Error! Bookmark not defined.CHAPTER 4
Error! Bookmark not defined.GUIDELINE FOR THE APPLICATION OF THE VULNERABILITY
Error! Bookmark not defined.ANALYSIS TO HURRICANES

Error! Bookmark not defined.1. INTRODUCTION

This chapter describes a guideline of the vulnerability analysis methodology explained in chapter 2 that applies to hurricanes. The key aspects in which the analysis should be focused and the references with the required information for the analysis are indicated.

The evaluation of the risk to hurricane impact is essential in order to estimate the vulnerability and the possible damages of the components at risk. This evaluation is simple since the paths periodically followed by hurricanes are well known. Historical information available in meteorological institutes and civil defense of countries affected by these phenomena should be used.

The greatest damages are caused to the structures exposed to strong water currents and strong winds that are located in areas subject to floods. However, the water level forecast in channels is usually determined for analysis conditions by a team of specialized private consultants or of the mentioned institutes, universities, and other professionals of the utility. The first ones will contribute with knowledge and specific technologies of hydrological risk analyses, and the second ones with knowledge of the structures, its operation and relative importance as part of the system in order to prioritize the mitigation measures and establish the emergency plan procedures.

The effects of hurricanes on the affected countries are of such a magnitude and impact on the service, that all the utilities located in risk areas are obliged to study in depth the vulnerability of their structures, to implement a mitigation plan, and to be prepared to face the emergencies and disasters that could be presented with an emergency plan in continuous updating and dissemination process.

The periods of extraordinary rains, the strong water currents and the floods they generate, together with the strong winds constitute a very high risky scenario for surface catchment structures, pipelines near to the water channels, and aerial electricity supply systems.

Error! Bookmark not defined.2. FIRST STEP: IDENTIFICATION OF THE ORGANIZATION AND LEGISLATION IN FORCE

Error! Bookmark not defined.2.1 National and regional organization

The national and regional organization and the standards and procedures of operation should be identified: organization, hierarchies, information and communication systems, governmental and

regional support to drinking water supply utilities and available resources that could be used for the drinking water supply in case of emergencies and disasters.

Usually these organizations have personnel, equipment and material resources to provide drinking water, including portable plants and heavy duty equipment, which can be available for repair and rehabilitation.

Error! Bookmark not defined.2.2 Legal regulation in force

The general legislation for the country's emergency and disaster preparedness and the particular one regarding seismological aspects should be identified at this stage, as follows:

i) Legislation and regulation regarding activities at different stages of emergencies and disasters: civil defense, emergency teams, national, regional and local organizations, etc.

ii) Civil responsibility and liabilities legislation in the management of emergencies and disasters at utility and staff members level, particularly for hurricanes and floods.

iii) Hydrological codes and regulations indicating the characteristics of the possible risk. It should be found out if they are up-to-date and if they respond to the updated knowledge of the country's or region's seismicity If they are obsolete, actions should be taken to find out which parameters should be used for the analysis.

Error! Bookmark not defined.3. SECOND STEP: DESCRIPTION OF THE AREA, OF THE SYSTEM AND ITS OPERATION

This step will follow the general methodology of chapter 2.

Error! Bookmark not defined.4. THIRD STEP: ESTIMATE OF THE OPERATIONAL VULNERABILITY (FIRST VULNERABILITY MATRIX)

This step will follow the general methodology of chapter 2.

Error! Bookmark not defined.5. FOURTH STEP: ESTIMATE OF THE PHYSICAL VULNERABILITY AND IMPACT ON THE SERVICE (SECOND VULNERABILITY MATRIX)

Error! Bookmark not defined.5.1 Identification of threats

In the first column, the type of the expected hurricane will be indicated. In the second column of the matrix the threat will be described briefly, as a summary of the information provided

in the fifth column. The period of occurrence, the expected magnitude and intensity, the areas with higher impact risk by strong water currents, wind, and flooded areas, will be indicated.

Error! Bookmark not defined.5.2 Characteristics of the hurricane threat

a. Brief general description

i) General information

Hurricanes are large tropical depressions characterized by strong atmospheric storms, around which the wind circulates with speeds above 32 miles per hour (115 km/h), that can reach up to 300 km/h.

They have different names according to the Region where they come from, such as hurricanes, cyclones, or typhoons. The ones of greater interest for the Region are those that are formed and travel through the North Atlantic Ocean or Caribbean Subregion; and those of the North Pacific Ocean that affect the Central American and Mexican coast, usually known as tropical depressions, tropical storms and hurricanes, depending on their magnitude. In some countries they are called cyclones.

The atmosphere of the ground surface is mobilized according to large patterns. The equatorial atmosphere receives much more heat than areas of greater latitude. This heating causes the air expansion toward the north or south of the equatorial region. In turn, in polar areas the air is colder and heavier which makes it settle at the ground level and move toward the hottest regions.

This unequal heating of the ground surface generates another type of wind. Thus, if in a small region the air gets hotter than the air that surrounds it, it expands and becomes lighter. This is called low pressure area. If on the contrary, the air is less hot than the one that surrounds it, the pressure in such area will increase, and will be called high-pressure area. The air moves from high-pressure areas to low-pressure areas in curves due to the earth rotation motion.

Hurricanes occur in regions where a strong heating and crossed winds are produced on the ocean in a mass with high moisture content. The cyclonic movement frequently begins with trade winds that converge among themselves and thus, begin to spin around themselves. This phenomenon occurs when the convergence area has been displaced from the Equator, in such a way that the earth rotation intervenes and generates the spin forces.

Toward this rotating low pressure area, the moist and hot air that tends to elevate, converges. This elevation causes moisture condensation and releases large quantities of heat, which increases the rotating air temperature and becomes lighter and elevates faster. As this process takes place, more and more moist tropical air enters to the spinning, replacing the one that raised and generating more condensation.

The eye of the hurricane presents a diameter ranging between 20 and 150 km and in its interior the meteorological conditions are calm with weak winds and partially cloudy sky, having a low pressure in the center.

The great difference of pressure between the eye border and the exterior limit of the storm is due to the eye condition. In addition, as the speed of the wind is proportional to the pressure slope, this explains the wind strength. In the northern hemisphere, the spin is unclockwise.

Surveillance systems, particularly the Center of Hurricanes of Florida, United States, continually monitor by radar the areas of hurricane formation in the Americas, and maintains the countries informed, through national organizations of emergency, about the formation and forecast of the magnitude, displacement and strength of the winds. This allows the authorities and utilities to apply the emergency plan measures in order to be prepared for the impact.

The mass media, mainly television, usually maintain continuous reports of this activity, alerting the population.

In general, the notifications are obtained in advance so that the respective measures are taken.

ii) Classification of the hurricanes

In accordance with the scales of Simpson/Saffir, hurricanes are classified in accordance with the speed of the wind and the damages they make, as follows:

Category	Speed of the wind in km/hour and damages
1	119-151; minimum
2	152-176; moderated
3	177-209; strong
4	210-248; severe
5	> of 248; catastrophic

iii) Incidence and frequency

Hurricanes season in the Caribbean and in the North Pacific subregion of the Americas is from June to December. The frequency varies, some years they have greater strength than others, but they occur every year. In 1995, there were hurricanes with greater frequency and strength, causing several destructions.

b. Evaluation of the threat and risk maps

The evaluation of the threat consists of determining the common path of the hurricanes, the areas usually impacted by strong winds, the watercourses affected by overflows and the flooded

areas with the estimated water levels. The overflow estimation can be made as first approximation, following the rational formula.

Error! Bookmark not defined.5.3 Relative priority

In the third column of the matrix, the relative priority of the threat with regard to all the possible threats of the region will be indicated. The priority assigned at this time will be tentative, and if necessary, it will be modified when completing the vulnerability analysis for all threats.

Error! Bookmark not defined.5.4 Information and alert system

In the first subcolumn of this fourth column of the matrix, the information and communication system of the country's specialized national institutes, civil defense, etc. with the drinking water utility will be registered, both for alert situations at different stages and impact occurrences in different regions of the country.

Although the media usually maintain the population well informed, it is necessary that the water utilities obtain first-hand information with details of the occurrence forecast, in order to activate in advance their emergency plan. This will facilitate the mobilization, the damage analysis and the quick, timely and effective attention.

In the second subcolumn, the utility's internal information and communication systems will be indicated, including the ones established toward their regions. In the third subcolumn, the information systems that will be activated after the occurrence will be registered.

The evaluation of these systems is essential to verify that the information is timely and truthful.

Error! Bookmark not defined.5.5 Impact area

In the fifth column of the matrix the direct impact areas will be described, information that will be obtained from the historical analysis of the occurrences. The impact areas are those where strong water currents, strong winds and flooded areas will occur. In general, the paths of the hurricanes are well known in the affected countries.

The previous information should be indicated on a map of the region to obtain the risk map. The overlapping of the drinking water system plans at the same scale of the hurricane impact risk map will indicate the structures or components of higher risk systems, which should lead to an essential analysis.

Error! Bookmark not defined.5.6 Components or elements exposed

In the first subcolumn of the sixth column of the matrix, the structures or components of the system ordered in the waterflow sense will be recorded: catchments (different types such as derivation dams, galleries, springs, wells, etc.) and their structures, pipelines, treatment plants,

pumping stations, storage tanks, main conveyance networks or main lines and distribution networks. The ones presenting a higher risk because of their location in higher risky and impact areas will be indicated.

In the second subcolumn of this sixth column the condition of each component or structure will be indicated, as a summary of the information obtained in the second step.

Error! Bookmark not defined.5.7 Characteristics of the impact (seventh column)

The general effects of the impact of hurricanes and tropical storms on the drinking water systems are associated mainly with the destruction caused by strong water currents and the strength of the winds, among which it is worth mentioning:

i) Strong water currents produced by rains that destroy surface catchments.

ii) Strong winds that destroy the exposed structures: poles, cables, etc. of the communication and energy systems.

iii) River, ravine and well pollution as a result of the floods.

iv) Destruction of structures such as sand traps and pipelines that are located in watercourses banks, and bridges.

v) Destruction of roofs and structures at open air.

vi) Pollution of private and commercial storage systems found in areas subject to floods.

vii) Destruction of access roads to the system structures.

Error! Bookmark not defined.5.7.1 *Results of the vulnerability analysis*

As a result of the vulnerability analysis the probable damages such as faults in concrete and steel structures; pipelines; and other services such as energy, communications and roads will be determined.

A thorough checking of all the system structures will determine many risk situations in case of hurricanes: surface catchments that are periodically swept by strong currents and that can be replaced by safer intakes such as infiltration galleries and groundwater; anchorages and supporting structures on watercourses located almost within the channels and with insufficient heights that cause their destruction by swift flows; unprotected pipelines placed near the river or watercourse banks and very close to the courses. This check and identification of risk situations should constitute the first stage of the analysis.

The results of the analysis will be registered in the three subcolumns of the seventh column of the matrix: in the first one the damages estimated in the component (type and number) will be described; in the second one, the RT estimated for the complete rehabilitation of each component, and at the end of the column, the RT for the whole system or water supply subsystem; in the third one, the remaining capacity of the component indicated in units of flow, liters per second, for instance, and as a percentage of the total capacity of the component.

In general, the RT estimate in this case should consider the occurrence duration, that sometimes can last several days; the time required to access to the structures, the mobilization time; the partial and total rehabilitation time; and the implementation time, which leads to cleaning and disinfection periods deserving essential implementation in this case.

Error! Bookmark not defined.5.8 Impact on the drinking water or sewerage system

In the eighth column of the matrix, the impact on the service of each damaged component will be recorded, quantified in number of people or the system's connections affected, as well as the essential connections of each area or subarea of supply.

Error! Bookmark not defined.6. FIFTH STEP: ESTIMATE OF THE ADMINISTRATIVE VULNERABILITY OF THE UTILITY AND RESPONSE CAPACITY (THIRD VULNERABILITY MATRIX)

This matrix should be filled out in accordance with the general methodology of chapter 2.

Error! Bookmark not defined.7. SIXTH STEP: MITIGATION AND EMERGENCY MEASURES (FOURTH VULNERABILITY MATRIX)

This matrix should be filled out in accordance with the general methodology of chapter 2.

Error! Bookmark not defined.CHAPTER 5
Error! Bookmark not defined.GUIDELINE FOR THE APPLICATION OF THE VULNERABILITY ANALYSIS TO FLOODS

Error! Bookmark not defined.1. INTRODUCTION

This chapter describes a guideline of the vulnerability analysis methodology explained in chapter 2 that applies to floods. The key aspects in which the analysis should focus and the references with the information required for the analysis are indicated.

The evaluation of areas subject to floods with their probability characteristics of occurrence and expected water levels is the basis to estimate the vulnerability and the possible damages of the risk components. This evaluation is simple, since the areas that have undergone the effects of floods in the past are well-known. In addition, it is common that intensity-duration relations of the rain exist for defined periods of occurrence enabling to forecast the expected levels.

The greatest damages are caused to structures and strong water currents located in flooded areas. On many occasions, the sewerage periods of the floods are more destructive than the previous ones, due to the generation of strong currents.

A team of private specialized consultants of specialized institutions such as hydrological institutes, universities, and other professionals of the utility, usually predict the water levels. The first ones will contribute with knowledge and specific technologies of hydrological risk analyses, and the second ones with knowledge of the structures, their operation and relative importance as part of the system in order to prioritize the mitigation measures and establish the emergency plan procedures.

The extraordinary rain seasons associated with annual rain periods and with phenomena such as El Niño in the Pacific, the strong current and floods they generate and the pollution risks constitute a very high risky scenario for surface catchment structures and pipelines that are close to the watercourses.

Error! Bookmark not defined.2 FIRST STEP: IDENTIFICATION OF THE ORGANIZATION AND LEGISLATION IN FORCE

Error! Bookmark not defined.2.1 National and regional organization

The national and regional organization and the standards and procedures of operation should be identified: organization, hierarchies, information and communication systems, governmental and regional support to drinking water supply utilities and available resources that could be used for the drinking water supply in case of emergencies and disasters.

These organizations usually have personnel, equipment and material resources to provide drinking water, including portable plants and heavy duty equipment for repairs, which will be useful during repair and rehabilitation.

Error! Bookmark not defined.2.2 Legal regulation in force

The general legislation for the country's emergency and disaster preparedness and the particular one regarding hydrologic aspects should be identified at this stage, as follows:

i) Legislation and regulation regarding activities at different stages of emergencies and disasters: civil defense, emergency teams, national, regional and local organization, etc.

ii) Civil responsibility and liabilities legislation in the management of emergencies and disasters at utility and staff members level, particularly for floods.

iii) Hydrological codes and regulations indicating the characteristics of the possible risk. It should be found out if they are updated. If they are obsolete, it should be found out which parameters should be used for the analysis and design of the exposed structures.

Error! Bookmark not defined.3. SECOND STEP: DESCRIPTION OF THE AREA, OF THE SYSTEM AND ITS OPERATION

This step will follow the general methodology of chapter 2.

Error! Bookmark not defined.4. THIRD STEP: ESTIMATE OF THE OPERATIONAL VULNERABILITY (FIRST VULNERABILITY MATRIX)

This step will follow the general methodology of chapter 2.

Error! Bookmark not defined.5. FOURTH STEP: ESTIMATE OF THE PHYSICAL VULNERABILITY AND IMPACT ON THE SERVICE (SECOND VULNERABILITY MATRIX)

Error! Bookmark not defined.5.1 Identification of threats

The type of flood expected and the associated phenomena (strong currents, weirs, source pollution, etc.) will be registered in the first column.

In the second column of the matrix the threat will be described briefly, as a summary of the information provided in the fifth column. The period of occurrence, the

expected magnitude and intensity, the areas with higher impact risks by strong water currents, and areas subject to floods, will be indicated.

Error! Bookmark not defined.5.2 Characteristics of the flood threat

a. Brief general description

i) General information

Floods are natural phenomena originated by rain, abnormal growth of the sea level, snow fusion in a great volume or a combination of these phenomena.

Rain precipitation over a given area is the result of several factors that affect it, such as

Latitude: in general, precipitation diminishes with the latitude because when the temperature decreases, it reduces the atmospheric moisture.

- **Distance to the moisture source**: the closer the area to moisture sources such as sea, lakes, etc., the greater the rain possibility.

- **Presence of mountains**: the orographic rise favors precipitation. Thus, in a mountain chain, heavier or intense precipitations in slopes exposed to winds occur, and only a few rain falls in the unexposed slope of the mountains.

ii) Factors that affect the runoff in a basin

The most relevant factors are the following:

- Climatic factors.
- Precipitation: form (rain, hail, snow, etc.), intensity, duration, distribution in time, distribution in the area, previous precipitations, soil moisture.
- Interception: type of vegetation, composition, age, and strata density, season of the year, and magnitude of the storm.
- Evaporation: temperature, wind, atmospheric pressure, nature, and form of the evaporation surface.
- Transpiration: temperature, sun radiation, wind, moisture, and type of vegetation
- Physiographic factors.
- Characteristics of the basin: geometric, size, form, slope, orientation and direction
- Physical: use and coverage of the land, infiltration conditions, type of soil, geological conditions such as permeability and capacity of groundwater formation, topographical conditions such as lakes, swamps and artificial drainages.
- Characteristics of the channel.
- Transportation capacity: size, form, slope, rugosity, length and tributaries.
- Storage capacity: still water curves.

iii) Variation and precipitation patterns

From the point of view of the emergency and disasters preparedness planning, rain variations or the determination of higher rain incidence and consequently higher risky periods, are important.

Rain patterns, combined with other factors such as soil characteristics, topographical and geological conditions, areas of the basin, determine the quantity of rain forming the runoff.

b. Evaluation of the threat and risk maps

The evaluation of the threat consists of determining the flood areas and the courses affected, with their characterization parameters: duration of the phenomenon, runoff, and possible maximum levels. This information should be indicated on maps of the area in order to prepare the maps related to flood risks. Civil defense institutions usually have these risk maps. The overlapping of these maps with the plans of the drinking water supply system will indicate the possible structures to be affected.

The runoff can be estimated following the rational formula, as a first approximation.

Error! Bookmark not defined.5 3 Relative priority

In the third column of the matrix, the relative priority of the threat will be indicated regarding all the possible threats of the region. The priority assigned at this time will be tentative, and if necessary, it will be modified when completing the vulnerability analysis for all threats.

Error! Bookmark not defined.5.4 Information and alert system

In the first subcolumn of this fourth column of the matrix, the information and communication system of the country's specialized national institutes, civil defense, etc. with the drinking water utility will be registered, both for alert situations at different stages and impact situations in the different regions of the country.

Although the mass media usually maintain the population well informed about the imminent strong and long lasting rain periods that might result in floods, it is necessary that water utilities obtain first-hand information with details of the occurrence forecast, in order to activate in advance their own emergency plan. This will facilitate the mobilization, the damage analysis and the quick, timely and effective attention.

In the second subcolumn, the utilities internal information and communication systems will be indicated, including the ones established toward their regions. In the third subcolumn, the information systems to be activated after the main occurrence will be registered.

Error! Bookmark not defined.5.7.1 *Results of the vulnerability analysis*

As a result of the vulnerability analysis the probable damages such as faults in concrete and steel structures; pipelines; and other services such as energy, communications, and roads will be determined.

A thorough checking by all the system structures will determine risk situations in case of floods: surface catchments periodically swept by strong currents and that can be replaced by safer intakes such as infiltration galleries and grounwater, anchorages and supporting structures on watercourses located within the courses and with insufficient heights that cause their destruction by strong currents; unprotected pipelines that flow in the river or watercourse banks located very close to the courses. This check and identification of risk situations should constitute the first stage of the analysis.

The results of the analysis will be recorded in the three subcolumns of the seventh column of the matrix: in the first one, the damages estimated in the component (type and number) will be described; in the second one, the RT estimated for the complete rehabilitation of each component, and at the end of the column, the RT for the whole system or water supply subsystem; in the third one, the remaining capacity of the component indicated in units of flow, liters per second, for instance, and as a percentage of the total capacity of the component.

In general, the RT estimate in this case should consider the occurrence duration, that can sometimes last several days; the time required to access to the structures, the mobilization time, the partial and total rehabilitation time; and the implementation time, which leads to cleaning and disinfection periods of essential implementation in this case.

Error! Bookmark not defined.5.8 Impact on the drinking water or sewerage system

In the eighth column of the matrix the impact on the service of each damaged component will be recorded, quantified in number of people or the system's connections affected, as well as the essential connections of each area or subarea of supply.

Error! Bookmark not defined.6. FIFTH STEP: ESTIMATE OF THE ADMINISTRATIVE VULNERABILITY OF THE UTILITY AND RESPONSE CAPACITY (THIRD VULNERABILITY MATRIX)

This matrix should be filled out in accordance with the general methodology of chapter 2.

Error! Bookmark not defined.7. SIXTH STEP: MITIGATION AND EMERGENCY MEASURES (FOURTH VULNERABILITY MATRIX)

This matrix should be filled out in accordance with the general methodology of chapter 2.

Error! Bookmark not defined.CHAPTER 6

Error! Bookmark not defined.GUIDELINE FOR THE APPLICATION OF THE VULNERABILITY Error! Bookmark not defined.ANALYSIS TO VOLCANIC ERUPTIONS

Error! Bookmark not defined.1 INTRODUCTION

This chapter describes a guideline of the vulnerability analysis methodology explained in chapter 2 that applies to volcanic eruptions. The key aspects in which the analysis should be focused and the references with the required information for the analysis are indicated.

In order to estimate the vulnerability and the possible damages to the drinking water systems components, the areas affected by eruption materials should be identified: lava, mainly gases and ashes, the affected watercourses and the formation of avalanches. This evaluation is simple since the areas that have been affected in the past are well-known, and are documented in the seismology, volcanology and meteorology, and civil defense institutes of the countries affected by these phenomena.

The greatest damages are caused to the structures exposed to the impact of lava currents and ash, stone, and water avalanches. In addition, treatment plants, metallic structures such as tanks and valve boxes in distribution networks, are affected by the impact of acid rains and ash.

The rain periods together with the eruptions generate avalanches in the watercourses as well as extremely destructive floods.

Error! Bookmark not defined.2. FIRST STEP OF THE ANALYSIS: IDENTIFICATION OF THE ORGANIZATION AND LEGISLATION IN FORCE

Error! Bookmark not defined.2.1 National and regional organization

The national and regional organization and the standards and procedures of operation should be identified: organization, hierarchies, information and communication systems, governmental and regional support to drinking water supply utilities and available resources that could be used for drinking water supply in case of emergencies and disasters.

These organizations usually have personnel, equipment and material resources for drinking water supply, including heavy duty equipment and portable plants that can be used for repairs and rehabilitation, which would reduce the rehabilitation time.

Error! Bookmark not defined.2.2 Legal regulation in force

The general legislation for the country's emergency and disaster preparedness and the particular one regarding vulcanologic aspects should be identified at this stage, as follows:

i) Legislation and regulation regarding activities at different stages of emergencies and disasters: civil defense, emergency teams, national, regional and local organizations, etc.

ii) Civil responsibility and liabilities legislation in the management of emergencies and disasters at utility and staff member level.

iii) Codes and regulations applicable to impact areas by vulcanological materials indicating the characteristic of the possible risk. It should be found out if they are updated. If they were obsolete, the respective measures should be taken.

Error! Bookmark not defined.3. SECOND STEP: DESCRIPTION OF THE AREA, OF THE SYSTEM AND ITS OPERATION

This step will continue with the general methodology of chapter 2.

Error! Bookmark not defined.4. THIRD STEP: ESTIMATE OF THE OPERATIONAL VULNERABILITY (FIRST VULNERABILITY MATRIX)

This step will continue with the general methodology of chapter 2.

Error! Bookmark not defined.5. FOURTH STEP: ESTIMATE OF THE PHYSICAL VULNERABILITY AND IMPACT ON THE SERVICE (SECOND VULNERABILITY MATRIX)

Error! Bookmark not defined.5.1 Identification of threats

In the first column of the matrix, the type of eruption expected will be recorded. In the second column, the threat will be described briefly, as a summary of the information provided in the fifth column. The areas and watercourses affected by the different types of eruptions, eruption periods and expected magnitude and intensity will be indicated

Error! Bookmark not defined.5.2 Characteristics of the vulcanological threat

a. Brief general description

Volcanos are structures composed of materials accumulated on the ground and that have a vent called chimney that communicates the earth surface with the interior of the earth crust. This vent follows a slightly vertical direction and has an orifice in its mouth called crater

Volcanos are classified according to the type of eruption. The Hawaiian type, for instance, erupts fluid magma composed of thin and often very extensive torrents of fluid lava.

The nature of the activity depends mainly on two factors: the magma viscosity and the quantity of released gases. The gases can be generated within the magma or can be a consequence of the magma contact with ground or surface waters that produce vapors.

The eruption materials range from strong torrents of fluid lava, incandescent materials pumps, clouds with burning gases, gases, and ashes of several sizes.

The lava torrents generated vary in volume, extension, thickness and speed. The extension and thickness depend on the volume, fluidity and the possibility of a lateral expansion or not. These torrents depend on the underlying topography, but deviations can be produced in their courses through shallow valleys, especially in the case of highly viscous torrents.

The volcanos eruption activity can last days and even years, as the case of the Irazu volcano in Costa Rica that erupted ash over the city of San Jose during two years.

b. Evaluation of the threat and risk maps

The evaluation of the threat consists of preparing the risk map indicating possible impact of lava currents, acid rain and ash flows; the affected watercourses; and the possible areas of flood and avalanche

Error! Bookmark not defined.5.3 Relative priority

In the third column of the matrix, the relative priority of the threat will be indicated regarding all the possible threats of the region. The priority assigned at this time will be tentative, and if necessary, it will be modified when completing the vulnerability analysis for all threats.

Error! Bookmark not defined.5.4 Information and alert system

In the first subcolumn of this fourth column of the matrix, the information and communication systems of the country's specialized national institutes, civil defense, etc with the drinking water utility will be registered, both for alert situations at different stages and impact situations in the different regions of the country.

Although the mass media usually maintain the population well informed, it is necessary that water utilities obtain first-hand information with details of the occurrence forecast, in order to activate in advance their own emergency plan. This will facilitate the mobilization, the damage analysis and the quick, timely and effective attention.

In the second subcolumn, the utilities internal information and communication systems will be indicated, including the ones established toward their regions. In the third subcolumn, the information systems to be activated after the occurrence will be indicated.

The evaluation of these systems is essential to verify that the information is timely and truthful.

Error! Bookmark not defined.5.5 Impact area

In the fifth column of the matrix, the direct impact areas will be described. This information will be obtained from the historical analysis of the occurrences. The impact areas are those covered with lava or affected by acid rains and ashes, as well as watercourses affected by these materials.

The previous information should be indicated on a map of the region affected or risk map. The overlapping of the drinking water system plans at the same scale of the risk map will indicate the structures or components of higher risk systems, which should lead to an essential analysis.

Error! Bookmark not defined.5.6 Components or elements exposed

In the first subcolumn of the sixth column of the matrix, the structures or components of the system ordered in the waterflow sense will be recorded: catchments (derivation dams, galleries, springs, wells, etc.) and their structures, pipelines, treatment plants, pumping stations, storage tanks, main conveyance networks or main lines and distribution networks. The ones presenting a higher risk because of their location in higher risk and impact areas will be indicated.

In the second subcolumn of this sixth column, the condition of each component or structure will be indicated, as a summary of the information obtained in the second step.

Error! Bookmark not defined.5.7 Characteristics of the impact (seventh column)

a. General effects

The effects of the volcanic eruptions are usually associated with:

Torrents of lava that destroy the drinking water sources located in the slopes or at the bottom of the volcanos.

- Emanations of gases, ashes, acid rain, and torrents of lava that disable the drinking water supply sources.
- Landslides and sludge avalanches caused by the effect of rains on ashes accumulated in basins and rivers The Armero case in Colombia is an example of this effect.
- Total impact of the water services when catchments and structures are located in basins affected by eruptions.

c. Results of the vulnerability analysis

As a result of the vulnerability analysis the probable damages on the exposed structures of the drinking water system and other services such as energy, communications and roads will be determined.

The results of the analysis will be recorded in the three subcolumns of the seventh column of the matrix: in the first one, the damages estimated in the component (type and number) will be described; in the second one, the RT estimated for the complete rehabilitation of each component, and at the end of the column, the RT for the whole water supply system or subsystem; in the third one, the remaining capacity of the component indicated in units of flow, liters per second, for instance, and as a percentage of the total capacity of the component.

In general, the RT estimate in this case should consider the occurrence duration, that sometimes can last several days, the time required to access to the structures, the mobilization time; the partial and total rehabilitation time; and the implementation time, which leads to cleaning and disinfection periods of essential implementation in this case.

Error! Bookmark not defined.5.8 Impact on the drinking water or sewerage system

In the eighth column of the matrix the impact on the service of each damaged component will be recorded, quantified in number of people or the system's connections affected, as well as the essential connections of each area or subarea of supply.

Error! Bookmark not defined.6. FIFTH STEP: ESTIMATE OF THE ADMINISTRATIVE VULNERABILITY OF THE UTILITY AND RESPONSE CAPACITY (THIRD VULNERABILITY MATRIX)

This matrix should be filled out in accordance with the general methodology of chapter 2.

Error! Bookmark not defined.7. SIXTH STEP: MITIGATION AND EMERGENCY MEASURES (FOURTH VULNERABILITY MATRIX)

This matrix should be filled out in accordance with the general methodology of chapter 2.

Error! Bookmark not defined.CHAPTER 7

Error! Bookmark not defined.GUIDELINE FOR THE APPLICATION OF THE VULNERABILITY ANALYSIS TO ACCIDENTS AFFECTING THE SERVICE

Error! Bookmark not defined.1. INTRODUCTION

This chapter describes a guideline of the vulnerability analysis methodology explained in chapter 2 that applies to operational accidents. The key aspects in which the analysis should be focused as well as the references with the information required for the analysis are indicated.

Although the results of the operational emergencies impact do not have the context of great disasters caused by natural threats, they require detailed and precise operational plans in order to face them, as well as implementation of mitigation measures to reduce their vulnerability. The case of ruptures of great-diameter water conveyance pipelines, and the contamination hazards, for instance, are risks that affect the service and consequently, require mitigation and emergency measures.

Actually, the occurrences described can be of greater consequence than the impact of a natural phenomenon. Hence the decision to consider the operational emergencies as part of these guidelines.

The accidents affecting the service are those emergency situations caused by interruptions in the drinking water service due to the system operation and not by the impact of natural phenomena such as earthquakes, hurricanes and others.

The evaluation of the contamination risk should be done for every water catchment and distribution area. The rupture risk evaluation will be applied to the pipelines or main lines of the system. The historical experience and statistics are very useful to identify these situations.

The vulnerability analysis of a drinking water system usually begins with the evaluation of these risks, both in order to determine the mitigation measures and emergency procedures to carry out the rehabilitations and provide the service, even with minimum requirements.

Error! Bookmark not defined.2 FIRST STEP OF THE ANALYSIS: IDENTIFICATION OF THE ORGANIZATION AND LEGISLATION IN FORCE

Error! Bookmark not defined.2.1 Institutional organization

The institutional organization and the resources available to face this type of emergencies, as well as the standards and procedures of operation should be identified: organization, hierarchies, information and communication systems, governmental and regional support to drinking water supply utilities and available resources that could be used for the drinking water supply in case of emergencies and disasters.

These organizations usually have personnel, equipment and material resources to provide drinking water, including heavy duty equipment and portable plants which would be useful for repair and rehabilitation.

Error! Bookmark not defined.2.2 Legal regulation in force

The general legislation for the country's emergency and disaster preparedness and the particular one regarding operational aspects should be identified at this stage, as follows:

i) Legislation and regulations regarding emergency preparedness; including insurances.

ii) Civil responsibility and liabilities legislation in the management of the operation and operational emergencies.

Error! Bookmark not defined.3. SECOND STEP: DESCRIPTION OF THE AREA, OF THE SYSTEM AND ITS OPERATION

This step will follow the general methodology of chapter 2.

Error! Bookmark not defined.4. THIRD STEP: ESTIMATE OF THE OPERATIONAL VULNERABILITY (FIRST VULNERABILITY MATRIX)

This step will follow the general methodology of chapter 2.

Error! Bookmark not defined.5. FOURTH STEP: ESTIMATE OF THE PHYSICAL VULNERABILITY AND IMPACT ON THE SERVICE (SECOND VULNERABILITY MATRIX)

Error! Bookmark not defined.5.1 Identification of threats

In the first column, the type of accident that can be presented (contamination of sources or distribution networks, ruptures of main lines, etc.) should be indicated.

In the second column of the matrix, the threat will be described briefly, as a summary of the information provided in the fifth column. The type and description of the emergency will be indicated specifically.

Error! Bookmark not defined.5.2 Characteristics of the threat

a. Brief general description

The possible emergencies caused by contamination of the source and ruptures in the distribution networks, or penetration of contaminated water in low pressure areas, or irregular service areas should be described. Other operational emergencies such as drought periods, general strikes (and those of the utility), etc. should also be evaluated.

b. Evaluation of threats

The contamination should be characterized through polluting materials, catchments and exposed networks, timely detected mechanisms, areas of population at risk, and information systems to the population.

In the case of pipeline ruptures, the evaluation should respond to the questions what happens if the conveyance breaks in this site?, which are the impacts of water spill in the nearby area?, what population will have the service interrupted?

Error! Bookmark not defined.5.3 Relative priority

In the third column of the matrix, the relative priority of the threat will be indicated with regard to all the possible threats of the region The priority assigned at this time will be tentative, and if necessary, it will be modified when completing the vulnerability analysis for all threats.

Error! Bookmark not defined.5.4 Information and alert system

In the first subcolumn of this fourth column of the matrix, the information and communication systems available at a national level for these emergencies will be registered, both for alert situations and emergency occurrences in the different regions of the country.

In the second subcolumn of this matrix, the utility's internal information and communication systems will be indicated, including the ones established toward their regions. In the third subcolumn, the information systems to be activated after the main occurrence will be recorded.

The evaluation of these systems is essential to verify that the information is timely and truthful.

Error! Bookmark not defined.5.5 Impact area

In the fifth column of the matrix, the direct impact, contamination, pipeline rupture and other areas, will be described.

Error! Bookmark not defined.5.6 Components or elements exposed

In the first subcolumn of the sixth column of the matrix, the structures or components of the system ordered in the waterflow sense will be recorded: catchments (derivation dams, galleries, springs, wells, etc.) and its structures, pipelines, treatment plants, pumping stations, storage tanks, main conveyance networks or main lines and distribution networks. The ones presenting a higher risk because of their location in higher risk and impact areas will be indicated.

In the second subcolumn of this column, the condition of each component or structure will be indicated, as a summary of the information obtained in the second step.

Error! Bookmark not defined.5.7 Characteristics of the impact (seventh column)

a. General effects

The effects of the contamination are the water quality deterioration and the related risks to public health.

The effects of large pipeline ruptures are the damages caused to the immediate environment and private property, the deterioration of the utility's image if rehabilitation is not handled properly, the service interruption and contamination possibilities.

b. Effects on the components of the drinking water systems

In the case of contamination, not only water gets contaminated, but the structures where this water passed through. Therefore, these should be cleaned, decontaminated, and disinfected

In the case of pipelines, the damages correspond to ruptures that should be repaired. This requires labor, equipment, materials, pipelines, and spare parts that should be available in the utility.

In both cases, monitoring and care procedures should be clearly and precisely established.

c. Results of the vulnerability analysis

The results of the analysis will be recorded in the three subcolumns of the seventh column of the matrix: in the first one, the damages estimated in the component (type and number), contamination, rupture, etc. will be described; in the second one, the RT estimated for the complete rehabilitation of each component, and at the end of the column, the RT for the whole water supply system or subsystem, in the third one, the remaining capacity of the component indicated in units of flow, liters per second, for instance, and as a percentage of the total capacity of the component.

Error! Bookmark not defined.5.8 Impact on the drinking water or sewerage system

In the eighth column of the matrix, the impact on the service of each damaged component will be recorded, quantified in number of people or the system's connections affected, as well as the essential connections of each area or subarea of supply.

Error! Bookmark not defined.6. FIFTH STEP: ESTIMATE OF THE ADMINISTRATIVE VULNERABILITY OF THE UTILITY AND RESPONSE CAPACITY (THIRD VULNERABILITY MATRIX)

This matrix should be filled out in accordance with the general methodology of chapter 2.

Error! Bookmark not defined.7. SIXTH STEP: MITIGATION AND EMERGENCY MEASURES (FOURTH VULNERABILITY MATRIX)

This matrix should be filled out in accordance with the general methodology of chapter 2.

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A.1.1 First vulnerability matrix (estimate of the operational vulnerability)

Matrix 1
Operational vulnerability, drinking water

Error! Bookmark not defined.(1)COMPONENT	(2A)COMPONENT CAPACITY	(2B)CURRENT REQUIREMENT	(2C) DEFICIT(-) SURPLUS(+)	(3)CONTINUITY	(4)WATER QUALITY

Matrix 1
Operational matrix, sanitary sewerage

Error! Bookmark not defined.(1) COMPONENT	(2) COVERAGE (%)	(3) CAPACITY (l/s)	(4) EFFLUENT QUALITY

A.1.2 Second vulnerability matrix (estimate of the physical vulnerability and impact on the service)

Matrix 2
Physical vulnerability and impact on the service

Error! Bookmark not defined.(1)	(2)	(3)	(4A)	(4B)	(4C)	(5)	(6A)	(6B)	(7A)	(7B)	(7C)	(8)
TYPE OF THREAT	CHARACTERISTICS OF THE THREAT	RELATIVE PRIORITY OF THE THREAT	INFORMATION AND ALERT SYSTEMS (INSTITUTIONS TO THE UTILITY)	INFORMATION AND ALERT SYSTEMS (WITHIN THE UTILITY)	INFORMATION SYSTEMS (AFTER THE OCCURRENCE)	IMPACT AREAS	COMPONENTS EXPOSED (RELATIVE RISKS)	CONDITION OF THE COMPONENT	ESTIMATED DAMAGES (Type and number)	RT 100 (days)	IMMEDIATE REMAINING CAPACITY l/s %	IMPACT ON THE SERVICE (connections)
							DRINKING WATER					
							RT OF THE SYSTEM					
							SANITARY SEWERAGE					
							RT OF THE SYSTEM					

A.1.3 Third vulnerability matrix (estimate of the utility's administrative vulnerability and response capacity)

Matrix 3
Utility's administrative vulnerability and response capacity

Error! Bookmark not defined. (1)	(2)	(3)	(4)
INSTITUTIONAL ORGANIZATION	**OPERATION AND MAINTENANCE**	**ADMINISTRATIVE SUPPORT**	**RESPONSE CAPACITY**
A. EMERGENCY PLANS	A. OPERATIONAL PROGRAMS	A. AVAILABILITY AND MANAGEMENT OF FINANCIAL RESOURCES	A INSTITUTIONAL ORGANIZATION
B. EMERGENCY COMMITTEE	B. PREVENTIVE MAINTENANCE PROGRAMS		B. OPERATION AND MAINTENANCE
C MITIGATION AND EMERGENCY PLANS FORMULATION COMMISSION	C CORRECTIVE MAINTENANCE		C ADMINISTRATIVE SUPPORT
E. INTERINSTITUTIONAL COORDINATION	E. TRAINED PERSONNEL		
F. INFORMATION AND ALERT SYSTEMS	F. MATERIALS AND ACCESSORIES	C. CONTRACTING OF A PUBLIC UTILITY IN THE MARKET	D INSTITUTIONAL
	G. EQUIPMENT AND MACHINERY AVAILABILITY		

A.1.4 Fourth vulnerability matrix (mitigation and emergency measures)

Matrix 4
Mitigation and emergency measures

OPERATIONAL VULNERABILITY (1)

Error! Bookmark not defined.COMPONENT	MITIGATION (1A)		EMERGENCY (1B)	
		COST US$		COST US$
DRINKING WATER				
SANITARY SEWERAGE				

SUBTOTAL (1)				

Matrix 4
Mitigation and Emergency Measures
ADMINISTRATIVE VULNERABILITY (3)

Error! Bookmark not defined. **AREA**	**MITIGATION (3A)**		**EMERGENCY (3B)**	
		COST US$		**COST US$**
INSTITUTIONAL ORGANIZATION				
OPERATION AND MAINTENANCE				
ADMINISTRATIVE SUPPORT				

SUBTOTAL (3)				
TOTAL				

Matrix 4
Mitigation and emergency measures

PHYSICAL VULNERABILITY (2)

Error! Bookmark not defined.		MITIGATION (2A)		EMERGENCY (2B)	
COMPONENT	CARE PRIORITY		COST US$		COST US$
DRINKING WATER					
SANITARY SEWERAGE					

SUBTOTAL (2)					