National Fish and Wildlife Foundation **Final Programmatic Report** *This material is based upon work supported by the Natural Resources Conservation Service, U.S. Department of Agriculture, under an NRCS Conservation Innovation Grant.*	
Project Name	**Managing Poultry-Source Nutrient Delivery (MD)**
Organization Name	**Caroline Soil Conservation District**
Organization Web Address	**N/A**

1) Summary of Accomplishments

Hydromodification

In August of 2010 the Caroline Soil Conservation District completed the construction of a hydromodification project along the Ober Schulyer drainage channel. The pre and post monitoring showed no difference in nutrient levels in the drainage ditch, six months to one year later, than background water nutrient levels from a control site and a site that had received a full ditch cleanout.

Algal Turf Scrubber

A second study of the nutrient removal effectiveness and costs of an algal turf scrubber was conducted over a two year period. Estimated yearly costs were $42/lb of Nand $230/lbs of P. For the seven month period the raceway operated approximately 350 lbs "N" and 40 lbs "P" were removed from the waterway by the scrubber system.

2) Project Activities & Results

Activities

Hydromodification

Phase 1
November of 2008 discussion began between the Maryland Department of Agriculture, Caroline Soil Conservation District, University of Maryland (Horn Point Laboratory) and Public Drainage Association Managers about a hydromodification site as well as a protocol to take water samples at the site, both pre and post construction. On January 8, 2009, a complete site evaluation for a hydromodification of a Public Drainage Association was completed and the Ober Schuyler Public Drainage Association was chosen for the hyrdromodification project. The distance of the hydromodification was 3770 LF. The Caroline SCD then proceeded with a survey and design of the hydromodification system on February 25, 2009 to allow the new low flow channel to be excavated to handle base flow conditions which will be confined to 1/2 of the existing channel width. The second tier of floodplain bench would be the remaining existing ditch bottom which is already vegetated and would provide enhanced nutrient reduction on high flow events. The Caroline Soil Conservation District with the assistance of Horn Point Laboratory also selected (6) six sites along the Public Drainage Association to be sampled for water quality throughout the process.

Phase 2
March of 2009, a final design for the hydromodication project was completed by the Caroline Soil Conservation District. On January 27, 2010 water sampling began at (6) six sites along Ober Schulyer Public Drainage Association for monitoring. The samples were delivered to Horn Point Laboratory for analysis. Water samples were also taken at the (6) six designated sites on February 17, 2010 and March 3, 2010, March 18, 2010, March 30, 2010, April 15, 2010. The Hydromodification project was laid out for construction on August 17, 2010 by the Caroline Soil Conservation District. August 19, 2010, a pre construction meeting was held with the Landowner/PDA manager and Hobbs Contractors, to go over the plans and grades for the project. August 20, 2010 Hobbs Contractors began construction of the hydromodification site. By August 30, 2010 the project had been completed and the site stabilized. The Caroline Soil Conservation then completed a construction check of the site. Upon the completed

construction check of the project and verification of quantities on the invoice, the Caroline Soil Conservation paid Hobbs Contractors on October 6, 2010 for completion of the Hydromodification Project.

Phase 3

The Caroline Soil Conservation District continued to take water samples at the (6) six sites along Ober Schuyler PDA and delivered them to Horn Point Laboratory on February 1, 2011, April 21, 2011, June 14, 2011, July 13, 2011, October 6, 2011, December 14, 2011 and February 8, 2012. The samples were continued to be monitored by Horn Point Laboratory, Caroline Soil Conservation District and the Maryland Department of Agriculture. The data was analyzed and results and conclusions are outlined below. The education process was continued by way of field tours, involving personnel from the Natural Resources Conservation Service, Beltsville Agricultural Research Service, University of Maryland, Choptank Trib Team, Choptank River Keeper, Caroline County Department of Planning & Codes and various Public Drainage Association Managers. These tours coincided with the tours of the Algal Turf Scrubber Project at the same farm.

Set up a monitoring protocol with Horn Point Laboratory to divide the system into 3 sections (see hydromodification sample site map). The upstream section was to be left untouched as a control sample sites 5 & 6, the middle section sample sites 3 & 4 were to be constructed with the hydromodification technique and sample sites 1 & 2 would have more of traditional cleanout application restoring the ditch to original dimensions. Samples were taken Pre and Post construction. Dates were 1/27/10,2/17/10,3/3/10,4/15/10,2/1/11,4/21/11,7/13/11, 10/6/11, 12/14/11 2/8/12. (see data tables)

Algal Turf Scrubber

The objective of this study was to determine rates of nutrient removal and costs using pilot scale ATS raceways located on a primary drainage canal (Long Marsh) near Bridgetown, Maryland. Additional objectives were to evaluate solar-powered pumping systems for off-grid ATS deployment and to determine the effect of water flow rate on algal growth and nutrient removal.

Six pilot-scale ATS raceways (each containing $50m^2$ growing area) were constructed at a 2% slope in a farm near Bridgetown Maryland. Raceways were operated continuously for 5 month periods (July to November in 2010 and 2011). Each raceway consisted of a 1 x 50m section of 0.045 mil EPDM pond liner (AKT Specialty Co., Newbern, TN) covered with 0.126" nylon mesh screen (Industrial Netting Co., Minneapolis, MN) and a 10 L tipping trough at the top of the raceway. PVC pipe (4", schedule 40) covered with black plastic sheeting separated the raceways. Influent water from Long Marsh was delivered to the raceways using two independent solar arrays connected and two variable speed well pumps. Effluent from all of the raceways drained through the mesh screen into a single EPDM lined sump (approximately 6 x 2 x 1.5m (depth), 1600 L capacity) prior to draining into an existing field drainage ditch and back into the Long Marsh. Water depth in the sump was controlled using an adjustable 10: PVC standpipe.

Wet algal biomass was harvested weekly using by sweeping the biomass onto mesh screens at the base of the raceways using nylon floor brooms. After each harvest, sump water (typically about 1200 L) was thoroughly agitated to re-suspend sediment and algal fragments and then pumped into a 800 L plastic tank for volume measurement and sump water sampling. Harvested biomass from the raceways was allowed to air-dry for a week in the open air prior to being collected and transported back to the lab for final drying (as needed) and analysis. In the lab, biomass was air-dried at 25°C using an electric fan to approximately 90% solids content.

Two separate solar power systems were installed and tested at the Bridgetown site. The first system was installed in June 2010 and was designed to pump water during daylight hours only. It consisted of twelve 80-watt panels (0.96 kw total) directly connected to a variable speed, 12-volt, Grundfos well pump.
The second system, 2.2 kw with battery backup, was designed to rum water continuously over the raceways. It consisted of ten 200-watt panels connected to eight 230 amp/hour 12V deep cycle batteries. A Grundfos well pump was connected to the batteries. The cost of the 2.2 kw system (including installation) was $15,300.

Dried harvested solids were ground in a Wiley Mill to pass a 3 mm sieve and stored in sealed plastic bags at 20-25°C prior to analysis for moisture, ash, total Kjeldahl nitrogen (TKN), and total phosphorus (TP) (Kebede-Westhead et al., 2003). Influent and sump water samples were collected on harvest days, acidified to pH 3-5 by the drop-wise addition of 6 N sulfuric acid, and stored at 4°C prior to analysis for TKN and TP.

The 1kV solar panel system without battery storage was completed in early 2010; the 2 kV solar panel system with battery storage was completed in June 2011. Experiments during 2011 involved comparing flow regimes: continuous flow (24 hours per day) from the pump powered by the solar panel-battery system versus daytime-only flow from the pump powered by solar panels alone. The first experimental hydraulic regime ran continuous flow through two raceways and daytime-only flow through two raceways. This experiment was run from mid-June to July 14 when it was stopped due to low algal productivity (results not shown). The second experimental hydraulic regime ran continuous flow through a single raceway and daytime-only flow through a single raceway from mid-July to the end of August 2011 when it was stopped due to disruption of the ATS by Hurricane Irene. The third experimental hydraulic regime ran combined continuous flow and daytime-only flow through four raceways from mid-September until the end of October.

Results

Hydromodification

Nitrogen (N)

Pre monitoring of the site, prior to the construction, was conducted over a three month period. A total of 12 samples of each of six sites was conducted. Values above the hydromodification site that would serve as the control, averaged 1.42 mg N in 2010 and 2.49 mg N in 2011 (pre and post construction). Values of the hydromodification site averaged 1.68 mg N in 2010 and 2.45 mg N in 2011 (pre and post) The full channel cleanout values were 1.98 mg N in 2010 and 2.55 mg N in 2011 (pre and post). Pre construction sample variability between the three sites was 0.5 mg N.

A comparison of the 2010 sampling N levels vs 2011 sampling N levels show a 1.0 mg increase in N from one year to the next in the control site. Comparable variations in average values of 0.8 mg N at the hydromodification site and 0.5 mg N at the full cleanout site were observed in 2010 and 2011.

Due to this variability from year to year no discernible change in the overall nitrogen loading was observed between the pre and post construction monitoring results. Additionally, no change in nitrogen loading was observed between the control, hydromodificaiton site and the full cleanout site post construction.

Phosphorus (P)

Pre monitoring of the site, prior to the construction, was conducted over a three month period. A total of 12 samples at each of the six sites were collected. Values above the hydromodificiation site that would serve as the controls, average 0.0096 mg Pin both 2010 and 2011 (pre and post construction). Values at the hydromodification site average 0.011 and 0.012 mg (pre and post construction). The full channel cleanout values were 0.010 and 0.013 mg P. Pre construction sample variability between the three sites was 0.002 mg P.

A comparison of the 2010 levels vs 2011 sampling levels shows no variation in the control sites. Comparisons of variations in the hydromodification site were less than 0.001 mg P from 2010 to 2011 and 0.003 mg P in the full cleanout site.

Due to individual sampling days variability no desirable difference was observed in 2010 vs 2011 (pre and post construction) monitoring results at all sites for P.

Algal Turf Scrubber

Throughout the 2011 growing season, the distribution of algae on the screens was characterized by two main zones. A 2-3 meter long zone was found at the top of the raceways, immediately below the dump buckets, where energy from the pulsing flow was the highest. This zone was dominated by a near monoculture of *Ulothrix,* a filamentous green algal genus which has a strong basal attachment cell. The rest of the screen had a brown-colored mat with small patches of concentrated filamentous green algae. The brown-colored mat was dominated by the filamentous diatom, *Melosira,* along with detritus and a diversity of pinnate diatoms that were either free-living or epiphytic on the *Melosria* filaments. Green algal filaments from the genera Spirogyra, *Microspora* and *Ulothrix* were found within the brown-colored mat as subdominants but they also formed patches with higher density. Blue-green algae represented by the genera *Oscillatoria*

and *Phormidium* were often present within the brown-colored mat but they were never abundant.

Water Flow

On a day to day basis, water flow powered directly by the 0.96 kw solar panel system (system 1) (day-only flow), was less stable than flow from the 2.2 kw system with batteries (system 2) (24-hour flow), since it was influenced to a greater degree by the degree of cloud cover. However, overall average water flow from system 1 was higher than that from system 2. Flow rates declined from the first to the second hydraulic regime experimental regimes probably due to a gradual clogging of the pipes. This was evident after the second hydraulic regime when the plumbing was checked and the pipes were found to be filled with sediment. Flow rates increased during the third hydraulic regime after the sediment was removed from the plumbing, but they did not return to the rates from the first hydraulic regime probably due to declining day length.

Nutrient Removal Rates

ATS raceways (each containing 50 m^2 growing area) were operated continuously for five month periods (June to November) in 2010 and 2011. Nitrogen (N) and phosphorus (P) removal rates were calculated by multiplying harvested algal mass and algal N or P content. Of these two factors, values for harvested solids had a greater determinative role since they varied with flow rate while nutrient values were much more consistent through time. Removal rates fluctuated considerably but averaged 100 md N, 11 mg P m^{-2} day^{-1} under continuous flow. Nutrient removal rates from raceways receiving only daytime flow were about 3-fold lower than raceways receiving continuous water flow. Spreading the combined flow over more raceways (and therefore decreasing the flow rate over each raceway) yielded the same amount of removed N and P, but decreased the calculated areal removal rate. The composition of the harvested material (composed of algae and trapped sediment) was relatively consistent, with mean values of 2% N, 0.25% P, and 70% ash.

N and P (and sediment) were also trapped in the ATS sump at the end of the raceways. Results show that the sump material accounted for 30 to 50% of the total N and P removed by the ATS. Calculated average annual total N and P removal rates (including the nutrients in the sump solids) varied from approximately 230 to 350 lb N and 35 to 40 lb P per acre under continuous flow. These values are calculated assuming a 7-month operating season in Maryland. These values are roughly comparable to rates calculated from small scale ATS units grown using water from the Patuxent River at Jug Bay (Mulbry et al., 2011).

Capital and Operating Costs

Costs were estimated by scaling up actual project costs but included less expensive HOPE landfill liner, nylon netting, and water surge boxes in place of the EPDM liner, nylon screen, and tipping buckets that were used at Bridgetown. Nutrient removal estimates were projected using nutrient removal rates. Costs are shown for systems running using conventional electric power at different flow rates. For systems using conventional electric power, capital costs ($51,000) were dominated by costs for the liner, labor for installation, water pumps, and site preparation. In contract, solar panels, batteries and related equipment constitute 70% of the 5-fold higher capital costs ($276,000) of the solar powered systems.

Costs of electrical power dominated the yearly operational costs for systems using conventional or solar electric power. For systems using conventional electric power (assuming $0.123 kwh^{-1}) power costs account for approximately 65 to 85% to annual costs. Relative power costs increase with increases in water flow rate and length of season (9 versus 7 months per year). For systems using solar electric power, power costs (as a capital charge) constitute> 95% of annual operational costs. In contrast to conventionally powered ATS systems, the operational costs of solar powered systems are particularly sensitive to the repayment terms for the capital investment. Doubling the payment period (from 10 to 20 years) for the capital charge leads to a 50% decrease in the annual operational costs.

Nutrient Removal Costs

Under the best case (solar powered system operating 270 days per year using a 20 year repayment schedule for capital costs), the yearly operational costs were $42 lb^{-1} of N, $230 lb^{-1} of P, and $1.15 lb^{-1} of dried algae. Estimated yearly operational costs for a comparable ATS system using conventional power were comparable for N ($45 lb^{-1} N) but much higher for P ($420 lb^{-1} P) compared to the solar powered

system.

3) Lessons Learned

Hydromodification

No downstream effects from a full ditch cleanout vs. a center channel cleanout were observed.

Algal Turf Scrubber

The algal turf scrubber requires high maintenance and, due to the fact that it requires a technically competent operator, is not a farmer friendly system. Systems performance, in the field, is highly variable. Costs per lb N and P extracted were higher than previous studies in Florida.

4) Dissemination

The Caroline Soil Conservation District completed the Phase 1 requirements of the grant by: Working with multiple Public Drainage Association managers and landowners to evaluate systems for hydromodification, selecting the site for the Best Management Practice, Working with numerous partners and agencies to develop a sampling protocol. Start the water sampling process and Survey / Design the Public Drainage System for the hydromodification of the ditch bottom.

The District completed the Phase 2 requirements of the project by: Completing the final design for the hydromodification site, continuing to monitor the site and take water samples, staking out the site to design grade, conducting a pre construction meeting with the contractor, on site evaluation and supervision as the hydromodification was being constructed, complete the as built certification of the project upon completion, pay contractor invoice in the amount of $4,912.50 for the work performed on 3,770 LF of drainage channel, work with various agencies on conducting field tours and conducting outreach and education and site tours.

Phase 3 requirements of the project were completed by: continuation of monitoring the sites, analyzing the water sample data and evaluating the project results and continuing to participate in field tours and outreach education.

5) Project Documents (if applicable)

Data Table