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No Fracking Way! A Study on the Spatial Patterns of and Changes in Perception and Distance from a Michigan Horizontal Hydraulic Fracturing Site

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NO FRACKING WAY! A STUDY ON THE SPATIAL PATTERNS OF AND CHANGES IN PERCEPTION AND DISTANCE FROM A MICHIGAN HORIZONTAL HYDRAULIC FRACTURING SITE

by

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The research investigates whether Michigan residents' perception of risk from an oil and natural gas (ONG) well site that employs the use of horizontal hydraulic fracturing (fracking) changes with distance. The research goal is to determine if residents that live farther from a fracking site perceive it to be more dangerous than those who live closer. Secondary research goals include determining if increasing distance from a fracking site cause residents to overestimate their proximity to a fracking site and if gender and education levels have an effect on residents' perception levels. Data were collected from residents in three counties in Michigan using a specially-designed questionnaire. These data were analyzed using Kruskal-Wallis, Spearman's rho, and Chi-squared statistical tests. Additionally, GIS was incorporated to perform distance analysis comparing residents' risk perception levels and the distance of their home addresses. Distance analysis suggest that residents possess differing levels of concern regarding a fracking site regardless of distance from the well site while statistical analysis indicates that gender does play a role in determining residents' levels of risk perception.

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Shannon McEwen

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CHAPTER I

INTRODUCTION

The demand for fossil fuel power has existed since the beginning of the Industrial Revolution (U.S. Department of Energy, 2013). Although access to coal was readably available, due to limited technologies, only the most convenient sources of oil and natural gas were accessed. However, in the twentieth century a new mining technique designed to access hard-to-reach areas of oil and natural gas, called hydraulic fracturing, began to develop (Montgomery and Smith, 2010). Hydraulic fracturing, a method where rock is fractured open through the force of a pressurized liquid, allowed mining companies to access deep oil and natural gas reserves for the first time (Palliser, 2012). While the early form of hydraulic fracturing was successful in mining oil and natural gas, this process was only able to efficiently extract resources from loose sedimentary geological formations. As a result, oil and natural gas deposits located in tight shale formations were deemed too expensive and inefficient to access. In the 1990s, advanced technology allowed for a new method of hydraulic fracturing. Horizontal hydraulic fracturing, or fracking, was able to effectively access previously inaccessible reservoirs (Montgomery and Smith, 2010).

However, much controversy surrounds the fracking process. The documentary, *Gasland* (Fox, 2010), brought forth information pertaining to unsafe fracking processes being conducted in states such as Pennsylvania and Colorado. As a result of the documentary, much of the nation became aware of the general idea of fracking and dangers associated with a site within a short time. Although the documentary brought forth information on dangerous fracking practices, it failed to inform the public on the technical aspect of the process. Due to the omitting of the technical aspect of and the negative spin on the fracking process, this led to a rise in a negative perception of risk related to fracking. Individuals perceived this practice as dangerous without knowing full information about the method or even if it was being conducted within their general area. This lack of understanding of the fracking process on the part of the public and how it relates to perceptions of fracking is the focus of my thesis.

Purpose

The purpose of my research was to investigate the differences in perceptions related to oil and natural gas (ONG) well sites that employed the use of fracking in the three Michigan counties (Hillsdale, Ionia, and Oceana). In addition, the research examined how distance from a fracking site affects differences in risk perception. The research could be particularly helpful in aiding the Michigan Department of Environmental Quality's Office of Oil, Gas, and Minerals as well as communities in proximity to fracking sites in addressing and alleviating area concerns regarding future fracking practices. It is believed that the results of the research could help identify specific areas to educate and inform residents about the aspects of the fracking process and thus reduce the amount of perceived risk.

Research Hypotheses

To date, there have been few perception studies applied to fracking and even fewer risk perception studies done. However unlike previous studies that investigate residents' perceptions of risk regarding fracking sites, there could be significant differences in how nearby residents assess levels of risk regarding a fracking site, compared to farther away residents. Additionally, individuals' perception levels of risk could also change as distance increases away from the fracking site. Thus, it is hypothesized that residents' levels of risk perception increase as distance increases away from a fracking site. Furthermore, it is also hypothesized that gender and education levels also have an effect on residents' perception levels regarding the nearby fracking site. Lastly, it is hypothesized that there will be difference among the three study counties (Hillsdale, Ionia, and Oceana) in perception levels pertaining to a fracking site.

Conclusion

The remainder of this thesis will be dedicated to investigating the stated research hypotheses. Chapter Two is composed of a thorough literature review discussing the fracking process, the development of concerns brought about by fracking, influential policies and regulations pertaining to the fracking process and fracking sites, and the development of perception of risk by individuals. Chapter Three discusses the research methodology and study areas. Chapter Four examines the results of data analyses and includes a discussion of results. The final chapter, Chapter Five, returns to the hypotheses and provides suggestions for future research.

CHAPTER II

LITERATURE REVIEW

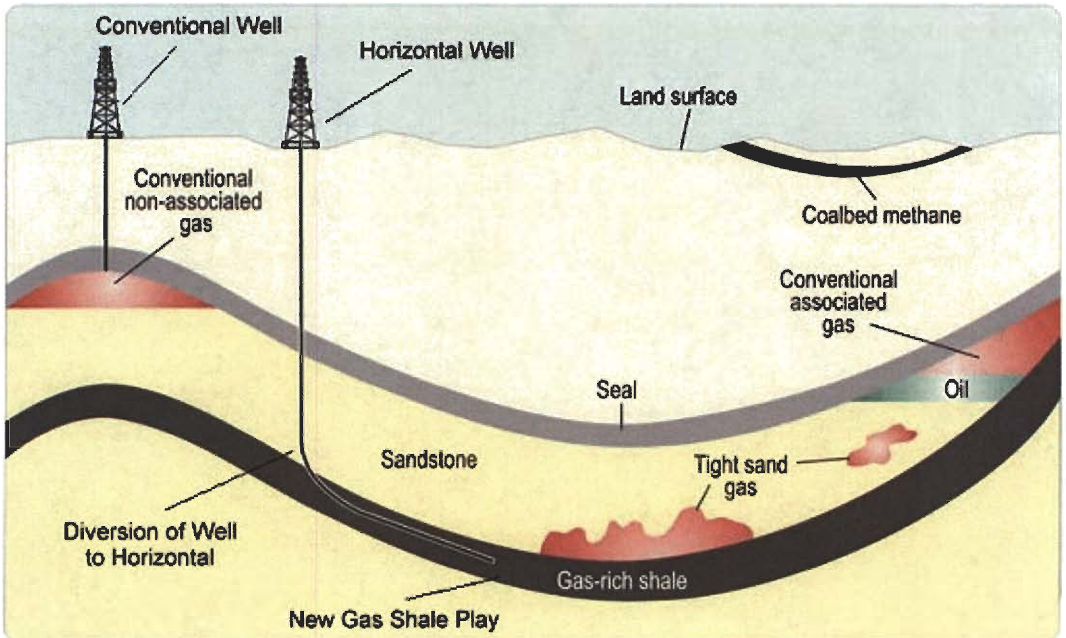
Fracking Process

Fracking is the process by which an oil and natural gas (ONG) deposit is located and drilled into in order to extract the product located thousands of feet deep in sedimentary rock formations. To extract the ONG deposit, the rock is first drilled into and a surface casing is then inserted into the hole in order to ensure that the oil, gas, or fracking fluid does not enter the area groundwater (Graves, 2012). The rock is then fractured by pumping large quantities of water, sand, and chemicals at high pressures down a pipeline fed into the rock formation (Palliser, 2012). The fracturing allows fissures within the rock to open up and the trapped ONG deposit is able to flow into the placed pipeline and pumped up to the surface (Palliser, 2012).

However, there is a very large difference between the two types of fracking practices. The first, known as conventional fracturing, was done by locating the ONG deposit and drilling directly over it in a vertical method (Palliser, 2012). Modern fracking (horizontal fracturing) differs from the first method in that while vertical drilling is done, roughly 500 feet above the deposit the drill begins to turn horizontally and will then continue into the deposit area (Figure 2.1; Graves, 2012).

Although the procedure of fracking is readily available to the public through federal and state government offices, there is a lack of comprehensive and easy-to-

Figure 2.1: Conventional Fracking Well vs. Modern Fracking Well (U.S. Energy Information Administration, 2011)



understand literature. It is believed that a combination of the reporting of misinformation and a lack in education on the fracking process has enabled and fostered fears in individuals (Kozera, 2012). Additionally, the knowledge of irresponsible fracking practices in states such as Pennsylvania and Colorado, as reported by the media, have led to a rise in concerns regarding fracking practices nationwide. However, there are legitimate concerns regarding the fracking process which are discussed next.

Concerns Regarding Fracking

Due to the influence of two widely known anti-fracking documentaries (*Gasland* and *Gassand Part II*) and media coverage, many individuals are aware of potential environmental and health hazards associated with the fracking process. In Brasier et al.'s (2013) recent study on risk perception associated with the Marcellus Shale natural gas development projects (fracking sites), the residents in Pennsylvania and New York were surveyed on their levels of risk perception in regard to nearby natural gas production. The researchers found that that in these cases, residents' level of risk perception correlated with three primary factors: knowledge of environmental impacts, knowledge of economic and social impacts, and amount of trust in the natural gas industry (Brasier et al., 2013). They also found that individuals who displayed high environmental concerns along with low trust in the natural gas industry were shown to have a heightened negative perception of risk than those who had knowledge of environmental impacts along with an understanding of economic and social impacts (Brasier et al., 2013).

When asked about concerns regarding the fracking process, many individuals were anxious about health, air and water quality, water security, and potential environmental impacts (Boudet et al., 2013; Brasier et al., 2013; Schafft et al., 2013). Various risk assessments and papers recognizing potential environmental impacts have also highlighted these same possible public concerns (Clark et al., 2012; Davis and Hoffer, 2012; Weinhold, 2012; Finkel et al., 2013). Studies have shown that residents who reside near refineries, drilling operations, or spill sites have an increased risk of suffering from and developing eye irritations, headaches, asthma symptoms, and several types of cancers resulting from exposure to a complex mixture of chemicals and air pollutants (Glass et al., 2003; White et al., 2009, McKenzie et al., 2012). Recently, additional concerns have been also been raised regarding the quality and safety of drinking water surrounding fracking sites. Reports of water quality issues from states with heavy fracking practices, such as Pennsylvania and have made various headlines and spread through viral videos showcasing individuals who have large quantities of methane in their water supply which may or may not be attributed to nearby fracking practices (Fox, 2010; Fischetti, 2013; Maln, 2013). This has caused various nearby residents to exhibit concern over the injection of both methane and other contaminates from the fracking process.

Additional concerns have been raised regarding the security of local water quantity. During the fracking process, between one and six million gallons of water can be used during a fracking operation (Graves, 2012). Though the amount needed in the fracking process varies depending on the site's geological formation, the water is either brought onto the site or is withdrawn directly from the site (U.S. Department of Energy, 2009). In most cases, water is taken from the site as it the less expensive option. This amount has caused many residents to worry about the water withdrawal amounts, fearing that a depression in the water table could result and cause surrounding water wells to go dry. Although this is not a concern in more water-rich areas, it is considered to be a legitimate concern in areas with little groundwater.

Air quality is another concern brought up by residents. Air quality can generally be affected through the venting process that occurs after the well has been fracked. It has been determined that between 3.6 and 7.9 percent of methane generally escapes into the local atmosphere during the venting process (Graves, 2012). While this amount may seem insignificant, if each fracking site allowed roughly eight percent of methane to escape this could create a large greenhouse gas (GHG) footprint due to methane's high specific heat capacity compared to other GHGs. Howarth, Santoro, and Ingraffea (2011) address the possibly of methane emission escaping from shale gas development contributing to the greenhouse gas footprint and conclude that it is entirely possible. The authors concluded that the GHG footprint associated with fracking is likely to be 35 – 250 percent larger than the GHG footprints of conventional natural gas extraction primarily due to the escape of methane. Although some methane escapes during the flow-back process, the remaining methane is either captured or burned off, a process that releases carbon dioxide into the atmosphere. Additionally, the fracking process can release volatile organic compounds (VOCs) and other hazardous air pollutants (HAPs) into the local atmosphere. Excess amounts of these VOCs and HAPs have been proven to cause a variety of health effects in humans and animals, some of which include an "increased risk of eye irritation and headaches, asthma symptoms, acute childhood leukemia, acute myelogenous leukemia" (Weinhold, 2012, p. 275; Waldner, 2008; Finkel and Law, 2011; Schmidt, 2011; Clark et al., 2012; McKenzi et al., 2012).

In addition to the potential impacts of groundwater and air quality, surrounding soil can be contaminated through spills of the water, proppant material, and chemical mixture (fracking fluid) used during the fracking process. In a 2011 study, Adams applied 303,000 liters of fracking fluid to 0.20 hectares of mixed hardwood forest within the West Virginia Fernow Experimental Forest during the early summer of 2008. According to the results of the study, within a few days of the application, nearly all of the area's ground vegetation died and many of the overstory trees showing distressed symptoms. The study area continued to be monitored for two years and by the end of the monitoring period, 56 percent of the trees within the study area were dead. Additionally, surface spills of fracking fluid and the resulting flowback water (fluid that is pumped out of the fractured well) could have a larger impact on the soil chemistry. Adams (2011) found statistically significant differences in concentrations of calcium, magnesium, aluminum, manganese, and zinc minerals. Furthermore, the soil carbon-to-nitrogen (C/N) ratio was greater on the areas that received the application of fracking fluid (Adams, 2012).

Within the flowback water materials, such as salts, radionuclides, heavy metals and other contaminants come up from the deep shale formations (Schmidt, 011). Also, toxic mud and radioactive rock can be brought up during the drilling process and must be treated and disposed of accordingly (Graves, 2012). Typically, the flowback water is stored in lined holding ponds or pumped into containers. However these options are not without their own environmental risks. According to Swartz (2011) holding ponds could overflow and allow the run-off of harmful chemicals, potentially impacting surrounding land and water resources. Additionally, chemicals could penetrate the plastic liners, seeping into the underlying soil and shallow aquifers. The same methods are also used to store soil, mud, and rocks dug up through the drilling process (Swartz, 2011).

Ultimately, the potential for environmental impacts is considered to be one of the more prevalent concerns regarding fracking practices (Clark et al., 2012). However, the lack of informational literature regarding the fracking process should be of even larger concern. It is believed that the presence of comprehensive literature could help resolve and mitigate many of these worries (Graves, 2012). Informative works, such as John Graves' (2012) *Fracking: America's Alternative Energy Revolution*, and Joseph Hilyard's (2012) *The Oil and Gas Industry: A Nontechnical Guide*, can offer readers a resource that enables readers to "move beyond dispute to resolution" (Graves, 2012, p. 19) by providing a comprehensive review of the entire fracking process and its impact on the natural gas industry. Although comprehensive and easy to understand information is difficult to come across, research for such literature more often results in the discovery of heavily biased, anti-fracking writings. This can lead to an increase in perceived risk of a fracking site by individuals. However, an increase in perceived risk is not always negative. In many cases, it can lead to a re-working of existing policy (Pierce, 2011; Weinhold, 2012; Davis and Hoffer, 2012; Buford, 2012).

Regulation and Policies Pertaining to Fracking

Although policies and regulations pertaining to oil and natural gas development are generally drafted at the state level, several existing influential federal environmental policies and acts happen to extend to the oil and natural gas industry. The main policies are the Clean Water Act, the Clean Air Act, and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA; Wiseman and Gradijan, 2012). Other federal regulations that can affect certain stages of the fracking process include the Endangered Species Act (ESA), the Migratory Bird Treaty Act (MBTA), the Emergency Planning and Community Right-to Know Act (EPRCA), and the Occupational Safety and Health Act (OSHA) (Wiseman and Graijan, 2012).

The Clean Water Act applies to the fracking process in two different ways. First, it aims to enhance the quality of storm water and other run off from construction sites by ensuring that erosion and other sedimentation occurring during the construction is kept to a minimal level. Second, the act protects against the dumping of pollutants, or in this case fracking fluid, into water bodies without a permit (Burford, 2012). Although the Clean Water Act only applies to surface bodies of water, it should be noted that the Safe Drinking Water Act (SDWA) ensures that the waste fluid generated from the fracking process does not contaminate groundwater stores when injected into underground control wells (Burford, 2012).

Fracking falls under the Clean Air Act through several circumstances. During the drilling process, methane and any other gas that leaks is vented or burned off, allowing contaminants to escape into the surrounding atmosphere. Later during the flowback of the fracking fluid, VOCs and HAPs have the potential to escape into the atmosphere. Additionally, through the Clean Air Act's application to fracking, gas operators must comply with individual states' emission standards by using VOC and HAP capture techniques (Wiseman and Gradijan, 2012). Also falling under the legislative purview of the Clean Air Act is if several fracking sites are relatively near to one another or operated by a single entity, the clustered sites could count as a major source of air emissions and must conform to additional Clean Air Act regulations (Wiseman and Gradijan, 2012).

Under CERCLA, well operators are not only required to disclose any releases of hazardous chemicals that exceed threshold quantities but are also required to report certain hazardous waste spills that exceed threshold quantities (Wiseman and Gradijan, 2012). CERCLA also holds owners and operators of fracking sites responsible for the disposal of hazardous waste in additional to being liable for the costs of any hazardous substance clean-ups (Wiseman and Gradijan, 2012).

As previously stated, other federal regulations that can affect certain stages of the fracking process include the Endangered Species Act (ESA), the Migratory Bird Treaty Act (MBTA), the Emergency Planning and Community Right-to Know Act (EPRCA), and the Occupational Safety and Health Act (OSHA). Under the ESA and MBTA, fracking operators are required to

> *consult with the Fish and Wildlife Service and obtain an incidental 'take' permit if endangered or threatened species will be affected by well development. Operators [additionally] are strictly liable for any harm to migratory birds under the MBTA and therefore must ensure that their maintenance of surface pits or their use of rigs does not attract these birds (Wiseman and Gradijan, 2012,p. 19).*

Additionally, under EPCRA and OSHA, fracking well operators "must maintain material safety data sheets (MSDS) for certain hazardous chemicals that are stored on site in threshold quantities" (Wiseman and Graijan, 2012, p. 19).

Although erosion, sedimentation and its effect on storm water quality is addressed in the Clean Water Act, Michigan has an additional regulation specifying that operators of fracking sites must obtain a soil erosion and sedimentation control permit from the county where the fracking is taking place (Wiseman and Gradijan, 2012). Michigan also requires that all fracking wells and any other associated surface facilities must be at minimum of 300 feet from all private water wells (Michigan Department of Environmental Quality, Wyant, D., & Fitch, H. R., 2012). Regulations regarding setbacks from public water wells are listed in Michigan Administrative Code r.324.301 (2012) which states that fracking operations including storage pits must be at minimum 2,000 feet from all Type I public water supplies (Figure 2.2) and at least 800 feet from both Types II and III public water supplies, including well separators, storage tanks, and treatment equipment (Michigan Department of Environmental Quality, Wyant, D., & Fitch, H. R., 2012).

Additional fracking well set back regulations stipulate that all fracking wells and/or storage pits must be at least 300 feet from any structure or dwelling in the area (Michigan Department of Environmental Quality, Wyant, D., & Fitch, H. R., 2012).

These various set back regulations ensure that that "if a spill or well blowout accidentally occurs during drilling or fracturing…it will not contaminate water or

Figure 2.2 Types of Public Water Supplies (Michigan Department of Environmental Quality, 2014)

Types of Public Water Supplies

Classification	Description	Examples
Type I Community Public Water Supply	Provides year-round service to not less than 25 residents OR not less than 15 living units	Municipalities, Apartments, Nursing Homes, Mobile Home Parks
Type II Nontransient Noncommunity Public Water Supply	Serves not less than 25 of the SAME people for at least six months per year	Schools, Industries, Places of Employment
Type II Transient Noncommunity Public Water Supply	Serves not less than 25 people OR not less than 15 connections for at least 60 DAYS per year	Hotels and Restaurants (with less than 25 employees), Campgrounds
Type III Public Water Supply	Anything not considered a Type I or Type II water supply: serves less than 25 people AND 15 connections, or operates for less than 60 days per year	Small Apartment Complexes and Condominiums, Duplexes, all Others
Private Water Supply	Serves a single living unit	Single Family Home

Type II noncommunity water supplies are also classified according to their water production. Type IIa water supplies have an average production during the maximum month equal to or greater than 20,000 gallons per day. Type IIb water supplies produce less than 20,000 gallons per day during the peak month.

other important natural resources" (Wiseman and Gradijan, 2012, p. 38) as well as endangering individuals.

During the drilling process, many states have regulations addressing the casing of the well shaft as well as regulating the depth of surface casing, the strength of the casing, the strength of the cement holding the casing, the cementing method, and the length of time for which the cement must set before the fracking process begins (Wiseman and Gradijan, 2012). Also required in many states are regulations preventing blowouts from occurring during both drilling and fracturing. According to

Wiseman and Gradijan, (2012), these regulations are necessary for the safeguard of surrounding underground water supplies. In the case of Michigan, the Michigan Administrative Code r.234.408 states that the fracking well casing must be at least…

> *100 feet below all fresh water strata and at least 100 feet below based of glacial drift into competent bedrock… [and] in certain portions of [the] Antrim Formation, [the] production casing must be set at least 50 feet below [the] shoe of [the] surface casing (Wiseman and Gradijan, 2012, p. 55).*

In the case of regulations regarding the strength of the surface casing, Michigan requires that all fracking wells must have a casing of "sufficient weight, grade, and condition to have a designed minimum internal yield of 1.2 times the greatest expected well bore pressure to be encountered" (Wiseman and Gradijan, 2012, p. 57). This ensures that there is very little potential of a blowout occurring during the fracking process. To further safeguard against the chance of a blowout happening, Michigan requires that all cement must set for at least 12 hours and must undergo a supervised pressure test before starting the fracking process (Wiseman and Gradijan, 2012). Lastly, Michigan has drafted additional regulations in an effort to further prevent blowouts from occurring by requiring that all fracking wells must have a "double ram blowout preventer, including pipe and blind rams [as well as] accessible controls on [the] rig floor and remote, kelly valve, drill pipe safety valve, flow line, and rated working pressure that exceeds maximum anticipated pressure," (Wiseman and Gradijan, 2012, p. 62).

In addition to developing regulations regarding the drilling process, Michigan has also developed regulations in order to monitor water withdrawal during the fracking process. However, Michigan regulations only state that if the proposed water withdrawal will likely cause an "adverse resource impact" or the withdrawal will originate from a "cold-transitional river system", the operators will not be able to withdraw water from that specific area (Wiseman and Gradijan, 2012). Further research indicates that other fracking states have much more complex regulations regarding water withdrawals, such as Louisiana, New York, Pennsylvania, and West Virginia (Wiseman and Gradijan, 2012). Specifically, Michigan regulation requires the daily monitoring of all water wells within 1,320 feet of the withdrawal area to ensure that cones of depression in the water table are not created (Wiseman and Gradijan, 2012).

In regards to chemical disclosure laws, Michigan has very limited regulations regarding chemical disclosure, resulting in many individuals and advocacy groups pressing for better disclosure laws. The only Michigan regulation regarding chemical disclosure requires that copies of material safety data sheets (MSDS) be made available for all fracturing additives used as well as the amounts of each additive used (Wiseman and Gradijan, 2012). Additional to limited chemical disclosure laws, Michigan is one of nine states that do not require providing area residents advance notice of the construction of a fracking site (McFeeley, 2012). Ultimately, disclosure regulations are important because they "provide the public with information concerning the hydraulic fracturing process" (McFeeley, 2012, p. 4) and in addition to the "practices and materials employed throughout the lifecycle" (McFeeley, 2012,

p. 4) of the fracking well. This ensures that the safety of the surrounding public is continued.

However, Michigan, along with several other states, does not have trade secret exemptions on the chemicals used during the fracking process (McFeeley, 2012). Trade secret laws allow companies to maintain confidentiality with their chemical formula, claiming that it protects their interests and gives their company an advantage against the competition. When a state has a trade secret exemption in place, it gives the fracking industry a "free pass to avoid disclosure requirements" (McFeeley, 2102, p. 12). Michigan provides no such cover. In order to help promote chemical disclosure, Michigan partners with the Ground Water Protection Council in order to disseminate information regarding chemicals used during the fracking process, which is published on FracFocus.org.

Unlike several other states, Michigan has developed several specific policies for the prevention and reporting of any spills occurring on a fracking site in addition to the existing federal CERCLA regulations. In the first line of defense against spill prevention and control, according to Michigan Administrative Code r.324-2006, well operators are required to have a pollution incident prevention plan in place if the amounts of chemicals used during the process are at the specified threshold quantities (Michigan Department of Environmental Quality, Wyant, D., & Fitch, H. R., 2012). Additionally, all wellheads and the accompanying pump jacks must have a secondary containment plan, as stated by Michigan Administrative Code r.324-1002 (Michigan Department of Environmental Quality, Wyant, D., & Fitch, H. R., 2012). Although, in the circumstance that a spill does occur on a fracking site Michigan requires that operators report spills immediately and report spills of "42 gallons or more of brine, crude oil, or oil and gas field waste" (Wiseman and Gradijan, 2012, p. 97) within eight hours of the spill occurring.

To further ensure that contamination does not happen between the fracking site and the surrounding water wells, many states require monitoring of the area water quality. Some states even go so far as to document water quality prior to the fracking operation taking place through baseline testing. In Michigan, state regulations require that a hydrogeological investigation of the area must take place in addition to performing water quality sampling before the fracking process occurs (Wiseman and Gradijan, 2012). Moreover, if operators plan on utilizing an on-site water supply with daily withdrawals averaging more than 100,000 gallons of water over a 30-day period, operators "must install [a] monitor well, measure and record water level daily during withdrawal and weekly thereafter until [water levels] stabilize" (Wiseman and Graijan, 2012, p. 103).

In the last stages of the fracking process, well operators must determine how to deal with waste storage and disposal. Regulations regarding the storage and disposal of fracking waste vary from state to state from utilizing open storage pits with liners to employing a closed-loop drilling system where the waste is contained in tanks (Wiseman and Gradijan, 2012). Michigan requires that the flowback water and the completion fluids be stored in storage tanks as opposed to open pits (Wiseman and Gradijan, 2012). However, drilling mud can be stored in pits as long as the pits are lined with 20-mil polyvinyl chloride liners (Michigan Department of Environmental Quality, Wyant, D., & Fitch, H. R., 2012). Although there is some risk associated with using open pits as opposed to storage tanks. Extensive flooding in North Dakota resulted in fracking waste stored in open pits being released into the surrounding environment and area waters (McAllister and Gebrekidan, 2013)

When the time comes to dispose of waste generated from the fracking process, Michigan has several regulations directing well operators how to do so. If operators come across naturally occurring radioactive material (NORM) during the drilling process, operators are to "store, reuse, or recycle [the material]" (Wiseman and Gradijan, 2012, p. 119). With water-based and oil-based drilling fluids, Michigan administrative code r.231.703 requires that they should be injected into "an approved underground formation in a manner that prevents waste. The disposal formation [should] be isolated from fresh water strata by an impervious confining formation" (Michigan Department of Environmental Quality, Wyant, D., & Fitch, H. R., 2012, p. 82). The same Michigan Administrative Code that regulates the disposal of water and oil-based drilling fluids also regulates how both the flowback water and the resulting brine water produced by the fracking process are to be properly disposed. Michigan also requires that flowback water volume to be reported to the Michigan Department of Environmental Quality (McFeeley, 2012; Michigan Department of Environmental Quality Office of Oil, Gas, and Minerals, 2013). Similarly, Michigan Administrative Code r.324.705 also stipulates that flowback and brine water are to be disposed of by injecting the waste waters into an approved underground formation (Michigan

Department of Environmental Quality, Wyant, D., & Fitch, H. R., 2012). It also stipulates that brine water can only be used for ice and dust control and road stabilization only in specific circumstances (Wiseman and Gradijan, 2012).

Although these extensive regulations and policies exist, they seem to have done little to alleviate some individuals' perceptions of risk. However, how does an individual's perception of risk develop? The next section will discuss the development of risk perception and influencing factors.

Development of Risk Perception

Common questions driving many risk perception studies is: Why do individuals perceive risks as they do? and What drives these specific risk perceptions? Slimak and Dietz (2006) put forth the theory that risk perception is developed through a combination of the characteristics of the risks themselves. Additionally, it is thought that that the development of risk perception represents complex social and psychological processes that are multi-dimensional (Brasier et al., 2013). These characteristics can include a variety of factors including: 1) perceived knowledge of the effects of the activity, 2) trust in the institutions responsible for the management of the perceived risk, and 3) critical demographic and geographic characteristics (Brasier et al., 2013).

According to Kasperson et al. (1988) and Renn et al. (1992), individuals develop their perception of risk through two causes. Individuals are first exposed to "individual and social 'amplification stations'" (Kasperson, 2012, p. 60) which includes the media, advocacy groups, agencies, and any other types of groups that amplify potential risk to the general population. The second cause is what is known as the ripple effect, the after effects of amplified risks that influence behavioral responses (Kasperson, 2012). Moreover, the amount of trust that an individual places on the institution responsible for managing can impact the risk perception associated with the perceived object. However, it has been found that signal events, such as spills, contaminations, or accidents, can lead to a decrease in trust in the managing entities, resulting in an escalation in individual risk perception (Slovic, 1987). Also influencing risk perceptions are various sociodemographic characteristics of individuals. Studies have found that both race and gender have an impact on the levels of individual risk perception (Flynn et al., 1994; Davidson and Freudenburg, 1996). In the case of gender, additional studies have discovered that women in general tend to perceive modestly higher levels of risk, as opposed to men. It is thought that women with children develop a greater concern for individual health and safety which, in turn, causes them to be more aware of environmental risks, both at the global and local levels (Stern et al., 1993, Flynn, Slovic, & Mertz, 1994; Davidson and Freudenburg, 1996; DeChano, 2000; Slimak and Dietz, 2006; Freudenburg and Davidson, 2007).

An additional aspect of risk perception is the impact of spatial scale on an individual's perception of risk associated with a particular object. Recent studies have shown that while people can separate local from global environmental issues, they consider those at the global-level to be more severe than local issues (Uzzell, 2000;

Garcia-Mira et al., 2005). However, when local problems present an immediate threat to the surrounding community they become more important. It is thought that this reversal occurs because while global-level issues are identified as being beyond individual control, local-level problems can be subjected to individual control, and as a result, perception of risk increases (Garcia-Mira et al., 2005).

Also influencing an individual's perception level of risk is how often they came into contact or interacted (i.e. strong presence in the community, driving past on a regular basis) with said object or institution, such as a nuclear power plant or a chemical factory. Research has shown that there is a relationship between spatial proximity and amount of interaction between the object of focus increases in that perception of risk increases as distance increases away from the specified object (Lima, 2004; Lima and Marques, 2005, Venables et al., 2012). It is believed that individuals who reside farther away from controversial institutions will have an increased perception of risk resulting from less contact with the site and, consequently, individuals who reside closer from the institution will have a decreased perception of risk due to more frequent interaction (Maderthaner et al., 1978)

The connection between spatial distance and increasing perception of risk is the driving force for this thesis. While several perception of risk studies have been applied to fracking sites recently, the connection between distance and level of perception of risk has yet to be applied to a fracking site.

CHAPTER III

METHODOLOGY

Geology of Michigan

Michigan's geologic composition is primarily due to a thick accumulation of marine sediment from a warm sea that once covered the region (Dorr and Eschman, 1971). Due to "the earth's crust beneath the Great Lakes region [sagging] downward," (Door and Eschman, 1970, p. 27) the sedimentary layers were formed into a bowl-like structure (Figures 3.1, 3.2). As a result, the rings of bedrock around the edge of the basin are the oldest with additional layers becoming increasingly younger toward the center of the area. As a result of the layering of Michigan's bedrock, many areas of the state have been identified as prime locations for oil and natural gas extraction. According to the Michigan Department of Environmental Quality Office of Oil, Gas, and Minerals (2012), there are currently 4,551 active oil wells and 11,191 active gas wells operating with numerous other well types existing.

Figure 3.1 displays the locations of the study area fracking sites and their position on various bedrock layers. The fracking sites are located on top of Michigan Coldwater Shale, Saginaw, and Marshal formation regions. While the Saginaw and Marshal formations are both composed of a sandstone, shale, and limestone mixture, in addition to the presence of dolostone, gypsum, and anhydrite found within the Marshal formation, the Coldwater Shale formation is primarily composed of shale and

Figure 3.1: Michigan Bedrock Layers and Study Fracking Sites (Michigan Department of Environmental Quality Geology Survey Division, 1987; Michigan Department of Environmental Quality Office of Oil, Gas, and Minerals, 2013).

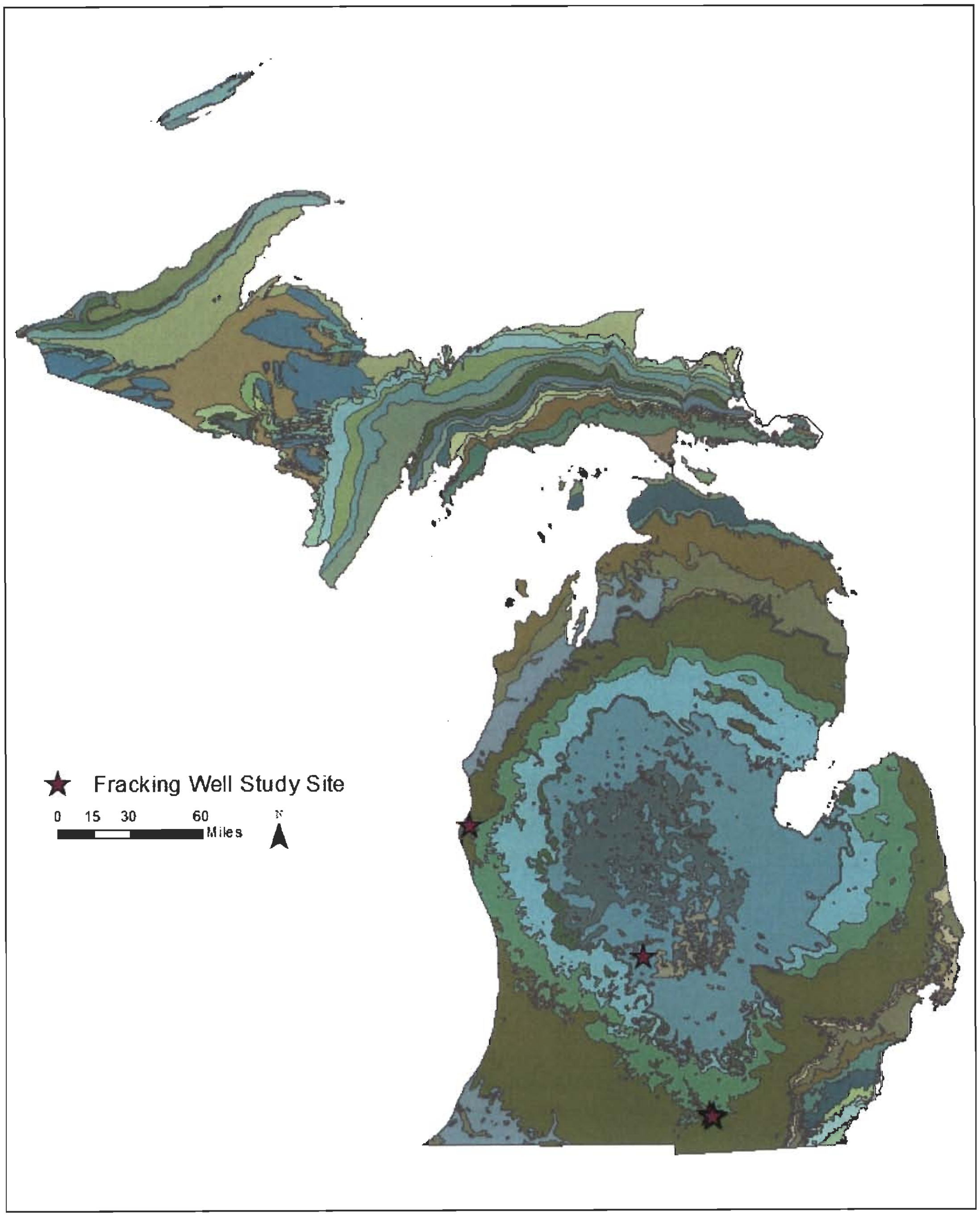


Figure 3.2: Michigan Bedrock Layers (Michigan Department of Environmental Quality Geology Survey Division, 1987).

limestone with deposits of dolostone, sandstone, and siltstone found throughout the formation (USGS, 2013a/b/c). While each fracking site is located on an individual shale or sandstone formation, the entire Michigan basin is grouped under the Antrim Shale play, an area of shale that covers roughly 39,000 square miles. Although the Antrim Shale play is not viewed as one of the major producing shale plays (estimated to be the 15th largest in the continental United States), it is still considered to be highly productive and produces a considerable yearly output of natural gas (Dolton and Quinn, 1996; Green, 2013). In 2012, the Antrim Shale play was recorded as producing 107.8 billion cubic feet of natural gas, an amount totaling less than one percent of the United States' use of 25.46 trillion cubic feet of natural gas in 2012 (Michigan Department of Licensing and Regulatory Affairs, 2013; U.S. Energy Information Administration, 2013).

Hydrology of Michigan

Like Michigan's geology, the water resources of the state are also unique in that every watershed eventually flows into the Great Lakes. Counties such as Hillsdale and Ionia Counties have deep groundwater reserves while Oceana County tends to have a higher water table that more readily drains into Lake Michigan (Michigan Department of Environmental Quality, et al., 2006). Because of this, contamination spills along the lakeshores can do greater damage than in the interior of the state.

Study Counties

As of September 2013, fracking permits have been issued for sites located in nineteen Michigan counties (Michigan Department of Environmental Quality Office of Oil, Gas, and Minerals, 2013). Due to the large number of sites, three counties were chosen that had at least one fracking site present and displayed similar socio-economic demographics of level of educational attainment and household income earned, in addition to being geographically distant from one another. These counties are Hillsdale, Ionia, and Oceana Counties (Figure 3.3).

Hillsdale County

Hillsdale County is located in southern Michigan, along the Michigan-Ohio border. The population of this county is 46,688. The major cities in this county include Hillsdale, Litchfield, and Reading. Hillsdale County is predominately Caucasian (97%) with a small percentage of the total population identifying as African American, American Indian and Alaskan native, Asian, and other races (U.S. Census Bureau, 2010). The majority of the county population has an educational attainment of a high school degree or some college (Figure 3.4; U.S. Census Bureau, 2010-2012). Additionally, the majority (80.8%) of Hillsdale County households earn less than $74,999 per year which is much higher than Michigan and United State household (59.6% and 66.4%, respectfully; U.S. Census Bureau, 2010-2012). Additionally, Hillsdale County households have a median household income of $47,641, similar to median amount of Michigan ($47,175) but still lower than the United States' median income amount ($51,771) (U.S. Census Bureau, 2010-2012).

Figure 3.3: Research Study Counties of Hillsdale, Ionia, and Oceana Counties (Michigan Department of Environmental Quality Office of Oil, Gas, and Minerals, 2013; Center for Shared Solutions and Technology Partnerships, 2013).

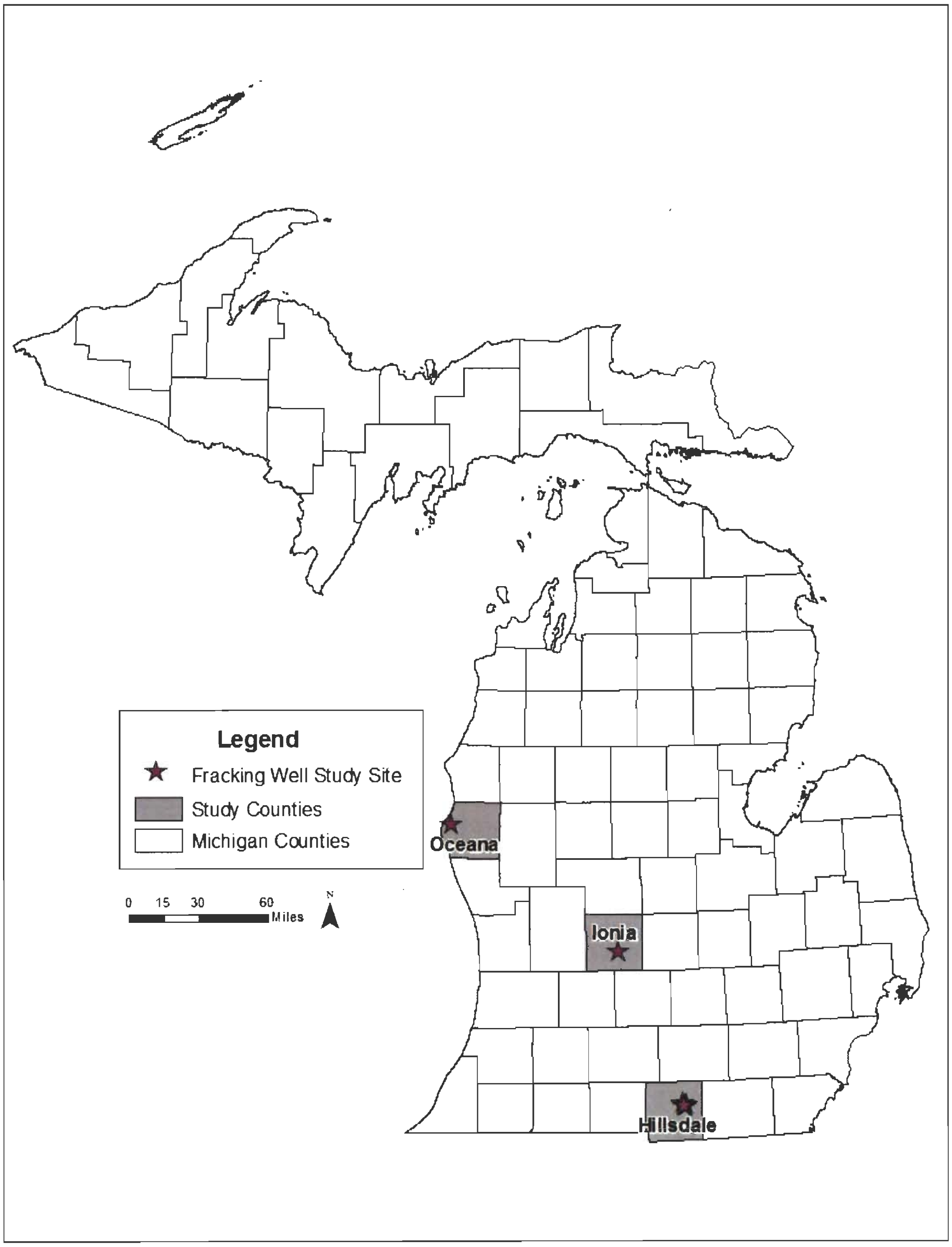
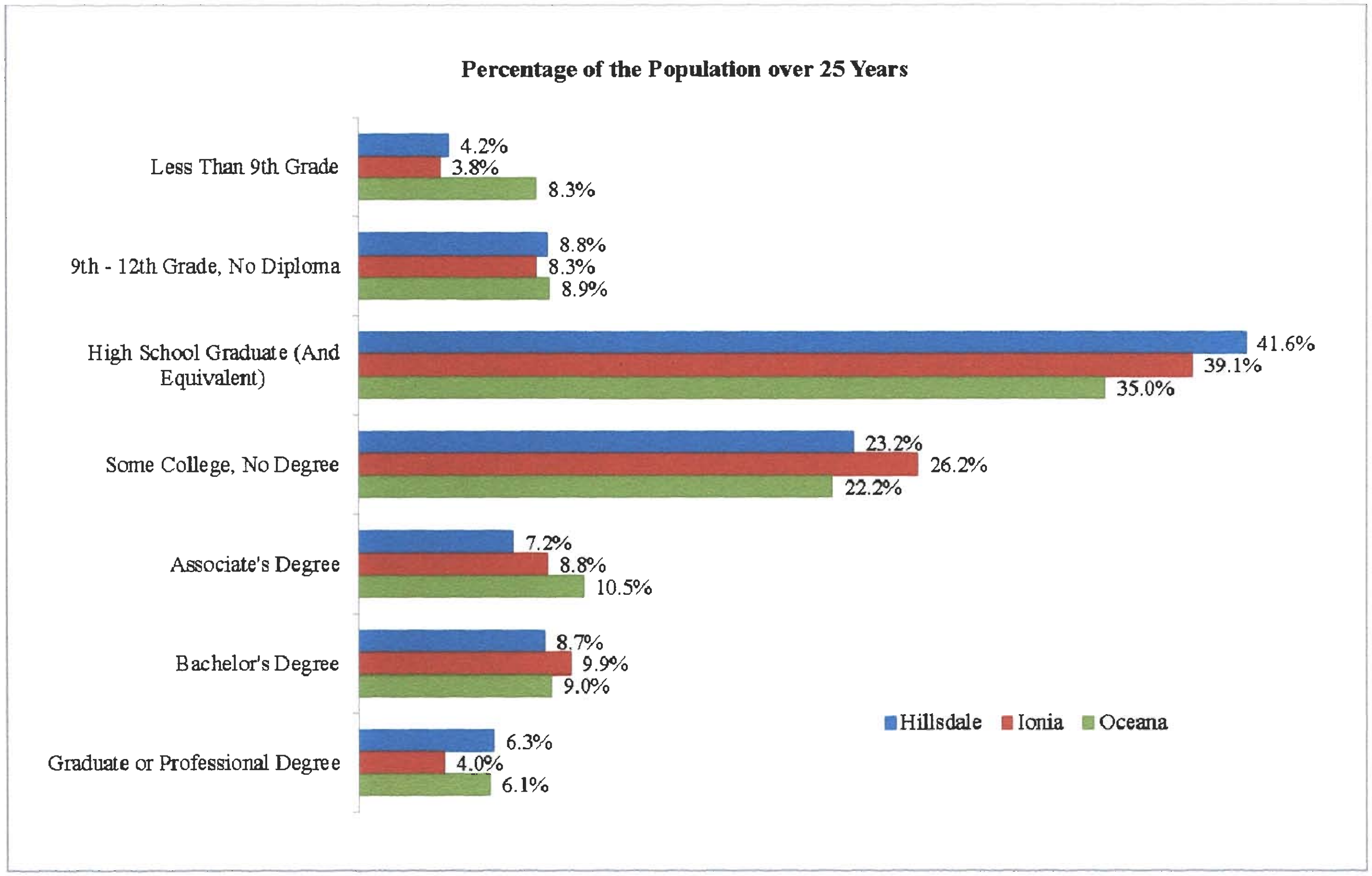


Figure 3.4: Level of Educational Attainment of Study County Populations over 25 Years (U.S. Census Bureau, 2010-2012).



Ionia County

Ionia County is located near the center of Michigan and a large portion of it is considered part of the Grand Rapids area. According to the U.S. Census Bureau (2010), 63,905 people reside in Ionia County with a large portion of the population residing in the cities of Belding, Ionia, and Portland. The county's population is primarily Caucasian (91.6%) with minority populations of African American, American Indian and Alaskan Native, Asian, and other races (U.S. Census Bureau, 2010). The majority of Ionia County residents have an educational attainment between a high school degree or the equivalent (39.1%) and some college (26.2%), similar to the educational attainment levels of both Michigan and the United States (Figure 3.4; U.S. Census Bureau, 2010-2012). According to the U.S. Census's Bureau's American Community Survey (2010-2012), 75.1% of the population reported a household income of less than $74,999 with a median household income of $47,392, compared to the lower Michigan (56.6% and $47,175, respectfully) and United States (66.4% and $51,771, respectfully) household income and earnings and median income amounts.

Oceana County

Oceana County is located on the coast of Lake Michigan in west Michigan. The county has a population of 26,570 residents with the only city being Hart (U.S. Census Bureau, 2010). The main villages of Oceana County include New Era, Pentwater, Rothbury, Shelby, Walkerville, and part of Hesperia. The county's demographic makeup is primarily Caucasian (90.1%) with minority populations of African American, Native American, Asian, and other races present (U.S. Census Bureau, 2010). Additionally, a large portion of the population (13.7%) also identifies themselves as Hispanic or Latino (U.S. Census Bureau, 2010). The majority of the county population has an educational attainment of a high school degree or the equivalent of (35.0%) and some college (22.2%) which is similar to the Michigan and United States educational attainment levels (Figure 3.4; U.S. Census Bureau, 2010-2012). Like Hillsdale and Ionia Counties, the majority (81.9%) of the Oceana County population reported a yearly household income of less than $74,999 with a median yearly household income of $38,289 (U.S. Census Bureau, 2010-2012). Compared against the Michigan household income earnings and median income amounts (56.6% and $47,175, respectfully) and the United States (66.4% and $51,771, respectfully) household income and earnings and median income amounts, this is significantly lower (U.S. Census Bureau, 2010-2012).

Unlike the other two study counties, much of Oceana County is covered by the Manistee National Forest. Oceana County also receives a large number of tourists due to several lakeshore vacation communities and various state and township parks.

Survey Areas

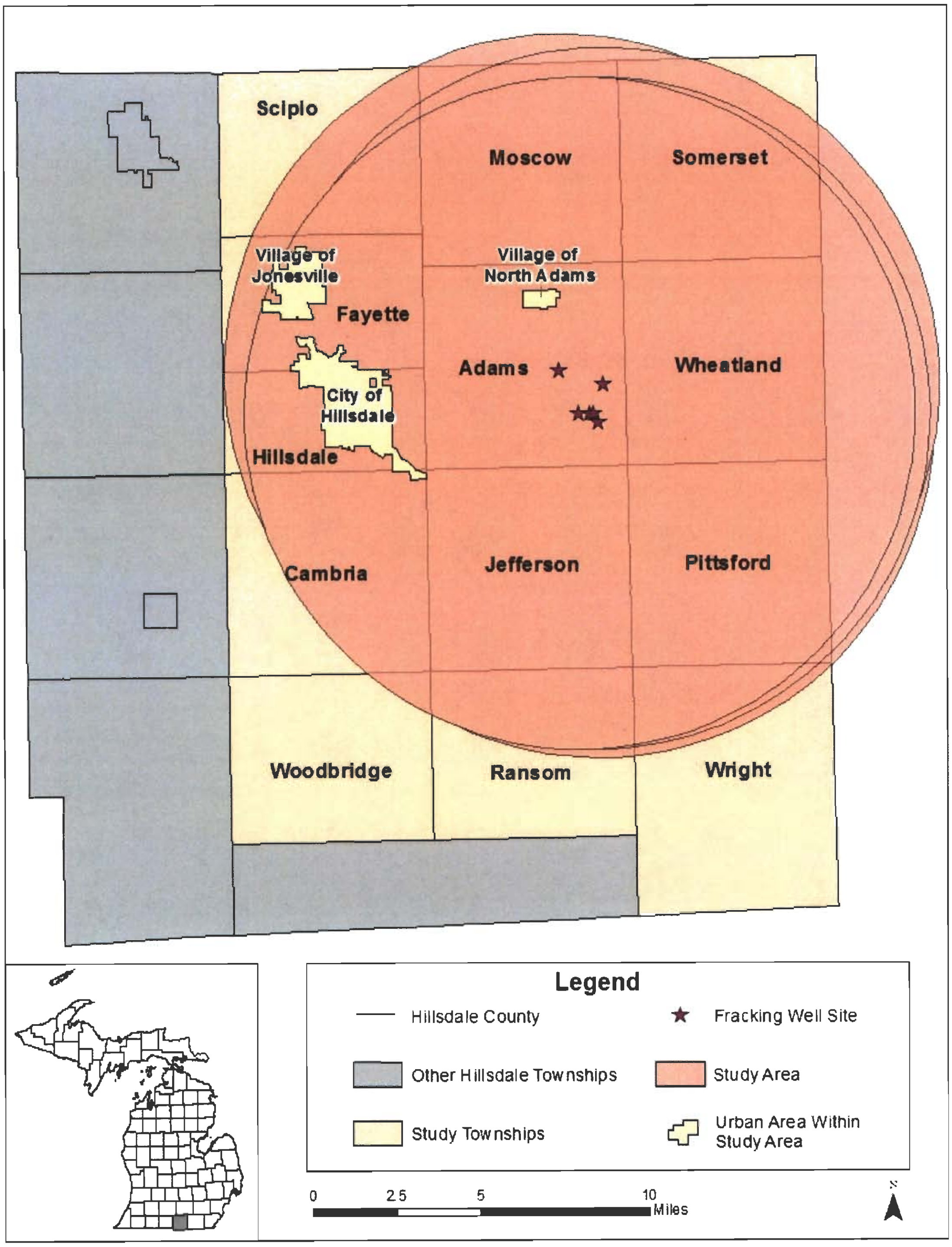
Each survey area incorporated a region extending in a ten mile radius from the location of an identified fracking site found within the study counties. The ten mile radius was adopted from Parkhill et al.'s (2010) and Vendables et al.'s (2012) study on risk perception levels and proximity to a controversial object, a nuclear power facility. While Parkhill et al.'s (2010) and Vendables et al.'s (2012) studies extends eight miles from the objects of concern, this study goes beyond that to ten miles. The ten mile radius was determined by the researcher due to the targeting of participants located a significant distance away from the fracking site to determine if there was a specific distance where concern regarding area fracking dropped to minimum levels. Additionally, the ten mile radius was set in order to identify individuals who would not come into contact with the fracking site regularly. The distance of ten miles was determined to be of significant distance from a fracking site within each individual study county while keeping the study confined within the individual study county's borders.

Within the designated survey areas, a minimum of forty-five surveys per study county were collected in order for collected data to be considered for statistical significance. In addition to the determined minimum total, a minimum collection of five surveys per township was set. However, if the entity of a township was not included within the ten mile study area, the amount of surveys to be collected reflected the proportion of the township included within the study area. For example, if roughly 75 percent of the township fell inside the study area, four surveys were collected; if roughly 50 percent of the township fell inside the study area, three surveys were collected; if roughly 25-30 percent of the township fell inside the study area, two surveys were collected; if roughly 15 percent of the township fell inside the study area, one survey was collected. However, any portion less than roughly 10 percent of a township falling inside the study area was not included as it was determined that there would not be a large enough population to sample. Minimum survey counts were done in order to ensure thorough representation of each total study area. Moreover, in order to ensure representation of residents within urban area, a minimum of one survey was collected from a village falling within the study area and a minimum of three surveys were collected from a city falling within the study area. A description of the individual survey areas follows.

Hillsdale County

Hillsdale County is divided into eighteen townships and has active permits for the development of six fracking sites, all within Adams Township (Michigan Department of Environmental Quality, 2012). A portion of or all thirteen townships fell within the ten mile study area (Figure 3.5). Of these six permitted fracking well sites, only two of the permitted wells have been listed as currently producing oil and natural gas (Michigan Department of Environmental Quality, 2012). The remaining four permitted sites are listed as having active permits but construction has yet to begin on the approved sites (Michigan Department of Environmental Quality, 2013). For the duration of the study, the additional four permitted sites were treated as actual sites as construction could begin on them at any time. Although Hillsdale County had the greatest amount of fracking sites, all of the approved sites were clustered in a small area, resulting in huge overlaps in the survey radii.

Figure 3.5: Study area of Hillsdale County



Ionia County

Ionia County is made up of sixteen townships, twelve of which are either entirely or have a portion within the ten mile study area (Figure 3.6). A fracking well exists in Orange Township and is less than six miles outside of the city of Portland (Michigan Department of Environmental Quality, 2013). However, as reported by Harger (2013), fracking activities were completed at the Ionia site sometime during July of 2013, during the time that surveying was being performed. This information was also confirmed by the Office of Oil, Gas, and Minerals database of fracking sites (Michigan Department of Environmental Quality, 2013).

Oceana County

Oceana County is composed of sixteen townships with a single fracking site located in Golden Township. A portion of or all of eleven townships fall within the ten mile study area surrounding the present fracking site (Figure 3.7). Recently, a new fracking site was granted approval for construction within Hart Township (Michigan Department of Environmental Quality, 2013). However, no signs of construction had been started done at the time of writing.

Data Collection

Survey Instrument

The survey (Appendix A) used in this study was developed to obtain a better understanding of residents' concerns and perceptions regarding the presence of fracking sites in their respective counties. Residents were deemed eligible to

Figure 3.6: Study Area of Ionia County ((Michigan Department of Environmental Quality Office of Oil, Gas, and Minerals, 2013; Center for Shared Solutions and Technology Partnerships, 2013).

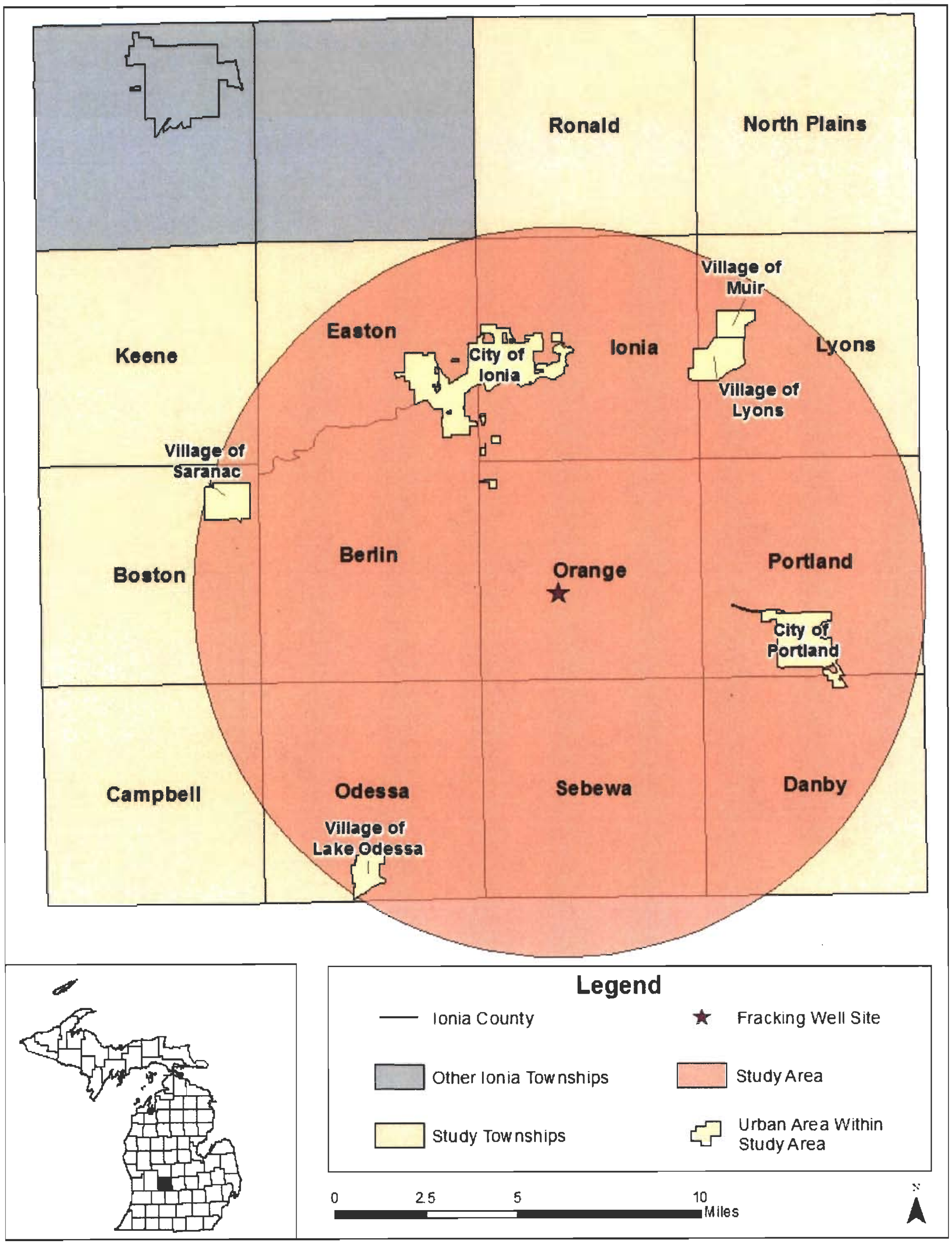
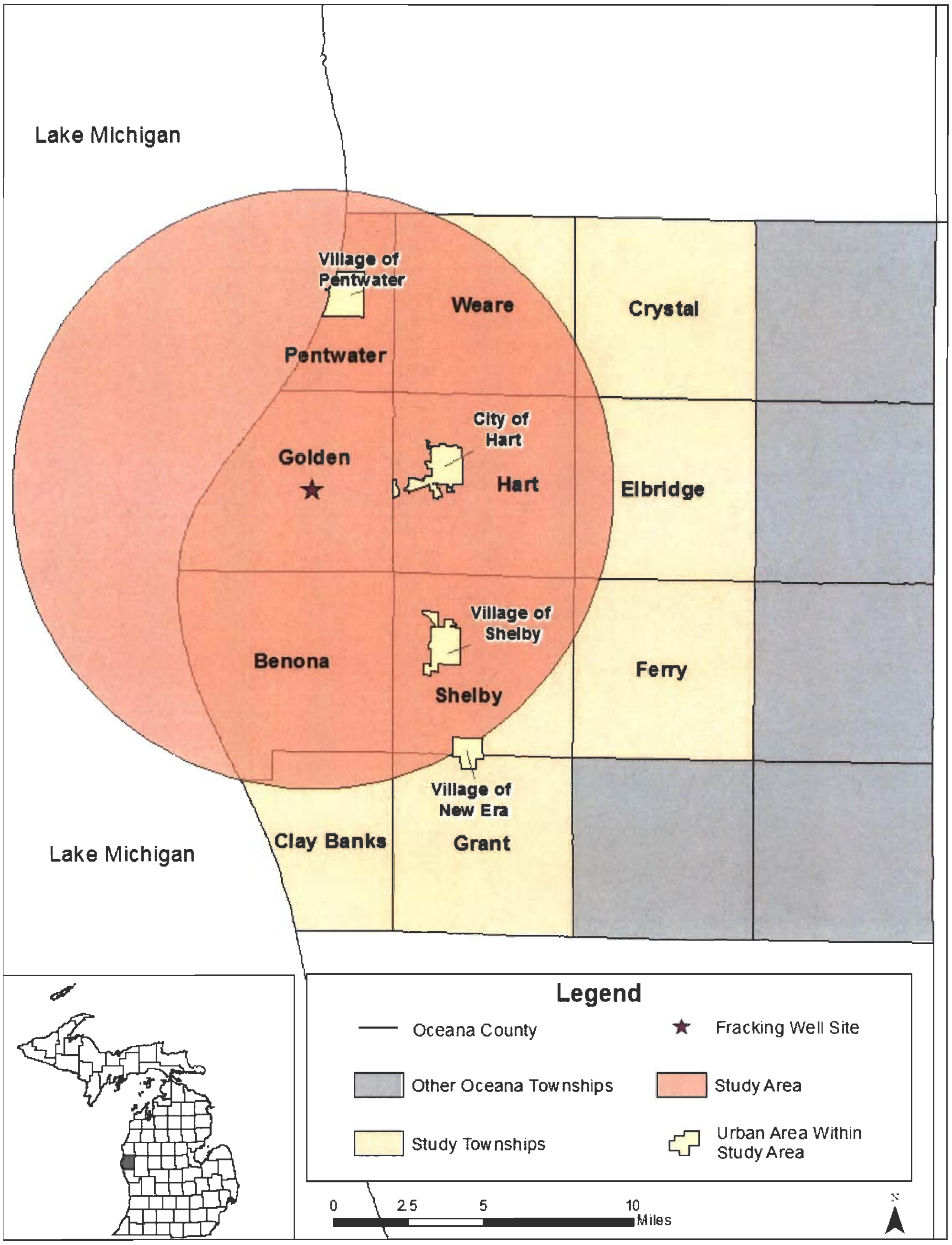


Figure 3.7: Study Area of Oceana County (Michigan Department of Environmental Quality Office of Oil, Gas, and Minerals, 2013; Center for Shared Solutions and Technology Partnerships, 2013).



participate in the survey if they were a resident of Hillsdale, Ionia, or Oceana Counties, over 18 years old, and spoke English. As a result, non-residents of Hillsdale, Ionia, or Oceana counties were excluded in addition to participants under 18 years old or did not speak English. Potential participants were also excluded from the study if their residence was not visible from the road in order to ensure the safety of the researcher.

Moreover, to ensure confidentiality, participants were not required to include their names or addresses on the survey. Participants were also given a coded consent form that included the researcher's contact information and were assured that they could withdraw their survey responses from the study at any given time by contacting the researcher and providing their unique code number. The developed survey was approved by Western Michigan University's Human Subjects Institutional Review Board (HSIRB; Appendix B).

Participants were asked a series of eight questions pertaining to what is believed to be major concerns brought about by the fracking process. Participants were then asked to rate their level of concern using a 1-5 Likert-type scale with 1 = "not concerned at all" and 5 = "very concerned" (Table 3.1).

Table 3.1

Likert-type Scale Levels of Concern Ratings

Rating Level	Corresponding With
1	Not at all concerned
2	Somewhat concerned
3	Neutral or neither concerned nor not concerned
4	Somewhat concerned
5	Very concerned

Residents were also asked to estimate how far away the closest fracking site was to them. Participants were asked whether or not their mineral rights had been sold or leased and if they were aware of the mineral rights status of the neighboring properties. The researcher also asked if the participant had any remaining concerns that the survey failed to address. Demographic questions included gender, any children under the age of 18 years at the residence, the highest level of education, and the participant's job or occupation.

Survey Methods

The majority of the surveys were collected primarily by going door-to-door in the survey areas of Hillsdale, Ionia, and Oceana Counties from July through October, 2013. Weekends were determined to be the best choice for surveying as more residents were present for a greater portion of the day than during the work week. Residences were visited between 10 a.m. – 5 p.m. on Saturdays and Sundays. It was found that response rates were higher later in the afternoon when the area's weather was pleasant, as many participants were surveyed while performing yard work. If a home was visited and no homeowner was present, the researcher moved on to the next residence. Residences without a homeowner were not revisited during the course of the study.

Surveying of residences was done through a combination of stratified, random, and convenient methods. Each township within the specified study county was quartered into sections with one or two surveys to be collected from each section. The researcher drove to the targeted township quarter and picked a starting residence randomly. From then, every third residence on a street or road was visited until a resident agreed to participate in the study. If no residents on the starting street agreed to participate in the study, the researcher moved onto the next road to the north, once again surveyed every third residence on that particular street. However, once a resident agreed to participate in the study, the researcher moved onto the next quarter section within that township and repeated the surveying methods.

Surveying of residences was performed using two methods: on foot in towns and villages found within the survey areas and using a vehicle to drive to each individual residence located in the surrounding countryside. Additionally, convenient method surveying was also performed in two instances utilizing local county fairs. It was discovered that response rates were better when surveying was performed on foot and at local county fairs. Participants were found to be generally more responsive and friendlier to the researcher as well as more inclined to have a discussion regarding fracking. In the instances where surveys were collected at local county fairs, the researcher and any participating assistants would position themselves in high traffic areas of the fairgrounds, asking every third person until someone agreed to participate in the study.

When contact was made with a potential participant, the researcher offered a statement that informed the participant of the researcher's name, affiliation with Western Michigan University and the purpose of the research. More often than not, the participant would inform the researcher of their personal opinions regarding fracking during data collection. Additionally, in the instances where surveying was done at county fairs, the researcher asked the potential participant if they resided in any of the study townships in order to ensure that only residents from the study areas were surveyed.

The researcher read the survey to the participants in order ensure full understanding of the survey. In several cases, the researcher had to explain to the participant what fracking was as they were unfamiliar with the process but did express that they had some knowledge on the subject. After the survey was completed, a note was made regarding the survey's location. In the case of surveys done at local county fairs, participants were asked to give the nearest intersection to their residences. In total, the duration of completing each individual survey took less than ten minutes.

Analysis

Participants were asked to rate their level of concern regarding several prevalent concerns associated with a fracking site. A 5 point Likert-type scale was used to determine residents' concern levels with 1 = "not concerned at all" through 5 = "very concerned". Survey questions were coded numerically according to the county they originated from and the information from the survey was recorded in a spreadsheet. Data was analyzed using SPSS Output Statistic (SPSS Inc., 2012) software. Survey results were stratified into three independent groups determined by county of residence.

Analysis of the Likert-scale responses was conducted in several ways. First, descriptive statistics of the survey responses were calculated for the study counties. Descriptive statics of the survey responses for the entire population and by county were compiled based on: gender and education attainment levels. Along with descriptive statists, statistical tests of Kruskal-Wallis and Spearman's rho were performed on the data sets by county dataset, estimated distance from a fracking site, gender and level of educational attainment in order to determine if there is statistical significance between the study counties. These tests were performed in order to determine how different (Kruskal-Wallis) and similar (Spearman's rho) the groups were. Statistical significance was determined at $p \leq 0.05$. When statistically significant differences did occur in Kruskal-Wallis analysis, a post-hoc test was performed in to determine where the differences lied.

Additionally the Chi-Squared test of independence was also included in order to analyze any association between datasets and Likert-scale questions to determine if there were significant differences in perceptions between the groups. In this test, the null hypothesis is that a difference in gender influences the level of concern among respondents while the alternative hypothesis is that gender does not influence the level of concern among respondents. Like Kruskal-Wallis and Spearman's rho, the two-tailed Chi-squared tests were conducted with a confidence interval of 95% and a 'p value' of less than 0.05 was considered to be statistically significant. Additional distance analysis was performed via GIS by analyzing residents' responses and the actual distance of their residents from the individual fracking sites. This was done in order to measure residents' estimated distance from the nearest fracking site and overall levels of concern regarding a fracking site against their actual distance from the specified fracking sites.

Conclusion

This chapter introduced the study areas surrounding the fracking sites of Hillsdale, Ionia, and Oceana County in addition to describing the research methodology and procedures used in this study for surveying and collecting data from residents of said study areas. The research methodology and procedures used in the study enabled the researcher to gain a representational study sample for this study. Following this chapter are the results produced from the described methods of analysis, as stated in the previous section.

CHAPTER IV

RESULTS AND DISCUSSION

Demographic Results

One hundred and sixty-four surveys were collected from June through early October, 2013. Through geocoding via ArcMap (ESRI, 2014), eight of the surveys fell outside of the study boundaries and were removed from the dataset. This left one hundred and fifty-six surveys from residents of Hillsdale, Ionia, and Oceana Counties. Fifty-nine surveys were collected from Hillsdale County, forty-eight surveys were collected from Ionia County, and forty-nine surveys were collected from Oceana County (Table 4.1).

Table 4.1 Demographic Results of Surveys

		Total	Hillsdale	Ionia	Oceana
	N =	156	59	48	49
		Percentage Amount			
Gender	Female	51.92	54.24	52.08	48.98
	Male	48.08	45.76	47.92	51.02
Level of Educational Attainment	High School Diploma/GED	17.95	20.34	12.50	20.41
	Associates/Vocational Degree	8.97	10.17	6.25	10.20
	Some College	18.59	13.56	27.08	16.23
	Bachelor's Degree	34.62	30.51	41.67	32.65
	Master's Degree	12.18	15.25	6.25	14.29
	Doctorate Degree	2.56	5.08	0.00	2.04
	Professional Degree	5.13	5.08	6.25	4.08

Near-equal representation between genders was presented in each county dataset (Table 4.1). Demographic results regarding level of educational attainment displayed that all survey participants had at least a high school diploma or a G.E.D. It was also found that the majority of respondents from each dataset and the entire dataset had a Bachelor's degree.

Concerns Pertaining to a Fracking Site

The mean Likert-scale responses for each county are presented in Table 4.2. The respondents of Hillsdale County displayed the lowest mean levels of concern, ranging from slightly not concerned to neutral. Respondents from Ionia and Oceana Counties displayed similar mean levels of concern which ranged from slightly not concerned to slightly concerned.

Table 4.2

Study County Mean Descriptive Statistics of Likert-Scale Questions on Levels of Concern on Common Concerns Pertaining to a Fracking Site on a 5-Point Likert-Scale (1=No Concern through 5=Very Concerned)

	Mean Levels of Concern		
	Hillsdale	**Ionia**	**Oceana**
Question 1: Concern level regarding the presence of a fracking site	2.64	3.25	3.29
Question 3: Concern level of [specified]that may be associated with a fracking site			
3a: Groundwater contamination	3.83	4.13	4.06
3b: Air pollution	2.85	3.10	2.92
3c: Local watershed contamination	3.20	3.31	3.74
3d: Adverse health effects	2.68	3.13	3.14
3e: Decreased property values	2.68	2.85	3.08
3f: Stress on the local groundwater supply	2.95	3.48	3.74
3g: Chemicals used during the fracking process	3.75	4.17	4.14
3h: Post-fracking waste management process	3.56	3.56	3.82

Kruskal-Wallis test on the Likert survey responses by individual study county revealed statistical significance at the established level of 0.05 between participants' responses for Questions 1 and 3f, displaying significance levels of 0.042 and 0.028, respectfully (Table 4.3). A pairwise comparisons post-hoc test (Table 4.4) further revealed that in Question 1, the significance lied between both the Hillsdale and Ionia County datasets (0.039) and the Hillsdale and Oceana County datasets (0.026). This indicates that for Question 1, Hillsdale County respondents not only answered their Liker-scale questions differently, but also had a significantly lower concern regarding a fracking site than the Ionia and Oceana County datasets.

Table 4.3

Kruskal-Wallis Test on Participants' Levels of Concern on Common Concerns Pertaining to a Fracking Site on a 5 Point Likert-Scale of Respondent Ratings by Study County

	Q1: Concern Level	Q3f: Stress on Local Groundwater
Chi-Square	6.341	7.120
Df	2	2
Asymp. Sig.	0.042	0.028

Additionally, the pairwise comparisons post-hoc test revealed that Oceana and Ionia County respondents gave similar concern levels for stress on the local groundwater supply. The statistical differences in how the datasets rated their levels of concern for Questions 1 and 3f could be attributed to the multiple fracking sites found in Hillsdale County compared to the single sites found in both Ionia and Oceana Counties.

Table 4.4

Pairwise Comparisons Post-Hoc Test on Participants' Levels of Concern on Common Concerns Pertaining to a Fracking Site on a 5 Point Likert-Scale of Respondent Ratings by Study County

Dependent Variable	County	County	Sig.
Q1: Concern Level	Hillsdale	Ionia	0.039
		Oceana	0.026
	Ionia	Hillsdale	0.039
		Oceana	0.889
	Oceana	Hillsdale	0.026
		Ionia	0.889
Q3f: Stress on Local Groundwater Supply	Hillsdale	Ionia	0.082
		Oceana	0.010
	Ionia	Hillsdale	0.082
		Oceana	0.423
	Oceana	Hillsdale	0.010
		Ionia	0.423

<u>Analyses of Likert-Scale Responses of Individual County Datasets by Estimated Distance from a Fracking Site</u>

The Likert-scale responses generated from the survey were analyzed by respondents' estimated distance from a fracking site (Question 2 on the survey) through Kruskal-Wallis and Spearman's rho statistical tests on the individual county datasets. The Kruskal-Wallis test on the individual county datasets' Likert-scale responses by respondent's estimated distance from a fracking site resulted in only the Ionia County dataset displaying statistical significance (Table 4.5). Statistical significance in the Ionia County dataset between estimated distance and Likert-scale responses displayed significance on Question 3d, with a significance level of 0.033 (Table 4.5).

Table 4.5

Kruskal-Wallis Test on Ionia County Participants' Levels of Concern on Common Concerns Pertaining to a Fracking Site on a 5 Point Likert-Scale of Respondents' Estimated Distance from a Fracking Site

	Q3d: Adverse Health Effects
Chi-Square	16.774
df	8
Asymp. Sig.	0.033

This indicates a participant's estimated distance from a fracking site influenced their levels of concern regarding potential health effects that could be associated with a fracking site. This could be a result of the proximity that the resident believes they are to a fracking site influencing their levels of concern regarding the fracking site. If a resident believed they were located far away from a fracking site, then they could be inclined to give a lower rating of their levels of concern. This contradicts previous literature discussed on distance and relation to level of perceived risk in Chapter Two.

Spearman's rho Analysis of Likert-Scale Responses of Individual County Datasets by Estimated Distance from a Fracking Site

Following the Kruskal-Wallis analysis of the Likert-scale responses by the individual dataset's estimated distance from a fracking site was a Spearman's rho test on the same variables. Spearman's rho analysis on the Hillsdale and Oceana County datasets presented inconclusive and non-significant results. However, results calculated from the Ionia County dataset presented a mixture of weak and moderate negative correlations along with significant values for Questions 1, 3a, 3c, 3d 3e, 3f, 3g, and 3h (Table 4.6). This suggests that for these specific questions, respondents' estimated distance from a fracking site did impact their Likert scale responses, specifically those who believed they were located farther away from a fracking site than they actually were.

Discussion of Statistical Analyses of Estimated Distance from a Fracking Site and Its Effects on Perception of Risk

Statistical significance between respondents' Likert-scale levels of concern against their estimated distances from a fracking site arose only for the Ionia County respondents. Statistical significance was calculated for the majority of the Likert-scale questions, meaning that for those specific questions, respondents' estimated distance from a fracking site did influence their Likert-scale responses, specifically, those who estimated their distance from a site was farther away than they actually were. Based on the findings expressed above, a respondent's estimated distance from a fracking site will have a greater impact on certain prevalent concerns than others, resulting in differing levels of concern for each individual concern.

Analyses of Likert-Scale Responses of Individual County Datasets by Gender

The mean responses to the Likert-scale questions of the individual study counties by gender are presented in Table 4.7. Analysis of the Likert-type scale mean responses of the separate datasets by gender determined that there were differences in the mean responses between females and males. Mean results of the individual county

Table 4.6

Spearman's rho Correlation Matrix on Ionia Respondents' Levels of Concern on Common Concerns Pertaining to a Fracking Site on a 5 Point Likert-Scale of Estimated Distance from a Fracking Site

			Est Distance	Q1: Concern Lvl	Q3a: Groundwater Contamination	Q3b: Air Pollution	Q3c: Local Watershed Contamination	Q3d: Adverse Health Effects	Q3e: Decreased Property Values	Q3f: Stress on Local Groundwater	Q3g: Chemicals	Q3h: Postfracking Waste Mgmt
Spearman's rho	Est Distance	Correlation Coefficient	1.000	-.421**	-.381**	-.108	-.304*	-.291*	-.396**	-.291*	-.315*	-.328*
		Sig. (2-tailed)	.	.003	.008	.467	.036	.045	.005	.045	.029	.023
		N	48	48	48	48	48	48	48	48	48	48
	Q1: Concern Lvl	Correlation Coefficient	-.421**	1.000	.659**	.420**	.309*	.459**	.463**	.539**	.465**	.473**
		Sig. (2-tailed)	.003	.	.000	.003	.033	.001	.001	.000	.001	.001
		N	48	48	48	48	48	48	48	48	48	48
	Q3a: Groundwater Contamination	Correlation Coefficient	-.381**	.659**	1.000	.631**	.541**	.580**	.440**	.759**	.585**	.558**
		Sig. (2-tailed)	.008	.000	.	.000	.000	.000	.002	.000	.000	.000
		N	48	48	48	48	48	48	48	48	48	48
	Q3b: Air Pollution	Correlation Coefficient	-.108	.420**	.631**	1.000	.599**	.535**	.534**	.535**	.336*	.468**
		Sig. (2-tailed)	.467	.003	.000	.	.000	.000	.000	.000	.020	.001
		N	48	48	48	48	48	48	48	48	48	48
	Q3c: Local Watershed Contamination	Correlation Coefficient	-.304*	.309*	.541**	.599**	1.000	.720**	.231	.658**	.201	.541**
		Sig. (2-tailed)	.036	.033	.000	.000	.	.000	.114	.000	.170	.000
		N	48	48	48	48	48	48	48	48	48	48
	Q3d: Adverse Health Effects	Correlation Coefficient	-.291*	.459**	.580**	.535**	.720**	1.000	.388**	.564**	.316*	.579**
		Sig. (2-tailed)	.045	.001	.000	.000	.000	.	.006	.000	.028	.000
		N	48	48	48	48	48	48	48	48	48	48
	Q3e: Decreased Property Values	Correlation Coefficient	-.396**	.463**	.440**	.534**	.231	.388**	1.000	.386**	.434**	.383**
		Sig. (2-tailed)	.005	.001	.002	.000	.114	.006	.	.007	.002	.007
		N	48	48	48	48	48	48	48	48	48	48
	Q3f: Stress on Local Ground Water	Correlation Coefficient	-.291*	.539**	.759**	.535**	.658**	.564**	.386**	1.000	.387**	.663**
		Sig. (2-tailed)	.045	.000	.000	.000	.000	.000	.007	.	.007	.000
		N	48	48	48	48	48	48	48	48	48	48
	Q3g: Chemicals	Correlation Coefficient	-.315*	.465**	.585**	.336*	.201	.316*	.434**	.387**	1.000	.560**
		Sig. (2-tailed)	.029	.001	.000	.020	.170	.028	.002	.007	.	.000
		N	48	48	48	48	48	48	48	48	48	48
	Q3h: Postfracking Waste Mgmt	Correlation Coefficient	-.328*	.473**	.558**	.468**	.541**	.579**	.383**	.663**	.560**	1.000
		Sig. (2-tailed)	.023	.001	.000	.001	.000	.000	.007	.000	.000	.
		N	48	48	48	48	48	48	48	48	48	48

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.7

Study County Mean Levels of Likert-Scale Questions on Levels of Concern on Common Concerns Pertaining to a Fracking Site a 5 Point Likert-Scale by Gender (1=No Concern through 5=Very Concerned)

Question	**Mean Levels of Concern by Gender**					
	Hillsdale		**Ionia**		**Oceana**	
	F	M	F	M	F	M
Q1	2.59	2.70	3.44	3.04	3.54	3.04
Q3a	4.13	3.48	4.44	3.78	4.13	4.00
Q3b	3.16	2.48	3.56	2.61	3.13	2.72
Q3c	3.38	3.00	3.92	2.65	3.79	3.68
Q3d	2.81	2.52	3.64	2.57	3.38	2.92
Q3e	2.91	2.41	3.20	2.48	3.08	3.08
Q3f	3.22	2.63	3.92	3.00	3.58	3.88
Q3g	4.00	3.44	4.36	3.96	4.17	4.12
Q3h	3.91	3.56	4.08	3.00	3.92	3.72

datasets display that female respondents have a higher level of concern than males the majority of the time. The only exceptions to this were found in Questions 1, 3e, and 3f. In Question 1, male respondents in Hillsdale County had a higher mean response than female respondents. In Question 3e, both female and male respondents in Oceana County had the same mean level of concern. Lastly in Question 3f, male respondents in Oceana County displayed a higher mean level of concern than female respondents.

Kruskal-Wallis analysis of these datasets found that only the Ionia County dataset calculated statistical significance. The Kruskal-Wallis analysis determined that there was statistical significance in the Ionia County dataset with Questions 3b, 3c, 3d, and 3h (Table 4.8). This suggests that a participant's gender did influence how they responded to those specific questions. In each of these situations female respondents exhibited a significantly higher level of concern than male respondents.

Table 4.8

Kruskal-Wallis Test on Ionia County Participant's Levels of Concern on Common Concerns Pertaining to a Fracking Site on a 5 Point Likert-Scale of Respondent Ratings by Gender

	Q3b: Air Pollution	Q3c: Local Watershed Contamination	Q3d: Adverse Health Effects	Q3h: Post-fracking Waste Mgmt
Chi-Square	5.970	6.771	6.402	7.085
df	1	1	1	1
Asymp. Sig.	.015	.009	.011	.008

Chi-Squared Analysis of Likert-Scale Responses of Individual County Datasets by Gender

Chi-squared analysis calculated statistical significance for both the Hillsdale and Ionia County datasets, while no statistical significance was calculated for the Oceana County dataset (Table 4.9). It was found that the Hillsdale County dataset generated statistical significance on Question 3d, displaying a Chi-Squared value of 12.160 and a significance value of 0.011 (Table 4.9). This indicates that for this certain dataset, a participant's gender influences how they rate their level of concern r regarding this specific question. Examination of the calculated crosstabs for Question 3d (Table 4.10) found that more women indicated "not concerned at all" and "very concerned" while more men indicated "slightly not concerned" and "neutral".

Table 4.9

Chi-Squared test of Participant's Levels of Concern on Common Concerns Pertaining to a Fracking Site on a 5 Point Likert-Scale of Respondent Ratings by Gender

Likert Survey Questions	**Dataset**			
	Hillsdale		**Ionia**	
	χ^2 value	**Sig. p≤0.05**	**χ^2 value**	**Sig. p≤0.05**
Q1: Concern level regarding a fracking site	2.155	0.707	4.703	0.319
Q3a: Groundwater contamination	3.158	0.532	6.061	0.195
Q3b: Air pollution	6.750	0.150	10.790	0.029
Q3c: Local watershed contamination	3.910	0.418	11.772	0.022
Q3d: Adverse health effects	11.444	0.022	7.161	0.128
Q3e: Decreased property values	3.274	0.512	6.756	0.149
Q3f: Stress on the local groundwater supply	5.973	2.01	5.433	0.246
Q3g: Chemicals used during the fracking process	3.623	0.459	7.685	0.104
Q3h: Post-fracking waste management process	2.506	0.644	14.850	0.005

Additionally, the Ionia County dataset produced high statistical values for Questions 3b, 3c, and 3h (Table 4.9). This suggests that for this specific dataset, a participant's gender strongly influences how they rated their levels of concern for those particular questions. Examination of the calculated crosstabs (Tables 4.10,4.11) for Question 3b found that more women indicated "neutral" and "very concerned" than men while more men indicated "not concerned at all" than women. Question 3c found that more women designated "slightly concerned" and "very concerned" while more men were "not concerned at all". Lastly, Question 3h found that more women indicated "very concerned" than men while more men specified "not concerned at all" and "neutral" than women.

Table 4.10

Crosstab of Chi-Squared test of Hillsdale County Participant's Levels of Concern on Common concerns Pertaining to a Fracking Site on a 5 Point Likert-Scale of Respondent Ratings by Gender

		Q3d: Adverse Health Effects					Total
		1	2	3	4	5	
Gender	Female	14	2	4	4	9	33
	Male	7	5	10	0	4	26
Total		21	7	14	4	13	59

Table 4.11

Crosstabs of Chi-Squared Test of Ionia County Participant's Levels of Concern on Common Concerns Pertaining to a Fracking Site on a 5 Point Likert-Scale of Respondent Ratings, by Gender

Likert Scale Question			Level of Concern					Total
			1	2	3	4	5	
Q3b: Air Pollution	Gender	Female	0	6	6	6	7	25
		Male	6	7	2	6	2	23
	Total		6	13	8	12	9	48
Q3c: Groundwater Contamination	Gender	Female	2	3	0	10	10	25
		Male	8	5	2	3	5	23
	Total		10	8	2	13	15	48
Q3h: Post-fracking Waste Management	Gender	Female	0	3	5	4	13	25
		Male	6	0	9	4	4	23
	Total		6	3	14	8	17	48

Unlike the Kruskal-Wallis analysis, statistical significance was calculated for both the Hillsdale and Ionia County datasets with Chi-Squared. However, statistical significance was not presented for the same question in each dataset. Regardless, because there was statistical significance calculated in both the Kruskal-Wallis and

Chi-squared analyses between participants' gender and their Likert-scale response indicates that gender does play role in a participants level of concern and their overall perception of risk. The female respondents almost always displayed a higher level of concern, agreeing with previous literature on the connection between perceived risk and gender (Stern et al., 1993, Flynn, Slovic, & Mertz, 1994; Davidson and Freudenburg, 1996; DeChano, 2000; Slimak and Dietz, 2006; Freudenburg and Davidson, 2007).

Analyses of Likert-Scale Responses of Individual County Datasets by Level of Educational Attainment

The mean responses calculated from these same survey questions by level of educational attainment education are presented in Table 4.12. No participants indicated a highest educational attainment of the "Some High School", "Other", and "Prefer Not to Answer", and, as a result, are not included in the mean response categories, as seen in Table 4.12. Analysis of the Likert-scale mean concern levels the individual dataset by level of educational attainment displayed levels of concern ranging from not concerned at all to very concerned regarding a fracking site in the specified study county across all education levels.

Kruskal-Wallis analysis of the Likert-scale responses of the individual county datasets was performed by the participants' indicated levels of educational attainment. Although no statistical significance was calculated for the Hillsdale and Oceana datasets, significance was displayed within the Ionia County dataset. Kruskal-

Table 4.12

Study County Mean Levels of Concern on Common Concerns Pertaining to a Fracking Site on a 5 Point Likert-Scale, by Level of Educational Attainment (1=No Concern through 5=Very Concerned)

Dataset	Education Level	Likert Survey Questions								
		Q1	Q3a	Q3b	Q3c	Q3d	Q3e	Q3f	Q3g	Q3h
Hillsdale	High School Diploma/G.E.D	2.50	4.00	3.33	3.58	2.83	2.58	2.75	3.67	3.83
	Associates/Vocational Degree	3.50	4.50	3.67	3.00	3.50	4.00	3.83	4.67	4.83
	Some College	2.38	3.63	2.63	3.00	2.00	1.63	2.50	3.00	3.38
	Bachelor's Degree	2.89	3.56	2.56	3.50	2.72	2.67	3.11	3.61	3.39
	Master's Degree	2.44	3.67	2.33	3.11	2.56	2.78	2.89	4.00	4.00
	Doctorate Degree	2.00	5.00	3.67	2.33	3.33	3.33	3.33	5.00	4.33
	Professional Degree	2.00	3.33	2.33	2.00	1.67	2.33	2.00	3.00	3.00
Ionia	High School Diploma/G.E.D	3.67	3.67	2.17	2.17	1.50	2.50	3.00	4.00	3.33
	Associates/ Vocational Degree	2.33	3.33	3.33	3.33	3.00	5.00	3.33	4.67	2.67
	Some College	3.23	4.31	3.54	3.62	3.31	2.54	3.77	4.23	3.85
	Bachelor's Degree	3.25	4.20	3.20	3.45	3.60	3.05	3.45	3.95	3.60
	Master's Degree	3.67	5.00	3.00	3.67	3.67	3.00	4.00	4.67	3.00
	Doctorate Degree	*	*	*	*	*	*	*	*	*
	Professional Degree	3.00	3.67	2.33	3.00	2.00	1.33	3.00	4.67	4.00
Oceana	High School Diploma/G.E.D	2.80	4.10	3.30	4.30	3.70	3.60	4.00	4.40	3.80
	Associates/ Vocational Degree	2.00	3.40	1.80	3.00	2.20	2.60	3.00	3.40	3.40
	Some College	3.75	4.38	3.50	4.38	3.63	2.88	3.50	4.13	3.88
	Bachelor's Degree	3.50	4.06	3.13	3.81	3.31	3.25	3.88	4.19	3.94
	Master's Degree	4.00	4.29	2.57	3.14	2.57	2.29	3.86	4.71	4.00
	Doctorate Degree	5.00	5.00	3.00	1.00	4.00	5.00	5.00	2.00	4.00
	Professional Degree	2.00	3.00	1.00	3.00	1.00	3.00	3.00	3.50	3.00

* Indicates no data

Wallis analysis of the Ionia County dataset exhibited significance on Question 3d (0.048; Table 4.13). A Mann-Whitney U post-hoc test (Table 4.14) was performed and displayed the significance was between the categories of "High School Diploma/G.E.D." and "Some College" (0.018); "High School Diploma/G.E.D." and "Bachelor's Degree" (0.006); and between "High School/Diploma/G.E.D." and "Master's Degree" (0.033). In each case, respondents with a high school diploma or G.E.D. exhibited a statistically significantly lower level of concern.

Table 4.13

Kruskal-Wallis Test on Ionia County Participant's Levels of Concern on Common Concerns Pertaining to a Fracking Site on a 5 Point Likert-Scale of Respondent Ratings by Level of Educational Attainment

	Q3d: Adverse Health Effects
Chi-Square	7.914
df	3
Asymp. Sig.	0.048

Table 4.14

Mann-Whitney U Post-Hoc Test on Ionia County Participant's Levels of Concern on Common Concerns Pertaining to a Fracking Site on a 5 Point Likert-Scale of Respondent Ratings by Level of Educational Attainment

Dependent Variable	Education	Education	Mann-Whitney U	Wilcoxon W	Z	Asymp Sig (2-tailed)
Q3d: Adverse Health Effects	High School /GED	Some College	13.000	34.000	-2.359	0.018
		Bachelors	16.500	37.500	-2.733	0.006
		Masters	1.500	22.500	-.2.132	0.033

This lower level of education could hinder respondents' knowledge or research abilities regarding fracking, and a lack in education on the subject could result in a sense of complacency among respondents. This could be the result of higher education's emphasis on research of information, allowing those with higher levels of educational attainment to discover information regarding the fracking process.

GIS Distance Analysis

Basic distance analysis displayed that around 40 percent of the participants for each dataset believed that the nearest fracking site to their residence was greater than ten miles away (Table 4.15), when in actuality, no participant was more than ten miles away from an individual fracking site. It was also found, as seen in Table 4.15, that few participants in each dataset offered estimated distances of under five miles from a fracking site.

Table 4.15

Categorical Composite of Participants' Estimated Distance from a Fracking Site by County

Distance Category	Percentage of Participants Estimation		
	Hillsdale	Ionia	Oceana
Under 1 mile	5.14%	0%	4.08%
2 – 3 miles	3.45%	6.25%	6.12%
4 – 5 miles	8.62%	8.33%	16.33%
6 – 7 miles	3.45%	6.25%	2.04%
8 – 9 miles	1.72%	10.42%	14.29%
10 – 11 miles	10.34%	14.58%	14.29%
12 – 13 miles	6.90%	4.17%	4.08%
14 – 15 miles	6.90%	10.42%	10.20%
16+ miles	29.31%	33.33%	12.24%
Unknown	24.14%	6.25%	16.33%

As seen in Figures 4.1-4.3, the majority of participants in each individual county dataset were found to have overestimated their estimated distance from a fracking site when compared to their actual distance from a fracking site. However, there was no real connection between estimated distances and actual distance from a fracking site. Meaning that many individuals were found to have overestimated their distance from a fracking site regardless of their proximity to a fracking site.

When distance analysis was applied to participants' overall level of concern regarding a fracking site, the results varied (Figures 4.4, 4.5, 4.6; Table 4.16.

Table 4.16

Categorical Composite of Respondents' Overall Levels of Concern Regarding a Fracking Site by County

Level of Concern	Percentage of Participants Overall Levels of Concern		
	Hillsdale	**Ionia**	**Oceana**
Not at all Concerned	35.59%	14.58%	16.33%
Slightly Not Concerned	15.25%	10.42%	10.20%
Neutral	15.25%	27.08%	28.57%
Slightly Concerned	16.95%	31.25%	18.38%
Very Concerned	16.95%	16.67%	26.53%

In the Hillsdale County dataset, the majority of the respondents (50.85%) indicated that they were either "not concerned at all" or "slightly not concerned" referring to their overall level of concern regarding a fracking site in their county while only 33.90 percent of respondents designated that they were either "slightly concerned" or "very concerned" about their overall level of concern regarding a fracking site in their county. It was also found that as distance increased from the fracking sites in

Figure 4.1: Hillsdale County Participants' Estimated Distances from a Fracking Site Compared to Actual Distance (Michigan Department of Environmental Quality Office of Oil, Gas, and Minerals, 2013; Center for Shared Solutions and Technology Partnerships, 2013).

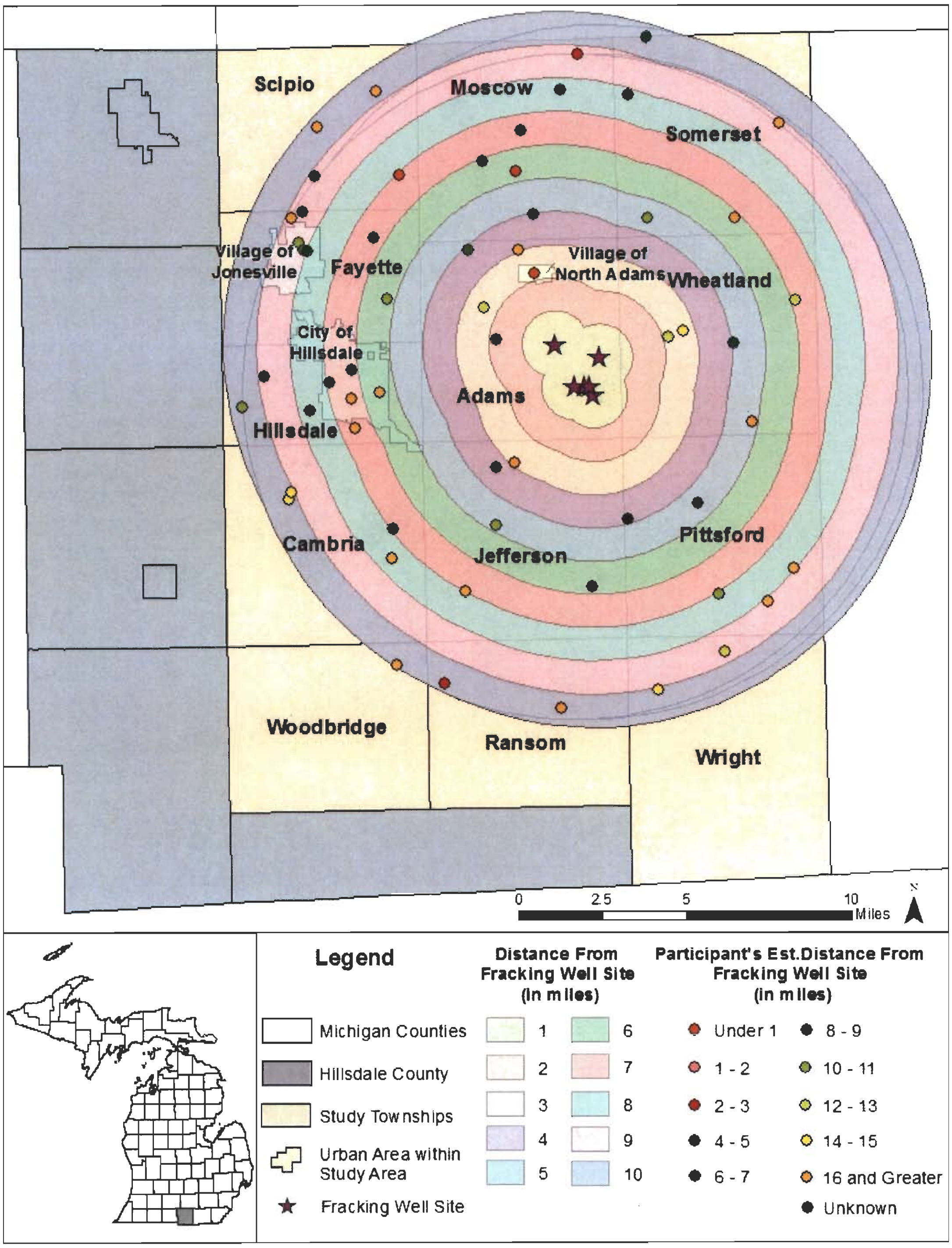


Figure 4.2: Ionia County Participants' Estimated Distances from a Fracking Site Compared to Actual Distance (Michigan Department of Environmental Quality Office of Oil, Gas, and Minerals, 2013; Center for Shared Solutions and Technology Partnerships, 2013).

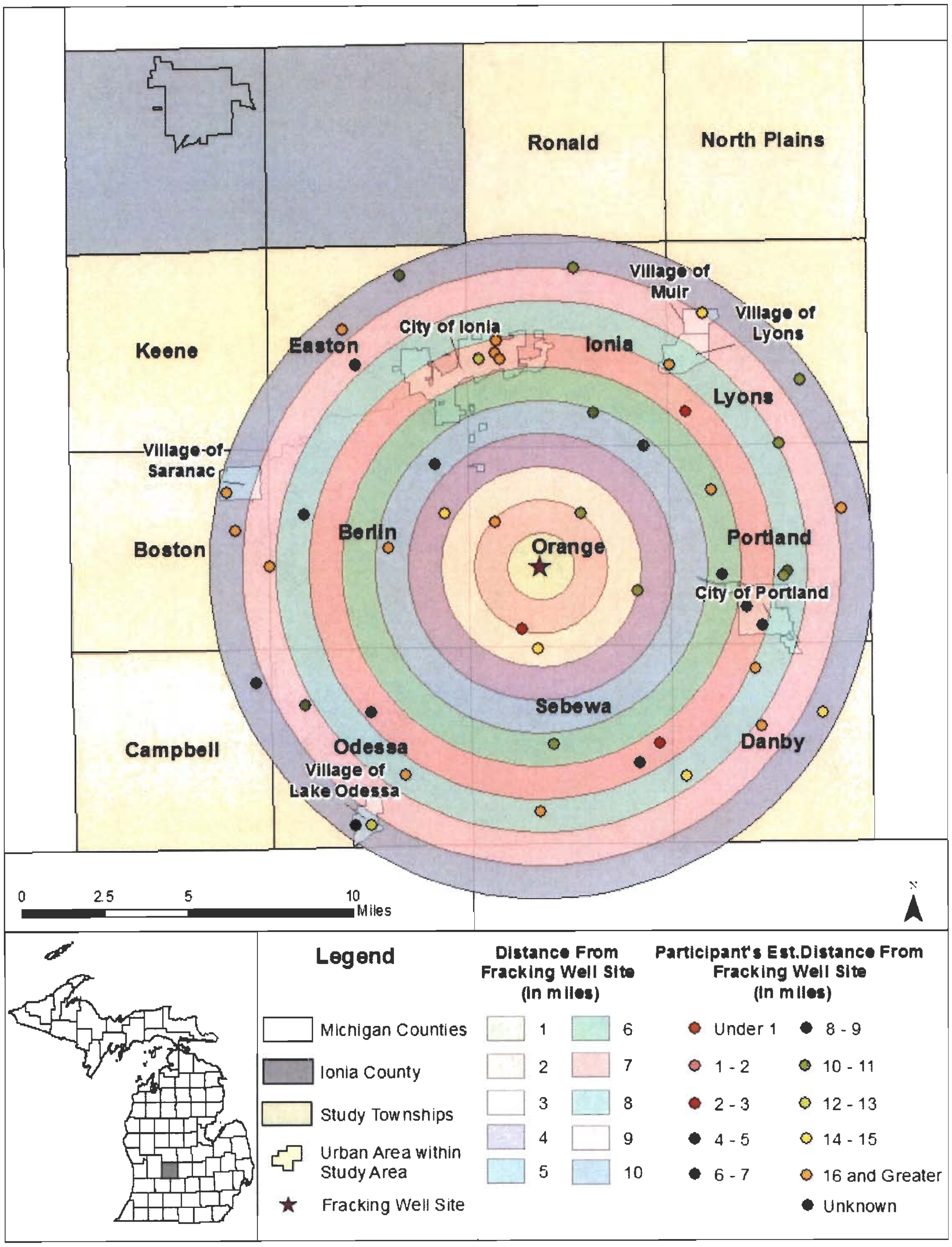


Figure 4.3: Oceana County Participants' Estimated Distances from a Fracking Site Compared to Actual Distance (Michigan Department of Environmental Quality Office of Oil, Gas, and Minerals, 2013; Center for Shared Solutions and Technology Partnerships, 2013).

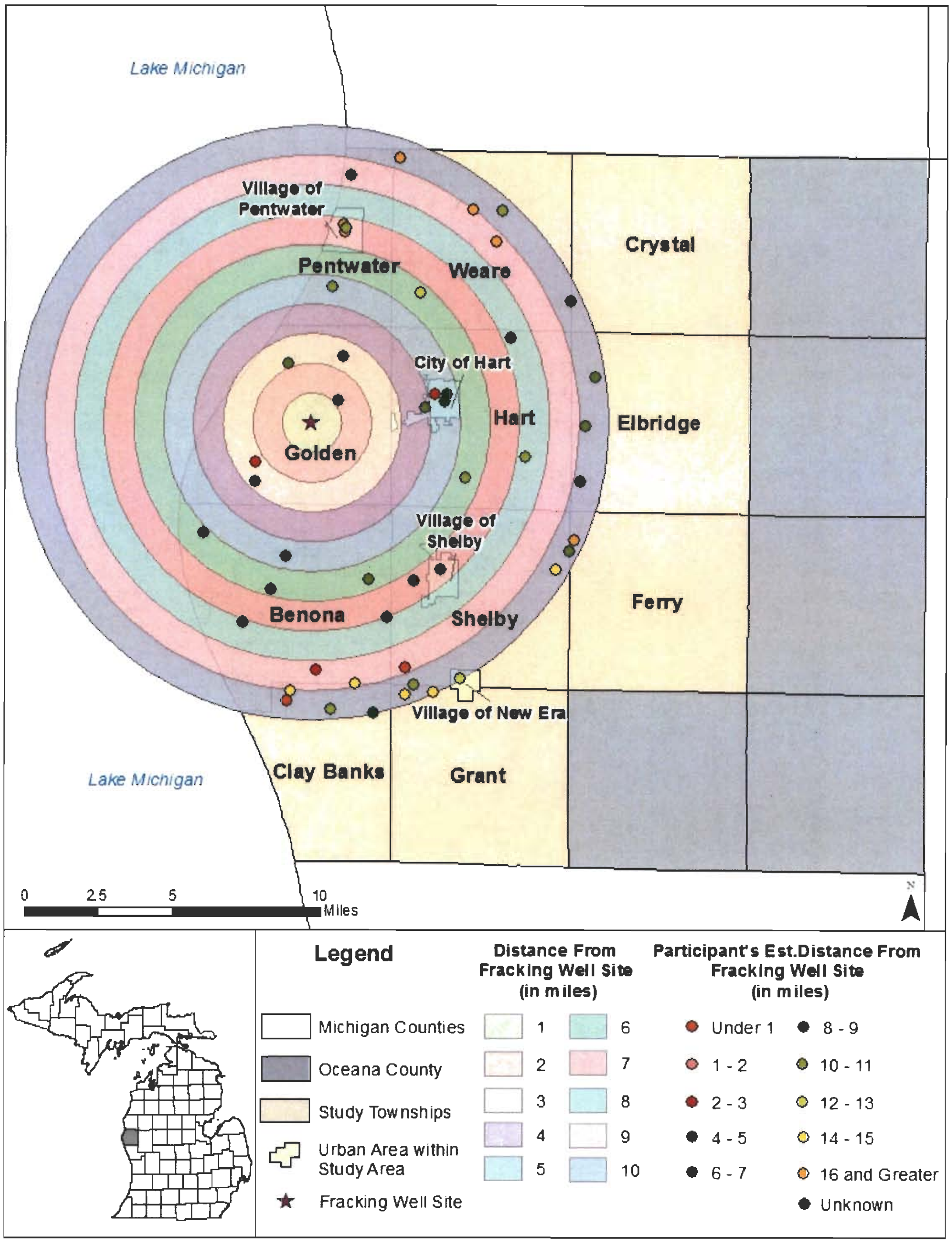


Figure 4.4 Hillsdale County Participants' Overall Level of Concern Regarding a Fracking Site by Distance from a Fracking Site (Michigan Department of Environmental Quality Office of Oil, Gas, and Minerals, 2013; Center for Shared Solutions and Technology Partnerships, 2013).

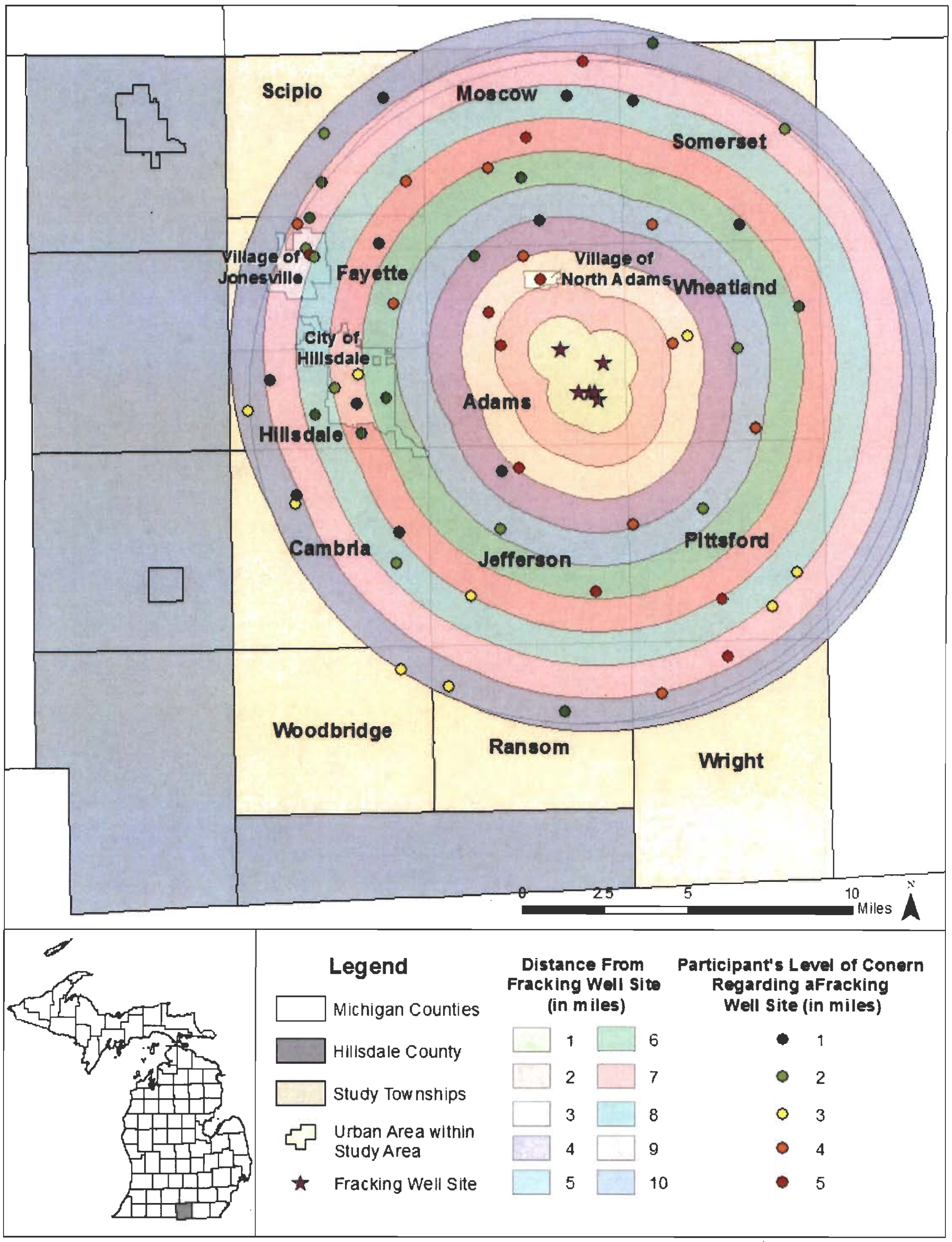


Figure 4.5: Ionia County Participants' Overall Level of Concern Regarding a Fracking Site by Distance from a Fracking Site (Michigan Department of Environmental Quality Office of Oil, Gas, and Minerals, 2013; Center for Shared Solutions and Technology Partnerships, 2013).

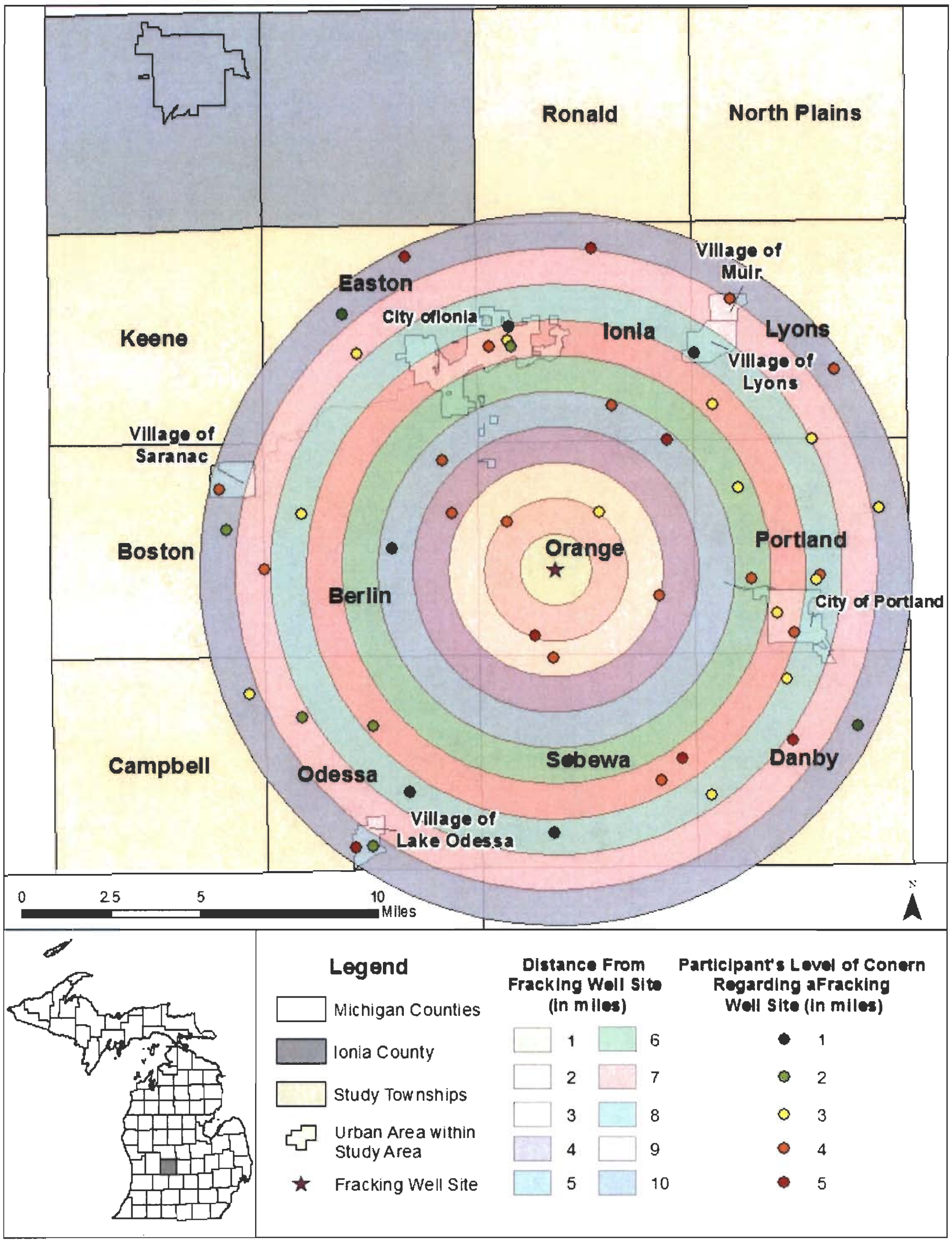
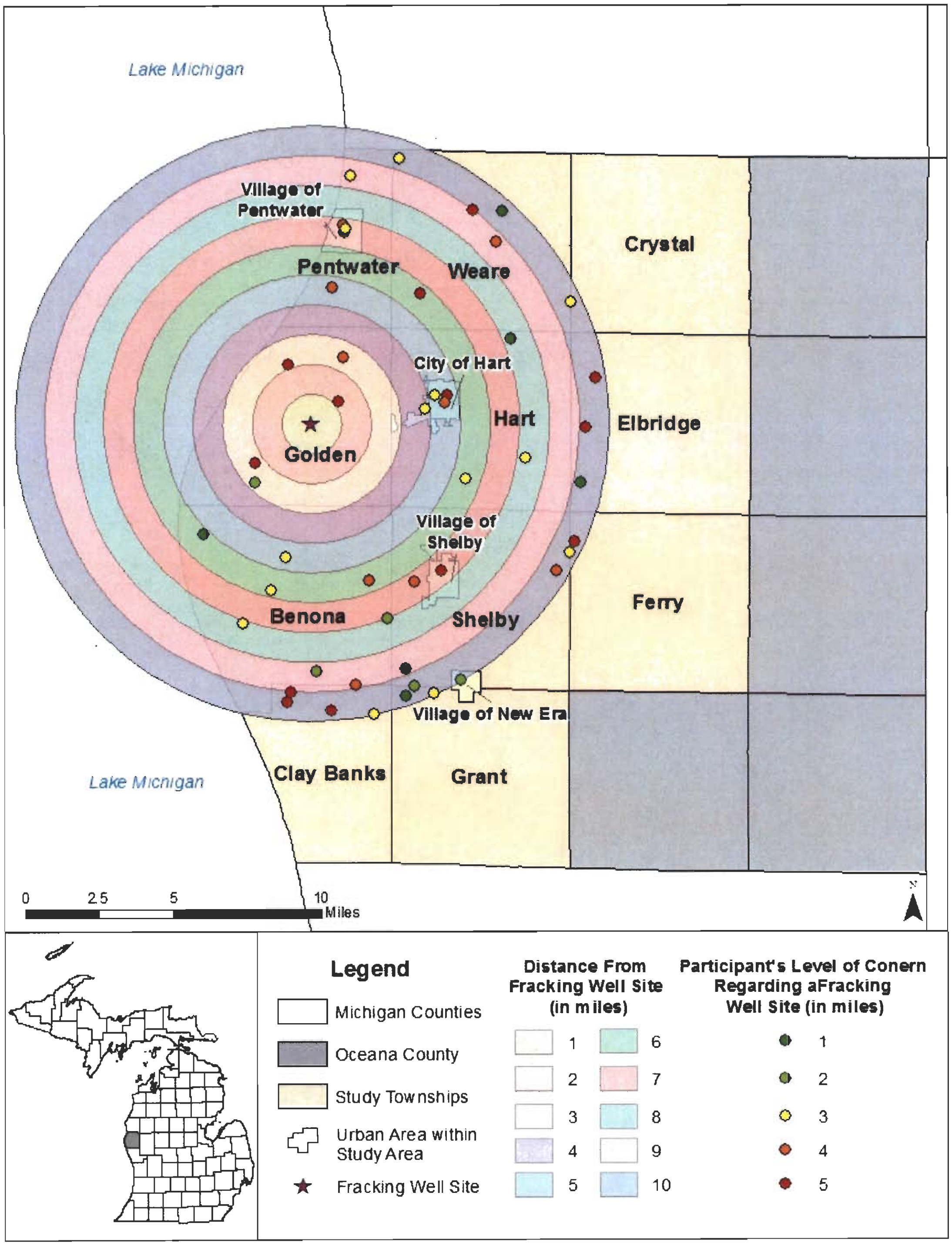


Figure 4.6: Oceana County Participants' Overall Level of Concern Regarding a Fracking Site by Distance from a Fracking Site (Michigan Department of Environmental Quality Office of Oil, Gas, and Minerals, 2013; Center for Shared Solutions and Technology Partnerships, 2013).



Hillsdale County, residents were more inclined to indicate a lower level of overall concern in regards to a fracking site (Figure 4.4).

Unlike the Hillsdale County dataset, the majority of respondents for both the Ionia and Oceana County datasets (47.92% and 44.90%, respectfully) indicated that they were either "slightly concerned" or "very concerned" in respect to their overall level of concern regarding a fracking site in their respective counties while 25.00 percent and 26.53 percent of the respondents specified that they were either "not concerned at all" or "slightly not concerned" referring to their overall level of concern regarding a fracking site in their county. Again, unlike the Hillsdale County dataset, it was found that as distance increased from the fracking sites found in Ionia and Oceana Counties, residents were more inclined to indicate a higher level of overall concern in regards to a fracking site (Figures 4.5 and 4. 6).

Similarly, as seen in Figures 4.4-4.6 participants' overall levels of concern regarding a fracking site varied between datasets. In the Hillsdale County dataset, it found that as distance increased from the fracking sites in Hillsdale County, residents were more inclined to indicate a lower level of overall concern in regards to a fracking site (Figure 4.4). The Ionia and Oceana County datasets, it was found that as distance increased from the fracking sites found in Ionia and Oceana Counties, residents were more inclined to indicate a higher level of overall concern in regards to a fracking site (Figures 4.5 and 4. 6). It should be mentioned that in many cases in each individual dataset, the participants' overall levels of concern regarding a fracking in the specified county did vary in rated levels of concern regardless of the distance from the specific fracking site.

Qualitative Responses

In addition to the distance estimation and Likert-scale questions, participants were also asked if they had any other concerns or comments regarding the fracking process that the survey did not address. Participants were allowed to list as many concerns and comments as they wished. Participant concerns and comments were organized into the following categories: not enough education/information, environmental- and energy-type concerns, comments pertaining to oil and natural gas extraction, fracking well management practices, comments pertaining to agriculture practices, economic impacts of fracking practices, long term impacts, and unaware of fracking in the area (Table 4.17).

Table 4.17

Participant Comments and Concerns regarding the Fracking Process

Concern Category	Count
Not enough education/information	14.10%
Environmental and energy type concerns	5.13%
Comments/Concerns pertaining to oil and natural gas extraction	5.13%
Fracking well management practices	2.56%
Comments pertaining to agriculture practices	2.56%
Economic impacts of fracking practices	1.28%
Unaware of fracking in area	3.21%

The majority of comments and concerns indicated by participants (14.10%) indicated that more information and education on the subject of fracking was needed or should be provided. However, according to Michigan State law companies are not required to provide area residents with advance notice of the construction of a fracking site (McFeeley, 2012). Several participants expressed surprise when informed about this law and felt that individuals had the right to know of area fracking practices. Certain individuals felt that if information would be provided to them, their concerns could be eased.

It should be stated that individuals wishing to procure information on area fracking will experience difficulty in discovering information. Research on newspaper articles regarding fracking in the study counties only resulted in two articles (Harger, 2013; Kloosterman, 2013) about fracking operations occurring in Ionia and Oceana Counties. Instead, individuals must rely on national news stories, movies and documentaries, or anti-fracking groups. There is an obvious lack of thorough information and education available to residents in these areas of Michigan.

Many individuals also shared comments regarding experience with oil and natural gas extraction. In Oceana County, several participants shared stories of improperly capped and managed old ONG wells. Participants stated that because of the poor management of the old ONG wells, groundwater reserves in some areas had become contaminated over the years. While the contamination was eventually contained, one participant also expressed his concern over the possible management of the Oceana County fracking site and hope that a repeat of past management practices would not occur.

Additionally, several participants compared fracking practices to agriculture practices. One individual stated that they were not as concerned with water usage by fracking operations as by agriculture irrigation, a practice that can use millions of gallons of water a day. Another participant mentioned that they were more concerned about the chemical sprays utilized by farmers due to their residence being surrounded by crop fields.

Conclusion

This chapter discussed the statistically significant results generated through statistical analysis of the Hillsdale, Ionia, and Oceana County participants' estimated distance from a fracking site, gender, and level of educational attainment against their Likert-scale responses using tests of Kruskal-Wallis, Spearman's rho, and Chi-Squared. Through the analysis of the data, it was found that the Hillsdale County dataset answered their Likert-scale questions statistically different from the Oceana County dataset. Additionally, it was discovered that the Ionia and Oceana County datasets answered their Likert-scale questions statistically similar. Furthermore, it was found that the Ionia County dataset indicated statistical significance for the testable variables the majority of the time. Lastly, distance analyses indicated that participants were more likely to overestimate their distance from a nearby fracking site, in addition to participants in Ionia and Oceana County displaying increasing levels of concern as distance increased from a fracking site. Following this chapter are the conclusions generated as a result of the earlier discussed analysis.

CHAPTER V

CONCLUSIONS

Conclusions

As previously stated in Chapter One, there were three hypotheses driving the research: 1) residents' levels of concern increase as distance increases away from a fracking site; 2) gender and education levels have an effect on residents' concern levels regarding the nearby fracking site; and 3) there is a difference among the three study counties' (Hillsdale, Ionia and Oceana) concern levels pertaining to a fracking site. With the first hypothesis, it was found statistically that many participants indicated a higher overall level of concern regarding a fracking site as distance increased. However, when GIS distance analysis was performed, it was found that individuals' overall levels of concern varied regardless of actual distance from a fracking site. Therefore, based on the evidence as seen in Chapter Four and due to the inconsistencies between results, the study cannot completely accept the first hypothesis and must reject it.

In regards to the second hypothesis, based on the statistical significance calculated from the statistical and demographic analyses as seen in Chapter Four, it was determined that gender and education levels did have an effect on participants' indicated levels of concerns for certain concerns as listed in the distributed survey. Analyses on the participants' Likert-scale responses by gender determined that women were more likely to indicate higher levels of concern pertaining to a fracking site. Additional analyses on the participants' Likert-scale responses by level of educational attainment found that individuals with higher levels of educational attainment displayed higher levels of concern than those with a high school diploma or G.E.D. Therefore, based on the statistical evidence, the study accepts the second hypothesis.

Lastly, in regards to the third hypothesis, the statistical and demographic analysis in Chapter Four determined that even though the Kruskal-Wallis analysis of the county datasets determined that the Hillsdale County dataset answered the Like survey questions differently from the Ionia and Oceana County datasets, the Hillsdale and Oceana County datasets still failed to produce much, if any, statistical significance in the analysis on the testable variables. The Ionia County dataset was the only dataset to regularly indicate statistical significance in the analysis on the testable variables. Therefore, due to the lack of statistical evidence with the Hillsdale and Oceana County datasets, the study cannot completely accept the third hypothesis, thus rejecting the last hypothesis.

Limitations of Study

Time was a major limitation of this study. Sometimes, a great amount of time was needed to produce only a few completed surveys. In one case, the researcher surveyed for over three hours before a resident agreed to participate in the study. Weather was another limitation of this study. Although the summer months had reasonably good weather, excessive heat, rainy days and severe thunderstorms did impact surveying excursions. However, the two instances where surveying took place at local county fairs resulted in more than thirty surveys collected each occasion. Nonetheless, the researcher concluded that though lengthy, door-to-door surveying was the best decision as it ensures that enough participants were recruited for the study. If a mail survey had been utilized for the study, the researcher strongly believes that very few residents would have filled out and returned the survey.

Other Changes for Future Research

If the research was to be repeated in the future, it would be interesting to explore the changes in results if the study area was to be limited to a five mile radius, or even a two mile radius, surround an individual fracking site. By limiting the research to a five mile radius, researcher could streamline the data collection process to a more manageable size. Alternatively, changes to the distributed survey could be made. Supplementary questions to include could be the specification of the resident's drinking water source (i.e. well water or municipal supplies) along with their personal stance on fracking. Furthermore, after reading several other recent perception studies, it would be beneficial to any future study to incorporate questions concerning residents' level of trust in certain institutions and governing bodies responsible for managing and regulating fracking sites (Barke and Jenkins-Smith, 1993; Slimak and Dietz, 2006; Whitfield et al., 2009; Truelove, 2012; Braiser et al., 2013).

Moreover, if future research were to be performed, it would be recommended to include a control group, a study county that does not have a fracking site, in order to compare levels of concern against counties that do have at least one fracking site. Another change of research could include choosing study areas from the different Michigan regions. Lastly, it was suggested that future research should not be contained to the study county boundaries, and instead, should be confined to the specified study area radius.

Throughout the data collection process, the researcher encountered various individuals with wide-ranging opinions and perceptions pertaining to fracking. The researcher found that some people were strictly anti-fracking while others supported the extraction process and wanted to see more of it done in Michigan. Unofficially, many of the participants had something to say about fracking. However, many individuals had not heard any information regarding fracking other than what the national news had reported. In cases like this, the researcher wished that the survey had been designed differently in order to more accurately capture and record a larger range of perceptions and outside influences resulting in these perceptions. These changes include having questions on whether or not individuals had received information from anti-fracking groups to see if that had any correlation to rated levels of concern; inquiring about participants' levels of trust in the managing entities of the fracking sites; and lastly, inquired about particpants' political affiliations in order to determine if there was any correlation between partisan associations and levels of concern regarding fracking sites.

Appendix A

Survey

WESTERN MICHIGAN UNIVERSITY
H. S. I. R. B.
Approved for use for one year from this date:

MAR 1 - 2013

x Amy Naugle
HSIRB Chair

Western Michigan University
Department of Geography

Principal Investigator: Lisa DeChano-Cook, Ph. D.
Student Investigator: Shannon McEwen
Title of Study: No Fracking Way! A Study on the Spatial Patterns of and Changes in Perception and Distance from a Michigan Horizontal Hydraulic Fracturing Site

You have been invited to participate in a research project titled "*No Fracking Way! A Study on the Spatial Patterns of and Changes in Perception and Distance from a Michigan Horizontal Hydraulic Fracturing Site.*" This project will serve as Ms. Shannon McEwen's thesis for the requirements of the Master's of Arts in Geography. This consent document will explain the purpose of this research project and will go over all of the time commitments, the procedures Please read this consent form carefully and completely and please ask any questions if you need more clarification.

This project will collect basic information on your perceptions regarding a local fracking site. I want to understand how you view this site and your concerns about the site. I am collecting this information independent of any fracking companies to gain people's perception of fracking to help local and state officials make informed decisions regarding fracking in Michigan.

Your responses will be completely anonymous. Please do not put your name or address anywhere on this form. This survey will take less than twenty minutes of your time and will be conducted at your home. Returning the completed survey indicates your consent for the use of the answers you supply. You can choose to stop participating in the study at any time for any reason.

Should you have any questions prior to or during the study, you can contact the primary investigator, **Dr. Lisa DeChano-Cook, at 269-387-3536 or lisa.dechano@wmich.edu**, or the student investigator, **Shannon McEwen, at 810-956-6102 or shannon.k.mcewen@wmich.edu.** You may also contact the Chair, Human Subjects Institutional Review Board at 269-387-8293 or the Vice President for Research at 269-387-8298 if questions arise during the course of the study.

This consent document has been approved for use for one year by the Human Subjects Institutional Review Board (HSIRB) as indicated by the stamped date and signature of the board chair in the upper right corner. Do not participate in this study if the stamped date is older than one year

Survey Code: __________

Resident Perceptions of Fracking Sites

1. On a scale of 1 to 5 with 1 being the least concerning and 5 being the most concerning, how concerned are you regarding a fracking site?

1 2 3 4 5

2. How far would you estimate the closest fracking site is to your home?

____ under 1 mile	___ 6-7 miles	___ 12-13 miles
____ 2-3 miles	___ 8-9 miles	___ 14-15 miles
____ 4-5 miles	___ 10-11 miles	___ 16 miles or more

3. On a scale of 1 to 5 with 1 being the least concerning and 5 being the most concerning, please rate how concerned are you regarding the following.

	1	2	3	4	5
Groundwater contamination					
Air pollution					
Local watershed contamination					
Adverse health effects from the fracking process					
Decreased property values					
Stress on local groundwater supply					
Chemicals used during the fracking process					
Post-fracking waste management process					

4. Do you have any other concerns regarding the fracking process?

____

____

5. Have your mineral rights been sold?

( ) Yes ( ) No ( ) unknown

6. Do you know if the neighboring properties have had their mineral rights sold?

( ) Yes ( ) No ( ) unknown

7. Gender: ( ) Female ( ) Male

8. Number of children under the age of 18 years that live within your household: ____

9. Ages of children under the age of 18 years

( ) 0 – 2 years
( ) 3 – 5 years
( ) 6 – 8 years
( ) 9 – 11 years
( ) 12 – 14 years
( ) 15 – 18 years
( ) prefer not to answer

10. Highest educational attainment:

( ) Some high school
( ) High school diploma/GED
( ) Associates/vocational degree
( ) Some college
( ) Bachelor's degree
( ) Master's degree
( ) Doctorate degree
( ) Professional degree
( ) other _____
( ) prefer not to answer

11. What is your job or occupation?

( ) Education
( ) Professional
( ) General/Technical
( ) Self-employed
( ) Homemaker
( ) Student
( ) Unemployed
( ) Retired
( ) Other _____
( ) Prefer not to answer

Appendix B

HSIRB Approval Letters

WESTERN MICHIGAN UNIVERSITY

Human Subjects Institutional Review Board

Date: March 19, 2013

To: Lisa DeChano-Cook, Principal Investigator
Shannon McEwen, Student Investigator for thesis

From: Amy Naugle, Ph.D., Chair Amy Naug

Re: HSIRB Project Number 13-03-20

This letter will serve as confirmation that your research project titled "No Fracking Way! A Study on the Spatial Patterns of and Changes in Perception and Distance form a Michigan Horizontal Hydraulic Fracturing Site" has been **approved** under the **exempt** category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note: This research may **only** be conducted exactly in the form it was approved. You must seek specific board approval for any changes in this project (e.g., ***you must request a post approval change to enroll subjects beyond the number stated in your application under "Number of subjects you want to complete the study***)." Failure to obtain approval for changes will result in a protocol deviation. In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

Reapproval of the project is required if it extends beyond the termination date stated below.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: March 19, 2014

Walwood Hall, Kalamazoo, MI 49008-5456
PHONE: (269) 387-8293 FAX: (269) 387-8276

WESTERN MICHIGAN UNIVERSITY

Human Subjects Institutional Review Board

Date: October 16, 2013

To: Lisa DeChano-Cook, Principal Investigator
Shannon McEwen, Student Investigator for thesis

From: Amy Naugle, Ph.D., Chair Amy Naugle

Re: HSIRB Project Number 13-03-20

This letter will serve as confirmation that the change to your research project titled "No Fracking Way! A Study on the Spatial Patterns of and Changes in Perception and Distance form a Michigan Horizontal Hydraulic Fracturing Site" requested in your memo received October 15, 2013 (to add collect data at town festivals; to ask participants for the nearest road intersection to use as a geographic location to perform geocoding) has been approved by the Human Subjects Institutional Review Board.

The conditions and the duration of this approval are specified in the Policies of Western Michigan University.

Please note that you may **only** conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: March 19, 2014

251 W. Walwood Hall, Kalamazoo, MI 49008-5456
PHONE: (269) 387-8293 FAX: (269) 387-8276

BIBLIOGRAPHY

Adams, M. B. (2011). Land Application of Hydrofracturing Fluids Damages a Deciduous Forest Stand in West Virginia. *Journal of Environment Quality*, *40*(4), 1340.

Barke, R. P., & Jenkins-Smith, H. C. (1993). Politics and Scientific Expertise: Scientists, Risk Perception, and Nuclear Waste Policy. *Risk Analysis*, *13*(4), 425-439.

Boudet, H., Clarke, C., Bugden, D., Maibach, E., Roser-Renouf, C., & Leiserowitz, A. (2014). "Fracking" Controversy and Communication: Using national Survey Data to Understand Public Perceptions of Hydraulic Fracturing. *Energy Policy*, *65*, 57-67.

Brasier, K. J., Mclaughlin, D. K., Rhubart, D., Stedman, R. C., Filteau, M. R., & Jacquet, J. (2013). Risk Perceptions of Natural Gas Development in the Marcellus Shale. *Environmental Practice*, *15*(02), 108-122.

Burford, E. (2012). The Need for Federal Regulation of Hydraulic Fracturing. *The Urban Lawyer*, *44*(3), 577-588.

Center for Shared Solutions and Technology Partnerships. (2013). "Michigan Geographic Framework: State of Michigan" [shapefile]. Created by Center for Shared Solutions and technology Partnership. Lansing, MI.

Center for Shared Solutions and Technology Partnerships. (2013). "Michigan Geographic Framework: Hillsdale County" [shapefile]. Created by Center for Shared Solutions and technology Partnership. Lansing, MI.

Center for Shared Solutions and Technology Partnerships. (2013). "Michigan Geographic Framework: Ionia County" [shapefile]. Created by Center for Shared Solutions and technology Partnership. Lansing, MI.

Center for Shared Solutions and Technology Partnerships. (2013). "Michigan Geographic Framework: Oceana County" [shapefile]. Created by Center for Shared Solutions and technology Partnership. Lansing, MI.

Clark, C. E., Burnham, A. J., Harto, C. B., & Horner, R. M. (2012). The Technology and Policy of Hydraulic Fracturing and Potential Environmental Impacts of Shale Gas Development. *Environmental Practice*, *14*(04), 249-261.

Davidson, D. J., & Freudenburg, W. R. (1996). Gender and Environmental Risk Concerns: A Review and Analysis of Available Research. *Environment and Behavior*, *28*(3), 302-339.

Davis, C., & Hoffer, K. (2012). Federalizing energy? Agenda Change and the Politics of Fracking. *Policy Sciences*, *45*(3), 221-241.

DeChano, L. M. (2000). *Geohazard Perception in Glacier National Park, Montana, USA* (Doctoral Thesis). San Marcos, TX: Southwest Texas State University.

Dolton, G. L., & Quinn, J. C. (1996). *An Initial Resource Assessment of the Upper Devonian Antrim Shale in the Michigan Basin*. Retrieved from United States Department of the Interior U.S. Geological Survey website: http://www.michigan.gov/documents/deq/GIMDL-USGSOFR9575K_303059_7.pdf

Dorr, J. A., & Eschman, D. F. (1970). *Geology of Michigan*. Ann Arbor: University of Michigan Press.

ESRI (Environmental Systems Resource Institute). 2014. ArcMap 10.2. ESRI, Redlands, California.

Finkel, M., Hays, J., & Law, A. (2013). The Shale Gas Boom and the Need for Rational Policy. *American Journal of Public Health*, *103*(7), 1161-1163.

Finkel, M. L., & Law, A. (2011). The Rush to Drill for Natural Gas: A Public Health Cautionary Tale. *American Journal of Public Health*, *101*(5), 784-785.

Flynn, J., Slovic, P., & Mertz, C. K. (1994). Gender, Race, and Perception of Environmental Health Risks. *Risk Analysis*, *14*(6), 1101-1108.

Freudenburg, W. R., & Davidson, D. J. (2007). Nuclear Families and Nuclear Risks: The Effects of Gender, Geography, and Progeny on Attitudes Toward a Nuclear Waste Facility. *Rural Sociology*, *72*(2), 215-243.

García-Mira, R., Real, J. E., & Romay, J. (2005). Temporal and Spatial Dimensions in the Perception of Environmental Problems: An Investigation of the Concept of Environmental Hyperopia. *International Journal of Psychology*, *40*(1), 5-10.

Glass, D. C., Gray, C. N., Jolley, D. J., Gibbons, C., Sim, M. R., Fritschi, L., et al. (2003). Leukemia Risk Associated With Low-Level Benzene Exposure. *Epidemiology*, *14*(5), 569-577.

Graves, J. (2012). *Fracking: America's alternative energy revolution*. Ventura, CA:

Safe Harbor International Publishing.

Green, J. (2013, March 24). Hydraulic fracturing in Michigan: Waiting for the boom._*Crain's Detroit Business*. Retrieved March 28, 2014, from http://www.crainsdetroit.com/article/20130324/NEWS/303249962/hydraulic-fracturing-in-michigan-waiting-for-the-boom.

Harger, J. (2013, July 18). "Why 'Fracked' Oil Well in Ionia County Was Plugged by Texas Firm." *Mlive* [Grand Rapids, MI] *MLive.com*. Web. 1 Dec. 2013.

Hilyard, J. (2012). *The oil & gas industry: a nontechnical guide*. Tulsa, Okla.: PennWell.

Howarth, R. W., Santoro, R., & Ingraffea, A. (2012). Venting and Leaking of Methane From Shale Gas Development: Response to Cathles et al. *Climatic Change*, *113*(2), 537-549.

Kasperson, R. E. (2012). The Social Amplification of Risk and Low-Level Radiation. *Bulletin of the Atomic Scientists*, *68*(3), 59-66.

Kasperson, R. E., Renn, O., Slovic, P., Brown, H. S., Emel, J., Goble, R., et al. (1988). The Social Amplification of Risk: A Conceptual Framework. *Risk Analysis*, *8*(2), 177-187.

Kloosterman, S. (2013, June 20). "DEQ: 'Nuisance' Sulfer Smell Hit Oceana County Residents as Well Finished Fracking." Mlive [Grand Rapids, MI] MLive.com. Web. 1 Dec. 2013.

Kozera, G. (2012). Afraid of Fracking? Not Fracking is What We Should Fear!.

In *West Virginia Natural Gas Association*. Retrieved from http://www.wvonga.com/EnergyEducation/AfraidofFracking.aspx.

Lima, M. L. (2004). On the Influence of Risk Perception on Mental Health: Living Near an Incinerator. *Journal of Environmental Psychology*, *24*(1), 71-84.

Lima, M. L., & Marques, S. (2005). Towards Successful Social Impact Assessment Follow-up: A Case Study of Psychosocial Monitoring of a Solid Waste Incinerator in the North of Portugal. *Impact Assessment and Project Appraisal*, *23*(3), 227-233.

Maderthaner, R., Guttmann, G., Swaton, E., & Otway, H. J. (1978). Effect of Distance Upon Risk Perception.. *Journal of Applied Psychology*, *63*(3), 380-382.

McAllister, E. & Gebrekidan, S. (2013, September 18). In Flood-Struck Colorado, Concerns About Fracking Spills. Reuters. Retrieved from http://www.reuters.com/article/2013/09/18/us-usa-colorado-flooding-fracking-idUSBRE98H15820130918.

McFeeley, M. (2012). State Hydraulic Fracturing Disclosure Rules and Enforcement: A Comparison. *Natural Resources Defense Council*, *0*, 1-16.

Mckenzie, L. M., Witter, R. Z., Newman, L. S., & Adgate, J. L. (2012). Human Health Risk Assessment of Air Emissions from Development of Unconventional Natural Gas Resources. *Science of The Total Environment*, *424*, 79-87.

Michigan Department of Environmental Quality. (2014). Types of Public Water Supplies. Retrieved from http://www.michigan.gov/deq/0,4561,7-135-3313_3675_3691-9577--,00.html

Michigan Department of Environmental Quality, U.S. Geological Survey, & Michigan State University [cartographer]. (2006). Estimated Depth to Water Table [map]. Retrieved from http://www.egr.msu.edu/igw/GWIM%20Figure%20Webpage/Webpages%20-%20Links/Figure7.html.

Michigan Department of Environmental Quality Geology Survey Division. (1987). "Bedrock Geology." [shapefile]. Created by Michigan Department of Environmental Quality. Lansing, MI.

Michigan Department of Environmental Quality Office of Oil, Gas, and Minerals [cartographer]. (2012, September) Oil and Gas Wells in Michigan [map]. Retrieved from http://www.visitidaho.org/mapsimages/maps.aspx.

Michigan Department of Environmental Quality Office of Oil, Gas, and Minerals. (2013, September 15). "Hydraulic Fracturing in Michigan." *Department of Environmental Quality Office of Oil, Gas, and Minerals*. Retrieved from http://www.michigan.gov/deq/0,4561,7-135-3311_4111_4231-262172--,00.html.

Michigan Department of Environmental Quality Office of Oil, Gas, and Minerals. (2013, April). Hydraulic Fracturing of Oil and Gas Wells in Michigan.

Department of Environmental Quality Office of Oil, Gas, and Minerals. Retrieved from http://www.michigan.gov/documents/deq/Hydraulic_Fracturing_In_Michigan_423431_7.pdf.

Michigan Department of Environmental Quality Office of Oil, Gas, and Mineral [cartographer]. (2013, February). High Volume Hydrological Fracturing Activity [map]. Retrieved from http://www.michigan.gov/documents/deq/High_Volume_Hydraulic_Fracturing_Activity_MAP_423435_7.pdf.

Michigan Department of Environmental Quality, Wyant, D., & Fitch, H. R. (2012). *Michigan's Oil and Gas Regulations*. Lansing, Mich.: Office of Oil, Gas, and Minerals, Michigan Dept. of Environmental Quality.

Michigan Department of Licensing and Regulatory Affairs. (2013). "Michigan Natural Gas Production." Retrieved from http://www.dleg.state.mi.us/mpsc/gas/pesec2.htm.

Montgomery, C. T., & Smith, M. B. (2012). Hydraulic Fracturing: History of an Enduring Technology. *Journal of Petroleum Technology*, *62*(12), 26-32.

Palliser, J. (2012). Fracking Fury. *Science Scope*, *35*(7), 20.

Parkhill, K. A., Pidgeon, N. F., Henwood, K. L., Simmons, P., & Venables, D. (2010). From the Familiar to the Extraordinary: Local Residents' Perceptions of Risk When Living With Nuclear Power in the UK. *Transactions of the*

Institute of British Geographers, *35*(1), 39-58.

Pierce, D. (2011). Developing a Common Law of Hydraulic Fracturing. *University of Pittsburgh Law Review, 72*(4), 685-699.

Renn, O., Burns, W. J., Kasperson, J. X., Kasperson, R. E., & Slovic, P. (1992). The Social Amplification of Risk: Theoretical Foundations and Empirical Applications. *Journal of Social Issues*, *48*(4), 137-160.

Schafft, K. A., Borlu, Y., & Glenna, L. (2013). The Relationship Between Marcellus Shale Gas Development in Pennsylvania and Local Perceptions of Risk and Opportunity. *Rural Sociology*, *78*(2), 143-166.

Schmidt, C. W. (2011). Blind Rush? Shale Gas Boom Proceeds Amid Human Health Questions. *Environmental Health Perspectives*, *119*(8), a348-a353.

Slimak, M. W., & Dietz, T. (2006). Personal Values, Beliefs, and Ecological Risk Perception. *Risk Analysis*, *26*(6), 1689-1705.

Slovic, P. (1987). Perception of Risk. *Science*, *236*, 280-285.

SPSS Inc. (2012). SPSS Base 20.0 for Window's User's Guide. SPSS Inc., Chicago.

Stern, P. C., Dietz, T., & Kalof, L. (1993). Value Orientations, Gender, and Environmental Concern. *Environment and Behavior*, *25*(5), 322-348.

Swartz, T. (2011). Hydraulic Fracturing: Risks and Risk Management. *Natural Resources & Environment*, *26*(2), 30-32.

Truelove, H. B. (2012). Energy Source Perceptions and Policy Support: Image Associations, Emotional, Evaluations, and Cognitive Beliefs. *Energy Policy,* *45*(2012), 478-489.

U. S. Census Bureau. (2010). Hillsdale County, Michigan, DP-1 Profile of General Population and Housing Characteristics: 2010 [Data]. *2010 Demographic Profile Data*. Retrieved from http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml ?pid=DEC_10_DP_DPDP1.

U.S. Census Bureau. (2010-2012). Hillsdale County, Michigan. DP03 Selected Economic Characteristics [Data]. *2010-2012 American Community Survey 3-Year Estimates*. Retrieved from http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml ?pid=ACS_10_3YR_DP03&prodType=table.

U.S. Census Bureau. (2010-2012). Hillsdale County, Michigan, S1501 Educational Attainment [Data]. *2010-2012 American Community Survey 3-Year Estimates*. Retrieved from http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml ?pid=ACS_12_3YR_S1501&prodType=table.

U. S. Census Bureau. (2010). Ionia County, Michigan, DP-1 Profile of General Population and Housing Characteristics: 2010 [Data]. *2010 Demographic Profile Data*. Retrieved from http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml ?pid=DEC_10_DP_DPDP1.

U.S. Census Bureau. (2010-2012). Ionia County, Michigan, DP03 Selected Economic Characteristics [Data]. *2010-2012 American Community Survey 3-Year Estimates*. Retrieved from http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_12_3YR_DP03&prodType=table.

U.S. Census Bureau. (2010-2012). Ionia County, Michigan, S1501 Educational Attainment [Data]. *2010-2012 American Community Survey 3-Year Estimates*. Retrieved from http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_12_3YR_S1501&prodType=table.

U.S. Census Bureau. (2010-2012). Michigan, S1501 Educational Attainment [Data]. *2010-2012 American Community Survey 3-Year Estimates*. Retrieved from http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_12_3YR_S1501&prodType=table.

U.S. Census Bureau. (2010-2012). Michigan, DP03 Selected Economic Characteristics [Data]. *2010-2012 American Community Survey 3-Year Estimates*. Retrieved from http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_12_3YR_DP03&prodType=table.

U. S. Census Bureau. (2010). Oceana County, Michigan, DP-1 Profile of General Population and Housing Characteristics: 2010 [Data]. *2010 Demographic*

Profile Data. Retrieved from http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=DEC_10_DP_DPDP1

U.S. Census Bureau. (2010-2012). Oceana County, Michigan, DP03 Selected Economic Characteristics [Data]. *2010-2012 American Community Survey 3-Year Estimates*. Retrieved from http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_12_3YR_DP03&prodType=table.

U.S. Census Bureau. (2010-2012). United States, DP03 Selected Economic Characteristics. [Data]. *2010-2012 American Community Survey 3-Year Estimates*. Retrieved from http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_12_3YR_DP03&prodType=table.

U.S. Census Bureau. (2010-2012). Oceana County, Michigan, S1501 Educational Attainment [Data]. *2010-2012 American Community Survey 3-Year Estimates*. Retrieved from http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_12_3YR_S1501&prodType=table.

U.S. Census Bureau. (2010-2012). United States, DP03 Selected Economic Characteristics. [Data]. 2010-2012 American Community Survey 3-Year Estimates. Retrieved from http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_12_3YR_S1501&prodType=table.

U.S. Department of Energy (2009). Modern Shale Gas Development in the United States: A Primer. *Office of Fossil Energy and National Energy Technology Laboratory. United States Department of Energy.*

U.S. Department of Energy (2013.). Fossil Energy: A Brief History of Coal Use in the United States. Retrieved from http://www.fossil.energy.gov/education/energylessons/coal/coal_history.html.

U.S. Energy Information Administration (2011, February 11). The Geology of Natural Gas Resources. Retrieved from http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_12_5YR_S1501.

U.S. Energy Information Administration (2013, April 30). "How Much Natural Gas is Consumed (Used) in the U.S.?" Retrieved from http://www.eia.gov/tools/faqs/faq.cfm?id=50&t=8.

USGS. (2013a). "Coldwater Shale." *Mineral Resources On-Line Spatial Data*. U.S. Geological Survey, Web. Retrieved from http://mrdata.usgs.gov/geology/state/sgmc-unit.php?unit=MIMc;0.

USGS. (2013b). "Marshal Sandstone." Mineral Resources On-Line Spatial Data. U.S. Geological Survey, Web. Retrieved from http://mrdata.usgs.gov/geology/state/sgmc-unit.php?unit=MIMm;0http://mrdata.usgs.gov/geology/state/sgmc-unit.php?unit=MIMc;0.

USGS. (2013c). "Saginaw Formation." Mineral Resources On-Line Spatial Data. U.S. Geological Survey, Web. Retrieved from http://mrdata.usgs.gov/geology/state/sgmc-unit.php?unit=MIPAs;0

Uzzell, D. L. (2000). The Psycho-Spatial Dimension of Global Environmental Problems. *Journal of Environmental Psychology*, *20*(4), 307-318.

Venables, D., Pidgeon, N. F., Parkhill, K. A., Henwood, K. L., & Simmons, P. (2012). Living with Nuclear Power: Sense of Place, Proximity, and Risk Perceptions in Local Host Communities. *Journal of Environmental Psychology*, *32*(4), 371-383.

Waldner, C. L. (2008). Western Canada Study of Animal Health Effects Associated With Exposure to Emissions From Oil and Natural Gas Field Facilities. Study Design and Data Collection III. Methods of Assessing Animal Exposure to Contaminants from the Oil And Gas Industry. *Archives of Environmental and Occupational health* , *63*(4), 201-219.

Weinhold, B. (2012). The Future of Fracking: New Rules Target Air Emissions for Cleaner Natural Gas Production. *Environmental Health Perspectives*, *120*(7), a272-a279.

White, N., teWaterNaude, J., der Walt, A. v., Ravenscroft, G., Roberts, W., & Ehrlich, R. (2009). Meteorologically Estimated Exposure but Not Distance

Predicts Asthma Symptoms in Schoolchildren in Environs of a Petrochemical Refinery: A Cross-Sectional Study. *Environmental Health, 8*(45), 1-10.

Whitfield, S. C., Rosa, E. A., Dan, A., & Dietz, T. (2009). The Future of Nuclear Power: Value Orientations and Risk Perception. *Risk Analysis, 29*(3), 425-437.

Wiseman, H. J., & Gradijan, F. (2011). Regulation of Shale Gas Development, Including Hydraulic Fracturing. *University of Tulsa Legal Studies Research, 2011*(11), 1-129.