Initiative 2	Create and gradually implement a mandatory programme for territorial ecological development in all Mexican municipalities, expanding its impact to urban areas.
Initiative 3	Create a National Observatory for Sustainable Territorial Development.
Initiative 4	Include the preventive evacuation of population under imminent risk in the DN-III emergency plan of the Ministry of National Defence.
Initiative 5	Increase investment focused on the development of risk maps of floods; definition of riverbeds, federal areas and flood areas; construction of protection infrastructure and maintenance of current hydraulic infrastructure.
Initiative 6	Strengthen the civil protection capacities of the municipalities.
Initiative 7	Consolidate the national and regional hydrological services.
Initiative 8	Speed-up the updating programme of the National Meteorological Service.
Initiative 9	Increase the sanctions applied to public servants who allow the non-compliance of urban development plans.

Source: SEMARNAT (2011), 2030 National Water Agenda, SEMARNAT, Mexico City, *www.conagua.gob.mx/CONAGUA07/Temas/AgendadelAgua2030.pdf*.

Box 4.2. **OECD review on water policies in Mexico**

The OECD/Mexico policy dialogue carried out in 2012 focused on four key areas identified as essential drivers for water reform: multi-level governance, river basin governance, economic efficiency and financial sustainability of water policies, and regulation of water supply and sanitation provision. The OECD review provided the following messages:

- Mexico has the opportunity to invent its own model for water governance. As a federal country, with large regional socio-economic and environmental disparities, Mexico would benefit from place-based responses to water challenges.
- Mexico needs to bring more flexibility into its water policies to ensure they can meet future challenges. Given climate change impacts and uncertainties about future water availability and demand, managing risks and trade-offs requires flexible, smart and green water policies to avoid being locked into sub-optimal options.
- Mexico needs to set incentives for policy coherence in support of inclusive, sustainable and efficient water policy. This implies, for example, removing harmful energy subsidies that work against water policy objectives, increase costs and put water security at risk in several basins. Pilot programmes that work well on the ground need to be scaled-up.
- Mexico needs to pay more attention to the cost-effectiveness of water-related spending and decisions. Well-targeted and cost-effective public expenditures and investments require co-ordination between departments and levels of government, access to other potential sources of financing and further incentives for efficient water use.
- Mexico needs to improve regulatory frameworks for better access to and the quality of water and sanitation services. Regulatory functions need to be properly designed and allocated across actors and places, and major gaps still need to be identified and bridged.

Meeting the water reform challenge in Mexico requires action on several fronts. Making Water Reform Happen in Mexico (OECD, 2013) highlights a number of levers that a new administration may wish to consider for setting up a cohesive and cost-effective water policy framework in Mexico.

Source: OECD (2013), *Making Water Reform Happen in Mexico*, OECD Publishing, doi: *10.1787/9789264187894-en*.

Land use and urban development

According to most SINAPROC stakeholders from federal, state and municipal levels, land use and urban planning is the most pressing challenge Mexico needs to face to reduce risks. As mentioned in Chapter 1, Mexico's rapid and continuous urbanisation linked to migration, both to metropolitan areas as well as to small and medium cities, tends to increase its exposure and vulnerability to disasters. Indeed, as this urban development was not planned nor accompanied with appropriate land-use policies or the development of infrastructures and basic services, some cities in Mexico have grown by the extension of informal settlements in hazard-prone areas. These "*colonias populares*" gradually received attention from the local and federal authorities through social programmes such as Programme HABITAT of the Ministry of Social Development (*Secretaría de Desarrollo Social*, SEDESOL), but they still concentrate most of the vulnerabilities in the country and cities are still expanding with new informal settlements in always more vulnerable and hazard-prone areas, such as river banks or unstable hills.

As in many OECD countries, changes to land-use policy require strong political will to reconcile vested interests. Competence for land use and planning is determined by Mexico's federal Constitution, specifically Article 27, which specifies the role of the federal government in land management, and Article 115.V, which entitles municipalities to manage land-use policies and building permits in their jurisdictions. Still, the federal government is responsible for managing 40% of the national territory: the Ministry of the Environment and Natural Resources (*Secretaría de Medio Ambiente y Recursos Naturales*, SEMARNAT) regulates the natural resources, the seas and the beaches; CONAGUA the riverbeds and their banks; the National Forest Commission (*Comisión Nacional Forestal*, CONAFOR) the forests; the Ministry of Communications and Transport (*Secretaría de Comunicaciones y Transportes*, SCT) the federal roads, etc. This fragmented landscape of federal competence overlaps with those of the states and municipalities, which has in some cases meant that regulations are not enforced (Box 4.3).

Box 4.3. **Informal settlements along the Río Santa Catarina in the Monterrey metropolitan area**

Informal settlements on the embankments of the Río Santa Catarina in the metropolitan area of Monterrey are located both on CONAGUA federal property and within the territorial jurisdiction of some municipalities. Before Hurricane Alex, CONAGUA had leased land to the municipality of Monterrey inside the river bed, where the city granted commercial concessions for an open market and other activities.

Neither federal nor local governments made an effort to remove the population from these informal dwellings, which had been illegally established in hazardous zones. While cities and towns in the metropolitan area of Monterrey are in charge of their urban development plans, their responsibility does not extend to federal lands. The municipalities, therefore, did not see themselves as competent to take enforcement actions on federal land; CONAGUA did not see its mandate as exercising police power to forcefully remove a population from dwellings.

Both Hurricanes Alex and Gilbert flooded the Río Santa Catarina, causing massive damages to these settlements. The responsibility to rescue this population fell directly to municipal and state civil protection services, which created an incentive for them to prevent the repopulation of these areas after the disaster. However, many invasive settlements were rebuilt along the river bank and are occupied as highly vulnerable shanty dwellings. The collective inaction is indicative of a clear governance deficit that could be rectified.

Source: Interviews with stakeholders.

Municipalities are mandated by the Constitution to develop their own urban development plans. Making vulnerability reduction a priority of these plans requires, first, to develop risk assessment at the municipal scale to map high risk zones, then to develop construction rules in these zones and/or other measures to reduce the exposure and vulnerability of existing construction and housing, such as retrofitting and possibly relocation. As municipal governments are elected for a single, non-renewable three-year term of office and their technical and financial capacities to develop plans taking such criteria into account are often limited, various incentives and support mechanisms have been established by the federal and state governments to support this process.

SEDESOL is the key federal ministry with regard to urban development issues in Mexico. Specific national urban development and territorial planning programmes were designed by SEDESOL in 1995-2001 and in 2001-06, and had among their objectives to foster better urban planning and reduce hazard vulnerabilities. The implementation and impacts of these regulations and strategies were limited. No such national programme was developed for 2007-2012 but these objectives were still included in SEDESOL's sectoral programme based on the National Development Plan. In 2011, SEDESOL initiated its Programme of Risk Prevention for Human Settlements (*Programa de Prevención de Riesgos en los Asentamientos Humanos*, PRAH), which provides studies and advice to reduce exposure and vulnerability in "high risk" and "very high risk" municipalities. In addition to the development of risk atlases (Chapter 3), the PRAH can finance studies for relocating settlements located in hazard-prone areas up to MXN 1 million. While the PRAH budget reached MXN 190 million in 2011, it was reduced by 75% in 2012 due to budget reallocation within SEDESOL social programmes. Another important programme managed by SEDESOL is HABITAT, which supplies basic services to poor settlements such as water, energy and sewage. Established in 2003 as the key federal programme to reduce poverty, HABITAT has reduced the informality of many *colonias populares* by investing in water supply and sanitation, electricity, public infrastructures and other services with annual resources close to MXN 3 billion. In doing so, it has participated in settling communities in hazard-prone areas, despite the fact it specifically included risk reduction as one of its objectives before PRAH was created.

SEMARNAT, through the General Law for Ecological Equilibrium and Environmental Protection (revised in 2012) (see Annex C), has been mandated to regulate land use. Through this law, SEMARNAT can deny a construction permit based on criteria that take into account natural hazards. Furthermore, its environmental attorney agency can close buildings and impose fines if the limits within the permit are not respected. However, this instrument, which can only be utilised on federally regulated land, is not fully implemented and is often challenged at the local level. In addition, this law regulates the environmental plans to be developed at national, regional and local levels as well as for maritime areas. In the development of these environmental plans, SEMARNAT provides technical support at the local level, but as the states and municipalities are responsible for issuing the plan, SEMARNAT's recommendations are not always taken into account. For example, during the development of the environmental land-use plan of the city of La Paz in Baja California, a large participatory process involving the municipalities, SEMARNAT, academics, the private sector and civil society was established. When SEMARNAT initiated discussions about limiting coastal construction, consensus could no longer be reached. The plan was finally adopted by the municipality without these specific rules.

Box 4.4. Land-use practices at the local level: Tabasco and Tamaulipas

Tabasco

The state of Tabasco revealed the need to review the boundaries of zones exposed to flood hazard and to implement land-use policies as disaster prevention measures. After the 2007 floods, a major surveying project was undertaken to update flood hazard zones. To discourage new construction in these areas, these zones were designated as hazardous areas in the Public Registry of Property (a cadastre for the registration of private real estate) so that any future potential buyers of the land could be informed.

Tamaulipas

Informal settlements in hazardous zones create the conditions for large-scale emergencies and constitute a significant challenge for civil protection services. Some individuals encourage people to build or squat dwellings in such areas with a view to pressure local governments to eventually legalise these illegal dwellings, possibly obtaining an economical benefit from them. The state of Tamaulipas has addressed this problem by penalising persons who encourage the population to build in such areas. These penalties are extended to owners who may permit illegal dwellings on their properties without informing the corresponding authorities. The law also penalises public servants who issue permits to build or use land in restricted areas. The state government has perceived a decrease in the quantity of illegal dwellings in Tamaulipas and a reduction of the negative externalities that they produce, which it attributes to these measures.

Source: Meetings held with the states of Tabasco and Tamaulipas during the OECD mission (May 2012).

The federal government has some limited leeway through various agencies and incentive instruments to influence local planning, but the federal Constitution primarily reserves competence in this area for the municipalities. SEDESOL has been active in this area in its programmes to fight poverty in municipalities, but results are limited, as informal settlements continue to increase: more than 250 000 were built illegally every year between 2000 and 2007. In 2008, this represented 60% of the new settlements built (Rodríguez-Oreggia et al., 2008). The environmental approach promoted and managed by SEMARNAT is a new tool for incentivising municipalities and claims to address this challenge, even though it has limited power. Many stakeholders consider the effects of these incentives to be too weak to ensure that local development planning properly takes vulnerability reduction into account.

The current institutional setting makes it difficult to build a joint approach to reduce the exposure of informal settlements. This requires appropriate instruments to strengthen the capacities of the 2 440 Mexican municipalities. CONAGUA made a proposal to create a dedicated Ministry for Territorial Planning in its 2030 National Water Agenda, and to strengthen the capacities of the municipalities. Different SINAPROC stakeholders suggest amending the federal Constitution and the balance of power between the three levels of government with respect to land use. The recently adopted 2012 General Law for Civil Protection states that risk atlases will now be binding instruments for the development of land-use plans at the municipal and state level. As these tools are in the process of being developed, territorial planning will remain on the front line of the policy agenda in the coming years. Ultimately, significant efforts would need to be made to prevent any increases to the already substantive population in highly exposed areas; reducing this number would also need to give support for moving people out of highly exposed areas.

Building codes and retrofitting

Improvements to building codes that enable new buildings to better resist earthquakes or enhance protection against floods, are an effective way to reduce two of the main vulnerabilities in Mexico to large-scale disasters. The building code of Mexico City was revised after 1985 based on an updated seismic risk analysis and updated again in 2004. Building regulations in the Federal District take into account the different sub-soil conditions and acceleration rates to define what types of constructions may be built in different areas of the city. As a consequence, buildings constructed post-1985 should be safer than those built prior to it. A large-scale project to retrofit schools, financed by a World Bank reconstruction loan, was undertaken to comply with the new standards. Between 1986 and 1991, 2 400 educational facilities were rehabilitated. Over the past two decades, CENAPRED has participated in the development and updating of construction regulations, conducting experimental research and convening specialists in technical committees to improve the seismic safety of structures against phenomena such as earthquakes, high winds, flooding or other forces that may arise during a building's foreseeable period of use.

The building stock still includes many older constructions, however, retrofitting them to comply with the new building codes comes at a high cost. There is no specific funding mechanism to support the retrofitting of private property, nor are tax deductions made available as an incentive for making such capital investments. In 1998, the Federal District required private buildings that conduct economic activity to be capable of withstanding an 8.0 magnitude earthquake to validate their internal civil protection programme, but did not offer any specific financial support to this end. The Federal District, through its Institute for Housing, can support poor households for seismic retrofitting, but apparently this programme is far from being fully implemented. There is also a specific programme for seismic retrofitting of hospitals called Safe Hospital (see Box 4.6).

Mexico City, with its high exposure to earthquakes and living memory of the 1985 events, has the most advanced building code in Mexico. Outside of the Federal District, building codes are, in theory, defined at the municipal level, but many municipalities do not have sufficient resources to create such codes. The building codes of many municipalities have not been revised for years, if not decades, and thus do not incorporate seismic codes, which means construction is unregulated for seismic risks in many areas. Some municipalities, such as Tuxla Gutiérrez in Chiapas, have adopted another municipality's code, in particular the one for the Federal District, which is not appropriate for their level of risk.

This reflects a challenge in terms of capacity at the local level, which although not specific to Mexico, is compounded by the size of the country and the diversity and the level of risks faced in various areas. In some cases, legislation has been passed at the local level to encourage the development of building codes. For instance, in 2009, the Urban Development Code of the state of Jalisco made it mandatory for municipalities to create their own building codes. SEDESOL's risk prevention programme PRAH can finance the development of building codes at the municipal level. However, the cost-sharing burden for municipalities (35% minimum) may still be too high for municipal budgets. In Chiapas, the seismic micro-zoning financed at the state level is a good practice that could be replicated in other states to inform the development of adapted building codes (Box 4.5). The role of the Federal Electricity Commission (*Comisión Federal de Electricidad*, CFE) also has to be highlighted, as its *Manual on Civil Works*

serves as a reference nationwide for the construction of earthquake- and wind-resistant infrastructures and buildings; it has been updated several times (most recently in 2008). In addition, the "SCT Regulations" set out homogenised guidelines for the construction of highways across Mexico. Finally, CENAPRED also plays an important role in this area, through its specific laboratory that tests structures' resistance to earthquakes; initially financed through Japanese co-operation after the 1985 earthquake, it is the technical basis for the improvement or creation of building codes.

Box 4.5. **Chiapas: Seismic micro-zoning to support building codes at municipal level**

One-third of earthquakes in Mexico have their epicentre in Chiapas. That is why the state of Chiapas has decided to strengthen its building codes and construction regulations. The objective is to create and implement a new seismic micro-zoning system. With support from the UNDP, the UNAM's Geophysics Institute and the National Seismological Service (SSN), the state is developing a micro-zoning system for its two largest cities: Tuxtla Gutierrez and Tapachula. The project includes the installation of seismographs in all government buildings and infrastructure and is intended to be developed in other municipalities within the state as well.

Currently, the Chiapas Civil Protection Institute for the Integral Disaster Risk Management (IPC) has started to develop this zoning in the state's capital, Tuxtla Gutiérrez. A high-technology laboratory will be created with seismic radars and accelerographs. The data thus obtained will be analysed to determine risk zones and update risk maps. In addition, the project aims to update the city's building regulations in order to define criteria to build earthquake-resilient infrastructures.

A seismic micro-zoning project is also being developed in Tapachula with the support of the Autonomous University of Chiapas (Universidad Autónoma de Chiapas, UNACH), the Tapachula Technological Institute (Instituto Tecnológico de Tapachula) and UNAM. One of its main objectives is to develop technical construction norms for the city. The first part of the project was developed in 2011 to measure the dynamic characteristics of earthquakes. The project also includes the establishment of a laboratory for the identification, mapping and monitoring of natural phenomena, including the activity of the Tacaná Volcano and seismic activity.

Source: Based on information provided by the Civil Protection Institute of the state of Chiapas.

Building codes can also be used to reduce vulnerability to floods, hurricanes and tsunamis, but it appears that, in Mexico, they are mostly focused on the risk of earthquakes. Recent disaster events such as the January 2010 earthquake in Chile and the 2011 Great East Japan Earthquake both triggered major tsunamis, which were the source of most of the damages to lives, livelihoods and infrastructures associated with these events.

With the adoption of the 2012 General Law for Civil Protection, which considers risk atlases as the reference for the construction of new buildings, the design of appropriate building codes at municipal level is a key challenge in the years to come. Developing such instruments requires specific technical knowledge, which presents some municipalities a challenging task.

Box 4.6. **Safe Hospital and Safe School programmes in Mexico**

Following a resolution of the Pan-American Health Organization (PAHO), in 2006 Mexico created the Safe Hospital Programme (Programa Hospital Seguro), co-ordinated by SEGOB and the Ministry of Health. Its objectives are included in the Action Framework of Safe Hospitals 2010-15 of the PAHO and give priority to the assessment, classification and certification of hospitals according to indicators aimed at measuring their level of safety in case of disaster. Hospitals are assessed to identify their level of exposure to risks according to an index of hospital safety designed by the PAHO (145 item checklist). A plan of actions is then developed to reduce the hospital's vulnerability, as well as to ensure that it can appropriately evacuate its patients, maintain critical operations and provide medical care to an important number of victims in case of a disaster. According to these criteria, 200 hospitals in Mexico have been classified as safe and prepared for disaster.

Regarding schools, two complementary programmes aim at reducing the vulnerability to disasters of the 246 000 schools in Mexico. On one side, an internal programme of school safety (Programa Internal de Escuela Segura, PISE) must be elaborated in each school according to the guidelines set out by the Ministry of Education and SINAPROC, which are aligned with the United Nations International Strategy for Disaster Reduction (UNISDR) programme "Disaster Prevention Begins at School" (2006). Internal programmes of school safety are organised around six main areas targeting the entire risk cycle: i) the creation of a committee of health and school safety as well as emergency brigades; ii) internal and external risk assessment (including a vulnerabilities approach); iii) training; iv) civil protection equipment (including signposting, warnings); v) drills; and vi) maintenance programmes.

Reducing the structural vulnerability of schools is an ongoing objective of the National Institute of Educational Physical infrastructure (Instituto Nacional de la Infraestructura Física Educativa, INIFED) which has the normative power to assess the quality of educational infrastructure. A series of rules were issued in co-operation with CENAPRED to determine the criteria for selecting school locations related to the proximity to coasts, volcanoes and the stability of hillsides, among others. In addition, INIFED conducts visits to assess schools' infrastructure vulnerability. Currently, around 25 000 schools are assessed annually.

The Safe Schools and Safe Hospital programmes are initiatives that are promoted worldwide by the UNISDR.

Source: Based on information provided by the SEP, INIFED and SEGOB.

Strengthening the risk culture

Strengthening the risk culture at all levels of the civil society is an integral part of risk prevention. Mexico has put in place numerous institutional mechanisms to increasingly disseminate a culture of prevention. Since its creation in 1988, CENAPRED has been at the forefront of these efforts, leading the elaboration of initiatives related to increasing the population's awareness of risks, including both knowledge of hazards, exposure and vulnerabilities, as well as the understanding of prevention actions and emergency preparedness procedures.

Engaging with citizens

With an average budget of MXN 700 000 for the development and diffusion of risk education materials during the last 10 years, CENAPRED has developed a series of pamphlets, guides, games, videos and other educational materials for all categories of the population. This risk education policy specifically targets the rural population and school

children, as they can disseminate their knowledge to their family. Rural communities are a particularly vulnerable population, as they are often isolated and must count on themselves when a disaster happens. Therefore, fostering a culture of self-protection is crucial.

The illustrated pamphlets developed for the general population offer synthetic information that first explain the nature of hazards and exposure to it, illustrate the measures to take to reduce damages and provide specific information on the EWS signals and other civil protection processes to follow in case of disaster. One of these series is the "What to do in case of", which is designed to provide information on earthquakes, floods, tropical cyclones, etc. They also promote the elaboration of a family plan, including: the identification of the specific risks of the household (structural vulnerability) and the elaboration of a family evacuation plan. Finally, a house damage assessment information sheet is attached to the document and can be directly transmitted to civil protection authorities in charge of recovery and reconstruction. This kind of pamphlet offers practical and useful information, explained in a simple way, which can be understood by the general population, and addresses all of the phases of the risk cycle, from risk assessment to vulnerability reduction, emergency preparedness, and response and reconstruction. However, they may not be able to convey their message to the most deprived social groups, which may be illiterate, and who are exposed to high risk areas.

The dissemination strategy of these educational materials is based on the massive distribution of pamphlets and publications and public access through the web. Although CENAPRED has more than 14 000 prevention-related publications, its budget is not sufficient to widely disseminate these materials to the population. In 2011 for instance, CENAPRED received specific federal funding of MXN 50 million to widely spread the culture of civil protection for earthquakes, which represented 70 times its annual budget for the promotion of prevention for all disasters. Risk communication strategies are also co-ordinated with the Ministry of Public Education (*Secretaría de Educación Pública*, SEP) to disseminate prevention information to children in schools at the elementary and secondary level. Since 2009, primary school programmes have integrated a dimension of risk management in their curricula in history, ethics, Spanish, natural sciences, mathematics and geography. Furthermore, SEP distributes free books including prevention information to each level of the primary education cycle.

Finally, the General Co-ordination of Civil Protection (*Coordinación General de Protección Civil*, CGPC) and the state civil protection authorities organise civil protection days at the state level to foster the development of the culture of risk among citizens (Box 4.7). Moreover, the development of communitarian brigades is being supported by the federal government. The purpose of these brigades is to provide training on basic emergency response and risk information to the population on the community level. Municipalities like Monterrey in Nuevo León, Guadalajara in Jalisco and the Cuauhtémoc borough in the Federal District have implemented such brigades.

Educating civil protection stakeholders

The quality and continuity of risk prevention activities as a coherent feature of SINAPROC is strengthened by the knowledge and technical expertise of the professionals working within civil protection services. To strengthen the risk prevention culture, the National Civil Protection Program 2008-2012 highlighted the need to establish a National Civil Protection School to standardise areas of studies, levels of specialisation and implement tools to qualify civil protection personnel. The main objective of this school,

established in 2011, is to certify competencies for civil protection specialists. CENAPRED will develop the school's curricula, which is meant to deliver technical-professional degrees and should provide technical assistance to other schools of civil protection at state and municipal level as well as to local communities. Its three main headquarters are located in San Luis de Potosí, Chiapas and Querétaro. This federal initiative is described by the DGPC as an important step towards a more professionalised civil protection system in Mexico, which could help to build a commonly shared understanding of the civil protection culture. It should be noted that several stakeholders working in civil protection services contest the usefulness of the National School on the grounds that the trainers know less than the professionals being trained. The system's certification requirement as an employment condition for certain positions and career advancement does not attribute proper value to work experience and education attained outside of the National School.

Box 4.7. **National Days of Civil Protection**

Improving the civil protection culture is one of SINAPROC's main objectives: population awareness is a crucial element of an effective civil protection system. Self-protection capacities play an important role during emergency response. The population's knowledge on the procedures to be followed during an emergency is a key element for risk management. The Days of Civil Protection (DCP) have been created with these objectives in mind, and are highly promoted by the General Directorate of Civil Protection (Dirección General de Protección Civil, DGPC).

The purpose of these public events is to inform the population of risks. They focus on developing self-protection capacities among the population. The wide range of climates and risks in Mexico make it necessary not only to provide this information to the population but also to regionalise it. Regional days of civil protection integrate preparation on common risks for certain regions in the country regardless of political boundaries.

During these events, held annually in several states and municipalities, training and workshops are organised to train local authorities and promote the federal government's initiatives in civil protection, such as the existing financing tools for prevention and reconstruction: the Safe Cities are Resistant to Disasters (Box 5.1) and Safe Hospital (Box 4.5) programmes. Specific events for rural communities, for school children, for company workers, as well as a civil protection fair accessible to all citizens, aim to disseminate this prevention culture as widely as possible.

In parallel, the DCPs give the population the opportunity to provide inputs for policy making. The use of questionnaires during the DCPs allowed the population to participate in the development of the National Plan of Civil Protection 2008-2012. This allowed policy makers to take citizens' perspective into account, thus opening a dialogue channel between the state and the population, making the DCP a valuable mechanism not only for building capacities within the population but for increasing the efficiency of the government's programmes and plans.

Source: Based on information provided by the DGPC and CENAPRED.

Another key element for fostering the development of the culture of risk from the federal level to the local level is the development of the Safe Cities are Resistant to Disasters programme (see Chapter 5, Box 5.1) targeted at municipalities. This benchmarking programme is based on emulation among municipalities to prioritise civil protection.

Box 4.8. The Prevention Program of Civil Protection (PP5) in Chiapas

In 2009, Chiapas, with support from the UNDP and the UNAM's Geophysics Institute, presented the "Prevention Program of Civil Protection" (Programa Preventivo de Protección Civil, PP5)" to FOPREDEN. The approved project, for a total of MXN 58.9 million, was co-financed by FOPREDEN (70%) and the government of Chiapas (30%).[1]

The PP5's objective is to train the population in the most risk-exposed municipalities in the state. Integrating an integral risk management approach, it is oriented to risk prevention and emergency response at the community level. The fact that the plan is implemented at the community level is one of its main strengths. This ensures the continuity of the PP5 as communities are not affected by the changes in local governments which occur every three years.

The plan starts with the creation of community committees of civil protection (CCCP), made up of community volunteers. As these volunteers have the best knowledge of their own area's exposure to risks, they are considered to be a reliable source of information for decision makers. All CCCPs receive training providing them with the capacity to develop their own community plan of civil protection. Training is focused on integral risk management, analysis and assessment of local risks, evaluation of damages and needs in emergency situations, and emergency planning. In addition, the PP5 encourages the establishment of radio-communication systems in community leaders' homes. These leaders are in charge of identifying and monitoring risk, thus ensuring a co-ordinated and permanent communication network comprising community committees, municipal and state civil protection offices. The plan also contemplates the development of a geographic information system (GIS) to systematically gather municipalities' and communities' civil protection data.

The PP5 was first developed in the ten most risk-exposed communities in Chiapas, determined according to Chiapas' Risk Atlas and social indicators. During this first stage, 106 community committees and community civil protection plans were created. In addition, 10 municipal risk atlases have been developed and 400 radio-communication systems installed. The second part of the plan concerned the remaining 112 municipalities in Chiapas. As a whole, more than 2 500 community committees have been created and trained, reaching the 122 municipalities in the state. The communication network now integrates over 3 500 radio-communication systems connecting federal and state ministries, the municipalities and the community committees.

Note: 1. This budget comprises the 2009 and 2010 stages of the Integrated System of Civil Protection for Risk Prevention of Natural Disasters. These two stages are considered to be two different projects.

Source: Based on information provided by the State of Chiapas and Chiapas Civil Protection System website, *www.proteccioncivil.chiapas.gob.mx/site/index.php*.

In order to involve the entire civil society in the prevention strategy, the federal government has encouraged the development of family plans of civil protection (*Plan Familiar de Proteccion Civil*, CENAPRED, 2007). This programme aims at helping each family in a personalised way to create their own emergency response plan taking into consideration the specificities of their house and neighbourhood. The plan is structured in four sections: house safety, risk exposure, reaction and drills. The main advantage of this kind of initiative is that it allows authorities to disseminate prevention culture in a pedagogic and dynamic way directly to families, including sectors of the population that do not have access to this information (the elderly for example). On the other hand, it is difficult to assess the impact of this programme or the number of households that have actually created such a plan.

The federal initiatives to expand and enhance a culture of prevention achieved broad uptake amongst the general population. While many programmes focus on special sectors of the population, such as rural communities, school children and the labour force, they have been less effective with indigenous populations who are not easily reached by educational campaigns. Moreover, considering that most of the prevention information is distributed in paper format, illiterate people are excluded. The Ministry of Tourism has made efforts to provide information related to prevention to tourists, who often confront linguistic barriers, and who are often difficult to inform.

Box 4.9. **Identification and communication of risks at local level in France**

In France, regulatory documents must be prepared at local administrative levels (district and municipality) related to the communication of information about risks to citizens.

At the district level, the District Major Risks Report (*Dossier départemental des risques majeurs*, DDRM) is developed under the central government's responsibility to inform all government services about the hazards and risks facing the different municipalities within the district. The DDRM lists all major risks identified in the district as well as their foreseeable impacts on persons, property and the environment, on the basis of available knowledge. It highlights any exposed critical sites, particularly in built-up areas; lists prevention, protection and safeguard measures; and describes the mitigation modes that can be implemented to alleviate impacts of natural hazards, depending on its intensity and the vulnerability of the exposed critical sites. Prefects are responsible for annually updating the list of municipalities that are mentioned in the DDRM as being subject to specific risks. The DDRM provides background on past events and accidents and summarises the main studies, Internet sites or reference documents available for consultation by those seeking more complete information. The DDRM is updated every five years, and must be publicly accessible to citizens via the Internet.

The central government may require the preparation of a Risk Prevention Plan (*Plan de Prevention des Risques*, PPR) in the municipalities mentioned in the DDRM. The PPR represents one of the essential tools for preventing risks or reducing the vulnerability of persons and property. Based on up-to-date knowledge of natural hazards and critical industrial sites at the local level, the PPR may levy land-use prescriptions upon municipalities, particularly with regard to urbanisation and spatial planning. Its primary goal is to delimit zones exposed to hazards. It produces maps (at least one map providing information on natural phenomena, a map of weather hazards and a map of critical sites) drawn up to medium scale at 1:25 000 or more detailed if available documents so allow. The French Minister of the Environment has introduced specific mechanisms for financing their preparation, and, as a result 7 000 PPRs have now been validated for the 36 000 municipalities in France, with around 500 new PPRs prepared every year (in the long run, 1 out of 2 communes should be covered by a PPR). The completion of a PPR promotes risk awareness by means of in-depth discussions with various administrative officials, elected community representatives, local associations, the private sector, etc. Subsequently, risk-related information is transmitted and circulated to citizens via the Municipal Information Document on Major Risks (*Document d'information communal des risques majeurs*, DICRIM), which can be consulted at the City Hall.

Source: Golnaraghi, M. (2012), *Institutional Partnerships in Multi-Hazard Early Warning Systems*, Springer, World Meteorological Organisation, New York.

The crucial role of early warning systems

A clear and measurable area of SINAPROC's progress over the past two decades is the progressive development and uptake of EWSs for tropical cyclones, floods, tsunamis, earthquakes and volcanoes.

Early warning systems are crucial civil protection tools that have demonstrated their effectiveness in enabling people to take quick action to protect themselves and their property from impending risks. Effective EWSs need to be supported by hazard monitoring and forecasting capacities, and the capacity to aggregate data into risk information that can be delivered as appropriate warning messages. These systems need to be supported by parallel efforts that ensure recipients understand what actions to take. EWSs can also be used to deliver continuous situation awareness for emergency response actions on the ground. Effectiveness hinges on the planning of co-operation and co-ordination processes between technical agencies, civil protection authorities, the media and the population at large.

SIAT-CT, a national tropical cyclone warning system

Tropical cyclone warning systems have to rely upon quality meteorological services. Here, Mexico can count on a variety of monitoring and forecasting capacities, which represents both an opportunity and a challenge. These include first the National Meteorological Service (*Servicio Meteorológico Nacional*, SMN), which is the authoritative provider of meteorological information and services, supplemented by specific systems developed by the Federal Electricity Commission (CFE), Mexican Petroleum (PEMEX), the Navy, some states such as Mexico City and Jalisco, and universities. While a wealth of information can help, it could also represent a challenge if insufficient institutional co-ordination and co-operation, a lack of information exchanges and a multiplicity of weather forecasts were to lead to confusion and duplicity. A system of co-ordination was clearly required and the Early Warning System for Tropical Cyclones (SIAT-CT) was set up in 2000 precisely for these reasons.

The SIAT-CT provides a co-ordinated and harmonised national response through cyclone watches and warnings sent to the states, municipalities, federal agencies and the public at large. Co-ordinated by SEGOB and designed by CENAPRED, the SIAT-CT disseminates incremental colour-coded warning signals (blue, green, yellow, orange or red) based on the cyclone's location and estimated path when a cyclone is approaching (approaching phase) and the inverse as it becomes more distant. An inter-agency group determines the forecast for tropical cyclones, gathering information from various meteorological services (Table 4.2), as well as through international co-operation with the Regional Specialised Meteorological Center of Miami (see Chapter 7). Warning messages include recommendations for action corresponding to each colour for state civil protection authorities, the population, and the maritime and air navigation sectors. These messages are widely distributed through the National Communications Center (*Centro Nacional de Comunicaciones*, CENACOM), the communication infrastructure set up by the DGPC of SEGOB (see Chapter 5).

Table 4.2. **Early warning systems in Mexico**

Hazard	Early warning system	Institutions (*lead institutions)	Coverage	Main characteristics			
				Operational date	Warning products	Lead time	Dissemination process
Earthquake	Earthquake Warning System (*Sistema de Alerta Sismica*, SAS)	CIRES*	Mexico City	1991	Public warnings	60 seconds	VHF radio Blackberry
	Earthquake Warning System for the State of Oaxaca (*Sistema de Alerta Sismica para el Estado de Oaxaca*, SASO)	CIRES*	Oaxaca City	2004		30 seconds	Local radio Public schools
Hurricane	Early Warning System for Tropical Cyclones (*Sistema de Alerta Temprana para Ciclones Tropicales,* SIAT-CT)	SEGOB* SEMAR CFE PEMEX	Nationwide	2000, updated in 2003	Colour-coded warning: blue, green, yellow, orange, red	72 hours	Media channels
Flood	Hydrometeorological Alert System (*Sistema de Alerta Hidrometeorológica*, SAH)[1]	CONAGUA* SMN CENAPRED	Municipal level	Project	Non-standardised, mostly colour-coded warnings	90-120 minutes	Civil protection authorities
Tsunami	Tsunami Warning Center (*Centro de Alerta de Tsunami*, CAT) (international monitoring)	SEMAR* SEGOB PTWC	Pacific coast	Under development	To be developed	Minutes (local tsunamis)	To be developed
	National Tsunami Warning System *(Sistema Nacional de Alerta de Tsunamis,* SINAT) (local monitoring)	SEMAR					

Note: 1. The SAH is a hydrometeorological monitoring system mainly monitoring water levels.

Sources: OECD based on information provided by CENAPRED, CONAGUA, SEGOB and SEMAR.

The SIAT-CT integrates all four components of an efficient EWS:

- the production of hazard forecasts;
- the development of risk information;
- the issuing of warnings;
- linkages to emergency response actions.

This system has proven its effectiveness over the past decade in the lead-up to land fall of several major hurricanes, such as Hurricane Emily in 2005, and more recently during the tropical storm Ernesto in August 2012. In the latter case, 34 warning bulletins were issued and disseminated by CENACOM to 211 SINAPROC stakeholders. Local capacities to ensure "the last mile" of the EWS, that is a warning to the population in a specific location with a clear message about what action to take, have sometimes been inadequate. For example, in Monterrey people died during Hurricane Alex in 2010 because they were in a marketplace in the middle of the river bed even though a red level

warning had been issued, demonstrating the ineffectiveness of warning dissemination and impact.

SIAT-CT also represents a good example of institutional co-operation in Mexico, reflecting an achievement for SEGOB/DGPC's and SINAPROC's leadership function. This also shows the potential for such co-operative arrangements to be used for other hazards as well. Within SIAT-CT, technical organisations, critical infrastructure operators and civil protection authorities work hand in hand at all levels of government. This also helps to develop emergency plans accordingly.

Consensus forecasts are elaborated jointly by the various meteorological organisations, limiting the scope for confusion. Still, these redundancies have a cost and might be more efficiently utilised under a single roof or framework. There could also be opportunities to use the co-ordination frameworks which have been developed for tropical cyclones for other meteorological hazards. For instance, the SMN publishes an average of 6 700 warning bulletins per year and tropical cyclones represent only a limited share of meteorological hazards. Conflicting warning messages are at times issued between these various institutions, such as during a thunderstorm in Mexico City in 2010 between the SMN and the Federal District's meteorological service. The ongoing co-operation between CENAPRED and the Mexican Institute for Water Technology illustrates a step forward in fostering co-ordination. This entails developing an EWS for cold and north fronts, which create winter storms, heavy rainfall and floods.

Flood warning systems at the local level

Unlike tropical cyclones, which can be detected and forecasted several days in advance, some types of floods are difficult to forecast with precision. Monitoring water levels and flow rates and flood forecasting requires significant investments in hydrometeorological stations and modelling at the river basin scale, especially in the case of Mexico where there are nearly 100 river basins with medium to high flood risk. Another difference with tropical cyclones is that floods, even though they can have large-scale impacts, are more of a local issue. Mexico faces different types of flood risks, from flash floods to river or coastal floods, with different time scales. Developing EWSs for all of the flood risks in Mexico is therefore challenging and resource intensive, which explains why these systems are less advanced than those for tropical cyclones.

CENAPRED and CONAGUA have led an effort to develop flood warning systems over the last decade with a focus on the most densely populated areas. FOPREDEN has been instrumental in this process, financing projects at the state and municipal levels. CENAPRED, in particular, developed the methodological approach and the technical tools for the Hydrometeorological Warning System (*Sistema de Alerta Hidrometeologica*, SAH) installed in 13 cities and/or basins in the country (Figure 4.2) with automatic pluviometric stations and hydraulic stations in some cases. The colour-coded approach to warnings is also utilised in this system. CONAGUA has developed guidelines in its *Flood Control Manual* (*Manual para el Control de Inundaciones*, 2011) as well and is operating hydrologic networks in many river basins. For example, CONAGUA conducts continuous monitoring of the Río Panuco basin located in Tamaulipas, which represents a constant risk to Tampico. CONAGUA provides information on water levels to the mayor and civil protection authorities in the city to enable them to take the proper preventive measures. However, CONAGUA's networks were initially designed for water resource management, not for flood monitoring: they often monitor water levels and discharge for dam management or irrigation canals and are therefore not necessarily adapted to the

development of flood EWS. Special operating procedures are based on these systems for dam management, and this infrastructure management process is a form of early warning system. Similar networks are operated by CFE to manage their hydroelectric dams following standard operating procedures aimed at mitigating damages to the infrastructures during extreme events.

Early warning systems for heavy rainfall have been developed by some states. Even though these systems do not measure river levels, they do issue warnings about the risk of flood based on the level of precipitation, and their coverage is broader than the few existing systems at river basin level. In Chiapas, for example, the State Civil Protection Institute produces "the PROCEDA", a daily colour-coded warning map that shows projected levels of heavy rainfall in its 15 sub-regions. PROCEDA follows the same five levels of alert as the SIAT-CT and messages for specific actions to take are available in text as well as in audio format in three languages (Spanish and two indigenous languages: *Tsotzil* and *Tseltal*). Similarly, the state of Tabasco implanted 15 new monitoring stations throughout its territory to upgrade its EWS following the 2007 floods. The private sector in Tabasco has also developed capacity to receive flood warnings for local businesses (Box 4.10).

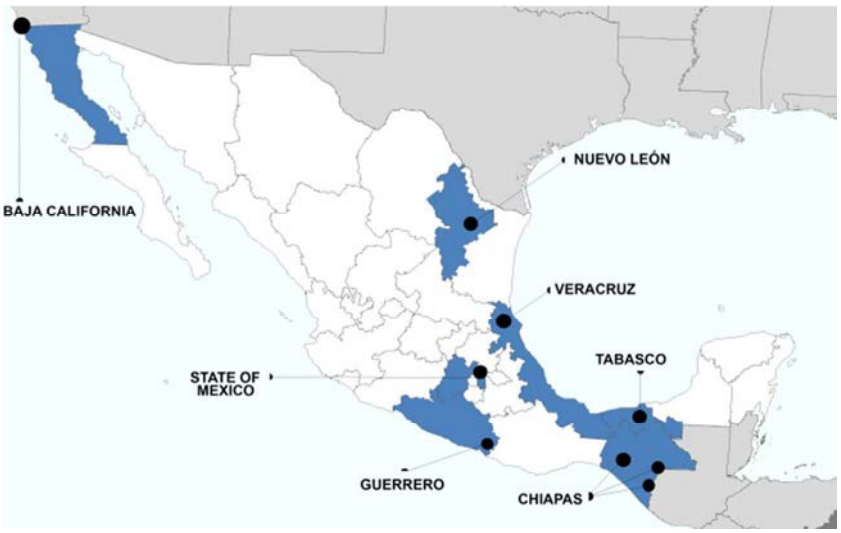
Box 4.10. **Early warning system for businesses in the state of Tabasco**

In the state of Tabasco, a specific flood early warning system dedicated to businesses was established following the massive floods which affected the state in 2007. This early warning system (EWS) was developed through a partnership between the Employers' Confederation of the Mexican Republic (Confederación Patronal de la República Mexicana, COPARMEX) in Tabasco, CONAGUA and the General Directorate of Civil Protection of Tabasco, with support from the Inter-American Development Bank. Six hundred fifty companies in Tabasco state have registered to receive this warning, allowing them to activate their emergency plans to reduce risks of damage to business infrastructures and ease business continuity. A web portal has been created (www.coparmexalerta.com) and businesses can receive warnings by e-mails and SMS. The portal also includes a diagnosis tool for businesses to help them analyse the vulnerability of their businesses to flooding and assist them in defining business continuity solutions. This project is financed equally by the Inter-American Development Bank and the businesses of Tabasco.

Source: Based on information provided by the state of Tabasco during the second OECD mission to Mexico (May 2012) and from COPARMEX website, *www.coparmexalerta.com*.

Extending river basin monitoring, modelling and flood EWS to all of the rivers at risk would require better harmonisation of the efforts between CONAGUA, CENAPRED, CFE, the SMN and the local authorities as well as financing and/or incentivising mechanisms beyond the current FOPREDEN financial resources. The creation of the five meteorological regions with their decentralised forecasting units in the SMN's modernisation plan is a first step in this direction. It may facilitate the availability of meteorological monitoring and forecasting information to inform flood and heavy rainfall EWSs at the local level. Furthermore, this could also facilitate the co-ordination between CONAGUA's hydrologists and the SMN's meteorologists. Ultimately, a national flood warning system could be useful to link all the local flood warning systems to inform federal civil protection authorities as well as the population at the national level on a daily basis, using the same model as the National Risk Atlas (see Chapter 3). Such a system could adopt the same colour-coded approach as the SIAT-CT, to create a harmonised multi-hazard early warning system that citizens would become more familiar with.

Figure 4.2. **Flood early warning systems in Mexico**



Flood early warning systems

BAJA CALIFORNIA *Tijuana* 10 pluviometric stations 2 registering centres	**GUERRERO** *Acapulco* 15 pluviometric stations 1 relay station 2 registering centres
CHIAPAS *Motozintla* 5 pluviometric stations 2 relay stations 2 registering centres *Tapachula* 7 pluviometric stations 3 water level stations registering centres *Tuxtla Gutiérrez* 8 pluviometric stations 3 water level stations 2 registering centres	**NUEVO LEÓN** *Monterrey* 8 pluviometric stations 2 registering centres 1 relay station **TABASCO** *Villahermosa* 7 pluviometric stations 6 water level stations 2 registering centres **VERACRUZ** *Poza Rica, Gutiérrez, Zamora, Martínez de la Torre, Álamo and Misantla* 5 SAH
STATE OF MEXICO *La Compañía* 5 pluviometric stations 4 water level stations 1 relay station 3 registering centres	

Source: OECD with information from CENAPRED.

Seismic warning systems in Mexico

Mexico City is located just 320 kilometres from the main seismic fault in Guerrero state. A Seismic Early Warning System (*Sistema de Alerta Sismica*, SAS) was developed and launched in 1991 to provide advance notice to federal, Federal District and Mexico state administrations, schools, civil protection authorities, private entities as well as to the subway operator in Mexico City. In cases where earthquakes exceed threshold criteria related to location, depth and magnitude, the Centre for Seismic Instrumentation and Record (*Centro de Investigacion y Registro Sismico*, CIRES), a scientific non-governmental organisation (NGO) located in Guerrero and Oaxaca, emits a radio wave to public authorities as well as to radio and television stations in case of a public warning.

A fundamental element of these systems is training and education. With such short lead times, people receiving the warning signals should act immediately to save their lives. Regular evacuation drills are organised in Mexican schools and large public buildings. The importance and efficiency of these drills was amply demonstrated during the 7.4 magnitude earthquake of 20 March 2012 which took place during the course of this review, in the presence of the OECD review team. The population in Mexico City remained very calm, both during the earthquake and the follow-up evacuation process.

A project to merge and expand the existing earthquake warning systems, Mexican Seismological Network II (*Red Sismologica Mexicana II*, RSM II), is under development. Financed by the federal government, its objectives are first to modernise and strengthen the seismic networks of the country and to promote interconnection and information exchange among all of the entities operating seismic stations. It is also meant to develop seismic information and products for decision making as well as to integrate and expand seismic early warning systems in high-risk zones. Increasing the seismic monitoring coverage to warn Mexico City and other cities should be a priority, as the SAS does not record earthquakes registered in Michoacán state, as was the case with the 6.4 magnitude

earthquake on 11 April 2012. In addition, the major earthquake of 20 March 2012 in Guerrero with a 7.4 magnitude was detected, but only a preventive warning, not a public one, was emitted.

Box 4.11. **Seismic alert systems: The SAS (Federal District) and SASO (Oaxaca)**

High seismic activity along the Pacific coast of Mexico poses a constant risk to the country. The high possibility of a major earthquake in the Guerrero Gap in particular pushed for the development of monitoring capacities.

The states of Guerrero and Oaxaca have developed seismic alert systems managed by CIRES. These systems also enable a radio signal to be sent to Mexico City and Oaxaca City as an alert in case of an earthquake. This alert is only issued if the epicenter is located on the Guerrero coast.

In 1986, the National Council for Science and Technology (Consejo Nacional de Ciencia y Tecnología, CONACYT) recommended studies be carried out for developing a seismic alert system to monitor seismic activity in the Valley of Mexico. CIRES was contracted in 1990 by the Federal District to develop the Earthquake Warning System (Sistema de Alerta Sismica, SAS). Since 1991, the SAS has been communicating the detection of significant earthquakes thanks to a network of 12 sensor stations located along Guerrero's coast. The sensors emit radio warnings for earthquakes stronger than 5.0 on the Richter scale.

The most important feature of this system is the lead time it provides to the population to move to safe areas before the arrival of a seismic wave. Since seismic waves propagate at a speed of between 4 and 8 km/s, a radio warning can be emitted and transmitted from Guerrero coast to Mexico City with a 40-80 second lead time before the ground begins to shake. Since its creation, the SAS has detected more than 2 300 earthquakes of low, moderate and high intensity. In 2007, the cities of Acapulco and Chilpancingo (Guerrero) were integrated into the system.

Recently, a Blackberry application has been developed to receive the warning on smart phones (Android and Iphone applications are being developed). In addition, 38 000 weather radios will be brought from the United States National Oceanic and Atmospheric Administration (NOAA) into the project of the National Seismic Network (Red Sismica Mexicana II, RSM II) with warning messages to be disseminated to each school, as well as to hospitals and public buildings.

In addition to the SAS, an earthquake monitoring system based on an earthquake's acceleration is also available in Mexico City. A system similar to the SAS is operated by the CIRES in the state of Oaxaca. In 1999, the state of Oaxaca developed the Seismic Alert System of Oaxaca (Sistema de Alerta Sismica para el Estado de Oaxaca, SASO), which became operational in 2003. It includes 36 seismic stations and disseminates public or preventive alerts according to the intensity of an earthquake. It has detected more than 600 seismic events. CENAPRED co-ordinates both of these systems to favour their integration. Their coverage is now intended to be extended to the states of Chiapas and Jalisco.

Source: CIRES website, *www.cires.org.mx*.

According to the National Seismological Service (*Servicio Sismológico Nacional*, SSN), the CIRES monitoring network is not adequate for such a role. If the EWS is expanded to cover several states, the institutional framework for the management of this system between the Federal District and CIRES and the federal government should be revised. Specifically, the roles of federal institutions such as CENAPRED and the SSN should be strengthened, especially if the development of the unified national seismologic network materialises.

Specific warning systems for tsunami

Sections of Mexico's Pacific coast are exposed to tsunami hazard. Although there has not been a tsunami in the recent past with impacts comparable to those that have occurred in Japan, Chile or the Indian Ocean since 2004, the frequent seismic activity and several highly populated coastal communities create the conditions to ensure that a tsunami early warning system is a worthwhile initiative.

In Mexico, early warnings for tsunamis, which are implemented through international co-operation, are not yet fully linked to the domestic earthquake monitoring system. Prevention and preparation are also less advanced than they are for earthquakes. As the result of a CENAPRED-SEMAR joint initiative, the Tsunami Warning Center (*Centro de Alerta de Tsunami*, CAT), operated by SEMAR and financed by SEGOB, was created in 2011 to disseminate the warnings it receives from the international Pacific Tsunami Warning Center (PTWC), operated by the United States' National Oceanic and Atmospheric Administration (NOAA). The PTWC issues real-time tsunami warnings based on an international seismic and oceanographic network, which are disseminated through the World Meteorological Organization Global Telecommunication System. The CAT does not currently monitor tsunamis generated by earthquakes occurring in Mexico, which would be the ones to reach the Mexican coast the most rapidly and with a potentially higher wave.

An effort to develop a tsunami warning system is ongoing, with the creation in May 2012 of the National Tsunami Warning System (*Sistema Nacional de Alerta de Tsunamis*, SINAT), between SEGOB, the Navy (SEMAR), the SCT (which is in charge of harbours), the National Seismological Service (within UNAM) and the University of Baja California.

As a tsunami can reach the coast very rapidly after an earthquake, improving the coastal population's awareness of tsunamis is crucial. In particular, stakeholders recognised the need to improve the coastal population's knowledge about what to do in case of a warning, to demarcate zones exposed to tsunamis and define the safety zones, as well as to provide harmonised signs along the Pacific coast leading to evacuation routes and safety zones. Scientific models for tsunamis built on probable scenarios of particular earthquake faults should be the basis for such actions. This would require significant research, as well as appropriate funding.

Several state initiatives are in place, for example in the state of Jalisco which demonstrated its lead in the implementation of the System of Massive Alert for Tsunamis and Tropical Cyclones, for developing emergency preparedness measures and organising a simulation exercise with all residents and businesses for a tsunami affecting the city of Puerto Vallarta. The exercise included sounding sirens and some practice evacuations from the largest coastal hotels, with for example, the following notice delivered to hotel residents: "Tomorrow, Tuesday September 21st at 10:00 am we will have an evacuation simulation at the tower and the hotel. All of the employees will participate as well as the interested guests. The city alarms will sound as most of the buildings in the bay will participate in this simulation. The government is doing the simulation to commemorate the 25th anniversary of the 1985 earthquakes and to educate people on how to proceed when this kind of event happens." The impact of these efforts in Puerto Vallarta to increase the population's awareness and preparation for a tsunami are difficult to gauge with certitude, but municipal and federal civil protection authorities reported a high number of calls from people seeking information about the arrival on the Pacific coast of the 2011 Great East Japan Tsunami.

Box 4.12. Early warning system for the Popocatepetl volcano

Early warning systems are crucial to inform the population about the threat of natural hazards. There are 14 active volcanoes in Mexico. This situation implies the development of monitoring, alert and emergency response processes. The location of the Popocatépetl volcano, whose last eruption occurred in 1994, is a common risk for three states in the country: Mexico, Morelos and Puebla. The volcano could affect approximately 25 million people in an 80-kilometre radius.

CENAPRED, with support from UNAM's Institute of Geophysics, is in charge of monitoring the Popocatépetl's activity. Permanent monitoring has been possible due to the use of specialised instruments. The system consists of a network of 25 remote stations and 1 central data-processing station located within CENAPRED, 60 kilometres from the volcano. Measurements include the volcano's seismic activity, gas emissions, chemical composition, changes in electric or magnetic fields, temperature and visual observations.

The central station generates more than 60 signals which are constantly transferred to CENAPRED and UNAM. It also issues daily bulletins which are disseminated on CENAPRED's website and a dedicated hotline provides the population with permanent information.

If an increase in the seismic activity is detected, an alert system is activated. It consists of the dissemination of automatic messages to a list of registered cell phones of emergency responder stakeholders and authorities and safety staff. The early warning system includes an alert code in order to provide information about the current situation to the institutions involved in the Popocatépetl Operational Plan, and, if needed, to inform the population to prepare for evacuation. In this respect, the warning message is colour-coded (green, yellow and red) based on the probability of an eruption and the potential risk that it represents for the population.

The Technical Scientific Advisory Committee is responsible for emitting a consensus opinion on the alert level. The General Co-ordination of Civil Protection is then responsible for informing the state government about the situation and the measures to implement according to the level of alert.

Source: Based on information provided by the CENAPRED.

Harmonising early warning systems toward a multi-hazard approach

In Mexico, the development and implementation of EWSs has been quite rapid since 2002 for many hazards. With the exception of the SIAT-CT, these mostly reflect a bottom-up, top-down approach, where a technical organisation relays messages based on its monitoring to public authorities (bottom-up) and public authorities relay this information to the public that it has been trying to sensitise on the issue (top-down). The SIAT-CT has shown the benefits of greater co-operation, which could be extended to other types of risks, such as earthquakes, tsunamis, floods and other extreme weather hazards. To this end, harmonising monitoring networks, data exchange and further institutional co-ordination and co-operation among the technical agencies is a prerequisite for achieving full organisational potential. Harmonisation, building on existing strengths, helps to avoid potential confusion generated when several systems communicate conflicting messages about the same event. Stakeholders suggested warnings could be improved if technical information is properly shared in real-time through harmonised monitoring networks. Mandates should be better clarified and redundancies avoided, in the areas of seismological and hydrometeorological monitoring.

Box 4.13. **Integrated Early Warning System in Korea**

Korea has adopted an integrated risk management approach that reflects its early warning systems (EWS) for natural, man-made and social disasters. Information from these systems is inserted into an Integrated Situation Center (ISC), which includes four sub-systems to monitor and disseminate information before and during a crisis. Through the Disaster Prevention and Meteorological Information System, the ISC monitors satellite and radar images, and contents of special weather reports. Specific monitoring systems are also established for floods, rainfall, tsunamis, earthquakes and highways (CCTV real-time monitoring). In case of a threat, alerts are emitted though the Internet to the report centre and through the cell broadcasting service (CBS), which sends a message to citizens' cell-phones to inform them about evacuation measures. In case of emergency, the ISC acts as a disaster management control tower to support response measures within a maximum of ten minutes. The Disaster Information Sharing System connects 34 organisations to real-time disaster information collection. It also centralises information from affiliated organisations, national and local authorities, civil protection entities, the media and affected citizens. Finally, the Disaster Management Information Data Base Centre provides information about the damage status while the Central Disaster Management System provides information to manage facilities, refugees and assess damage situation.

Source: Presentation by the Korean Ministry of Public Administration and Security, OECD Workshop on Inter-Agency Crisis Management, Geneva, Switzerland, 28 June 2012.

In fact, many stakeholders saw scope for the development of a harmonised multi-hazard federal warning system to avoid treating natural hazards in isolation. The Great East Japan Earthquake has shown how several natural hazards can combine with technological risks to produce complex risks. A harmonised system nationwide using the same symbology, colour-coding, protocols and dissemination channels at federal, state and local levels would increase synergies, efficiencies and avoid risks of confusion. Promoting a branding approach of the national EWS would also allow citizens to be more familiar with it, and could then serve as a powerful risk communication and awareness tool at the national level.

A national warning map could also be published daily, as in the case of the French Vigilance System (Box 4.14). As the responsibility to warn the populations and/or to decide to evacuate remain a key responsibility of the local level, a good link with the state network should be designed for such a system to be efficient: a national map with colour-coding at the state level could be produced after exchanging views with the concerned states. States could then link to it with a more precise map at a lower scale. CENAPRED could be in charge of co-ordinating such system with all the federal entities and states, based on the model used for the National Risk Atlas (see Chapter 3).

Addressing the challenge of communication

The effective communication of warnings and alerts as well as training the population to understand their meaning are key challenges for civil protection authorities. The challenge is especially important for rapid-onset hazards, such as earthquakes, tsunamis or flash floods. Partnerships with the media could be developed so that early warnings are properly communicated through all available channels, especially when there is an imminent threat. The use of social media should also be considered for communicating individual warnings. Traditional means of warnings, such as sirens and VHF-radio, remain fundamental for rapid-onset hazards, together with population awareness and training. In these cases, possibilities of direct warning from the federal level to the local population could be further explored.

However, besides the classic use of the SEGOB Media Center, no specific agreements with media channels or telecommunication operators have been signed to facilitate the dissemination of these warnings. The utilisation of private foreign companies' meteorological forecasts is also more and more common in the broadcast media in Mexico, and can create problems as far as meteorological warnings are concerned, as warning citizens remains a key governmental responsibility.

Box 4.14. **The French Vigilance System: An evolving multi-hazard early warning system**

The French Vigilance System was initially developed by Météo France after a major storm in 1999 killed 100 people, even though it had been properly forecasted by Météo France. This EWS produces daily a national colour-coded map of hydrometeorological risks in its 96 regional jurisdictions, which is widely disseminated in the media and is now known by 96% of French citizens. Since its inception by Météo France and the French civil security, this system has gradually evolved to include more hazards through the development of partnerships among technical agencies. The flood warning function was included in 2005 after operating procedures between the meteorological and the hydrological services were developed. The heat-health warning was developed between Météo France and the Health Monitoring Institute, after the massive 2003 heat wave in Europe. A storm surge warning is currently being developed between Météo France and the oceanographic service.

Source: Golnaraghi, M. (2012), *Institutional Partnerships in Multi-Hazard Early Warning Systems*, Springer, World Meteorological Organisation, New York.

Financing prevention

Investing in disaster prevention projects has often shown to be more cost-effective than paying for *ex post* disaster relief and reconstruction costs (World Bank, 2010). Aggregate calculations about the cost-effectiveness of disaster prevention, however, are a challenge for most countries as it is difficult to know what expenditures are made for prevention alone, as it is difficult to avoid double counting. Prevention encompasses many public policies, from protective infrastructures to education, land-use restrictions and building codes, and early warning systems. Many policies and programmes spanning various institutions need to be taken into account to assess the effectiveness of prevention. Precise accounting would indeed be a powerful tool to demonstrate the effectiveness of prevention and compare these costs to emergency relief and reconstruction as well as to the economic damages caused by disasters.

FOPREDEN: A dedicated fund to finance disaster prevention

The federal government provides financial support to states and municipalities for disaster prevention programmes through the Fund for the Prevention of Natural Disasters (FOPREDEN). FOPREDEN complements FONDEN – the federal government fund to finance disaster recovery and the reconstruction of public assets (see Chapter 6). Its creation in 2003 reflects a change of strategy within SEGOB to steer away from a reactive disaster management system focused on *ex post* financing towards an increasingly proactive system that promotes *ex ante* prevention. SEGOB's long-term goal in providing financial support for disaster prevention projects is to eventually decrease demand for support in reconstruction expenditures.

FOPREDEN co-finances federal, state and municipal projects in three main areas related to disaster prevention: risk assessment (e.g. risk atlas), mitigation or risk reduction (e.g. EWSs or small flood protection infrastructures) and strengthening the culture of prevention (e.g. educational materials). CENAPRED convenes technical and scientific committees to evaluate the merits of all proposals based on a clearly defined list of selection criteria and priorities related to the quality of the project, its technical relevance and the expected impacts.

Financial transfers from the central government, whether for disaster prevention or recovery and reconstruction, are confronted with a delicate trade-off between accountability and accessibility. The federal government rightly demands projects to demonstrate their utility in meeting an identified need, but several states and municipalities have found the FOPREDEN selection process overly rigorous and have abstained from applying for funds altogether. On the other hand, given the relatively modest budget of FOPREDEN compared to the enormous and widespread needs to reduce disaster damages, the objectivity and scientific rigour in the selection process needs to be preserved.

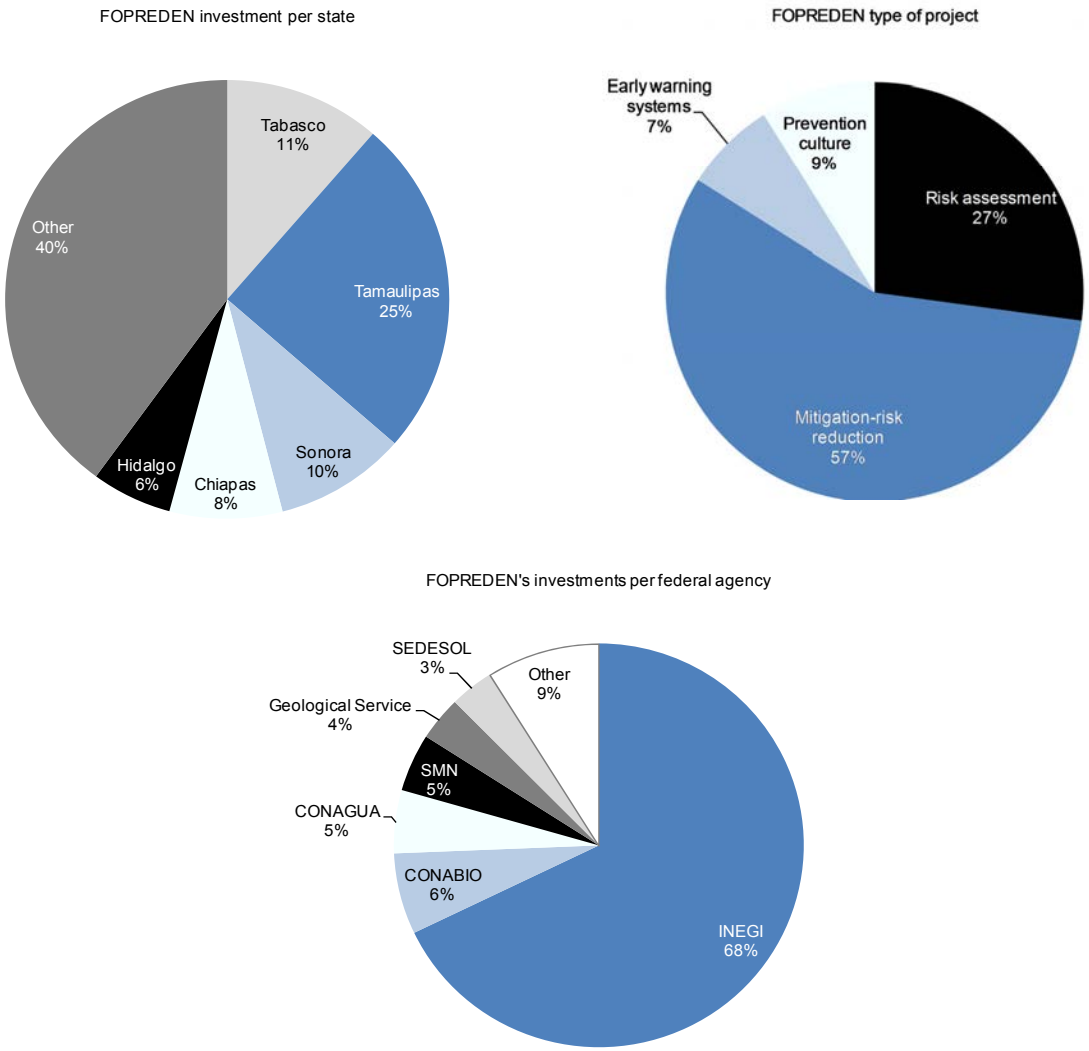
With a continuous budget of MXN 300 million annually since 2008, FOPREDEN has financed 130 preventive projects for a total of MXN 1.4 billion in the 8 years of its existence. FOPREDEN funding is modest compared to other prevention infrastructure projects, particularly the previously mentioned structural measures.

Each Mexican state has applied for and received FOPREDEN funding at least once, with an average project cost of MXN 10.6 million. More than 54% of the total transfers, however, have gone to the states of Tamaulipas, Tabasco, Sonora and Chiapas, while Veracruz (the state most severely affected by disasters in terms of reconstruction costs) has received only 1.4% of FOPREDEN total expenditure. In this respect, the distribution of FOPREDEN funding appears to be linked more to the proactive behaviour of certain states to submit proposals, rather than to identified vulnerabilities.

FOPREDEN has a clear strategy to incentivise states to develop risk atlases (Figure 4.3). Twenty-seven percent of its expenditures are related to risk assessment, and this share is expected to increase with the new operational rules that require states to have, or be in the process of developing, a risk atlas as a condition to apply for financial support for prevention projects. Among the more common prevention projects funded by FOPREDEN are those related to risk mitigation, and in particular flood risk infrastructure in small river basins. FOPREDEN also finances the development of local EWSs (7%) and projects related to the development of risk prevention culture (9%).

FOPREDEN can also finance disaster prevention projects from federal agencies. Seventeen percent of its funding has gone to finance 20 federal agency projects on a 50% cost-sharing basis. Approximately 70% of these funds went to the National Institute of Geography and Statistics (*Instituto Nacional de Estadística y Geografía,* INEGI) for the development of specific cartographic products with modern GIS and remote-sensing technologies to support the development of risk atlases. With this important project, FOPREDEN appears to have been utilised in its maximum capacity to foster the development of a holistic approach towards developing harmonised risk atlases from the national to state levels promoted by CENAPRED. In this respect, FOPREDEN played the role of a strategic federal financial instrument for prevention, financing the tools that will support all three levels of governments to develop the first step of risk prevention: risk assessment.

Figure 4.3. **FOPREDEN projects**



Source: OECD based on information from FOPREDEN (2012).

FOPREDEN's operational rules have been adapted through the years for more efficiency and transparency. The initial rules from 2003 were updated twice, in 2006 and 2010, to make it a more flexible instrument and adapt it to the requirements and specificities of the states as well as municipalities, which can now apply directly to FOPREDEN rather than through the states. The new rules (2010) modified the cost-sharing scheme, from one where a recipient state was supposed to contribute at least 30% of project funding, to a more dynamic one, where FOPREDEN may support up to 90% of the total cost according to the marginalization index developed by the National Population Council (*Consejo Nacional de Población*, CONAPO) (see Chapter 3). As a result, more than 80% of the applications have been accepted since 2008, whereas the rate was only 52% in 2004. To reinforce transparency and accountability, FOPREDEN now allocates financial resources directly to the contractors who carry out the work based on contracts and invoices and not to the states as was the previous practice, as several funded projects were not implemented in the previous scheme leading to wasted resources.

Conclusion

Mexico's ambition to place disaster risk prevention on a par with emergency response is progressing, with federal policy documents providing a strong push and guidance in this direction. Implementing this objective into concrete actions across levels of government, however, faces several challenges. In terms of reducing exposure to natural hazards, two main measures are to move populations from hazard zones and to prevent new construction through prescriptions on land use. The size of the population residing in hazardous zones in Mexico continues to increase, however, and this indicates a lack of public awareness due to ineffective risk communication, and lack of incentives to help meet the objectives of disaster risk prevention. Municipalities have the legal competence to issue building permits within their jurisdiction, and their incentives are often aligned toward new development. Furthermore, some municipalities have shown they are unable to prevent informal settlements. While there has been relatively little effort until recently to adopt non-structural risk prevention measures, major investments in structural measures to reduce exposure to floods are ongoing with mixed results. Insufficient incentives are in place to incite exposed households and businesses to move out of the most exposed areas.

While SINAPROC has ambitions to advance disaster risk reduction, its current institutional setting is anchored in emergency response. Implementation of risk prevention measures will require a joint action across levels of government, for instance to ensure the results of risk atlases are linked to land-use prescriptions in zones exposed to a high level of hazard. It is crucial, therefore, that the provision of the 2012 General Law requiring the development of a risk atlas be given priority attention in terms of implementation. In jurisdictions where there is a gap between territorial and urban planning decisions and the local risk atlas, control and sanction mechanisms combined with incentives may be needed to help close the gap. This may be justified in furtherance of instituting evidenced-based decision making and transparency, which are pillars of good governance.

Another issue is to address capacity gaps. Many municipalities lack technical capacities and resources to produce risk atlases, and in these cases it will be key to continue and strengthen partnerships to support them. Capacity building efforts can help to foster the implementation of disaster risk prevention measures at the local level. This will also create pressure upon different federal and state bodies to meet the standards for land management that they advocate for municipalities.

The establishment of FOPREDEN demonstrates the federal government's commitment to taking a comprehensive approach to risk management. It stands out amongst OECD countries as one of only a few known central government funds expressly set up to co-finance disaster prevention. Its budget is modest relative to the needs of states, but it is impossible to fund all such projects and doing so would create a culture of reliance among decentralised governments and disincentives to invest in prevention on their own. The FOPREDEN budget and magnitude of the projects are still quite modest compared to recovery and reconstruction expenditures through FONDEN. While the incentives to produce risk atlases show that FOPREDEN can impact states' behaviour, the patterns of its projects do not seem to follow an integrated preventive strategy, but more a set of *ad hoc* responses to the isolated needs of states or federal agencies.

As in many other OECD countries, tracking prevention funding is not easy, but looking at a few projects and initiatives demonstrates that FOPREDEN resources do not

represent a major share of the prevention funding in Mexico. While SEDESOL's risk prevention programme (PRAH) had a budget of MXN 190 million in 2010, which is comparable to FOPREDEN's annual resources of MXN 300 million, CONAGUA's infrastructure development projects go far beyond that in terms of public expenditure. Hydraulic projects of MXN 9 or 20 billion are being financed in Tabasco and the Valley of Mexico, and the 2030 Water Agenda has projected another MXN 107 billion in infrastructures for risk reduction over the next 20 years (SEMARNAT, 2011). The National Meteorological Service's modernisation plan is evaluated at USD 170 million. In comparison, the project for the modernisation of the seismological network (see Chapter 3) developed by UNAM is estimated to cost MXN 184 million but cannot find financial support.

Recommendations

- Build greater coherence between risk management, territorial planning and urban development and adaptation to climate change.
- Territorial and urban planning should become a national priority supported by an appropriate institutional framework.
- States and municipalities should prepare under their responsibility a disaster risk prevention plan based on a risk atlas indicating structural and non-structural measures needed to prevent disaster risk in their jurisdictions.
- Extend early warning systems on the model of the SIAT-CT and the SAS throughout the national territory, particularly for flood and tsunami warnings.
- Invest more in disaster risk prevention following thorough analysis of costs, benefits and effectiveness. A practical measure to facilitate this would be to establish a registry of 4-6 specific building codes at the federal level that municipalities could choose and adapt based on their risk exposure, particularly for earthquakes, floods and tsunamis.

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