Peru: Disaster Risk Management in Water and Sanitation Utilities
Volume I: Catastrophic Risk Profile, Mitigation Measures and Financial Protection. The Case of SEDAPAL and EMAPICA

October 2012
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The Case of SEDAPAL and EMAPICA

Author
This publication has been produced by Consorcio Evaluación de Riesgos Naturales – América Latina, ERN – AL, conformed by Centro Internacional de Métodos Numéricos en Ingeniería (CIMNE), Evaluación de Riesgos Naturales, Ingenieros Consultores S.C., ITEC Ltda. and INGENIAR Ltda.

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The production of this study was made possible by the financial support from the Canadian International Development Agency (CIDA).

Graphic Design
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First Edition: October, 2012
Press Run: 150 copies
Printing: GMC Digital S.A.C.
Lima, Peru
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Foreword

The seismic risk in Peru is the highest catastrophic risk in the country. According to a World Bank study, Peru is located on the 20th spot of the world ranking of countries with highest economic risk due to threats caused by extreme events such as earthquakes, floods, frosts, among others. In August 2007, Peru's south region was hit by an 8.0 Mw earthquake, affecting the population with infrastructure damage. This disaster put in evidence the weakness in disaster risk management politics, and holes especially in the reduction of vulnerability and emergency management.

As part of the support that the World Bank offered the Peruvian government in facing reconstruction, infrastructure seismic risk evaluation was developed for SEDAPAL and EMAPICA, two Peruvian companies that provide drinking water and sanitation services. The study looked to quantify the probable losses that these companies are exposed to for damages on their infrastructure due to the occurrence of future earthquakes. The results of this evaluation are constituted in a fundamental input for future analysis in the design and prioritization of disaster risk reduction measures of these companies. The study features some recommendations of risk management policies and emphasizes on the need to continue improving the knowledge of threats and risks.

Due to its reach and methodology (probabilistic risk modeling, using the CAPRA platform) it is the first to be developed in the water and sanitation sector in Peru. In this sense, the study also offers an excellent opportunity to review and learn the usefulness of the probabilistic approximation and to promote new studies in other regions of the country.

The study had the decided support of Board Members and officers of SEDAPAL and EMAPICA companies for the collecting and arrangement of the baseline information and the technical studies.

We would like to express our acknowledgement to those who, with their invaluable contribution, made possible the development of this publication; Fernando Ramirez (Disaster Risk Management Senior Specialist, LCSDU), Oscar Ishizawa (Disaster Risk Management Specialist, LCSDU), Diana Rubiano (Disaster Risk Management Senior Specialist ETC, LCSDU), Iris Marmanillo (Water and Sanitation Senior Specialist, TWILC), Gustavo Perochena (Senior Economist, TWILC), Yehude Simon (Communications Officer, TWILC), Juan Chong (Consultant, TWILC) and Marisol Noriega (Program Assistant, TWILC). We also thank the Canadian International Development Agency (CIDA), for funding this study.

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3 Company located in the city of Lima (Central coast of Peru) with 9 millions of inhabitants.
4 Company located in the city of Ica (South of Lima) with 500 thousand inhabitants.
5 The study was advanced by Consorcio ERN LA
I. Introduction

1.1 Overview
A rigorous risk assessment for water supply and sanitation service providers in Peru (EPS is the Peruvian acronym) and an analysis of the institutional context (State agencies, service providers, insurance companies) are the baseline for proposing a financial risk protection scheme and the requirements for each of the providers in the sector at large to implement them through sector policies.

The catastrophic risk assessment of a water supply and sanitation system in order of priority must take into account the main natural hazard(s) to the system and a vulnerability assessment of the different components, that is to say, the predisposition that said elements have of becoming damaged if a major event occurs.

Peru is subject to a series of natural hazards. Their intensity and area of influence are illustrated in Figure 1.1 below. It is evident that earthquakes and hydro-meteorological phenomena are the main hazards that can give rise to catastrophic disasters in Peru. It is also evident that recurrent landslides and flooding that are not visible at a national level but that locally are, cause ongoing effects that are significant on an accumulative basis. Moreover, for the relatively smaller service providers situated in highly vulnerable areas, such events can have more critical effects than a seismic event.

![Figure 1.1: Area of Influence in Percentages, by Type of Hazard](source: Munich Re)
From a risk perspective, the most important natural events for Peru are earthquakes and flooding, in particular the latter produced by the El Niño phenomenon. These extreme events will most likely cause the most potential losses with the greatest consequences and effects in the future. However, to compensate that grim scenario, they have a very low probability of occurrence. We should also mention other natural events that are generally less severe but capable of producing significant local damage, such as tsunamis.

Regarding seismic hazard in Peru, most of the seismic activity is related to the subduction of the Nazca plate under the South American plate (the continental plate), which generates a high seismic hazard level for practically all of the Pacific Coast of Peru.

As to hydro-meteorological hazards, in Peru the El Niño phenomenon has a periodical recurrence. It pronounces itself with the presence of rainfall and abnormally high temperatures on the Pacific Coast during the hot dry season (from the end of November to the end of April), especially during the months of January, February, and March. The phenomenon creates torrential rainfall, flooding, and landslides in the North (Lima, Ancash, Lambayeque, La Libertad, Piura, and Tumbes) and draughts in the South (Arequipa, Moquegua, Tacna, Puno, Ayacucho, Apurimac, Huancavelica, and Cusco), greatly affecting the Peruvian agricultural and livestock sector.

Below is a list of the recently occurred major catastrophes in Peru; it reveals the overall hazard level of the country.

- The earthquake in 1970 with magnitude 7.8 on the Richter scale caused 66,794 deaths (the highest number ever recorded in Peruvian history) and affected 3,216,240 persons.
- The flooding in 1983 caused 364 deaths and affected 700,000 persons.
- The flooding in 1983 caused 620,000 persons.
- The drought in 1990 affected 2,200,000 persons.
- The drought in 1992 affected 1,100,000 persons.
- The flooding in 1997 spread over 540 km2; it caused 340 deaths and affected 580,750 persons.
- The extreme temperatures in July 2003 and in June 2004 affected 1,839,888 and 2,137,467 persons, respectively.
- The earthquake in August 2007 with magnitude 8.0 on the Richter scale caused more than 500 deaths.


Considering the great impact of earthquakes in Peru, proven by the above statistics, and given that this study focuses on the estimation of catastrophic losses, the risk analysis gives priority to earthquake events.

Also, in order to use reliable information for the scope of the study, the water and sanitation service providers SEDAPAL in the city of Lima and EMAPICA in the city of Ica were used as representative case studies and for each one the systems a probabilistic risk assessment was conducted.

1.2 Objective
The main objective of this part of the study (Volume I) is to produce the catastrophic risk assessment for seismic events, to develop and recommend a financial protection strategy and produce the base elements for a risk management
policy, to contribute to closing the gap between economic losses from possible future catastrophic events and available resources for two service providers who are representative of the sector in Peru, the companies SEDAPAL and EMAPICA.

1.3 Scope and Limitations
The risk assessment aimed at estimating the maximum probable economic losses for each of the two selected public utility service providers was made by applying probabilistic risk analysis models, taking into account the hazard assessment and the inventory valuation and characterization of the exposed infrastructure.

The probabilistic risk analysis made in the context of this project is limited to seismic hazard because earthquakes are responsible for the most important catastrophic events. For each one of the two service providers under study, a preliminary assessment of flooding or landslide hazard allowed drawing the conclusion that an event associated with a flooding or a landslide generally affects the system less than an event tied to an earthquake.

Volume I of this report contains the results of the technical risk assessment as well as specific recommendations relating to mitigation and financial protection measures for each of the two selected public utility service providers. It also includes challenges and recommendations for a more in-depth financial protection policy design and implementation for the sector. The target audience is water and sanitation service provider directors and technicians, as well as sector professionals interested in company risk analysis. Detailed information can be found in the annexes, for readers to further study each one of the technical results presented in the main portion of the report.

To develop the financial protection strategy and the suggestion of sector risk management policy elements, a detailed analysis was made of the two representative sector service providers selected, the results of which furnish the elements needed to meet the desired general objectives. The study includes an analysis of each company’s financial capacity and its catastrophic risk expressed in terms of average economic losses after the occurrence of natural events such as earthquakes, flooding, and landslides.

Volume II analyzes the institutional context of the water supply and sanitation sector and presents existing laws, regulations, and policies regarding service providers, the general methodological aspects for sector probabilistic risk assessment and the aspects related to disaster risk management, as well as the financial protection measures for the sector. It is mainly aimed at regional and national government public sector personnel in charge of establishing and supervising sector policy. It is also a fine reference document for sector service providers that wish to implement a risk management system.

1.4 Case analysis selection
1.4.1 Selection Criteria
In order to select case studies representative of the general situation of public utility service providers, a detailed review of the available information of a set of representative providers jointly selected with the Peruvian National Sanitation Services Superintendence (SUNASS) was made. The criteria taken into account for the selection are listed below:

- Company size (in principle at least one large company and one small one were to be studied)
- Available information that each Company had (quantity and quality) and willingness to prepare and share that information
- Occurrence of prior events, for some information about the vulnerability of the components and on the risk to the system
- Existing information regarding seismic microzonation studies and records of nearby seismic events that impacted the system
- The company’s degree of exposure to natural events
- The impact and applicable nature of the analysis results on other sector companies.
After a detailed analysis of the above aspects and a series of consultations to different individuals and entities involved, the service providers SEDAPAL (in Lima) and EMAPICA (in Ica) were chosen for the case analysis. EMAPICA is an interesting case; this provider has some institutional, organizational, and financial characteristics in common with different public utility service providers in Peru classified in the same company size category.

1.4.2 SEDAPAL
This public utility service provider is State-owned. It is organized as a sociedad anónima. It provides its services in the city of Lima (with more than 8,000,000 inhabitants) and boasts a broad infrastructure comprised of plants, tanks, wells, pipelines, and administrative buildings.

Lima is located in a zone with a history of earthquakes and has experienced recurring flooding and landslides in some specific sectors. The company SEDAPAL has all the required information for the analysis, including economic and financial information, operating and service statistics, and all of the technical information relating to each one of the company's main assets. In addition, it has an insurance policy, which indicates its high degree of exposure as well as its need to have this type of detailed information in order to manage its financial protection strategy.

1.4.3 EMAPICA
EMAPICA is a State-owned public utility company under private law. It provides water supply and sanitation services in the provinces of Ica and Palpa, as well as in the districts of Parcona and Los Aquijes.

The town and the service provider alike have the information required for the proposed study. In fact, the service provider has almost all of the information in digital format as well as reports and damage assessments for the important earthquakes and floods that greatly affected its assets. It is representative of the typical sector providers in small towns and then, small sized companies in Peru.
II. Risk profile of the analyzed infrastructure

2.1 Seismic hazard assessment

2.1.1 Introduction
Peru is located in one of the zones with greatest seismic activity in the world. Historical narratives of destructive earthquakes date back to Pre-Colombian times and, in many ways, this activity has determined the configuration and architecture of its cities. Most recently, Lima suffered the occurrence of big shakes in 1966, in 1970 (the earthquake that officially caused the greatest number of victims in the history of Peru), and in 1974. Also, in 2007 the population of Ica recently suffered an earthquake that generated a catastrophic situation in the municipality and in the surrounding areas.

2.1.2 Seismic hazard assessment
The seismic hazard assessment at a national level involves a series of specialized activities, which are described in Technical Annex Section 5.1. Seismic hazard can be understood through a series of hazard maps that are drawn up considering different intensity parameters and different return periods for the selected intensities. Figure 2-1 illustrates a hazard map corresponding to maximum acceleration on rock for a return period of 500 years at the country level.

The most common manner to present the seismic hazard for a certain place is through the exceedance probability that a typical parameter has. Therefore, a time frame is defined, related to the useful life of the infrastructure under analysis and the different exceedance probabilities of the selected parameter during a time frame.

The return period corresponds to the inverse of the exceedance rate, normally stated in the average number of events per year. The return period thus corresponds to the average number of occurrences of an average intensity.

The fact that the return period of an event corresponds to a determined number of years does not guarantee that an event will occur during that period of time and it must always be understood that return period represents the mean occurrence of an event that exceeds certain established parameter.

2.1.3 Site effects
For Lima and its metropolitan area, CISMID (2005) a proposed seismic microzonation based on environmental vibration records obtained at distinct points in Gran Lima and in Callao is available. The microzonation study defined five (5) zones. Figure 2-2 presents the proposed seismic zoning for the city.
The town of Ica also has seismic microzonation information thanks to an Inter-institutional Cooperation Agreement between the Provincial Municipality of Ica and Universidad Nacional de Ingeniería. Figure 2-3 presents the microzonation map for Ica.
2.2 Risk analysis

A probabilistic approach for the risk analysis was chosen for the study. The seismic risk analysis involved the following specific activities:

1) Conduct a local seismic hazard assessment in the area of influence, by assessing all possible scenarios and their corresponding frequencies of occurrence.
2) Making an inventory of exposed assets by localizing, characterizing, and doing an economic appraisal of every element within the database.
3) Qualifying the seismic vulnerability of each of the exposed components.
4) Making a probabilistic risk assessment by integrating the specific hazard in the specific location of each one of the components along with its corresponding vulnerability, to obtain the risk results for all of the hazard scenarios calculated.

For the purpose of the study, risk is represented using these specific metrics:

- Probable maximum economic losses for the whole system for different return periods under analysis (PML curve)
- Average economic losses for each one of the components and for each one of the groups within each component, such as types of pipe lines (materials), types of tanks, and all other available sub-classifications.
- Average losses for each one of the earthquake scenarios under analysis, in particular for critical scenarios, that is to say, those that may cause the greatest potential economic losses.

Average losses can be graphically represented, especially for pipelines, in order to analyze the geographic distribution of the damage and the risk concentration zones.

The procedure used for the seismic probabilistic risk analysis is described in detail in Volume II.

Next, the main results of the analysis made for each of the two selected service providers is presented below. The specifics of the analyses and the results are described in detail in Technical Annex Section 5.

### 2.3 Exposure and risk analysis results for SEDAPAL

#### 2.3.1 Exposure

Table 2-1 summarizes the exposure in terms of the exposed economic value for the system, broken down for each of the components. Technical Annex Section 5.2 gives a detailed description of this assessment as well as the geographic distribution of each one of the components.

#### TABLE 2.1: DETERMINISTIC ANALYSIS RESULTS, BY COMPONENT (SEDAPAL)

<table>
<thead>
<tr>
<th>Component</th>
<th>Exposed Value²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[US$]</td>
</tr>
<tr>
<td>Primary network pipe lines</td>
<td>$ 695,109,878</td>
</tr>
<tr>
<td>Secondary network pipe lines</td>
<td>$ 1,553,783,128</td>
</tr>
<tr>
<td>Tanks</td>
<td>$ 146,384,562</td>
</tr>
<tr>
<td>Wells</td>
<td>$ 91,065,627</td>
</tr>
<tr>
<td>Water supply treatment plant</td>
<td>$ 271,757,768</td>
</tr>
<tr>
<td>Waste water treatment plant</td>
<td>$ 25,796,568</td>
</tr>
<tr>
<td>Control Stations</td>
<td>$ 2,523,779</td>
</tr>
<tr>
<td>Water supply pumping stations</td>
<td>$ 26,768,413</td>
</tr>
<tr>
<td>Sanitation pumping stations</td>
<td>$ 11,724,415</td>
</tr>
<tr>
<td>Administrative buildings</td>
<td>$ 20,296,886</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$ 2,845,211,024</strong></td>
</tr>
</tbody>
</table>

² The exposed value corresponds to the replacement value for each one of the components.

### 2.3.2 Comprehensive economic loss for the system

Table 2-2 is a summary of the Average Annual Loss (AAL) and the Probable Maximum Loss (PML) results for different return periods with the analysis results, taking all system components into consideration. Figures 2-4 and 2-5 show the system loss exceedance curve, the loss exceedance probability for different periods of exposure, and the PML curve for the system.
TABLE 2.2: GENERAL RISK ASSESSMENT RESULTS (SEDAPAL)

<table>
<thead>
<tr>
<th>Results</th>
<th>Exposed Value</th>
<th>Average annual loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>US$ x10^6</td>
<td>%</td>
</tr>
<tr>
<td>Exposed Value</td>
<td>2,845.21</td>
<td>18.353</td>
</tr>
<tr>
<td>Return Period</td>
<td>Loss</td>
<td></td>
</tr>
<tr>
<td>Years</td>
<td>US$ x10^6</td>
<td>%</td>
</tr>
<tr>
<td>100</td>
<td>$109.71</td>
<td>3.86</td>
</tr>
<tr>
<td>250</td>
<td>$144.59</td>
<td>5.08</td>
</tr>
<tr>
<td>500</td>
<td>$169.97</td>
<td>5.97</td>
</tr>
<tr>
<td>1000</td>
<td>$195.14</td>
<td>6.86</td>
</tr>
</tbody>
</table>

FIGURE 2.4: RISK ANALYSIS RESULTS (SEDAPAL)
(Left: Loss exceedance curve; Right: Loss exceedance probability for different exposure periods)

FIGURE 2.5: RISK ANALYSIS RESULTS: PML CURVE (SEDAPAL)

Return Period (in years)
2.3.3 Impact and economic loss broken down by component

Figure 2-6 and Figure 2-7 show the average annual number of damages to pipe line materials for the water supply and sanitation networks in the city of Lima.
Table 2-3 and Figure 2-8 show the risk results classified by type of component.

**TABLE 2.3: RISK RESULTS, BY TYPE OF COMPONENT (SEDAPAL)**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tubería red primaria</td>
<td>$ 695,109,878</td>
<td>24.4</td>
</tr>
<tr>
<td>Tubería red secundaria</td>
<td>$ 1,553,783,128</td>
<td>54.6</td>
</tr>
<tr>
<td>Tanques</td>
<td>$ 146,384,562</td>
<td>5.1</td>
</tr>
<tr>
<td>Pozos</td>
<td>$ 91,065,627</td>
<td>3.2</td>
</tr>
<tr>
<td>PT agua potable</td>
<td>$ 271,757,768</td>
<td>9.6</td>
</tr>
<tr>
<td>PT aguas residuales</td>
<td>$ 25,796,568</td>
<td>0.9</td>
</tr>
<tr>
<td>Cámaras de Control</td>
<td>$ 2,523,779</td>
<td>0.1</td>
</tr>
<tr>
<td>CR acueducto</td>
<td>$ 26,768,413</td>
<td>0.9</td>
</tr>
<tr>
<td>CR alcantarillado</td>
<td>$ 11,724,415</td>
<td>0.4</td>
</tr>
<tr>
<td>Locales administrativos</td>
<td>$ 20,296,886</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$ 2,845,211,024</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

[^3]: The exposed value corresponds to the replacement value for each one of the components.

**FIGURE 2.8: RISK RESULTS BY TYPE OF COMPONENT (SEDAPAL)**
2.3.4 Seismic risk analysis conclusions
The seismic risk analysis enabled drawing the following general conclusions:

(1) The total exposed value for the system is approximately US$ 2.845 billion, including water supply pipelines, sanitation pipe lines, wells, tanks, administrative buildings, control stations, pumping stations, and treatment plants.

(2) The system components that represent the highest exposed values are:
- Primary network pipelines, with 24.4%
- Secondary network pipelines, with 54.6%
- Drinking water treatment plants, with 9.6%.

(3) The probable maximum loss for the system for a return period of 1,000 years is around US$ 195.1 million, corresponding to approximately 6.9% of the total exposed value.

(4) The average annual loss values for the whole system are around US$ 18.3 million, corresponding to 6.45 per thousand of the total exposed value. This value represents the average annual value of all possible situations of disaster due to earthquakes. It is also the pure risk insurance premium.

(5) The system components that have the greatest risk levels are:
- Tanks (elevated and underground)
- Wells
- Groups of particular water supply and sanitation network pipe lines (those made of the most vulnerable materials).

(6) The types of water supply pipe lines that have the greatest risk levels are:
- Asbestos cement pipe lines
- PVC (house connections, anchoring elements, derivations, etc…)
- Ductile iron pipe lines
- Cast iron pipe lines.

(7) The types of sanitation pipe lines that have the greatest risk levels are:
- Plain concrete pipe lines
- PVC pipe lines
- Asbestos cement pipe lines.

2.4 exposure and risk analysis results for EMAPICA

2.4.1 Introduction
The risk analysis for the town of Ica took into consideration the recent occurrence of events that have had a great impact on the company infrastructure, such as the 1998 flood and the 2007 earthquake (the Pisco earthquake). Such events and their impact on the company infrastructure obliged the service provider to undertake a series of repair and retrofitting works that are still in course. That is why the current level of vulnerability of the system components is not precisely known, but, for the purpose of this analysis, it is assumed that the new construction and the repair and risk mitigation works have been performed in compliance with basic earthquake resistant design requirements. Notwithstanding, the system components not yet submitted to repair or retrofitting have been assigned a high level of vulnerability, based on the original information.

2.4.2 Exposure
Table 2-4 summarizes exposure in terms of the exposed economic values for the system for each one of the components. Technical Annex Section 5 presents the details of this assessment as well as the geographical distribution of each one of the components.
### TABLE 2.4: EXPOSED ECONOMIC VALUES, BY SYSTEM COMPONENT (EMAPICA)

| Component                  | Exposed Value  
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary network pipe lines</td>
<td>$11,694,760</td>
</tr>
<tr>
<td>Secondary network pipe lines</td>
<td>$21,995,034</td>
</tr>
<tr>
<td>Wells</td>
<td>$10,634,321</td>
</tr>
<tr>
<td>Plants</td>
<td>$4,836,856</td>
</tr>
<tr>
<td>Tanks</td>
<td>$4,606,112</td>
</tr>
<tr>
<td>Total</td>
<td>$53,767,083</td>
</tr>
</tbody>
</table>

### Table 2.5: OVERALL RISK RESULTS (EMAPICA)

<table>
<thead>
<tr>
<th>Results</th>
<th>Exposed Value</th>
<th>Average annual loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>US$ x10⁶</td>
<td>%</td>
</tr>
<tr>
<td>Exposed Value</td>
<td>53.77</td>
<td></td>
</tr>
<tr>
<td>Average annual</td>
<td>1.233</td>
<td>22.94</td>
</tr>
<tr>
<td>loss</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Return Period</td>
<td>Loss</td>
<td></td>
</tr>
<tr>
<td>Years</td>
<td>US$ x10⁶</td>
<td>%</td>
</tr>
<tr>
<td>100</td>
<td>$7.13</td>
<td>13.25</td>
</tr>
<tr>
<td>250</td>
<td>$8.64</td>
<td>16.08</td>
</tr>
<tr>
<td>500</td>
<td>$9.26</td>
<td>17.23</td>
</tr>
<tr>
<td>1000</td>
<td>$10.51</td>
<td>19.54</td>
</tr>
</tbody>
</table>

2.4.3 Comprehensive overall economic loss for the system

Table 2-5 is a summary of the Average Annual Loss (AAL) and the Probable Maximum Loss (PML) results for different return periods with the analysis results, taking all system components into consideration. Figures 2-9 and 2-10 show the system loss exceedance curve, the loss exceedance probability for different periods of exposure, and the PML curve for the system.

### FIGURE 2.9: RISK ANALYSIS RESULTS (EMAPICA)

(Left: Loss exceedance curve; Right: Loss exceedance probability for different exposure periods)

---

4 The exposed value corresponds to the replacement value for each one of the components.
2.4.4 Impact and economic losses broken down by component

Figure 2-11 and Figure 2-12 show the average annual number of damages to pipe line materials for the water supply and sanitation networks in the town of Ica.
Table 2-6 and Figure 2-13 show the risk results, classified by type of component for the EMAPICA system.

**TABLE 2.6: EXPOSED VALUES AND AVERAGE ANNUAL LOSS, BY TYPE OF COMPONENT (EMAPICA)**

<table>
<thead>
<tr>
<th>Component</th>
<th>Exposed Value 5</th>
<th>Average annual loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary network pipe lines</td>
<td>$11,694,760 21.8</td>
<td>$49,631 4.2</td>
</tr>
<tr>
<td>Secondary network pipe lines</td>
<td>$21,995,034 40.9</td>
<td>$69,990 3.2</td>
</tr>
<tr>
<td>Wells</td>
<td>$10,634,321 19.8</td>
<td>$396,271 37.3</td>
</tr>
<tr>
<td>Plants</td>
<td>$4,606,112 8.6</td>
<td>$693,679 150.6</td>
</tr>
<tr>
<td>Tanks</td>
<td>$4,836,856 9.0</td>
<td>$23,712 4.9</td>
</tr>
<tr>
<td>Total</td>
<td>$53,767,083 100</td>
<td>$1,233,284 22.9</td>
</tr>
</tbody>
</table>

The analysis enabled identifying that the components well and tanks (elevated and ground) represent a considerable part of the total loss; that is because they are the most vulnerable system components, which is common among the different water supply and sanitations in earthquake zones.

2.4.5 Seismic risk analysis conclusions
The seismic risk analysis made for the service provider EMAPICA enabled drawing the following general conclusions:

---

5 The exposed value corresponds to the replacement value for each one of the components.
(1) The total exposed value for the system is approximately US$ 53.8 million, including water supply pipe lines, sanitation pipe lines, wells, tanks, and treatment plants.

(2) The system components that have the highest exposed values are:
- Primary network pipe lines, with 21.8%
- Secondary network pipe lines, with 40.9%
- Wells with 19.8%.

(3) The probable maximum loss for the system with a return period of 1,000 years is around US$ 10.5 million, corresponding to approximately 19.5% of the total exposed value. That value, relatively high if compared to equivalent values in other towns, can be explained by the combination of a high seismic hazard and of high pipe line component vulnerability, despite the intervention works, given that the pipe lines themselves were not submitted to a retrofitting or replacement process after the above-mentioned flood and earthquake events.

(4) The average annual loss values for the whole system are around US$ 1.23 million, corresponding to 22.9 per thousand of the total exposed value. That value is also considered high compared to other similar cases and can be interpreted as the great potential future affection due to recurring events of an average or small magnitude.

(5) The system components that have the greatest risk levels are:
- Wells
- Tanks
- Groups of particular water supply and sanitation pipe lines (those made of the most vulnerable materials).

(6) The types of water supply pipe line subcomponents that have the greatest risk levels are:
- Asbestos cement pipe lines
- PVC (house connections, anchoring elements, derivations, etc…).

(7) The types of sanitation pipe line subcomponents that have the greatest risk levels are:
- Reinforced concrete pipe lines
- Structural plain concrete pipe lines.
III. Application of the results obtained, to identify mitigation and financial protection measures

3.1 Cost-benefit analysis of infrastructure risk mitigation work

3.1.1 Introduction

In practice, the most efficient way to decrease infrastructure risk is to perform structural and non-structural retrofitting and retrofitting works. The process requires a large economic investment aimed at diminishing the vulnerability of the element and, thus, its future risk level. Reducing vulnerability and risk translates into lower average losses for future events. The decrease is seen not only in direct physical losses but also in affected component content losses, in losses due to business interruption, in losses due to indirect impacts, such as how the event will affect the people involved (injuries and deaths), and in losses associated with diminished or interrupted operations related to indirect social effects that are generally very difficult to quantify and, thus, rarely taken into account.

The above enables a cost-benefit assessment for different retrofitting and/or retrofitting alternatives, for the purpose of having clear criteria and be able to define the optimum intervention option and propose a priority for a series of intervention alternatives, all technically viable in an environment of limited resources. In the ratio, benefit corresponds to savings made on future average losses (including direct losses; indirect losses; losses due to business interruption; social, environmental and functional losses; and, in general, all losses associated with the affected component) and cost corresponds to the value of each one of the different intervention work alternatives.

The assessment of future average losses is based on the reoccurrence of events with different intensities. Given the uncertainty associated with the occurrence of future events, a simulation of the processes that represent the historical reoccurrence is used or a probabilistic model assessment also calibrated with the historical occurrence of the events. Therefore, each simulation of events calculates future eventual losses at present value in order to compare (during the same time, present) such losses against the initial investment that the proposed intervention represents.

A probabilistic assessment requires determining the probability distribution of the cost-benefit ratios. In this case, the present net value of the savings on future average losses is used (taking into consideration the intervened scenario as well as the non-intervened scenario) and that value is compared against the cost of the intervention (structure retrofitting) under current conditions.

The objective of the simulation, the results of which are presented further on, is to assess the potential risk that some water supply and sanitation network components have when faced with future seismic events, stated in terms of average annual economic losses (AAL), in order to do a cost-benefit exercise and observe the simulation process of future average losses and how to reduce them through an intervention alternative that will significantly improve the resistance of the components.

This analysis solely took into consideration a decrease in the direct losses of each one of the components. It did not consider eventual losses regarding the following: construction contents; business interruption; or indirect effects and losses, such as persons affected, service suspension, users indirectly affected, macro-economic effects or impacts, etc.
To make the cost-benefit analysis, the following activities were carried out:

- Proposing a vulnerability reduction model for each one of the critical components (those with the greatest risk) based on its current condition and on its ideal condition (reinforced condition).
- Making an economic assessment of the intervention work required for the proposed reduction in vulnerability.
- Suggesting the vulnerability functions corresponding to the original condition and to the retrofitted condition.
- Making two risk analyses, one for the original condition and the other for the reinforced condition of the different components identified.
- The analyses enabled obtaining the average value of the savings on future average annual loss as well as the probability of the cost-benefit ratio being greater than 1.0.

Technical Annex Section 5-6 presents those analyses in detail for SEDAPAL and for EMAPICA.

### 3.1.2 Cost-benefit analysis of mitigation work for SEDAPAL

The cost-benefit ratio assessment is based on the risk analysis results obtained for the SEDAPAL water supply and sanitation system.

Table 3-1 summarizes the results for each of the system component groups. The table further presents the exposed value for each one of the component groups, the estimated intervention value, average savings on future losses (Lu-Lr), the average value of the cost-benefit ratio (E(Q)), and the probability of the cost-benefit ratio value being greater than 1.0 (that is to say, the probability of the benefit actually being greater than the investment cost).

**TABLA 3.1: RESUMEN DEL ANÁLISIS DE BENEFICIO-COSTO PARA EL SISTEMA COMPLETO**

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Water supply primary network</td>
<td>355.0</td>
<td>119.0</td>
<td>24.3</td>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>Water supply secondary network</td>
<td>929.0</td>
<td>685.4</td>
<td>25</td>
<td>0.04</td>
<td>0</td>
</tr>
<tr>
<td>Sanitation primary network</td>
<td>340.0</td>
<td>1523.5</td>
<td>17.4</td>
<td>0.01</td>
<td>12</td>
</tr>
<tr>
<td>Sanitation secondary network</td>
<td>625.0</td>
<td>433.0</td>
<td>79.7</td>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>Tanks</td>
<td>101.0</td>
<td>14.0</td>
<td>70.9</td>
<td>5.1</td>
<td>100</td>
</tr>
<tr>
<td>Administrative buildings</td>
<td>20.0</td>
<td>7.2</td>
<td>2.3</td>
<td>0.3</td>
<td>100</td>
</tr>
</tbody>
</table>

6 Technical Annex Section 5.6.2.1 presents the cost model used to assess the intervention work on the different components.
The above results enable suggesting a defined strategy for reducing system vulnerability for SEDAPAL S.A. The strategy includes the following aspects:

(a) Technical information management and updating strategy. The service provider must develop a strategy for consolidating all technical information regarding exposure and risk and keeping it updated. To do so, it is advisable to manage all available information in geographic information systems and to design internal mechanisms for all technical information to be included in such systems from now on. To initiate the process, all of the information gathered for this project must be included and the databases used, to further develop the activity. In particular, all information related to the maintenance and retrofitting work forwarded must be recorded including the type of work performed, the date, evaluation, reinforced or replaced elements, detailed drawings, technical specifications, and other related information.

(b) System functional vulnerability assessment. SEDAPAL must have an assessment of the functional vulnerability of the system, to identify the relative importance of each one of the system components in terms of its functionality (number of users who would no longer have service if the component should fail and the estimated recovery cost and time) as well as the degree of redundancy or the difficulty entailed in repairing or replacing the component should it become damaged. That information will allow establishing a priority for future interventions or new investments in the system.

(c) Risk mitigation intervention plan. Based on the conducted studies, the intervention plan that SEDAPAL should adopt is proposed below, with an order of priority.

i. Tanks intervention. Tank structures are some of the system components that have the greatest level of risk; therefore, they are the components with the greatest cost-benefit ratios. That implies that investing in such components would result in more effective system risk reduction. The components with most intervention priority are the oldest elevated tanks, followed by the newer elevated tanks that do not fully meet earthquake resistant standards, and finally by the larger ground tanks. To define the order of intervention and the optimum types of intervention, SEDAPAL must conduct detailed technical studies based on local laws, regulations and specifications, for the earthquake resistant design and construction of this type of component, with the assessment of specialized consultants.

ii. Administrative and storage buildings intervention. Administration and storage sites, especially the oldest ones, must undergo detailed vulnerability assessments, to evaluate the optimum retrofitting alternative, mainly considering earthquake-resistant design aspects. Specialized consultants must produce specific work designs before the intervention can be carried outs. Although, in terms of physical value, this group does not represent a large portion of all of the exposed assets, the functionality of the system would be seriously affected if such components were damaged to an extent endangering the contents of such sites, such as control centers, computing centers, etc.

iii. Water supply and waste water treatment plant intervention. Due to their age and level of maintenance, water supply and waste water treatment plants must undergo detailed vulnerability assessments, to evaluate the optimum retrofitting alternative, mainly considering earthquake-resistant design aspects. Given the characteristics proper to each treatment plant, it is not feasible to suggest a comprehensive retrofitting; specific individual studies are required.
iv. Pipe line intervention and replacement. The water supply pipe line components that have the greatest risk levels include asbestos cement pipe lines, PVC pipe lines (in specific critical points), and ductile iron and cast iron pipe lines. The sanitation pipe lines most susceptible to damage are plain concrete pipe lines and asbestos cement pipe lines. Given the high costs and great difficulty entailed in making an integral intervention of such components due to the high impact that the work implies not only on the system but also on the whole city, the proposed strategy is described below.

- SEDAPAL must adopt its own rules and regulations regarding the type of pipes and materials that it should use for its pipe line system expansion, recovery, repair or intervention projects.

- From the functional vulnerability perspective, SEDAPAL must identify which pipe stretches are the most critical ones with the least redundancy, assessing the impact that the lack of such pipe stretches would represent on overall service provision, including the time foreseen to reestablish it.

- Based on the above information, SEDAPAL must be able to establish an annual budget for pipe line system interventions, to enable starting mid-term and long-term processes for replacing the types of pipes that represent the greatest risk and that are most relevant to the system.

- A manner of creating redundant systems after a catastrophic event must be sought, especially for ensuring service provision to essential institutions. System redundancy also allows carrying out specific work without affecting the normal water supply.

v. SEDAPAL must make an assessment of water extraction well functionality. As it is impossible to protect the wells from earthquakes or floods taking structural measures, a contingency plan must be implemented in the event that each one of the currently operating wells goes out of service due to an earthquake.

(d) Long-term intervention budget. The initial appraisal of possible interventions indicates a value of around US$ 14 million for retrofitting and reinforcing the main tanks and a budget of several billion dollars for adequate retrofitting of the pipe line system, which, due to its characteristics, would entail replacing the pipes. Therefore, the intervention in the pipe line system must be done using alternate mid-term and long-term strategies, as was stated above. Also, an additional budget must be considered for edification intervention (administrative buildings, control centers, and operations centers, storage sites, and others), which usually represents around US$ 200 to US$ 500 per square meter of intervention, depending on the structural type of the construction, solely considering the work associated with structural intervention (not including finishings, installations, equipment, and others).

3.1.3 Cost–benefit analysis of mitigation work for EMAPICA

The cost-benefit ratio assessment is based on the risk analysis results obtained for the EMAPICA water supply and sanitation system.

Table 3-2 summarizes the results for each one of the system component groups. The table further presents the exposed value of each one of the component groups, the estimated intervention value, the average savings on future losses (Lu-Lr), the average value of the cost-benefit ratio (E(Q)), and the probability of the cost-benefit ratio value being greater than 1.0 (that is to say, the probability of the benefit actually being greater than the investment cost).
The above results enable suggesting a defined strategy of system vulnerability reduction for EMAPICA. The strategy includes the following aspects:

(a) Technical information management and updating strategy. The service provider must develop a strategy for consolidating all technical information regarding exposure and risk and keeping it updated. To do so, it is advisable to manage all available information in geographic information systems and to design internal mechanisms for all technical information to be included in such systems from now on. To initiate the process, all of the information gathered for this project must be included and the databases used, to further develop the activity. In particular, all information related to the maintenance and retrofitting work forwarded must be recorded including the type of work performed, the date, evaluation, reinforced or replaced elements, detailed drawings, technical specifications, and other related information.

(b) System functional vulnerability assessment. EMAPICA must have an assessment of the functional vulnerability of the system, to identify the relative importance of each one of the system components in terms of its functionality (number of users who would no longer have service if the component should fail and the estimated recovery cost and time) as well as the degree of redundancy or the difficulty entailed in repairing or replacing the component should it become damaged. That information will allow establishing a priority for future interventions or new investments in the system.

(c) Risk mitigation intervention plan. Based on the conducted studies, the intervention plan that EMAPICA should adopt is proposed below, with an order of priority.

i. Tanks intervention. Tank structures are some of the system components that have the greatest level of risk; therefore, they are the components with the greatest cost-benefit ratios. That implies that investing in such components would result in more effective system risk reduction. The components with most intervention priority are the oldest elevated tanks, followed by the newer elevated tanks that do not fully meet earthquake resistant standards, and finally by the larger ground tanks. To define the order of intervention and the optimum types of intervention, EMAPICA must conduct detailed technical studies based on local laws, regulations and specifications, for the earthquake resistant design and construction of this type of component, with the assessment of specialized consultants.

### TABLA 3.2: RESUMEN DEL ANÁLISIS DE BENEFICIO-COSTO PARA EL SISTEMA COMPLETO

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Water supply primary network</td>
<td>5.5</td>
<td>3.6</td>
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<td>0.04</td>
<td>0</td>
</tr>
<tr>
<td>Water supply secondary network</td>
<td>14.0</td>
<td>1.2</td>
<td>0.2</td>
<td>0.2</td>
<td>81</td>
</tr>
<tr>
<td>Sanitation primary network</td>
<td>6.2</td>
<td>3.7</td>
<td>0.4</td>
<td>0.1</td>
<td>0</td>
</tr>
<tr>
<td>Sanitation secondary network</td>
<td>8.0</td>
<td>3.1</td>
<td>0.5</td>
<td>0.2</td>
<td>1</td>
</tr>
<tr>
<td>Tanks</td>
<td>4.6</td>
<td>0.6</td>
<td>4.0</td>
<td>6.5</td>
<td>100</td>
</tr>
</tbody>
</table>
ii. Administrative and storage buildings intervention. Administration and storage sites, especially the oldest ones, must undergo detailed vulnerability assessments, to evaluate the optimum retrofitting alternative, mainly considering earthquake-resistant design aspects. Specialized consultants must produce specific work designs before the intervention can be carried outs.

iii. Pipe line intervention and replacement. The water supply pipe line components that have the greatest risk levels include asbestos cement pipe lines and PVC pipes (house connections, anchoring, derivations, etc.). The sanitation pipe lines most susceptible to damage are reinforced concrete pipe lines and plain concrete pipe lines. Given the high costs and great difficulty entailed in making an integral intervention of such components, the proposed strategy is described below.

- EMAPICA must adopt its own rules and regulations regarding the type of pipe and materials that it should use in all its pipe line system expansion, recovery, repair or intervention projects.

- From the functional vulnerability perspective, EMAPICA must identify which pipe stretches are the most critical ones with the least redundancy, assessing the impact that the lack of such pipe stretches would represent on overall service provision, including the time foreseen to reestablish it.

- Based on the above information, EMAPICA must be able to establish an annual budget for pipe line system intervention, to enable starting mid-term and long-term processes for replacing the types of pipes that represent the greatest risk and that are most relevant to the system.

iv. EMAPICA must make an assessment of water extraction well functionality. As it is impossible to protect the wells from earthquakes or floods taking structural measures, a contingency plan must be implemented in the event that each one of the currently operating wells goes out of service due to an earthquake.

(d) Long-term intervention Budget. The initial appraisal of the possible interventions indicates a value of around US$350,000 for retrofitting and reinforcing the main tanks and a budget of several million dollars for adequate retrofitting of the pipe line system, which, due to its characteristics, involves replacing the pipes. Therefore, the intervention in the pipe line system must be done using alternate mid-term and long-term strategies, as was stated above. Also, an additional budget must be considered for edification intervention (administrative buildings, control centers and operations centers, storage sites, and others), which is usually around US$ 200 to US$ 500 per square meter of intervention, depending on the structural type of the construction and solely considering the work associated with structural intervention (not including finishings, installations, equipment, and others).

3.2 Financial protection recommendations

3.2.1 Financial protection strategy proposal for SEDAPAL

3.2.1.1 Comprehensive diagnosis and financial gap
SEDAPAL is the largest out of a total of 50 public utility service providers that comprise the Peruvian water supply and sanitation sector, based on available information from the National Sanitation Services Superintendence (SUNASS).

SEDAPAL’s exposure and risk scenario is presented below.
General indicators
- Total number of estimated connections: 1,285,348
- Total served population: 7,235,363 inhabitants representing approximately 24% of the total population of Peru, which is 30,578,435 inhabitants
- Level of water supply and sanitation coverage: around 80.6% and 76.6%, respectively
- Percentage of treated waste water: around 21%
- Service continuity: around 22%
- Average fee: around US$ 0.79 per m³ of water
- Total operating income: US$ 403,457,570
- Mean work ratio: meaning total operating costs (not including depreciation and bad debt allowance) over total operating income, around 57.3%
- Average operating margin: approximately 22.5%, worth around US$ 90 million
- Unbilled water: around 38.5%

Exposure, risk, and financial management indicators
- Estimated total exposed value in goods and assets: US$ 2.845 billion
- Probable maximum loss for a return period of 1,000 years: US$ 195 million
- Probable maximum loss for a return period of 1,000 years as a percentage of the insurable amount: 6.9%
- Pure risk premium with 0% deductible: estimated at 6.45 per thousand of the exposed value and equal to 4.53% of the annual operating income for the year 2009.

3.2.1.2 Description of the effective insurance policy
SEDAPAL currently has an all risk insurance policy with full coverage for the goods that it owns based on the list attached to the policy. Coverage is underwritten on a first loss basis (the basis for calculating the first risk is unknown).

Coverage
The insurance policy includes all basic coverage under the All Risk scheme for property, electronic equipment, and engineering equipment. It covers everything related to physical damage, including natural events, such as earthquake, flood, and heavy rainfall, and terrorist events, such as vandalism, strikes, civil commotion, and intentional damage but with a secondary limit of 50% of the insured amount for damages.

Business interruption
The insurance policy does not cover business interruption.

Effective term
The evaluated insurance policy started on October 31 and had a one (1) year term ending on October 31, 2011.

Insurance company
La Positiva Compañía de Seguros Generales S.A.

Reinsurance scheme
Insurance agreements and reinsurance agreements are not the same from a legal perspective; therefore, reinsurance will never be mentioned in an insurance policy because the two types of policy are risk transfer agreements under different parameters from those of the assignor taking on the responsibility of the insurance. Pursuant to Peruvian law, the insurance company must have reinsurance policies to partially cover average losses.

Insurable Amount
The insurance policy has an insured amount of US$ 1.092 billion. That value is quite low when compared against the replacement values estimated in the risk study to be around US$ 2.845 billion. That indicates that the insurance is being handled based on historic values or accounting values that have not been updated to reflect the replacement value, at least those estimated for this study. That circumstance is highly inconvenient when considering the volatility of the replacement values and recovering the infrastructure to its operating condition.

SEDAPAL does not have a risk management policy.
**Liability Limits**

The insurance policy sets forth a liability limit of US$ 120 million for physical damage and a secondary limit of US$ 60 million for malicious third-party acts/strike, riot and civil commotion.

If the insurable amounts are not duly updated, SEDAPAL will face a situation of latent “underinsurance” because the first loss limit was calculated based on amounts that do not correspond to the replacement values.

**Deductibles**

The insurance policy has the following deductibles:

- **All** risk for each loss: US$ 30,000. Based on the reviewed, updated insurable amounts, it is worth validating if the deductible is actually operative because, although it is low and does not have a minimum percentage, it may be high in a situation of reoccurrence of low events that are always under the established absolute amount; coverage may be more appropriate using a percentage deductible and a minimum. Moreover, the history of the affectations to be assessed is unknown because the indicated deductible is calibrated.

- **Political risks**: 10% of the recoverable amount with a US$ 30,000 minimum. During the past ten years, SEDAPAL’s activity has been classified on the international insurance markets as a risk target for subversive groups or terrorist groups, disregarding the current regional and national reality of Peru. Therefore, it is necessary to assess the risk in function of public disturbances and strikes instead, reviewing the reoccurrence of the events and the amounts involved, to negotiate the deductible and the coverage annex text, if any, because it is not evident in the policy itself.

- **Earthquake and/or quake and/or volcano eruption and/or underground fire**: 1% of the declared value of the affected item with a US$ 90,000 minimum. Normal deductible on the international reinsurance market. Review of the coverage annex should include seeing if sequeakes and tsunamis are also defined because the earthquake annex does include them; if they are defined, that means that such an important exposure is defined in another section in a more burdensome manner.

- **Other risks due to natural events**: 10% of the recoverable amount with a US$ 90,000 minimum. Most assuredly, if there were a loss due to a tsunami or seaque, it would be indemnified under this deductible; it is difficult to establish if it is very high or very low because the actual exposure values for the risk of a seaque as such (evidence of underinsurance) are unknown. Risk dispersal and risk conditions are the premises on which this deductible was defined.

- **Other deductibles for other coverage based on the policy**.

**Exclusions**

None were seen in the text furnished by SEDAPAL; however, clauses must exist, which exclude exposure inherent in contamination, biological risk, nuclear risk, transportation risk, civil liability risks, and other Lloyds clauses regularly defined in all risk coverage insurance.

**Costs and financing**

The premium without tax is US$ 1,163,209 defined based on a fee per thousand of 1.06 corresponding to the result of applying the premium without tax to the declared insurable amount of the insurance policy, which is US$ 1,092 billion.

The means of payment is not defined but normally the market defines payment maximum ninety (90) days after the beginning of the effective term. In some cases, it offers discounts of 5% to 10% for prompt payment at 30 days or 45 days; it may even offer similar discounts if the risk is renewed with the same reinsurance companies and the same reinsurance broker.
Additional clauses

Underinsurance clause
As this policy has been defined as creating a situation of underinsurance for the service provider given the lack of appraisals, the following text in the insurance policy, which is part of the special conditions, must be reviewed:

The replacement values stated under this policy represent values when new. The underinsurance or insufficient insurance clause will not apply when there is a difference of up to 10% between the value when new and the declared value.

That text and the apparent reality of the defined values at risk versus the actual replacement values may lead to believe that SEDAPAL is not well insured and that it has a high exposure due to detriment to equity.

Debris removal clause
Joint work with the insurance companies and the adjustors, to define debris removal due to the atomization of risk from a geographical and internal operations perspective, above all for large risks.

Maintenance programs and plans
Must be available along with the maintenance logs that the manufacturers have suggested and all part replacement records and spare parts inventory for future maintenance for all equipment manufactured more than ten years ago.

Claim control clause
The salary for the adjustors in charge of each specialty must be set in advance in the situation of a claim that is very demanding and requires a high degree of specialization to carry out the associated activities. That is especially important if the benefit loss coverage is contracted because for the insurance company this aspect is critical to the adjustor’s capacity of response and for the insured party it is critical to the time involved in claim compensation.

Avoid this clause for losses of less than US$ 50,000 and state that in the clause.

72-hour clause
The insurance policy must contain this clause for the recovery of catastrophic losses due to natural events regarding the number of times that it can affect the deductibles considering the definition of time range for any event or the quantity of related losses.

Risk acknowledgment clause
The insurance company accepts that the contracting entity or insurance taker has given the opportunity to the insurance companies to make an inspection visit of the assets and risks to which they are subjected as well as the equity of the insured party. Therefore, this clause certifies the knowledge and acceptance of the facts, circumstances and, in general, the conditions related thereto.

3.2.1.3 Specific recommendations for modifying SEDAPAL’s insurance policy for future effective terms at a short term
The aspects that must be revised based on the new information are the following:

Coverage
The insurance policy must include under the All Risk scheme basic coverage for property, electronic equipment, and engineering equipment, that it covers everything related to physical damage, including natural events, such as earthquake, flood, heavy rains, and events of terrorism, such as vandalism and strikes; it should also cover civil commotion and intentional damage, for which a secondary limit can be established.

Proposals under the modality of named risks and basic conditions and coverage for which no secondary limit is stated must not be accepted; they must operate at 100% of the insured amount.

Insurable Amount
This corresponds to the replacement value of each one of the system components. In particular, for pipe lines that are the components that control the risk, the value must be updated, taking into account updated replacement values.
for pipe stretches according to their diameter and specific location. Such update must be done using real estimates of replacement costs for pipe stretches at updated prices, in order to avoid the figure of underinsurance that, under the current insurance policy conditions may be applied in an eventual claim. Normally the value of the annual premium to be paid must be a percentage of the total insurable amount.

**Insured amount**

In this case the insured amount corresponds to the probable maximum loss amount. In the current insurance policy the insured amount is equal to the insurable amount. However, this amount must be defined using the critical situation deemed to reflect the probable worst impact on the system with its corresponding return period. In this case the insured amount with the current information would be around US$ 195 million, corresponding to an amount near the PML value for a return period of 1,000 years.

**Coverage**

It is likely that some of this coverage is excluded through the annex, which means that, for reinsurance purposes, the insurance company cannot give unlimited coverage regarding the value at risk; however, it can possibly cover the exposure at the secondary limit level through special conditions.

**Deductible**

The negotiation of new insurance conditions must seek the minimum deductible possible with the best corresponding premium. According to the possible reserves that Sedepal can make to cover losses occurred in minor events, greater levels of deductibles can be suggested, thus enabling the negotiation of significant reductions in the premiums charged. The deductible amounts for future negotiations will also depend on market conditions and on the claims (amount and frequency) that the Company submits to the insurance Company.

**Business interruption**

SEDAPAL must assess the eventual maximum loss due to business interruption based on the catastrophic risk scenarios proposed in the study. For this type of estimation, it is normal to estimate the time during which service will be suspended by sectors and thus see what the actual reduction in billing caused by the event would be. Usually business interruption covers the net loss presented in the company profit and loss statement for the year in which the event occurs regarding projected previous year statements.

**General market aspects**

To renew the insurance policy, the recommendation is to update the total insurable amount, establish an insured amount (limit) according to the estimated PML value. A deductible amount must be negotiated (also depending on the established premium), and also the insurable amount for business interruption must be evaluated. In general, to ensure a good negotiation (especially with the reinsurance companies), it is convenient to present all of the risk management that Sedepal has done in recent years, especially including parts of the conducted risk study.

It is possible to carry out a contracting process through public award in which the insurance companies must submit a bid for an insurance scheme established by SEDAPAL establishes. An alternative is an invitation to bid, process through which an insurance company is selected according to the competitive advantages that the interested bidders offer. There is even the possibility of contemplating an agreement for several years of coverage, which can be an additional negotiation factor in Sedepal’s favor.

Due to its size, the alternative recommended for SEDAPAL is Alternative 1 presented in detail in Volume II Section 3.4. It involves making a series of changes to the current insurance policy based on the above comments.

3.2.1.4 Conclusions regarding the financial protection proposal for SEDAPAL

SEDAPAL is the service provider with the best overall financial and operating indicators. The risk analysis for this company indicates that probable maximum losses due to catastrophic events would be around US$ 195 million, corresponding to 6.9% of the total exposed value and near 50% of the total annual operating income worth around
US$ 404 million. That figure represents about twice the current operating margin that is approximately US$ 90 million. On one hand, the service provider has an all-risk insurance policy with an insured value limit of US$ 120 million. If that amount were to be covered by the insurance company, it might generate adequate capacity to partially cover average maximum losses, by adding the annual operating margin to it. However, as is analyzed below, the current policy has a series of deficiencies that could result in said losses not being fully covered, which, adding deductibles and other exclusions, might generate a significant financial gap, and the company might take several years to recover from it. On the other hand, the average annual loss that is around US$18.3 million (6.45 per thousand of the total insurable amount) approximately represents 1.3% of average annual operating income. Therefore, it would be feasible to propose a risk transfer scheme. The above amount represents approximately 20% of the existing annual infrastructure maintenance budget and 2.2 times the service provider’s investment in advertising.

Given the possible average risk situations, in principle SEDAPAL would be able to attend to conventional emergency situations but it would not have the resources to carry out repair or reconstruction processes after possible catastrophic events. If SEDAPAL is able to improve its insurance policy conditions, it would probably have a much better capacity to cover such catastrophic impact with possibilities of short-term and mid-term recovery.

3.2.2 Financial protection strategy proposal for EMAPICA

3.2.2.1 Comprehensive diagnosis and financial gap
EMAPICA is a service provider classified in the group of small enterprises among a total of 50 public utility service providers that comprise the Peruvian water supply and sanitation sector, according to available information from the National Sanitation Services Superintendence (SUNASS).

EMAPICA’s exposure and risk scenario is presented below.

**General indicators**
- Total number of estimated connections: 43,359
- Total served population: 166,763 inhabitants representing approximately 0.5% of the total population of Peru, which is 30,578,435 inhabitants
- Water supply and sanitation coverage level: around 70% and 60%, respectively
- Percentage of treated waste water: around 43%
- Service continuity: around 15%
- EMAPICA average fee: around US$ 0.31 per m3 of water
- Total operating income: US$ 4,285,325 for 2009
- Mean work ratio: meaning total operating costs (not including depreciation and bad debt allowance) over total operating income, around 89%.
- The average operating margin is negative.
- Unbilled water is around 53%.

**Exposure, risk, and financial management indicators**
- Estimated total exposed value in goods and assets: US$ 53.7 million
- Probable maximum loss for a return period of 1,000 years: US$ 10.5 million
- Probable maximum loss as a percentage of the insurable amount: 19.5%
- Pure risk premium with 0% deductible: estimated at an approximate value of US$ 1.23 corresponding to 22.9 per thousand of the exposed value and equal to 28.7% of the annual operating income for the year 2009.

In spite of having severely suffered from critical natural disasters, such as the 1998 floods and the 2007 earthquake, EMAPICA has no risk management strategy. It has no risk identification plans; nor does it have risk mitigation plans based on specific system interventions. Although stretches of pipe have been replaced, those actions stemmed from circumstances such as the 2007 earthquake that obliged the service provider to build new networks that were installed using less vulnerable materials. EMAPICA does not have an insurance policy to cover natural disasters so it has no financial protection whatsoever against the occurrence of a catastrophic event. Although it has contingency plans for
specific events, they would not be sufficient to attend to a catastrophe, for example, caused by an earthquake.

Currently, it is not deemed feasible to adopt either of the two risk retention and risk transfer scheme alternatives presented in Volume II Section 3.4. Therefore, the proposal consists of a long-term action plan that, after taking a series of risk identification and reduction steps, would enable focusing on financial protection schemes, critical components, and insurance policies grouped with other small and medium-sized enterprises.

3.2.2.2 Conclusions regarding the financial protection proposal for EMAPICA

For the service provider EMAPICA, probable maximum losses are estimated at around US$ 10 million, corresponding to 20% of the total exposed value and to more than twice the total annual operating income of around US$ 4.3 million.

In particular, indirect losses and economic flow losses estimated for the sector after the Pisco earthquake in 2007 were around US$ 6.6 million whereas direct losses related to infrastructure damages were quantified at approximately US$ 30 million. Considering that the service provider’s operating margin is negative, it is impossible for it to have sufficient resources to cover such losses. Also, the average annual loss represents 2.2% of the average annual operating income. So, if the company can strengthen its financial situation, it would be more feasible for it to be able to cover a premium and thus be able to transfer the risk. EMAPICA has a low level of investment in existing infrastructure maintenance although it has plans to renew and replace components, mainly pipe lines.

Faced with possible average risk situations, it is evident that the service provider has little capacity or none to attend to the ensuing emergencies and even less capacity to initiate reconstruction and repair processes. In this case its financial gap corresponds to the total value of the probable maximum loss because it does not have the capacity to attend to even a fraction of such loss. Therefore, seeing the situation from the national government perspective, the gap that EMAPICA has is, in practical terms, reduced to zero, given the fact that the national government would cover the gap by providing all of the resources for reconstruction. At times, that is inevitable for economic, financial, political, and social reasons given the conditions of certain service providers. Notwithstanding, it is clearly a perverse incentive because it means that there is little hope that the service provider or the municipality will seek a risk reduction and transfer strategy; ergo, the national government becomes the service provider’s taker or insurer. That already occurred during the above-mentioned Pisco earthquake when, reconstruction costs were borne by the Nation’s public finances due to EMAPICA’s lack of capacity and lack of prior strategy.
IV. Challenges and recommendations for an in-depth look at designing and implementing a sector policy

4.1 Elements of a specific policy
Taking into account the adverse conditions that water supply and sanitation service providers and, in general, the sector at large face regarding disaster risk and disaster risk management, it is clear that, to contemplate any plan or program, it is necessary to first achieve notable results in risk identification and management, risk reduction, and management of significant disasters. That will generate trust among national and international insurance and reinsurance industry and capital market risk takers.

Therefore, the first priority is to adopt a comprehensive company risk management plan that must contain the basic aspects below as a minimum. (The risk management plan is presented in detail in Volume II Section 3.3.)

1. Risk Identification
Risk identification consists of identifying the exposed elements as well as the hazards and vulnerabilities associated with each one of them. To do so, the exposed elements that comprise the system must be characterized; and more importantly, all available information regarding them must be documented and it must be easy to access and to understand. In addition, to characterize the system, the vulnerability of each one of its components must be known. Likewise, studies to enable identifying the hazards that possible affectations represent must be conducted, to acquire knowledge of the types of possible catastrophic events. Armed with all of the above, then risk studies can be conducted, to allow identifying critical components or those that suffer most damage when a catastrophic event hits.

2. Risk reduction
Using the risk analysis results, service providers can propose a strategy to effectively reduce the risk by means of mitigation plans. Mitigation plans must be built as a step-by-step program, including measures such as the ones described below.

   a. Hazard reduction (when possible)
      In some cases it is possible to reduce the impact of the hazards, for example, by building civil works to control the effects of flooding or landslides.

   b. Vulnerability reduction
      Reducing the vulnerability of the water supply and/or sanitation components consists of performing civil works on such components, in a manner that reduces the effect of the hazard on them. This comprises structural repair, modification or retrofitting.

3. Risk transfer
In spite of the measures that can be taken for effective risk reduction, it is still necessary to transfer part of the risk. To do so, service providers must consider options such as insurance and reinsurance, as well as other capital market instruments.

4. Disaster management
When an emergency occurs, the service provider’s normal operations are interrupted. Therefore, an efficient immediate response is required for the purpose of reestablishing normal operations as soon as possible. Proper disaster management
implies avoiding negative effects to the system operations and to the population. To do so, contingency plans must be prepared and be ready for implementation.

a. Contingency plans

It is important for the service providers to develop contingency plans as one of the key elements in the preparation of an immediate response to an emergency. The plans should also be periodically updated. Contingency plans must describe the reaction procedures that define the action groups’ and the personnel’s duties; they must further identify possible sources of financing because significant economic, human, and logistics resources will be required to attend to the emergency. There must be different contingency plans for different types of hazards or emergencies.