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WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Feasibility of controlled drainage for mitigating nutrient loss from tile drainage systems in south central Minnesota

Keywords: tile drainage, controlled drainage, watertable control, nutrient management.

Duration: March/99 to February/01

Federal Funds: $ 50,318

NonFederal Funds: $ 100,636

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Congressional District: 4th

Critical Regional Water Problem

There is evidence that local and regional nonpoint source nutrient loading is having national-scale consequences. A 6,000 to 7,000 square-mile hypoxic (oxygen-starved) zone-the largest in the Western Hemisphere-existed until 1997 in the Gulf of Mexico at the mouth of the Mississippi River (the hypoxic zone was mapped at about 4800 mi2 in 1998). Oxygen starvation to such an extent poses a major threat to one of the nation's most valuable fisheries. This hypoxic zone has doubled in size over the past six to eight years, ostensibly in response to the escalating use of nitrogen fertilizers by the agricultural and urban sectors within the Mississippi River Basin (Rabalais et al., 1996). The Minnesota River Basin (MRB) has been identified by Antweiler et al. (1995) as a significant source of nutrient and sediment loading in the Mississippi River Basin. Artificial, subsurface or "tile" drainage systems in the MRB have the potential to increase nutrient losses to surface waters. Drainage systems have been shown to increase nitrate-nitrogen (nitrate-N) movement from fields when no additional fertilizer is applied (Baker and Johnson, 1977). Drainage, however, permits more intensive agricultural activity, and thereby can exacerbate nitrate losses. A significant portion of agriculture in the MRB, the eastern region in particular, is dependent on tile drainage because of poor natural drainage conditions. According to a recent report, 20 percent of Minnesota's agricultural cropland has been drained (Zucker and Brown, 1998). These figures, however, do not adequately represent drainage activities in the MRB, where in some areas, nearly 50 percent of cropland has been drained (Binstock, 1998). Moreover, producers are now more able to accurately assess yield increases on or near tile drains through the use of GIS and yield monitors. As a result, the installation of new drainage systems and augmentation of existing systems are proliferating rapidly-nearly 100 million feet of tile, or 180,000 acres annually in the Minnesota (Binstock, 1998) (depending on an assumed tile spacing of 80 feet).

As public scrutiny of agriculture intensifies, increased efforts are called for to mitigate environmental impacts associated with agricultural systems. Agricultural producers want to be responsible stewards of the environment, if it can be done economically. As total maximum daily loadings (TMDL's) are phased in, regulatory agencies will need new tools for mitigating the impacts of drainage systems and other nonpoint pollutant sources. Two groups of strategies currently exist for mitigating the increased nutrient loading associated with tile drainage: (1) cultural practices intended to minimize nutrients reaching the drainage system, involving nutrient and tillage management schemes, and (2) management or treatment of drainage waters before they enter surface waterways, including, controlled drainage (Figure 1), riparian buffers, wetland treatment (both constructed and natural), and treatment within drainage ditches. Unfortunately, cultural practices designed to reduce runoff, erosion, on nonpoint source pollution can, under certain circumstances, have negative impacts on the groundwater that is removed by drainage systems (Skaggs et al., 1994). Research has shown that controlled drainage offers great potential for reducing nitrate by reducing drainage outflows and providing an increased anaerobic zone for denitrification. Such are its potential environmental benefits that Skaggs et al. (1994) noted that controlled drainage has been accepted as a best management practice by regulatory agencies in North Carolina. Skaggs et al. (1994) further noted that simulation studies indicate that controlled drainage systems, if not properly designed and managed, could produce negative water quality effects. The effectiveness and feasibility of controlled drainage in Minnesota has not yet been determined and hence, the goals of this two-year research project are to develop an experimental facility and assess the technical/economic feasibility of controlled drainage in south central Minnesota.

Expected Results and Benefits

The proposed research will attempt to quantify the technical and economic feasibility for controlled drainage for south central Minnesota. Two years of data will be collected to begin to assess the environmental and economic impacts of controlled drainage. It is anticipated that this research will result in: (1) design and installation of a facility for controlled drainage research and demonstration on the University of Minnesota Southern Experiment Station's (SES) Agricultural Ecology Research Farm (AERF); (2) collection of at least one year of initial data, including water quantity and water quality data (runoff and nitrogen for both surface and drainage water, total suspended solids for surface), crop yield, water table elevations and soil moisture; (3) calibrate and validate an existing model for controlled drainage; (4) conduct a model-based estimate of feasibility of controlled drainage for the MRB; (5) dissemination of information related to controlled drainage feasibility and design, to farmers, extension educators, and drainage administrators within the MRB, and; (6) creation of graduate and undergraduate student research opportunities.

Although controlled drainage is a practice that has been used and found to be effective in other states, it is yet untried and unresearched in Minnesota. The Water Resources Center has an opportunity to break ground on this important research area by establishing a research and demonstration facility at the SES. The proposed research can be used to develop policies and educational programs for improved management of nitrogen in tile drained fields in the Minnesota River basin. The research places feasibility (the producer's bottom line) at the forefront. This focus, combined with its strategic location on the SES, will give the site high visibility as a point-of-interest during field days at the station. The dissemination of specialized publications will help farmers, county extension educators and drainage/watershed administrators understand the principles and potential benefits of controlled drainage. Once established, the research facility will be used to leverage funding to pursue other avenues of continued research, which may include: additional water table management strategies, modeling of controlled drainage in Minnesota, investigation of pesticide movement and losses in drained fields, and further quantification of the hydrologic impacts of drainage.

Nature and Objectives of the Research

Data presented by Antweiler et al. (1995), showed that the upper Mississippi River Basin States of Illinois, Iowa, and Minnesota contribute more than one half of the total nitrate-N load in the entire Mississippi River Basin while contributing less that one-fourth of the total water. The 10-million acre Minnesota River Basin with its intensive row-crop production is Minnesota's chief contributor of nitrate loading in the Mississippi River (Randall and Mulla, 1997). Much agricultural production in the MRB is dependent on artificial drainage systems, both surface and subsurface, because of the predominance of poorly drained soils. The tremendous economic gains realized by resurrecting these poorly drained soils have come, however, at an environmental price-drainage systems provide improved hydraulic pathways for nutrients, sediments, and pesticides. With recent trends in drainage installation, or "tiling" (some estimates are as high as 100 million feet of tile annually) it is imperative that strategies be developed to mitigate the effects of these drainage systems while allowing for the needs of agricultural production.

Two groups of strategies currently exist for mitigating the increased nutrient loading associated with tile drainage: (1) cultural practices intended to minimize nutrients reaching the drainage system, involving nutrient and tillage management schemes, and (2) management or treatment of drainage waters before they enter surface waterways, including: controlled drainage (Figure 1), riparian buffers, wetland treatment (both constructed and natural), and treatment within drainage ditches. It is unlikely that any particular practice will prove to be the "silver bullet" for reducing nutrient loading from drainage systems. For example, cultural practices designed to reduce runoff, erosion, on nonpoint source pollution (e.g., conservation tillage) can, under certain circumstances, have negative impacts on the groundwater that is removed by drainage systems (Skaggs et al., 1994). Wetlands have been shown to be effective at removing nutrients but require a farmer to retire productive lands. It seems more likely that "best management practices" for drainage might involve the adoption of several practices that are complementary to one another. Hence, efforts must be undertaken to assess the regional performance of as many techniques as possible for mitigating the impacts of drainage systems

Controlled drainage, as illustrated in Figure 1, involves raising the water level at the outlet of a lateral or portion of the drainage system. This, in turn, establishes an elevated water table over the area served by the outlet, at approximately the water level of the outlet. While controlled drainage has proven to be effective at reducing nitrate loss in other states, it remains to be seen whether these benefits can be realized in Minnesota with its rolling, depressional topography. Much of the poorly drained regions of the MRB are on slopes of one to two percent. Figure 2 illustrates this for the Le Sueur watershed, within the MRB. The design and cost of controlled drainage systems are highly dependent on local climate, soils, and topography. Therefore, the feasibility of controlled drainage in Minnesota and the MRB must be established through research. Controlled drainage, if technically and economically feasible, may offer other potential advantages for farmers in addition to nutrient loss mitigation, including increased yields due to water conservation, little or no loss of productive area, and the possibly of retrofitting to existing drainage systems. These added benefits, however, must also be established through research.

A research project is proposed to investigate the feasibility of controlled drainage in south central Minnesota. Funding is requested to break ground for the initial two years of an investigation that is intended to span a longer time frame. The goals for the first two years of the research project are to develop a facility for controlled drainage research and demonstration, and provide an initial assessment of the controlled drainage's feasibility in south central Minnesota. The specific objectives of the proposed research are the following:

(1) Design and install a facility for controlled drainage research and demonstration on the University of Minnesota Southern Experiment Station's Agricultural Ecology Research Farm (AERF).

(2) Collect two years of data to include, water quantity and water quality (flow and nitrogen, for both surface and drainage water, sediment for surface water), crop yield, water table elevations and soil moisture.

(3) Calibrate and validate a model for conducting long-term modeling of controlled drainage under Minnesota conditions.

(4) Conduct a modeling-based estimate of feasibility of controlled drainage for the MRB.

(5) Disseminate information related to feasibility and design to farmers, extension educators, and drainage administrators within the MRB.

(6) Create graduate and undergraduate student research opportunities.