CAPRA Initiative:

Integrating Disaster Risk Information Into Development Policies and Programs in Latin America and the Caribbean

owards Safe and Sustainable Urban Environments

APRA
c Risk Assessment Initiative

CEPREDENAC
Centro de Coordinación para la Prevención de los Desastres Naturales en América Central

GFDRR
Global Facility for Disaster Reduction and Recovery

IDB
International Development Bank

GOBIERNO DE ESPAÑA | MINISTERIO DE ECONOMÍA Y HACIENDA
Spanish Fund for Latin America and the Caribbean

ISDR
United Nations
International Strategy for Disaster Reduction

THE WORLD BANK


RECENT IR SATELLITE STILLS

FOREWORD

Governments in Latin America, the Caribbean and other regions face the challenge of mainstreaming disaster risk reduction into their development policies and programs. The Probabilistic Risk Assessment Initiative CAPRA team would like to present the following report that details the accomplishments and future plans of the Initiative. At its core, CAPRA is an institutional strengthening effort to integrate disaster risk information into urban development policies and programs to ensure the sustainable development of cities worldwide. Recent experiences in the region indicate that such integration may only take place if two conditions are satisfied: (a) government agencies with interest in the sustainability of urban development policies and programs have the technical capacity to generate, understand and integrate disaster risk information, and (b) agencies demonstrate institutional leadership and take ownership of the risk assessment process and results. Therefore, CAPRA provides a framework that creates an enabling environment for the mainstreaming of disaster risk reduction in infrastructure development and territorial planning. Specifically, CAPRA focuses on six sectors, which have been strategically identified as priorities areas for intervention: education, health, water and sanitation, transport, housing and watershed protection. CAPRA aims to provide these sectors with needed disaster risk information and analytical tools to identify and prioritize vulnerability reduction measures for existing infrastructure and improve building codes and construction standards for new assets. Thus, CAPRA seeks to enhance the capacity of institutions to plan and build safer and sustainable critical infrastructure. The results obtained thus far in Belize, Chile, Colombia, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama and Peru have encouraged countries in the South Asia region to use the same methodological TAP approach. Bangladesh, Bhutan India, Nepal, Pakistan and Sri Lanka have projects under development. The international community is already following the achievements of the Initiative. The 2011 Global Assessment Report on Disaster Risk Reduction published by The United Nations included for the first time seismic risk assessments for three countries that used the software platform built as part of the Initiative. The United Nations expects to progressively increase the use of the platform.

Award Categories

ENVIRONMENT/CLIMATE AND INFRASTRUCTURE

Project Information

Project Name: Probabilistic Risk Assessment (CAPRA) Initiative

Location: Latin America and the Caribbean Region

Amount: $4.28 million

Project Duration and Dates: 2008-2010 (Phase I), 2010-2012 (Phase II), 2012-2015 (Phase III, expected)

DEVELOPMENT PROBLEM

The Latin America and the Caribbean Region has experienced significant urbanization over the past few decades. Between 1950 and 2010, the population living in urban areas increased by almost 600 percent according to UN-HABITAT. Considering that the region is exposed to a wide variety of natural hazards, including earthquakes, floods, landslides, and hurricanes, whose occurrence patterns are affected by climate change, an increasing concentration of people and assets implies higher exposure to these events. For many developing countries, these elements remain highly vulnerable. Unfortunately, for many of these countries, a single hazard event can now cause nationwide development problems and impact global and regional markets due to today's interconnected economies. Thus, reducing disaster risk has emerged as a national priority for these governments. Nonetheless, government continue to face two important challenges: (a) developing a thorough understanding of disaster risk that will enable them to generate, refine and interpret disaster risk information, and (b) integrating this information into policies and programs that will enable them to properly manage disaster risks emerging from changing built, socio-economic and natural environments.

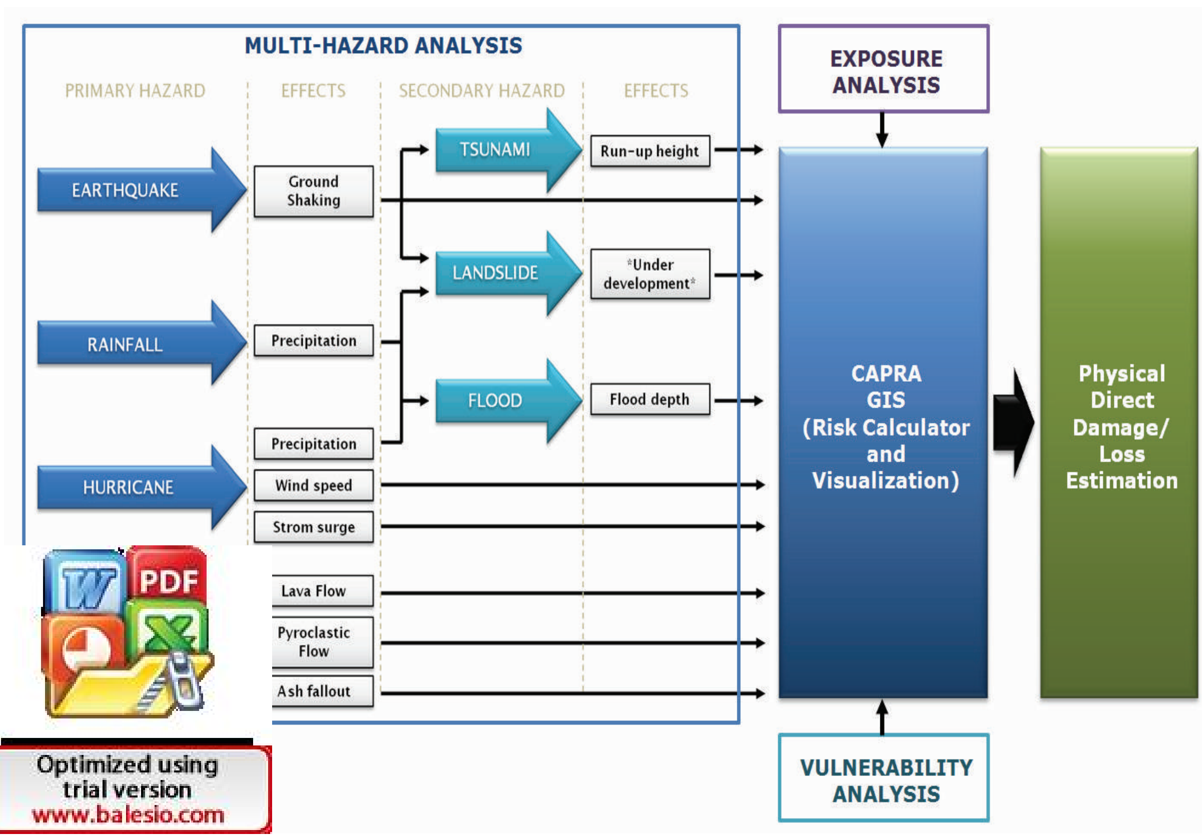
PREVIOUS APPROACHES

In the past, in order to accomplish these goals, government agencies had to gain access to specialized software at high cost –preventing governments from accessing needed tools to facilitate the assessment of disaster risk. Moreover, approaches used in the region heavily emphasized the application of deterministic methods for hazard assessment. Although these methods have been useful for understanding hazard characteristics, they unfortunately do not address the estimation of probable losses due hazard occurrence. The derivation of this information is critical for identifying and prioritizing risk reduction investments. Probabilistic methods, on the other hand, are able to model different hazard and risk scenarios, empowering decision makers by presenting an array of possible outcomes. Countries today are seeking ways to implement cost-effective comprehensive disaster risk reduction strategies that will help them move away from responding and recovering from disaster events and move towards the proactive mitigation of adverse effects. The Latin America and the Caribbean Region's Urban and Disaster Risk Management Unit at The World Bank (LCSDU) has focused the dialogue with governments over the last decade in four lines of action –understanding risk, risk reduction, risk financing, and recovery and reconstruction. The implementation of programs and activities under these areas enabled The World Bank to identify an evident priority for governments in the region: generating disaster risk information that could be integrated into policies and programs in the long-term.

ANALYSIS AND APPRAISAL

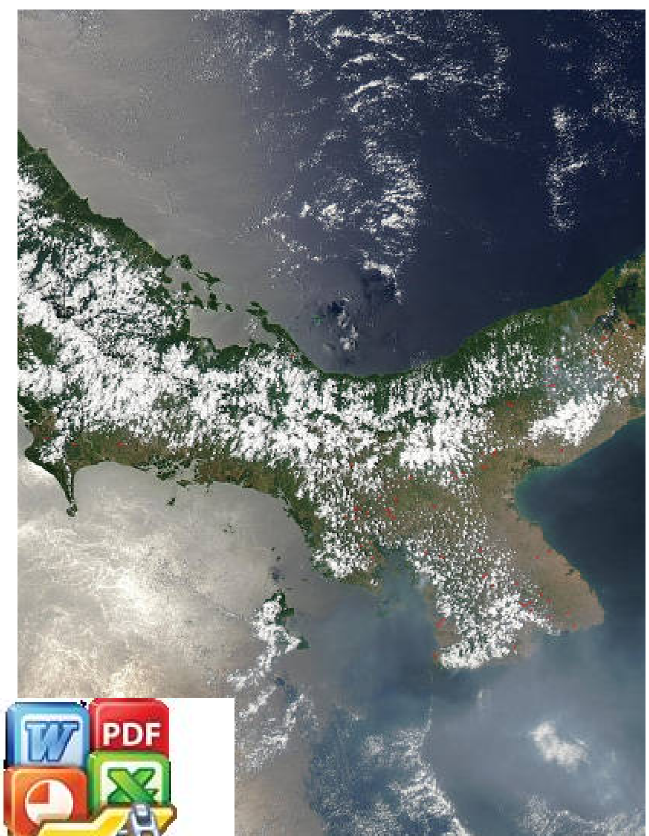
In order to meet this growing need, in partnership with other organizations, The World Bank launched the Probabilistic Risk Assessment Initiative CAPRA in 2008. The first phase resulted in the development of the disaster risk analysis framework, the creation of a software platform to support the framework and the generation of disaster risk information for Belize, Costa Rica, El Salvador, Guatemala, Honduras and Nicaragua. The second phase shifted the focus to supporting government agencies with (a) specific needs requiring disaster risk information and (b) interest in building their institutional capacity to understand and apply disaster risk information for decision making. The objective was to engage governments as owners of the risk analysis process and the results. This level of engagement was accomplished through the implementation of Technical Assistance Projects (TAPs) –a partnership between The World Bank and government institutions. The actual scope of a TAP depends on the needs and priorities of requesting government institutions. Hence, institutional strengthening becomes an internal self-sustaining initiative. Under this approach government agencies receive training and technical advisory services, lead the risk analysis process, liaise with other agencies to establish an interdisciplinary and cross-agency team for the risk analysis processes, and ultimately become interested in integrating the results of assessments into specific policies or programs. At present, TAPs are under implementation in Chile, Colombia, Costa Rica, El Salvador, Panama and Peru. Over the next few months, CAPRA will expand its activities to other continents and support the 2013 Global Assessment Report on Disaster Risk Reduction.

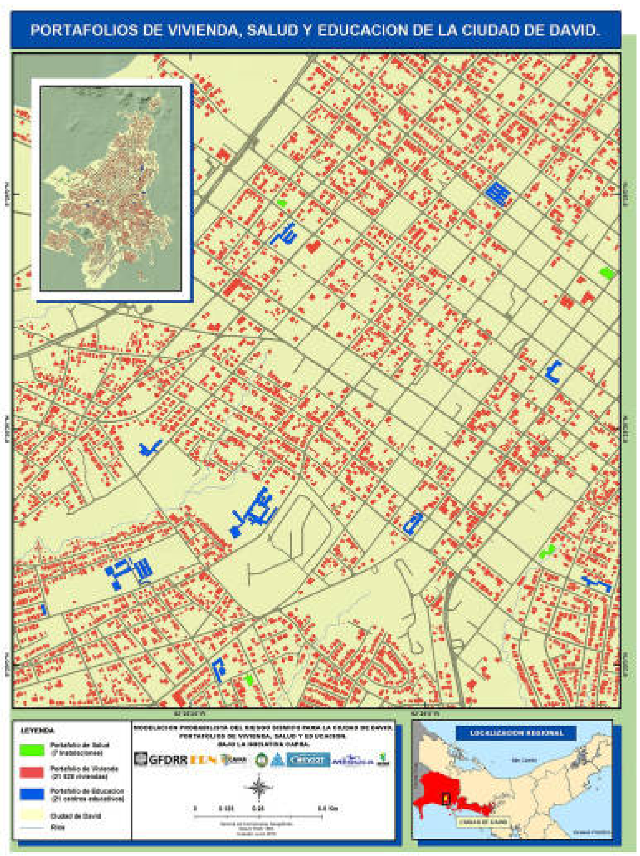
Figure 1. CAPRA Risk Assesment Model



RATE OF RETURN

The cost of building the platform amounted to approximately $2.6 million, including 30 risk assessments conducted for 6 countries in the first phase. Prior to the platform, experts in need of disaster risk information had to pay for expensive software to facilitate the risk assessment process. With the new platform, government, academic and private sector experts worldwide have access to free and open risk assessment software. In fact, the United Nations International Strategy for Disaster Reduction (UN-ISDR) recently decided to use the CAPRA platform for the 2011 Global Risk Assessment Report on Disaster Risk Reduction[1]. Moreover, almost $1.5 million has been allocated to the implementation of the TAPs. While 8 TAPs are under implementation, 2 more TAPs are under design in Panama and Colombia. Through every TAP, government institutions increase their understanding of risk information and the risk analysis process, improve their ability to assess and articulate their analysis needs, are able to work more effectively with partnering institutions in the development of risk information, and understand the importance of mainstreaming risk reduction in development policies and programs. Another $180 thousand has been used for knowledge management and dissemination activities to increase awareness of the activities and results. The integration of risk information into decision making will reap additional benefits in the upcoming months. The supplementary section describes two TAPs and the tangible results obtained thus far.





. (2011). "Global Assessment Report on ...tion 2011." <http://www.preventionweb. ...ar/2011/en/home/index.html> (Sep. 18, 2012)

BENEFICIARIES

While immediate beneficiaries -partners ot The World Bank- are listed below, ultimate beneficiaries are the people that reside in the geographic areas under study.

Table 1. Partners and Beneficiaries

Country	Immediate Beneficiary	Short-Term Results	Long-Term Results
Chile	Planning and Development Division of the Atacama Regional Government	Assess seismic and tsunami risk in northern Chile	Integrate risk reduction criteria into regional land use planning
Colombia	National Geological Service	Assess volcanic risk in Pasto	Advise Government of Colombia on volcanic risk management
Colombia	Municipality of Pereira	Assess seismic risk in the health and education sectors in Pereira	Update seismic micro-zoning for land use planning
Costa Rica	Costa Rican Water and Sanitation Institute	Assess seismic risk in the water and sanitation sectors in the San Jose Metropolitan Area, San Isidro and Higuito	Guide infrastructure investments
El Salvador	Ministry of Environment and Natural Resources	Assess seismic risk in the health and education sectors in the San Salvador Metropolitan Area	Develop seismic risk reduction programs
Panama	Ministry of Housing and Land Use Planning	Assess seismic risk in the health, education, and housing sectors in David	Develop seismic risk reduction programs, and feed further financial analysis for risk financing
Peru	Geophysical Institute of Peru	Assess seismic hazard and complete a natural hazard database	Update building code standards and regulate infrastructure investments
Peru	Ministries of Health and Education and the Pontifical Catholic University of Peru	Assess seismic risk in the health and education sectors in the Lima Metropolitan Area	Improve construction design requirements, and develop the capacity of young professionals

MONITORING AND EVALUATION

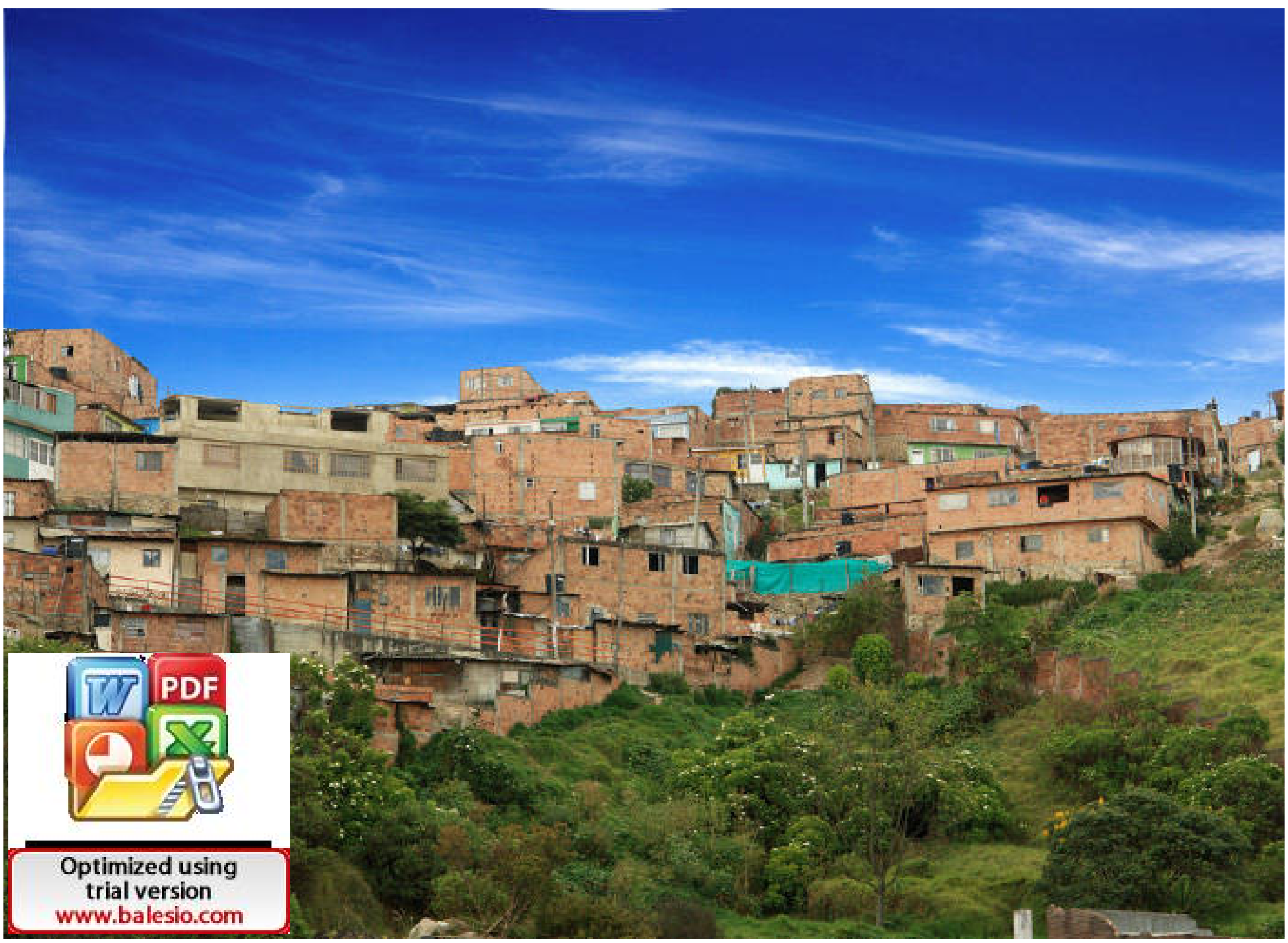
Monitoring of activities differed from the first phase to the second phase given their individual scopes. During the first phase, external consultants delivered 102 risk assessment technical reports for 6 Central American countries. CAPRA delivered 20 trainings to 400 experts. Also, the International Institute for Geo-Information Science and Earth Observation (ITC) conducted a third-party assessment of the framework and support platform. The second phase, on the other hand, demanded a deeper level of participation of government agencies, and therefore, resulted in a larger number of indicators. Nonetheless, the monitoring and evaluation process was deemed to be very organic given the lead role adopted by government agencies along with their evolving needs. Each TAP had a technical lead at the World Bank who was engaged throughout the process, monitored the successful completion of activities and accomplishments of results and evaluated the performance of activities. The following are some of the results obtained thus through the TAPs:

Table 2. Technical Assistance Projects Results

Indicator	Phase II Results (as of September 2012)
Number of countries benefited	6
Number of TAPs implemented	8
Total population of the geographic areas under study	31.7 million
Size of the total geographic area under study	1.3 million km^2
Number of elements at risk	51,885 buildings (schools, hospitals, housing units) 228 water and sewer system facilities 497 km of water and sewer pipelines
Population directly benefited from the TAPs	29.7 million
Number of risk assessment trainings	27
Total number of people trained	113
Number of institutions that participated in the risk analysis process	24

RISKS

Disaster risk analysis needs the participation of many different players, becoming a complex technical and organizational process. Hazard and cadastral experts, engineers, GIS specialists, economists, and policy makers are some of the groups that need to be brought together; risk analysis requires an interdisciplinary and cross-institutional arrangement in place to effectively undertake the process. Unfortunately, in the region there is no strong tradition of cross-institutional coordination and collaboration. Lack of adequate organizational frameworks impacts the completeness of generated disaster risk information, and prevents the process from being conducted in an integrated manner. Overcoming this barrier demanded CAPRA to work with beneficiaries who, given their existing needs for risk information and analyses, were already in the process of building these institutional frameworks, or had the willingness to establish such arrangements. These were institutions such as the Costa Rican Water and Sanitation Institute, whose motivation for increasing the resilience of their infraestructure drove the organization to bring together in-house experts from different technical backgrounds. Another risk is related to guaranteeing the sustainability of risk assessment activities in the region and the integration of disaster risk information into decision making. Turnover is a problem in many government organizations, with many people leaving their positions to consulting jobs. Therefore, strengthening the capacity of institutions as organizations has been critical. Additional solutions are presented in the sustainability section.



LESSONS LEARNED AND APPLIED

Our experience indicates that the integration of disaster risk information into policies and programs may only take place if (a) government agencies with interest in the sustainability of policies and programs have the technical capacity to generate, understand and integrate disaster risk information, and (b) agencies demonstrate institutional leadership and take ownership of the risk analysis process and results. Additional lessons learned may be drawn:

- ⊗ Using the probabilistic risk analysis framework offered by CAPRA resulted in the identification of important challenges the third phase: (a) understanding quantitative risk metrics, (b) integrating uncertainty into the analysis, (c) establishing cross-institutional interdisciplinary arrangements, and (d) communicating probabilistic risk.
- ⊗ Disaster risk information developed under a TAP is and needs to remain (a) targeted and strategic, responding to specific needs, (b) dynamic, continuously building from existing and newly generated information, and (c) formal –generated under an institutional and legal framework, guaranteeing legitimacy and increasing reliability.
- ⊗ Designing risk reduction policies and programs cannot solely rely on information. The process should consider existing institutional priorities and constraints. Phase III shall leverage the experience of The World Bank in supporting decision making processes and integrate additional methods into the risk analysis framework for policy and program design and implementation.
- ⊗ Understanding risk is necessary for mainstreaming disaster risk information into policies and programs. CAPRA has built institutional and technical capacity around the understanding of risk, where risk is regarded as a key development issue for cities and countries. This particular effort must continue.

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cts Planned for Phase III

Work in Asia

DISSEMINATION

The CAPRA Initiative has an interactive portal (www.ecapra.org) that provides information to visitors on the probabilistic risk assessment, the CAPRA software, the technical assistance projects in Latin America and other activities in South Asia countries. Project highlights are available in English and Spanish for implemented TAPs. The website has been visited by people from 110 countries. Visitors may download the CAPRA software modules, take e-learning tutorials, and join as m... community of practice, being ... nents, questions, photos and ... nmunity has approximately ... tiative is also using social ... a larger audience. CAPRA ... with 38 tutorials, interviews ... government officials, and informational videos. During the last year, the channel reported 3,900 views. Moreover, CAPRA has a Flickr Photostream with 500 photos. Finally, the Initiative has a capacity building and training component. Over the last year, CAPRA has organized workshops in cities such as Atacama, Bangkok, Barcelona, Cape Town, Colombo, David, Islamabad, Kathmandu, Lima, New Delhi, Pasto, Pereira, San Jose, San Salvador, and Washington DC. In July 2012, the Initiative organized a session for the community of practice in Cape Town, South Africa at the Global Understanding Risk Conference that had approximately 500 participants from around the world, including more than 50 people directly working with the CAPRA platform attended the meeting. For the next few months, the Initiative is planning to continue expanding the network of users.

SUSTAINABILITY

Sustainability has been a core component of CAPRA. During the first phase, governments were external stakeholders to the risk analysis process, providing data for the assessments and receiving the results. This role hindered their understanding of risk and the analysis process. During the second phase, agencies adopted a different role, engaging in every step the process, safeguarding the sustainability of results achieved. To support the development of agencies, the third phase of CAPRA will work towards consolidating the existing community of practitioners. Through this community, government officials, industry experts, and academic and research scholars will exchange experiences and provide feedback to enhance the risk analysis framework and supporting platform. This community becomes the primary instrument to advance the practice, foster collaboration, and support risk analysis efforts. Furthermore, since the software platform is open and free, its further refinement and development is expected to be dynamic and driven by user demands. Then, sustainability may be tracked by (a) evaluating the understanding of generated risk information and following the development of policies and programs, (b) qualifying the interaction among practitioners and further developing the existing virtual environment for the growth of the community of practice, and (c) monitoring the enhancements made to the application to address particular needs in the field. At a broader level, The World Bank will continue working with regional institutions, including the Coordination Center for the Prevention of Natural Disasters in Central America (CEPREDENAC), and government agencies to promote collaboration among neighboring countries, leverage results and exchange experiences.

PARTNERSHIPS

CAPRA was developed in partnership with key institutions, including CEPREDENAC –the institution responsible for coordinating disaster prevention, mitigation and response in Central America. CEPREDENAC was instrumental in establishing contacts with national institutions and promoting activities. Also, UN-ISDR has supported outreach and dialogue activities, focusing on stakeholders not covered by CEPREDENAC. In 2011, CAPRA was featured in The United Nation's Global Risk Assessment Report on Disaster Risk Reduction. Furthermore, CAPRA is expected to support the development of the upcoming 2013 report. The Inter-American Development Bank (IADB) and The World Bank collaborate on the development and financing of activities. Since inception, CAPRA has been working with government and non-governmental institutions, including the Central American Commission on Environment and Development (CCAD), Central American Higher University Council (CSUCA), Group on Earth Observation (GEO), Google, National Aeronautics and Space Administration (NASA), National Centre for Atmospheric Research (NCAR), National Oceanic and Atmospheric Administration (NOAA), Pan American Health Organization (PAHO), United Nations Development Program (UNDP), and World Meteorological Organization (WMO). CAPRA hopes to develop new partnerships with academic institutions and expand the scope of current ones. Present and potential partnering universities include the Pontifical Catholic University of Peru, Florida International University, Diego Portales University, Harvard University, the University of the Andes in Colombia, the University of Cambridge, and ITC, among others.

Main Partners

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Centro de Coordinación para la Prevencion de los Desastres Naturales en América Central

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GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMÍA Y HACIENDA
Caribbean

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SUPPLEMENTAL MATERIAL

TESTIMONIES

EL SALVADOR

"This was an explicit request that I made to The World Bank after learning the results of the program's first stage in Central America. El Salvador is in an area highly prone to earthquakes and the question we always ask here is what will the consequences of the next earthquake be when it occurs." –Hernan Rosa Chavez, Ministry of Environment

PERU

"This is a specific project with advice from experts, not only local experts, but also renowned international experts, to address the problem of quantitatively assessing earthquake hazard of different magnitudes in Peruvian territory." –Ronald Woodman, Geophysical Institute of Peru

COSTA RICA

"Our specific aim is to apply the CAPRA platform to develop expertise. Therefore, these platforms are only utilized or knowledge of these processes gained if we engage in the exercise of calibrating them to our own reality." –Luis Carlos Vargas, Costa Rican Institute of Water and Sanitation

COLOMBIA

"I consider the platform to be a very important tool for applying existing knowledge on the assessment
ıent of risk, which ultimately
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Issue #8
July 2012

Project highlights

San Jose, Costa Rica.

Costa Rica Prepares for the Next Earthquake

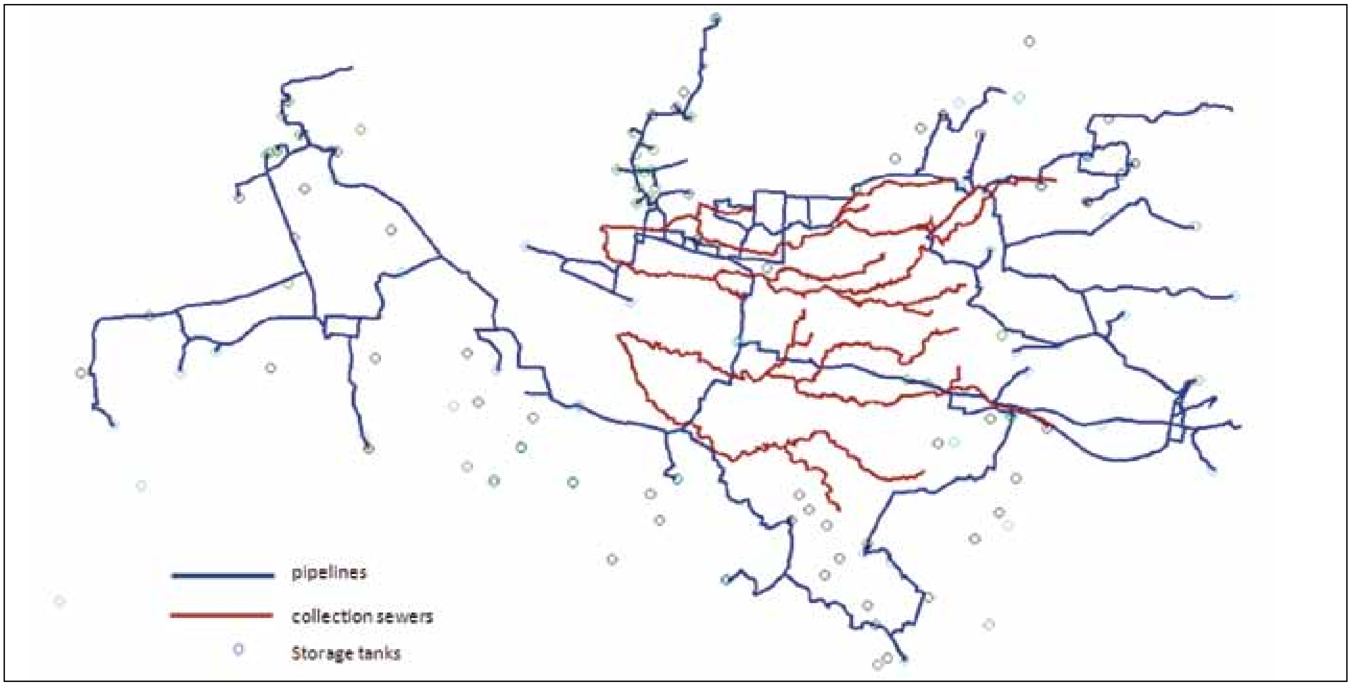
Ensuring Water and Sanitation Systems

Costa Rica is one of the most earthquake prone and volcanically active countries in the Latin America and the Caribbean Region. It also suffers from torrential rains, tropical storms, flooding and landslides. These natural events place major stress on the country's infrastructure and threaten it with natural disasters. The Costa Rican government is working to reduce the risk of natural disasters through policies and investment programs in risk management.

According to Luis Carlos Vargas, Director of Research and Development Unit of the Costa Rican Water and Sanitation Institute (*Instituto Costarricense de Acueductos y Alcantarillados*, AyA) disaster response usually means the restoration and reestablishment of systems after a natural event, such as an earthquake or a flood. Risk management, however, addresses the di- m the understanding of risk prevention and mitigation naker considering how best ents, the primary concerns vulnerable components of a understanding of expected ons, to identify the affected populations, and, finally, to set investment priorities with limited financial resources.

To achieve this, the AyA has been implementing the CAPRA Probabilistic Risk Assessment Initiative to preserve and protect the water supply and ensure a working water and sanitation system as soon as possible after an earthquake. A well-functioning water and sanitation system that provides clean water and adequate sewage disposal after a natural event will ensure that the affected inhabitants have access to basic services and can avoid the waterborne diseases that come from polluted drinking water and broken sanitation systems.

The CAPRA Initiative began in January 2008 as a partnership of the Coordination Center for Natural Disaster Prevention in Central America (*Centro de Coordinacion para la Prevención de Desastres Naturales en América Central*, CEPREDENAC), an inter-governmental organization, founded in 1987, within the Central American Integration System (*Sistema de Integración Centroamericana*, SICA). The Initiative was developed to assist the Central American governments in the analysis and management of the threats from natural events (earthquakes, floods, volcanoes, and the like) and the design and adoption of standards that reduce the risk of natural disaster. CAPRA Techni-



Exposure Map of the San José Greater Metropolitan Area.

cal Assistance Projects (TAPs) are under implementation in Central America and South America and will soon be implemented in other parts of the world, such as South Asia, where natural events can turn into natural disasters.

The CAPRA software suite is a free, modular, open-source, and multi-hazard tool for risk assessment. CAPRA provides a risk calculation platform (CAPRA-GIS) integrating exposure databases and physical vulnerability functions under a probabilistic approach. CAPRA evaluates risk in terms of physical damage and estimates direct economic and human losses. CAPRA uses a display platform geographical information system (GIS) to estimate the disaster risk of earthquakes, tsunamis, hurricanes, floods, landslides, and volcanoes.

Protecting Three Systems

The Costa Rica CAPRA TAP focused on the water and sanitation systems in the San José Greater Metropolitan Area, the San Isidro Region, and the Higuito Area. The three systems operate at different levels of sophistication and size of demand. Thus, the TAP was challenged with developing a risk assessment approach that accounted for water and sanitation systems in different contexts. The idea, according to Diana Marcela Rubiano, World Bank Consultant, is that all three areas under the responsibility of AyA “will be working to gain knowledge of the tool so that it can be disseminated to differ- ... a.”

... ropolitan Area is around 235 square ki- ... lation of around 1.2 million. The area’s ... e rivers and reservoirs (58 percent), ... and artesian wells (20 percent). They ... ne of 479,476 cubic meters. The water ... Metropolitan Aqueduct, with more than ... mary pipework and around 2,610 kilometers of secondary pipework. The water system includes 14 water treatment plants, 65 storage tanks, and 43 pumping stations. The wastewater system analyzed includes 85 kilometers of sewers collectors, nine pumping stations, and five wastewater treatment plants. Much of this infrastructure needs repair or replacement.

In the San Isidro Region, water is supplied through the Quebradas and the San Isidro systems. The component’s assessment includes use two water treatment plants, 35 storage tanks, 10 pumping stations, and 250 kilometers of pipeworks. The wastewater system was built between 1971 and 1974 and serves San Isidro, the nearby communities of Las Rosas and El Clavel and some parts of the Barrio El Prado and Ciudadela Blanco. It includes 25.3 kilometers of sewers collectors and one pumping station. Only 21.5 percent of the population uses the sanitation system. In Las Rosas and El Clavel, inhabitants use the pumping station to move the wastewater towards the Rio Peje. Other parts of the San Isidro Region use septic tanks.

In the Higuito Area, inhabitants receive water from two streams, a small treatment plant, and eight storage tanks. Water is distributed through distribution lines and tanks. There is no wastewater treatment facility.

CAPRA and the Water Sector

The CAPRA TAP’s four activities are:

- Collect existing information about seismic hazard in order to define the parameters for modeling,
- Inventory and categorization of exposed components of the water and sanitation systems and definition of vulnerability functions,
- Evaluation of disaster risk by seismic events, and
- Formulation of the disaster vulnerability reduction framework for the analyzed systems.

> *This ongoing TAP proves the usefulness of CAPRA for inputs into the disaster risk management process for different different water and sanitation systems.*
>
> —Diana Marcela Rubiano, Disaster Risk Management Specialist, the World Bank.

The TAP began by collecting data from several previously compiled regional and local studies on the seismic hazard and soil response in the study areas. One of the most complete was the Central America Seismic Risk Reduction Project Phase II (RESIS II) study, which covered a number of countries in the region, led by CEPREDENAC and the Norwegian Development Agency (NORAD). Another study related to maximum probable loss of the National Insurance Institute (*Instituto Nacional de Seguros*, INS) was used for the characterization of seismic soil response for site effects.

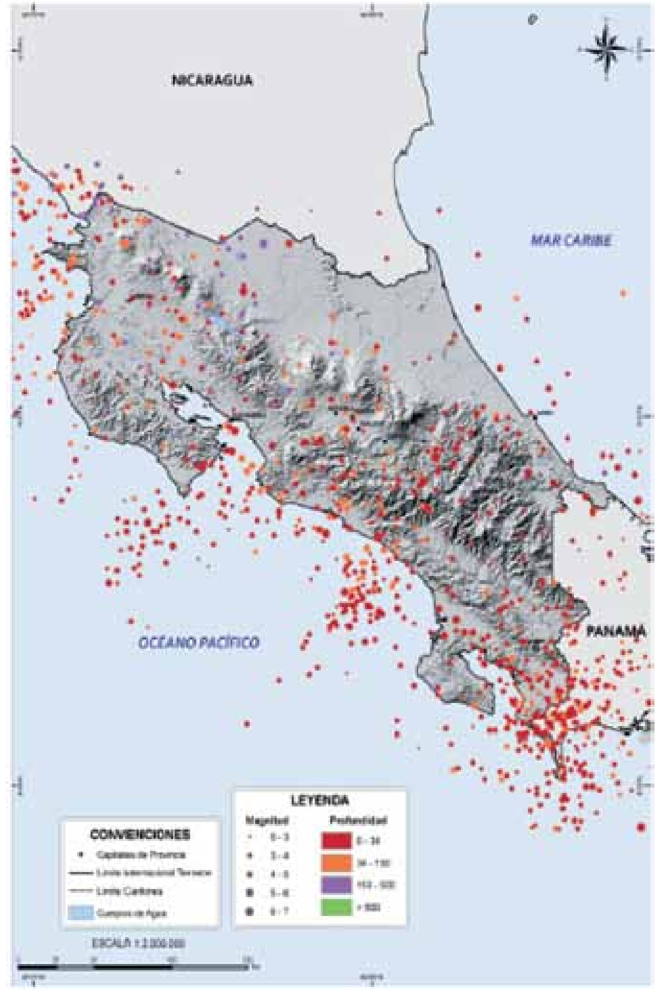
AyA also had an inventory of the water and sanitation infrastructure for the three areas. The TAP analyzed the data from these and other sources and incorporated the information into the CAPRA platform. For those components with missing information, researchers conducted on-site surveys.

The first workshop took place in March 2011. Participants began training and capacity building in seismic risk analysis and in the CAPRA platform, including, the Geographic Information System (GIS) and vulnerability components. They discussed such central topics in seismic analysis as vulnerability and calculation and estimation of seismic vulnerability functions and curves. At the second workshop in August 2011, participants reviewed the progress made and discussed advances in hazard and exposure analysis, vulnerability curves and risk modeling.

TAP activities included compiling and analyzing the data regarding seismic threat and local impacts on the water and sanitation systems. The project uses data on the main networks and the vulnerability curves for each component to assess maximum probable and economic losses from a seismic event. The probabilistic risk assessment activity integrates the CAPRA platform, hazard, exposure, and vulnerability to determine probable physical and economic losses.

Assessing Seismic Risk

Sei... ...ity that a seismic movement of a sp... in a defined geographical area and ...istics that generally cannot be mo... frequency and level of earthqua... The analysis of seismic threat dep... standing of the characteristics of t... e include regional seismic atten... e seismic wave passes through the ... s displacement effects (probable movement of a structure caused by earthquake). The



The Seismic History of Costa Rica.

strength of the ground movement depends as much on scale, frequency, size, and location as on the site's geological, geotechnical and topographic characteristics. The threat becomes a risk when the water and sanitations systems are vulnerable to the shaking ground. The level of risk is a function of the ability of the infrastructure to withstand the shaking.

An important part of risk analysis is the definition of vulnerability to a seismic hazard. The vulnerability function is a measure of the the damage to the original state as a percentage of the total value of the asset. The measure includes as a parameter the selected intensity of spectral acceleration (maximum acceleration in an earthquake as measured at a spectral acceleration station). A vulnerability curve demonstrates the structure's capacity to withstand the movement of the earth (or other natural event) at different levels of stress.

Because there were no representative vulnerability curves for the various components of the water and sanitation systems, the TAP used vulnerability functions from other countries for the seismic risk modeling. Advised by the engineering consulting firm responsible for training and support, *Evaluación de Riesgos Naturales—América Latina* (ERN-AL), the researchers from AyA selected the curves to be used for the risk model, using engineering criteria.

The Technical Assistance Project (TAP) in Costa Rica is focused on preserving and protecting the water supply and ensuring a working water and sanitation system as soon as possible after an earthquake.

Before the earthquake, the decision maker needs to ask some sensible questions, such as:

- What are the most vulnerable components?
- What is the expected damage?
- Where is the damage concentrated?
- How many of the population will be affected, and for how long?
- What are the priority investments?

Using Data for Better Results

The result of the analysis for each component is given by the maximum probable physical and economic losses resulting from probable seismic events. The next step is to assess the financial costs of improving the system, and to establish priorities based on several scenarios.

The results of the CAPRA TAP provide the baseline for the formulation of a seismic risk reduction program for water and sanitation systems that includes the investments for the short, medium, and long term. The objective will be to improve knowledge, establish prevention, maintenance, and mitigation activities and identify possible financial instruments to include in the program. With this approach, the authorities will be able to establish risk avoidance, prevention, and mitigation activities, and identify cost-effective financial mechanisms to insure fully against earthquakes.

In addition, the Presidential Decree No. 36721-MP-PLAN establishes the CAPRA as the standard tool for disaster risk management purposes and provides for an active government-sponsored risk management approach. The seismic risk reduction program for the water and sanitation systems will serve as a guide for the Costa Rican government's investments. The program will be implemented in terms of location, construction, and operation. A safe location, appropriate designs and construction methods, and safe operations will significantly reduce risk.

According to Diana Marcela Rubiano, this ongoing TAP proves the usefulness of CAPRA for inputs into the disaster risk management process for different water and sanitation systems. The result of these decisions and activities is a geographic information system that organizes all water and sewer networks and system components "to be able to estimate the impact at the time of the earthquake, relocate certain infrastructure, or create redundant systems, among others" and enable authorities to identify alternative solutions before the event. In the end, the purpose of the CAPRA Initiative is not only to implement a new technology or to create capacity in risk assessment, but to provide the knowledge base necessary for policy makers, planners, and local leaders to be able to plan risk reduction programs. In this way the country's wealth and infrastructure will be preserved and lives will be saved.

Issue #7
July 2012

Project*highlights*

Technical Assistance Project (TAP), San Salvador, El Salvador.

El Salvador Reduces Risk using a Probabilistic Approach

Assessing Risk in San Salvador

The CAPRA Probabilistic Risk Assessment Initiative began in January 2008 as a partnership of the Center for the Prevention of Natural Disasters in Central America (*Centro de Coordinación para la Prevención de Desastres Naturales en América Central,* CEPREDENAC), an inter-governmental organization, founded in 1987 within the Central American Integration System (*Sistema de Integración Centroamericana,* SICA). The Initiative's objective was to assist the Central American governments in the analysis and management of the hazards from natural events, such as earthquakes, floods, volcanic activity, among others, and the design and adoption of standards that reduce the risk of natural disaster.

e suite is a free, modular, azard tool for risk assess- sk in terms of physical dam- ucture) and estimates direct f human life. This provides tial losses from six different Assistance Projects (TAPs) have been under implementation as a part of the CAPRA Initiative in Central America and South America. It is also being implemented in other regions of the world, such as South Asia, where natural events can become disasters.

This issue of Project Highlights describes the CAPRA TAP in the San Salvador Metropolitan Area (*Área Metropolitana de San Salvador,* AMSS), in El Salvador. Minister of the Environment and Natural Resources Herman Rosa Chávez points out that, because El Salvador lies in an area "highly prone to earthquakes, the question we always ask here is what will be the consequences of the next earthquake, whenever it occurs."

To that end, the TAP's objectives were to (i) conduct a seismic risk assessment for the portfolio of buildings of the Ministries of Health, Education, and Government, (ii) estimate probable losses and damage to the buildings, (iii) improve on the first approximations of general losses and damage, and (iv) support the formulation of guidelines for a risk reduction program.

Understanding the Metropolitan Area

The San Salvador Metropolitan Area includes 14 municipalities, of which 12 are in the Department of San Salvador and two in the Department of La Libertad. With a population of over 1.6 million in a total urban land area of 159.71 square kilometers, the AMSS has a population density approaching 10,000 inhabitants per square kilometer. Earthquakes have struck San Salvador and nearby areas on average every decade for the past century. In 1986, a magnitude 5.7 Mw struck immediately below the AMSS and resulted in around 1,500 deaths, 10,000 injured, and 100,000 victims. More recently, two earthquakes in January and February 2001 led to over 1,200 deaths and the destruction of over 1,200 public buildings, almost 150,000 housing units, 14 hospitals, over 800 churches, and over 500 landslides. The UN Economic Commission for Latin America (ECLA/CEPAL) estimated the economic losses at US$1.6 million, which is equivalent to 12 percent of the previous year's GDP.[1]

Since the events of 2001, the government's response to the hazard of earthquakes has been to prepare for the future with improved data gathering, analysis, and planning. The Ministry of the Environment and Natural Resources (MARN) Office of Territorial Studies, is the implementing agency[2], with the support of CEPREDENAC.

CAPRA Completes its Activities

The CAPRA TAP's four activities are:

- Collect existing information about seismological, geological and geotechnical information and identification of seismic hazard parameters,
- Inventory and categorization of exposed buildings and definition of vulnerability functions,
- Evaluation of disaster risk by seismic events, and
- Formulation of the disaster vulnerability reduction framework for the AMSS.

The San Salvador CAPRA TAP began at the first workshop in January 2011 led by the Ministry of Environment and Natural Resources (MARN). The initial inventory of exposed and vulnerable buildings included 352 health centers (hospitals and other healthcare facilities), 1,050 educational facilities (schools and related buildings), and 148 government buildings. Moreover, the AMSS's Office of Planning provided a database of 1,700 buildings affected by the earthquakes of 1,986 and 2,001 and information on 160 tall buildings (between four and 18 floors).

Seismic Hazard in the San Salvador Metropolitan Area (AMSS)

Seismic hazard is the probability that a seismic movement of a specific intensity will occur in a defined geographical area and time. It reflects characteristics that generally cannot be modified, such as seismicity (frequency and level of earthquake activity) and geology. The analysis of seismic threat depends on an accurate understanding of the characteristics of the area under study. These include regional seismic attenuation (loss of energy as the seismic wave passes through the ground), and the ground's displacement effects (probable movement of a structure caused by earthquake). The strength of the ground movement depends as much on scale, frequency, size, and location as on the site's geological, geotechnical and topographic characteristics. The hazard becomes a risk when buildings and other structures are vulnerable to the shaking ground. The level of risk is a function of the ability of the structures to withstand the shaking.

The Seismic Response Model for the AMSS included the compilation and validation of existing information regarding the area's geology, stratigraphic analysis (study of soils and rock strata), water wells, down hole (dynamic parameters), and accelographic records (to measure ground movement). This information is available in the geographic information system administered by MARN's information monitoring office.

The analysis of site effects is crucial for a complete understanding of the impact of the earthquake on the built environment. The site effects include the type (rock or hard ground, ash or soft layer, etc.) and strength, breadth, and depth of the shaking ground. The greatest damage occurs when the structure's vibration period coincides with the vibration period of the land beneath it.[3]

A zone map presents the various scenarios associated with each probability of occurrence. The map estimates the maximum acceleration of the ground and movements of structures of different heights for each seismic scenario. The probabilistic model for the AMSS included 24,996 probable seismic scenarios. Map 1 shows the seismic hazard for a 500-year return time (interval of time between probable occurrences) seismic threat in terms of peak ground acceleration (PGA). Map 2 shows general estimates of zones with similar seismic response levels, taking into account the ground characteristics.

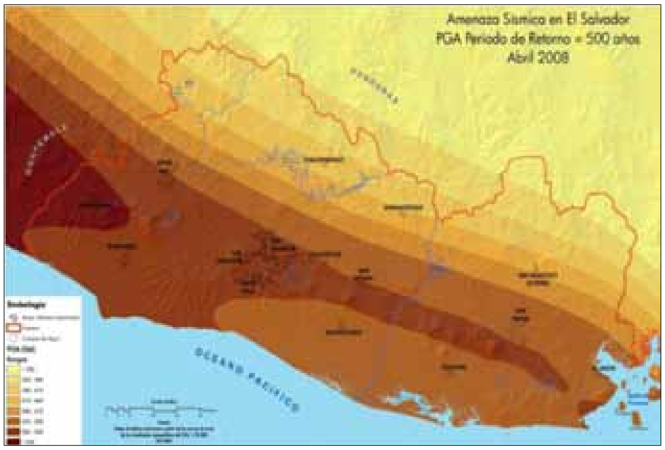
Assessing Vulnerability

According to Hermán Rosa Chávez, Minister of the Environment and Natural Resources, based on specific vulnerability analysis of infrastructure, "actions can be taken

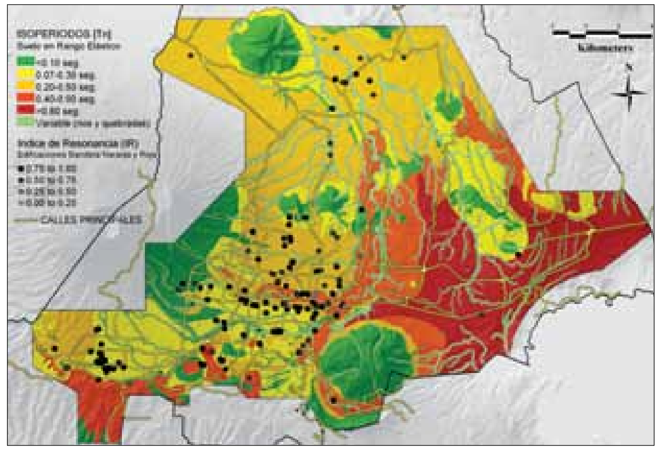
1 Zapata, R. (2001). ECLAC: Summary of the damage caused by the earthquakes of 13 January and 13 February 2001 in El Salvador. ISDR Informs 3, 12-17.

2 The participating Salvadoran agencies included MARN, the Ministry of Agriculture and Livestock (MAG), the Ministry of Economy, the Ministry of Public Works (MOP), the Social Investment Fund for Local Development (*Fondo de Inversión Social para el Desarrollo Local*, FISDL), the National ... the National Geographic Institute and National ... *onal Geográfico y del Catastro*, IGN), the Central ... Office of Civil Protection (*Dirección General de* ... ed Forces, the University of El Salvador Faculty of ... thematics, and the University of Central America. ... NGOs included the World Food Programme, ... ons Development Programme, the Inter-American ...), and the World Bank. The engineering consulting ... *gos Naturales—América Latina* (ERN) provided ... vice for the seismic analysis.

3 Vibration period is an engineering parameter related to the dynamic performance of structures (building, bridges, towers, and tanks, among others).



Map 1. Seismic Threat for a 500-year Return Time.



Map 2. Similar Seismic Response Zones.

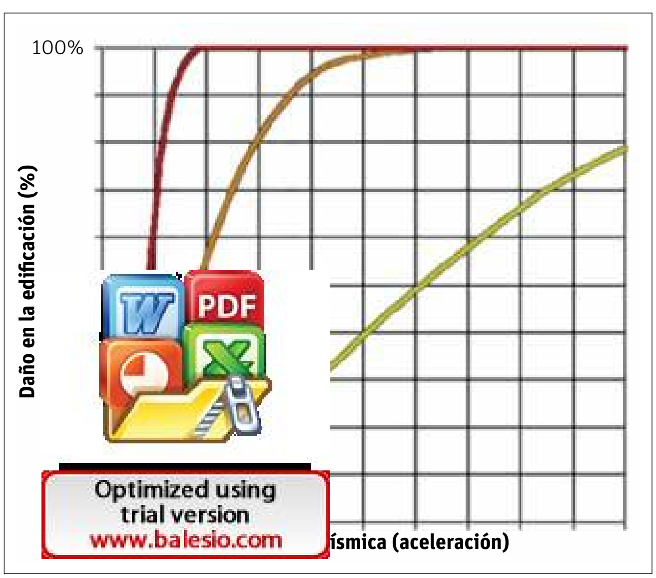
for maximum damage mitigation in the next earthquake." An important part of risk analysis is the definition of susceptibility to damage, or vulnerability to a specific hazard. The vulnerability function is a measure of the cost to repair the damage to the original state as a percentage of the total value of the asset. The measure includes as a parameter the selected intensity of spectral acceleration (maximum acceleration in an earthquake as measured at a spectral acceleration station). In San Salvador, the vulnerability curves were calibrated using seismic damage information from the 2001 database and accelographic record for each structure. The closest spectral acceleration station to each building provided the acceleration information. Figure 1 is an example of a vulnerability curve showing probable damage at different intensities.

The analysis focused on the buildings of the Ministries of Health and Government and a 20 percent sample of buildings belonging to the Ministry of Education. The Education selections were based on geographic location, public or private sector ownership (10 percent private), rural or urban identity, and size or height. For each structure, the project collected information regarding seismic vulnerability as year of construction, materials used, damage from previous events, height, number of floors, and the like.

The TAP partnered with the TAISHIN Project to codify this information for each structure and use the results to complete the vulnerability curves. The TAISHIN Project is a partnership among El Salvador, Mexico and Japan to conduct full scale seismic resistant tests of one-story low-income housing. To develop the vulnerability curves, the Project established the Large Structures Laboratory at the University of Central America and a Shake Table Laboratory at the University of El Salvador and conducted full scale seismic resistant tests of various materials.

The probabilistic analysis of seismic risk included 257 institutions and 24,996 possible scenarios for 1550 buildings of which 1050 (68 percent) belonged to Education, 352 (23 percent) belonged to Health, and 148 (9 percent), belonged to Government. The analysis included a study of the probable damage on current infrastructure from previous earthquakes.

The TAP identified the main vulnerability factors as the building's height, structural system, design (level of earthquake resistance), and construction year (seismic design code). Exposure was made worse by the lack of planning and haphazard growth. For the 257 institutions, the analysis obtained a "pure risk premium" value (annual cost of risk, excluding administrative costs) of US$14.7 million, approximately 6 percent of the value of exposed infrastructure. The



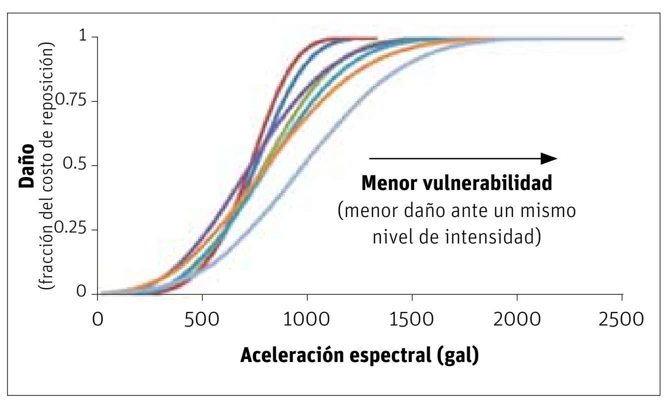


Figure 1. Vulnerability Curve Showing Probable Damage at Different Intensities.

City of San Salvador, El Salvador.

pure premium represents the annual amount that should be set aside in reserve to cover the cost of future expected losses.

The Government Responds

Based on these results, the government of El Salvador is designing a seismic vulnerability reduction program with focus initially on the Education sector. This program will complement other risk reduction policies that the government has implemented in last five years. The program aims not only to define urgent actions for buildings in critical condition but also establish a long term strategy to improve the structural and functional characteristics of both existing and new buildings.

Conclusion

This initial CAPRA analysis should be thought of as an estimate of probable damage based on existing information within implied limitations. The results are open to review and revision as researchers develop new information. Despite this limitation, the analysis is proving invaluable for decision-making. The purpose is to determine existing risk levels in a specific location with the goal of reducing risk to an "acceptable" level, given a country's economic limitations.

In urban areas, like the AMSS, where earthquakes occur on a regular basis, the existing infrastructure and knowledge regarding the potential danger determine the level of vulnerability. During the initial information-gathering phase, the project's analysis of parameters with greatest influence on the behavior of the infrastructure during an earthquake was based on past information. The field studies to update the information revealed a very high level of vulnerability because of the extraordinary number of buildings and because of the "improvisational" nature of their construction. This led to a combination of systemic and structural defects and high seismic vulnerability.

The impact of structural defects on seismic behavior is an important factor for analysis, especially where the defects have led to more damage than expected. Therefore, studies should place special attention on structural and construction defects and conduct detailed field studies. As Minister Herman Rosa Chavez points out, the advantage of the CAPRA's "clear approach" is the ability to obtain not only simple models that may be of academic interest, but "criteria for avoiding massive loss of life." Researchers can use this new information to update their vulnerability studies, improve construction techniques and, most importantly, save lives.

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