Examining the Effects of Ecological and Political Boundaries on the Potential for Water Quality Trading: Lessons from a Southeastern Trading Framework

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by

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Abstract

Water quality trading (trading) as a means to improve water quality has become an increasingly popular instrument considered by environmental policy makers. Although the U.S. Environmental Protection Agency lists more than forty current trading programs in the U.S., only a few active markets exist. The literature identifies several hurdles to trading, overcoming which requires a deeper understanding of the interaction between local environmental, legal, and economic conditions. Particular challenges include thin markets, uncertainty related to the course and fate of nutrient flows, varying degrees of political support, and high transaction costs related to market infrastructure, monitoring, and enforcement. These hindrances often arise from and contribute to the confinement of trading to tight ecological and political boundaries. This paper explores the effect of these boundaries on the potential for trading in two southeastern reservoirs and their respective watersheds. Results provide insight into the effects of the spatial expansion of markets. These findings contribute to the current dialogue that seeks to better understand barriers to trading.

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INTRODUCTION

Water Quality Trading

As one of the world's most precious resources, fresh water serves a multitude of vital human and ecological purposes that range from drinking water supply to fish and wildlife habitat. However, a variety of man-made sources of pollution threaten the health of the rivers and lakes that supply this resource. As a consequence, water quality issues stand as a significant environmental challenge throughout the United States (U.S.) and the world.

With the Clean Water Act (CWA) of 1977, U.S. environmental policy makers took significant steps to curb water pollution through strict command and control regulations of direct, or point source (PS), dischargers. Although significant improvements resulted from these policies, a large percentage of U.S. water bodies remain impaired (U.S. Environmental Protection Agency, 2009). Much of the recent blame is attributed to substantial contributions from indirect, or non-point (NPS), sources of water pollution (Nguyen, et al., 2006). A command and control approach struggles to adequately regulate these NPS's due to the complexity and uncertainty that underlie their discharges. Therefore, in order to realize further water quality improvements, a command and control approach needs to impose even stricter regulations on PS discharges. However, researchers argue that such an approach is not cost effective (Nguyen, et al., 2006). Consequently, U.S. environmental policy makers seek new methods that engage all types of water pollution sources in order to achieve national water quality goals at reduced societal costs.

One increasingly popular policy tool, water quality trading (trading), possesses many theoretical advantages over previous approaches. Trading is a market-based approach to achieve a specified water quality standard. To attain this standard, a regulatory agency decides on a water body's allowable limit of a pollutant. The agency then distributes an initial load allocation of this limit among the water body's sources of the pollutant; Total Maximum Daily Loads (TMDLs) often define these loading limits. Stakeholders that can reduce below their load allocation can sell their excess allotment of pollution as credits. Those that wish to discharge above their limit must purchase credits that account for the additional pollutant. Trading is based on the idea that stakeholders facing high abatement costs will purchase credits from those with lower abatement costs. Thus, the desired water quality standard is realized at a lower total cost to the watershed (U.S. Environmental Protection Agency, 2008). Theoretically, trading engages NPS's with a monetary incentive since NPS's often have lower abatement costs than PS's (Nguyen, et al., 2006). In these circumstances, NPS's supply pollution reduction credits to PS's at a cost that is less than what the PS's would otherwise face. Trading between PS's that face different abatement costs may also occur.

In 2003, the Environmental Protection Agency (EPA) issued "The Final Water Quality Trading Policy" to provide states with a framework for trading within their watersheds. This policy signifies EPA's growing receptiveness towards a market-based approach to achieve water quality standards required by the CWA. Although the EPA lists more than forty current trading programs in the U.S. (U.S. Environmental Protection Agency, 2008), only a few active markets exist. The literature identifies several hurdles to trading, overcoming which requires a deeper understanding of the interaction between local environmental, legal, and economic conditions. Particular challenges include thin markets (Hoag and Hughes-Popp, 1997, Woodward, 2003), uncertainty related to the flow and fate of nutrient flows (Hall and Raffini, 2005, Horan, 2001), varying degrees of political support (McGinnis, 2001), and high transaction costs related to market infrastructure, monitoring, and enforcement (Woodward, 2003). These hindrances often arise from and contribute to the confinement of trading to tight ecological and political boundaries. This paper explores the effect of these boundaries on the potential for trading in two southeastern reservoirs and their respective watersheds.

Relevant Reservoirs & Watersheds:

This research focuses on two reservoirs and a chain of watersheds located in northwestern Georgia and northeastern Alabama (See Figure 1). These reservoirs are Lake Allatoona and Weiss Lake; the relevant watersheds, as defined by their 8-digit Hydrologic Unit Codes (HUC), are the Conasauga (03150101), Coosawattee (03150102), Etowah (03150104), Oostanaula (03150103), and Upper Coosa (03150105) [1].

Lake Allatoona:

Lake Allatoona is located roughly thirty miles north of the city of Atlanta and sits within the Etowah watershed. An impoundment of the Etowah River in 1950 formed the lake; today it serves many purposes including flood control, hydroelectric power, public water supply, recreation, and fish and wildlife habitats (US Army Corps of Engineers, 2009). However, nutrient impairment threatens the health of Lake Allatoona and the continued support of its designated uses. In a 2004 TMDL, the Georgia Environmental Protection Division (GA EPD) addresses excessive chlorophyll a for a section of Lake Allatoona known as the Little River Embayment. This 2004 TMDL requires reductions in total phosphorus (P) for individual PS's, urban loadings from storm water discharges, and other NPS's. More recently, a 2009 draft

[1] Carters Lake, sits to the north of Lake Allatoona in the Coosawattee watershed. Like Lake Allatoona, Carters Lake is listed on Georgia's 303(d) list for not meeting designated uses due to excessive chlorophyll a. GA EPD is currently developing a model of nutrient loads to the lake and plans to prepare a TMDL in 2010. Future papers will expand this analysis to include Carters Lake.

TMDL from GA EPD addresses impairment from excess chlorophyll a for two additional segments of Lake Allatoona: the Etowah River Arm and Allatoona Creek Arm. The Etowah River and Allatoona Creek TMDL requires reductions in both total P and total nitrogen (N) for individual PS's, urban loadings from storm water discharges, and other NPS's. Loading limits are defined separately for the Etowah River Arm and Allatoona Creek Arm.

Weiss Lake:

Weiss Lake is located in northeastern Alabama approximately fifty miles to the west of Lake Allatoona. As seen in Figure 1, Weiss Lake resides within the Upper Coosa watershed, which straddles the Alabama and Georgia border. In 1961, an impoundment of the Coosa, Chattooga, and Little Rivers created the reservoir. Like Lake Allatoona, Weiss Lake serves a variety of purposes including hydroelectric power generation, flood control, public water supply, irrigation, recreation, and fish and wildlife habitats (U.S. Environmental Protection Agency Region 4, 2008). As with Lake Allatoona, an excessive chlorophyll a concentration threatens the health of Weiss Lake. A 2008 TMDL addresses this chlorophyll a concentration through required total P reductions; it specifies a 30 percent reduction in total P loads to the lake. To achieve this goal, the TMDL outlines reductions in total P for Alabama and Georgia separately. For Alabama, reductions are defined for major PS's (≥1 Million Gallons per Day (MGD)), minor PS's (< 1 MGD), and NPS loads. Limits for Georgia are defined by aggregate loads from the Coosa and Chattooga Rivers at the Georgia state line. In addition to the Upper Coosa, the TMDL identifies the Conasauga, Coosawattee, Oostanaula, and Etowah as watersheds that drain to Weiss Lake.

Lake Allatoona and Weiss Lake Trading Research:

Trading frameworks for Lake Allatoona and Weiss Lake are in their investigate states[2]. For Lake Allatoona, the River Basin Center at the University of Georgia's School of Ecology conducts research that examines the potential for trading. Of particular importance, researchers recently modeled the spatial distribution of P loads to the lake (Lin, et al., 2009, Radcliffe, et al., 2009). However, only modest progress has been made to investigate the economic components of a Lake Allatoona trading framework. There are no known frameworks for trading for Weiss Lake and its applicable watersheds.

This research addresses the missing economic component in Lake Allatoona's P trading framework and expands the analysis to include Weiss Lake. Lake Allatoona's TMDL specifications for separate segments of the lake provide an opportunity to examine the effects of ecological boundaries on trading. In particular, this research explores the effects of restricting trading for Lake Allatoona to tightly defined sub-watersheds versus allowing trading to occur over a more broadly defined ecological boundary (the lake's greater watershed). The fact that state lines divide Weiss Lake and its relevant watersheds provides the opportunity to examine the effects of political boundaries on trading.

DATA AND METHODOLOGY

Overview:

The methodology follows similar steps to those outlined in EPA's "Water Quality Assessment Handbook" (U.S. Environmental Protection Agency, 2004). Released in 2004, this handbook serves as a guideline to analyze the potential for trading in a watershed. In particular,

[2]No market structures or formal plans for trading exist for either lake; no trades have occurred. However, the 2009 draft TMDL mentions the potential for future trades for Lake Allatoona.

the chapters on Pollutant Suitability and Financial Attractiveness provide a framework to define a tradable pollutant, characterize the fate and flow of this pollutant, and identify potentially viable trades (alpha trades). From this framework, the impacts of ecological and political boundaries on alpha trades are examined.

Discussed in more detail in the following sections, this analysis makes a few key assumptions for trading[3]:

- The tradable pollutant is total P[4].
- PS's must comply with loadings limits as defined by TMDLs.
- NPS's do not face loading limits.
- A tradable credit is defined as the annual reduction in 1 pound (lb) of total P delivered to the relevant lake (Lake Allatoona or Weiss Lake).
- NPS-to-PS trading ratio for all participants equals 2:1.
- Delivery ratios discount NPS credit calculations based on modeled flow and fate of total P to the relevant lake (no discounts for PS's).
- No retirement of credits.
- All costs are in 2008 U.S. dollars.

Markets:

The ecological boundaries for trading are defined by the TMDLs for Lake Allatoona, Lin et al. and Radcliffe et al.'s studies of Lake Allatoona, and the 2008 TMDL for Weiss Lake. The Alabama-Georgia and Georgia-Tennessee state lines serve as the relevant political boundaries.

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[3] These assumptions present a baseline case for trading to determine the potential effects of ecological and political boundaries. Future papers will address the impact of changes to these assumptions and other trading parameters.

[4] Although the Lake Allatoona 2009 draft TMDL also requires reductions in total N, only total P is considered at this time, as information regarding the flow and fate of N is limited.

Using these boundaries seven trading markets are defined and referred to as the Allatoona-All, Allatoona-Creek, Allatoona-Etowah, Allatoona-Little, Weiss-Alabama, Weiss-Georgia, and Weiss-Tennessee markets.

Lin et al.'s study delineates the Lake Allatoona watershed as that which contains the major inflows into Lake Allatoona. Within the Lake Allatoona watershed Lin et al. further define six sub-watersheds: Acworth/Allatoona, Little/Noonday, Owl/Kellogg, Shoal Creek, Stamp/Rowland, and Upper Etowah. As a broader ecological boundary, the six sub-watersheds define the Allatoona-All market (See Figure 2). Individually, the sub-watersheds Acworth/Allatoona, Upper Etowah, and Little/Noonday sub-watersheds outline the Allatoona-Creek, Allatoona-Etowah, and Allatoona-Little markets respectively. Since Lake Allatoona and its greater watershed are both in the state of Georgia, there is no relevant political boundary for this trading framework.

Watersheds that drain into Weiss Lake are grouped into three separate markets by their respective states. The Weiss-Alabama market includes the Alabama portion of the Upper Coosa watershed that drains to Weiss Lake. The Georgia portions of the watersheds that drain to Weiss Lake compose the Weiss-Georgia market. These watersheds are: a.) The Coosawattee and Oostanaula, b.) The portion of the Etowah watershed that is distinct from the Lake Allatoona watershed, c.) The portion of the Conasauga watershed located within the state of Georgia, and d.) The portion of the Upper Coosa watershed located within the state of Georgia. The Weiss-Tennessee market includes the Tennessee portion of the Conasauga watershed. Ecological boundaries, as defined by these greater watersheds, delineate the entire Weiss framework. However, for Weiss Lake, this analysis examines the effects of limiting trading to individual states, not by limiting trading to even tighter ecological boundaries.

Total P and Loadings Profile:

Next, loadings profiles determine the location and quantity of total P that the primary PS's and NPS's discharge in each market. PS's are identified individually. NPS's are summarized by watershed by land cover and/or land use type. These profiles serve as lists of primary market participants.

Lake Allatoona Market(s):

Individual PS's and corresponding discharge data are identified from the 2009 draft TMDL (See Table 1)[5]. Lin et al.'s list of PS's within all six sub-watersheds corresponds to that of the draft TMDL. There are no additional major PS's for Owl/Kellogg, Shoal Creek, or Stamp/Rowland.

To classify NPS loadings, this analysis uses results from Lin et al. since they provide results on the modeled P loads by land cover type. These categories are: Row Crop, Less Developed Urban, Highly Developed Urban, Pasture Receiving Litter, Pasture Not Receiving Litter, and Forest. Also included in Lin et al.'s analysis are P loads from Cows in Stream; although Lin et al. refer to these loads as PS's, this paper groups Cows in Stream with NPS's due to the similarities in regulatory frameworks and abatement practices. See Table 2 for a loadings profile. In addition, Lin et al. provide delivery ratios by sub-watershed; these ratios represent the estimated percent of total P loads delivered to Lake Allatoona from each sub-watershed (See Table 3).

Corresponding land cover area for Row Crop, Urban, Pasture, and Forest come from the 2001 National Land Cover Dataset (NLCD). Less Developed Urban represents less than 20

[5] For purposes of determining trading potential, municipal and industrial PS's with permitted flows greater than 0.1 MGD were included.

percent imperviousness and Highly Developed Urban includes urban areas with greater than or equal to 20 percent imperviousness. Lin et al. estimate area for Pasture Receiving Litter by overlaying aerial photos of poultry houses in the Lake Allatoona watershed with pasture acreage from the NLCD data and assuming a 0.75 kilometer radius for each poultry house. The area for Pasture Receiving Litter is assumed as area for cattle grazing; Lin et al. estimate cows in the Lake Allatoona watershed with, “a grazing density of one cow per 0.8 ha of litter-amended pasture” (Lin, et al., 2009). See Table 4 for Lake Allatoona land cover area.

Weiss Markets:

A combination of sources is used to create a PS loadings profile for the Weiss-Alabama, Weiss-Georgia, and Weiss-Tennessee markets. As a starting point, the 2008 TMDL for Weiss Lake lists 14 major dischargers in the watersheds that flow directly to the Coosa River and Weiss Lake. Discussions with GA EPD regarding their Coosa River Modeling Project yield additional relevant PS’s. All loadings are updated to reflect available 2008 National Pollutant Discharge Elimination System (NPDES) data from EPA’s Enforcement & Compliance History Online (ECHO) (See Table 5). The Tennessee-Weiss market contains no PS’s.

Unfortunately, a current limitation to this analysis is that P loads by land cover type by watershed are not available for Weiss Lake. Through discussions with GA EPD and Tetra Tech, a consulting firm, a Weiss Lake watershed model that should provide insights similar to that of Lin et al. is expected by June/July 2009. Land cover data for each Weiss market is gathered from 2001 NLCD data to gain a better picture of land use may look like in the Weiss markets (See Table 6)[6].

[6] Data is not available for Pasture Receiving Litter; however, the quantity of litter applied in the Weiss markets is estimated in the section “Poultry Litter Transfer Quantity and Cost Estimates”.

Point Source Abatement – Quantity and Cost Estimates:

Abatement to Meet Loading Limits:

For individual Lake Allatoona PS's, required abatement in annual lbs of total P per year is:

(1) $a^{pA}_{i} = (d_i * 365) – WLA_{i,}$,

where a^{pA}_{i} is the reduction in annual lbs of total P from PS i to meet yearly Waste Load Allocation WLA_i; d_i is PS i's current average daily total P discharge in lbs per day.

For Weiss Lake, the 2008 TMDL specifies limits of a total P concentration of 1.0 milligrams/liter (mg/l) for major PS's in Alabama and a max of 8.34 lbs of P per day for minor PS's. Since all Alabama PS's are currently minor, required total P reductions are:

(2) $a^{pW}_{i} = (d_i – 8.34) * 365$,

where a^{pW}_{i} is the reduction in annual lbs of total P from PS i to meet TMDL compliance; d_i is PS i's average daily total P discharge in lbs per day. Since the Weiss Lake TMDL only specifies aggregate reductions for Georgia PS loads, potential reductions are estimated based on the Alabama criteria[7]. For major PS's in Georgia, required total P reductions are:

(3) $a^{pG}_{ij} = \{d_i –[(m_j * k) * f_i * g]\} * 365$,

where a^{pG}_{ij} is the reduction in annual lbs of total P from PS i to meet total P concentration limit j mg/l; d_i is PS i's average daily P discharge in lbs per day; m_j is total P concentration limit j in mg/l; k is 2.20462262 lbs per kg; f_i is PS i's average flow in MGD; g is 3.7854118 liters per gallon. For minor PS's in Georgia, required total P reductions are calculated the same as (2) and referred to as a^{pG}_{i}.

[7] Applying this criteria reduces total Georgia PS discharge by approximately 75%. The results of the Coosa River Modeling Project will provide insight into what percentage of this discharge reaches the Alabama-Georgia border. The study will provide insight into the adequacy of applying Alabama loading limits to Georgia PS's.

Abatement Costs:

Jiang et al.'s estimation of costs of adapting existing wastewater treatment facilities for P removal is used to approximate the abatement costs of wastewater treatment plants in the Lake Allatoona and Weiss markets (Jiang, et al., 2005). Their simulation upgrades a base-case treatment plant for a range of total P concentration limits: 0.05, 0.13, 0.5, 1.0, and 2.0 mg/l. In addition, they present three alternative upgrade options for each limit. For each concentration limit and design combination, Jiang et al. estimate total P abatement and total annual economic costs[8] for facilities of five different capacities: 1, 10, 20, 50 and 100 MGD. Their goal is to provide estimates for P removal costs as part of greater study into the feasibility for offset banking schemes within Georgia's watersheds. Although the wastewater treatment plants in the Lake Allatoona and Weiss Lake frameworks do not exactly match the baseline case used by Jiang et al., the estimates provide a good starting point to estimate Georgia and Alabama wastewater abatement costs.

Each Allatoona wastewater treatment plant is assumed to choose the upgrade that minimizes costs of compliance:

(4) Minimize $z^{pA}_i = C_{ij}(s_i, ch_i)$, subject to:

(5) $b^p_{ij} \geq a^{pA}_i$,

where z^{pA}_i is the cost of compliance for Lake Allatoona wastewater treatment plant i; $C_{ij}(s_i)$ is the total annual economic cost function to upgrade a facility i in order to meet a total P concentration of j; these costs vary depending on PS i's capacity, s_i (MGD)[9] and treatment choice

[8] Total annual economic costs equal the sum of annualized capital cost and annualized operations & maintenance costs but exclude land costs.

[9]When a facility's capacity does not exactly match one of the 5 simulated by Jiang et al., a weighted average of costs and abatement quantity is calculated using the lower and higher bounds in which the facility's capacity falls. For

ch_i. Upgrading facility i to concentration j produces b^p_{ij} lbs of total P abatement; the upgrade choice is constrained by the requirement that b^p_{ij} must be greater than or equal to the required abatement a^{pA}_i.

Similarly, the costs of abatement for Weiss treatment plants are estimated. Each minor Weiss-Alabama wastewater treatment plant i facing required abatement a^{pW}_i is assumed to choose the upgrade that minimizes abatement costs z^{pW}_i as above. Similarly, the cost of compliance for each minor Weiss-Georgia wastewater treatment plant i is z^{pW}_i. Each major Weiss-Georgia wastewater treatment plant i chooses the upgrade that minimizes abatement costs z^{pG}_{ij} to comply with concentration limit j (1.0 mg/l). Wastewater treatment facilities comprise 30 of the 36 PS's within the Lake Allatoona and Weiss markets[10]. For the additional 6 PS's, abatement cost estimates are not available at this time.

Credits for Trading:

For purposes of trading, the total yearly quantity of credits demanded and supplied by each Lake Allatoona PS are:

(6) $Q^{pAd}_i = a^{pA}_i$

(7) $Q^{pAs}_i = (b^p_{ij} - a^{pA}_i)$,

where Q^{pAd}_i is the total number of credits per year demanded by PS i; Q^{pAs}_i is the total number of credits supplied by PS i. It is assumed that PS's only supply credits if they choose to upgrade their facility and have additional units of abatement[11]. Delivery ratios are not used to calculate the credits demanded or supplied by PS's since their regulation is currently defined by discharge

facilities with operating capacity less than 1 MGD, abatement costs and quantity are assigned values from the 1 MGD simulation. Where capacity information is missing, average daily flow is assumed for capacity.

[10] Wastewater treatment facilities were those with EPA designation of "Sewerage Systems".

[11] This assumption rules out the possibility where a PS currently operating under its TMDL sells credits of abatement to other PS's seeking compliance, resulting in little to no total watershed reduction in total P.

quantities and concentrations, not by the quantity of P that is delivered to the lake. Where available, the corresponding prices per credit demanded and supplied by Lake Allatoona PS's are:

(8) $p^{pAd}_i = z^{pA}_i / a^{pA}_i$

(9) $p^{pAs}_i \geq 0$,

where p^{pAd}_i is maximum cost PS i is willing to pay for a credit of total P abatement; p^{pAs}_i is greater than or equal to zero since Q^{pAs}_i are the additional units of total P abatement that result from the choice to upgrade; in a completely competitive market p^{pAs}_i will equal the market price for credits. Similarly, the credits demanded and supplied by Weiss PS's are: Q^{pWd}_i (Weiss-Alabama demanded), Q^{pWs}_i (Weiss-Alabama supplied), Q^{pGd}_{ij} (Weiss-Georgia demanded), Q^{pGs}_{ij} (Weiss-Georgia supplied). Corresponding prices are: p^{pWd}_i (Weiss-Alabama demanded), p^{pWs}_i (Weiss-Alabama supplied), p^{pGd}_{ij} (Weiss-Georgia demanded), p^{pGd}_{ij} (Weiss-Georgia supplied).

Non-point Source Abatement – Quantity and Cost Estimates:

Abatement Quantity:

Potential total P abatement quantities for NPS's are calculated for a range of applicable best management practices. These calculations use current loadings, land cover data, and estimates for total P removal efficiencies. Available cost and P removal efficiencies for agricultural best management practices (BMP's) are identified with data provided by the Georgia Natural Resources Conservation Service (GA NRCS) (Georgia Natural Resources Conservation Service, 2007) and information from CH2M HILL's analysis of a potential trading framework for North Carolina's Jordan Lake watershed (CH2M HILL, 2008) (See Table 7). In the same fashion as the CH2M Hill analysis, cost and P removal efficiencies for urban BMP's as specified by EPA (U.S. Environmental Protection Agency, 1999) are employed (See Table 8). No abatement quantities are calculated for the Forest land cover type.

For each Lake Allatoona agricultural NPS type i (i = Row Crop, Pasture Receiving Litter, Pasture Not Receiving Litter, Cows in Stream) using applicable bmp j (j = 50 Foot Riparian Buffer, Cattle Exclusion, Cattle Exclusion with 50 Foot Riparian Buffer, Cover Crop, Grassed Waterway, Land Conversion: Land Conversion: Cropland to Forest, Cropland to Pasture, Land Conversion: Pastureland to Forest,) in sub-watershed t (t = Acworth/Allatoona, Little/Noonday, Owl/Kellogg, Shoal Creek, Stamp/Rowland, and Upper Etowah), the potential abatement per acre per year is:

(10) $a^{na}_{ijt} = r^{a}_{j} * (x^{a}_{it} / ar^{a}_{it})$,

where a^{na}_{ijt} is the annual reduction in lbs of total P per acre by agricultural NPS type i by bmp j in sub-watershed t; r^{a}_{j} is the reduction efficiency in lbs of total P removed per acre by agricultural bmp j; x^{a}_{it} is the annual average lbs of total P discharged by agricultural NPS type i in sub-watershed t; ar^{a}_{it} is the area (acres) of agricultural NPS type i in sub-watershed t. Total potential abatement by each agricultural NPS is:

(11) $A^{na}_{ijt} = a^{na}_{ijt} * ar^{a}_{it} = r^{a}_{j} * x^{a}_{it}$,

where A^{na}_{ijt} is the reduction in annual lbs of total P if bmp j is implemented on all acres of agricultural type i in sub-watershed t. It is unrealistic to assume BMP's can be implemented on 100 percent of the agricultural land cover; however, these quantities provide an upper bound on the number of agricultural credits available for supply by land cover type by sub-watershed.

Similarly, for each Lake Allatoona urban NPS type i (i = Less Developed Urban, Highly Developed Urban) using applicable best management practice j (j = Bioretention, Dry Extension Basin, Filter Strip, Grassed Swale, Infiltration Devices, Restored Riparian Buffer, Sand Filter, Stormwater Wetlands, Wet Detention Basin) in sub-watershed t (t = Acworth/Allatoona, Little/Noonday, Owl/Kellogg, Shoal Creek, Stamp/Rowland, and Upper Etowah), the available abatement per acre is:

(12) $a^{nu}_{ijt} = r^{u}_{j} * (x^{u}_{it} / ar^{u}_{it})$,

where a^{nu}_{ijt} is the annual reduction in lbs of total P per acre by urban NPS type i by bmp j in sub-watershed t; r^{u}_{j} is the reduction efficiency in lbs of total P removed per acre by urban bmp j; x^{u}_{it} is the annual average lbs of total P discharged by urban NPS type i in sub-watershed t; ar^{u}_{it} is the area (acres) of urban NPS type i in sub-watershed t. Total abatement by urban NPS type is:

(13) $A^{nu}_{ijt} = a^{nu}_{ijt} * ar^{u}_{it} = r^{u}_{j} * x^{u}_{it}$,

where A^{nu}_{ijt} is the reduction in annual lbs of total P if urban bmp j is implemented on all acres of urban land cover type i in sub-watershed t. Again, it is unrealistic to assume BMP's can be implemented on 100 percent of the urban land cover; however, these quantities provide an upper bound on the number of urban credits available for supply by land cover type by sub-watershed.

Since Weiss NPS modeling data is not available, abatement by land cover type for the Weiss markets is not calculated. Instead, poultry litter transfer is used to estimate the potential NPS component of trading for the Weiss markets (as discussed in the section below on Alpha Trades).

Abatement Costs:

Using a combination of cost estimates from GA NRCS , CH2M HILL (CH2M HILL, 2008), and EPA (U.S. Environmental Protection Agency, 1999), corresponding abatement costs by NPS type by bmp by sub-watershed are calculated. Unit costs of abatement are the present value estimate of capital costs and O&M per acre over the lifetime of the bmp[12].

For each Lake Allatoona agricultural NPS type by bmp by sub-watershed, the abatement cost per acre per year is:

(14) $z^{na}_{ijt} = v^{a}_{j} / a^{na}_{ijt}$,

where z^{na}_{ijt} is the annual cost per lb of total P abatement by agricultural NPS type i with bmp j in sub-watershed t; v^{a}_{j} is the average annual present value cost per acre by agricultural bmp j; a^{na}_{ijt} is as defined above. Total abatement cost for agricultural NPS i practicing bmp j on ar^{a}_{it} acres of agricultural land in sub-watershed t is:

(15) $Z^{na}_{ijt} = z^{na}_{ijt} * ar^{a}_{it}$.

Similarly, for each Lake Allatoona urban NPS type by bmp by sub-watershed, the abatement cost per acre per year is:

(16) $z^{nu}_{ijt} = v^{u}_{j} / a^{nu}_{ijt}$,

where z^{nu}_{ijt} is the annual cost per lb of total P abatement by urban NPS type i with bmp j in sub-watershed t; v^{u}_{j} is the average annual present value cost per acre by urban bmp j; a^{nu}_{ijt}, is as defined above. Total abatement cost for urban NPS i practicing bmp j on ar^{u}_{it} acres of urban land in sub-watershed t is:

(17) $Z^{nu}_{ijt} = z^{nu}_{ijt} * ar^{u}_{it}$.

Credits for Trading:

Aggregate credits for agricultural and urban NPS's by bmp by sub-watershed are[13]:

[12] Following CH2M HILL, calculations assume an interest rate of 7.5 percent, inflation rate of 5 percent, and lifetimes of 10 years for agricultural BMP's and 20 years for urban BMP's. Urban BMP's assume an EPA specified rainfall adjustment factor of 0.67 for rainfall zone 3. CH2M increase their cost estimates for both agricultural and NPS BMP's by 35 percent to account for design and contingency costs. This adjustment is not included. Land costs are included and estimated from georgiastats.uga.edu.

(18) $Q^{na}_{ijt} = A^{na}_{ijt} * (e^{a}_{it} * np^{a}_{ijt} * rt^{a}_{ijt})$

(19) $Q^{nu}_{ijt} = A^{nu}_{ijt} * (e^{u}_{it} * np^{u}_{ijt} * rt^{u}_{ijt})$,

where Q^{na}_{ijt} and Q^{nu}_{ijt} represent the number of available credits per year from an agricultural or urban NPS of type i using bmp j on ar^{a}_{it} or ar^{u}_{it} acres of a land in sub-watershed t; A^{na}_{ijt} and A^{nu}_{ijt} are defined as above; e^{a}_{it} and e^{u}_{it} are the delivery ratios of agricultural and urban NPS's by type i in sub-watershed t as defined by the loadings profile tables (See Table 3); np^{a}_{ijt} and np^{u}_{ijt} represent the trading ratios of agricultural and urban NPS's by type i by bmp j in sub-watershed t; rt^{a}_{ijt} and rt^{u}_{ijt} are the retirement ratios of agricultural and urban NPS's by type i by bmp j in sub-watershed t[14].

The unit prices for credits supplied by agricultural or urban NPS's by type by bmp by sub-watershed t are:

(20) $p^{na}_{ijt} = Z^{na}_{ijt} / Q^{na}_{ijt}$

(21) $p^{nu}_{ijt} = Z^{nu}_{ijt} / Q^{nu}_{ijt}$,

where p^{na}_{ijt} and p^{nu}_{ijt} are the minimum prices that agricultural and urban NPS's of type i, with bmp j, in sub-watershed t are willing to accept for abatement practices that earn one credit of P reduction. Z^{na}_{ijt}, Z^{nu}_{ijt}, Q^{na}_{ijt}, and Q^{na}_{ijt} are as defined above.

Poultry Litter Transfer Quantity and Cost Estimates:

Poultry litter transfer as a bmp is treated separately from other agricultural BMP's due to the unique role litter transfer may play in the Lake Allatoona and Weiss markets. As seen in

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[13] The trading frameworks assume that NPS's do not face enforced loading limits from a regulatory agency; thus, any NPS abatement reflects a potential supply of credits for trading.

[14] The trading ratios np^{a}_{ijt} and np^{u}_{ijt} are assumed to equal 0.5 across all NPS types, BMP's, and sub-watersheds. This ratio creates a NPS:PS ratio of 2:1. The retirement ratios rt^{a}_{ijt} and rt^{u}_{ijt} are assumed to equal 1.0 across all NPS types, BMP's, and sub-watersheds (no retirement).

Table 2, P loads from Pasture Receiving Litter account for 56.29 percent of all NPS loads to Lake Allatoona; the extent of litter operations in the Weiss markets may suggest similar results for Weiss Lake. Following Lin et al., trading frameworks assume a loading baseline that all manure generated in the watershed is currently applied in the watershed[15]. The bmp for litter transfer is defined as the quantity (tons) of manure that is generated but not applied; this analysis assumes that litter must be transported out of the borders of all markets to classify as not applied.

Abatement Quantity:

The total P abatement resulting from the transfer of one ton of litter out of a Lake Allatoona sub-watershed is:

(22) $a^l_t = x^l_t / mn^l_t$,

where a^l_t is the reduction in lbs of total P per ton of manure transferred from sub-watershed t; x^l_t is the total average annual lbs of total P delivered by pasture receiving litter to sub-watershed t; mn^l_t is Lin et al.'s estimate of tons of manure applied in sub-watershed t. Since P load data is unavailable for Weiss-markets, these markets assume a reduction in lbs of total P per ton of manure transferred equal to the average of Lake Allatoona's sub-watersheds.

Vest et al.'s estimate of 1.2 tons of manure per 1,000 broilers determines the amount of manure generated in all markets (Vest, et al., 1994) [16]. 2007 U.S. Agricultural census data provides the number of broilers for each applicable county (U.S. Department of Agriculture, 2009). These numbers are then weighted by the percent of the county that falls within each applicable watershed to determine the quantity of manure available for transport:

[15] As stated in the 2009 draft TMDL, this assumption does not account for the significant amount of litter that is currently transported out of the watershed as fertilizer for other counties in Georgia.
[16] Lin et al. provide an estimate for manure within the Lake Allatoona market, but as stated in the 2009 draft TMDL, the quantity of manure generated may have been overestimated.

(23) $mn^{A}_{it} = (br_i * vt) * cn_{it}$,

where mn^{A}_{it} is the tons of manure generated in the portion of county i that is in Lake Allatoona sub-watershed t; br_i is the number of broilers (in thousands) in county i; vt is equal to Vest et al.'s estimate of 1.2 tons of litter per 1,000 broilers; cn_{it} is the percent of county i's area that falls within watershed t. Similarly, for Weiss market watersheds, these estimates are mn^{W}_{it} (Weiss-Alabama), mn^{G}_{it} (Weiss-Georgia), mn^{T}_{it} (Weiss –Tennessee). Tables 9 and 10 provide these estimates.

Thus, total possible total P abatement for county i in sub-watershed t is:

(24) $A^{A}_{it} = a^{l}_{t} * mn^{v}_{it}$,

where A^{A}_{it} is the total available abatement of annual lbs of total P from litter transfer out of the portion of county i that is Lake Allatoona sub-watershed t. a^{l}_{t} and mn^{A}_{it} are as defined above. Similar to total agricultural and urban abatement estimates, this calculation estimates an upper bound for the total P that can be exported from each county. Likewise, for Weiss markets, these estimates are A^{W}_{it} (Weiss-Alabama), A^{G}_{it} (Weiss-Georgia), A^{T}_{it} (Weiss-Tennessee).

Abatement Costs:

In a 2008 report, Risse et al. provide a thorough review of the potential for poultry litter transfer in the state of Georgia and develop a model that calculates incentive prices for litter transfer throughout the state (Risse, et al., 2008). In particular, the model minimizes the cost of meeting plant nutrient needs based on crop nutrient requirements, soil tests, and 2008 fertilizer prices. Their results present the prices that counties would be willing to buy or sell a ton of litter as fertilizer for crops[17]. These prices serve as abatement costs for this paper since they are the incentive prices for poultry litter transfer. Abatement costs for each ton of litter transported out of county i in Lake Allatoona sub-watershed t are referred to as z^{lA}_{it}. Likewise, for Weiss markets, these costs are z^{lW}_{it} (Weiss-Alabama), z^{lG}_{it} (Weiss-Georgia), z^{lT}_{it} (Weiss –Tennessee)[18]. If a county i in sub-watershed t chooses to export all manure mn^{A}_{it}, total costs are:

(25) $Z^{lA}_{it} = z^{lA}_{it} * mn^{A}_{it}$.

where Z^{lA}_{it} is the total cost of transferring mn^{A}_{it} tons of litter out of county i in sub-watershed t. For Weiss markets, these costs are Z^{lW}_{it} (Weiss-Alabama), Z^{lG}_{it} (Weiss-Georgia), Z^{lT}_{it} (Weiss – Tennessee).

Credits for Trading:

The available credits for litter transfer are:

(26) $Q^{lA}_{it} = A^{A}_{it} * (e^{l}_{it} * np^{l}_{it} * rt^{l}_{it})$,

where Q^{lA}_{it} represents the total credits available for litter transport out of county i in watershed t; A^{A}_{it} is as defined above. e^{l}_{it}, np^{l}_{it}, and rt^{l}_{it} are the trading ratios for poultry litter similarly defined as those for agricultural and urban NPS's. For Weiss markets, the credits are defined as Q^{lW}_{it} (Weiss-Alabama), Q^{lG}_{it} (Weiss-Georgia), Q^{lT}_{it} (Weiss –Tennessee).

The price for an individual credit supplied by litter transfer from county i in Lake Allatoona sub-watershed t is:

(27) $p^{lA}_{it} = Z^{lA}_{it} / Q^{lA}_{it}$,

[17] Scenario I results from Risse et al. provide the incentive costs for counties without excess litter based on P needs of crops. Cost differentials between Scenario I and Scenario II divided by the difference in excess litter between the two scenarios provide the incentive costs for counties with excess litter based on P needs of crops.

[18] Since this analysis does not calculate costs for Tennessee or Alabama counties, transport costs are estimated by comparing surrounding Georgia counties, crops grown in each county, and total manure generated.

where p^{l}_{it} is the minimum price that a litter transporting producer in county i and watershed t is willing to accept for one credit of abatement. Z^{l}_{it} and Q^{l}_{it} are as defined above. For Weiss markets, these prices are p^{lW}_{it} (Weiss-Alabama), p^{lG}_{it} (Weiss-Georgia), p^{lT}_{it} (Weiss –Tennessee).

Alpha Trades With and Without Boundaries:

The EPA handbook on trading defines and discusses the importance of alpha trades in the chapter on Financial Attractiveness. The handbook states that alpha trades are:

> …those trades with sufficient economic return to be viable even after water quality ratios are applied. Analyzing these trades should provide a good indication of trading viability in your watershed; if the watershed can support several Alpha Trades, trading is likely to be financially viable. Although this chapter discusses detailed calculations, a typical analysis will produce 'ballpark' estimates.
>
> (U.S. Environmental Protection Agency, 2004)

The demand of credits from PS's under TMDL limits are compared with the potential supply of credits from NPS's to produce these 'ballpark' estimates of alpha trades. Total quantity demanded by individual PS's and their corresponding prices for the maximum willingness to pay for credits are calculated as described previously. For purposes of trading, it is assumed that agricultural and urban NPS's of type i in sub-watershed t can implement only one type of bmp j on land cover ar^{a}_{it} and ar^{u}_{it}. Thus, for exploring alpha trades, it is assumed that that NPS land cover types supply Q^{na}_{ijt} and Q^{nu}_{ijt} that correspond with the minimum of prices p^{na}_{ijt} and p^{nu}_{ijt} by sub-watershed t. Results summarize the potential level of credits supplied by agricultural, urban, and poultry litter transport as well as corresponding price levels.

Two trading scenarios for Lake Allatoona are examined to explore the effects of ecological boundaries on the potential for trading. Scenario 1 examines the number of alpha trades when the ecological boundary is defined by the entire watershed that drains to Lake Allatoona. In this scenario Allatoona-All is treated as one market; buyers and sellers can exchange credits with anyone in the six sub-watersheds; this scenario allows for the spatial expansion of markets across sub-watersheds. Scenario 2 tightens ecological boundaries for trading to the sub-watershed level; Allatoona-Creek, Allatoona-Etowah, and Allatoona-Little are treated as separate markets. Buyers and sellers can only exchange credits with other stakeholders in their sub-watershed. In addition, the 2009 draft TMDL states, "If there is a new facility or an (sic) currently listed a (sic) facility that expands its capacity in the future and its permitted flow increases, the WLA for the facility would decrease in proportion to the flow, unless a LA can be reduced via pollutant trading". The impacts of ecological boundaries on the supply of future credits from NPS's are explored for these two scenarios.

To examine the effects of political boundaries on trading, two trading scenarios for Weiss Lake are explored. Scenario 3 allows trades across state lines; Weiss-Alabama, Weiss-Georgia, and Weiss-Tennessee markets are combined into one market. Buyers and sellers can exchange credits with anyone in these three markets. Scenario 4 introduces political boundaries such that Weiss-Alabama, Weiss-Georgia, and Weiss-Tennessee markets are treated as independent markets. Buyers and sellers are restricted to trade with only those participants in their state markets. Since modeling data is currently limited, poultry litter transfer is used to estimate the NPS component of trading for Weiss markets. This bmp serves as a good measure for the quantity and price of NPS abatement options due to the volume of broilers in the Weiss markets and the fact that litter transfer has been a low hanging fruit for NPS abatement options in other trading schemes (Pennsylvania Department of Environmental Protection, 2009).

RESULTS AND DISCUSSION:

Allatoona Markets:

For Scenarios 1 and 2, the credits demanded and corresponding compliance costs for PS's are summarized in Table 11. As shown, only 2 of the 10 PS's in the Lake Allatoona markets need to reduce their loadings in order to meet TMDL standards. Woodstock Rubes Creek WPCP (Woodstock) needs 2,179 credits to meet compliance. If Woodstock decides to upgrade its facility, it would face a compliance cost of approximately $34 per credit, or a total annual cost of $73,096. The other Lake Allatoona facility, City of Canton WPCP (Canton), needs 12,165 credits to meet compliance. If Canton decides to upgrade its facility, it would face a compliance cost of approximately $157 per credit, or a total annual cost of $1,906,039. For NPS credits, litter transfer abatement (Table 13) generally dominates agricultural and urban abatement options (Table 12) in terms of the number of credits supplied and price.

For Scenario 1, Woodstock and Canton can choose to upgrade or purchase credits from any source in any sub-watershed. As Table 13 shows, litter transfer from several counties in the Etowah sub-watershed provides a cheap source of NPS credits. There are six counties in the Etowah sub-watershed with an estimated credit price of $12 or less; these counties supply a total of 129,519 credits. Even if only a quarter of these credits are available (32,380), there is still a sufficient supply of credits to meet demand from Woodstock and Canton at a substantial cost savings to those PS's. At $12 a credit, Woodstock saves approximately $47,000 per year in P abatement costs. For Canton, the savings are even higher at approximately $1.8M per year. In Scenario 1, alpha trades clearly exist between the PS's (Woodstock, Canton) and poultry litter transfer producers.

For Scenario 2, Woodstock and Canton must choose to upgrade or purchase credits from NPS's within their sub-watershed. For Canton, the alpha trade with litter transfer remains the same as in Scenario 1 since Canton is a PS within the Etowah sub-watershed. For Woodstock, a PS within the Little/Noonday sub-watershed, alpha trades are no longer available. Riparian Buffers on Cropland provide a cheap source of credits ($6 per credit), but even if this BMP is implemented on all acres of cropland, it only produces 299 credits. The only litter transfer option that is cheaper than the upgrade cost is litter transfer from Cherokee County (1,332 credits at $29 per credit); even at this maximum supply level, the number of credits is less than the 2,179 credits Woodstock needs for compliance. Thus, the best option for Woodstock would be to upgrade its facility. Neither Scenario 1 nor 2 suggest alpha trades for PS-to-PS.

Weiss Markets:

For Scenarios 3 and 4, the credits demanded and corresponding compliance costs for PS's are summarized in Table 14. For Alabama, only Town of Centre WWSB Lagoon (Centre) needs to reduce current loadings. To meet compliance, Centre needs 3,304 credits; if it chooses to upgrade the facility, compliance costs are $23 per credit, or $76,685 per year. For the Georgia markets, the current market limits require that 16 of the 22 PS's reduce loadings. A total of 754,460 credits are needed at an average cost of $60 per credit and a total annual cost of $31,053,363. Cartersville WPCP (Cartersville) and Calhoun WPCP (Calhoun) account for the largest number of required credits (60%). If Cartersville upgrades, it faces total annual abatement costs of $7,851,456 at $30 per credit. Calhoun faces total annual compliance costs of $9,960,462 at $52 per credit. The NPS component of trading for Weiss Lake is summarized in Table 15. As one can see, the majority of credits for poultry transfer are in the Weiss-Alabama market (80% of the total across all markets). When examining just the Weiss-Alabama and Weiss-Georgia markets, poultry litter credits from Weiss-Alabama comprise 99% of the total number of credits.

In Scenario 3, PS's are allowed to purchase credits across all markets. Although there are cheaper credits available in the Weiss-Georgia market, De Kalb County, AL supplies the largest number of credits (19,288,751) at a competitive price ($21). The number of credits supplied from De Kalb is more than enough to meet demand; even if only a quarter of De Kalb litter transfer producers participate, the supply of credits (4,822,188) still far exceeds total demand (757,765). Due to the volume and price of credits from De Kalb, $21 is used as the price for determining alpha trades for PS-to-NPS. In Scenario 3, only two PS's (Rome Blacks Bluff WPCP and Lafayette WPCP) do not benefit from trades with litter transfer producers in De Kalb County. These PS's, if they upgrade, face compliance costs of $10 and $11 respectively. If PS-to-PS trading is allowed, these PS's would have the incentive to upgrade and sell additional credits at, or below, market price. However, total supply from Rome and Lafayette (23,953) falls substantially short of total demand. If all other PS's were able to purchase NPS credits at $21 per credit, the total cost savings would be $16,170,371. It should be noted that not all of these PS's face significant alpha trades since some unit costs to upgrade are close in costs to the approximate $21 litter transfer cost; nevertheless, there are 11 facilities with a $10 or greater unit cost differential between the cost to upgrade and a $21 litter estimate. These results suggest that significant alpha trades exist between PS's and NPS litter transfers when trading is allowed across all borders.

In Scenario 4, trading is restricted by state lines. Under these conditions, the potential for alpha trades diminishes significantly. For the Weiss-Alabama market, these conditions do not affect the decision for Centre. As before, the cost differential between the unit cost to upgrade and litter transfer is marginal ($2). However, the alpha trades for Weiss-Georgia PS's are significantly impacted by the restriction of markets. Even if all litter transfer credits are produced, this number of 315,703 credits falls short of the 754,460 credits demanded. The political boundaries clearly limit the number of alpha trades available in this scenario.

Discussion:

Overall, the findings from Scenarios 1-4 suggest that restricting trading to tight ecological and political boundaries has a negative impact on the potential for trading in Lake Allatoona and Weiss Lake respectively. As recognized by the 2009 draft TMDL, water quality standards for Lake Allatoona cannot be achieved through further PS reductions alone. However, for the PS's that do face additional required reductions, a trading framework that allows trades across all of Lake Allatoona's sub-watersheds offers significant cost savings. Limiting trading to individual sub-watersheds impacts the ability of one PS (Woodstock) to find alpha trades. Other PS's are not impacted by this restriction because they can either find a sufficient supply of cheap credits in their sub-watershed (Canton) or are currently discharging below their TMDL limit.

The biggest impact of restricting trading to the sub-watershed level for Lake Allatoona could be on future PS's or current PS's that experience significant increases in loads. The 2009 draft TMDL offers nutrient trading as a means for offsetting these future PS loads. However, results suggest that trading options for additional PS loads could be limited if ecological boundaries for trading are defined on a sub-watershed level. Very few, if any, cheap credits are available within Acworth/Allatoona, Owl/Kellogg, and Stamp/Rowland. Only a limited number of credits are available within Little/Noonday and Shoal Creek. New PS's or PS's with increased loads within one of these 5 sub-watersheds would likely face a scarcity of alpha trades.

For Weiss Lake, results from Scenarios 3 and 4 show that restricting trading by political boundaries has a negative impact on the potential for trading. In this case, PS's in Georgia are separated from the majority of cheap NPS credits in Alabama. When trading is restricted to individual states, the majority of PS's that require reductions have limited alpha trades available. However, the expansion of trading across these political boundaries unlocks potential trades. Further information from the Coosa River Modeling Project will provide insight into the accuracy of market assumptions and the ability of trading to meet water quality goals for the lake. Nonetheless, a large PS presence in Georgia and a large NPS supply of credits in Alabama suggest the need for an interstate trading framework. Cooperation between Alabama and Georgia policy makers could lead to trading as a cost-effective solution to meet water quality standards for the lake.

The outcome of this research is not surprising considering the experience of current markets and the literature on barriers to trading. Nevertheless, the implications of these findings help policy makers better understand and minimize the limitations to trading. TMDLs that rely heavily on nutrient trading to meet future load limits could face obstacles with regards to thin markets if trading boundaries are defined on the sub-watershed level. On the other hand, a TMDL that allows the expansion of markets across these ecological boundaries promotes more trading opportunities. Political boundaries also limit trading opportunities; an expansion of markets across these barriers could promote alpha trades. In this example, a TMDL that recognizes an interstate trading framework would provide an opportunity for significant alpha trades that otherwise do not exist.

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Figure 1. Lake Allatoona, Weiss Lake and Relevant Watersheds

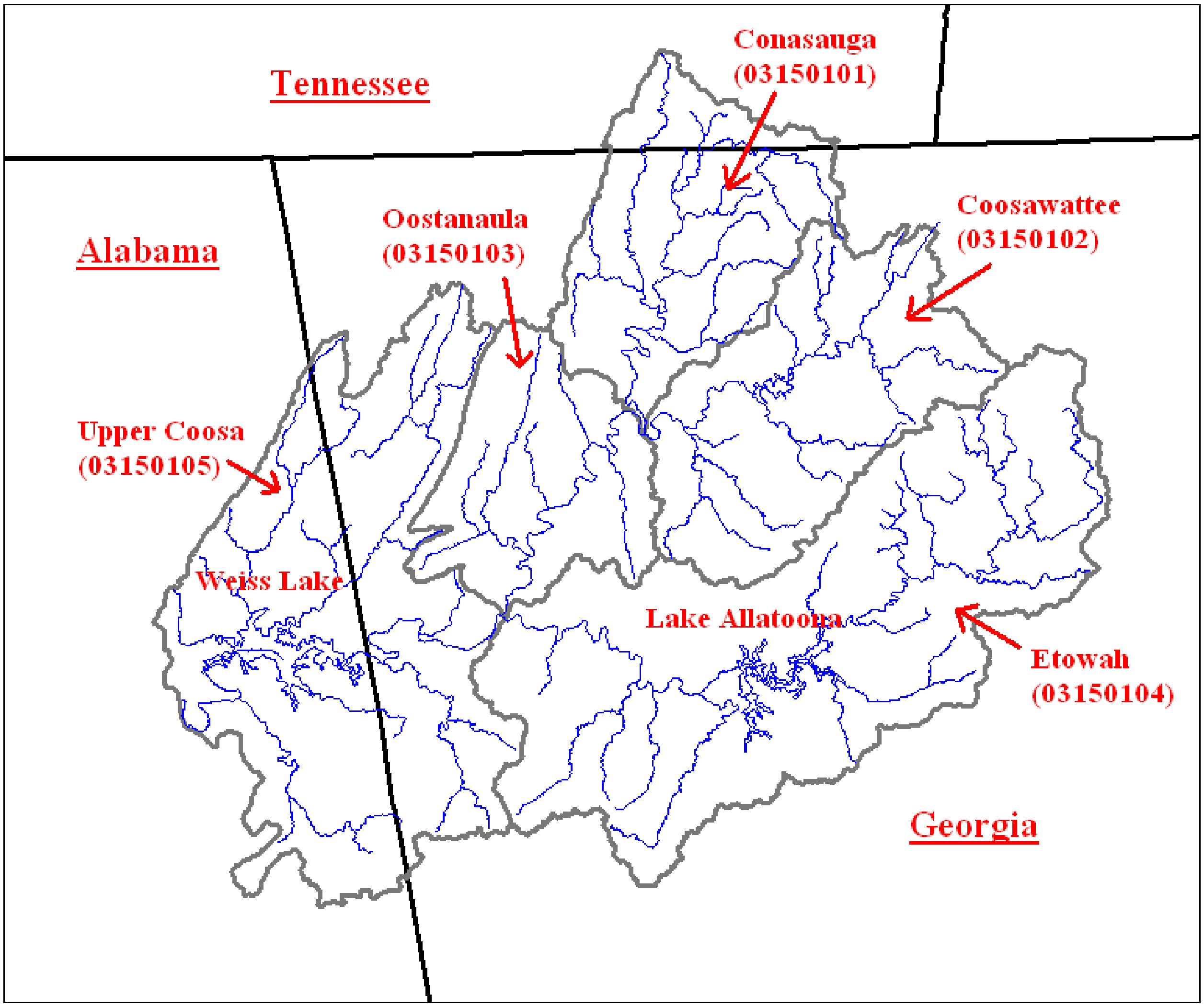
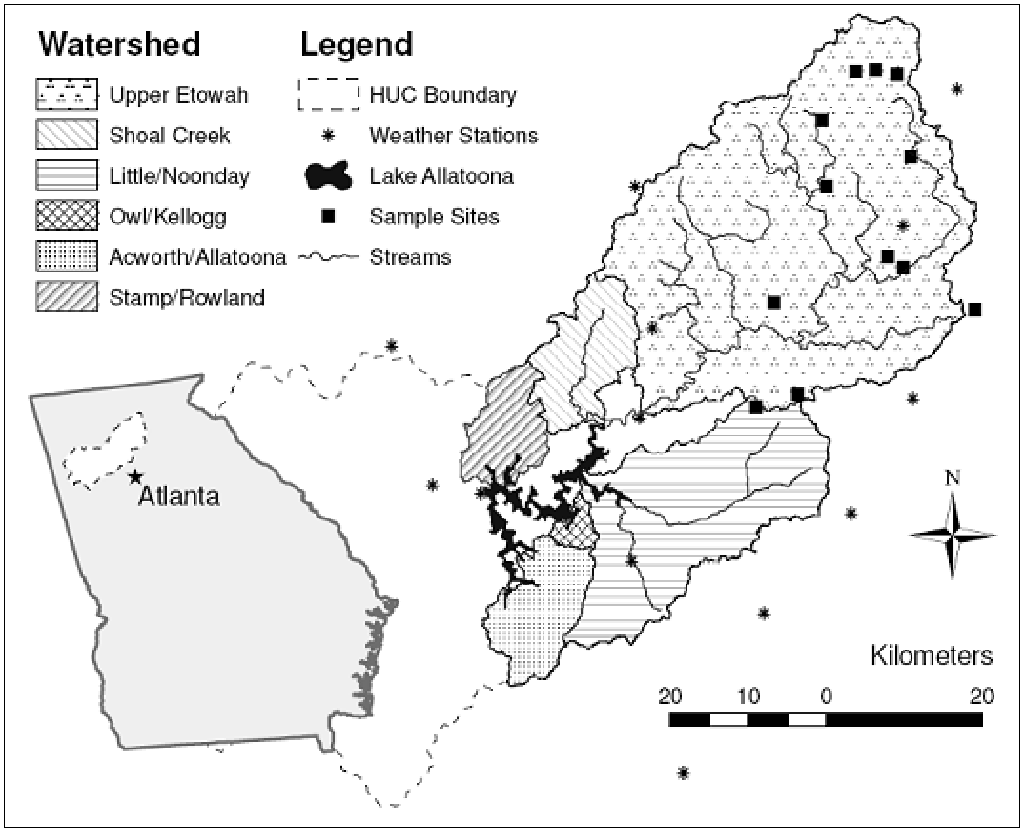


Figure 2. Six Sub-watersheds for Lake Allatoona Markets



(Radcliffe, et al., 2008)

Table 1. Loadings Profile – Lake Allatoona Individual Point Sources (≥ 0.1 MGD) by Sub-Watershed (2000-2007)

Point Source1	NPDES Permit No.[1]	Sub-watershed	Average Flow (MGD)[1]	Average Total P (mg/l)[1]	Average Total P (lbs/yr)[2]	TMDL Total P (lbs/yr)[1]	Total Reduction to meet TMDL (lbs/yr)
Cobb County Northwest WPCP	GA0046761	Acworth/Allatoona	6.19	0.11	2,074	5,601	-3,527
			Total by sub-watershed		**2,074**	**5,601**	**-3,527**
Cherokee County Fitzgerald Creek	GA0038555	Little/Noonday	1.03	1.54	4,832	4,992	-160
Cherokee County Rose Creek	GA0046451	Little/Noonday	3.50	0.17	1,812	6,575	-4,763
Cobb County Noonday Creek WPCP	GA0024988	Little/Noonday	9.78	0.21	6,256	10,960	-4,704
Fulton County Little River WPCP	GA0033251	Little/Noonday	0.74	0.23	518	1,522	-1,004
Woodstock Rubes Creek WPCP	GA0026263	Little/Noonday	0.72	1.34	2,939	760	2,179
			Total by sub-watershed		**16,357**	**24,809**	**-8,452**
Big Canoe WPCP	GA0030252	Upper Etowah	0.02	0.51	33	761	-728
City of Canton WPCP	GA0025674	Upper Etowah	1.77	2.79	15,042	2,877	12,165
Goldkist Poultry Byproducts	GA0000728	Upper Etowah	0.16	1.79	872	3,000	-2,128
Jasper WPCP	GA0032204	Upper Etowah	0.48	-	-	2,435	-2,435
			Total by sub-watershed		**15,947**	**9,073**	**6,874**
			Total for Lake Allatoona		**34,379**	**39,483**	**-5,104**

1 2009 Draft TMDL from GA EPD (includes point sources identified in Little River Embayment TMDL); excludes Land Application Systems.

[2] Calculated from average flow and average total P (mg/L).

Table 2. Loadings Profile - Lake Allatoona Non-point Sources by Land Cover and/or Land Use
(Annual average lbs of P delivered to tributaries of each sub-watershed from 2001-2004)[1]

Sub-watershed	Row Crop	Less Developed Urban	Highly Developed Urban	Pasture Receiving Litter	Pasture Not Receiving Litter	Forest	Cows In Stream	Total NPS
Acworth/Allatoona	0	1,836	3,080	282	256	172	31	5,657
Little/Noonday	1,041	19,758	44,253	7,650	1,501	2,701	811	77,715
Owl/Kellogg	0	236	403	99	20	35	13	807
Shoal Creek	0	1,345	1,556	8,091	459	7,968	289	19,707
Stamp/Rowland	0	346	536	0	187	1,010	0	2,079
Upper Etowah	1,519	11,438	21,162	235,591	12,736	51,921	6,808	341,174
Subtotal (load to tributaries)	2,560	34,957	70,996	251,713	15,161	63,806	7,952	447,144
Delivered to lake	2,313	31,566	64,110	227,303	13,691	57,618	7,180	403,781
Percentage of NPS Load	0.57%	7.82%	15.88%	56.29%	3.39%	14.27%	1.78%	100%

[1] Loads converted to lbs/yr from kg/yr as given by Lin et al. (2009).

Table 3. Lake Allatoona Delivery Ratios by Sub-watershed[1]

Sub-watershed	Delivery Ratio (%)
Upper Etowah	93.4
Shoal Creek	99.6
Little/Noonday	76.6
Owl/Kellogg	128.8
Acworth/Allatoona	89.9
Stamp/Rowland	49.1

[1] Per Lin et al. (2009).

Table 4. Lake Allatoona 2001 NLCD Land Cover (Acres) by Type by Sub-watershed[1]

Sub-watershed	Row Crop	Less Developed Urban	Highly Developed Urban	Pasture Receiving Litter[2]	Pasture Not Receiving Litter	Forest	Total
Acworth/Allatoona	10	12,311	6,797	96	2,844	17,433	39,492
Little/Noonday	12	37,719	20,826	2,461	14,846	61,509	137,373
Owl/Kellogg	-	1,608	888	42	336	3,012	5,886
Shoal Creek	79	1,985	1,096	880	2,802	36,171	43,014
Stamp/Rowland	40	1,711	945	-	1,685	24,842	29,223
Upper Etowah	509	23,680	13,075	20,683	29,870	308,232	396,048
Total	650	79,014	43,627	24,162	52,384	451,200	651,036

[1] Per Lin et al. (2009).

[2] Same area assumed for cattle grazing.

Table 5. Loadings Profile – Weiss Lake Individual Point Sources (≥ 0.1 MGD) by Designated Weiss Market

Weiss Market	Point Source[1]	NPDES Permit No.[1]	Watershed	Average Flow (MGD)[1]	Average Total P (mg/l)[1]	Average Total P (lbs/yr)[2]	TMDL Total P (lbs/yr)[1]	Total Reduction to meet TMDL (lbs/yr)
Weiss-Alabama								
	Cherokee WPCP[3]	AL0057592	Upper Coosa, AL	0.06	5.70	1,042	3,044	-2,002
	Piedmont WWTP	AL0024376	Upper Coosa, AL	0.59	1.35	2,421	3,044	-623
	Town of Cedar Bluff WWTP	AL0024678	Upper Coosa, AL	0.16	0.86	425	3,044	-2,619
	Town of Centre WWSB Lagoon	AL0062723	Upper Coosa, AL	0.52	4.03	6,349	3,044	3,304
				Total by Weiss Market		**10,237**	**12,176**	**-1,940**
Weiss-Georgia								
	Chatsworth WPCP	GA0032492	Conasauga, GA	1.21	1.87	6,929	3,698	3,231
	Dow Chemical Co	GA0000426	Conasauga, GA	0.11	0.65	223	3,044	-2,821
	Ellijay-Gilmer Water & Sewer	GA0021369	Conasauga, GA	2.04	11.54	71,613	6,203	65,410
	Cartersville WPCP	GA0024091	Lower Etowah	11.00	8.75	293,184	33,507	259,678
	City of Rockmart	GA0026042	Lower Etowah	1.20	8.86	32,490	3,669	28,821
	Dallas North WPCP	GA0026034	Lower Etowah	0.23	4.05	2,868	3,044	-176
	Dallas West WPCP	GA0026026	Lower Etowah	0.44	3.48	4,685	3,044	1,641
	Emerson Pond	GA0026115	Lower Etowah	0.17	6.25	3,236	3,044	192
	Rome Blacks Bluff WPCP	GA0024112	Lower Etowah	10.89	3.10	102,817	33,167	69,650
	Adairsville South WPCP	GA0032832	Oostanaula	0.38	32.50	37,619	3,044	34,575
	Calhoun WPCP	GA0030333	Oostanaula	8.75	8.22	219,083	26,663	192,420
	City of Adairsville - North	GA0046035	Oostanaula	0.51	17.54	27,130	3,044	24,086
	OMNOVA Solutions Inc	GA0000329	Oostanaula	0.12	0.08	27	3,044	-3,017
	Cave Spring WPCP	GA0025721	Upper Coosa, GA	0.15	2.00	908	3,044	-2,136
	City of Cedartown	GA0024074	Upper Coosa, GA	1.82	4.27	23,694	5,548	18,146
	City of Summerville WPCP	GA0025704	Upper Coosa, GA	0.95	1.54	4,436	3,044	1,392
	Geo Specialty Chemicals	GA0001708	Upper Coosa, GA	0.26	2.73	2,158	3,044	-886
	Inland Rome (Outfall 001)	GA0001104	Upper Coosa, GA	15.98	1.08	52,724	48,669	4,056
	Inland Rome (Outfall 002)	GA0001104	Upper Coosa, GA	6.95	0.53	11,107	21,157	-10,050
	Lafayette WPCP	GA0025712	Upper Coosa, GA	1.74	2.55	13,508	5,291	8,217
	Rome-Coosa WPCP	GA0024341	Upper Coosa, GA	0.55	2.47	4,106	3,044	1,062
	Trion WPCP	GA0025607	Upper Coosa, GA	5.00	3.75	57,114	15,230	41,883
				Total by Weiss Market		**971,661**	**236,287**	**735,374**
				Total for All Weiss Markets		**981,898**	**248,463**	**733,435**

[1] Point source data from EPA ECHO for NPDES data (average daily 2006-2008), GA EPD Coosa Study (2005-2006), and 2008 Weiss Lake TMDL (2005 NPDES Data).

[2] Calculated from average flow and average total P (mg/L).

[3] Although average daily flow is < 0.1 MGD, Cherokee WPCP is included since Weiss TMDL lists this PS.

Table 6. Weiss Lake 2001 NLCD Land Cover (Acres) by Type by Market by Watershed

Market	Sub-watershed	Row Crop	Less Developed Urban	Highly Developed Urban	Pasture	Forest	Total
Weiss-Alabama	Upper Coosa, AL	42,076	21,827	6,640	83,248	307,905	461,696
Weiss-Georgia	Conasauga, GA	9,531	30,771	17,804	56,370	239,945	354,421
	Coosawattee	8,301	31,247	4,456	62,312	412,775	519,091
	Oostanaula	11,012	22,116	10,897	60,263	225,835	330,123
	Lower Etowah	15,119	41,052	22,666	60,900	299,921	439,659
	Upper Coosa, GA	14,267	31,911	12,471	76,189	288,754	423,592
	Total by Market	58,230	157,098	68,294	316,034	1,467,230	2,066,886
Weiss-Tennessee	Conasauga, TN	2,770	3,968	839	21,885	42,823	72,285
	Total for All Weiss Lake Markets	**103,076**	**182,892**	**75,774**	**421,167**	**1,817,958**	**2,600,867**

Table 7. Agricultural BMP's - P Removal Efficiencies and Costs

BMP[1]	Total P Removal Efficiency (lbs /acre)[2]	Average Annual Cost per Acre Treated[1] Acworth/ Allatoona	Little/ Noonday	Owl/ Kellogg	Shoal Creek	Stamp/ Rowland	Upper Etowah
50 Ft Riparian Buffer (Forested)	0.75	$87.06	$138.21	$139.07	$134.99	$110.03	$86.05
Cattle Exclusion (50 Ft Riparian Buffer)	0.82	$129.88	$181.03	$181.89	$177.81	$152.85	$128.87
Cattle Exclusion (No Buffer)	0.28	$41.73	$41.73	$41.73	$41.73	$41.73	$41.73
Cover Crop	0.11	$27.39	$27.39	$27.39	$27.39	$27.39	$27.39
Grassed Waterway	0.45	$187.15	$289.44	$291.16	$283.01	$233.09	$185.13
Land Conversion: Cropland to Forest	0.94	$3,497.98	$5,543.80	$5,578.20	$5,415.24	$4,416.75	$3,457.60
Land Conversion: Cropland to Pasture	0.80	$3,506.39	$5,552.20	$5,586.60	$5,423.64	$4,425.15	$3,466.01
Land Conversion: Pastureland to Forest	0.69	$3,509.55	$5,555.36	$5,589.76	$5,426.80	$4,428.31	$3,469.17

[1] BMP's and cost estimates follow CH2M HILL's analysis of Lake Jordan, NC; costs updated with GA NRCS data where available and reflect present value capital and O&M costs. As CH2M, costs assume an interest rate of 7.5 percent, inflation rate of 5 percent, and lifetime of 10 years for agricultural BMP's. Land costs are included and estimated for each sub-watershed from georgiastats.uga.edu.

[2] Total P removal efficiences from CH2M HILL's analyis of Lake Jordan, NC.

Table 8. Urban BMP's - P Removal Efficiencies and Costs[1]

BMP[1]	Total P Removal Efficiency (lbs /acre)[2]	Average Annual Cost per Acre Treated[1] Acworth/Allatoona		Little/Noonday		Owl/Kellogg	
		Highly Devel.[2]	Less Devel.[2]	Highly Devel.[2]	Less Devel.[2]	Highly Devel.[2]	Less Devel.[2]
Bioretention	0.45	$2,574.03	$1,851.37	$2,497.74	$1,843.79	$2,258.74	$1,811.69
Dry Extension Basin	0.1	$552.90	$191.56	$514.75	$187.78	$183.19	$497.74
Filter Strip	0.35	$633.13	$300.70	$598.04	$297.22	$293.00	$582.38
Grassed Swale	0.2	$2,657.55	$489.55	$2,428.68	$466.83	$439.31	$2,326.59
Infiltration Devices	0.35	$1,743.31	$1,381.98	$1,705.16	$1,378.19	$1,373.60	$1,688.15
Restored Riparian Buffer	0.35	$435.73	$103.30	$400.64	$99.82	$95.60	$384.98
Sand Filter	0.45	$2,444.45	$2,227.65	$2,421.56	$2,225.37	$2,222.62	$2,411.35
Stormwater wetlands	0.35	$932.28	$354.14	$871.25	$348.08	$340.75	$844.02
Wet detention basin	0.4	$632.37	$271.03	$594.22	$267.25	$262.66	$577.21

BMP[1]	Total P Removal Efficiency (lbs /acre)[2]	Average Annual Cost per Acre Treated[1] Shoal Creek		Stamp/Rowland		Upper Etowah	
		Highly Devel.[2]	Less Devel.[2]	Highly Devel.[2]	Less Devel.[2]	Highly Devel.[2]	Less Devel.[2]
Bioretention	0.45	$2,129.68	$1,795.25	$2,013.77	$1,779.00	$2,087.06	$1,789.00
Dry Extension Basin	0.1	$330.72	$163.50	$272.76	$155.38	$309.41	$160.38
Filter Strip	0.35	$428.73	$274.89	$375.41	$267.41	$409.12	$272.02
Grassed Swale	0.2	$1,324.48	$321.18	$976.75	$272.44	$1,196.64	$302.46
Infiltration Devices	0.35	$1,521.13	$1,353.91	$1,463.18	$1,345.79	$1,499.82	$1,350.79
Restored Riparian Buffer	0.35	$231.33	$77.49	$178.01	$70.01	$211.72	$74.62
Sand Filter	0.45	$2,311.14	$2,210.81	$2,276.37	$2,205.94	$2,298.35	$2,208.94
Stormwater wetlands	0.35	$576.79	$309.25	$484.06	$296.25	$542.70	$304.25
Wet detention basin	0.4	$410.19	$242.97	$352.23	$234.85	$388.88	$239.85

[1] BMP's, P removal efficiencies, and cost estimates follow CH2M HILL's analysis of Lake Jordan, NC and use EPA estimates (EPA, 1999). As CH2M HILL, costs assume an interest rate of 7.5 percent, inflation rate of 5 percent, and lifetime of 20 years for urban BMP's. Costs reflect present value capital and O&M costs. Land costs are included and estimated for each sub-watershed from georgiastats.uga.edu.

[2] Highly Developed Urban (≥20% imperviousness) and Less Developed Urban (<20% imperviousness).

Table 9. Lake Allatoona Litter Transfer - Manure and Cost Estimates by County by Sub-Watershed[1]

County	Sub-Watershed	Manure Applied (tons)	Costs of Litter Transfer ($/ton)
BARTOW	Acworth/Allatoona	123	$13
CHEROKEE	Acworth/Allatoona	63	$13
COBB	Acworth/Allatoona	-	-
PAULDING	Acworth/Allatoona	89	$13
	Total by sub-watershed	**275**	
CHEROKEE	Little/Noonday	3,045	$13
COBB	Little/Noonday	-	-
FORSYTH	Little/Noonday	163	$23
FULTON	Little/Noonday	-	$100
	Total by sub-watershed	**3,208**	
CHEROKEE	Owl/Kellogg	214	$13
COBB	Owl/Kellogg	-	-
	Total by sub-watershed	**214**	
BARTOW	Shoal Creek	16	$13
CHEROKEE	Shoal Creek	1,870	$13
PICKENS	Shoal Creek	538	$13
	Total by sub-watershed	**2,424**	
BARTOW	Stamp/Rowland	3,256	$13
CHEROKEE	Stamp/Rowland	182	$13
	Total by sub-watershed	**3,438**	
CHEROKEE	Upper Etowah	3,997	$13
DAWSON	Upper Etowah	34,323	$15
FANNIN	Upper Etowah	36	$62
FORSYTH	Upper Etowah	4,297	$23
GILMER	Upper Etowah	1,459	$14
LUMPKIN	Upper Etowah	5,472	$20
PICKENS	Upper Etowah	16,701	$13
UNION	Upper Etowah	-	$62
	Total by sub-watershed	**66,285**	
	Total Lake Allatoona	**75,844**	

[1] Vest et al.'s estimate of 1.2 tons of manure per 1,000 broilers determines the amount of manure generated in all markets; broiler data from US Agricultural Census (2007). Cost per ton from Risse et al.

Table 10. Weiss Lake Litter Transfer - Manure and Cost Estimates by Market by County by Sub-watershed [1]

Market	County	Sub-Watershed	Manure Applied (tons)	Costs of Litter Transfer ($/ton)
Weiss-Alabama				
	CALHOUN, AL	Upper Coosa, AL	1,225,097	$81
	CHEROKEE, AL	Upper Coosa, AL	14,750,735	$81
	CLEBURNE, AL	Upper Coosa, AL	4,092,303	$19
	DE KALB, AL	Upper Coosa, AL	21,379,402	$19
	ETOWAH, AL	Upper Coosa, AL	121,196	$19
		Total by Weiss Market	**41,568,732**	
Weiss-Georgia				
	CATOOSA	Conasauga, GA	7	$17
	FANNIN	Conasauga, GA	745	$62
	GILMER	Conasauga, GA	694	$14
	GORDON	Conasauga, GA	3,486	$32
	MURRAY	Conasauga, GA	21,273	$21
	WALKER	Conasauga, GA	432	$21
	WHITFIELD	Conasauga, GA	26,673	$21
	BARTOW	Coosawattee	6,707	$13
	CHEROKEE	Coosawattee	664	$13
	DAWSON	Coosawattee	196	$15
	FANNIN	Coosawattee	167	$62
	GILMER	Coosawattee	87,274	$14
	GORDON	Coosawattee	44,170	$32
	MURRAY	Coosawattee	4,095	$21
	PICKENS	Coosawattee	16,360	$13
	BARTOW	Oostanaula	3,082	$13
	CHATTOOGA	Oostanaula	-	-
	FLOYD	Oostanaula	7,969	$100
	GORDON	Oostanaula	39,348	$32
	WALKER	Oostanaula	8,376	$21
	WHITFIELD	Oostanaula	1,048	$21
	BARTOW	Lower Etowah	24,324	$13
	COBB	Lower Etowah	-	-
	FLOYD	Lower Etowah	5,819	$100
	HARALSON	Lower Etowah	7	$62
	PAULDING	Lower Etowah	4,838	$13
	POLK, GA	Lower Etowah	7,880	$81
	CHATTOOGA	Upper Coosa, GA	-	-
	DADE	Upper Coosa, GA	349	$21
	FLOYD	Upper Coosa, GA	8,782	$100
	HARALSON	Upper Coosa, GA	566	$62
	POLK, GA	Upper Coosa, GA	9,752	$81
	WALKER	Upper Coosa, GA	14,842	$21
		Total by Weiss Market	**349,921**	
Weiss-Tennessee				
	BRADLEY, TN	Conasauga, TN	9,080,921.16	21.24
	POLK, TN	Conasauga, TN	669,573.45	34.83
		Total by Weiss Market	**9,750,495**	
		Total from All Weiss Markets	**51,669,148**	

[1] Vest et al.'s estimate of 1.2 tons of manure per 1,000 broilers determines the amount of manure generated in all markets; broiler data from US Agricultural Census (2007). Cost per ton from Risse et al.

Table 11. Credit Summary - Lake Allatoona Point Sources by Sub-watershed

Point Source	Sub-watershed	Total Reduction to meet TMDL (lbs/yr)	Credits Supplied[1]	Credits Demanded[2]	Max Unit Cost for Demand[1,2]	Cost of Compliance (Upgrade Facility)	Cost Savings with Credit at $12
Cobb County Northwest WPCP	Acworth/Allatoona	-3,527	-	-	-	-	-
	Total by sub-watershed (Average)	**-3,527**	**-**	**-**	**-**	**-**	**-**
Cherokee County Fitzgerald Creek	Little/Noonday	-160	-	-	-	-	-
Cherokee County Rose Creek	Little/Noonday	-4,763	-	-	-	-	-
Cobb County Noonday Creek WPCP	Little/Noonday	-4,704	-	-	-	-	-
Fulton County Little River WPCP	Little/Noonday	-1,004	-	-	-	-	-
Woodstock Rubes Creek WPCP	Little/Noonday	2,179	5,923	2,179	$34	$73,096	$46,949
	Total by sub-watershed (Average)	**-8,452**	**5,923**	**2,179**	**($34)**	**$73,096**	**$46,949**
Big Canoe WPCP	Upper Etowah	-728	-	-	-	-	-
City of Canton WPCP	Upper Etowah	12,165	-	12,165	$157	$1,906,039	$1,760,054
Goldkist Poultry Byproducts	Upper Etowah	-2,128	-	-	-	-	-
Jasper WPCP	Upper Etowah	-2,435	-	-	-	-	-
	Total by sub-watershed (Average)	**6,874**	**-**	**12,165**	**($157)**	**$1,906,039**	**$1,760,054**
	Total for Lake Allatoona (Average)	**-5,104**	**5,923**	**14,344**	**($95)**	**$1,979,134**	**$1,807,003**

[1] Credits Supplied equals number of credits available if PS chooses to upgrade to meet TMDL compliance; cost to supply will be≥ $0 depending on market demand. If PS chooses to upgrade and credits supplied equals 0, then Jiang et al. maximum upgrade can not meet TMDL reduction needed; demand costs reflect maximum available upgrade.

[2] Credits Demanded equals number of credits needed to meet TMDL compliance; Max Unit Cost for Demand equals unit compliance cost.

Table 12. Credit Summary - Lake Allatoona Non-Point Sources by Sub-watershed by Land Cover

					Range of Credit Supply[2]			Range of Credit Prices[2]		
Sub-watershed	Land Cover	BMP[1]	Supply Credits (lbs/ year)	Min Credit Price (Unit Price)	Min (lbs/year)	Avg (lbs/year)	Max (lbs/year)	Min ($/credit)	Avg ($/credit)	Max ($/credit)
Acworth/Allatoona	Cropland		`	$0	-	-	-	$0	$0	$0
Acworth/Allatoona	Pasture (Litter)	Pasture (Litter): Riparian Buffers (Forested)	95	$88	4	45	95	$88	$1,099	$3,864
Acworth/Allatoona	Pasture (No Litter)	Pasture (No Litter): Riparian Buffers (Forested)	86	$2,872	13	13	86	$2,872	$36,292	$125,845
Acworth/Allatoona	Urban (Highly)	Highly Developed: Restored Riparian Buffer	485	$6,113	138	461	623	$6,113	$23,049	$65,243
Acworth/Allatoona	Urban (Less)	Less Developed: Restored Riparian Buffer	289	$4,402	83	275	371	$4,402	$33,507	$73,829
		Total by Sub-watershed (Average)	**955**	**($3,369)**	**238**	**794**	**1,176**	**($3,369)**	**($23,487)**	**($67,196)**
Little/Noonday	Cropland	Cropland: Riparian Buffers (Forested)	299	$6	44	243	375	$6	$86	$215
Little/Noonday	Pasture (Litter)	Pasture (Litter): Riparian Buffers (Forested)	2,197	$155	87	1,034	2,197	$155	$1,766	$6,763
Little/Noonday	Pasture (No Litter)	Pasture (No Litter): Riparian Buffers (Forested)	431	$4,758	63	63	431	$4,758	$58,916	$207,872
Little/Noonday	Urban (Highly)	Highly Developed: Restored Riparian Buffer	5,932	$1,406	1,695	5,650	7,627	$1,406	$5,450	$14,921
Little/Noonday	Urban (Less)	Less Developed: Restored Riparian Buffer	2,649	$1,422	757	2,522	3,405	$1,422	$11,071	$24,649
		Total by Sub-watershed (Average)	**11,508**	**($1,549)**	**2,646**	**9,512**	**14,036**	**($1,549)**	**($15,458)**	**($50,884)**
Owl/Kellogg	Cropland		-	$0	-	-	-	$0	$0	$0
Owl/Kellogg	Pasture (Litter)	Pasture (Litter): Riparian Buffers (Forested)	37	$157	2	18	37	$157	$1,689	$6,861
Owl/Kellogg	Pasture (No Litter)	Pasture (No Litter): Riparian Buffers (Forested)	7	$6,281	1	1	7	$6,281	$77,764	$274,422
Owl/Kellogg	Urban (Highly)	Highly Developed: Restored Riparian Buffer	71	$1,202	20	67	91	$1,202	$10,099	$22,091
Owl/Kellogg	Urban (Less)	Less Developed: Restored Riparian Buffer	41	$14,995	12	39	53	$14,995	$56,707	$158,590
		Total by Sub-watershed (Average)	**157**	**($5,659)**	**35**	**125**	**188**	**($5,659)**	**($36,565)**	**($115,491)**
Shoal Creek	Cropland		-	$0	-	-	-	$0	$0	$0
Shoal Creek	Pasture (Litter)	Pasture (Litter): Riparian Buffers (Forested)	3,022	$39	40	1,369	3,022	$39	$698	$1,717
Shoal Creek	Pasture (No Litter)	Pasture (No Litter): Riparian Buffers (Forested)	171	$2,209	25	25	171	$2,209	$27,372	$96,508
Shoal Creek	Urban (Highly)	Highly Developed: Restored Riparian Buffer	271	$935	78	258	349	$935	$4,510	$9,365
Shoal Creek	Urban (Less)	Less Developed: Restored Riparian Buffer	234	$656	67	223	301	$656	$6,096	$14,563
		Total by Sub-watershed (Average)	**3,699**	**($960)**	**210**	**1,876**	**3,843**	**($960)**	**($9,669)**	**($30,538)**
Stamp/Rowland	Cropland		-	$0	-	-	-	$0	$0	$0
Stamp/Rowland	Pasture (Litter)		-	$0	-	-	-	$0	$0	$0
Stamp/Rowland	Pasture (No Litter)	Pasture (No Litter): Riparian Buffers (Forested)	35	$5,374	5	5	35	$5,374	$67,142	$235,099
Stamp/Rowland	Urban (Highly)	Highly Developed: Restored Riparian Buffer	46	$3,654	13	44	59	$3,654	$20,094	$36,345
Stamp/Rowland	Urban (Less)	Less Developed: Restored Riparian Buffer	30	$4,029	8	28	38	$4,029	$40,313	$98,732
		Total by Sub-watershed (Average)	**110**	**($4,352)**	**27**	**77**	**132**	**($4,352)**	**($42,516)**	**($123,392)**
Upper Etowah	Cropland	Cropland: Riparian Buffers (Forested)	532	$82	78	433	667	$82	$1,261	$3,109
Upper Etowah	Pasture (Litter)	Pasture (Litter): Riparian Buffers (Forested)	82,516	$22	890	37,256	82,516	$22	$514	$1,022
Upper Etowah	Pasture (No Litter)	Pasture (No Litter): Riparian Buffers (Forested)	4,461	$576	654	654	4,461	$576	$7,286	$25,250
Upper Etowah	Urban (Highly)	Highly Developed: Restored Riparian Buffer	3,459	$800	988	3,294	4,447	$800	$4,028	$7,916
Upper Etowah	Urban (Less)	Less Developed: Restored Riparian Buffer	1,869	$945	534	1,780	2,404	$945	$9,024	$21,762
		Total by Sub-watershed (Average)	**92,837**	**($485)**	**3,145**	**43,418**	**94,494**	**($485)**	**($4,423)**	**($11,812)**
		Total for Lake Allatoona (Average)	**109,266**	**($2,527)**	**6,300**	**55,803**	**113,869**	**($2,527)**	**($20,233)**	**($61,462)**

[1] BMP represents the BMP with lowest credit price by land cover type.

[2] Range of Credit Supply and Credit Prices are for all BMPs by land cover type.

Table 13. Credit Analysis - Lake Allatoona Litter Transfer by Sub-watershed by County

Sub-watershed	BMP	Supply Credits (lbs/ year)	Min Credit Price (Unit Price)
Acworth/Allatoona	Litter Transport from: BARTOW	59.15	$27
Acworth/Allatoona	Litter Transport from: CHEROKEE	30.30	$27
Acworth/Allatoona	Litter Transport from: COBB	-	$0
Acworth/Allatoona	Litter Transport from: PAULDING	42.85	$27
	Total by Sub-watershed (Average)	**132.31**	**($27)**
Little/Noonday	Litter Transport from: CHEROKEE	1,331.85	$29
Little/Noonday	Litter Transport from: COBB	-	$0
Little/Noonday	Litter Transport from: FORSYTH	71.43	$52
Little/Noonday	Litter Transport from: FULTON	-	$0
	Total by Sub-watershed (Average)	**1,403.28**	**($41)**
Owl/Kellogg	Litter Transport from: CHEROKEE	92.84	$29
Owl/Kellogg	Litter Transport from: COBB	-	$0
	Total by Sub-watershed (Average)	**92.84**	**($29)**
Shoal Creek	Litter Transport from: BARTOW	26.79	$8
Shoal Creek	Litter Transport from: CHEROKEE	3,146.59	$8
Shoal Creek	Litter Transport from: PICKENS	904.54	$8
	Total by Sub-watershed (Average)	**4,077.92**	**($8)**
Stamp/Rowland	Litter Transport from: BARTOW	-	$0
Stamp/Rowland	Litter Transport from: CHEROKEE	-	$0
	Total by Sub-watershed (Average)	**-**	**($0)**
Upper Etowah	Litter Transport from: CHEROKEE	7,813.69	$7
Upper Etowah	Litter Transport from: DAWSON	67,102.34	$8
Upper Etowah	Litter Transport from: FANNIN	70.64	$32
Upper Etowah	Litter Transport from: FORSYTH	8,400.74	$12
Upper Etowah	Litter Transport from: GILMER	2,853.24	$7
Upper Etowah	Litter Transport from: LUMPKIN	10,698.01	$10
Upper Etowah	Litter Transport from: PICKENS	32,650.88	$6
Upper Etowah	Litter Transport from: UNION	-	$0
	Total by Sub-watershed (Average)	**129,590**	**($12)**
	Total for Lake Allatoona (Average)	**135,296**	**($19)**

Table 14. Credit Summary - Weiss Lake Point Sources

Weiss Market	Point Source	Watershed	Total Reduction to meet TMDL (lbs/yr)	Credits Supplied[1]	Credits Demanded[2]	Max Unit Cost for Demand[1,2]	Cost of Compliance (Upgrade Facility)	Cost Savings with Credit at $21
Weiss-Alabama								
	Cherokee WPCP	Upper Coosa, AL	-2,002	-	-	-	-	-
	Piedmont WWTP	Upper Coosa, AL	-623	-	-	-	-	-
	Town of Cedar Bluff WWTP	Upper Coosa, AL	-2,619	-	-	-	-	-
	Town of Centre WWSB Lagoon	Upper Coosa, AL	3,304	1,722	3,304	$23	$75,685	$6,292
	Total by sub-watershed (Average)		**-1,940**	**1,722**	**3,304**	**($23)**	**$75,685**	**$6,292**
Weiss-Georgia								
	Chatsworth WPCP	Conasauga, GA	3,231	6,492	3,231	$25	$79,902	$12,055
	Dow Chemical Co	Conasauga, GA	-2,821	-	-	$0	$0	$0
	Ellijay-Gilmer Water & Sewer	Conasauga, GA	65,410	-	65,410	$35	$2,267,812	$894,202
	Cartersville WPCP	Lower Etowah	259,678	-	259,678	$30	$7,851,456	$2,398,224
	City of Rockmart	Lower Etowah	28,821	-	28,821	$89	$2,564,347	$1,959,106
	Dallas North WPCP	Lower Etowah	-176	-	-	$0	$0	$0
	Dallas West WPCP	Lower Etowah	1,641	1,600	1,641	$32	$52,676	$18,224
	Emerson Pond	Lower Etowah	192	3,048	192	$274	$52,676	$48,636
	Rome Blacks Bluff WPCP	Lower Etowah	69,650	20,828	69,650	$10	$679,292	-$783,357
	Adairsville South WPCP	Oostanaula	34,575	-	34,575	$40	$1,378,207	$652,134
	Calhoun WPCP	Oostanaula	192,420	-	192,420	$52	$9,960,462	$5,919,641
	City of Adairsville - North	Oostanaula	24,086	-	24,086	$52	$1,249,730	$743,919
	OMNOVA Solutions Inc	Oostanaula	-3,017	-	-	$0	$0	$0
	Cave Spring WPCP	Upper Coosa, GA	-2,136	-	-	$0	$0	$0
	City of Cedartown	Upper Coosa, GA	18,146	295	18,146	$52	$947,030	$565,956
	City of Summerville WPCP	Upper Coosa, GA	1,392	5,090	1,392	$48	$66,289	$37,063
	Geo Specialty Chemicals	Upper Coosa, GA	-886	-	-	$0	$0	$0
	Inland Rome (Outfall 001)	Upper Coosa, GA	4,056	-	4,056	$0	$0	$0
	Inland Rome (Outfall 002)	Upper Coosa, GA	-10,050	-	-	$0	$0	$0
	Lafayette WPCP	Upper Coosa, GA	8,217	3,125	8,217	$11	$86,709	-$85,856
	Rome-Coosa WPCP	Upper Coosa, GA	1,062	5,419	1,062	$62	$66,289	$43,985
	Trion WPCP	Upper Coosa, GA	41,883	-	41,883	$90	$3,750,487	$2,870,933
	Total by sub-watershed (Average)		**735,374**	**45,898**	**754,460**	**($60)**	**$31,053,363**	**$15,294,866**
	Total for Weiss Markets (Average)		**733,435**	**47,620**	**757,765**	**($58)**	**$31,129,047**	**$15,301,157**

[1] Credits Supplied equals number of credits available if PS chooses to upgrade to meet TMDL compliance; cost to supply will be ≥ $0 depending on market demand. If PS chooses to upgrade and credits supplied equals 0, then Jiang et al. maximum upgrade can not meet TMDL reduction needed; in these circumstances, demand costs reflect maximum available upgrade.

[2] Credits Demanded equals number of credits needed to meet TMDL compliance. Max Unit Cost for Demand equals unit compliance cost; costs only shown for wastewater treatment plants.

Table 15. Credit Analysis - Weiss Lake Litter Transfer by Market by County

Market	Watershed	BMP	Supply Credits (lbs/ year)	Min Credit Price (Unit Price)
Weiss-Alabama				
	Upper Coosa, AL	Litter Transport from: CALHOUN, AL	1,105,297	$90
	Upper Coosa, AL	Litter Transport from: CHEROKEE, AL	13,308,289	$90
	Upper Coosa, AL	Litter Transport from: CLEBURNE, AL	3,692,124	$21
	Upper Coosa, AL	Litter Transport from: DE KALB, AL	19,288,751	$21
	Upper Coosa, AL	Litter Transport from: ETOWAH, AL	109,344	$21
		Total by Weiss Market (Average)	**37,503,805**	**($48)**
Weiss-Georgia				
	Conasauga, GA	Litter Transport from: CATOOSA	6	$19
	Conasauga, GA	Litter Transport from: FANNIN	672	$69
	Conasauga, GA	Litter Transport from: GILMER	626	$16
	Conasauga, GA	Litter Transport from: GORDON	3,145	$36
	Conasauga, GA	Litter Transport from: MURRAY	19,192	$24
	Conasauga, GA	Litter Transport from: WALKER	390	$24
	Conasauga, GA	Litter Transport from: WHITFIELD	24,064	$24
	Coosawattee	Litter Transport from: BARTOW	6,051	$15
	Coosawattee	Litter Transport from: CHEROKEE	599	$14
	Coosawattee	Litter Transport from: DAWSON	177	$16
	Coosawattee	Litter Transport from: FANNIN	151	$69
	Coosawattee	Litter Transport from: GILMER	78,740	$16
	Coosawattee	Litter Transport from: GORDON	39,851	$36
	Coosawattee	Litter Transport from: MURRAY	3,694	$24
	Coosawattee	Litter Transport from: PICKENS	14,760	$14
	Oostanaula	Litter Transport from: BARTOW	2,781	$15
	Oostanaula	Litter Transport from: CHATTOOGA	-	$0
	Oostanaula	Litter Transport from: FLOYD	7,190	$111
	Oostanaula	Litter Transport from: GORDON	35,500	$36
	Oostanaula	Litter Transport from: WALKER	7,557	$24
	Oostanaula	Litter Transport from: WHITFIELD	945	$24
	Lower Etowah	Litter Transport from: BARTOW	21,945	$15
	Lower Etowah	Litter Transport from: COBB	-	$0
	Lower Etowah	Litter Transport from: FLOYD	5,250	$111
	Lower Etowah	Litter Transport from: HARALSON	6	$69
	Lower Etowah	Litter Transport from: PAULDING	4,365	$15
	Lower Etowah	Litter Transport from: POLK, GA	7,109	$90
	Upper Coosa, GA	Litter Transport from: CHATTOOGA	-	$0
	Upper Coosa, GA	Litter Transport from: DADE	315	$24
	Upper Coosa, GA	Litter Transport from: FLOYD	7,923	$111
	Upper Coosa, GA	Litter Transport from: HARALSON	511	$69
	Upper Coosa, GA	Litter Transport from: POLK, GA	8,798	$90
	Upper Coosa, GA	Litter Transport from: WALKER	13,391	$24
		Total by Weiss Market (Average)	**315,703**	**($41)**
Weiss-Tennessee				
	Conasauga, TN	Litter Transport from: BRADLEY, TN	8,192,915	$24
	Conasauga, TN	Litter Transport from: POLK, TN	604,097	$39
		Total by Weiss Market (Average)	**8,797,012**	**($42)**
		Total from All Weiss Markets (Average)	**46,616,521**	**($42)**