Economic Valuation for the Saluda-Reedy Watershed

By

Jeffery Allen, Robert T. Carey, T. Brian Hock, Robert H. Becker

July 2007

Table of Contents

Step back from the edge of the water, be it a lake or river, and let us look at pollution as an exchange of money – some group is going to pay (incur costs) others will save (incur benefits). Those that save did not have to go through the expense of eliminating contaminants from water. These types of savings can occur at points of treatment by discharging waters with higher levels of contaminants. More often, however, the savings occurs in small increments over large areas and populations through improper sediment management, poor land use regulations and inadequate storm-water control. These types of inadequate provisions or weak regulatory actions for pollution control may be difficult to summarize, but they impose the same costs on downstream users.

Water is a scarce resource. This is obvious when one examines the Saluda and Reedy Rivers. Use of the watershed by those upstream in Greenville has an effect on how the watershed's resources can be used by those downstream in Greenwood. The task of this economic valuation study is to attempt to describe these differences more precisely. The first step in this process is to examine water quality at different points on the watershed. There are many ways to define water quality. For the purpose of this study, we are looking solely at nutrient levels, specifically phosphorus and nitrogen. The watershed can be divided into political jurisdictions by county; we have obtained data on nutrient levels from the following DHEC monitoring stations in Greenville and Laurens Counties:

- S-073, located on the Reedy River above Traveler's Rest,
- S-013, located above the WCRSA Mauldin Road facility,
- S-072, located near Fork Shoals, and
- S-021 above the Reedy arm of Lake Greenwood east of Ware Shoals.

The general trend is that nutrient levels increase markedly between S-073 and S-013, but then decrease the further downstream samples are taken. This can be seen looking at nutrient levels on the Reedy River from available data from 1995-2002, and will be demonstrated in this report by statistical regression.[1] For example, the median total phosphorus level at the Greenville station (S-013) was 261 pounds per day during this time. At the Fork Shoals station (S-072), the total phosphorus level had decreased to a median level of 166 pounds per day; it decreased further to a median level of 108 pounds per day at S-021. There are different ways to look at this difference. First, note that nutrient levels decrease as water flows towards Lake Greenwood. In effect, Laurens and Greenwood Counties are treating some of Greenville's waste. Water use is not as heavy in these areas, so the large load placed on the Reedy River by Greenville can be reduced through dilution (from water entering the river from tributaries and other sources),

[1] It is important to note that moderate-to-severe drought conditions existed in the region between the years 1997-2002. As a result, pollutants entering the river from runoff resulting from rain events will likely be understated by this analysis.

binding of phosphorus ions to sediments, and denitrification. This study finds that the economic value of treatment in effect subsidized by downstream users is $15,912,902.41 per year. The question of the equity of this situation will be addressed as well as what economic incentives can be instituted to rectify any inequities. Some options that are to be examined include the institution of a tradable permit regime, fees imposed on pollutants, or a combined permit-fee approach. These options and the benefits of each and the approach taken by regulators in the Tar-Pamlico basin in North Carolina are also discussed.

I. Project Overview

Estimating Damage from Nutrient Loading. In order to determine the efficacy of any economic incentive approaches, it is necessary first to model economic damage caused by nutrient loading on the Reedy River. This can be estimated by determining the costs of treating polluted water to municipalities downstream, as well as by determining the costs imposed on users by the presence of nutrients and other pollutants in the water. The latter costs include lost property value of property fronting the Reedy or Lake Greenwood, lost recreational use or amenity value, and diminished non-use value, i.e. value as a habitat for wildlife.

Estimating Costs of Reducing Pollutants. The next task in evaluating the efficacy of various economic incentive structures is the estimation of the costs of reducing pollutants at their source. The "Dirt 2" Project in Atlanta, Georgia has studied the costs to contractors of reducing erosion on construction sites though the construction of berms, retention ponds and planting of grass. The Project found that these measures are substantially more effective in retaining sediment on site. The measures cost four to five percent more than typical erosion-control measures.[2] The Tar-Pamlico Basin Association estimated in 1990 that reducing each unit of non-point pollution using Best Management Practices (BMPs) cost one-tenth the amount of treatment at a wastewater facility.[3]

The primary focus in determining the cost of reducing pollutants in this report is the marginal savings from discharge as estimated for the Western Carolina Regional Sewer Authority (WCRSA). This estimation is based on the operating costs of the WCRSA at different nutrient load levels. These figures are intended to represent the costs that would be borne by downstream users in order to remove nutrients using wastewater treatment – this is used a proxy to value the service being in essence provided by downstream users through dilution or removal of pollutants through natural processes.

II. Modeling

Two sets of analysis are undertaken in this section. First, the change in nutrient load in the Reedy River is estimated at different locations along the stream; then marginal savings from discharge of nutrients are estimated using WCRSA cost data. Finally, the two analyses are considered together, using the WCRSA data as a surrogate for costs of pollution abatement, in

[2] See Dirt 2 Report, June 25, 2001.
[3] EPA (2005).

order to determine the economic value of the service being rendered to upstream users via downstream dilution of nutrients.

Changes in Nutrient Load. The models presented in this report are intended as a first step in estimating the costs imposed on downstream users by nutrient loading between the Travelers' Rest and Mauldin Road monitoring stations. Specifically, this report models changes in nutrient load between the Mauldin Road station (S-013) and the station east of Ware Shoals (S-021). These stations represent terminal points of the problem area: S-013 is immediately south of the city of Greenville, where the significant increase in nutrient loading occurs, and S-021 is located near the point where the Reedy River empties into Lake Greenwood. It should be noted that DHEC water quality measurements are taken irregularly and without regard to varying conditions. As such, the number of observations that can be used in these models is limited to months in which data exist for each reporting station.

The models used for this report are the following:

Model 1: $TP_{it} = \alpha + \beta_1 T_i + \beta_2 * S021_t + \beta_3 * FLOW_{it} + \varepsilon_{it}$

Model 2: $N_{it} = \alpha + \beta_1 T_i + \beta_2 * S021_t + \beta_3 * FLOW_{it} + \varepsilon_{it}$

where:

- TP_{it} is total phosphorus loading (in pounds per day) at station "i" and time "t";
- N_{it} is nitrogen loading (in pounds per day) at station "i" and time "t";
- T_i is a time index included to capture any secular trends not accounted for by the other variables;
- $S021_t$ is a dummy variable that is set equal to one for the S-021 station;
- $FLOW_{it}$ is the quantity of water passing through station "i" in cubic feet per second at time "t". Note that flow data was obtained from USGS stations located close to the DHEC reporting stations.[4]
- ε_{it} is a random error term that is assumed to have a mean value of zero.

Note that natural logs were used for TP, N, and FLOW, so the estimated coefficients returned are stated in terms of percent change. The results of both models are presented in **Appendix I**. All variables in both models show a high level of statistical significance, indicated by the t-statistic (in parentheses); each shows significance in the 90 to 99 percent confidence level, which indicates that the probability of committing a Type 1 error (incorrectly rejecting the null hypothesis that there is no correlation between the respective variable and the load level) is very low. Both models also exhibit high adjusted R-square values; the adjusted R-square tells how much of the variation in loading about its mean level is explained by the model. In this case, the two models explain 63 and 70 percent of variation in phosphorus and nitrogen loading respectively.

---

[4] The FLOW variable will have the effect of holding constant any decreases in flow resulting from drought conditions.

Model 1a examines the change in TP between the Mauldin Road station and S-021; the estimated coefficient for “T” in this model indicates a small (<1%) but statistically significant negative trend over time in phosphorus loading, holding all of the other variables constant. Flow shows a strong positive effect on phosphorus loading, which may be attributable to runoff associated with rain events. The variable for the S-021 reporting station confirms that phosphorus loading levels are substantially lower at the lower end of the Reedy than at the Mauldin Road reporting station. The model indicates that it is in fact nearly 87 percent lower as it enters Lake Greenwood. This indicates that nutrients in the Reedy are being diluted and partly removed by natural processes, along the path of the river.

Model 2a, which examines nitrogen loading between Mauldin Road and S-021, presents very similar results to the first model. The only major difference in results between the two models is that the model for nitrogen loading indicates a small but significant upward trend in nitrogen loading over time, all of the other variables held constant. This could be indicative of an increase in the use of nitrogen-based fertilizers in the Greenville area over this time. The model also shows that a larger amount of nitrogen is removed as the water flows downstream than phosphorus, but the difference is fairly small.

Models 1b and **2b** demonstrate the net change in nutrient load between the Traveler’s Rest station (S-073) and the Ware Shoals station – the terminal points of the study region. The results of **Model 1b** are not surprising, indicating that phosphorus levels near the entrance to Lake Greenwood are more than three times the level that they are at S-073. This indicates that, holding time and flow constant, phosphorus loading occurring in Greenville is not being fully removed or diluted before reaching Lake Greenwood.

The results of **Model 2b**, however, are somewhat more surprising, showing a net decrease in nitrogen loading between Traveler’s Rest and S-021, holding flow and time constant. This seems counterintuitive, but a reasonable explanation is that a portion of the nitrogen load observed at S-021 may be entering the river from tributaries downstream from the Mauldin Road station. If it is the case that *most* or *all* of the remaining nitrogen at S-021 comes from tributaries (where of course the increased flow likewise originates), it might be expected for the Flow variable to explain the lion’s share of the nitrogen load. This underscores a significant problem in attempting to isolate the source of nutrient loading in a watershed. It is not possible with the available data to attribute all of the nutrients to their original source; nitrogen in the water may originate from runoff in Greenville, or it may result from agricultural runoff along one of the tributaries in Laurens County, or it may even result from natural processes. As such, these models are not sufficient to fully explain the amount of nutrients in the lower Reedy River in terms of causation. However, we may proceed by limiting our observations to the nutrient load that can be isolated as originating above the Mauldin Road station.

<u>*Marginal Savings from Discharge*</u>. As above, two models are here utilized to estimate the marginal savings from discharge of nutrients to WCRSA. It is important to note that these models are not intended to imply, nor need they assume, that WCRSA is responsible for most of the nutrient load in the Reedy River at the Mauldin Road station. These costs are merely used as a surrogate for the amount saved by dischargers (point or nonpoint) by allowing a given quantity of nutrients to flow into the river – the inverse of this would be the cost of abatement. These

costs are in turn assumed to extend to other users who discharge into the river. The WCRSA cost data was obtained from the Authority's 2004 Comprehensive Annual Report[5]. The Marginal Savings from Discharge (MS_D) is interpreted as the change in treatment costs for each additional unit of pollutant discharged.

The two models used are as follows:

$$\textbf{Model 3:}\ C_t = \alpha + \beta_1 * TP_t + \varepsilon_t$$

$$\textbf{Model 4:}\ C_t = \alpha + \beta_1 * N_t + \varepsilon_t$$

where:

- TP_{it} is total phosphorus loading (in average pounds per day per year) at station S-013 at time "t";
- N_{it} is nitrogen loading (in average pounds per day per year) at station S-013 at time "t";
- C_t is the total annual cost of operation for WCRSA for time "t"; [6]
- ε_t is a random error term that is assumed to have a mean value of zero.

The data in Model 3 cover the years 1992 through 1998 and 2002, with no observations for TP in the years 1999, 2000, and 2001. Model 4 data are from 1992 through 2002, inclusive. As in Models 1 and 2, natural logs were used for TP, N and C; as such, the coefficients reported are stated in terms of elasticity. The results are reported in **Appendix II**.

The results for Model 3 show no significant correlation between phosphorus loading at the Mauldin Road station and WCRSA treatment costs. This is likely due to phosphorus binding with sediment in the river, making it more difficult to detect; however, it is important to recognize that, even bound to suspended solids, the nutrient can have an effect on algae growth leading to eutrophication.

Changes in turbidity between stations S-013 and S-021 were also examined as a surrogate for sedimentation that may transport phosphorus.[7] The results for turbidity, however, mimicked that of phosphorus. The model indicated that turbidity was 77.2 percent lower at the S-021 station than at S-013, holding flow and time constant, but there was no significant correlation with treatment costs.

The results for Model 4 show that a 10 percent increase in nitrogen loading produces a corresponding 6.2 percent savings in treatment costs. This result is significant at the 99 percent confidence level. Additionally, the adjusted R-square indicates that this model explains fifty-five percent of the variation in nitrogen loading about the mean. The marginal savings from discharge is shown graphically in **Chart 1**. Because no significant correlation can be adduced

[5] Schedule of Revenues and Expenses (pp.56-57).
[6] Cost includes Total operating expenses, depreciation, amortization of bond issuance costs, and interest expenses. Dollar figures discounted using chain-type GDP deflator (2000=100).
[7] There were insufficient data for total suspended solids (TSS) for inclusion in the model.

between phosphorus loading and treatment costs, the following section will focus on nitrogen loading.

<u>*Treatment Cost Applied to Nutrient Load Changes*</u>. In the previous sections it was found that nitrogen levels decrease by approximately 88.2 percent between the Mauldin Road station and the station east of Ware Shoals, holding constant time and flow, and that the elasticity of the marginal savings from discharge for nitrogen is -0.62. With this information, using the average of discounted WCRSA operating costs over the study period as a surrogate, the cost imposed upon downstream users by nitrogen loading north of the Mauldin Road station can be estimated.

The elasticity of marginal savings from discharge (from Model 4) is multiplied by the flow-adjusted percent change in nitrogen loading between the S-013 and S-021 stations as estimated in Model 2a. This product is then multiplied by the average cost of operation as follows:

$$(\% \text{ Change } N_{it} * \%MS_D) * \text{WCRSA Average Operation Cost}$$

or

$$(-0.8818 * -0.6158772) * \$29{,}301{,}184.57.$$

This calculation provides the estimated value of cost effectively subsidized by downstream users annually, in terms of the cost to treat contaminated water, of $15,912,902.41. This amount represents the amount saved by upstream users by allowing nutrient discharge into the Reedy River. In other words, it is the value of the service that is in effect rendered to upstream users by those downstream through nutrient dilution and through other natural processes as discussed earlier.

III. Economic Incentive Regimes

As stated previously, there are three alternatives that must be considered for the remediation of inequities created by nutrient loading upstream on the Reedy: tradable permits (i.e. quantity regulation), a fee structure, and a combined permit-fee regime.

Tradable Permits. A tradable permit approach is based on the issuance of legal instruments granting the holder a license to discharge a set amount of pollutants into the environment. These permits are tradable, thus allowing polluters for whom pollutant reduction is high-cost to purchase discharge rights from those whose costs of pollutant reduction is relatively low. In essence, high-cost polluters are subsidizing pollution reduction activities of low-cost polluters, while their pollutant levels are themselves held in check. As such, in addition to reducing overall pollution levels, this regime can allow for the efficient allocation of the resources necessary for pollution abatement. The number of permits distributed is dependent on the costs of pollutant reduction by polluters and the costs imposed on users downstream by the pollution. Where abatement measures are costly, efficiency requires less abatement, and thus more permits are issued; conversely, where damages are high, fewer permits will be issued in order to achieve greater reductions in pollution levels.

A potential drawback of a tradable permit regime is that it can be susceptible to distortions in reported abatement costs by polluters. Because number of permits issued is partly dependent on the costs of reducing pollutants, it is in the interest of polluters to overstate their treatment costs to regulators, thus allowing them to reduce the cost imposed on them.

Pollutant Fees. An alternative approach to a tradable permit scheme is to charge polluters a fee for pollutants discharged into a river. Optimally, this fee will be equal to the cost of pollutant reduction to the polluter at the desired level of abatement, thus creating the incentive not to pollute above that level. The potential drawback of this option is evident: if the fee charged a polluter is equal to the reported cost of abatement, then the polluter has a clear incentive to understate his costs. As such, without certain knowledge of abatement costs, both the fee and permit regimes have the potential to reduce pollution by less than the optimal amount.

A Possible Solution. Given that accurate pollution abatement costs are typically known only to the polluters themselves, there is an alternative that can still allow the evaluation of which of the two policy options is likely to minimize the problems outlined in the above paragraphs without requiring exact figures for either abatement costs or damages to downstream users.[8] All that need be known is the rate at which damage from incremental amounts of additional pollution increases relative to the increase in the cost of abating incremental amounts of pollution. In other words, if an additional unit of pollutants imposes a greater cost on downstream users than abating it would impose on the polluters, then a pollutant quota (i.e. permits) is the most efficient policy choice; this applies especially if there is a threshold pollution level above which costs to downstream users increase asymptotically. Conversely, if costs of abatement increase more rapidly, then a fee structure would be the more efficient choice.

An intuitive explanation is that when damages (costs to downstream users) increase rapidly with incremental increases in pollution and abatement costs are relatively flat, an pollutant quota can be set at a level to hold damages to an acceptable level while imposing relatively little cost on polluters. If the costs of abating an additional unit of pollution increases more rapidly, but damages from additional units of pollution emitted are relatively flat, polluters, as noted above, may understate costs, but the resulting pollution emitted above the optimal level will impose relatively little damage. Additional refining of the data will be necessary to determine which scenario most closely describes the economic environment along the Reedy River, but such an analysis is believed to be feasible.

The Third Option. The last of the three options is a combined fee-permit regime[9]. As in the preceding section, an exact figure for abatement costs and damages is not necessary to implement such a policy. Under this regime, permits are issued to establish an pollutant quota. Polluters who emit above this level of emissions must pay a fee as under the pollutant fee option; polluters who emit a level of pollutant below the quota receive a subsidy to offset their additional abatement costs. This scheme removes the incentive for polluters to over-report or under-report their costs, as over-reporting will inflate the amount that polluters will have to pay under the fee portion of the regulation, and under-reporting will result in too few permits being issued, thus

[8] This approach was suggested by Weitzman (1978). For a more concise explanation, see Kolstad (2000), pp. 183-187.
[9] Roberts & Spence (1976).

increasing the amount of pollution for which the polluter will have to pay a fee. This regime also reduces inefficiency seen under either a strict fee or strict permit arrangement; high-cost polluters will purchase permits from low-cost producers and will pay to emit above the quota level (it is worth noting that in the case of asymptotic damages above a certain level of pollution, the fees may be graduated to reduce the probability of polluters breaching the threshold level – this policy can also be modified to simply apply the subsidy portion and to not allow any pollutants above the level allowed by the quota). Low-cost polluters will have an incentive to reduce their emissions below the level allowed by the permits that they do not sell in order to receive the subsidy.

Table 1 – Strength and Weakness of Alternative Regimes

	Strength	Weakness
Permits	Allows efficient allocation of abatement costs among polluters	Incentive for dischargers to overstate abatement costs, leading to allowance of discharge above socially optimal level
Fees	Allows polluters to discharge at most cost-effective level, increasing efficiency of abatement	Incentive for dischargers to understate abatement costs, leading to insufficient fees to reduce discharge to socially optimal level
Combined	Removes incentives to over- or understate abatement costs. Allows for efficient allocation of abatement costs and for socially optimal abatement levels	No significant weaknesses relative to other options

One *caveat* to all of these policy options is that enforcement is of course never costless. Although economic incentive regimes are meant to replace high-cost command and control regimes, without adequate monitoring and enforcement of quotas or assessment of fees, the potential for shirking on the part of polluters is always present. As such, any regime will require costs in the form of man hours and technological assets in order to be effective.[10] Additionally, fee and permit regimes are generally more applicable to point-source pollution; enforcement of either of the above policies against non-point-source pollution will entail substantially more costs. These costs must be included in weighing the expense of regulating against the costs of maintaining the status quo. The North Carolina Environmental Management Commission (EMC) has implemented a highly successful nutrient trading regime for the Tar-Pamlico basin; in considering such a policy for the Saluda-Reedy basin, it would be useful to examine the approach taken there.

The Tar-Pamlico Strategy. The regulatory regime in the Tar-Pamlico basin has been in the process of being phased in since 1992.[11] In January 2005, the strategy entered Phase III, which will extend through December 2014. This strategy targets nitrogen and phosphorus pollution

[10] WCRSA has a testing fee structure in place for point-source pollution, but non-point runoff abatement will require a different enforcement structure.
[11] EMC Agenda Item No. 05-11 (April 14, 2005). <http://h2o.enr.state.nc.us/nps/documents/PhIIIAgreementFinal4-05.pdf>

from both point and non-point sources, and has seen decreases in nitrogen loads of 45 percent and phosphorus loads of 60 percent between the years 1990 and 2003; during this period, flow increased by roughly 30 percent.[12] As in the tradable permit and modified tradable permit regimes discussed above, the EMC strategy allows for reductions of nutrient loading in keeping with program goals while allowing for efficiency in resource allocation among point-source polluters. Additionally, it extends efficiency in pollutant reduction to non-point-source polluters through a program to allow point-source polluters to subsidize non-point pollutant reduction.

Under the EMC strategy, major point-source dischargers are organized into the Tar-Pamlico Basin Association. Overall nitrogen and phosphorus load caps are assigned to the Association collectively; the goal is a 30 percent reduction in nitrogen loading over the 1991 baseline and a zero net gain in phosphorus loading over the baseline. Allocation of pollutant reduction is determined within the association. Association membership may be changed by firms entering and exiting at any time; load caps will be adjusted accordingly by the NC Division of Water Quality. Non-Association polluters are regulated using more traditional discharge permits and Best Available Technology limitations. However, EMC indicates that Association members are currently responsible for 98.7 percent of permitted discharge.[13]

The strategy also allows the Association to offset any pollutants above the cap in a given year by funding the control of non-point pollutants. This expands the range of choices to members on the most efficient means of reducing discharge beyond reductions within Association facilities, thus increasing the economic efficiency of the program while maintaining pollutant reduction goals. The most commonly used mechanism is currently implementation of agricultural BMPs.[14] EMC anticipates that other nutrient reduction methods will be considered in the future, such as wetland and riparian restoration.[15]

In monitoring non-point pollutant levels, EMC has employed land-based accounting to determine percentage reduction of discharge rather than in-stream sampling. This is due to the number of exogenous variables involved between the point of discharge and entrance into the stream.[16] In addition to Association-sponsored offsetting activities, non-point pollutant regulation is applied to agriculture, urban storm drainage, riparian buffer protection and fertilizer management.[17] EMC initially instituted a voluntary compliance plan, but transitioned into a mandatory compliance plan starting in 2000 due to unsatisfactory results.

IV. Conclusion

This report utilized data gathered from DHEC monitoring stations along the Reedy River from Traveler's Rest to Lake Greenwood. The data indicate a trend of decreasing nutrient loads as water moves downstream from the higher-use Greenville area.

---

[12] EMC, p.7.
[13] EMC, p.9.
[14] EMC, p.16.
[15] EMC, p.17.
[16] EMC, p.15.
[17] EMC, pp.19-21.

There is a persistent problem of isolating the source of nutrient loading in the lower end of the Reedy. Nutrients flow into the river, not only from point and non-point sources in the heavily urbanized Greenville area, but from other sources along tributaries to the Reedy south of Greenville and from natural processes. However, it is possible to follow the course of nutrients originating from above the Mauldin Road station due to the inclusion of the flow variable in the first set of models. This allows the use of WCRSA cost data as a surrogate to estimate the marginal cost of reducing discharge into the Reedy, a cost that we contend is being effectively subsidized by downstream users through dilution of the nutrient load.

While the costs of assimilating these nutrient loads is not explicitly borne by downstream users in the form of water treatment costs incurred by the WCRSA, they are borne in the form of effects on the environment and on amenity values due to nutrient dilution along the river and in Lake Greenwood. The cost estimates stated in this report are intended to provide a proxy for these costs by representing the amount of savings enjoyed by upstream users from allowing pollutants to be discharged into the river. This was done by estimating the cost of treating for an equivalent amount of loading by water treatment facilities.

Works Cited

Environmental Protection Agency (EPA), Office of Water. (2005). "TMDL Case Study: Tar-Pamlico Basin, North Carolina". Retrieved August 11, 2006, from http://www.epa.gov/owow/tmdl/cs10/cs10.htm

Gujarati, Damodar N. (2003). Basic Econometrics, 4th Ed. Boston: McGraw-Hill.

Halvorsen, Robert and Raymond Palmquist. (1980). "The Interpretation of Dummy Variables in Semilogarithmic Equations." The American Economic Review, 70(3), 474-475.

Kolstad, Charles D. (2000). Environmental Economics. New York: Oxford University Press.

Roberts, Marc J. and Michael Spence. (1976). "Effluent Charges and Licenses Under Uncertainty." Journal of Public Economics, 5(3-4), 193-208.

Weitzman, Martin L. (1978). "Optimal Rewards for Economic Regulation." The American Economic Review, 68(4), 683-691.

Appendix I – Results of Nutrient Load Models

Model 1a – Phosphorus levels in Reedy River as a function of Time, Flow and Location (Stations S-013 versus S-021) – 1/1/1995 to 6/30/1998.

Dependent Variable: (Log) Phosphorus Load (lbs/day)

Parameter	Estimate	Interpretation
Intercept	2.5296 (7.79***)	
Time	-0.007 (-1.68*)	Small negative trend in TP load over time
Station S-021	-2.0295 (-11.52***)	Median load is 86.9% lower at station S-021.[18]
(Log) Flow	0.8149 (10.43***)	A 10% increase in flow increases loading by 8%.

Adjusted R-Square = 0.6264

* Denotes significance at the 90% confidence level.
** Denotes significance at the 95% confidence level.
*** Denotes significance at the 99% confidence level.

[18] [EXP(-2.0295) – 1] * 100. See Gujarati (2003), pp.320-321; Halvorsen & Palmquist (1980).

Appendix I (Cont.)

Model 2a - Nitrogen levels in Reedy River as a function of Time, Flow and Location (Stations S-013 versus S-021) – 1/1/1995 to 6/30/1998.

Dependent Variable: (Log) Nitrogen Load (lbs/day)

Parameter	Estimate	Interpretation
Intercept	2.3067 (7.59***)	
Time	0.0110 (2.80***)	Small positive trend in N load over time
Station S-021	-2.1356 (-12.95***)	Median load is 88.2% lower at station S-021.[19]
(Log) Flow	0.7467 (10.21***)	A 10% increase in flow increases loading by 7.5%.

Adjusted R-Square = 0.6993

* Denotes significance at the 90% confidence level.
** Denotes significance at the 95% confidence level.
*** Denotes significance at the 99% confidence level.

[19] [EXP(-2.3067) – 1] * 100.

Appendix I (Cont.)

Model 1b – Phosphorus levels in Reedy River as a function of Time, Flow and Location (Stations S-073 versus S-021) – 1/1/1995 to 6/30/1998.

Dependent Variable: (Log) Phosphorus Load (lbs/day)

Parameter	Estimate	Interpretation
Intercept	-1.6129 (-3.70***)	
Time	-0.0042 (-0.76)	No significant trend in TP load over time
Station S-021	1.1360 (4.76***)	Median load is 211.4% greater at station S-021.[20]
(Log) Flow	0.9723 (10.43***)	A 10% increase in flow increases loading by 9.7%.

Adjusted R-Square = 0.8818

* Denotes significance at the 90% confidence level.
** Denotes significance at the 95% confidence level.
*** Denotes significance at the 99% confidence level.

[20] [EXP(1.1360) – 1] * 100.

Appendix I (Cont.)

Model 2b - Nitrogen levels in Reedy River as a function of Time, Flow and Location (Stations S-073 versus S-021) – 1/1/1995 to 6/30/1998.

Dependent Variable: (Log) Nitrogen Load (lbs/day)

Parameter	Estimate	Interpretation
Intercept	-1.3071 (-5.91***)	
Time	0.0252 (8.87***)	Small positive trend in N load over time
Station S-021	-0.4658 (-3.84***)	Median load is 37.2% lower at station S-021.[21]
(Log) Flow	1.0210 (19.20***)	A 10% increase in flow increases loading by 10.2%.

Adjusted R-Square = 0.9269

* Denotes significance at the 90% confidence level.
** Denotes significance at the 95% confidence level.
*** Denotes significance at the 99% confidence level.

[21] [EXP(-0.4658) – 1] * 100.

Appendix II – Results of Marginal Savings from Discharge Models

Model 3 – WCRSA Annual Operating Cost as a function of Average Annual Phosphorus Levels in Reedy River (Station S-013) – 1992-2002 (with gaps).

Dependent Variable: (Log) WCRSA Annual Operating Cost

Parameter	Estimate	Interpretation
Intercept	16.9882 (82.38***)	
Phosphorus Loading	-0.0737 (-1.08)	Negative but statistically insignificant.

Adjusted R-Square = 0.0229

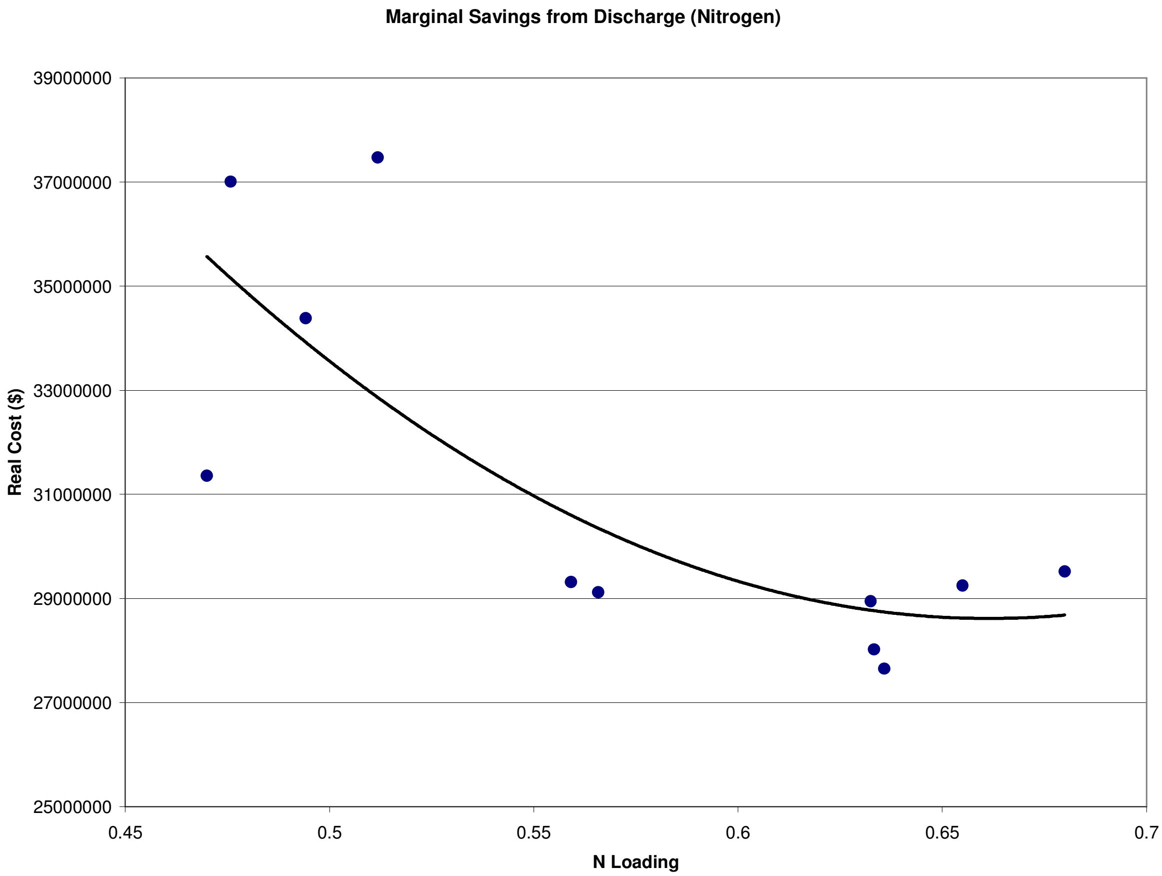
Model 4 – WCRSA Annual Operating Cost as a function of Average Annual Nitrogen Levels in Reedy River (Station S-013) – 1992-2002 .

Dependent Variable: (Log) WCRSA Annual Operating Cost

Parameter	Estimate	Interpretation
Intercept	16.8999 (172.60***)	
Nitrogen Loading	-0.6159 (-3.64***)	A 10% increase in nitrogen load saves 6.2% in treatment costs.

Adjusted R-Square = 0.5503

* Denotes significance at the 90% confidence level.
** Denotes significance at the 95% confidence level.
*** Denotes significance at the 99% confidence level.



Marginal Savings from Discharge (Nitrogen)
39000000
37000000
35000000
33000000
31000000
29000000
27000000
25000000
Real Cost ($)
0.45
0.5
0.55
0.6
0.65
0.7
N Loading

Approximate location of DHEC Monitoring Stations on the Reedy River