An Assessment of the Decision-Making Processes and Ecological Effects of Stream bank Fencing Projects in Berks County, PA

I. INTRODUCTION

Stream bank fencing, also known as cattle exclusion, is a type of Best Management Practice (BMP) that is utilized in order to minimize the negative impacts of agricultural areas on riparian health. Specifically, stream bank fencing provides a barrier between livestock bearing farmland and nearby waterways, which results in a vegetated buffer between farmland and streams. Theoretically this should result in reduced erosion and nutrient pollution, and also should improve the water quality of the area. In recent years, Berks County and its neighboring counties have implemented programs to encourage local farm owners to implement stream bank fencing on their property in an effort to maintain a safe water supply in an intensely agricultural area. This project is twofold, as we will 1) be analyzing the decision-making process and means of implementation from organizations and individuals involved in stream bank fencing in Berks County 2) we will be determining the relative effects that stream bank fencing has on riparian health compared against a control site stream from Lebanon County, and whether the results of implemented fencing align with the initial goals of the project.

II. BACKGROUND INFORMATION

Environmental Effects of Cattle

More than 330 million acres of agricultural land in the United States is responsible for the production of countless amounts of crops, and animal products. In the U.S., livestock cultivation brings in billions of dollars in revenue per year, and with over 14.6 million large grazing animals such as 1,200 pound cows, there is a high risk of damage to the environment (Agouridis, et al. 2005). The adverse effects of agricultural practices are taking a toll on water sources, especially

those located on farms (EPA 2014). It is estimated that at least 80 percent of damage to streams and riparian systems derive from grazing livestock (Agouridis, et. al 2005). These riparian zones support a variety of aquatic organisms that depend on this area for survival and assist in the cycling of the nutrients (Aarons and Gourley 2012). When the livestock disturb this cycle, this causes changes to the ecosystem's processes.

Livestock, particularly cattle, consume 28.5 pounds of biomass in the form of plant matter and water on a daily basis (beef.unl.edu). When excreted, nutrients from the plant matter not only affect the soil and hydrology, but the high concentrations of pathogens such as *fecal Streptococci, Escherichia coli and Salmonella* present in their waste can have a harmful effect on the health of animals and humans (Aarons and Gourley 2012). Moreover, improper control of grazing of riparian areas can contribute to nonpoint source pollution through manure and urine of livestock, which can elevate the levels of nutrients in the waterways (Hoorman and McCutcheon n.d.). Researchers found that the livestock defecate 50-60 times more in the streams than on the land, especially in the riparian zone of the river (Aarons and Gourley 2012).

When crossing or drinking from streams, livestock tend to trample the stream banks, which alter the natural shape of the stream and increase the risk of erosion. The hoofs of cattle exert a great amount of pressure to the riverbank and subsequently cause increases in runoff and decreases in the infiltration process of the water into the soil. This can diminish the livelihood of organisms that are vital for the soils such as earthworms and microbes (Aarons and Gourley 2012). Additionally, disturbance by the cattle is often not equally distributed across the entire stream area, which creates more issues to the soil’s overall health such low oxygenation and low hydraulic conductivity (Aarons and Gourley 2012).

In addition, livestock also tend to overgraze and eat vegetation along the banks, reducing the ability for the plants to survive and reproduce (Hoorman and McCutcheon n.d.). Native plants are important for protecting the water quality by reducing erosion, filtering sediment, and capturing the excess nutrients from the runoff (Washington State Department of Ecology). Overgrazing to these areas may result in a disturbance great enough to allow for invasive species to take hold. Overhanging vegetation also provides shade and cools the stream, and its removal leads to higher stream temperature which has a negative impact on fish and native aquatic life (Hoorman and McCutcheon n.d.).

Unrestricted livestock access to pastoral stream riparian regions has been known to be detrimental to the stream's water quality. This occurs through the alteration of elemental and nutrient composition (*i.e.* nitrate, chloride, silica, etc.), water quality and hydrology, channel morphology, and plant community composition through time (Miller et al., 2009 & Vidon et al, 2008). This is a result of a combination of direct deposit of fecal material, increased runoff of fecal material from surrounding land, and increased erosional forces and sediment deposition due to livestock trampling (Miller et al., 2009).

The physical deterioration of the stream bank results in an alteration of hydrology through increased discharge of the cow's excretions and excess nutrients, which then further facilitates the diffusion of discharge and has the potential to alter channel depth and morphology. This increased discharge acts in concert with cattle trampling to exacerbate erosional forces and yield increased nutrient loads, sediment deposition and particulate concentration (turbidity) (Miller et al., 2009 & Vidon et al, 2008). Extensive grazing as a function of livestock access creates barren ground void of a developed plant community, and this destabilizes the soil around

the stream bank through the decrease in root mass further increasing runoff and discharge, erosional forces and sediment loads into the channel.

Stream bank Fencing as a BMP

The term best management practice (BMP) can best be described as a way to control both point source and non-point source pollution, which often occurs through a variety of different ways, in order to help improve land, air, and water quality in a sustainable manner. There are a variety of possible BMPs that may be used by farmers in the agricultural industry, which include the following: animal grazing management, erosion and sediment control, and animal feeding operations (Best Management Practices). Of the three, animal grazing management is the most relative to our study, in that, stream bank fencing, also referred to as cattle exclusion, and is a type of animal grazing management which restricts livestock access along riparian zones. This type of BMP is created by strategically installing fencing around a riparian zone in an attempt to facilitate riparian recovery by controlling the movements of livestock relative to the location of streams. Stream bank fencing has been known to decrease the degradation of water quality variables (*i.e.* increased nitrate, chloride, turbidity) downstream of the fenced area. This decrease is due to the fact that the fence limits the livestock's access to the riparian buffered area and the stream. This restricted access benefits the stream because the livestock aren't able to trample the stream bank or defecate into the river. Through restricting livestock access to the riparian areas, the buffering and filtration capacity of the riparian zone and adjacent land are increased through creation of a diverse, native vegetation community. This stabilizes the bank structure with root mass, which in turn decreases erosion and the impact of harmful deposited chemicals from runoff (Miller et al., 2009).

Stream bank fencing is a straightforward, low maintenance, cost-effective way to reduce the adverse effects of agriculture on nearby streams (Pennsylvania Associate of Conservation Districts, Inc. 2009). The installation of fences and crossings help control the livestock's path when grazing and creates an access point for the livestock to drink water along the stream. This aids in reducing the trampling of the stream banks, reducing erosion, preventing extinction of native vegetation and improves the overall water quality of the stream. Other benefits include the improved health of the livestock and the farm's aesthetics (Pennsylvania Associate of Conservation Districts, Inc. 2009). When cows walk into the stream, they are at risk for coming in contact with waterborne bacteria which can cause illnesses such as *Gangraena emphysematosa* (blackleg) and mastitis. Thus, reduced access of the cattle to the stream can promote herd health. In terms of the farm's aesthetics, the vegetation buffer is a mixture of different vegetation, which can benefit the appearance of the farm's landscape

Local Stream bank Fencing Projects

Berks County is an area of Pennsylvania that is intensely agricultural; it ranks third in the value of farm products sold in the state. In addition, with 1,568 farms, it also ranks third for the most farms out of all the counties in Pennsylvania (Southern Berks Region Comprehensive Plan, n.d). and thus the environmentally detrimental effects of raising livestock are well known. In recent years, local environmental organizations have been working with local farmers to increase the implementation of stream bank fencing in order to improve water quality throughout the area.

In a phone interview, Jeff Overstreet, agricultural resource conservationist with the Berks County Conservation District, indicated that the two main reasons that stream bank fences are implemented are to create cattle exclusion and to act as a riparian buffer (J. Overstreet personal

communication, 2015). Two of the most common stream or pond pollutants include nitrate and phosphate. In most instances, nitrate comes from cattle waste, which also holds a negative charge, resulting in non-adherence to soil (J. Overstreet personal communication, 2015). Overstreet referenced a recent study done by Bernard Sweeney and Denis Newbold, who are research scientists with the Stroud Farm Research Facility (The Berks County Conservancy has signed a contract with the Stroud Farm Stewardship Program in order to work in conjunction to provide incentives to farmers willing to install stream bank fences). Their research shows that at a distance of 150 feet from the edge of the riverbank to the fence 90% of the nitrate is absorbed, while at 35 feet only 45% of nitrate is absorbed (Sweeney & Newbold 2014). Overstreet also went on to further explain how a minimum of 35 feet is required by relevant policies in any buffer that is created, which is the main reason that percent absorption was calculated at this distance (J. Overstreet personal communication, 2015). All in all, Overstreet argues that a buffer of 35 feet really doesn't adequately filtrate the run-off of nitrate into the stream. Overstreet also makes the point that farmers do not want to give up any of their land at all because of several factors. Some believe that they are simply giving up their own land that is part of their personal property, while others truly believe that this buffer area is truly productive in growing crops although this is not the case. From this study we see that a buffer area of greater than 35 feet is ideal, more specially up to 150 feet, although 35 feet is more of a compromise made between organizations like the conservation district and the farmers. It is likely that new policy recommendation should be made regarding a distance that could filtrate higher than 55% of nitrate concentrations, while still being in agreance with the farmer's wants.

Through the Stroud Farm Stewardship Program, stream bank fencing can be implemented through the Conservation Reserve Enhancement Program (CREP). This program, created by the

Farm Service Agency, provides up to 100% reimbursement to farmers (FSP Brochure). Additionally, every acre that is buffered along a stream results in a $4,000 voucher provided by the Pennsylvania Department of Environmental Protection. This voucher can be used by the farmers to install other best management practices on their land. These practices include both barnyard runoff, storage, and other nutrient reduction practices (FSP Brochure). Aside from this voucher, additional payments are made on a yearly rate for the "rental" of the land used to create the buffer zone located from stream bank to fence. The terms of the voucher include a 15 year contract between the Farm Service Agency and the farmer (J. Overstreet personal communication, 2015).

One other aspect of the contract can be seen in the physical movement of cattle in relation to the stream. It is noted, under chapter 102 of the Clean Streams Law, that cattle must be given access to a stream as a source of drinking water (103.2. Compliance & Enforcement Provisions). Although this is true, according to Overstreet, when a farmer signs a contract with the NRCS the cattle are not permitted in the buffer area at all, but rather cattle are provided with a permanent alternative drinking water source (Overstreet personal communication, 2015). This source is most often seen in the form of a portable water supply trough.

Decision Making Processes

Since stream bank fencing technology potentially provides many benefits toward farmers, livestock, and the environment as a whole, a New Zealand study looked at what may affect the farmer's decision-making process on implementing the fences. They specifically assessed why

some farmers participate and others do not consider stream bank fencing. A farmer's reluctance to participate in new agricultural practices, such as stream bank fencing can be difficult to predict (Bewsell and Kaine, 2005). On the social side of any best management practice, there can be economic, political, and psychological factors that influence decision making.

The psychological aspect of decision making has been observed in the consumer behavior theory. In this theory, Bewsell and Kaine (2005) hypothesized the decision processes that farmers make when purchasing products. This process depends on several factors that include the importance of the purchase and the time and effort made when making the decision. High involvement is associated with purchases that are important to the consumers, generally expensive, and involve some form of financial, social, and psychological risk (Bewsell and Kaine, 2005). When the risks are high, there will be more time and effort required when making the decision for the purchase. Bewsell and Kaine (2005) gave examples of high involvement purchases: homes, cars, and clothing. In contrast, low involvement purchases are unimportant to the consumer, inexpensive, involve little risk and do not involve some form of financial, social, and psychological risk. There is little time and effort devoted to these purchases. They gave examples of low involvement purchases which are groceries, toiletries, and laundry products. From this information, Bewsell and Kaine (2005) hypothesized that agricultural best management practices are high involvement purchases because the technique is new, which means that the farmer has to change and adapt their own practices; this creates a high risk. It is also financially risky, because a farmer may have to invest in the technique to maintain it. The outcome of the new technology or practice is difficult to predict, which also makes it an uncertain move.

Meanwhile, certain factors relate to circumstances regarding the farmer and the farm. One factor that is thought to influence a farmer's decision to take on a project is the degree of effort the farmer is willing to invest to learn about the project (Bewsell and Kaine 2005). For stream bank fencing, costs have been cited as the main reason why farmers were not willing to fence off their streams (Bewsell and Kaine 2005). Bewsell and Kaine (2005) also reported that certain factors, such as farm size or personal income did not affect whether or not a farmer would participate in conservation practices.

Bewsell and Kaine (2005) interviewed multiple dairy farmers to identify the factors that influenced the farmer's decision to voluntarily participate in stream bank fencing. Some farmers simply did it because the stream was on their property boundary and they did not want the livestock to get on their neighbor's property. Others participated in order to prevent the cows from getting stuck in the stream. They also interviewed farmers who decided not to participate in stream bank fencing, and these farmers did not believe that the fences would benefit the livestock or the stream at all. For example, one farmer stated that the animals are hardly in the stream and only enter during the winter when they break feeding (Bewsell and Kaine 2005).

Farmers mainly volunteered to put up fences to help with controlling the livestock's path (Bewsell and Kaine 2005). Bewsell and Kaine (2005) also found similar results from other researchers and added that weed control was an issue when fencing off the streams. Before, cows were able to control the weed population when they fed, but since they cannot access the areas, the weeds are able to grow out of control. Regarding helping the environment, they found that the farmers did agree that it is important, but their participation was not strongly influenced by sustainability, instead, controlling livestock's path or property boundaries were important influences on their decision (Bewsell and Kaine 2005). Moreover, they found that the interest in

environmental practices increase if external pressures, such as penalties and fines, are made to demonstrate the use of environmental practices that continue to rise.

In another study, specifically looking at Louisiana cattle producers, Kim, et al. (2005) measured whether socioeconomic factors play a role in the farmer's decision in adopting all BMPs. By looking at the factors that affect the farmer's adoption of the BMP and understanding BMP adoption behavior, Kim et al. (2005) stated that this knowledge will help the policymakers give priority to the most effective methods in reducing water pollution. They stated that in the United States, BMPs are primarily adopted on a volunteer basis and are not mandatory because many farmers believe that the adoption will "increase costs more than discount future benefits" (Kim et al. 2005). Kim et al. (2005) collected surveys from the farmers that asked questions relating to whether or not they were using the recommended BMPs and other socioeconomic factors.

Kim et al. (2005) used a variety of factors to determine the influences of adopting a BMP. One of the factors related to the farm's size; studies show that larger farms are expected to adopt BMPs more often because of the greater tendency to utilize a variety of technologies. In addition, larger farms can reduce their average total cost by spreading the costs of the BMP over "more units of production" (Kim et. al 2005). To calculate the farm's size, they looked at the number of animals in the herd. Another factor that was considered included the sole purpose of the animals (raising for breeding, dairy or slaughter). For example, a farmer that is raising their cattle to sell privately would want to have a well-managed farm to better market the animals, thus wanting to adopt a BMP.

Whether the farm is rented or owned can also influence a decision on whether or not to implement a BMP on the farm. Studies have shown that farmers were less likely to implement a BMP on rented land (Kim et. al 2005). Kim et al. (2005) factored in how well the farmer was informed in terms of whether or not the farmers were approached by environmental conservation association such as the National Resources Conservation Service (NRCS). Having contact with these organizations will increase the adoption of a BMP; this is crucial in the decision making process of a farmer. In addition, whether or not a family member will take over a farm was another important factor, and it is shown to increase the action of adopting a BMP. Other studies that Kim et al. researchers looked at was age; older farmers were less likely to adopt a BMP because they are after the short-term goals instead of long-term benefits. Other factors included the number of crops on the farm, the land characteristics, education level, risk, and financial situation.

The results showed how each socioeconomic factor affected a farmer's decision to adopt a BMP. First, compared to renters, farmers who owned their land are more likely to adopt a BMP. Kim et al. (2005) states that policymakers should give economic incentives towards renters, which would serve as motivation. Also, contrary to the earlier studies, they found that the larger farms were less likely to adopt a BMP, which was explained by the fact that they may not see the BMP as greater profit (Kim, et al. 2005). In addition, when considering the purpose of the animals, Kim et al. (2005) found that farms that temporarily owned the animals for sale were less likely to adopt a BMP than dairy farmers that own the cattle longer. Considering age, education level, and contact with other organizations, older farmers, farmers with a higher education level and farmers who were in contact with an organization were more likely to adopt a BMP.

When looking at the influence of environmental companies, such as Natural Resources Conservation Services (NRCS), they found that it had a large, positive impact on the adoption process. Having a family member taking over a farm did in fact increase the adoption of a BMP, but only with livestock exclusion. Interestingly, when compared to previous research, age had a different result. Older farmers were found to care more about maintaining and conserving the land and saw BMPs as a retirement hobby (Kim, et al. 2005). The factors of education level, risk, and financial situation were the expected impacts on adoption of BMPs: the more education, the greater chance of adopting; farmers that saw the BMPs as risky were less likely to adopt; and farmers with more financial resources also more likely to adopt (Kim, et al. 2005).

III. THEORIES AND HYPOTHESES

Decision Making Process

We hypothesized that the decision making process of the farmers will be influenced by incentives. Specifically, we expect the farmers to report incentives as a very strong reason for implementation of stream bank fencing. We believe this will be the case because many farmers may not value the environmental benefits associated with stream bank fencing. It is also possible that the farmers will not believe that the fences will benefit the livestock or the stream (Bewsell and Kaine 2005). Therefore, the farmers may only recognize the benefits provided by incentives as opposed to benefits such as improvements to stream health, livestock health, and the farm's aesthetics (Pennsylvania Associate of Conservation Districts, Inc. 2009).

We also hypothesized that factors such as state environmental health requirements and federal legislation will influence, which streams to target for the implementation of stream bank fencing. We expect that the organizations will report that EPA standards and other environmental regulations are very strong reasons to implement stream bank fencing. We believe

this will be the case because the environmental organizations may use these standards as a means of identifying which streams are in most need of stream bank fencing. Organizations may also pursue stream bank fencing in order to help farmers meet the water quality standards set by the Clean Water Act (Meals, 2001).

Finally, we hypothesize that the decision making process used to select land for the implementation of stream bank fencing will be a top-down process. That is, the decision to implement stream bank fencing will be initiated at the government and non-profit organization level rather than at the level of the farmer. We expect respondents to report that the organizations contacted the farmers about stream bank fencing more frequently than reporting that the farmers contacted the organizations about stream bank fencing. We believe that this will be the case because the environmental organizations will be more interested in environmentally friendly projects than the farmers. As stated earlier, "There is an ideological component behind farmer's unwillingness to simply give the government their land because they fear it."(J. Overstreet personal communication). This fear may deter individuals from initiating the implementation of stream-bank fencing on their land. The ideologies shared by many local farmers are contrasted by farmers in New Zealand who reportedly volunteered to implement stream bank fencing because of the benefits to the environment and livestock (Bewsell and Kaine 2005).

Variables not included in study

Variables such as the age, financial situation, and education level of the farmers were also thought to impact the decision making process (Kim et. al, 2005). For instance, (Kim et. al, 2005) found that younger farmers were more likely to pursue long term goals than older farmers. We also expect that farmers who owned their land would be significantly more likely to invest in

BMP's than those who rent their land (Kim et. al, 2005). Additionally, variables such as number of crops, land characteristics, and livestock use (i.e. whether cattle were used for dairy, slaughter, or breeding) were also thought to influence the decision making process (Kim et. al, 2005). These variables were not investigated due to time and resource restraints. For instance, our study was dependent on the availability of farmers. The time available to meet with the farmers was particularly limited due to the fact that our study took during the beginning of the growing season. Also, we wanted the study to focus strictly on the decision-making process, so these other variables were less important for this particular study.

Ecological Effects

We expect the ecological outcomes of the management plan to match the goals of the project. Palmer et al. (2005) describes a well-organized and efficient way to set our goals and assess them. Since river restoration's value is ecological, unlike building a business or improving a road, it should be distinguished from other types of improvement. In the ideal situation, projects that satisfy stakeholder needs and advance the science and practice of river restoration (learning success) could also be ecological successes (Palmer et al., 2005). Their first step is to view what a healthy river at that site should look like. They argue for the river to be the least degraded as possible in order to be successful rather than try to restore a river to an unreachable standard such as it might have been previously (Palmer et al., 2005). Their second step is that undisturbed or restored sites can be used as references to base restoration on (reference standard sites). The last step that we used is their third step in which an analytical approach will be used. Our analytical approach will break down the problem into separate manageable elements in order to study it such as separating the social and natural sciences. Using these three steps, our goals

included measuring the success of stream bank fencing on the health of the riparian floodplain found in agricultural sites.

Ecologically successful restoration will induce measurable changes in physicochemical and biological components of the target river or stream that move towards the agreed upon guiding image (Palmer et al., 2005). Improved water clarity and quality are signs of ecological recovery and the returning health of a riparian floodplain. By implementing crossings and fencing this will increase vegetative growth along the waterways. This buffer would help to reduce soil erosion, absorb excess water and nutrients, and control runoff. We believe that this would increase the quality of the water in the stream, farm, and ultimately the watershed. The incentives from the social aspect and increase in water quality would benefit the farmer through financial and material gains, such as a boost in livestock health. The reduction of pollution into the streams would put less pollutant pressure on the watershed thus benefiting those who live within it as well. Resilience is an essential factor in successful restoration of streams and rivers. Rivers and ecosystems change due to constant changes by both humans and natural factors. A resilient stream bank is one that has the capacity to recover from rapid change or stress (Folke et al., 2002). A degraded stream is one that is characterized by a major reduction in variability in biodiversity and temporal variation (Channel alignment, levels of productivity). Unless some level of resilience is restored, projects are likely to require on-going management and repair, the very antithesis of self-sustainability (Palmer et al., 2005).

We tested whether or not stream bank fencing is improving resilience in areas where it is found by comparing the sites with it present to our control. Also the time that the fencing was installed will increase the resilience compared to one where fencing is more recent. This will affect the variability of plant species on the buffer and the water quality. The variability present

would be a measurement of if this action is occurring or not. The theoretical tools we used to test resilience within the buffer are structured scenarios and active adaptive management (Folke et al., 2002). Structured scenarios are different visions of the future for our project. Active adaptive management views policy as a set of experiments to test resilience. Testing nitrate, nitrite, dissolved oxygen, and plant species abundance are examples of what we have done to do that. The independent variable for this is the presence of stream bank fencing with and without the presence of cows and the dependent variables are vegetative growth and water quality parameters.

IV. METHODS

Decision Making

In order to gather information about the decision making process behind the stream bank fencing projects, we interviewed both farmers who accept the implementation of the project as well as individuals working for local environmental groups involved in advertising and educating the community about stream bank fencing as well as installation of the fences. Although it would have been optimal to interview farmers who did not accept the implementation of stream bank fencing, we were not able to contact said farmers. Because the organizations had a hard time contacting the farmers initially and talking to them about stream bank fencing, this made it very hard for us to contact farmers who were already resistant and did not have stream bank fencing on their land. It would have been interesting to receive information about reasons farmers did not implement fencing against those who did implement, but the interview time was very limited due to the farmers' busy schedules. The organizations we interviewed included the Berks Conservancy, Berks County Conservation District, the Schuylkill Action Network and the Pennsylvania Department of Environmental Protection. The questions within the questionnaire

gathered information regarding the decision making process behind the implementation of stream-bank fencing on agricultural lands. Two different questionnaires were utilized for each different sampling frame.

There are two different Sampling frames. Sampling frame A consisted of farmers located in southeastern Pennsylvania who had stream bank fencing installed on their property. Questionnaire A for the farmers was conducted on site through verbal conversation and was written down by a NIH certified member of the interview team (all members of the team are NIH certified). Questionnaire A (located in Appendix II) consisted of eight questions. Two of the eight questions, are answered through a Likert Scale but the rest required a qualitative response. Since the farmers were contacted through the organizations that previously worked with them, only farmers who have implemented stream bank fencing were interviewed. Sampling frame B consisted of the aforementioned environmental groups involved in the implementation of stream bank fencing on agricultural lands in southeastern PA. Questionnaire B (located in Appendix III) was also mainly qualitative; however, one question was answered via a Likert scale. We have contacted many environmental groups, which lead us to the farmers they have worked with to implement stream-bank fencing, ensuring that the organizations and farmers have previously collaborated on this project. A statistical assessment for the Likert Scale data was not engaged due to the minimal amount of data received; however charts were created to display patterns in the data.

Our study consisted of two interview categories, one targeted to farmers and the other focused on the environmental organizations. Firstly, our study intended to investigate the motives behind the decision making process of farmers to implement this particular best

management practice. Second, our study investigated the decision making processes of the environmental organizations, whether it was top-down or bottom-up.

In total there were three hypotheses related to social issues regarding stream bank fencing and its implementation. In addition there was one hypothesis which related the decision making process to the ecological impacts. Hypothesis #1 focused on the decision making process of farmers and the influences on their decision to implement stream bank fencing on their land. This hypothesis was measured through responses to questionnaire A. Questionnaire A, located in Appendix II, was administered to the farmers by a team member while on-site with a representative from the environmental groups. The dependent variable is whether or not they decided to implement the stream bank fences. The independent variables include the economic incentives and educational resources provided by the organizations. Incentive is defined as a motivator for an individual to carry out an activity. Economic and educational incentives were measured through questionnaire A. Responses were measured specifically through questions 5 and 8 on a Likert scale of 1-7, 1 being a very strong reason to 7 being a very weak reason. Data results were analyzed based on the responses to qualitative questions (except for questions 5 and 8) to see if the farmers were influenced by incentives to accept the project on their land. The number of proposed farmers to interview was 5. We would have liked to interview more farmers, but we were limited in time. Due to this project research taking place in the spring months, it was the peak time of crop preparation season, and dairy farmers were very busy tending to and milking cows during the afternoon.

Hypothesis #2 focuses on the decision making process of the environmental organizations methods of selecting what streams to target and implement stream bank fencing on. We suspect that farms are likely to be influenced by federal requirements. This hypothesis

was measured through questionnaire B, which was administered through a personal interview. The dependent variable of the decision making process of the environmental organizations to choose and prioritize streams will be measured through qualitative questions on questionnaire B. The influence of the independent variable of EPA water requirements was be measured through open ended questions #4-7 on questionnaire B and more quantitatively through question #6 which measured the strength of the influence of the stream ranking system by the EPA on organizational decisions. This was measured via a Likert scale 1 being a very strong reason to 7 being a very weak reason. Through these methods, we measured what level of influence existed, if there was any influence of EPA standards on organizational decisions at all.

Hypothesis #3 evaluates the decision-making process of choosing certain land areas and implementing stream bank fences and suspects that this process is likely to occur in a top-down approach, starting with the organizations and ending with the land owner. This hypothesis was measured through questions 1 and 2 in questionnaire A as well as questions 1 and 2 in questionnaire B (as shown in Appendices II and III). The dependent variable of the type of approach was categorized as either top-down or bottom-up. The independent variable of top-down process, or "a system of government or management in which actions and policies are initiated at the highest level; hierarchical" was determined based on the cross reference of reports from both the farmers and institutions to ensure validity of response. If it is concluded that the organizations contacted the farmers more frequently than the farmers contacted the organizations, the decision making process was categorized as top-down. If it was found to be the opposite that it is more frequent for the farmers to contact the organizations first, the process would be determined be bottom-up.

Ecological Effects

We hypothesize that the implementation of stream bank fencing by farmers will positively impact riparian ecosystem health. The implementation of stream bank fencing indicates that the farmers have an interest in repairing the health of the riparian ecosystem on their property, and therefore based on this best management design would result improved riparian health. Riparian health is indicated by biodiversity and relatively healthy water chemistry for that particular environment which can be measured by pH, nitrate, nitrite and phosphorus concentration. Addressing these hypotheses guided our investigation of the decision-making process surrounding stream-bank fencing implementation and its effects on the riparian and stream ecology.

Field ecology testing was implemented in order to determine the ecological effects of stream bank fencing. Our field ecology was not used in determining if riparian health remediation was successful by the organization's standards due to lack of prior data on riparian health. Instead we compared fenced farm areas to non-fenced areas. Sampling took place at three sites corresponding to different locations provided by our contacts, all of which utilized stream bank fencing. A fourth site, the former Myerstown Reservoir, used as a communal grazing pasture, acted as a control site, which was without stream bank fencing. Sites included in this study are located within Berks and Lebanon County, PA. Through the use of handheld GPS units, coordinates of each sampling site were recorded. Within each site a suite of abiotic and biotic measurements were taken in triplicate at upstream, treatment and downstream areas. The treatment sites were locations in which stream bank fencing was utilized. Sites Farm #1 and Farm #2 were sampled along the stream continuum, upstream and downstream, which were outside of the fenced areas, as well as at midstream or fenced areas. Farm #3 had samples taken at a two treatment sites, which were both within the fenced in areas, one sample downstream, as

well as sample taken at a runoff site. Sites were sampled along the stream continuum to analyze how the variables differed along the continuum.

Abiotic variables measured at each site will include: temperature, pH, conductivity, and dissolved oxygen (DO) which will be measured utilizing an YSI standard multi-probe. Additionally, water samples were collected via drop-samplers and brought back for chemical analysis. Plant community composition will be characterized and quantified along the bank of the channel through the use of quadrats (0.25 m^2) along a 30 meter transect, measurements were taken at every 10 meters. Water samples and measures were also conducted at each of these distances. Biotic measurements will include: plant species identification and richness, individual abundance, and percent cover contributed to each species, coarse woody debris and ground cover.

Water samples collected were analyzed for nitrate, nitrite, and phosphate concentrations utilizing an YSI photometer. Turbidity was determined through the use of an YSI turbid meter. Additional pH measurements were taken using a Hanna pH meter. Statistical analysis was performed using R software. General linear models were utilized to elucidate differences between biotic and abiotic variables as a function of treatment and position in the stream. specifically a MANOVA was ran preceding protected ANOVAs. Tukey Kramer post-hoc analyses were ran to further refine variation as a function of treatment (*i.e.* farm type) and stream position (*i.e.* upstream, downstream and treatment).

V. RESULTS

Decision Making

Through questionnaires and personal interviews we sought to discover the incentives behind farmers' decisions to implement stream bank fencing on their farms, what guidelines the organizations use to determine what sites to target, and whether or not the decision-making process of choosing certain land areas and implementing stream bank fences is likely to occur in a top-down approach, starting with the organizations and ending with the land owner.

Hypothesis #1: The decision making process of farmers to implement stream bank fencing projects is likely to be influenced by incentives.

For hypothesis #1, we looked at economic incentives and educational resources provided to farmers about the process of implementing stream bank fencing on their farms. The dependent variable is the decision making process of farmers, or their reasons for deciding to implement the stream bank fences. The independent variable for hypothesis #1 is incentives, or a motivator for an individual to carry out an activity. As illustrated in Table 1 question 5, Farmer #2 and Farmer #3 all stated that the funding provided by the organization had a very strong influence (1 on the Likert scale) on their decision to implement. Farmer #1 gave two different responses, however. He stated that the funding provided by the organization had a very weak influence (7 on the Likert scale) on the decision to implement on the smaller tributary site on his land, yet, there was a very strong influence (2 on the Likert scale) of funding to implement stream bank fencing along the larger tributary on his property.

In regard to education provided, the NRCS was the most mentioned source of education regarding stream bank fencing. As shown in Table 1 question 7, all three of the Farmers said that the NRCS provided some source of information whether it was through different programs and seminars or pamphlets with information. The levels of influence that education had on the Farmers' decision making process are demonstrated in Table 1, question 8. On a scale of 1-7, 1

being the strongest and 7 being the weakest, unlike the responses regarding the financial assistance provided, there was not a strong leaning to either side. Farmer #1 stated that education had a weak influence (6 on the Likert scale) on his decision to implement. This particular farmer felt that it was a solution of "common sense" to allow his cattle to drink from the stream but not ruin the stream. On the other hand, Farmer #2 stated that education provided to him about the stream bank fencing had a moderate influence (4 on the Likert scale). Finally, Farmer #3's response indicated that the education provided played a major role in his decision making process. Farmer #3 stated that the education from the Berks Conservancy was most helpful and that it had a very strong influence (1 on Likert scale) on his decision-making process.

Hypothesis #2: The decision making process of the environmental organizations of what streams to target and work to implement stream bank fencing on farms is likely to be influenced by federal requirements.

In Table 2 "Questionnaire B", question 3 asks how sites are prioritized. Both the Berks County Conservancy (BCC) and the Schuylkill Action Network (SAN) mentioned that streams used for drinking water supply are important. The BC stated that the government designates areas that fencing should be implemented and the focus is placed on streams linked to drinking water. The BCC takes into consideration these targeted areas and then sees which one they can find funding for. The Berks County Conservation District (BCCD) declared that they do not prioritize one stream over the other. SAN mentioned that impaired streams not reaching EPA's drinking water quality standards are targeted in order to remediate them. According to the Pennsylvania Department of Environmental Protection (PA DEP) a sub-watershed approach is used to reach restoration rather than simply picking sites on impaired stream segments.

Table 2 question 5 seeks to find information regarding the use of EPA ranking system in order to prioritize streams. The BC states that the focus of remediation is based on funding. The BCCD states that funding also plays a major role in decision-making and that they work with the PA DEP to decide what areas are most important. The SAN mentioned that goals are focused on obtaining EPA drinking water standards but there was no mention of the use of the EPA ranking system. The DEP stated that they have a different method of focusing on smaller sub-watershed rather than focusing on larger regional watersheds like the EPA does. In regards to the Likert scale used in this questionnaire to scale the influence of the EPA ranking system, the BC and SAN gave no clear response while the BCCD and DEP gave a response of 2 "weak".

Hypothesis #3: The decision-making process of choosing certain land areas and implementing stream bank fences is likely to occur in a top-down manner, starting with the organizations and ending with the land owner.

Through questionnaire A, data was gathered from Farmers #1, #2, #3. The responses to the questionnaire are shown in Table 1. From the data in Table 1, all three of the farmers interviewed stated that they were approached by the organization. Both Farmer #1 and Farmer #2 stated that the National Resource Conservation Service (NRCS) talked to them about stream bank fencing. Farmer #3 did mention the NRCS; however the Berks Conservancy was the main organization that approached Farmer #3.

Questionnaire B was used to gather data from the organizations about stream bank fencing and the prioritization of streams. Table 2 displays the responses to each question on the questionnaire of each organization. For question 1, all four organizations (Berks Conservancy (BC), Berks County Conservation District (BCCD), Schuylkill Action Network (SAN), and PA Department of Environmental Protection (DEP)) responded by saying it is more frequent than

not that they approach the farmers, rather than the farmers approaching them. However, while the Berks Conservancy stated that they arrive to the farmer ready to educate and get them involved, the BCCD, SAN, and PA DEP, all mention that in the beginning it was mainly them approaching farmers, but now the word is being spread by the farmers involved to other farmers that were not aware of the process.

Ecological Effects

Species richness was marginally greater within downstream stretches of the streams regardless of treatment, peaking at an average of 3-4 species per quadrat ($F=3.26$, $P_2=0.06$) (Figure 1.). The treatment sites within the farms had comparable species richness to the upstream sites also peaking with an average of 3-4 species per quadrat. Those sites which corresponded to the farm upstream and downstream sites had the greatest total species richness totaling to 36 species (Figure 2). These sites also had the greatest amount of species which contributed to greater than or equal to 3% of area covered within the plant community. There were at least 4 invasive species (*Phalaris arundinacea*, *Microstegium vimineum*, *Lonicera japonica* and *Alliaria petiolate*). Two of the prominent invasive species identified were *M. vimineum* and *P. arundunaceae* which contributed to approximately 66% area of the plant community within those sites that were grazed and 47% within the upstream and downstream sites combined which were not grazed (Figures 2,3 & 4). The control sites which were grazed in particular had a plant community which was 100% composed of *P. arundunaceae*.

Water Quality

Almost all water quality variables (*i.e.* Nitrate, Nitrite, dissolved oxygen, pH, and turbidity) differed significantly as a function of treatment type (*i.e.* control or farm) and location

within the stream (*i.e.* upstream, downstream or treatment) (Table 3). Phosphate concentrations did not significantly differ as a function of treatment or location *(*0.28±1.43), and neither did temperature (12.7±8.1). pH varied as a function of treatment type with the control sites exhibiting significantly higher pH relative to the farm sites ($F=5.59$, $P_1=0.03$) (Figure 3). Turbidity varied as function of treatment with the control sites displaying significantly higher turbidity ($F=17.03$, $P_1<<0.0001$) (Figure 4). Turbidity also had a significant treatment and location interaction with the downstream sites corresponding to the farm treatment being significantly lower than those downstream sites corresponding to the control sites ($F=6.10$, $P_1=0.02$) (Figure 5). Nitrate (mg/L) varied as a function of treatment with the control sites displaying marginally significant lower nitrate levels than the farm sites ($F=4.073$, $P_1=0.056$) (Figure 6). The opposite pattern was displayed in nitrite levels with the controls having significantly higher nitrite when compared to the corresponding farm sites ($F=4.96$, $P_1=0.04$) (Figure 7). Dissolved oxygen (mg/L) varied as a function of location within the stream with the farm treatment sites displaying significantly higher dissolved oxygen than both the downstream and upstream sites ($F=4.18$, $P_2=0.03$) (Figure 7).

VI. DISCUSSION

Decision Making

<u>Hypothesis #1:</u> The decision making process of farmers to implement stream bank fencing projects is likely to be influenced by incentives.

Farmer #1 stated that that the funding provided by the organization had a very weak influence on the decision to implement on the smaller tributary site on his land. However, he indicated that funding had a strong influence on his decision to implement stream bank fencing

along the larger tributary on his property. It can be concluded overall that funding provided had a strong influence. Other than the response of a 7 from Farmer #1 when discussing the smaller tributary, all farmers indicated that funding provided had a strong or very strong influence on their decision to implement. This shows how important it is to have resources for the farmers to obtain financial assistance in order to implement best management practices on their land. It can also be inferred that economic incentives are very influential.

In regard to education provided, the NRCS was the most mentioned source of education regarding stream bank fencing. All three of the Farmers said that the NRCS provided a source of information through programs, seminars, or paper pamphlets. Unlike the unanimous level of influence funding had on the decision of the farmers to implement stream bank fencing, the levels of influence that education had on the Farmers' decision making process differed greatly. Farmer #1 stated that education had a weak influence (6 on the Likert scale), while Farmer #2 stated that education provided to him about the stream bank fencing had a moderate influence (4 on the Likert scale), and Farmer #3's indicated that the education provided had a very strong influence (1 on Likert scale) in his decision making process. Farmer #1 and Farmer #2 only mentioned education provided by the NRCS and both responded with moderate or lower than moderate influence of education on their decision making. In contrast, Farmer #3 mentioned the education from the NRCS, but emphasized the education from the Berks Conservancy. It is interesting to see that Farmer #3 rated the influence of education as "1-very strong" and is the only one that mentioned the help and education of the Berks Conservancy. This may lead to conclusions that although the NRCS provides education and it has some effect (no Farmers responded with a 7 "very weak influence") it is outreach and education by environmental groups from the community that may have a more effective education approach.

<u>Hypothesis #2:</u> The decision making process of the environmental organizations of what streams to target and work to implement stream bank fencing on farms is likely to be influenced by federal requirements.

Through the results it can be concluded that drinking water tributaries and funding available are the most influential variables in the decision making process of the organizations to choose and prioritize streams. Unlike the proposed hypothesis of state requirements and federal legislature having a strong influence on this decision-making process, all of the organizations interviewed declared that the EPA standards and ranking system had weak influence. The focus of the organizations was on tributaries that provided drinking water, tributaries coupled in a sub-watershed, and the funding available for the targeted streams. Therefore it can be concluded that state and federal requirements are not the most influential in the decision-making process of environmental organizations of what streams to implement stream bank fencing on.

<u>Hypothesis #3:</u> The decision-making process of choosing certain land areas and implementing stream bank fences is likely to occur in a top-down manner, starting with the organizations and ending with the land owner.

Because all three farmers stated that they were approached by an organization, rather than approaching the organizations themselves, it can be deduced that the decision-making process of choosing certain land areas and implementing stream bank fences is likely to occur in a top-down manner. That is, starting with the organizations and ending with the land owner. Farmer #1 and Farmer #2 stated that the National Resource Conservation Service (NRCS) talked to them about stream bank fencing, while Farmer #3 stated that the Berks Conservancy was the main organization that approached Farmer #3. Therefore, from the data gathered it can be reasoned

that the process is frequently conducted in a top-down manner, starting with the organizations and ending with the land owner.

The data collected from the organizations regarding the approach further supports this notion of top-down because all four of the organizations indicated that they approach farmers in order to implement this best management practice on their land. However, the BCCD, SAN, and PA DEP, all mention that word is spreading through the farmers that have implemented stream bank fencing on their farms. In the beginning it was mainly the organizations approaching farmers, but now the BCCD, SAN, and PA DEP are experiencing farmers coming to them because they were recommended by another farmer. This may indicate that stream bank fencing is viewed as a positive project by farmers because they speak well of it to their neighboring farmers and recommend it. This phenomenon may also indicate that the approach of the decision-making process of the streams on which to implement the stream bank fencing may be experiencing a transformation from a top-down approach to a bottom-up approach, where the farmers approach the organizations because they are interested in implementing stream bank fencing on their land. As hypothesized, this may be the start of an auto-catalytic process whereby initial stream restorations lead to further restorations as more farmers learn of the benefits.

Ecological Effects

Processes (*e.g.* cattle trampling and grazing) that disrupt natural plant dispersal dynamics cause species abundance and compositional changes which increase the susceptibility of a site to be colonized, often by invasive species. Although ecological disturbance is not necessary for exotic plant invasion, it has been identified as an indicator of invasion vulnerability. The unambiguous relationship between invasion prominence and disturbances has been attributed to variables within disturbed sites that pertain to resource and space availability and competition for

newly allocated resources (Huebner et al. 2008). Community-level theory predicts that most organisms are spatially discrete and are affected by other individuals within reasonable proximity. At the same time, no single species can fully occupy a site or niche, which leaves space open for other species to be recruited (Tilman, 1997). Therefore, a site's susceptibility to invasion is dependent upon interspecific interactions in relation to competition for space (Didham et al. 2005). Disturbances often have the effect of the re-allocation of site nutrients; early in the successional process these nutrients act as driving factors for competition within colonizing plant communities (Tognetti et al. 2009). Invasive species' ability to better exploit these newly allocated resources and space often results in the dominance of that invasive species throughout the system, a decrease in species richness, and the homogenization of the plant community (Adams & Engelhardt, 2008).

Those sites which corresponded to the disturbed stretches of the stream (*i.e*. those stretches which were grazed or trampled) displayed higher percentage area attributed to invasive species and as a result, lower species richness. The upstream and downstream sites combined contained a total of 44 species. The sites that were subject to grazing and cattle presence, in contrast, contained a total of 16 species. The upstream and downstream sites also displayed the least plant community cover attributed to invasive species being 47%. Those plant communities which were in contact with the livestock had 67% area attributed to invasive species. The lack of species richness within the grazed and trampled sites might be a result of the relatively greater plant community area attributed to those species that are considered to be invasive (*i.e. M. vimineum* and *P. arundunaceae*). It is important to note that the increased species richness within the upstream and downstream reaches within the farm sites might also be due to the fact

that there were a total of three farm sites sampled in terms of species richness as opposed to the control sites which only had one.

Those sites which corresponded to the stretches of the stream that had fencing on the farms also contained relatively high species richness. This could be a result of the elevated nitrate levels running off? the agricultural lands within reasonable proximity of the plant community. Most terrestrial plant communities are limited by nitrogen as a resource. Metabolic processes, leading to increase in vegetation biomass, are dependent upon adequate supplies of nitrogen. Greater nitrogen availability yields greater photosynthetic capacity and leaf nitrogen content because 75% of leaf nitrogen is found in chloroplasts and is invested in ribulose biphosphate carboxylase, the main catalyst in the reaction of photosynthesis (Cechin & Fumis, 2004). The nitrogen inputs due to the presence of the livestock and corresponding waste might also play an integral role in the increased species richness downstream of the grazing sites. This nitrogenous input would deposit downstream and further elevate nitrogen availability to those plant communities.

The control sites which corresponded to livestock grazing and trampling but did not have fencing implemented were the only sites to display 100% plant community cover attributed to an invasive species. This might be a result of the constant disturbance trampling and grazing yields which has the possibility to halt the plant community successional process. Additionally the dominant presence of the invasive species itself also has the possibility of completely altering the plant community successional trajectory. Certain variables, such as invasive species and constant disturbance, can hinder the predictability of this process which yields a novel trajectory of the developing plant community and consequently a potentially different climax community. In extreme cases factors can prevent the community from climaxing at all (Smith, 1996). This

might be an indicator that in the presence of livestock the implementation of stream bank fencing may provide an important outlet and opportunity for native? plant communities to establish themselves along the riparian zone.

Water Quality

In this study, three Berks County farm sites were compared to one Lebanon County control site, which was a non-agricultural area utilized by cattle for grazing. Each site consisted of upstream, treatment, and downstream locations. Nitrate concentrations were significantly higher at farm sites as compared to control sites (Figure 6), and nitrite concentrations were significantly higher at control sites as compared to farm sites (Figure 7), though differences in these concentrations did not differ significantly as a function of location in the stream. Nitrate is a major component of synthetic fertilizers that are used in agriculture to increase crop yield, and runoff from fertilized areas has been known to pollute water systems with excess nitrates (Ruidisch et al., 2013). These likely account for high concentrations of nitrate found at farm sites as opposed to the non-agricultural control sites. Farm sites are far more likely to use synthetic nitrogenous fertilizer than the non-agricultural sites, which would result in excess nitrates from the fertilizer being present in the stream as a result of runoff.

Significantly higher amounts of nitrite found at control sites can likely be attributed to the lack of synthetic fertilizer and the presence of cattle in the area. Cattle waste contains high concentrations of ammonia, which naturally undergoes nitrification into nitrite (Vidon et al., 2008). The presence of cattle in the area would likely result in ammonia and subsequent nitrite

runoff into neighboring water systems, which would explain the high concentration of nitrite found in control site samples.

One of the farm sites that we sampled was an organic farm, which exhibited similar nitrate concentrations as the conventional farms that were sampled. Organic agriculture emphasizes the reduction of external inputs into the system, which includes synthetic fertilizer (USDA, 2013). Logically, the samples taken from the organic farm should therefore exhibit a lower relative nitrate concentration as compared to the two conventional farms sampled due to a lack of fertilizer and subsequent lack of nitrogenous runoff. However, compost and animal manure are often utilized as fertilizer on organic farms, and could account for nitrate concentrations that were found.

Farm sites exhibited significantly lower pH as compared to control sites, which may be attributed to restricted cattle access. As nitrogen bearing compounds are typically basic, an excess of nitrates from cattle waste would result in increasing the alkalinity of the water system and subsequently raising the pH, as was found at the control site. The control site consisted of a non-agricultural cattle grazing area without stream bank fencing present, resulting in unrestricted cattle access to the stream on the premises. Compared to the significantly lower pH found at the farm sites, this may indicate that stream bank fencing reduces the access of cattle to the stream and subsequently stabilizes the stream's pH. Though the pH differed significantly across farm and control sites, there was not a large increase in pH as a potential result of cattle access to the stream at the control sites, likely due to the fact that nitrogen bearing bases found in waste are typically weak in nature.

Turbidity is also likely associated with cattle access, as control sites exhibited a significantly greater turbidity as compared to farm sites. Cattle access to the stream at the control site would result in trampling and disturbance of the sediments in the stream, which would increase turbidity of the water. The downstream location within the control site was significantly greater in turbidity, which may indicate that cattle access upstream causes sediment disturbance which then washes downstream. Upstream, treatment, and downstream locations at the farm sites did not differ significantly, implying that restricted cattle access via stream bank fencing may maintain lower turbidity levels.

Farm treatment sites were significantly higher in dissolved oxygen at the treatment location compared to both the upstream and downstream sites, indicating that areas in which stream bank fencing is implemented results in higher dissolved oxygen. Treatment sites indicate areas in which stream bank fencing has been implemented, and cattle have limited access to the stream directly. The increase in dissolved oxygen at treatment sites is likely a reflection of the decreased waste from the cattle directly entering the stream. Cattle waste contains an excess of nitrogenous compounds, which in tandem with nitrate runoff from fertilizer may result in eutrophication of the system. In a eutrophic system, an influx of nitrogen bearing compounds results in algal blooms which die off and sink to the bottom to be processed by bacteria. The breakdown of this matter by bacteria utilizes oxygen, which may then decrease the dissolved oxygen of the system substantially (Smith, et al. 1999).

Therefore, the significantly greater concentration of dissolved oxygen at treatment sites may imply that stream bank fencing can result in a minimization of such eutrophic effects and can subsequently boost the dissolved oxygen concentration of the water body. Water temperature likely did not influence dissolved oxygen concentrations substantially, as water temperature did

not differ significantly across location or site. However, dissolved oxygen concentrations may also increase as a result of greater photosynthetic production, so further testing would be needed to assess the impact of stream bank fencing upon dissolved oxygen concentrations.

VII. CONCLUSION/SUMMARY

Through the results of the questionnaires of both the farmers and the organizations, it can be concluded that the stream bank fencing implementation process occurs in a top-down manner (the organizations approaching the land-owners). The order of this hierarchy can be seen in Figure 10. Although this confirms hypothesis #3, there were interesting findings. Due to the growing implementation of stream bank fencing on farms in Southeastern PA, more farmers are talking, and it is becoming more frequent that farmers are approaching organizations. This may indicate that stream bank fencing is viewed as a successful best management program by the farmers who implement it and because of this they are likely to recommend it to their friends and neighboring farms. Therefore more farmers are beginning to approach environmental organizations. Second, the qualitative research led to finding that economic incentives play a major role in the decision making process of farmers, while education did not have such a strong influence on their decision to implement. Finally, it was found that the organizations do not put as much emphasis on federal requirements to decide what streams to target as we thought, rather it is more focused on sub-watersheds that are providers of drinking water and what funding is available for projects. There is a lot of collaboration between the environmental organizations no matter if they are governmental or nongovernmental; they all work together in order to accomplish goals. We learned that the Berks Conservancy works mostly alongside with the William Penn Foundation to choose sites for implementation. They both also work with the Philadelphia Water Department. The Berks County Conservation District works in close

affiliation with the Department of Environmental Protection. The Schuylkill Action Network meets once every three months with multiple organizations in and around Berks County. The Reading Area Water Authority is also very influential with the Schuylkill Action Network. The SAN chooses locations in and around the Berks area for stream bank fencing implementation. The DEP are the largest contributor to funding efforts toward stream bank fencing. They pick areas in smaller watersheds rather than larger watersheds opposed to the EPA.

We found that at the farms with treatment sites showed evidence that the stream bank fencing was effective in improving pH, turbidity, and dissolved oxygen levels. Nitrate and nitrite were higher at the farms with fencing, which does not support part of our hypothesis. In our study, evidence shows that stream bank fencing increased plant diversity compared to our control sites. Eutrophic effects were also less likely to occur in the water due to nitrogen being used by the plant species present in the buffer zone, as evidenced by increased levels of dissolved oxygen at treatment sites. Restricted cattle access stabilized lower turbidity levels. Fertilizers are typically more basic and the slightly alkaline water at the farms with stream bank fencing shows that pH is being stabilized. Limestone is common in the area which also makes the water more basic and could have attributed along with the fertilizers. Higher nitrate and nitrite levels at farm one, which was the only organic farm we visited, could be attributed to the runoff from the nearby sewage treatment plant and non-organic farm. These factors of plant diversity and increased water quality show that resilience has been increased in the areas with fence cover.

Overall, analyses of the decision making processes and ecological effects of stream bank fencing revealed that stream bank fencing can be an effective best management practice for improving riparian health of agricultural areas, and is typically implemented via top-down

processes. Due to noticeable improvements of riparian health attributed to implementation of stream bank fencing, more farmers are beginning to approach environmental organizations to gain funding for stream bank fencing projects. This may result in a change from top-down implementation to bottom-up. Ultimately, the outreach of environmental organizations, education along with incentives for farmers, and public awareness of ecological effects of stream bank fencing are all imperative for furthered implementation and success of stream bank fencing as a BMP.

APPENDIX I: SCHEDULE

March 3rd- March 8th **Work On Project Proposal**

- Gather more Information on Stream Bank Fencing
- Start Contacting Berks County Conservancy, Berks County Conservation District and Schuylkill Action Network, Ask Questions in regards to research topic.
- Create questions regarding the project's interdisciplinary nature and decision making process for interviewing institutions

March 9th **Prepare for Proposal Presentation**

- Finalize Proposal and PowerPoint Presentation

March 10th **Presentation of Proposal Presentation**

March 11th-22nd **Prepare work over break**

- Continue Contact with Berks County Conservancy, Berks County Conservation District and Schuylkill Action Network.
- Make any Changes needed to project proposal; Schedule, Interview Questions, etc.

March 24th **Prepare for Project**

- Go over information collected about Storm Bank Fencing
- Clarify Hypothesis
- Create Survey for farmers and organizations

March 28th **Edit Proposal/Continue Contact w/ Organizations**

- Discuss options for sites and dates to visit sites
- Finalize survey and have it approved

March 30th **Prep. Work**

- Gather supplies for field work
- Review proposal
- Group Meeting in Library at 7pm

March 31st **Field Work /Lab Work**

- Travel to site 1 & Collect data
- Conduct interviews
- Input Data

April 6th **Meeting**

- Meet at 7pm in library to discuss project/review data

April 7th **Field Work /Lab Work**

- Travel to site 2 & Collect data

- Conduct interviews
- Input Data

April 13th **Meeting**

- Meet at 7pm in library to discuss project/review data

April 14th **Lab Work**

- Input data into the system
- Continue testing water samples
- Run any tests (statistical analysis)

April 21st **Lab Work**

- Update all data in the system
- Continue to test and input water sample information
- Begin to analyze data

April 28th **Lab Work**

- Finalize all data in the system
- Analyze both surveys and field samples
- Interpret Data and draw conclusions
- Go over interview results and interpret data
- Begin to revise and edit sections of previous drafts

April 5th **Final Paper Draft Due**

- Combine and Review all sections
- Complete maps/upload images
- Send out Invitations & Thank you to organizations and farmers
- Go over interview results and analyze data
- Finalize Draft

March 11th- 15th **Work on Project Presentation**

March 18th **Final Presentation**

APPENDIX II: Questionnaire A for Farmers

Questionnaire on Stream bank Fencing for Farmer(s) Code Name:_____

1. Did an organization approach you about stream bank fencing?
2. If no, where did you find out about stream bank fencing from?
3. Why did you implement this on your farm?
4. Did you voluntarily implement?
5. On a scale of 1-9 to what extent did the funding provided to you by the organization influence you to implement?

1	2	3	4	5	6	7
Very	Strong	Some	Moderate	Some	Weak	Very
Strong	Reason	What	Reason	What	Reason	Weak
Reason		Strong		Week		
		Reason		Reason		

6. Were you responsible for any of the costs of implementation or maintenance of the stream bank fencing?

7. Was education provided of the benefits stream bank fencing provides to your farm/cattle?

8. On a scale of 1-9 to what extent did that education influence you to implement stream bank fencing?

1	2	3	4	5	6	7
Very	Strong	Some	Moderate	Some	Weak	Very
Strong	Reason	What	Reason	What	Reason	Weak
Reason		Strong		Week		
		Reason		Reason		

APPENDIX III: Questionnaire B for Organizations

Organization Code: Individual Code:

1. What occurs more frequently, you approach the farmer or they approach you?
2. Did this farmer approach you or did you approach them? (site specific)
3. How do you prioritize some sites over others?
4. What characteristics made this site more of a priority?
5. Do you utilize the ranking system by the EPA to prioritize streams?
6. On a scale of 1-5, how strongly does the stream ranking system by the EPA influence your organizations prioritization of streams?

1	2	3	4	5	6	7
Very Strong Reason	Strong Reason	Some What Strong Reason	Moderate Reason	Some What Week Reason	Weak Reason	Very Weak Reason

7. If you do not utilize the EPA stream ranking system, do you have your own ranking system or characteristics that are of more importance?

TABLE AND FIGURE LEGEND

Table 1: A table encompassing the farmers' responses to Questionnaire A

Table 2: A table encompassing the organizations' responses to Questionnaire B

Table 3: A MANOVA table of all variables (*i.e.* Nitrate, Nitrite, vertical cover, species richness, Phosphate, conductivity, dissolved oxygen, temperature, and turbidity) as a function Treatment and Location

Figure 1: A bar graph depicting the mean species richness within the plant community per quadrat as a function of treatment and location within the stream. Where C = control sites, F = treatment farm sites, DS = downstream sites, US = upstream sites and Trt = those farm sites where fencing was implemented. It is also important to note that those sites which pertained to the upstream stretches of the control sites were subject to livestock grazing.

Figure 2: A pie chart depicting the percent area attributed to each species within the plant community of the upstream and downstream sites corresponding to the farms. The "Other" category is composed of those species that attributed less than 3% of the area within the plant community.

Figure 3: A pie chart depicting the percent area attributed to each species within the plant community of the downstream control sites. The "Other" category is composed of those species that attributed less than 3% of the area within the plant community.

Figure 4: A pie chart depicting the percent area attributed to each species within the plant community of the fenced farm sites. The "Other" category is composed of those species that attributed less than 3% of the area within the plant community.

Figure 5: A bar graph depicting the mean pH within the water as a function of treatment. Where C = control sites, F = treatment farm sites, DS = downstream sites, US = upstream sites and Trt = those farm sites where fencing was implemented. It is also important to note that those sites which pertained to the upstream stretches of the control sites were subject to livestock grazing.

Figure 6: A bar graph depicting the mean turbidity within the water as a function of treatment and location within the stream. Where C = control sites, F = treatment farm sites, DS = downstream sites, US = upstream sites and Trt = those farm sites where fencing was implemented. It is also important to note that those sites which pertained to the upstream stretches of the control sites were subject to livestock grazing.

Figure 7: A bar graph depicting the mean nitrate within the water as a function of treatment. Where C = control sites, F = treatment farm sites, DS = downstream sites, US = upstream sites and Trt = those farm sites where fencing was implemented. It is also important to note that those sites which pertained to the upstream stretches of the control sites were subject to livestock grazing.

Figure 8: A bar graph depicting the mean nitrite within the water as a function of treatment. Where C = control sites, F = treatment farm sites, DS = downstream sites, US = upstream sites and Trt = those farm sites where fencing was implemented. It is also important to note that those

sites which pertained to the upstream stretches of the control sites were subject to livestock grazing.

Figure 9: A bar graph depicting the mean dissolved oxygen within the water as a function of location within the stream Where C = control sites, F = treatment farm sites, DS = downstream sites, US = upstream sites and Trt = those farm sites where fencing was implemented. It is also important to note that those sites which pertained to the upstream stretches of the control sites were subject to livestock grazing.

Figure 10: A flowchart that represents what has been learned through our research expressing the hierarchy system and connections between government and non-government agencies in relation to the implementation of stream bank fencing. It shows how the non-government system depends on the funding an organization can receive before selecting a site to implement fencing. The Government side starts with the EPA, who monitors all sites, and then continues to state level and local agencies before reaching the farmers.

Table 1:

Questionnaire A	Farmer #1	Farmer #2	Farmer #3
1. Did an organization approach you about stream bank fencing?	**NRCS talked to him** some about the program.	**NRCS talked to him** some about the program. Or maybe BCCD- he did not clearly remember. At first the land was not developed- very old and full of brush. It was pastured but not functional for a while.	The Berks Conservancy played a major role. The soil conservation group and **NRCS was talked about** but he really focused on the Berks Conservancy and Larry Lloyd's participation. He mentioned that the NRCS was not new, but the concept of Larry coming and bringing money was new.
2 .If no, where did you find out about stream bank fencing from?	No Response	No Response	He did mention that farmers talk a lot and that some of his friends did pasture fencing. He was knowledgeable that there are politics behind what areas are targeted to improve water quality and realized that if he did not do it now, he would have to do it eventually.
3. Why did you implement this on your farm?	Cattle erosion was becoming a big problem and he wanted to stabilize the erosion. First there were hog-slats and stone for cow crossing but he did not like how the stones hurt the cows- limestone modifications.	He was opposed at first about the fencing idea, did not like the idea of fencing off any area. The NRCS created concrete springs for cattle to drink from in 2000 (1st BMP they did) but the cattle still went into the stream. He thought it was not logical and that fencing made more sense in order to make the cattle use drinking springs.	PA regulations are changing and there was not much of a choice, he knew that eventually these guidelines would be laws
4. Did you voluntarily implement?	He really wanted it done "[erosion] was destroying the environment and this was the ideal solution"- farmer #1	NRCS came to him after he bought the farm from his uncle, one of the first projects they did. Signed contract with them for 3 years- work on storage, heffer shed, waterway around manure. He is now entering his 3rd year in contract with the NRCS.	Technically he said he did volunteer compared to CAFOs which are forced into management plans. He had to create a nutrient management plan.

Questionnaire A	Farmer #1	Farmer #2	Farmer #3
5. On a scale of 1-7 to what extent did the **funding** provided to you by the organization influence you to implement?	**7- very weak reason** for the smaller tributary site, the water was creating a lot of erosion and he needed to fix it. **2- Strong reason** for the larger tributary	**1- very strong reason**, the project cost a lot and the cost share was a big incentive	**1- very strong reason** concerned about future laws and that if he did not accept money and help from Berks Conservancy he would not be able to afford these practices in the future and would have to sell. He was willing but the BC made it all work and help with future management
6. Were you responsible for any of the costs of implementation or maintenance of the stream bank fencing?	EQIP paid 75%, farmer was responsible for 25% of cost of stream-bank fencing, he said it was not that big of a monetary cost and he also cared and wanted it to help the environment. The farmer said he tries to take care of the fence but he is not required. He removes invasive species through mechanical removal in order to reach the fence.	The farmer said he was responsible for about 10% of cost of fencing. He paid his share and they designed and installed it (he was not a part of the process). They fenced off the creek and th4e wetland. He said the entire project cost several thousand on own his own it would have been a lot, many thousands of dollars.	The cost share was about 25-75, the Conservancy helped a lot and the farmer ended up spending 10% or less
7. Was **education** provided of the benefits stream bank fencing provides to your farm/cattle?	**NRCS provided some programs;** they stopped by to suggest it to him. The Blue Marsh Lake easement is located below his farmland.	**NRCS provided some education**. He learned how to distinguish a wetland through NCRS. Pamphlets/ info on paper given to him (but he did not read them). No fence on the other side of stream.	He felt that he was very educated. He mentioned that they told him anything he wanted to know and that he had no problems, the construction workers and contractors did not like the federal construction requirements, however. **Many seminars were provided by NRCS,** a crop consultant helped with nutrient management plans. Plenty of education.

Questionnaire A	Farmer #1	Farmer #2	Farmer #3
8. On a scale of 1-7 to what extent did that education influence you to implement stream bank fencing?	**6-weak reason** He felt it was more so **"common sense"** to implement this on his land so the cattle could drink but not ruin the steam. He said it works well with tributaries, but larger streams are a bigger challenge.	**4- Moderate reason**	**1- people in Berks Conservancy** made the difference, many other counties are not as agreeable to these BMPs and he said that Larry made all the difference

Table 2:

Questionnaire B	Berks Conservancy	Berks County Conservation District	Schuylkill Action Network	PA Department of Environmental Protection
1. What occurs more frequently, you approach the farmer or they approach you?	"**I come with the brochures, letters**, the farmer signs a contract where the institution promises to help with the application process" "**I go to the farmer and talk about it**, give names to the people that did the stream bank fencing".	We operate simply off of complains or calls from bystanders who might happen to drive past a farm that appears to be in need. This is often seen in stream banks that are obviously impaired due to erosion. **A farmer does not usually approach us**, although there have been a small number of rare occasions where a farmer has called to inquire about stream bank fencing if they hear from a neighboring farmer.	A little of both, **at first it was mainly the organizations reaching** out to farmers because this project was new and unknown, now it is more well-known, farmers are talking, and sometimes they are approached by farmers.	Initially, **we approach them** but as successful restoration projects occur near concerned farmers, they begin to approach us as they see the myriad benefits associated with healthy waterways and conservation of agricultural land uses.
2. Did this farmer approach you or did you approach them? (site specific)	No Response	see question 1	No Response	No Response
3. How do you prioritize some sites over others?	**Government comes up with ideas of where fencing should be implemented**. **Scores them by most in need**, focus is placed on streams that are linked to **drinking water**. The **Conservancy looks for where they can get funding** for fencing being implemented.	**We do not prioritize one stream over another**, however, being that there is government action being taken to improve the Chesapeake Bay Water Shed, we would be more inclined to take immediate action on a site located in this area. There is a small area in south western Berks County where several sites have had stream bank fencing implemented.	"Following **drinking water standards of the EPA**, all areas assessed are impaired streams that are not meeting these standards Goals are for the Schuylkill river and all tributaries leading to it to be healthy and meet the EPA's drinking water quality standards"	First, subwatersheds are prioritized by our regional office biologists and county conservation districts based on the **level of pollutant loads** and whether or not there is a **likeliness of community involvement** to rectify the impairment usually in the form of a **watershed association or a group like Trout Unlimited**. We use a **subwatershed approach to restoration rather than simply picking sites on impaired stream** segments and attempt to gain restoration of that entire subwatershed within five years.

Questionnaire B	Berks Conservancy	Berks County Conservation District	Schuylkill Action Network	PA Department of Environmental Protection
4. What characteristics made this site more of a priority?	Focus is placed on streams which lead to **drinking water**, Government tries to **"couple" sites in order to get funding.**	**High nitrate and phosphate levels** that are seen in the control areas, located with the Chesapeake Bay Watershed, typically get prioritized higher than those where nitrate may be the only issue.	No Response	Once a watershed is targeted for restoration, a Watershed Implementation Plan (WIP) is developed. The WIP is site specific and ranks priority sites within the sub watershed based on the level of impairment and visibility to the public which serves to display the work to others so they may join in the effort. **We make every attempt to work from the headwaters to the mouth but are mostly limited by the willingness of the landowners of particular sites.**
5. Do you utilize the ranking system by the EPA to prioritize streams?	**Focus is funding based**	**We do not utilize a ranking system** (impaired, endangered, etc.) although we do communicate with the **DEP in order to receive funding** and decide which areas and sites are most important.	**Goals** are for the Schuylkill river and all tributaries leading to it to be healthy and meet the **EPA's drinking water quality standards**	DEP has its own method focusing on smaller sub watersheds and targeting them for complete restoration with a five year window of time unlike **EPA that targets larger watersheds for regional pollutant reduction rather than local restoration of waterways**. While overall pollutant reduction on a regional scale is important to both EPA and DEP, we would like to see complete restoration of our targeted waterways locally as being the driving force behind our restoration efforts.
6. On a scale of 1-5, how strongly does the stream ranking system by the EPA influence your organizations prioritization of streams?	No Response	Weak reason	No Response (did not exist during interview)	If 5 is the strongest than 2. Strong Reason

Questionnaire B	Berks Conservancy	Berks County Conservation District	Schuylkill Action Network	PA Department of Environmental Protection
7. If you do not utilize the EPA stream ranking system, do you have your own ranking system or characteristics that are of more importance?	No Response	Implementation is mostly based on **complaints and calls received from bystanders.** Aside from the Chesapeake Bay Watershed being of upmost importance, all other sites are treated similarly and are not necessarily ranked.	**Following drinking water standards of the EPA,** All areas assessed are impaired streams that are not meeting these standards. Meeting every 3 months between representatives of different organizations including but not limited to: Berks Conservancy, BCCD, NRCS, BCFPP, and all drinking water suppliers of the area: RAWA, PWD etc..	Yes as mentioned above and as follows: 1. Are there any non-profit groups to receive grant funds (usually 319 or Growing Greener grants) in the watershed and to drive restoration? 2. Does the regional staff and county conservation district recommend targeting the watershed? 3. Is restoration going to occur within five years to the point of delisting the waterway based on size, number of cooperative landowners, land uses and level of impairment ? 4. Will there be a significant reduction in local and regional pollutant loads? 5. Is there already a WIP and if not, should one be developed based on the first four conditions mentioned?

Table 3:

	Df	Pillai	approx F	num Df	den Df	P value
Treatment	1	0.99	25.06	12	2	0.04
Location	2	1.92	5.80	24	6	0.02

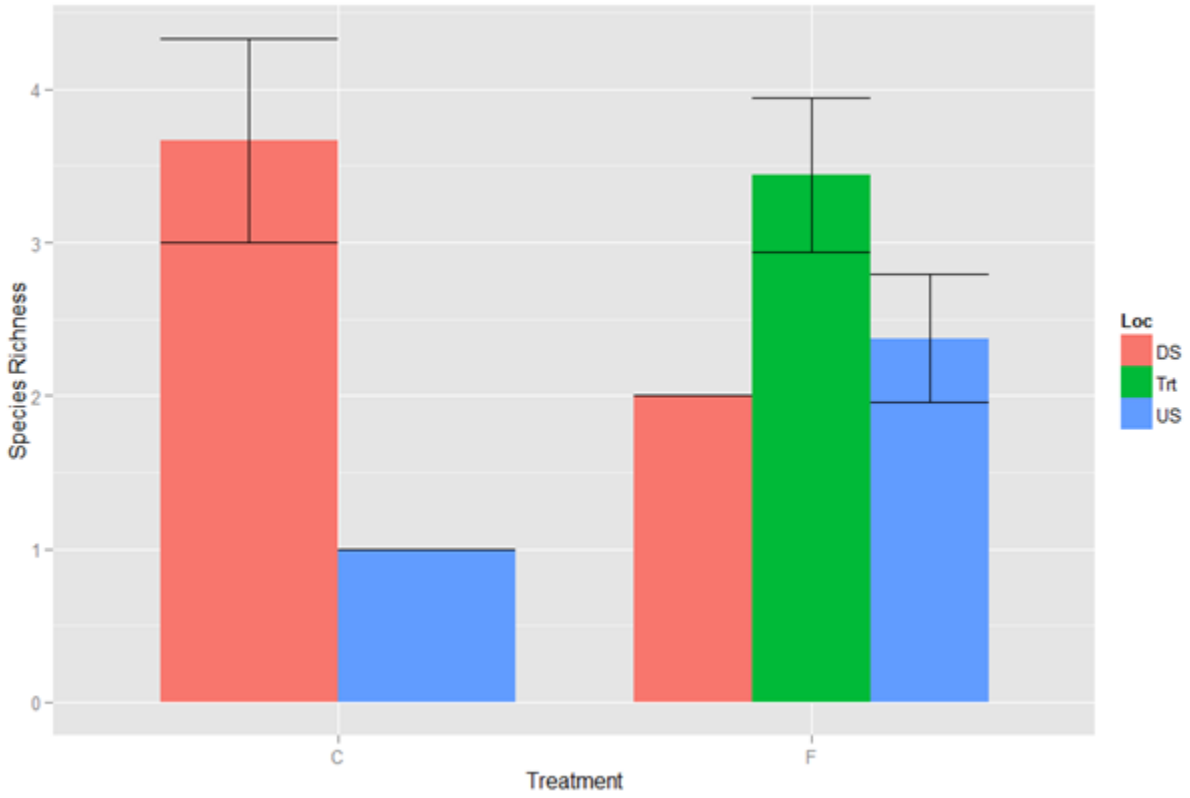

Figure 1. Note for all subsequent figures: DS and US denote downstream and upstream sampling locations, respectively. Trt denoted the treatment reach of the riparian zone. C and F denote control and farm stream reaches.

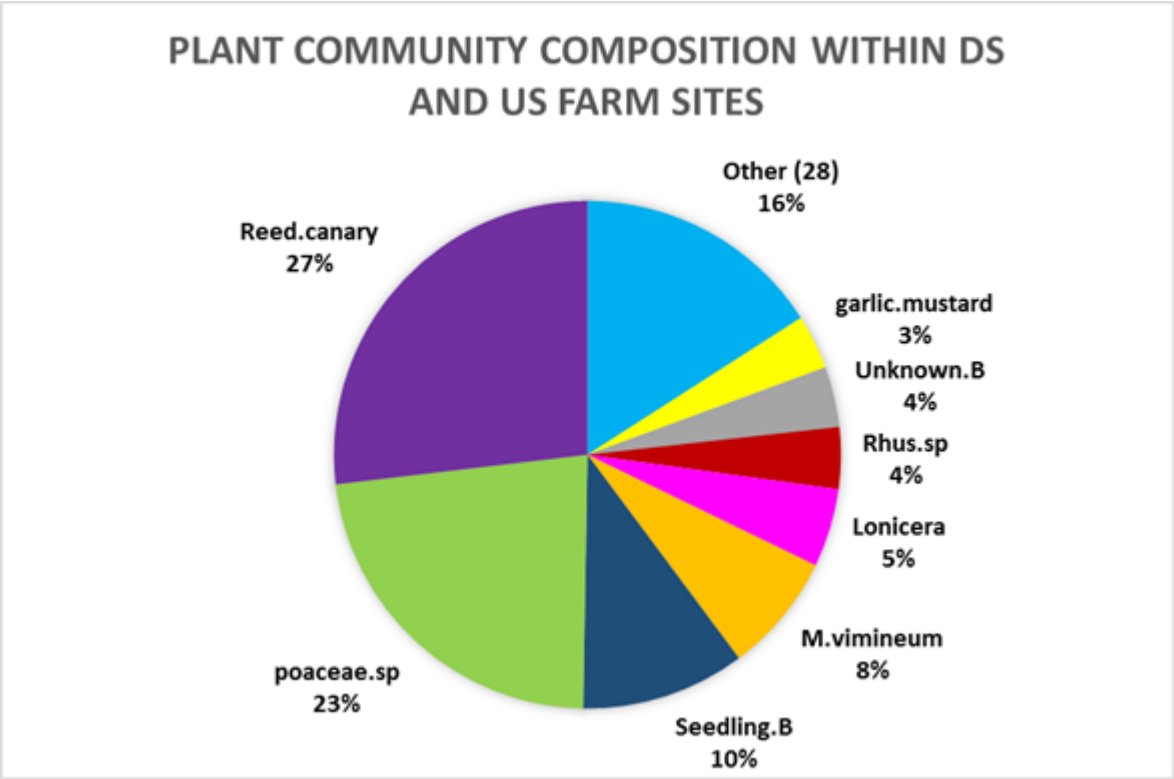

Figure 2.

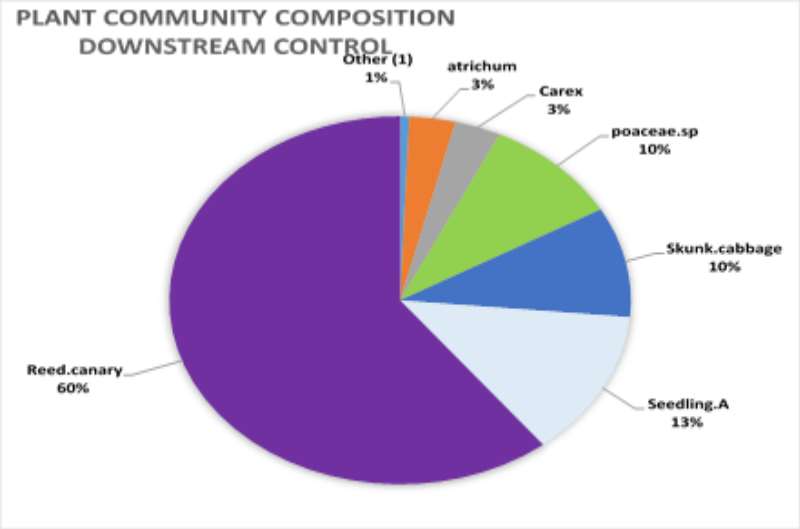

Figure 3.

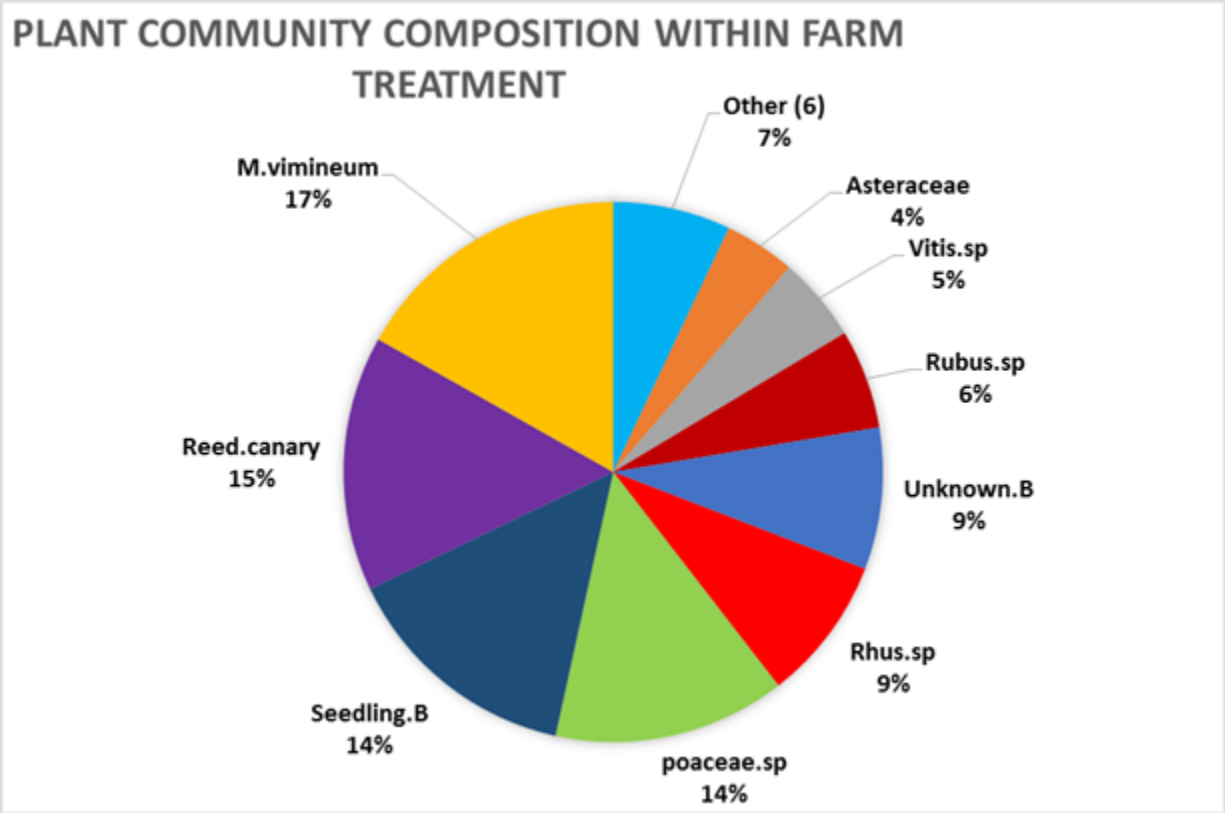
PLANT COMMUNITY COMPOSITION WITHIN FARM TREATMENT
Other (6)
7%
Asteraceae
4%
Vitis.sp
5%
Rubus.sp
6%
Unknown.B
9%
Rhus.sp
9%
poaceae.sp
14%
Seedling.B
14%
Reed.canary
15%
M.vimineum
17%

Figure 4.

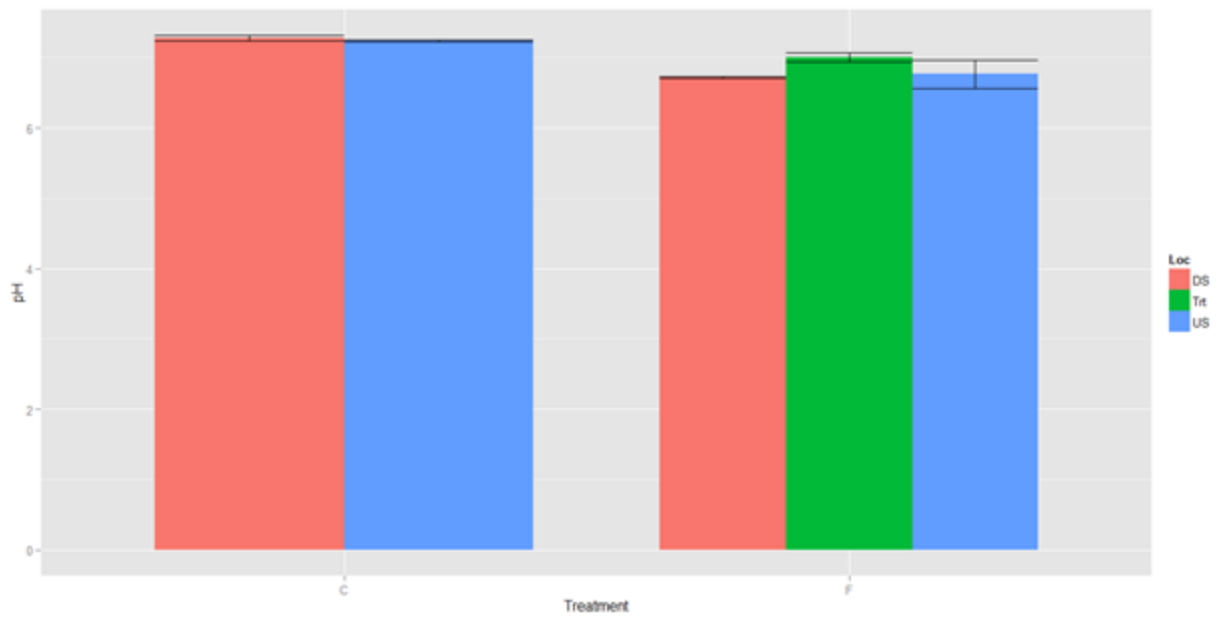

Figure 5.

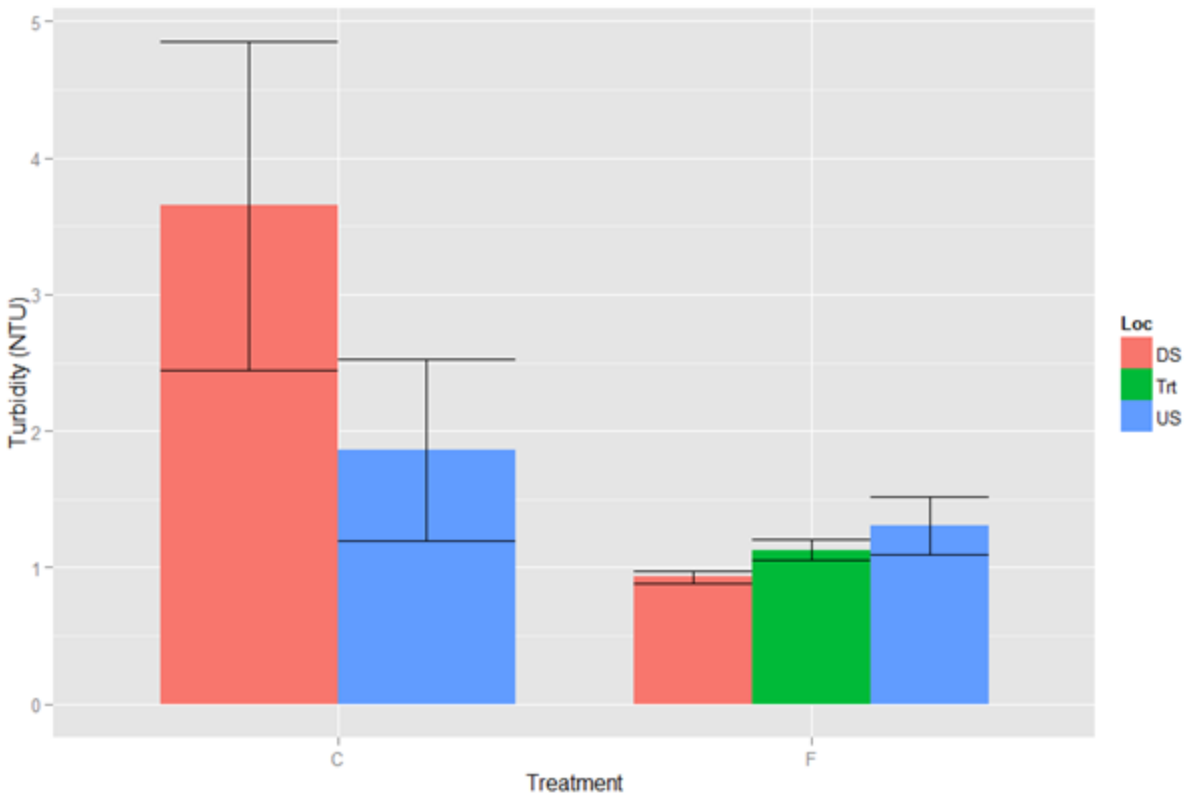

Figure 6.

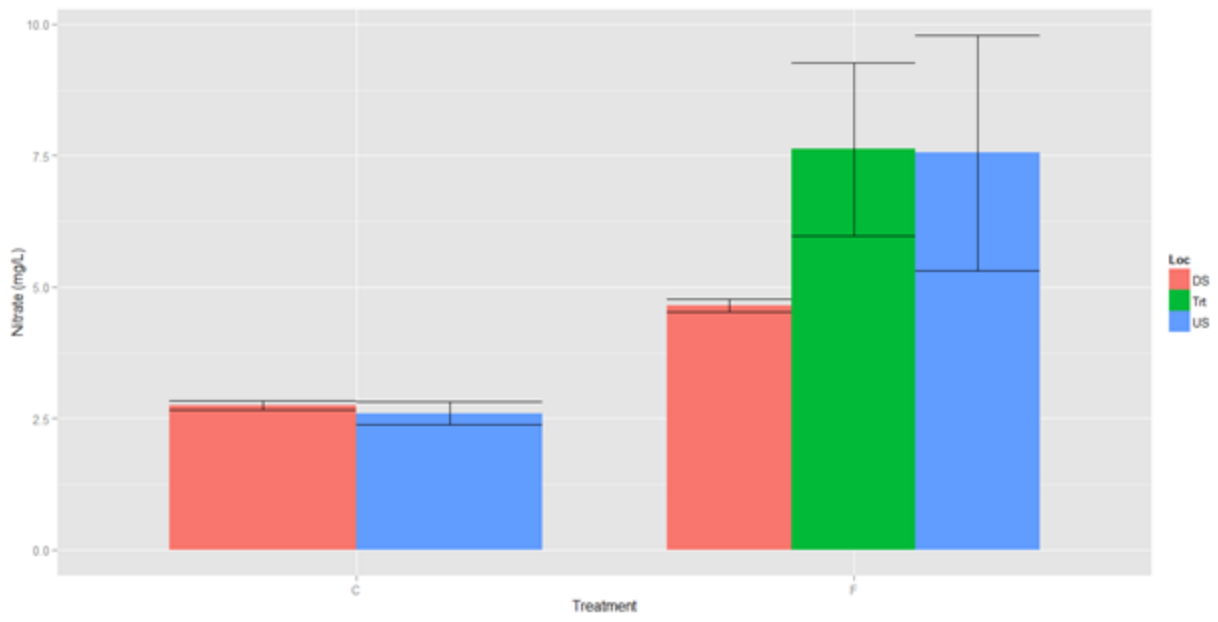

Figure 7.

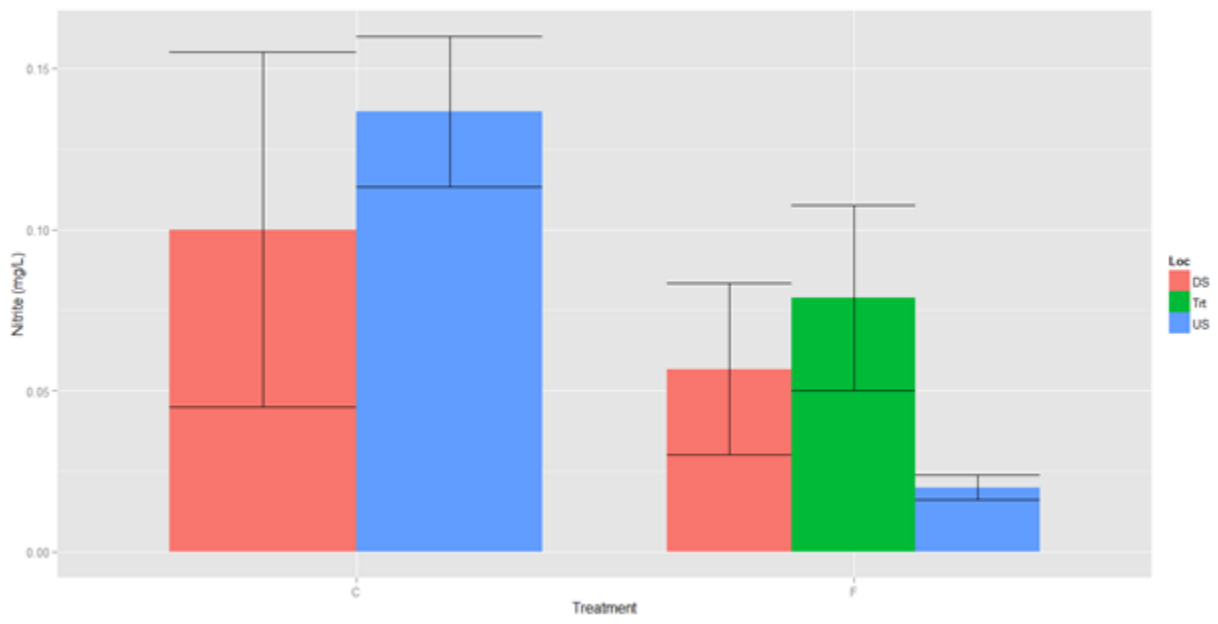

Figure 8.

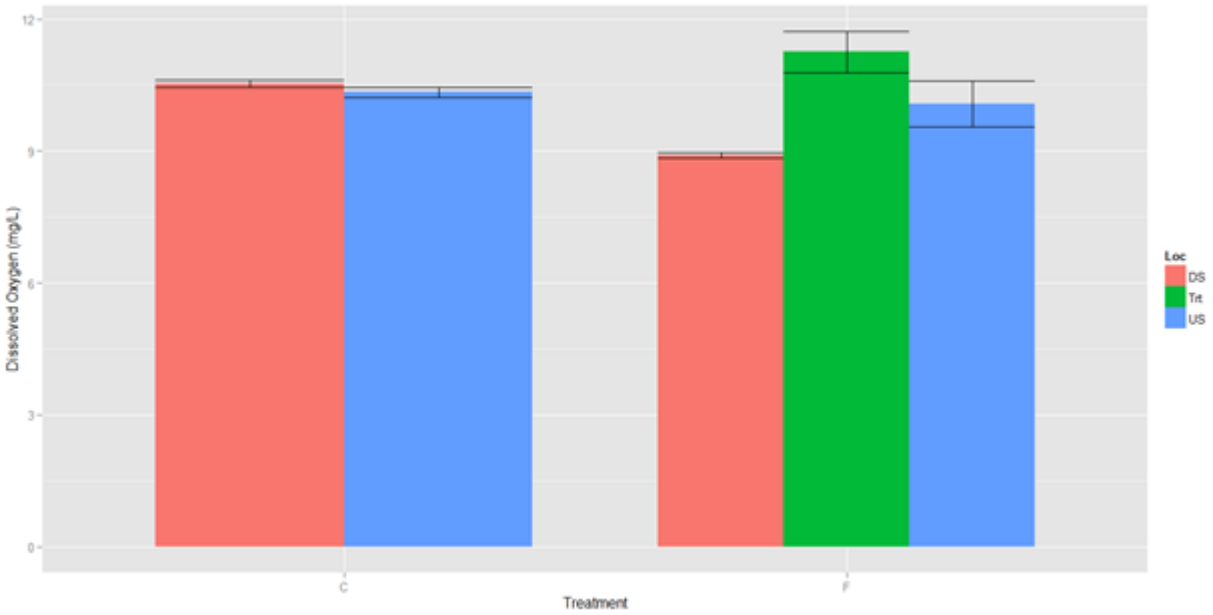

Figure 9.

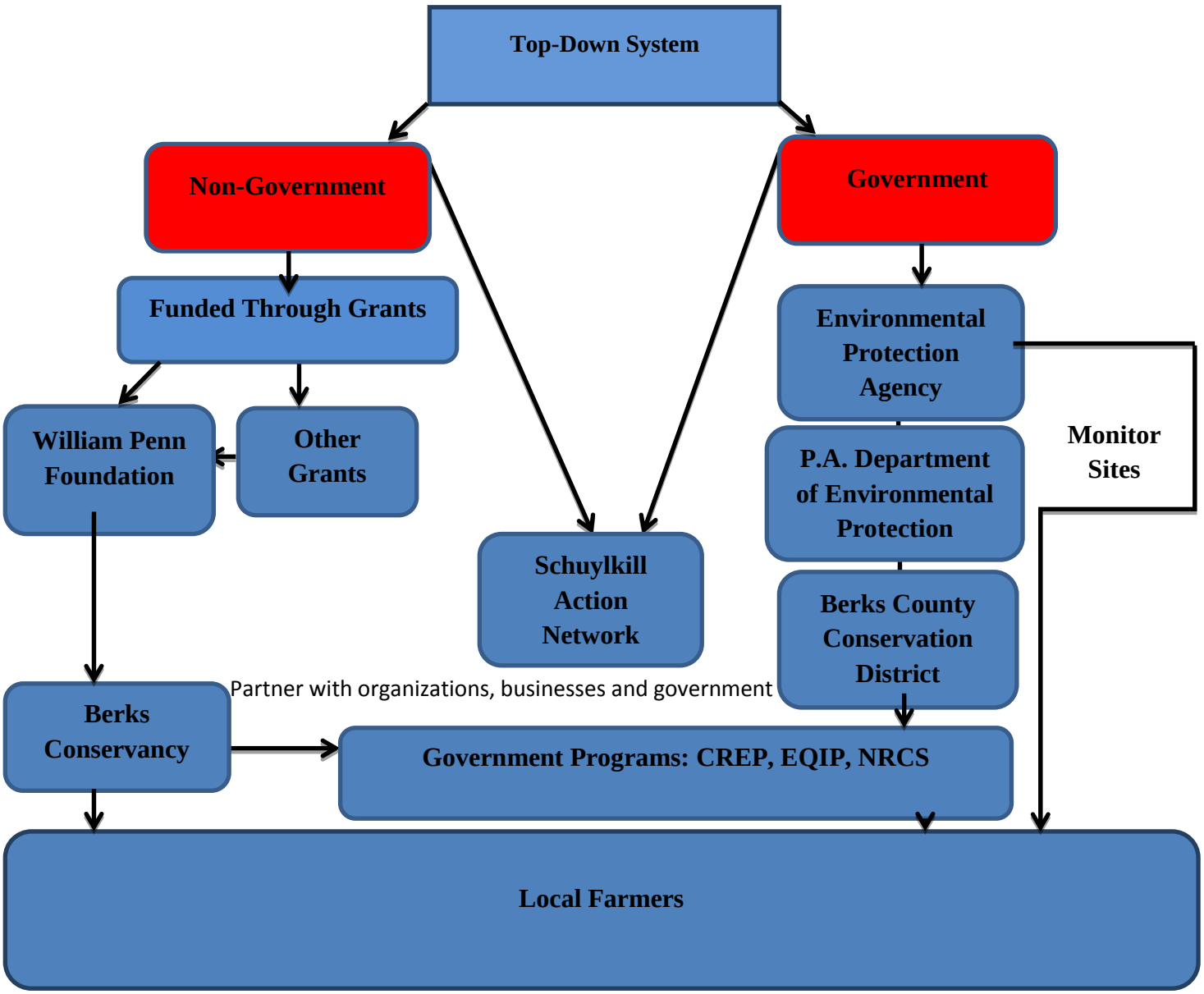
Top-Down System
Non-Government
Government
Funded Through Grants
Environmental Protection Agency
William Penn Foundation
Other Grants
P.A. Department of Environmental Protection
Monitor Sites
Schuylkill Action Network
Berks County Conservation District
Partner with organizations, businesses and government
Berks Conservancy
Government Programs: CREP, EQIP, NRCS
Local Farmers

Figure 10.

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