

Table of Contents

Preface and Acknowledgments	vii
Introduction	1
Chapter 1	
Planning Emergency Preparedness and Response	3
Introduction	3
Emergency Preparedness and Response Program	3
Institutionalization and Organization of the Program	4
Legal Aspects	4
Institutional Organization	5
Inter-Institutional Coordination	6
Vulnerability Analysis	7
Mitigation Plan	7
Emergency Response Plan	7
Chapter 2	
Basics of Vulnerability Analysis	9
Introduction	9
Defining Vulnerability	10
Nature of the Problem	10
Expected Behavior of Physical Components	11
Quantification of Vulnerability	11
When to Conduct Vulnerability Analysis	12
Calculating Physical Vulnerability	12
General Scheme	12
Damage Probability Matrices	13
System Vulnerability	13
Matrices 1A and 1B—Operation Aspects	14
Matrix 2: Administration and Response	14
Matrix 3—Physical Aspects and Impact on Service	15
Matrices 4A and 4B—Mitigation and Emergency Measures	16
Chapter 3	
Natural Hazards and Their Impact on Water Systems	17
Introduction	17

Characteristics of Hazards and Their Effects	18
Earthquakes	18
Measuring Earthquakes	20
Calculating a System's Physical Vulnerability	20
General Effects of Earthquakes	21
Damage Caused by Earthquakes	22
Hurricanes	30
Calculating Vulnerability of Components	31
Calculating Physical Vulnerability of the System	31
General Effects of Hurricanes	32
Damage Produced by Hurricanes	32
Floods	33
Generalities	33
Factors Affecting Runoff in a Watershed	33
Variations and Patterns of Precipitation	34
Evaluating Flood Hazards and Risk Mapping	34
General Effects of Floods	34
Contamination of Drinking Water by Floods	35
Physical Damage Caused by Floods	35
Landslides	36
Historical Slide Areas	36
Geology of a Region	37
Topography and Stability	37
Rainfall	37
Erosion	37
Liquefaction as a Result of Earthquakes	38
Characteristics of Landslides	38
General Effects of Landslides	39
Landslide Damage	40
Volcanic Eruptions	41
Areas of Impact	41
Evaluation of Hazard	42
Recurrence	42
General Effects of Volcanic Eruption on Water Systems	42
Damages Caused by Volcanic Eruptions	42
Droughts	43
General Effects of Droughts	43
Damage Caused by Droughts	44
Chapter 4	
Vulnerability Analysis	45
Introduction	45

Identification of Organization and Prevailing Regulations	45
Description of the Area, System, and Its Operation	46
Methodology	46
Matrix 1A — Operation Aspects (Drinking Water Systems)	46
Matrix 1B — Operation Aspects (Sewerage Systems)	46
Matrix 2 — Administration and Response Capacity	49
Institutional Organization	49
Operation and Maintenance	49
Administrative Support	51
Matrix 3 — Physical Aspects and Impact on the System	51
Exposed Components	51
Condition of Components	51
Estimates of Potential Damage	51
Rehabilitation Time	53
Remaining Capacity	54
Impact on Service	54
Matrix 4A — Mitigation and Emergency Measures (Administration and Operation) ...	54
Matrix 4B — Mitigation and Emergency Measures (Physical Aspects)	56
Annex 1	
Examples of Effects of Earthquakes on Pipeline Systems (1969–1997)	59
Annex 2	
Application of Vulnerability Analysis: Case Study of Limón, Costa Rica.	65
Introduction	65
Case Study of Limón, Costa Rica	65
Seismic Hazard in the City of Limón	66
Matrix 1A — Operation Aspects	68
Matrix 1B — Operation Aspects	69
Matrix 2 — Administration and Response	70
Matrix 3 — Physical Aspects and Impact on the Service	72
Matrix 4A — Mitigation and Emergency Measures (Administration and Operation) ...	74
Matrix 4B — Mitigation and Emergency Measures (Physical Aspects)	77
Annex 3. Method for Estimating Damage in Pipes as a Consequence of	
Intense Earthquakes.	79
Introduction	79
Evaluation of Seismic Hazard	79
Estimating Vulnerability	80
Calculation of Expected Breaks	81
Definitions	83
Bibliography	85

Preface and Acknowledgments

For several years, the Pan American Health Organization has provided technical assistance to the water and sanitation authorities in Latin America and the Caribbean in improving their preparedness for natural disasters and other emergencies. In 1993 a book was published that served as a guide for organizing and planning responses to emergency situations that affect drinking water and sewerage systems. In addition to having emergency response capability, it is necessary to identify and carry out measures that will lessen the impact of disasters on components of water systems. Applying disaster prevention and mitigation measures is the next step in the disaster preparedness process.

This book provides basic tools that water service companies can use to evaluate the components of their systems that are vulnerable to major natural hazards (earthquakes, hurricanes, floods, landslides, volcanic eruptions, and drought).

The methodology for vulnerability analysis was presented in a document prepared by Herber Farrer for the Pan American Sanitary Engineering Center in 1996. Based on this work, four case studies were conducted with the financial support of the Humanitarian Assistance Work Group of the Ministry of Foreign Affairs of Germany. The purpose of these studies was to validate the methodology that is presented here. The four studies focused on: experience with earthquakes in Costa Rica, prepared by Saúl Trejos; landslides, prepared by José Grases in Venezuela; floods in Brazil, prepared by Ysnard Machado; and finally, a study prepared by David Lashley in Barbados on hurricanes and volcanic eruptions. The elaboration of this document was possible thanks to the valuable technical contributions of these individuals. In addition, we would like to thank Vanessa Rosales of Costa Rica, who made valuable comments during the final revision of this text.

Introduction

The countries of the Region of the Americas are exposed to a large variety of natural hazards. Earthquakes, hurricanes, volcanic eruptions, landslides, droughts, and floods affect many of the countries of the Region and cause major disasters. The number of deaths, injuries, and persons seriously affected, damage to infrastructure, disruption of public services, and economic losses are on the increase and present a threat to the development of the countries of Latin America and the Caribbean. Table 1.1 lists some major disasters in recent years.

Table 1.1. Selected natural disasters affecting countries of the Region of the Americas and the Caribbean

Year	Event	Name	Area Affected
1987	Earthquake	Napo Province	Ecuador
1989	Hurricane	Hugo	Caribbean
1989	Earthquake	Loma Prieta	California, U.S.A.
1991	Forest Fires		California, U.S.A.
1991	Earthquake	Limón	Costa Rica
1992	Hurricane	Andrew	Florida, U.S.A.
1993	Floods	Mississippi Valley	U.S.A.
1994	Earthquake	Northridge	California, U.S.A.
1995	Hurricane	Luis	Caribbean
1995	Earthquake	Trans-Cucutá	Ecuador
1995	Volcano	Soufrière Hills	Montserrat
1995	Hurricane	Marilyn	Caribbean
1996	Earthquake	Nasca	Peru
1996	Hurricane	Fran	U.S.A.
1997	Earthquake	Cariaco	Venezuela
1998	Earthquake	Aiquile-Totora	Bolivia

If we add to natural hazards the increasing vulnerability caused by human activity, such as industrialization, uncontrolled urbanization, and the deterioration of the environment, we see a dramatic increase in frequency and effects of disasters. Disasters follow a cycle that includes the stage prior to impact, response to the disaster, and reconstruction and rehabilitation activities. The costs of reconstruction consume a major portion of available assets, reduce the resources for new investment, and can delay the development process.

Drinking water and sewerage services are essential in ensuring the health and well-being of populations and as such fulfill an important role in the development process. In emergency or disaster situations these basic services are imperative for the rapid return to normalcy. The impact of a natural disaster can cause contamination of water, breaks in pipelines, damage to structures, water shortages, and collapse of the entire system. Depending on the level of preparedness that the water system authorities have adopted, repair of the system can take days, weeks, and even months.

The best time to act is in the first phase of the disaster cycle, when preventive and mitigation measures can strengthen a system by reducing its vulnerability to hazards.

Drinking water and sewerage supply are the direct responsibility of companies, public or private, that provide the service. A combination of programs are directed at guaranteeing high quality and uninterrupted service to clients. Performance of the systems in emergency situations should be planned in the same way that programs for routine operation and preventive and corrective maintenance are planned. Even during routine operations there are often service interruptions due to equipment failure, breaks in pipelines, and rationing due to low water supply. The risk of damage to water systems in disaster situations dramatically increases with factors such as uncontrolled growth in urban areas, deficiencies in infrastructure, and, above all, the location of system components in areas that are vulnerable to natural hazards.

The forces of nature should not be viewed as uncontrollable, against which no action can be taken. Damage is lessened when measures are taken to strengthen systems and to have response mechanisms in place in the event of an emergency. The implementation of programs that continually update disaster mitigation and emergency response plans guarantee a responsible and effective response to disasters.

Vulnerability analysis, the subject of this document, provides a simple approach for addressing the question: "What is the vulnerability of each component of the system to the impact of hazards existing in an area?" The outcome will assist in defining the necessary mitigation measures and the emergency response procedures should a disaster occur before mitigation measures are carried out, or if the measures do not prevent damage.

Vulnerability analysis is the basis for establishing mitigation and emergency plans for (i) execution of the mitigation measures for different components of the system, (ii) organization and preparation, and (iii) attention to the emergency. It requires a response before, during, and after the disaster and includes a combination of measures with the common objective of reducing the impact on provision of service and ensuring that drinking water and basic sanitation services are restored to the affected population in a timely manner.

This book is organized into four chapters. The first explains how an emergency and disaster program is established, and defines the program's content and steps to be taken to develop, execute, and keep the program up to date. The second chapter outlines the principles of vulnerability analysis for drinking water and sewerage systems. It discusses how vulnerability is quantified and how damage probability matrixes are used in the process. The third chapter provides a general description of the major natural hazards and discusses the type of damage they can cause to components of the water system. The fourth chapter presents new approaches to applying vulnerability analysis to different hazards. It provides a detailed description of how to complete the damage probability matrixes.

Three annexes, a short list of definitions, and a bibliography complete this volume.

These guidelines are meant to be consulted by engineers and technical personnel in water service companies to project the performance of drinking water and sewerage systems in case of natural disasters.