Agricultural Drainage:
Design & Management for Production & the Environment

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Artificial Drainage: MN Footprint
25% of Ag Soils Artificially Drained

Data on the extent of drained agricultural land is from:
Question:

- Is there another way to do drainage?
  - w/o sacrificing production
  - But more environmentally friendly
Old School: 24-7-365 Drainage

Drainage pipes or "tile"

Flow to main or ditch

Water table

Saturated soil
New School: “Conservation Drainage”

Drain only enough to …

ensure trafficability and

ensure a healthy crop –

and not a drop more!
Road Map

- What’s up – has Sands gone mad??
- Back to school
- Experimental results
- Where to get more info
So What?

Why do we need to “reinvent our agricultural drainage systems?”
The seafood business is an estimated $4 billion a year industry.

GOM was 25% of U.S. commercial catch (fish/shellfish - 2000, $900m)
DRAINABLE WATER
What is a Water Table?

- “Gravitational” water removed (from largest pores)
- Water remains in smallest pores
- Drier toward surface
- Water table drop occurs over hours to days

3 – 4 feet
Soil Water & Air w/Depth

e.g. field capacity = 28%

Height Above Water Table

% water % air

empty pores

water-filled pores

25 30 35 40

Pore Volume (% of soil volume)

Water Table

Soil Surface
Volume of Water Drained

Vol. Drained = \( P_d \times h \div 100 \)

Initial watertable position

Final watertable position

Pore Volume (% of soil volume)

25 30 35 40

Height Above Watertable

Soil

Water-filled pores

Empty pores

drained pores
Influence of Soil Type

Soil Surface

Height Above Water Table

Pore Volume (% of soil volume)

Water Table

empty pores

water-filled pores

Coarser

Finer
Influence of Drain Depth

Soil Surface

- empty pores
- water-filled pores

Pore Volume (% of soil volume)

25 30 35 40

Soil Surface

- empty pores
- water-filled pores

Pore Volume (% of soil volume)

25 30 35 40
Influence of Drain Depth

- $P_d = 10\%$
- Drained inches from full profile:
  - 4-ft system: $4\times12\times0.1=4.8"$
  - 3-ft system: $3\times12\times0.1=3.6"$

- What happens next rainfall?
- Drain depth influence drained volume?
- What about drain spacing?
Drain Spacing

- Soil surface
- Water table
- Equivalent confining layer
- Confining layer
- Drain Spacing, L
- Tile drain
- $D_d$
- $d$
- $D$
- $m$
- $h$
Drain Spacing: How Close is Close Enough?

- Good Crops
- Drains Spaced Correctly
- Area of Severe Crop Damage
- Drains spaced too far apart

--- Water table 24 hours after a heavy rain
--- Water table 48 hours after a heavy rain
Drain Spacing Equation

\[ DC = \frac{(8 \times k_2 \times d \times h)}{L^2} + \frac{(4 \times k_1 \times h^2)}{L^2} \]

Hooghoudt (1940)

Soil

Water
Spacing x Depth (and soil factors) = Drainage Coefficient
Spacing, Depth, and DC

The graph illustrates the relationship between drain spacing and drain depth for different values of DC. The x-axis represents drain depth in feet, ranging from 2.0 to 5.0, while the y-axis represents drain spacing in feet, ranging from 0 to 160. Different colors indicate various values of DC: Dc = 0.25, Dc = 0.375, Dc = 0.5, Dc = 0.625, Dc = 0.75, and Dc = 2. The graph shows that as drain depth increases, drain spacing also increases, with different slopes for each DC value.
Why Does Any of This Matter?

- Drainage coeff affects crop yield
- Drainage coeff affects nitrate losses
- Less water drained may = less nitrates lost
- Can we get away with this?
Looking for Answers
Drainage Research

...on Location

Crookston & Brooks
Tilney & Red Top Farms
St. Paul
Waseca
Lamberton
Morris
Drainage Design & Management

Conventional Drainage

Shallow Drainage 2½-3 ft

Controlled Drainage
Could Shallower Be Better?

- Typical 4-ft Design
- Proposed 3-ft Design
SROC (Waseca) Drainage Spacing & Depth Study

2001 – Present
Drainage Designs in Study

Drain Spacing (ft) vs. Drain Depth (ft) for different values of Dc:
- **Dc = 0.5**
- **Dc = 2**
Volume x Drain Depth

Year

Tile depth = 4 ft
Tile depth = 3 ft
Precipitation
Volume x Drainage Coefficient

Drain coefficient = 2.0 in/day
Drain coefficient = 0.5 in/day

Year

Annual precipitation (in)
Annual drain volume (in)

2001s
2002c
2003s
2004c
2005s
2006c

Annual precipitation (in)

14.3% Precipitation
21.7%
20.5%
25.6%
29.8%
17.8%
N-Loss x Drain Depth

![Graph showing annual precipitation and nitrate loss for different tile depths and years.]

- Tile depth = 4 ft
- Tile depth = 3 ft
- Precipitation

### Annual Nitrate Loss (lb-N/acre)

<table>
<thead>
<tr>
<th>Year</th>
<th>Tile depth = 4 ft</th>
<th>Tile depth = 3 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001s</td>
<td>17.5%</td>
<td></td>
</tr>
<tr>
<td>2002c</td>
<td>29.7%</td>
<td></td>
</tr>
<tr>
<td>2003s</td>
<td></td>
<td>31.2%</td>
</tr>
<tr>
<td>2004c</td>
<td>5.2%</td>
<td></td>
</tr>
<tr>
<td>2005s</td>
<td>27.3%</td>
<td></td>
</tr>
<tr>
<td>2006c</td>
<td>34.1%</td>
<td></td>
</tr>
</tbody>
</table>

### Annual Precipitation (in)

- Year 2001: 60 in
- Year 2002: 60 in
- Year 2003: 50 in
- Year 2004: 60 in
- Year 2005: 60 in
- Year 2006: 60 in
N-Loss x Drainage Coefficient

![Graph showing annual nitrate loss (lb-N/ac) and precipitation (in) for different years and drainage coefficients.]

- **Drain coefficient = 2.0 in/day**
- **Drain coefficient = 0.5 in/day**
- **Precipitation**

Year:
- 2001s
- 2002c
- 2003s
- 2004c
- 2005s
- 2006c

Annual nitrate loss (lb-N/ac):
- 2.9%
- 15.5%
- 25.0%
- 25.6%
- 22.7%
- 18.1%

Annual precipitation (in):
- 0
- 20
- 40
- 60
- 80
- 100
- 120
Annual subsurface drainage depth (in)

Flow-weighted nitrate concentration (ppm)

Annual nitrate leaching loss (lb-N/ac)

Tile depth = 4 ft

Tile depth = 3 ft

22.5%

0.7%

22.0%

a

b
Annual subsurface drainage depth (in) | Flow-weighted nitrate concentration (ppm) | Annual nitrate leaching loss (lb-N/acre)

Drainage coefficient = 2.0 in/day

Drainage coefficient = 0.5 in/day

21.4%  0.9%  18.8%

18.8%
Drain Depth and Crop Yield

Combine Yield Monitor

- Tile depth = 4 ft
- Tile depth = 3 ft

Annual rainfall (in)
Crop yield (Bu/ac)

Year
2001S
2002C
2003S
2004C
2005S

Crop yield (Bu/ac)

0.4%
0.7%
0.2%
3.3%
0.3%

Annual rainfall (in)

0
30
60
90
120
150
2001-2005 Crop Yields

Combine Yield Monitor

Crop yield (Bu/ac)

<table>
<thead>
<tr>
<th></th>
<th>Corn</th>
<th>Soybean</th>
<th>Corn</th>
<th>Soybean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage Depth</td>
<td>2.1% ± 0.3%</td>
<td>5.4% ± 0.2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drainage Coefficient</td>
<td>0.3% ± 0.2%</td>
<td>5.4% ± 0.2%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Summary & Conclusions

- 15-30% reductions in drain flow observed
  - 6-year results ~ 22%

- 0-30% reductions in N-loss observed
  - 6-year results ~ 18%

- Impacts to crop yields appear small to none

- Shallow drainage will need incentives (spacing)

- More work needed to determine C/B for backing off drainage intensity (DC)
Where to Get More Info
The Agricultural Drainage series covers topics including basic concepts, planning and design; surface waters; economics; environmental impacts; wetlands; and legal issues.

The growing use of artificial subsurface or "tile" drainage in Minnesota and across the U.S. has sparked much debate about its impact on local hydrology and water quality. These discussions are typically focused on the following topics:

- Does subsurface drainage lessen or worsen localized flooding?
- Are catastrophic floods more frequent because of subsurface drainage?

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SUBSURFACE DRAINAGE

Artificial subsurface drainage systems are common in Minnesota, as well as in other states and countries around the world. Subsurface drainage systems are the practice of placing perforated pipe at a specified depth below the soil surface. Excess water from the crop root zone can enter the pipe through the perforations and flow away from the field to a ditch or other outlet. Subsurface drainage systems increase the productivity of poorly drained soils by lowering the water table, providing greater soil aeration, and enabling faster soil drying and warming in the spring. This may allow fields to be planted earlier and other field operations to take place in a timely fashion. It also provides a better environment for crop emergence and early growth, and can reduce soil compaction. Once a crop has been established, subsurface drainage greatly reduces the risk of crop water stress from the amount of water available, and can help prevent salt accumulation. These subsurface-drained soils represent the most productive soils worldwide.

Does subsurface drainage alter the q in a river basin?
- Does subsurface-drained soils respond "spongily" to excess rainfall, as compared to drained soils?
- How do surface inlets (intakes) affect the quality of drainage flow?
- How do artificially drained lands impact water quality?

Planning an Agricultural Subsurface Drainage System

Many soils in the Upper Midwest, as well as the region, experience high water tables that can interfere with crop growth. Saturated soils can provide sufficient oxygen for crop roots, but they can also reduce the ability of the soil to supply water and nutrients to the plant. Soil conditions that are too wet can negatively impact some agricultural lands and can limit the productivity of crops. Planning an effective drainage system takes time and requires consideration of a number of factors, including:

- Local, state, and federal regulations
- Soil information
- Wetland impacts
- Adequacy of existing systems
- Field elevation, slope (grades), and topography assessment
- Economic feasibility
- Present and future cropping strategies
- Environmental impacts associated with drainage discharge
- Land uses and right-of-ways
- Quality of the installation

The U.S. Department of Agriculture (USDA) Farm Bill of 1985, 1988, and 1990 created several special wetlands restrictions and mandates that all drainage projects, including smaller infrastructure systems, must follow. It is also very important that the landowner, system designer, and contractor understand other applicable federal laws, as well as the local watershed and state laws dealing with drainage. People considering installation of a new drainage system should also know their rights and responsibilities concerning the removal of water from land and its transfer to other land. So the first steps of any installation project should always include visits to the offices of the Soil and Water Conservation District (SWCD), the Natural Resources Conservation Service (NRCS), and the local watershed administrative unit.

While developing a drainage plan and specifications, it is useful to consult a number of information sources. These include county soil and site topography surveys, the Minnesota Drainage Guide, local drainage experts, Farm Service Agency aerial photos, and lists and discussion of subsurface drainage management authorities. It's also a good idea to do some surface and subsurface evaluation of a field.

ECONOMICS

To decide whether a new drainage system is needed, or if there is an existing system, it's important to determine or estimate the following: (1) the cost of installation; (2) the impact of the system on the soil and water quality; and (3) the impact of the system on the economics of the operation. The cost of installation includes the cost of the drainage system, the cost of labor, and the cost of materials. The impact of the system on the soil and water quality includes the effects of the drainage system on the soil and water quality, the effects of the drainage system on the economics of the operation, and the effects of the drainage system on the value of the land. The cost of installation is the sum of the installation cost and the cost of materials.
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