Report No: AUS0000904

Forensic Analysis of the Conditions of Disaster Risk in the 2018 Volcano of Fire (Volcán de Fuego) Eruption.

Opportunities for the Strengthening of Disaster Risk Management in Guatemala

GFDRR
Global Facility for Disaster Reduction and Recovery

WORLD BANK GROUP

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1. INTRODUCTION

The eruption of the Fuego volcano on June 3, 2018, caused substantial soul searching, both nationally and internationally. The loss of human life and the destruction of infrastructure and economic production sparked debates and raised questions regarding the capacities available in Guatemala to manage disaster risk and disasters associated with volcanic activity in general and on that day specifically. The entire process, from risk knowledge and analysis, to warning and evacuation, to risk reduction and reconstruction, was subject to examination by public institutions, productive sectors, scientific organizations and affected communities. What portion of the damage and human loss were avoidable and what part was almost the "natural" result of this explosive and sudden type of event?

The eruption of the Volcano of Fire evidenced needs in knowledge of risk and scientific monitoring, in education and the participation of communities, in the organization and logistics of preparation and response and, more generally, in the processes of territorial adaptation and planning when faced with volcanic processes. The case of the Volcano of Fire is that of an extremely active volcano, with activity cycles and patterns still little understood by experts and with limited historically recorded direct human impacts.

Faced with these circumstances, alternatives must be analyzed and proposed for the future to reduce the occurrence of impacts such as those that occurred the 3rd of June, taking advantage of a change or broadening of focus that is based increasingly on the notion of the social construction of disaster risk, as opposed to explanations based on the notion of a "natural" and, thus, inevitable, disaster. Experience shows how an approach from a social perspective is appropriate for understanding and reducing the drivers of disaster risk (see Wisner et al, 2004, Lavell and Maskrey, 2015, Sendai, 2015, Oliver Smith et al, 2016).

The present document provides an analysis of the Fuego volcano disaster applying a Forensic Investigation of Disasters methodology (FORIN)[1], an initiative of the International Council of Science (now International Science Council) (ICSU), and its Integrated Research on Disaster Risk Program (IRDR). This method allows us to focus on the socio-economic, cultural and political root causes of disaster risk and disaster through comparative, longitudinal or contemporary research. This includes contrasting the differentiated impact of similar events in different areas; disasters suffered in the same geographical area but at different points in time; or comparison between countries that have suffered similar events at similar times, but with different underlying conditions and social responses.

The FORIN method, considered as a process, takes the physical event that triggers the disaster as a base point of reference, obviously of differentiated importance depending on the magnitude or intensity of the event. However, the essence of the method does not

[1] Oliver-Smith, Alcántara, Burton & Lavell (2016).

search to ascribe impact to the event per se, but rather, makes it possible to answer the question: Why, given the circumstances of the event and its characteristics, did the impacts occur in the way they did in terms of effects on population, sectors, production, territory and temporality? The method seeks to demonstrate which component of this impact can be explained by human actions and social processes that could have evolved in safer ways and with less accumulation of disaster risk.

This approach considers risk (probability of future damages and losses) and disasters (damage, materialized loss) as processes, not just products. In a study on social responses to the concatenation of hazards associated with the eruption of the Volcano of Fire and the following mudflows from the Agua volcano in 1717, Hutchison et al (2016) wrote:

> "*... recent events naturally tend to concentrate on immediate impacts. Studies for hazard management focus on responses to immediate physical impacts, often at the cost of not developing long-term sustainable mitigation strategies (resilience). This approach ignores the "long shadow" (Grattan and Torrence, 2007) of such disasters, where long refers to scales of time relevant to political or cultural change ...* "

On the other hand, Hewitt, in 1983, clearly exposed the way in which disasters do not represent abrupt ruptures with the everyday but represent a continuity of every-day living conditions, where pre-existing conditions calibrate and condition the impacts and contribute in good part in determining those who receive them.

These approaches call attention to the need for analysis in a framework of historical processes, an intrinsic component of the FORIN method.

It is hoped that this document will contribute to a reflection as to mechanisms for strengthening the design and implementation of public policies in the future; and influence the actions of individuals, the private sector and civil society. The document does not present a series of finished or certain explanations, but a systematized account, based on existing evidence of elements to be considered in such an explanation, gleaned over a short period of time and that can be subject to further research and discussion by the wider national and international community.

Resources and research methods.

The method, extent and depth of the investigation are conditioned by the time and resources available. Thirty-five days were spent in total on the present component of the research, including data collection, analysis and interpretation and the preparation of reports, the conduct of a workshop-conference discussion and translation to English from the original Spanish language document (our thanks to Chris Lavell for his revision of the original first draft translation). Two field trips to Guatemala to interview key informants were made by the authors during 8 working days.

Forensic risk and disaster research can use various investigative techniques. In the current case the following sequenced series of methods and instruments were applied:

♣ An **analysis of secondary information** published in reports, investigations, newspapers, plans and other relevant documents. This allowed a first approach to the problem, understanding of impacts and elements of primary causality, including information on the territorial and sector impacts of the event. Additionally, it allowed an approximation to aspects of causality related to the concrete social dynamics of exposure and vulnerability.

♣ Phase of **interviews with key informants**. Members of academic and government entities, national technicians and specialists, national and international experts and agencies were interviewed in order to gather information and systematize ideas and knowledge, contrasting them with information obtained from documentary sources. This included establishing possible optimal scenarios for the management of disaster risk in an environment such as Fuego against which one can compare what existed at the time of the event (this analysis is incorporated in a second component of research to be completed after this report). Additionally, the knowledge, attitudes and experience of the affected population were researched, contrasting the scientific knowledge gleaned with popular and experiential knowledge (a list of the interviewees can be found in Annex 1; only those who expressly consented to be interviewed and cited are referred to by name in the text). The interviews were sometimes structured, sometimes semi-structured, and other times left open. In the case of field interviews with the affected population, authorities and others some were filmed, with the permission of the interviewees (our thanks to Mischa Prince for the opportunity to film some 10 interviews with key informants).

The forensic research method offers a sequenced chain of notions of causality, moving from the immediate, the epiphenomenal, to the structural. The most reliable possible descriptions of impacts, effects, events, damage and loss are associated in first instance with the levels of exposure, hazard and vulnerability existing at the time of impact. This offers a first superficial explanation. For example, people died because they were in the area of impact of the pyroclastic flow. Houses were destroyed for the same reason, as were production areas and livelihoods. People were affected because the early warning based on the volcanic prognosis was not correct, assertive or appropriate. However, this does not constitute an explanation in a scientific sense but rather it offers a territorial and temporal association of different circumstances. The essence of the forensic method is to go further and explain why territorial development, land use occupancy, livelihood schemes and other processes acquire certain characteristics. Why a possible volcanic event becomes a hazard and why there are specific existing conditions of vulnerability[2]. From such a thorough assessment, it is possible to determine which adverse conditions are indeed avoidable, within the specific context of the country and the localities considered.

[2] We define vulnerability as the predisposition to damages and losses in human beings and their livelihoods, in this case, volcanic phenomena. That is, the conditions that typify or establish differences between people and their livelihoods. Insufficiencies in other areas, such as infrastructure, institutional or social organization, are factors that contribute to this vulnerability and must be explained in their origins and existence through in- depth forensic investigation.

2. PARTICULARITIES OF DISASTER RISK MANAGEMENT ASSOCIATED WITH VOLCANISM

It has been established that the risk of disaster is a social, historical, collective and multidimensional construction, which is defined by the inability of human systems to adequately couple to the natural dynamics and milieu with which they interact or on which they depend. This also occurs because many times the very same hazards that affects them are socially constructed through processes of environmental change and degradation. This implies placing the emphasis in the explanation of disasters on social, economic, cultural and political processes rather than attempting to make nature responsible for damage and loss. Under this approach, the role of potentially damaging natural phenomena (seen here as natural hazards) lessens in relevance. Although it remains a central consideration within disaster risk management strategies, it is not taken to be the main explanation for the materialization of associated risk, nor the element that can be most readily affected through social based disaster risk management.

In general terms, the challenge societies face is to avoid or assimilate the energy released by natural phenomena and that negatively affects human systems. When this capacity to avoid or absorb is exceeded, the natural resource, the geographical environment in which society or a component of it is located, becomes a hazard. An episode of heavy rain can exceed the capacity of a reservoir and compromise its operation. The amount of water discharged in a relatively short period of time may exceed the drainage capacity of the dam and generate upstream flooding or, also, force the reservoir to vent to prevent damage to the dam, which then could generate downstream flooding. Or a rich agricultural area proximate to a river or on the slopes of a volcano is subject to medium or long-scale intensive flooding or ash fall and pyroclastic flows. The resource itself is transformed into a hazard according to different intensities and temporalities with which the resource (the water, rain, land etc.) is expressed.

Disaster risk management, understood here as a social process focused on reducing (correction), avoiding (prospection) or facing risk conditions (reaction), seeks to maintain a balance between natural and human systems. The tools that have been developed are aimed at permanently increasing the adaptive capacities of society to its environment. It does not seek to cancel the risk of loss and damage completely, but, rather, assimilate it under technical and political parameters that guarantee a level of security that is considered acceptable for the greatest number of people and activities.

Knowledge and understanding of disaster risk is essential to design disaster risk management strategies that are technically, socially and politically viable[3]. This knowledge and its importance are captured in priority 1 of the Sendai Framework for Disaster Risk Reduction 2015-2030; and it is the base of corrective, prospective and

[3] Yamín et al. (2013).

reactive/compensatory components of disaster risk management, including financial protection, preparation and recovery (Ghesquiere and Mahul, 2010). Specifically, it involves understanding and dimensioning the process of interaction between risk factors (hazards, vulnerability and exposure). This is vital because it establishes the limits of assimilation and possible coexistence of human systems with natural systems in time and space.

The central role of disaster risk knowledge: the physical hazard.

Traditionally, risk knowledge starts with the physical hazard. This should not be interpreted in the sense that the hazard is more important in the risk formula than exposure or vulnerability, but rather that it establishes the backdrop to the relationship between society and environment. Obviously, it is not environment that adapts to society, but the reverse. Disaster risk is best dimensioned with the knowledge of vulnerability and exposure, which are eminently social components.

The generic term "hazard" includes possible damaging events, the environment in which they occur, and the possible concatenated or linked interactions with other events. This is particularly frequent in the case of Central American countries, where the context of multi-hazard risk covers a good deal of the territory. Hazard analysis seeks to determine the intersection between the temporal and spatial scales of natural and human processes, and how this can disturb the normality of territorial dynamics. It attempts to determine, for a given phenomenon, the forms and intensities of the energy discharge, located within specific temporal and spatial scales. When studying the hazard, we seek to recognize and understand the fluctuations of energy over time. This involves not only the probable intensities of the event (for earthquakes, floods or landslides, for example), but also, what is their probable recurrence and which areas could be affected. With this information it is possible to deal with associated exposure and vulnerability processes, including response in conditions where exposure and vulnerability already exist. In short, the capacity for adjustment and coexistence of human systems depends on how well they understand the dynamics of the environment in which they are located.

Clearly, the levels of knowledge about hazards vary according to factors such as the type of phenomenon and the generic and specific scientific advances in a particular place available for analysis or monitoring. This is, from an eminently technical point of view, the main factor that makes the combination of the other components of disaster risk management more flexible. To the contrary, when there is little data and high uncertainty, it is necesarry to establish measures based on precautionary principles. That is, given little hazard information, the versatility of possible direct management measures must necessarily be diminished.

Box 1. The precautionary principle within disaster risk management

The precautionary principle was originally conceived as an approach that sought to guarantee people's safety in contexts in which science did not allow a validating or refuting of potentially harmful activities or projects. Its application began where controversies existed regarding the installation of industrial activities in developing countries. However, its usefulness has been extended to other areas of development, to the point of being considered in the 1992 Rio Declaration on Environment and Development.

The precautionary principle establishes a way to handle levels of uncertainty about specific processes that escape human control and generate negative effects for a given community. When institutions, often state run and the ultimate guarantor of citizen security, cannot ensure adequate and safe operating conditions for an activity, the best alternative is to avoid or stop its implementation.

There are six notions that are often seen as ways to implement this principle in different situations:

1. **Preventive anticipation**. When there is a willingness to anticipate potential harm, even if the scientific evidence does not exist, considering that, should the worst occur, the damages can be extremely expensive and affect future generations.

2. **Safeguard**. This refers to the extension of the absorption capacity of natural systems that are considered so valuable or fragile, that minimum human intervention could affect them.

3. **Proportionality.** Cost-benefit evaluations seek to determine that the costs of assuming the damages that may occur within acceptable margins of error will not generate excessive expenses for future generations.

4. **Duty of care**. Proposes parameters to limit calculated risks in the use of any given resource. It also tries to determine the ways to compensate for possible losses, as well as establish who would be responsible for repairing potential damage.

5. **Promotion of intrinsic natural rights**. This concept extends the legal notion of ecological damage, requiring human intervention processes to consider the ability of natural systems to operate under their own dynamics as a mechanism to guarantee their functioning and regeneration.

6. **Payment for a past ecological debt**. The precautionary principle has a clear emphasis on future actions. However, there are current situations that are explained by significant damage in the past, which was not adequately prevented and that has generated a problematic situation in the present. This implies that someone should compensate others

for existing problems. This is the case for example of the notion of shared but differentiated responsibilities when talking of climate change.

In terms of disaster risk management, the application of these notions is very useful to organize the technical and political resources that really allow stakeholders to visualize the existing management capacities, the distribution of responsibilities within these management schemes, and the mechanisms of compensation that can be guaranteed by the institutions in cases of damage. The questions that must be asked when considering the six concepts of the precautionary principle reveal in a clear way what elasticities exist to take risks, manage the uncertainty and establish the social distribution of profits and losses when a disaster happens.

Source: Adapted from Artigas (2001)

Disaster Risk associated with Volcanism

The analysis of disaster risk associated with volcanism implies the understanding of highly complex, highly volatile hazards under substantial levels of uncertainty, both regarding their recurrence and the behavior of their "byproducts". Although in recent decades there has been an important advance in the field of probabilistic modeling, experiences world- wide confirm that the associated multifactorial nature of processes is still not captured in a way that can offer security to different groups of decision makers, scientific and political, and the general public. It is one of the hazard complexes where the application of the precautionary principle can be most useful in organizing the location of human activities in the vicinity of active volcanoes.

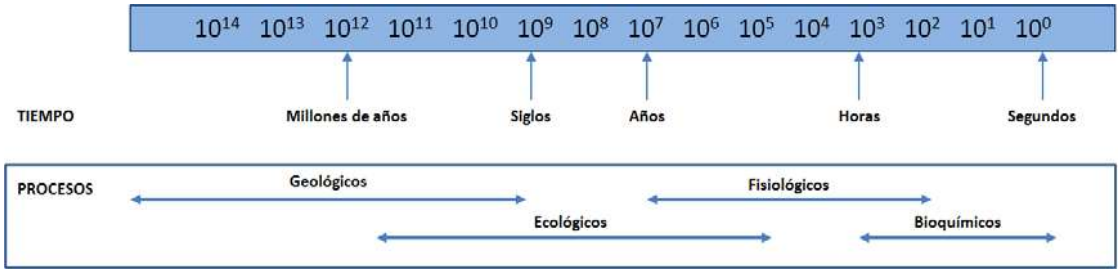
Volcanic activity is a hazard intrinsic to the development dynamic of Central America (Map 1), and the natural history of the countries of the region is closely linked to processes of volcanism. The characteristics of volcanism are a geological factor offering opportunities for the development of agricultural activities, both for its pedological implications and for its impact on the formation of landscapes. Additionally, volcanoes are one of the main pillars of tourism in the countries of the area. Tourism continues to grow in importance in a region that is slowly but steadily moving towards more economic activities related to services.

Map 1. Central America: Location of the main volcanoes.

Source: Elaboration by the authors based on information from the World Bank and CCAD (2002).

Due to the characteristics of regional volcanism, human groups have had to develop integrated environment-society strategies that are still in formation. Adaptation to the context of volcanic threat is complex because it requires tuning widely different time scales. For human activities, the influence of a volcano is positive and negative on contrasting medium and long-term time scales. The balance between hazard and opportunity must be contextualized in three-time scales: geological, ecological and physiological (Figure 1). For many it is acceptable to run the risk of settling near a volcano given the relatively broad periods of opportunity and usufruct of the land resource that exists, versus the potential negative impact which, in many cases, does not occur more than once every few generations.

Figure 1. Superimposition of three temporal scales that define the disaster risk associated with volcanism.



Source: Elaboration by the authors based on Mass (2004).

In the frame of volcanic hazard it is necessary to detail its concrete manifestations in order to capture the configuration that risk associated with the volcano can acquire. In many cases there is a predominance of paroxysmal episodes; in others, manifestations occur in periods of low intensity, but of long duration, as in the case of emissions of gases that result in acid rain, and that can affect a territory for years. Table 1 describes the different manifestations of volcanic activity that should be considered within integral strategies of disaster risk management. According to the characteristics of relief, the eruptive processes can be ranked according to their relevance in terms of hazard and probability of occurrence, as well as according to levels of uncertainty in their modeling.

Table 1. Description of the main eruptive processes of Central American volcanoes.

Volcanic Process	Description
Ash fall	Consists of the expulsion of small particles of magmatic material that may be suspended in the atmosphere by the action of the ascending gases. Depending on the size of the particles and the meteorological conditions, the ash can travel hundreds of kilometers and affect territories far from the volcano.
Pyroclastic flows.	Pyroclastic flows are composed of a mixture of magmatic material and gases at high temperatures that are driven vertically in the form of columns of material and which, due to their density, collapse under the effect of gravity on the source of emission. These conglomerates of material descend at speeds that can exceed 100 kilometers per hour and reach temperatures of hundreds of degrees Celsius. The behavior of pyroclastic flows is influenced by the

	surrounding geographic features, which usually determine the course they take.
Lava flows	When magma is expelled to the surface, it usually turns into lava flows, which, essentially, is molten rock material. These flows, like pyroclastic flows, are displaced by gravity, although their dynamics also depend on the viscosity of the lava, which results from its chemical composition and dissolved gases. As a rule, it is accepted that the more viscous lavas have a slower displacement, although they present higher levels of explosiveness; otherwise, it is the most fluid lavas, also known as basalts, which have lower explosive rates, but travel at speeds of up to 30 kilometers per hour.
Ballistic projections	They are pyroclasts that, expelled to the atmosphere and due to their size, do not manage to stay in suspension and acquire free fall trajectories, which can reach several kilometers from the source of ejection.
Lahars.	They constitute currents of water, mud, stones and other materials that move on the slopes of the volcanoes, generally occupying the channels of rivers and surrounding ravines. Depending on the amounts of accumulated material or the interaction with meteorological phenomena, their magnitude can vary, and they can travel great distances carrying hundreds of tons of material.
Acid rain	Acid rain is formed when the gases emitted by a volcano (mainly sulfur dioxide) contact the humidity of the air. From this combination, fluids with high corrosive capacity are precipitated, affecting the surrounds over a large area and which, depending on the intensity of the degassing processes of the volcano, can remain for several years.

Source: Adapted from ERN (2010).

Hydrometeorological conditions also play an important role in the construction of volcanic risk. As can be seen in Table 1, the interaction land-atmosphere determines the behavior of the potential impacts of a volcano. The example of lahars is one of the clearest: in the case of Fuego. Active lahars are the result of a combination of material deposited on the slopes of the cone and then dragged towards the channels during rainfall (Image 1). In cases like this, the temporality of the lahars can be estimated according to the seasonality of the atmospheric conditions. Possibly, in years to come, due to factors such as climate change the occurrence of these flows will be greater during the rainy season.

Image 1. Guatemala. Zone of influence of the lahars of Fuego volcano in the sector of San Miguel Los Lotes. September 2018

Source: The authors (2018).

On other occasions, interaction can occur when vapors emitted into the atmosphere, with high concentrations of sulfuric acid, condense and precipitate in the form of acid rain. This is a classic case of long-term processes, which contrast with the paroxysmal episodes of great destructive power in short time periods. In contrast, acid rain can have a highly damaging effect on ecosystems, people and infrastructure over long periods of time. Image 2 shows the effects that acid rain had on the surroundings of the Turrialba volcano, in Costa Rica, where the main affectation has occurred in agricultural activities (vegetables and dairy products) located in the foothills of the volcano for decades.

Image 2. Costa Rica. Impact of acid rain on the slopes of the Turrialba volcano. 2015

Source: The authors (2015).

Because volcanic risk is multi-hazard based and evident in Central American countries, it is essential for decision-makers to achieve the most comprehensive understanding of the situation as possible. This level of understanding is still incipient in the region but will be of increasing relevance for the planning of socioeconomic activities in the future. In the Guatemalan case, the sectoral ramifications of the impacts of the Fuego eruption are still being discovered; and the spatial scope of the event can cover, directly or indirectly, large extensions of surrounding lands. The next few years will provide an opportunity to improve knowledge of the phenomenology of Fuego, but more importantly, to strengthen management strategies and adaptation in this highly dynamic hazard context.

3. THE EMERGENCY AND DISASTER OF JUNE 3, 2018: VOLCANO OF FIRE AND ITS IMPACTS.

The Fuego volcano (or Chi gag in Cachiquel) has an altitude of 3,763 meters above sea level, and is located in southern Guatemala, between the departments of Chimaltenango, Sacatepéquez and Escuintla (Map 2), in a chain of Quaternary volcanoes that runs parallel to the coast of Guatemala. Its period of formation is estimated between 13 and 100 thousand years, although age is still difficult to establish with accuracy. The estimates are made from the analysis of the volcanic mass and the approximate time for its formation, together with some evidence obtained by carbon dating.

Map 2. Guatemala. Location of the Fuego volcano.

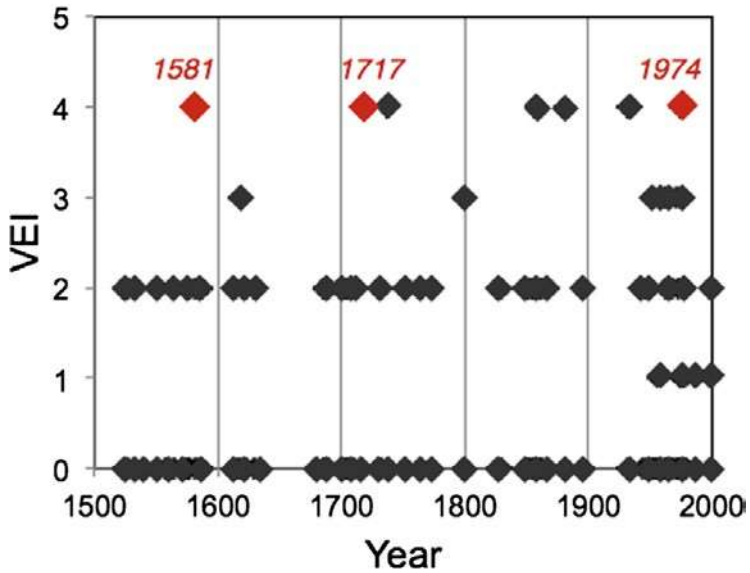
Source: CONRED (2018)

Fuego is a stratovolcano exhibiting volcanic-strombolian activity. Fumaroles, ash explosions, eruptions with columns of incandescent material (which can reach up to 15 or more kilometers in height), pyroclastic flows, lahars and avalanches are amongst the more common hazards. Lava flow is not a typical by-product and has only appeared as precursors to major events.

Between 1524 and 2018 there have been around 60 eruptions classified as 4 on the Volcanic Explosive Index (VEI), which ranges from 0 to 8 (maximum) (see Figure 2). The volcano has experienced five major periods of eruption since 1524 (the date of first

recordings on establishment of the colony by Spain), separated by periods of quiescence or continuous low-scale activity of 25 to 70 years. The most recent period of continuous activity began between 1999 and 2002, after a period of calm since 1974, the year in which the last major eruption occurred before that of June 3, 2018.

Figure 2. Guatemala. Fire volcano. Record of the eruptions classified according to their corresponding VEI.



Source: Based on data from the Global Vulcanism Program of the National Museum of Natural History (Available at: http://volcano.si.edu/database/search_eruption_results.cfm)

Although there remain important gaps regarding the scientific knowledge of the volcano, there are evidence and arguments to suggest that it is one of the most active and potentially dangerous in Guatemala and Central America (Table 2 provides a description of the eruptive episodes between 1986 and 2012). In addition, there is evidence of a change in its dynamics in recent years (see Naismith et al. (2018).

The science of volcanoes is not part of our core expertise and will not be discussed in further detail. We can however affirm that insofar as the dynamics of the volcano are not fully known, there will be considerable ramifications and consequences for the study of its hazards and risk, as a whole. This also occurs in a context where available information does not seem to have had a great impact on past decision making. Evidence suggests, for example, that volcanic hazard mapping in the past[4] has not been accounted for in norms and controls over the location of human settlements and productive activities.

Table 2. Guatemala. Eruptive events of Fire between 1986 and 2012.

Year	Event(s)
1986	Incandescent tephra ejection, visible from Antigua, Guatemala. Reports of fumarolic activity throughout the year.
1987	Gas emission, microquakes and expulsion of water vapor.
1988	Fumaroles and moderate emission of SO2 that continued until 1992.
1999	Moderate eruption with ash emission that mainly affected the east of the volcano (San Juan Alotenango). Pyroclastic flows inside the ravines on the sides of the cone. Lahars in the rainy season, causing the death of one person and damage to road infrastructure.
2000	Constant explosions with audible rumbling in nearby towns and limited ash fall.
2002	Descent of lava along the eastern flank of the crater, visible at night, which filled the crater. Increase in strombolian activity, visible from the capital. The flow of lava in Barranca, Las Lajas ravines reached almost 1,500 meters. A cone almost 50 meters high was formed inside the crater.
2003	Moderate eruption various pyroclastic flows. The largest in Quebrada Santa Teresa (southwest of the volcano) with partial filling of the ravine. Months later, the flows filled the ravine and spread, affecting local vegetation. In the rainy season, a number of lahars, mainly in Quebrada Santa Teresa, partially dragged the materials from recent pyroclastic flows further downhill.
2004	Moderate lava flows reached the base of the volcano, mainly towards the west at the head of Quebrada Santa Teresa.
2005	Moderate eruption with ash explosions 1,500 meters high. It generated pyroclastic flows in the Taniluyá, Santa Teresa and Ceniza canyons. Lava flows were observed. The plume of ash dispersed more than 25 kilometers in a west - southwest direction. This caused changes in the channel of the river due to the drag of abundant material with trees and large rocks that came down as lahars.

[4] See Vallance et al. (2001) & Rose et al. (1983).

2006	This year there were no eruptions; only explosions.
2007	The year with the most eruptive activity during the most recent reactivation phase, with 6 eruptions: March 25, June 29, July 17, September 11, December 7 and December 16. Moderate eruptions generated thick ash columns affecting populations to the west, such as Yepocapa and the villages of Sangre de Cristo, Panimache, Santa Sofia and Morelia. The lahars descended the Taniluyá, Santa Teresa, Ceniza and las Lajas ravines. In winter the lahars causing most damage were those that descended the rivers El Jute, Las Lajas, Taniluyá and Ceniza, causing destruction of road infrastructure.
2007 – 2011	Constant activity was maintained in the crater with many explosions (weak, moderate and strong), ejecting columns of ash 300 to 800 meters above the crater. Some of these explosions generated rumblings and shock waves. Lahars remained active in winter and mud and debris descended causing problems for roads and vehicles. The rivers with greater lahar activity were Las Lajas, El Jute, Ash, Taniluyá and Pantaleón.
2012	Eruption with abundant ash, lava flows and moderate pyroclastic flows in the Las Lajas canyon. The flows reached 1,000 meters in length, accompanied by small pyroclastic flows. In September, a strong eruption occurred, with a pyroclastic flow 7 kilometers long inside the Ceniza Canyon. Thick ash columns covered the villages of the southwest, Panimaché, Panimaché II, Morelia, Porvenir and others, forcing the evacuation of 5,000 people to Santa Lucia, Cotz. This had not happened since 1974 (nor would occur again until 2018).

Source: World Bank, ECLAC and UNDP (2018).

3.1. The June 3, 2018 event

Fuego registered three major eruptions during 2018. The first was during the month of February, the second triggered the disaster on June 3, and a third which occurred the week of October 8.

On June 3, Fuego started its activity around 06:00, and five eruptions of different intensities occurred over the day until activity ceased. Near midday the strongest eruption occurred[5]. In its bulletin emitted at 22:00, on June 3, the National Institute of Seismology, Volcanology, Meteorology and Hydrology of Guatemala (INSIVUMEH) announced the

[5] Although the INSIVUMEH bulletin reported the eruption at 13:40, there is no official register or consensus we can conclude to on the exact time of this eruption.

end of the activity after 16 hours and 50 minutes of eruption.

As a result of this activity several hazards affected the population, their livelihoods, production and infrastructure: tephra-ash dispersed up to 100 kilometers away and pyroclastic flows reached 20 kilometers from the crater. The lahars presented dangers at the time of the eruption and during the following weeks because of the concatenated effect of the rain of the season. Pyroclastic flows filled and surged from Las Lajas Canyon between noon and 3:30 p.m. causing the greatest amount of damage and loss registered. It has not been easy to specify times and location of specific pyroclasts nor know for sure the number that traversed the Las Lajas ravine that day. However, it is known that previous flows the same day filled the ravine and caused later flows to overflow their course, affecting areas outside the immediate area of influence of the ravine, including San Miguel Los Lotes, where maximum levels of destruction and death were experienced (Image 3).

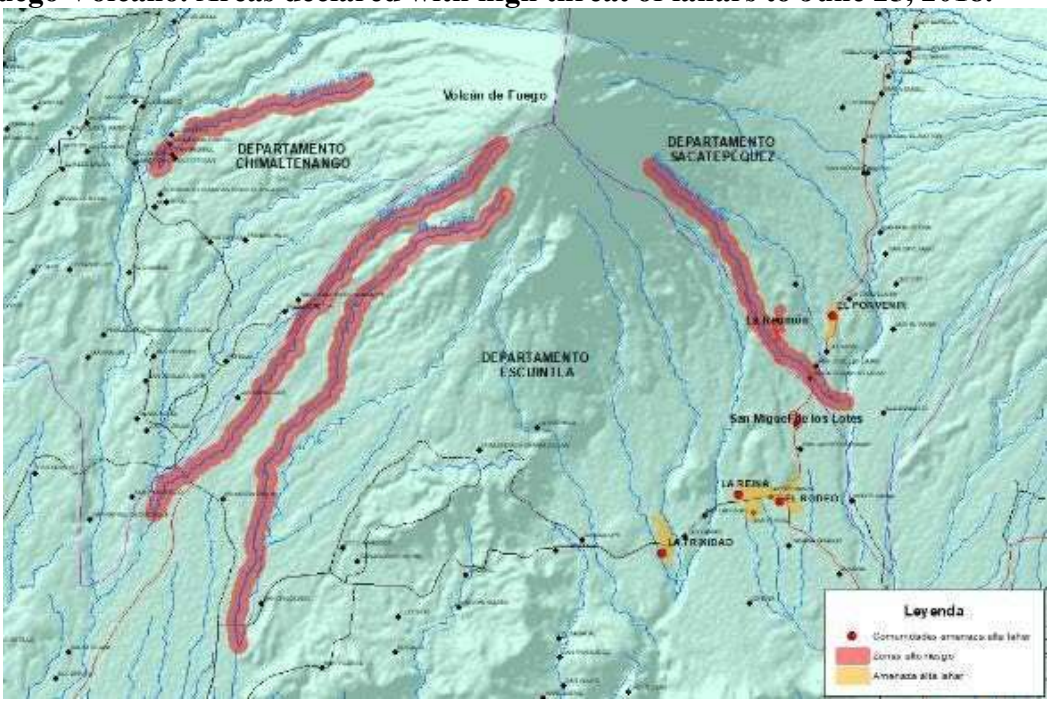
Image 3. Trail of the pyroclastic flow of Fuego volcano on June 3, 2018.

Source: CONRED (2018).

On June 25, 2018, the Scientific Council of the National Coordinator for Disaster Reduction (CONRED) issued an ex post declaration in which the Las Lajas, Seca, Taniluyá and Cenizas canyons were classified as high risk. In addition, San Miguel Los Lotes, municipality of Escuintla, department of Escuintla; and Finca La Reunión, municipality of

Alotenango, department of Sacatepéquez were declared high risk and uninhabitable. It also established that those communities facing high hazard levels due to potential descent of lahars were La Trinidad, La Reina and El Rodeo, in Escuintla Department; and the village El Porvenir, in the Department of Sacatepéquez. There is no precise official information available in the short term on whether these places had already been declared high risk based on existing hazard maps, prior to June 3.

Map 3. Fuego Volcano. Areas declared with high threat of lahars to June 25, 2018.



Source: CONRED (2018).

3.2. The impacts of the eruption: damage and loss

The impact of the volcanic events has been exhaustively summarized and analyzed in the DaLA (damage and loss assessment) report, prepared by the World Bank, ECLAC and UNDP, in collaboration with other national and international organizations, and published at the beginning of August 2018. For basic data on human impacts and infrastructure, the official CONRED website publishes a newsletter with monthly updates. From both sources it is clear that the most important direct impacts on people and infrastructure occurred in the Department of Escuintla, and to a much lesser degree in Sacatepéquez, and was concentrated around the settlements of San Miguel Los Lotes, el Rodeo and the Golf Club- Hotel La Reunion.

Up to September 23, 2018, when the research for this document was concluded, the SE-CONRED announced 178 dead and 250 missing during the eruption. Of these, 172 and 243 respectively were in Escuintla, particularly in San Miguel Los Lotes. Besides Los Lotes and

the Hotel La Reunion which suffered extensive damage to buildings, infrastructure and land other affected communities included San José Las Lajas, El Rodeo, La Reina, San Jacinto Miramar El Porvenir, La Union, Ceylon, El Zapotillo, Guadalupe, Las Lagunas, La Trinidad, Santa Rosa, Las Cañas and La Rochela. Nearly half of the population in these communities are internal migrants, from other departments and displaced for economic reasons or political violence.

The evacuated population totaled 12,823 people with 10,823 from Escuintla. Evacuations were carried out in 19 communities of six municipalities. Twelve shelters were installed, eleven in Escuintla and one in Sacatepéquez, which, at the end of September housed 3,200 people, 2,640 in Escuintla. The affected infrastructure was also recorded in Escuintla: destroyed homes, 186; at risk, 750; destroyed bridges, 2; the destroyed educational and health facilities were all in San Miguel Los Lotes.

These impacts are by far the most significant in recent times. Only in an event of 1963 was any significant number of deaths (7) recorded due to a secondary lahar. In a 2012 event, the evacuation of 33,000 people was planned, with 10,000 finally evacuated from 17 communities (mostly the same as those affected by the June 3 event). Furthermore, by 2018, the total number of communities that are between four and ten kilometers from the crater is thirty-seven.

The DaLA report concluded that:

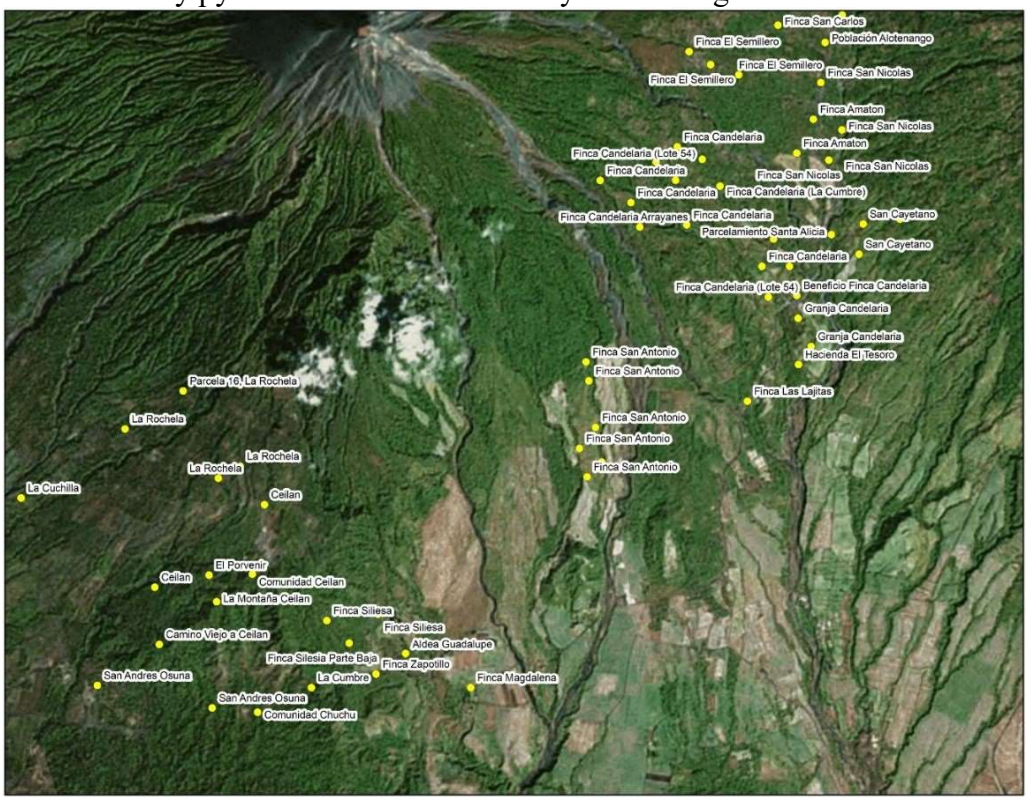
"The total economic losses associated with the June 3 eruption of Fuego were Q1,635 million quetzales (219 million dollars at August 22, 2018 exchange rate). The direct damage (what was lost at the time of the events) represented 56.6% of total cost; opportunities sacrificed due to the immediate impacts accounted for 28.6%; and the additional costs (to attend the emergency) were 14.7%. Note that the private sector suffered 88.1% of total affectation. Additional cost was the only dimension in which the public sector exceeded the private sector. In general, the productive sector was the most affected, registering 63.2 percent of total effects, due to damage and loss in the agriculture and tourism subsectors.

The damage to the agriculture sub-sector was associated with damage to the soil for coffee production and coffee trees. The damage in these subsectors was strictly to the private sector. The second most affected sector was the social sector, 23.9 percent, corresponding two thirds of this to the private sector. The affectation in the social sector was associated with housing that represented 98 percent of total damage. The affectation in Infrastructure represented 6.2 percent of the total. The transportation subsector accounted for 68.5 percent of this amount, mainly associated with damage and removal of debris from National Route 14. "

The Ministry of Agriculture, Livestock and Food (MAGA), through its Activity Report of the Directorate of Animal Health VISAR-MAGA (no date), reported 39,614 animals

receiving attention-28,473 birds, 5,284 canines, 1,726 pigs and 990 cattle[6]. In the agricultural sector, 2,923 users were attended and reported affectation of 4780 ha of coffee, 1524 ha of sugarcane, and 708 of rubber, in addition to small amounts of avocado, orange and basic grains. The area of affectation to surrounding communities and their productive capacities by pyroclasts and ash can be seen in Map 4.

Map 4. Areas affected by pyroclastic fall in the vicinity of the Fuego volcano.



Source: CONRED (2018).

Given the nature of our inquiry, it is not our intention nor is there time and space to analyze in further detail the impacts and effects. Rather, we search to identify the most critical points in terms of the explanation of affectation and the process of response to the threat.
Based on this, a cause-effect analysis is provided in the following sections insofar as the data, secondary and primary, allow.

[6] Toledo pork producer reported 3,000 units lost on the day of the eruption, and 500 more over the following days due to problems with food and water access.

4. TOWARDS AN UNDERSTANDING OF CAUSATION: POSITED SCENARIOS AND CRITICAL POINTS OF INQUIRY IN ORDER TO UNDERSTAND THE DISASTER, ITS IMPACTS AND THE SOCIAL RESPONSES.

As often happens, what is described as a single "disaster" has particular, and consequently different, manifestations depending on the location or features of the affected population and their livelihoods. In the present case, the greatest direct impact was concentrated in and around the towns of San Miguel Los Lotes and the La Reunion hotel-golf club as well as on the nearby Las Lajas bridge on RN-14.

Limiting analysis to these areas would be an error for several reasons. This includes the fact that by doing this these cases could be seen to be sui generis, special or anomalous, where the impacts were conditioned by fortuitous circumstances of location and atypical behavior of the volcano or by aberrant social responses determined by the circumstances of the affected population and the authorities. (there is, in fact, evidence of attitudes and differentiated structural social responses among the populations according to their location with respect to the volcano (see Gates, 2007, and Escobar, 2012)). However, it may be suggested that in general many high-risk scenarios exist around the volcano and that what happened in this one place in 2018 could be repeated elsewhere on another occasion under a similar or different activity pattern of the volcano.

The history of the volcano and its direct and indirect hazards is sufficiently documented to show important differences between the impacts of different VEI 4 events between 1524 and 2018. What in this event was disaster for San Miguel Los Lotes could easily be disaster for almost any other community around the volcano at some point in the future. Instead of seeing these as one-off cases, we propose to analyze them as examples that illustrate more generic problems and/or opportunities found in communities around the volcano. The main concerns that derive from the events of the June 3, 2018 eruption, their contexts and impacts, and the patterns of social risk construction found in the area, include:

a. **The process of occupation of territory in general and its changes, particularly since the eruption of 1974**. The movements of population into and out of the area after 1974 (the date of the last major VEI 4 eruption before the June 3, 2018 event) are of interest due to the possible effects of said eruption on the population's subsequent awareness and response. The event of 1974 was succeeded by a relatively long period of little or no activity (until the commencement of a new phase of activity starting between 1999 and 2002 and continuing today), which may have generated greater feelings and perceptions of security in established and new populations. Of analytical interest is the existence or lack of land use plans using hazard information and analysis generated post 1974, and the existence or not, and implementation of local norms and controls which take account of information on volcanic hazard and risk. In particular, understanding the origins and development

of San Miguel Los Lotes since its foundation in 1964 is important, accompanied by an analysis of the location of the Toledo pork company, proximate to San Miguel Los Lotes, but in a higher and safer location and the La Reunion hotel resort. The detailed study of these locations would of course be justified by the damage associated with the last event. But, as commented above, it must also be considered illustrative of other possible unforeseen circumstances in the future due to the uncertainty of potential volcanic activity and its impacts. Finally, the influence of national route 14 (RN 14) in the process of occupation or articulation of territory is of interest in understanding risk construction in the area[7].

b. **The pyroclastic flow in Las Lajas Canyon that affected San Miguel Los Lotes and La Reunión**. Here it is interesting to note that the seven deaths recorded in an eruption of the volcano in 1963, the only major number recorded in reports of eruptions in the last century, also resulted from a diverted flow from its main path. Part of the explanation of the tragedy of June 3 can be found in the direction of the flow or surge. However, what could be interpreted as abnormal or anomalous is probably a reflection of the dynamic behavior of a volcano in constant change and with hazards that vary over time, especially with reference to lahars and pyroclasts and their natural routes of channeling and displacement. In the case of San Miguel Los Lotes, there is evidence of pyroclastic flows in the past that were not considered in zoning tools or location although they were recorded in geological deposits.

c. **The differentiated response in terms of early warning and evacuation between San Miguel Los Lotes and La Reunion Hotel**. This must be considered in detail for the lessons it offers to improve response mechanisms in the future. While the hotel was evacuated between 11:30 and 14:45 without incident, there were few anticipated evacuation processes from San Miguel Los Lotes, located a short distance from the hotel and also under the influence of Las Lajas ravine. It is also important to research if there was an early evacuation from Toledo, located close to San Miguel Los Lotes, but in a relatively higher location. On a more generic level, the rationality and evacuation process of people in other villages that were not directly affected except by ash and tephra, should be researched. This could include a comparison of the 2012 evacuations, which were similar by location to those of 2018, although the event was less intense. How are the anticipated evacuations of those communities, where little happened, and the lack of an evacuation in San Miguel to be explained? The influence of historical, economic, social, cultural and

[7] In general terms, transport networks act as territorial dynamization elements. One of the concrete effects of this dynamization has to do with increases in the occupation of the territory for housing or productive purposes. Although the planning institutions seek to establish mechanisms for controlling and organizing the effects derived from this type of infrastructure, many of the occupation processes are beyond the scope and control of land-use planning tools. They are in the very dynamic of "development" according to established if not always explicit goals

political considerations at the time of the event must be analyzed, as well as its impact on the decisions taken, or not taken.

d. **Previous knowledge of the volcano, its behavior and the monitoring performed**. Changes and signals must be the object of research. Beyond scientific analysis, monitoring and knowledge about hazard, it is also essential to understand the ways in which knowledge of the hazard was part of the daily understanding of people living in the area and business managers of private sector interests. Also, to what degree was the volcanic threat part of the school curriculum of students in the area? At the same time, it is fundamental to understand the rationalities and actions taken autonomously by the population of the area, both families and individuals. And the role played in the tragedy by such factors as the normalization and minimization of the importance of the explosive behavior of the volcano, religious beliefs, family solidarity and compliance with the wishes and interpretations of the elder members of the family and community. In short, a synthesis between an understanding of the institutional approach and the influence of cultural and daily living features of the exposed populations.

e. **The process of communication of information and analysis**. This includes between INSIVUMEH and the SE-CONRED, as well as local authorities, leaders and population. How attitudes and levels of trust or distrust between residents and INSIVUMEH and SE-CONRED could vary by zones and characteristics of the population should also be investigated. What was the role and the result of the recent drills (such as those of FAHUM or those of La Réunion) in the light of the early warning and evacuation of communities on June 3, 2018?

5. INQUIRY INTO THE OCCUPATION OF THE TERRITORY, KNOWLEDGE OF THE VOLCANO, AND COMMUNICATION ON RISK, ALERT AND EVACUATION: AN INDICATIVE ESSAY IN FORENSIC ANALYSIS.

During the first years of the 1970s, Kates, Burton and Whyte (see Burton, Kates and White, 1993) postulated the notion of a continuum of resource-hazard locations in different areas of our planet. Many places provide natural resources or locational attributes that make them very attractive for settlement and economic production, but also areas of high threat due to the irregular, temporally spaced incidence of potentially dangerous natural events. Floodplains, coasts, the shores of lakes, areas crossed by tectonic faults and the slopes of volcanoes have these characteristics. Such areas currently attract increasing amounts of population and productive activities (ISDR-GAR, 2015).

In these places there will always be economic exploitation and consequently, human usage for purposes of housing, services, transportation systems or employment. People with limited resources will be the most likely locate in potentially dangerous places. The principle that production and services can be lost and recovered in and after a disaster, but not human life, is often contradicted in such areas, where unnecessary loss of life is suffered.

The essence of disaster risk management in such circumstances is to anticipate and control human occupation of the most dangerous areas that carry with them unacceptable levels of risk. This is done through plans and land use and territorial occupation norms, in general. Actions such as the resettlement of populations or productive activities seek to mitigate or eliminate existing risks while early warning systems allow risk mitigation in areas already occupied that exceed acceptable safety thresholds.

From the prospective of corrective and reactive types of management, the best possible scientific knowledge about the social processes that condition physical hazards is required: form, recurrence and spatial incidence need to be analyzed and systematized. For this, it is essential to have permanent monitoring, as well as an efficient and protocolized system that guarantees understanding among the different social actors. It is equally important to generate a full understanding of the exposure and vulnerability factors that could interfere with such processes, and their conversion into consequential actions.

Regarding the responses of actors to different facets of a crisis related to a particular threat and the final realization of a disaster situation, it is fundamental that such crisis conditions and their effects are recognized as the continuity and result of processes that condition the daily life of the territory in question, and not as a rupture of the normal routine conditions of existence of the affected population. For this reason, the weight of the history of the country and its regions and localities, the conditions of poverty or well-being that prevail, formal educational levels, the type and nature of predominant economic activities, knowledge of the surroundings, religious beliefs, and the levels of social capital and grassroots social organizations will be projected and reflected in preventive, mitigative and particularly reactive social responses.

As social constructions, the impacts of physical events are structurally and historically conditioned within their changing natural environment, and it would be an oversimplification to consider them as just momentary eventualities, in which the physical event is considered to determine the ultimate outcome and the impact suffered. In general, the lack of adequate social response from both the population and the authorities to the events that began at 6:00am on June 3 with the first manifestation of the eruption and its report in the first INSIVUMEH bulletin of the day, reflect part of these structural and historically constructed deficiencies. The risk was a social construction that in its particularities can be traced and known through applied interdisciplinary research.

At the same time, through contrasting cases of effective and ineffective response that occurred that day, we can illuminate the way in which history and structure, society and culture influence the levels of damage and loss recorded. It is in this historical process, in an examination of the ways in which different groups and sectors of society constructed the risk in which they lived, that we can understand what happened on June 3. It is also through the forensic lens that it is possible to clarify, expand and rectify several of the often poorly founded rumors or interpretations of loss and damage that circulated after the event. This includes some press analysis in countries like Mexico and Spain that sought to explain the more serious impacts on the poorer population, deprived of resources or assets, as compared to the more affluent population, resident or passing through the area on the day of the event, as if it had been an act of omission or deliberate indifference, as opposed to the playing out of a given historical condition in which wealth and poverty play a role but not as a deliberate omission or forgetfulness on the day of the event.

Without saying that the position of class or welfare of the potentially affected groups did not play a role in terms of reactions and impacts, it is more important to learn from the responses that in some way favored the more economically well of population as opposed to using the debate to raise invalid arguments about preferences and discriminations on the day of the event that are not demonstrable with concrete evidence. The discriminations and vulnerabilities existed before and were revealed the day of the event when two very different series of circumstances operated with disastrous consequences for certain populations and of lesser impact for others.

The above delimited context is reflected in the impacts and reactions of the two different, but physically close and functionally related "communities": San Miguel Los Lotes and La Reunion Hotel and Golf Club, both seriously affected by the pyroclastic surges, with widescale material losses in buildings, infrastructure and land, but, nevertheless, with very different affectations in terms of human losses and later recovery and reconstruction conditions. In both cases, lessons can also be drawn that contribute to generating more constructive thinking regarding prospective risk management and the analysis can also serve to illustrate factors that, under future eruptive circumstances of such an open-system volcano with no clear precursors of an imminent severe eruption, would have affected other communities around the volcano. A "dangerous" volcano with no history of previous large-scale human loss, but which, with each different major eruption, (about 60 eruptions of 4

VEI between 1524 and 2018) affected different areas with different effects. Certain areas have been affected more than once, with evidence of this in the conformation of their soils and local geology influenced by the impact of pyroclastic flows, lahars, lava and ashes and tephra (consider, for example, the eruptions of 1542, 1717, 1932, 1963, 1974, 2012 to identify differentiated effects with each eruptive event of level 3 or 4 VEI).

5.1. Where does the history of the social construction of risk begin? In the process of settlement and land use around the volcano.

General considerations.

Without the location of production, population or infrastructure in the area subject to a direct possible impact of a volcano, there can be no large-scale volcanic risk. However, the Fuego volcano, together with all the active volcanoes of Guatemala and Central America, in different degrees, have important numbers of inhabitants and communities, levels of economic use of the land resources and the existence of support infrastructure and transport systems between different regions located around them.

The settlement of territories around volcanoes is dynamic and responds to the same logic as the occupation of flood plains (rivers, lakes, sea) which have benefits and risks in terms of natural resources. Population movements to and from these types of zones may vary according to the economic and employment opportunities that arise.

There are cases around Fuego volcano of the search for and occupation of land by populations that varies between those with economic resources to invest in large scale agriculture and agro-industries through to those that exist in conditions of poverty and destitution. The latter include those expelled previously from Guatemala by internal wars and then resettled in areas of opportunity around the volcano once peace accords were signed. The repatriation led to the settlement of several villages including La Rochela, 28 years ago, and La Trinidad shortly thereafter, for which the government donated land.

Other cases cover landless population that was not displaced by the war but had access to land after the signing of those agreements. This was promoted as a solution to existing land conflicts and scarcity and many bought a farm with the advice and financial assistance of FONTIERRA, a government organization set up with such aims. According to interviewees in La Reina, they were landless peasants from different departments of the country who saw an opportunity to access the land after the armed conflict and bought the land with the financial assistance of FONTIERRA. La Reina is officially called an ECA Agricultural Peasant Enterprise.

Another differentiated case of land occupation is through land subdivisions within private farms as a compensation for longstanding service by the settlers to the owners. (Case of El Porvenir).

The process of settlement of the repatriated or migrant population in the foothills of the volcano is to be told in more detail with new research. At present, there are anecdotal and unsubstantiated stories of settlement ignoring the existing hazard conditions and the proximity to the volcano and even of decisions to accept and purchase land taken on cloudy days without sight or knowledge of the volcano itself.

In the case of the Fuego volcano and its surroundings (along with the nearby volcanoes of Acatenango and Agua) there is a long history of settlement and relocation recorded since colonial times. The establishment of the second capital of the new colony in 1525 and its relocation due to the mud flows of the Agua volcano in 1542 was followed centuries later with the impact of eruptions of Fuego in 1717 followed by an earthquake and mud flows (a case of concatenated threats described and analyzed by Hutchison et al, 2016) affecting several communities and leading to demands for another relocation of the capital.
Hutchison's analysis shows how the collective memory of 1542 and the fear of a repetition of such events was followed by a demand for relocation, which in turn led to an investigation by the authorities to discover the true dimensions of what had happened. Fear of the loss of the city's natural drainage system due to a blocking of the river was one of the main causes of concern. No relocation took place at that time but did so later on in the 18th century.

Key informants noted that the events of 1974, the last VEI 4 eruption, led to much emigration from the zone. At the same time, the expansion of coffee, sugarcane and other agricultural products attracted labor to the area. As in many places of agricultural production in hazard prone areas, such as banana growing areas subject to hurricanes and tropical storms in Honduras or Nicaragua, the risk to production is offset by high productivity in periods of calm and by the existence of agricultural insurance. However, this is not usually the case for the population that serves as a labor force for that production where many times the location and quality of housing is very risky and deficient. In other parts of Central America it has been the expansion of industry that attracted residents, subsequently living in conditions of permanent hazard, such as in the case of Choloma in Honduras. Volcanoes, as are lakes and oceans, serve as great tourist attractions: Arenal in Costa Rica, Fuego and Agua in Guatemala, Masaya and Momotombo in Nicaragua; and Cotopaxi and Tungurahua in Ecuador, for example.

The slopes of volcanos and adjacent areas, with their productive agricultural booms, attract residents which, when experiencing conditions for employment and settlement, then establish themselves permanently. Despite the obvious risk involved around active volcanos, a sense of security is inculcated as regards a large part of the territory which has not been affected in recent times. It is with the direct impact of an event that the process is interrupted, and the population abandon their homes and lands, by their own volition or being forced to do so. This is a classic case of successive, calibrated adaptation.

On the flanks of Fuego there are more than 37 communities, towns or settlements populated by some estimated 100,000 people.

The community closest to the active cone is just 4 kilometers away, La Rochela. La Reunion and San Miguel Los Lotes, El Rodeo and La Reina are 7 kilometers away (see Annex 2 for some succinct information about the settlement process of the more affected villages around the volcano). The location and growth of these population centers was enhanced by the opportunity for agricultural and recreational exploitation of the land, without, as is the case with many other volcanoes in other parts of the world, buffer zones or national parks that inhibit occupation in clearly dangerous areas. There was no controlled and normed settlement in accord with agricultural or urban plans or with the use of volcanic hazard maps prepared by institutions such as the USGS. Such considerations were tempered in their effects by the simple interpretation or accumulated experience of the population, which interpreted the noises and rumblings of the volcano and other manifestations of low intensity activity as "normal" with low potential impact on the economy and population. The volcano was an attraction, not a distraction or latent danger. Sitting out at night watching the volcano in flames or with lava extrusion was a family pastime and all part of living with the volcano.

Prior to June 3 the danger, according to general local and even scientific perception, was considered greater on the west and southwest flanks than on the southeast flank, where the event finally had the greatest impacts (until midday the most important impact of the eruptions was in fact on the southwest flank). This was guided by historical experience with the volcano. The location of the two INSIVUMEH volcanic observatories on the SW flank, in addition to the more persistent experience of pyroclastic flows and lahars there confirmed that perception. But, the day of the eruption it was a private, non-governmental or formal observer from Hotel La Réunion and her staff who first recognized important changes in the volcano that led them to the early evacuation of the hotel and condominium site (see later for more details).

The villages around the volcano provided sources of employment for workers and their relatives on local, larger scale farms, in animal husbandry and recreational facilities. The location of their housing stock is explained primarily for that reason. Many residents, originally transient population renting houses to work in agriculture, ended with the passage of time buying lots and building their own homes, often with government assistance. As owners, their attachment to the land and the area increased with time, regardless of the potential level of danger. The location of schools, clinics, and other social and economic infrastructure followed the population.

The transport system and roads-RN 14 in particular-served as an attraction to the area, with the location of towns and villages nearby. The RN 14 is an important connecting route between the coast and the high plateau, used among other things to rapidly access cruise ship tourists arriving from the coast and headed to Antigua and surrounding indigenous communities. Bridges cross the ravines that come down from the volcano and in which an important number of lahars and pyroclasts surge.

The generic processes described above find, in the cases of San Miguel Los Lotes and La Reunión, illustrative forms of expression.

San Miguel Los Lotes

San Miguel Los Lotes was founded in 1964 with the forced sale of agricultural land due to the debt of its owner. Fourteen founders established the community, all agricultural workers in the area. Adjacent to National Route 14, the town grew steadily between 1964 and the mid-1990s when, like many towns around the volcano, it began to grow more rapidly following the end of the internal war and the repatriation of Guatemalan migrants from abroad, and a renewed confidence in rural areas as places to live. It was a community located and constructed on near to 220 land plots of 80 by 15 square meters, on which an unknown number of houses and families built and lived. The total population of the town is not known accurately.

San Miguel was exposed that day to the impacts of a large pyroclast due to its "deviation", surge from the normal route of pyroclasts and lahars down the Lajas Canyon. The village had no prior experience over its previous fifty years of pyroclasts. Was this then a true anomaly or an effect that could have been expected at some point given known behavior of volcanos and their hazards?

Located in a depression formed by a former quarry, Las Lajas Canyon, down which the pyroclast and lahars flowed, is located to the north a few hundred meters from San Miguel Los Lotes. But that day the pyroclast overflowed the canyon and deviated in part from its straight course surging directly south over San Miguel Los Lotes. The pig farm Toledo was also affected directly, but to a much lesser extent because it had a higher location behind a forest barrier. The Lajas bridge was destroyed at very near to the same time as San Miguel Los Lotes, as was a good part of the hotel and club house complex of La Reunion.

Explanations for the deviation of the pyroclast have posited three elements: the prior accumulation of volcanic detritus due to earlier pyroclasts that day in the ravine that caused part of the last pyroclast to be diverted. Second, the Las Lajas bridge downstream operated as a brake on the flow of part of the material. And, third, an elbow in the ravine immediately above San Miguel Los Lotes affected flow and directionality.

It is clear in retrospect that the exposure of San Miguel Los Lotes to surges emanating from Las Lajas canyon has always been present. Geological deposits show this historically. That this was not known or considered by the population is something else and illustrates the need for permanent education on the changing and dynamic nature of the environment and the threats it presents or could present. Most people interviewed in the communities talk of “the lava” and obviously did not distinguish the differences with pyroclastic materials, lahars, etc. This is significant as lava travels slowly while pyroclasts and lahars travel very rapidly.

Near to a hundred of the up to 200 employees of the nearby La Reunion Hotel and Golf Resort, were from San Miguel Los Lotes, according to information provided by the hotel administrator. Three of these, together with 17 of their relatives, died, a relatively low number if you think about the total number of workers at the hotel and the high number of deaths in San Miguel Los Lotes- more than 400 hundred. Further research on this fact is warranted as a greater understanding of the way and extent to which prior training at La Reunión may have influenced the evacuation practices of that working population the day of the event would provide important information for the future.

La Reunión Hotel and Golf Resort

La Reunion started full operations in 2011. The construction process was carried out between 2008, when the 800 plus manzanas of land was bought, and 2011. By 2018 it had a clubhouse near the hotel with its luxury suites and a prime view of the nearby Agua volcano. There was also a large separate area of 43 condominiums. An 18-hole golf course with privileged views of the Fuego volcano was located next to the Las Lajas ravine where the pyroclast surged destroying 30% of the total area of the Resort, including the hotel, the golf course and the clubhouse. The rest of the land including the condominiums was not touched directly and is expected with renewed occupancy permits to be redeveloped, including the idea of a plan for an ecological park, which was proposed before the June 3 event.

The land was purchased from a large coffee farmer in the area who sold at an attractive price and later bought a larger and more productive coffee farm at La Candelaria (here there are discrepancies in the data that should be clarified). Many of the workers at La Reunion had previously worked on that farm in coffee. Before the purchase there were attempts to buy other contiguous land off small owners, endowed with the land as part of the peace process but who wanted to get rid of their land to migrate to the city. The problem with land titles dissuaded the investors in La Reunion from continuing with the purchases.

The central objective of the investors, the Roesch family, with the purchase and development of the land was the promotion of golf in Guatemala and for which hotel and club house, the golf course and, later, independently owned condominiums, were developed. More than 50 million dollars were invested. One of the basic ideas of the investment was the development of the community, the creation of non-agricultural local employment sources, and the development of skills, education and health opportunities for the local population. Recognition of the existence of resettled expelled population was present in this decision.

The selection of the land was dictated by the beauty of the view of the volcano and the conformation of the terrain and its attraction for golfers. International golf tournaments were often held at the site. La Reunión also obtained insurance coverage with Mapfre of Spain against damages and losses. The hazard maps of the area developed by the USGS and others were not considered or known when selecting the site, although, according to the

administrator, an environmental impact analysis was conducted where the recurrence of major eruptions was indicated every 80-100 years. This was considered a sufficient margin to continue with the investment.

With the development of facilities and infrastructure at La Reunión, despite the existence of sufficient land in areas further away from the La Lajas ravine for the purpose of golf course development, the views of the volcanos and even proximity to the canyon were major location attractions for the hotel, clubhouse and course. As has been mentioned, the condominiums and their extensive lands of beautiful gardens were not touched by the event of June 3 given their distance from the ravine. The resource represented by the volcano determined the location of the components of the development with preference for hotel and golf course location in view of the volcano and condominiums in areas with less direct visibility.

Summary

The location of towns around the volcano followed the logic of proximity to work in the cultivation of coffee and sugar cane, fruit trees, legumes and others. The settlement of the area was also inspired by a confidence in the safety of the volcano from serious eruption and the opportunities found in it as a resource. The boom in production was from the 70s onwards when for more than 20 years the volcano had one of its quiet periods and little activity, creating an aura of confidence in investment. In between was a period of boom in the resettlement of the countryside, after the end of the internal war and the signing of peace agreements in Central America.

No control or planning existed, no consideration of hazard maps. Investments in transportation infrastructure, in schools and clinics inspired settlement even more. In the case of private investment some consideration of risk is taken, but the economic calculation of profit in the medium term combined with optimistic estimates regarding the level of risk associated with the volcano led to a decision to take the risk.

Once settled, the population, some with a long history of living in the area, configured perceptions, attitudes, ways to rationalize their existence in an area clearly under the dangerous influence of a volcano. The volcano erupted regularly, but at the same time irregularly and low scale, and during the last 50 years there was no major experience of disruptions or major impacts. In addition, it had a period between the mid-70s and the end of the century almost without activity. This can be compared to the more recent period, between 2015 and the present, in which the number of eruptions and their levels increased without large impacts on the population. In these recent years there had been around 15 eruptions annually. Only in 2012 was an early warning issued and significant evacuation of villages implemented in the southwestern and western segments. And that on a sunny summer day with the volcano easily visible, a situation that was not repeated on June 3 when clouds and rain hid the cone for much of the time. Even the increase in eruptive activity from 2015 onwards had no impact on perceptions and precaution given that the

rumblings just became more frequent but at the same time nothing serious happened. These changes were normalized in the population in favour of feelings of security, not precaution.

Levels of schooling, levels and sources of income, degrees of religiosity and belief in a protective God (there were 4 different evangelical churches and a Catholic church in Los Lotes), the degrees of identification with the land and the different senses of pertinence and mooring to place among others, all influenced the way in which collectivities, settlers, families and others reacted in different villages on June 3. Once the exposure to the threat is established, the future, in terms of impacts, is based on the vulnerability factors existing among a population of very varied characteristics, origins, levels of permanence, levels of access to information, etc.

Among the factors related to information, knowledge, understanding of hazard and risk, the forms of generation, coverage, access to and understanding of the scientific information available about the volcano and its eruptive process are extremely significant. This includes the process of monitoring the changes suffered in the volcanos dynamic and in the identification of possible precursors of a major eruption and its antecedents. These constitute the topics of the next section.

5.2. What was scientifically known about the volcano and its dynamics, what opportunities did the scientists have to employ their knowledge and what was the monitoring and forecasting process during the days and hours before the eruptions of June 3?

The elements that come into play in explaining failures and lack of process must be studied and documented in greater detail, but the following concerns seemed to be present in different degrees and offered the hypothetical basis of the inquiry made through our research.

On the part of the Guatemalan State, the study and monitoring of the Fuego volcano and other active volcanos of the country (Pacaya, Santa María, etc.) is the responsibility of INSIVUMEH, the institution also in charge of the study and monitoring of other physical processes and potential hazards. It is functionally and budget-wise linked to the Ministry of Communications, Infrastructure and Housing. The Guatemalan universities do not currently offer degrees in volcanology or promote significant research on the subject. This is one of those "anomalies" that is hard to understood in a country of volcanoes, just as it has been difficult to understand why there has never been a geography degree in the country's universities, when geography is almost determinant of everything that happens with development in the country.

An early warning about the probability of a dangerous volcanic eruption signifying unacceptable levels of risk to the population is based on the scientific knowledge available on the volcano, its processes, as well as dynamic, eruptive signals and much less noticeable precursors.

National capacity in Guatemala is very low due to problems related to funding, which limits resources for personnel and instruments, limits renewable contracts for periods of as little as three months, and leads to a high rotation of scientists and low analytical capacities. At the time of the June eruption, there was only one scientist for each of the four volcanoes considered most dangerous. Five years ago, only one volcanologist existed in INSIVUMEH for all volcanoes. All this signifies a high level of dependency on external scientific sources in order to understand, analyze and track volcanic activity.

The above is combined with a low relative level of system based monitoring of the Fuego volcano and other volcanoes considered dangerous in the country (4 have monitoring to some degree, but the other 3 that are considered dangerous do not have any monitoring). Two seismometers, combined with a thermal camera (installed by the University of Bristol and destroyed the day of the last eruption), and two visual observatories on the western flank of the colossus constituted the coverage at the time of the June 3, 2018 event.

The ability to recognize and interpret the messages received from such monitoring and how to distinguish clear signs of greater activity and hazard was admittedly low. The ability to speak with certainty or confidence and issue scientifically based alerts and early warning, recognizing changes in behavior and clear predecessors, has not existed. The general, irregular historical behavior of the volcano with an almost permanent low level of activity combined with shorter periods of greater activity has not helped in this regard.

The day of the event and the previous night there was no capacity to receive signals in real time due to failures in the instruments and communications system in INSIVUMEH. Notices of possible precursors collected by observers on the flanks of the volcano could not be transmitted to the scientists because they were resting that Sunday.

The low autonomous capacity of INSIVUMEH forced its scientists to work under suboptimal conditions, but with high levels of performance and commitment within those limitations, according to observations from international and national experts. This lack of capacity has been complemented with collaboration over the last 4 decades by international institutions dedicated to research, monitoring, instrumental development, training and financing.

The work of the USGS since the 1970s in collaboration with INSIVUMEH, and its contribution to the production of knowledge about the volcano's process and the hazards it presents is of recognized high quality. The hazard maps produced in 1981 and 2002 by Rose and Vallance et. al., are state of the art. They identified many of the high-hazard areas existing today. However, these maps were little known amongst local scientists and practitioners, even new scientists at INSIVUMEH, were rarely used and mostly ignored in more recent hazard studies. The absence of a budget for duplication and distribution of maps has been adduced as an explanation for this apparent anomaly.

Subsequently, much assistance, training, instrumentation and research has been carried out through other international institutions. Important among these are Michigan Tech in the United States and the University of Bristol in the United Kingdom. Important contributions have also been made by the Universities of Edinburgh, Liverpool, Puerto Rico, among others, and collaboration has been forthcoming from Latin America, particularly from Ecuador, Mexico and Central America. Since the June 3 event, the volcano's monitoring capacity has increased enormously as a result of international donations and loans. At the same time the INSIVUMEH budget has been increased more than 70% since the event and promises to go higher in the future. Probably a case of too little too late but certainly a step in the right direction that once more reveals the tragic circumstance that signify that many times only with disaster is there a reaction and response from government and other important social actors. It was commented by a scientist at INSIVUMEH that on a visit by a Guatemalan President to the institution some years ago when asked why he did not invest more in the institution and its equipment, the reply was simply, “that is not good politics, how do we see results from such an investment?”

Even accepting the inherent difficulties of understanding and processing information on open volcanic systems like Fuego and the difficulties of placing land deformation equipment due to the characteristics of the terrain, an analysis is severely needed of the ways in which priorities for research, instrumentation, monitoring systems, etc., supported by international collaborators, were determined and how they adjusted (or failed to adjust) to real needs over time.

For the external observer recognizing the magnitude of collaborations of international organizations for the science of hazard in the Central American region during the last decades, it is difficult to understand the severe deficits that have historically existed and existed the day of the eruption. Compared to Guatemala, important advances have been made in El Salvador, Nicaragua and Costa Rica. How is it possible to explain such a serious deficit in a country subject to large scale volcanic risk in densely populated and productive areas?

On the day of the eruption, INSIVUMEH issued 6 bulletins, the first one at 6:00 AM and the last one close to 11:00 PM with the cessation of activity, 16 hours 50 minutes after the first eruption. The bulletins were explicit as far as registered activity and its increase goes, and cautious in terms of recommendations to authorities, ministries and tourism. Given the inadequate monitoring conditions existing at the time of the eruption and given the cloudy and rainy characteristics of the day, the bulletins were probably as accurate as could be expected. But it must be made explicit that much information circulating amongst other actors neither got to INSIVUMEH or arrived late.

Bulletin 27-18 of 6:00 AM warned of the beginning of the second eruption of the year and commented that pyroclastic flows should be alerted for and considered in "any canyon around the volcano". It recommended that CONRED implement the alert status it deems

necessary due to the current eruption, mainly in the area of Sangre de Cristo and San Pedro Yepocapa, both traditionally alerted to activity due to their closeness to both the cone and the INSIVUMEH observatories on the southwest flank .

Bulletin 28-18 of 10:00 AM warned about the possibility of pyroclastic flows in any of the ravines and warned about the permanence of people in or near them. It recommended CONRED to maintain alert status, again especially with reference to Sangre de Cristo and San Pedro Yepocapa, distant from La Réunion and San Miguel San Miguel Los Lotes.

Bulletin 29-18 of 1:40 PM announced "the eruption of Fuego, is the strongest recorded in recent years, generating strong pyroclastic flows in the Seco, Ceniza, Mineral, Taniluya, Las Lajas, Barranca Honda ravines "..." The eruption is in its maximum phase " .... "Due to this INSIVUMEH recommends SE-CONRED: to raise the state of alert it deems necessary due to the energy of the eruption and consider the evacuation of the people of Sangre de Cristo due to pyroclasts, as well as maintaining a monitoring on the south, southwest and southeast flanks."

Here, it is both interesting and relevant to indicate that this information issued at 1:40 PM referred to the strongest eruption which, according to information provided by international and national experts, occurred at approximately 12 noon. This was not directly known by INSIVUMEH, however, due to problems with its instruments and direct observation capabilities. Information about this phase of the eruption came from outside the country, using satellite images of the explosive column processed in the USA (Michigan Tech) and Japan.

Bulletin 30-18 at 1:55 PM repeated the very same information and recommendation as at 1:40 PM. This and the previous bulletin were the last two issued before the tragedy of San Miguel Los Lotes, La Reunión and Lajas bridge. Neither of them warned specifically about the danger for these places, the most affected areas. Monitoring was the only recommendation, although the volume and level of activity announced should have alerted the authorities about the risk to the communities.

Bulletin 31-18 of 4:50 PM said: the eruption of the Fuego volcano continues with the same energy levels, and **moderate** pyroclastic flows (our emphasis) in the Seco, Ceniza, Mineral, Taniluya, Las Lajas, and Barranca ravines. This eruption generates strong shaking with shock waves causing vibration in roofs and windows of houses 20 kilometers distant covering the entire volcanic complex. Lahars are reported in the Pantaleón, Mineral, and other rivers in this area, so it is recommended not to stay near or cross, because of the possibility of larger lahars that can easily overflow the channels. The communities of Sangre de Cristo, Fca. Palo Verde, Panimaché and others have been evacuated by CONRED to shelters. Due to the above, INSIVUMEH recommends that SE-CONRED continue with the alert status they consider necessary due to the energy of the eruption as well as maintaining monitoring on the south, southwest and southeast flanks.

This last bulletin refers to evacuations on the southwest flank, but makes no reference to the destruction of San Miguel Los Lotes, La Reunion and Las Lajas bridge between 12.55 and 3.20 pm. The best estimates possible using video information and times and information from interviewees is that the hotel complex was first affected in the upper golf course area-around 1pm. The Hotel and club house, San Miguel Los Lotes and the bridge were destroyed between 3.10 and 3.20pm.

For the southeast flank where all the destroyed infrastructure was located, monitoring was recommended as if nothing had happened. This was clearly due to the fact the information on these impacts had not been passed to INSUVUMEH and their limited or destroyed monitoring capacity, both physical and human, did not allow them to obtain the information independently of other sources. This represents a failure in information that circulated between organizations, in this case SE- CONRED and INSIVUMEH. The case of information generated at the La Reunión hotel on the increase of activity of the volcano around 11.30 will be dealt with in the next section on response and constitutes a further piece of evidence and information relevant for decision making processes and their improvement in the future.

5.3. Incorporation of the knowledge of the characteristics of the eruption on the decision-making process of diverse actors, and the result in terms of early warning and evacuation

The knowledge we have gained as to the way in which the social response, the alert and the communication process occurred in the face of the June 3, 2018 eruption is derived from four main sources.

First, local INSIVUMEH and SE-CONRED officials, and collaborators from outside Guatemala (Rudiger Escobar of Michigan Tech in particular). Second, volunteers and local formal members of CONRED, in addition to other people linked to the official institutions of the State. Third, private sector officials present or linked to economic activities in the area. And fourth, the population of the area, including survivors of the pyroclastic flows that impacted the area.

Despite a multiplicity of circumstances and conditions, the explanation of the tragedy and of the differentiated forms of response and reaction can be reduced to a limited number of central reasons, considering three types of actor: the population itself, the government and other response agencies and the private sector interests present..

In principle, the response of the population in hazard prone, high risk areas reflect their own ways of facing up to the problem based on life experience, education and training and conjunctural conditions. The role played by the state through emergency organizations in charge of communication, alert and evacuation processes will reflect the type and depth of training and organizational norms and protocols existing along with the role played by simulations and practice, understanding and knowledge of the volcano and its dynamic.

The responses of the two private enterprises present in or near to "zone zero" -La Reunion and Toledo reflect conjunctural conditions present the day of the event and their structural levels of consciousness, training, awareness and corporate social responsibility.

We will first deal with the essence of the successful response from the private sector in order to convey what it tells us about organization, responsibility and reaction.

The private sector response: La Reunión and Toledo.

The **Hotel La Reunion** since its commencement of operations in 2011 had always been concerned about the processes and protocols of early warning and evacuation in case of volcanic hazard. This reflects two primordial conditions. To start with, a consideration and discussion of the level of hazard and its possible manifestations from the moment the investment and construction process began and during its operation and the clear recognition of the potential danger of the volcano and the exposure of La Réunion to the hazards it poses. This was complemented by the interest that the national authorities of INSIVUMEH and SE-CONRED had in the hotel as a point for observation and placement of monitoring equipment on the southeast flank of the colossus, and universities Bristol in particular, in using the hotel as a base for observations and placement of a thermal camera. Finally, in the framework of a tourist activity in which third-party clients of the hotel-resort were under potential danger, together with up to 200 employees in high season, the existence of a clear notion of corporate social responsibility existed, which also implies, of course, protecting the name and reputation of the company.

The basic parameters described above were reflected in terms of ongoing training and preparatory processes, access to information and a capacity to process it. This all resulted in a highly anticipatory, precautionary and totally successful evacuation of more than 300 guests and employees on the day of the event. In addition to the importance of the process itself and the integration of different components to reach a decision, it is also important to highlight the importance of leadership and decision makers with criteria in times of potential danger This was the case of the manager and the leadership team at the hotel the day of the event, the role they played in the final decision to evacuate and the process that followed thereafter.

In the context of volcanic risk, the hotel established early coordination and alliances with SE-CONRED and the University of Alabama, who placed instrumentation on the volcano in coordination with INSIVUMEH. In 2011, SE-CONRED offered a one-week course on risk, together with the Guatemalan Social Security Institute. From that event, an Incident Command System (ICS) and an Emergency Control Centre (ECC) were internally created. This allowed a defined organizational structure that coordinated with the Municipality of Alotenango.

The ECC had an evacuation commission, with brigades tasked with specific functions. For example, the housekeeper was part of the Occupational Health and Safety committee. This organization did not respond to the normal institutional hierarchy, and it was expected that

even in times of emergency, a subordinate could be commissioned and give instructions to someone of higher rank. In the same way, regular drills were carried out, both day and night, every month.

All of the employees, from waitresses to head of security and administrator, were instructed in processes of resuscitation and fire control, among others; and they had communication mechanisms with each other, by radio and cell phone. The bulletins of INSIVUMEH were regularly received online, read and archived. Clearly, a systematization of the meaning of the visual and auditory signals of the volcano had been internalized and given meaning, even if it was not in writing.

Before the event on June 3, between 2001 and 2018, La Reunion had undertaken 8 previous evacuations of guests and workers, when faced with signs of non-normal activity of the volcano. All with a precautionary note and under conditions of uncertainty.

The verbal account given us by the administrator of their actions and logic on the day of the event is as follows:

> *"at 11:00 a.m. I go up to the lobby to look at the volcano and to check if the information from the electronic bulletin that we had downloaded on the internet had changed or evolved with the latest one that I had on my cell phone at 10:00 a.m. and whether it agreed with what was happening. 11:15 a.m. I begin to observe that the cone has more continuous eruptions and in a matter of 15 minutes eruptions come not only from the cone, but also from the sides in several directions and the gases begin to reduce the visibility. 11:30 a.m. We conducted a briefing of 2 minutes in the motor lobby with the Security Supervisor, the Operations Manager and the General Manager and start the evacuation process. The protocol is activated, and the evacuation of golfers, guests and collaborators is concluded at 12:55 p.m. Three golf carts are sent with caddies to bring the golfers who are in the upper holes of the field near the cone. In one hour and 30 minutes all the guests are alerted and staff that did not have a vehicle is taken to the meeting points. The siren is activated. Guests with their own vehicles begin to leave and some to pay their bills, pick up where they see fit their belongings and leave at 12:55 p.m. The invasion of the golf course by the pyroclast happened from 1:00 p.m. on when the ravines were full. Due to this we had to evacuate through another exit booth. I assume that from 1:00 p.m. to 3:12 p.m. the flow reached the Clubhouse, the 9 holes above the field and the hotel Suites. Two security officers, and the General Manager proceed to conduct a tour of the condominiums. This tour extends until 2:45 p.m. because some guests do not want to leave, and we have to go house to house verifying that they were vacant. 2:45 p.m. We met with Officer Galindo of CONRED on Las Lajas bridge and informed him that the resort is evacuated. Officers of the CONRED ask permission to enter, but they did not return to the resort. We proceed to leave, and we go to Alotenango. On the way there, there are children in the street and old people, we proceed to ride them in the minibuses of the hotel and take them to a safe place in the Municipality. 3:12 p.m. We stopped receiving transmission of the location of the*

vehicles that had GPS and had been parked at Casa Club. We assumed that at that time the pyroclastic flow had already covered the resort facilities. "

The early evacuation called by the administrator and undertaken between about 11:30 AM and 1:00 PM and, subsequently, with respect to the condominiums, between 1:00 and 2:45 PM was, according to the administrator, another precautionary evacuation in the series they had instituted since opening the facility and she herself expected that within three hours they would all be back as on previous occasions. This was transmitted to guests some of whom wanted to pack before leaving, pay their bills, wait for their travel agents or objected to the inconvenience of the buses that were put at the disposal of the guests. The evacuation was 100% successful. And it was facilitated by the existence of collective transportation means at the hotel itself as well as private vehicles of the guests, and by the existing internal communication systems. The second evacuation phase of the condominiums meant employees knocking on the doors of all 42 houses, separated by a considerable distance. Before 3:00 PM everyone had been evacuated. And the hotel transport was also used in part to evacuate some people with mobility problems in the area of San Miguel Los Lotes.

On the day of the event, the administrator had received and read the INSIVUMEH reports from 6:00, 10:40 and 10:55 AM. None mentioned explicitly the need for an evacuation of the area of Las Lajas ravine or the hotel and San Miguel Los Lotes. At 11:15 AM with a clear view of the volcano for a moment between periods of cloudiness she noticed an important change in the rhythm of the volcano and its noise and eruptive manifestations. She saw that the pyroclasts moved more quickly and frequently. The eruptions were concatenated and simultaneous. According to INSIVUMEH experts it was at 12:00 PM that the volcano had its strongest eruption indicating that the administrator was seeing important precursors of the future maximum level event.

The **Toledo** pig farm had up to 50 thousand animals and on the Sunday of the event only 4 people worked as guardians at the facility, near to San Miguel Los Lotes. As a result of the event, 3000 pigs were lost due to heat, ash and tephra and in the following days up to 500 died due to problems of access to water and food. It has not been possible to examine the process of training at the company in aspects of early warning and evacuation at the time of writing this report. What is known is that the person in charge of the facility on the day of the event, seeing the earlier pyroclasts and noticing the hazard these implied, called the headquarters in Guatemala City at about 2:30 PM asking for a decision on what to do. The leadership, upon hearing that the volcanic process and dynamic was completely different to previous occasions, ordered the immediate evacuation of the facility- at that time four occupants. What is an unknown is what would have happened if the leadership did not order the evacuation - would an autonomous decision have been made by the occupants of the facility, what regulations existed in these cases?

Se requieren más detalles sobre el caso de Toledo, donde muy pocas personas de San Miguel Los Lotes trabajaron a pesar de la proximidad. Por supuesto, la ubicación de las instalaciones fue dictada, entre otras cosas, por la relativa seguridad del área y difería de San Miguel Los Lotes debido a su posición más alta protegida detrás de una barrera de vegetación. Su ubicación en la Ruta Nacional 14 ofrecía oportunidades en términos de la operación de la instalación. La rapidez y la preocupación por la reparación de la carretera fue la causa de mucho antagonismo por parte de los sobrevivientes de San Miguel que no encontraron un nivel similar de apoyo del gobierno cuando se trataba de excavar y buscar a los miembros de su familia perdidos. De hecho, la empresa toledana facilitó este proceso con el suministro de 15 excavadoras a los habitantes del área durante el período posterior al impacto. Esto facilitó la reducción de las protestas y el cierre de la carretera, lo que permitió que los alimentos y el agua se transportaran a las instalaciones para aliviar el sufrimiento del ganado.

San Miguel Los Lotes and Other Fuego villages.

Among the villages directly affected (that is, beyond affectation by deposits of ashes and tephra), San Miguel Los Lotes is iconic and unique given the lack of adequate evacuation and the levels of death and destruction suffered. This impact paralleled in greater degree the destruction and loss of life on Las Lajas bridge over the RN 14. An analysis of these cases can provide important lessons for the future.

At the same time attention should also be given to settlements evacuated during the afternoon of the 3rd, on the southeast flank, including La Reina, La Trinidad and El Porvenir and on the southwestern flank, such as Sangre de Cristo and Panamache 1 and 2, the morning of the same day. Whether such evacuations would have been undertaken in the same way and had effective and timely results in the case these villages had been under greater real danger that day, similar to that affecting San Miguel Los Lotes, we will never know. However, we do know that these evacuated towns had an understanding, experience and formal training far beyond what had been experienced in towns such as San Miguel Los Lotes and La Rochela. In San Miguel Los Lotes SE- CONRED had several times tried to provide training and put evacuation instructions in the town. In the case of training, very few arrived at the initial session in 2008 or in subsequent efforts and the evacuation signs were always stolen according to CONRED interviewees.

Of the better drilled and led communities-La Reina and Trinidad-these had participated in the April FAHUM exercise organized by the US military Southern Command. San Miguel Los Lotes did not participate. Here, it is worth researching what level of post-FAHUM evaluation was undertaken and, given the tragic circumstances of the San Miguel Los Lotes event, what potential or real relevance did it have for this and for other communities that did or did not participate. Interviews revealed that the day of the event in the communities that participated in FAHUM, the evacuation did not look

anything like what the simulation had taught. The order and calm the day of the simulation, was substituted by alarm, disorder, spontaneity etc. No established meeting point was established or respected, and anguish, running, and saving oneself as best one could, prevailed.

San Miguel Los Lotes had an unknown total fixed and floating population that Sunday. We know that there were members of other communities, as well as family and friends who were visiting due to it being a Sunday. We know there were baby shower parties, church attendance, family meals all happening at the time of the event. As for the total fixed population of the community, estimates can be made indirectly based on the recorded number of 220 land lots of 80 by 15 meters, and the fact that each lot had between 3 and 5 family dwellings with maybe an average of 4 people per family. With this we can estimate a total population of over 3000 people. In addition, there were an unknown number of land rentiers.

The real number of deaths was and is subject to dispute and discussion. Whole families disappeared, so no family member was looking for survivors or reporting their non-existence. On the other hand, we know that there were about 600 nuclear families from San Miguel Los Lotes in the ATUS of Escuintla in September 2018 and 60 more in other shelters.

The number of early evacuees either guided by La Reunion employees or others could not be researched during our work and is not known accurately. Based on the testimony of relatives, La Reunion employees, or local authorities and volunteers, the people who were saved at the last moment, were those who could, running, escape from a fast moving up to 700-degree pyroclast. Many of them lived near the entrance to the town next to the RN 14 roadway.

Among those that refused, did not or could not evacuate, entire families hid in houses or churches because it seemed a way to protect themselves, without obviously having any idea or information about the nature of a volcanic pyroclast or because, as some interviewees commented, they were advised by local authorities or response agencies-firemen or CONRED to do so. In the case of Doña Eufemia, who when we interviewed her was determined to stay in the town until her dead relatives were found, her call to her family to evacuate was ignored and members of her family took refuge in her mother's house, with prayers to God. Her mother was old and had problems with her legs that made movement difficult. Some families survived in the town itself, in places where, fortunately, the pyroclast did not affect directly.

In sum, the negative of residents to attend the training offered by SE-CONRED or others and ignorance of the existence of an emergency plan for San Miguel Los Lotes, combined with widespread ignorance of the hazards of the volcano, fed by the long period during which the town had not been impacted by volcanic hazards impacts, led to a process of mental “normalization” of the activity of the volcano to the point of

ignoring changes and differences and taking everything as being normal. Religious sentiments and the fact of not being on or in immediate contact with the Las Lajas ravine increased the sense of security. The refusal or negation of the townsfolk to prepare or collaborate with official agencies was to an unknown degree encouraged by antagonisms to government and the armed forces common in many towns in the post peace agreements era. The differentiated sum of all these contexts led to many residents ignoring official or family warnings or simply doing as they saw fit.

One facet of the response was the widescale use of cell phones to film the pyroclasts on the Lajas bridge and in San Miguel itself when these were very proximate. And, many did this with a seeming sense of non-urgency nor fear. This involved private persons and even government officials. The role of cellular phones in disaster response has been well analyzed from its positive side. Little has been researched as to the ways they possibly distract from reality, construct notions of distance from the events and increase risk.

The Authorities

The relations and communication between INSIVUMEH and SE-CONRED, and the decision-making process on early warning and evacuation among the local and national authorities was clearly very deficient. The "anomaly" of the impact on San Miguel Los Lotes and the completely unexpected impact on that town, was combined with an early warning and evacuation routine that worked for villages traditionally considered in danger and subject to previous evacuations and drills and where both authorities and population were more aware and experienced. The lack of standard but differentiated protocols was evident and some field officers, like many people in the street, were clearly distracted by the novelty of the pyroclast. This probably meant that even with the most sophisticated systems of monitoring and information, disaster would probably not have been avoided. The impossible nature of tragedy dominated over caution in the minds of too many.

The lack of adequate response by the authorities and the population itself can also be attributed to the lack of real time information on the event and it’s dynamic due to instrument failures and atmospheric conditions amongst others. Here, the fact that La Reunion employees did not pass on the early information they had when observing the volcano at 11.30am and which supported their decision to evacuate cannot be criticized as some would have liked given their preoccupation with evacuating and the impossibility of knowing that such information was not available to the authorities.

However, such a context and the high relevance that individual or collective non- official sources of information can have suggested that protocols, norms and agreements, could be reached for the socialization of information under conditions of emergency. How to guarantee or promote that "private" information is accessible to the formal, government and other social actors of response and the scientific agencies is a challenge for the future. This could be informed by the role of the mountain lookouts in

Tungurahua, Ecuador in passing information to the local observatory, for example.

Conclusion

The tragedy clearly reflected a normal daily routine that quickly became tragedy under the circumstances that 3rd of June. The structural became conjunctural. The disaster revealed a history of inadequate systems of knowledge and monitoring without basic field equipment, maintenance or mountain lookouts. What could be interpreted as being anomalous reveals important lessons about systems and comprehensive risk management in which responsibility is and must be shared between authorities and the population The tragedy of June 3, 2018 is as much the result of the inefficiency or inoperability of the official organizations as of the reaction-inaction of the population who, for various reasons rooted in consolidated conditions of vulnerability played disaster risk off against every day risk and life needs or simply did not know or did not care to know how to respond.

6. PRELIMINARY CONCLUSIONS AND INDICATIONS ON FUTURE ACTION

a. Settlement around the volcano associated with employment, income, livelihoods, agricultural production, have combined to construct substantial exposure to volcanic hazards in the area. The threat-opportunity-resource continuum came into play as in any resource rich area subject to floods, storms, droughts or volcanic activity. Some residents were aware of the risk, others minimized it or displaced it in their consciousness, and many others had no choice but to accept the risks inherent in the choices available to their economic strata.

b. The open system, strato-volcanic type of volcano, its irregular pattern of eruption, without major human consequences over long periods, combined with the need for families to acquire land and livelihoods, led to a minimization of risk considerations among many residents in the area.

c. The history of the towns and their occupants and the antagonism of many to government, armed and security forces contributed to a lack of participation by many in aspects of formal risk management, drills and local organization. Belief systems including those based on religion will most surely have inculcated feelings of security and protection not justified by the nature and state of the volcano.

d. Ignorance of the nature and characteristics of a pyroclast among many residents due to their low prior exposure to such phenomena led to overconfidence which added new risk factors.

e. The ineffectiveness and low coverage of scientific monitoring instruments combined with low visibility conditions the day of the event made prognosis difficult within adequate time frames. A population, many of which were not aware of the risks inherent in their environment and thus able to correctly understand variations and hazards created a dependency on science in conditions in which science could not contribute as it should.

f. The forms and content of communication between scientists and local and national authorities was severely inadequate. This led to a situation in which the former could not read the given signals well and the latter were not willing to be more forceful with their advice and decisions. Better systems with deep integration between the necessary stakeholders and more informed warning and evacuation systems are absolutely needed in the future.

g. The response of the administration of the Hotel la Reunión revealed admirable aspects as to documentation, updating, monitoring, momentary and varied reading of situations combined with a high awareness of danger and corporate social responsibility towards the population they served. This is worthy of study and internalization in the design of warning and evacuation systems.

g. Basic early warning and evacuation principles failed and the approach to early warning and simulation exercises must be analyzed and revised or expanded, including FAHUM.

h. Great concern for the other volcanoes of the country must exist. There is a risk that by strengthening surveillance of the Fuego Volcano with new equipment, other active volcanoes may receive less attention, and funding. The strengthening of INSIVUMEH in its science and its communication should be inclusive of the entire hazard system in the country.

i. In general collaborating and participating with the local population is essential in increasing awareness, the ability to read the volcano and its dynamics, its messages and phases, to self-organize and to be able to evacuate in a precautionary way. Dependence on the formal scientific community and state response does not always work. Increased self-reliance and support for this in sensitive, culturally adequate ways is imperative.

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8. ANNEXES

Annex 1: PROGRAM OF VISITS AND INTERVIEWS

Agenda of field visits

Wednesday, September 5, 2018 (Alonso Brenes Torres)

Time	Theme	Location	Participants (see Annex 3 for details)
9:00-12:00	**Meeting with INSIVUMEH:** Semi-structured interview about processes and current hazard monitoring equipment.	INSIVUMEH	• INSIVUMEH team (volcanology area) • World Bank Team
14:00-17:00	**Meeting with SECONRED:** Semi-structured interview on the current processes of preparation and response to volcanic threats	Executive Secretariat CONRED	• Team SE- CONRED (areas of volcanology and response) • World Bank Team

Thursday, September 6, 2018 (Alonso Brenes Torres)

Time	Theme	Location	Participants
9:00-12:30	**Meeting with INSIVUMEH:** Semi-structured interview on the current threats evaluation and forecasting processes	INSIVUMEH	• INSIVUMEH team (volcanology area) • World Bank Team

Friday, September 8, 2018 (Alonso Brenes Torres)

Time	Theme	Location	Participants
9:00-17:00	**Field visit to affected areas:** Semi-structured interviews with neighbors and community leaders from areas affected by the June 3 eruption.	Area affected by the eruption of June 3: • Alotenango • The Rodeo • Escuintla	• World Bank Team

Monday, September 24, 2018 (Allan Lavell)

Time	Theme	Place	Participants
14:00 a 15:00	**Meeting PCI-USAID**: Information on post impact actions	Hotel Intercontinental	• Pascale Wagner and Ernesto Paiz • World Bank group
15:30 a 17:00	**Meeting with British Embassy** Interview on field trip and evaluation and coordination	British Embassy	• Carlos Rivera • . Carolyn Davidson. • Marijose Vilá Prosperity Officer • World Bank Group
17:30 a 18:30	**Employees of the Reunion Hotel and Golf Resort** Interview on site selection and risk analysis	Hotel Intercontinental	• Evelyn Ordoñez • Henry Lewin • World Bank Team

Tuesday 25th September 2018 (Allan Lavell)

Time	Theme	Place	Participants
9:30 a 11:00	**Coordination meeting** Ideas and interview structure	Hotel Intercontinental	• World Bank team
11:30 a 13:00	**Meeting with Ministry of Agriculture-MAGA Agricultural use around the volcano**	MAGA	• Ing. Rudy Vásquze-jefe SIG • Ing Royohan Monzón • World Bank team
14:30 a 16:00	**Meeting with SEGEPLAN** **Territorial organization**	SEGEPLAN	• Technical team SEGEPLAN • World Bank team
16:30 a 17:30	**Meeting INSIVUMEH:** Volcanic process, monitoring, instrumentation, information, alert.	INSIVUMEH	• Juan Pablo Oliva • Oscar Porras • Gustavo Chigna • Carla Chun • Leonel Campos • Francisco Juárez • Robin Yani • Helbert De León • World Bank team

Wednesday 26th September 2018 (Allan Lavell)

Time	Theme	Place	Participants
9:00 a 17:00	**Visit to the impacted zone with British Embassy officials** Interviews with population and response agencies	Zone Zero	• British, German, Swiss and North American ambassadors and high level members of AECID, UNDP and SECONRED

Thursday 27th September 2018 (Allan Lavell)

Time	Theme	Place	Participants
7.00 a 8.30	**Organization of days work**	Hotel Intercontinental	• Mischa Prince (film maker) • World Bank
9.00-11.30	**Visit to La Reunion hotel and club** Early warning and evacuation procedures	La Reunión	• Mischa Prince • Evelyn Ordoñez Administrator • Julio Gaitán Head of Security • World Bank team
14:30 a 17:00	**Visit to ATUS Acatenango** • Interviews with survivors from villages	ATUS – Acatenango	• Doña Rosa de la Reina Toledo employee • Impacted from El Porvenir • World Bank team

Friday 28th September 2018 (Allan Lavell)

Time	Theme	Place	Participants
9:00 a 17:00	**Field visit to affected areas** • Interviews with survivors from Los Lotes and with population in ATUS La Industria in Escuintla	Los Lotes morning and Finca la Industria Escuintla afternoon	• Survivers Los Lotes • Residents of the Escuintla ATUS survivors from Los Lotes • World Bank team

Annex 2: LIST OF INTERVIEWEES FROM INSTITUTIONS AND ORGANIZATIONS

Name	Entity	Position	Email
Eddy Sánchez	INSIVUMEH	Director	indirección@insivumeh.gob.gt
Juan Pablo Oliva	INSIVUMEH	Sub-director	jp.olivah@gmail.com
Dulce González	INSIVUMEH	Volcanology Department	dulcitagonzalezd@gmail.com
Francisco Juárez	INSIVUMEH	Volcanology Department	ciscoj239@gmail.com
Carla Chun	INSIVUMEH	Volcanology Department	refma.cq7@gmail.com
Gustavo Chigna	INSIVUMEH	Volcanology Department	gchigna@gmail.com
Robin Yani	INSIVUMEH	Geology Department	robinyani@gmail.com
Leonel Campos	INSIVUMEH	Hydrology Department	leonelcampos55@hotmail.com
Oscar Porras	INSIVUMEH	Geology Department	oporras@insivumeh.gob.gt
Helbert de León	SE-CONRED	Risk monitoring and analysis	arq.heledeleon@gmail.com
Carolyn Davidson	British Embassy	British Ambassador	Bernhard.garside@fco.gov.uk
Marijose Vilá	British Embassy	Prosperity and Projects Officer	Marijose.Villa@fco.gov.uk
Luis Ovando	SEGEPLAN	secretary of Planning and Territorial Planning	lovando@segeplan.gob.gt
Hortensia del Cid	SEGEPLAN	Directorate of Sector Planning	mhcdelcid@yahoo.com
Álvaro Martínez	SEGEPLAN	Manager, Risk Management	alvarohums@gmail.com
Jorge Gudiel	SEGEPLAN	Specialist, Risk Management	jorgegudiel10@gmail.com
Jorge Raúl Escobar	SEGEPLAN	Specialist, Risk Management	Jorge.escobar@segeplan.gob.gt
Rudy Vásquez	MAGA	Head of SIG	rudyvas@gmail.com
Rovohan Monzón	MAGA	SIG Specialist	rovoham@gmail.com
Pascal Wagner	PCI-GLOBAL USAID	PCI Director	pwagner@pciglobal.org

Ernesto Paiz	PCI-GLOBAL USAID	Housing Specialist	pwagner@pciglobal.org
Evelyn Ordoñez	Club de Golf La Reunión	Manager	eordonez.saborio@gmail.com
Henry Lewin	Club de Golf La Reunión	Landscape manager	-
Julio Gaitán	Club de Golf La Reunión	Security manager	-
Marlene Monterrico	SOSEP	Coordinator ATU Escuintla	-

List of International Volcanologists Interviewed
Andy Lockhart-USGS
John Lyons USGS
Matt Watson University of Bristol
Ailsa Naismith, University of Bristol
Eliza Calder University of Edinburgh
Servando de la Cruz, UNAM Rudiger
Escobar, Michigan Tech Piergiorgio
Scarlatto, Naples, Italy.
Lizette Rodriguez University of Puerto Rico
Hugo Yepes Polytechnic of Quito

Affected population from San Miguel and other villages

16 interviews

Others interviewed
Mischa Prince filmmaker and collaborator with U of Edinburgh
Matt Purvis, operator of volcanic tourism
Kate Graves, thesis written about Fuego.

Annex 3: INFORMATION ON AFFECTED AND AT RISK COMMUNITIES (prepared by Carlos Puac)

a. Colonia San Miguel San Miguel los Lotes:

This colony was located at kilometer 95 of the National Route 14, between San Juan Alotenango, Sacatepéquez and Escuintla. Its geographical location is close to the Fuego volcano and it was the one community most affected by the eruption of the colossus on June 3, 2018, being completely buried. (Paredes & Pitán, 2018)

According to a report by Paredes and Pitán (2018), San Miguel de los Lotes was founded in 1964. Mr. Víctor Cancinos Arenales, a survivor of the eruption of the Fuego volcano in the 1950s and Mr. Francisco Ochoa, an entrepreneur from the department of San Marcos, used the area adjacent to the village of El Rodeo for raising livestock, specializing in the care of oxen to plow land used for growing coffee and for hauling firewood to other farms. A family problem and debt obliged Mr. Ochoa to subdivide the area in 1964 for sale. The dismembered lands were of 900 square meters, and sold at a cost of Q. 60.00 each and the payment was made in installments.

The first inhabitants were 15 older adults, none were farm workers.
Arenales, who at that time was the supervisor of the property where he earned Q. 1.00 a week, took a risk and bought land as did the others. The study consulted does not specify if the subdivision of land had municipal permits for house construction.

b. San José El Rodeo:

The village El Rodeo is located in the municipality of Escuintla, at a distance of 14 kilometers from the municipal capital along the National Route 14 to the northwest. In 2009 it had a population of 8,611 inhabitants according to the census carried out by the Community Development Council. It had 991 homes and approximately 995 families. (Sánchez, Navarro, Gómez, & Machán, 2016)

The village was founded in 1918, and its founders were Pedro Juárez Aroche, Ladislao García, Alberto Acajabón, Margarito Sey and Flavio Cardoza Mijangos. The village derived from the purchase of land by these people at that time (Mijangos, 2007).

c. La Trinidad:

First settled by population that returned from Mexico after the signing of the Agreements for Firm and Lasting Peace. The population was originally from Santa Ana Huista, Huehuetenango, mostly Jakalteco Indians. Comprising 145 families, some 725 people, they settled in the Trinidad Los Cascos area with an extension of

21.6 Ca. The land was acquired through a coffee producing credit source. It is located at kilometer 48 of the highway from the capital city, between Escuintla and Antigua Guatemala and 3 kilometers by dirt road from El Rodeo village. It is situated at the foot of the Fuego volcano.

d. ECA La Reina:

Community formed as an Agricultural Farming Company (ECA) and founded on September 23, 2001, located in the municipality of Escuintla 14 kilometers from the municipal capital. It neighbors to the North with the road that leads to Antigua Guatemala and to the south with El Rodeo, to the East with the Las Lagunas farm and the Cañas stream and to the West with the Magdalena sugar mill. It has a territorial extension of 5 ha., 147 houses and about 906 inhabitants. The main activity is the cultivation of lemon, mango, orange, coffee, and pineapple. (Juárez, 2003)

e. Santa Marta El Zapote:

Located in the municipality of Escuintla and accessed through the village Guadalupe el Zapote. Settled first in 1972 on the Santa Inés farm, property of Mr. Arturo Cuyún. Following dismembering of the existing estate, the village took the name of Santa Marta. Its population oscillates around 342 inhabitants. (Juárez, 2003)

Its main source of income is the provision of labor in the sugar industry and other companies and performing agricultural activities on leased land.

f. El Tabacal (Asociación Unión Maya-Quiché):

Agrarian community located in the municipality of Escuintla, bordering to the north with Santa Marta El Zapote, to the south with Lucernas village, to the east with land owned by the Magdalena sugar mill and to the west with Chuchú community. It has a territorial extension of 215 manzanas where approximately 60 families live, mostly from Chichicastenango. Its economic activity focuses on the cultivation of corn and tropical fruits.

It comprises one of the communities that migrated to the coast as a result of the internal armed conflict. After the signing of the peace agreements, at least 53 families organized to qualify for a loan from the Fund for access to land. They acquired the farm where they currently reside, called "Unión Maya Quiché". In 2003 there were 60 families that made up the community. (Juárez, 2003)

g. Village Guadalupe:

Guadalupe is located in the municipality of Escuintla and was founded in 1903. To the North it borders on the Volcán de Fuego, to the South with the municipality of Siquinalá, to the East with Santa Rosa and to the West with Chuchú. Its population oscillates around 600 families, about 4,500 people. The main economic activity is the cultivation of corn and beans. Its origin links it to the community of San Felipe and the dismemberment of the land of the farm called El Zapote carried out there by Aleman Leon Peterson. This bordered the municipality of Siquinalá. The dismembered land was granted to the workers of the El Zapote farm, under the agreement that the coffee and corn crops passed into the hands of Aleman, and with that financing Guadalupe Village was settled, by approximately 15 families, among them the family of Mr. Felix Flores. (Juárez, 2003)

h. Caserío San Felipe:

The San Felipe community was annexed to Guadalupe village, but in May 28, 1957, it was separated from the village. It is located in the municipality of Escuintla and borders to the North with El Zapotillo farm, to the South with the El Caracol farm, to the East with Guadalupe village and to the West with the La Lucerna community of the municipality of Siquinalá.

Its population oscillates around 80 families, about 351 people. Its main economic activity is agriculture, mainly the planting of coffee, corn, beans and bananas. The sowed land is leased.

It is only in 1996 that they introduce a piped water system and in 2000, the electric power service. Like Guadalupe village, it originated with the dismemberment of lands on the estate owned by Mr. Leon Peterson. (Juárez, 2003)

i. Finca Don Pancho (Junan Kusamuj Civil Association):

Settled as an Agricultural Peasant Company (ECA), its foundation was on October 20, 2003, (Fondo de Tierras, s / f). It is located in the municipality of Escuintla about 57 kilometers from the capital city, very close to the El Rodeo village. It borders to the North with La Trinidad farm and Las Lajas farm, to the South with La Trinidad farm, to the East with Las Lagunas farm and Las Cañas creek, to the West with La Trinidad farm and the Zapote road. It has a territorial extension of 177 Ha.

Total population is around 49 families about 358 people originally from the village Estancia de la Virgen of the municipality of San Martín Jilotepeque, department of Chimaltenango. The population organized in 1997 to have access to land but two years afterwards the organization was dissolved leaving only 12 families. On approaching the Land Fund through the National Coordinator of Peasant Organizations (CNOC) led by Gilberto Atz, the Fund required the grouping of 55 families in order to be able to have access to a farm. The legalization of the Junan Kusamuj Civil Association was achieved in 2002, achieving integration and access to land. By the year 2003, the group had the support of the CNOC and the Committee of the Altiplano Peasant (CCDA), granting them the farm that today they call Don Pancho. (Juárez, 2003)

j. El Porvenir:

Village in the municipality of San Juan Alotenango, located at kilometer 91.5 on the national road R-14. Founded in 1936 with the purchase of 10 manzanas, first settlers included Mr. Rafael Acajabón Cabrera and his children. Today it has an extension of 7 square kilometers with land divided into 10 manzana lots. It borders to the north with finca Candelaria, to the south with what used to be San Miguel Los Lotes, to the east with El Tesoro farm and to the west with the Finca La Reunion Golf Resort & Residences. (Way, 2017)

k. Aldea Morelia:

The collective agrarian heritage "Morelia" is part of the Land Fund and was settled in 1981 (formerly the National Institute of Agrarian Transformation -INTA-), year in which farmers acquire the land. Constituted as an ECA, with 352 Has of land and made up of 220 families with an average of 1.60 hectares each. It is located in the municipality of San Pedro Yepocapa and it borders to the North with the Palo Verde and La Pastorcita farms, to the South with Finca San José la Unión and Santa Sofía, to the East with finca Mercedes and Panimaché village, to the West with the El Tigre farm and San José la Unión. (Quevedo, 2014)

l. Panimache I and II:

Panimaché village is located in the municipality of Yepocapa department of Chimaltenango, far from the municipal capital 15 kilometers south. Accessed by a dirt road it is located 85 kilometers from Guatemala City.

Houses are built mainly of wood and roofs of zinc sheet. The agricultural population own their own land and cultivate mainly corn, beans, papaya, banana and coffee.

Production is for sale and personal consumption. The climate is tempered by its location in the vicinity of the Volcán de Fuego. Because the Panimaché village is located in the foothills of the volcano, the population is constantly alarmed by the activity of the volcano. In 1973 the National Observatory initiated monitoring of the Volcán de Fuego from Panimache.

In 1974 Panimaché village was relocated 800 meters, as a result of volcanic activity that year. At present, INSIVUMEH, through the Volcanic Research and Services Unit, continues monitoring. The population was estimated at 510 settlers between men and women. (Baján, 2003)

Table 1: Communities affected by volcanic activity of the volcano of Fuego

No.	Township	Municipality[8]	Department
1	San Miguel Los Lotes	Escuintla	Escuintla
2	El Rodeo[9]	Escuintla	Escuintla
3	La Trinidad	Escuintla	Escuintla
4	La Reina	Escuintla[10]	Escuintla
5	Santa Marta El Zapote	Escuintla	Escuintla
6	El Tabacal	Escuintla	Escuintla
7	Guadalupe	Escuintla	Escuintla
8	San Felipe	Escuintla	Escuintla
9	Don Pancho	Escuintla	Escuintla
10	El Porvenir[11]	San Juan Alotenango[12]	Sacatepéquez
11	Aldea Morelia[13]	San Pedro Yepocapa	Chimaltenango
12	Panimaché I y II[14]	San Pedro Yepocapa	Chimaltenango
13	Sangre de Cristo	San Pedro Yepocapa	Chimaltenango
14	Santa Sofía[15]	San Pedro Yepocapa	Chimaltenango
15	Los Yucales	San Pedro Yepocapa	Chimaltenango

[8] Data on the location and main land use of the affected villages, Municipal Development Plans of Escuintla, Alotenango, San Pedro Yepocapa.
[9] Brief description Aldea el Rodeo in table No. 2 (Sánchez, Navarro, Gómez, & Machán, 2016) and (Mijangos, 2007)
[10] The data referring to the farms delivered by the Land Fund (La Reina, Don Pancho, Tabacal) and others referring to the thesis of (Juárez, 2003)
[11] Data from President COLRED, taken from the thesis report of Way (Way, 2017)
[12] Brief description of Caserío El Porvenir in table No. 2 (Romero, 2015)
[13] Brief description of Patrimonio Agrario Morelia in table No. 2 (Quevedo, 2014)
[14] Brief description of Panimaché I, in table No. 2 (Baján, 2003)
[15] Brief description of Santa Sofía in the municipality of Yepocapa in table No. 2 (Marín, 2014)

16	El Porvenir	San Pedro Yepocapa	Chimaltenango
17	La Rochela	Siquinalá	Escuintla
18	Ceilán	Siquinalá	Escuintla

Source: Prepared with information from various sources cited in the bibliography.

Table 2: Communities founded before 1974[16]

Township	Location	Founded	Type of acquisition	Main use of land	Plans and/or studies
San José El Rodeo (aldea)	Escuintla	1918	Land purchase	Housing	Included in the PDM[17]
Aldea Guadalupe	Escuintla	1903	Land purchase	Housing	Included in the PDM
Caserío San Felipe	Escuintla	1957	Land purchase	Housing	Included in the PDM
San Miguel Los Lotes	Escuintla	1950-1964	Land purchase	Housing with use for coffee production	Included in the PDM
El Porvenir (caserío)	Alotenango	1936	Land purchase	Coffee	Local emergency plan (COLRED)
Panimaché I y II	San Pedro Yepocapa	1974	Not specified	Coffee, corn, banana, citruses	Included in the PDM

Source: Prepared with thesis information (see notes at the bottom of the page).

Table 3: Communities founded after 1974[18]

Township	Location	Founded	Type of acquisition	Main use of land	Plans and/or studies
Aldea Morelia (patrimonio)	San Pedro Yepocapa	1981	Adjudication of Instituto de	Coffee	Included in the PDM

[16] Contact in the village Jorge Vidal Hernández (president of COLRED, celular 45095737)
[17] PDM Municipal Development Plan
[18] Year in which an eruption of the volcano almost buried San Pedro Yepocapa.

			Transformación Agraria		
La Trinidad (15 de octubre) (colonia)	Escuintla	1998	Adjudication of FONTIERRAS	Coffee and corn	Included in the PDM
La Reina (ECA El Rodeo)	Escuintla	2001	Adjudication of FONTIERRAS	Various crops	Without risk analysis; Included in the PDM
El Tabacal (Asociación Unión Maya-Quiché)	Escuintla	2004	Adjudication of	Corn and tropical fruits	Included in the PDM
Finca Don Pancho Junan Kusamuj)			Adjudication of		Included in the
(Asociación Civil	Escuintla	2003	FONTIERRAS	Coffee	PDM

Source: Prepared with thesis information (see notes at the bottom of the first page).

Table 4: Other affected communities

Township	Municipality	Principal land use	Plans and/or studies
Santa Sofía	San Pedro Yepocapa	Housing	Included in the PDM [19]
El Porvenir		Housing	
Los Yucales		Housing	
Comunidad Agraria San Andrés Osuna y anexo Chuchú	Siquinalá	Coffee and banana	Included in the PDM [20]
Ceylán		Coffee and banana	
La Rochela		Coffee	

For the communities mentioned in Table 4, despite being highly exposed due to their geographic location, we did not find information on their date of foundation, land tenure,

[19] According to the PDM of San Pedro Yepocapa, the communities of El Porvenir, Yucales, Santa Sofia, Morelia, Sangre de Cristo and Panimaché I and II, are constantly exposed to volcanic eruptions, are highly at risk, the main impacts are in agriculture, commerce, infrastructure, health and economy.

[20] Included in the PDM of Escuintla, these communities have a peculiarity in common, all are located in the jurisdiction of Siquinalá.

among others. But in the image below, the location of each community located in the vicinity of the volcano is observed. However, no information was placed regarding the vulnerability of the mentioned communities.

Registry data from where the San Andrés Osuna, Ceylon and Chuchú farms were dismembered: Finca 2897 folio 229 and book 36 of Escuintla; It has an extension of 83 caballerias, 41 manzanas and 3561 square yards equivalent to 3774 hectares, 32 areas and 63.84 centiáreas, was registered on May 14, 1925, according to the first inscription of domain, it is located in Siquinalá, Escuintla, denominated San Andrés Osuna (Registry of Cadastral Information, 2009)

Planned evacuation routes for Fuego Volcano

Annex 4: AFFECTED PRIVATE SECTOR ENTERPRISES

Farm "La Flor":

Located in the village El Rodeo, Escuintla; km 93.7 of the National Route 14 road that leads from the capital city to Escuintla. It is located at a distance of 15 km from the department of Escuintla and 23 km from Antigua Guatemala. The height is 780 meters above sea level and the climate is subtropical warm. The temperature oscillates on average at 25º C with a Maximum of 28º C and a minimum of 20º C. The annual pluvial precipitation on average is 3900 mm. (Estrada, 2008)

Golf Club-Hotel "La Reunion":

Located at kilometer 91.5 on the road to Antigua, San Juan Alotenango Sacatepéquez, with a territorial extension of 595 ha. Project begun by several entrepreneurs who were looking to build a prestigious place.

It was considered and designed by the architect Pete Dye, recently exalted to the Hall of Fame of Golf for the construction of golf courses and recognized worldwide, in places such as Europe, Latin America, the Caribbean, Central America and the United States among others .

The Reunion project was previously a coffee plantation and began construction in January of 2007, and the golf course was inaugurated on March 28, 2009, with unique views of the imposing volcanoes of Guatemala and the south of the coast. Its climate is humid tropical sub-forest in the foothills of the Pacific slope. (Marroquín, 2013)

After the eruption of the Fuego volcano, on June 3, 2018, it was declared uninhabitable.

Information provided in an interview by the Human Resources Manager of the Club at the time of the eruption of the Volcán de Fuego:

"The idea of working aspects of preparation for volcanic risk arises from the area of occupational health, as a section of Human Resources. It also arises within the legal framework that includes worker protection, benefits, health services, among others.

A Private Foundation was initially founded, which will later give rise to the Club Golf- Hotel "La Reunión". This foundation emerged with a community vision and principles directed towards community development. In 2008, a diagnosis was made in order to generate local health and educational projects, as well as strengthening community organization, where they could also be supported in these areas. The diagnosis allowed an understanding of the environment where the club. It is worth recalling that most of the local population came from the Mexican border as returnees, affected by the internal armed conflict.

An important point was the risk analysis for the Volcán de Fuego. One understands the scenic attraction that the Volcano presents, from which one of its slogan emerged: "Concentrate the forces of life".

In the context of volcanic risk, coordinations and alliances were established with the SE-CONRED and the University of Alabama, who placed an identifier of movements of the volcano in coordination with INSIVUMEH, which allowed a clear awareness of where it was.

In 2011, the SE-CONRED offered a one-week course on risk, together with the Guatemalan Social Security Institute. From that event, an Incident Command System (ICS) and the conformation of a COE were internally created. This allowed a defined structure that presented coordination with the Municipality of Alotenango.

The EOC of the Club had an evacuation commission, with brigades with specific functions. For example, the housekeeper was part of the Occupational Health and Safety committee. This organization did not respond to the normal institutional hierarchy, so it was expected that even in times of emergency, a subordinate could be commissioned and give instructions to someone of higher rank.

In the same way constant drills were carried out, both day and night, with alarm and without alarm every month.

According to the interviewee, these processes do not work equally at the community level, since there is no firm work in the communities that allows them to understand the risk where they are. This explains the differentiated response between hotel staff and the communities affected by the recent volcanic eruption.

The successful work done in the evacuation carried out on the day of the volcanic eruption on Sunday, June 3, 2018, was mainly due to the participation of a multidisciplinary team (not a single person) that includes social workers, experts and managers.

The eruptive phase began at 6:00 am on Sunday, June 3, while the evacuation in the Club, according to information from the person in charge of human resources, was completed at 12:30.

An important fact gathered by the author of this document is that the Finca Sábana Grande, in El Rodeo Escuintla Village, owned by the University of San Carlos of Guatemala, was evacuated at 1:30 p.m., with the support of the Study Center of Safe Development and Disasters -CEDESYD-.

Annex 5: BIBLIOGRAPHIC REFERENCES FOR ANNEX 4

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