Drainage Water Management Implementation Costs

Abstract

Joanna E. Allerhand
James A. Klang, P.E.
Mark S. Kieser

KIESER & ASSOCIATES
ENVIRONMENTAL SCIENCE & ENGINEERING
536 E. Michigan Ave, Suite 300
Kalamazoo, MI 49007
www.kieser-associates.com

Build-up of the current agricultural drainage network began during the 1870s as part of a national land reclamation policy. Since then, drainage has been both criticized and praised. Overall, agricultural drainage enabled previously marginal land to become highly productive and profitable farmland.[i] However, intense drainage also contributed to negative environmental impacts, including substantial losses of wetlands and wildlife habitat.[ii]

Subsurface drainage lines act as conduits of nitrate – the mobile form of nitrogen – to surface waters. Under natural conditions, nitrate-laden water passes through the soil profile and is removed, at least partially, through denitrification. In fields with subsurface drainage, tile lines intercept the water before denitrification can occur. As a result, subsurface drainage effluent contributes to excess nitrate loading to surface waters, which can lead to water quality impairments.[iii] Figure 1 illustrates the estimated extent of subsurface drainage.[iv]

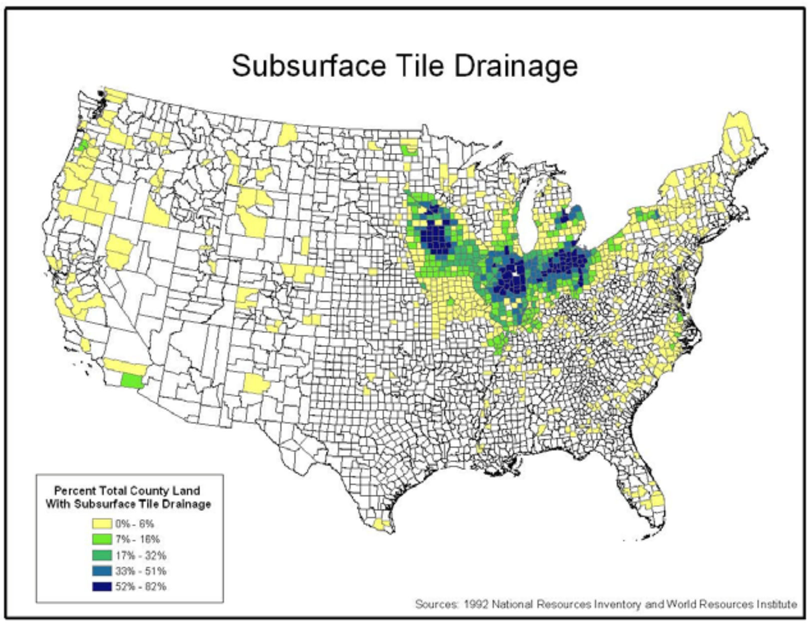

Figure 1. Extent and location of subsurface drainage, as estimated by Sugg, 2007.[iv]

Nitrate export through tile lines can be reduced by implementing drainage water management (DWM). One such practice involves installing a device that controls the volume of water leaving a field. These controlled drainage devices can be adjusted based on the season and drainage needs. The control device can adjusted such that water tables drop prior to planting to allow the fields to become sufficiently dry for equipment access. Subject to producer desires and time constraints, the device can be used to adjust water levels throughout the growing season. Then after harvest, the water level is raised to minimize drainage during the non-cropping season.

DWM reduces nitrate export by reducing the drainage volume from tile drain outlets as opposed to reducing the concentration of nitrate in the effluent. Most of the nitrate reductions from DWM systems occur when drain flow is reduced during the non-cropping season. In humid temperate regions, approximately 88 to 95-percent of nitrate loss through conventional tile drainage occurs during the fallow period.[v] DWM systems allow the producer to raise the drainage outlet and bring the water table near the surface, thus reducing flow volume and nitrate losses during the non-cropping season.

DWM implementation has been shown to substantially reduce nitrate losses from farm fields, thereby contributing to water quality improvements. Jaynes *et al.*[vi] estimated DWM could be implemented on 11.9 million acres of cornland in the Midwest. Of these lands, 7.2 million acres were located in the Upper Mississippi and Tennessee/Ohio watersheds, which drain to the Gulf of Mexico. Within these watersheds, DWM could reduce nitrate-N loading to the Gulf by 114.4 million pounds.[vii] This amounts to a reduction of 15.97 lb/acre. From 2001-2005, an average of 1.8 billion pounds of nitrate-N per year were transported to the Gulf.[viii] Based on this loading estimate and the DWM reduction estimate of 114.4 million pounds from Jaynes *et al.*, implementing DWM on all suitable lands in the Upper Mississippi and Tennessee/Ohio watersheds could reduce overall nitrate loading to the Gulf by 6.4%.

Costs of implementing DWM vary based on site characteristics, drainage system design, and the type of control structure installed. One study estimated costs could range from $65/acre for a new installation on a 6-inch main to $88/acre for a retrofit on a 12-inch main.[ix] Annualizing these costs based on a 15-year lifetime and a 19.8-acre treatment area, estimated costs ranged from $6.73/year on a 6-inch main and $9.08/year on a 12-inch main.[x] Cooke *et al.*[xi] estimated $20-$40/acre for a retrofit installation and $89/acre for a new system in complex topography. Assuming a 30-percent nitrogen load reduction, the costs for a retrofit would be $0.66/lb to $0.93/lb and the costs for a new installation would be $2.86/lb to $4.17/lb.[xii] Jaynes *et al.*[xiii] estimated a cost of $1.23/lb when the costs were applied over a 20-year lifetime at a 4% interest rate, and found this price to be cost-competitive with other nitrogen removal practices. For example, constructed wetlands cost $1.48/lb, fall cover crops cost $5.02/lb, and bioreactors cost $1.08/lb to $6.88/lb.[xiv] Advances in technology are likely to reduce the cost of DWM implementation.

A simple analysis was conducted to estimate the cost of DWM under various scenarios and assumptions. Whereas the estimated cost of $1.23/lb from Jaynes *et al.*[xv] was for a 20-year period, the analysis conducted here uses similar assumptions but only considers upfront capital costs for a one-year period. Jaynes *et al.* determined that 7.2 million acres of cornland in the Upper Mississippi and Tennessee/Ohio watersheds were suitable for DWM. Within these areas, 20-percent of DWM implementation would be retrofits and 80-percent would be new installations[xvi]. A retrofit was assumed to drain 11.86 acres while a new installation would drain 19.77 acres. Both the new and retrofit practices had a unit cost of $1,100, and new installations included an additional cost of $32.53/acre[xvii]. Applying these assumptions, a basic analysis indicated the total cost of implementing DWM on 7.2 million acres of suitable cornland in the Upper Mississippi and Tennessee/Ohio watersheds would be $638 million ($89/acre). The cost of retrofit installations would be $133 million ($93/acre) and the cost of new installations would be $505 million ($88/acre). The unit costs of nitrate-N reductions achieved by implementing

DWM on all suitable cornland in the Upper Mississippi and Tennessee Ohio watersheds would be $5.81/lb for retrofits and $5.52/lb for new installations, with a weighted average of $5.58/lb. These are based only on initial capital costs and one year of nitrate-N reductions. The unit costs for a 5, 10, and 20-year project lifetime are estimated to be $1.24/pound, $0.67/pound, and $0.37/pound, respectively, using a 4% discount rate and assuming operation and maintenance are 2.5% of the capital costs.

DWM implementation costs potentially could be offset by a yield increase or covered through a water quality trading (WQT) program. Any potential yield increase would depend on the specific application of controlled management. A yield increase of 1.68 bushels/acre for a 6-inch main and 2.27 bushels/acre for a 12-inch main would offset the control structure expense, assuming $4/bushel corn.[xviii] A WQT program could provide producers with a method of payment for implementing DWM. With the adoption of nutrient criteria, some municipal wastewater treatment plants (WWTPs) will be required to reduce nitrogen discharges. These plants could meet their regulatory compliance goals by purchasing nitrogen reduction credits from producers implementing DWM. In many cases, nitrate reductions achieved through DWM would be highly cost-effective compared to achieving reductions through WWTP upgrades.

Drainage water management (DWM) can be an effective strategy for reducing nitrate losses from farm fields. DWM structures allow the producer to control the water level in the soil. When the level is raised during the fallow period, substantial reductions of nitrate loading to surface water can be achieved. The costs of DWM can be competitive with other management strategies.

- ***7.2 million acres*** *of Midwest cornland is suitable for DWM in the Upper Mississippi and Tennessee/Ohio watersheds*
- ***1.43 million acres*** *of this cornland* ***(20%)*** *could be served by retrofits and* ***5.73 million acres (80%)*** *by new installations*
- ***114.4 million pounds*** *nitrate-N could be reduced if DWM was implemented on all 7.2 million acres*
- *DWM could reduce nitrate losses by* ***nearly 16 pounds/acre***
- *Total costs of implementing DWM on all 7.2 million acres would be* ***$638 million ($133 million for retrofits*** *and* ***$505 million for new installations****)*
- *Retrofit costs are estimated to be* ***$93/acre,*** *and new installations are* ***$88/acre,*** *with a regional* ***weighted average of $89/acre***
- *First year nitrate-N reductions from DWM using only capital costs are estimated to be* ***$5.58/pound (weighted average); $5.81/pound (retrofits), and $5.52/pound (new installations)***
- ***Nitrate-N reduction costs for a 5, 10, and 20-year project lifetime are estimated to be $1.24, $0.67, and $0.37/pound, respectively.***

(These numbers are derived from Jaynes, D.B., K.R. Thorp, D.E. James (2010) Potential Water Quality Impact of Drainage Water Management in the Midwest USA. Proceedings of the 9th International Drainage Symposium held jointly with CIGR and CSBE/SCGAB, June 13-16, 2010, Quebec City, Canada.)

[i] Strock, J.S., P.J.A. Kleinman, K.W. King, J.A. Delgado (2010) Drainage water management for water quality protection. *Journal of Soil and Water Conservation* 65(6): 131A-136A; and
USDA. Pavelis, G. A., Ed. (1987) *Farm Drainage in the United States: History, Status, and Prospects*. USDA-ERS Miscellaneous Publication Number 1455. Washington, DC.
[ii] USDA, 1987
[iii] Dinnes, D.L., D.L. Karlen, D.B. Jaynes, T.C. Kaspar, J.L. Hatfield (2002) Review and Interpretation: Nitrogen Management Strategies to Reduce Nitrate Leaching in Tile-Drained Midwestern Soils. *Publications from USDA-ARS / UNL Faculty. Paper 263*. Accessed January 31, 2012 at http://digitialcommons.unl.edu/usdaarsfacpub/263;
Mitsch, W.J., J.W. Day, J.W. Gilliam, P.M. Groffman, D.L. Hey, G.W. Randall, N. Wang (2001) Reducing nitrogen loading to the Gulf of Mexico from the Mississippi River Basin: Strategies to counter a persistent ecological problem. *BioScience*, 51(5): 373-388; and
Randall, G.W., D.J. Mulla (2001) Nitrate nitrogen in surface waters as influenced by climatic conditions and agricultural practices. *Journal of Environmental Quality*, 30:337-344.
[iv] Sugg, Z. (2007) Assessing U.S. Farm Drainage: Can GIS Lead to Better Estimates of Subsurface Drainage Extent? World Resources Institute, Washington, D.C. Accessed January 20, 2012 at http://pdf.wri.org/assessing_farm_drainage.pdf.
[v] Drury, C.F., C.S. Tan, W.D. Reynolds, T.W. Welacky, T.O. Oloya, J.D. Gaynor (2009) Managing Tile Drainage, Subirrigation, and Nitrogen Fertilization to Enhance Crop Yields and Reduce Nitrate Loss. *J. Environ. Qual.* 38:1193-1204.
[vi] Jaynes, D.B., K.R. Thorp, D.E. James (2010) Potential Water Quality Impact of Drainage Water Management in the Midwest USA. Proceedings of the 9th International Drainage Symposium held jointly with CIGR and CSBE/SCGAB, June 13-16, 2010, Quebec City, Canada.
[vii] Jaynes *et al.*, 2010
[viii] EPA (2007) Hypoxia in the Northern Gulf of Mexico: An Update by the EPA Science Advisory Board. EPA-SAB-08-003, USEPA, Washington, D.C.
[ix] Agricultural Drainage Management Coalition [ADMC] (2011) Drainage Water Management for Midwestern Row Crop Agriculture. Conservation Innovation Grant 68-3A75-6-116 Report.
[x] ADMC, 2011
[xi] Cooke, R.A., G.R. Sands, and L.C. Brown (2005) Drainage water management: A practice for reducing nitrate loads from subsurface drainage systems. pp. 27-34. Proceedings of the Gulf hypoxia and local water quality concerns workshop. Sept. 26-28, 2005, Ames, Iowa.
http://water.epa.gov/type/watersheds/named/msbasin/upload/2006_8_24_msbasin_symposia_ia_session2.pdf.
[xii] Cooke et al., 2005
[xiii] Jaynes, D.B., K.R. Thorp, D.E. James (2010) Potential Water Quality Impact of Drainage Water Management in the Midwest USA. Proceedings of the 9th International Drainage Symposium held jointly with CIGR and CSBE/SCGAB, June 13-16, 2010, Quebec City, Canada.
[xiv] Jaynes *et al.*, 2010
[xv] Jaynes *et al.*, 2010
[xvi] Personal correspondence (2012) with D.E. Jaynes confirmed that new and retrofit installations were assumed to have equivalent reduction efficiencies.
[xvii] It was not specified by Jaynes *et al.* (2010) as to how they derived these annualized costs for nitrate reductions associated with DWM. As such, some of the numbers included here differ from those reported by Jaynes *et al.* (2010). The cost analysis could be adjusted to include data that might better represent the current status of DWM technologies.
[xviii] ADMC, 2011