AGRICULTURAL DRAINAGE publication series

Issues and Answers

by Lowell Busman and Gary Sands

*The **Agricultural Drainage** series covers such topics as basic concepts; planning and design; surface intakes; economics; environmental impacts; wetlands; and legal issues.*

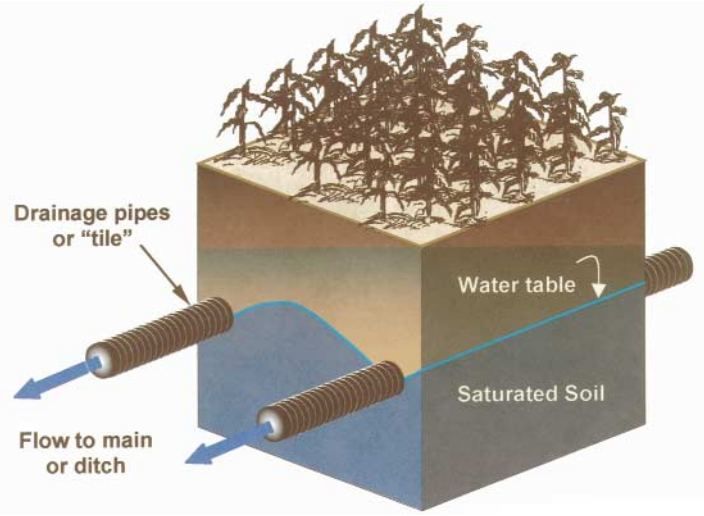
WHAT IS AGRICULTURAL DRAINAGE?

Agricultural drainage is the use of surface ditches, subsurface permeable pipes, or both, to remove standing or excess water from poorly drained lands. During the late 1800s, European settlers in the Upper Midwest began making drainage ditches and channelizing (straightening and reshaping) streams to carry water from the wet areas of their farms to nearby streams and rivers. Later, farmers increased drainage by installing subsurface drainage pipes generally at a depth of three to six feet. Until the 1970s, most subsurface drainage pipes were made from short, cylindrical sections of concrete or clay called “tile.” That is why terms like tile, tile drainage, and tiling are still used, even though most drainage pipe today is perforated polyethylene tubing. When installing a subsurface drainage system, pipes are either strategically placed in a field to remove water from isolated wet areas or installed in a pattern to drain an entire field. In some areas, surface inlets or intakes (risers extended from underground pipes to the surface) remove excess surface water from low spots in fields.

Poorly drained agricultural land immediately following a storm

WHY IS AGRICULTURAL DRAINAGE NEEDED?

Many soils in the Upper Midwest, as well as soils in other regions of the U.S. and the world, have poor natural internal drainage and would remain waterlogged for several days after excess rain without artificial drainage. This prolonged wetness prevents timely fieldwork and causes stress to growing crops because saturated soils do not provide sufficient aeration for crop root development. The roots of most crops grown in Minnesota cannot tolerate excessively wet conditions for more than a couple of days. Soil conditions that make drainage a necessity for some agricultural lands include those with slow soil water permeability or dense soil layers that restrict water movement, flat or depressional topography and, in some areas, high levels of salts at the soil surface. Large areas of Minnesota would not reliably produce crops if artificial drainage systems had not been installed.

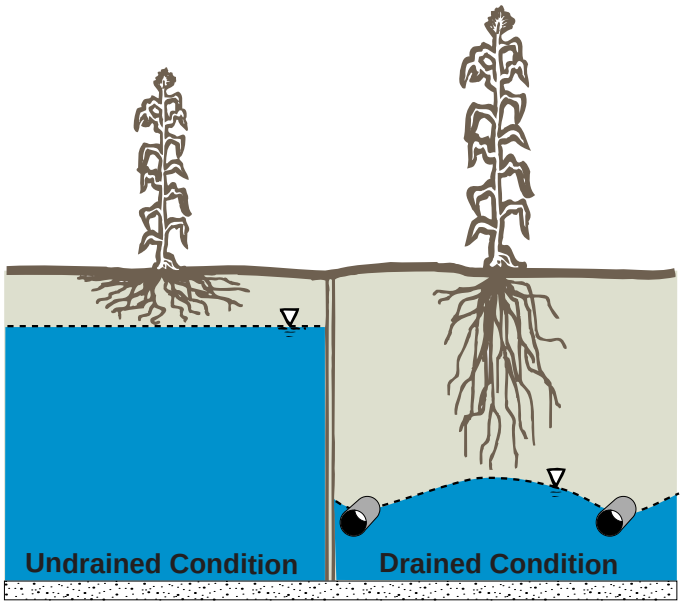


Subsurface drainage pipes are typically placed at depths of 3 to 4 feet in poorly drained soils.

Farmers must make a significant financial investment when installing an agricultural drainage system. They are willing to make this investment for two major reasons:

1. Agricultural drainage systems usually increase crop yields on poorly drained soils by providing a better environment for plants to grow, especially in wet years.
2. The systems generally help improve field conditions for timely tillage, planting and harvesting.

These two factors have improved agricultural production on nearly one-fifth of U.S. soils[1]. The most recent USDA comprehensive survey of drained lands showed that in 1985, 30 percent of all agricultural lands in the Upper Midwest (Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin) were artificially drained[2]. Minnesota has large areas of poorly drained soils: e.g., 66 and 59 percent of the soils in the Red River and Minnesota River basins, respectively[3]. In recent years, farmers have installed as much as 100 million feet of subsurface drainage pipe in Minnesota annually[4]. A significant portion of new drainage activities is replacement and enhancement of old drainage systems. As old systems age and decay, replacement activities will likely continue.



Subsurface drainage promotes better root growth and plant health when soils have poor internal drainage.

WHAT ARE THE ISSUES?

Although agricultural drainage has benefited agricultural production in many regions and countries, there are concerns about its potential environmental impact. Subsurface drainage systems have a positive impact because they generally decrease the amount of surface runoff, thereby reducing the loss of substances generally transported by overland flow. There are concerns, however, about the potential negative impacts of drainage on the hydrology of watersheds, the water quality of receiving water bodies, and the amount and quality of nearby wetlands.

Hydrology

Drainage systems are designed to alter field hydrology (water balance) by removing excess water from waterlogged soils. There are concerns about the downstream hydrological effects caused by draining this excess water. Anecdotal evidence indicates that streams and ditches have become “flashier” over time, spilling over their banks and causing localized crop damage. Some research articles suggest that the most dramatic hydrological changes in a landscape occur when it’s converted from native vegetation to agricultural production, and that subsurface drainage may reduce peak flows in some situations[5, 6, 7]. A recent regional publication[8] summarized the environmental impacts of subsurface drainage on agricultural land. The authors concluded that subsurface drainage reduces surface runoff by 29 to 45 percent, reduces peak flows from watersheds by 15 to 30 percent, and has little impact on the total annual flow from watersheds. A publication that summarized drainage studies from several countries concluded that subsurface drainage generally decreases peak flows in fine textured soils but often increases those flows in coarser, more permeable soils[9]. This publication also found that subsurface drainage often increases base flow to streams. Locally based research is necessary, however, to better understand the impact that drainage can have at watershed scales. In addition, the impact of surface inlets on watershed hydrology is an important issue currently being examined.

Water quality

Surface drainage (enhancing overland runoff) tends to increase the loss of nutrients and sediment that occur with surface runoff. Subsurface drainage, however, can decrease surface runoff, thereby reducing sediment losses by 16 to 65 percent and phosphorus losses by up to 45 percent[10]. The main water quality concern about subsurface drainage is the increased loss of nitrates and other soluble constituents that can move through soil to drainage systems and end up in nearby surface water. In addition, surface intakes, which are common across southern Minnesota and northern Iowa, provide a fairly direct pathway for sediment and other contaminants in surface runoff to reach nearby surface waters.

Wetlands

Despite the fact that wetlands are protected by various regulations, it is estimated that over 60,000 wetland acres are lost nationally each year[11]. The loss of wetland ecosystems — valued for their wildlife habitat, for water storage, and increasingly for their potential role to improve water quality — is not easy to quantify. But it's likely that agricultural and urban drainage activities both cause wetland loss.

WAYS TO REDUCE THE POTENTIAL IMPACTS OF AGRICULTURAL DRAINAGE

Many current drainage research and Extension programs throughout the country are trying to find ways to reduce the potential environmental impacts of agricultural drainage while retaining its agronomic benefits. Some management practices have been effective; others are presently being examined. Both are described in the following sections:

Improved Nutrient Management on Drained Soils

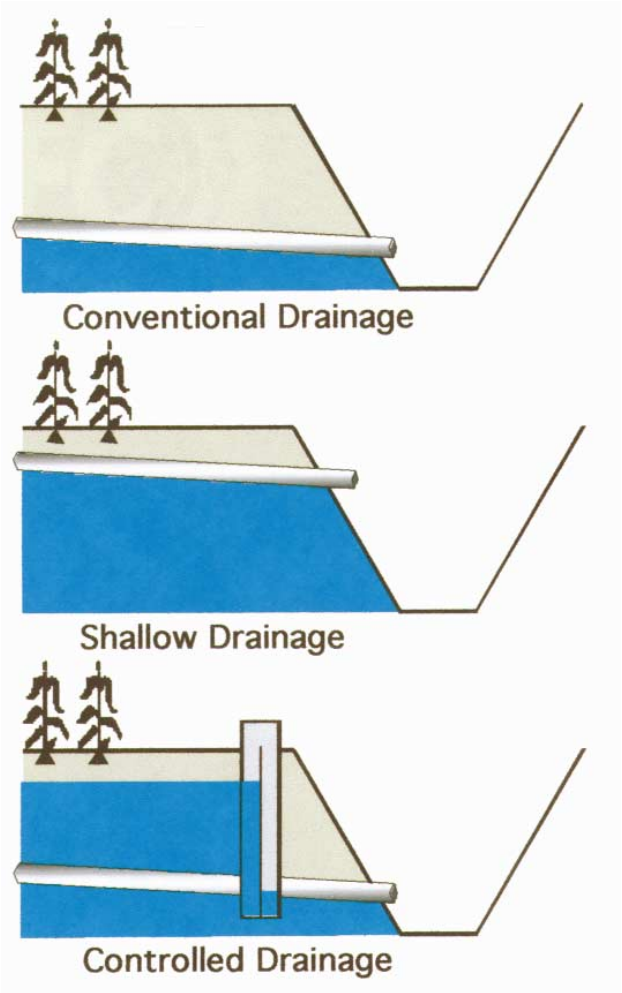
The proper management of crop nutrients (nutrient source, application rate and timing) is an important way to help control the loss of nutrients through surface runoff and subsurface drainage water. It's been shown that the application of nitrogen fertilizer at rates higher than those recommended by the University of Minnesota increases the amount of nitrate removed through subsurface drainage systems[12]. Since university recommendations are based on an optimum economic return, over-application of nitrogen fertilizer should be less profitable. It should be noted, however, that drained agricultural soils have significant nitrate losses from the natural process of organic matter mineralization. Improved nutrient management can potentially reduce nitrate losses on drained lands by up to 30 percent[13].

Changes in Cropping Systems

Row crops such as corn and soybeans experience considerably more nitrate loss through subsurface drainage flow than perennials such as alfalfa and brome grass[14]. So the incorporation of alfalfa or other perennials into farmers' crop rotations could significantly decrease nitrate losses to nearby surface water. While alfalfa may be a financially sound crop for some operations, it is not an economically viable solution for many Minnesota farmers.

Improved Drainage System Design

Subsurface drainage systems are designed to remove excess water from soil quickly enough to minimize crop stress in most years. Agricultural engineers have developed depth and spacing guidelines for installing drainage pipes. For example, recommendations for the many clay-loam soils prevalent in much of southern Minnesota call for placing drainage pipes approximately three feet deep and 60 feet apart or four feet deep and 80 feet apart. Either design should remove water at the same rate and give similar crop yields. It has been proposed that placing drainage pipes at shallower depths might result in less nitrate loss. This would happen because nitrate would be more likely to reach a biologically active but saturated zone and be converted to nitrogen gas by denitrifying bacteria. The conversion of nitrate/nitrogen to nitrogen gas would prevent the nitrate from reaching the drainage pipes and nearby surface waters. This practice, if proven effective, offers the advantage of being applicable anywhere that drainage systems are installed. It also requires no new management or capital investment.



Studies will determine if shallow drainage and controlled drainage reduce nitrate losses in Minnesota.

Controlled Drainage

Controlled drainage has become recognized as an effective practice — and in other states, a best management practice — for mitigating nitrate losses from drainage systems. This practice involves placing simple water control structures at various locations in the system to raise the water elevation. This elevated water causes the water table in the soil to rise, which, in effect, decreases the drained depth of the field. Researchers from North Carolina, Ohio, Michigan and Canada have demonstrated that controlled drainage decreases the volume of water drained (15-35 percent), slightly increases surface runoff (because soils have less space to store water), and significantly decreases (up to 50 percent) nitrate losses seen in conventionally drained fields[15]. Decreases in nitrate losses have been attributed primarily to reductions in the volume of water drained and, to a somewhat lesser extent, by increased denitrification in the soil. If managed properly, controlled drainage has the potential to improve crop yields by making more water available to plants.

The application of controlled drainage techniques is limited, however, by topography. The process is economically unfeasible on land slopes greater than about one percent because more water control structures are needed as slopes increase. In addition, controlled drainage adds new management requirements to systems (also increasing with slope) that some will view as a disadvantage.

Surface Inlet Alternatives

Alternatives to the traditional "open inlet" are being used more frequently around Minnesota. One design involves digging a trench, placing drainage pipe at its bottom, and filling the trench with small rock. These "rock" or "blind" inlets slow the flow of water (compared to open inlets) and may reduce the amount of sediment reaching the drainage system. Another design involves the installation of subsurface drainage pipes in a very tight pattern in a small area in the middle of a wet spot. Another, more traditional, technique involves replacing open inlets with perforated risers. All these designs have the potential to do a better job of protecting water quality than open inlets, while still providing adequate drainage so crops don't "drown."

Wetlands

Wetlands have been proposed as a means of treating water from drainage systems before it is released into nearby rivers or lakes. Biological activity in wetlands can be effective at removing nitrate by converting it to nitrogen gas through a denitrification process that's similar to what occurs in soils. Researchers in Iowa[16] suggest that wetlands can remove from 20 to 80 percent of the annual nitrate in subsurface drainage water depending on the ratio between the areas of drained land and wetland.

This approach to "treating" drainage water presents some challenges. Site topography may pose difficulties in getting subsurface drainage waters to the surface and into wetlands. Land requirements and the cost of construction are also important economic factors. Finally, the bulk of nitrate losses from drained lands in Minnesota occur in early spring when wetlands are not functioning at their peak capacity to remove nitrate, because of low temperatures and high water flow rates. The potential effectiveness of wetlands in treating drainage water in colder climates requires more research.

WHAT RESEARCH ACTIVITIES ADDRESS THESE ISSUES?

An array of new and ongoing research and Extension projects target important drainage issues in both the Minnesota River and Red River of the North basins. These projects involve research facilities at the University of Minnesota's St. Paul Campus, the university's Research and Outreach centers, and cooperating farmers' fields. Current projects include:

Crop-Nutrient Management and Cropping Systems

Subsurface drainage plots established over 20 years ago continue to examine how much impact fertilizer and manure application rates and timing, cropping systems, and other management practices have on the amount of nutrient loss from drainage flow.

Drainage System Design

Field-size plots of two to six acres at the University of Minnesota Southern Research and Outreach Center in Waseca (SROC) measure the effects of drainage depth and spacing on crop yield and surface/subsurface water quality. Computer simulations will be used in concert with field research to estimate the long-term effects of these practices. It is anticipated that this research will lead to better drainage design recommendations for southern Minnesota.

Controlled Drainage

The SROC is investigating the effects of controlled drainage on crop response and water quality on six half-acre plots. Researchers hope to see if this practice is feasible so they can develop water management strategies for southern Minnesota. Computer simulations will also be used to estimate the long-term performance of this technique.

Alternative Designs for Surface Inlets

Farmers, contractors, local governmental units and university researchers have been examining alternative surface inlet designs to see if they will provide adequate drainage and control the delivery of contaminants to receiving bodies of water. These projects include laboratory work, small research plots, and on-farm field-scale research. “Rock” inlets are being evaluated for their effectiveness in removing water and trapping sediment. A design and monitoring process is in place to assess the longevity and efficacy of these techniques.

Computer Simulation of Drainage Systems

A variety of projects have used computer modeling to investigate the performance of drainage systems and landscapes over several (often many) years. This work complements field research that is typically conducted over a shorter time frame. Some of these projects include simulating the effects of various management practices on drained watersheds, assessing the hydrology of drainage systems, and evaluating best management practices for drained fields.

Wetland Areas for Mitigation and Water Treatment Studies

Natural and constructed wetlands at SROC and the University of Minnesota Southwest Research and Outreach Center (SWROC) measure wetlands’ potential to mitigate nutrient loss in southern Minnesota. The Agriculture Ecology Research Farm at SROC has wetlands that receive drainage water from approximately 100 acres of land. These wetlands function in a total water management system designed to improve water quality and reduce peak flows.

Drainage Ditch Design

Significant amounts of denitrification can occur in ditches that can reduce the amount of nitrate that reaches area rivers. A paired-ditch evaluation project is underway at SWROC. The project compares the ability of two similar ditches to remove nitrogen under varying physical and flow characteristics. There is also research being conducted on a drainage ditch at SROC.

Yield and Hydrologic Impact of Subsurface Drainage in Northwest Minnesota

Research on farms and on plots at the University of Minnesota Northwest Research and Outreach Center in Crookston is investigating the impact of subsurface drainage on crop yields, water quality and hydrology in the Red River Valley.

WHAT EXTENSION ACTIVITIES ADDRESS THESE ISSUES?

A number of Extension initiatives address drainage issues, including:

- **Agricultural Drainage Publication Series.** This publication is the first in a series that addresses a variety of agricultural drainage issues. Series topics are:
  - The fundamentals of subsurface drainage and soil water
  - Planning a drainage system
  - The environmental impacts of drainage
  - The economics of drainage
  - Alternatives for surface inlets
  - Recommended management practices for drained soils
  - A summary of Minnesota drainage law
  - How to determine the benefits of a drainage system
  - The role of wetlands
  - The design and management of pumping stations
  - Frequently asked questions about drainage

- **The Drainage Outlet Website.** This provides another medium for discussion, education, and information sharing among drainage stakeholders. *The Drainage Outlet*, found at http://d-outlet.coafes.umn.edu, contains eight information pages: Research and Outreach, Ask Dr. Drainage, Contacts, Surface Intakes, Planning and Design, Meetings/Events, Links, and Photo Archives.

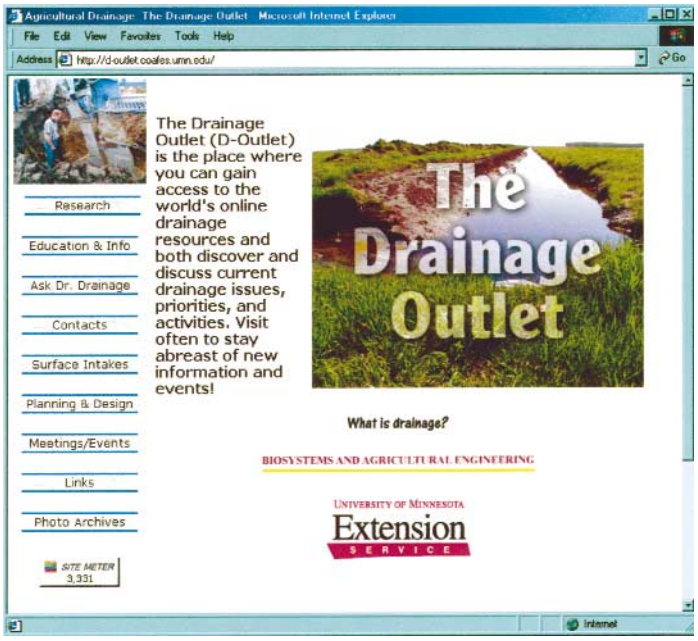


Fig. 5. The “Drainage Outlet” website can be found at http://d-outlet.coafes.umn.edu

- **Annual Drainage Design Workshops.** Held in early March each year, these hands-on workshops are for people involved in drainage design from beginner through advanced levels.
- **Annual Iowa-Minnesota Drainage Forum.** The University of Minnesota and Iowa State University signed a memorandum of agreement in 2000 to collaborate on drainage research and outreach programs. The agreement calls for an annual bi-state drainage forum where a diverse group of drainage stakeholders can discuss needs, priorities and plans for drainage research and extension.

WHAT ARE THE EXPECTED OUTCOMES OF THESE PROJECTS?

Because research requires several years to acquire adequate data before any conclusions can be made, computer models and data from previous studies will be used to develop recommendations on agricultural drainage methods that will help protect the environment while meeting agronomic objectives. Recommendations will cover topics such as the best depth and spacing for pipes so systems deal successfully with environmental and economic considerations; design criteria for controlled drainage and alternative surface intakes; wetland design for water storage and treatment; and management of soils with subsurface drainage. Along with these recommendations will come improved predictions on the impact of agricultural drainage methods on water quality and economic return.

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OTHER RESOURCES

Agricultural Drainage Publication Series: Soil Water Concepts, 2001, Pub. #07644. University of Minnesota Extension Service, St. Paul. To order call 800-876-8636.

Agricultural Drainage Publication Series: Planning an Agricultural Subsurface Drainage System, 2001, Pub.#07685. University of Minnesota Extension Service, St. Paul. To order call 800-876-8636.

Department of Biosystems and Agricultural Engineering www.bae.umn.edu/extens

ACKNOWLEDGMENTS

The authors wish to thank the many institutions, agencies and organizations that have contributed generously to furthering science and education initiatives in drainage. These include the Minnesota Land Improvement Contractors Association, the Minnesota Department of Agriculture, the Minnesota Pollution Control Agency, the Minnesota Agricultural Experiment Station, many departments and centers of the University of Minnesota, and drainage pipe and equipment manufacturers. A special thanks to the many individuals who reviewed earlier drafts of this publication and provided valuable insights.

This publication is printed with funds from the the Minnesota Department of Agriculture – Agriculture Development Division

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