ABSTRACT

Title of Thesis: Gastrointestinal Illness in Rural Cambodia: Identifying Protective and Risk Factors in Pohm Sammnang

Casey Chmura, Bachelor of Science, 2018

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Gastrointestinal illnesses represent a large burden of disease in contemporary Cambodia. Currently, more than half of the population resides in rural regions with reduced access to basic health services, including sources of clean water, sanitation and hygiene stations, and education. This thesis analyzes demographic and lifestyle factors that correlate with prevalence of gastrointestinal symptoms in Pohm Sammnang, a rural village in Cambodia's Banteay Meanchey province. It argues that both exposure and sensitivity factors play important roles in gastrointestinal illness in Pohm Sammnang. In this local context, households that own canines - an exposure factor - have the greatest risk of gastrointestinal illness. School attendance, filtering drinking water, and relative wealth – all sensitivity factors – protect households against gastrointestinal illness. This thesis uses spatial analysis of these factors to identify the most vulnerable regions of Pohm Sammnang. It also suggests methods of intervention that focus on increasing access to basic health services. While these findings result directly from Pohm Sammnang, they apply to the many villages in the Banteay Meanchey region that share Pohm Sammnang's infrastructural features.

Gastrointestinal Illness in Rural Cambodia:
Identifying Protective and Risk Factors in Pohm Sammnang

By
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List of Abbreviations

CWP	Ceramic Water Purifier
GI	Gastrointestinal
IPI	Intestinal parasitic infection
LBI	LightBridge International
NGO	Non-governmental organization
STH	Soil-transmitted helminths
WASH	Water, sanitation, and hygiene
WHO	World Health Organization

Chapter 1: Health in Cambodia

Cambodia, located in Southeast Asia, has a population of 15.8 million people ("Country Profile: Cambodia," 2016). Cambodia's Gross National Income (GNI) per capita in 2016 was $1,140 (USD) and the United Nations classifies Cambodia as a Least Developed Country (LDC), which indicates low income, low human resources, and high economic vulnerability (*Gross National Income per Capita 2016, Atlas Method and PPP*; *Least Developed Country Category: Cambodia Profile*).[1] In 2014, Cambodia's total healthcare expenditure per capita was only $183 (*Cambodia: Noncommunicable Diseases (NCD) Country Profiles, 2014*, 2014). Low expenditure and lack of adequate healthcare infrastructure results in high levels of morbidity and mortality in the Cambodian population, especially among young children. These issues in healthcare delivery are particularly aggravated in rural areas, where 80% of the Cambodian population resides (*Health Service Delivery Profile: Cambodia, 2012*, 2012).

1.1 Research Question and Argument

In June 2016, I conducted fieldwork in Pohm Sammnang, a rural village in Cambodia's Banteay Meanchey province. In interviews with village residents, 42.9% of households reported symptoms of gastrointestinal illness. Throughout this thesis, I will explore the question, what factors influence gastrointestinal (GI) illness in Pohm Sammnang most significantly? Individuals living in rural areas of Cambodia have particular vulnerability to disease. Little research, however, addresses the impact of exposure to pathogens and vulnerability factors in local regions in Banteay Meanchey. Additionally, while research investigates preventative and risk factors for

[1] LCD status is based on a set of criteria including income, human assets, and economic vulnerability. GNI per capita indicates income. Health and education indices indicate the human assets rating. Finally, exposure and shock indices indicate level of economic vulnerability ("Least Developed Countries: UN Classification," 2018).

GI illnesses in Cambodia as a country, these factors have not been addressed in Pohm Sammnang specifically (e.g.: McIver et al.; Meng et al., 2011). The region hosts a variety of non-governmental organizations (NGOs) with stakes in the healthcare field, and these organizations must properly understand behaviors that prevent and drive GI illnesses to properly address those illnesses. This thesis provides quantitative results that may be used to inform health interventions around specific prevention and risk factors not only in Pohm Sammnang, but also in similar contexts in the Banteay Meanchey province.

In this thesis, I investigate four factors, developed from the literature, as most influential on GI illnesses in Pohm Sammnang. The strongest risk factor for GI illness is owning one or more canines. The most influential factors for preventing GI illness in Pohm Sammnang are attending school, filtering water, and owning livestock. These aspects of lifestyle represent a combination of factors that directly expose individuals to pathogens and increase vulnerability to developing infection following exposure.

In this introductory chapter, I will provide a summary of the limited health infrastructure in rural Cambodia to contextualize the prevalence of GI illnesses. I will explain this infrastructure using the events and aftermath of the Cambodian Genocide, which has significantly impacted access to healthcare since the mid-1970s. Finally, I will introduce Pohm Sammnang and characterize the village using factors relevant to GI health, including methods of income, sources of food and water, and access to services such as education.

1.2 Contextualizing Gastrointestinal Health in Cambodia

Currently, about 1,050 healthcare facilities serve Cambodia's population. While the Cambodian Ministry of Health sets a minimum number for services[2] offered in healthcare centers, only 43% of facilities in rural areas met these minimums in 2010 (*Health Service Delivery Profile: Cambodia, 2012*, 2012). Today, failure to provide satisfactory healthcare to a large proportion of the population results in a significant burden of communicable disease in Cambodia. Leading causes of morbidity include "acute respiratory infection; diarrhoea; malaria; cough (at least 21 days); gynaeco-obstetric issues; tuberculosis; road accidents; measles; dengue hemorrhagic fever; and dysentery" (*Health Service Delivery Profile: Cambodia, 2012*, 2012). These health problems particularly impact children; 34% of children in these rural areas evidence stunting,[3] and the infant mortality rate is 42 (for 1,000 live births) (*Cambodia Demographic and Health Survey 2014*, 2015).

In rural Cambodia, little infrastructure services water, sanitation, and hygiene (WASH) facilities. According the World Health Organization (WHO), WASH factors account for 10,900 deaths a year in Cambodia (*Country Profile of Environmental Burden of Disease*, 2009). In 2008, 58.1% of the population reported using unimproved drinking water sources,[4] and only about 30% of the rural population had a source of drinking water on the premises of their household. Further, nearly half of the rural population practices open defecation; merely 23.2%

[2] A package of minimum services consists of "initial consultations and primary diagnosis, emergency first air, chronic disease care, maternal and child care (including normal delivery), birth spacing advice, immunization, health education, and referral" (*Health Service Delivery Profile: Cambodia, 2012*, 2012)

[3] The 2014 Demographic and Health Survey measures stunting by comparing height against weight. Stunting "indicates chronic malnutrition" (*Cambodia Demographic and Health Survey 2014*, 2015).

[4] An improved source of drinking water "by nature of its construction, adequately protects the water from outside contamination, in particular from fecal matter." Unimproved drinking water sources are unprotected dug wells, unprotected springs, surface water, vendor-provided water, bottled water, and tanker truck water (*Guidelines for Drinking Water Quality, Forth Edition, 2011*).

of rural households had a toilet on the premises in 2008 (*General Population Census of Cambodia 2008*, 2009). High rates of illness result from this lack of WASH infrastructure, which fails to support ideal sanitation and hygiene habits.

Research indicates a significant correlation between attending school and lower rates of diarrhea, a common GI illness, in Cambodia (McIver et al., 2016). Schools teach knowledge of best sanitation and hygiene practices, as well as equip students with skills to navigate pre-existing healthcare services. Further, schools may offer access to WASH facilities, such as toilets and hand-washing stations, that students do not have at home (*Water, Sanitation, and Hygiene*). Children in Cambodia may attend primary school beginning at age 6, and secondary school concludes at age 18. According to UNICEF, the net primary school attendance ratio was 85.2% for males and 83.4% for females between 2008 and 2012. The net secondary school attendance ratio, however, was 45.9% for males and 44.7% for females during the same time period ("Cambodia: Statistics," 2013). In 2014, the literacy rate was 72.8% and 82.0% in rural regions, for women and men respectively, as opposed to 90.5% and 94.7% in urban regions (*Cambodia Demographic and Health Survey 2014*, 2015). Education, like other services, fails to serve rural regions adequately.

1.2.1 The Cambodian Genocide

Throughout the mid-1900s, Cambodia – currently a constitutional monarchy – experienced political conflicts involving France, Vietnam, and the United States. In 1975, the Party of Democratic Kampuchea (Khmer Rouge), a Communist regime led by Pol Pot, overthrew the Cambodian government and initiated a period of violent control that lasted until 1979 ("Cambodia Profile - Timeline," 2918). The Khmer Rouge forced citizens out of major cities and into camps in the countryside, where they encountered great violence, a lack of resources, and oftentimes death. During the 4-year genocide, 1.7 million people died – 21% of Cambodia's population at the time ("Cambodian Genocide Program," 2018). The Khmer Rouge targeted adults, especially those who had been educated or held government positions. The regime also installed landmines along the country's border to ensure that residents could not flee the country. The genocide had, and continues to have, a profound impact on population health throughout Cambodia.

Because the Khmer Rouge specifically targeted educated adults for death, they murdered many physicians, nurses, and other healthcare professionals. The regime also destroyed physical infrastructure, including hospitals and other structures providing healthcare, such as clinics. Further, the Khmer Rouge outlawed the practice of Western medicine, teachings from Western nations regarding health, during its period of control. Reliance on traditional medicine,[5] a necessity at the time, survives to present day; the Ministry of Health estimates the 40-50% of the population practices traditional medicine, with the highest rates of use occurring in rural areas and areas of low socioeconomic status (*Health Service Delivery Profile: Cambodia, 2012*, 2012). Rebuilding healthcare infrastructure, both human and physical, is a challenge that continues to complicate healthcare delivery in Cambodia.

[5] The WHO defines traditional medicine as "the sum total of the knowledge, skill, and practices based on the theories, beliefs, and experiences indigenous to different cultures, whether explicable or not, used in the maintenance of health as well we in the prevention, diagnosis, improvement or treatment of physical and mental illness" ("Traditional, Complementary, and Integrative Medicine," 2017). Practitioners of traditional medicine in Cambodia include the Khmer Kru…mediums known as "Kru Chol Ruup" and Buddhist monks (*Health Service Delivery Profile: Cambodia, 2012*, 2012).

1.3 Pohm Sammnang

This thesis focuses on Pohm Sammnang, located in the Banteay Meanchey province. In 2016, I conducted fieldwork in Pohm Sammnang on behalf of LightBridge International (LBI), an NGO that focuses on sustainable development in Pohm Sammnang and other regions of Banteay Meanchey. In preparation for an upcoming project, I interviewed the adult heads of 45 households in the village. Of the 44 households that reported on health status, 35 (79.5%) reported some sort of health issue, ranging in nature from injury to communicable disease to chronic illness. Of the households reporting health issues, 15 (42.9%) reported symptoms of GI illness. I chose to explore GI illness in this particular village because it is unique in that it exhibits rural qualities while being situated merely kilometers from the quickly expanding city of Poi Pet. Pohm Sammnang also displays qualities that clearly exhibit the lack of government involvement in public health infrastructure, rendering residents particularly vulnerable to GI illness. While my fieldwork occurred only in Pohm Sammnang, the village represents other villages in the surrounding area, as they share many prominent features regarding health, such as lack of access to WASH factors and limited sources of income.

Banteay Meanchey lies in western Cambodia, where it shares a border with Thailand. The province covers 6,148 km^2 and had a population of about 678,000 people in 2008, about 5% of Cambodia's population at the time (*General Population Census of Cambodia 2008*, 2009). A survey by the Cambodian Ministry of Health in 2014 considered 29% of children in Banteay Meanchey stunted, a figure slightly lower than the average in rural regions across Cambodia.[6] The province also maintains a slightly better infant mortality rate than the rural average, with 29 infant deaths per 1,000 live births in Banteay Meanchey and 42 infant deaths per 1,000 live

[6] 34% of children living in all rural regions of Cambodia are stunted (*Cambodia Demographic and Health Survey 2014*, 2015).

births across all rural regions (*Cambodia Demographic and Health Survey 2014*, 2015). These figures may be due to close proximity to the Thai border, which offers greater opportunity for employment than other rural regions may experience.

Map 1.1
The location of Poi Pet in the Banteay Meanchey province[7]

Pohm Sammnang lies within kilometers of both the city of Poi Pet and the Thai-Cambodian border. It sits on a former minefield, which a professional organization demined most recently in 2011. In June 2016, Pohm Sammnang contained 231 homes. At the point of data collection, residents occupied 155 homes, and 76 homes were vacant.[8] One-roomed structures

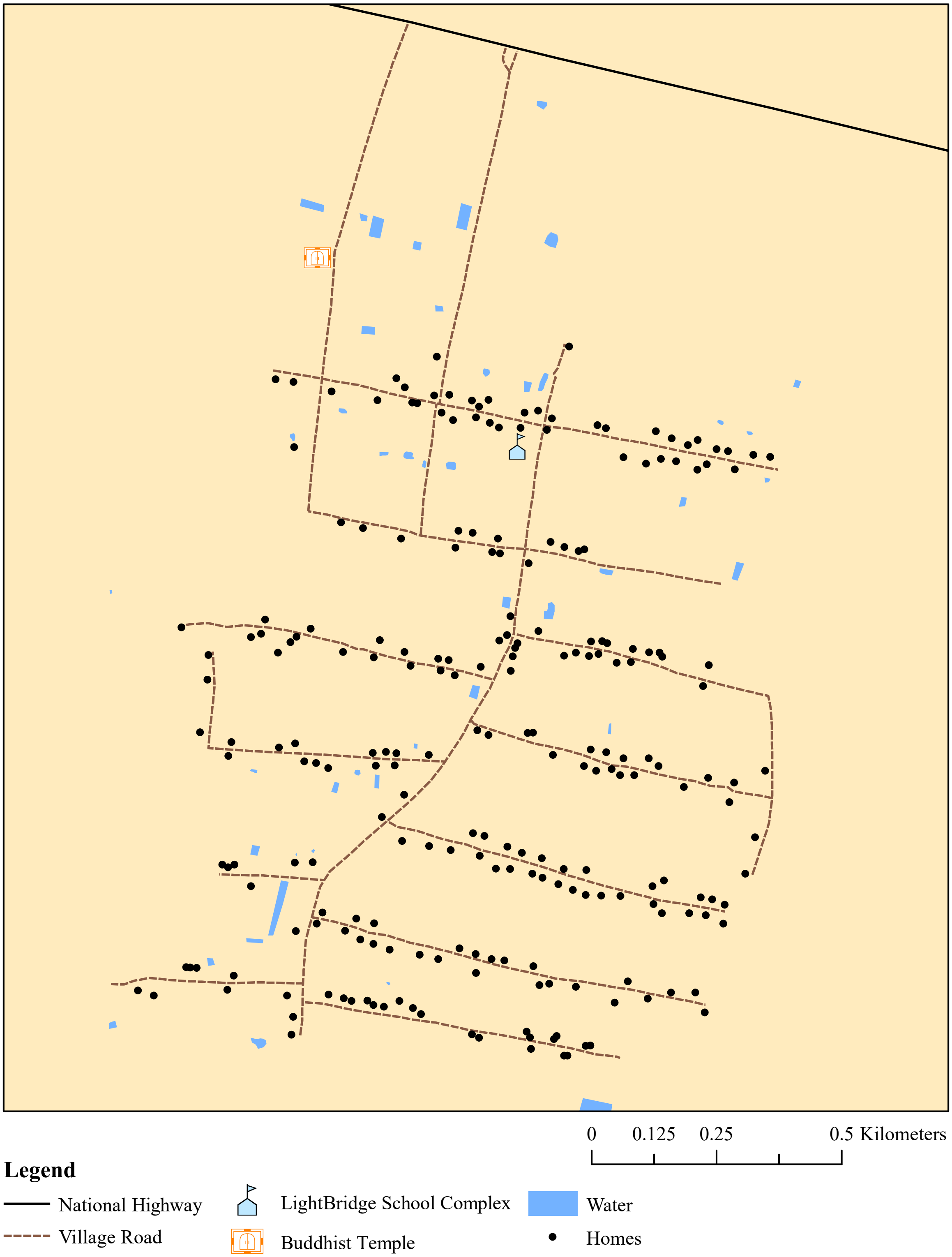
[7] Data Source: Cambodia_Province_Feature_Layer (2017) [download]. [2 February 2018]. Edits applied by author.
[8] Individuals conducting interviews determined occupancy status. Unkempt structures with no individuals, animals, gardens, drying laundry, etc. were defined "vacant." Locked structures that appeared orderly were considered occupied.

built of wooden walls and metal roofs form the majority of homes. Many also include portions raised off of the ground; these spaces often function as sleeping quarters. Several homes in Pohm Sammnang serve as markets that sell fresh produce, packaged food and drink items procured outside of the village, and/or household items. In 2016, the village had no freestanding stores or shops unassociated with specific homes. Pohm Sammnang also contains a Buddhist temple, as nearly all village residents identify as Buddhist.

In addition to homes, markets, and the temple, Pohm Sammnang hosts a school. As of this writing in 2018, the school teaches about 160 students up to Grade Four (D. Baca, personal communication, March 21, 2018). LBI funds school operations. The school employs adult residents from Pohm Sammnang as a principal and teachers, and it teaches a curriculum provided by the Cambodian government. The school opened in 2012; for this reason, older children may attend classes, even though primary school in Cambodia typically begins at age six and ends at age twelve (*Cambodia: Age Distribution and School Attendance of Girls Aged 9-13 Years*, 2013). Students pay minimal fees to attend the LBI school, and it provides one meal a day to all students. Additionally, most students attend school only during the morning or the afternoon and spend the rest of the day assisting their families with farming responsibilities. The school complex includes two covered toilet facilities that students may use, as well as water tanks that collect rainwater, which is used for washing hands. Students who have passed the fourth grade may also attend schools outside of Pohm Sammnang, although transportation challenges render this uncommon.

As in many rural areas in Cambodia, villagers have limited access to WASH facilities in Pohm Sammnang. The village has 36 ponds, both public and private, and the average distance from a home to a water source is 208 meters. These ponds serve many functions, including as sources of drinking water for residents, animals, and crops. In addition to this surface water, residents obtain water by collecting rainwater or by purchasing water from vendors (such as the previously mentioned markets) or large tanker trucks. Pohm Sammnang does not have any sources of piped water. During my time there, I did not observe any toilets outside of those located in the school complex, and LBI staff report that most residents practice open defection (D. Baca, personal communication, March 2018). Map 1.1 displays prominent features of the Pohm Sammnang community, including roads, the location of households, the school, and the Buddhist temple.

Map 1.2
Features of Pohm Sammnang, 2016



In 2016, the only sources of electricity in Pohm Sammnang were batteries and gas-powered generators. Village residents generally cook over fires outside of their living structures. During my time interviewing at homes in the village, I observed numerous cases of battery-powered televisions, radios, and other small electronic devices. In my observation, residents used lights and electrical appliances inconsistently and for entertainment purposes.

Many households in Pohm Sammnang farm, both as a food source and for the purpose of sale. Residents typically have small gardens in which they grow vegetables and spices, including cucumbers, corn, eggplant, chilies, and lemongrass. Some families also have fruit trees on their household premises that produce mangos, papayas, and/or bananas. While many households reported members who work in rice fields, few residents grow rice themselves. In addition to produce, most households raise some sort of poultry, including chickens, ducks, and turkeys. Poultry often roam household premises freely, although a minority of families keep their animals in enclosures. Finally, a small number of families raise livestock such as cows or pigs. Owners typically tie these animals in their yards or fields, although some cows and pigs do wander freely.

In June 2016, village residents reported a significant drought that limited access to drinking water, water for animals, and water for crops. Cambodia has a tropical monsoon climate, with a rainy season that begins in May and lasts through October. Average rainfall varies between the central lowlands and coastal regions; in the Banteay Meanchey province, where this thesis focuses, the average yearly rainfall is 1,000 mm (*Cambodia: Geography, Climate, and Population*). In any given year, 80-90% of Cambodia's rainfall occurs during the monsoon season (Khmau et al., 2011). During the rest of the year, the climate is dry. Temperatures peak just prior to the monsoon season, when they reach a maximum of 26°C to

30°C. The rest of year, temperatures range between 25°C and 27°C (McSweeney, New, & Lizcano, 2006). As a country, Cambodia is vulnerable to future changes in climate. Scholars large attribute this vulnerability to the low adaptive capacity of the country; although most regions of Cambodia have low exposure to climactic hazards, other factors -- socioeconomic factors, technology, and infrastructure -- dictate low adaptability for the country (Anshory Yusuf & Francisco, 2009). Climate has a profound impact on GI health, as it directly impacts water sources. Changes in climate, therefore, pose risks to human health. To obtain drinking water during the 2016 drought, many residents purchased water from large tanker trucks that frequently drive through village roads. Outside of cases of drought, purchasing drinking water is unusual, because it represents a significant expense for households. In 2016, several families also indicated reduced income-generating abilities due to failure to produce crops as result of the lack of rain and extreme heat.

1.4 Conclusion

In the next four chapters, I will identify and explain the important roles of attending school, filtering water, and owning livestock in protecting households against GI illness. I will also explain why owning one or more canines places households at risk for GI illness. In Chapter Two, I present literature that discusses the current understanding of GI illness in rural Cambodia. I specifically focus on diarrheal diseases, the most common GI illnesses in Cambodia, because the largest portion of literature focuses on these illnesses. I also describe my methodology, specifically focusing on my interview method and questions. In Chapter Three, I provide results of chi-square testing for independence between reported GI symptoms and demographic and lifestyle factors. In Chapter Four, I interpret the results expressed in Chapter Three and speculate as to why the factors are the most influential. Finally, in Chapter Five, I address which regions of Pohm Sammnang are most vulnerable to GI illnesses and provide recommendations for organizations supporting GI health in the Poi Pet region.

Chapter 2: Literature Review and Methodology

This chapter provides an overview of causes of gastrointestinal diseases in Cambodia. It focuses specifically on current understanding of various causes of diarrheal illness to explain the profound impact of such illnesses on residents of rural Cambodia. In the literature review, I describe current understanding of the causes of GI illness by addressing significant exposure factors leading to GI symptoms, which are parasites, bacteria, viruses, and climate change. I also describe significant sensitivity factors, which are socioeconomic status and WASH factors. I address these factors primarily in the context of rural Cambodia. This chapter also addresses the methods used to collect and analyze data regarding GI illness in Pohm Sammnang.

2.1 Literature Review

Ranked as one of the UN's Least Developed Countries,[9] Cambodia experiences large burdens of both communicable and non-communicable diseases ("Least Developed Countries: UN Classification"). GI illnesses, specifically diarrhea, dengue fever, and dysentery, comprise three of the top ten causes of morbidity in Cambodia (*Health Service Delivery Profile: Cambodia,* 2012*)*. Other common diarrheal illnesses in Cambodia include viral and bacterial gastroenteritis and cholera, all of which spread through contaminated water sources (Davies et al., 2014). Notably, according to Davies et al. (2014), diarrhea is the most common inpatient and outpatient diagnosis throughout Cambodia. Research regarding GI disease in Cambodia primarily investigates causes and outcomes of diarrheal illnesses, with a special focus on impacts on children under the age of five. The 2014 Demographic and Health Survey reports that 12.8% of children under five suffer from diarrhea; national agencies do not report rates of diarrheal

[9] Least Developed Countries have the lowest socioeconomic status of all nations, as determined by the UN using indicators of income, human assets, and economic vulnerability. Currently, the GNI per capita must fall at or below $1,035 ("LDC Identification Criteria and Indicators").

illness among adults. Multiple studies rely on analysis of such data, reported though national censuses and government-associated surveys and interviews (McIver, Imai, et al., 2016; Moench-Pfanner et al., 2016). Due to the availability of research, I focus on diarrheal illness in this literature review, rather than non-communicable or chronic GI conditions.

Throughout the literature, authors categorize causes of GI illness into one of two categories of factors, exposure or sensitivity. Exposure factors lead to disease through contact with specific pathogens. In rural Cambodia, these factors include parasites, bacteria/viruses, and changes in water sources due to climate change. Sensitivity factors cause vulnerability to acquisition of disease and often relate to socioeconomic status. In rural Cambodia, significant sensitivity factors include poverty, education, and WASH factors. Prominent factors regarding water include source and sanitation of drinking water. Scholars identify poverty in particular as a sensitivity factor that drives various exposure factors of GI illness, such as WASH factors and ability to receive education (McIver, Imai, et al., 2016). Although individual projects tend to focus on either exposure or sensitivity factors, most authors acknowledge the significant role of both types (e.g. Davies et al., 2014; Inpankaew et al., 2014). Furthermore, authors recognize their often-inextricable interplay, wherein exposure and sensitivity factors cannot be distinguished from one another (e.g. "Diarrheal Diseases and Climate Change in Cambodia: Environmental Epidemiology and Opportunities for Adaptation").

2.1.1 Exposure Factors

High prevalence of parasitic infection results in GI symptoms, such as diarrhea and other GI discomfort, in rural Cambodia. A study by Schar et al. (2014) contributes to our understanding of the zoonotic[10] potential of intestinal parasitic infection (IPI) by testing fecal samples for parasites. They found that the most prevalent human parasitic infections include those of various species of hookworm, *entamoeba* spp., *strongyloides stercoralis,* and *Blastocytis.* Notably, helminth co-infections[11] increase in prevalence with increasing age, and infection by *strongyloides stercoralis* occurs twice as frequently in adults over 30 as compared to other age groups. Results suggest that canines may be the source of zoonotic *Ancylostoma ceylanicum* infection, as 51.6% of human infection and over 90% of canine infections were of *A. ceylanicum* (2014). In addition to addressing a wide range of parasites and zoonotic infections, the study addresses risk (sensitivity) factors for parasitic infection. George et al. conducted similar research regarding the distribution of soil-transmitted helminthes (STH) among school children and animal species in Cambodia. This study found a significant prevalence of hookworm infections, with infection by *Necator americanus* occurring in 52.5% of samples (2017). This research used DNA extraction and PCR[12] to differentiate between human and animal hookworm species, thus allowing tracing to likely sources of zoonotic infection. This strategy, however, fails to label any specific region(s) or group(s) as most vulnerable to high prevalence of zoonotic infection. My study will address GI illness in rural populations specifically living along the western border of Cambodia. Despite a lack of location within Cambodia, George et al. contributes the significant distinction between human and animal STH, important when identifying zoonotic pathogens. Both studies found that while canines in particular pose the risk of zoonotic transmission of parasites, IPIs spread mainly though human interaction. These findings indicate the importance of WASH practices in preventing illness.

[10] The WHO defines zoonoses – zoonotic illnesses - as diseases "transmissible from animals to humans through direct contact or through food, water, and the environment" ("Zoonoses," 2017).
[11] Helminth co-infections occur when two or more species of helminth simultaneously reside in the body.
[12] PCR, polymerase chain reaction, is a method of replicating specific parts of DNA to perform analysis.

Bacteria and viruses also play causative roles in diarrheal disease in Cambodia. A study by Meng et al. (2011) tested fecal samples of children under five with and without acute diarrhea[13] in a hospital in Phnom Penh, Cambodia. They found that bacteria with a statistically significant ($p < .05$) relationship to diarrhea include *Shigella Aeromonas* and *Campylobacter jejuni*, as well as various strains of pathogenic *E. coli*. Viruses include rotavirus and adenovirus. Researchers isolated the most common pathogen, rotavirus, in over 25% of the cases and enteroaggregative *E. coli* in approximately 20% of cases (2011). Significantly, *Shiggella* causes bacterial dysentery, one of the top ten causes of morbidity in Cambodia ("Dysentery," 2010). While the study contributes significantly to the connection of specific bacteria and viruses with diarrheal disease, it fails to address the causes of these pathogens. Further, it includes only short-term diarrheal illness. Conducted in a hospital in Phnom Penh, Cambodia's urban capital, the findings may not accurately represent health in rural Cambodia. My research will address potential causal factors in Pohm Sammnang, a rural region. Few studies investigate specific bacteria in the rural regions of Cambodia. One such study, however, explored risk factors for *C. jejuni* infections in humans and livestock in these regions. Researchers found that 5-30% of the population sample tested positive for *C. jejuni*, depending on age group (Osbjer et al., 2016). This study addresses all ages, not only children, and covers three diverse regions of Cambodia. Data analysis, however, relies on self-reported GI symptoms, which may result in misreporting. Despite the potential for misreporting, scholars in this field widely use methods of self-reporting, and I will also use this method (eg: Brown & Sobsey, 2012; McIver, Imai, et al., 2016). Findings established through self-reporting may be used to hone to more specific research topics in the future.

[13] Schar et al. define acute diarrhea as "3 or more loose stools per 24-hour period with at least 1 other symptom (nausea, vomiting, abdominal pain, fatigue/lethargy, fever)."

Climate change, resulting in both flooding and drought, causes GI illness throughout Cambodia by influencing environmental factors. In 2014, Cambodia ranked 8th (of 193 countries) in infrastructural vulnerability to climate change (Davies et al., 2014). Extreme weather events particularly impact water-borne diseases, because they may result in standing water and/or a lack of sufficient sources of clean water. A study by Davies et al. (2014) indicates that in Cambodia, increases in the incidence of diarrheal illnesses follows periods of major flooding, and periods of drought correlate with increased risk of water-borne diseases. Controlling for sensitivity factors strengthens analysis of incidence of diarrheal illness following periods of major flooding; self-reported census responses, however, limit the data by potentially not including all cases of diarrhea that occurred during the study period. The report also fails to analyze data regarding drought and incidence of diarrheal illness (Davies et al., 2014). McIver, Imai et al. (2016) find a slight negative association between amount of rainfall and monthly cases of diarrheal disease in the Banteay Meanchey province; however, there is no statistically significant association found between increases in temperature and diarrheal disease. Analysis of similar rainfall and temperature data in other provinces provides trends between climate change indicators and diarrhea that vary in direction and magnitude (McIver, Imai, et al., 2016). Although the study control for sensitivity factors, specifically socioeconomic, demographic, and WASH indicators (McIver, Imai et al., 2016), it found inconsistent results throughout Cambodia. While McIver, Imai, et al. contribute an initial understanding of the interaction between diarrheal illness and climate change in Cambodia, further research, especially that in smaller contexts, is needed to confirm the trends. My research addresses this weakness by examining GI illness in relation to water sources and other factors during a drought.

2.1.2 Sensitivity Factors

Globally, scholars and medical professionals associate lower socioeconomic status with increased vulnerability to disease (World Health Organization, 2010). Cambodia's rural populations report higher levels of poverty than those living in urban centers (Asian Development Bank). Despite this discrepancy in poverty rates, the 2014 Cambodian Demographic and Health Survey found little difference in reported prevalence of diarrhea between children under five in rural and urban areas. Prevalence of diarrhea differed significantly, however, between wealth quintiles. The lowest quintile reports that 16.1% of children under five suffer from diarrhea, while the highest quintile reports 11.3% (2015). Wealth-related sensitivity factors impacting diarrheal diseases include educational factors and nutrition status. School attendance rates, among which female school attendance rate is strongest, have the strongest negative correlation with diarrheal disease when compared to WASH factors (McIver, Imai, et al., 2016). Malnourishment can also play a role in diarrheal disease, as it weakens the immune system's ability to counteract pathogens and toxins ("Diarrhoeal disease," 2017). Occupation, closely related to socioeconomic status, may also play a causal role in diarrheal disease among adults. Agricultural workers in Cambodia, specifically those that farm rice, are especially susceptible to GI illness. Agricultural work places, such as the standing water in rice fields, places workers at risk for water-borne pathogens (McIver, Chan, et al., 2016).

WASH factors, particularly lacking in Cambodia, also cause GI illness. About 44% of Cambodia's population does not have access to adequate sanitation facilities (Moench-Pfanner et al., 2016). Many scholars consider higher levels of sanitation health-protective; access to improved sanitation facilities[14] and certain lifestyle factors, such as wearing shoes while defecating, lessen the risk for GI illness (Schar et al., 2014; Inpankaew et al., 2014). In analysis of the 2008 Cambodian census, McIver, Imai et al. (2016) found that unimproved drinking water sources[15] and lack of on-premise toilets increases the risk for diarrheal disease. The study also found that a toilet on the household premises has a negative association with rates of diarrheal disease, as does having a protected dug well or tube/pipe well as the main source of drinking water. The study also notes latrines as mildly health-protective (McIver, Imai, et al., 2016).

This study will explore exposure and sensitivity factors of GI illness in Pohm Sammnang through analysis of demographic and lifestyle factors obtained through interviews.
While various studies analyze GI illnesses on a national level, few studies examine both exposure and sensitivity factors within a single village. I will examine various types of exposure and sensitivity factors to draw conclusions regarding drivers of health in Pohm Sammnang. This thesis will equip local non-profits and other actors to more effectively address GI disease by highlighting the factors most strongly correlated with disease. It will indicate spatial regions that are particularly vulnerable to GI illness and speculate as to why this is the case.

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[14] Improved sanitation facilities "hygienically separate human excreta from human contact." Unimproved sanitation facilities fail to separate human excreta from human contact; these include open pit latrines, hanging latrines, bucket latrines, and open defecation (UNICEF, 2012).
[15] An improved source of drinking water "by nature of its construction, adequately protects the water from outside contamination, in particular from fecal matter." Unimproved drinking water sources are unprotected dug wells, unprotected springs, surface water, vendor-provided water, bottled water, and tanker truck water (UNICEF, 2012).

2.2 Methodology

2.2.1 Design and Setting

Data collection for this thesis took place in June 2016 on behalf of LightBridge International (LBI) in Pohm Sammnang, located in the Banteay Meanchey province. With a team of LBI volunteers, I conducted 45 household interviews and collected data concerning demographics and pertinent problems, particularly those relating to resources and health, in the village. These interviews came third in a series of annual interviews, and they intended to provide direction for future infrastructural intervention. Karla Tillapaugh, Director of LBI, and the University of Michigan Institutional Review Board approved the interview data and accompanying mapping data for secondary use in August 2017.[16]

2.2.2 Interview Questions

I formulated interview questions through modifications of questions from the previous years' interviews. These questions covered topics such as demographics, health problems of household members, occupation, education, and religion. The questions attempted to understand common health problems, so I could identify points of intervention. I added questions regarding water sanitation and use (Questions 5 and 10), as well as questions regarding specific details about agriculture and food procurement (Questions 10 and 12). I also included various clarifying sub-questions and rewrote each question in the second person to allow for conversational interviews. These additions and subtractions of questions intended to elicit detailed information on behaviors and decisions regarding water and use so I could understand drivers of consumption of contaminated water. After the first day of interviews, I removed Question 7, as several

[16] I obtained consent from Karla Tillapaugh through a series of emails. The IRB identification for this study is HUM00131240.

volunteer translators advised me that it was inappropriate and uncomfortable for residents to discuss toilet use with a stranger. In analysis, I have removed this factor completely, as I used the question only in a small portion of household interviews. I also removed the follow-up to Question 15 (regarding Chinese land ownership) after several interviews, because it was leading. Table 2.2 (page 29) displays the total set of questions and follow-ups.

Questions 1 through 4, 13, and 14 ask about household demographic information to connect certain conditions with specific groups of people. I omitted Question 1, which asked for family name, from this thesis to protect the privacy of individuals involved in this study. Question 2 (Total Number of Residents) inquires how many individuals live in each home. The question intends to provide information regarding how the number of individuals living in a single home impacts sensitivity factors. Question 3 requests that households provide the ages and genders of individuals living in each household. This question intended to allow for detailed connections between groups of individuals and lifestyle factors, especially health outcomes. I later removed it from the data set because most households reported the ages and genders of some, but not all, residents. Question 4 (Duration of Residence) asks the number of years since establishing residence in Pohm Sammnang; this question intends to identify new residents of the village and how their health may differ from residents who have lived in Pohm Sammnang longer. Question 13 (School Attendance) provides evidence of education among children, which the literature has shown to be important in preventing diarrheal illness (McIver, Iami et al., 2016). For Question 14 (Religion), households identify which religion, if any, the household practices. Religion is pertinent because religious beliefs may affect factors such as diet and food procurement.

The subsets of question 5 request that residents report factors related to water. These questions focus on determining common ways of using and sanitizing water throughout Pohm Sammnang; this allows greater insight into the spread of water-borne GI diseases. For part A (Water Source), residents reported where they collect or buy their water, given that different sources of water contain different health risks. Part B (Water Sanitation, Filter Water, Boil Water) asks how residents sanitize their water, if at all. Sanitation of water can remove certain pathogens that cause GI illness and should theoretically lead to lower incidence of GI illness.

Questions 6 and 8 inquire about health factors. Question 6 (GI Symptoms) requests that residents report any health problems in their home. I used these results to separate households into two groups, those that report symptoms involving the GI tract and those that do not report symptoms involving the GI tract. For Question 8 (Deaths), residents report any deaths that may have occurred throughout the year prior and the cause of death. This question identified prevalent causes of death for village residents.

Questions 9 through 12 ask residents questions regarding agriculture and food. Question 9 (Food Procurement, Purchase Food) regards how residents procure their food, to identify certain methods that may be more closely correlated with increased incidence of GI disease. In Question 10 (Grow Food), residents indicate if they grow food at their home; research shows that involvement in agriculture can increase risk for parasitic infection (McIver, Chan, et al., 2016). It also asks what kind of produce they grow, if any. Question 11 (Daily Meals) inquires how many meals the household eats per day and helps to indicate malnutrition, which can drive diarrheal illness ("Diarrhoeal disease," 2017). Finally, Question 12 (Animals, Canines, Poultry, Livestock) asks residents if they raise animals and what kind. Animals may harbor zoonotic infections, which can cause GI diseases.

Questions 15 and 16 ask that residents provide information regarding perceived changes in life and needs. For Question 15 (Changes), residents reported any large changes that occurred in their life in the prior year. Question 16 ask residents about aspects of life in which they desire assistance and/or would like to see community-wide changes, such as improvements to infrastructure. Responses to Question 16 have been removed due to the question being leading and therefore unreliable for determining independence from GI Symptoms. I included these questions in the interviews because they were significant for LBI, which conducted the interviews in the previous years. While they do not specifically address health factors, responses to these questions have been included in the study to maintain the integrity of the question set and explore possible connections to health that may arise.

2.2.3 Interview Procedure

Under my direction, LBI volunteers and local translators conducted interviews in groups. I also trained one other volunteer to leads groups so that two groups could perform interviews each day. Groups consisted of one interviewer, one translator, and at least one volunteer. During each interview, the interviewer asked questions, the translator translated for both the interviewer and the household representative, and another individual recorded responses.

This process aimed to approach and conduct an interview in every household in Pohm Sammnang. At each home, the LBI team requested to interview an available adult. If there were not any adults available, the team returned a second time. If the team failed to interview an adult during the second visit, they made no further attempts. To request an interview, the interviewer approached the entrance of the home and expressed a formal Khmer greeting to nearby adults.

They explained that the group was from LBI and asked if we could interview them. LBI did not compensate households for completing an interview, nor did households receive repercussions for refusing to participate in an interview. In 2016, Pohm Sammnang had 155 occupied homes. We requested 46 interviews; 45 households accepted and 1 household declined. Not all households in the village participated, because no one was home or all adults were occupied at the point of interview request.

To maintain order while conducting interviews, the teams spread outward from the LBI school complex, which acted as a central point. Interviewers spoke with adults living in homes closest to the school first, and, each day, interviews began with the homes next to the previous day's ending point. As the teams conducted interviews, they created a map to indicate the position of each home. Group members also noted vacant homes, which served as reference points for occupied homes, on the map. At the end of each day, I compiled interviews into an Excel spreadsheet.

2.2.3 Translators

All translators for this project came as volunteers from a local church that historically partners with LBI to carry out projects in the village. Residents of Pohm Sammnang generally receive this church, located in Poi Pet, and its members positively. The translators did not specifically explain their relation to the church while conducting interviews, and I did not observe evidence of unfriendly or uncomfortable interactions between respondents and translators due to religion. Prior to beginning interviews, I instructed the translators to directly interpret the questions that the interviewer asked and to repeat the exact response of the interview subjects. Mistranslations may have occurred, as none of the volunteers translate as a profession, and I do not speak any Khmer. The responses recorded do not seem to indicate any significant problems with translation, as responses varied in exact answers but remained centered on logical progressions of topics. LBI did not formally compensate the translators in any way, outside of providing lunch for them on days that they assisted our interviewing teams. The group of translators varied from day to day based on individual availability.

2.3 Data Analysis

I performed Pearson's Chi-Square Test of Independence on the 45 sets of interview data to understand which factors GI symptoms are the most dependent on. I tested each of the other 20 factors against the GI Symptoms factor. Some households chose not to report answers to one or more questions; non-responses have been removed, rather than coded into a non-response field. I did this to prevent skewing of the data, as GI Symptoms are not dependent on responding to interview questions. Chi-square testing is an appropriate method for use with interview data, because it expresses how strongly a given set of data deviates from what would be expected from two completely independent variables. This association proves correlation (*not* causation), fitting for self-reported, observational data. I used SPSS 24 to perform all statistical analysis.

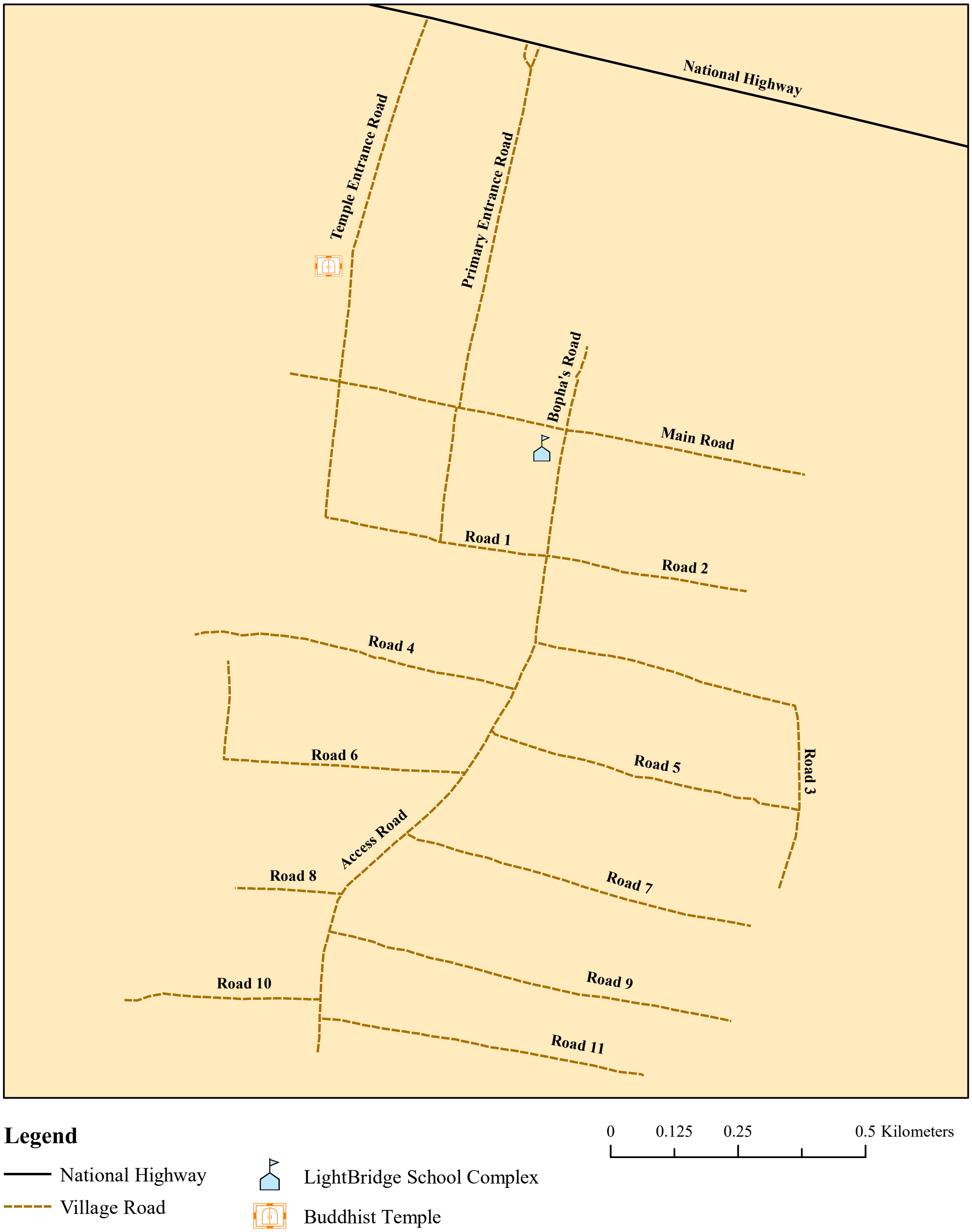
I also used geographic information system (GIS) software, specifically ArcGIS 10.5.1, to understand geospatial factors in Pohm Sammnang. This includes locations of water sources, distances from the LBI school, and distances from water sources. To produce a map of Pohm Sammnang, I cross-referenced a hand-drawn map with a satellite image of the village. I digitized all roads, buildings, and ponds indicated on the map. In all maps displaying individual household locations, I include all homes, not just occupied homes, to protect the privacy of respondents. Map 2.1 (page 27) shows the road names, which I generated for the purpose of differentiating regions throughout this thesis. I did not digitize buildings not noted on the original map, due to uncertainty regarding their occupation status and presence in 2016. All maps use the WGS 84/UTM 48N projected coordinate system, the standard coordinate system for Cambodia.

I separated all factors derived from the interview questions into two categories, exposure or sensitivity, to distinguish the roles of these factors in GI illness in Pohm Sammnang. Exposure factors include factors that directly expose individuals to pathogens that cause GI illness. Sensitivity factors include factors that cause an individual to be more susceptible to GI illnesses when exposed to disease-causing pathogens. This division intends to determine if one type of factor is more significant than the other in GI illness. Table 2.1 displays into which category each factor falls.

Table 2.1
Exposure and Sensitivity Factors

Exposure	**Sensitivity**
Water Source	Total Number of Residents
Water Sanitation	Duration of Residence
Filter Water	Deaths
Boil Water	Daily Meals
Agricultural Occupation	School Attendance
Occupation in Thailand	Religion
Food Procurement	Changes
Grow Food	
Purchase Food	
Animals	
Canines	
Poultry	
Livestock	

Map 2.1
Roads in Pohm Sammnang, 2016



2.3.1 Coding Interview Responses

To use interview responses in chi-square testing, I separated all responses into nominal categories. I generated categories that intend to illicit the most meaning while condensing responses into the minimum number of categories. In the following paragraphs, I explain why I created specific categories. I assigned each nominal category a number code (indicated parenthetically throughout this section) to create meaningful summaries of the data. Table 2.2 displays interview questions, nominal response categories, coding values, and frequencies. Table 2.3 shows descriptive statistics including the range, mean, and standard deviation of responses for each factor.

Table 2.2
Interview Questions, Response Factors, Coding, and Frequencies

1. **What is your family name?**
   Question removed from interview question set

2. **How many people live in your home?**
   Total Number of Residents
   0 – 1-5 residents (29 households, 64.4%)
   1 – 5-10 residents (14 households, 31.1%)
   2 – More than 10 residents (2 households, 4.4%)

3. **What are the ages and genders of people living in your home?**
   Response excluded from data

4. **How long has your family lived here?**
   Duration of Residence
   0 – Has lived in Pohm Sammnang for 0-10 years (26 households, 57.8%)
   1 – Has lived in Pohm Sammnang for more than 10 years (19 households, 42.2%)

5. **Where do you get your water? Do you boil your water before you drink or cook with it? Do you filter your water before you drink or cook with it?**
   Water Source
   0 – Collects drinking water from other sources (11 households, 25%)
   1 – Purchases drinking water (33 households, 75%)

   Water Sanitation
   0 – Does not sanitize drinking water (9 households, 22%)
   1 – Sanitizes drinking water (any method) (32 households, 78%)

Filter Water
0 – Does not filter drinking water (34 households, 82.9%)
1 – Filters drinking water (7 households, 17.1%)

Boil Water
0 – Does not boil drinking water (12 households, 29.3%)
1 – Boils drinking water (29 households, 70.7%)

6. **Is anyone in your home sick?**
GI Symptoms
0 – Does not report symptoms of esophagus, stomach, or intestines (27 households, 64.3%)
1 – Reports symptoms regarding esophagus, stomach, or intestines (15 households, 35.7%)

7. **Where do you use the toilet?**
Question removed from question set

8. **Have there been any deaths in your family in the last year?**
Deaths
0 - Reports no deaths of household members between June 2015 and June 2016 (33 households, 86.8%)
1 – Reports one or more deaths of household members between June 2015 and June 2016 (5 households, 13.2%)

9. **What work do you do? Who in your family works?**
Agricultural Occupation
0 – Reports occupation unrelated to agriculture (22 households, 50%)
1 – Reports agricultural occupation (22 households, 50%)

Occupation in Thailand
0 – Reports occupation not in Thailand (32 households, 72.7%)
1 – Reports occupation in Thailand (12 households, 27.3%)

10. **Where do you get your food? Do you grow food at home? Is there enough water to take care of what you grow?**
Food Procurement
0 – Grows some or all of food (8 households, 19%)
1– Purchases some or all of food (16 households, 38.1%)
2 – Purchases and grows food (18 households, 42.9%)

Grow Food
0 – Does not grow any food (11 households, 25%)
1 – Grows some or all of food (33 households, 75%)

Purchase Food
0 – Does not purchase any food (8 households, 19%)
1 – Purchases some or all of food (24 households, 81%)

11. **How many meals do you eat each day?**
Daily Meals
1 - Household eats 1 meal a day, on average (7 households, 21.9%)
2 – Household eats 2 meals a day, on average (17 households, 53.1%)

3 – Household eats 3 meals a day, on average (8 households, 25%)

12. **Do you raise animals at home? (If yes, what kind? Where? What are challenges? What do you use the animals for?)**
    Animals
    0 – Does not raise any animals (9 households, 20.9%)
    1 - Raises one or more species of animal (34 households, 79.1%)

    Canines
    0 - Does not own any canines (30 households, 68.2%)
    1 – Owns one or more canines (14 households, 31.8%)

    Poultry
    0 - Does not own any chickens, ducks, or turkeys (11 households, 25%)
    1 – Owns one or more chickens, ducks, or turkeys (33 households, 75%)

    Livestock
    0 – Does not own any cows or pigs (40 households, 90.9%)
    1 – Owns one or more cows and/or pigs (4 households, 9.1%)

13. **Do the children in the family attend school? (If yes, where?)**
    School Attendance
    0– Children of primary or secondary school age do not attend primary school (5 households, 12.2%)
    1 – Children of primary or secondary school age attend school (30 households, 73.2%)
    2 – No children of primary or secondary school age in household (6 households, 14.6%)

14. **What is your religion?**
    Religion
    0 - Report Christian religion (6 households, 14%)
    1– Report Buddhist religion (37 households, 86%)

15. **In the past year, have there been any changes in your life, in any category?**
    Changes
    0 – No changes (30 households, 78.9%)
    1 – Major changes in personal life (3 households, 7.9%)
    2 – Major changes in finances (5 households, 13.2%)

16. **What is your biggest need?**
    Responses removed from data set

Table 2.3
Descriptive Statistics*

	Possible Range	Mean	Standard Deviation
Exposure			
Water Source	0 – 1	.75	.438
Water Sanitation	0 - 1	.78	.419
Filter Water	0 - 1	.17	.381
Boil Water	0 - 1	.71	.461
Agricultural Occupation	0 - 1	.50	.506
Occupation in Thailand	0 - 1	.27	.451
Food Procurement	0 - 2	1.23	.759
Grow Food	0 - 1	.75	.438
Purchase Food	0 - 1	.81	.397
Animals	0 - 1	.79	.412
Canines	0 - 1	.32	.471
Poultry	0 - 1	.75	.438
Livestock	0 -1	.09	.291
Sensitivity			
Total Number of Residents	0 - 2	0.40	.580
Duration of Residence	0 - 2	.42	.499
Deaths	0 - 1	.13	.343
Daily Meals	1 - 3	2.03	.695
School Attendance	0 - 2	1.02	.524
Religion	0 - 1	.86	.351
Changes	0 - 2	.34	.708

*Table 2.2 contains frequencies for all factors.

I coded health-related responses into two categories each, which separates the factors into the absence and presence of disease or condition. GI Symptoms included categories of households that did not report any individuals with GI symptoms (0) and households that reported at least one individual with GI symptoms (1). I define GI symptoms as any symptom relating to the GI tract, which includes the esophagus, stomach, and/or intestines (“Gastrointestinal Tract (GI Tract)”). The former category includes households that reported no health issues or reported symptoms unrelated to the GI tract. Categories for the Death factor include no deaths in the past year (0) and at least one death in the past year (1). This study makes no further distinctions regarding death.

Due to the wide variety of responses to questions eliciting demographic data, I separated most of these responses into three categories each, with the exception of the Duration of Residence and Religion factors. Categories for Total Number of Residents include 0-5 residents (0), 6 – 10 residents, and more than 10 residents (2). Heads of household reported a minimum of 1 resident and a maximum of 12 residents. I separated Duration of Residence into 0 – 10 years of residence (0) and greater than 10 years of residence (1). Years of residence in Pohm Sammnang range from 2 years to 23 years. Using these specific categories accounts for households that report a range of years, rather than a single year, while also maintaining categories with similar ranges.[17] Some households reported the year that they moved to Pohm Sammnang. In those cases, I calculated the years the household had been present in the village as of June 2016. For the School Attendance factor, I divided responses into categories of school-aged children do not attend school (0), school-aged children do attend school (1), and no school-aged children in household (2). This study considers children of primary and secondary ages "school-aged;" in Cambodia, following the traditional course of school attendance, this corresponds with ages 6 through 18.[18] This was done to distinguish failure to attend school from the absence of school-age children. In the Changes factor, I separated responses into no changes (0), changes in personal life (1), and changes in finances (2).[19] This was done to separate financial change, which directly relate to poverty status, from other changes. There is no distinction in these categories between positive and negative changes, as this is both subjective and went unrecorded in some interviews. Finally, I coded Religion into two categories, Christian (0) and Buddhist (1), as residents did not report following any other religions. In households that reported aspects of

[17] Two households, for example, reported living in the Village for "10 – 12 years."
[18] In Cambodia, primary school begins at age 6. Secondary school begins at age 15 and lasts 3 years (*Cambodia: Age Distribution and School Attendance of Girls Aged 9-13 Years*, 2013).
[19] Changes in personal life included familial death, children moving away, etc.

both religions, I coded responses using the primary religion.[20] Only two households reported this type of response, so I did not create a separate category.

I coded water-related lifestyle factors into two categories per factor. Responses for Water Source included collection from ponds (private and public), rainwater, and wells, in addition to various types of purchasing. To best capture differences in exposure to pathogens, as Water Source is an exposure factor, I divided the sources into the categories of purchase water (1) and other source (0). The purchasing water category includes purchasing water from village markets and water trucks, while other sources include all water collected from ponds, rainwater, and wells. This divides cleaner water sources from those likely to harbor higher concentrations of pathogens due to outdoor exposure. Water Sanitation contains categories of household does not sanitize drinking water (0) and household does sanitize drinking water (1). For this factor, I coded any method of water sanitation in response to Questions 5a and 5b as sanitizes water (1). To determine any relevant differences between boiling and filtering water, I coded Filter Water and Boil Water separately. Categories for Filter Water include household does not filter drinking water (0) and household filters drinking water (1). Categories for Boil Water include household does not boil drinking water (0) and household boils drinking water (1). In houses that report both filtering and boiling drinking water, I coded both factors as 1.

The two sets of responses regarding occupation factors – the Agricultural Occupation and Occupation in Thailand - include two categories each. This reflects households containing individuals that either do or do not engage in specific types of work. Categories for Agricultural Occupation include no individuals in the household have occupations related to agriculture (0) and at least one individual in the household has an occupation related to agriculture (1). For the

[20] For example, one household reported religion as "Buddhist, but loves Jesus." In this case, Religion was coded as Buddhist.

purpose of this study, I consider occupations wherein individuals are involved in farming, planting, or harvesting crops as related to agriculture. This does not include individuals who engage in subsistence farming, as subsistence farming does not occur outside of the home. Further, the Grow Food factors accounts for subsistence farming. Many households also reported a resident who works in Thailand, as the Thai border is located within kilometers of Pohm Sammnang. [21] Categories for Occupation in Thailand include no individuals in household work in Thailand (0) and at least one individual in household works in Thailand (1). These categories do not differentiate between different types of work in Thailand, as this was not reported through the interviews. Occupation categories do not consider the number of residents for each occupation, because the majority of households reported a single employed individual.

I separated responses for food-related factors into source categories. Food Procurement includes: household grows food (0), purchases food (1), and both purchases and grows food (2). To determine potential differences in GI symptoms between purchasing food and growing food, I use the factors Purchases Food and Grows Food. Categories for Purchases Food includes household purchases no food (0) and household purchases at least some food (1). Grows Food categories include household does not grow any food (0) and household grows at least some food (1). For Daily Meals, I created categories for 1, 2 and 3 meals eaten per day. To account for households that reported a range rather than an integer value, I coded the reported number as the lower end of the range.[22] Chi-square testing requires nominal values, necessitating this rounding, as opposed to creating averages. While averages could be considered nominal variables, this would create too many categories with small numbers of cases to produce meaningful results.

[21] To protect the privacy of individuals, I do not provide the exact distance.
[22] For example, households that report eating "1-2 meals per day" have been coded as eating 1 meal per day.

Finally, I separated all factors regarding the ownership of animals into two separate categories. In each case, these categories include owning or not owning animals or a specific species of animal. Categories for Animals include household does not own any animals (0) and household owns one or more animals (1). I created factors separating animals into related species to examine potential differences in GI symptoms produced by different animals. Categories for Canines include household does not own any canines (0) and household owns one or more canines (1). Categories for poultry include household does not own any poultry (0) and household owns at least one poultry (1). For the purposes of this study, poultry includes chickens, ducks, and turkeys. Categories for Livestock include household does not own any livestock (0) and household owns at least one head of livestock (1). Livestock includes both pigs and cows. No households report owning any animals outside of the aforementioned species.

2.4 Limitations

This study uses indicators of broader phenomena, such as poverty, to determine correlation between demographic and lifestyle factors and GI illness. Indicators, however closely related, cannot define the nuances of some phenomena. For examples, ownership of cows or pigs may indicate relative poverty, but livestock alone cannot determine the poverty or illness status of a household. Because this study relies on interview data collected prior to the onset of the study, it does not include household income, which could be used to determine relative poverty. In the future, such information would be useful in confirming indicators of poverty.

Additionally, this thesis describes correlational, rather than causal, relationships. A correlational study appropriately uses interview data, but it restricts explicitly defining causality.

Factors on which GI symptoms depends may not directly cause the symptoms to occur. Thus, this thesis defines which local factors in GI illness should be investigated further in the future.

The unit of a household also limits this study. In exploring cause of illness, the individual is a significant unit, as illness can affect some members of a household but not others. Other factors are also more significant at the individual level than at the household level, such as occupation. In the future, collecting similar data at an individual level would produce more robust results.

2.5 Conclusion

In the next chapter, I use the previously explained methodology to discuss the results of statistical testing. I also provide the results of chi-square testing, specifically focusing on four factors that approach significance.

Chapter 3: Results

In this chapter, I provide the results of Pearson's chi-square test for independence between GI Symptoms and other factors. I use GI Symptoms as the dependent variable for testing. I also discuss important aspects of lifestyle in Pohm Sammnang to clarify the nature of trends. Finally, I identify four factors – Filter Water, Canines, Livestock, and School Attendance – as most the significant preventative and risk factors for GI outcomes.

3.1 Statistical Analysis

Throughout June 2016, my team conducted interviews with 45 households in total (N = 45). Respondents at some households chose not to answer specific questions; these non-responses have been removed from the data associated with each factor, such that each factor has a unique value (n) representing the number of responses received for that specific factor. This adjustment to number of responses (n) prevents skewing of the chi-square test due to non-response. Table 3.1 displays the total number of valid responses gathered for each factor, as well as the number of missing responses. For the purpose of this study, a valid response indicates that respondents provided an answer to the associated interview question; missing responses indicate the residents gave no response. I consider any answer given by a participant in response to a specific interview question was considered as a valid response, such that there are no invalid responses.

Table 3.1
Total Responses

	Valid (%)	Missing (%)
Exposure		
Water Source	41 (91.1)	4 (8.9)
Water Sanitation	38 (84.4)	7 (15.6)
Filter Water	38 (84.4)	7 (15.6)
Boil Water	38 (84.4)	7 (15.6)
Agricultural Occupation	41 (91.1)	4 (8.9)
Occupation in Thailand	41 (91.1)	4 (8.9)
Food Procurement	39 (86.7)	6 (13.3)
Grow Food	41 (91.1)	4 (8.9)
Purchase Food	39 (86.7)	6 (13.3)
Animals	40 (88.9)	5 (11.1)
Canines	41 (91.1)	4 (8.9)
Poultry	41 (91.1)	4 (8.9)
Livestock	41 (91.1)	4 (8.9)
Sensitivity		
Total Number of Residents	42 (93.3)	3 (6.7)
Duration of Residence	42 (93.3)	3 (6.7)
Deaths	36 (80)	9 (20)
Daily Meals	30 (66.7)	15 (33.3)
School Attendance	38 (84.4)	7 (15.6)
Religion	42 (93.3)	3 (6.7)
Changes	36 (80)	9 (20)

To perform statistical analysis, I tested the GI Symptoms factor for independence against each other factor in the data set using Pearson's chi-square test. GI Symptoms acts as the dependent variable throughout analysis. This testing produced 18 different p-values, none of which I consider significant ($p \leq 0.10$). Four factors, however, near significance; for the purpose of this study, I define a p-value of less than 0.2 ($p \leq 0.20$) as nearing significance. These factors include Filter Water, Canines, Livestock, and School Attendance. Table 3.2 displays the p-values produced by Pearson's chi-square test for all factors tested. The table also includes the p-values produced by Fisher's exact test.[23] These p-values follow a trend similar to that of the p-values produced by Pearson's chi-square test.

[23] Fisher's Exact Test accounts for cases in which expected count falls below 5 for any given cell.

Table 3.2
Pearson Chi-Square *P*-Values

	P-Value*
Exposure Factors	
Water Source	.311 (.453)
Water Sanitation	.537 (.689)
Filter Water	.157 (.203)**
Boil Water	.858 (1.000)
Agricultural Occupation	.658 (.751)
Occupation in Thailand	.797 (1.000)
Food Procurement	.654 (.639)
Grow Food	.574 (.719)
Purchase Food	.735 (1.000)
Animals	.868 (1.000)
Canines	.123 (.170)**
Poultry	.653 (.712)
Livestock	.130 (.280)**
Sensitivity Factors	
Total Number of Residents	.559 (.686)
Duration of Residence	.890 (1.000)
Deaths	.708 (1.000)
Daily Meals	.982 (1.000)
School Attendance	.142 (.114)**
Religion	.430 (.649)
Changes	.651 (1.000)

*This table reports *p*-values as determined using Pearson's chi-square test for independence. It includes, in parenthesis, the *p*-value produced by Fisher's exact test.
**Factor approaching significance using the *p*-value produced by Pearson's chi-square test.

3.2 Factors Approaching Significance

Among the factors tested, outcomes in GI health depend most on the factors Filter Water, Canines, Livestock, and School Attendance. Table 3.3 summarizes these results. In this section, I describe, in detail, the outcomes of statistical testing for these four factors. Results produced for all other factors, upon which GI illness is less dependent, can be found in Appendix A (page 70).

Table 3.3
Factors Approaching Significance

	P-Value
Exposure Factors	
Filter Water	.157 (.203)
Canines	.123 (.170)
Livestock	.130 (.280)
Sensitivity Factors	
School Attendance	.142 (.114)

In Pohm Sammnang, the outcome of GI Symptoms depends on the filtration of drinking water. Of the 38 households that responded to the question regarding water filtration, 7 households reported filtering their drinking water. 31 households reported *not* filtering drinking water. Testing the dependence of GI illness on filtration of water produced a *p*-value of 0.157. In conjunction with the literature, these findings indicate that not filtering water correlates with greater reporting of GI Symptoms. Table 3.4 provides a full description of results.

Table 3.4
Dependence Between GI Symptoms and Filtering Water

	GI Symptoms		
	Symptoms	No symptoms	Total
Filtration			
Filters	4	3	7
Does not filter	9	22	31
Total	13	25	38

n = 38, d.f. = 1
p = .157 (.203)

The outcome of GI Symptoms also depends on ownership of canines. The chi-square test for independence between GI Symptoms and Canines produces a *p*-value of 0.123. 14 households in the sample reported owning one or more canines; 7 of those households reported GI symptoms in at least one member of the household. Table 3.5 displays the full description of results.

Table 3.5
Dependence Between GI Symptoms and Ownership of Canine(s)

	GI Symptoms		
	Symptoms	No symptoms	Total
Canine(s)			
Owns canine(s)	7	7	14
Does not own canine(s)	7	20	27
Total	14	27	41

n = 41, d.f. = 1
p = .123 (.170)

The prevalence of GI Symptoms similarly depends on ownership of livestock. Of the 41 households that responded to the question regarding livestock, four homes reported owning livestock (cows and/or pigs). While the reporting of only four households results in a small sample, the results are important because all cases of owning livestock fall into the same category, no symptoms of GI illness. The *p*-value for independence between GI Symptoms and Livestock is 0.130. Table 3.6 provides a full description of results.

Table 3.6
Dependence Between GI Symptoms and Ownership of Livestock

	GI Symptoms		
	Symptoms	No symptoms	Total
Livestock			
Owns livestock	0	4	4
Does not own livestock	14	23	37
Total	14	27	41

n = 41, d.f. = 1
p = .130

Finally, GI Symptoms depend on school attendance among school-aged children, as determined using Pearson's chi-square test. Chi-square testing produces a *p*-value of 0.142 for this factor. 38 households reported on school attendance; among these households, 32 had children of primary or secondary school age living in them in 2016.[24] These finding indicate that

[24] School-aged children are ages 6-18. See Chapter 2 for further explanation.

school attendance among school-aged children correlates with reduced reporting of GI Symptoms. Table 3.7 displays the full description of results.

Table 3.7
Dependence Between GI Symptoms and School Attendance Among School-Aged Children

	GI Symptoms		
	Symptoms	No symptoms	Total
School Attendance			
Attends school	6	21	27
Do not attend school	3	2	5
No school-aged children	3	3	6
Total	12	26	38

n = 38, d.f. = 2
p = .142

3.3 Conclusion

In the following chapters, I use the results produced by statistical analysis to argue that filtering water, owning livestock, and attending school reduces incidence of GI illness. I also argue that owning one or more canines is a risk factor for GI illness. In Chapter 5, I use these outcomes to address implications for future public health interventions by government agencies and NGOs in the region.

Chapter 4: Factors Approaching Significance in Gastrointestinal Illness

In this chapter, I describe which factors most strongly influence GI outcomes in Pohm Sammnang. I define three factors, Filter Water, Livestock, and School Attendance, as protective against GI illness in the village. I discuss attending school, owning livestock, and filtering drinking water as preventative behaviors against GI illness. Finally, I describe one factor, Canines, as a risk factor for GI illness; cases of GI symptoms correlate with households owning at least one canine.

4.1 Influential Factors

In Chapter Three, I provided results of Pearson's chi-square test for independence. This test demonstrated the extent to which the outcome of GI Symptoms depends on demographic and lifestyle factors reported by households. Testing the independence of GI Symptoms from other factors did not produce any factors that are statistically significant factors ($p \leq .10$). In this chapter, I report factors with a p-value of less than 0.2 ($p \leq .20$) as having the strongest influences on GI symptoms in Pohm Sammnang, because these factors approach significance. This methodology is appropriate for two reasons.

First, this study used a small sample size of only 45 households (N=45). However, the sample likely represents the population of households in Pohm Sammnang because it captures a significant proportion of the total number of occupied households. The map accompanying the interview data shows 155 occupied homes (2016), so the sample includes about 30% of the total number of households. Some factors do have a sample size of less than 45 ($N < 45$), due to households' choice to not answer specific interview questions. All interviews, however, have at least 30 responses, the commonly accepted size of a valid sample. The minimum number of households included in a factor is 30 (N = 30), and the maximum number of households is 42 (N = 42) (see Table 3.1 on page 39). While the sample *does* represent the population of households in Pohm Sammnang, slight variations in samples of this size strongly influence statistical outcomes.

Secondly, reporting factors that approach significance accounts for potential misreporting by households. Households self-reported all factors through interviews, which may have resulted in inaccurate data in two ways. First, respondents may have intentionally or mistakenly misreported health problems, which would alter the number of cases of GI illness found by this study. The majority of households reported a single illness or injury; it is likely, however, that multiple individuals in each household experienced some sort of health complication. More apparent issues in health, such as an individual who has been debilitated by chronic illness, may have overshadowed conditions experienced and managed daily, including diarrhea and other GI conditions. Additionally, households may have misreported other factors addressed in the interviews.[25] For various factors, respondents may have felt compelled to report answers perceived as correct because interviewers represented LBI, a non-profit organization engaged in the provision of resource to Pohm Sammnang. Because LBI provides resources to all individuals in Pohm Sammnang without discrimination[26] and the organization did not connect interviews to any benefit or restriction of resources, interview results remain valid. Additionally, similar studies regarding GI illness effectively utilize survey data collected using self-report methods (e.g.: McIver et al., 2016). Despite this, it remains possible that a small minority of households misreported responses, which would strongly influence statistical outcomes. Reporting factors

[25] One anecdotal example is the case of the Boils Water factor. 29 households reported boiling drinking water prior to consumption. While completing interviews, however, I did not observe a single case of water being boiled.
[26] For example, LBI funds the only school currently operating in the Village. For very minimal fees, any child in the Village may attend the school.

that approach significance as the most influential allows for the recognition of impactful factors even in the case of minor misreporting.

Testing factors that strongly influence GI illness in Pohm Sammnang may result in p-values approaching significance, rather than statistically significant results, due to the small sample size and potential misreporting. Small variations that occur in small samples can influence results substantially. To exhibit the impact of a small sample size, I provide theoretical results involving manipulation of single cases in the following sections. These tests indicate that for some factors, a single response can decrease a p-value from approaching significance ($p \leq .20$) to statistical significance ($p \leq .10$). Therefore, it is appropriate to report values that approach significance as the most influential on GI outcomes in Pohm Sammnang.

4.2 Health-Protective Factors

In this section, I use the results produced by chi-square testing to argue three household behaviors as the most influential in preventing GI illness in Pohm Sammnang. These behaviors include filtering drinking water, owning livestock, and school-aged children attending school.

4.2.1 Filtering Drinking Water as Health-Protective

Testing the independence of GI Symptoms and Filter Water produces a p-value of 0.157 ($p = .157$), indicating that filtering water strongly influences GI illness. While the deviation of actual values from the expected values produced by chi-square testing does not evidence a clear trend -- whether filtering drinking water acts as a risk or prevention factor for GI illness -- previous research establishes the role of contaminated water in GI illness in rural Cambodia (e.g.: Davies et al., 2014; McIver, Chan, et al., 2016; McIver, Imai, et al., 2016). Pathogens that cause GI illness reside in untreated drinking water, so I consider Filter Water an exposure factor. Filtering drinking water removes pathogenic bacteria and viruses from water sources before consumption, thus protecting individuals against developing GI infections.

Given that Filter Water confirms the important nature of water quality in preventing or contributing to GI illness, results of testing for independence between GI Symptoms and the factors Boil Water and Water Source should also approach statistical significance. These factors, however, do not approach significance in this study. Misreporting of household behaviors regarding boiling water, as described on page 45, likely influenced the results of the Boil Water factor. Previous research in Cambodia indicates that boiling water occurs at a rate much lower than that which individuals report, which may result from overestimating the practice of boiling when self-reporting (Brown & Sobsey, 2012; Heri & Mosler, 2008). Additionally, in a 2012 study, Brown and Sobsey reported that boiling strategies utilized in peri-urban Cambodia reduced, but did not remove, the presence of pathogenic *E. coli*. The study also identified improper storage as a common factor that contaminates water after boiling (Brown & Sobsey, 2012). Therefore, even households that do boil drinking water prior to consumption have the risk of developing GI illness, such as diarrhea. For these reasons, GI illness does not depend on the Boil Water factor in Pohm Sammnang.

The nature of the sources from which individuals purchase water complicates the Water Source factor. Although water purchased from a vendor or tanker truck may appear to be more clean than water collected from a pond, the WHO considers these sources unimproved sources of drinking water (UNICEF, 2012).[27] In Pohm Sammnang, the tanker truck that many village

[27] An improved source of drinking water "by nature of its construction, adequately protects the water from outside contamination, in particular from fecal matter." Unimproved drinking water sources are unprotected dug wells, unprotected springs, surface water, vendor-provided water, bottled water, and tanker truck water (*Guidelines for Drinking Water Quality, Forth Edition*, 2011).

residents purchase their drinking water from also collects the water from a nearby pond (S. Eng Phorn, personal communication, June 2016). The water purchased from the trunk and surface water, therefore, likely have similar characteristics. This explains why the Water Source factor does not produce statistically significant results. In the future, greater understanding of specific sources of drinking water – which ponds, vendors, etc. residents obtain water from – would provide greater clarity for understanding the root cause of GI illness in Pohm Sammnang.

4.2.2 Livestock as Health-Protective

Testing for independence between GI Symptoms and Livestock produces a *p*-value of 0.130 ($p = 0.130$), indicating that ownership of livestock influences GI illness in Pohm Sammnang. Interestingly, all four households that own Livestock in the sample report *no symptoms* of GI illness (see Table 3.6 on page 42). I report ownership of livestock as highly influential on GI illness, despite the small number of cases, because *all* households that report owning livestock report the same GI outcome (no GI symptoms). This finding indicates that owning livestock protects health in Pohm Sammnang.

Because research typically implicates livestock in the spread of zoonotic illness, ownership of livestock likely acts an indicator of relative wealth in this local context. Previous research establishes a variety of zoonotic illnesses, including GI illnesses, transmitted from livestock to humans. Important factors in this mode of infection include free-range management[28] and failure to wash hands after handling livestock, both behaviors that I observed in Pohm Sammnang (Kristina Osbjer et al., 2015). Therefore, owning livestock likely does not

[28] "Free-range management" describes livestock being free to roam rather than confined to a particular space. This leads to close interaction between humans and livestock, and livestock potentially have a presence within the home, in cooking spaces, and in the yard (Kristina Osbjer et al., 2015).

reduce exposure to pathogens in Pohm Sammnang. A cow in Cambodia costs about $650 (USD, 2018), which represents a significant investment by a household, as the GNI per capita is only $1,140 (USD) ("Cows for Cambodia," 2018; *Gross National Income per Capita 2016, Atlas Method and PPP*, 2017). The ability to expend resources through the purchase and maintenance of livestock indicates potentially higher income in households that own livestock. Because the literature associates higher socioeconomic status with better health outcomes across Cambodia, Livestock serves as an indicator of relative wealth – a latent variable in GI illness – in Pohm Sammnang (McIver, Imai, et al., 2016). Although Livestock typically acts as an exposure factor, due to cows and pigs being potential carriers of pathogens, it functions as a sensitivity factor in this local context.

4.2.3 School Attendance as Health-Protective

Testing the independence of GI Symptoms and School Attendance produces a result approaching significance, with a *p*-value of 0.142 ($p = .142$). School Attendance act as a health-protective sensitivity factor in Pohm Sammnang. Given equal exposure to pathogens, households with children attending school are more protected against GI illness than those with children not attending school. This result affirms findings by McIver, Imai et al. (2016) regarding interactions between school attendance and diarrheal illness (McIver, Imai, et al., 2016). The protective nature of school attendance may be due to several reasons. First, children attending the LBI school have access to a toilet in the school complex. The WHO reports that the use of improved sanitation facilities, including toilets, reduces the risk of diarrhea and the spread of IPIs ("Sanitation Fact Sheet," 2017). The curriculum at the school also teaches the importance of hand-washing, and school facilities provide clean water and soap for students to engage in the practice of hand washing (D. Baca, personal communication, 2018).

4.3 Canines as a Risk Factor

Testing for independence between GI Symptoms and Canines produces a *p*-value of 0.123 (*p* =.123)., which indicates that owning canines strongly influences GI Symptoms. Three of four cells in the 2x2 table produced by chi-square testing contain seven cases each (see Table 3.5). Replacing one case of "no GI symptoms" with a case of "GI symptoms" at random (such that Table 4.1 is created) results in a *p*-value of .059 (*p* = .059). This indicates that the distribution of responses significantly influences the results of a small sample.

Owning canines acts an exposure factor, because members of households that own canines come into close contact with the canines, which harbor pathogens. These pathogens include various species of hookworms and other parasites, which cause GI infections (Schar et al., 2014). While conducting interviews, I observed that the majority of owners in Pohm Sammnang did not confine their canines to any specific area, and the animals could typically enter both the cooking and sleeping areas of households. The health risk posed by canines in Pohm Sammnang is consistent with other studies that indicate the zoonotic nature of pathogens that canines may harbor (George et al., 2017; Inpankaew et al., 2014).

Table 4.1
Theoretical Dependence Between GI Symptoms and Ownership of Canine(s)

	GI Symptoms		
	Symptoms	No symptoms	Total
Canine(s)			
Owns canine(s)	8	6	14
Does not own canine(s)	7	20	27
Total	14	27	41

N = 41, d.f. = 1
p = .059

4.4 Summary and Conclusion

The findings reported in the previous sections indicate the important roles of both sensitivity and exposure factors in GI illness in Pohm Sammnang. The sensitivity factors of school attendance and owning livestock protect against the acquisition of GI illness among household members. Filtering drinking water, an exposure factor, protects households from ingesting harmful pathogens that cause GI symptoms. Finally, owning canines exposes households to zoonotic pathogens that cause GI illness. As these factors all relate to relative wealth through access to resources such as education, livestock, and clean water, these findings also indicate the significant role of relative poverty in driving GI illness in Pohm Sammnang.

In Chapter 4, I explained which factors in Pohm Sammnang most strongly influenced health by protecting against and posing the risk of GI illness. I also speculated on the sources of these patterns. In Chapter 5, I will use the previously described factors to address which regions of Pohm Sammnang are most vulnerable to GI illness. I also use the factors approaching significance to provide recommendations for NGOs and governmental organization working to reduce the burden of GI illness in this area.

Chapter 5: Supporting GI Health in Pohm Sammnang

In previous chapters, I discussed the primary factors correlated with GI illness in Pohm Sammnang. In this chapter, I use those findings to address specific ways that NGOs and governmental organizations working in the region, specifically in rural Banteay Meanchey, can bolster village infrastructure to decrease prevalence of GI illness. I begin by using factors related to water, education, and relative wealth to identify the regions where the residents most vulnerable to GI illness live. Then, I address how NGOs and community members can promote health-protective behaviors, including water filtration, school attendance, and accumulation of financial resources. I also suggest how these organizations can mitigate the risk of GI illness resulting from contact with canines. I conclude with an explanation of applying these finding to other regions in rural Banteay Meanchey.

5.1 Vulnerability Index

To effectively prevent GI illness, organizations must understand where the most vulnerable populations live. Based on the findings that I presented in Chapter 4, I identified these regions by using ArcGIS by create a Vulnerability Index that includes households' distance from surface water (ponds), distance from the LBI school complex, and distance from the most frequented exit from Pohm Sammnang. Although owning canines places households at risk for developing GI illness, ownership likely does not have a geographic trend; therefore, I did not include it in this spatial analysis. This index considers close proximity to ponds a risk factor for GI illness, as this is more likely to result in use of potentially contaminated pond water for drinking than living further from ponds. Living further from the LBI school complex represents greater challenges to attending school regularly, as most children in Pohm Sammnang walk or bike to school.[29] Therefore, further distance from the school indicates higher vulnerability to GI illness than close proximity. Finally, living further from the Pohm Sammnang exit results in lesser economic opportunity due to difficulties in travel; there are few opportunities for formal or informal employment in Pohm Sammnang, and many residents indicated leaving the village for employment purposes during interviews. Economic opportunity relates to GI illness because the Livestock factor described in Chapter 4 indicates that greater relative wealth, such as that accumulated through employment outside of Pohm Sammnang, correlates to lesser incidence of GI illness.

To create three individual indices addressing water, school attendance, and economic opportunity, I assigned quantitative distance values to categorical levels of access to the particular resource. I then designated an index value – describing relative level of vulnerability – for each category and added the three indices together to produce overall index values. All distance values in this chapter represent direct distance, rather than distance via roadways or informal pathways, to account for differences in length of preferred route. Lower index values represent lesser relative vulnerability to GI illness, and higher values represent greater vulnerability to GI illness. While the Vulnerability Index could theoretically produce values ranging from 3 to 12, it produced values from 6 to 12. In the final index, I assigned each household the index value of the region in which it is located.

Greater access to surface water results in greater risk of developing GI illness, because close proximity likely results in the consumption of contaminated water. To calculate distance between homes and potentially contaminated water, I created buffer zones around all sources of surface water (ponds) visible on a satellite image of Pohm Sammnang. Because of sparse tree

[29] Observation by author during fieldwork in June 2016.

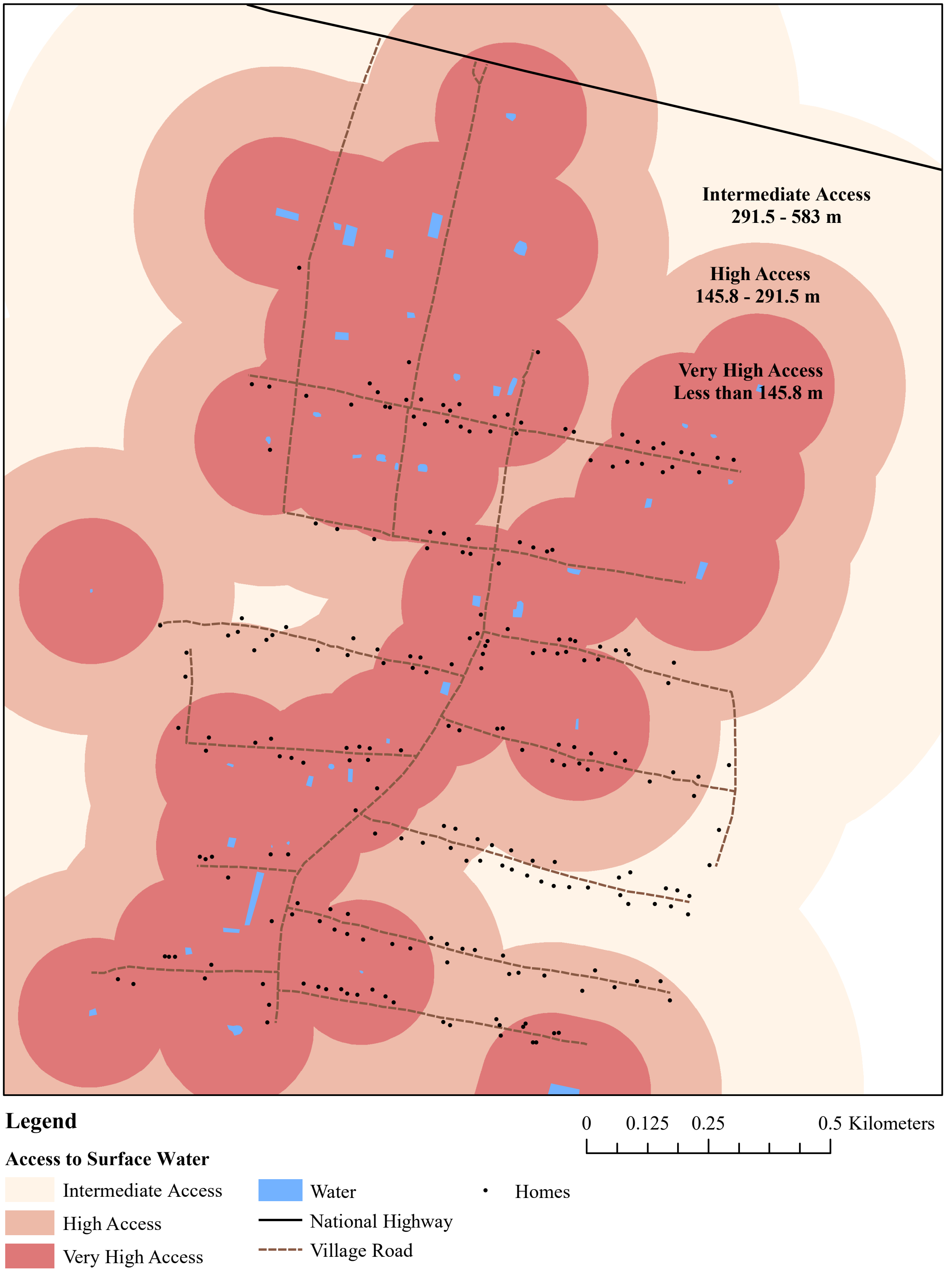
cover, I could easily identify surface water. I calculated the extent of each buffer zone using the average length of Roads 1 through 11, 583 meters, because most homes in Pohm Sammnang lie along these roads. The Water Index considers one quarter of this distance (145.8 meters) or less to be Very High Access to surface water. Distances between one quarter and one half (291.5 meters) of the average distance are High Access. One half to the average distance is considered Intermediate Access. Finally, distances greater than 583 meters have Low Access to surface water. Table 5.1 displays distance values, access category, and values for the Water Index. It also includes the number of households at each access level. Map 5.1 displays distance from surface water. Map B1, located in Appendix B (page 75), shows the Water Index value applied to each individual home.

Table 5.1
Water Index

Distance (m)	Access Level	Index Value	Households
< 145.8	Very High Access	4	152
145.8 – 291.5	High Access	3	55
291.5 – 583	Intermediate Access	2	24
> 583	Low Access	1	0

.

Map 5.1
Distance from Surface Water, Pohm Sammnang, 2016



Living further from places of education places children at risk of transportation challenges that impede their ability to attend school. As I described in Chapter 4, attending school protects households against GI illness. A 2010 report by USAID found that for girls in particular, distance– coupled with inadequate means of transportation – poses a challenge to school attendance (Johnson-Welch, 2010). Most children who attend primary school in Pohm Sammnang walk or ride a bicycle to school.[30] Muddy roads, such as those resulting from heavy rains during the monsoon season, complicate these methods of travel, as shoes or bicycles may become stuck. The prospect of having to overcome challenges may compel parents or guardians to keep children at home to assist with household work, rather than send them to attend school (Johnson-Welch, 2010).

To account for the role that attending school plays in vulnerability to GI illness, I created buffer zones around the LBI school complex. I used the UNICEF Child-Friendly School Guidelines to identify the level of risk posed to school attendance by specific distances between households and the school complex. While these guidelines do not specify an exact distance at which children become at risk for lesser school attendance, the UNICEF report cites one kilometer as the standard acceptable walking distance adopted by various nations (*Child Friendly Schools*). The School Attendance Index considers less than a half-kilometer between a household and the LBI school complex as Very High Access to schooling. A half-kilometer to one kilometer is High Access, and one kilometer to one-and-a-half kilometers is Intermediate Access. Finally, greater than one-and-a-half kilometers is Low Access to school. This index only considers distance between households and the LBI school complex; therefore, it does not consider access to secondary schooling. At the time of the interview process, the LBI school only

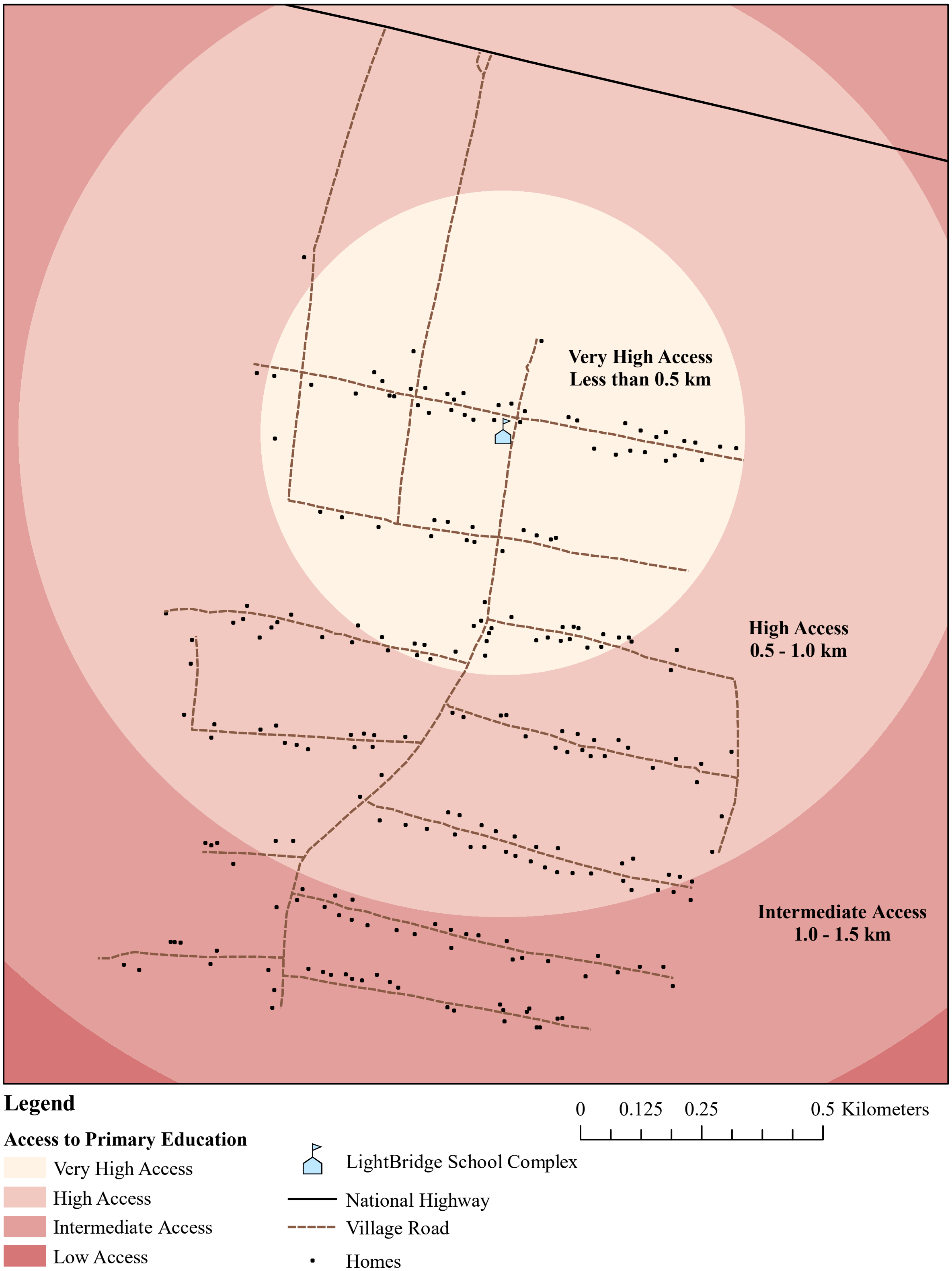
[30] Observation by author in June 2016.

taught through Grade Four. Children who attend higher grades – importantly, secondary school – must travel much further distances and therefore have greater risk of decreased school attendance. Table 5.2 displays distance values, access level, and index values for distance between households and the LBI school complex, as well as the number of households that fall into each access level. Map 5.2 displays household distance from the LBI school complex. Map B2, located in Appendix B, shows the School Attendance Index value applied to each individual home.

Table 5.2
School Attendance Index

Distance (km)	Access Level	Index Value	Households
< 0.5	Very High Access	1	73
0.5 – 1.0	High Access	2	91
1.0 – 1.5	Intermediate Access	3	67
> 1.5	Low Access	4	0

Map 5.2
Distance from School Complex, Pohm Sammnang, 2016

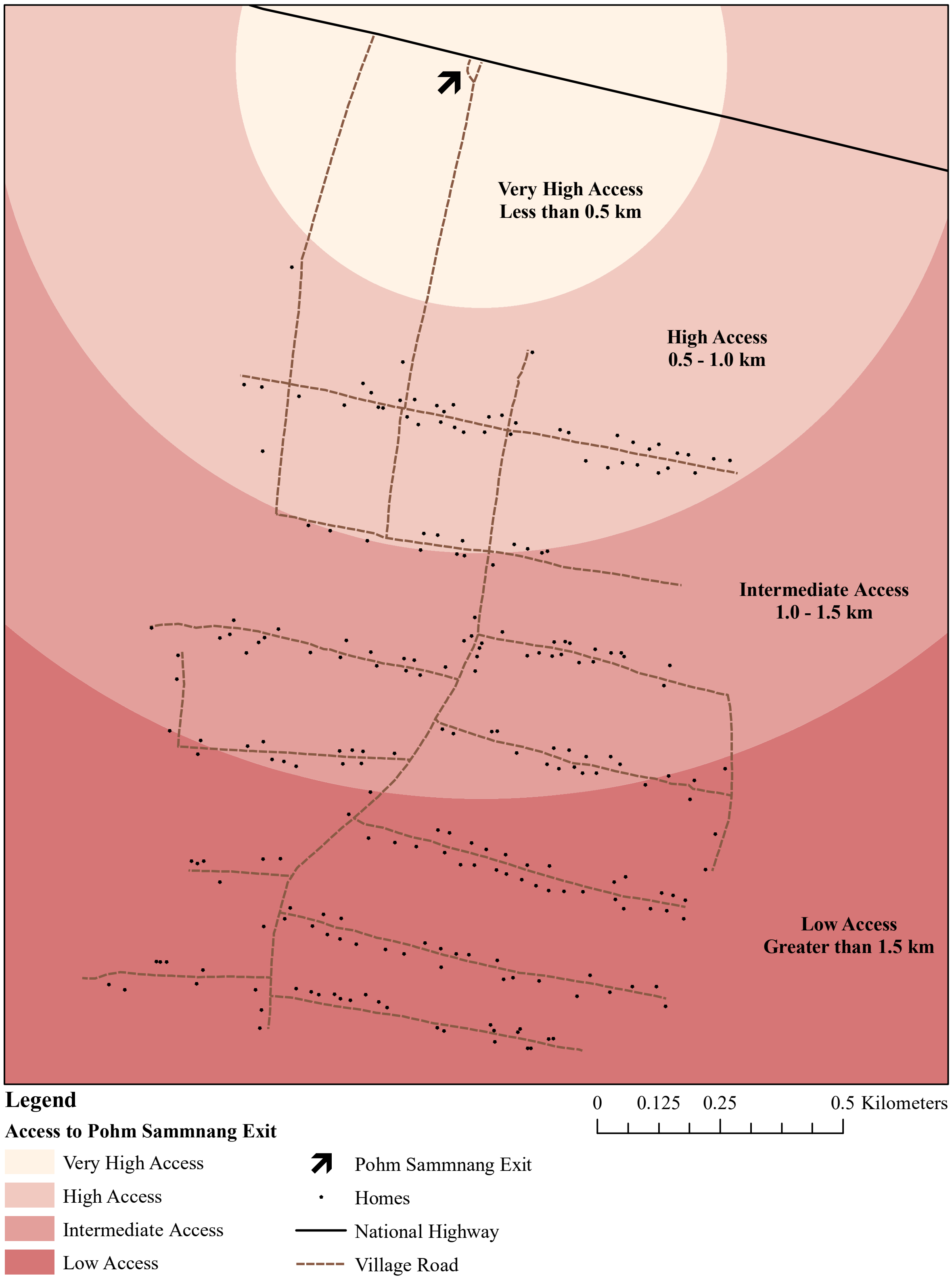


Increased distance from the exit from Pohm Sammnang decreases opportunity for income, because most formal employment, such that an employee works regularly for the same employer, exists outside of the village. As I described in Chapter 4, increased relative wealth protects against GI illness. By travelling outside of Pohm Sammnang, including across the Thai-Cambodian border, residents may access places of formal employment. All roads and pathways in the village remain unpaved, which represents a significant physical barrier for residents who wish to leave Pohm Sammnang. Unpaved roads cause especially significant problems during the rainy season, typically May through October (*Cambodia: Geography, Climate, and Population*). The unpaved roads become so muddy that bicycles and motorbike struggle to travel along them, and residents may be unable to reach the nearby paved highway. Closer distance to the Pohm Sammnang exit, therefore, decreases vulnerability to GI illness by reducing barriers to holding formal employment. For the Exit Index, I created a buffer zone around the primary village exit, which lies along a national highway. This index uses the same buffer zone distances used in the School Attendance Index, as no previously-established standard for acceptable travel distance to the workplace exists. Access to work among adults is analogous to access to schooling among children. Table 5.3 displays distance values, access level, and index values for distance between households and the Pohm Sammnang exit. It also includes the number of homes that fall into each access category. Map 5.3 displays distance from the Pohm Sammnang exit. Map B3, located in Appendix B, shows the Village Exit Index value applied to each individual home

Table 5.3
Village Exit Index

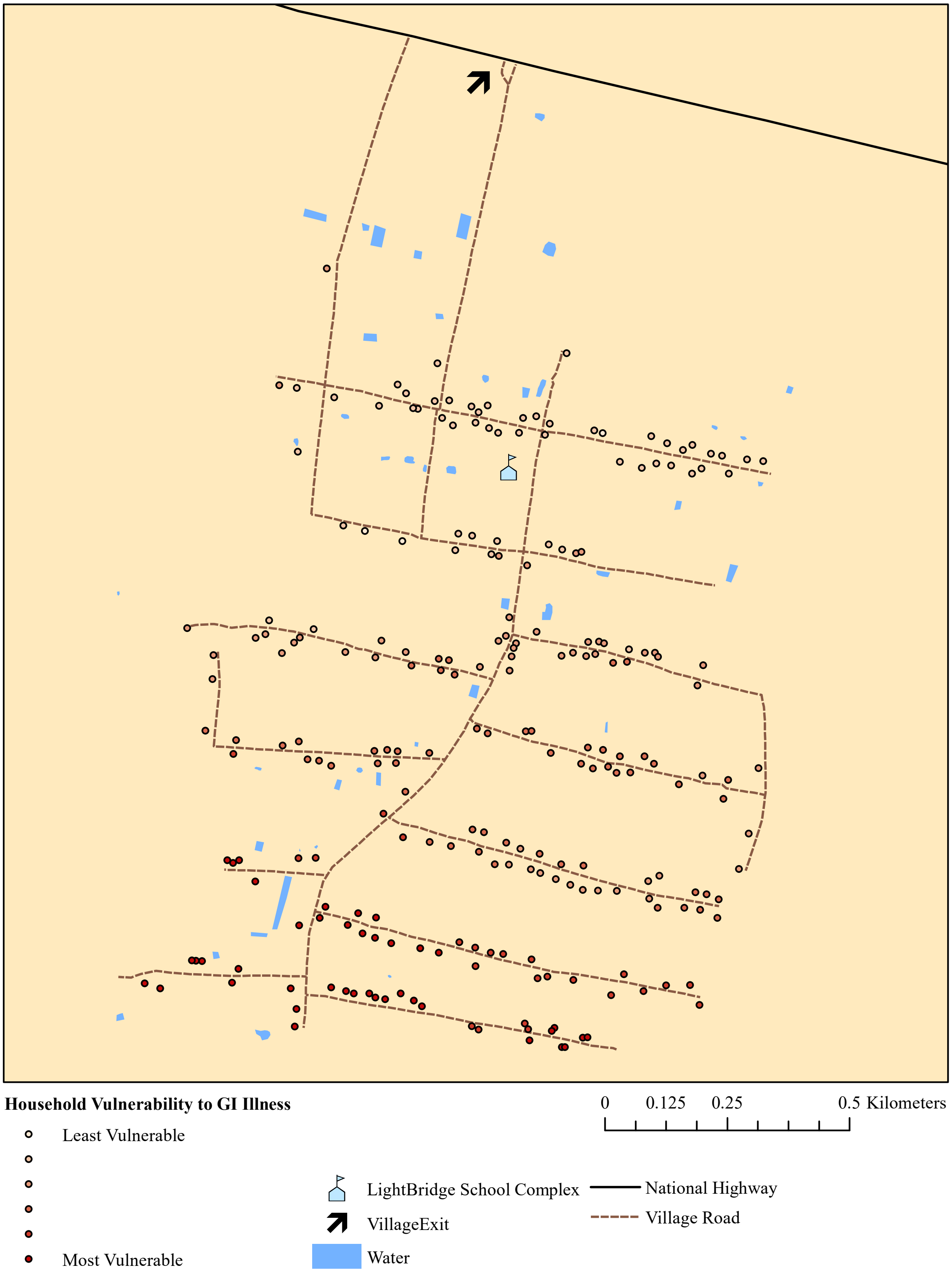
Distance (km)	Access Level	Index Value	Households
< 0.5	Very High Access	1	0
0.5 – 1.0	High Access	2	53
1.0 – 1.5	Intermediate Access	3	78
> 1.5	Low Access	4	100

Map 5.3
Distance from Village Exit, Pohm Sammnang, 2016



Map 5.4, displayed on page 62, shows the combination of proximities to surface water, the LBI school complex, and the Pohm Sammnang exit. For each region of the village, buffer zones overlap additively to produce a total Vulnerability Index value. Notably, this value combines the impact of sensitivity factors (access to education and economic opportunity) and an exposure factor (contaminated drinking water). I assigned each household in Pohm Sammnang the Vulnerability Index value of the region in which the household is located. To protect the privacy of households involved in this study, Map 5.4 includes all households in the village, including those that were vacant in 2016. Darker red coloring indicates higher vulnerability to developing GI illness, whereas lighter red coloring indicates lower vulnerability to GI illness. The most vulnerable households lie primarily along Roads 8 through 11, as these regions sit furthest from the LBI school complex and the Pohm Sammnang exit. These areas should be prioritized as NGOs and community members take action to prevent GI illness; these households have the highest vulnerability to GI illness, as well as possess the fewest resources for future prevention of illness. While households indicated in lighter red, primarily in regions near the Primary Entrance Road and Main Road, have the least vulnerability to GI illness, illness should still be addressed in those regions. In the next section, I discuss specific actions local organizations can take to prevent GI illness by bolstering health infrastructure in Pohm Sammnang.

Map 5.4
Vulnerability to Gastrointestinal Illness, Pohm Sammnang, 2016



5.2 Addressing GI Health in Pohm Sammnang

5.2.1 Bolstering Access to Education

As I described in Chapters 3 and 4, households with school-aged children who attend school have lesser incidence of GI illness. A 2014 report by Cambodia's Ministry of Health confirms that when children are educated, households experience lower incidence of illness (Odi). As of June 2016 – as well as this writing – families paid 4000 riel per year per child in school fees, the equivalent of $1 (USD) (D. Baca, personal communication, March 2018). Given this reasonable fee, local organizations must work to increase accessibility to schooling by addressing other reasons that children may have low rates of attendance or drop out of school entirely.

In Pohm Sammnang, distance from the LBI school complex ranges from the home next door to more than a kilometer away, and children above Grade Four must travel outside of Pohm Sammnang to attend school. Given that many children utilize bicycles for travel to school, local NGOs should consider addressing the challenges posed by unpaved roads. All roads in Pohm Sammnang remain unpaved, and they become extremely difficult to travel along during the monsoon season, which typically lasts from May to October (*Cambodia: Geography, Climate, and Population*). The thick mud makes walking difficult and riding a bicycle nearly impossible, which prevents access to school. This rainy season lasts seven months, including about four full months when children could potentially attend school. Improving the road system by paving the Main Road and the Access Road would reduce challenges that children face in attending the LBI school (see Page 29 for Map 2.1: Roads in Pohm Sammnang, 2016). It would also support children beyond Grade Four by relieving a portion of the burden of travelling outside of Pohm Sammnang. This would also support higher enrollment in secondary school, because regular attendance allows children to move on to higher grades. By increasing access to schooling, local actors would support GI health through education.

5.2.2 Supporting Access to Clean Drinking Water

In Chapter 4, I identified filtering drinking water as a lifestyle factor that protects households against GI illness. This finding suggests that water in Pohm Sammnang may be contaminated with bacteria, viruses, or other pathogenic organisms. To best address GI illness, local organizations should, with permission from pond owners, test several sources of surface water for a variety of pathogens. Interventions will be most effective if they address specific organisms, as removing different organisms from water requires different methods. Ceramic water filters, for example, can typically remove bacteria from water but may be unable to remove viruses (Center for Disease Control, 2012).

To support more sustainable sources of clean water at the community level, local actors should provide education about improved sources of drinking water, as well as practical trainings on how these sources can be obtained or constructed. For best health conditions, the WHO recommends access to piped water, ideally on the premises of a household (UNICEF, 2012). Although future goals should include access to piped water for residents in Pohm Sammnang, the current physical infrastructure of the village cannot support this. Other sources of improved drinking water include "public taps or standpipes, tube wells, or boreholes, protected dug wells, protected springs, and rainwater collection" (UNICEF, 2012). Some of these methods are more realistic for Pohm Sammnang than others, due to the limitations of current infrastructure. These limitations, such as the lack of electricity and a community-wide source of clean water, allow for the realistic implementation of only *portions* of improved water sources. For example, improved sources of drinking water restrict contamination of water by outside interference. At a community level, this may be supported through installation of fences around sources of surface water to prevent animals from drinking from or entering the water.

At the household level, local actors should increase access to personal water filtration systems. Provision of water filters directly to households more effectively prevents GI illness than intervention at the community level (Clasen, Roberts, Rabie, Schmidt, & Cairncross, 2009). Residents of rural Cambodia commonly use the Ceramic Water Purifier (CWP) system, in which water passes through a layer of porous clay before being deposited in a 10 – 20 liter holding tank. A 2007 study found that households actively using CWPs experience only half the incidence of diarrhea as households not using a CWP. In the same study, users cited broken filters as the primary reason of discontinuing their use (Brown, Sobsey, & Proum, 2007). With this in mind, NGOs in Pohm Sammnang should pair ceramic filtration systems with educational resources. In the past, village residents requested that LBI staff teach health-based educational workshops in Pohm Sammnang, indicating that they consciously engage in achieving effective health behaviors. Therefore, in-person trainings, taught in Khmer, should accompany water filters. These workshops should teach which pathogenic organisms reside in water, the risks these organisms pose, how to clean filters, and how to repair broken filters. Because of the current multi-use nature of surface water in Pohm Sammnang, workshops should also include education regarding the importance of preventing animals from drinking or bathing in ponds used to collect drinking water. NGOs should conduct trainings regularly, as use of water filters decreases over time (Brown, Sobsey, & Proum, 2007).

During the monsoon season (typically May through October), residents have access to a large amount of clean water. In the Banteay Meanchey region, about 800 – 900 mm of rain falls during this season (*Cambodia: Geography, Climate, and Population*, 2011). Local actors should provide education regarding the proper methods of collecting and maintaining clean rainwater during these times. One effective and widely-used method of collecting and maintaining clean rainwater is through covered clay basins. Individuals who conduct workshops should indicate the importance of preventing animal access to this type of source, as well as the importance of using taps, rather than dipping collection objects into the basin. By protecting sources of water, as well as providing new strategies of filtration, local NGOs can partner with village residents to promote GI health.

5.2.3 Protecting Against Zoonotic Illness

In Chapter 4, I explained that owning at least one canine places households at risk for GI illness. In a 2015 study, Inpankaew et al. found parasitic eggs or cysts in 96% of a sample of canines from a village in Cambodia (Inpankaew et al., 2015). Contact with such canines, especially with their feces, poses risk for the transfer of zoonotic illness. In Pohm Sammnang, 31% of households at least one canine. These animals function as important protection for individual households, as well as serve roles as pets.[31] Therefore, suggesting the removal of canines from homes may be harmful. Instead, local actors should provide education to adult residents regarding the connection between canines and illness, as well as teach methods of prevention that allow a similar canine presence. Through previous requests for health workshops from LBI, adult residents of Pohm Sammnang have displayed a desire to understand and implement health-protective behaviors. Further, the LBI school should educate children about connections between canines and GI illness by incorporating trainings into the school curriculum.

[31] Observation by author in June 2016.

Education regarding the spread of zoonotic illness through canines should begin with the connection between canines and GI illness. In a study of three regions throughout Cambodia, Obsjer et al. (2015) found that less than 10% of households surveyed considered zoonotic transmission of illness likely in their home village. Additionally, handwashing before or after cooking increased in regions where subjects knew about the potential for zoonotic spread of illness (Kristina Osbjer et al., 2015). This showcases an important point of improvement in rural Cambodia, where only 82% of households have a place for washing hands on their premises (*Cambodia Demographic and Health Survey 2014*, 2015). Although adult residents of Pohm Sammnang have likely encountered of the concept of zoonotic illness, they may not perceive it as likely in their community or homes. Therefore, NGO staff should address the zoonotic potential of bacteria residing in canines by explaining that pathogenic organisms can transfer between animals and humans through direct contact or contact with feces. Then, NGO staff should elaborate on methods of preventing transmission between canines and animals.

Because households commonly own canines, local NGOs must find ways of equipping residents of Pohm Sammnang with strategies for mitigating the inevitable contact with canines. Residents generally allow canines to roam freely within Pohm Sammnang, including inside homes and around outdoor cooking areas.[32] As one method of prevention of zoonotic illness, canines should be restrained from entering cooking or sleeping areas of homes. This may be done through verbal deterrence, which does not require physical resources, rather than structural barriers. Additionally, to prevent contact with canine feces, residents should remove feces from highly-trafficked areas of the village. This includes yards and walking pathways, as well as areas where children may play without shoes. Finally, educational workshops should address the

[32] Observation by author in June 2016.

importance of hand-washing before cooking and eating, as well as after contact with canines or their feces. Because limited access to clean water poses challenges to handwashing, residents should be equipped with strategies for handwashing with limited clean water. Through these methods, residents may prevent the spread of zoonotic GI illness while maintaining similar relationships to canines.

5.2.3 Supporting Income

In Chapter 4, I addressed ownership of livestock as an indicator of wealth. Across communities globally, greater wealth correlates with better health outcomes (World Health Organization, 2010). Such wealth allows greater access to health resources, including healthcare, methods of sanitation and hygiene, and better nutrition. Therefore, supporting economic development in Pohm Sammnang prevents GI illness. The accumulation of wealth in the village is incredibly complex, and NGOs cannot address many structural aspects of poverty in a sustainable manner. However, there is one specific method of supporting economic development that NGOs may pursue.

Organizations in the Pohm Sammnang region can support economic growth among households by developing a system of paved roadways. In the previous section, I addressed reasons why roadways contribute to accumulation of wealth. Currently, all roads and pathways in Pohm Sammnang remain unpaved. These roadways pose challenges to leaving the village and act as barriers to formal employment. Organizations should prioritize paving the Primary Entrance Road, the Main Road, and the Access Road (see Map 2.1 on page 29 for roads). Because many community members use these roads frequently, they are already well established.

In creating a system of paved roads, actors not only support economic growth but also school attendance, which I previously defined as important for reducing GI illness.

5.3 Summary and Conclusion

While I derived the results and recommendations presented in this thesis directly from data collected in Pohm Sammnang, a single village, the findings apply to other rural regions of Banteay Meanchey. This thesis draws upon both sensitivity and exposure factors - filtering water, school attendance, canines, and relative wealth - to explain and address GI illness in Pohm Sammnang, which likely shares many pertinent characteristics with other villages in Banteay Meanchey. These characteristics may include low levels of access to WASH facilities, long distances between homes and places of education or employment, and living in close proximity with animals. For this reason, the factors that I have discussed as health-protective and risk factors are likely not unique to this specific village. Through conducting similar spatial analysis in other nearby regions, organizations may identify vulnerable households and support GI health not only in Pohm Sammnang, but also in other at-risk communities.

Appendices

Appendix A: Factors Not Approaching Significance

Table A1
Independence of GI Symptoms and Total Number of Residents

	GI Symptoms		
	Symptoms	No symptoms	Total
Number of Residents			
0 - 5	11	16	27
6 – 10	4	10	14
More than 10	0	1	1
Total	15	27	42

n = 42, d.f. = 2
p = .559

Table A2
Independence of GI Symptoms and Duration of Residence in Pohm Sammnang

	GI Symptoms		
	Symptoms	No symptoms	Total
Duration			
10 years or less	8	15	23
More than 10 years	7	12	19
Total	15	27	42

n= 42, d.f. = 1
p = .890

Table A3
Independence of GI Symptoms and Source of Drinking Water

	GI Symptoms		
	Symptoms	No symptoms	Total
Source			
Purchases water	10	21	31
Other source*	5	5	10
Total	15	26	41

n = 41, d.f. = 1
p = .311 (.453)
*Other sources include ponds, rain water, and wells

Table A4
Independence of GI Symptoms on Water Sanitation

	GI Symptoms		
	Symptoms	No symptoms	Total
Sanitation			
Does not sanitize	2	6	8
Sanitizes	11	19	30
Total	13	25	38

Table A5
Independence of GI Symptoms and Boiling Water

	GI Symptoms		
	Symptoms	No symptoms	Total
Boiling			
Boils	4	7	11
Does not boil	9	18	27
Total	13	25	38

n = 38, d.f. = 1
p = .858 (1.000)

n = 38, d.f. = 1
p = .537 (.689)

Table A6
Independence of GI Symptoms and Deaths in Past Year

	GI Symptoms		
	Symptoms	No symptoms	Total
Deaths			
No deaths	11	21	3
At least one death	1	3	4
Total	12	24	36

n = 36, d.f. = 1
p = .708 (1.000)

Table A7
Independence of GI Symptoms and Agricultural Occupation

	GI Symptoms		
	Symptoms	No symptoms	Total
Occupation			
Related to agriculture	8	12	20
Not related to agriculture	7	14	21
Total	15	26	41

n = 41, d.f. = 1
p =.658 (.751)

Table A8
Independence of GI Symptoms and Occupation in Thailand

	GI Symptoms		
	Symptoms	No symptoms	Total
Occupation			
In Thailand	4	6	10
Not in Thailand	11	20	31
Total	15	26	41

n = 41, d.f. = 1
p =.797 (1.000)

Table A9
Independence of GI Symptoms and Method of Food Procurement

	GI Symptoms		
	Symptoms	No symptoms	Total
Food Procurement			
Grow food only	2	3	5
Purchase food only	4	12	16
Grow and purchase food	7	11	18
Total	13	26	39

n = 39, d.f. = 2
p = .654

Table A10
Independence of GI Symptoms and Growing Food

	GI Symptoms		
	Symptoms	No symptoms	Total
Grow food			
Grows food	11	19	30
Does not grow any food	3	8	11
Total	14	27	41

n = 41, d.f. = 1
p = .574 (.719)

Table A11
Independence of GI Symptoms and Purchasing Food

	GI Symptoms		
	Symptoms	No symptoms	Total
Purchase food			
Purchases food	11	23	34
Does not purchase food	2	3	5
Total	13	26	39

n = 39, d.f. = 1
p = .735 (1.000)

Table A12
Independence of GI Symptoms and Ownership of Animal(s)

	GI Symptoms		
	Symptoms	No symptoms	Total
Animal(s)			
Owns animal(s)	11	21	32
Does not own animal(s)	3	5	8
Total	14	26	40

n = 40, d.f. = 1
p = .868 (1.000)

Table A13
Independence of GI Symptoms and Ownership of Poultry

	GI Symptoms		
	Symptoms	No symptoms	Total
Poultry			
Owns poultry	10	21	31
Does not own poultry	4	6	10
Total	14	27	41

n = 41, d.f. = 1
p = .653 (.712)

Table A14
Independence of GI Symptoms and Average Number of Meals per Day

	GI Symptoms		
	Symptoms	No symptoms	Total
Number of Meals			
1	2	4	6
2	6	10	16
3	3	5	8
Total	11	19	30

n = 30, d.f. = 2
p = .982

Table A15
Independence of GI Symptoms and Religion

	GI Symptoms		
	Symptoms	No symptoms	Total
Religion			
Buddhist	12	24	36
Christian	3	3	6
Total	15	27	42

n = 42, d.f. = 1
p = .430 (.649)

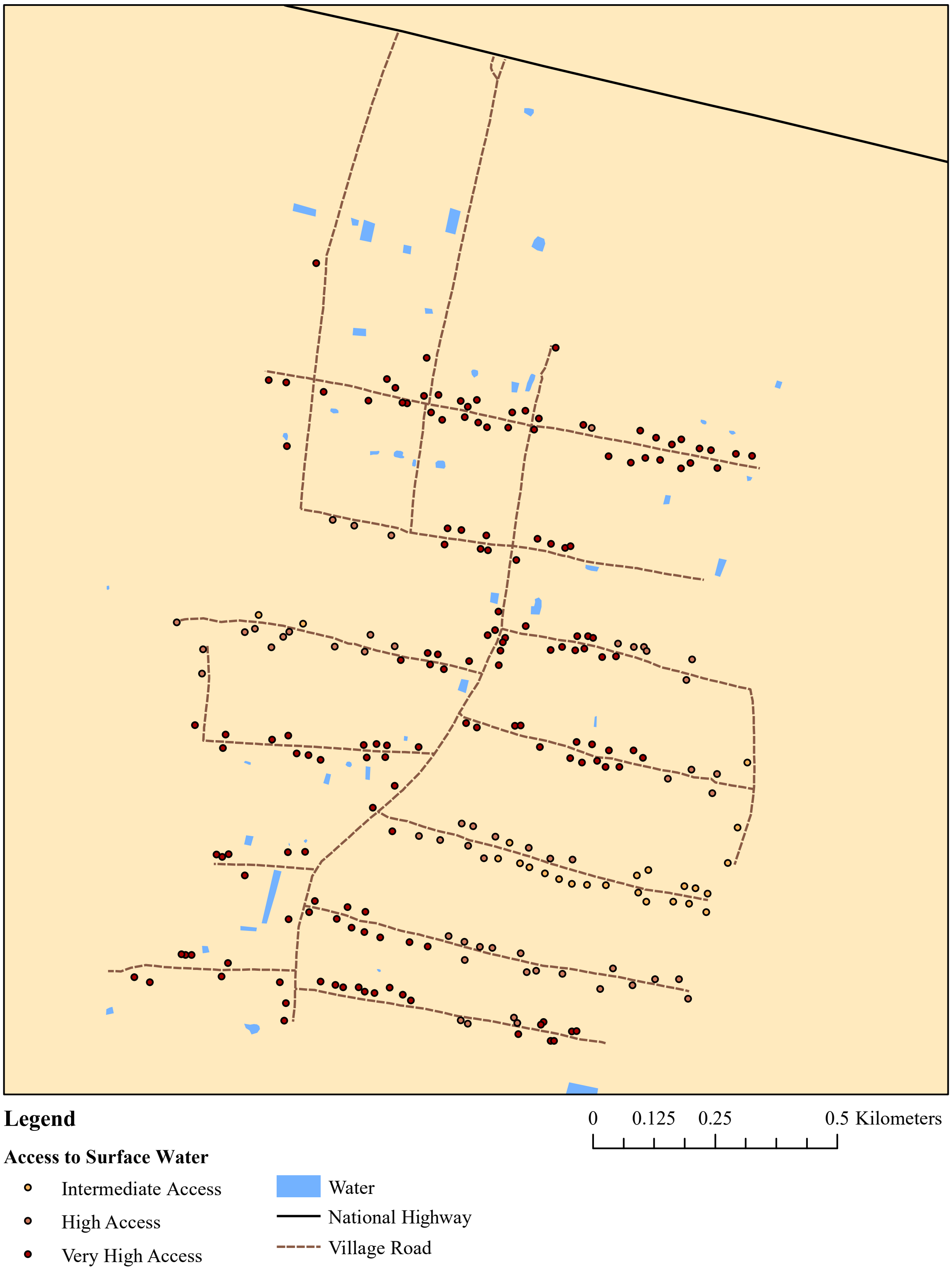
Table A16
Independence of GI Symptoms and Major Changes in Past Year

	GI Symptoms		
	Symptoms	No symptoms	Total
Changes			
None	9	21	30
Personal life	0	2	2
Financial	1	3	4
Total	10	26	36

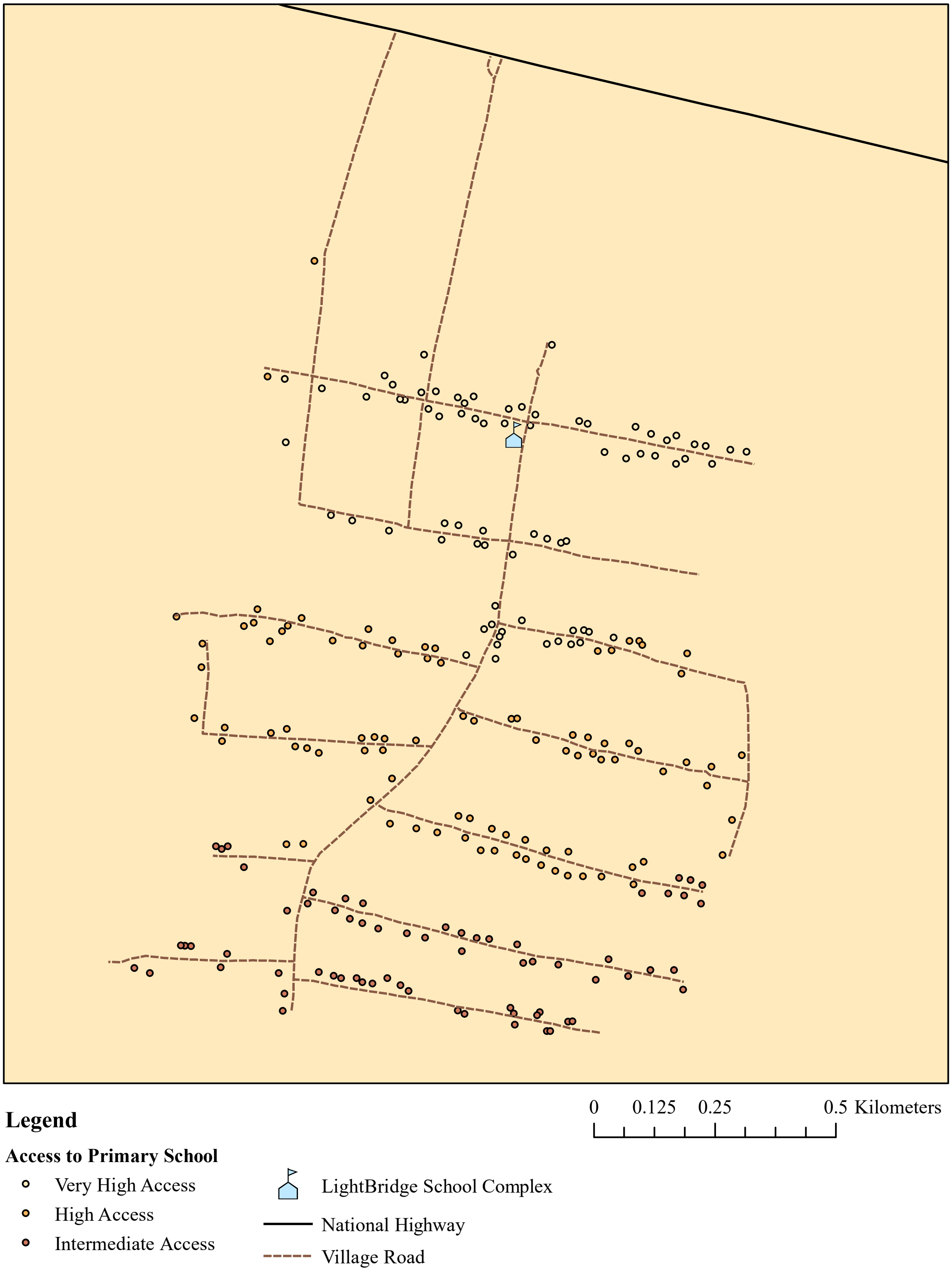
n = 36, d.f. = 1
p = .651

APPENDIX B

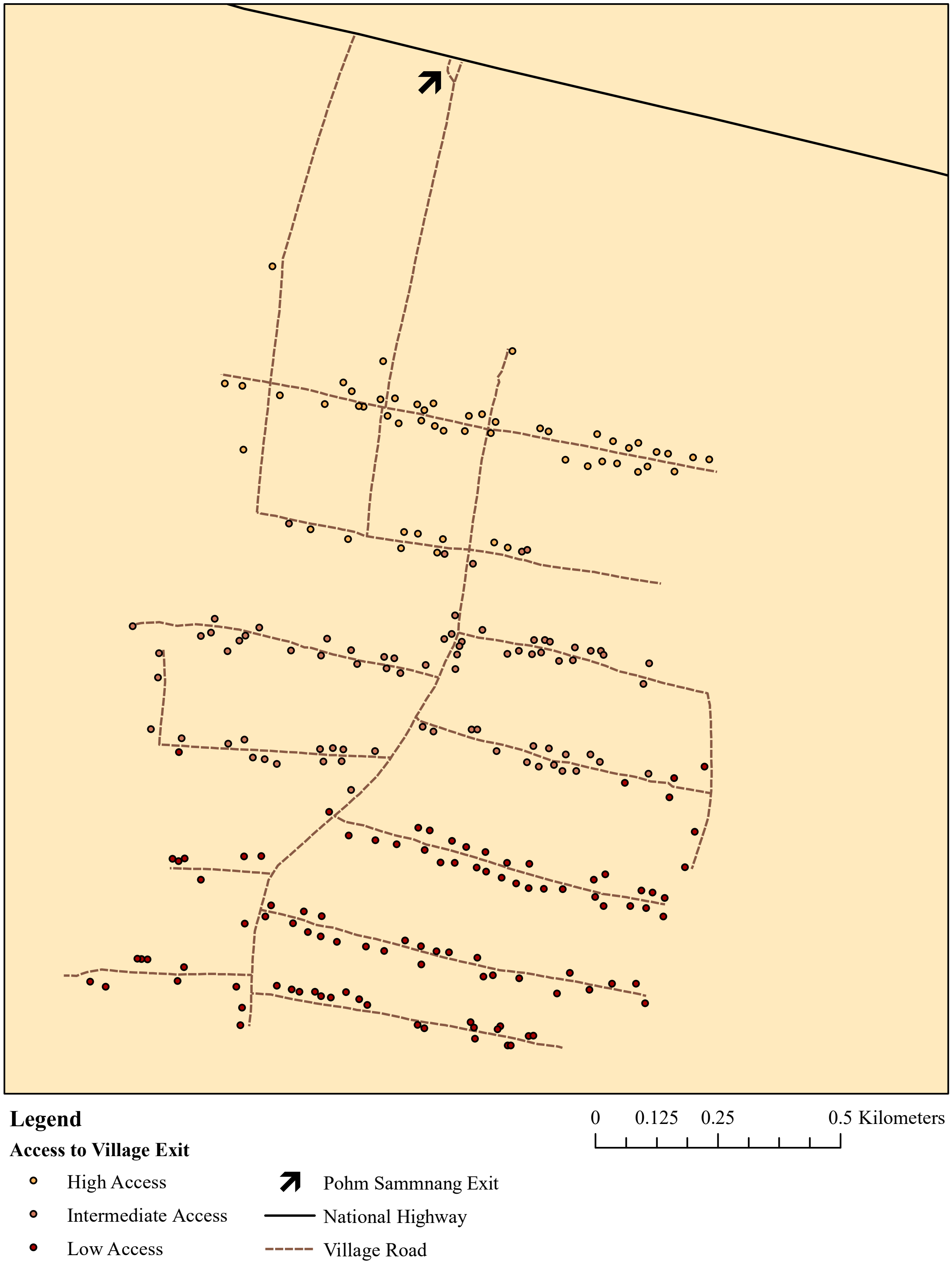
Map B1
Water Index Values, Pohm Sammnang, 2016



Map B2
School Attendance Index, Pohm Sammnang, 2016



Map B3
Village Exit Index, Pohm Sammnang, 2016



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