STAKEHOLDER PREFERENCES AND PREFERENCE MODELING

AGRICULTURAL BMP PREFERENCES IN THE RIVER RAISIN WATERSHED AND HOW THOSE PREFERENCES MAY AFFECT WATER QUALITY

by

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ABSTRACT

The management of water issues at the watershed scale has become common practice among policy makers throughout the world. To help improve both policy and acceptance of policy, the inclusion of stakeholders in policy and decision-making processes has become the modern paradigm of watershed management. A recent addition to this method is the pairing of stakeholder input and computer modeling. At the same time, conflicts between farmers and non-farmers have been increasing at the rural-urban interface, with water-quality concerns as a central issue. This paper utilizes Preference Modeling to compare how stakeholder preferences, with a specific focus on farmers and non-farmers, would impact water quality in a large-scale watershed. Preference Modeling consists of scenarios developed from the preferences of stakeholder groups as determined by survey results. Using two different survey methods, this study sought the preferences of the general public within one watershed in southeast Michigan towards Best Management Practices that reduce agricultural runoff from fields. Survey results were analyzed based on stakeholder type, and preferences were run through the SWAT computer model of watershed hydrogeochemisty to simulate possible outcomes of stakeholder preferences. According to the SWAT model, the most effective stakeholder preference for improving water quality resulted in a 3% reduction in suspended sediments, a 22% reduction in total phosphorus, and a 27% reduction in total nitrogen. This study found that different stakeholder groups often had common ground and that opinions were often similar but the reasons behind those opinions were different. The preference futures demonstrated several paths to a similar result; most of the stakeholder preference futures in this study resulted in improved water quality over status quo.

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INTRODUCTION

Nonpoint Pollution and Watershed Management

Efforts to reduce pollution in surface waters such as streams, rivers, and lakes often focus on point and nonpoint source pollutants. Point source and nonpoint source are two descriptors for how pollutants enter a waterway. Point source pollution describes any pollution release that can be traced to a specific location (Peterson *et al.*, 1998). Examples include outflow from sewage water treatment plants, pipes from industry that drain into the river, and cooling water from power plants. Nonpoint source pollutants cannot be traced to a single location; the pollutant instead enters the waterway across a broad area via surface water runoff, sub-surface flow, or atmospheric deposition. The origin of a nonpoint source pollutant is therefore often more difficult to determine than that of a point source. Common nonpoint source pollutants include lawn-care chemicals, agrochemicals used in agriculture, urban water runoff, and soil erosion.

By definition, nonpoint source pollutants can result from practices that occur anywhere within the watershed. This is part of the reason why states are addressing nonpoint source pollutants through watershed management (Korfmacher, 2001). Indeed, for the purposes of research, planning, and management, it has become increasingly common to divide geographic areas based on watershed boundaries (Erickson, 1995). Watershed management planning is utilized in guidelines for water pollution controls at both the federal and state level (Peterson *et al.*, 1998, EPA, 1999). These same guidelines also call for the inclusion of public opinion in the development of management plans (EPA, 1999, Peterson *et al.*, 1998). Collaborations between public and governmental agencies have increased over the past decade as government agencies have become more willing to have the decision-making occur at the local level (Leach & Pelkey, 2001). According to Margerum (2008), management through collaboration is important for four reasons:

- "First, collaboration involves a wide range of stakeholders representing a cross-section of organizations.
- Second, collaboration engages the participants in an intensive and creative process of consensus building, which leads to more creative solutions and increased likelihood of acceptance.
- Third, it works to achieve consensus on problems, goals, and proposed actions.
- Finally, collaboration requires a sustained commitment to problem solving."

In addition to these four reasons, studies have also shown that people are more resistant to outside ideas if those ideas are forced upon them (Habron, 2004). The inclusion of stakeholders in the process will also help increase the degree to which they are educated on the subject (Bellamy & Johnson, 2000) and allow stakeholders access to information and to people they normally would not have access to, thus leading to more acceptance to change (Habron, 2004). For their part, the public can see the effects of local watershed management decisions on their lives, which makes them more likely to take an interest in the decision-making process (Korfmacher, 2001). This is especially true with management decisions on nonpoint pollutants; a greater percentage of the public are affected by changes in nonpoint source pollution policy as opposed to point source pollution policy (Korfmacher, 2001). However, while all sides often see the benefit of a more open planning and decision-making process, there is no consensus as to the best way to achieve it (Korfmacher, 2001). Methods that have been used include surveying the public and involving the public in the modeling process.

The Use of Models and Surveys

Models have become a core tool for the management of watersheds (Korfmacher, 2001). Computer models can help predict how watersheds are affected by change or how attributes of a watershed can dictate pollution transport, such as nonpoint source pollutant movement through the watershed over time (Korfmacher, 2001). Computer modeling of environmental systems attempts to be an accurate and scientifically pure process, and computer models are often considered a “rational” way to demonstrate possible futures (Korfmacher, 1998). Indeed, a computer model that is viewed as unbiased by all stakeholders can help mediate a negotiation (Ozawa & Susskind, 1985). However, attempting to predict how complex natural systems will act under different conditions requires predictions and estimations and thus the model is open to some degree of value judgment by the developer and operator (Korfmacher, 2001). Because of this, models developed by agencies that are involved in the decision-making process can be perceived by the public as biased and therefore the public may be less likely to accept the model results (Maguire, 2003). Some watershed managers have attempted to address these concerns by including public participation in the computer modeling process. Examples of this include the watersheds for the Neuse and Catawba rivers in North Carolina, the Latrobe River in Australia, the Chesapeake Bay, and the Patuxent River in Maryland.

Public participation in the Neuse River computer model was sought through surveys, meetings, and interviews (Maguire, 2003). The researchers queried the public as to which model output measures were most important to ensure that the model reflected the public's concerns and priorities (Borsuk *et al.*, 2001, Maguire, 2003). Involving the public drew out the model development and testing process, to the extent that it took over three years to complete and, as a result, stakeholder turnover became a concern (Maguire, 2003). Stakeholders who were present at the beginning may not have stayed throughout the three year-long process, potentially taking with them some of the preferences they lobbied for. Stakeholders who became involved late in the process often needed to be brought up to speed on the technical details (Maguire, 2003) and may have come in too late to have their preferences incorporated into the model.

In the Latrobe River watershed in Australia, stakeholders were encouraged to help both identify the information needed for the computer model and develop it (Grayson, 1994). According to the researchers, the goal of direct involvement by the public was to ensure "that the capabilities and limitations of the model are well understood by all" (Grayson, 1994). At the time of publication, the model had not been used to develop policy options, but was viewed as successful by the researchers because the process was educational to the stakeholders and because it helped "compare management options" (Grayson, 1994).

The Chesapeake Bay Community Watershed Model was developed independently from public input, but was available to the public to download and run on personal computers (Korfmacher, 2001). This allowed the public to better understand how the model worked and any shortcomings the model possessed (Korfmacher, 2001). It also provided an opportunity for those with enough understanding of the model to run their own scenarios, the information from which could then be used during public participation events to support or refute the decisions of the Chesapeake Bay Program (Korfmacher, 2001).

In the Patuxent River watershed, stakeholders helped design the basic structure of the model, experts calibrated it, and then stakeholders helped run various model scenarios (Korfmacher, 2001). Stakeholders in the Catawba River model process were not involved in the development of the model itself, but were asked to help develop “scenarios and alternatives” for the model runs (Korfmacher, 2001). In this case, the stakeholders had an opportunity to better understand the decision-making process and what options were possible (Korfmacher, 2001).

As these studies demonstrate, public participation to guide model design has been used effectively to bring more stakeholders into the process and to encourage a collaborative atmosphere. In most cases, this method has proved successful at both educating stakeholders in the multitude of facets of each issue and in exposing decision makers to unique perspectives that ultimately make the resulting policy more sustainable. Drawbacks to this technique have included longer decision making processes, reduced model credibility, and models that are biased towards the preferences of stakeholders who have more time to invest in the process. The concern is that the stakeholders who attend meetings may only represent small segments of the population, giving a potentially skewed glimpse into public preferences (Korfmacher, 2001).

One method that can be used to combat skew is survey sampling. Survey sampling of a population, especially via random sampling techniques, has the advantage of including people who may not be able to attend meetings and may, therefore, more accurately portray the opinions of the population. It can also increase turnout at public events by informing all who receive the mailing that the issue is under consideration. The survey results can also reveal whether or not the concerns of the vocal stakeholders at a meeting reflect or clash with the concerns of those who participated in the survey.

For use in watershed planning, surveys have been distributed via e-mail (McSherry *et al.*, 2006), mail (Lomnicky *et al.*, 2002), and a combination of mail, telephone, and in-person interviews (Borsuk *et al*., 2001). A literature review demonstrates that surveys have commonly been used to obtain the opinions and preferences of farmers (Marshall, 2004, Habron, 2004, Kelsey & Vaserstein, 2000, Sharp & Smith, 2003, Smith *et al.*, 2008). In the state of Michigan, a mail survey was distributed to both farmer and residential stakeholders with regards to management in their local watershed (Kaplowitz & Witter, 2008). The watershed that is the focus of the present research has been surveyed several times in the past, including a mail survey to determine how private owners manage their woodlots (Erickson *et al.*, 2002).

A survey of the general public similar in nature to the present research was undertaken by Hudson *et al* (2005). Focusing on the issue of the hypoxic zone in the Gulf of Mexico, telephone surveys were conducted at a nationwide level to better understand the general public's familiarity with the hypoxic zone and whether the public believes that precision agriculture may help alleviate the problem (Hudson *et al*., 2005). Their results suggested that, on the whole, the public was unaware of the problem of hypoxia and believed that factory waste and sewage constitute greater threats to water quality than runoff from agriculture (Hudson *et al*., 2005). Participants from the Midwest and Southeast perceived runoff from agriculture to be a larger threat to water quality than participants from the rest of the country, although they are not more aware of the problem of hypoxia (Hudson *et al*., 2005). The public, however, supported assisting farmers' efforts to reduce agricultural runoff by encouraging wide-spread use of precision agriculture (Hudson *et al*., 2005).

Farming and Fertilizer Use

The introduction of mechanized farming led to an increase in the practice of large-scale farming. Large-scale farming, in tandem with the creation of artificial fertilizers that could be cheaply produced, led to a management style known as uniform treatment (UT), where an entire field is managed as a single unit. This style of management is most effective on a field that exhibits uniform soil characteristics across its entirety. However, heterogeneity in soil conditions can exist even in heavily managed fields (Lowenberg-Deboer *et al.*, 1994). Because of heterogeneity, UT could result in the over-fertilization of some sections of a field while at the same time under fertilizing other sections of the same field. Whether over or under-fertilized, not applying the correct amount of fertilizer the crops can use may lead to problems. Over-fertilization wastes fertilizer and increases the chance of leaching, and under-fertilization can reduce yield. Because fertilizer has historically been cheap and leaching was not a primary concern, the drawback of reduced yield from under fertilizing has been worse for farmers than the drawbacks from over fertilizing. Farmers, therefore, tended to err on the side of too much fertilizer on the chance that it might be a bumper crop year. However, due to temporal variations, a bumper crop is not realized every year and the excess fertilizer is lost from the system through runoff, groundwater infiltration, or denitrification. It is estimated that in some areas, as little as 20% of the nitrogen that is added to a field in the form of fertilizer is taken up by the plants before the nitrogen leaves the root zone (Dybas, 2005). Once out of the root zone, the fertilizer can become a pollutant of both ground and surface waters.

According to the Environmental Protection Agency's report to Congress, states have identified agricultural activities as the number one source of impairment of rivers and streams (EPA, 2002). In general, nitrogen is the limiting agent for plant growth in marine ecosystems while phosphorus is the limiting agent for aquatic plant growth in freshwater ecosystems (Dressing, 2003). When excess nitrogen and phosphorus accumulate in an aquatic ecosystem, they can spark the rapid growth of aquatic plants, especially algae (Dressing, 2003, Borsuk *et al*., 2001). Excessive aquatic plant growth in the water column, known as eutrophication, can reduce water clarity, release unpleasant odors, and can pose health risks to aquatic animals (Dressing, 2003). If water clarity diminishes too much, it can restrict sunlight penetration enough that aquatic plants on the bottom may not receive enough sunlight to survive, negatively impacting the fish and insects dependent upon their shelter (Dressing, 2003). When the resulting bloom reaches the end of its life cycle, bacteria begin to decompose the organic matter (Borsuk *et al*., 2001). Bacteria require oxygen as part of the decomposition process, which they draw from the water column (Dressing, 2003). Depending on the water conditions and size of the bloom, the decomposition process can lead to a near anaerobic state in the surrounding waters, suffocating aquatic life (Dressing, 2003, Borsuk *et al*., 2001). This is known as a hypoxic zone.

A prime example of this is found in the Gulf of Mexico, a case that demonstrates both the potential reach of agrichemicals and the economic and environmental impact they can have if unmitigated. The fertilizers that farmers in the Midwest apply to their fields have been found to run off into local rivers and eventually reach the Gulf of Mexico (Dybas, 2005, Hudson *et al*., 2005). Once there, the nitrogen and phosphorus from the fertilizer feed algal blooms, the decomposition of which suffocates local sea life, creating a hypoxic zone (Dybas, 2005). While the size of the hypoxic zone fluctuates depending on time of year and currents, recently it has averaged the size of New Jersey (Hudson *et al*., 2005). The hypoxic zone has negatively impacted important local fisheries, including the brown shrimp fishery (Dybas, 2005, Hudson *et al*., 2005).

World-wide, hypoxic zones are a growing problem. A total of 43 coastal hypoxic zones have been documented in the United States and another 146 throughout the world's oceans (Dybas, 2005). Not exclusive to marine systems, dead zones have also been found in freshwater lakes. The hypoxic zone in Lake Erie (Castillo *et al.*, 2000, Dybas, 2005) is one of the reasons behind the present study. The study area for the present research, the River Raisin watershed, drains into Lake Erie and has the highest percentage of land dedicated to agriculture of any watershed in the state of Michigan (Dodge, 1998).

In addition to being an environmental and economic threat, the runoff of agrichemicals is also dangerous to human health. In the 1980's, a study of drinking water wells found detectable levels of 17 pesticides in the wells of 23 states (Logan, 1993). Similarly, the use of nitrogenous fertilizers has led to increased levels of nitrates in the groundwater (Kross *et al.*, 1992). The consumption of water laced with high levels of nitrates can reduce the hemoglobin's ability to carry oxygen in infants, which can lead to lethargy or coma, a medical condition known as methemoglobinemia, or Blue Baby Syndrome (Kross *et al*., 1992). Tests of wells in Iowa between 1988 and 1989 revealed that 18% of the private rural drinking water wells exceeded the health advisory limit for nitrates (Kross *et al.*, 1993). Elevated nitrate levels in drinking water are also suspected of being linked to a number of other illnesses (Ward *et al.*, 2005), including increased thyroid dysfunction in pregnant women (Gatseva & Argirova, 2008) and urothelial cancer (Volkmer *et al.*, 2005).

Because of the health risks, researchers are seeking ways to reduce human consumption of nitrates, including at the source filtration (Matos *et al.*, 2006, McAdam & Judd, 2006) and improving techniques for finding less polluted water sources (Nolan & Hitt, 2006). If successful, these projects have the potential to improve the health of humans who live in areas where farming with nitrogenous fertilizers is prevalent. However, the downstream environmental and economic impacts of the runoff are unmitigated by these measures. In order to achieve this, the agrichemicals applied to the field have to be completely used by the crops, or systems need to be in place to prevent the agrichemicals from running off the field and entering either surface or subsurface waterways. A new strategy that may have the potential to achieve the former is called precision agriculture, while Best Management Practices have been used for years to address the latter. These two approaches were the central topics for both the survey and modeling work for the present research.

Precision Agriculture

Precision agriculture (PA) has been hailed as a promising way to reduce agricultural runoff while at the same time increasing economic returns for the farmer (Wolf & Buttel, 1996). Precision agriculture is defined as “a management strategy that uses information technology to bring data from multiple sources to bear on decisions associated with crop production” (National Research Council, 1997). At its core, PA aspires to deliver the exact amount of agrichemical a particular plant needs at the time it needs it, thereby eliminating any runoff and excess agrichemical costs.

Two primary components of the PA system are GPS and auto-steer capability. To date, these systems have become the most widely adopted PA systems and it is estimated that by themselves these systems can reduce input costs 5-15% from the reduction of over-lapping (Jochinke *et al.*, 2006). Over-lapping occurs when a farmer positions a new row to slightly overlap the adjacent row to ensure no gaps in coverage. The savings come in the form of reduced fuel, pesticide, and fertilizer use (Jochinke *et al*., 2006).

Several other systems used in PA are classified as variable rate technology (VRT). These include sprayers and seeders that utilize a computer that continually adjusts flow rates as the machinery crosses the field in order to perform site-specific crop management. To accomplish this, most VRT systems need GPS to pin-point locations and the use of auto-steer is recommended. These systems rely on information gathered from each individual field (or from multiple locations within one field), the proper interpretation of that data, and the ability to apply it towards the management of the field. The degree of variability in the field, the scale at which the information is gathered, and the sources of information all play important roles in whether or not VRT is successful.

The target fertilizer rate often cited in research on VRT is called EONR, which stands for economically optimal nitrogen (N) fertilizer rate (Scharf *et al.*, 2005). The results of one study revealed that the EONR was vastly different between fields, ranging from 68 to 208 kg N ha $^{-1}$ (Scharf *et al*., 2005). When those values were compared to the traditional N fertilizer rates, the traditional rates would have over-fertilized 75% of five of the experimental plots and under-fertilized others (Scharf *et al*., 2005).

In an attempt to quantify how different strategies might affect leaching, one study looked at differences in post-harvest residual nitrate (RSN) that resulted from a variety of fertilization rates. It used six fields in Missouri over a two year period to compare RSN levels from nitrogen fertilization rates below, at, and above the EONR (Hong *et al.*, 2007). The traditional mean producer rate was 187 +/- 6 kg N ha $^{-1}$ while the EONR ranged from 49 to 228 kg N ha $^{-1}$ with an average of 145 +/- 11 kg N ha $^{-1}$(Hong *et al*., 2007). The results of the study revealed little difference in RSN between the unfertilized control plot and fields fertilized at EONR. Once the EONR was surpassed, however, the researchers discovered that there was a linear relationship between the amount of excess nitrogen added to the field and RSN (Hong *et al*., 2007). At or below the EONR, the RSN average was approximately 21 kg N ha $^{-1}$, but when the fertilization rates exceeded the EONR by up to 50 kg N ha $^{-1}$, the RSN increased to an average 39 kg N ha $^{-1}$(Hong *et al*., 2007). Between 50 and 100 kg N ha $^{-1}$ above EONR, the RSN averaged 49 kg N ha $^{-1}$ and fertilization rates above EONR by over 100 kg N ha $^{-1}$ had an RSN average of 91 kg N ha $^{-1}$(Hong *et al*., 2007). Unfortunately, the EONR is difficult to determine prior to the harvest with current technology. One study tested a number of nitrogen fertilization rates on various parcels of land, and the EONR was "calculated for each 20-m yield response cell from the yield response function for that cell using a corn price of $0.08/kg and a N fertilizer price of $0.55/kg" (Scharf *et al*., 2005). In other words, the EONR was calculated after the harvest by comparing cost of fertilizer to yield. Further advances in soil testing may make it possible to assess the

EONR across a field on the fly. Until then, comparing the EONR to UT allows us a glimpse of what potential, if any, VRT has in maximizing fertilizer use efficiency.

As discussed above, PA has shown positive results in several research trials (Godwin *et al.*, 1999, Hong *et al*., 2007, Rejesus & Hornbaker, 1999, Wang *et al.*, 2003), but that success has largely been in addressing variability at the spatial but not the temporal scale. A field which shows low spatial variance and large temporal variance may be almost entirely influenced by the climate, negating the ability of VRT to have a positive impact on yield (Whelan & McBratney, 2000). Temporal variability refers to yield differences across years due to climatic conditions and is generally considered to be the dominant factor influencing crop yield variability (Whelan & McBratney, 2000, Pan *et al.*, 1997). A 37-year study in Minnesota attributed 67% of the variability in corn yield to temporal variation (Pan *et al*., 1997). Over three seasons, a different study concluded that crop variability due to temporal variability was at least twice that of spatial variability (Whelan & McBratney, 2000). In fact, it would appear that farmers have long recognized temporal variability. As previously mentioned, farmers often apply uniform treatment of fertilizer in large amounts in the hopes that climatic conditions of the new season will be optimal and a bumper crop will be realized. As our ability to predict temporal variations improves and weather forecasting becomes more accurate, PA may eventually be able to accommodate temporal variations into its systems to further reduce runoff. However, until runoff from fields is prevented, the need for systems that prevent that runoff from entering waterways will remain.

BMPs

While PA is a system that is still becoming established within the farming community, a more common strategy to reduce the amount of agrichemicals that enter receiving waters is called Best Management Practices (BMPs). These are the focus of the present study. The United States Environmental Protection Agency (EPA) consider BMPs to be "pollution prevention practices" (EPA, 1993). The EPA's *Guidance Manual for Developing Best Management Practices* says that BMPs have traditionally "focused on good housekeeping measures and good management techniques intending to avoid contact between pollutants and water media as a result of leaks, spills, and improper waste disposal" (1993). Best Management Practices are used in multiple commercial arenas, including petroleum refining, metal finishing, pesticide formulation, and manufacturing processes (EPA, 1993). Within watershed management, the Michigan Department of Environmental Quality (DEQ) defines BMPs as "any structural, vegetative or managerial practice used to treat, prevent or reduce water pollution" (Peterson *et al*., 1998). The sole objective of a BMP, therefore, is to reduce water pollution. Any side-effects it may have on farm productivity or operating costs are secondary. As will be discussed later, some BMPs can positively impact a farmer's business. Other BMPs can necessitate, among others, increased tractor hours, expensive equipment, or reduced crop area. Cooperation between farmers and state / federal governments and other agencies have helped offset some of these side-effects, but assistance is not yet universally available.

Over the past few decades, BMPs have been used by farmers and agencies to reduce leaching from fields with varying degrees of success. Agricultural BMPs often work by one or more of the following mechanisms: reducing the amount of agrichemicals applied to the field, increasing the time the agrichemicals remain within the root zone, decreasing runoff rates, and absorbing agricultural runoff before it reaches waterways (Dressing, 2003). In agricultural systems, two of the most targeted runoff pollutants are nitrogen and phosphorus, although BMPs also target other agricultural pollutants such as sediment, animal wastes, and pesticides (Dressing, 2003). Agricultural BMPs (here after referred to as BMPs) are typically categorized into three different classes: structural, cultural and management (Logan, 1993). Examples of each type of system can be found in Table 2. Farm managers will often use several BMPs on or around a single field, which will be referred to as a BMP system. As discussed earlier, field heterogeneity is common and farming methods can be equally diverse, therefore currently there is no standard as to which BMPs are best for all conditions (Dressing, 2003). For any given situation, the needs of the field, the target pollutant(s) and the needs of the farmer will be weighed before the appropriate BMPs can be decided upon (Dressing, 2003).

The Michigan Department of Agriculture (MDA) does not use the term BMP, instead referring to them as "generally accepted agricultural and managerial practices" (GAAMPs) (MDA, 2008). In *Generally Accepted Agricultural and Managerial Practices for Nutrient Utilization*, the MDA [2008] recommends soil conservation practices to reduce nonpoint source pollution and to protect soil productivity. The GAAMP examples the report names are: conservation tillage, crop rotation, strip cropping, contour planting, cover crops, vegetative filter strips and runoff control structures (MDA, 2008).

Within each class of BMP, oftentimes there are multiple sub-BMPs. For example, no till, ridge till, and mulch till all fall under the purview of conservation tillage (NRCS, 1999).

Topography, weather, crop-type, and other variables can affect the efficiency of the sub-BMPs differently despite the fact that all three are considered conservation tillage.

BMP Descriptions

Conservation tillage was one of the first BMPs used within the United States to mitigate agricultural runoff, dating back to 1978 (Logan, 1993). According to the Natural Resources Conservation Service (NRCS), conservation tillage is characterized by three different tilling methods: no till/strip till, ridge-till, and mulch till (NRCS, 1999). These three tilling methods all increase the deposition of crop residue on the surface of the field after harvest, a system called residue management (NRCS, 1999). Crop residue prevents raindrops from falling on bare soil, thus reducing the energy of the impact, and promotes infiltration of rain water into the soil by forming barriers to surface flow (NRCS, 1999). While the quantity of residue left on the field varies due to crop type and tilling method, a field that has been no-tilled after the reaping of a high residue crop can reduce surface water runoff by 94% over a field with exposed soil (NRCS, 1999). Conservation tillage can also help reduce erosion by wind as the residue prevents the gusts from reaching bare soil (NRCS, 1999). Conservation tillage, specifically no-till, can help increase the quantity of organic matter in the soil, which helps the soil hold more nutrients and increases the soil's ability to retain water (NRCS, 1999). Conservation tillage can be economically beneficial for farmers as it reduces operating time of the farm equipment, therefore saving in fuel and maintenance costs (NRCS, 1999).

A no-till system, however, can have negative environmental consequences as well. If the field is farmed using no-till for an extended period of time and thus the soil is not mixed and broken up, the weight of the farm equipment over time can compact and harden the soil, increasing runoff and reducing infiltration of both water and agrochemicals into the soil (Lerch *et al.*, 2005).

According to the NRCS [1999], "proper nutrient management economizes the natural process of nutrient cycling to optimize crop growth and minimize environmental losses". Soil and water quality testing, irrigation/draining, nutrient budgets, and the proper use of animal manure all constitute elements of nutrient management (NRCS, 1999). On crop lands, nutrient management utilizes a combination of soil testing and realistic crop yields to anticipate the amount of nutrients the plants will need, while proper timing can help ensure that the fertilizer applied to the field is captured by the target plants (Dressing, 2003).

The use of animal manure in the River Raisin watershed is important both environmentally and economically. Within the watershed there are a number of Concentrated Animal Feeding Operations, which produce large quantities of animal manure. Animal manure can provide many of the essential nutrients plants require and can help reduce the use of inorganic fertilizers (NRCS, 1999). However, over-application of animal manure can lead to contamination of the water, soil, and air (NRCS, 1999).

Riparian buffers and grass filter strips are vegetated barriers that are either cultivated or occur naturally in the path of surface and subsurface water flow between the field and waterway (Dressing, 2003, MDA, 2008). The vegetation slows the progress of the water, increases infiltration, captures fertilizer, and allows sediments to settle out (Dressing, 2003, NRCS, 1999). The shade these systems produce can also help reduce the water temperature of the runoff, adding a layer of thermal protection to the system (NRCS, 1999). Especially in the case of riparian buffers, these systems often act as the last line of protection between the field and water body.

The vegetation in a grass filter strip typically consist of grasses planted specifically for the purpose of increasing infiltration and therefore may not contain a diverse mixture of species. Riparian buffers, on the other hand, are primarily comprised of shrubs and trees, often a natural stand of vegetation that grew next to the water body (NRCS, 1999). As such, it can serve also as habitat for both plants and animals (Dressing, 2003). Naturally occurring riparian buffers should not be altered in an attempt to increase their sediment-trapping abilities as this may reduce their ability to perform other ecosystem services (Dressing, 2003). Utilizing a riparian buffer as the only BMP for a field may eventually damage the riparian buffer (NRCS, 1999). To ensure a healthy riparian buffer and to most effectively reduce agricultural runoff, riparian buffers and grass filters should be used in tandem with other BMPs (NRCS, 1999, Dressing, 2003).

Contour cropping helps reduce sediment transport in fields (Dressing, 2003). It is the practice of planting rows of crops following the curve of a slope in a manner similar to a terrace, where an entire row is planted at the same elevation (Dressing, 2003). With crop lines following the contour of the slope, surface water runoff is prevented from running directly down the hill, thus slowing the water’s progress (Dressing, 2003). This promotes infiltration, reducing surface water runoff and the erosive effects it can have (Dressing, 2003). This practice is most effective on fields with moderate to steep slopes.

Cover cropping involves planting a grass, legume, or grain in a field to provide soil cover during periods of cash crop inactivity, such as over winter, between summer crop rotations, or during longer fallow periods (Dressing, 2003). Cover cropping becomes especially important following the harvest of low residue crops (NRCS, 1999). The roots of the cover crop help stabilize the soil while the green vegetative cover absorbs the impact of raindrops and helps protect the soil from wind erosion. Some cover crops, especially legumes such as clover, can add nutrients back into the soil in preparation for the planting of a cash crop (NRCS, 1999).

Crop rotation is considered an integral part of a conservation tillage system (NRCS, 1999). Crop rotation is the act of varying crop type on a field throughout the year, typically with crops of different nutrient needs and structure, such as shallow or deep roots (NRCS, 1999). This most efficiently utilizes nutrients throughout the root zone and, especially when a legume such as soybean is included, can help reduce the amount of fertilizer needed (NRCS, 1999).

Pressures on Farmers

Farmers face mounting pressure on multiple fronts. Farming as an occupation has been on the decline and crop surpluses have driven down prices and forced many farmers to rely on subsidies from the government to survive (Ahnstrom *et al.*, 2009). At the same time, small family farms are being replaced by factory farms. Farmers are also concerned about increasing rules and regulations on how they manage their farms (Ahnstrom *et al*., 2009, Klapproth & Johnson, 2009) and they want the ability to be flexible in their ability to manage their lands (Klapproth & Johnson, 2009).

Added pressure on farmers is coming from an increasing number of non-farmers who are becoming their neighbors (Ribaudo & Johansson, 2007). Urban areas are growing and many people who work in urban areas are looking to rural areas for a quieter place to live (Sharp & Smith, 2003). This has led to an increase in conflicts between farmers and non-farmers over how local farms are run (Sharp & Smith, 2003, Smith *et al*., 2008, Ribaudo & Johansson, 2007, Kelsey & Vaserstein, 2000). Increasing contact and dialogue between these two groups is seen as a potential solution to this growing problem (Kelsey & Vaserstein, 2000, Sharp & Smith, 2003, Ribaudo & Johansson, 2007). If non-farmers better understand how a neighboring farm is being managed and have a friendly enough relationship with the farmer to bring up concerns directly with the farmer, the non-farmers are less likely to contact authorities over complaints (Kelsey & Vaserstein, 2000, Ribaudo & Johansson, 2007, Sharp & Smith, 2003). From their perspective, farmers are more willing to voluntarily install BMPs on their lands if they have more productive contact with their non-farming neighbors (Ribaudo & Johansson, 2007).

SWAT Model

The Soil and Water Assessment Tool (SWAT) is a continuous-time model that provides output measures daily and is used worldwide by governments and research scientists to simulate watershed dynamics (Gassman *et al.*, 2007). Developed as an improvement to previous models in the 1990's by the USDA Agricultural Research Service (Gassman *et a*l., 2007), SWAT has been used "to predict the impact of land-management practices on water, sediment, and agricultural-chemical yields in large, complex watersheds" (Anand *et al.*, 2007). It can track a variety of measures, including nitrogen, phosphorus, sediments, pesticides, and flow-rates (Gassman *et al*., 2007). Hydrology simulations within SWAT include precipitation, snowmelt runoff, infiltration and surface runoff, evapotranspiration, and subsurface flow (Gassman *et al*., 2007). Decades of updates and calibrations to the model from sources worldwide have improved the model's prediction accuracy, and in the last decade many studies have demonstrated its accuracy through comparing predictions to observations in the field (Gassman *et al*., 2007).

Previous application of SWAT in the River Raisin watershed demonstrated that model predictions for suspended sediments and total phosphorus were accurate on a monthly time-scale, while total nitrogen predictions were accurate at an annual time-scale (Bosch, 2008). When comparing SWAT model predictions for pollution reductions from the installation of BMPs and observed data, a study in New York found SWAT to perform well in predicting BMP-influenced changes to sediment and phosphorus loads (Gitau *et al.*, 2008). Weaknesses of this model include a lack of spatial detail and the reduction of complex natural systems into simple systems (Gassman *et al*., 2007). The lack of spatial detail prevents the use of riparian buffers in model simulations and the simple nature of the watershed dynamics compared to the natural systems may leave important interactions out of model scenarios that could influence outputs (Gassman *et al*., 2007).

GOALS AND OBJECTIVES

The goal of this project is two-fold: to understand stakeholder preferences towards BMPs and to determine how those stakeholder preferences, if acted upon, would affect the water quality of a watershed where the dominant land-use is agriculture. For most farmers, the choice of whether or not they install a BMP on their land is a voluntary decision or is driven by enrollment in programs such as the Conservation Reserve Enhancement Program (CREP) and the

Conservation Reserve Program (CRP). The externalities of modern farming, however, often extend well beyond the farmers' lands and may affect the abilities of others to make a living. This, combined with increasing conflicts at the rural-urban border, is creating a push for farmers to make changes to their farming practices that would reduce the impact of farms on the environment.

Despite the mounting tension, laws such as The Right To Farm Act in Michigan and intense pressure from farming lobbies on governments mean that farmers are still in control over what changes, if any, will occur on their lands. Programs such as CREP and CRP have been successful at bringing about more wide-spread use of BMPs across the U.S., but enrollment is still voluntary. Are these programs pushing some farmers away because they proffer BMPs that farmers are unwilling to install? Are members of the non-farming public frustrated because these programs do not push farmers to use BMPs they feel are needed to keep their water clean or because they feel powerless to affect change? This study attempts to provide a voice to all sides of this debate to better understand what the differences, if any, are. To meet these goals I designed a survey that will help discern if stakeholder differences exist, with a specific focus on farmer and non-farmer opinions, and what the reasons are behind those preferences.

The opinions of stakeholders may be influenced by factors beyond water quality concerns, for example some residents may not like the smells associated with some farming practices. Therefore, while understanding the preferences of the stakeholders and acting on that knowledge to bring stakeholder groups together is a very important first step, the most popular BMP is not necessarily the best BMP for water quality improvement goals.

For this study, I collaborated with Nate Bosch, a Research Investigator in the School of Natural Resources and Environment at the University of Michigan, who developed and calibrated a computer model specifically for the River Raisin watershed based on the widely-used SWAT model (Bosch, 2008). SWAT was utilized to test the implementation of BMPs throughout the watershed based on stakeholder preferences. The goal of the modeling was to better understand how each stakeholder group's opinions would impact water quality in the watershed. The results of the model can have important policy implications. If the survey showed that stakeholders hold diverse preferences towards BMPs but the model showed that all of those BMPs were almost equal in their agrichemical buffering capacity, compromise may be easier to find. However, if the model results were to demonstrate clear water quality differences between stakeholder groups' preferences, it could help focus the discussion on the BMPs that perform the best.

METHODS FOR PREFERENCES SURVEY

STUDY AREA

Centered on the city of Adrian, Michigan, the River Raisin watershed covers 2,776 km^2 in southeastern Michigan and northwestern Ohio. The main stem headwaters are located southwest of Manchester, MI, and the river flows east approximately 217 km before emptying into Lake Erie along a course windy enough that it is considered the "world's most crooked river" (USDA, 1994). The River Raisin is host to a variety of recreational activities including canoeing, fishing, and swimming; it also serves as the primary water source for several communities. Land use within the watershed is predominately agricultural (73%), urban (6%), and forest (11%) (Castillo *et al*., 2000).

The watershed is comprised of ten subwatersheds spread across six counties and two states. The ten subwatersheds are: Saline River, Upper River Raisin, Iron Creek, Evans Creek, Goose Creek, South Branch, Black Creek, Macon Creek, Little River Raisin, and Lower River Raisin (Gothie *et al.*, 2007). The watershed falls within Hillsdale, Jackson, Lenawee, Monroe, and Washtenaw counties in Michigan, along with Fulton County in Ohio (Figure 1). Within Michigan, 40 townships are found in the watershed, along with three in Ohio (Figure 2). Urban areas include Adrian, Tecumseh, Milan, Saline, Dundee, Blissfield, Monroe, and Manchester.

Over 50% of the watershed falls within Lenawee County and most of Lenawee County drains into the River Raisin watershed (Figure 1). Census information from Lenawee County provides an indicator for the general demographics of the watershed. In 2006 Lenawee County had a population of 102,191 and in 1999 the per capita income was $20,186 (Gaquin & DeBrandt, 2008). The unemployment rate in 2006 was 7.3% with a labor force of 50,586 (Gaquin & DeBrandt, 2008).

The 2002 census for Lenawee County listed 1,446 farms covering 353,000 acres, with an average size of 244 acres, selling $103,000,000 worth of products, which is the most of any county within the watershed (Gaquin & DeBrandt, 2008). Crops made up 62.2% of all farm products sold, with the remaining 38% coming from livestock (Gaquin & DeBrandt, 2008). Census data for both Washtenaw and Fulton counties reveal similar farm product percentages, but Hillsdale and Jackson counties are closer to 50-50 for livestock and crop production (Gaquin

& DeBrandt, 2008). Monroe County farms almost exclusively sold crop products; only 7% of farm products sold were livestock (Gaquin & DeBrandt, 2008).

Major threats to the water quality of the River Raisin include sewage overflows, PCBs in the sediment, urban pollution, and agricultural pollutants (Dodge, 1998). Urban pollution is a growing problem due to increased urbanization as more people who work in Detroit and Ann Arbor choose the open spaces of the watershed to reside in (Erickson *et al*., 2002). During the last 30 years, point source pollutants have been greatly reduced within the River Raisin Watershed (Dodge, 1998). Sewage overflows during major rain events have historically been a major point source pollutant and municipal treatment plants throughout the watershed have worked to install systems to reduce this pollutant (Dodge, 1998). Point sources are estimated to contribute at most 25% of the total phosphorus (TP) in the river, and only "a fraction" of the total nitrogen (TN) found in the River Raisin (Castillo *et al*., 2000). Nonpoint source pollutants, therefore, are the greatest contributor of water quality degrading contaminants in the river (Allan *et al.*, 1997), with agriculture-related pollutants the most common of these (Castillo *et al*., 2000, Dodge, 1998).

Farming in the headwaters of the watershed accounts for 50 to 85% of total land use, a number that increases to almost 100% near the mouth of the river (Dodge, 1998, Allan *et al*., 1997). Increased sediment loads in the river due to tilling, the channelization of the river in part due to drainage improvements for the fields, and the leaching of fertilizers, herbicides, and pesticides from fields into the river pose significant threats to the health of the native aquatic biota of the River Raisin (Dodge, 1998). Runoff is of greatest concern in the southeastern section of the watershed where clay till soils are common (Dodge, 1998).

Extensive water testing throughout the watershed in 2006 found total nitrogen (TN) concentrations from 0.52 mg/L to 13.04 mg/L, with a median of 3.67 mg/L (Gothie *et al*., 2007). Total phosphorus (TP) concentrations ranged from 21.2 μg/L to 412.9 μg/L with a mean of 98.8 μg/L (Gothie *et al*., 2007). Total suspended matter (TSM) had a low value of 2.3 g/L and a high value of 122 g/L, with a mean of 22.3 g/L (Gothie *et al*., 2007). The results of the testing revealed that four subwatersheds with the highest concentrations of nutrients in the water were those with more land dedicated to agriculture. The four subwatersheds were South Branch, Black Creek, Saline River, and Macon Creek (Gothie *et al*., 2007). Seasonal TN levels peak in the Spring (Castillo *et al*., 2000) while sediment loads are greatest in the Fall and Winter, corresponding to the times of the highest precipitation levels and least amount of vegetative cover on the fields (Allan *et al*., 1997). Along its course, the River Raisin flows through more than 50 dams and impoundments (Allan *et al*., 1997). Recent research into how dams may impact nutrients loads in the River Raisin revealed that the dams and the slack water they create help reduce TP and TN loads by 13% (Bosch, 2008). When the nutrient levels in the River Raisin are compared with nutrient levels in other rivers that feed Lake Erie, the River Raisin watershed is one of the least polluted (Gothie *et al*., 2007). A study of seven watersheds that drain into Lake Erie showed that the River Raisin has lower than expected levels of herbicides in the water per unit area when compared to the other agriculture-dominated watersheds in the study (Richards *et al.*, 1996). The study concluded that the sandier soils of the River Raisin watershed allow more infiltration and therefore more of the herbicides are filtered out prior to reaching the river (Richards *et al*., 1996). "Based upon comparisons with [studies of the Lake

Erie basin] and other collected field data, overall stream health in the River Raisin appears to be moderate to good" (Gothie *et al*., 2007).

Within the River Raisin watershed, BMPs have been utilized for over 15 years. From 1991-1994 the River Raisin Watershed Project set a goal of reducing sediment deposition by 33%, nitrate and phosphorus levels by 12%, and pesticide concentrations by 40% (Dodge, 1998). To achieve these goals the project primarily relied upon field windbreaks and grass filter strips, and to a lesser degree conservation tillage, cover crops, livestock exclusion, nutrient and pest management, and erosion control structures. It also had a public awareness campaign component (Dodge, 1998). While direct measurements of the impact of the project are unavailable, proxy measurements applied to their methods suggest that an estimated 5,745 tons of sediment and 10,590 pounds of phosphorus were kept out of the river because of the project (Dodge, 1998).

The team of researchers that performed water quality tests throughout the River Raisin watershed in 2006 and studied past and current managerial practices recommended the following BMPs for the River Raisin watershed: conservation coverage, conservation tillage, nutrient management, residue management, riparian buffers, rotational grazing, contour cropping, cover cropping, critical area planting, and irrigation management (Gothie *et al*., 2007). The Lenawee County division of the NRCS promotes a BMP system known as the Core4. The Core4 consist of conservation tillage, nutrient management, pest management, and buffers (NRCS, 1999). The Core4 are often a starting point for the management of a new field, especially for farmers enrolled in CREP and CRP. The NRCS also helps farmers implement other BMPS, such as wetlands, conservation set-asides, cover cropping, and irrigation management. The criteria for selecting BMPs for inclusion in the present research were drawn from the recommended BMPs by the NRCS, MDA, and Gothie *et al.*, and based on this research's focus on nitrogen, phosphorus, and sediment reduction.

Survey Design

The survey consisted of thirteen main questions, many of which had several parts (Appendix 1). To answer, participants most often circled a number on a scale of 1 to 5 or checked a box to indicate their answer. Space was often provided for the respondent to write in an answer or to expand upon their answer. The intent of the survey was to not only determine the participants' preferences towards BMP use, but to assess their general knowledge of the subject, the reasoning behind their preferences, and what changes, if any, they believed needed to occur to improve the water quality in the watershed.

A cover letter was included with each survey (Appendix 1). The cover letter explained the purpose of the survey, how the data would be used, and how participants could access the results after the analysis and report were complete. The back of the cover letter contained brief definitions of each BMP included in the survey. To ensure clarity of questions, establish appropriate response options, follow common terminology, and increase ease of use, the survey was vetted by professors at the University of Michigan and local experts who work in the watershed on water and farmer-related issues. The survey was then pre-tested by members of the general public in the watershed utilizing one-on-one pre-test interviews. Pre-testing revealed that several stakeholder groups in the watershed, especially farmers, have received multiple surveys in recent years. It has been shown that individuals who are asked to participate in multiple surveys sometimes experience survey fatigue, a factor that could reduce participation rates (Stephen R. Porter, 2004).

To increase participation rates, the survey was designed to meet the following three goals: to be accessible to adults of all backgrounds, completely anonymous, and quick to complete. Because many local farmers know and work with government officials and local NGOs, by maintaining anonymity the participants may have been more likely to give their true opinions. Aside from their opinions, personal information from participants was limited to their relationship to the watershed, what township they lived, worked, and recreated in, and, for farmers, the size of their farms and what crops they farmed. The survey specifically asked farmers which of the following five commonly farmed goods the farmers grew or raises: wheat, corn, soybeans, vegetables (such as tomatoes and lettuce), and livestock. They were also given space to write in any goods not provided to them.

For the purpose of this research, the responses of each survey were grouped based on the participant's self-declared relationship with the River Raisin watershed. The relationship choices were: Farm Owner, Farm Renter, Government Employee, Non-Governmental Organization Employee, Recreational User of the River, and Local Resident. The primary BMPs listed in the survey were: conservation tillage / residue management (CTR), nutrient management (NM), riparian buffers / grass filters (RBs), contour cropping (CC), cover cropping (CV), and crop rotation (CR) (Table 1). Farmers were also asked to rate their willingness to install wetlands and conservation set-asides on their land. While each BMP covers a variety of systems (i.e. no-till, mulch till, and ridge-till are different types of conservation tillage), the level of public education on BMPs in the River Raisin watershed was unknown and therefore in the interest of making the survey accessible to as wide a cross-section of the public as possible, only general categories were used.

The general nature of the BMP categories might have prevented individuals who are very familiar with BMPs from providing the input that more specific categories would have allowed. Therefore, designing the BMP questions in this fashion may have reduced the survey's ability to accurately portray a well-informed respondent's preferences, but it helped less-informed respondents participate in the discussion. Likewise, a survey that included all possible BMP subcategories would have been longer, which could have driven down response rates.

In addition to BMP preference, the survey covered topics related to BMP knowledge and river water quality. These included self-assessed knowledge of BMPs, where the respondents learned about BMPs, and opinions on both the current pollution level in the River Raisin and what sources contributed to that pollution. The survey included a section with questions specifically for farmers and another section for participants who do not farm.

The section of the survey designed for farmers questioned them on their current farming practices, including the degree to which they incorporated BMPs into their farms. Farmers were asked which BMPs they would be willing to use on their own lands if provided technical support and supplies to set up the BMPs, but with no compensation for future crop loss or any other possible economic losses due to the use of BMPs. The question was designed to analyze the long-term sustainability of the BMPs. All non-farmers were asked to consider which BMP they believe is best under three different conditions: which BMP is best at reducing agricultural runoff from the fields with cost as no object, which is the best at reducing agricultural runoff when cost is a consideration (i.e. installation costs or crop yield reductions), and which provides the best compromise between effectiveness in reducing agricultural runoff and cost. For each of these questions, non-farmers were asked to pick only one BMP from the list of six provided to them.

While non-farmers were asked to select only one BMP for each situation, farmers were given the opportunity to individually rate their opinions of each BMP. This was to better understand if farmers preferred or avoided certain BMPs and to analyze whether or not their responses were correlated to farm type or location within the watershed. Any such correlations would have important implications on future policy decisions.

Survey Dissemination and Statistical Analysis

The research question required the input of all segments of the general public within the watershed, with an emphasis on the farming community. Simple random sampling is considered one of the strongest survey methods for obtaining an accurate representation of the broader general public from a sample population (Fink & Kosecoff, 1998). However, comparing farmer responses to those of non-farmers would require a higher number of farmer responses than would be expected from a random sample of 1000 people, the sample size used for this research. Because approximately 0.7% of the working population in the counties that lie within the watershed are farmers (Riche & Gaquin, 2003), a truly random sample would deliver approximately 7 surveys to farmers per 1000 distributed questionnaires. Given the competing goals of a random survey sample of all stakeholder groups and adequate representation from farmers, two separate distribution techniques were used.

The first distribution method was a simple random sampling via mail. A random sample of 1,000 residential addresses within the watershed was generated with the help of Compact Information System, Inc. in Redmond, WA. Each address received a mailing addressed to the head of household that contained the survey, cover letter, and a pre-addressed and stamped return envelope. Participants were asked to reply within four weeks of receiving the packet. To increase response rates, the packet was mailed using University of Michigan envelopes that were stamped by hand, and each cover letter was individually signed.

The second method used was a Snowball method. While the Snowball method does not provide as accurate a representation of the population as the random method, it can increase the response rates of target groups within the general population (Black, 1999). Under this method, 360 questionnaires were distributed at public gatherings, town hall meetings, in-person, and through local networks. Events and meetings that farmers attend were specifically targeted. To increase response rates, in addition to the steps taken with the random sample, the researcher was available at the events to answer any questions potential participants might have had about the research.

For each research question, statistical analysis was performed individually for each survey method and stakeholder group utilizing the computer program SPSS. Statistical tools used for the analysis of the responses were ANOVA, T-Test, Paired T-Test, Chi-Square, McNemar Test, and Goodness of Fit. Partially filled out questionnaires were included in all statistical analysis where applicable and a non-response was treated as missing. Where the two survey methods or group results were determined to be statistically different, the results are reported individually. For the purpose of this research, the significance level was set at $p = 0.05$. Results that are reported in means ($\bar{x}$) are from questions that were on a scale of one to five, with one equal to "not at all" and five equating to "very" (Appendix 1).

RESULTS OF PREFERENCE SURVEY

For simplicity, stakeholder groups will be referred to by their survey method and primary relationship to the River Raisin watershed. For example, those who participated in the Snowball survey method and listed 'resident' as their relationship to the watershed are referred to as "Snowball residents". Where the two survey methods were not statistically different and the value reported is the combination of the Snowball and Random survey responses, it is referred to as "Combined".

Response Rates

All returned surveys that were at least partially filled out counted towards the overall response rate. Several returned surveys were duplicates, in which case the original was counted and the duplicates were removed from the sample to maintain equal weight for all respondents. The random sample method had 131 of the 1000 distributed surveys returned, a response rate of 13%. Out of the 360 surveys distributed via the Snowball method, 123 were returned, a response rate of 34%.

Participant Demographics

From the 131 respondents of the Random method, the breakdown of relationships to the watershed was as follows: 12 farm owners, 5 farm renters, 2 government employees, 2 non-governmental organization employees, and 23 recreational users of the river. All 131 respondents resided in the watershed. Many of the respondents fit into two or more stakeholder categories (i.e. a resident who was also a farm owner). Therefore, for the purpose of statistical analysis, each respondent who had more than one relationship with the river was categorized based on the relationship most likely to influence their opinions on BMPs. In the case of a respondent who was both a resident and farm owner, that respondent's survey responses were added to the farmer category and not the resident category. This is referred to as the respondent's primary relationship to the watershed. The resulting breakdown of primary relationships to the watershed for the Random method was as follows: 14 farmers (F), 3 government / non-governmental employees (GNGO), 18 recreational users of the river (RUR), and 96 local residents (LR) (Figure 3). Throughout the present study, abbreviations are used for these stakeholder groups (Table 1). The Random survey was represented by participation from 27 townships (Figure 4), the 14 farmers in the Random survey were distributed across 10 townships, and respondents recreated in ten of the townships.

The Snowball method had 123 surveys returned. This survey method targeted farmers and the response rates reflected that approach. The relationships as reported in the responses were: 79 farm owners, 35 farm renters, 14 government employees, 1 non-governmental employee, 18 recreational users of the river, and 111 local residents. When divided into their primary relationship to the river, the result was as follows: 80 farmers, 15 government / non-governmental employees, 9 recreational users of the river, and 19 residents (Figure 5). Participants in the Snowball survey were distributed across 25 of the 44 townships in the River Raisin watershed (Figure 6), the 80 farmers were distributed across 21 townships, and respondents recreated in 7 townships.

Self-reporting of farm area by Random farmers totaled 7,334.5 acres, with an average farm size of 564.2 acres and 46% reported farming less than 100 acres (Figure 7 and Table 3). Sixty-four percent had been farming their land for more than 20 years and fifty-five percent of the farmland reported utilized at least one BMP. Corn (69%) was the most common crop grown, followed by soybean (62%) and vegetables (46%). Wheat and livestock were the least common, at 38% and 8% respectively. Four participants wrote in answers: two wrote in hay, one wrote in trees, and the other oats.

Snowball farmers reported farming a total area of 72,779.5 acres, with an average farm size of 921.3 acres and 8% of farms were less than 100 acres in size (Figure 8 and Table 3). Ninety percent of the farmers reported farming the same land for at least 20 years and eighty-four percent of the land contained at least one BMP. Both corn and soybeans were the most commonly grown items, at 95% each. Wheat followed at 73%, then livestock (29%), and only 4% of the farmers reported growing vegetables. Twelve participants wrote in that they grew grass, alfalfa, or hay (15%), one wrote in trees, and another wrote in dairy. With a total of 80,114 acres of farmland reported between both surveys, the farms included in the survey represented nearly 10% of the total 870,000 acres of land dedicated to agricultural uses in the watershed (Figure 9).

The dichotomy of the participant demographics between the two survey methods was likely due to the distribution methods for the two surveys. If the Random method was truly random, then the 1000 questionnaires would have been distributed to each relationship category in numbers equal to their presence within the watershed. According to a census of the area, approximately 0.7% of the population were farmers (Riche & Gaquin, 2003), and a total of 12 farmers responded, almost twice the expected response of seven. By contrast, the Snowball method questionnaires were distributed at events heavily attended by farmers and the response demographics reflected that fact. Due to the different distribution methods, the farmers disproportionally represented the results of the Snowball method while local residents are heavily represented in the Random method. The fact that the township representation for both survey methods were similar was expected because a random distribution would send more questionnaires to the more heavily populated areas while the Snowball method utilized meetings for distribution, most of which were held in urban areas.

Perceived Pollution Level of the River Raisin

Comparing the two survey methods, Snowball respondents perceived the river as less polluted than Random respondents, but the difference was not statistically significant (Table 4). Within each survey type, comparing stakeholder groups revealed no significant differences in perceived pollution level. With the exception of the highest (Random GNGO; $\bar{x}$ = 4.33) and lowest (Snowball RUR; $\bar{x}$ = 2.89) values, the means for each stakeholder group from both surveys were close to $\bar{x}$ = 3.5, which fell between moderately and heavily polluted on the survey.

Perceived Threats to the Water Quality of the River Raisin

Combining all survey results, urban pollution and industrial runoff were the greatest perceived threats to the water quality of the River Raisin (Table 5). Agricultural or animal waste runoff, failed septic systems, and urban sprawl rounded out the top five perceived threats. The least perceived threats were dams, tourist activities, and golf courses. The Snowball results had the same top five and bottom three answers as the Combined results, but tourist activities were the least perceived threat. For the Random method, the three lowest perceived threats were the same as the combined threat results, but the order of the top responses was different. Industrial runoff and agricultural or animal waste runoff were the top perceived threats among the Random survey respondents.

In the Snowball survey, a significant difference was found between the opinion of farmers and non-farmers for the threats posed by agricultural / animal waste runoff and dams (Figure 10). Within the Snowball results, no other stakeholder group responses were statistically different from each other. In the Random survey groups, a significant difference between farmers and non-farmers was found for the potential threat urban pollution (Figure 11). No other Random survey stakeholder group responses were significantly different for any of the other potential threats. Comparing the two survey methods, significant differences were found in responses for urban pollution, urban landscaping, sedimentation, water demand, and golf courses (Figure 12). In each the five significantly different opinions between the two survey results, as well as for most of the listed threats, Snowball respondents perceived each threat as greater than did Random respondents. Only with agricultural / animal waste runoff, industrial runoff, and tourist activities did Random respondents rank the threat as either equal to or more dangerous than Snowball respondents. However, none of these differences were statistically significant.

Source of Information on BMPs

When combined, the sources of knowledge for BMPs ranked from first to last in the following order: Fellow farmers, community members, formal education, state / federal employees, non-profit organizations, and national / local news. However, comparing Snowball results to Random results for this question revealed two important distinctions between the two survey groups: the difference between ranks of information sources and how much information each survey group received from the information sources (Figure 13 and Table 6).

Overall, the Snowball respondents ranked state / federal employees as their most important source of information, but that same source was the lowest ranked source among Random responses (Table 6). Community members were the most important source of information for Random respondents, but are fourth in the Snowball results. Comparing the amount of information each survey group received from the listed sources, it was clear that the Snowball survey respondents received more information about BMPs than the Random survey group (Figure 13 and Table 6). With the exception of national and local news, Snowball results were significantly higher than the Random results for each information source.

In the Snowball survey sample, local residents overall received less information from all sources than all other stakeholder groups (Figure 14 and Table 7). In contrast, farmers had the highest or second highest mean results for most of the information sources. GNGO received more information from NGO's, formal education, and farmers than all other stakeholder groups. Comparing farmer and non-farmer responses, farmers received significantly more information from both federal and state employees and fellow farmers than non-farmers did. Non-farmers, in contrast, received significantly more information from non-profit organizations than farmers did. Write-in knowledge sources for BMPs were the conservation district office, the respondent's "Dad", their own experience with BMPs, newsletters, universities and agricultural companies.

Similar to the Snowball results, the farmers in the Random method overall received more information on BMPs from all sources than any other group with the exception of the source non-profit organizations, from which farmers received less information than any other group aside from residents (Figure 15 and Table 8). With the exception of the news, residents learned the least from all information sources when compared to the other stakeholder groups. Grouping all non-farmer responses together and comparing them to farmer responses, farmers reported receiving significantly more information from state and federal employees, community members, fellow farmers and formal education. Write-in responses included the respondents' personal experience, independent study, common agricultural sense, and local seed or chemical dealers.

Familiarity with Best Management Practices

Participants in the Snowball survey self-reported familiarity for all six BMPs were significantly greater than the corresponding familiarity reported by the Random survey group (Figure 16). Crop rotation was the most familiar of the BMPs for both survey methods while contour cropping was the least familiar BMP to Snowball participants and nutrient management was least familiar to Random participants.

Broken into stakeholder groups, Snowball farmers are more familiar with all BMPs than Random farmers with the exception of contour cropping (Figure 17 and Table 9). The differences in familiarity between farmers of each method were significant with regard to contour cropping, conservation tillage/residue management, and nutrient management. The two lowest values for farmers were Snowball farmers for CC (2.37) and Random farmers for CTR (2.86); all other means were above 3.00. With only three government / NGO respondents in the

Random method, no significant difference was found between the two survey methods for this stakeholder group. Likewise, no statistical differences were found between the two survey methods for the recreational users of the river. Snowball residents had more familiarity with each BMP than their Random method counterparts (Table 9). However, in no case was the difference statistically significant. Looking at the residents' results for both survey methods, in stark contrast to the farmers, only the three highest means were above 2.00. These were familiarity with crop rotation for Snowball residents (2.74) and Random residents (2.52), and also Snowball residents' familiarity with riparian buffers or grass filters (2.11). Otherwise, all mean familiarity responses of non-farmer residents were less than 2.00, which was defined as "Unfamiliar" in the survey.

Familiarity with CTR was highest among Snowball farmers (3.75) (Table 9). Random farmers had a mean of 2.86 and all non-farmers had a mean of 1.87. The familiarity means for all three groups were significantly different from each other. Snowball farmers (3.49), Random farmers (3.00), and non-farmers (1.84) were significantly different in their knowledge of nutrient management. Familiarity with riparian buffers / grass filters was found to be significantly different between Snowball non-farmers (2.53) and Random non-farmers (1.97), while Combined farmers (3.62) were significantly more familiar with RBs than all non-farmers. For CC, non-farmers (1.90) were significantly different from farmers and Snowball government / NGO employees (2.67). Farmers were significantly more familiar with both cover cropping and crop rotation than non-farmers.

BMP PREFERENCES: FARMERS

In the Snowball results, no statistical differences in BMP preferences were found between farmers who rent and those that farm their own land; their responses were subsequently grouped. Two individuals who farmed rented land participated in the Random survey, however only one provided answers to the BMP preference questions, so no statistical analysis was possible between renters and owners and their responses were combined for all statistical analysis. Within each survey group, no statistical difference in BMP preference was found between farmers with large farms and those with small farms. The division between the large and small farms was tested at 500 acres, 1000 acres, and 2000 acres.

In the Snowball survey group, the highest reported currently "in use" BMPs were CTR, NM, RB, and CR, at between 31% and 35% (Figures 18 & 19 and Table 10). Additionally, between 63% and 68% of all Snowball farmers said they would be willing to either partially or fully install these BMPs on their lands, the highest willingness to install values for this survey. Cover cropping "in use" and willingness to fully or partially install percentages were lower, at 27% and 57% respectively. Contour Cropping had the lowest "in use" and willingness to install percentages, at 12% and 28%, respectively. Snowball farmers' current use and future willingness to use CC was significantly different from all other BMPs. Because CTR was significantly the same as NM, RB, and CR, for simplicity CTR represents the other four BMPs in Figure 19 in order to compare the differences between those four BMPs, CC, and CV.

When Random farmer responses were analyzed, with the exception of CC compared with CR, no differences were statistically significant (Table 10). However, trends in the Random responses were similar to those of the Snowball method (Figures 18 & 19). Contour cropping had the lowest “in use” (9%) and willingness to use (27%) values. Willingness to install for CTR, NM, and CR were the highest values, all at 58%. However, the “in use” responses were 17%, 17%, 25% respectively, which were lower than the corresponding Snowball percentages. On the other hand, RBs were in use by 42% of farmers surveyed, the highest reported BMP in use during this study.

Snowball farmers answered differently than Random farmers for CTR, NM, RBs and CR. Random farmers reported higher current use of RB and equal current use of CV to Snowball responses, but all other “in use” Random percentages were lower than their respective Snowball values. Similarly, willingness to use percentages for the Random method were all lower than the Snowball method with the exception of CC (27%), which was almost equal to the Snowball responses (28%).

BMP Preferences: Non-farmers

For each survey method, no statistical distinction was found between the answers of the non-farmers. Therefore, for the statistical analysis of BMP preferences, all non-farmer stakeholder groups in each survey method were condensed into one group under their respective survey method. For each of the three BMP preference questions posed to the non-farmers, both survey methods returned significant results. While response rates for “not sure” are discussed here for each question and are shown on the corresponding figures, when determining which BMPs were preferred by non-farmers, only responses that selected a BMP were compared.

These are referred to as "sure" responses, and because these values were recalculated without the "not sure" responses, these values differ from those shown in the figures.

Best BMP for reducing agricultural runoff

Twice as many Random respondents (41%) were not sure which BMP is the best at reducing agricultural runoff as Snowball respondents (21%) (Figure 20). For both survey methods, sure respondents overwhelmingly chose Riparian Buffers/ Grass Filters. The results of a Goodness of Fit test revealed that for both survey methods RBs was the only BMP with a positive residual, which indicates that it was the only BMP to be selected more often than statistically expected. Of the sure responses, RBs were selected by 54% of Random respondents and 58% of Snowball respondents (Data not shown). Contour Cropping and CR were the least selected BMPs for this question by Random non-farmers (6%) while both of those BMPs tied with NM (3%) for the lowest in the Snowball method.

Best BMP based on cost considerations

Half of all Random non-farmers were unsure which BMP is best based on cost considerations while 33% of Snowball non-farmers were also unsure (Figure 21). The Goodness of Fit test for sure Random non-farmers revealed positive residuals for RBs, CTR, and CR, the largest of which was for RBs (31%) (Data not shown). Both CTR (44%) and RBs (38%) had positive residuals for sure Snowball non-farmers. Only 4% of Random non-farmers chose either NM or CV, and no Snowball non-farmers chose CV.

Best BMP overall

More respondents were unsure on which BMP is best overall than for any other question, with 39% of Snowball respondents and 56% of Random respondents selecting the "not sure" option (Figure 22). However, 49% of the sure Random respondents and 57% of the sure Snowball respondents chose RBs (Data not shown). For each survey method, no BMP besides RBs had a positive residual. CV was only supported by 2% of Random non-farmers as the best overall BMP while Snowball non-farmers chose CR, CV, and CC equally at 3% each.

Wetlands and Conservation Set-asides

Farmers that participated in this survey were split between unwilling and unsure as to whether or not they would be willing to install wetlands, conservation set-asides, or both on their lands (Figures 23 & 24). Of the 79 Snowball farmer respondents, only 17% stated that they would be willing to install wetlands on their land while 18% would install conservation set-asides. Thirty-eight percent of snowball farmers were unwilling to install wetlands and another 30% are unsure. The remaining 16% of farmers preferred conservation set-asides to wetlands. Thirty-two percent of Snowball farmers did not want conservation set-asides on their land and 46% were unsure if they did or not. Only three farmers were willing to install both wetlands and conservation set-asides on their land.

Similarly, 25% of Random farmers would install wetlands and 33% conservation set-asides. Fifty percent of Random farmers were unsure if they would install conservation set-asides on their land and 17% said they would not. Wetland results for Random farmers were almost the reverse of the conservation set-asides, with 42% refusing to install them and 25%

unsure. Two Random farmers stated that they would be willing to have both wetlands and conservation set-asides installed on their lands.

Use of GPS and Auto-guide Systems on Farming Equipment

Most farmers surveyed for this research either used GPS or Auto-guide systems on their machinery or did not envision using them within three years (Figure 25). Both survey methods returned similar results; approximately 34% of farmers used some form of these systems in their farming practices and 39% did not. Within the next three years, 16% of the farmers planned on adding one or both of these systems to their farm machinery and 11% were unsure.

Participation with Local Soil and Water Conservation Districts or NRCS

For both survey types, the majority of farmers participated to some degree with one or both of these organizations. Ninety percent of Snowball farmers reported that they participated compared with a reported 50% of Random farmers who participated.

SWAT MODEL METHODS, SCENARIOS, AND RESULTS

For the present study, a previously applied River Raisin watershed SWAT model was used for developing the preference futures (Bosch, 2008). It was parameterized and calibrated based on available local data. The scenarios for model runs conducted for the present study were based on public opinion drawn from survey results reported above.

Questionnaire Inputs to Model

Responses to the survey were received from approximately half of townships that make up the watershed; results were extrapolated across the watershed into model scenarios that represented watershed-wide averages. However, the 2000 census revealed that the counties that comprise the watershed differed in the proportions of their lands that were dedicated to crops and to livestock (Gaquin & DeBrandt, 2008). These difference could be due to of a number of factors that are influenced by geographic location, including soil type, slope, rainfall, elevation, proximity to supplies, and zoning. In order to take into account any farmer preferences or local environmental conditions that were due to geographic location, farmer responses were separated based on the township they farmed in to spatially weight preferences. Some townships were more heavily represented than others in the survey results and therefore each township's BMP preference results were averaged in order to obtain a single value between 0 and 100 percent. Farmers who responded that they currently use a specific BMP were not included in the farmer model scenarios for that BMP because the future scenarios focus on how the status quo would change based on farmer willingness to increase the use of these BMPs. The farmers who chose any option other than "currently in use" were divided up based on the township where they farmed. For each survey method, farmers who selected "fully" added 100% to the township they farmed in for that BMP, those who selected "partially" added 50%, and farmers who were not sure or were unwilling added 0% to the township. The totals for each township were then divided by the number of farmers in that township who answered "fully", "partially", or "unwilling" to arrive at a value between 0 and 100% (Table 11).

Keeping each survey method separate, the percentages for all townships were then averaged to arrive at BMP preference percentages for the entire watershed based on survey method. This helped to ensure that each participating township was represented equally in the model runs to avoid skewing the scenarios towards the preferences of a heavily represented township that may have had farming characteristics that were not representative of other townships. These percentages were then used to create future scenarios using the baseline scenario as a starting point.

Model Scenarios

The model runs were broken into four categories: baseline, public, Snowball farmer, and Random farmer (Table 12). The baseline scenario was based on recorded data from the River Raisin watershed from 1998-2005, including land use, weather patterns, flow rates, and farming practices. Baseline model outputs were compared to water quality data from a water monitor gauge near the river's outlet at Monroe, Michigan, for 1998-2005 to ensure model prediction accuracy.

Within each model scenario, all variables were held constant across all eight years of the model run with the exception of climate conditions and crop rotation schedules. For the eight years of each model run, recorded weather observation data from the watershed during those years were used. Crop rotation schedules were varied to ensure that planting, tilling, and crop selection were not static and therefore more accurately reflected farming dynamics within the watershed. Crop rotation order for the model was based on typical watershed farming patterns of corn – bean – corn – bean – wheat.

The baseline scenario output resulted in loads of total phosphorus (TP) of 168 Mg/yr, total nitrogen (TN) of 4,859 Mg/yr, and suspended sediments (SS) of 115,609 Mg/yr. The stakeholder preference scenarios used the baseline scenario model design as a starting point and then changed only the parameters to be tested in each individual preference scenario. As mentioned above, climate conditions and crop rotation schedules varied across years, but they did not vary between scenarios. For example, the climate conditions and crop rotation schedules for 2001 in the stakeholder scenarios were the same as the baseline scenario's conditions for 2001.

Calculations of the responses from Snowball farmers showed no significant difference between the three highest ranked BMPs, therefore all were run together in one model scenario. While crop rotation was statistically similar to CTR, NM, and RBs, the baseline scenario already contained CR at a 100% implementation level and therefore it was not possible to further augment its usage in the stakeholder scenarios. Therefore CTR (94%), RBs (88%), and NM (92%) were run together as one scenario. For Random farmers, the same three BMPs from the Snowball scenario were focused on independently to contrast any differences between their effectiveness. For each of the three BMPs, Random farmers were willing to increase overall use by 50% over the baseline and the scenarios reflected that willingness. As discussed earlier, RBs were favored by the majority of non-farmer participants, therefore the two non-farmer model scenarios were run based on this preference. While there was a clear preference for RBs by non-farmers, it was unclear what percentage of RB augmentation they preferred. Factoring in that a RBs scenario for Random farmers at 50% was already being tested, the non-farmer scenarios instead looked at two futures: the same percentage of RBs that was found in the Snowball farmer scenario (88%) but without its increase in CTR and NM, and 100% coverage of RBs.

Developing the stakeholder preference scenarios required modifying the baseline scenario to reflect those preferences. For the stakeholder scenarios that consider CTR, tillage type for both soybean and wheat were changed to no till within the model. NM changes to the baseline scenario reflect recommendations by agricultural experts in the watershed who said that NM strategies within the watershed would reduce phosphorus fertilization rates by 60% compared to regular farming practices. To achieve this within the model, fertilizer use was changed from 160 kg/ha of 10-34-00 (N-P-K) to 75 kg/ha of 20-20-00. Manure application rates were unchanged in the NM scenarios from the baseline scenario. RBs were less straightforward to implement in SWAT. In its most recent version, the SWAT model has the ability to adjust the use of grass filter strips but not riparian buffers. Therefore, the model scenarios that use RBs only increased the use of grass filter strips and not riparian buffers. For example, the non-farmer 100% RBs scenario adjusted the baseline scenario so that all farm fields were bordered on all sides by a 10 m–wide grass filter strip.

Stakeholder preference percentages for BMPs were integrated into the model by adjusting the proportion of the subwatersheds implementing the BMP. For example, in the Random 50% CTR scenario, 50% of the subwatersheds were set to the new CTR method of no till wheat and soybeans while the other half of the subwatersheds maintained the same tilling practices as the baseline scenario. The preference scenarios were run from 1998-2005 to ensure that direct comparisons were possible between the baseline and all preference scenarios.

Continuing the above example, the 50% CTR changes were fully installed by 1998 and were held to that level for all eight years of model runs.

For all scenarios, the values for the three water quality measures reflected their annual load at the mouth of the river, averaged across the eight years of model results. The model reported results on a daily timescale; the daily results were averaged to obtain each year's average daily load for each water quality measure. Average daily results were then averaged across the eight years to remove inter-annual variability in nutrient and sediment loads that resulted from differing weather and soil conditions. For example, the average daily load of SS for the Baseline scenario in 2001 was 475 Mg, which was over twice its average daily load of 231 Mg in 2003.

Model Water Quality Results

Overall, the scenarios developed from public opinion resulted in water quality that exceeded that of the status quo, or baseline scenario. The baseline scenario had the following water quality result: TP of 168 Mg/yr, TN of 4,859 Mg/yr, and SS of 115,609 Mg/yr. The Random farmer scenario for NM had no impact on the water quality indicators for this study and the 50% CTR scenario for Random farmers resulted in only a small improvement over the baseline (Tables 13a, 13b, &13c). The 50% RBs scenario for Random farmers had over twice the impact of the other two Random farmer scenarios, with an 11% decrease in TP, 12% decrease in TN, and a 2% decrease in SS. Combining the three individual Random farmer scenarios resulted in an additive effect, and as a result it was the most effective of the Random farmer scenarios. All scenarios for the Random farmers resulted in the least amount of pollution reduction out of all stakeholder scenarios.

In contrast, the Snowball farmer scenario was the most effective at reducing TP, with a 23% reduction. This scenario's reductions of 25% TN and 2% SS were only 2% and 1% less than the best TN and SS-reducing scenarios, respectively. Therefore this scenario was about equal to the best pollution-reducing scenarios considered for this study.

The non-farmer 100% RBs scenario was the most effective scenario at reducing both TN and SS, at 27% and 3%, respectively. The 88% RBs scenario equaled the 100% RBs scenario for SS reduction, and was 2% less effective than the 100% scenario for both TN and TP. Comparing the 88% RBs scenario to the Snowball farmer's scenario reveals how a 94% CTR and 92% NM increase affect water quality: an increase of SS by 1% and a 3% decrease in TP. From a water quality perspective, the CTR and NM do little compared to RBs.

With the exception of the 50% increase in NM scenario, all scenarios and preferences tested with the model resulted in an improvement in the water quality in the River Raisin. Combining the three BMPs in the random scenarios into one model run, however, demonstrates that the effects of the BMPs were cumulative; the addition of one BMP in the Random farmer scenario had an additive impact on the effectiveness of the other BMPs. However, doubling RB use from 50% to 100% resulted in a reduction of TN by more than double. Therefore, the addition of different types of BMPs had an additive effect on pollution reduction while increasing the use of one type of BMP could result in a reduction greater than the sum of its parts.

As discussed above, the trends in the averaged outputs across the eight years of model runs revealed a hierarchy between the model scenarios for each water quality measure (Table 13a). For example, the annual TP average for the Snowball farmer scenario (129 Mg/yr) was lower than that of the non-farmer 100% RBs scenario (131 Mg/yr). However, an analysis of individual years demonstrated that annual conditions within the watershed can restructure that hierarchy. In 2003, the non-farmer 100% RBs scenario (311 kg/day) had lower average daily TP values than the corresponding Snowball farmer scenario (317 kg/day). Studying annual variations in average daily pollutant loads across years within individual model scenarios revealed annual fluctuations in pollutant loads that can, in the case of SS, be in excess of 100%. This was likely the result of climate variations.

DISCUSSION

Stakeholder Group Opinions on Pollution and its Sources

Surveying the stakeholders of the River Raisin watershed revealed that many opinions were commonly held and were not related to the respondent's relationship to the watershed. On specific points, however, the survey exposed preferences and beliefs that were correlated to the stakeholder group the respondent identified with. Although responses were received from people who identified with all five stakeholder groups, when significant differences surfaced, they were most commonly between farmers and another stakeholder group. In fact, the responses from all non-farmer stakeholder groups were similar enough for most questions that they were often grouped together as a "non-farmer" stakeholder group. Within the farmer category, a comparison of answers based on different farm characteristics did not reveal any differences in opinion that were correlated to farming demographics. Therefore, when differences arose on the topics of agriculture and BMPs between the people who live, work, or recreate within the River Raisin watershed, those differences were commonly between two overarching stakeholder categories: farmers and non-farmers.

Stakeholder affiliation was not correlated to perception of water quality in the River Raisin; 76% of all respondents believe that the pollution level of the river is moderate to high. This perception mostly agrees with water quality testing performed throughout the watershed in 2006, where testing showed that "overall stream health in the River Raisin appears to be moderate to good" (Gothie *et al*., 2007). Out of 243 responses to this question, only 3 respondents, none of whom were farmers, believed the river to be unpolluted. Conversely, 24 respondents (10% of all responses) believed the river to be very polluted, five of whom were farmers.

The difference in opinions between farmers and non-farmers was evident in who they felt was most responsible for polluting the River Raisin. When comparing farmers and non-farmers, important distinctions can be seen in how these two stakeholder groups perceived threats. In the Random survey group, non-farmers ranked agricultural runoff as the second greatest threat while farmers ranked it third. The discrepancy between farmers and non-farmers was even greater in the Snowball method results. Snowball non-farmers ranked agricultural pollution as the number one threat to the river while farmers ranked it as fifth.

Over the past half-century, farmers within the River Raisin watershed have witnessed changes in land use that may influence their perceptions of pollution sources. From 1968-1988, the watershed experienced increasing levels of urbanization and forest cover combined with decreases in agricultural land (Erickson, 1995). However, a model of the River Raisin watershed demonstrated that while increased urbanization does increase nutrient loads and sedimentation, agriculture results in higher levels of sedimentation than urbanization while forest cover reduces the levels of both of these pollutants (Allan *et al*., 1997). Agriculture's effect on sediment is demonstrated by comparing two River Raisin subwatersheds: Iron Creek and Evans Creek. Evans Creek has almost twice as much area dedicated to agriculture (68%) as Iron Creek (45%), but its contribution to the sediment load in the watershed ranges from two to ten times that of Iron Creek (Allan *et al*., 1997). Therefore, even though urban area has increased, the net effect of this combined with a decline in agriculture and an increase in forest cover would be expected to be decreased nutrient and sediment concentrations. When this is combined with the model results from the present study that demonstrate that BMPs can reduce approximately 25% of both TN and TP in the river and the fact that agriculture is still the dominant land use within the watershed, it is clear that agriculture still has a major impact on the River Raisin water quality.

Farmers perceived their role in local water pollution to be overshadowed by other pollution sources, a perception that was not unique to this watershed. Many studies have found that farmers recognize that their local rivers and groundwater are polluted, but they did not believe themselves to be responsible (Tucker & Napier, 2002, McCann *et al.*, 1997, Pease & Bosch, 1994, Kaplowitz & Witter, 2008). Even when the land they farmed had been classified as high risk for either runoff or leaching, farmers did not feel that their farms were in fact contributing to the pollution of ground and surface waters (Pease & Bosch, 1994). Pease *et al.* (1994) reported that of the farmers they surveyed, "all crop farmers and nearly all livestock farmers state that there is little risk" of runoff or leaching from their fields. This belief was pervasive even among organic farmers (McCann *et al.*, 1997). The survey responses to the study by McCann *et al*. (1997) suggested that an individual farmer may believe that agriculture can have a negative effect on the environment, but that his or her farm was not part of the problem. When farmers were asked if agriculture pollution is a serious problem, both organic and conventional farmers responded that they agree (McCann *et al*., 1997). However, when these same farmers were asked if "pollution from the use of agricultural chemicals is a serious problem on your farm", organic farmers strongly disagreed and conventional farmers were split between disagree and neutral (McCann *et al*., 1997). Tucker and Napier (2002) hypothesized that for farmers the use of agrichemicals results in positive outcomes in terms of crops, and therefore it may make it more difficult to perceive agrichemicals as dangerous.

Wetlands, Conservation Set-asides, and Precision Agriculture

Over 30% of all farmers who participated in the present study would be willing to install wetlands, conservation set-asides, or both on their land if provided with assistance in setting them up and if rent was paid to them for the land used. Given that approximately 1 in 3 farmers were open to these measures, lands vital to the protection of water quality and ecosystem services of the River Raisin watershed have the potential to be protected in this manner.

As discussed earlier, precision agriculture (PA) is an emerging system of farming that could have enormous positive impacts on river water quality if the results of numerous studies prove indicative of real-world results. Approximately 50% of the farmers surveyed either already used GPS or auto-guide systems on their farming equipment or planned to within the next three years. Another 11% were unsure. If farmers who utilize these systems on their farms are successful and their peers witness this success, non-users may reconsider using these systems on their own fields even if they had been previously adverse to this technology. While the model was not able to analyze any environmental impacts that may result from using GPS and auto-guide systems on farm equipment, the potential impacts they may provide are important to note for future research. Regardless whether the change is positive or negative, it is unlikely that water quality trends in the River Raisin over the next 10 years will follow those of the last 10 years if 50% of farmers change their farming habits. What the net effect of PA on the River Raisin will be over the next few decades will need to be evaluated along with which BMPs best match the runoff characteristics of this emerging system of farming.

BMP Preferences

In general, non-farmers and farmers agreed in their preference to have more riparian buffers (RBs) installed throughout the watershed, however the necessity of making the survey accessible to people of all BMP knowledge levels resulted in fewer direct comparisons between farmers and non-farmers. Non-farmers overwhelming chose RBs as their top BMP choice, with conservation tillage / residue management (CTR) and crop rotation (CR) becoming important when cost was considered. Both Snowball and Random farmers chose RBs among the top three BMPs they would be willing to augment on their own farms. As shown in Table 11, in two of the townships farmers said that they would be willing to increase RBs more than any other BMP, in six they would increase CTR or nutrient management (NM) more than RBs, and in 16 of the townships they would increase RBs in equal amounts to CTR or NM. CTR was the BMP farmers would be most willing to increase the usage of on their farms (Table 11). Only in three townships were BMPs other than CTR selected for a higher willingness to install, once each by RBs and NM, and once by a farmer who said he or she would not increase use of CTR but did not answer what his or her intentions with RBs were. Therefore, while farmers in some townships would be willing to increase other BMPs more than RBs, in general they were willing to significantly increase their use of the BMP preferred by non-farmers.

Of the NRCS three Core4 practices that were included in the survey (CTR, NM, and RBs), all three had the highest in use and willingness to install percentages among all farmers. Considering that 90% of the Snowball farmers and 50% of Random farmers participated with the NRCS or their local Soil and Water Conservation district, the results of the survey may reflect the initiatives that these organizations were promoting.

Contour cropping (CC), on the other hand, was the least known, used, and desired of all the BMPs. In general, the topography of the watershed is relatively flat and the use of this BMP on flat lands is not recommended (Dabney *et al.*, 2006) as it would require more fuel and equipment to implement. Therefore it is not surprising that most farmers either had not heard of this BMP or were not willing to implement it on their lands. While contour cropping may have an important role to play in specific areas within the watershed, it is unlikely to become one of the more commonly used BMPs throughout the River Raisin watershed.

My survey approaches revealed that Snowball farmers (those more likely to attend group meetings related to farming and water quality issues) were overall more familiar with BMPs and also used them more often than Random farmers (those randomly selected from the population in the watershed). This is a key finding because Snowball farmers, after learning about the BMPs and using them on their own land, were willing to increase their implementation of BMPs; this is encouraging to their sustainability. It suggests that these farmers regarded them as beneficial and worth their effort. Previous research discovered a possible positive connection between willingness and use of conservation measures and years farming the land (McCann *et al*., 1997). My results strengthen that connection. In my surveys, Snowball farmers were more willing to use BMPs than Random farmers. Nearly all of the Snowball farmers (90%) had farmed their land for more than 20 years, compared with 64% of Random farmers (Table 3).

The River Raisin watershed has the highest percentage of agricultural land in the state of Michigan but is still among the best watersheds for the cleanest water in the entire basin, which is a testament to the farmers in this watershed. Despite not recognizing the degree of their responsibility for water quality issues in the watershed, or at least while not recognizing the level of impact their own farming practices might have on the watershed, farmers have installed BMPs on their fields and demonstrated a willingness to further augment their use of BMPs. Some BMPs have economically-beneficial side effects for farms, such as decreased machine hours and fuel, which may partially explain farmers' willingness to adopt them. Another reason may be programs such as the Conservation Reserve Enhancement Program and the Conservation Reserve Program, which provide a financial incentive for farmers to adopt BMPs which may not have positive side-effects for farmers, such as grass filter strips.

Growing conflicts between farmers and non-farmers as urban expansion occurs in the watershed may be another reason why farmers are installing BMPs. With more people relocating to rural or agricultural watersheds from urban areas, citizen complaints, conflicts, and even lawsuits over farming 'nuisances' have been increasing (Smith *et al*., 2008, Ribaudo &

Johansson, 2007, Sharp & Smith, 2003). Therefore farmers may regard BMPs as a way to quiet complaints non-farming neighbors have against their farm and, if it goes that far, as a safeguard against potential liability suits (Ribaudo & Johansson, 2007). Increasing communication between farmers and their neighbors has been shown to be important for reducing conflict and increasing understanding between both parties (Sharp & Smith, 2003). Also, as farmers have more contact with non-farming neighbors, the farmers are more likely to use conservation practices on their land (Ribaudo & Johansson, 2007). The results of this study reveal that farmers indeed have significant contact with others.

In both survey groups, non-farmers ranked community members and farmers as two of their top sources of information for BMPs. Likewise, farmers listed fellow farmers as either the first or second most important source, with community members ranked just below farmers. In general, news media and non-profit organizations were the least important sources of information, which contrasts with the findings of a study in a nearby watershed. While word-of-mouth sources were not included in their research, newspaper and broadcast media were the preferred sources of information on watershed issues for both residents and farmers, while state and federal agencies received less than half the votes of media sources (Kaplowitz & Witter, 2008). In the present study, state and federal agencies ranked as more important than news sources to the Snowball survey group but the opposite was true for the Random survey group. Farmers were also the top source of agricultural information for residents in Charlotte, Vermont (Smith *et al*., 2008). Government agencies and not-for-profit organizations in general were the least important sources of agricultural information for Charlotte residents, although not-for-profit organizations were an important information source for people who did not support the dairy farm expansion the survey was developed around (Smith *et al*., 2008). That farmers in the River Raisin watershed are a top source of BMP information for many of the respondents of this survey is important for farmers as they try to build social capital within the community (Sharp & Smith, 2003). The survey results, however, show that farmers could still improve their communication with residents, at least with regard to information about BMPs. Resident respondents for both survey methods ranked the degree to which farmers are a source of information for BMPs as closer to "not at all" than "moderate", indicating that more interaction between these two stakeholder groups may be important (Figures 14 & 15).

STAKEHOLDER PREFERENCE OUTCOMES

With one exception, all future scenarios based on stakeholder surveys and simulated using the SWAT model were an improvement over the baseline scenario. The non-farmers surveyed for this project overwhelmingly believed RBs to be the most effective BMP at reducing agricultural runoff. Despite knowing less about BMPs than their farmer counterparts, the model scenario results show that non-farmers were correct.

Snowball farmers, who overall knew more about the subject matter on the survey than any other group, demonstrated a preference to implement a combination of BMPs, and the resulting model scenario was one of the most effective at improving water quality. Random farmers, who used fewer BMPs on their farms and did not participate with local soil conservation groups to the extent their Snowball counterparts did, were less willing to increase BMPs use on their lands, and the resulting model scenarios were the least effective of all scenarios. One of their scenarios, 50% CTR, resulted in higher SS levels than the baseline.

To put the potential of the stakeholder preferences in perspective, consider the outputs of the stakeholder scenarios with the goals of the 1991-1994 River Raisin Watershed Project (RRWP). While a 50% increase in grass filters would achieve their 12 % TN and TP reduction goals, none of the scenarios would reach the RRWP goal of a 10% reduction in sediment (Table 13c). With regards to the RRWP estimated results, the stakeholder scenarios in the present study were more effective. Converting their estimated annual reductions of 5,745 tons of sediment and 10,590 lbs of P into Mg, their predicted reductions would amount to 0.168 Mg/yr of SS and 4.80 Mg/yr of P. The Snowball farmer scenario would result in significantly greater reductions in both SS and TP: 2655.8 Mg/yr and 34.2 Mg/yr more, respectively.

How Each Water Quality Measure is Affected by the BMPs According to the Model

Suspended Sediments

The BMPs tested for this research resulted in very little reduction of SS (Figure 26). Only RBs had a positive impact on SS within the River Raisin. Increased use of CTR resulted in higher levels of SS within the river while NM had no impact. Further research is necessary to determine why these BMPs had little impact on SS within the river. A different model previously demonstrated that runoff from agricultural lands, especially during the Fall and Winter seasons, was a significant contributor to overall SS within the River Raisin (Allan *et al*., 1997). Other empirical studies performed in different watersheds have shown that grass filters can reduce sediment runoff by more than 90% (Fiener & Auerswald, 2003) and that certain forms of phosphorus leaching (particulate) are tied to sediment transport (Baker, 1991). Therefore the reductions seen in TP from the model should have been tied to a larger decrease in

SS. The model scenarios for this research utilized 10m wide grass filter strips, which have been shown to be the most efficient size of buffer for sediment load reduction (Liu *et al.*, 2008). Therefore the reduction of suspended sediments demonstrated by the model scenarios, even with 100% RB implementation, were less than previous studies would suggest it should have been.

Total Phosphorus and Total Nitrogen

Near 100% use of both RBs and CTR resulted in an approximate reduction of 25% for both of these pollutants (Figures 27 & 28). Doubling the use of RBs from 50% to 100% resulted in further reductions of 100% for TP and 125% for TN. The 50% CTR scenario results agree with previous research that the increased use of CTR would be more effective at reducing TP than TN, and may even result in an increase in TN (Baker, 1991). The sandier soils of this watershed compared to surrounding watersheds would increase subsurface flow, which emphasizes the importance of using RBs within the watershed for capturing subsurface TN flow.

Outside Influences on Outputs

The influence of factors beyond the control of managers and farmers, such as the climate, should not be underestimated. For example, the average daily load of SS in the baseline scenario in 2001 (475 Mg) was over twice the level in 2003 (231 Mg), a difference of 244 Mg/day. In the model, farming practices were held constant throughout all eight years of each individual model scenario; annual variation occurred due to factors outside the farm. Compared to a variation of 244 Mg/day, the differences between BMPs were small. The greatest difference in average daily SS load for a single year was in 2004 between the 100% RBs scenario and the 50% NM scenario. In that year, the average daily SS load for the 100% RBs scenario was 319 Mg, compared to 334.6 Mg for the 50% NM scenario. The difference of 15.6 Mg/day, while significant, is over 10 times less than the variation between 2001 and 2003.

AN EVALUATION OF THE BMPS BASED ON MODEL RESULTS

Based on SWAT model simulations, nutrient management as a specific BMP (Table 1) is not an effective measure to combat any of the water quality measures used for this study. Nevertheless, nutrient management is an important BMP for this watershed for factors beyond the three water quality measures considered in SWAT. In recent years, Concentrated Animal Feeding Operations have become more common within the watershed and NM can be an effective way to reduce the impact livestock have on the river. By acting as a substitute for chemical fertilizers and providing an effective way for disposing of animal by-products (NRCS, 1999), the importance of NM to the watershed should not be underestimated.

Conservation Tillage / Residue Management decreased levels of both TP and TN. This BMP, however, did increase SS levels within the river. This is likely due to the hardened soils that may result from not turning over the soil, which can lead to increased surface water runoff (Lerch *et al*., 2005). However, CTR can also decrease surface water runoff because it promotes the buildup of crop residue on the surface (NRCS, 1999). TP levels in a river are typically tied to overland flow, while TN generally leaves the field via sub-surface flow (Baker, 1991). Therefore, because CTR would enhance the infiltration of runoff, the expected result would be a decrease of TP and an increase in TN export (Baker, 1991, Pionke *et al*., 2000).

Riparian Buffers / grass filter strips were the best BMPs for reducing all of the water quality measures of this study. Full coverage of grass filters resulted in approximately a 25%

reduction of both TN and TP. Grass filter strips have been shown to be as effective as riparian buffers at denitrification (Dabney *et al*., 2006), therefore a change in nitrogen levels in the river would not be expected with a switch from grass filter strips to riparian buffers. Unfortunately, the SWAT model was not capable of incorporating riparian buffers into scenarios, so how a combination of grass filter strips and riparian buffers might affect pollution levels could not be determined. Previous studies on farmer preferences have shown that of the two, farmers were more willing to install grass filter strips than riparian buffers (Klapproth & Johnson, 2009). Farmers viewed riparian buffers, and the planting of trees that would be involved, as a measure that would reduce their ability to be flexible in how they manage their land whereas grass filter strips could later be converted to other uses with minimal effort (Klapproth & Johnson, 2009). Farmers also feared that once the trees were established, other laws might be enacted that would prevent them from converting it back to agricultural uses if they saw fit (Klapproth & Johnson, 2009). Health-related concerns regarding the wildlife that can inhabit BMPs have impacted RB use in California recently, an issue that may affect their future implementation and use in the River Raisin watershed. Recent *E.coli* outbreaks in that state and the negative impacts an outbreak can have on entire crops have led farmers to reconsider BMPs that house "possible disease vectors" (Dowd *et al.*, 2008). These fears have prompted some farmers to remove any wildlife habitat near their fields, including riparian buffers and wind breaks (Dowd *et al*., 2008).

Riparian buffers and grass filter strips are effective at filtering both surface and subsurface flow from agricultural fields (Dabney *et al*., 2006). The ability of the roots of the plants in buffers to tie up and absorb contaminants in subsurface flow is important to the River Raisin watershed. A comparison of seven Lake Erie watersheds revealed that the River Raisin had much lower than expected levels of pesticides in the water, which the authors attributed to the sandier soils of this watershed (Richards *et al*., 1996). If an increased amount of subsurface flow is occurring in this watershed, then the buffers' capacity to effectively filter subsurface flow makes their use in this watershed even more important. Despite the effectiveness of RBs compared to the other BMPs tested here, it is not recommended that RBs be installed without other BMPs to support them. Other BMPs, especially on-field BMPs such as residue management, would help slow water flow through the system, giving RBs more time to absorb contaminants (Dabney *et al*., 2006). Furthermore, direct flow straight from the field into the RBs may damage them and reduce their ability to slow runoff and filter agrichemicals. Therefore installing RBs as part of a more complete BMP system will help ensure the RBs remain healthy and effective (NRCS, 1999, Dressing, 2003).

CONCLUSION

This research demonstrates that farmers believe the river is as polluted as all other groups do; the difference lies in what different stakeholder groups perceive to be the sources responsible and the most effective remedies. Farmers involved in this study did believe that agrichemicals negatively impact the environment but believed that other sources were more of a threat. These results suggest that public discussion on water quality could benefit from an open dialogue between scientists and the public over water testing results so that the impacts of various threats in the watershed are better understood by all. As noted by Hudson *et al*. (2005), "it is difficult to mobilize public support for improving water quality if the public does not understand the sources of water quality problems." Taking this observation and applying it to this study, it would be difficult to convince farmers to change elements of their farming practices by installing and maintaining BMPs if farmers believe that other sources cause more damage.

Farmers that implement a broader range of BMPs on their farms, especially cropland reducing measures such as RBs, may need to charge more for their products to offset lower yields or higher production costs. But will consumers be willing to pay more for these products or even understand what they are paying a higher price for? Fair trade and organic farm products have become popular enough to be sold in grocery chains and some fast food restaurants, suggesting that there might be a market for water-quality conscious products from farms. Looking at applying fair-trade concepts to U.S. farm production, a nation-wide survey found that consumers are willing to pay 68% more for strawberries if the extra money ensured fair wages for farmworkers and a safe working environment (Howard & Allen, 2008). However, the concepts of fair trade and organic goods may be easier for consumers to understand than hypoxia and groundwater contamination. Considering consumer's willingness to pay for farm products that reduce local contamination, a study in Italy determined that local residents would be willing to pay an additional €1,465 ($2,046) annually in food costs to "eliminate soil and groundwater contamination in farmland areas" (Travisi & Nijkamp, 2008). In the United States, when a survey group was asked how much they would be willing to give up in the form of taxes to support precision agriculture and the water quality improvements it promises, the average response was $30.49 (Hudson *et al.*, 2005). However, only 12.4% of this same survey group understood what hypoxia was and they perceived industrial waste and city waste water to be larger contributors to water pollution than agricultural sources (Hudson *et al.*, 2005). As stated by Howard and Allen (2008), "one well-known limitation of willingness to pay studies has been termed the ‘attitude behavior gap’, which means that purchasing behaviors do not correspond to stated intentions.” If consumers do not understand the degree to which current agricultural practices affect their water supplies, it is unclear whether the results these studies documented would translate to real world purchases of products that cost more but are labeled as “water-friendly”.

From a governmental perspective, finding appropriate incentives that would encourage farmers to maintain and expand BMP use in spite of worsening economic conditions could prove an important challenge over the next few years. This is the subject of a new initiative: on May 6, 2009, Michigan’s Agriculture Deputy Secretary announced the availability of new nation-wide funding to encourage organic farming practices. Michigan would be available to receive a portion of the $50 million in funds “to provide financial assistance to National Organic Program (NOP) certified organic producers as well as producers in the process of transitioning to organic production” (NRCS, 2009). “Under the Organic Initiative required minimum core conservation practices will be determined by specific resource concerns.” The practices are “Conservation Crop Rotation; Cover Crop; Nutrient Management; Pest Management; Prescribed Grazing; and Forage Harvest Management” (NRCS, 2009).

How aquatic life in the River Raisin would benefit from a 25% reduction in both TP and TN, or if these reductions would have any impact on the hypoxic zone in Lake Erie, are beyond the scope of this study. However, model results from NOAA predict that the Gulf of Mexico hypoxic zone would see an increase in dissolved oxygen by 15-50% with a 20-30% decrease in nutrients (Hudson *et al*., 2005). Farmers in this watershed express a willingness to implement measures on their own lands that would decrease the levels of these pollutants low enough in the

River Raisin to where the NOAA model predicts positive changes for the Gulf of Mexico, indicating that it is also a positive step towards the eventual elimination of the hypoxic zone in Lake Erie.

From a policy standpoint, it is important to remember that the scenarios used for the model runs reflected the preferences of a variety of segments of the general public and in all but one case water quality improved. Most importantly, the lowest resulting values for the three water quality indicators used in the model were split between the preferences of two different stakeholder groups: non-farmers and Snowball farmers. In this case, if the extra 12% of RB that the best non-farmer scenario has over the Snowball scenario proves too costly for farmers, the differences between the two scenarios might be small enough that nurturing the spirit of cooperation among all parties could be a more important outcome. Instead, the conversation should perhaps focus on bridging the gap between Random farmer and Snowball farmer preferences, as well as how to enable farmers to achieve the level of BMP implementation they indicate they desire. The survey results suggest that many farmers within the watershed would like to increase their use of certain BMPs, including the BMP preferred by non-farmers. Working together to help farmers achieve those goals would not only reduce water pollution in the River Raisin but would also help generate trust across stakeholder groups and foster creative solutions.

TABLES AND FIGURES

TABLE 1: COMMON TERMS AND ABBREVIATIONS

Best Management Practices	Abbreviation
Conservation Tillage & Residue Management	CTR
Nutrient Management	NM
Riparian Buffers	RB
Contour Cropping	CC
Cover Cropping	CV
Crop Rotation	CR

Survey Method	Name
Random Mail Distribution	Random
Targeted Distribution through Local Networks	Snowball

Stakeholder Groups	Abbreviation
Farmer (Renter or Owner)	Farmer
Governmental or Non-governmental Organization Employee	GNGO
Recreational User of the River	RUR
Resident of the River Raisin Watershed	Resident

Target Water Quality Indicators	Abbreviation
Total Phosphorus	TP
Total Nitrogen	TN
Suspended Sediments	SS

TABLE 2: BMP CATEGORIES

Structural	**Cultural**	**Management**
Terraces, Hillside Ditches	Conservation Tillage	Integrated Pest Management
Grass Waterways	Contour Cropping	Nutrient Management
Irrigation Systems	Cover Cropping	Irrigation Management
Sediment Basins	Crop Rotation	

Common BMPs and the three classification categories according to Logan (1993).

TABLE 3: FARM CHARACTERISTICS

	Random Survey	Snowball Survey
Number of Townships	27	25
Total Farm Area (acres)	7,334.5	72,779.5
Average Farm Area (acres)	564.2	921.3
Percentage of Reported Farms < 100 Acres	46%	8%
Percentage Farming the Land for 20+ Years	64%	90%
Percentage Growing Wheat	38%	73%
Percentage Growing Corn	69%	95%
Percentage Growing Soybeans	62%	95%
Percentage Growing Vegetables	46%	4%
Percentage Raising Livestock	8%	29%
Average Percentage of Farmland Dedicated to BMPs	55%	84%

Breakdown of self-reported farm characteristics by survey method.

TABLE 4: PERCEIVED LEVEL OF POLLUTION OF THE RIVER RAISIN

	Perceived Level of Pollution	**Standard Deviation**
Random	3.42	0.89
Snowball	3.25	0.86
Random Farmers	3.33	0.89
Snowball Farmers	3.17	0.80
Random GNGO	4.33	1.15
Snowball GNGO	3.40	0.83
Random RUR	3.76	0.75
Snowball RUR	2.89	0.78
Random Residents	3.38	0.95
Snowball Residents	3.47	0.77

The mean perceived pollution level for the River Raisin by stakeholder group and survey method. The first two columns, “Random” and “Snowball”, reflect the mean values for all respondents to each respective survey method. The values correspond to a numeric scale from 1 (Unpolluted) to 5 (Very Polluted). Stakeholder groups and survey methods are as defined in Table 1.

TABLE 5A: TOP FIVE PERCEIVED THREATS TO THE RIVER WATER QUALITY

	Combined	Snowball Method	Random Method
1	Urban Pollution	Urban Pollution	Industrial Runoff
2	Industrial Runoff	Industrial Runoff	Agricultural / Animal Waste Runoff
3	Agricultural / Animal Waste Runoff	Agricultural / Animal Waste Runoff	Urban Pollution
4	Failed Septic Systems	Failed Septic Systems	Failed Septic Systems
5	Urban Sprawl	Urban Sprawl	Urban Sprawl

TABLE 5B: BOTTOM THREE PERCEIVED THREATS TO THE RIVER WATER QUALITY

	Combined	Snowball Method	Random Method
1	Dams	Tourist Activities	Dams
2	Tourist Activities	Dams	Tourist Activities
3	Golf Courses	Golf Courses	Golf Courses

Potential sources of pollution to the River Raisin and how the survey respondents ranked them as threats to the river. "Combined" refers to the results when all surveys from both survey methods are analyzed together. Snowball and Random are as defined in Table 1.

TABLE 6: MEAN RANK OF INFORMATION SOURCES FOR BMPS

Information Source	Random Method	Snowball Method
Fellow Farmers	2.36	3.28
Community Members	2.46	2.8
Formal Education	2.23	2.88
State / Federal Employees	1.76	3.33
Non-Profit Organizations	2.01	2.42
National / Local News	2.23	2.07

Comparison of all Random method respondents and Snowball method respondents as to what degree each information source informs the respondents on BMPs. The values represent the mean for all respondents of each survey method based on a numeric scale of 1 to 5, where 1 is "not at all" and 5 is "very".

TABLE 7: SOURCES OF BMP INFORMATION FOR SNOWBALL SURVEY RESPONDENTS

Stakeholder Group	Fellow Farmers	Community Members	Formal Education	State / Federal Employees	Non-Profit Organizations	National / Local News
Farmers	3.60	2.92	2.87	3.92	2.16	2.16
GNGO	3.67	2.53	3.47	3.13	3.00	1.86
RUR	2.83	2.89	2.56	1.78	2.89	2.44
Residents	1.6	2.47	2.59	1.65	2.68	1.67

The degree to which each stakeholder group is informed by the sources on BMP-related topics. Numeric scale as in Table 6. Stakeholder groups are as defined in Table 1.

TABLE 8: SOURCES OF BMP INFORMATION FOR RANDOM SURVEY RESPONDENTS

Stakeholder Group	Fellow Farmers	Community Members	Formal Education	State / Federal Employees	Non-Profit Organizations	National / Local News
Farmers	3.64	3.33	3.00	2.75	1.92	2.83
GNGO	3.33	3.00	3.00	2.33	2.33	1.33
RUR	2.86	3.24	2.44	1.88	2.73	2.47
Residents	2.07	2.18	2.07	1.59	1.89	2.13

The degree to which each stakeholder group is informed by the sources on BMP-related topics. Numeric scale as in Table 6. Stakeholder groups are as defined in Table 1.

TABLE 9: BMP FAMILIARITY

BMP	Random Farmers	Snowball Farmers	Random GNGO	Snowball GNGO	Random RUR	Snowball RUR	Random Residents	Snowball Residents
CR	3.57	3.86	4.00	3.00	3.00	3.00	2.52	2.74
RB	3.29	3.68	3.67	2.87	2.28	2.89	1.86	2.11
CTR	2.86	3.75	3.00	2.73	2.22	1.89	1.66	1.74
CV	3.00	3.38	3.33	2.47	2.17	2.22	1.78	1.95
NM	3.00	3.58	3.33	2.53	2.00	2.00	1.64	1.84
CC	3.07	2.37	3.33	2.67	2.33	2.22	1.66	1.68

Mean BMP familiarity for both Random method respondents and Snowball method respondents, based on their stakeholder group. The values represent mean familiarity based on a number scale of 1 (Unfamiliar) to 5 (Very Familiar). Stakeholder groups and BMPs are as defined in Table 1.

Table 10: Farmer "In Use" and Willingness to Install BMPs

BMP	Snowball In Use	Random In Use	Snowball Partially	Random Partially	Snowball Fully	Random Fully
CTR	35	17	13	17	52	42
NM	33	17	15	17	51	42
RB	34	42	11	0	51	33
CC	12	9	13	0	15	27
CV	27	27	22	9	35	27
CR	31	25	5	17	63	42

Breakdown of farmer responses to BMP use by survey type. The numbers represent number of respondents who chose that answer on their survey, with only one response per BMP. "In Use" signifies that the farmer already employs that BMP on his or her fields. A response to "partially" means that farmers are willing to install this BMP on their fields, but only on some of their fields. "Fully" means that a farmer is willing to install this BMP on all of his or her land. BMP abbreviations are as defined in Table 1.

TABLE 11: BMP WILLINGNESS TO INSTALL BY TOWNSHIP

Township	**Snowball CTR**	**Snowball NM**	**Snowball RB**	**Random CTR**	**Random NM**	**Random RB**
Adrian	100%	100%	100%	--	--	--
Blissfield	100%	100%	100%	--	--	--
Cambridge	100%	100%	100%	0%	0%	0%
Columbia	--	--	--	50%	50%	50%
Deerfield	--	--	100%	100%	100%	100%
Dover	100%	100%	85%	--	--	--
Dundee	--	--	--	100%	100%	100%
Fairfield	100%	100%	100%	--	--	--
Franklin	--	--	--	50%	50%	0%
Freedom	--	--	50%	--	--	--
Macon	70%	80%	70%	--	--	--
Madison Charter	100%	100%	100%	--	--	--
Manchester	100%	100%	100%	--	--	--
Monroe	--	--	--	0%	0%	
Ogden	90%	80%	90%	100%	100%	100%
Palmyra	88%	88%	67%	--	--	--
Raisin	100%	100%	75%	--	--	--
Ridgeway	100%	100%	100%	--	--	--
Riga	100%	83%	100%	--	--	--
Rome	75%	83%	67%	--	--	--
Seneca	83%	67%	75%	--	--	--
Tecumseh	100%	83%	100%	0%	0%	0%

Farmers responses their willingness to install BMPs on their lands, with the exception of farmers who currently use the BMP on their fields, sorted by the township they farm in. Farmers who selected “Fully” for a BMP added 100% to their township, while “partially” added 50%, and “unwilling” added 0%. If a township had more than one respondent, the responses were added together and divided by the number of responses to reach the final percentage for each BMP and township. BMPs and survey type are as defined in Table 1.

TABLE 12: BREAKDOWN OF MODEL SCENARIOS FOR STAKEHOLDER PREFERENCES

Stakeholder Group	SWAT Model Scenario
Baseline	--
Non-Farmer	88% RBs
	100% RBs
Farmer, Snowball	88% RBs + 94% CTR + 92% NM
Farmer, Random	50% RBs
	50% CTR
	50% NM
	50% RBs + 50% CTR + 50% NM

Simulated BMPs for eight SWAT model scenarios studied, broken down by stakeholder group. The Baseline scenario described current conditions in the watershed. Scenarios other than Baseline differed from the Baseline scenario by the values in the second column. For example, the 50% NM Random Farmer scenario was identical to the Baseline scenario with the exception that 50% of the farm land in the watershed was adjusted to use nutrient management (NM). BMPs as defined in Table 1.

TABLE 13A: MODEL SCENARIO RESULTS FOR AVERAGE ANNUAL LOADS

Stakeholder Group		*Farmer, Random*				*Non-Farmer*		*Farmer, Snowball*
Model Scenario	Baseline	50% NM	50% CTR	50% RBs	50% RBs; 50% CTR; 50% NM	88% RBs	100% RBs	88% RBs; 94% CTR; 92% NM
Water Quality Measure								
Total Phosphorus	168	168	160	150	141	134	131	129
Total Nitrogen	4,859	4,859	4,785	4,272	4,198	3,661	3,528	3,623
Suspended Sediments	115,609	115,604	115,676	113,323	113,355	112,593	112,121	112,953

Average annual loads (Mg/yr) at the mouth of the River Raisin for the Baseline (or current conditions) scenario and the seven stakeholder preference scenarios. BMP abbreviations are as defined in Table 1. Model Scenarios are as in Table 12.

TABLE 13B: STAKEHOLDER SCENARIOS: REDUCTIONS FROM BASELINE FOR AVERAGE ANNUAL LOADS

Stakeholder Group	*Farmer, Random*				*Non-Farmer*		*Farmer, Snowball*
Model Scenario	50% NM	50% CTR	50% RBs	50% RBs; 50% CTR; 50% NM	88% RBs	100% RBs	88% RBs; 94% CTR; 92% NM
Water Quality Measure							
Total Phosphorus	0	-8	-18	-26	-34	-37	-39
Total Nitrogen	0	-75	-587	-661	-1,199	-1,332	-1,237
Suspended Sediments	-5	67	-2,286	-2,254	-3,017	-3,488	-2,656

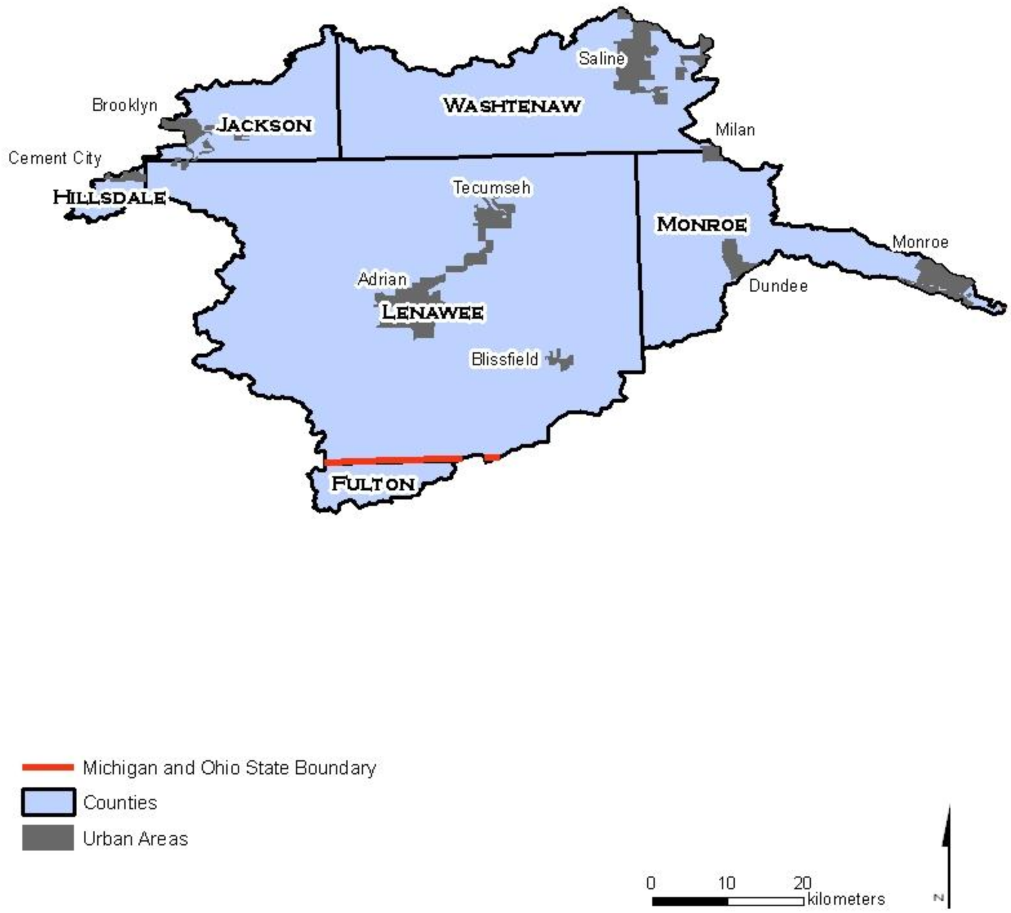
The amount (Mg/yr) which each stakeholder scenario reduced, from the Baseline scenario, average annual loads of water quality measures shown in Table 13a. BMP abbreviations are as defined in Table 1. Model scenarios are as in Table 12.

TABLE 13C: STAKEHOLDER SCENARIOS: PERCENT REDUCTIONS FROM BASELINE

Stakeholder Group	*Farmer, Random*				*Non-Farmer*		*Farmer, Snowball*
Model Scenario	50% NM	50% CTR	50% RBs	50% RBs; 50% CTR; 50% NM	88% RBs	100% RBs	88% RBs; 94% CTR; 92% NM
Water Quality Measure							
Total Phosphorus	-0.2%	-4.7%	-10.9%	-15.8%	-20.0%	-22.0%	-23.2%
Total Nitrogen	0.0%	-1.5%	-12.1%	-13.6%	-24.7%	-27.4%	-25.5%
Suspended Sediments	0.0%	0.1%	-2.0%	-2.0%	-2.6%	-3.0%	-2.3%

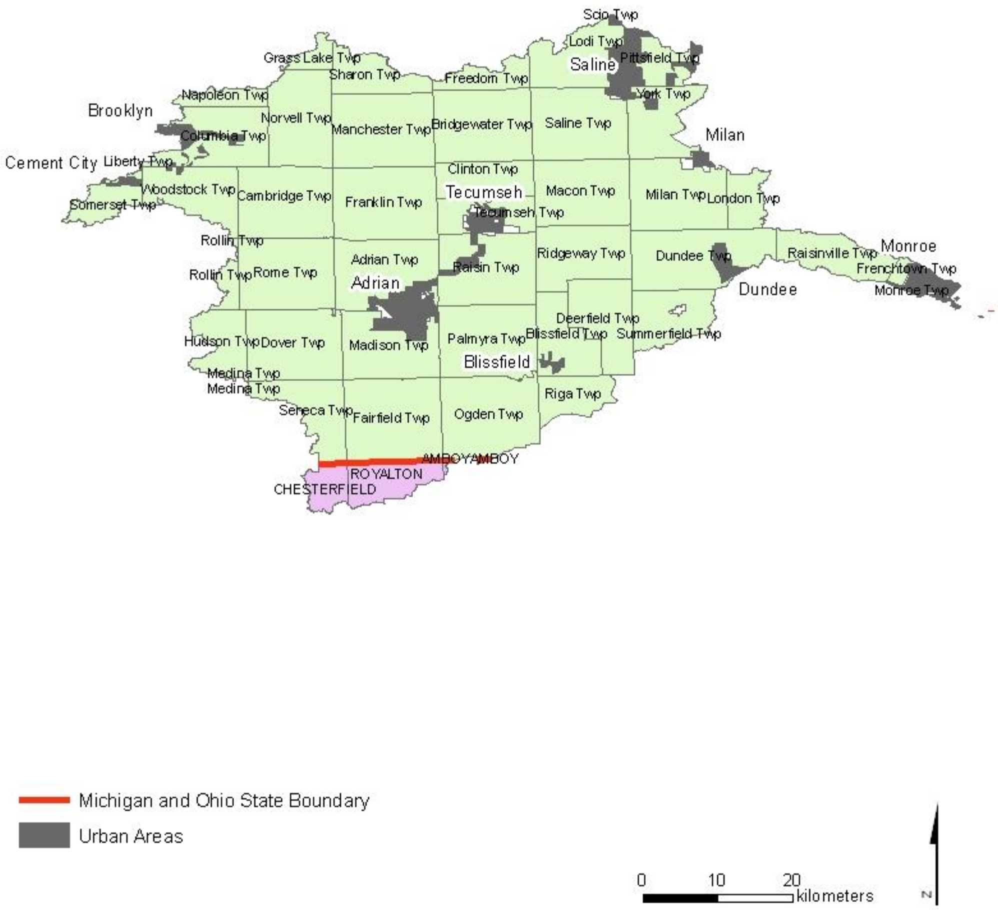
The percentage, as reductions from the Baseline scenario, by which each stakeholder scenario reduced average annual loads for water quality measures as shown in Table 13a. BMP abbreviations are as defined in Table 1. Model scenarios are as in Table 12.

FIGURE 1: RIVER RAISIN WATERSHED URBAN AREAS AND COUNTIES



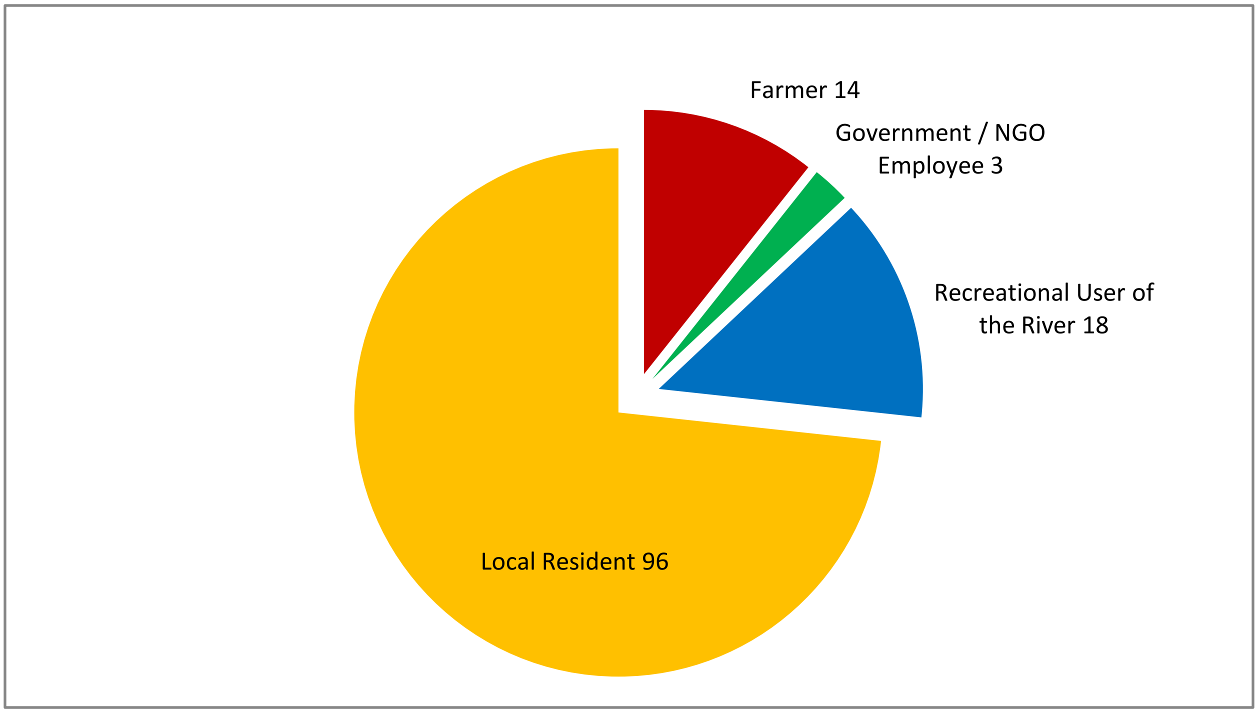
The River Raisin watershed and the six counties it lies in: Jackson, Hillsdale, Washtenaw, Monroe, Lenawee, and Fulton (in Ohio). Black border represents the edges of the River Raisin watershed; black lines within represent county lines. Grey areas and small text indicate major urban areas found within the watershed (EPA, 2006, MCGI, 2007a, 2007b, 2007c, 2007d, 2007e, ODOT, 2009).

FIGURE 2: TOWNSHIPS OF THE RIVER RAISIN WATERSHED



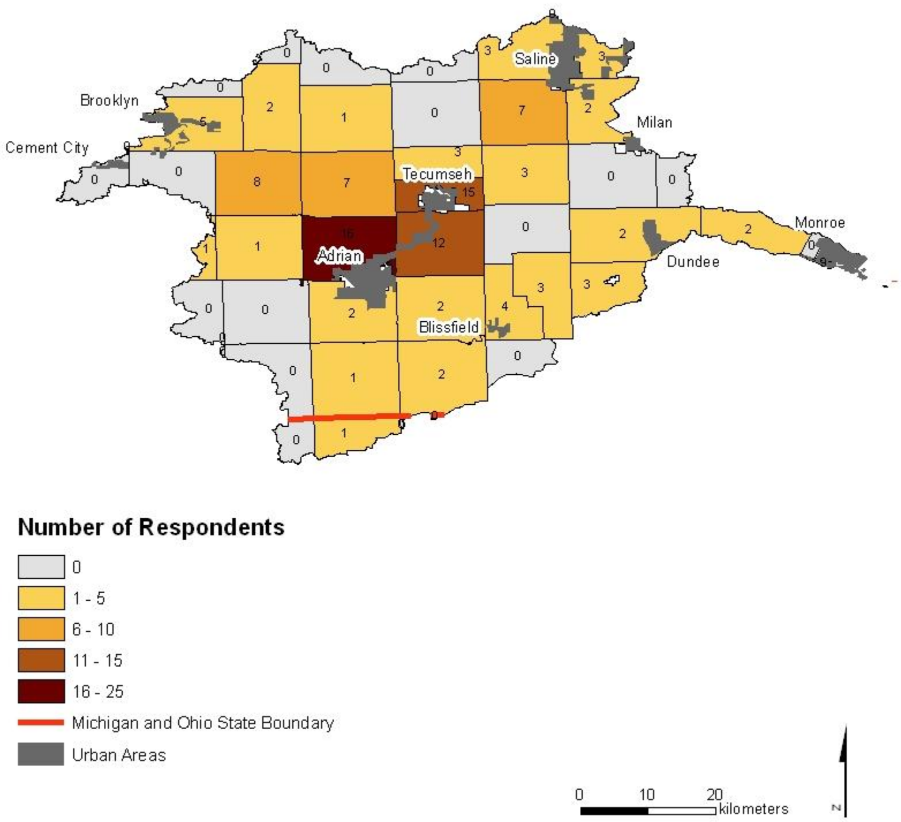
Townships in Michigan are shaded in light green; the three townships in Ohio are shaded light purple. Urban areas are grey and labeled with larger text and a white halo (EPA, 2006, MCGI, 2007a, 2007b, 2007c, 2007d, 2007e, ODOT, 2009).

Figure 3: Primary Relationships of Random Survey Respondents



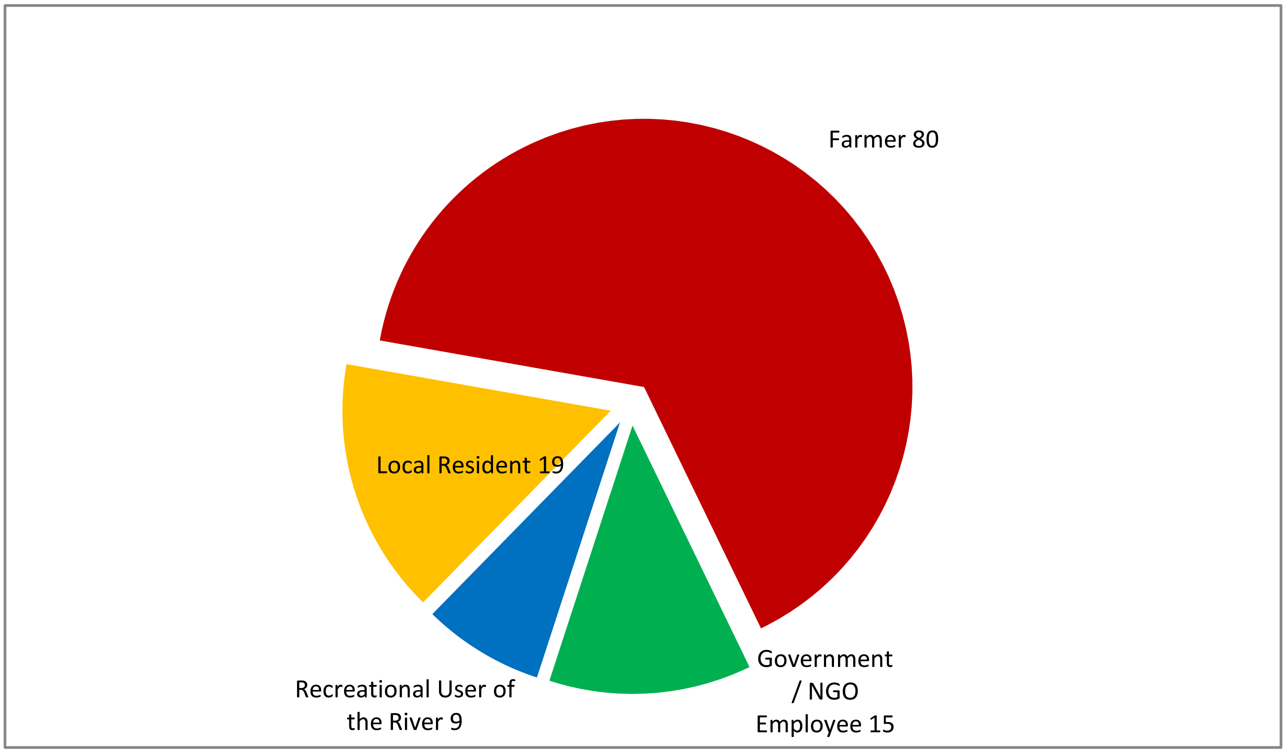
The primary relationships respondents of the Random survey method had with the River Raisin Watershed.

FIGURE 4: RANDOM METHOD RESPONDENTS RESIDENCY BY TOWNSHIP



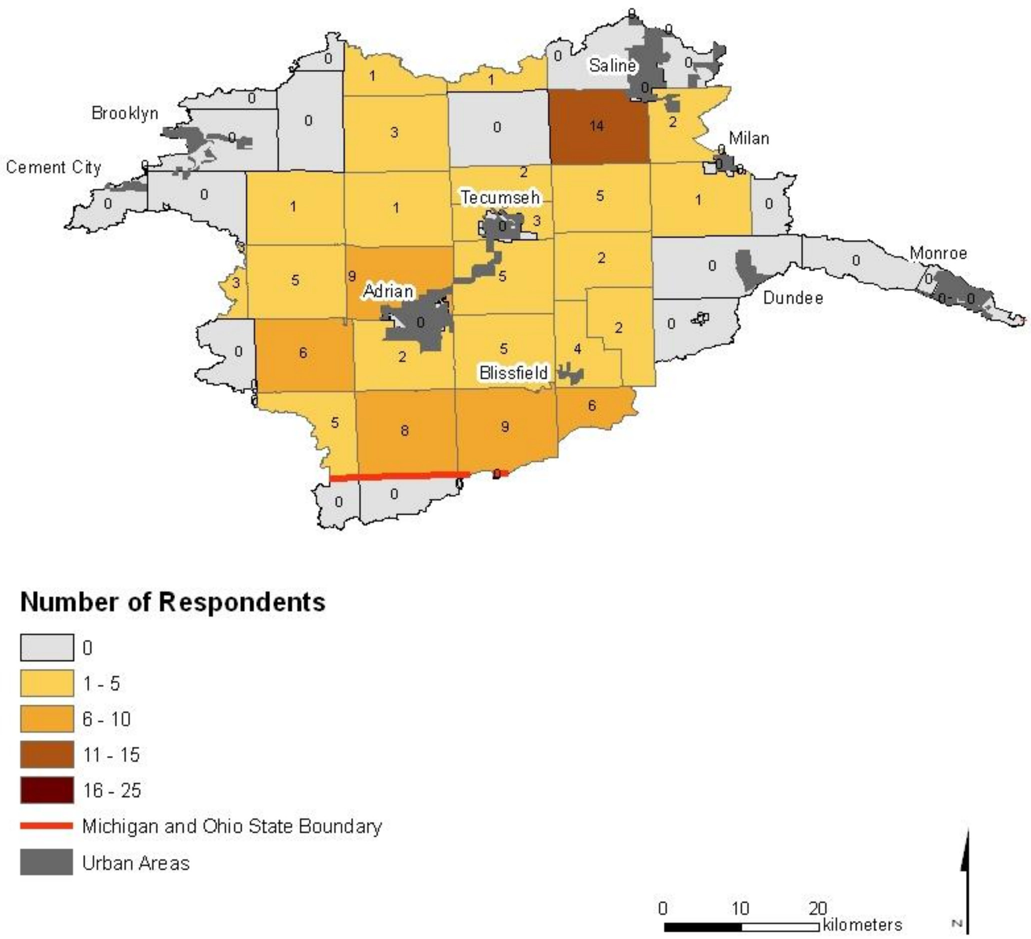
Number of respondents to the Random survey method, grouped by the township they reside in. Dark grey areas represent urban areas (EPA, 2006, MCGI, 2007a, 2007b, 2007c, 2007d, 2007e, ODOT, 2009).

FIGURE 5: PRIMARY RELATIONSHIPS OF SNOWBALL SURVEY RESPONDENTS



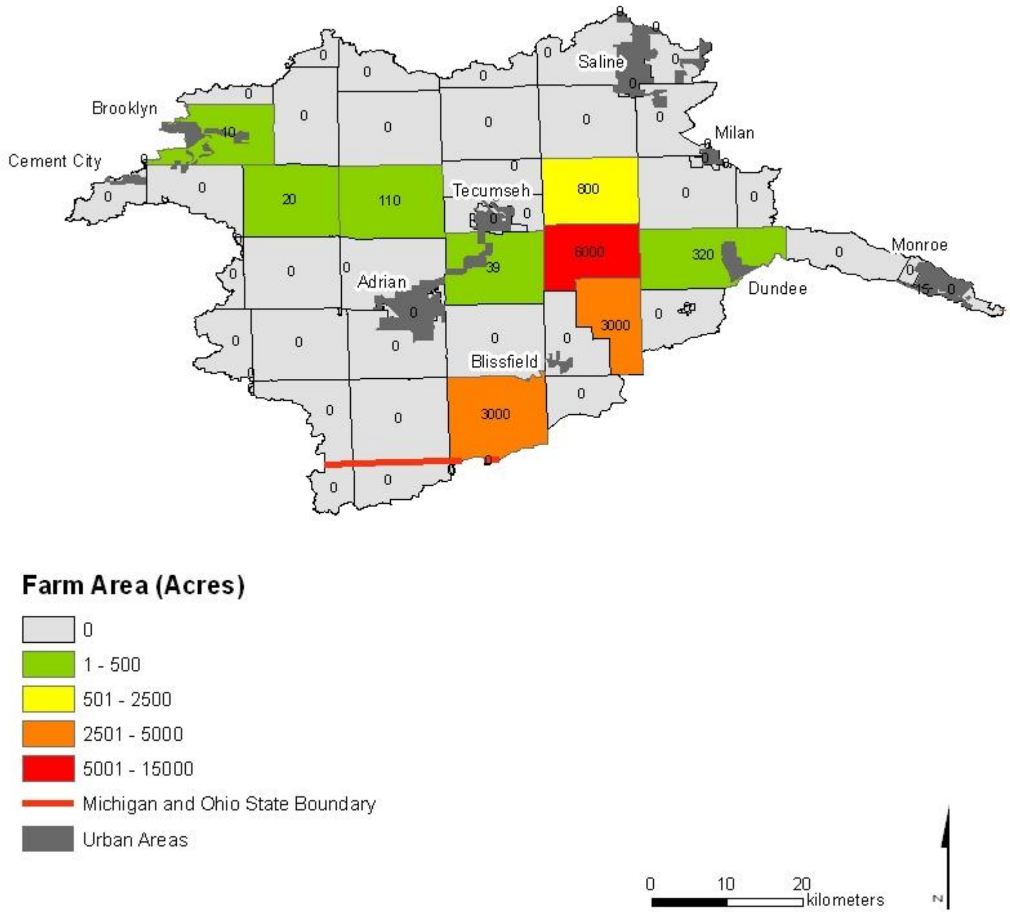
The primary relationships respondents of the Snowball survey method had with the River Raisin Watershed.

FIGURE 6: SNOWBALL METHOD RESPONDENTS RESIDENCY BY TOWNSHIP



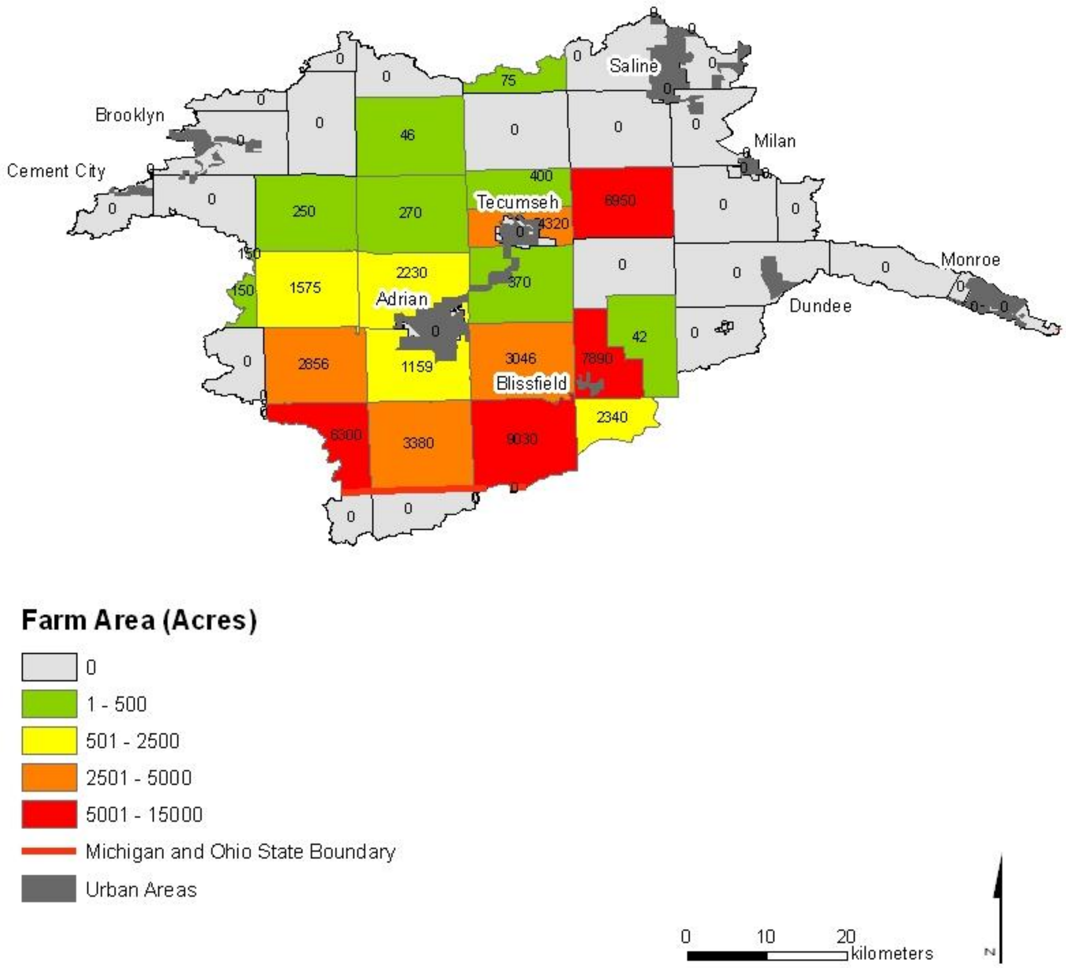
Number of respondents to the Snowball survey method, grouped by the township they reside in. Dark grey areas represent urban areas (EPA, 2006, MCGI, 2007a, 2007b, 2007c, 2007d, 2007e, ODOT, 2009).

FIGURE 7: FARM AREA BY TOWNSHIP FOR RANDOM FARMERS



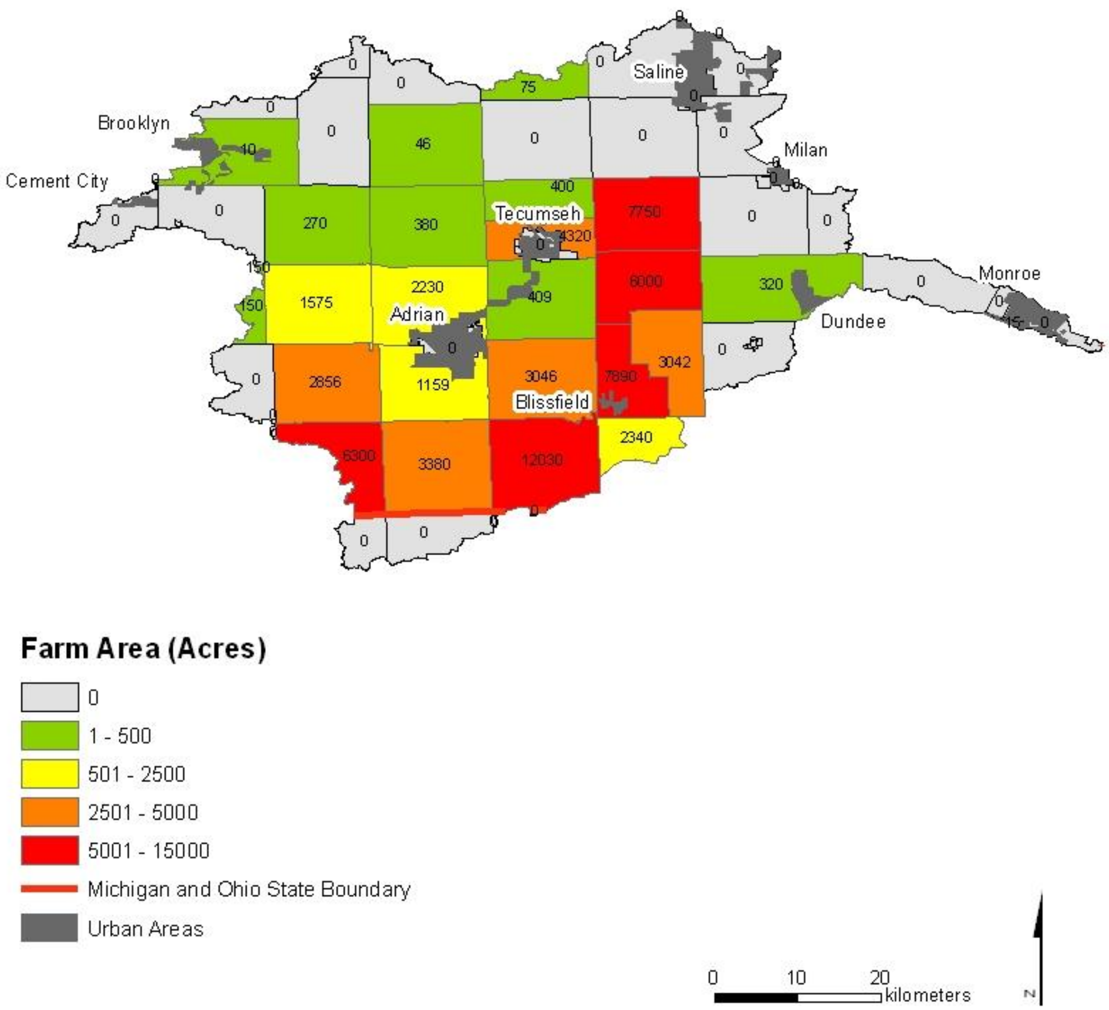
Total farm area in acres by township for the farmers who participated in the Random survey (EPA, 2006, MCGI, 2007a, 2007b, 2007c, 2007d, 2007e, ODOT, 2009).

FIGURE 8: FARM AREA BY TOWNSHIP FOR SNOWBALL FARMERS



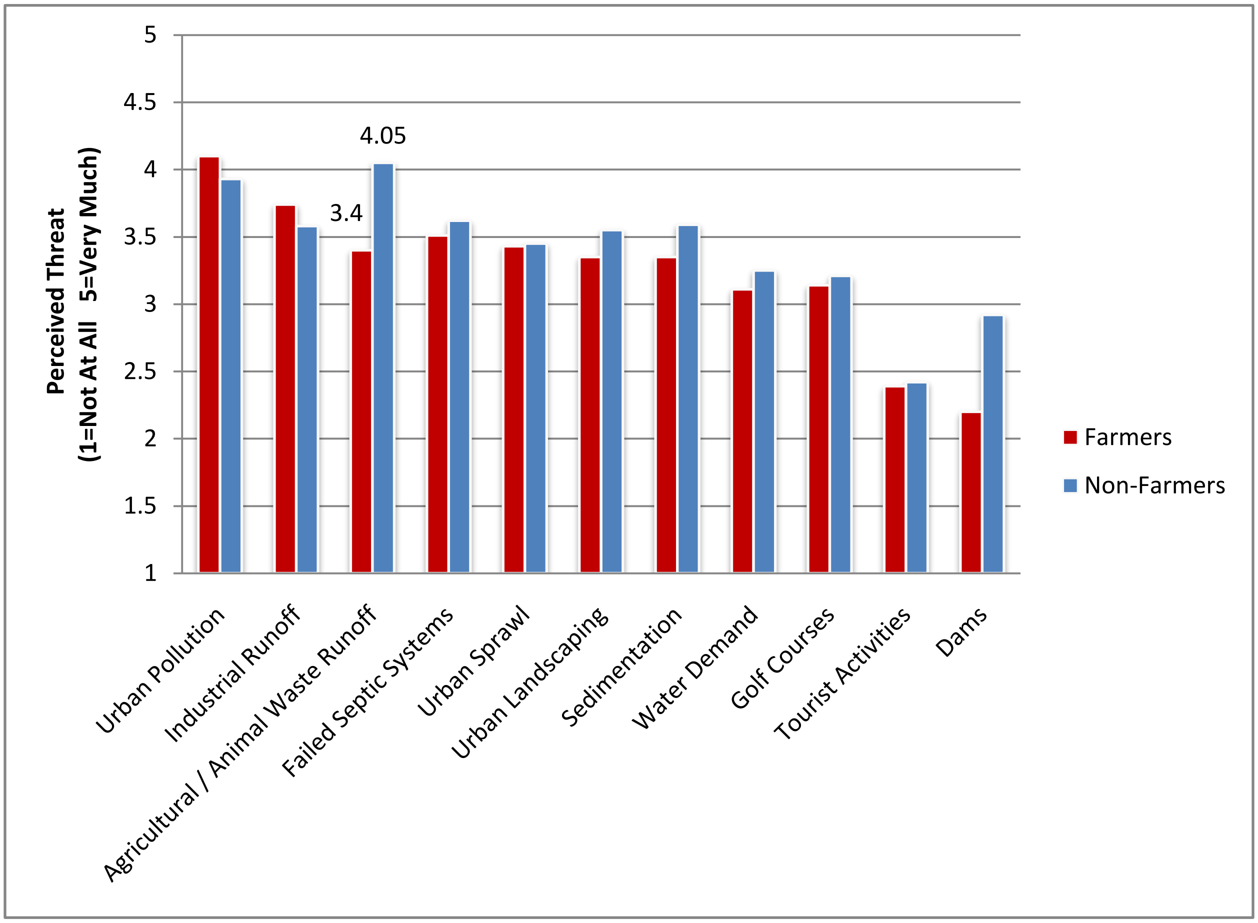
Total farm area in acres by township for the farmers who participated in the Random survey (EPA, 2006, MCGI, 2007a, 2007b, 2007c, 2007d, 2007e, ODOT, 2009).

FIGURE 9: FARM AREA BY TOWNSHIP FOR ALL FARMERS



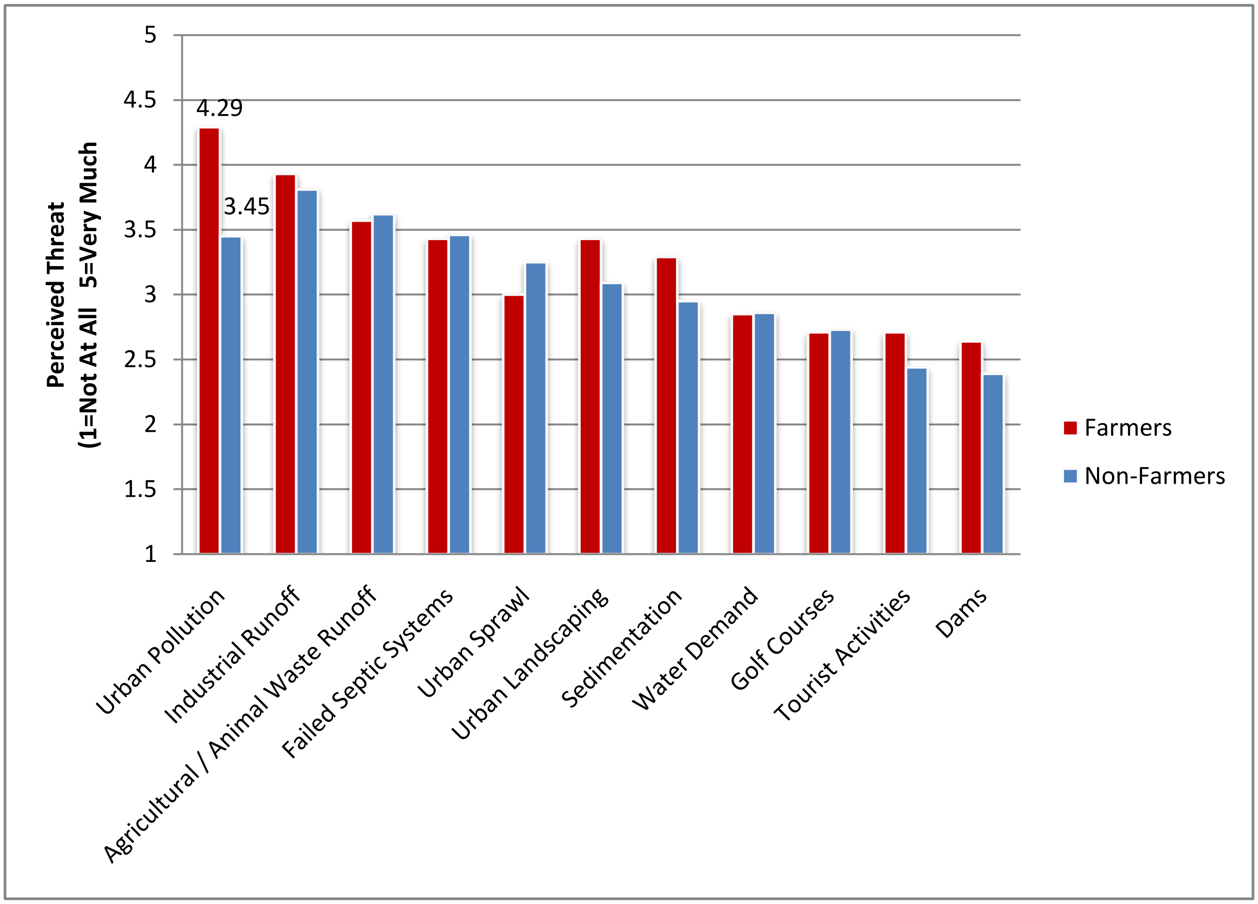
Total farm area in acres by township for the all farmers who participated in the present study (EPA, 2006, MCGI, 2007a, 2007b, 2007c, 2007d, 2007e, ODOT, 2009).

FIGURE 10: PERCEIVED THREATS TO THE RIVER RAISIN BY SNOWBALL SURVEY RESPONDENTS



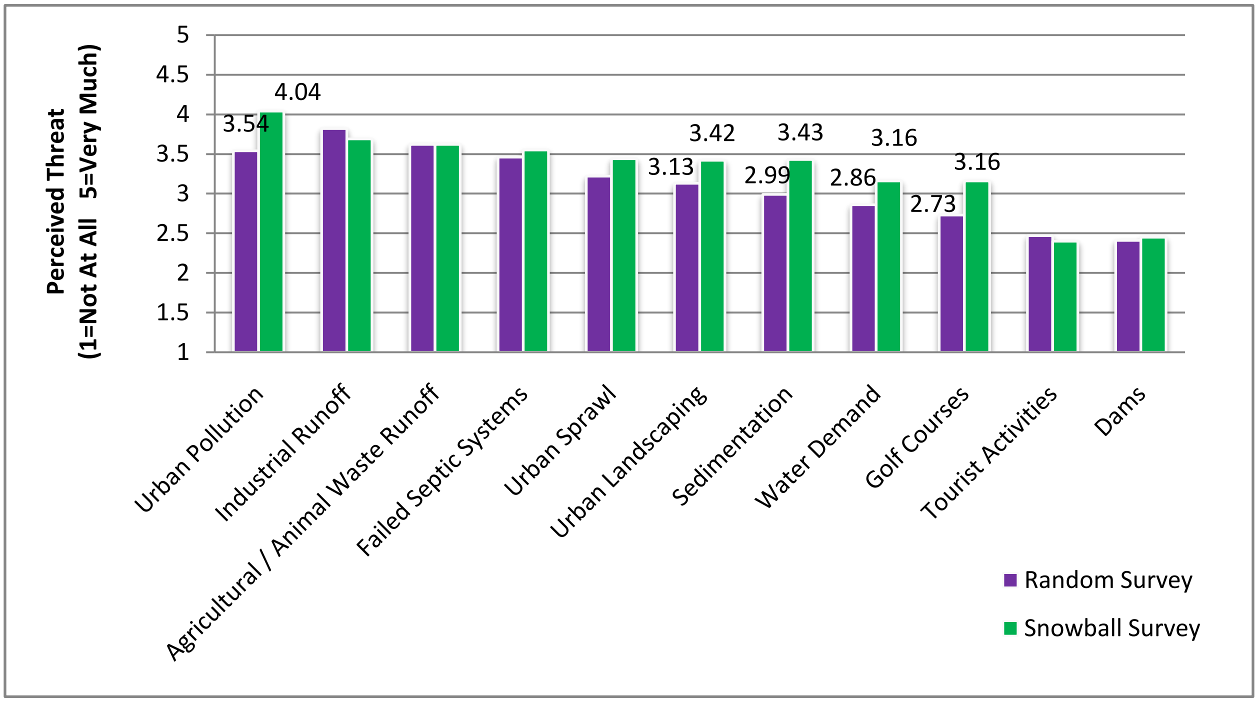
The mean perceived threats to the water quality of the River Raisin according to the Snowball survey respondents, divided into farmers and non-farmers. Responses were on a numerical scale from 1 (Not at all) to 5 (Very much). A statistical difference between farmer and non-farmer responses was found for Agricultural and Animal Waste Runoff ($p = 0.001$).

FIGURE 11: PERCEIVED THREATS TO THE RIVER RAISIN BY RANDOM SURVEY RESPONDENTS



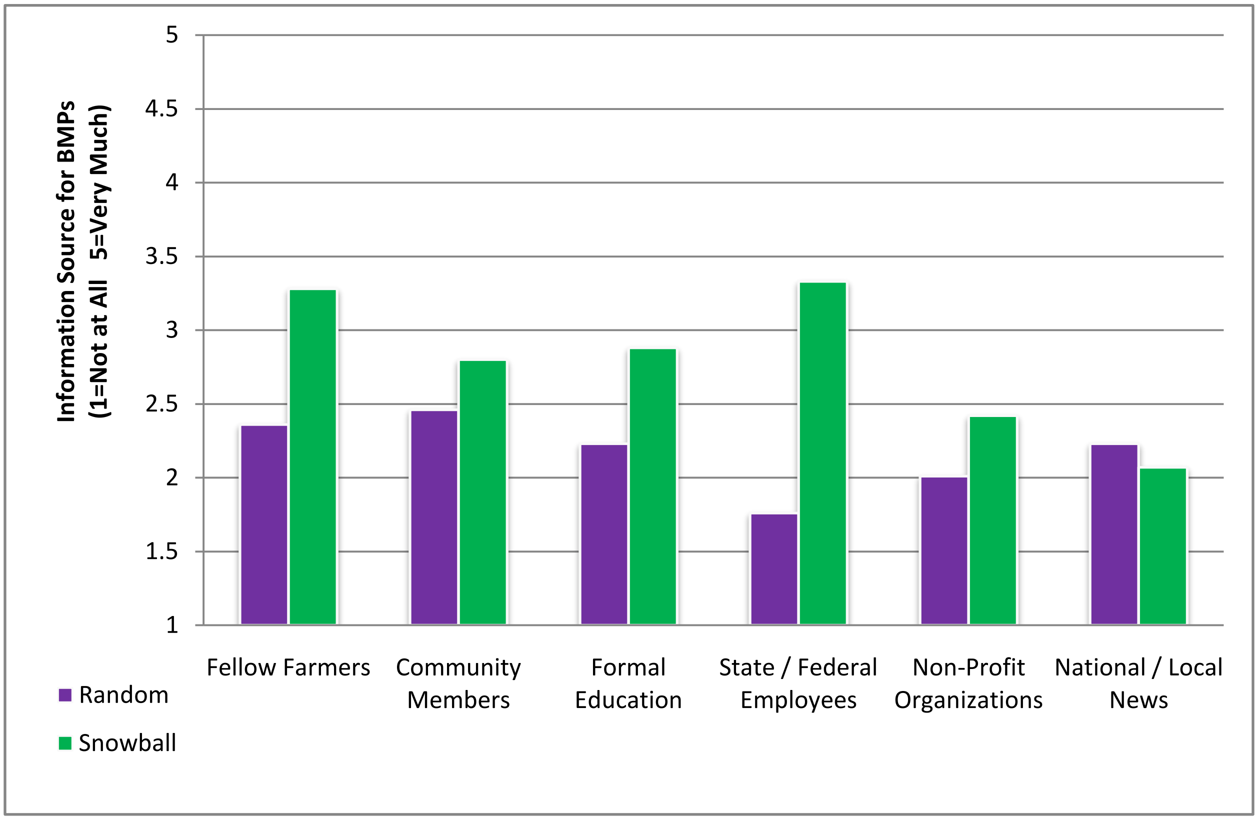
The mean perceived threats to the water quality of the River Raisin according to the Random survey respondents, divided into farmers and non-farmers. Responses were on a numerical scale from 1 (Not at all) to 5 (Very much). A statistical difference between farmer and non-farmer responses was found for Urban Pollution ($p= 0.005$).

FIGURE 12: PERCEIVED THREATS COMPARED BETWEEN SNOWBALL AND RANDOM SURVEYS



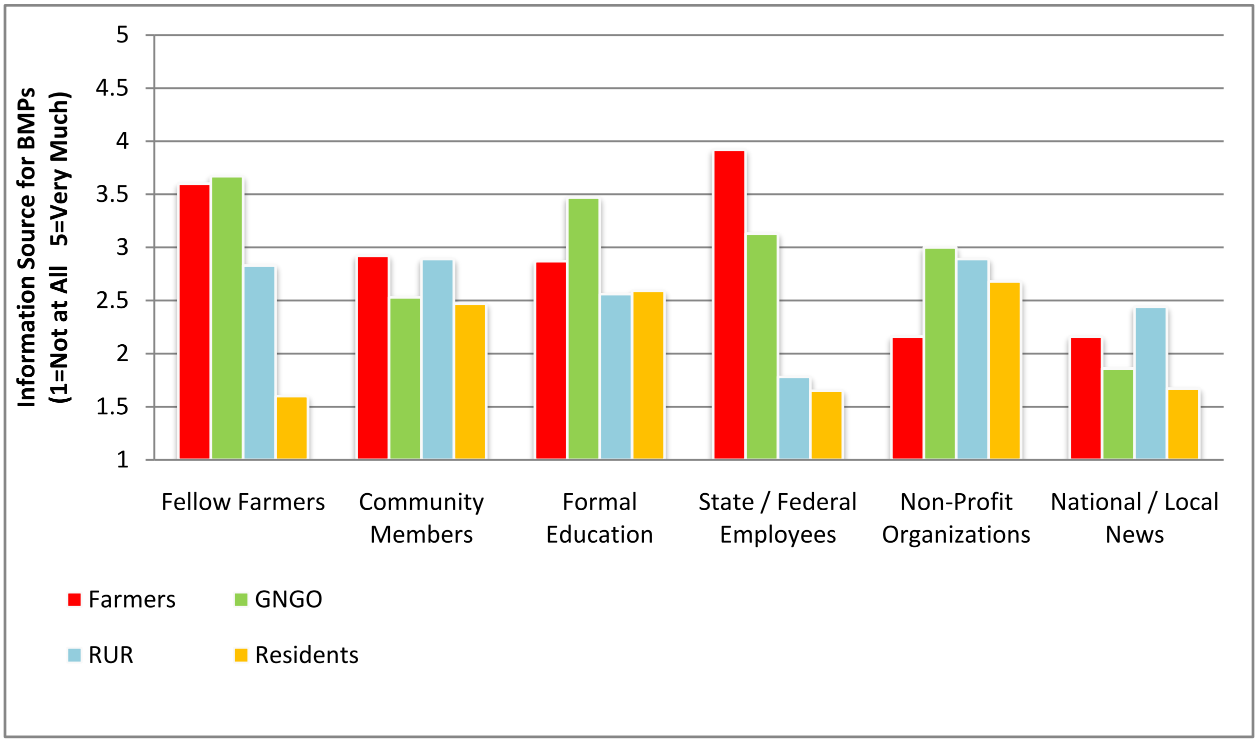
A comparison of the mean perceived threats to the water quality of the River Raisin values between all Snowball survey respondents and all Random survey respondents (Table 1). Responses were on a numerical scale from 1 (Not at all) to 5 (Very much). A statistical difference between the responses of the two survey methods for Urban Pollution (p= 0.0001), Urban Landscaping (p= 0.019), Sedimentation (p= 0.0001), Water Demand (p= 0.025), and Golf Courses (p=0.001).

FIGURE 13: INFORMATION SOURCES FOR BMP KNOWLEDGE FOR SNOWBALL AND RANDOM SURVEY RESPONDENTS



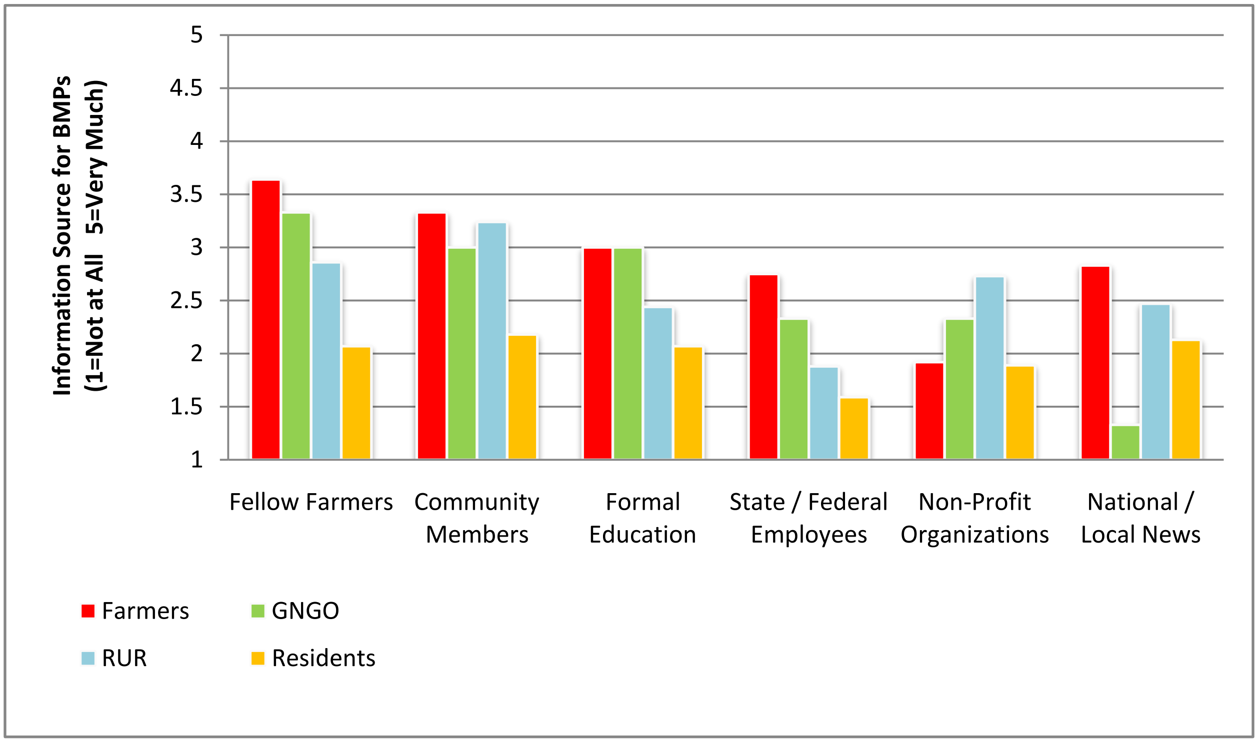
A comparison of the mean values between all Snowball survey and Random survey method respondents for how much knowledge about BMPs they received from the sources listed above. Except for National and Local News sources, Snowball respondents received statistically significantly more information than Random survey respondents from the sources listed above ($p= 0.05$). Responses were on a numerical scale from 1 (Not at all) to 5 (Very much). Random and Snowball refer to survey methods in Table 1.

FIGURE 14: INFORMATION SOURCES FOR BMP KNOWLEDGE FOR SNOWBALL SURVEY RESPONDENTS



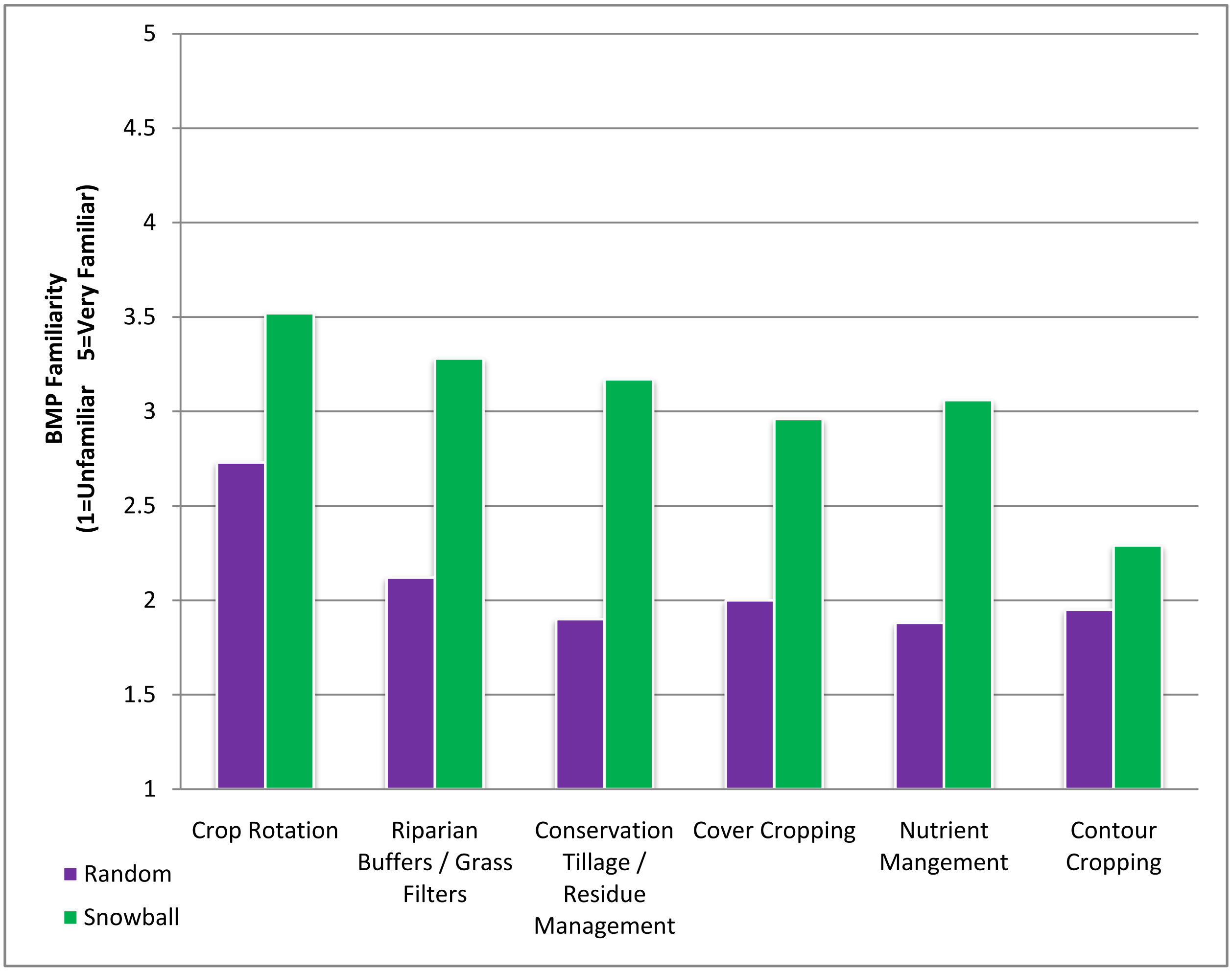
A comparison of the mean values between the Snowball survey method stakeholder groups for how much knowledge about BMPs they received from the sources listed above. Stakeholder group definitions are as defined in Table 1. Responses were on a numerical scale from 1 (Not at all) to 5 (Very much).

FIGURE 15: INFORMATION SOURCES FOR BMP KNOWLEDGE FOR RANDOM SURVEY RESPONDENTS



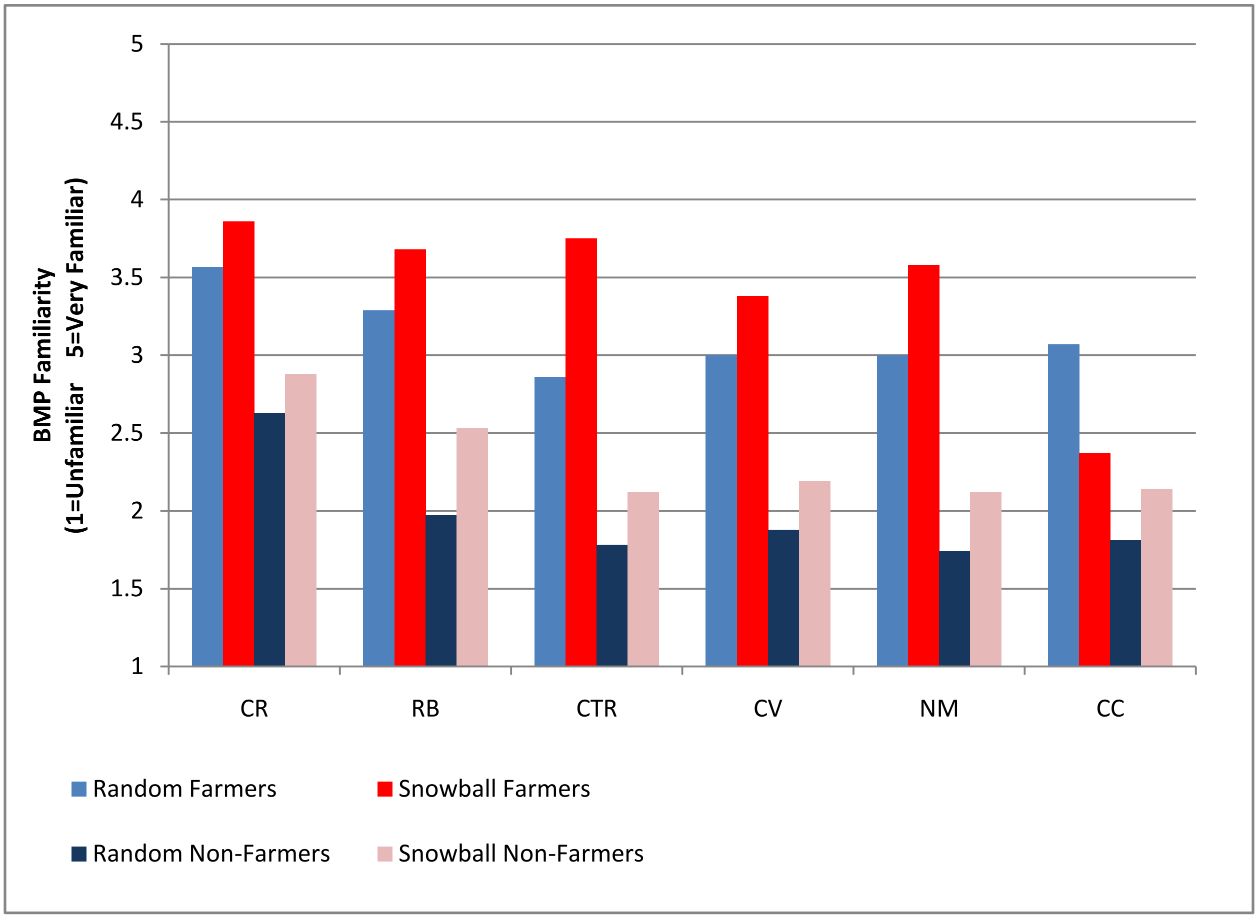
A comparison of the mean values between the Random survey method stakeholder groups for how much knowledge about BMPs they received from the sources listed above. Stakeholder group definitions are as defined in Table 1. Responses were on a numerical scale from 1 (Not at all) to 5 (Very much).

FIGURE 16: BMP FAMILIARITY COMPARISON BETWEEN ALL SNOWBALL AND RANDOM SURVEY RESPONDENTS



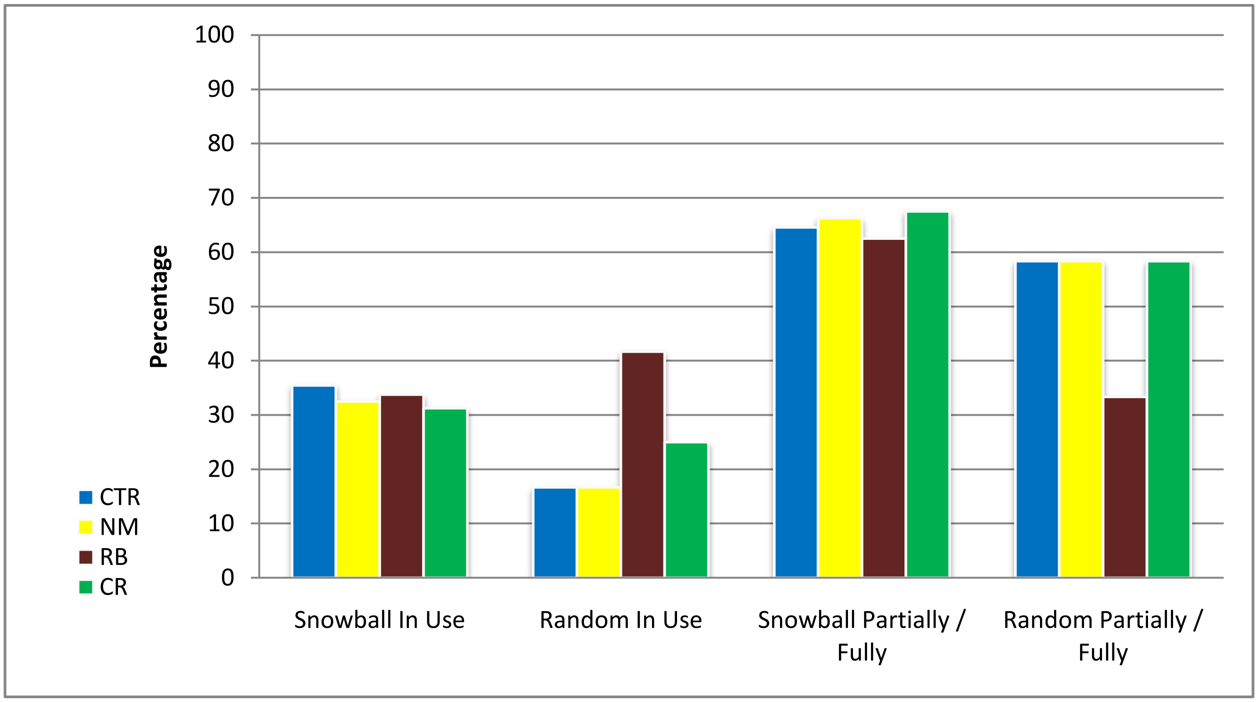
A comparison of the mean values between the Snowball survey and Random survey methods respondents for how familiar they rated themselves with regards to BMPs. For all BMPs, the self-ratings of the Snowball respondents were statistically significantly higher than those of the Random survey respondents (p= 0.05). Responses were on a numerical scale from 1 (Not at all) to 5 (Very much). Random and Snowball refer to survey methods in Table 1.

FIGURE 17: BMP FAMILIARITY COMPARISON BETWEEN SNOWBALL AND RANDOM FARMERS AND NON-FARMERS



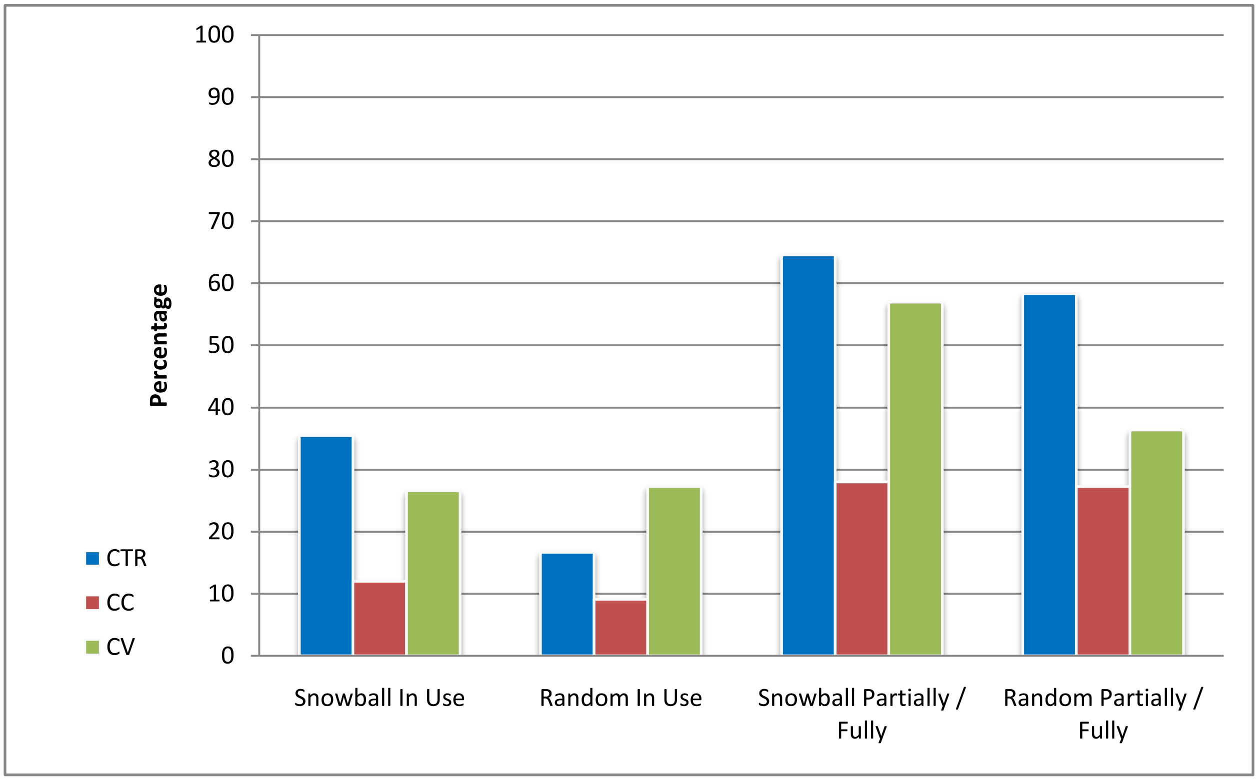
A comparison of the mean values between the Snowball survey farmers and non-farmers and Random survey farmers and non-farmers on how familiar they were with BMPs. Responses were on a numerical scale from 1 (Not at all) to 5 (Very much). Random and Snowball refer to survey methods in Table 1. BMP abbreviations are as found in Table 1.

Figure 18: Farmer "In Use" and Willingness to Install CTR, NM, RB, and CR



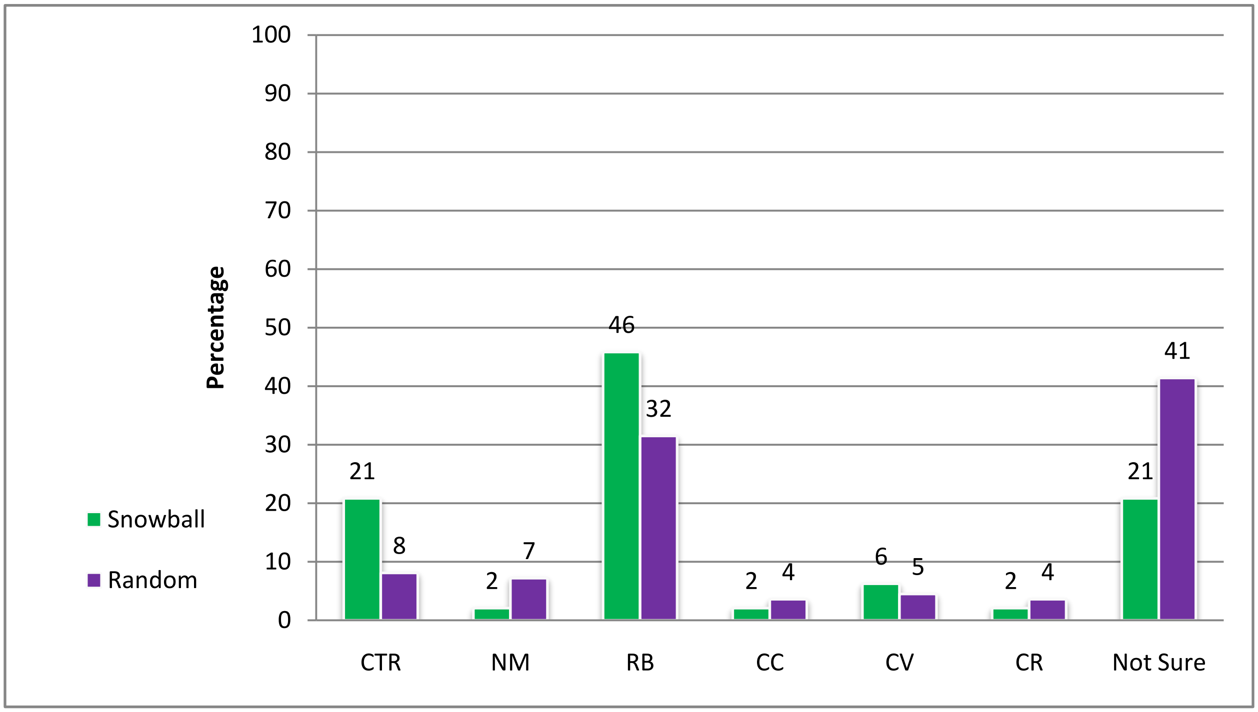
The percentage of farmer respondents by survey method who either used or would use CTR, NM, RB, or CR. Random and Snowball refer to survey methods in Table 1. BMP abbreviations are as defined in Table 1.

FIGURE 19: COMPARING FARMER "IN USE" AND WILLINGNESS TO INSTALL CTR WITH CC AND CV



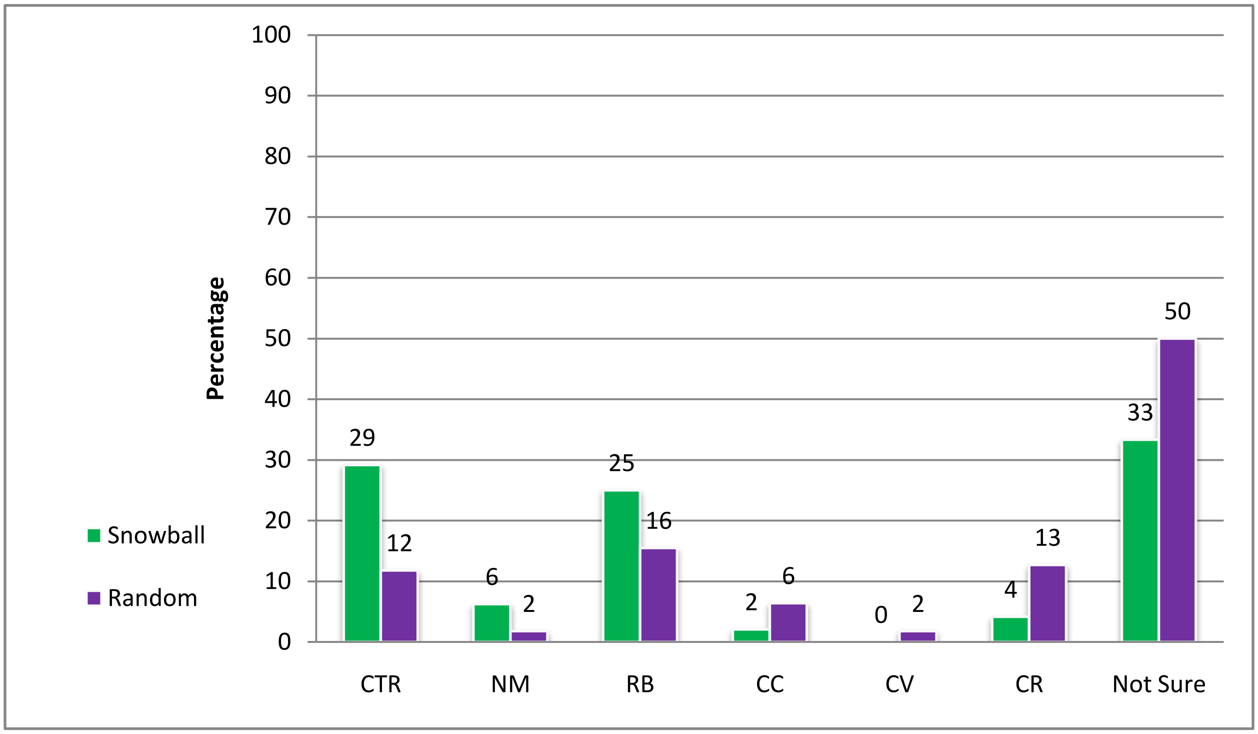
The percentage of farmer respondents by survey method who either used or would use CC and CV, as compared with their response to CTR. Random and Snowball refer to survey methods in Table 1. BMP abbreviations are as defined in Table 1.

FIGURE 20: NON-FARMERS OPINIONS ON WHICH BMP IS BEST AT REDUCING RUNOFF



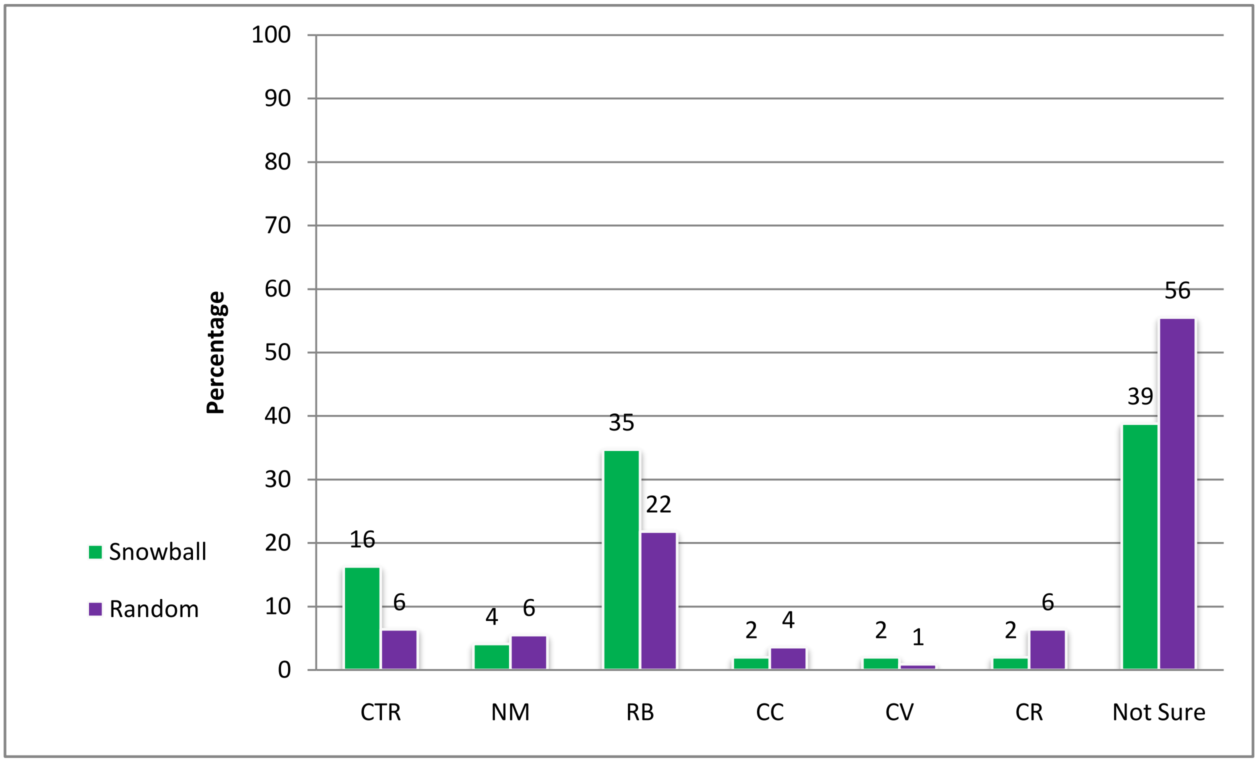
Percentage of non-farmer respondents who listed each BMP as best at reducing nutrient runoff. Random and Snowball refer to survey methods in Table 1. BMP abbreviations are as found in Table 1.

FIGURE 21: NON-FARMERS OPINIONS ON WHICH BMP IS BEST AT REDUCING RUNOFF WITH COST AS A CONSIDERATION



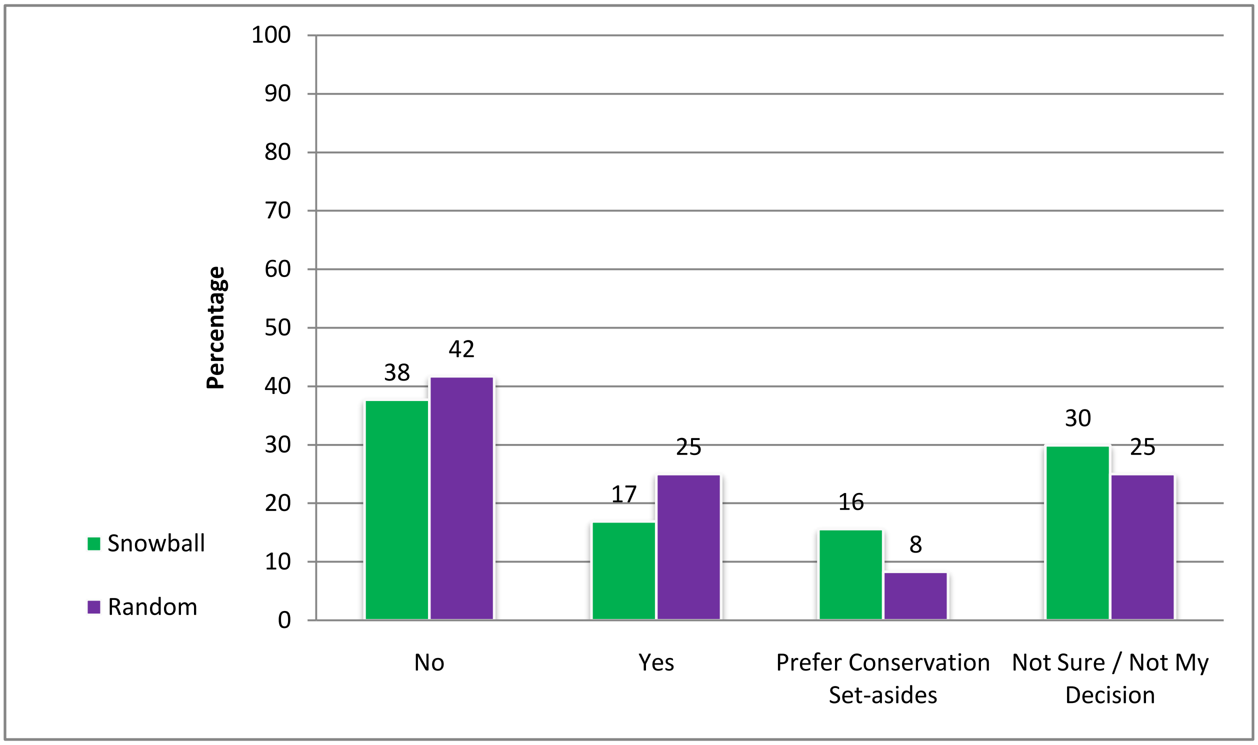
Percentage of non-farmer respondents who listed each BMP as the best for the watershed when the overall cost of the BMP is considered. Random and Snowball refer to survey methods in Table 1. BMP abbreviations are as found in Table 1.

FIGURE 22: NON-FARMERS OPINIONS ON WHICH BMP IS BEST AT REDUCING RUNOFF CONSIDERING BOTH EFFECTIVENESS AND COST



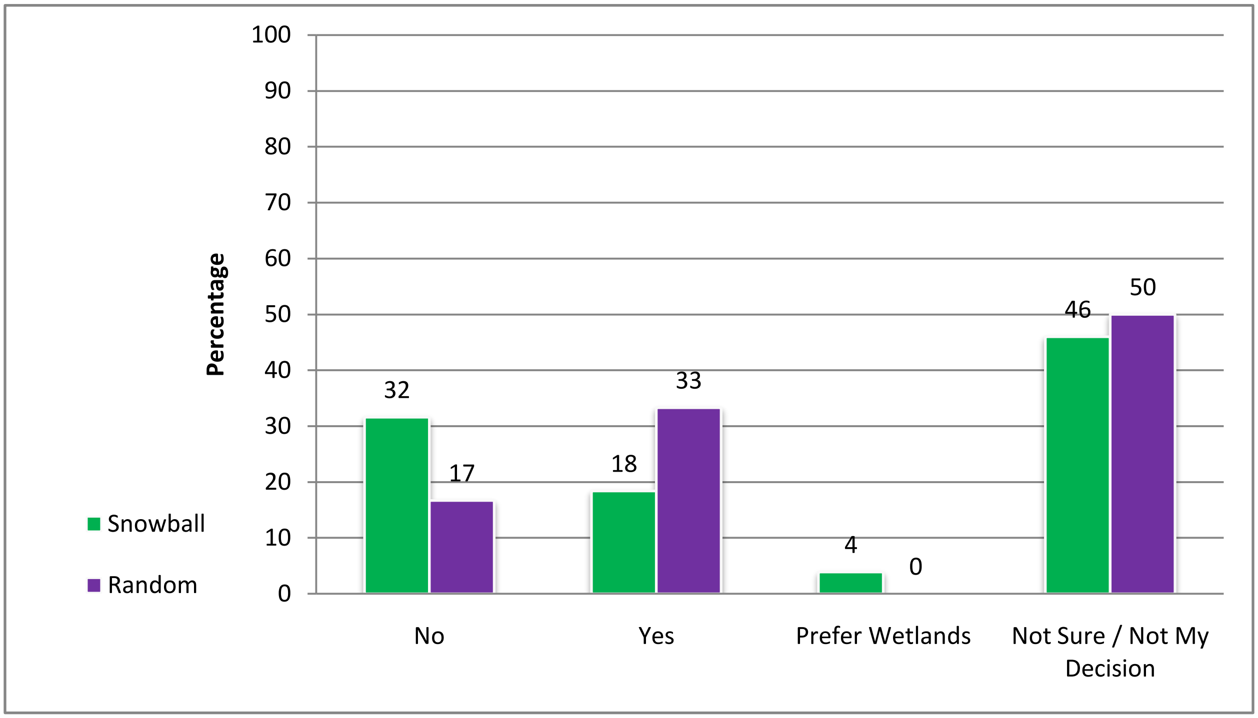
Percentage of non-farmer respondents who listed each BMP as best for the watershed when factoring in both cost and effectiveness at reducing nutrient runoff. Random and Snowball refer to survey methods in Table 1. BMP abbreviations are as found in Table 1.

FIGURE 23: FARMER WILLINGNESS TO INSTALL WETLANDS ON THEIR FARMS



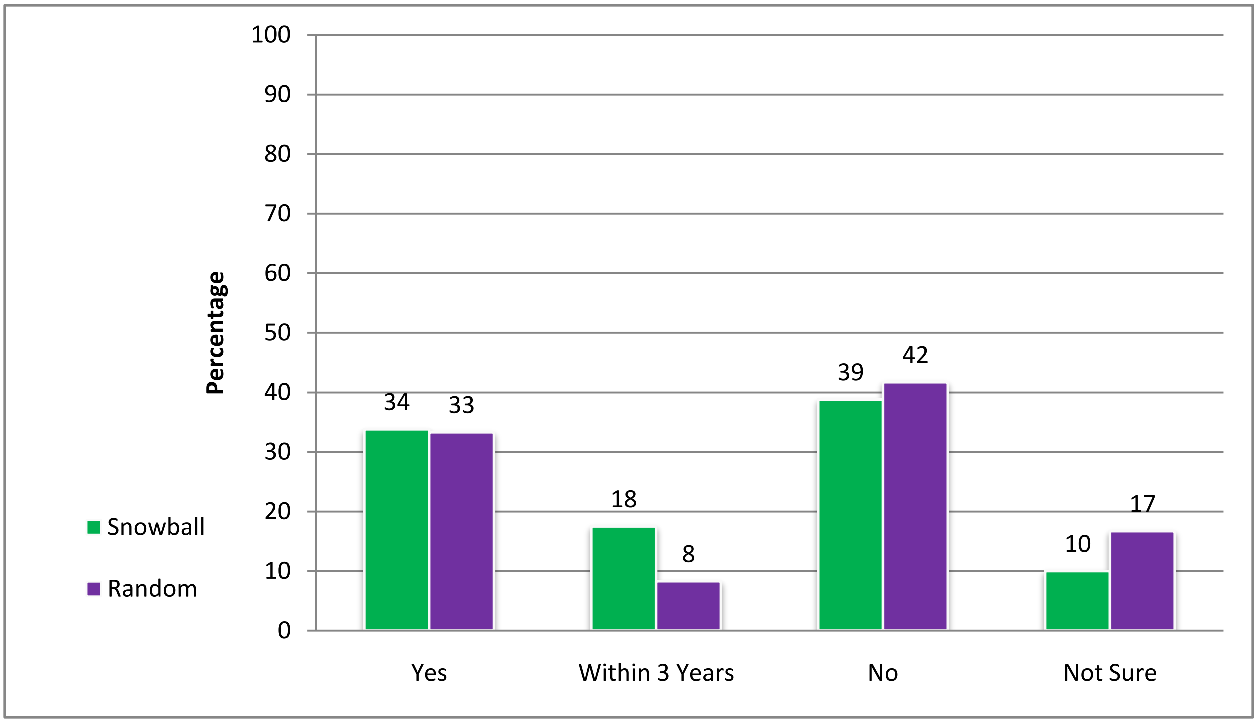
Percentage of farmer respondents who listed their willingness to install wetlands on their farms if provided with free installation and rent. Random and Snowball refer to survey methods in Table 1.

FIGURE 24: FARMER WILLINGNESS TO INSTALL CONSERVATION SET-ASIDES ON THEIR FARMS



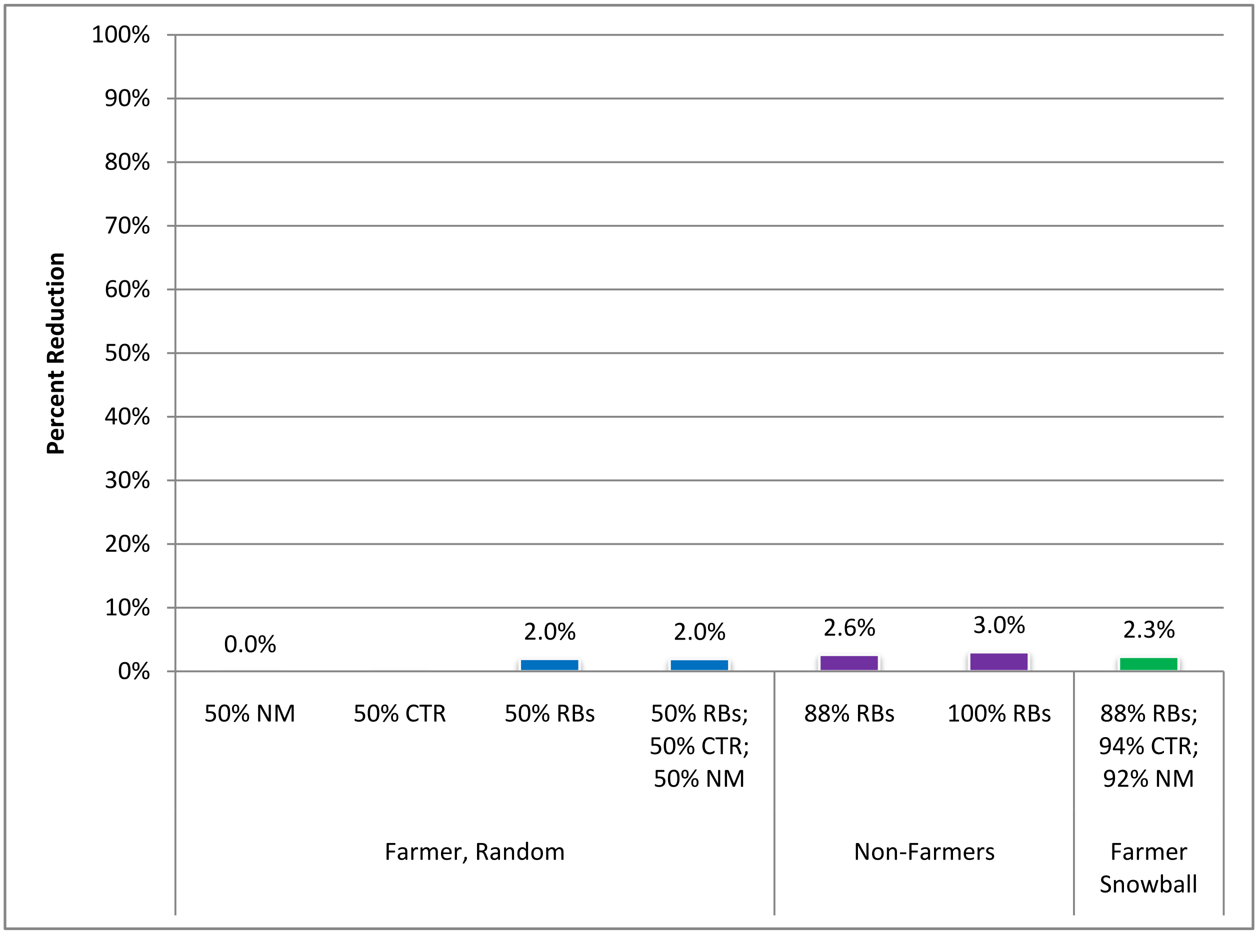
Percentage of farmer respondents who listed their willingness to install conservation set-asides on their farms if provided with free installation and rent. Random and Snowball refer to survey methods in Table 1.

FIGURE 25: FARMER USE OF GPS ON THEIR FARMING EQUIPMENT



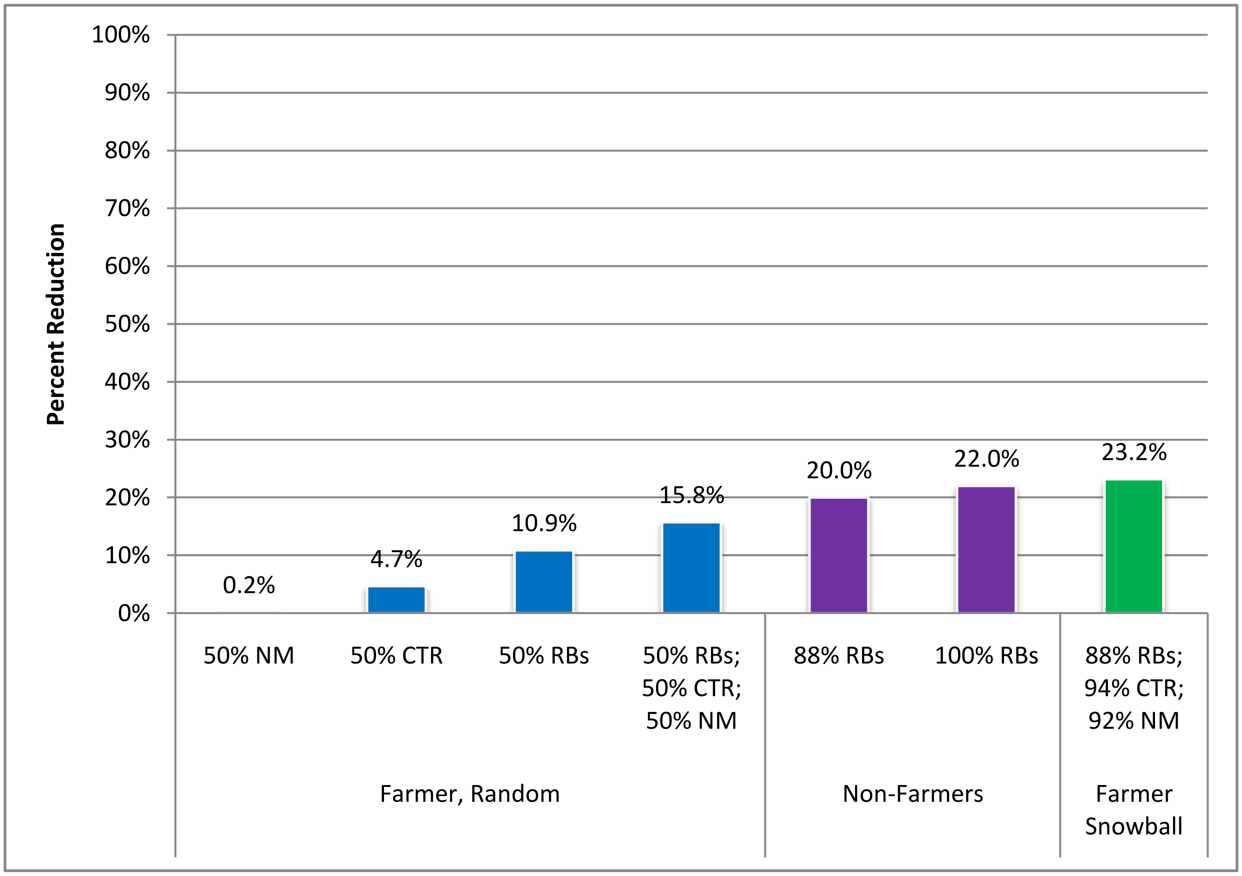
Percentage of farmer respondents who listed their current or intended use of GPS on their farming equipment. Random and Snowball refer to survey methods in Table 1.

FIGURE 26: PERCENT REDUCTION IN SUSPENDED SEDIMENTS FROM THE BASELINE SCENARIO FOR EACH STAKEHOLDER PREFERENCE SCENARIO ACCORDING TO SWAT



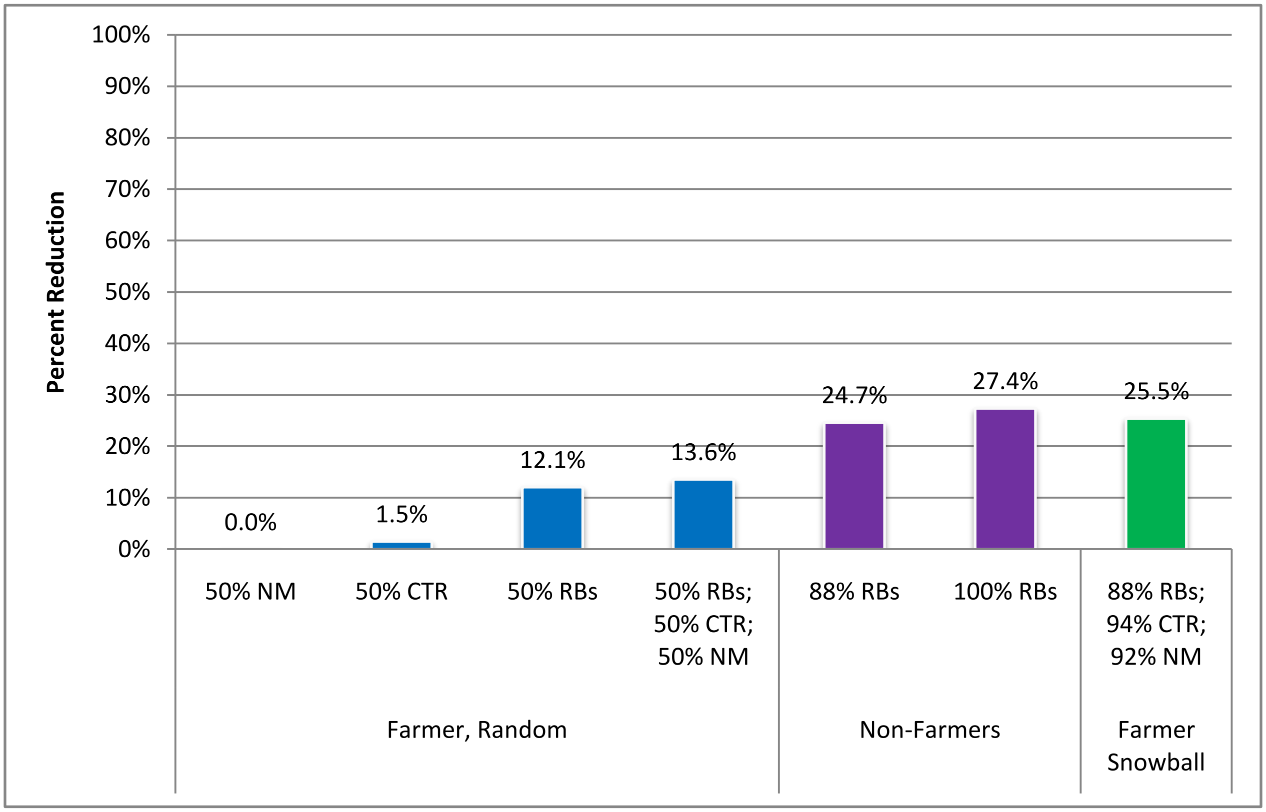
Percent average annual load reductions in suspended sediments relative to Baseline Scenario, in BMP scenarios studied. Percentage for 50% CTR is not shown as it resulted in a slight increase in suspended sediments. All BMP abbreviations are as found in Table 1. Scenarios are as in Table 12.

FIGURE 27: PERCENT REDUCTION IN TOTAL PHOSPHORUS FROM THE BASELINE SCENARIO FOR EACH STAKEHOLDER PREFERENCE SCENARIO ACCORDING TO SWAT



Percent average annual load reductions in total phosphorus relative to Baseline Scenario, in BMP scenarios studied. All BMP abbreviations are as found in Table 1. Scenarios are as in Table 12.

FIGURE 28: PERCENT REDUCTION IN TOTAL NITROGEN FROM THE BASELINE SCENARIO FOR EACH STAKEHOLDER PREFERENCE SCENARIO ACCORDING TO SWAT



Percent average annual load reductions in total nitrogen relative to Baseline Scenario, in BMP scenarios studied. All BMP abbreviations are as found in Table 1. Scenarios are as in Table 12.

APPENDIX 1

Dear Friend of the River Raisin Watershed:

The School of Natural Resources and Environment at the University of Michigan is working to better understand the resource management preferences of people who live, work, or recreate in the River Raisin watershed. Currently, **Best Management Practices** (BMPs) are being implemented in the River Raisin watershed, the goals of which are to reduce agricultural runoff into the river. However, little is known about public opinion towards these BMPs.

Attached to this letter is a survey designed to allow people like you who benefit from the River Raisin watershed to make their opinions known, confidentially, about resource management in the watershed. The survey asks you about several BMPs and which, if any, you believe should be implemented. The information generated from this survey will increase our understanding of how the preferences of the public can be incorporated into watershed management decisions. For your convenience, a brief definition of each BMP can be found on the back of this page.

Most people are able to complete the survey in less than fifteen minutes and we are asking that you return your survey in the attached envelope by August 15th, 2008. Your individual responses and comments will be anonymous and treated with utmost confidentiality, therefore your candid and thoughtful responses are greatly appreciated. Even if you have never heard of a BMP, your responses are important.

After the survey responses are analyzed, we will create a report containing the general preferences from all completed surveys and the results of the analysis we have performed. Once completed, the report will be distributed to organizations involved in BMP implementation in the River Raisin watershed and will be available online for free to the general public at: http://sitemaker.umich.edu/currielab/nic_enstice

Thank you in advance for your time and should you have any questions about the survey or the study it is a part of, please feel free to contact me via e-mail (riversurvey@umich.edu), phone, or regular mail (contact information is below).

Sincerely,

Nic Enstice

E-mail address: **riversurvey@umich.edu**
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Best Management Practice (BMP) Definitions

Conservation tillage / Residue management – Crop residue from the previous crop is left on the field, onto which the new crop is planted utilizing a minimal to no-till system.

Nutrient management – Utilizing soil testing to determine the optimal amount and type of fertilizer necessary for the crop to be planted. Often used in manure application systems.

Riparian buffers / Grass filters – Strips of vegetation, either along the banks of waterways (riparian buffers) or at the edge of a field (grass filters) that slow surface water runoff.

Contour cropping – The practice of planting rows of crops following the curve of a hill, where the entire row is at the same elevation.

Cover cropping – Planting a crop in a field to provide soil cover during periods of cash crop inactivity, either over winter, between summer crop rotations, or during longer fallow periods.

Crop rotation – Changing the variety of crops that are grown in a field each successive growing season, often in a corn – wheat – soybean cycle.

Conservation set-asides – Active cropland or pastureland which is removed from active farming and allowed to go fallow, often for 10 to 15 years.

River Raisin Survey

1. Please circle the number that best corresponds with how familiar you are with each of these Best Management Practices (BMPs) for reducing agricultural nutrient runoff:

Conservation Tillage / Residue Management . . .	0	1	2	3	4
Nutrient Management	0	1	2	3	4
Riparian Buffers / Grass Filters	0	1	2	3	4
Contour Cropping	0	1	2	3	4
Cover Cropping	0	1	2	3	4
Crop Rotation	0	1	2	3	4

0 = Not Sure
1 = Unfamiliar
2 = Somewhat Familiar
3 = Familiar
4 = Very Familiar

2. What is your relationship to the River Raisin Watershed (Please check all that apply):

Farmer (Owner)*	Farmer (Renter)*	NGO Employee**	Government Employee**	Recreational User of River**	Local Resident**
O	O	O	O	O	O

*** If you checked farmer, please continue to Question 3.**

**** If you did *NOT* check farmer, please continue to Question 9.**

3. How many acres do you farm? ______________

How many years have you farmed some or all of your land? ______________

Approximately what percentage is presently dedicated to BMPs: _______%

What crop(s) /livestock do you most often grow/raise on your farm? (Check all that apply):

Wheat	Corn	Soybeans	Vegetables	Livestock	Other
O	O	O	O	O	_________

4. Based on your familiarity with these BMPs, to what extent would you be willing to use them on the land you work if provided with full technical support and supplies?

Conservation Tillage / Residue Management	0	1	2	3	4	5
Nutrient Management	0	1	2	3	4	5
Riparian Buffers / Grass Filters	0	1	2	3	4	5
Contour Cropping	0	1	2	3	4	5
Cover Cropping	0	1	2	3	4	5
Crop Rotation	0	1	2	3	4	5

0 = Not My Decision
1 = Not Sure
2 = Not Willing
3 = In Use
4 = Partially
5 = Fully

5. How many wetlands would you be willing to install on your lands if provided 100% reimbursement and paid $100 per acre each year in rental fees?

- None
- Wetlands: #_______
- I prefer conservation set-asides
- Not sure
- Not my decision

6. How many conservation set-asides would you be willing to install on your lands if given 100% reimbursement and paid $100 per acre each year in rental fees?

- None
- Conservation set-asides: #________
- I prefer wetlands
- Not sure
- Not my decision

7. Do you currently use GPS and auto-guide systems in your tractors?

- Yes
- No, but I plan on using these systems within the next 3 years
- No, I do not plan on using these systems within 3 years
- Not sure

8. Do you participate with local Soil and Water Conservation Districts and/or NRCS on your lands?

- Yes
- No
- Not sure

Please continue on to Question 10

9. The BMPs listed in Question 1 have different impacts on agricultural runoff and on a field's production, as well as differing costs of installation and maintenance. Based on your familiarity with the BMPs, in your opinion which of these BMPs do you think is:

(A) Overall the best for reducing agricultural runoff (Please check only one)

Conservation Tillage/ Residue Management	Nutrient Management	Riparian Buffers/ Grass Filters	Contour Cropping	Cover Cropping	Crop Rotation	Not Sure
O	O	O	O	O	O	O

(B) Overall the best based on cost considerations (Please check only one)

Conservation Tillage/ Residue Management	Nutrient Management	Riparian Buffers/ Grass Filters	Contour Cropping	Cover Cropping	Crop Rotation	Not Sure
O	O	O	O	O	O	O

(C) Overall the best compromise between (A) & (B) (Please check only one)

Conservation Tillage/ Residue Management	Nutrient Management	Riparian Buffers/ Grass Filters	Contour Cropping	Cover Cropping	Crop Rotation	Not Sure
O	O	O	O	O	O	O

****Please continue on to Question 10****

10. To what degree do these sources help inform you on BMP's?

	Not at all				Very Much
National/Local News	1	2	3	4	5
State/Federal Government Employees	1	2	3	4	5
Non-profit Organizations	1	2	3	4	5
Formal Education	1	2	3	4	5
Community Members	1	2	3	4	5
Fellow Farmers	1	2	3	4	5

Other: ______________________________

11. How polluted do you think the River Raisin is?

Unpolluted				Very Polluted
1	2	3	4	5

12. How much of a threat do you think each of these is to the River Raisin's water quality?

	Not at all				Very Much
Urban Pollution (e.g. storm water)	1	2	3	4	5
Water Demand (Urban or Agricultural)	1	2	3	4	5
Failed Septic Systems	1	2	3	4	5
Urban Landscaping	1	2	3	4	5
Agricultural / Animal Waste Runoff	1	2	3	4	5
Golf Courses	1	2	3	4	5
Sedimentation	1	2	3	4	5
Dams	1	2	3	4	5
Industrial Runoff	1	2	3	4	5
Tourist Activities	1	2	3	4	5
Urban Sprawl	1	2	3	4	5

Other threats: ______________________________

13. Where applicable, please state the township(s) in the River Raisin Watershed where you:

Live:__________________ Work:__________________ Recreate:______________________

__________________ __________________ ______________________

Please add any comments: ____

____

____

____

____

____

____

Thank you very much for participating in this survey!

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