The Canadian Society for Bioengineering
The Canadian society for engineering in agricultural, food, environmental, and biological systems.

La Société Canadienne de Génie Agroalimentaire et de Bioingénierie
La société canadienne de génie agroalimentaire, de la bioingénierie et de l'environnement

Paper No. 06-157

Issues And Challenges In Implementing The TMDL For Delaware's Inland Bays

by

William F Ritter
Bioresources Engineering Department
University of Delaware
Newark, DE. 19716

Written for presentation at the
CSBE/SCGAB 2006 Annual Conference
Edmonton Alberta
July 16 - 19, 2006

A Total Daily Maximum Load (TMDL) was developed for Delaware's Inland Bays. The TMDL calls for nonpoint source nitrogen loads to be reduced by 40 to 85% and phosphorus loads by 40 to 65% in the different tributaries. All point sources are to be eliminated. To meet the TMDL requirements presents many challenges. A large percentage of the nitrogen load enters the Bays by groundwater discharge. Some BMPs being proposed may not be very effective because of the sandy soils and a large percentage of runoff occurring as interflow.

Issues and Challenges in Implementing the TMDL for Delaware's Inland Bays

William F. Ritter

Introduction

Section 303 (d) of the U.S. Clean Water Act, as amended by the Water Quality Act of 1987 requires all States in the U.S. to identify and list all those water within their boundaries that do not meet the applicable water quality standards. The States have to prioritize all water bodies on the 303 (d) list and develop Total Daily Maximum Loads (TMDL) for the pollutants of concern. A TMDL is defined as the amount of a specific pollutant that can be discharged into a water body and still meet water quality standards. In setting a TMDL for a water body, waste loads allocations are set for all point and nonpoint sources with a margin of safety factored into the load allocations.

One of the major recreational areas in Delaware is the Inland Bays next to the Atlantic Ocean in southern Delaware. The Bays are estuaries and are inhabited by plant and animals which are typical of the Mid-Atlantic region. Delaware's Inland Bays consist of the three interconnected water bodies, Rehobeth, Indian River, and Assawoman Bays (Figure 1). The Assawoman Canal connects Little Assawoman and Indian River Bays. The three bays and their tributaries have a surface area of approximately (8300 ha and a drainage area of approximately 77,000 ha. The Inland Bays are tidally flushed, with estimates typically converging on 90-100 days for Indian River Bay and 80 days for Rehobeth Bay. No flushing estimates are available for Little Assawoman Bay. Groundwater is a highly significant component of freshwater flow into the Inland Bays.

The Bays are highly eutrophic. Using a classification system developed for the Chesapeake Bay, the Inland Bays are among the most highly enriched of the 32 sub-estuarine system in the Chesapeake Bay rankings. The middle and upper segments of Indian River Bay are more nutrient enriched than any segment of the Chesapeake Bay. Total nitrogen concentrations are generally in excess of 1.0 mg/L and total phosphorus concentrations generally range from 0.1 to 0.2 mg/L. An EPA report concluded Delaware's Inland Bays have some of the highest nitrogen loads in the world (News Journal, 1998).

Land Use

Land use in the watershed is summarized in Table 1. (DOSPC, 2002). Agriculture cropland is the major land use in the watershed (32.6%). Both agricultural cropland and forestland have decreased from 1992 to 2002 while urbanization has increased rapidly. From 1992 to 2002 agricultural cropland decreased from 28,060 ha to 26,400 ha and forestland decreased from 17,250 ha to 14,900 ha. Urban land use increased from 10,150 ha in 1992 to 13,700 ha in 2002.

Table 1. Land Use in the Inland Bays

Land Use	Percent of Area
Agriculture	32.8
Forest	18.6
Urban	17.0
Wetlands	15.8
Water	12.1
Rangeland	2.0
Other	1.6

Sussex County is the largest poultry county in the U.S. The Inland Bays watershed is a major poultry production area in the county. Martin et al (1998) estimated over 71 million broilers a year are raised in the watershed. The poultry density ranges from 7,170 broilers/ha/yr for Little Assawoman Bay to 2,356 broilers/ha/yr for Indian River Bay and 612 broilers/ha/yr for Rehobeth Bay.

Martin et al (1998) estimated that the broiler manure produced annually in the Inland Bays watershed contained 126.1 kg/ha cropland/yr of nitrogen and 43.8 kg/ha cropland/yr of phosphorus. Little Assawoman Bay had broiler manure production of 355.2 kg/ha cropland/yr of nitrogen and 123.4 kg/ha cropland/hr of phosphorus. Recommended nitrogen fertilizer application rates for dryland corn are 112 kg/ha and in many cases phosphorus is not required on many fields in Delaware because of the existing high soil phosphorus levels. Sims (1999) reported that 65% of the agricultural soils sampled by the University of Delaware from 1992 to 1996 had excessive phosphorus levels.

Because of the increasing urbanization and the intensive poultry production in the watershed, improving water quality conditions in the Inland Bays will be a real challenge. The other problem is that the sediments of the Inland Bays have high phosphorus concentrations. In the summer months anaerobic conditions exist in the sediments and soluble phosphorus is released into the water column. The phosphorus is not flushed out to the Atlantic Ocean because of the high detention time of the Inland Bays, but taken up by excessive phytoplankton growth. Over time the phytoplankton dies and settles to the bottom where the phosphorus becomes tied up again in the sediments.

TMDL for the Inland Bays

The Delaware Department of Natural Resources and Environmental Control developed a TMDL for the Inland Bays in 2001 (DNREC, 2001). The baseline used for setting the TMDL was from water quality monitoring data from 1988 to 1991. A hydrodynamic model and water quality model were used to set the TMDL. The TMDL calls for eliminating all point sources from the Inland Bays. Nonpoint source nitrogen loads in the different tributaries will be reduced from 40 to 85% of existing loads and phosphorus loads will be reduced from 40 to 65% of existing loads in the different tributaries. Atmospheric deposition rates are to be reduced by 20%.

Nitrogen and Phosphorus Loads

The nitrogen and phosphorus loads to the Inland Bays area summarized in Table 2. Agriculture is the largest contributor of nitrogen and phosphorus to the Inland Bays. Each of the three sub-watersheds contributes differently, however. For all three watersheds agriculture is the largest contributor of nitrogen. For Indian River and Little Assawoman Bays, agriculture contributes the most phosphorus. For Rehobeth Bay, wastewater treatment plants contribute the most phosphorus, with agriculture as the second largest contributor.

Table 2. Percent Nitrogen and Phosphorus Loads from Different Sources (DNREC, 2001)

Land Use	N Load %	P Load %
Agriculture	45	53
Forest, wetlands	6	11
Urban	25	36
Atmospheric Deposition	24	Trace

Major sources of nutrients from agriculture are from runoff and groundwater discharge. Ritter (1986) estimated that for a normal year 75% of the nitrogen from nonpoint sources is in groundwater discharge. Recent tributary monitoring indicates that the percentage of nitrogen and phosphorus in base flow and storm flow varies from tributary to tributary. Part of the watershed has poorly drained soils that have an extensive drainage ditch system. The drainage ditches are believed to be a pathway for phosphorus to the Inland Bays. Under anaerobic conditions, the sediments release phosphorus into the overlying waters (Sallade and Sims, 1997).

Pollution Control Strategy

The Delaware Department of Natural Resources and Environmental Control (DNREC) have developed a Pollution Control Strategy (PCS) to meet the TMDL requirements of the Inland Bays. The PCS was developed based upon the recommendations of the Inland Bays Tributary Actions Team, which was comprised of local government representatives, business people, environmentalists, farmers and residents. Seven public forums were held to develop the recommendations and elicit comments from 130 residences. The strategy addresses nutrient loading reductions from point sources and nonpoint sources. The nonpoint sources control strategy addresses agriculture and urban/residential including development, onsite wastewater treatment and disposal and stormwater management. The PCS contains both voluntary and regulatory elements.

Agricultural BMPs

The Delaware Nutrient Management Act which is administered by the Delaware Nutrient Management Commission gives the authority to regulate the application and generation of nutrients to achieve water quality standards. The PCS calls for agriculture to implement additional BMPs to meet the nitrogen and phosphorus load reductions to meet the requirements of the TMDL. The specific strategies recommended in the PCS are:

1. All agricultural areas should have a nutrient management plan.
2. An annual goal of 15,840 ha in cover crops, preferably planted one week before the published date of the first killing frost, and not fertilized.
3. Establish 673 ha of riparian forested buffer.
4. Restoring 660 ha of wetlands in areas previously converted to cropland.
5. Maintain all of the existing wildlife habitat, grassed waterways and grassed filter strips.
6. Increase the annual quantity of manure located or put into alternative use from 12,800 tons to 21,730 tons.
7. Establish 520 ha of grassed buffers.
8. Continue to use poultry manure storage sheds and composters for dead birds disposal and build an additional 50 of each.
9. Continue to use feed amendments, such as phytase and to minimize calcium di-phosphate in poultry feed in order to reduce nutrients in poultry manure.
10. Install additional water control structures to treat 182 ha of cropland and maintain the 620 ha currently treated by these structures.

There are a number of issues and challenges in implementing some of the recommended BMPs. The pollutant removal BMPs that are being promoted in the Inland Bays for cropland include conservation tillage, filter strips, riparian buffers, and cover crops. The primary effect of conservation tillage on water quality is to decrease the potential of erosion on cropland and the transport of sediments attached pollutants. There are some concerns that it may increase the potential pollution of other transport processes. In conservation tillage, manure or fertilizer is usually applied to the surface. Delaware is one of the leading states in conservation tillage. In 1996, 30% of the corn and 95% of the soybean crop in Sussex County were in conservation tillage. With the large area of conservation tillage and the large amount of poultry manure spread on cropland in the Inland Bays, conservation tillage may be increasing the amount of nitrogen and phosphorus transported to the Inland Bays because the poultry manure is not incorporated. Probably 50% or more of the ammonia in the poultry manure will be lost by volitalization if the manure is not incorporated which may contribute to atmospheric deposition. Research has shown that the phosphorus concentration in the top few inches of the soil is important in transport processes.

The most prominent removal processes in vegetative filter strips tend to be deposition of sediment bound pollutants and infiltration of dissolved pollutants. There is a question of how effective filter strips would be in the Inland Bays, because most of the soils have high infiltrations rates and most of the surface runoff occurs as interflow.

The main purpose of winter cover crops is to provide soil cover and protection against erosion and remove excess nutrients remaining in the soil profile. Crops such as wheat, barley, annual rye, and oats are used for cover crops. Hairy vetch, a legume, is also used sometimes as a cover crop. On the Delmarva Peninsula, research has shown variable results with cover crops. Ritter et al (1998) found that a rye winter cover crop cannot be counted on to remove large amounts of excess nitrogen from sandy soils in the fall in Delaware. The largest amounts of nitrogen removed by the rye cover crop were 69 kg/ha for no-tillage and 78 kg/ha for conventional tillage. Brinsfield and Staver (1991) found nitrate leachate concentrations were consistently lower when a rye cover crop was used and groundwater nitrate concentrations were reduced to below 10 mg/L. They conducted their research on a silt loam soil.

Incorporating manure into the soil as soon as possible after it is spread and applying it as near as possible to the time when plants will use the nutrients reduces nutrient losses and potential for odor and surface water pollution. Present manure practices in Delaware have some farmers spreading manure in January and February when the potential for nitrogen losses is greatest. Nitrification starts to occur in early March and nitrates are leached to the groundwater before being used by the crop.

Wastewater Management

There are currently 10 wastewater facilities that discharge into the Inland Bays. Between 1988 and 1998, the nutrient loads from point sources were reduced by 20% for nitrogen and 52% for phosphorus due to treatment plant upgrades. The TMDL calls for the elimination all point source discharges from the Inland Bays. The proposal is for the existing plants to use land treatment or hook to an ocean outfall. There are 7 land treatment systems used in the watershed. The problem with going to land treatment is as more development occurs around the Inland Bays, land costs become more expensive for land treatment and the wastewater will have to be pumped further from the source to find cost effective available land.

The PCS also allows for nutrient trading. When the point source chooses to engage in nutrient tracking in order to comply with the TMDL, the amount of nutrients reduced from nonpoint sources must equate to twice the level the point source is allowed to discharge. The reduction in nutrient loads from nonpoint sources must be over that required in load reductions from nonpoint sources to meet the TMDL.

More than 19,200 septic tanks are permitted in the Inland Bays. Before 1968 there were no septic tank regulations. Between 1968 and 1985 on-site wastewater regulations were adopted, but thousands of systems were installed that are unsuitable by today's regulations. In 1985 the regulations were revised and included soils evaluations. The regulations were again revised in 2001 to require maintenance. There are also 200 holding tanks used in the watershed on properties that do not meet septic tank requirements. Many of the old homes near the Bays have small lots with sandy soils and

some still have cesspools or seepage pits. It is estimated that 50% of the septic systems in the Inland Bays do not meet the current on-site wastewater regulations.
The PSC calls for implementing a compliance and inspection program for individual onsite wastewater systems in order to enforce existing requirements that tanks be pumped every three years and that alternative systems are maintained in accordance with manufacturer's specification. The issue with this strategy is that at the present time there are no licensed inspectors and DNREC does not have the funding to do the inspections.

The PCS also calls for converting an additional 5,000 septic tanks to central sewers. New developments not in a sewer district will have to have individual onsite systems that meet TMDL level nutrient reductions or a community system that utilizes technologies which meet TMDL reductions.

Urban BMPs

The PCS calls for urban/residential riparian buffers of 30 m from all waters and wetlands. All parcels of land being developed or improved must have a nutrient budget produced that estimates the current nutrient loading of that parcel to ground and surface water and the proposed nutrient loading from the new use. The nutrient budget must illustrate that the future land use will reduce nutrient loading by the percentage required by the TMDL for the tributary in question. DNREC has developed a protocol for producing the nutrient budgets. The issue with the developed protocol is that some of the loading rates DNREC are using are based upon very limited data from other areas. A coalition of developers and farmers have taken issue with the proposed DNREC protocol and have been meeting regularly for the last year to come to an agreement that will satisfy all parties.

For stormwater management the PCS calls for the following action plans:

1. Where practicable, all permanent sediment and stormwater management plans shall be designed and implemented to include design criteria to further reduce nutrient contributions by the percentage required by the TMDL.
2. Develop a program to assist homeowners' associations in the creation of a stormwater maintenance plan as well as to assist in the establishment of a funding mechanism for it.
3. Encourage Sussex County to create a stormwater utility for the Inland Bays.
4. Create stormwater management facilities and source reduction strategies for 1,800 ha of urban and residential lands developed pre-1990.
5. Institute tax incentives that encourage an increase in open space in commercial developments and reducing imperious area.

Conclusions

The following conclusions can be drawn from the Inland bays TMDL:

- Inland Bays are highly entropic.
- Alternative uses and export of poultry manure out of the watershed are required to meet the TMDL.

- Some of the BMPs being installed may not be effective in meeting nutrient load reductions.
- Eliminating all point source from the Inland Bays will be a real challenge because of development and high land prices for land application.
- TMDL nutrient load requirements may be impossible to meet under the current proposed strategies.

References

1. Brinsfield, R.B. and K.W. Staver. 1991. Role of Cover Crops in Reduction of Cropland Nonpoint Source Pollution. Tech. Report, University of Maryland, Agricultural Experiment Station, College Park, MD. 17 p.

2. DNREC. 2005. Proposed Pollution Control Strategy. Dover, DE. Draft. 5/16/2005.

3. DNREC. 2001. TMDL. Analysis for the Indian River, Indian River Bay and Rehobeth Bay. Technical Report, Dover, DE. 99p.

4. DOSPC. 2002. 2002 Land Use and Land Cover Data. Delaware Office of State Planning Coordination, Dover, DE.

5. Martin, J.H., J.G. Farrell and J.E.A. MacKenzie. 1998. An Analysis of Nutrient Utilization Efficiency by Agriculture in the Inland Bays Drainage Basin: Center for the Inland bays, Nassau, DE. Technical Report. 62 p.

6. Ritter, W.F. 1986. Nutrient Budgets for the Inland Bays. University of Delaware, Newark, DE. 69 p.

7. Ritter, W.F., R.W. Scarborough and A.E.M. Chirnside. 1998. Winter Cover Crops as a Best Management Practice for Reducing Nitrogen Leaching. J. of Contaminant Hydrology. 34:1-15.

8. Sallade, Y.E. and J.T. Sims. 1997. Phosphorus Transformation in the Sediments of Delaware's Agricultural Drainageways II Effects of Reducing Conditions on Phosphorus Release. J. of Environ. Qual. 26:1579-1588.

9. Sims, T.J. 1999. The Role of Soil Testing in Environmental Risk Assessment for Phosphorus. In Agriculture and Phosphorus Management: The Chesapeake Bay. A.N. Sharpley, Ed. Lewis Publ. Boca Raton, FL. pp. 55-82.

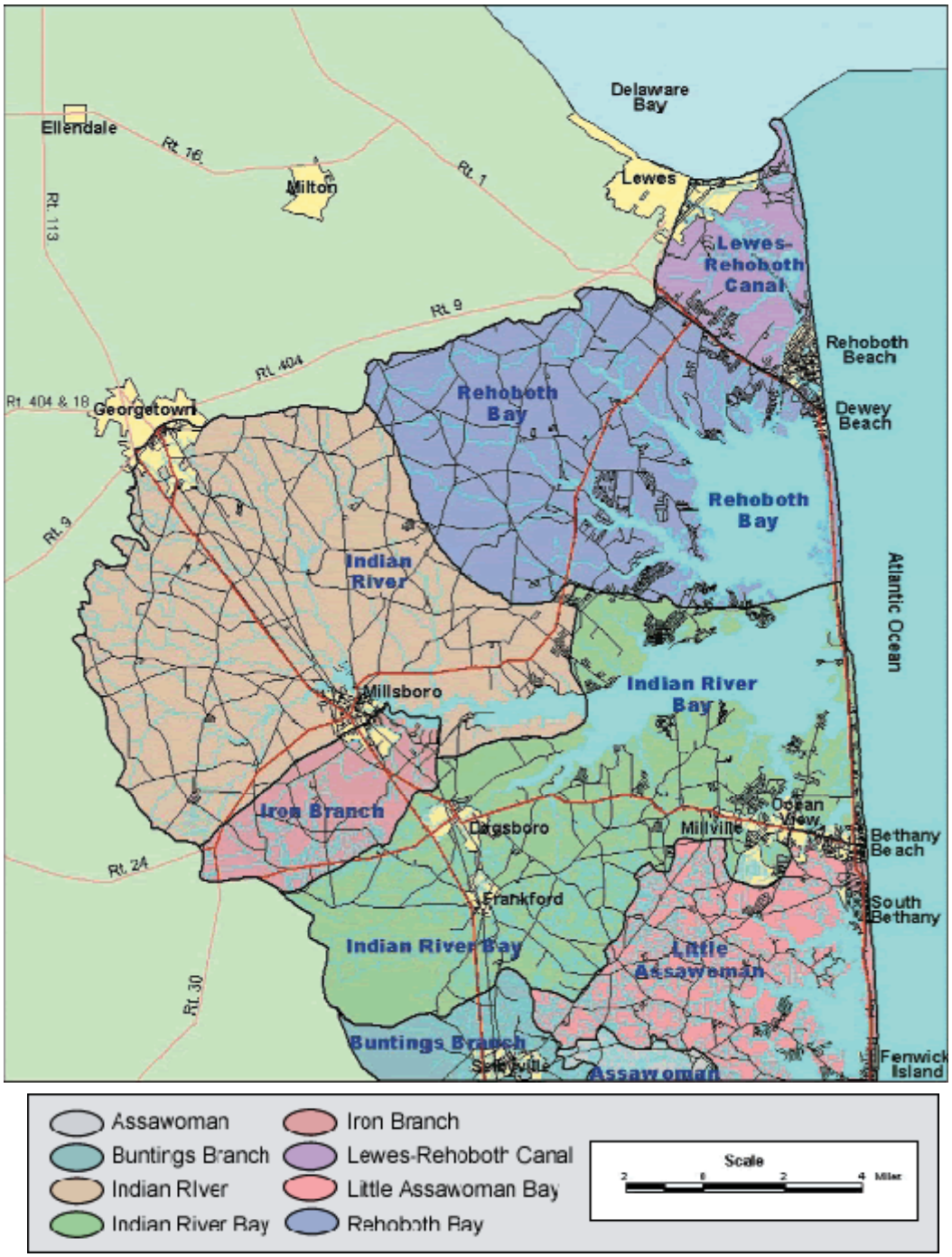

Figure1. Inland Bays Watershed