CHESAPEAKE BAY PROGRAM
NUTRIENT REDUCTION STRATEGY REEVALUATION

REPORT # 8:

"EXECUTIVE SUMMARY"

FINANCIAL COST EFFECTIVENESS OF POINT AND NONPOINT SOURCE NUTRIENT REDUCTION TECHNOLOGIES IN THE CHESAPEAKE BAY BASIN

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EXECUTIVE SUMMARY

Purpose:

This report is one of a series of reports prepared for the Chesapeake Bay Program Reevaluation of the Nutrient Reduction Strategy. This report provides information on the financial cost effectiveness and nutrient removal effectiveness of point and nonpoint source technologies in the Chesapeake Bay Basin. The report evaluates financial costs of different nutrient reduction technologies in a uniform way and expresses the costs on an equivalent annual basis, so that relative comparisons can be made among nutrient removal options.

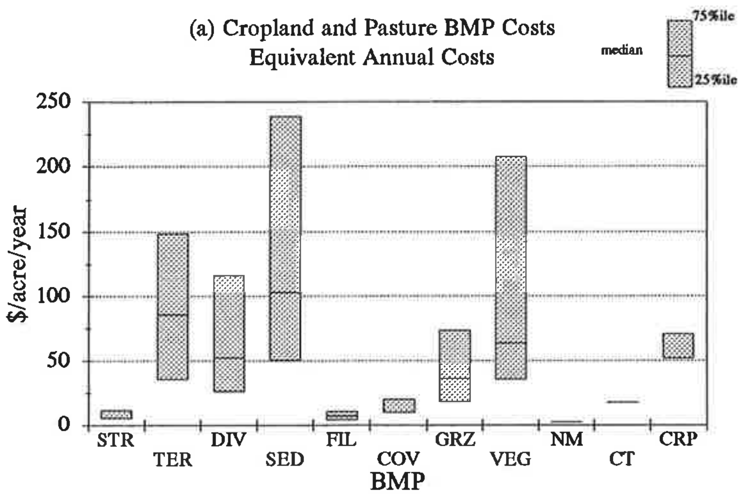
Use of the cost information provided by this report with the Chesapeake Bay Watershed Model will allow relative cost comparisons of nutrient reduction scenarios to determine cost effective strategies for point and nonpoint source nutrient reduction. Unit costs and nutrient reduction efficiencies presented in this report can also be used in optimization models to identify cost effective nutrient reduction strategies.

The report cannot be used to calculate the absolute cost of implementation of nutrient removal programs. Those costs will depend on factors such as local/state/federal government cost-share programs, schedule of implementation etc., in addition to site-specific conditions. Site-specific considerations can significantly affect costs and the application of nutrient removal technologies. Potential economic benefits of nutrient reduction controls also are not evaluated but may need to be considered.

Process and Approach:

Nonpoint Source Costs - The report focuses on the financial cost effectiveness of agricultural Best Management Practices (BMPs). Cost and BMP longevity information have been obtained from the Chesapeake Bay Program BMP tracking database, BMP longevity studies (Rosenthal and Urban, 1990), and the states' BMP unit cost data. Information also is presented for urban BMPs. Capital, technical assistance, and operation and maintenance (O&M) costs are expressed on an equivalent annual basis for comparisons. Nonpoint source BMP unit costs (in equivalent annual dollars per acre) are shown in Figure 1.

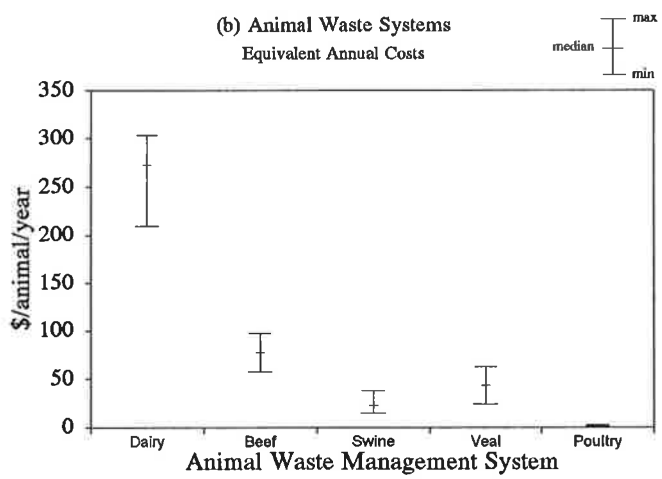
Figure 1. Nonpoint Source BMP Unit Cost Ranges



STR = Strip-cropping
TER = Terraces
DIV = Diversions
SED = Sediment Retention and Water Control Structures
FIL = Filter Strips
COV = Cover Crops
GRZ = Grazing Land Protection
VEG = Permanent Vegetation on Critical Areas
NM = Nutrient Management
CT = Conservation Tillage
CRP = Conservation Reserve Program

Grassed Waterway Annual Unit Cost Range : $0.39 - $1.50 per linear foot.

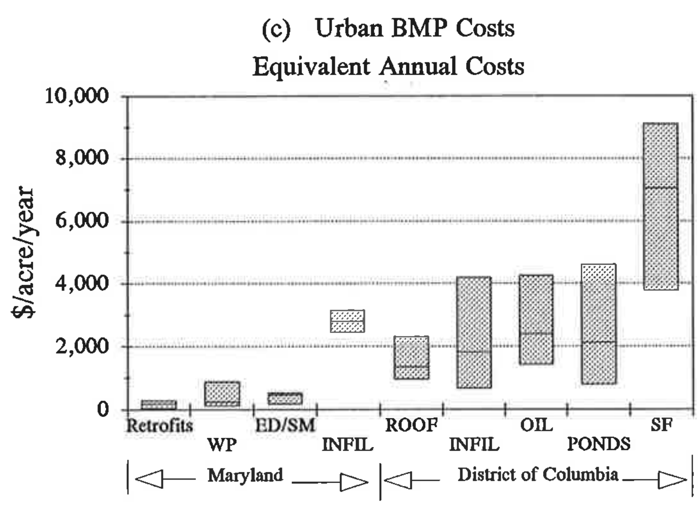
Unit costs obtained from the Chesapeake Bay Program BMP Tracking data base and states' unit cost data.
Equivalent annual costs includes construction, planning, technical assistance, and O&M costs.
Cost for CT and CRP are government incentive costs.



Unit cost ranges obtained from examples of animal waste management systems developed by Pennsylvania (Ritter, 1990).

Equivalent annual costs including capital, labor and energy costs for collection, storage, transport, and utilization of manure.

Animal waste system costs
(CBPO tracking database):
Interquartile range = $1.99/ton - $3.88/ton
Median= $2.81/ton
(ton = ton of manure treated)



Retrofits = Dry Pond->Extended Detention/Wet Pond
Wet Pond->Extended Detention
WP= Wet Ponds
ED/SM= Extended Detention/Shallow Marsh
INFIL= Infiltration Trenches
ROOF= Rooftop Detention
OIL= Oil Grit Chambers
PONDS= Ponds
SF= Sand Filters

Equivalent annual costs including construction and O&M costs

Point Source Costs - The focus is on the financial cost effectiveness of upgrading municipal wastewater treatment plants (WWTPs) for nutrient removal. Based on earlier U.S. Environmental Protection Agency (EPA) studies (Hazen and Sawyer Engineers and J. M. Smith and Associates, 1988), planning level cost equations have been developed for retrofitting WWTPs for two sets of effluent levels (TN*=8.0 mg/l,TP*=2.0 mg/l; and TN=3.0 mg/l,TP=0.5 mg/l) on a seasonal and annual basis. Capital and O&M costs are expressed in equivalent annual dollars. Unit cost data ($/mgd/year) from these equations are depicted in Figure 2. Figure 3 shows retrofit planning level unit cost ranges from planning level studies prepared for Maryland (Beavin Co., Camp Dresser and McKee Inc., and Metcalf & Eddy Inc., 1989), Virginia (CH2M-HILL, 1989) and the District of Columbia (Greeley and Hansen, 1989; and McName, Porter, and Seeley Engineers/Architects, 1990).

Nutrient Removal - Watershed Model runs will determine nutrient removals for BMP implementation scenarios. Nutrient removal for each scenario is the difference between the loads generated by that scenario and the "Base Case" model run. Relative cost comparisons of scenarios will be made by comparing the product of unit costs (e.g. Figures 1-3) and acres put under BMPs, plus cumulative costs to retrofit WWTPs for each scenario.

Cost Effectiveness - Cost effectiveness is defined as the ratio of the cost per pound of pollutant removed per year. It may be expressed in several ways depending on the scale of analysis. For instance, cost effectiveness can be expressed for individual nutrient reduction controls, or combination of controls ("Resource Management Systems"), or basin-wide management scenarios.

Findings and Conclusions:

Based on the cost effectiveness information presented in this report, and other aspects related to the implementability of point and nonpoint source nutrient reduction controls, the following conclusions are presented for the nonpoint and point source nutrient reduction controls examined in this study:

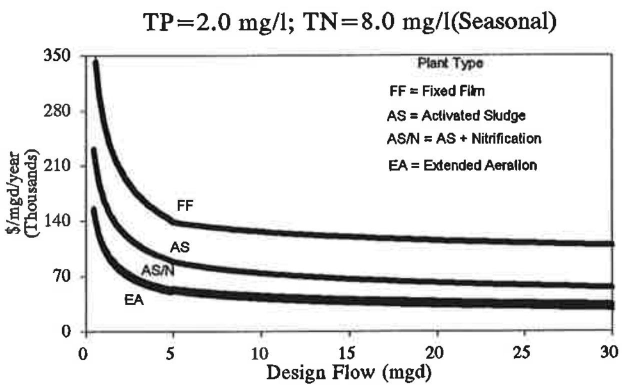
Nonpoint Sources

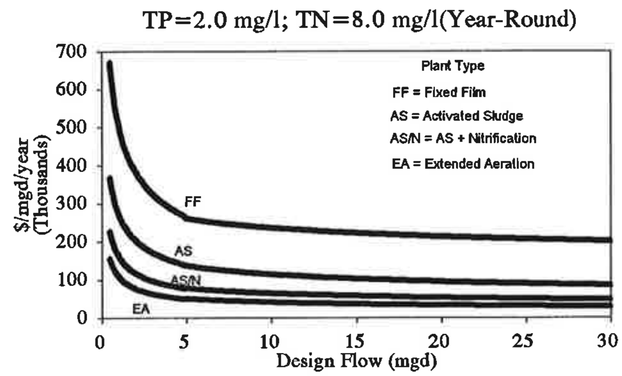
- BMP cost effectiveness should not be judged only on individual BMP nutrient reduction performance, but rather on combinations of BMPs or "Resource Management Systems" that together more effectively reduce the pollutant loads.

* TN = Total Nitrogen
TP = Total Phosphorus

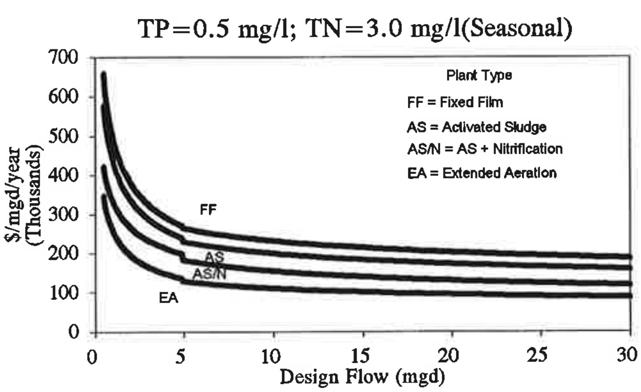
Figure 2. Biological Nutrient Removal (BNR) Planning Level Retrofit Unit Costs for Municipal Wastewater Treatment Plants *

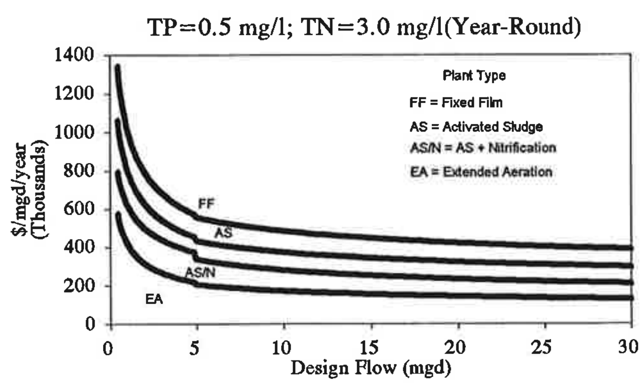
(a) High Level Nutrient Discharge





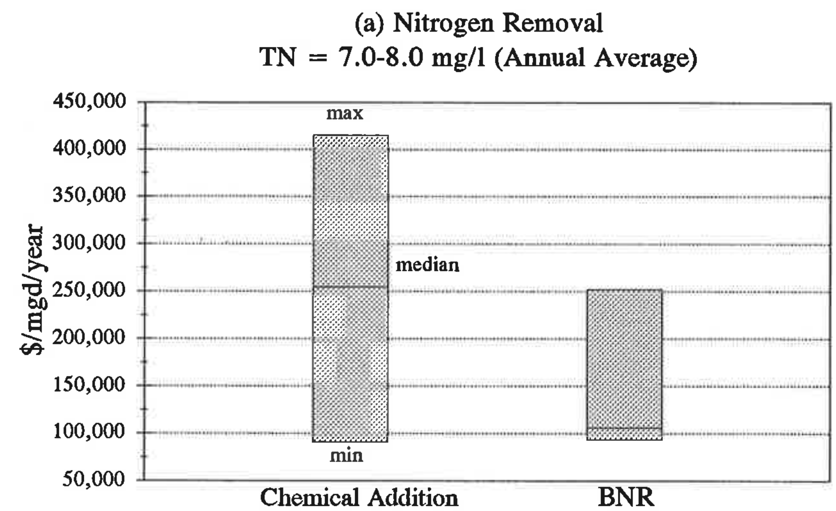
(b) Low Level Nutrient Discharge



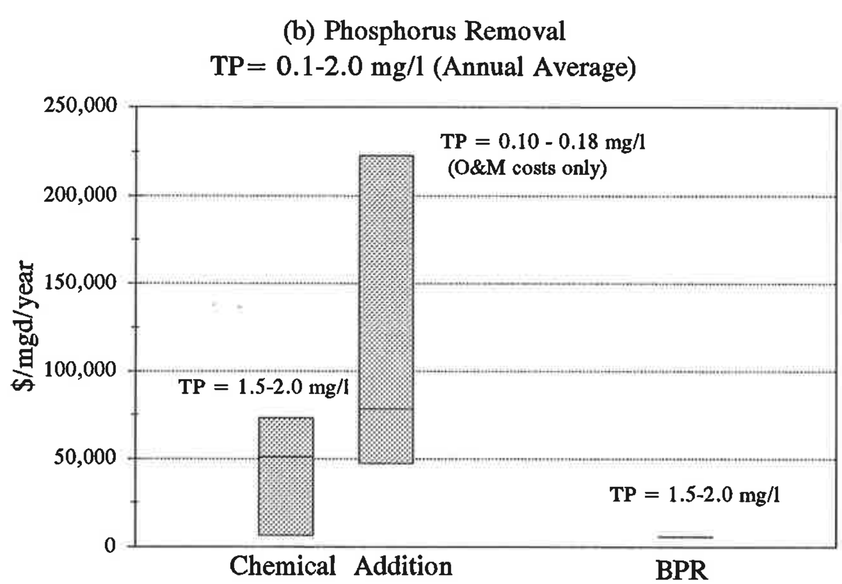


* Adapted from: Hazen and Sawyer Engineers and J.M Smith and Associates (1988).

Figure 3. Planning Level Retrofit Unit Cost Ranges (States' Nutrient Removal Studies)



BNR = Biological Nitrogen Removal



BPR = Biological Phosphorus Removal

- In-field BMPs that reduce runoff and sediment, such as terraces and conservation tillage, can increase infiltration, thus increasing the potential of pollutant leaching into the groundwater. Conservation tillage may increase the concentration of pollutants in the soil surface. Therefore, any reductions achieved through surface runoff and sediment reductions may be offset by the increase in pollutant concentrations and the potential leaching of pollutants into the groundwater (Heatwole, et al., 1991). However, with nutrient management (i.e. proper fertilizer application rates, timing, and methods) nutrient losses to both surface waters and groundwater can be reduced. This accounts for the favorable cost effectiveness ratios for nutrient management.

- Results of the watershed model show nutrient management to be the most cost effective (Figure 4-a). Also, from field-scale research studies, nutrient management in combination with in-field BMPs such as strip-cropping, conservation tillage, and winter cover crops (where appropriate) have been found cost effective management alternatives for nutrient reduction.

- Winter cover crops have been found very effective in removing excess nitrates during the non-growing season after the main crop harvest. Excess nitrates accumulated in the soil may be significant after dry periods during the growing season.

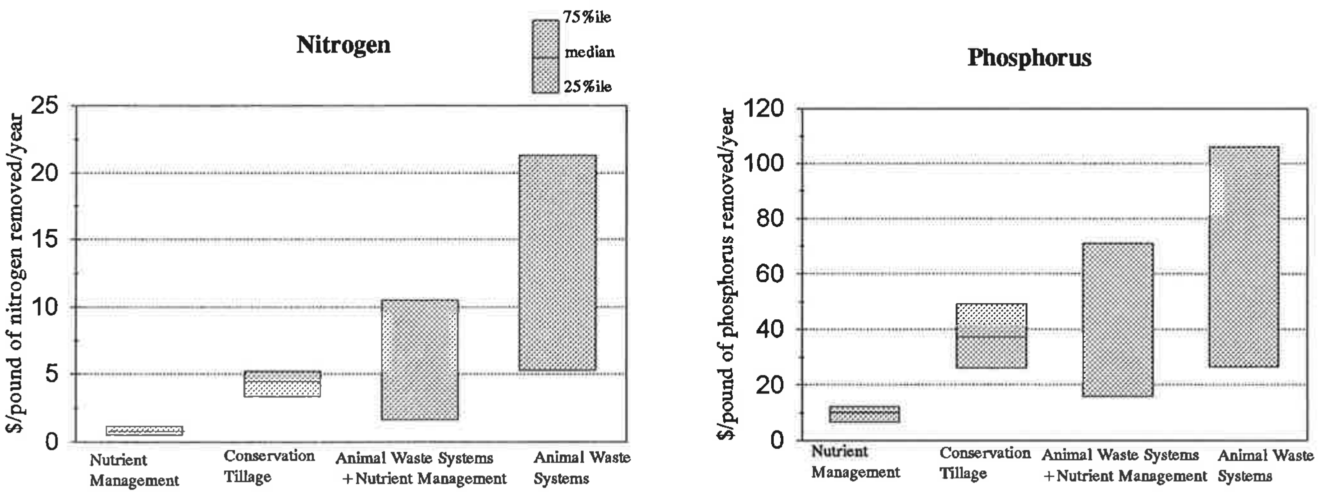
- Edge-of-field BMPs that reduce pollutant delivery into streams may be required for cases where nutrient loads are high due to increased runoff concentrations and sediment loads in large fields with long slope lengths. Some of these BMPs are structural BMPs such as erosion or water control structures, or non-structural BMPs such as filter strips, riparian zones, etc. However, structural BMPs are often expensive (see Figure 1-a), and despite the cost-share money available, implementation of these can result in a negative net field income (Hamlett and Epp, 1991). Also, despite the benefits of some of these structural BMPs in decreasing the sediment loads delivered into the streams, they should be accompanied by an in-field BMP to protect against severe soil losses that can have detrimental effects on the long term productivity of the fields.

- Conversion of highly erodible land (HEL) to permanent vegetation has been shown to be cost effective since it can considerably reduce sediment, runoff, and nutrient loads.

Figure 4. Financial Cost Effectiveness Ratios for Point and Nonpoint Source Nutrient Removal Technologies

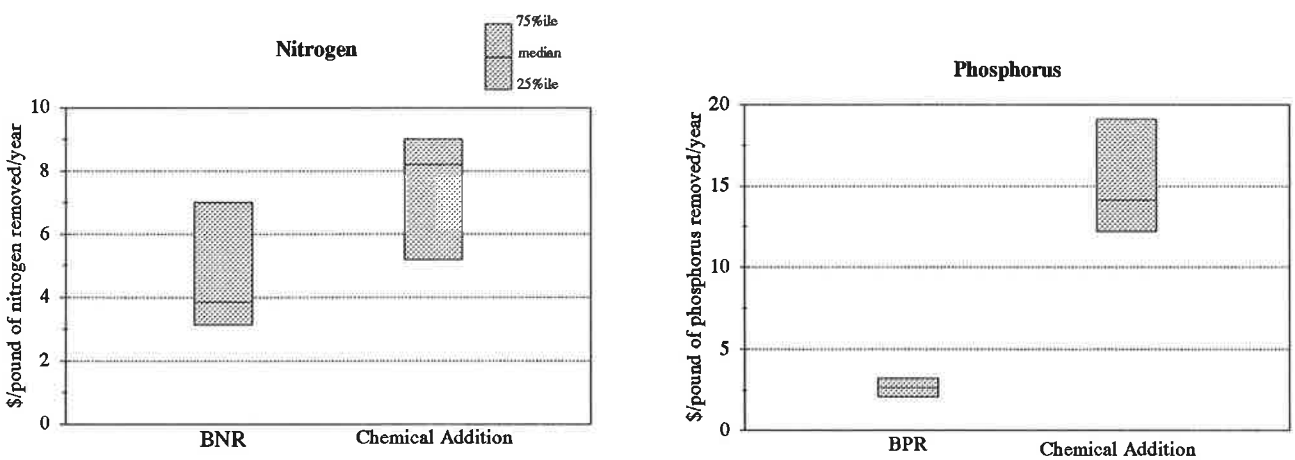
(Interquartile Ranges)

(a) Nonpoint Sources



Cost effectiveness is calculated as the ratio of the total annualized BMP cost divided by the pounds of nitrogen or phosphorus removed per year. Interquartile ranges reflect different nutrient removals within the Chesapeake Bay Basin. Nutrient Removals are at the edge-of-stream (Chesapeake Bay Watershed Model).

(b) Point Sources



Cost effectiveness ratios for nitrogen are calculated as the total annualized cost for nitrogen removal divided by the pounds of nitrogen removed per year. Similarly, cost effectiveness ratios for phosphorus are calculated as the total annualized cost for phosphorus removal divided by the pounds of phosphorus removed per year. Nutrient removals are calculated at the "end-of-pipe." The information shown in these figures came from the states' nutrient removal retrofit studies for municipal WWTPs and some existing retrofits in Maryland.

- Animal waste has been identified as a significant contributor of nutrient loads. Animal waste management systems should be considered important components of "Resource Management Systems." Proper design of animal waste facilities, including collection, storage, and transport, together with waste utilization will make these facilities cost effective (Figures 4-a). Figure 1-b shows that animal waste management systems including collection, storage, transport and labor costs, can be expensive. Nevertheless, experiences from the Rural Clean Water Program (U.S. EPA, 1990) projects show that there also are simple cost effective measures such as keeping animals away from the streams, controlling animal waste runoff, and protecting riparian areas.

- For urban BMPs, wide ranges of cost effectiveness ratios have been reported in the literature. Mostly, these ratios are higher than those shown in Figure 4, suggesting that they are the least cost effective controls for nutrient removal. However, urban BMPs have other important functions, such as aesthetics, water quantity control, and removal of petroleum hydrocarbons and heavy metals.

Point Sources

- Biological Phosphorus Removal (BPR) can be a cost effective alternative for phosphorus removal (Figure 4-b). It has potential for cost savings in chemical use and sludge handling. However, site-specific economic evaluations as well as the reliability of this technology for each plant should be carefully investigated. Also, it is important to point out that plants implementing BPR technologies may need chemical phosphorus removal facilities as a backup for permit compliance or when the effluent requirements are below 1.0 mg/l.

- Biological Nitrogen Removal has been found cost effective. Full-scale retrofits of WWTPs have supported this finding. However, planning level studies show, for certain facilities, that chemical addition (methanol) also can be cost effective. Therefore, the selection of chemical addition vs. Biological Nitrogen Removal without the use of chemicals would depend on site specific constraints.

- Seasonal nitrogen removal appears more cost effective than annual removal. Costs can significantly increase for annual removal (see Figure 2) because at lower temperatures biological activity is reduced. Therefore, longer wastewater retention times are needed requiring larger reactor tank sizes, thereby increasing costs. In addition, selection of the months for seasonal nitrogen removal and the permit compliance period can have a significant impact on the retrofit designs and therefore the costs associated with meeting the required effluent limitations.

- Regulatory measures such as the phosphate detergent ban have proven to be cost effective. Due to lower influent phosphorus levels to WWTPs, the chemical use required to meet the effluent level limitations and the amount of sludge created will decrease. Reduction in sludge and chemical use for phosphorus removal can significantly decrease the O&M costs in a WWTP. Another example of a regulatory measure being suggested is the adoption of permitting approaches such as the "bubble concept" (Virginia Retrofit Study) where the combined nutrient discharge of a group of plants are also regulated within a tributary, basin, etc. This approach would allow flexibility in the implementation of the most cost effective nutrient removal alternatives to a subset of plants within the "bubble". Nevertheless, individual permit limitations would still be required according to a careful examination of the quality of the receiving waters.