Pollutant mitigation in the ditch network of tributary 46, Owasco Lake, NY

by Nicole C. Pionteck

December 12, 2014

Environmental Science Capstone

State University of New York College of Environmental Science and Forestry

Syracuse, New York

ABSTRACT

Storm events within the Owasco Lake Watershed cause eroded sediment and excess nutrients to enter the lake. These pollutants often come from agricultural fields, which make up over half of the land use within the watershed. The road ditch network intercepts field runoff, and carries it into nearby tributaries that feed directly into the lake. Once in the lake, sediments and nutrients cause problems including promoting algal and plant growth and inhibiting drinking water treatment. In order to mitigate these effects, runoff must be slowed within the ditches to allow for sediment settling and nutrient absorption. This is done through effective solutions such as check dams, retention basins, and revegetation. These solutions are affordable to local government, farmers, and landowners.

INTRODUCTION

Owasco Lake is the sixth largest Finger Lake, located in central New York. It has a watershed of 208 square miles and has the largest watershed to lake volume ratio of all the Finger Lakes. This means land use type and activities on land have a huge impact on the quality of the water. Water quality is of the utmost importance because the lake is a drinking water source for over 44,000 people in the city of Auburn and Town of Owasco. Over half of the watershed, approximately 55%, is classified as agricultural land use (Fig. 1, Table 1). This means over 60,000 acres are intensively cropped or pastured farmland. Therefore, much of the runoff within the watershed has come in contact with agricultural fields before entering Owasco Lake, and typically contains high amounts of fertilizer nutrients and sediments (Halfman et al. 2006). Excess nutrients and sediments diminish the water quality of the lake, and impact both the lake ecosystem and the drinking water supply.

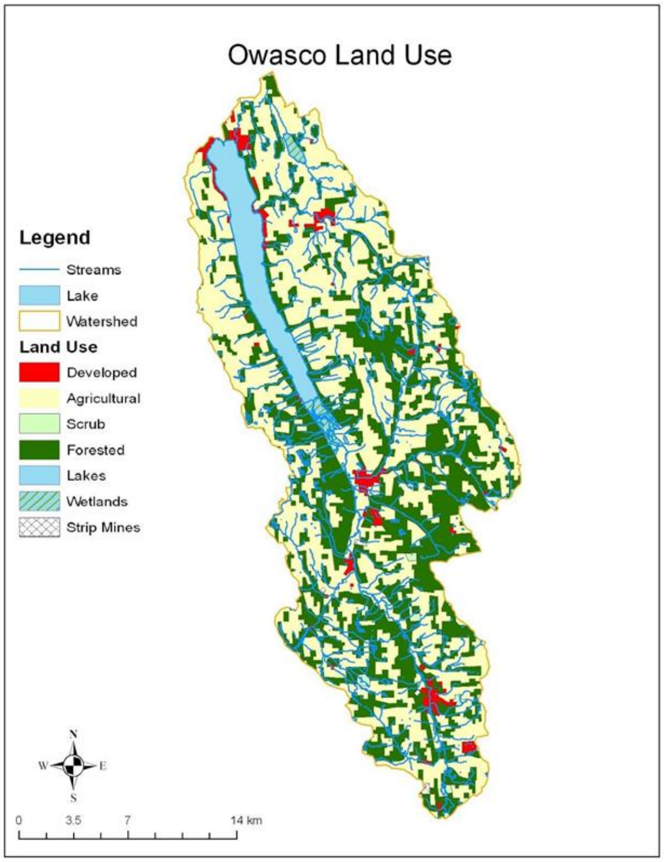

Figure 1. Map of Owasco Lake Watershed land use. Adapted from Halfman et al. (2006).

Table 1. Percentages of land use type within the Owasco Lake Watershed (Halfman et al., 2006)

Land Use	Acreage	Percentage of Total
Cropland and Pasture	67562	54.9%
Mixed Forest Land	47373	38.5%
Evergreen Forest Land	2549	2.1%
Residential	1769	1.4%
Non-forested Wetland	980	0.8%
Other Urban or Built-Up	905	0.7%
Shrub and Brush Rangeland	790	0.6%
Commercial and Services	424	0.3%
Mixed Urban or Built-Up	313	0.3%
Other Agricultural Land	210	0.2%
Strip Mines	196	0.2%
Lakes and Reservoirs (other than Owasco)	60	0.1%
Total	123,131	

On February 21, 2014, there was a manure runoff event on the northwest side of the lake. Figure 2 is an aerial image of an agricultural field affected by the event. Manure, containing high amounts of nutrients such as phosphorus, and sediment ran off into the headwaters of nearby tributaries. These tributaries, some of them classified as protected by the Cayuga County Department of Planning, enter the lake directly. Therefore, the manure and sediment exited the mouths' of the tributaries and washed out onto the still ice-covered waters of Owasco Lake (Fig. 3). The cause of this runoff event was a combination of rapid snow melt, heavy rainfall, and poor manure application sites, creating a perfect storm of conditions.

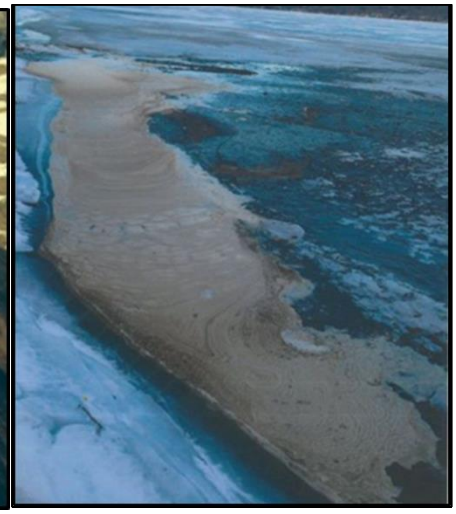

Figure 2. Aerial of a field affected by the runoff event of February 21st. Image provided by Cayuga County SWCD.

Figure 3. Sediment and manure wash out onto Owasco Lake. Image from the Auburn Citizen.

Although multiple tributaries were affected by the runoff event, much of the media coverage was on Fire Lane 26, located in the Town of Scipio. Images of the sediment/manure runoff were taken from this area. The shoreline residents from Fire Lane 26 were also the most vocal about their concerns of the runoff affecting their water quality and property value. Individuals were concerned that the excess fertilizer entering the lake would cause the water to be unsafe to swim in. Another concern was that sediment loading was occurring and would need to be dredged near the shore. During the summer following the runoff event, the Owasco Lake Watershed Inspection Program, Owasco Watershed Lake Association, Cayuga County Planning, and Cayuga County Health Department performed water testing and site visits at the mouth of tributary and around its watershed. Weekly water testing for total fecal coliform counts at the mouth of tributary 46 did not produce any alarming results. Site visits also confirmed that there was not enough excess sediment for dredging to be necessary. However, residents noted a change in the amount of sediment on the bottom of the lake near shore, specifically in a swimming area, and were still concerned that excess nutrients from fertilizer could cause harmful algal blooms. Therefore, although multiple tributaries and Fire Lanes were affected by the runoff event, the area of interest for this project is the sub-watershed of protected tributary 46, with its mouth located on the lower part of Fire Lane 26. Figure 4 shows the extent of the entire watershed and the study area which is the watershed of protected tributary 46. The watershed of this tributary is characterized by gentle slopes at the headwaters, with intensive agriculture, specifically row crops. Further down the tributary, the slopes descend rapidly through narrow corridors of forested areas. However, much of the water fed into this tributary, and likely the source of concern for the sediment and nutrient loading, originates from the road ditch network. Various state and town road ditches feed into the tributary at multiple locations.

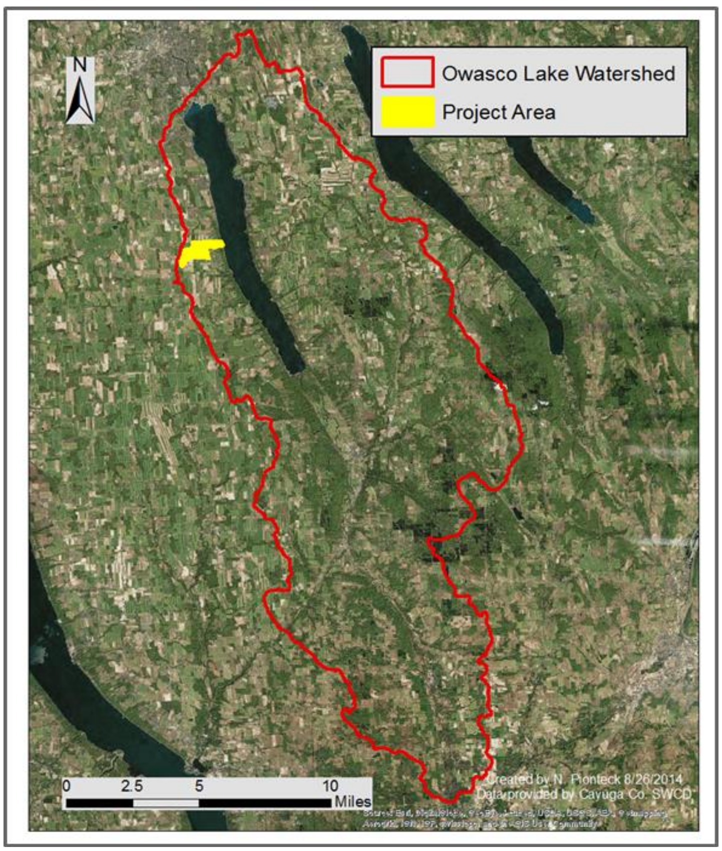

Figure 4. Map of the Owasco Lake Watershed and the sub-watershed of tributary 46. The sub-watershed area in yellow is the study site for the project.

Road ditches are designed to move water off and away from the roadways as quickly as possible, usually into nearby tributaries. However, in high agricultural environments like the

Owasco Lake watershed, this means runoff from fields is also quickly moved into the tributaries, carrying sediment and nutrients to the lake during runoff events like that which occurred on February 21st. A plan was designed to add check dams and sediment retention basins in the road ditches feeding tributary 46, as well as seeding an unvegetated section of ditch, to try to reduce flow rates and mitigate sediment movement to Owasco Lake. The goal of this project is to improve road ditches to allow them be primary containment for field runoff, reducing sediment transport by slowing down and holding water before it enters the tributaries. The project involved determining the watershed of tributary 46, the state of the tributary itself, and where to place the check dams and retention basins. Although the project only focuses on a small area of the Owasco Lake watershed, the methods and applications can be applied to other critical tributaries and their watersheds, which will continue to improve the quality of Owasco Lake and its watershed as a whole.

METHODS

The first step of the project was to determine the extent of the tributary and its watershed. First, the United States Geological Survey (USGS) website StreamStats for New York State was used, which uses topographic contours to determine the watershed from a user-placed point at the tributary's mouth. The program determines the delineation and generates a shapefile that can be used in ESRI ArcMap 10.1. However, the roads, ditches and other development change the topography and the drainage pattern. Therefore, field verification was needed. On July 9, 2014, the watershed area was surveyed, and specific changes in the slope of roads and ditches were marked using a Trimble Juno T41/5 GPS unit. During this time, points of interest along the main branch of the tributary were also marked with the Trimble. The headwaters of the tributary are located on the Allen Farm property in the Town of Scipio, NY. Allen's Farm Compliance planner joined us during the survey of the headwaters and provided details of the farm while the points of interest were marked. These points were then downloaded and exported as shapefiles to ArcMap. The StreamStats-generated watershed shapefile was then edited based upon the field observations and marked points of interest. Several maps were created using ArcMap 10.1 showing the field-verified watershed, topographic contours, and soils. The watershed delineation shapefile was placed over a base map showing aerial imagery, provided by ESRI. The 4-foot topographic contour shapefile was provided by Cayuga County Soil and Water Conservation District (CCSWCD). The soils shapefile was also provided by CCSWCD. The ArcMap tool "Clip Feature" was used to create a subset of the shapefile within the watershed delineation. Separate shapefiles were created to display each soil type and its abundance within the watershed.

Once the watershed of protected tributary 46 was established, areas within the watershed where management practices could be installed were determined. This was done by performing multiple field visits and viewing aerial images and topographic maps of the area. The areas chosen are portions of the ditch network that are undersized with steep slopes and depressions in the topography that have a large drainage catchment. Sections of ditch that have no vegetation were also noted. These observations were noted from the aerial images or marked with the Trimble and a map of placement practices was generated using ArcMap 10.1.

Since these practices would occur in the town right-of-ways and on farmer's property, cost effectiveness is key. In order to make this plan a success, the practices used need to be inexpensive as well as effective. The management practices chosen were based upon their cost to produce or buy, their effectiveness based upon various articles, and experience from the Owasco Lake Watershed Specialist, Andrew Snell.

RESULTS

Figure 5 shows the watershed delineation generated by the USGS StreamStats program. A point was placed at the mouth of tributary 46 on Fire Lane 26 and the StreamStats tool generated the delineation based upon the topographic contours. The image shown was downloaded as a shapefile and placed on top of a base map in ArcMap. This was then edited using ArcMap's Editor tool to produce the field verified watershed (Fig. 6). This general map was then used to produce the maps showing topographic contours and soil types (Fig. 7) and a map of the contour lines in the bottom portion of the tributary (Fig. 8).

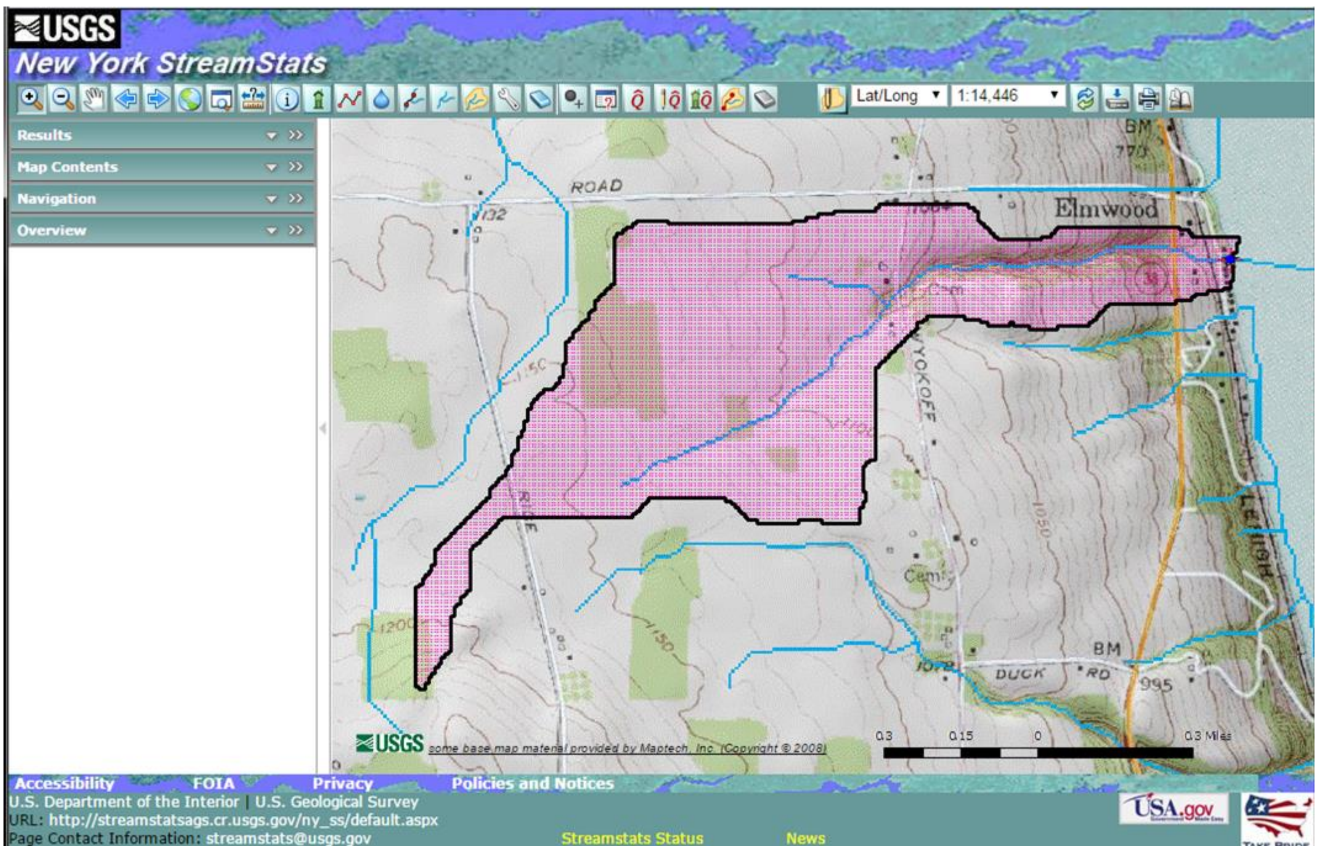

Figure 5. The StreamStats-generated delineation. The area in pink was downloaded as a shapefile from the website.

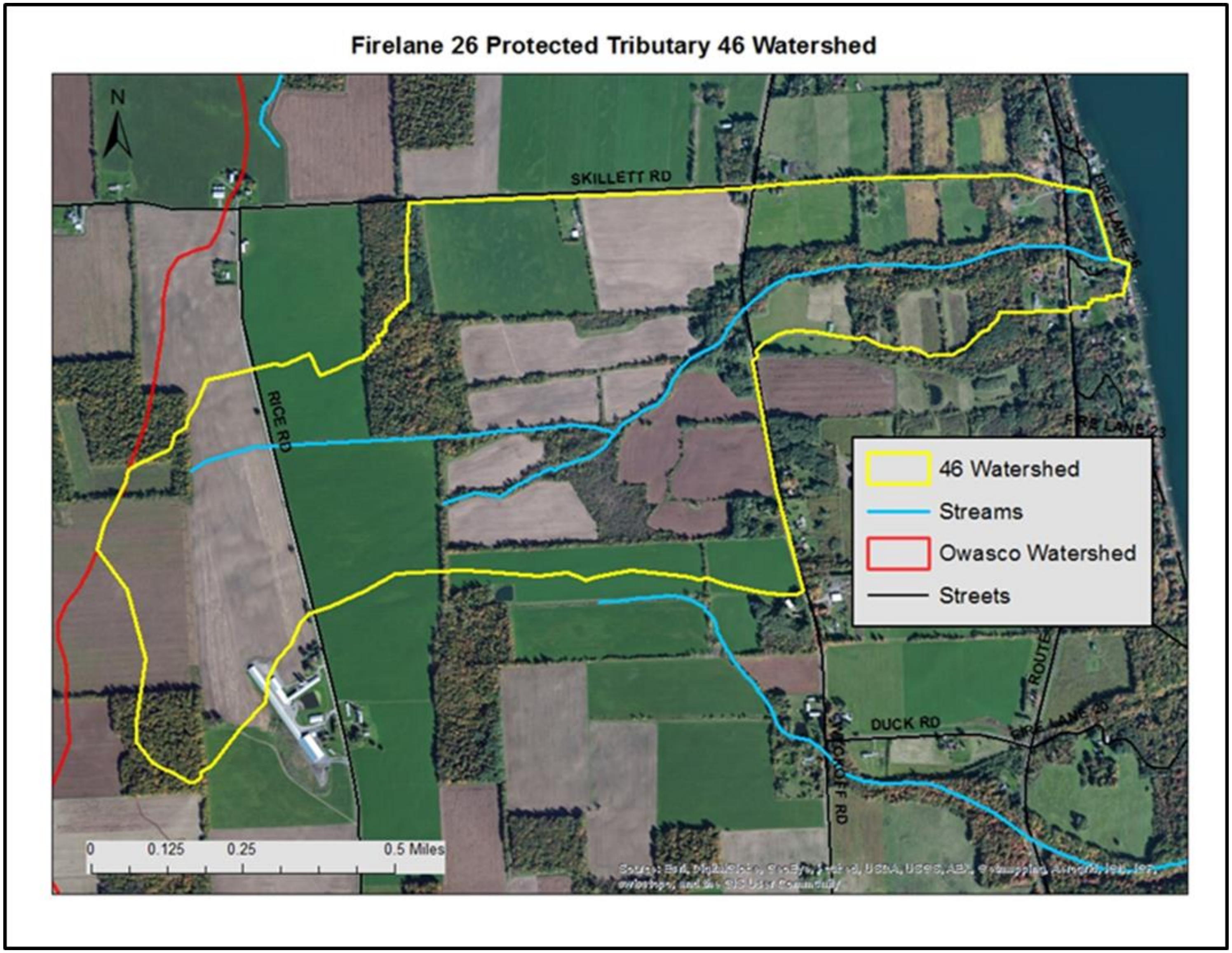

Figure 6. Map of the final watershed delineation. The headwaters of tributary 46 begin at the drainage swale near Rice Rd. The flow then enters a farm ditch before meeting with another branch within the hedgerow. Once the tributary passes Wycoff Rd, it the topography becomes very steep.

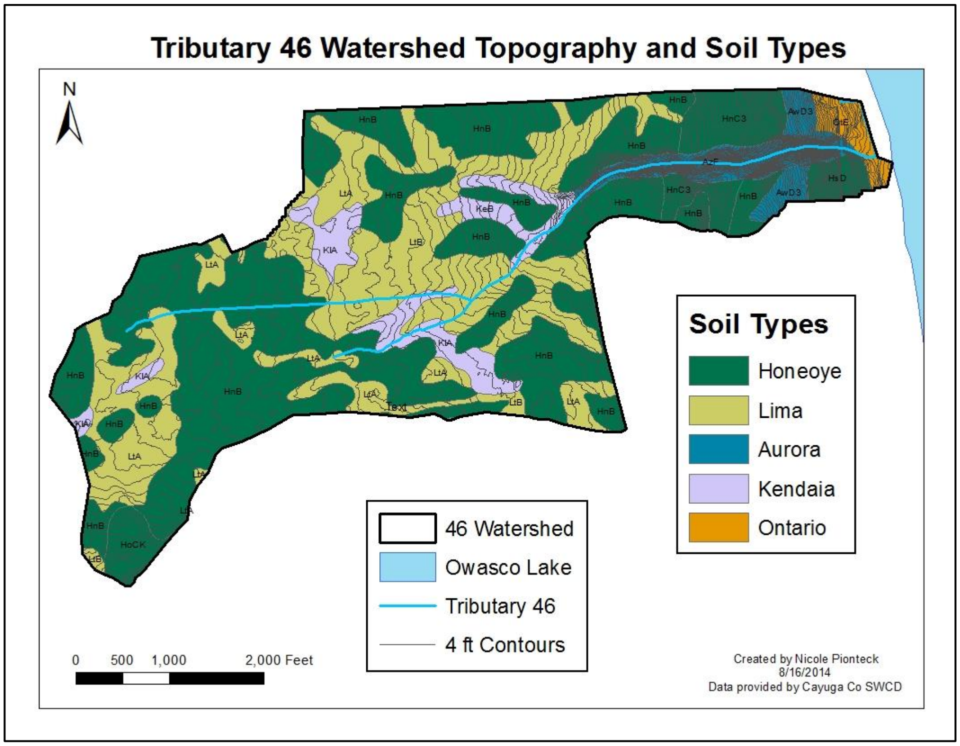

Figure 7. Map of tributary 46 watershed topography and soil types. The dominant soil types are Honeoye and Lima silt loams.

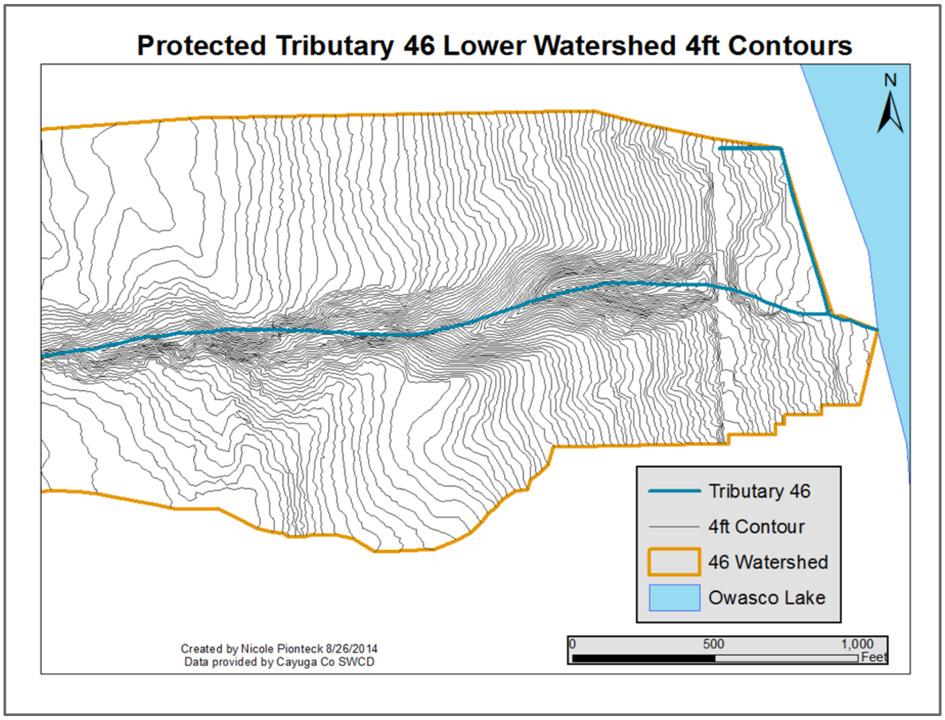

Figure 8. Map of the lower watershed contours to give better detail of the steepness of the topography near the lake.

Figure 9 is a map of the proposed locations for placement of the management practices. The stone check dams (Fig. 10) would be designed based on the specifications in the Vermont Better Back Roads Manual. The ditch located on the map would also have to be redesigned since it is extremely undersized. “Build your own” sediment retention basins would be placed at the location given on the map. The retention basin design is taken from the Essex County Highway Department’s plans (Fig. 11). Figure 12 shows images of the areas where the management practices would be placed.

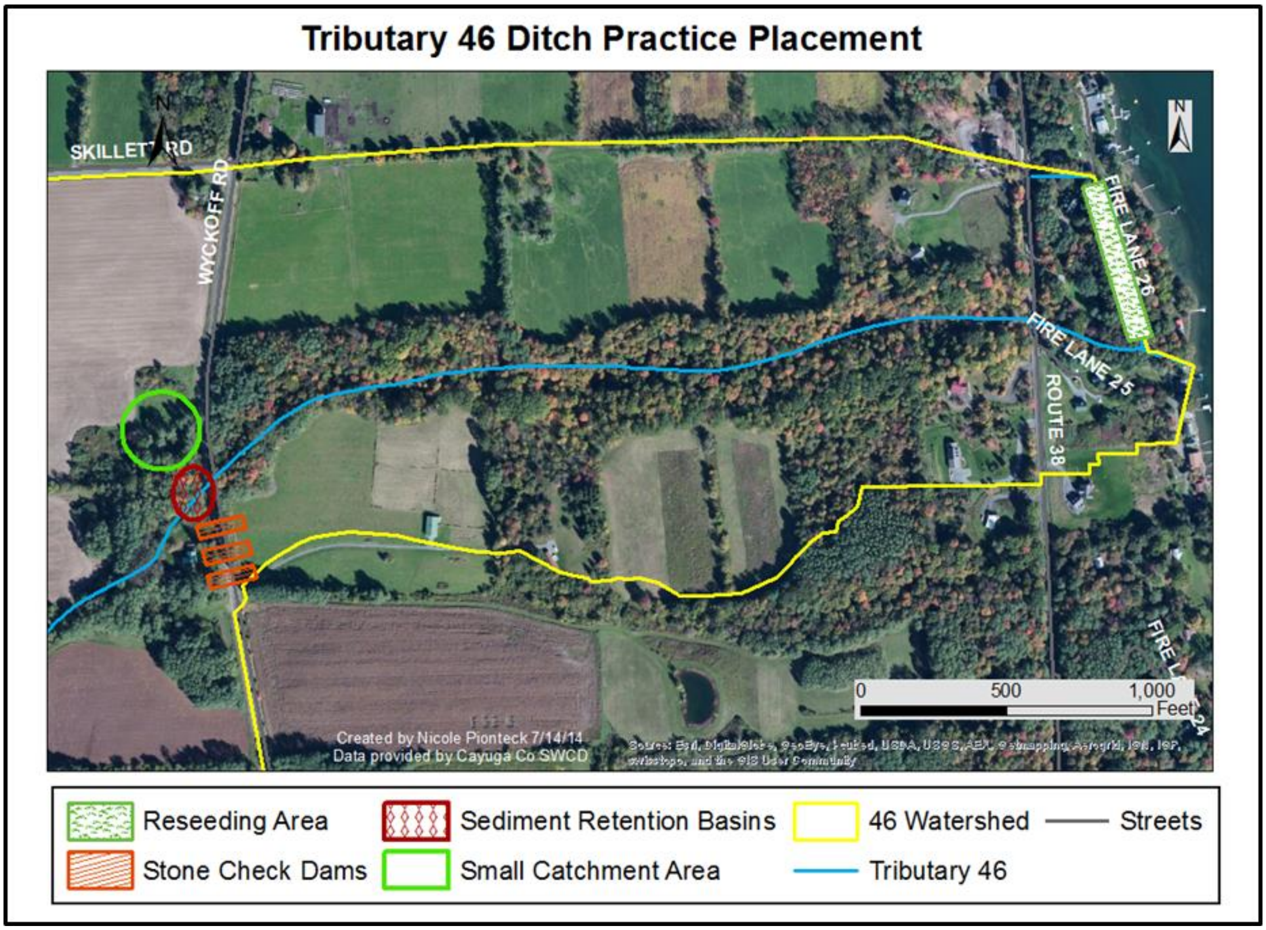

Figure 9. Map showing placement of the management practices. The areas chosen have steep ditch slopes and depressions in the topography that have a large drainage catchment. The reseeding area is a ditch along Fire Lane 26 that consists of all loose sediment that needs to be vegetated

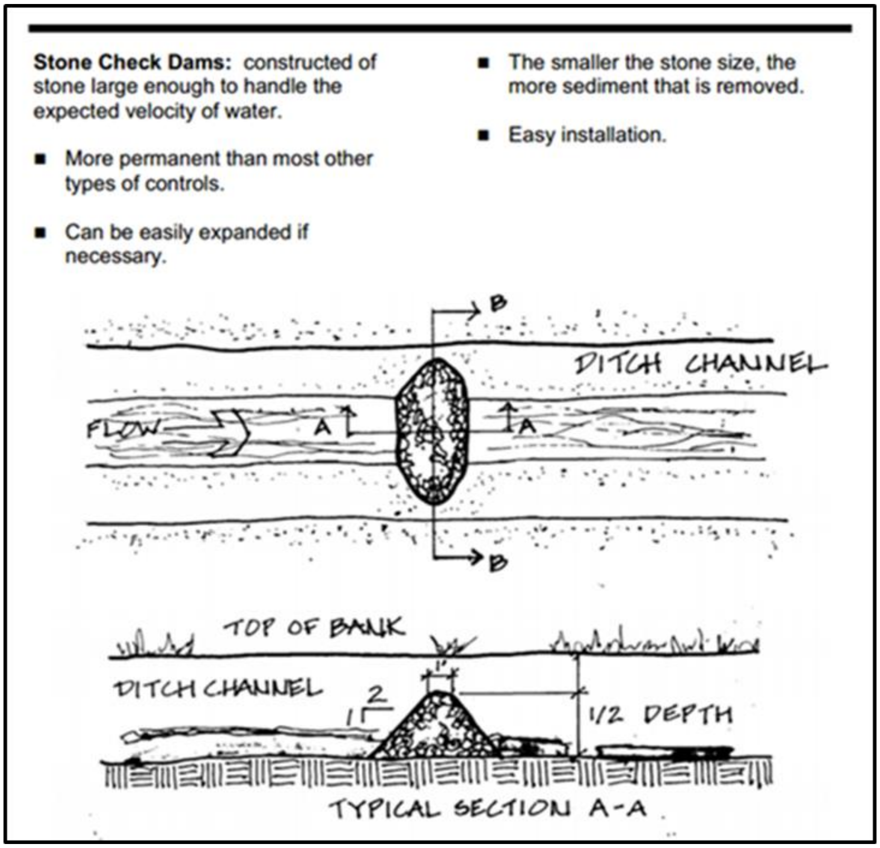

Figure 10. Schematic of a stone check dam from the Vermont Better Backroads Manual (2009).

Figure 11. A “build your own” sediment retention basin, created by the Essex County Highway Department (2006).

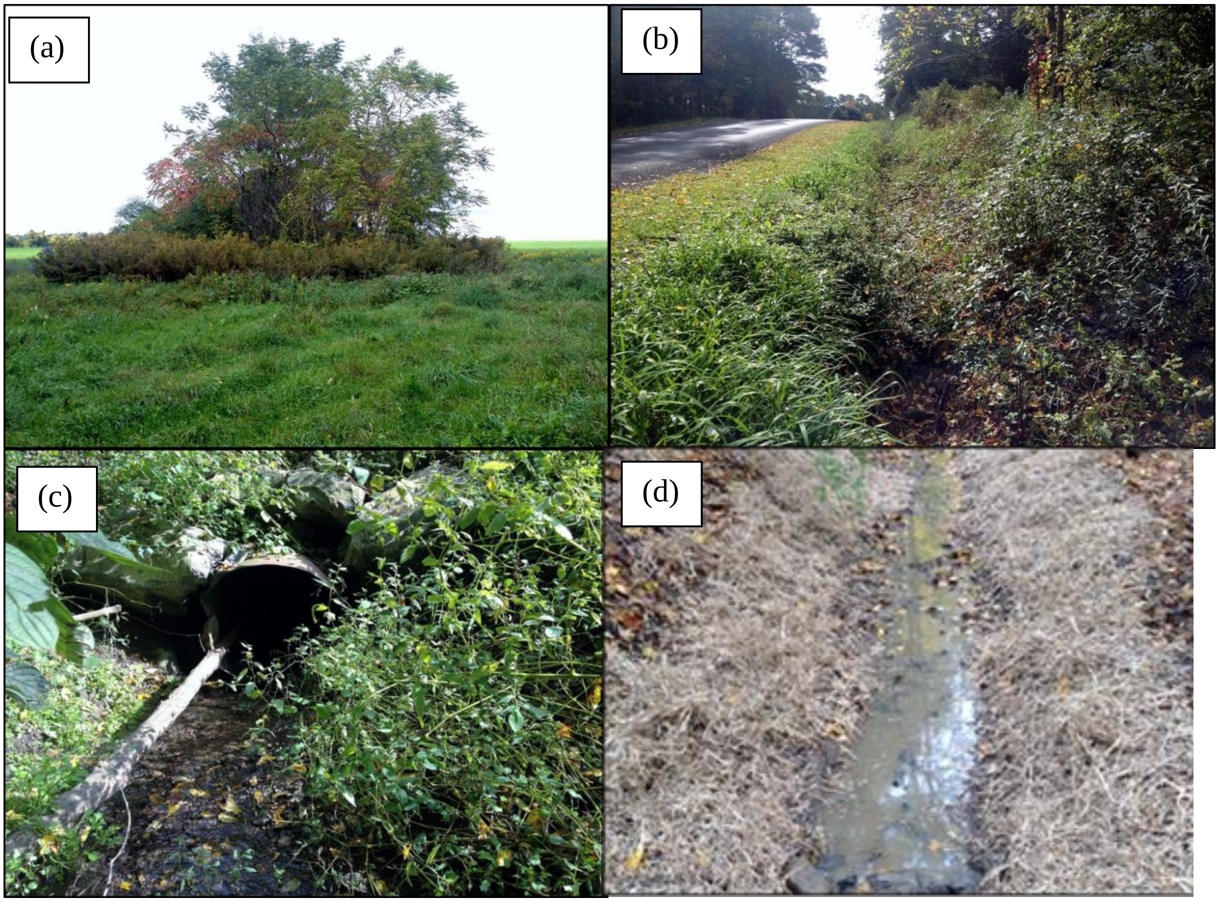

Figure 12. Images corresponding to sites on the placement map. (a) Small catchment area at the corner of a field. (b) Undersized ditch where check dams would be placed. (c) Bed of tributary where sediment retention basin would be placed. (d) Portion of ditch that was seeded [seen here with soybean straw].

DISCUSSION

Storm events characterized by heavy rainfall and/or snowmelt contribute the most particulate pollutants to Owasco Lake. Specifically, in the high agricultural land use portions of the watershed such as the sub watershed of tributary 46, storm runoff contains high amounts of eroded soil and manure (Simon & Makarewicz, 2009). The component that was part of the February 21st runoff event that had the most attention was the poor manure application. It is well known that excess manure application can run off into nearby tributaries or infiltrate into groundwater. This is why large farms, including Allen Farms located at the headwaters of Fire Lane 26, participate in Farm Planning Practices. These plans dictate when and where manure should be spread. Areas with steep slopes or near water bodies should not receive manure application in the winter (Lewis & Makarewicz, 2009). Allen Farms had to spread manure during the winter, as their storage tanks were at maximum capacity; however, a better application site could have been chosen. Farmers within the Owasco Lake Watershed to continue to follow their farm planning practices as this will contribute the most to nutrient mitigation (Lewis & Makarewicz, 2009). At the farm scale, this includes: not applying in high risk areas (such as near water bodies), applying near roots in lieu of broadcasting methods, avoiding applying before heavy rainfall, and creating manure storage of sufficient capacity (Schoumans et al., 2014).

Farms, especially those that have livestock such as Allen Farms, are a significant source of ammonium, phosphate, and fecal coliforms (Edwards, Watson, & Cook, 2012). Water testing performed weekly at the mouth of tributary 46 shows that these contaminants are present; however, the data cannot be confirmed due to significant differences between three different lab's results. However, it is most likely that the source of phosphorus and other contaminants to the lake at this site is due to the influx of manure from the fields above. Other sources of phosphorus within the tributary 46 watershed could include residential septic tank leaks and lawn fertilizer.

Although most people view the phosphorus as coming only from manmade sources, it does occur naturally. Phosphorus makes up less than 1% of the lithosphere. Its primary mineral source is apatite: $3\ [Ca_3\ (PO_4)_2]\ Ca\ \{Cl^-, F^-, OH^-, CO_3^{2-}\}_2$, and its inorganic form is PO_4^{3-} (phosphate). In soils it can exist in multiple forms: inositol (ester) phosphates, phospholipids, nucleic acids, phosphoproteins, and metabolic phosphate. Some forms of phosphate are nearly insoluble, such as iron phosphate ($FePO_4$). Others such as hydrogen and dihydrogen phosphate are soluble based on pH ranges. The majority of soils within the Owasco Lake Watershed are

Honeoye and Lima silt loams. Figure 9 shows that the majority of tributary 46's watershed is comprised of these soils, which are comprised primarily of limestone and calcareous shale (Soil Survey Staff, NRCS, & USDA, n.d.), the latter of which could produce insoluble calcium phosphate compounds (Driscoll, 2014).

Phosphorus is a limiting nutrient in fresh water systems. It can be critical for algal growth, but is species dependent. For example, *Asterionella formosa* has low P requirements, while *Scenedesmus* has high P requirements and can be an indicator of eutrophication. Plant production also increases with increased phosphorus. When consumed by plants and animals, the inorganic P is converted to organic P and excreted. Organic P is also released into the water column when the organisms die. During decomposition, the organic P is converted back to inorganic P by bacteria and returned again to the water column (EPA, n.d.). Owasco Lake is currently borderline oligotrophic – mesotrophic (Halfman, Holler, & Philip, 2006), meaning continued phosphorus loading could cause the lake to become eutrophic. Reoccurring events like that which occurred on February 21st could exacerbate the problem. The nutrient loading that occurred because of this caused Owasco Lake to experience minor episodes of blue-green algae and increased aquatic plant growth during the summer months. Phosphorus also affects water quality by interfering with drinking water treatment plants (EPA, n.d.).

Outside of farm management, nutrients in runoff can be managed within ditches, which is the main goal of this project. Vegetated ditches intercept runoff loaded with nutrients and can act as a mock wetland. This is especially the case of the unvegetated ditch along Fire Lane 26 (see Fig. 9) because it is long with a very shallow slope. Vegetated ditches repeatedly have the ability to decrease 45% of total phosphorus loads in runoff (Flora & Kröger, 2014). Check dams and retention basins slow water velocity, which not only allows sediment to settle out, but also increases chemical residence time. By holding water, check dams and retention basins allow for biological transformations to occur, which could lower nutrient loads before reaching the lake (Flora & Kröger, 2014).

The main purpose of ditches is to carry away collected surface water to keep roads, fields, and developed areas dry. Because ditches are the most integral part of preventing flooding, many of the problems with roadways stem from drainage issues. Excess water in ditches can case road washouts and erosion (Orr, 2003); therefore, it is important that any management practice that slows or contains water in or near the ditches does not cause road failure. Implementing these practices within the ditches would involve the local government, state government, and landowners. Local jurisdictions such as counties, towns, cities, and villages maintain approximately 85% of road mileage in New York State. The placement of the management practices would be located along Wycoff Road, which is under the jurisdiction of the Town of Scipio. The town has specific rights in the Right-Of-Way (Fig. 13). Outside of that area, landowners must be compensated or an easement obtained. The installation of these practices also needs to be within state regulations. When working in and around tributary 46, regulations and laws are enforced by the New York State Department of Environmental Conservation (Orr, 2003).

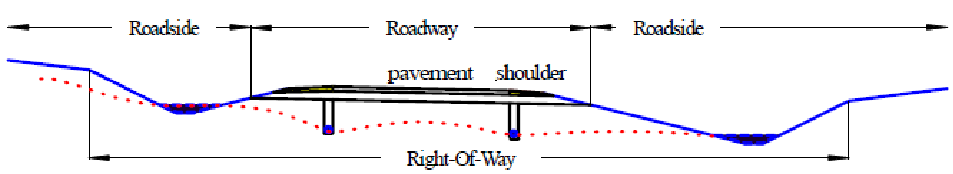

Figure 13. Schematic of a right-of-way (Orr, 2003).

The portion of ditch where the stone check dams will be placed was chosen because it is undersized and has a relatively steep slope of approximately 10%. The ditch is also undersized and poorly shaped. Ideally, the ditch would be reshaped to a trapezoid shape (flat bottomed). This shape is the most hydraulically efficient and has the most capacity to carry large amounts of water. The flat bottom distributes flow and therefore reduces erosion. This shape is more difficult to construct, but the design will reduce the need for future maintenance caused by erosion (Orr, 2003).

Steep slopes cause erosion in the ditches. In this case, the stone check dams are the best option to reduce velocity. Check dams can fail due to the lack of flow dissipation and the presence of downstream scouring (Orr, 2003). This is why the Vermont Better Backroads Manual was used. The trapezoidal shape and rock size allows for flow dissipation while still reducing flow velocities. The proposed trapezoidal shape of the ditch will also reduce downstream scouring. Stone check dams are also cost effective. The price will depend upon gravel prices and the labor, but will be relatively inexpensive.

The concrete sediment retention basin placement is located in a shallow sloped area within the tributary channel. It is an area where two branches of the tributary meet and create a deltaic plain. There is some sediment settling occurring, therefore the retention basin should be installed here as it will be easier to maintain than dredging. The use of the Essex County Highway Department design means the basin can be built to a size that best suits the area. It is cost effective because the frames that the concrete is poured into can be reused for other projects.

Vegetating ditches should be used wherever possible. Seeding is cheaper than other methods of ditch cover, such as rip rap or concrete, and is highly effective at reducing sediment movement. It is also aesthetically pleasing, as opposed to more man-made options (Orr, 2003). CCSWCD had the seed available for use on the unvegetated ditch along Fire Lane 26 and has more seed for use in other ditches within the watershed, making seeding for both the town and landowners extremely inexpensive. For the project, the soybean straw used was donated by a local farmer. Seeding took place on October 23, 2014. A fescue mix was used which is recommended by the Roadway and Roadside manual (Orr, 2003). Fescue tolerates the shaded conditions of this ditch better than other grasses. Only a small portion of the ditch was seeded, and was successfully established as of November 6th. Therefore, the rest of the 800 ft ditch will be seeded next year. As noted on the placement map (Fig. 10), there is also a small catchment area with trees and other vegetation. These kinds of catchments can be planted in other critical areas of the watershed where there are high amounts of agricultural field drainage that can be intercepted.

CONCLUSION

This pilot project focuses on just one sub-watershed on Owasco Lake, but can be used as a template for almost all the other sub-watersheds. The goal is to protect the living environment through keeping the lake healthy and the drinking water clean, by altering the physical environment through installation of check dams, retention basins and seeding to keep sediment in place, all while keeping the social environment in mind by using cost effective solutions for the town and landowners. If this project is applied to other areas of Owasco Lake, the water quality and the lives of the visitors, residents, and biota will improve. In the future, runoff events like that which occurred on February 21st should be monitored by obtaining flow rates and water samples to determine nutrient and sediment levels in order to provide quantitative data. Another major step to improving Owasco Lake water quality would be to determine the delineations for the other numerous small tributaries that feed directly into the lake.

References

Buchanan, B., Easton, Z. M., Schneider, R. L., & Walter, M. T. (2013). Modeling the hydrologic effects of roadside ditch networks on receiving waters. *Journal of Hydrology*, *486*(0), 293–305. doi:10.1016/j.jhydrol.2013.01.040

Driscoll, C. T. (2014, October 22). *Biogeochemistry of Phosphorus*. Syracuse University. Retrieved from blackboard.syr.edu

Edwards, A. C., Watson, H. A., & Cook, Y. E. M. (2012). Source strengths, transport pathways and delivery mechanisms of nutrients, suspended solids and coliforms within a small agricultural headwater catchment. *Science of The Total Environment*, *434*, 123–129. doi:10.1016/j.scitotenv.2011.10.055

EPA, U. (n.d.). Phosphorus. Retrieved December 7, 2014, from http://www.epa.gov/agriculture/ag101/impactphosphorus.html

Flora, C., & Kröger, R. (2014). Use of vegetated drainage ditches and low-grade weirs for aquaculture effluent mitigation: I. Nutrients. *Aquacultural Engineering*, *60*(0), 56–62. doi:10.1016/j.aquaeng.2014.04.006

Halfman, J. D., Holler, B. L., & Philip, H. M. (2006, January 10). A Preliminary Water Quality Study of Owasco Lake, NY, and its Watershed. Finger lakes Institute and Hobart and William Smith Colleges.

LaVinge, T. (2006). Building your own sediment traps. Essex County Highway Department.

Lewis, T. W., & Makarewicz, J. C. (2009). Winter application of manure on an agricultural watershed and its impact on downstream nutrient fluxes. *Special Issue on Watershed Management and Nearshore Lake Water Quality, The Conesus Lake Watershed Study*, *35, Supplement 1*(0), 43–49. doi:10.1016/j.jglr.2008.08.003

New York State Department of Transportation. (2011, June). Environmental handbook for transportation operations: a summary of the environmental requirements and best practices for maintaining and constructing highways and transportation systems. NYSDOT Environmental Science Bureau.

Orr, D. P. (2003, February). Roadway and roadside drainage. Cornell Local Roads Program, Ithaca, NY.

Reichert, M. M. (2009). Vermont better backroads manual. George D. Aiken & Northern Vermont Resource Conservation & Development Councils. Retrieved from http://www.nvtrcd.org/bbr.html

Rickson, R. J. (2014). Can control of soil erosion mitigate water pollution by sediments? *Science of The Total Environment*, *468–469*, 1187–1197. doi:10.1016/j.scitotenv.2013.05.057

Schoumans, O. F., Chardon, W. J., Bechmann, M. E., Gascuel-Odoux, C., Hofman, G., Kronvang, B., … Dorioz, J.-M. (2014). Mitigation options to reduce phosphorus losses from the agricultural sector and improve surface water quality: A review. *Science of The Total Environment*, *468–469*(0), 1255–1266. doi:10.1016/j.scitotenv.2013.08.061

Simon, R. D., & Makarewicz, J. C. (2009). Storm water events in a small agricultural watershed: Characterization and evaluation of improvements in stream water microbiology following implementation of Best Management Practices. *Special Issue on Watershed Management and Nearshore Lake Water Quality*, *The Conesus Lake Watershed Study*, *35, Supplement 1*(0), 76–82. doi:10.1016/j.jglr.2008.12.002

US Geological Survey, U. D. of the I. (n.d.). StreamStats. Retrieved from http://water.usgs.gov/osw/streamstats/ssonline.html