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DISASTER RISK IN THE LAKE NYOS AREA, CAMEROON: EFFECTS OF THE GAS HAZARD AND SOCIALLY PRODUCED VULNERABILITY

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DISASTER RISK IN THE LAKE NYOS AREA, CAMEROON: EFFECTS OF THE
GAS HAZARD AND SOCIALLY PRODUCED VULNERABILITY

By

Mary Witucki

A THESIS

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

In Geology

MICHIGAN TECHNOLOGICAL UNIVERSITY

2018

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This thesis has been approved in partial fulfillment of the requirements for the Degree of MASTER OF SCIENCE in Geology.

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Abstract

Effective disaster risk reduction (DRR) efforts depend on comprehensive risk assessments that consider potential hazard events and social vulnerability. The Lake Nyos Disaster (LND) caused the deaths of about 1,700 people, forced another 4,000 people from their homes, and left survivors more vulnerable to future hazards. There is considerable research on the gas hazard and some work on local vulnerability; however studies rarely consider both aspects of disaster risk (DR). This study addresses both the hazard and vulnerability and uses qualitative and quantitative methods that are applied for the first time to LND survivor vulnerability and gas hazard. Interviews, participant observation, the Pressure and Release (PAR) and Access models are used to analyze vulnerability. A modified LAHARZ model and GIS mapping are used to categorize the gas hazard. By modeling various gas release scenarios and determining the main factors affecting vulnerability, DR for survivors in the Nyos area is calculated.

1. Introduction

Disaster risk reduction (DRR) is being increasingly recognized as an important development goal in many countries as well as in international and intergovernmental organizations. Natural hazards are complex problems which are happening more frequently due to increased exposure to hazards, increased vulnerability in urban areas, global climate change, and other reasons. It is because of the continually growing risk of natural hazards that both hazard and vulnerability assessments are becoming increasingly significant to DRR efforts. A comprehensive risk assessment considers the full range of potential disaster events and the underlying drivers that contribute to vulnerability. It may start with the analysis of historical events and influences, as well as incorporating forward-looking perspectives and integrating the anticipated impacts of phenomena that are altering historical trends such as climate change. It is well recognized that risk is not static and that it can change very rapidly as a result of evolving hazards, exposure, and vulnerability. This is why it is vital to consider all of these factors when defining disaster risk.

Disasters are the combination of one or more hazards and human behaviors and actions. A disaster is defined as “a serious disruption of the functioning of a community or society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope with using its own resources.” (UNISDR, 2017). Disasters can be evaluated as the product of long term processes which create risk over many years, decades, or longer. According to Wisner et al. (2004), disaster risk is the result of the interaction of one or more hazards with a vulnerable population. A disaster cannot occur without both of these dynamics. There is no disaster if there is a hazard but no vulnerable population or if there is a vulnerable population but no hazard event. A population is vulnerable when their characteristics and situation influence their capacity to anticipate, resist, cope with, and recover from the impacts of a natural hazard (Wisner et al., 2004). Natural hazards are extreme natural events and processes which are categorized by their varying degrees of severity and frequency.

The 1986 Lake Nyos Disaster (LND) significantly impacted the populations living in the affected areas. The lake experienced a limnic eruption and released a cloud of CO₂ into the valleys around the lake. The disaster killed over 1,700 people, displaced more than 4,000, and killed many domestic and wild animals (Tuttle et al., 1987). Survivors were evacuated, after which aid and mitigation efforts began. There have been many studies done on the LND focusing mainly on the hazard's origin, trigger, and the composition and structure of the gas and water in the lake. However, less research has been devoted to the exposure, risk, and social vulnerability of those affected.

This study aims to understand disaster risk in the Lake Nyos area by looking at the effects of the gas hazard and socially produced vulnerability on the populations affected by the LND. Hazard and vulnerability assessments were produced for this study. Data was gathered from interviews, participant observation, review of literature, and satellite imagery. The theoretical frameworks and models used to analyze the hazard and vulnerability include the Pressure and Release model, Access model, an adapted LAHARZ model, and ArcMap. The object of this study is to determine the disaster risk for LND survivors in the Lake Nyos area, as well as understand the impacts of various gas release scenarios. It will also be determined how a risk assessment based on these methods could inform policy and DRR efforts in the Nyos area. Hazard and vulnerability assessment studies such as this can be used to establish priorities when addressing hazards and vulnerability.

1.1 Geological Setting and Study Location

Cameroon is located on the west coast of Africa, on the Gulf of Guinea, and sits on a line of young (Tertiary to Recent) volcanic activity which trends NE-SW across Cameroon (Schlüter, 2008). This line of volcanism is the Cameroon Volcanic Line (CVL) which extends for 1,600km from the island of Pagalu (aka Annobón), in the Atlantic Ocean, through the Gulf of Guinea, and along the Cameroon-Nigeria border (Fitton, 1980). The geography of Cameroon varies greatly across the country's 475,440km² (CIA, 2017). The country includes a variety of climatic zones ranging from

tropical rainforests to hot semi-arid climates (Sahel). Due to its diverse climates and varied geology, Cameroon is exposed to a wide variety of climatological, geological, biological, and ecological hazards. Some of the most well-known natural hazard events in Cameroon have been caused by Mount Cameroon, a stratovolcano in the Southwest Region, and by Lake Monoun in the West Region and Lake Nyos in the Northwest Region.

The landscape of the Northwest Region of Cameroon is defined by features of the CVL. There are old cinder cones, lava flows, and many crater lakes which have formed in the circular maars caused by volcanic explosions (Kling et al., 1987; Tuttle et al., 1987). Lake Nyos and Lake Monoun also sit on the CVL and contain high concentrations of carbon dioxide. Large emissions of CO₂ have occurred at each of these lakes, at Lake Monoun in August 1984 and at Lake Nyos in August 1986 (Kling et al., 1987). The 1986 LND caused the deaths of over 1,700 people in the villages of Nyos, Cha, Subum, as well as the surrounding areas. This study focuses on the hazard that caused this disaster, the vulnerability of the people affected by it, and the disaster risk constructed by these factors.

Figure 1: Location map for Lake Nyos and Lake Monoun and other features along the CVL (Ohba et al., 2013).

Lake Nyos, located approximately 500km by road from Cameroon's capital of Yaoundé, is a crater lake in Menchum Division. The lake is 208m at its deepest point. Underlying basement rock has distinct fault lines running through it, which have been active in the area's recent history (Freeth & Rex, 2000; Kling, 1987). The Nyos maar was formed by volcanic explosions and the collapse of adjacent rocks (Tuttle et al., 1987). Beneath the maar is a diatreme, or an approximately vertical tube that formed above a dike and is packed with disjointed rock fragments and ash (Kling et al., 1987). The CO₂ present in the lake is released by the melting of the metasomatized mantle deep below the lake and seeps into the bottom waters of the lake dissolved in groundwater (Aka, 2015; Kling et al., 1987; Nojiri et al., 1993). Based on measurements and evidence collected after the 1986 event by the USGS and

corroborated by subsequent studies, it was determined that Lake Nyos still posed a threat to the surrounding communities because there remained the potential for gas eruptions in the future (Lockwood & Rubin, 1989; Nojiri et al., 1993; Tuttle et al., 1987). This led to the evacuation of the area and the relocation of the inhabitants into resettlement camps outside of the disaster zone: Buabua, Esu, Ipalim, Kimbi, Kumfutu, Upkwa, and Yemnge.

The area of interest (AOI) is located on the border of the Menchum and Boyo Divisions in the Northwest Region of Cameroon, 120km north of Bamenda, the region's capital (Figure 2). Menchum Division (4,469km²) and Boyo Division (1,592km²), of which Wum and Fundong are the divisional headquarters respectively, have a total population of about 325,000 people. These divisions are made up mostly of rural agricultural communities with only a few large economic and political centers. There are many small communities in Menchum and Boyo Divisions and their populations are concentrated in small communities that are widely dispersed across the divisions. The villages of Nyos and Cha and the resettlement camps of Upkwa, Esu, Ipalim, Kumfutu, and Yemnge are in Menchum Division, while the village of Subum and the resettlement camps of Kimbi and Buabua are in Boyo Division. Subsistence farming, cattle grazing, and petty trading are the primary occupations of the majority of community members.

Figure 2: Study location, AOI (red line) and the locations of Cha, Nyos, Subum, and Buabua (green points).

1.2 Overview of Recent Socio-economic and Political History of Cameroon

The Republic of Cameroon has a population of about 23 million and is known for its cultural and environmental diversity (CIA, 2017). Often called “Africa in miniature”, French and English are the official languages of Cameroon though West African Pidjin English and at least 240 national languages are also spoken (Bilola &

Echu, 2008; Republic of Cameroon, 2018). The country is divided into ten administrative regions, the Extreme-North, North, Adamawa, East, Center, South, Littoral, West, Southwest, and Northwest. Cameroon ranks 153rd out of 188 countries on the global human development index (HDI) scale putting the country in the low human development category (UNDP, 2016). The 2015 HDI for Cameroon, 0.518, is below the 0.523 average HDI for countries in Sub-Saharan Africa; however it is above the 0.497 average of countries in the low human development category (UNDP, 2016).

The Southwest and Northwest Regions are anglophone and the rest of the regions are francophone. There are more than 240 ethno-linguistic groups in Cameroon that are part of the three main language groups, the Bantu, the Semi-Bantu, and the Sudanese (Republic of Cameroon, 2018). A variety of religions are practiced in Cameroon, the two most prevalent being Christianity and Islam. Many people practice animism and other traditional belief systems in conjunction with their Christian, Islamic, or other non-traditional beliefs.

In the 15th century, Portuguese traders established contact with the area that is now Cameroon and though no permanent settlements were maintained, slaves were purchased from the local peoples (Worger et al., 2010). In 1884, the region came under German rule after protectorate treaties were negotiated with local chiefs (Hargreaves, 1990). This region was invaded by French and British forces during WWI. After the war, former German-controlled Cameroon was divided between the United Kingdom and France (Hargreaves, 1990).

In 1946, the recognition of emerging political parties established a basis for Cameroonian nationalism (Atangana, 2010; Lewis, 1965; Ndille & Rose, 2016; Worger et al., 2010). The Union of Cameroon Peoples (UPC), one of the many emerging parties, demanded immediate reunification of British-controlled Cameroon and French-controlled Cameroon along with eventual independence (Konings, 1996, 1999; Stevenson, 2008). In 1957, the French government created the autonomous state of Cameroon basing its government on French parliamentary democracy. In 1958, the Legislative Assembly of Cameroon voted to gain independence by 1960 and obtained full internal autonomy in 1959. Ahmadou Ahidjo became prime minister of French-

controlled Cameroon and John Foncha became prime minister of British-controlled Cameroon. Soon Foncha and Ahidjo were discussing the possibility of unification upon attaining independence (Achankeng, 2015; Konings & Nyamnjoh, 2003).

On January 1, 1960, Cameroon became an independent republic and in April 1960, Ahidjo's UPC party won a majority and Ahidjo, who ran unopposed, was elected president. During 1960, discussions between Foncha and Ahidjo continued, and a future federation was tentatively outlined. In 1961, a vote organized by the United Nations was held in British-controlled Cameroon and the people chose either to be part of the independent Nigerian state or to be reunified with the independent Republic of Cameroon. The predominantly Muslim northern section of British-controlled Cameroon voted to join Nigeria and the largely Christian southern section voted to join the Republic of Cameroon, which then became the Federal Republic of Cameroon (Konings & Nyamnjoh, 1997, 2003). The previously British-controlled part of Cameroon became known as West Cameroon and the French part as East Cameroon. Ahidjo accepted the federation, considering it a stepping stone towards full reunification (Konings & Nyamnjoh, 2003). The federal constitution was adopted, with Ahidjo as president and Foncha as vice president. Buea became the capital of West Cameroon, while Yaoundé doubled as the federal capital and the capital of East Cameroon (Figure 3). East Cameroon and West Cameroon retained substantial autonomy and continued following the rules and laws of their respective colonizers (Konings & Nyamnjoh, 2003).

Figure 3: Map of regional capitals in Cameroon. Map provided courtesy of the UN Office for the Coordination of Humanitarian Affairs. (Retrieved from <https://reliefweb.int/map/cameroon/cameroon-location-map-2013>).

In 1972, a new constitution replaced the federation with a unitary state called the United Republic of Cameroon (Figure 4). In 1975, Paul Biya was appointed vice president. Ahidjo resigned as president in 1982 and was constitutionally succeeded by Biya. Ahidjo later regretted his choice of successor and in a coup in 1984, his supporters failed to overthrow Biya (Akum, 2009). Biya won single-candidate elections in 1983 and 1984 and the country returned to being named the Republic of Cameroon. According to the U.S. Department of State Cameroon Human Rights Reports from 2011 and 2017, Biya has remained in power, winning non-transparent multiparty

elections in 1992, 1997, 2004 and 2011. His Cameroon People's Democratic Movement (CPDM) party continues to hold a sizeable majority in the legislature.

Figure 4: Cameroon's changing borders throughout recent history. *"Cameroon boundary Changes"* by Roke is licensed under CC BY-SA 3.0.

Politically, Cameroon is a republic in which the presidency has a central role in terms of political power and has control over all branches of the government (Department of State, 2017). Although the country has a multiparty system, the CPDM has remained in power since its foundation in 1985. Paul Biya has been president of Cameroon since 1982 (Department of State, 2017). The government of Cameroon is centralized, each subsequent level of government has less and less decision making power; most decisions for villages, subdivisions, divisions, etc. are made at higher presiding levels (Bang, 2009, 2012, 2013, 2014).

2. Background

2.1 Previous Work

The LND inspired many scientists and researchers to delve into various aspects of the disaster, hazard, and its effects. The largest portion of these studies focus on the hazard's origin, trigger mechanism, and the composition and structure of the gas and water in the lake. Initial studies conducted on the disaster and its origin detailed the extent of the gas flow and found that the gas released was primarily CO₂ originating from a deep-seated magmatic source beneath the lake (Baxter & Kapila, 1989; Baxter et al., 1989; Morin & Pahal, 1986; Tuttle et al., 1987). The chemical and medical evidence from investigations conducted after the disaster showed that the victims died of CO₂ asphyxiation (Baxter & Kapila, 1989; Baxter et al., 1989; Kling et al., 1987). It was also determined that although the CO₂ is originating from a magmatic source, the release of gas was not directly caused by volcanic activity (Aka, 2015; Tuttle et al., 1987).

In order to better understand the hazard, researchers considered the trigger mechanism that caused the eruption as well as the composition of the gas and lake stratification. Studies considered internal and external mechanisms such as landslides, turnover, volcanic eruptions, seasonal mixing and density inversion (Chau et al., 1996; Cotel, 1999; Kling et al., 1987; Kling et al., 1994; Touret et al., 2010; Tuttle et al., 1987). Little consensus exists on the exact trigger mechanism for the 1986 gas release, though a small landslide is often cited as a possible cause. It is, however, usually agreed upon that a disruption of the lake's stratification decreased pressure on the bottom layers and released the gas (Kling et al., 1987; Tuttle et al., 1987). Additionally, subsequent studies found that gas continues to accumulate in the bottom water of the lake, creating a potential hazard (Evans et al., 1993; Evans et al., 1994; Nojiri et al., 1993). Sano et al. (1990), Nojiri et al. (1993), and Kusakabe et al. (2000) all found that though there was a continuous influx of CO₂ into the lake, the gas build-up process is not dominated by a steady-state flux and that this makes it difficult to estimate how often degassing events might occur.

Numerous studies considering mitigation approaches and various modeling techniques examine possible hazard reduction strategies. Degassing the lake was suggested immediately after the LND and was followed up with studies investigating the safety of possible procedures and methods (Evans et al., 1993; Evans et al., 1994; Kling et al., 1987; Kling et al., 1994; Kusakabe et al., 2000; Tuttle et al., 1987). Later, Schmid et al. (2006) also examined CO₂ concentrations and stratification in the lake to determine the effect of the degassing mitigation strategy. Results showed that without degassing the CO₂ would reach levels as high as or higher than pre-disaster levels.

Mapping and modeling of the LND gas flow was done after the disaster in order to assist possible mitigation efforts (McCord & Schladow, 1998; Pierret et al., 1992). More recently studies attempting to model the LND and possible future gas releases been done using a variety of computer and weather prediction modeling techniques (Burton et al., 2017; Costa & Chiodini, 2015; Folch et al., 2017). These models have variable levels of success in matching the dispersion pattern of the gas during the LND. The mapping and modeling studies, along with considering possible mitigation efforts, also investigate exposure. Work done shortly after and since the disaster probes into risk due to exposure to the hazard (Baxter & Kapila, 1989; Baxter et al., 1989; Le Guern et al., 1992; Tchindjang, 2018). These studies consider risk based mainly on physical exposure and less on vulnerability and how that affects the disaster risk. The survivors' vulnerability at the time of the disaster was examined by Shanklin (1988, 1989) and Le Guern et al. (1992). Their studies found that many survivors lost their livelihoods and social support networks in the disaster. Bang (2008, 2009, 2012, 2013, 2014, 2016) has delved deeper into social vulnerability in the Lake Nyos area than many of his predecessors. He also conducted a study on social vulnerability in the Lake Nyos area using the Sustainable Livelihoods framework. This framework however does not equally consider the hazard and vulnerability, both of which are important aspects of DR. Bang's work has shown that the people's vulnerability and the disaster risk in the area are formed by a variety of factors and stresses the importance of addressing more than the physical hazard.

2.2 The 1986 Lake Nyos Disaster (LND)

2.2.1 The Event

On the night of August 21st 1986, a limnic eruption occurred at Lake Nyos, which released a dense cloud of CO₂ into the surrounding valleys (Kling et al., 1987). The gas mainly affected the villages of Nyos, Cha, and Subum and the surrounding areas. The disaster caused the deaths of over 1,700 people and displaced more than 4,000 others (Tuttle et al., 1987). Livestock and local fauna were also significantly impacted, about 3,500 cattle died as well as many other domesticated and wild animals (Tuttle et al., 1987). This was a significant loss for the people living in the area since agriculture and cattle grazing were the main livelihoods for a substantial portion of the population. In a single night many people living in the Nyos area lost both their livelihoods and their families.

The morning after the disaster people from neighboring villages, outside the affected area, discovered that something had happened and began to assist survivors. The area was evacuated; survivors who were able fled the area while others were assisted by people from neighboring, unaffected villages, missions, and the government. It took longer for a formal response because of the area's relative isolation and distance from cities with suitable resources. The government and NGO responders arrived a few days after the disaster and, over the next days and weeks, finished evacuating the area and burying the dead.

2.2.2 Response and Management

Disaster management in Cameroon is very centralized (Bang, 2012, 2014). The response and management of the LND started at the national level with a presidential decree creating a National Committee for the Reception and Management of Relief Aid. Then a ministerial decree created provincial committees, one in Douala to manage foreign aid and another in Bamenda to manage national aid coming into the region (Bang, 2012). International and local NGOs were not included in the committees (Bang, 2012; Othman-Chandev, 1987). At the regional level, the disaster was managed by a government committee overseen by the governor of the Northwest Region in

Bamenda. Then at the divisional level, a committee was formed and was directed by the senior divisional officer (SDO) of Menchum in Wum. This committee was finally responsible for the evacuation of survivors from the disaster zone (Bang, 2012; Othman-Chandev, 1987). The official response and evacuation was able to begin a few days after the eruption, when it was determined that the area no longer posed any immediate risks. The military was also deployed to the disaster zone to assist since they had vehicles that could handle the poor road conditions (Bang, 2012; Krajick, 2003; Othman-Chandev, 1987). Since the Nyos area did not have health facilities, many of the survivors were taken to the hospital in Wum, Nkambe, and other villages farther along the Ring Road.

After the evacuation, the government and local people worked to bury all those who had died and the survivors were housed in temporary tent camps (Bang, 2009). Daily necessities were provided for the survivors by missionaries, international aid organizations, local citizens, NGOs, and the government of Cameroon. Two years after the disaster, resettlement camps were established by the government with assistance from non-governmental organizations and individuals to relocate the survivors from the affected villages and the surrounding area to safe areas outside of the disaster zone. The permanent resettlement camps were built and the survivors were moved into these about two years after the disaster had forced them from their homes (Bang, 2009).

In the decades following the disaster, the government and international aid continued sporadically. According to some interviews with community members, aid stopped coming a few years after the disaster and is no longer being distributed. This, in addition to perceived benefits of living in the villages near the lake, has prompted many of the survivors to move back to the disaster zone (Bang, 2009; Bang & Few, 2012). Though the disaster zone was reopened for habitation by the government in 2014, most of the survivors who have moved back did so long before this announcement and only a few interview respondents were aware of the announcement.

Disaster response tasks for the LND were inhibited by the lack of agency capacity as well as the distance of government agencies and their resources from the lake. The disaster spurred the government to strengthen its disaster aid and response

capabilities. However, the government agencies are still very centralized and this makes them less effective in mitigating and responding to hazard events (Aka et al., 2017; Bang, 2012, 2013, 2014; Gaston et al., 2012).

In Cameroon, the responsibilities of disaster and risk management are shared by several agencies that work in conjunction with international organizations, NGOs, and scientists (Tchindjang, 2018). The hierarchy of these agencies and organizations, as described by Tchindjang (2018), is depicted in Figure 5. The Directorate of Civil Protection (DPC) manages response efforts and coordinates between the necessary administrations. However, the Department of Civil Protection of the Ministry of Territorial Administration and Decentralization (DPC/MINATD) is the organization that actually works with and coordinates disaster management with the various other agencies. The offices and agencies that collaborate on disaster management and response are the Institute of Geological and Mining Research (IRGM), the National Institute of Cartography (INC), the Ministry of Public Health (MINSANTE), and the National Fire Brigade Corps, not to mention various UN, WHO, and Red Cross representatives (MINATD/DCP, 2009; Tchindjang, 2018).

Figure 5: Hierarchy of disaster management in Cameroon.

2.2.3 Mitigation

After the disaster, it was determined that the lake still posed a threat to people living in the areas surrounding the lake, which led to the suggestion that the lake be degassed in order to mitigate the hazard (Tuttle et al., 1987). Studies showed that the level of CO₂ in Lake Nyos was quickly increasing. It was estimated that within 15 - 30 years the lake would be recharged with more CO₂ than was present before the LND (Evans et al., 1994; Kantha & Freeth, 1996; Kling et al., 1994; McCord & Schladow, 1998; Nojiri et al., 1993). Although suggested at the time of the disaster, degassing did not start for another 15 years (Evans et al., 1993; Evans et al., 1994; Kling et al., 1994; Kusakabe et al., 2008).

In 2001, with the CO₂ at its highest recorded level, degassing began at Lake Nyos (Kusakabe, 2017). The project started with one degassing pipe though it quickly became clear that more pipes would be needed to mitigate the hazard (Halbwachs & Sabroux, 2001; Halbwachs et al., 2004; Kling et al., 2005; Schmid et al., 2006). Two more pipes were installed in 2011 which reduced the total gas content to 40% of the level it was in 2001, though there was still a significant amount of gas in the lake (Evans et al., 2012).

Since the disaster, the technical management of the CO₂ hazard and the degassing has been conducted by international organizations and scientists in collaboration with Cameroonian agencies and scientists (Bang, 2012; Kusakabe, 2017; Tchindjang, 2018). Technical expertise of the hazard is provided by Cameroonian scientists and research institutions based in Yaoundé and they remotely monitor the lake from there.

The government disaster managers focused on the technical aspects of the disaster during its management and mitigation, though local groups and organizations near the disaster area noticed that the survivors had suffered great socio-economic losses that were not being addressed. They were now living in poorer conditions, their family ties and social networks had been broken by the disaster, and that the small parcels of land allotted to each family living in the camps had created tensions over

farming space (Bang, 2012). These socio-economic factors of vulnerability have yet to be fully addressed.

3. Methods

Disaster risk (DR) is the interaction of a hazard with a vulnerable population; therefore both the specific hazard and vulnerability were characterized for this study. It is necessary to examine these two sets of opposing factors of DR in order to understand how it is constructed and what DRR measures might be most effective. Individual interviews and participant observation were used to gather data for the vulnerability analysis while satellite images were used for the hazard analysis. Literature review and primary document review were used to gather data for both analyses. The Pressure and Release model and Access model were used to analyze the vulnerability of the LND survivors. The gas hazard was analyzed using an adapted LAHARZ model in MATLAB R2018a and ArcMap 10.5.1. The results of the vulnerability and hazard analyses were used to rank the various factors of survivor vulnerability and the gas hazard and used with a risk matrix to determine DR.

3.1 Data Collection

The researcher lived and worked in Cameroon for just over two years as a Peace Corps Volunteer (PCV). For more than a year and a half of that time the researcher was located in Bamenda in the Northwest Region. During that time the researcher made frequent trips to villages in and around the Nyos area. On these trips the researcher collaborated on various projects with other PCVs and local schools, NGOs, farmers, and farming groups.

Interviews for this study were conducted over eight weeks, from October to November 2015, in the Mezam, Menchum, and Boyo Divisions of the Northwest Region of Cameroon. These divisions contain the villages, resettlement camps, and offices of government and non-governmental organizations where interview respondents were living and working. The research project [#799717-1] was approved through expedited review by the Michigan Technological University Institutional Review Board (IRB). There were 88 semi-structured interviews conducted to investigate the circumstances, actions, and perceptions of the survivors of the 1986

Lake Nyos Disaster (LND). In addition to interviews, field and participant observation and review of literature and primary documents were used to gather data for the study. Interviews were done individually with survivors of the LND living in the three villages most affected by the disaster, the seven resettlement camps, as well as with government and NGO representatives who were or have been involved in the management of the LND.

The interview guide was made up of ten open-ended questions (see Appendix A). Respondents discussed their personal and survivor perceptions of the formal and informal responses, management, and mitigation of the LND as well as their personal and survivor actions and circumstances before, during, and since the disaster. The guide was adjusted for the individual interviews with government and NGO representatives so that they could assist in verifying the timeline of events and clarifying the level and nature of their personal and organizational involvement in the disaster response and management. To ensure the protection of each respondent's confidentiality, all of their identities were coded and no personally identifiable information was collected. RCA Digital Voice recorders were used to record the interviews for translation and transcription later on.

The interviews were conducted in English, West African Pidgin English, Fulfulde, and Hausa. This way the respondents could hear and respond to the questions in a language with which they were comfortable. Two local translators, who are fluent in these languages, were trained by the researcher and assisted with conducting and translating the interviews. The researcher was present at every interview to observe and take notes as well as certify that the IRB approved project protocol was properly conducted. The translators were employed to ensure accurate translation and interpretation of the interviews as well as to assist with proper conduct of local protocols, which often varied between communities and ethno-linguistic groups within the study area.

The interviews utilized open-ended questions and "snowball" sampling techniques to obtain a wider variety of viewpoints and larger number of qualified respondents. The interviews used open-ended questions to allow respondents to talk

about what they know and not be influenced by the researcher's opinions (Morgan et al., 1992). This method allows respondents to discuss a topic as much or as little as they wish and to feel free to share any information that they feel is relevant or important even beyond the exact topic of the question. It also allows the conversation to carry on longer when a respondent has more information or knowledge about a certain topic. The sampling method, "snowball" sampling, is done by asking key individuals and respondents to suggest people who may be good candidates for the research until no new candidates are suggested (Bernard, 2006). To incorporate a wider variety of viewpoints, men and women of each ethno-linguistic group present in each location were interviewed.

Later the transcribed interviews, literature, primary documents, and field notes were compiled, organized, and coded by hand to identify themes, connections, and to categorize relevant and recurring information in order to assist with analysis. The information from field notes, literature and primary document review, participant observation, and the interviews was compared and cross-referenced. This ensured the quality and accuracy of the data and information that was collected.

3.2 Vulnerability Assessment

This study used the Pressure and Release (PAR) model and Access model (Wisner et al., 2004; Wisner et al., 2012) to assess the vulnerability of survivors in communities in the Lake Nyos area. In the PAR model, the progression of vulnerability and hazards converge to define the disaster risk of a community. This model considers a wide range of factors affecting vulnerability and goes beyond physical exposure and losses. This model is complimented by the Access model, which examines the circumstances, actions, and responses of a population affected by a disaster event. The Access model comes in where the progression of vulnerability and hazards meet to describe and elaborate on how 'normal life' is affected and how it changes throughout the disaster process. The use of these two models allows for the consideration of different factors that affect vulnerability in the study area and which factors play the largest role in that vulnerability. Data for the models came from the interviews, field

notes from participant observation, literature review, and primary documents. An open coding process that utilized inductive and deductive thematic analysis was used to identify themes and common threads and ideas in these data sets (Elo & Kyngäs, 2008; Fereday & Muir-Cochrane, 2006). First inductive coding was used to elicit data-driven themes. Then, to ensure that all relevant points had been described, the data sets were coded again deductively using themes from the original PAR model, Access model, interviews, field notes, and literature.

3.2.1 PAR Model

The PAR model (Figure 6) has two converging sets of factors: the progression of vulnerability and the hazard. The progression of vulnerability has different levels of causal factors. At the overarching level are the root causes, resulting in dynamic pressures at an intermediate level, and fragile livelihoods and unsafe locations at the local level.

The analysis began at the point of convergence; the unsafe conditions were described and enumerated using the various coded data sets. The fragile livelihoods and unsafe locations were examined first because they are the links between socially produced vulnerability and hazards. The local level factors are also the most apparent since they directly affect daily life and decision-making. Continuing outward, in the opposite direction of the progression of vulnerability, the dynamic pressures were assessed in the same manner as the unsafe conditions. The dynamic pressures help explain and underscore the impact of root causes on current unsafe conditions. The root causes were examined last since a large part of the information needed for these factors came from literature review. It was also helpful to understand the way these factors have established a foundation and produced the dynamic pressures, macro-forces, and unsafe conditions in the area.

Figure 6: PAR model from Wisner et al. (2012).

The PAR model was used for identifying and classifying the different factors affecting survivor vulnerability in the Lake Nyos area. By considering these factors this way, a “chain of explanation” can be seen and examined. The model helps discover how the vulnerabilities affecting risk are manifesting. This information can help determine possible courses of action for DRR as well as ensure that mitigation and DRR strategies that are attempted address the underlying causes of local vulnerability.

3.2.2 Access Model

The Access model (Figure 7) was used to organize and examine the anecdotal evidence from interview data. This model was used to investigate how the respondents’ lives and livelihoods were affected by the LND and at what point in the disaster process these aspects were affected. The Access model shows how different vulnerability factors and resource access from the PAR model are affected during a disaster event.

By examining these changes, the factors that are the more fragile factors can be identified. Data from interviews, participant observation, and literature review were used to examine how the disaster affected various aspects of survivors' lives at the triggering of the disaster and during the disaster in process.

The Access model is iterative which allows each iteration of the disaster process and its effects on resource access and livelihoods to be studied. There are four general stages depicted in the model and described by Wisner et al. (2004). The first stage is 'normal Life' (Boxes 1 & 2); the combination of unsafe conditions and livelihoods, level of access to resources, how resources are used, and decision-making on potential investments. Social relations and structures of domination act on and construct 'normal life' and unsafe conditions. The trigger event (Box 5) occurs when the time and space factors of the gas hazard (Boxes 3 & 4) and 'normal life' come together in the second stage. This stage is the transition to disaster (Box 6) where the first impacts, after being counteracted by any available social protections, start to affect the various aspects of 'normal life'. The third stage is the disaster in process (Box 7), which considers the reactions and coping strategies that are used to adapt to new conditions. The new conditions, coping strategies, and social protections then interact with interventions and actions taken for disaster reduction (if any) in stage four (Box 8). Stage four starts a new cycle with 'normal life' now including the changed or addressed factors. It describes the new combination of unsafe conditions and livelihoods, level of access to resources, investment opportunity decisions, and how resources are used. The outcome can be a safer, more secure 'normal life', one that is essentially equivalent to life before the disaster, or a less safe and secure life. In other words, the vulnerability of a population may decrease, stay the same, or increase through each iteration a disaster event. The features of the new 'normal life' depend on which actions are taken or not taken to improve safety and secure livelihoods after a disaster.

Since the Access model is iterative, it was used to observe the changes in access to resources and livelihoods of survivors during and after the LND. It was also used to observe the potential effects of the modeled gas eruption scenarios on current, survivor vulnerability in the Nyos area.

Figure 7: The Access model from Wisner et al. (2004).

The Access model examines how the survivors' livelihoods, access to resources, and decision-making changed throughout the disaster process. The interviews conducted with the government and NGO workers assisted in relating and connecting all of the information gathered from the interview data. This model provides the connecting point between the hazard and the progression of vulnerability.

3.3 Hazard Assessment

This study utilized an adapted LAHARZ model in MATLAB R2018a and ArcMap 10.5.1 to categorize the gas hazard posed by Lake Nyos. Both the potential

flow extent and affected populations were determined for a set of 15 gas release scenarios. The adapted LAHARZ model, which was adapted from the LAHARZ model from Iverson et al. (1998); Schilling (1998), was used to find inundation patterns similar to the LND and for a variety of gas release scenarios. Using a linear regression model, derived from the LND inundation pattern, the extent of each scenario's flow was calculated. By mapping the gas flow patterns in ArcMap, potential affected populations were found for each scenario.

3.3.1 Mapping

All of the houses within the AOI were mapped using Google Earth Pro and ArcMap 10.5.1. While running the model and mapping the scenarios, it was found that several of the scenarios extended past the AOI boundary. The houses that were considered affected by the gas flows in these scenarios were mapped so that the affected populations could be calculated. The images used for mapping were all from 2015 or later, most are from 2017 and 2018. Each house which was partially or completely overlapped by a modeled gas flow scenario was considered to be affected. The total population affected by a scenario was found by multiplying the number of houses affected by the average household size (hhs). The national average household size in Cameroon is five people and in rural areas is it eight people per household (Balgah et al., 2016; Ngwa & Balgah, 2016). A base model was created to simulate what a disaster equivalent to the LND would be like today.

3.3.2 Modeling

There were 15 scenarios modeled for this study. To do this, a base model was created using maps and point data (showing percent lethality in surveyed households) of the LND from the literature (Figure 8) (Sigurdsson, 1988; Sigurdsson et al., 1987; Stupfel & Le Guern, 1989). Since the maps did not completely agree on what areas the gas flow covered, the lethality point data was used to adjust the maps so that they agreed with the point data. Then the maps were combined to make a single map of the LND on which to test the model. The model was run using a variety of cross-sectional

areas. Starting at the lake edge, the cross-sectional area that best fit the extent of the LND flow was taken at 500m intervals. This was done for the east and west arm of the flow. These measurements were then plotted in a scatter plot by distance from the lake and each set of cross-sectional areas was fit with a line of best fit. The average slope of the two lines (-1.47) was used to create a linear regression model to determine the distal extent of each modeled scenario.

Figure 8: Outline of the LND gas path with points showing locations where people were affected (Sigurdsson, 1988; Stupfel & Le Guern, 1989).

The adapted LAHARZ model delineates inundation zones based on a given cross-sectional area and starting point. From the starting point, a pixel in the accumulation raster, the model maps the given cross-sectional area within the channel for each pixel in its path. The code follows the path of steepest descent using a DEM and an accumulation raster and continues from the chosen starting point to the edge of the raster or given stopping point. The stopping point for each scenario was determined by the linear regression model from the base model of the LND scenario. The starting point for each branch of the flow was the pixel in the accumulation raster that was closest to the lake's edge in that drainage channel. This was done for each valley except the valley just east of the lake, where Buabua is located. This area was affected by the LND but is not along one of the primary drainage paths near the lake edge. In order to map this area a pixel farther south along the valley on the accumulation raster was chosen for each scenario large enough to affect that area. The distance into the valley was based on the relative size of the gas flow. Though LAHARZ was designed to map gravity flows, it was used here because the villages that were affected by the LND are topographically lower than Lake Nyos and CO₂ is heavier than air and fills topographic lows. The adapted LAHARZ model shows which areas would be affected by flows with different cross-sectional areas.

The 15 scenarios modeled for this study have cross-sectional areas ranging from 5,000m² to 100,000m². The cross-sectional areas are in increments of 5,000m² for scenarios 1 - 10 and 10,000m² for scenarios 10 - 15. Scenarios 1 - 10 have more resolution because they are more possible than larger scenarios. Since degassing started at the lake, the amount of gas has been reduced from the amount measured just after the LND. The first eight scenarios have smaller cross-sectional areas than the model of the LND done for this study. These scenarios are relatively more likely to happen than the larger scenarios because of the reduced gas content. Scenarios 11 - 15 have a lower possibility of happening so they are given less resolution and weight in calculating the disaster risk.

ArcMap was used to determine the population and areas affected by each scenario; the people and areas that could be affected by a disaster similar to the LND

and by the 15 other scenarios. Each modeled scenario mapped in ArcMap delineated the affected area in each case. The buffering tool in ArcMap was used to determine how close the modeled flows come to each village. If part of the village intersects with the flow's buffer, it is considered to be affected and it is considered to be more greatly affected if it is intersected by the flow itself. Using the intersect tool in ArcMap, the houses that were partially or completely overlapped by each flow were found. The number of houses affected by each flow was multiplied by an average household sizes (hhs), five is the national average hhs and eight is the average rural hhs (Balgah et al., 2016; Ngwa & Balgah, 2016).

This method for analyzing this hazard is useful because it does not require many inputs and seems to replicate the extent of the LND gas path fairly accurately (Figure 9). This is difficult to verify since there is only one case with which to compare it and there are not many similar disasters on which to test the method. However, this model is simple and it covers the areas that were affected by the LND more accurately than other, more complex models (Burton et al., 2017; Costa & Chiodini, 2015). One downfall of the model is that it cannot model the flow of gas right near the lake. The way the gas must have moved around the lake during the disaster is more complex than what this model can map. It can also only model one direction and course of a flow at a time. Several starting points were required to map the LND and each gas release scenario.

Figure 9: Model of the 1986 LND using the adapted LAHARZ model.

3.4 Disaster Risk Assessment

To determine DR, from LND survivor vulnerability and the gas hazard, the resulting factors from each assessment are ranked. There are several studies which work toward quantifying qualitative vulnerability data and there are many studies, throughout a variety of disciplines, which attempt to quantify vulnerability (Birkmann, 2006; Cutter et al., 2008; Ferrier & Haque, 2003; Luers et al., 2003; Roberts et al.,

2009). Though the PAR model is usually described as a qualitative model some of the factors of vulnerability can be measured quantitatively (Birkmann et al., 2013). Roberts et al. (2009) describe how qualitative and quantification description of vulnerability factors are not always studied exclusively. Often considering vulnerability in both of these ways can facilitate the understanding of vulnerability and its multifaceted nature (Ferrier & Haque, 2003; Füssel, 2007). In this study the resulting factors of vulnerability and how they have changed since the LND, from the PAR and Access models, are considered both qualitatively and quantitatively.

Bollin et al. (2006) expresses the importance of being able to compare the variety of factors contributing to DR in order to facilitate tracking changes over time. In their study they assign each factor a number from one to three and then created a composite score for the hazard and vulnerability. They did this because of the multitude of factors they considered for each assessment. Since there are many factors that determine vulnerability in the Nyos area, a composite ranking was used for each village. Each composite ranking was based on the average (mean) of all of the vulnerability factor rankings in a village. This study used the same type of methodology as Bollin et al. (2006) and Nirupama (2012), who used a similar method and quantified factors from Wisner et al. (2004)'s PAR and Access models. One of the goals of this study is to ascertain which vulnerability and hazard factors contribute most to DR and to inform DRR efforts and policies. In order to do this the various measurements of each factor (i.e. scenario's intersection with a village, condition of roads/infrastructure, and awareness of degassing project) are ranked so that they can be compared. This was done by assigning a value from 1 - 5, based on data from the interviews, participant observation, and the literature, according to a set of criteria for each factor (described in results).

For the gas hazard, the potentially affected population for each scenario is based on the total number of houses affected. This allows the gas hazard to be ranked based on distance from the village or extent of the village covered by the modeled gas flow. Where, as a gas flow gets closer to a village the hazard ranking increases. Probability, or likelihood, is an essential component to assessing risk. However, calculating or

determining, with certainty, the probability of this hazard becoming a disaster is not feasible due to the multitude of unknown or unsure elements involved. There has only been one recorded gas release at Lake Nyos, the rate of the influx of gas into the lake is not constant, and the specific trigger mechanism is unknown. The lack of confidence in the exact nature of necessary elements used to calculate time of return or frequency makes determining a precise probability impractical. So, in this study the hazard is ranked without a probability. However, since probability is such a crucial component of hazard assessments, an additional hazard ranking, a composite score including likelihood, is determined using subjective probability.

Subjective probability is used to estimate the likelihood of an event using intuition and experience. In this case, the likelihood of each modeled scenario was determined based on information from the literature and the researcher's personal opinion. Subjective probability is often used for risk assessments, especially when there are unknown factors or there is not enough data to determine frequency (Aven & Zio, 2011; Clemen & Winkler, 1999; Cooke, 1991; Tversky, 1967). It is also used in natural hazard and disaster risk assessments (Aven & Renn, 2009a, 2009b; Marzocchi et al., 2004; Marzocchi & Woo, 2007; Neri et al., 2008; Woo, 1999). Many risk and hazard assessment studies focus on volcanoes because of their complexity and unpredictable nature (Aspinall et al., 2003; Donovan et al., 2012; Martí et al., 2008; Marzocchi et al., 2004; Sobradelo et al., 2014; Sobradelo & Martí, 2010; Woo, 2008). The LND is similar in its unpredictability. This is mainly due to the lack of specific knowledge on the nature and mechanisms of the hazard. Owing to the lack of information that usually informs disaster event probability; this study uses evidence that is known about the gas hazard to advise the interpretation of the likelihood attributed to each modeled scenario. It should be noted that the likelihoods used for this study are the researcher's personal opinion and intuition. It is known that there is less gas in the lake now than there was just after the disaster in 1986 and that the lower gas content is due to the active artificial degassing that is ongoing at the lake (Kusakabe, 2017). However, it is also known that the recharge rate of the gas is variable (Evans et al., 1993; Evans et al., 1994). These elements were used to inform the researcher's opinion when attributing likelihood to

each modeled scenario. The concept that smaller disasters happen with more frequency than larger disasters was also considered because of the nature of the hazard and the way gas accumulates in the lake (Camerer & Kunreuther, 1989; Kaplan & Garrick, 1981; Kunreuther, 1996; Merz et al., 2009).

The likelihood factors used are between zero and one so that when they are combined with the hazard rankings to make a composite score they are still comparable to the vulnerability rankings. This was also done so that the composite score could also be used in the risk matrix used to exam the DR. Risk matrices are often used to examine the likelihood and consequences of a disaster event. In this study vulnerability is also considered in the matrix, which is sometimes done when risk matrices are used specifically with natural hazards (Aven, 2007; Garvey & Lansdowne, 1998; Glade, 2003).

4. Results and Discussion

4.1 Vulnerability Analysis

The Pressure and Release model was used to explore current unsafe conditions in the Lake Nyos area while the Access model was used to examine the changes in access to resources throughout the process of the 1986 LND. In this way differences in how current access could be affected in the event of another gas release can be investigated. Understanding the factors that create disaster risk and how those factors may be affected by specific disaster events is essential to effective DRR, risk management, mitigation efforts, and disaster-related initiatives. Disaster risk is created by the interaction of one or more natural hazards and vulnerability, making it important to consider the variables from both sides (Wisner et al., 2004; Wisner et al., 2012). Disaster risk in the Nyos area comes from vulnerabilities specific to the area and created by root causes, dynamic pressures, and unsafe conditions which developed on the local and national levels. Vulnerabilities vary among populations due to a variety of factors, including socio-economic status, age, gender, and access to resources. These factors are dynamic and change as conditions and access change (Birkmann & Wisner, 2006; Wisner et al., 2004).

4.1.1 The Disaster Process of the LND

On the evening of the Lake Nyos Disaster, people in the villages were going about their regular evening tasks. They were cooking, eating dinner, children were playing, and many families had already retired for the evening when Lake Nyos erupted. Many survivors described how they had no idea what was going on and quickly became disoriented. This was due to the lack of oxygen, which was displaced by the carbon dioxide (Baxter & Kapila, 1989; Baxter et al., 1989). One survivor described how she became confused and did not know what was happening:

“On that day, we were out in the fields. And immediately after we came back from the farm, we had our bath, ate, and slept. It all began

with my baby. The baby began to stress and stretch her body. I thought, “What is happening?” The lamp was on, then immediately, it died down by itself. I got up and called my child and asked, “Where are the matches? I want to light the lamp again.” I took the match and I lit it but to no avail. Then the other children, who were sleeping, started falling in different directions. Even the baby I was holding in my arms, fell down and I didn’t even realize. We struggled and struggled until we moved out of the house, not even dressed, moving around. We did not even know what we were doing. I also didn’t know where I was going. My senses only came back a long time after that. When my sense came back, I realized I had been watching the children. I went back to the house. I found the children; they were lying where they had fallen. The ones under the bed had excreted. Then I joined all the children in the same place. At that point we smelled something like gunpowder. The children were breathing heavily, gasping for air. Then my husband’s brother came down and was crying, saying that he didn’t know what he would tell his brother about what had happened to his family. [His family was similarly affected.] We sat there until it was morning. And then we heard that it did not only occur in our compound but it was everywhere in the village.”

Many people found it difficult to move and were often unable to help themselves. Those who could, went to give help and get help from their families, friends, and neighbors. A respondent describes how difficult it was to walk or even move:

“So, actually what happened that night to me was that we were sleeping. Everybody was asleep. I was not sleeping, I just lay in bed. And all of the sudden it sounded as if there was a storm outside. At first I thought, “Oh, we need water. I should go and get the pots so they’ll be

outside.” Then I thought, “No, they are already outside.” And then I worried, “Oh, I hope the lids don’t get blown away. I should go protect them, put stones on them.” And then it occurred to me, “Oh, no, it will be okay, they are safe outside”. So, that was the last thing I could remember, thinking about the pots and the buckets outside. And when the people finally came to our compound, I did not know exactly what was happening. So, as I was gaining consciousness, I heard a woman talking to me. And I felt as though the ground beneath me was shaking and I was falling again and again on the floor. And the woman was still talking to me. And when my eyes opened, I realized that I was bundled in a blanket from inside but I was outside. And Alhagi [a title given to a Muslim person who has completed the pilgrimage to Mecca], who lives below us was there. So, Alhagi who lives below us was one of the people who helped drag me outside. I was wrapped in a blanket. And I could still feel the ground under me turning and turning. And I started vomiting. But all that I was thinking was that I was sick, that I was recovering from a fit. So, in the morning I was unable to recognize anybody. I opened my eyes, I could see but I was unable to recognize the children. And I realized that all the fowls in the compound were dead. Alhagi was making desperate attempts to reach out to people to come and find out what is happening. That night he rushed out, fell down, couldn’t breathe. When he recovered and regained consciousness he rushed back to the compound and tried to go out again. He was trying to run out that night to call people to come and see what is happening but he was unable. He was just lucky, he would have died too. So, that morning I was unable to stand up and I had a baby, a small child by then. Another woman had to carry that baby. We were struggling to go up to Alhagi’s compound up the hill from our compound. And so I was down, kneeling down, creeping on the ground as we were going up. I was unable to move.”

As people started to recover, they went around checking on their families, friends, and neighbors. Many respondents explained how they found very few people alive, so many had died. A respondent recounts the scene that many of them found:

“Nearly all of those who survived, they went round to various compounds to see the type of damage and people dead. They went down to the village of Nyos to see how everyone was, they were dead. I was just lying down I was unable to move, I was just weak, I couldn’t even stand up. So, after two days I felt a little better and I was able to move. So, I went down to the village of Nyos and I saw corpses thrown here and there but I didn’t go to any Aku [an ethnic subgroup in the Northwest Region known for being cattle grazers] man’s compound to see the situation. I only had the opportunity to go to Nyos village and arriving there I saw corpses thrown left and right beside the road, trees, plantains and banana stems uprooted from the ground, their roots lying outside. So, everywhere there were corpses. So, things were just scattered anyhow, every living thing was motionless, was dead. Every living thing was dead.”

One of the first NGO responders who arrived at Lake Nyos after the disaster also describes what they saw:

“Yes, on Sunday morning, I heard that something had happened somewhere between Kumfutu and Misaje. In that area, the valley there. So, I happened to meet the SDO, who had also heard reports and was preparing to go and investigate. So, I asked him whether I could join the party and go with them. So, he accepted and I joined them. And when we reached the level of Kumfutu, which is still high up, the whole convoy

stopped. So, I then inquired and said that, "What happened? Why are we stopping here?" And they said, well they don't want to go any further. So, I asked for permission to proceed because I saw some people coming out of the valley. So, I reasoned with them, that if people can come out of the valley, I could go in too. And then I went ahead and then I reached first, Cha. Then I went to Nyos. And from there I continued to Subum. And, so, in Cha, I met people who survived, who had woken up and regained consciousness. And I also saw many people who were dead there. Then in Nyos, I met also people who were sitting there but they were not the people who had been in the village on the night of the disaster. These were people who had come down from the hills, so they were mostly Aku people, who had cows on top of the hills, and who were now, you know, sitting there just... just not knowing what to do. And of course, everywhere again, I saw dead people, dead cattle, just no sign of life, not even a mosquito or a fly or anything. Nothing. So, it then happened that a helicopter pilot flew over. He had also, apparently, heard that something had happened and he flew over the lake. He noticed me and came down and I asked him then, could he bring me back to the point where I had left the SDO and the other people? So, he accepted and we went back and we couldn't see anybody anymore at that point where I'd, where I'd left them. And so, we went back as far as Weh, and no one was there. So, he brought me back to Nyos and then took off and went his own way. And I continued to Subum, where I again met people who had survived the gas eruption and others... many of them were, dead. When I went back and I took people with me who wanted to be evacuated, who had burns and other kinds of injuries, I deposited them at the Wum Hospital. And then I went to see the SDO, at his residence, at Wum Lake, and I gave my report. Then we went together to the post office, because at that time there was no

telephone connection or what there. There was no connection. You could only call through the post office.”

Many survivors lost their social networks, their support systems. Family and friends are the first place community members go to for physical help, financial assistance, or shelter in times of hardship. Many of them also lost a significant portion of their assets and in some cases, their entire livelihood. The LND killed many cattle and other domesticated animals. For some survivors their livestock had been their main source of income. A respondent describes how his life has changed from losing his main livelihood:

“I prefer the way life was before the disaster because, by then, I had my milk and I would drink it. And I had my cattle... I was fine then and I did not have so many worries. But now I’m not living fine. I’m in ‘level one’ now. I have nothing. By then I was in ‘level two’. But I’m in level one now.”

Many survivors talked about how they felt as though they had not been able to return to the same standard of living that they had in 1986. They often expressed their hopes for their children. One survivor talks about his current situation and his hope that his children might have a better life some day:

“No, I have not really gotten my life back. Maybe my children will one day have something like that. But for now, there is nothing... Even the house that I had before that disaster, I don’t have it now.”

4.1.2 The Progression of Vulnerability in the Lake Nyos Area

In order to understand disaster risk in the Nyos area, it is necessary to understand the unsafe conditions present there and which are created by historic socio-

economic structures and ideologies. The root causes, dynamic pressures, and fragile livelihoods and unsafe locations of the progression of vulnerability in the Lake Nyos area are presented in the PAR model for the Nyos area (Figure 10). The Access model augments the PAR model and reinforces the determination of the fragility of vulnerability factors.

Figure 10: The progression of vulnerability in the Lake Nyos area, Cameroon, adapted from Wisner et al. (2012).

Root causes

The vulnerability of survivors in the Nyos area is deeply embedded in the country's history and power structures. The anglophone regions of Cameroon have a history of federal and national-level socio-economic and political marginalization which has led to the underrepresentation and powerlessness of anglophone Cameroonians (Achankeng, 2015; Akum, 2009; Vubo & Ngwa, 2001). Since reunification, anglophone Cameroonians have felt that they were being subjugated by the francophone federal government. In turn, this has led to a sense of cultural nationalism among anglophone Cameroonians. The federal government, under the guise of attempting to drive uniformity for national unity, often tries to impose the

French systems of law, education, and other institutions on the anglophone regions (Akum, 2009; Vubo & Ngwa, 2001). Since Cameroon is a bilingual country, all of the francophone students are taught English and all of the anglophone students are taught French. There is a clear difference in the level of enforcement this system receives between the anglophone and francophone regions. Anglophone civil servants and government agents posted in francophone regions speak French whereas francophone civil servants in anglophone regions often speak little to no English (Akum, 2009; Ayafor, 2005). Ideologies shaped by the region's history and culture also affect vulnerability in this area. Although the gas hazard represents one of the most potentially disastrous natural hazards in the area, many community members do not consider the gas hazard an important safety threat. When asked about their perception of the gas hazard, many respondents expressed either that the gas hazard no longer presents a danger or that it does not matter whether or not it is dangerous. Many respondents believe that they will certainly die if an eruption occurs because it would be fate:

“Well, there is nothing. I’ve just come back with only one aim in my mind, if it is to happen, let it happen and if I am to die in that particular incident, I will aim to die. That will be my fate.”

This fatalistic worldview is shared by many in the local communities and even talking about the disaster is seen as asking it to happen. One respondent, living outside of the disaster area, discusses this viewpoint:

“The only thing I can tell you is that, your conscience should be clear because it is an emergency, something that nobody expected is going to come. So, feel free and I beg you we should only be thanking God. Whatever comes, whether it is good or bad, we just have to accept it. We cannot say, this things has come as if you were expecting it to come. It is a surprise, just like death too. Because all of us are visitors

here, we will go back as we came. And you cannot refuse to go back because you did not even know how you came. So, I can only say, it is God who gives and he is the one who takes away. So, sorry. All of us are a part of who will go, nobody will remain here. That's all the advice I can give you if you were to have any problem too."

Survivors believe that there is nothing that they can do to change how they might be affected. In conjunction with this, there is also a belief that is summed up by a common phrase used by Cameroonians, "On va faire comment?" When the people use this phrase they mean, "What can anyone do?" Many stated that even if they are afraid of the hazard or think it is dangerous, they have no way, financially or physically, to escape from a gas eruption. Many also stated the importance of living in the place where you were born, even if it is dangerous. One survivor expresses this feeling:

"It's just that we don't have anywhere to go. Like, if we had a place to go then we would not be here. That's why, in case that lake, that thing happens again it will only kill us. But we don't have a place to go because this is where we were born."

These ideologies and beliefs discourage disaster preparedness because death is viewed as inevitable if the disaster occurs no matter what is done in preparation. Many respondents expressed that preparing for a disaster is pointless:

"Hmm... I don't think, I don't think there is anything people can do except prayers, except prayers. There is nothing that we can do; it is only prayers to God, little prayers to God. Yes."

There is not much of a culture or idea of disaster and disaster preparation in Cameroon. One of the NGO workers discusses this during their interview:

“And I have no knowledge of whether they do anything to protect themselves against natural disasters. There is always a question, whether people here, in Cameroon, believe in natural disasters. When something happens, then they try to find an explanation for that. Maybe because of their lack of scientific knowledge, or what, but mostly they find the causes of a disease or a natural disaster in relationships, in relationships with other people who are still alive or in relationships with people who have deceased already, who are dead. So, their forefathers may be displeased because of certain things, that they have not followed certain traditions, or what, or maybe because of jealousy from some people against others. These they normally see as the causes of disasters.”

Dynamic pressures

The centralized political structure delays and curtails decision-making on the regional, divisional, and local levels. Local and regional politics are also dominated by this centralized power structure which leads to a lack of representation for small, rural communities like those in the Nyos area. Dynamic pressures in the PAR model are the ‘chain of explanation’ that convey the influence of historic root causes on current unsafe conditions (Wisner et al., 2004). The Access model also considers these factors and how access to them could change during a disaster event. Poor access to resources has negative impacts on many aspects of village and community life and makes the community less able to cope with a potential disaster.

There is a general lack of local institutions in the Lake Nyos area; though there are several more schools and health clinics than there were in 1986. Shortly after the disaster, buildings for accommodating researchers and government agents were built at the lake (Bang, 2008). However, permanent institutions dealing with risk, disasters, and first response are still located far from the area. Local institutions that are present usually lack offices or official meeting places and those that do have offices are often understaffed and ill equipped (Bang, 2012, 2013, 2014; Gaston et al., 2012). The

government agencies that deal with natural disasters include departments specifically dedicated to monitoring hazards posed by Lake Nyos and evaluating the conditions in which survivors live. However, these agencies maintain little to no presence in the Lake Nyos area. The closest offices are in Wum, about 30km from Nyos, and most of the monitoring is done remotely from offices in Yaoundé (Bang, 2008, 2012, 2016). Although 30km is not a long distance, due to poor road conditions and infrastructure, it takes an hour to travel this distance in the dry season, sometimes more in the rainy season. When asked if he believes that another disaster like the LND would be worse than in 1986, one respondent passionately describes the poor road conditions and unfulfilled promises of assistance:

“Yes! For example, the problem is that they said they will dig this road, since then right up til now, they have not done it. So you see, they have not done anything. They said they will dig this road, they have not dug it. The road leading from here to the lake, they said they would dig it and put tar on it, they have not done it. So all those fake promises are never fulfilled, that is what I am trying to say. And even this road that you used to come to this place, if not of the benefit of WADA [Wum Area Development Authority, a local NGO], because this area was the WADA zone, like there would be no road linking this place to other places.”

At the time of the LND, there were no hospitals or health centers in the area. Survivors went by foot or were taken to the hospitals in Wum and Nkambe, 30km and 63km from Nyos, respectively. When asked how long it took survivors to arrive at the hospital and mission in Wum, an NGO worker recalls:

“Well, I can say, some two or three days. And then a week went by and people were still coming.”

Many people remember not knowing what was happening. They discussed how people from other villages came to help. Respondents often spoke about waking up in the hospital, one remembers:

“We discovered that we were in the hospital. And we did not know what we were doing and we did not even know what had happened. When news had circulated about the disaster, people had come from Fonfuka, Wum, and Nkambe. They rushed to help us. They all came with vehicles. They took some people to the hospital in Wum while others were taken to the hospital in Nkambe.”

According to an employee at the hospital in Wum, the hospital has been made a district hospital so that it might better assist people if another gas eruption occurs. A health center has also been built near Subum. This increases community access to health care. However, the clinic is within the area affected by the LND and the community would not be able to use the facility in the event of a similar eruption.

Many people in the Nyos area do not fully understand what happened during the disaster and the nature of the hazard (Bang, 2012, 2013, 2016). There is a lack of training and scientific knowledge generally and regarding the gas hazard. A few schools have been built since the disaster and, according to respondents; it is not an easy task getting such investments for their communities. Members of the community are usually required to buy materials and build the schools. Once the building is complete and the school has teachers and students, the government will come and approve it as a government school. Many respondents talked about the lack of schools and how they struggle to get them made:

“If you look at our schools, they have been constructed by us. The government has approved our G.S. school here, government secondary school here.”

This is a difficult feat to accomplish for the communities because of the financial burden that it puts on community members. Training and scientific knowledge is also lacking due to the corruption of some officials and normal bureaucracy of government offices. Permission must be obtained to post information publicly or disseminate information through schools or similar means and this permission often requires a bribe payment (Bang, 2013; Daniel, 2016; Neneh, 2014). This keeps information from being shared easily and freely, which contributes to the community members' lack of knowledge on the hazard.

After the LND, the population of the Nyos area changed completely due to the evacuation. Several thousand survivors fled their homes and went to stay at missions, hospitals, and even in fields in other villages (Bang, 2008, 2012, 2016). Most displaced survivors lived away from the disaster area for the following two years in temporary tent camps. One NGO worker describes the areas where the displaced survivors stayed for those two years:

“The whole [Nyos] valley was then out of bounds. And then, of course, the question came up, “Where do we put these people?” So, at the mission, in Wum, St. Martins, there was a former domestic science school, which we didn’t use anymore. So, it was decided that it should be offered to put up people. Fields were made available, where you see the health center now. That was a field. So we put up the area with tents. We had the parish hall, which was made available. They made available the field in Kumfutu, where there was an out station. So, a small church community there, a school, and a field. Those were made available too. So, all that happened in just the week after the disaster.”

In 1988, almost two years after the disaster, the government and local missions, with assistance from international aid, built resettlement camps where survivors could be permanently relocated. Some of these camps were built next to villages where survivors had stayed during the two year period while others were built next to villages

closer to the lake. Although many survivors stayed away from the Lake Nyos area, some moved back to their homes shortly after the disaster and others followed when they faced difficulties in the resettlement camps. A respondent discusses how many people have moved back to the villages around Lake Nyos:

“I think the life in Subum was better. That’s why people are going back there. Or if the life in this camp was better for them, they would have not been going back there. For here we don’t even have our farming lands. If you even have the farming lands, the lands are ill fed. So, there is nothing good in this place. That is why most of them are going back there. We want to get the population of those who are living here and those who are going back there. So, that population of those going back there are more than those who are staying here. All of those who are living here, they are still farming but up there. So, there is nothing good here.”

Another respondent describes life in the resettlement camp, how aid was unevenly distributed, and why he and others decided to move back to the Lake Nyos area:

“[The government would] usually bring us food and other items, like blankets and sometimes when they come, to the head of each family, they will give him some amount of money like 5,000, which is not even enough. They will give him 5,000 francs to run for the whole week. And you don’t even know what to do, it is not even enough. Then they will stay away for like 12 months and then they will come again, they will bring food stuffs like rice, beans... In fact they usually just bring food and throw it to us like we are fowls. The way you feed fowls, you throw the food on the ground, they come and pick and eat. That is how the government usually comes. Then after that they came with some cattle.

They gave people cattle too, but we, most of us who are living this way, nobody received a single cow. But other survivors, like those who were in Upkwa and in Kumfutu and Esu, they all received cattle from the government. Even some people in Kimbi and Ipalim also received cattle. But those of us who are around this area, did not receive anything like that. And the government, by that time, tried to explain to us why it happened like that. They said that, “Why did we move out of the place that they gave us?” We told them that our cattle are dying where they kept us and we cannot sit and watch them die, meanwhile we have other places that we can take them to. That is why we decided to move out.”

During the two year period between the disaster and the building of the camps, people moving into the area found empty houses with farm land and took up residence there. Later, this barred many survivors from returning to their ancestral homes near the lake so they had to stay in the camps or move to different villages (Bang, 2009; Bang & Few, 2012). This also happened in the resettlement camps. Several interview respondents living in camps indicated that houses vacated by their neighbors when they returned to the disaster area were taken over by people attempting to take advantage of incoming aid.

When survivors were resettled in camps most families were given a 30m² plot of land and a house. The spacing and size of each parcel of land does not provide sufficient space for farming and restricts local farmers' choices in what crops they grow (Bang, 2009, 2012; Bang & Few, 2012). Even survivors who live in the villages near the lake or have found space elsewhere choose to grow crops that they are sure will grow and that their family will use. In some cases, resettlement camps were built on land that was already being used by other cattle grazers or farmers. This, in addition to poorly defined field and pasture borders, has caused significant discord between farmers and grazers (Bang, 2008, 2012). This can be even worse in areas where there are semi-nomadic cattle grazers who do not use defined grazing pastures. One respondent describes how serious this conflict is in some areas:

“As we are here, the cows do not allow us to farm. They are everywhere. We cannot even farm next to our own houses because the cows come and eat everything. And there is nothing that we can do. If we try to tell anyone [in the government or city council], the Mbororos [an ethnic group who are nomadic cattle herders] come and kill that person. There is one boy here who is about to go to Wum because they killed his brother. Cows ate his crops and he wanted to tell someone, so they beat him and killed him. We can work a small piece of land in front of your door and you still won’t be able to eat.”

There is ongoing ethnic discrimination in the area that is rooted in the region’s history but is exacerbated by the lack of arable land. Several interview respondents, like the one quoted above, described how this or that ethnic group was part of the reason their living situations are not as good as they could be. There was blame being placed on farmers’ or cattle grazers’ ethnicities as being the cause of the farmer/grazer conflict (Bang, 2009; Pelican, 2006, 2008). Some respondents also described how various ethnic groups benefited more or less than another from the resettlement and aid that was distributed after the disaster. Sometimes this is tied to the ongoing conflict and terrorism happening in neighboring countries. Some respondents, when approached as a possible interviewee, expressed suspicion of people from outside the area or other strangers. Some talked about their fear that agents from terrorist groups or refugees from conflict zones would come to the area since they live so close to the border with Nigeria.

Fragile livelihoods and unsafe locations

Fragile livelihoods and unsafe locations are the direct links between a disaster and the deeper causes of socially produced vulnerability. They are the most evident factors because they apply directly to the resources and functions of daily life and livelihoods. Communities in the Lake Nyos area rely mainly on agriculture; subsistence

farming and cattle grazing are the two primary occupations. Community members have limited land and limited access to land on which to farm and graze their cattle, especially in the resettlement camps. One respondent who has moved back to the Nyos area stresses the limited space available for farming:

“As we were in Kimbi, it was the government that was feeding us, paying for everything. As for me, on my own part, I’m telling you what I know, I was just doing farming on a smaaaall piece of land.”

This has compelled many survivors to move back to the disaster zone. Some moved back because they were able to farm on their original fields and others moved because of more fertile soil and available land (Balgah et al., 2016; Bang, 2012).

Many survivors of the LND report that their health has not been the same since the disaster and because they are older and do not have the strength or endurance that they used to. Life expectancy in Cameroon is about 55 years (CIA, 2017) and those interviewed were all at least 30 years old, many were much older. Several interview respondents expressed that they would not be able to escape a disaster if it depended on their strength or moving quickly. They said that they would just have to wait for it to come since they wouldn’t be able to run.

Many people in the area complete grade school and sometimes at least part of secondary school. After school most of them become farmers or cattle grazers, learning by helping their parents in the fields (Balgah et al., 2012; Bang, 2008). Those who are able to go to cities have more opportunities for training in skills other than farming and cattle grazing (Balgah et al., 2012).

People in the Lake Nyos area, especially if they are survivors of the disaster, have limited social networks. Family members, relatives, and neighbors usually make up a person’s social network but survivors of the LND lost many of these people in the disaster, either through death or separation (Bang, 2008, 2009, 2012, 2016; Bang & Few, 2012). In times of hardship, the first place people in the area go is to this social network for assistance (Fleischer, 2007). Respondents described how they ran to

relatives and neighbors for help when the disaster happened. Many survivors can no longer do this; they have had to create new social networks since the disaster. This has not been easy for them to do because they were moved into the resettlement camps where the neighbors living in the houses on either side of them could be from a different village, religion, ethnic group, or even speak a different native language (Pelican, 2006). It was also difficult because of increased social tension over farming and grazing land (Bang, 2012).

Local market access is hindered by poor roads and infrastructure as well as low income levels which keep people from traveling. Due to poor road conditions and lack of income available for travel and transport, vendors from outside the area rarely come through and local farmers with produce to sell are rarely able to travel to markets where there could be improved access to buyers. Communities around Lake Nyos, especially in the resettlement camps, have limited land for agriculture and economic factors that tie people's livelihoods to the land affect local markets. The lack of physical locations and structures are due to the lack of local investments. However, the lack of buying and selling is caused by lack of crop diversity and poor transport. One respondent expressed discontent with government aid and the state of market roads:

"I think in 2012, they came with some food items, some blankets, some mattresses, and gave people here. But, I, for one, don't consider that as, as a good help. Because if the government really wants to help they would select some few children from this area and sponsor [them to go to school]. There is even no farm to market road, even if the government can help us to open up this road [motions to Buabua-Fundong road], I think it will pass through Fundong to here. You've seen the nature of the road. So, if the government was to do that or if the government did that we'd have been very happy. I would not cry of my poverty here again. Everything, everything does well here [crops grows well]. But there is no means to transport it to the market."

A majority of community members are farmers and they grow crops that do well in the environment and that they will use in their households (Amin & Manga, 2010; Ngwa & Balgah, 2016). Community members would rather not than spend money on produce they already grow or can grow for themselves. Subsistence farmers also rarely buy produce because they grow many of the same crops and have even less disposable income (Amin & Manga, 2010). The lack of income also causes a lack of job diversity and opportunities. People are not able to risk what little they have in order to invest in a new venture or opportunity.

In most places in Cameroon, even in some larger cities, formal credit is almost nonexistent; items must be paid in full before they can be taken home. Banks do provide loan services but have very stringent guidelines for borrowers (Mayoux, 2001). These services are rarely available outside of larger towns and cities and are not usually financially accessible to rural farmers (Balgah et al., 2012; Bime & Mbanasor, 2011a, 2011b). Common forms of credit used locally are njangis and tontines. These are groups formed by community members and are a way to save money and also to get access to loans in times of financial need. A respondent describes why so many people in the community use njangis:

“My reason for playing Njangi is that, as I am like this now, if I have two hundred francs in my hand, I will go and play it in the njangi. Because it can happen tomorrow that I’m sick. I can go to the njangi house and say, “Let them assist me.” They can decide to give me even five thousand for me to use and go to the hospital. Or even if it might be my child who is sick, I will just rush to the people and say, “Please, my sisters, assist me. You know I usually come and play njangi here. Please, assist me and give me money.” They will easily decide and give me money to take my child to the hospital.”

The exact terms of the group are decided by the members, i.e. the order and timing of loans given out, the interest rates on loans, etc. (Bime & Mbanasor, 2011a,

2011b). Another respondent explains how each member contributes a small amount of money to the total to be handed out as loans:

“Yeah. I sold my planks. I have a hundred francs, I go and play there every country Sunday [local day for resting]. Like yesterday was a country Sunday. When we receive this money we will send our children to school. Like now we have recently shared the njangi, then we are starting back again. Sometimes when you have an accident or an emergency you can rush there and then collect some money to solve the problem or you go and buy your medicine. So we play in the njangi every country Sunday and Sunday is 100 francs.”

Often group meetings are also a social opportunity for the members and food and drink are shared. Many of these groups run without issue however there is a great deal of distrust between people when it comes to dealing with and handling money (Azibo & Buchenrieder, 2011). This makes it difficult for some groups because of the interest rates and loan pay back times they impose and the action taken when someone cannot or does not pay back their loan on time. This is the main way of gaining access to credit in the camps and villages, so many community members belong to a njangi or tontine.

Before the LND there was very little in the way of disaster preparedness and though this has increased since the disaster, there are not many emergency service workers or offices kept in the Nyos area (Bang, 2008, 2009, 2012, 2013, 2016; Bang & Few, 2012; Le Guern et al., 1992; Shanklin, 1988; Tchindjang, 2018). There is also not a strong social protection network setup in the area. Most government offices and resources dealing with disaster preparedness and social protection are at least an hour or more away by car. This, in conjunction with poor road conditions, makes it difficult for emergency responders to get in and out of the area and for community members to reach or have access to these types of resources.

4.1.3 Vulnerability Ranking

Each factor in each village was considered individually and was determined by participant observation data, interviews, and literature. The factors were ranked from 1 - 5, where generally 1 represents a factor that was not discussed as significantly contributing to the survivors' vulnerability due to excellent access to the resource and/or the factor was discussed as something of very low concern or importance to the respondents, 2 represents good access to the resource and/or was described as being of low concern or importance, 3 represents fair access to the resources and/or of moderate concern or importance, 4 represents mediocre access to the resource and/or of high concern or importance, and 5 represents poor access to the resource and/or of very high concern or importance. All of the vulnerability factors considered are summarized and ranked in Table 1. The factors that are root causes are not included because they are too deeply ingrained and require significantly more in depth study to be cover thoroughly within the scope of this study.

Cha and Buabua generally ranked higher in all the factors because they do not have the same access or same quality or quantity of resources as Nyos and Subum. They rank higher in societal deficiencies than Nyos and Subum because Nyos and Subum are located on the Ring Road and have easier access to certain resources through transportation and services that come along the road. The Ring Road is the main access road through the Northwest Region. Cha also sits on this road but has no health clinic or market like Subum and no school or several hundred meters of improved road like Nyos. This is the same case with the macro forces. Cha and Buabua have higher rankings because factors such as 'farmer/grazer conflict' and 'ongoing ethnic and linguistic discrimination' were discussed more often and respondent's expressed their significance in the community.

Since Nyos and Subum are on the Ring Road they are easier to reach than Buabua. This means that they receive more visitors, government and NGO assistance, and local government investment. Buabua also typically ranks higher than Nyos and Subum because there is little to no infrastructure there. Buabua has a market structure but little buying and selling happens there, the roads are very poor, and there is no cell

phone reception. In the villages on the Ring Road cell phone reception is sometimes available. Cha also ranks higher than Nyos and Subum because it is a smaller village and only recently began the process of building its own market. The occasional market that is held in Nyos and the weekly market in Subum help those villages attract buyers and sellers from nearby who bring some money to these villages.

Table 1: Ranking of vulnerability factors. Factors are ranked from 1 - 5, 1 being excellent access and/or of very low concern, 2 being good access and/or of low concern, 3 being fair access and/or of moderate concern, 4 being mediocre access and/or of high concern and 5 being poor access and/or of very high concern.

Dynamic pressures		Nyos	Cha	Subum	Buabua
<i>Societal deficiencies, lack of</i>	Local institutions	4	5	3	4
	Training/scientific knowledge	3	5	5	4
	Local investments	3	3	3	5
	Local markets	3	4	2	5
	Infrastructure and maintenance	4	5	4	5
<i>Macro-forces</i>	Rapid population displacement/change	5	5	5	4
	Change in local demographics	3	3	4	5
	Ongoing ethnic and linguistic discrimination	2	4	2	3
	Farmer/grazer conflict	2	5	2	4

	Poor governance and corruption	4	4	4	5
	Ongoing conflict/terrorism in neighboring countries	3	3	2	3
Fragile livelihoods and unsafe conditions		Nyos	Cha	Subum	Buabua
<i>Natural resources</i>	Lack of arable land	1	4	1	5
	Lack of water	1	3	3	1
	Lack of crop diversity	3	3	3	5
<i>Physical resources</i>	Dangerous location	5	5	4	3
	Poor infrastructure	4	4	4	5
<i>Human resources</i>	Fragile health	3	3	3	4
	Limited skills and formal education	4	5	4	4
<i>Social resources</i>	Marginalized groups or individuals	3	4	3	5
	Limited social networks	5	5	5	5
<i>Economic resources</i>	Poor access to market	3	4	3	5
	Low income levels	3	5	4	5
	Limited access to formal credit	4	5	5	5
	Lack of job diversity and opportunities	2	4	3	4
<i>Political resources</i>	Lack of disaster preparedness	4	4	4	4

	Poor social protection	5	5	5	5
	Poor government/community relationship/trust	3	5	3	3
Total		89	116	93	115
Average (mean)		3.30	4.30	3.44	4.26

Considering the vulnerability assessment alone, the survivors in Cha are the most vulnerable of the population interviewed for this study. However, this changes once the assessment of the gas hazard is taken into account. It should also be noted that vulnerability is not constant; it is continually changing as different factors are changed or addressed.

4.2 Hazard Analysis

4.2.1 Scenario Models

By analyzing the social vulnerability and exposure to the gas hazard a disaster risk profile can be created for the villages in the Nyos area. The social vulnerability of many survivors in villages where interviews were conducted has increased since the LND. A few improvements have been made in some areas though many still do not have sufficient access to basic resources and secure livelihoods. The mapping and scenario modeling show that a gas release similar to the LND could affect approximately the same number of people as in 1986. In 1986, about 5,700 people either died or were affected by the disaster. The population affected by the base model created for this study was 3,655 to 5,848 people. There were 731 houses that intersected with the LND base model. The modeled scenarios show that even smaller scenarios could affect many people if they occurred. Each run of the scenarios also indicates that the distance the gas travels has more impact on the potentially affected population than the cross-sectional area of the gas. The grade of the valley walls usually lead people to build along the valley floor rather than on the slopes. Due to the slope of the valley

walls, an increase in the cross-sectional area of the flow would mainly extend vertically. This means that the distal extent of the gas flow, which is calculated using the average slope of the regression model and which extends horizontally, covers more of the populated space.

Figures 11 - 25 show the 15 modeled scenarios with the gas flow depicted as orange polygons and the AOI outline in red. The village of Nyos is affected in every scenario, Cha is affected by 14 of the 15 scenarios, Scenarios 4 - 15 affect Subum, and Scenarios 5 - 15 affect Buabua.

Figure 11: Scenario 1 with 5,000m² cross-sectional area and AOI.

Figure 12: Scenario 2 with 10,000m² cross-sectional area and AOI.

Figure 13: Scenario 3 with 15,000m² cross-sectional area and AOI.

Figure 14: Scenario 4 with 20,000m² cross-sectional area and AOI.

Figure 15: Scenario 5 with 25,000m² cross-sectional area and AOI.

Figure 16: Scenario 6 with 30,000m² cross-sectional area and AOI.

Figure 17: Scenario 7 35,000m² cross-sectional area and AOI.

Figure 18: Scenario 8 with 40,000m² cross-sectional area and AOI.

Figure 19: Scenario 9 with 45,000m² cross-sectional area and AOI.

Figure 20: Scenario 10 with 50,000m² cross-sectional area and AOI.

Figure 21: Scenario 11 with 60,000m² cross-sectional area and AOI.

Figure 22: Scenario 12 with 70,000m² cross-sectional area and AOI.

Figure 23: Scenario 13 with 80,000m² cross-sectional area and AOI.

Figure 24: Scenario 14 with 90,000m² cross-sectional area and AOI.

Figure 25: Scenario 15 with 100,000m² cross-sectional area and AOI.

Table 2 shows the number of houses and population range affected by each modeled scenario. Scenario 1 affects 35 houses and almost 200 people even though it is a relatively small gas release scenario. The largest scenario, Scenario 15, could affect as many as 14,000 people, some as far as 40km from the lake.

Table 2: Number of houses and population range affected by each modeled scenario.

Scenario	Cross-sectional area	Houses affected	Population affected (hhs 5-8)
1	5,000m ²	35	175 to 280
2	10,000m ²	119	595 to 952
3	15,000m ²	171	855 to 1,368
4	20,000m ²	243	1,215 to 1,944
5	25,000m ²	457	2,285 to 3,656
6	30,000m ²	480	2,400 to 3,840
7	35,000m ²	530	2,650 to 4,240
8	40,000m ²	552	2,760 to 4,416
9	45,000m ²	747	3,735 to 5,976
10	50,000m ²	808	4,040 to 6,464
11	60,000m ²	1,061	5,305 to 8,488
12	70,000m ²	1,142	5,710 to 9,136
13	80,000m ²	1,226	6,130 to 9,808
14	90,000m ²	1,669	8,345 to 13,352
15	100,000m ²	1,750	8,750 to 14,000

One assumption made when calculating the affected population for each scenario was that all of the houses that were mapped are currently occupied. This is one of the reasons why the affected population is presented as a range. The other reason is to take into account unevenly distributed population; five is the national average

household size in Cameroon and eight is the rural average household size (Balgah et al., 2016). By considering this range of household sizes, the likely best and worst case scenarios can be examined. Additionally, for the houses to be considered as affected had to intersect with the extent of the actual modeled scenario rather than the 500m buffer used for the hazard ranking criteria. This was done so that the potentially affected populations were less likely to be overestimated.

4.2.2 Hazard Scenario Ranking

Each scenario was considered based on severity and ranked from 1 - 5. Table 3 shows the hazard ranking and criteria used for severity.

Table 3: Hazard ranking and criteria.

Hazard Ranking	Description of Criteria	Numerical Ranking
Catastrophic	Completely covers more than one major center of the village.	5
Major	Completely covers one major center of the village.	4
Moderate	Intersects with part of the village.	3
Minor	Comes within 500m of the village without intersecting with the village.	2
Negligible	Does not come within 500m of the village.	1

Since probability is an important aspect of hazard assessment and is difficult to determine for this hazard, a subjective likelihood was used. Table 4 shows the hazard ranking for each village along with the subjective likelihood for each scenario. The hazard rankings in Table 4 only include the severity from the hazard ranking criteria.

The rankings which include the subjective likelihood are shown in Table 5. When only the hazard is considered, Nyos has the highest risk. This is because it is catastrophically affected by every modeled scenario, based on the ranking criteria. After Nyos, Cha is the most vulnerable village when considering only the hazard risk since it is catastrophically affected by all but the first scenario.

Table 4: Ranking of scenarios, based on the 1 - 5 scale of the hazard ranking criteria, along with the subjective likelihood used to calculate the composite hazard ranking in Table 5.

Hazard Severity Ranking and Probability	Nyos	Cha	Subum	Buabua	Likelihood (Subjective)
Scenario 1	5	1	1	1	1.00
Scenario 2	5	4	1	1	0.95
Scenario 3	5	5	1	1	0.90
Scenario 4	5	5	4	2	0.85
Scenario 5	5	5	5	3	0.75
Scenario 6	5	5	5	3	0.65
Scenario 7	5	5	5	3	0.55
Scenario 8	5	5	5	4	0.45
Scenario 9	5	5	5	5	0.35
Scenario 10	5	5	5	5	0.25
Scenario 11	5	5	5	5	0.15
Scenario 12	5	5	5	5	0.10
Scenario 13	5	5	5	5	0.08
Scenario 14	5	5	5	5	0.05
Scenario 15	5	5	5	5	0.03

When the hazard ranking is combined with the subjective likelihood, Nyos still has the highest hazard risk. A subjective likelihood was used because probability is very important when assessing hazards and risk but there is a lack of historical data and other information that does not allow a probability to be calculated for the gas hazard. By using a subjective likelihood, the DR can still consider the likelihood of each modeled scenario.

Table 5: Hazard ranking (Severity x Subjective Likelihood).

Hazard Ranking	Nyos	Cha	Subum	Buabua
Scenario 1	5.0	1.0	1.0	1.0
Scenario 2	4.8	3.8	1.0	1.0
Scenario 3	4.5	4.5	0.9	0.9
Scenario 4	4.3	4.3	3.4	1.7
Scenario 5	3.8	3.8	3.8	2.3
Scenario 6	3.3	3.3	3.3	2.0
Scenario 7	2.8	2.8	2.8	1.7
Scenario 8	2.3	2.3	2.3	1.8
Scenario 9	1.8	1.8	1.8	1.8
Scenario 10	1.3	1.3	1.3	1.3
Scenario 11	0.8	0.8	0.8	0.8
Scenario 12	0.5	0.5	0.5	0.5
Scenario 13	0.4	0.4	0.4	0.4
Scenario 14	0.3	0.3	0.3	0.3
Scenario 15	0.1	0.1	0.1	0.1

4.3 Disaster Risk

The LND caused affected families the loss of many of their assets, resources, and in some cases their entire livelihoods. The results of the modeling show that if any of these scenarios was to occur many people could be affected. It is important to

consider both the hazard and vulnerability when examining disaster risk. As shown above, the most at risk village changes depending on which aspect is focused on. The DR presented here considers both assessments. It is important to consider the likelihood of a disaster event occurring, however, this is a very complex and little understood aspect of this hazard. So, a subjective likelihood was used to provide a composite hazard ranking that was also used to calculate DR including likelihood. The disaster risk is determined from the vulnerability and hazard analyses and shows which villages where survivors are living are at higher risk if any of the modeled scenarios were to occur.

A risk matrix was used to evaluate the disaster risk (Table 6), where the hazard and vulnerability rankings were multiplied together. The risk matrix also provides a non-numerical representation of the DR for each village. The matrix is color coded with green representing low risk, yellow representing medium risk, and red representing high risk. One DR is calculated without the subjective likelihood (Table 7) and one is calculated which includes the subjective likelihood (Table 8).

Table 6: Matrix used for disaster risk.

Disaster Risk	Vulnerability				
Hazard	1	2	3	4	5
1	1	2	3	4	5
2	2	4	6	8	10
3	3	6	9	12	15
4	4	8	12	16	20
5	5	10	15	20	25

DR without likelihood:

$DR = H \times V$, where DR is disaster risk, H is the hazard (severity), and V is the vulnerability.

DR with likelihood:

$DR = H \times V$, where DR is disaster risk, H is the hazard (severity and likelihood), and V is the vulnerability.

Tables 7 and 9 show that as the severity of the hazard increases DR for the LND survivors living in the Lake Nyos area also increases. This also shows that without considering probability the larger scenarios become the priority for any DRR efforts. Due to the nature of the Lake Nyos gas hazard, gas release scenarios quickly become catastrophic and without probability the hazard appears to affect the DR more significantly than vulnerability. Without considering probability, DRR efforts would likely focus on the hazard. Tables 8 and 10 account for probability with the use of the subjective likelihood and give a more accurate idea of which combination of hazard and vulnerability factors should be the focus of DRR efforts. As the scenarios get larger, they become less likely which reduces the overall risk.

Table 7: DR ranking, including hazard without likelihood.

Hazard & Vulnerability	Nyos	Cha	Subum	Buabua
Scenario 1	16.5	4.3	3.4	4.3
Scenario 2	16.5	17.2	3.4	4.3
Scenario 3	16.5	21.5	3.4	4.3
Scenario 4	16.5	21.5	13.8	8.5
Scenario 5	16.5	21.5	17.2	12.8
Scenario 6	16.5	21.5	17.2	12.8
Scenario 7	16.5	21.5	17.2	12.8
Scenario 8	16.5	21.5	17.2	17.0
Scenario 9	16.5	21.5	17.2	21.3
Scenario 10	16.5	21.5	17.2	21.3
Scenario 11	16.5	21.5	17.2	21.3
Scenario 12	16.5	21.5	17.2	21.3
Scenario 13	16.5	21.5	17.2	21.3
Scenario 14	16.5	21.5	17.2	21.3
Scenario 15	16.5	21.5	17.2	21.3

Table 8: DR ranking, including hazard (severity x likelihood).

Hazard & Vulnerability (including likelihood)	Nyos	Cha	Subum	Buabua
Scenario 1	16.5	4.3	3.4	4.3
Scenario 2	15.7	16.3	3.3	4.0
Scenario 3	14.8	19.3	3.1	3.8
Scenario 4	14.0	18.3	11.7	7.2
Scenario 5	12.4	16.1	12.9	9.6
Scenario 6	10.7	14.0	11.2	8.3
Scenario 7	9.1	11.8	9.5	7.0
Scenario 8	7.4	9.7	7.8	7.7
Scenario 9	5.8	7.5	6.0	7.5
Scenario 10	4.1	5.4	4.3	5.3
Scenario 11	2.5	3.2	2.6	3.2
Scenario 12	1.6	2.1	1.7	2.1
Scenario 13	1.2	1.6	1.3	1.6
Scenario 14	0.8	1.1	0.9	1.1
Scenario 15	0.4	0.5	0.4	0.5

Tables 9 and 10 show the disaster risk, non-numerically for each village based on the risk matrix classification.

Table 9: Disaster risk (without likelihood) in the Nyos area, by village and scenario.

Disaster Risk	Nyos	Cha	Subum	Buabua
Scenario 1	High	Medium	Medium	Medium
Scenario 2	High	High	Medium	Medium
Scenario 3	High	High	Medium	Medium
Scenario 4	High	High	High	Medium
Scenario 5	High	High	High	Medium
Scenario 6	High	High	High	Medium
Scenario 7	High	High	High	Medium
Scenario 8	High	High	High	High
Scenario 9	High	High	High	High
Scenario 10	High	High	High	High
Scenario 11	High	High	High	High
Scenario 12	High	High	High	High
Scenario 13	High	High	High	High
Scenario 14	High	High	High	High
Scenario 15	High	High	High	High

Table 10: Disaster risk (with likelihood) in the Nyos area, by village and scenario.

Disaster Risk	Nyos	Cha	Subum	Buabua
Scenario 1	High	Medium	Medium	Medium
Scenario 2	High	High	Medium	Medium
Scenario 3	High	High	Medium	Medium
Scenario 4	High	High	Medium	Medium
Scenario 5	Medium	High	Medium	Medium
Scenario 6	Medium	High	Medium	Medium
Scenario 7	Medium	Medium	Medium	Medium
Scenario 8	Medium	Medium	Medium	Medium
Scenario 9	Medium	Medium	Medium	Medium
Scenario 10	Medium	Medium	Medium	Medium
Scenario 11	Low	Medium	Low	Medium
Scenario 12	Low	Low	Low	Low
Scenario 13	Low	Low	Low	Low
Scenario 14	Low	Low	Low	Low
Scenario 15	Low	Low	Low	Low

5. Conclusion and Recommendations

Disaster risk assessments are an integral part of effective disaster risk reduction. By assessing local hazards and vulnerability, the deeper causal factors of disaster risk can be more effectively addressed. Disaster risk is not a constant state but an ever changing, dynamic condition. The disaster risk calculated for this study shows the disaster risk in the Lake Nyos area at the time of the study. The results of this study show that if an equivalent gas eruption to the LND were to occur today, it would affect approximately the same number of people as in 1986. Although this is not likely with the degassing system that is in place, it gives an idea of what could happen if the system is not maintained. The adapted LAHARZ model utilized in this study seems to accurately map the areas that were affected by the LND and possible inundation zones for the 15 modeled scenarios. When compared with other models used to map the 1986 LND gas flow, the adapted LAHARZ model is able to map the flow pattern more accurately than some of the more complex models. This model also shows that even a relatively small gas release could potentially affect many people, which again underlines the importance of considering both the hazard and vulnerability for effective and sustainable DRR.

As long as the degassing system is well maintained the hazard seems to be under control. This makes it important to consider additional disaster risk reduction efforts in the area in the event that there is a system failure. The survivors in the villages and camps near the lake are vulnerable due to a variety of social factors. The disaster risk can be reduced by addressing some of these factors. Income and access to resources, relationship with government and aid, and social relationships were found to have a strong bearing on the socially produced vulnerability in the Lake Nyos area. The lack of disaster preparedness, emergency management offices, and first responder presence and agency should be addressed. The presence and agency capacity of these offices should be increased in order to be more effective and accessible during a disaster event. Infrastructure and road improvement would allow first responders and response agents to have enhanced access in and out of the area and would also allow community members to evacuate more easily. By addressing these factors, disaster

response can be made more efficient while also helping to improve local community members' access to physical and social resources. Government/community relationships and trust are more difficult to improve and are much more difficult to regain once lost. However, to help possibly improve and reduce further impairment of these relationships, community participation and input should be utilized and considered in future DRR and mitigation efforts. This may improve both community understanding of the gas hazard and participation for project efficiency.

Future research could also help to further clarify the factors that contribute to risk, vulnerability, and hazards. A more detailed analysis could be done focusing on the general population of the area and could examine what might be done for the survivors not living in the Nyos area. This area is also affected by more than just the CO₂ hazard. Future studies could focus on one of the other hazards or all the hazards together and both qualitative and quantitative risk analyses could also be done for those hazards. Interdisciplinary studies and cooperation could also be beneficial in adding to the level of knowledge and understanding of the interaction of various social factors and hazards in the area.

The first piece of disaster preparedness and risk reduction is defining and analyzing hazards and vulnerabilities of potentially affected populations. Although all hazards and vulnerabilities should be addressed, resources are often limited. In this way, conducting hazard, vulnerability, and risk assessments, which consider a broad range of factors, can be used in establishing priorities on what can and should be addressed through disaster risk reduction efforts. As exemplified in this study, it is crucial that risk from both hazards and vulnerability be examined. When only one aspect is considered, risk reduction and mitigation efforts taken may only partially address or may misdiagnose the most significant causal factors and immediate needs of a population. By considering risk through the assessment of both vulnerability and hazards, the actions taken can more effectively and efficiently reduce disaster risk as well as more appropriately integrate with a population's, community's, or country's larger development goals.

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7. Appendix A – Interview Information [IRB project #799717-1]

A1. Informed Consent: Oral Model

English Version

*Note: Written as it will be read to the participant by the translator.

Mary Witucki is a graduate student at Michigan Technological University in the United States. She is conducting a study at her school to write her thesis and complete her master's degree in Mitigation of Natural Hazards. And I am Useini Musa; I am collaborating and translating for this study. We would like to talk to you about the Grassroots Strategies of Relief and Adaptation of the 1986 Lake Nyos Disaster survivors; in order to find out about how the survivors and the descendants of the victims and survivors managed and adapted after the disaster and what they have done to protect themselves from future disasters. Your participation in this study is completely voluntary. There is no compensation for participation in this study. The interview will take between thirty minutes and one hour though it may run longer if you so choose. We would like to tape record our conversation, so that we can accurately record your responses. You may ask us to turn the machine off or back on again according to your comfort.

You may ask us questions at any time and talk about things you think we should know about, even if we don't ask. You should feel free to interrupt us if you want to ask questions about the Grassroots Strategies of Relief and Adaptation of the 1986 Lake Nyos Disaster survivors. You are not required to talk to us or to answer our questions. Even if you decide now to talk to us, you may later ask us to stop asking you about it. You may stop participating at any time. Nothing bad will happen to you or to us if you decide not to answer our questions.

We will not reveal anything that you say to us beyond anyone helping us with the study whom we trust to maintain your confidentiality. We will do everything we can to

protect your privacy, but there is always a slight chance that someone could find out about our conversation.

We are asking if you would agree to participate in this study, and to talk to us about the Grassroots Strategies of Relief and Adaptation of the 1986 Lake Nyos Disaster survivors. Do you agree to participate? Will you allow us to record our conversation?

A2. Interview Questions

English Version

Getting to know the interviewee:

- 1) Are you a survivor of the 1986 Lake Nyos Disaster or a relative of a victim of the disaster?
 - a. Where were you living at the time of the disaster?
- 2) About how old are you?

Awareness of:

Disaster-
- 3) Can you tell me about what happened during the 1986 Lake Nyos Disaster?
 - a. What do you think caused the disaster?
 - b. Do you consider Lake Nyos to be dangerous? Why or why not?

Government activities-
- 4) Can you tell me about what the government did and has done, if anything, since the disaster?
 - a. Are they still doing anything or have they done anything recently?

Other activities-
- 5) What can you tell me about government or other activities, if any, that have been going on at the lake since the disaster?
 - a. If there have been activities, have any been going on recently or are any going on currently?
- 6) Have you been back to the disaster zone since the disaster happened?
 - a. Why or why not?
 - b. Would you like to move back there if you had the opportunity?

After/since 1986 LND:

Response/Relief/Adaptation-

- 7) What did you, personally, do or what did your family and your community do when the disaster happened?
 - a. What prompted you to do those things?
- 8) What did you, personally, do or what did your family and your community do to manage and to restart after the disaster?
 - a. Why did you decide to do those things rather than something else?
 - b. Do you feel that you and/or your family have been able to recover from the disaster?

Preparation/Adaptation/Risk and Vulnerability Reduction-

- 9) Is there anything that you or your family and your community have done to prepare for future natural hazards or disasters?
 - a. If yes, what? If no, why not?
 - b. How did you come to make those decisions?
 - c. Due to those preparations, do you feel that you, your family, and your community could better handle a natural hazard or disaster now?
- 10) What, if anything, have you been doing to make sure that you are not as affected if another disaster happens?
 - a. What prompted you to decide to do those things?
 - b. If no, why have you decided not to do anything?

Closing:

Is there any more information that you feel would be relevant to our research?

Are there some people that you think might be willing and useful for us to talk to?

8. Appendix B – Copyright Permissions

B1. Permission for Use for Figure 3.

Michigan Tech

Mary Witucki <mwitucki@mtu.edu>

(no subject)

2 messages

Mary Witucki <mwitucki@mtu.edu>
To: ochavisual@un.org

Wed, Dec 5, 2018 at 2:19 PM

Mary Witucki
mwitucki@mtu.edu

12/05/2018

ochavisual@un.org

To whom it may concern:

I would like to ask your permission to use the following image in my master's thesis concerning natural hazards in Cameroon.

Cameroon: Location Map (2013)

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If you agree with the terms as described above, please sign and return the letter to me, specifying any credit line, fees, or other conditions you require. Your signing of this letter confirms that you own the copyright to the above described material. If you do not currently hold the rights, I would appreciate any information that can help me contact the rights holder.

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Thank you for your time and consideration.

OCHA-Visual <ochavisual@un.org>
To: Mary Witucki <mwitucki@mtu.edu>

Thu, Dec 6, 2018 at 9:23 AM

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Kind regards,

Design and Multimedia Unit

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United Nations Office for the Coordination of Humanitarian Affairs

B2. Permission of Use for Bang (2010, 2016).

Michigan Tech

Mary Witucki <mwitucki@mtu.edu>

Request for permission to cite and quote

3 messages

Mary Witucki <mwitucki@mtu.edu>
To: hbang@bournemouth.ac.uk
Bcc: Mary Witucki <mwitucki@mtu.edu>

Sun, Nov 18, 2018 at 3:05 PM

Mary Witucki
mwitucki@mtu.edu

11/18/2018
Dr. Henry Bang
hbang@bournemouth.ac.uk
Dorset House D236, Talbot Campus, Fern Barrow, Poole, BH12 5BB

Dr. Bang,
I would like to ask your permission to cite and quote your following publications, with full credit (no figures, charts, graphs, tables, photos/pictures, or illustrations will be used):

[Bang, H.](#), 2010. Natural Disaster Risk, Vulnerability and Resettlement: Relocation Decisions following the Lake Nyos and Monoum Disasters in Cameroon. PhD Thesis. School of International Development, University of East Anglia, Norwich, UK.
[Bang, H.](#), 2016. *30 Years After the Lake Nyos Disaster: What Prospects for Rehabilitation and Reintegration in the Region? Disaster Management, Social Vulnerability, Risk Perception and Relocation Decisions in Cameroon*. US: Book Venture Publishing.

My name is Mary Witucki and I am a masters student at Michigan Technological University. I am writing my thesis on disaster risk and I am examining the Lake Nyos area and the 1986 Lake Nyos Disaster as a case study. Your many works on the subject have been very helpful in aiding my understanding of the topic. I would like to include citations and quotations from the above material in my thesis, with full credit.

If you agree with the terms as described above, please sign and return the letter to me, specifying any credit line, fees, or other conditions you require. Your signing of this letter confirms that you own the copyright to the above described material. If you do not currently hold the rights, I would appreciate any information that can help me contact the rights holder.

I would be very grateful for your permission. If you require any additional information, do not hesitate to contact me at mwitucki@mtu.edu.
Thank you for your time and consideration.

Sincerely,
Mary Witucki
mwitucki@mtu.edu

Henry Bang <hbang@bournemouth.ac.uk>
To: Mary Witucki <mwitucki@mtu.edu>

Tue, Nov 20, 2018 at 9:35 AM

Hi Mary,

Thanks for your mail.

I hold the copyrights for both materials and grant you permission to use them.

Regards!

Henry

Dr Henry N Bang (BSc, MSc, MSc, PhD)

Research Fellow/Lecturer

Disaster Management Centre

Bournemouth University

Talbot Campus, Fern Barrow,

Poole, Dorset,

BH12 5BB

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Mary Witucki <mwitucki@mtu.edu>
To: Henry Bang <hbang@bournemouth.ac.uk>

Tue, Nov 20, 2018 at 9:40 AM

Dr. Bang,

Thank you so much! I really enjoy and am inspired by your work. I am so grateful for your allowing me to use them!

Sincerely,
Mary Witucki
mwitucki@mtu.edu

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Publication Year:	2012
Description of Work:	The Handbook provides a comprehensive statement and reference point for hazard and disaster research, policy making, and practice in an international and multi-disciplinary context. It offers critical reviews and appraisals of current state of the art and future development of conceptual, theoretical and practical approaches as well as empirical knowledge and available tools.
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