Role of Weather on Design of a Water Quality Trading Program Baseline: A Case Study of the Jordan Lake Watershed, North Carolina

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Abstract

Water quality trading (WQT) has been suggested as a cost effective approach to achieve water quality goals for many watersheds (EPA, 2007), including the Jordan Lake watershed in North Carolina. Although, theory supports the concept, its implementation has experienced a numbers of failures in the United States. A broad spectrum of physical, social, economic, and intuitional factors have diverted success. One of the institutional hindrances is the WQT baseline. WQT baseline is a reference point that must be met by credit sellers and buyers before being allowed to buy or sell credits. Favorable (unfavorable) weather compared to the baseline can result in gains (losses) attributed to conservation technology. We construct a WQT market applied to the new Jordan Lake Watershed program in North Carolina to examine the role of weather on baseline period as related to total nitrogen (TN) loads in Jordan Lake. Results of our models show that the baseline weather condition has a profound impact on the water quality credits supply. The purpose of this study is to alert policy makers to this issue and to suggest ways to better match the baseline incentives with emission reduction goals when taking weather variability and trends into account.

Keywords: Water Quality Trading, Baseline, Riparian Buffers, Weather, Jordan Lake

Introduction

There have been increasing calls to establish water quality trading (WQT) markets for nutrients (EPA, 2001, 2004; Willamette Partnership, et al., 2015). Nutrients are the primary culprit in many of the impaired or threatened lakes, reservoirs, and ponds in the United States (Selman et al. 2009) and are a seemingly suitable candidate for trading. In theory, water quality can be improved at a lower cost using WQT than command and control policies such as regulation, which was successfully demonstrated for mitigating Sulfur Dioxide emission into the atmosphere (Stavins, 2005). The U.S. Environmental Protection Agency estimated that allowing trading between point sources (PSs) and nonpoint sources (NPSs) could reduce the cost of implementing water quality goals nationally by $140-235 million annually (EPA, 2001). The conservation measures used to produce nonpoint source credits can also result in co-benefits, such as improved wildlife habitat (Lentz et al., 2014).

Conceptually, WQT programs allow polluters with high abatement costs to purchase credits from firms with lower abatement costs to meet their own regulatory limits. For example, a waste treatment plant might find it less costly to pay a farmer to install conservation practices to abate a pollutant, such as nitrogen, than to upgrade their own systems. Although WQT is conceptually appealing, programs that have been implemented thus far have struggled to show a meaningful success (Greenhalgh and Selman, 2012; Ribaudo and Gottlieb, 2011; Stepheson and Shabman, 2010), with only a few trades occurring in any of the programs. A growing list of reasons why these programs have not found more success have been identified in economic literature, including high transaction costs, high trading ratios, and trust or uncertainty on the part of buyers and sellers (Breetz, et al., 2004; Ribaudo, 2013; Newburn and Woodward, 2011; Stepheson and Shabman, 2010).

One of those hurdles is a baseline requirement, which establishes a threshold that must be exceeded before credits can be offered to others (Ribaudo, 2013). While there is a vast body of research showing that weather can have a significant effect on the level of pollutant loads to water bodies (Kang, et al. 2009; Lang, et al. 2013), there has been little attention paid to how this variation might affect the efficacy of baselines. Therefore, in this study, we determine how weather congruity between the baseline and implementation date in a water quality trading program effects the number of credits traded and the impact on cost savings and abatement. Typically, the amount of pollution in a baseline is dependent on some weather scenario, and many other factors such as soil types, conservation practice and distance to water. Both point sources and nonpoint sources are regulated by Total Maximum Daily Load (TMDL) limits, which establishes a cap for an impaired watershed. Typically, PSs are obliged to adhere to those limits and NPs, like agriculture, are not. While we found a number of studies that detailed limitations stemming from the way baselines are established and implemented, we found only one that discussed temporal distortions in detail related to how pollution is measured between the baseline and point of implementation (Michaelowa, 2009). The point of that study was to illustrate difficulties related to estimating pollution across large regions where countries are trading greenhouse gas emissions through Joint Implementation programs. In the case of Nutrients, data and models are available to make more precise forecasts, which hides a problem that has not been previously examined. Of course, many of the problems already discussed in the literature will persist, but none have focused on the distortion that can be created by rules related to how the weather pattern is chosen by baseline and implementation decisions.

We build a supply and demand model for an active WQT program in the Jordan Lake Watershed, North Carolina. Then we isolate the impact of weather on a farmer’s ability to supply credits. We show that if the weather conditions for the baseline were severe, leading to a lot of pollution, a farmer has a weather advantage toward supplying credits, and vice versa, which either leads to a lack of additionality in preventing pollution or in raising the cost of the program, respectively. Using our market model, we then estimate these distortions, and finally we examine how to improve assumptions about the weather to reduce distortions.

Methodology

A detailed description and study about how baselines affect farmer's willingness to install conservation practices and to supply nutrient credits can be found in Ribaudo, Savage and Talberth, 2014. They establish no lose (Millard-Ball, 2013) baselines that act as eligibility requirements (Horowitz and Just, 2013) that farmers must achieve before being able to supply credits in the Chesapeake Bay Watershed. They include a business-as-usual (BAU), or current practice, baseline and five baselines with limits on Nitrogen loss per acre, ranging from 15 to 65 pounds. More stringent baselines increase the cost for farmers to provide credits by increasing the amount of abatement that cannot be counted, shifting the supply curve to the left, and making it more difficult to provide credits (Ghosh et al., 2011; Ribaudo et al., 2014; Stephenson et al., 2010). Abatement that cannot be counted toward selling credits provides additionality but reduces the number of producers that sell credits and reduces the ability of WQT to reduce program costs (Ribaudo and Savage, 2014). Likewise, if the baseline is set below that currently occurring, payments result in no additionality.

Similar to Ridaudo, Savage and Talberth (2014), we estimate supply and demand for credits in a case study. However, our focus is on climate congruence related to the establishment of the baseline and the performance of the conservation practice. Credits in our case study in the

Jordan Lake Watershed are awarded based on the reduction of Nitrogen from using a conservation practice, riparian buffers in this case, compared to a baseline, currently the five-year average between 1997 and 2001. Similar to many programs, Nitrogen reduction is estimated by models and in this case is measured as the quantity predicted to enter Jordan Lake based on average weather during the five-year baseline and weather in the year the practice is applied. We focus just on the implications of how these two weather points affect credit generation, abatement, costs savings and additionality. All other forms of baseline distortions, such as misrepresenting conservation efforts (Miller and Duke, 2013), setting baselines low to award good stewards (Ribaudo and Savage, 2014), changes in technology over time (Michaelowa, 2009), shifting baseline syndrome (Papworth et al., 2009) and informational asymmetries between buyers, sellers and monitors (Millard-Ball, 2013) are ignored.

The Jordan Lake Watershed is located in the Piedmont region of North Carolina. The 4,367 km^2 watershed is comprised of three sub-watersheds: Haw, Upper New Hope and Lower New Hope covering 80%, 13% and 7% of the total watershed area respectively (figure 1). The Jordan Lake Watershed is located in the Piedmont region of North Carolina and is a significant water resource within the Cape Fear River Basin. In addition to serving as a crucial water supply, Jordan Lake was created to provide flood control, protection of water quality downstream, fish and wildlife conservation, and recreation services. The lake has been declared as hyper-eutrophic by the Environmental Management Commission since its impoundment.

The no-lose baseline in the Jordan Lake program is the five-year average total nitrogen (TN) yield into the lake. As shown in figure 2, the amount of TN from any one farmer that enters the lake will vary by year, depending on climate patterns. A flat trend with a consistent pattern is depicted for simplicity. If the baseline happened to occur in a period when the pollution was very low, the baseline would represent a point below the average, B. If a farmer wanted to get into the program when the climate happened to result in a very high level of pollution, P_c, keeping the practice constant for now, he would find that he is already exceeding the baseline due to differences in the climate, not because of his practices. If he then applies a conservation practice, he is made less likely to overcome the weather penalty. For example, if the practice reduced TN delivered to the lake to P_{P1}, the farmer could not achieve baseline, even though $P_c - P_{P1}$ is abated. If the conservation practice reduced pollution to P_{P2}, the farmer could supply credits based on the difference between $B - P_{P2}$. In either case, the number of credits is fixed even though the net reduction in TN would ebb and flow along with the climate patterns. If for example, credits were based on the current year, instead of the implementation year, a farmer would have a weather advantage in some years, where he could reach the baseline with no effort in conservation (figure 2).

There are a number of solutions that can be applied to address the distortion caused by weather incongruences. The weather cycle could be de-trended and credits based on longer periods. With models, one could even hold the weather cycle constant for each period, regardless of what the weather was. We look at the distortion caused by the current program baseline rules and at some adaptations below.

Credit Supply

We develop an empirical model based on actual WQT program rules and goals, and then evaluate how weather will affect the baseline design and amount of generated credits based on cost and pollution data for individual farms in the Haw sub-watershed. In the Jordan Lake WQT program, farmers can install riparian buffers as the conservation practice to reduce TN loads delivered to the

Lake to meet the baseline and then sell credits to new urban developers. The TMDL utilized loading results from 1997-2001 to establish a background condition for the Jordan Lake Watershed upon which reductions were based.

To estimate the credits supply curve, total nitrogen reduction (TNR) credits were estimated for each agricultural field based on data for 3,718 Common land Units (CLUs) for which conservation practice data were available. It is infeasible to measure pollutant loads from all nonpoint sources within a watershed. Hence, simulation models are commonly used to estimate nonpoint source pollutant loads from conservation practices (Arabi et al. 2012). The purpose of using a watershed model in this study was to simulate the hydrology, water quality, and management operations at different spatial scales (watershed, field, etc.). A Soil and Water Assessment tool (SWAT) model was developed for simulation of stream flow and water quality (nutrients) for the watershed. SWAT is a process-based semi-distributed watershed model which operates on daily time-step. The model is widely used in the literature to evaluate water quality benefits of agricultural conservation practices (SWAT literature database 2016) which makes it an ideal candidate for the purpose of this study.

Delivery ratios were applied based on SPAtially Referenced Regressions on Watershed (SPARROW) coefficients (Smith et al. 1997) to estimate TN load delivery to Jordan Lake. Yield and price data for North Carolina crops and hay (NASS 2014) were then combined with these delivery ratios to calculate the marginal cost (MC) of conservation practice adoption for each field (see Motallebi 2015 for details).

To be qualified to sell the credits, nonpoint sources, such as farmers, must first accede to the baseline requirements. In order to meet the baseline and then sell the credits, farmers are required to install riparian buffers. Installing riparian buffers generates costs for farmers including:

1) installation cost, 2) opportunity cost (lost yield), and 3) maintenance and monitoring cost. A farmer can maximize his/her profit by selling crops and primary TNR credits as follows:

$$max_{x,Z} \quad \pi = P_Y Y + P_N TNR(Z) - TC(Z) - r_x x \qquad (1)$$

where x and Z are traditional crop production inputs and the inputs required for installing conservation practices, respectively. Z is the amount of the conservation practice implemented that supplies TNR. The first term $P_Y Y$ is crop revenue; the second term is the TNR credit revenue. P_Y and P_N are crop prices and credit prices, respectively. Y and $TNR(Z)$ are crop production and the amount of TNR credits, respectively. The product of $r_x x$ indicates the total cost of crop production and $TC(Z)$ encompasses the installation and the opportunity cost of implementing the conservation practice. Z is a function of required water pollution reduction, $Z = f(\bar{e} - e_0) = f(\Delta e)$. Where $\bar{e}$ and e_0 are the amount of pollution emission in baseline and the amount of current emitted pollution respectively. That is,

$$\begin{cases} \text{If } \bar{e} > e_0 \text{ farmers can sell credits} \\ \text{If } \bar{e} < e_0 \text{ farmers are not eligible to participate in WQT program} \end{cases} \qquad (2)$$

The baseline condition has the effect of truncating the lower end of the supply function, and effectively requiring a farmer to supply up to the baseline at their own expense. Therefore, $\bar{e}$ is a major factor in deciding whether a farmer can provide credits to a WQT market. Finally, the baseline weather conditions are varied as described later.

Credit Demand

In the Jordan Lake watershed, the demand function represents the needs of urban developers, which are regulated non-point emitters. New urban developers have two options to reduce their nutrient emissions into water. They can either install waste water treatment plants (WWTP) including bio-retention, sand filters, ponds, or wetlands; or participate in the WQT program to buy credits. If the marginal cost of participating in trading is less than the marginal cost of installing technology, developers can meet their pollution requirements at lower cost with the WQT program.

The cost of installing the WWTPs including construction cost, 20 year maintenance cost, and the opportunity cost of lost production were extracted from the economics of structural stormwater best management practices (BMPs) report for NC (Wossink and Hunt, 2003). Net present value (NPV) of these costs with a discount rate of 4.6% was used to calculate the cost of WWTP for the 2014. Our model will utilize the TN loads before and after installing BMPs for a new urban development based on the Jordan Lake Nutrient Loading Accounting Tool (NCDENR, 2007). The total storm water management requirement's threshold for urban developments in the Haw watershed for TN is 3.8 and 1.43 (lbs/ac/yr), respectively (See Appendix Table 2). Loading from developments will vary highly across the region. Therefore, we used the results from a 43.3 acre residential and commercial development located in the city of Durham as a proxy for the region. According to the Jordan watershed model report (TETRA TECH 2014), the imperviousness (representing urban growth here) between 1999 and 2010 increased by 33,211 acre in the Haw River watershed, or by 3,019 acre per year. We assume for simplicity and lack of data that the imperviousness growth indicates the urban development growth. Therefore, the urban development in the Haw sub-watershed will continue to grow at 3,019 acres per year, and that all growth will have the same impact as our case study, we can assume that there would be the equivalent of 70 new developers in 2014.

Results

Tasdighi et al. (2016) showed an observed increase of 50% in TN loads by farmers in 2012, compared to the Jordan baseline in 1997-2001, could be almost completely explained by weather, not on conservation measures. To demonstrate the effects of weather we compared a rolling five-year baseline starting with 1997-2001 and ending in 2012. This created various entry points, B, along the annual pollution curve presented in figure 2. At this time, we have only aggregated results for the impact of these baseline assumptions at the watershed level for all fields and do not have information about each field's performance.

Results for each rolling five-year baseline, and baselines for the maximum and minimum loads, are presented in table 1. Note that the number of participants that are able to meet the baseline and supply credits roles with the baseline as demonstrated in figure 3. That is, when TN from the baseline is lower than TN from current practices, farmers are less able to supply credits due to the weather penalty and vice versa. Accordingly, the number of credits supplied varies commensurately, from a low of 966 to a high of 6,653. The maximum credit shows the largest number of credits supplied from any single field. The minimum and maximum MC show how much a producer needed to supply those credits given the cost of implementing a riparian buffer and the amount that made it to the lake. Social surplus, producer plus consumer surplus, is also provided.

Clearly, the baseline is making a difference on the number of credits provided and social surplus, and it rolls with the weather as demonstrated in figure 2. To demonstrate how extensive this distortion can be, we also added a scenario where the baseline was at the lowest level it could be, min load, and at the highest level it could be, max load. The social surplus between these two scenarios varied from $109,070 to $11,346,343. We are in the process of extending the time period examined and looking at other variations in the baseline assumptions (such as de-trending the data when the trend might be increasing due to climate change) in time for the presentation of this article in the 2016 AAEA meeting. We are also working to report the individual implications on abatement, versus credit supply (weather penalty or advantage), and program cost and additionality.

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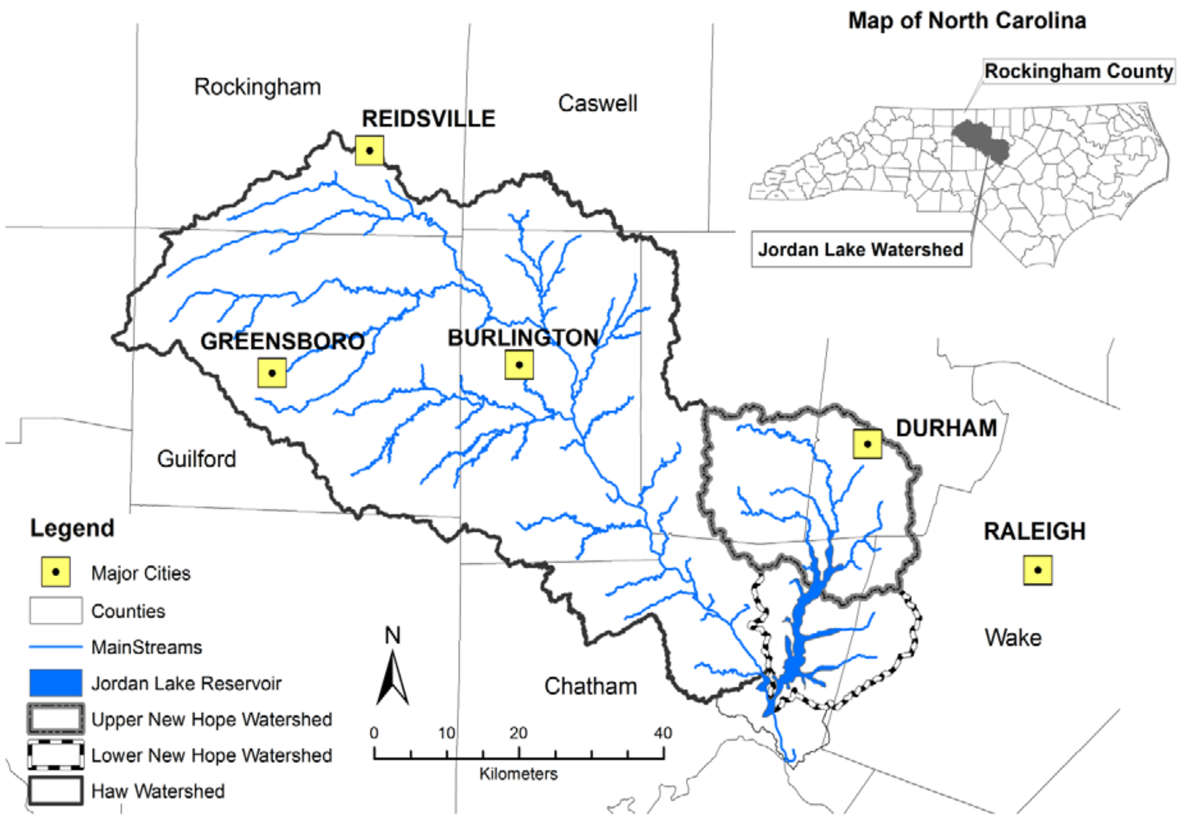

Figure 1. Jordan Lake watershed

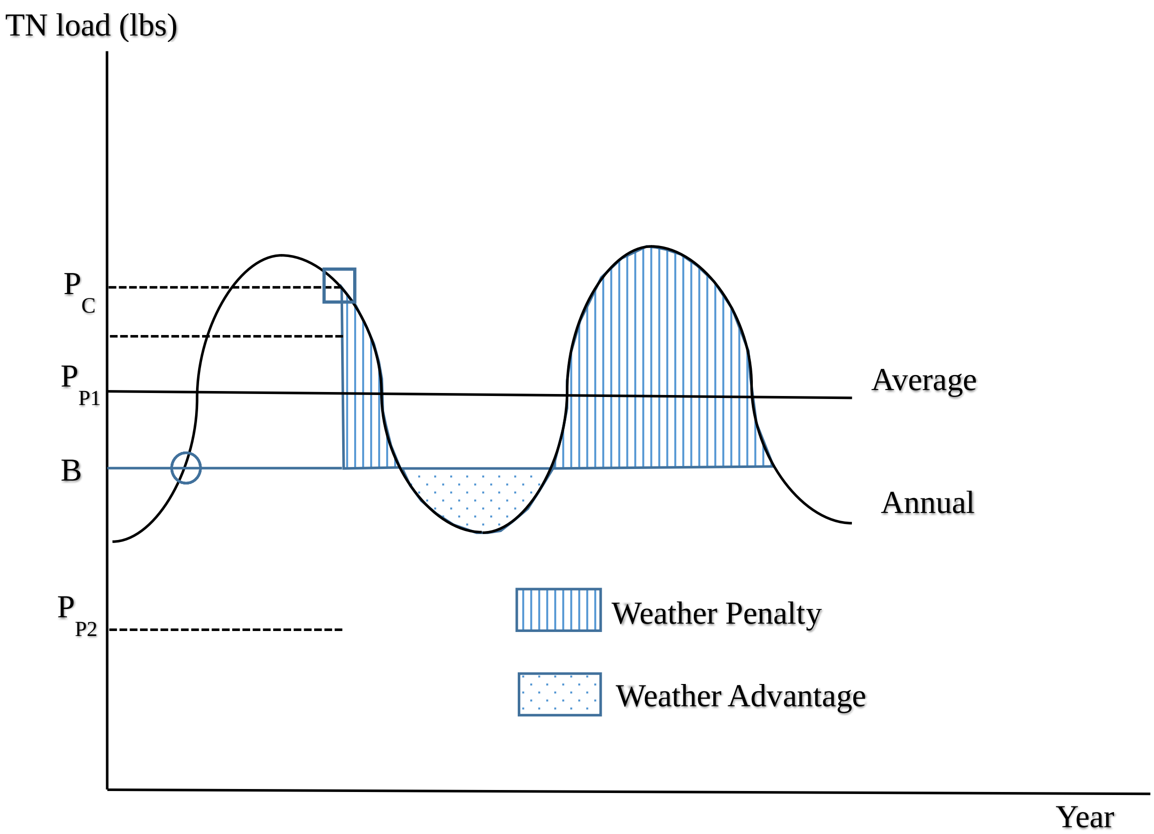

Figure 2. Annual pollution and average pollution with baseline (B), current pollution (P_C), and pollution after installing two differing conservation practices (P_{P1} and P_{P2}) for a hypothetical agricultural field.

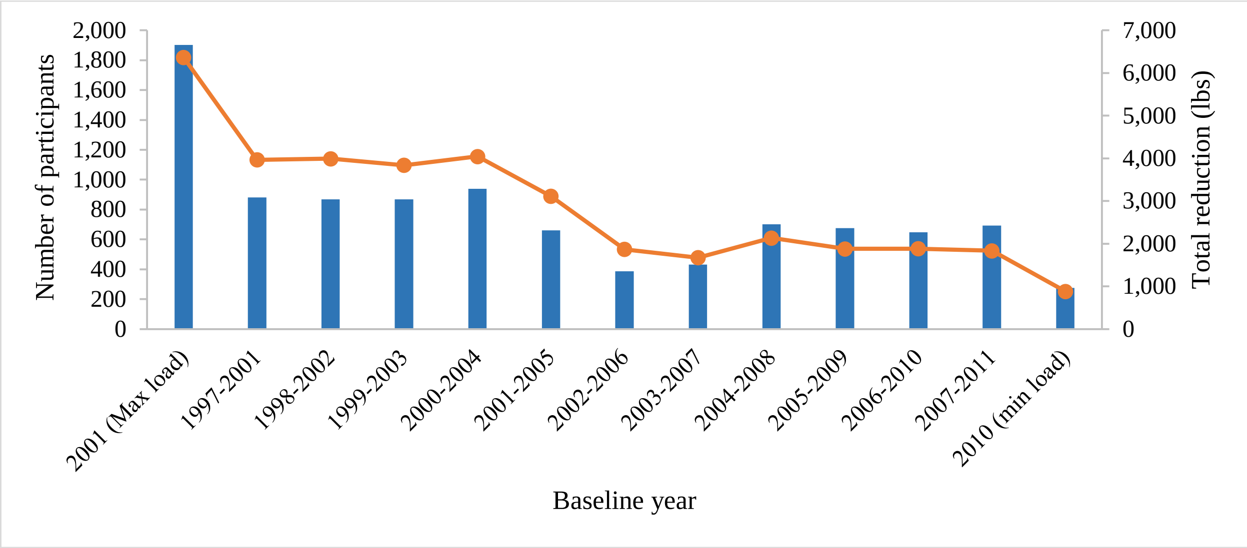

Figure 3. Number of participant fields and TN reduction under different baseline scenarios

Table 1. Number of participant fields, total and maximum credits, Max and min MC, social surplus, and average rainfall under different baseline scenarios

Baseline	Number of participant fields	Total Credit (lbs)	Max credit (lbs)	Min MC	Max MC	Social Surplus	Average rainfall (inch)
1997-2001	1,133	3,083	43.6	284	16,209	7,248,496	1337.5
1998-2002	1,141	3,039	40.8	271	15,189	7,470,540	1362.6
1999-2003	1,097	3,035	46.6	238	16,544	7,501,701	1432.8
2000-2004	1,156	3,285	52	207	17,002	7,333,082	1416.4
2001-2005	889	2,313	39.7	227	26,142	4,683,675	1377.4
2002-2006	534	1,351	34	241	31,589	2,374,150	1111.7
2003-2007	478	1,509	50.6	246	26,286	3,075,376	1058.0
2004-2008	610	2,457	74	168	24,088	6,331,799	982.9
2005-2009	537	2,364	72.6	171	22,089	5,931,253	995.8
2006-2010	538	2,266	67	185	17,923	5,983,925	1013.0
2007-2011	524	2,428	57.2	217	15,196	6,301,852	986.8
2001 (Max load)	1,818	6,653	76	145	11,016	11,346,343	-------
2010 (min load)	252	966	50	307	23,911	109,070	-------

Appendix

Table 2 shows that a 0.7acre commercial new urban developer is required to reduce its pollution by 6.8 (lbs/ac/yr). Currently, this developer has reduced its reduction by 4.4 (lbs/ac/yr) by installing a bio-retention. Therefore, the developer needs to reduce its load by 2.35 additional lbs/ac/yr, either by expanding the current BMP or by trading with farmers. If he/she chooses the first option, he/she requires 1.65 lbs offset per year. The marginal cost of expanding the current BMP to reach the required reduction is 4,139 ($/lbs). Likewise, a 4acre, a 6.4acre, and a 32.2acre urban developer will spend $18,083, $163,126, and $618,238 per lbs of load reduction if they upgrade their current BMPs to reach the required TN reduction. Figure 4 shows the demand for water quality credits in the Jordan Lake Watershed.

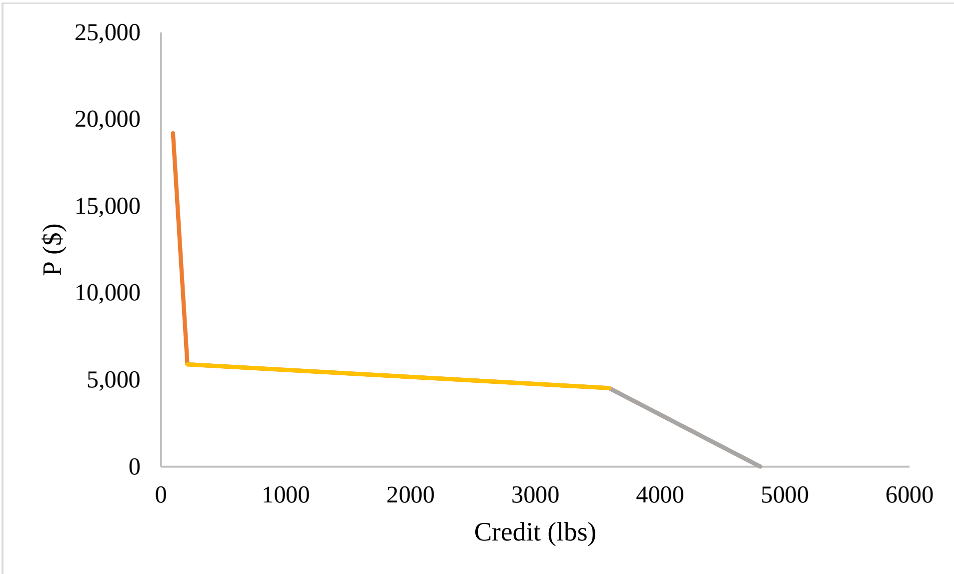

Figure 4. Demand for water quality credits in Jordan Lake Watershed

Table 2. New urban developers' BMP size and BMP cost based on case study in Durham County, North Carolina

Development	Type	Size (ac)	Location	BMP	Current reduction (lbs/ac/yr)	Required reduction (lbs/ac/yr)	Total individual offset (lbs/yr)	TC (NPV) for current reduction ($)	TC (NPV) for required reduction ($)	MC ($/lbs)
The Villas at Hope Valley	Residential	4.00	Durham	BRC w/IWS[1]	2.1	2.4	1.36	123,051	129,199	18,083
City Center	Commercial Building	0.70	Durham	BRC w/IWS	4.4	6.8	1.65	35,612	45,338	4,139
Hendrick South Point	Commercial Auto Mall	32.20	Durham	2 Ponds and Sand Filter	2.3	3.8	48.30	3,840,143	4,767,501	618,238
BCBS of NC	Commercial	6.40	Durham	Wetland and Sand Filter	2.2	4.9	17.28	921,651	1,362,092	163,126

[1] Bio-retention cell with or without internal water storage