I. EXECUTIVE SUMMARY

The State of Wisconsin Natural Resources Code, NR 217, allows the imposition of phosphorus limits in treatment plant discharge permits. A trend in the water quality industry is to attempt to achieve water quality goals by addressing pollution on a watershed basis. Multiple entities in the Rock River Watershed joined to assess water quality in the Rock River. This report presents a summary of the multiple projects completed.

The Rock River Watershed Partnership (RRWP) was formed in 1996. The major objectives of the group are described in their Mission Statement below:

> *The Rock River Watershed Partnership is a stakeholder group committed to addressing nutrient and other water quality management issues within the Rock River Watershed in an integrated, holistic manner using the tools of watershed-based planning/decision-making.*

The Partnership identified a number of goals they wished to accomplish. These are:

- Identify nutrient concerns and prioritize
- Identify water quality objectives/desires
- Establish least cost mix of control alternatives
- Inventory existing pollutant sources
- Identify strategies for achieving objectives
- Implement least cost alternatives
- Monitor progress

After initial formation of the partnership, a membership "drive" was conducted that resulted in the formation of a truly diverse membership. Initially, the Partnership worked to receive a funded overall evaluation of the watershed from the World Resources Institute. This study concluded that trading of phosphorus credits may be a viable method of improving water quality in the Rock River where phosphorus was contributing to water quality degradation. It also suggested that trading should be considered as part of a least cost mix of alternatives that could be used to achieve water quality goals.

Working with the Wisconsin Department of Natural Resources (DNR), the Partnership entered into an agreement to suspend implementation of phosphorus limits on the point dischargers pending the outcome of studies to be done under the guidance of the Partnership. A Memorandum of Understanding (MOU) was written to formalize this delay of inclusion of phosphorus criteria in the Publically Owned Treatment Works (POTW) permits. This delay in implementation of phosphorus limits was only available to those municipalities actively participating in the work of the Partnership.

A separate group was formed to enable receipt of grants and to provide a legal entity for intermunicipal cooperation and funding. The Rock River POTW Watershed Group was formed under Wisconsin State Statute §66.30. The Group formulated the studies to be done and the funding for those studies. The six specific tasks identified by the Group to be accomplished were:

- Task 1 - Computer modeling of the watershed to determine the relative sources of phosphorus and sediment
- Task 2 – Monitoring of the actual water quality characteristics at multiple locations in the watershed
- Task 3 – Evaluation of the requirements for effluent trading

- Task 4 – Evaluation of the costs for phosphorus removal from point and non-point sources
- Task 5 – Assessment of the actual biological water quality at multiple locations in the watershed
- Task 6 – Management of the entire program for schedule, budget, and task coordination

Although the Group has accomplished a great deal, much more remains to be done. Ongoing data collection will enable better future analysis of loadings and impacts. Pilot trades will enable testing of the trade process. Continued activities on the local and national level will allow better water quality-based decisions to be made.

Task 1 - Modeling

As a part of an overall phosphorus analysis and management program within the Rock River Basin, a comprehensive pollution source computer modeling effort was conducted as Task 1. The focus of the modeling was to construct an intermediate level, macro-scale model to better quantify phosphorus loadings from point and non-point sources throughout the basin. The three major goals of the modeling effort are:

1. Estimate the average annual phosphorus load from external sources to the Rock River surface water system.

2. Estimate the relative contribution of phosphorus loadings from non-point and point sources.

3. Estimate the changes on annual phosphorus loadings from the application of global non-point best management practices and point source controls (based on NR 217 effluent levels).

General Description of the SWAT Modeling Effort

The SWAT (Soil and Water Assessment Tool) model was selected for the modeling effort. It is the continuation of a long-term effort of non-point source pollution modeling with the USDA - Agricultural Research Service (USDA - ARS). The purpose of the model is to predict the effect of different management techniques on hydrology, sediment, and agricultural chemical yields in large ungaged watersheds. To satisfy these objectives, SWAT is a continuous time model (daily time step) which incorporates the effects of weather, surface runoff, evapotranspiration, crop growth, irrigation, groundwater flow, nutrient and pesticide loading, and water routing on the long-term impacts of varying management practices.

The results of the calibration procedure compared favorably to monitored data. Validation data supported that the model was accurately predicting flows, sediment, and phosphorus on an average annual basis.

Under existing land use and management conditions, the model predicted a total average annual phosphorus load of approximately 1,680,000 pounds. Point sources accounted for 41% of this value, and 59% was from non-point sources. These numbers are reported as total phosphorus and do not distinguish between the different forms (ortho, soluble, particulate, etc.) of phosphorus.

Evaluation of various BMP scenarios shows that implementation of NR 217 (applicable point sources effluent at 1 mg/l of phosphorus) and changes in tillage practices and nutrient application practices, the total phosphorus can be reduced across the basin by approximately 40%. This reduction is the representation of a hypothetical “best case” condition. An estimated 25% reduction in phosphorus loads can be obtained by just implementing NR 217 and a 14% reduction can be obtained with implementing improved tillage and nutrient management practices. Other BMPs could result in significant, additional phosphorus reductions.

In addition to phosphorus loads, information was generated on sediment loads stemming from non-point sources. Modeling results indicate that under existing conditions, approximately 160,000 tons of sediment are delivered to the water bodies within the Rock River Basin on an average annual basis. These sediment loadings were identified by the Task 5 study as significantly impacting water quality. SWAT predicted that through the implementation of improved tillage practices (predominantly conservation tillage), sediment yields could be reduced by almost 20%. Other practices further reduce sediment loads. These were not evaluated as part of this study.

Based on the modeling results, it becomes clear that additional studies are needed. Past and current research shows that fields with excessively high soil phosphorous levels (levels well beyond the point where there are crop responses to additional phosphorous) can contribute significant phosphorus loads to surface waters through runoff and sediment loss. However, not all farm fields contribute to this problem. It is imperative that point source effluent guidelines, non-point source BMPs, and restrictions on phosphorus usage have a scientific basis. Research needs to address these issues include additional modeling, continued monitoring, and research into effective BMPs.

Recommended additional modeling needs include:

- In-stream water quality modeling to relate the loads generated in this study by SWAT to in-stream conditions. The results of this effort could be used to help determine the numerical criteria for water quality as it relates to the type of water body and its use.

- The SWAT model should continue to be refined to better simulate transport phenomena. The nutrient routines should reflect the most current research and modifications should be made to allow more flexibility.

- Overall phosphorus loading levels should be identified which will not impair designated water uses or cause violations of water quality standards. The feasibility of achieving a reduction in phosphorus loading to this level, using feasible and implementable point and non-point controls, should be evaluated. Phosphorus loading reduction efforts must be practical and implementable, directed towards an achievable and tangible goal in terms of observable water quality improvement, with control efforts and costs equitably shared between the various point and non-point sources.

- Future monitoring work should be considered for further use for comparison and verification of the model.

- This study was performed at a macro scale. Additional modeling at a finer resolution coupled with field reconnaissance will be needed to properly target non-point BMPs at specific sites or in specific areas.

Additional monitoring needs include:

- Continuation of sampling at key locations to provide additional data for model input and calibration. Long term monitoring records are also needed to generate trends and perform relevant statistical analysis.

Recommended further evaluation and study of BMPs includes:

- Further evaluate various designs of vegetative filter strips for efficacy in filtering phosphorus. If a heavy reliance is to be placed on filter strips as a control mechanism, studies should be conducted that reflect conditions in the Rock River Basin.

- Evaluate various designs of wetlands for efficiency in removing phosphorus.

- Evaluate composting processes to reduce volume of manure and produce a product that is easily transported and commercially acceptable and examine economic and social acceptability of manure cooperatives or banks that would help distribute manure to fields needing phosphorus. Current modeling results do not reduce phosphorus from manure applications because of the lack of such a framework. However, this type of strategy is key to creating a stable phosphorus balance. In addition, the use of animal feed that will lower phosphorus content of manure should be investigated.

Task 2 - Monitoring

Water quality data were collected at nine water quality monitoring stations in the Rock River Basin. Continuous flow data were also available from USGS flow gages at each site, which allowed the computation of mass pollutant loadings. Samples were collected by cooperative POTW staff, using procedures recommended by USGS and DNR. All water quality samples were analyzed by the Madison Metropolitan Sewerage District's DNR-certified laboratory. Analysis QA/QC was performed on split samples by the Wisconsin State Laboratory of Hygiene. Bill Krug of USGS developed a database system for logging and publishing (to the World Wide Web) collected flow and water quality information. Mr. Krug also estimated annual phosphorus and sediment loadings for the monitoring locations for the September 1998 through August 1999 period.

In general, the results compare closely with estimates made by USGS on the basis of hydrologic, soil, topographic, land use and other information as part of their nation-wide nutrient loading estimation project Spatially Referenced Regressions On Watershed Attributes ("Sparrow").

Task 3 - Trading

The "Trading Structure Workgroup" developed a list of forty-seven items of concern regarding the implementation of trades. Three items were forwarded to the "Trading Ratio Workgroup" for resolution. The workgroup reached consensus on how 42 of the remaining 44 items would be addressed in a trading scenario.

The "Trade Ratio Workgroup" reached consensus on a simplified numeric basis for establishing trade ratios. In general the ratio would be developed based upon a base number (1.75 for point to non-point trades and 1.0 for point to point trades) with additive modifiers for site-specific conditions.

There are a number of factors that must be considered for a trade to occur. Some of these are:

- The Group, in its original charge, was to take into consideration the least cost mix approach when the trade ratio was finalized. The effectiveness of some of the pilot projects may be in jeopardy because of the conservative approach with regard to the trade ratio.

- The limitation, due to permit constraints, of a maximum 5 year "guaranteed" trade period. Longer periods will make more trades cost-effective by spreading capital costs over a longer period.

- Political boundaries can impact trades. Many point dischargers are unwilling to spend funds for improvements outside of their jurisdictional boundaries.

The "Trade Targeting Workgroup" identified eight specific areas of the Rock River Basin where incentives should be given to encourage trading.

Task 4 - Treatment Cost Evaluation

Representatives of POTWs considering a "trade" require information concerning the comparative economic cost of phosphorus control at POTWs and by implementing agricultural best management practices. General information on POTW costs for phosphorus control has been provided in memoranda dated April 28, 1997 and January 12, 2000. The January 2000 information includes actual costs from twenty "case studies." The "case study" costs generally show that biological phosphorus control, where implementable, has been more economical for larger POTWs. The "case study" results also show that actual costs have been lower than projected in April 1997, apparently because it has been possible at a number of facilities to adapt existing structures and tankage, and because replacement of "lost capacity" (e.g., because of lower volatility in the activated sludge process with chemical phosphorus removal systems) has not generally been replaced as part of the projects in the "case studies."

A useful spreadsheet has been developed to allow estimation of the physical requirements and unit costs for implementing agricultural best management practices (BMPs) to reduce phosphorus loadings from agricultural lands. Two BMPs are addressed in the spreadsheet: (1) buffer strips and (2) conservation tillage practices. For buffer strips, the length of buffer strip and the unit cost ($/lb P controlled) is provided for silt loam soils, different buffer strip widths, different slopes, and different type of tillage practices. For conversion from moldboard plowing to conservation tillage practice, the required acreage and unit costs ($/lb P controlled) are provided for silt loam soils, different slopes, and different conservation tillage practices.

The information developed as part of this task provides useful information to help POTWs evaluate the economics of phosphorus "trading." Some adaptation and refinement of the information to local conditions will be necessary for its use in a detailed analysis.

As future efforts are made to control phosphorus at POTWs and to implement agricultural BMPs, there will be more "case study" information developed regarding costs and control effectiveness. Additional research and data gathering should be conducted in compiling information of this type to provide a more extensive database for projecting costs for POTW and BMP approaches to phosphorus control.

Task 5 - Biological Impact Assessment

The response of lakes and impoundments to nutrient loadings has been intensely studied. The response of rivers and streams to nutrient loadings is historically less well studied and, therefore, the principal cause-effect relationships between environmental stimuli and river and stream response are not well understood. Task 5 was undertaken to help evaluate this. Furthermore, although the Rock River Partnership was proceeding to collect water quality data for larger rivers and streams in the Rock River Basin as part of the overall effort (please see the summary for Task 2), it was recognized that phosphorus impacts might be more directly observed in smaller stream segments.

To provide additional knowledge concerning water quality issues and relationships for smaller streams in the Rock River Basin, the Rock River Watershed POTW Group commissioned a research effort led by Professor Kenneth W. Potter of the Department of Civil & Environmental Engineering at the University of Wisconsin-Madison. The results of this research are summarized herein.

Principal findings were reported as:

- All water quality indicators except nitrate nitrogen, total Kjeldahl nitrogen and unit-area base flow were found to be correlated with a subjective ranking of water quality.

- Fine grained sediment deposits, derived primarily from agricultural activity, were judged to be the most serious problem in the streams studied.

- Cultural eutrophication (nutrient enrichment) was evident in the streams studied, with eight of the fourteen streams studied exceeding "background" phosphorus levels of 0.1 mg/L as reported by the USGS for natural streams with minimal impacts. *Chlorophyll a* concentrations were found to correlate with phosphorus levels. Minimum diurnal DO levels were also found to correlate with phosphorus levels, and two of the studied streams had minimum diurnal DO levels <2 mg/L with two other streams having minimum diurnal DO levels <5 mg/L (stream standard).

- Most of the sediment and phosphorus in the streams studied is ultimately derived from runoff from agricultural lands.

- The presence of extensive drain tiling systems in four watersheds complicates the relationships observed between water quality indicators and the extent of agricultural activity. Drain tiling decreases soil moisture, increases infiltration rates, and decreases surface runoff and runoff-transport of sediment and phosphorus.

- There is little evidence that wetlands in the watersheds study are providing a beneficial effect, likely because the wetlands have been degraded by agricultural activities such as channelization.

It is stated that fine-grained sediment is "clearly the most serious problem in our study streams." It is recommended that efforts to improve rural streams in the Rock River Basin focus on control of sediment. A caution is given that improved water clarity could worsen problems with low minimum diurnal DO and that phosphorus loading reduction may be required in such streams. It is also stated that restoration of degraded wetlands may be an effective strategy for improving stream quality. Lastly it is stated that "serious efforts to improve stream quality in the Rock River Basin should target degraded streams with high potential for significant improvement. This would include streams that have high-gradient reaches, flow into larger streams with good fish populations, and have opportunities for wetland restoration."

The following recommendations for future research were made:

- The basis for phosphorus "trading ratios" should be evaluated. Recognizing the importance of sediment loading to stream impairment in the watersheds studied, it is stated that "a strong argument can be made for a trading ratio of one or even less than one."

- The need to develop more effective and expedient means of estimating sediment loadings and assessing the impacts of sediment load on stream quality is stated.

- Additional data should be collected relating the Hilsenhoff Biotic Index with minimum daily diurnal dissolved oxygen levels.

- The potential benefits of tile draining, in conjunction with constructed wetlands, should be considered as a potential means of improving water quality in some streams.

Task 6 - Program Management

Task 6 consisted of Program Management assistance from the Group's engineering consultants. The issues addressed included budget planning and tracking, meeting attendance, technical guidance, coordination of many participants in the overall program, miscellaneous management tasks, and preparation of this Summary Report. The management tasks required review and tracking of the efforts of each of the other tasks as they impacted the overall objectives of the Group.

Summary

The tasks completed under the guidance, direction or funding from the Rock River POTW Watershed Group have provided a significant increase in the data available on the flows, loadings, pollutant inputs, and water quality in the Rock River and its tributaries. In addition, the work has identified the significant amount of future work required to obtain a level of understanding of the Rock River relating to phosphorus that would support science-based decisions regarding the regulation of all sources of phosphorus and the benefits of that regulation.