Questions and Answers About Drainage Water Recycling in the Midwest.

Jane Frankenberger
Purdue University

Benjamin D Reinhart
Purdue University

Kelly A. Nelson
University of Missouri

Mohamed A. Youssef
North Carolina State University

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Jane Frankenberger, Ben Reinhart, Kelly Nelson, Laura Bowling, Chris Hay, Mohamed Youssef, Jeff Strock, Xinhua Jia, Matt Helmers, Barry Allred

WHAT IS DRAINAGE WATER RECYCLING?

Drainage water recycling is the practice of capturing excess water drained from fields, storing the drained water in a pond, a reservoir, or a drainage ditch, and using the stored water to irrigate crops when there is a water deficit. Relative to conventional drainage, drainage water recycling has two major benefits: (1) increased crop yield and (2) improved downstream water quality.

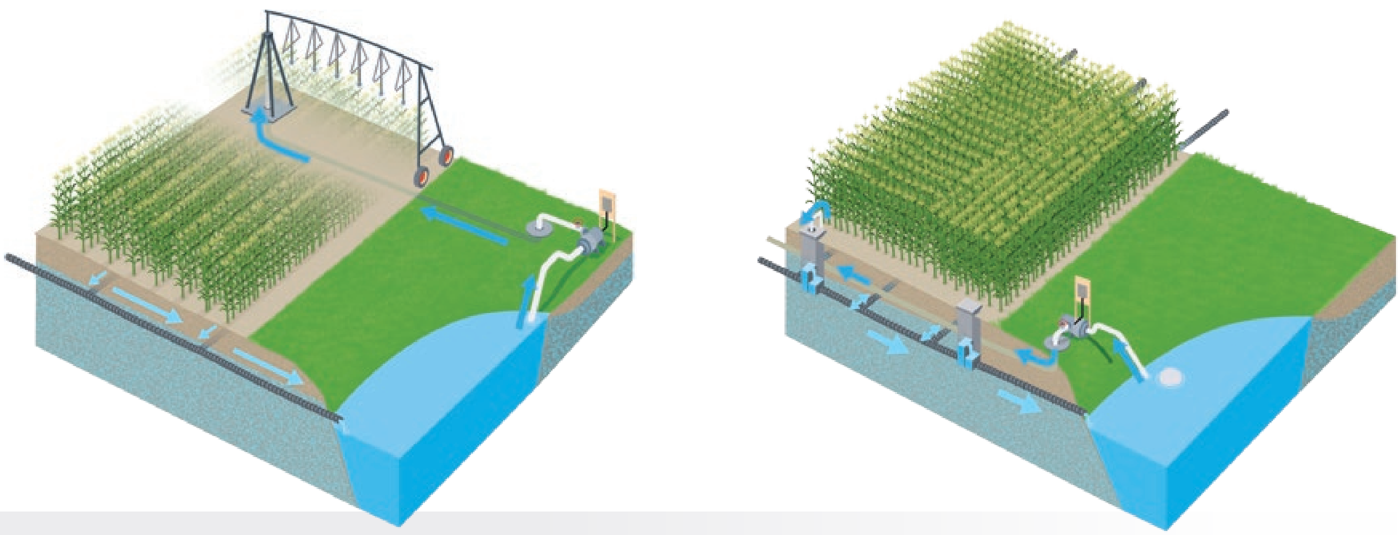


Figure 1: *A drainage water recycling system consists of storing drainage water in a pond, which is then used for field irrigation. Irrigation methods vary with site conditions and may include overhead irrigation (left) or subirrigation (right).*

Although precipitation in the Midwest is generally plentiful, the timing and amount do not always coincide with crop water needs. Drainage occurs mostly in the spring due to excess precipitation, while crop water use in mid- to late summer may result in periods when available water is insufficient. Storing drainage water can provide value to crops during periods when crop water needs exceed available soil water. The practice can also provide an opportunity for irrigation where certain limitations exist, such as inadequate water supplies or poor water quality.

Water quality also benefits from this system, because drained water, which typically contains nitrogen, phosphorus, and potentially other contaminants that can harm downstream water, is diverted into the water storage pond instead. Storing and recycling drainage water for beneficial use on crops prevents it from causing water quality problems, such as algae blooms in Lake Erie or hypoxia in the Gulf of Mexico.

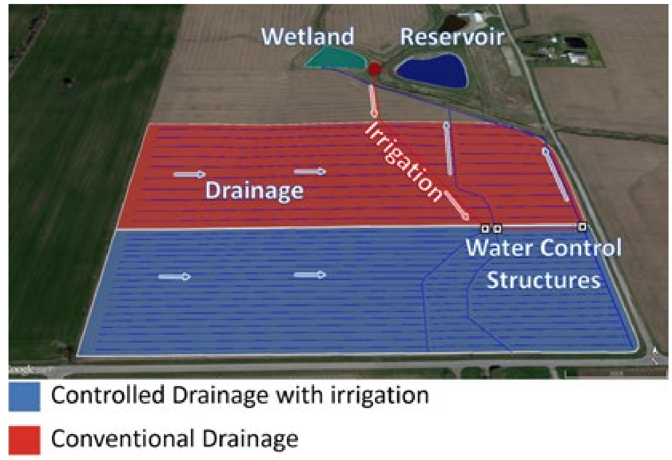
Drainage water recycling can be a closed loop system where the drained water from a field is recirculated onto the same field, or water drained from one field can be used to irrigate a different field. Irrigation may be through subirrigation that raises the soil water table by adding water to the subsurface drain tiles, sprinkler irrigation systems, drip irrigation, or other technologies.

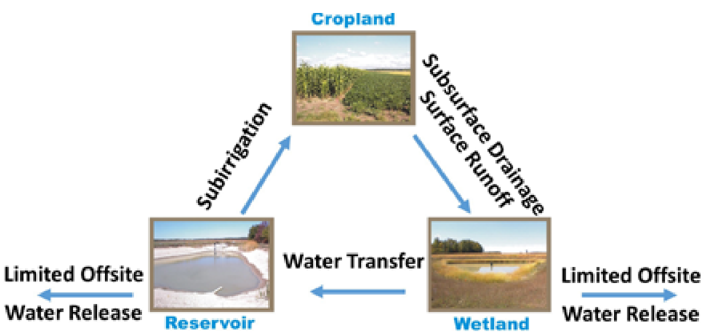
Two Examples of Drainage Water Recycling

OHIO

Limited research has been published on drainage water recycling systems. Examples in this publication draw from systems in Ohio and Missouri, and journal articles reporting these findings are listed in the "References" section.

In Ohio, three drainage water recycling systems installed in the 1990s included water storage and irrigation, and also a wetland for water treatment. These systems, known as Wetland-Reservoir-Subirrigation Systems, or WRSIS, showed substantial crop yield increases over a paired non-irrigated field, especially in dry years, (References 1, 2) in addition to water quality benefits (3) and providing wetland habitat (4).



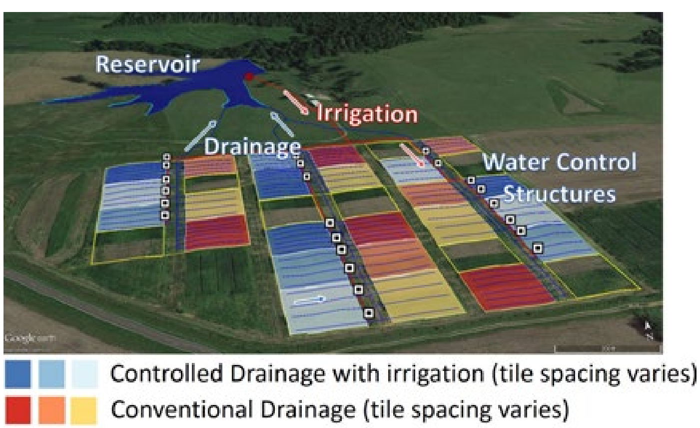


Above: *At the Ohio Wetland Reservoir Subirrigation System (WRSIS) located in Fulton County, drainage water from the field enters the wetland and then the reservoir, and the water is later used for irrigation by pumping back to water control structures.*

Left: *The addition of a wetland to the drainage water recycling system provides additional water treatment and beneficial habitat, but adds to the cost of the system.*

MISSOURI

In Missouri, a reservoir originally constructed for livestock watering has been used as a closed-loop system to capture drainage water, in a system known as the Missouri University Drainage and Subirrigation (MUDS). The captured water is pumped from the reservoir to water level control structures that allow for subirrigation through the subsurface drainage system. This system also collects surface water runoff to help recharge the reservoir and maintain an adequate water supply. Significant yield benefits have been observed and were affected by management of varieties, fertilizers, and pesticides (5-9).



Missouri drainage water recycling system. The reservoir in the top left stores drainage water and is used for irrigation of 32 research plots.

Storage reservoir and irrigation pump at the Missouri site.

HOW MUCH CROP YIELD INCREASE CAN BE EXPECTED FROM DRAINAGE WATER RECYCLING?

Crop yield benefits can be expected to be similar to those generally expected from adding supplemental irrigation in a humid region such as the Corn Belt. At three Ohio sites (described on page 2), the average corn yield increase in subirrigated fields over 37 site-years was 19%, with a 29% increase in dry years, while soybean increase was 12% overall and 25% in dry years. Drain spacing was narrower in the irrigated fields, so the yield increase resulted not only from supplemental irrigation, but also from improved soil drainage efficiency.

After 14 years of operation at the Missouri site described on page 2, drainage water recycling increased average corn yields over 20 bu/acre (> 15%) when compared with subsurface drained soil. Soybean yields have been 3 bu/acre (6%) greater than subsurface drainage only. Wet conditions in the spring can limit root growth, and crops respond strongly to drainage as well as irrigation.

In a drainage water recycling system, the volume of water in the water storage pond may limit water available for irrigation. In the Ohio study, there was plenty of irrigation water at two of the sites, while the pond volume limited irrigation at one site. At the Missouri site, the subirrigation system applied 0.3 to 5 inches of water during 2004-2007 to maintain target water table levels throughout the season.

Figure 2: *At the Missouri site, water recycling through a subsurface drainage system (left) increased yields compared to non-drained soil (right) in the drought of 2012.*

HOW DOES IT BENEFIT WATER QUALITY?

Drainage water recycling systems improve water quality in two ways, illustrated in Figure 3. The first way is by capturing drain flow before it leaves the field, which is the difference between flow into the pond (Point A, Figure 3) and into the ditch (Point B, Figure 3). Because tile drainage can have high concentrations of nitrate and some phosphorus, recycling the nutrients contained in the drainage water back into the field where the crop can use them provides a water quality benefit.

Example: A system that captures and stores 3 inches of drain flow, with a concentration of 15 parts per million (ppm) nitrate-N and 0.5 ppm phosphorus, can prevent 20 lbs. of nitrate and 0.6 lbs. of phosphorus per acre from reaching downstream waterways. If this system drains 160 acres (Figure 3), it could reduce downstream loads by more than 800 lbs. of nitrate and 27 lbs. of phosphorus/year.

The second way drainage water recycling can improve water quality is through natural removal processes present in the pond itself, such as settling and denitrification. At one of the Ohio sites, wetland field tests showed that natural processes could remove 28% of the nitrate present in the drainage inflow (Reference 3).

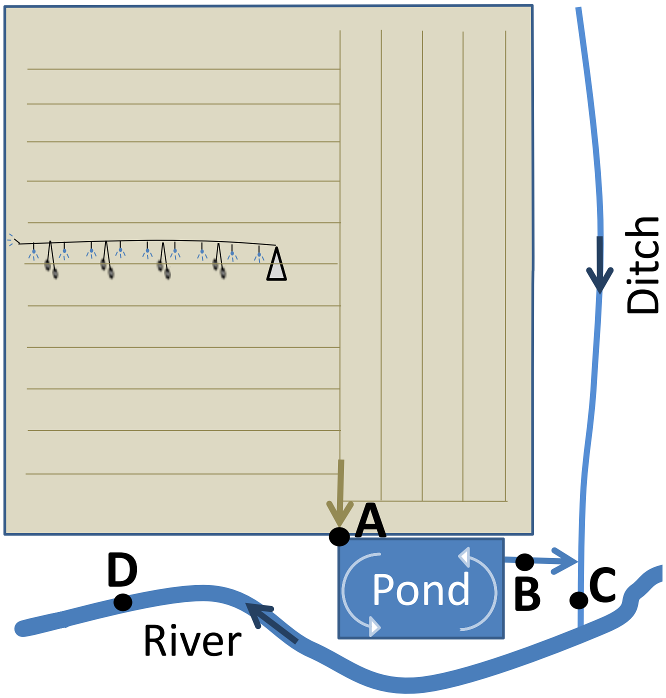


Figure 3: *Example 160-acre field drains to a pond and is irrigated by pond water. Water quality is improved both because the water captured in the pond is recirculated into the field rather than discharging into waterways, and because processes in the pond may reduce nutrients.*

HOW LARGE DOES THE POND NEED TO BE?

Ponds can be sized based on either the desired irrigation water availability, or amount of drain flow and runoff to be stored. Irrigation needs are typically calculated based on the difference between crop water needs and the water provided by precipitation that is stored in the soil root zone. In humid areas where crops are usually rainfed (not irrigated), much of the crop water need is provided by precipitation and soil moisture storage in most years. For example, corn uses approximately 18-20 inches of water during the 5-month growing season (Reference 10), while precipitation in the growing season ranges from 14 to 24 inches. Supplemental irrigation that provides 5 inches of water could significantly improve crop yields in some years, and even 3 inches will provide crop yield benefits in many years (Figure 4). If runoff or drainage occurs after the irrigation has begun, additional water will be available. Some water in the pond will be lost through evaporation and seepage. Deeper ponds will lose a smaller percent of their volume through these pathways.

For initial planning purposes, the minimum pond volume needed can be estimated by multiplying the number of inches of irrigation water to be stored by the area of the field.

$$PV = FA * ID \qquad \textit{(Equation 1)}$$

where PV = pond volume, FA = field area, and ID = irrigation depth. Using acre-feet for volumes simplifies these calculations.

For example, the pond volume needed to provide 3 inches (= 0.25 feet) of irrigation water to 80 acres is 20 acre-feet. Final pond design would need to account for all inputs (e.g., drainage, runoff, groundwater) and losses (e.g., irrigation or other withdrawals, seepage, and evaporation).

The pond area needed for this pond volume depends on the average depth

$$PA = PV/PD \qquad \textit{(Equation 2)}$$

where PA=pond area and PD=pond depth. For example, the pond area and pond depth for a pond volume of 20 acre-feet could be any of the following:

- 20 acre area with an average depth of 1 foot
- 4 acre area with an average depth of 5 feet
- 1 acre area with an average depth of 20 feet.

Practical pond depths vary by site, but depth can be greater by including a portion of storage above ground, if the spoil dug out of the pond is used to form an embankment.

An alternative basis for pond sizing is to estimate the available drain flow and runoff, which vary widely across the Midwest, from a few inches or less in the west to more than 12 inches in the east. Basing the volume on average runoff availability is standard pond design practice (for example, Reference 11).

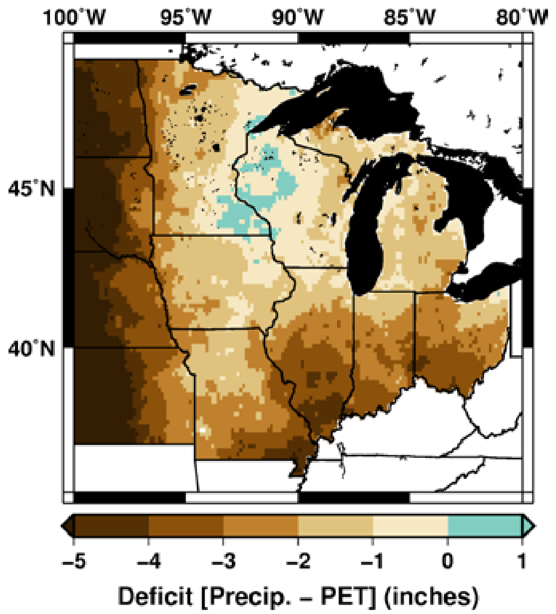


Figure 4: *Average July-August water deficit (1981-2010), calculated as the difference between precipitation and potential crop water demand for corn (PET). Supplemental irrigation could provide a crop benefit in many years. (Image by C. Lee and L. Bowling, Purdue University).*

Figure 5: *Pond volume is calculated from the irrigated area and depth of irrigation needed. This irrigation pond in Michigan is about 20 feet deep.*

WHAT WILL THE POND LEVEL BE THROUGH THE YEAR?

The pond is likely to be full of water in the spring after recharge from winter rain or snowmelt and spring rain. As water is used for irrigation starting in midsummer, the water depth will go down. If the pond is large enough to hold more than the irrigation amount needed, water can be stored throughout the year to provide aesthetic benefits and recreational opportunities, such as fishing and wildlife habitat. Figure 6 shows typical pond water levels.

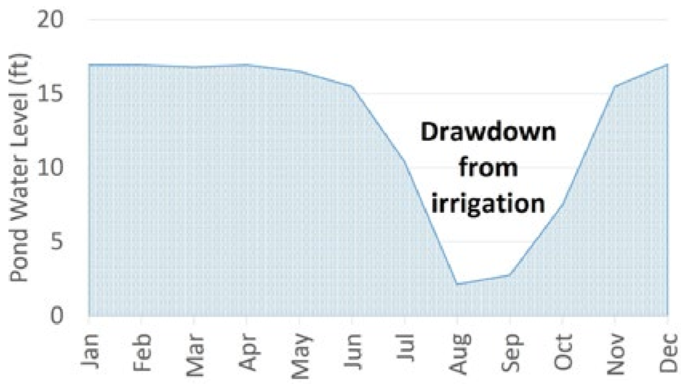


Figure 6: *Pond water level is highest in spring and lowest during the summer irrigation season.*

CAN IT REDUCE DOWNSTREAM FLOODING?

Drainage water recycling has the potential to reduce high flows downstream, during times when storage volume is available in the pond. This occurs when the pond level has been drawn down due to irrigation (Figure 6). If the pond level is drawn down more frequently, including during the high flow season (Figure 7), the potential for high flows to be buffered by water storage in the reservoir increases. The volume available in a few ponds may be significant in the ditch immediately downstream of the pond (Point C, Figure 3), but this is unlikely to make a substantial impact in a stream or river downstream (Point D, Figure 3) unless ponds are constructed throughout the watershed.

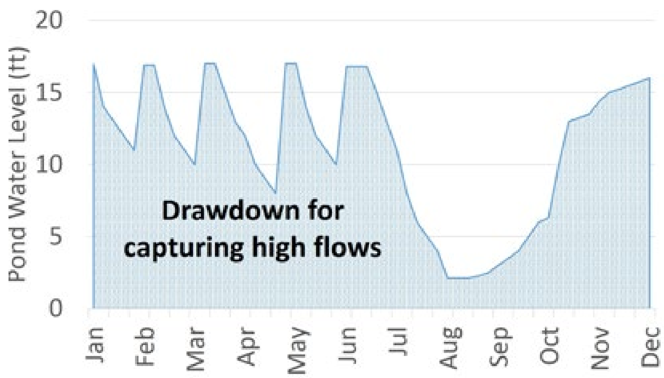


Figure 7: *If the pond level is frequently drawn down, storage is available to reduce high flows.*

WHAT ARE THE COSTS?

A drainage water recycling system includes numerous components. If any of these already exist, such as a pond previously created for a different purpose, costs will be reduced.

TYPE OF COSTS	INFLUENCES ON COST
Pond construction	Costs vary with size and the amount of earth that needs to be moved. Ponds in sloping areas cost less than in flat areas. $1,000 to $3,000 per acre-foot is a rough estimate.
Conveyance and pumping into the pond	If gravity flow is not possible into the pond, water may need to be pumped.
Irrigation system	Costs depend on the type of system (subsurface, sprinkler, etc.), field size and shape, and energy available, among other factors.
Land taken out of production	Cost depends on land value and alternative uses. Often 5% to 10% of the field area is needed for the pond.
Additional costs	Design costs, inlet and outlet flow control structures, and labor should also be considered.

WILL IT BE PROFITABLE?

Drainage water recycling systems are likely to be costly, but the large costs can be offset by the expected long-term yield increases due to irrigation, and also by payments for the public benefits that may be available. These may include Farm Bill programs such as EQIP, payments for flood control benefits, and nutrient trading or other market-based programs.

CAN IT BE USED FOR RECREATION?

Ponds and reservoirs can provide opportunities for recreation and enjoyment, depending on the size, location, and management of the system. Ponds that are deep enough and can maintain adequate water levels are often stocked with fish to provide recreational opportunities. Waterbodies located next to natural areas, or developed and managed in a way to support wildlife, may offer opportunities for hunting, birdwatching, camping, etc.

These ponds are designed to capture runoff and drainage from surrounding lands, and may not be suitable for swimming due to water quality concerns. If full-contact water activities are planned, water quality monitoring is recommended to ensure state water quality standards for recreation and use are met.

Figure 8: *Ponds can provide recreation opportunities.*

WILL IT BE HELPFUL TO WILDLIFE?

Drainage water recycling ponds can provide valuable habitat for wildlife. These ponds can serve as both a water source and transitional edge between agriculture and adjacent habitats that helps to increase landscape complexity and promote greater diversity in biological communities. Green sunfish, bluegill, largemouth bass, and black bullhead were documented in reservoir systems where water level was relatively stable and a permanent pool was provided (Reference 4). Reptiles and amphibians, such as frogs, salamanders, and turtles, can often be found in or near shallower wetland systems. Ponds and reservoirs with gently sloping banks, shallow water benches or shelves, and well-vegetated and protected shorelines will likely provide additional attraction for birds and other wildlife.

Figure 9: *Ponds can provide habitat for many types of wildlife.*

WILL THE WATER BE SUITABLE FOR IRRIGATION?

The pond water will contain nitrogen and phosphorus, which could provide benefits to the crop. However, other substances may also be in the pond. Pesticides applied to the field that drains into the pond could be a concern if the irrigation is applied to a crop not labeled for that product. This is not likely to be a problem if the water in the pond is drained from one field and recycled back onto the same field, but if several fields drain into the pond, there may be a potential for application to a crop that would be harmed. More research is needed to assess the risk. In general, risk should be less than if ditch water is used for irrigation. Other undesirable contributions, such as household wastewater from the drainage network or surface water runoff, should be considered when making the decision to implement a drainage water recycling system.

WHAT MANAGEMENT IS NEEDED?

Management of the drainage water recycling system will be required to ensure that water can be drained, captured, stored, and reapplied as needed to meet production and environmental goals. The table below lists some of the activities that will likely be required.

SYSTEM COMPONENT	POTENTIAL MANAGEMENT ACTIVITIES
Drainage system	Adjust water control structures if they are being used to manage water table depths.
Irrigation system	Track soil moisture and/or crop conditions to determine when irrigation is needed. Monitor water quality and quantities to maintain suitable conditions for irrigation and ensure a stable water supply throughout the growing season.
Pond	Maintain dams and levees; control shore and bank erosion. Control aggressive aquatic vegetation, particularly near pumping intakes and other infrastructure

In addition to these management activities, regular maintenance of system components will be required.

WHAT PERMITS ARE NEEDED?

Some permits will likely be needed to implement a drainage water recycling system. Types of permits that may be required are listed below. Many relevant regulations differ by state, so seek advice from local authorities.

1. If the site proposed for the pond is currently a wetland or stream, the Army Corps of Engineers (ACOE), which implements the federal Clean Water Act wetland regulations, will require a permit. However, farm ponds or irrigation ponds constructed on dry land (land that has been determined not to be a wetland) are explicitly exempted from Clean Water Act jurisdiction. It is therefore important to obtain a wetland determination from ACOE early in the process.
2. In addition to ACOE requirements, there may be state wetland regulations that apply.
3. Projects that capture water from large drainage areas (e.g. ≥ 1 sq. mi.) may require state permits related to construction in a floodway.
4. Dam construction may require a permit by state dam safety agencies.
5. Building and construction sites, particularly those more than 1 acre in size, may require a permit related to sediment and erosion control.
6. Local agencies may require a permit for pond construction in addition to state permits (e.g. zoning, regulated drainages). This varies widely by location.
7. Water withdrawal for irrigation may require a permit. In most of the Midwest (Minnesota, Iowa, Missouri and states further east), landowners are generally allowed to use water on or adjacent to their property, also known as riparian water rights, but water use is regulated differently in states further west.

CONCLUSION

Drainage water recycling is an innovative practice that can provide crop benefits through supplemental irrigation and may benefit water quality by limiting the release of nutrient-laden drainage water into streams. On-farm reservoirs can be managed by farmers, which enhances their control of their water supply and can provide long-term, sustainable food production.

This publication provides a broad overview of the benefits, costs, and other issues related to this practice. However, design and implementation of a drainage water recycling system will require much more information and site-specific analysis. Additional research is needed to address many questions that remain. Researchers across the Midwest are addressing these issues through a project called "Transforming Drainage", which conducts research, extension, and education to implement storage of drainage water and increase the resiliency of drained agricultural land.

FOR MORE INFORMATION

- The Transformation Drainage project, visit: *transformingdrainage.org*.
- Your local USDA Natural Resources Conservation Service office.
- Drainage and/or irrigation contractors.

AUTHORS

The authors of this publication are part of the **Transforming Drainage** project team, and the North Central Extension and Research Activity 217 (NCERA-217).

Jane Frankenberger, Agricultural and Biological Engineering, Purdue University

Ben Reinhart, Agricultural and Biological Engineering, Purdue University

Kelly Nelson, Plant Sciences, University of Missouri

Laura Bowling, Agronomy, Purdue University

Chris Hay, Environmental Programs and Services, Iowa Soybean Association

Mohamed Youssef, Biological and Agricultural Engineering, North Carolina State University

Jeff Strock, University of Minnesota Southwest Research & Outreach Center

Xinhua Jia, Agricultural and Biosystems Engineering, North Dakota State University

Matt Helmers, Agricultural and Biosystems Engineering, Iowa State University

Barry Allred, USDA-ARS Soil Drainage Research Unit, Columbus, Ohio

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