Chapter 3

General Criteria for Selecting a Safe Site

1. Introduction

The identification of siting options and the selection of the definitive site for the facility must be based on an assessment of the healthcare needs of the population and the characteristics of the existing health network. The choice of the definitive site will also be determined by public health policies and any demographic, geographical, sociopolitical, or economic criteria the client institution may have stipulated.

Minimum criteria for characterizing the site should contemplate the following issues:

- Location and accessibility
- Supply and quality of essential services
- Urban questions: climate, esthetics, conditions in adjacent areas
- Common risks: noise, dust, vibrations, others
- Topographic and geotechnical issues
- Legal issues
- Economic issues

Other key considerations include the performance objectives sought for the facility at normal times and during emergencies, the comparative analysis of the natural and technological hazards present at the various potential sites, the estimated cost and technical feasibility of implementing protection systems to withstand such hazards, the economic resources available, and the findings of a cost/benefit analysis of the options as illustrated in *Flowcharts 3.1* and *3.2*.

Such an assessment must not confine itself to the potential building sites. It should also consider the characteristics of the overall surroundings and the way adverse natural phenomena can affect the referral population and local infrastructure, particularly lifelines and access roads.

2. The process for selecting potential sites

Variables governing site selection

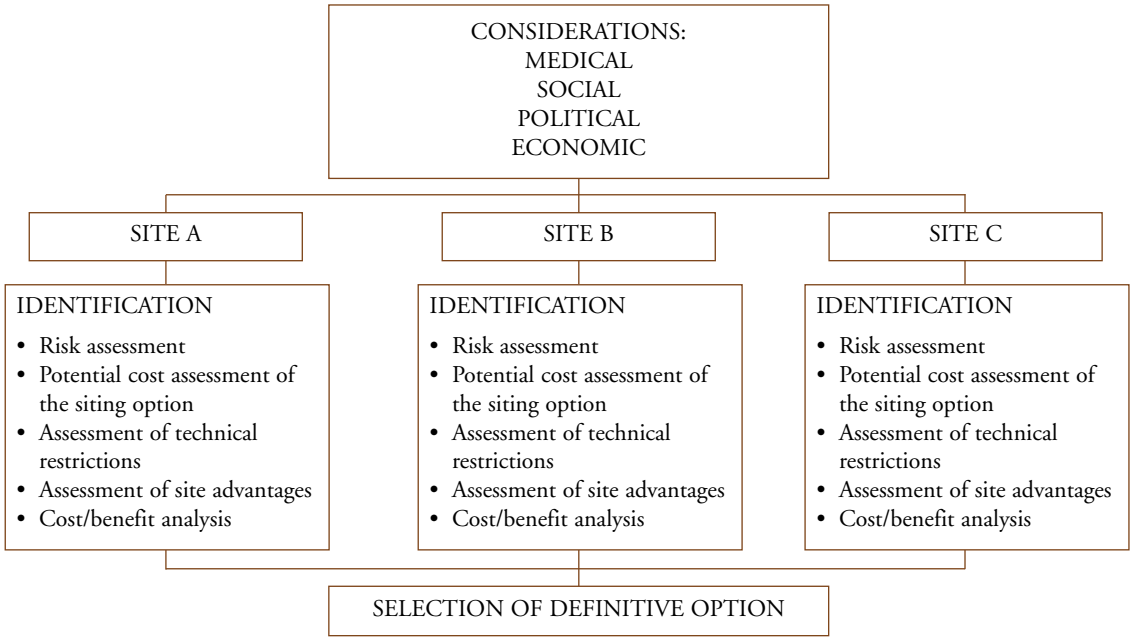
It is not the purpose of this handbook to explain at length how to rank the various siting options. Instead, relevant criteria, such as the key factors to be taken into account when selecting an adequate and safe location will be mentioned; it is advisable that the client institution issue qualitative and quantitative specifications for assessing and comparing each of the siting options.

These specifications may be of varying degrees of complexity. What matters is that they facilitate the decision-making process by testing each site's capacity to meet the desired protection objective. If none of the siting options can meet it, a less ambitious protection objective should be chosen—or more acceptable siting options should be sought.

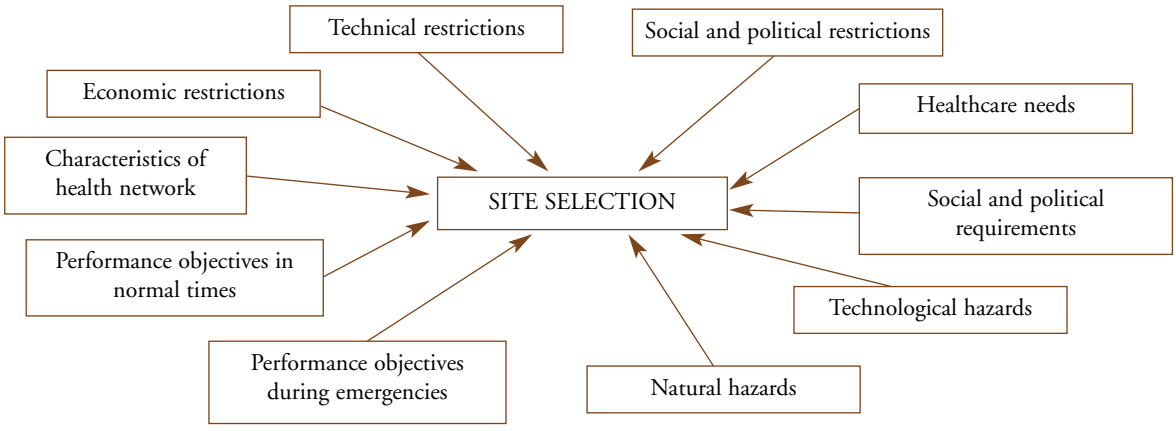
When preselecting the siting options, existing data on prevailing hazards, found in land-use management plans, local or regional development plans, technical reports, local zoning laws and regulations, or expert opinions, may suffice. Even so, an on-site inspection of each of the options and their surroundings should be carried out by the siting team.

If the health facility is designed to meet a high protection objective in the face of a natural event, however, detailed studies must be carried out to characterize the prevailing hazards. No site should be selected if any of the information required is lacking.

Flowchart 3.1 - Site preselection



Flowchart 3.2 - Site selection



In selecting the site, moreover, a key consideration is proximity to industrial facilities (chemical plants, refineries, mining processing plants, etc.), military facilities, landfills, airports, routes used for the transport of hazardous materials, and so on. Because of their operations, the habitual or accidental emission of toxic agents, or the possibility of accidents at normal times or during an emergency, having such facilities as neighbors might compromise the safety of the contemplated health facility.

In this connection, another course of action well worth exploring by the client institution is having local zoning regulations modified so that in future no building permits can be issued, within a given radius, to facilities that might endanger the hospital or its operations.

Site selection procedures

The selection of the site involves three stages, each with its own set of requisite procedures. The three stages are the following:

Stage 1: Compilation of background data;

Stage 2: Assessment of siting options;

Stage 3: Site selection.

Stage 1: Compilation of background data

Preliminary data compilation

At the start of the project, the client institution must appoint a siting coordination team that must in turn hire the professionals who will advise on the correct selection of the project site. It must also set the performance objective for the facility in the event of a natural disaster—that is, the level of damage, or time needed for functional recovery, that will be acceptable to the institution.

The client institution must also define overall siting criteria based on factors such as total surface required (construction plus grounds), lifelines and other infrastructural requirements, and the facility's intended perimeter of influence and reference population. Site preselection should consider the criteria outlined at the beginning of this chapter.

Once siting options have been selected it will be necessary to examine all available records on the natural hazards that threaten the potential sites. They include general information on the location, relevant characteristics of human settlements and infrastructure in the region, existing zoning regulations, regional and local development plans, existing maps, records of natural disasters that have occurred there, available geotechnical and other scientific information, data compiled by other projects carried out in the region, and the opinions of government bodies, professional associations, academic institutions and nongovernmental organizations.

The siting team should determine whether additional data must be compiled to compare the risk factors at the various siting options. At this point, the team must consider whether the likelihood of various natural disasters in the area is high or low, so as to define the degree of detail required in the risk assessments to be carried out. In the event that not enough information is available, or there are doubts regarding its validity, the team must inform the project administrator and coordination committee, and recommend additional studies needed to assess the hazards at each potential site. The level of detail of the studies will also be determined, naturally, by the performance objective (from life safety to functional protection) chosen for the facility.

Table 3.1 lists some of the activities that should be carried out during this phase.

Table 3.1 Preliminary tasks

Selection of professional team (see Chapter 5)
Definition of protection objectives and expected level of damage
Definition of siting options
Delimitation of the boundaries within which the potential site must be located
Surface area to be occupied by the facility
Perimeter of influence
Roads
Lifelines
Review of local regulatory plans
Preliminary studies
Human settlements and infrastructure in the region
Inhabited area
Services
Roads and available forms of transportation
Review of existing laws and regulations
Review of regional development plans
Review of existing maps
Review of general information regarding the sites of interest and their surroundings
Review of background data regarding adverse natural phenomena that have taken place in the region, such as landslides or mudslides, strong winds, floods, seismic events or volcanic eruptions
Compilation of preliminary geotechnical data regarding the potential sites
Compilation of information gathered for other projects developed in the area
Opinion of government bodies and NGOs
Opinion of experts

Stage 2: Assessment of the siting options

At the beginning of this phase, the siting team must determine if the information compiled during the preliminary phase is sufficient to preselect the facility's potential sites. If the information required is not available, the team of specialists must carry out all studies necessary for producing the information that will characterize the hazards prevalent at each siting option and produce a "short list" of the most likely candidates (see *Annex 3.1*).

Processing background data

The information compiled during the preliminary studies, or that obtained later as needed, must be processed in order to characterize the level of risk of all recorded or potential natural hazards at each of the siting options. *Table 3.2* summarizes the main variables that must be quantified in order to determine the natural hazards present at each siting option.

Table 3.2 - Quantification of risk

Quantification of risk					
Earthquake	Snow	Strong winds	Landslides and mudslides	Floods	Volcanic activity
Dimension Magnitude Duration Likelihood of occurrence Affected area Description Design spectrum Seismic verification records Direct geotechnical impact Mitigation potential	Dimension Magnitude Duration Likelihood of occurrence Affected area Description Design load Mitigation potential	Dimension Magnitude Duration Likelihood of occurrence Affected area Description Design speed Mitigation potential	Dimension Magnitude Duration Likelihood of occurrence Affected area Description Volume Height Speed Mitigation potential	Dimension Magnitude Duration Likelihood of occurrence Affected area Description Volume Height Speed Mitigation potential	Dimension Magnitude Duration Likelihood of occurrence Affected area Description Volume Speed

The variables listed in this table must be quantified through geological, geomechanical, seismological, meteorological, and hydrological studies.

The following information must be processed and evaluated:

- Data suggesting the possibility of **landslides:** historical records, stratification maps, and information about vegetation, natural deposits, steep slopes, soil strata cohesion, shear strength, watercourse hazards, drainage and permeability conditions, seismic activity, climatic conditions, and human intervention. The stability of slopes in the area must be examined, and an assessment made of the likelihood of a landslide, its probable speed and volume, surface potentially affected, and so on.
- **Seismic risk** information affecting the potential site must also be taken into account, including active faults and other potential triggers of seismic activity, as well as the soil mechanics of the site and its potential for liquefaction or densification of the foundation soil and the resultant risk of landslides. An assessment must likewise be made concerning the maximum probable intensity and duration of an earthquake in the area, the influence of attenuation laws, and the linear response spectrum.

- **Volcanic risk** must be assessed by examining the historical records and current topography in order to determine the likely routes of pyroclastic flows in relation to potential sites for health facilities. The area of influence of lateral explosions and gas emissions, ashfall and the ejection of solid and particulate material, as well as the likelihood of lahars as a result of ice melting must also be evaluated. The likely severity of an event must be determined, including the total land surface that might be affected, the likely speed of the various flows, the degree of toxicity of the released gases and the magnitude of related seismic phenomena, not to mention the probability of such an event. In the case of coastal areas, attention must be paid to the likelihood of tsunamis as a result of submarine seismic or volcanic activity.

- Background information regarding the possibility of floods caused by **tsunamis**, originated by underwater seismic activity or volcanic activity.

- Historical records and other background information should also be reviewed regarding the **meteorological and hydrological conditions** of potential sites to assess the risk of floods, mudslides, and hurricanes. At least one year's worth of such information should be assessed, so long as the data represent historical conditions regarding spatial and temporal distribution of precipitation, thermic oscillations, location of the snow line, and so on. The risks posed by nearby watercourses, lakes, dams, and reservoirs should be examined, including available historical records of flash floods, areas affected by floods in the past, population affected, gauged water height, and the precipitation levels that led to such phenomena. An assessment must also be made of surface drainage and soil permeability, and soil use in the area. Wind patterns should also be examined, taking into account the intensity, direction and height-distribution of gusts. Topography should similarly be looked into, to rule out the possibility that the site's relative altitude might make it susceptible to floods, or that local morphology might encourage turbulences.

- Characteristics of **strong winds** in the region, evaluating historical data and determining at least the intensity, direction and height distribution of the probable winds.

- **Topography of the site** to ensure the site is not located in a low zone, **prone to flooding**, and to ensure that no morphologic conditions are present that could cause an incidence in the formation of turbulence.

- Safety of the specified site with regard to its **geotechnical** characteristics: support capacity and stability against different demands. Sites that should be particularly avoided include those with liquefaction potential, collapsibility, or important terrain settlements.

Annex 3.1 summarizes the questions that must be answered when assessing the risk posed by various natural hazards at any given site, and the variables that should be examined when assessing the merits of that site.

Technical and economic feasibility of protection systems

In the case of each likely natural hazard, an assessment must be made of the technical and economic feasibility of implementing overall protection systems for the structure through the execution of peripheral works and other actions aimed at mitigating known local hazards.

- The risk of **landslides**, for instance, calls on mitigation experts to examine the cost and difficulty of increasing slope stability through the building of retaining walls and alluvial terraces, the use of geotextiles, compacting unstable soil, reforestation, the clearing of watercourses that might undermine the soil in the event of flood, and the implementation of permanent monitoring and early warning systems.
- ∑ A similar cost/benefit and technical feasibility assessment must be made regarding **strong winds** and the development and implementation of technical specifications for appropriate detailing, reforestation, or early warning systems.
- In the case of **flood risk**, attention should be paid to how realistic it would prove, in technical and financial terms, to implement prevention measures such as the building of protective dams in critical flow points, gavions along the embankments, the clearing of watercourses, water diversion through canals and drainage facilities, or improved collection of rainwater.
- **Seismic hazards** call for a cost/benefit analysis of the application of seismic-resistant standards.
- Where **volcanic activity** is a major hazard, an assessment should be made of the feasibility of permanent monitoring of acitivity and early warning systems.

Annex 3.2 lists several of the options available for the overall protection of health facilities in the face of the natural hazards considered in this handbook.

Impact of hazards on the sites under consideration

In the case of each prevailing hazard, an assessment must be made of its likely impact on the population to be served, as well as on local lifelines, related services, and overall access to health care. The likely impact of the phenomenon on the health network of the region—and, where appropriate, of the country—must also be assessed. This assessment should not only consider the network's infrastructure but also the health, economic, and political aspects. All too often, while damage to health infrastructure may be manageable from a technical viewpoint, the political and social impact can be devastating.

Stage 3: Site selection

Selection of the best option

The information compiled must be processed in order to select the safest and most convenient site for the facility. This process includes the following activities: classification of hazards and evaluation of risk for alternative sites; production and superimposition of risk maps; analysis of technical feasibility, costs of overall protection of the structure, impact of hazards, and comparative cost/benefit studies of alternative sites; and finally, definitive selection of the structure's location.

In some circumstances it may not be possible to meet the desired performance objective due to the extreme conditions in which the reference population lives. Given the lack of safe locations, the project's performance standards should guide alternative site decisions such as the following:

- Divide the functions of the facility so that they are carried out in different locations, remote from each other;
- Ensure that mobile or temporary facilities are available in the event of a disabling event;
- Create effective referral systems, allowing the smooth transfer of patients to health facilities in other areas.

Such approaches can help to distribute or decrease the risk, however they increase costs and make operations more complex than might be desired, but they may be the only reasonable alternative.

Production of summary document

The information obtained during the three stages of site selection must be summarized in a document that should contain, at the very least, the following:

- Explanation of the reasons for the choice of site;
- Description of the risks identified at the site;
- Causes of those risks;
- Characterization of the risks;
- Design recommendations for the facility, including the length of time it can remain cut off from basic services (water, electricity, etc.);
- Design and protection recommendations for the area of influence;
- Protection objectives for the intended health facility.

3. Assessment of site safety

The form *Site selection*, included in *Annex 3.3*, should assist the project administrator and the coordination committee in selecting a safe site for the hospital.

References

ASCE 7-98, *Minimum Design Loads for Buildings and Other Structures*, American Society of Civil Engineers, 1998.

Centro Colaborador OPS/OMS en Mitigación de Desastres en Establecimientos de Salud, *Bases Metodológicas: Evaluación de Vulnerabilidad Sísmica de Edificaciones Estructuradas con Pórticos de Hormigón Armado, Evaluación de Elementos Arquitectónicos y Evaluación de Equipamiento*, Universidad de Chile, 2000.

FEMA 55: *Coastal Construction Manual*, Federal Emergency Management Agency, Washington, 1996.

Hallent, B., *Photogrammetry, Basic Principles and General Survey*, McGraw-Hill, 1960.

Key, D., *Structures to Withstand Disasters*, Ed. Thomas Telford, London, 1995.

Kuroiwa, J., *Reducción de Desastres: Viviendo en Armonía con la Naturaleza*, Lima, 2002.

Ministerio de Vivienda y Urbanismo, *Planificación de Asentamientos Humanos en Zonas Propensas a Desastres*, Chile, 1982.

Organización Panamericana de la Salud, *Manual para la Mitigación de Desastres Naturales en Sistemas Rurales de Agua Potable*, 2001.

Organización Panamericana de la Salud, *Mitigación de Desastres Naturales en Sistemas de Agua Potable y Alcantarillado Sanitario*, Guías para el Análisis de Vulnerabilidad, 2000.

Pan-American Health Organization, *Disaster Mitigation for Health Facilities*, Guidelines for Vulnerability Appraisal and Reduction in the Caribbean, 2000.

Simiu, E., *Wind Effects on Structures: an Introduction to Wind Engineering*, John Wiley & Sons, 1978.

Taype , V., *Aplicación de Mapas Geodinámicos en la Prevención de Desastres Naturales*, Memorias 4to Simposium Nacional de Prevención y Mitigación de Desastres Naturales, Lima, CISMID, 1990.

Annex 3.1: Summary of additional tasks required for risk assessments

The scope of the studies needed to characterize natural hazards depends in large part on local conditions in each region. However, as reference, this table summarizes the additional information that should be obtained in order to assess the risk posed by a variety of natural hazards to contemplated health facilities.

Assessment of landslide risk
Assessment of conditions for a landslide
Historical background
Vegetation
Geological conditions
Topographical conditions
Soil conditions (based on soil mechanics studies)
Hazards due to water-courses
Seismic hazard
Human intervention
Assessment of slope stability
Preliminary and detailed assessment
Likely impact of a landslide
Affected surface and volume of displaced soil, debris, other material
Speed of landslide
Safety factors for landslide
Likelihood of event
Production of risk maps (microzoning)

Assessment of mudslide risk
Assessment of conditions for a mudslide
Historical background
Meteorological conditions
Vegetation
Geological conditions
Topographical conditions
Soil conditions
Drainage and permeability
Human intervention
Likely impact of a mudslide
Affected surface and displaced soil, debris, other material
Speed of mudslide
Likelihood of event
Production of risk maps (microzoning)

Assessment of risks due to strong winds
Assessment of conditions for strong winds
Historical background
Meteorological conditions
Topographical conditions
Likely impact of strong winds
Gust speeds and other load parameters
Likelihood of event
Production of wind maps (microzoning)

Flood risk assessment
Conditions for floods to occur
Historical background
Meteorological conditions
Water courses in the area
Topographical conditions (low-lying areas)
Permeability and use of the soil
Risk of tsunami-induced flooding
Human intervention
Critical point identification
Identification of points along watercourses likely to overflow in conditions of extreme precipitation
Likely impact of flood hazard
Affected surface
Flood elevation (inches or centimeters above ground level)
Flow speed and other load parameters
Likelihood of event
Production of risk maps (microzoning)

Seismic risk assessment
Characterization of sources of seismic risk
Determination of frequency/magnitude ratio
Estimation of maximum likely earthquake
Estimation of seismic risk
Estimation of strong ground movement in probabilistic or deterministic terms
Definition of one or more attenuation factors
Estimation of likely duration of strong ground movement
Estimation of predominant period of strong ground movement
Likely impact of seismic risk
Spectrum of responses, records and other load parameters
Potential for liquefaction of foundation soil
Potential for landslide (see section on landslides)
Likelihood of tsunami (see section on floods)
Production of seismic risk maps for the various siting options

Risk assessment of volcanic activity
Assessment of likelihood of volcanic activity
Possibility of lateral explosions
Possibility of pyroclastic flows
Possibility of lava flows
Possibility of landslides or rock slides
Possibility of mudslide
Possibility of contamination due to gases and ashes
Possibility of ejection of solid and particulate materials
Possibility of flood due to tsunami
Likely impact of volcanic risk
Affected surface (area of influence)
Speed of flows
Degree of toxicity of expelled gases
Magnitude of associated tremors
Characterization of derivative loads (landslides, floods, etc.)
Likelihood of event
Production of volcanic risk maps (microzoning)

Annex 3.2: Summary of options for the overall protection of the structure

The following table lists some of the options available for ensuring the overall protection of the intended structure.

Actions that can assist in the overall protection of the structure
Strategies for protection against landslides and mudslides
Slope stabilization
Soil stabilization through the use of geotextiles
Knocking down unstable masses
Reforestation
Cleaning natural watercourses, canals
Construction of drainage facilities
Construction of alluvial terraces
Constant monitoring (instrumentation); early warning systems
Other
Strategies for protection against strong winds
Production of technical detailing specifications
Reforestation
Permanent monitoring of meteorological conditions; early warning systems
Other
Strategies for flood protection
Construction of protection barriers at critical points of the watercourse
Construction of gavions [retaining walls made of rocks and chicken wire] along the full length of the watercourse
Cleaning natural watercourses and canals
Construction of drainage facilities
Reassessment and improvement of rainwater collection and drainage
Reinforcement of the structural system
Other
Strategies for seismic protection
Production of technical specifications for seismic-resistant design
Other
Strategies for protection against volcanic activity
Permanent monitoring and early warning system
Other

Annex 3.3
Form: Site selection

Site selection[1]

General information on planned hospital

Name of hospital: . . . . . .

Health system: . . . . . .

Siting option: . . . . . .

Natural hazards prevalent in siting option:

	Available information		Hazard level		Assessment	
Hazard	Sufficient	Insufficient	High	Low	Detailed	Basic
Landslide or mudslide						
Earthquake						
Volcanic eruption						
Flood						
Hurricane						

Disciplines required for risk assessment:

Urban development	
Topography	
Geology	
Soil mechanics	
Meteorology	
Hydrology	

Hydraulic engineering	
Seismology	
Wind and hydrodynamic engineering	
Seismic engineering	
Structural engineering	
Vulcanology	

Other aspects to consider in site selection:

Near:	Yes	No
Industrial sites		
Chemical plants		
Refineries		
Processing centers		
Military facilities		

	Yes	No
Landfills		
Airports		
Major trasnport routes		
Other (please specify):		

Hazard characteriscis [2]

Landslide

Affected surface and volume displaced: . . . . . .

Slide speed: . . . . . .

Landslide safety factors: . . . . . .

Likelihood: . . . . . .

Feasibility of controlling impact: Yes ☐ No ☐

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Form for Site selection[1] (continued)

Mudslides

Affected surface and volume displaced: . . . . . .

Slide speed: . . . . . .

Likelihood: . . . . . .

Feasibility of controlling impact: Yes ☐ No ☐

Hazard characteristics [2]

Strong winds

Likelihood: . . . . . .

Feasibility of controlling impact: Yes ☐ No ☐

Flooding

Affected surface: . . . . . .

Flood altitude: . . . . . .

Flow speed: . . . . . .

Likelihood: . . . . . .

Earthquake

Design spectrum: . . . . . .

Direct geotechnical consequences (description): . . . . . .

Feasibility of controlling impact: Yes ☐ No ☐

Otro

(Description) . . . . . .

Feasibility of controlling impact: Yes ☐ No ☐

Approximate cost of implementing protection systems (US$):

Landslide	----------	+
Earthquake	----------	+
Volcanic activity	----------	+
Flood	----------	+
Strong winds	----------	+
Other	----------	+
Total	----------	=

Notes: 1 A similar form must be completed for every siting option. This table complements the site selection from different points of view: sanitary, urban, accesibility, basic services, topography, geotechnical, legal and economic.

2 The team of specialists in charge of assessing the risk of the various hazards prevalent in the area must present a written report to the project administrator and the coordination committee on those hazards and their likely effect on the siting option.