

ECONOMIC ANALYSIS OF DRAINAGE WATER RECYCLING

Opportunities for supporting
farm resilience and water quality



Environmental
Defense
Fund

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EXECUTIVE SUMMARY

Unpredictable, inconsistent weather—from heavy rain, to wind and hail, to persistent drought—have become the norm for Midwestern farmers. In 2019, excessive spring rains in the Mississippi River Valley flooded farmlands, causing nearly 20 million acres to go unplanted, resulting in yield and economic losses^[1]. Only four years later, weather patterns shifted to extreme drought conditions, causing more than \$16 billion in crop losses across the U.S., with the Midwest among the most significantly impacted regions^[2]. Increasingly, farmers must navigate these volatile and extreme weather patterns that can directly threaten agricultural productivity and profitability. In response, innovative solutions have emerged to help farmers adapt to these conditions.

Drainage water recycling (DWR) is one solution that presents a promising strategy to manage increasingly variable rainfall and enhance both yield resilience and farm economics.

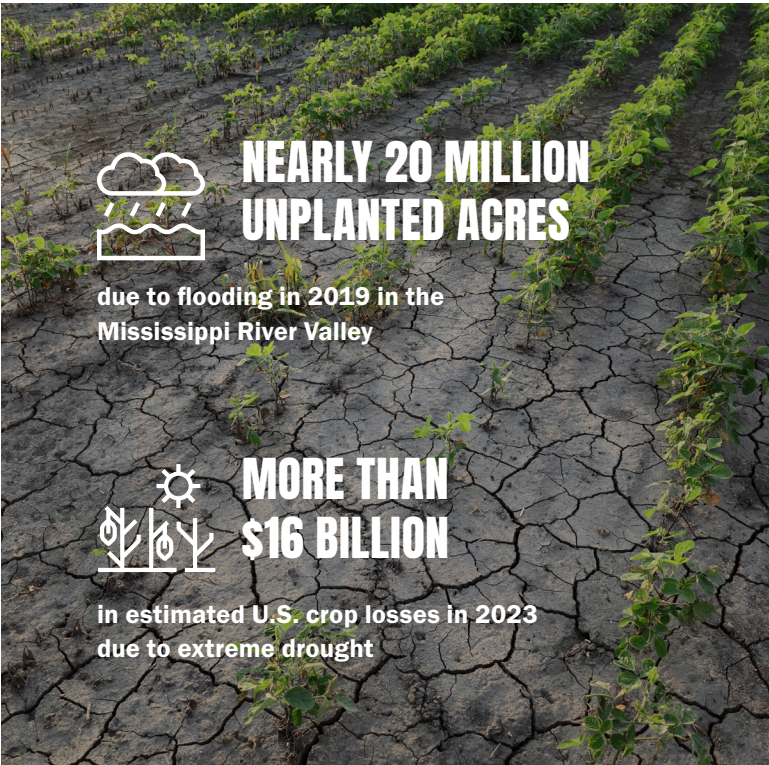


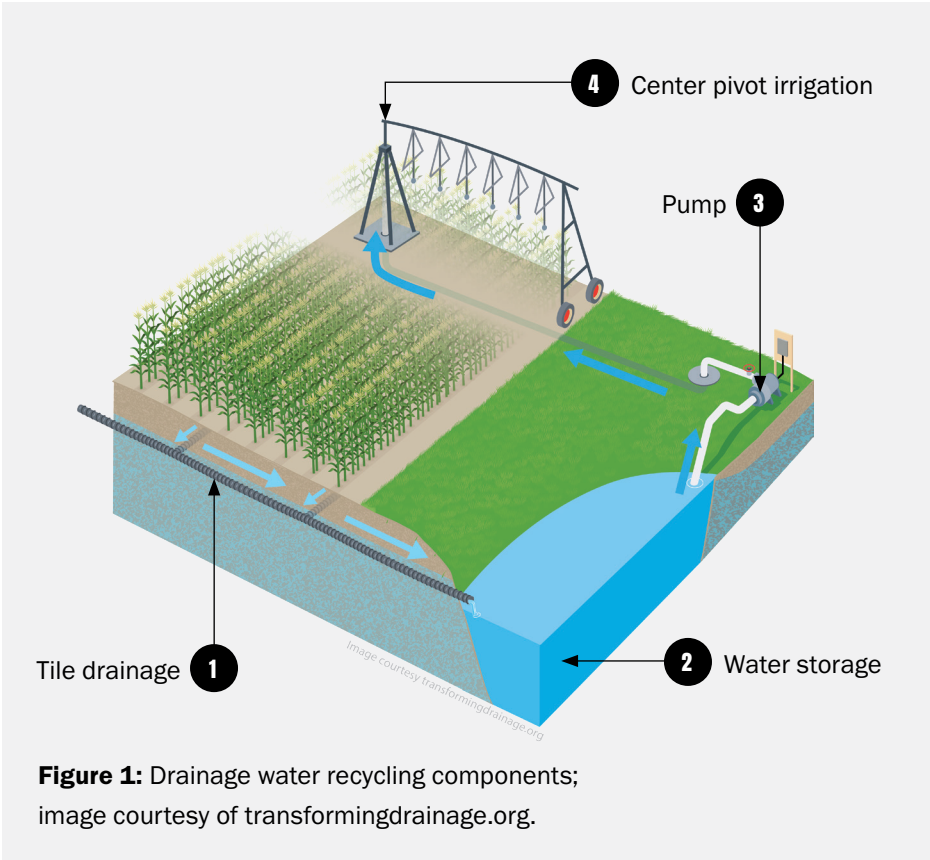
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This report evaluates drainage water recycling as a strategy to strengthen farm resilience by assessing its costs, benefits, and funding pathways.

Many farmers use water management systems, such as tile drainage, to remove excess water from the soil. **Drainage water recycling captures and stores this drained water and repurposes it for irrigation, supporting consistent crop production.** Drainage water recycling systems can be designed within a variety of drainage methods (surface, subsurface or both) and irrigation systems (such as center pivots and microirrigation). It should not be considered on previously undrained lands, as adding new tile drainage can result in negative environmental outcomes. Early data shows drainage water recycling also has the potential to enhance water quality through nutrient reduction from storing and recycling water. Additional water quality benefits can be achieved when practices such as wetlands, saturated buffers, and denitrifying bioreactors are incorporated into the operation.

Due to its complexity and scale, effective drainage water recycling implementation requires collaboration among farmers, landowners, and drainage districts to ensure these systems are practical and sustainable. Support from planners and public agencies is also important for successful implementation, aiding with site selection, technical resources, and possible public funding opportunities.

Although interest in drainage water recycling is growing, key questions remain about its cost, financial risk, and return on investment (ROI). This report was developed to address those gaps in financial information. The report evaluates drainage water recycling as a farm resiliency strategy and aims to provide cost and benefit data to inform effective funding models for implementation. Specifically, it quantifies drainage water recycling’s implementation costs, assesses its direct and indirect benefits, and explores potential funding pathways for implementation. The report focuses only on systems where tile drainage already exists, such as upgrading existing infrastructure to improve drainage capacity, due to the environmental risks associated with installing new tile drainage on previously undrained land.



A DWR system includes multiple components, as illustrated in Figure 1. Excess water is removed from agricultural fields with *subsurface tile drainage* 1 which outlets into a *water storage basin* 2. Later in the growing season, when there is a water shortage, a *pump* 3 moves the water through a *center pivot irrigation sprinkler* 4, to irrigate the crops.

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The analysis is based on data from four Midwest projects and an idealized 1,500-acre model site.

The study draws data from one planned and three existing drainage water recycling projects in the Midwest as well as a literature review. To illustrate economic implications, costs and benefits were estimated for an idealized model site representing a 1,500-acre drainage area with 125 to 155 irrigated acres and an appropriately sized storage reservoir.

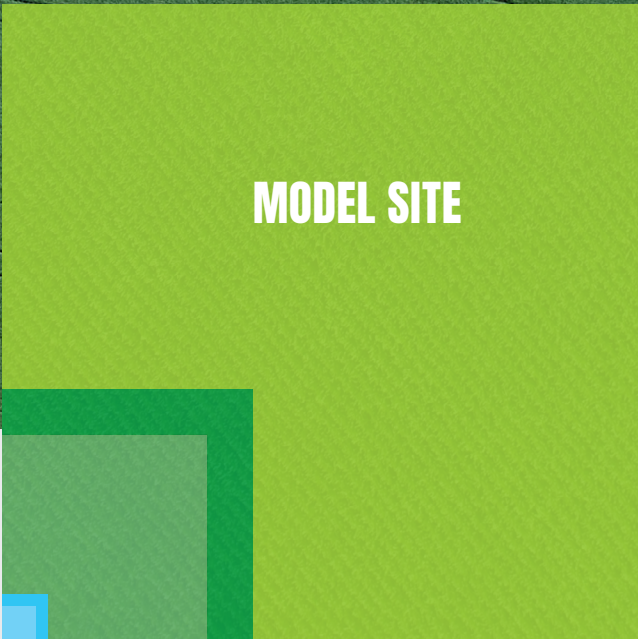


Figure 2: Model site.

- 1,500-acre drainage area
- 125-155 irrigated acres
- 42-78 acre-feet reservoir storage area

Acre-foot: One acre-foot is the amount of water that would cover an acre of land one foot deep.

Table 1: Implementation cost summary for site planning, design, construction, and ongoing operations and maintenance (O&M) for the model site.

Upfront	Cost Range	
	Minimum	Maximum
Drainage improvements	\$1,237,500	\$1,939,500
Design, planning, and site development	\$102,500	\$195,000
Site investigation	\$14,750	\$24,250
Storage land acquisition	\$120,000	\$120,000
Storage construction	\$225,000	\$706,000
Natural infrastructure	\$2,500	\$20,000
Irrigation systems	\$144,000	\$310,000
Monitoring systems	\$4,500	\$4,500
Total	\$1,850,750	\$3,319,250

Annual	Cost Range	
	Minimum	Maximum
Irrigation operation and maintenance	\$2,500	\$4,000
Storage maintenance	\$1,500	\$2,500
Total	\$4,000	\$6,500

Public funding opportunities

Cost share programs
Nutrient reduction credits

YIELD BENEFITS & COST SAVINGS

\$130-\$146 PER ACRE

annual increase in yield improvements from supplemental irrigation

\$10-\$20 PER ACRE

annual farm operating cost savings from reduced equipment and fuel costs for applying fertilizer and fungicide

\$100-\$180 PER ACRE

economic benefits from watershed storage capacity improvement

ENVIRONMENTAL BENEFITS

8,871 POUNDS

average annual nitrate removal

590 POUNDS

average annual phosphorus removal

UP TO \$40,277 PER YEAR

in added benefits to downstream communities from nitrogen reduction

Estimations based on model site

Drainage water recycling provides substantial farm-level and public benefits through supplemental irrigation, operating cost savings, and enhanced water quality, despite requiring significant upfront investment.

The implementation of drainage water recycling comes with substantial upfront investments, with total costs ranging from approximately \$1.8 million to \$3.3 million.

For farmers, drainage water recycling systems provide repurposed water for irrigation, which can increase crop yield income by \$130 to \$146 per acre annually and can be particularly useful in dry years. The repurposed water from drainage water recycling also has the potential to save \$10 to \$20 per acre in farm operating costs as the irrigation system can be used for fertigation and chemigation, thereby reducing equipment and fuel expenses.

For both farmers and landowners, the implementation of drainage water recycling is most effective when combined with overall drainage capacity improvements.

When done in combination, integrated drainage and irrigation improvements can lead to an 8% to 15% yield increase, equating to \$300 to \$500 per acre. These improvements can also reduce drainage system costs by \$100 to \$180 per acre through improved watershed storage capacity.

Based on the analysis, the most effective approach to implementing drainage water recycling is with an active storage design, constructed on an existing waterway with shared storage across multiple farms to reduce per-acre costs.

Beyond farm-level gains, the report also identified additional potential public benefits that should be explored further. Drainage water recycling can improve water quality within the larger watershed, potentially benefiting local municipalities. These benefits can be enhanced by adding natural infrastructure practices that support water quality, such as wetlands and saturated buffers. However, more research is needed to understand the extent of these benefits.

Additionally, drainage water recycling may offer stormwater control benefits. On a local scale, the practice has been observed to modulate runoff from weather events through additional storage capacity, with benefits for farmers, landowners, and local downstream communities. Further research is needed to quantify the flood benefits for public stakeholders, including the necessary scale of drainage water recycling implementation to achieve a meaningful impact.

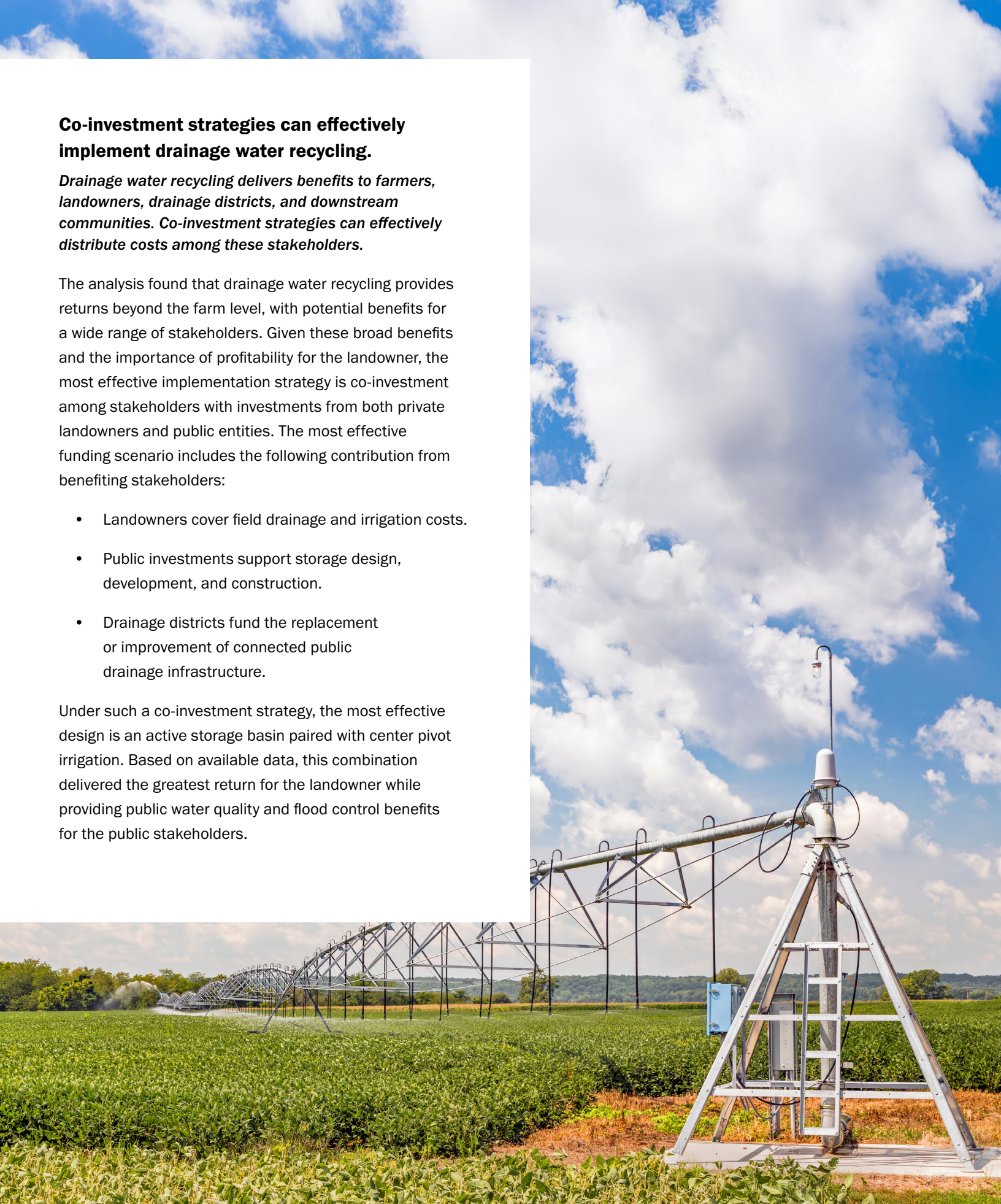
Co-investment strategies can effectively implement drainage water recycling.

Drainage water recycling delivers benefits to farmers, landowners, drainage districts, and downstream communities. Co-investment strategies can effectively distribute costs among these stakeholders.

The analysis found that drainage water recycling provides returns beyond the farm level, with potential benefits for a wide range of stakeholders. Given these broad benefits and the importance of profitability for the landowner, the most effective implementation strategy is co-investment among stakeholders with investments from both private landowners and public entities. The most effective funding scenario includes the following contribution from benefiting stakeholders:

- Landowners cover field drainage and irrigation costs.
- Public investments support storage design, development, and construction.
- Drainage districts fund the replacement or improvement of connected public drainage infrastructure.

Under such a co-investment strategy, the most effective design is an active storage basin paired with center pivot irrigation. Based on available data, this combination delivered the greatest return for the landowner while providing public water quality and flood control benefits for the public stakeholders.





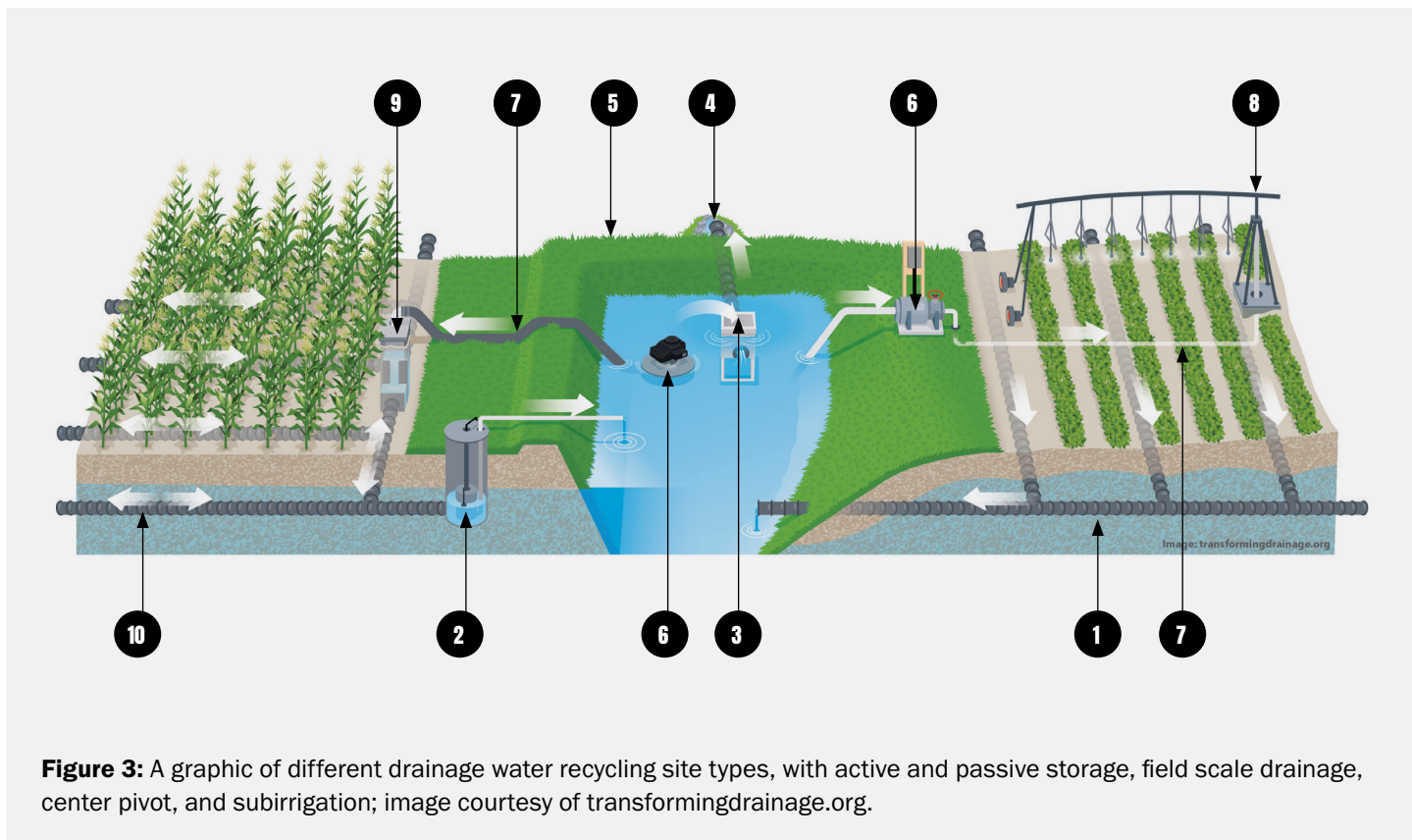
SECTION 1

DRAINAGE WATER RECYCLING OVERVIEW

DRAINAGE WATER RECYCLING TECHNOLOGY AND APPLICATION EXPLANATION

Drainage water recycling systems are primarily designed to manage excesses and shortages of water within agricultural crop production. These systems are typically comprised of three main components: pre-existing subsurface drainage, used to drain water from agricultural lands during times of excess water; a water storage system, used to capture and hold the excess water; and an irrigation system, used to resupply the stored water to agricultural lands during a water shortage^[3].

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Subsurface drainage infrastructure will exist prior to the addition of a drainage water recycling project, and storage and irrigation components can be added to it. Since each component varies based on specific site characteristics and needs, drainage water recycling projects can take many different shapes and sizes. The full components (shown in Figure 3) include:

Drainage

- 1 Drainage pipes, which also serve as distribution pipes when subirrigation is used
- 2 Drainage lift station

Storage

- 3 Storage outlet spillway
- 4 Storage outlet pipe
- 5 Embankment dams or levees

Irrigation

- 6 Irrigation pumps
- 7 Irrigation supply lines
- 8 Center pivot
- 9 Subirrigation control structure
- 10 Drainage and subirrigation distribution pipe

The water supply and movement within a drainage water recycling system is impacted by many factors.

Water is introduced to the drainage water recycling system through *precipitation* ❶. Excess water from precipitation exits the field as *surface runoff* ❷ or *tile drainage* ❸ into a storage basin. The remaining water in the soil is either used by the crop through *upward flux* ❹ and *evapotranspiration* ❺ or lost through *deep percolation* ❻, depending on the presence of a *restrictive layer* ❼. Excess water in the storage basin is removed through *overflow discharge* ❽. Remaining water in the storage basin is either lost through *evaporation* ❾ or *seepage* ❿ or recycled back to the crop as *irrigation* ⓫.

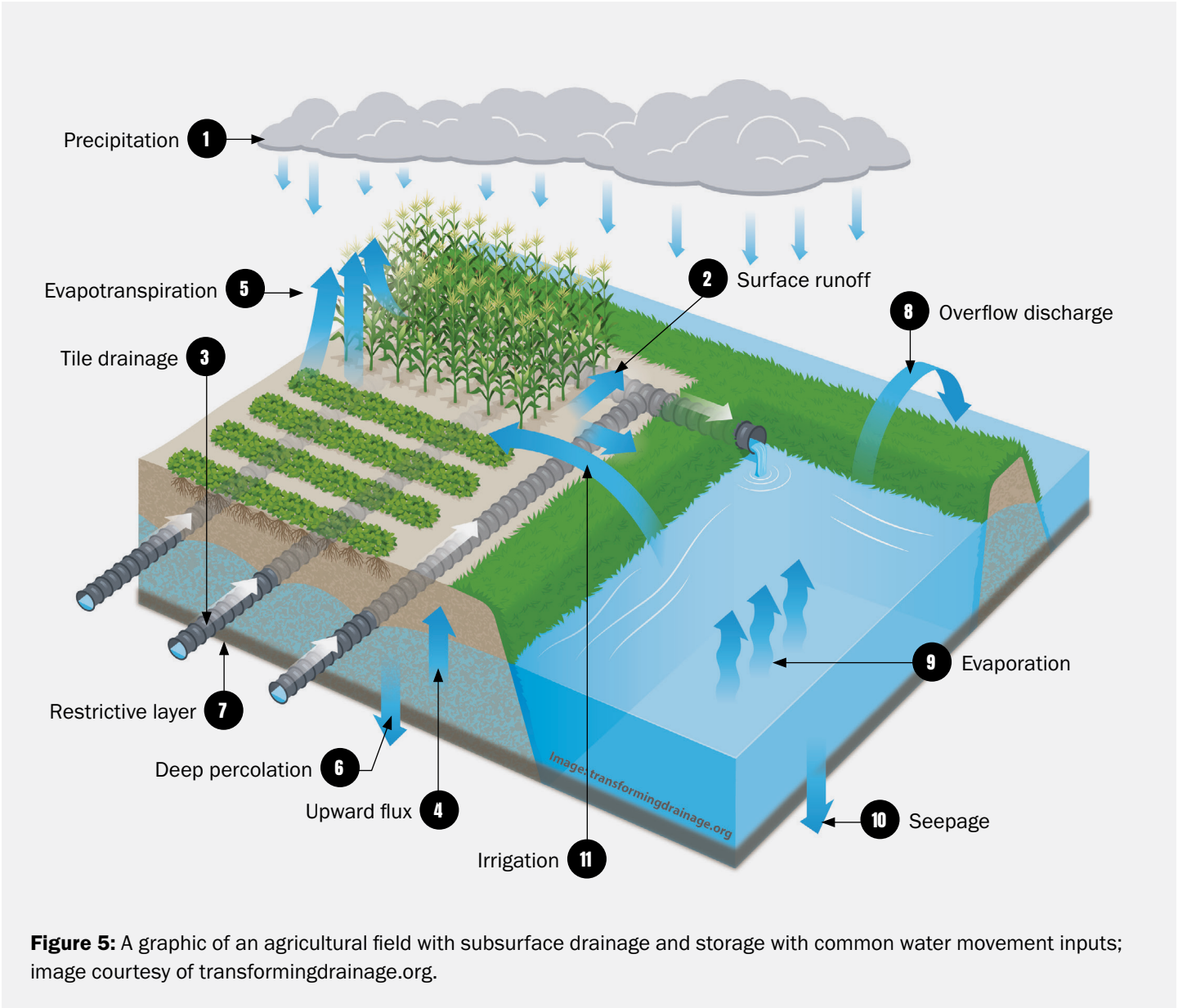


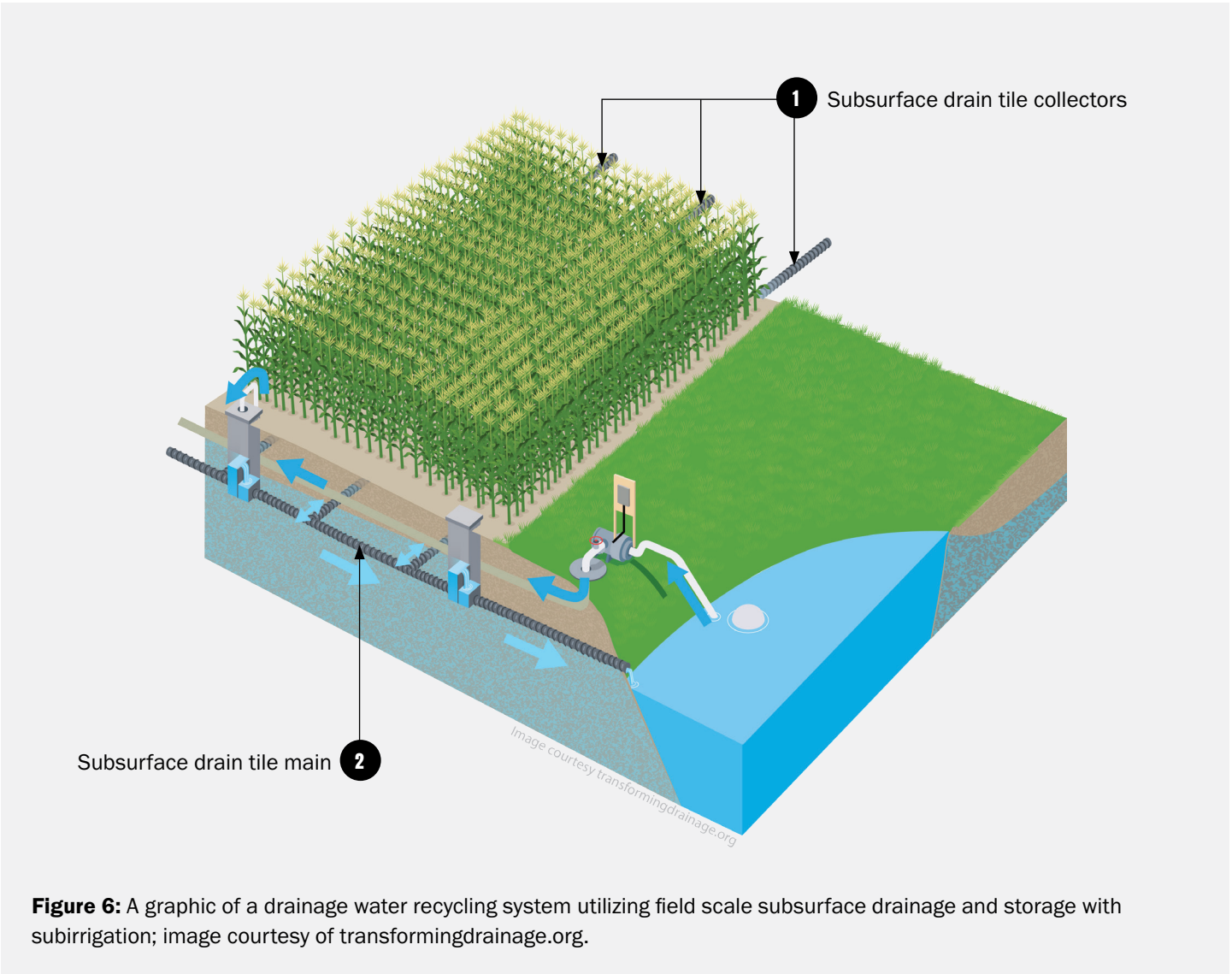
Figure 5: A graphic of an agricultural field with subsurface drainage and storage with common water movement inputs; image courtesy of transformingdrainage.org.

DRAINAGE COMPONENT CLASSIFICATIONS

Drainage systems can be classified by system scale and drainage type. Drainage types include subsurface drainage, surface drainage, or a combination.

Subsurface drainage is typically comprised of *subsurface drain tile collectors* ❶ and *mains* ❷, often called tile drainage, including components ranging from 4-inch perforated tubing for collectors to 60-inch pipes for large mains. Surface drainage is typically accomplished with excavated surface channels, such as waterways, swales, or drainage ditches. In many cases, drainage ditches convey surface drainage while also serving as an outlet for subsurface drainage.

In this report, drainage systems are classified on both field and watershed scales. For example, field-scale subsurface drainage is made up of targeted or pattern tile collectors and some smaller mains, while field-scale surface drainage is comprised of waterways and small surface ditches. Watershed-scale subsurface drainage is made up of large conveyance mains and branches, while watershed-scale surface drainage may include large drainage ditches, streams, creeks, or rivers.



The analysis in this report includes systems that improve drainage to increase the drainage capacity or to replace the existing failing drainage infrastructure on previously drained lands. New drainage on previously undrained lands is not considered in this analysis because tile drainage, in some cases, can lead to negative environmental outcomes, such as increased nutrient runoff and altered hydrology, that can drain wetlands or reduce their function. When drainage systems are improved or replaced, environmental best practices should be considered to avoid, reduce, or properly mitigate negative upstream wetland impacts.



Figure 7: An example of watershed scale surface drainage that also serves as an outlet for subsurface drainage.



STORAGE BASIN CLASSIFICATION TYPES AND CHARACTERISTICS

Storage location

The first classification of storage basins is by their location relative to their water source. Active storage basins are located on-channel and passive storage basins are located off-channel. More specifically, an active storage basin is constructed on a stream, channel, drainage ditch, tile main, tile outfall, waterway, or other water source. The basin receives and stores all the water contributed from the source. The basin outlet conveys water that surpasses the storage capacity downstream.

A passive storage basin is typically adjacent to or very near, but not directly on, a water source. This leaves the water source mostly undisturbed, except for connections to the basin. A passive storage basin collects a portion of the water from the source, while any excess water bypasses the storage basin. The characteristics and considerations for each type are summarized below.



ACTIVE
storage basins are located on channel



PASSIVE
storage basins are located off-channel



ACTIVE

Active storage basins typically require a larger, more expensive outlet structure, as they must be designed to handle storm flows from their contributing water source. Oftentimes, active basins can use existing topography as storage, minimizing excavation costs. Active basins most commonly collect surface water and subsurface water, but can be designed to collect one water type exclusively depending on site characteristics. Since all catchment-area water flows through an active storage basin, it all receives some level of treatment depending on the water's residence time in the basin. Longer residence times incur more treatment during low flows, while shorter residence times incur minimal treatment during larger storm flows. Because of this treatment, active storage basins are more likely to have greater positive impacts on nutrient load removal. Similarly, by providing some detention time over a range of flows for all incoming water, active basins are more likely to provide flood peak reduction benefits. However, active basins can be more difficult than passive basins.

Typical challenges of active storage include a more complex, lengthy floodplain and stream permitting process because they are often constructed on streams and/or floodplains. Active basins also require more regular maintenance and cleaning, as they receive and collect more flow and sediment than passive basins.

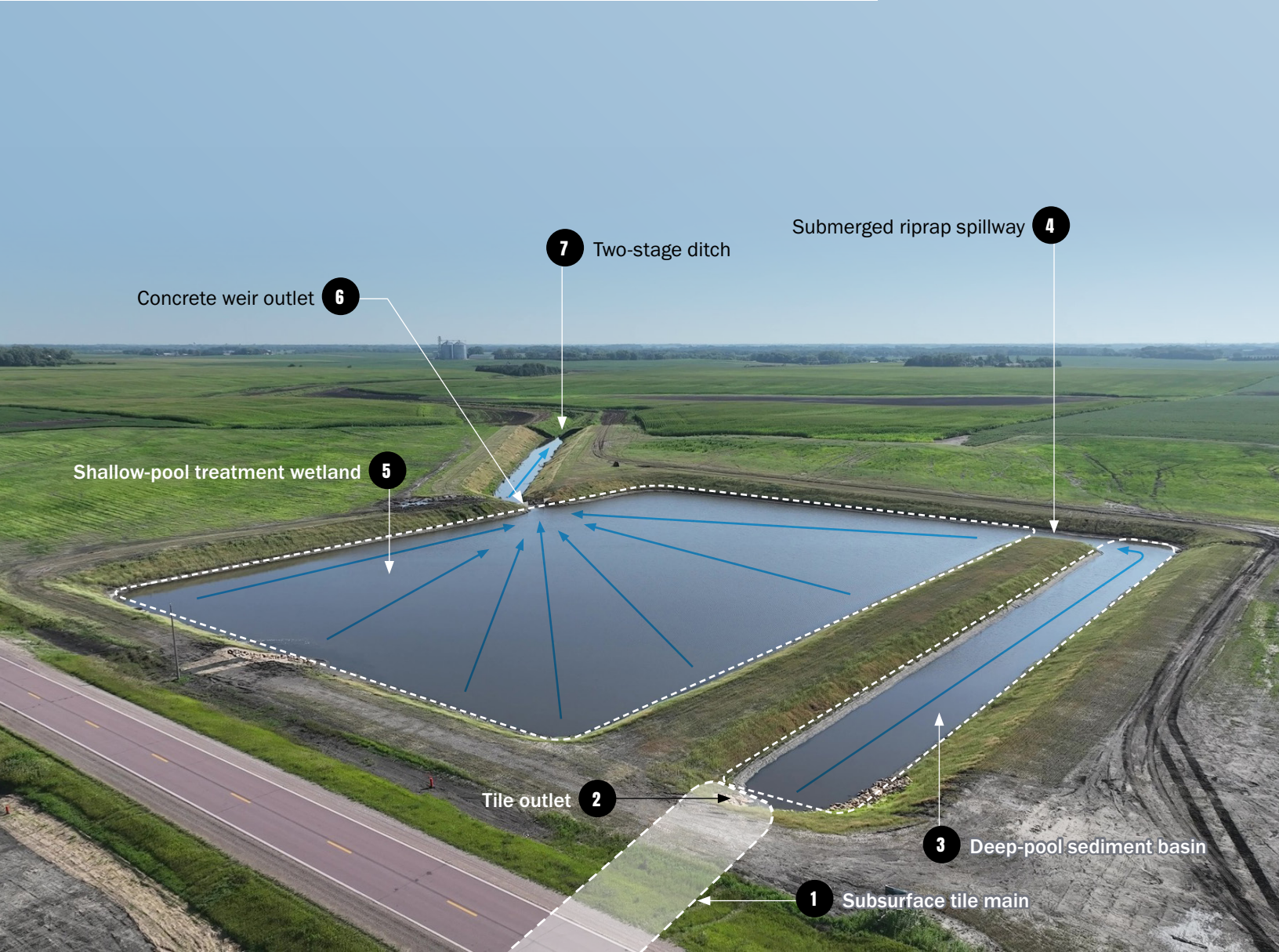
Quick takeaways

- Higher cost and large outlet required
- Efficient land use with minimal excavation
- Comprehensive water treatment and nutrient removal
- Flood peak reduction
- Frequent maintenance for high flow and sediment
- Complex permitting in stream/floodplain areas



A subsurface tile main ❶ flows into the active storage basin. The tile outlet ❷ flows into a deep-pool sediment basin ❸, which allows for efficient sediment capture and removal. Water then flows over a submerged riprap spillway ❹ into the shallow-pool treatment wetland ❺ which provides multiple benefits, including denitrification and improved water quality. Water exits the storage basin over a concrete weir outlet ❻ and flows through a downstream two-stage ditch ❼.

Figure 8: An example of a recently constructed active storage basin on a drainage system in Martin County, Minnesota.





PASSIVE

Passive basins typically require more excavation for construction and may require a pump to fill them. They can also be filled using gravity, which requires significant excavation. However, unique topography may minimize the amount of excavation needed. Since passive basins only capture a portion of upstream drainage, there are typically less nutrient load removal and flood reduction benefits, compared with active basins. There is, however, flexibility on placement when using a passive basin within a drainage water recycling project site, which may minimize permitting and design challenges. Passive basin regular cleaning and maintenance requirements are less than that of an active basin, except for pump maintenance. Passive storage basins can be designed to collect surface water, subsurface water, or both.

Water from upstream tile flows through *subsurface drainage mains* ① that outlet into a *drainage ditch* ②. A *passive subsurface collection and pumping system* ③, powered by a nearby *solar array* ④, removes a portion of the water from the tile mains and pumps it into the *deep pool storage reservoir* ⑤. Water in the storage reservoir is available for use in the nearby cropland *irrigation area* ⑥. After the storage basin is full, water flows through a *shallow pool wetland* ⑦ for additional treatment.

Quick takeaways

- Flexible placement and easier permitting
- Lower maintenance with minimal cleaning
- Versatile surface and subsurface water collection
- Requires more excavation and possible pumping
- Less nutrient removal and flood reduction

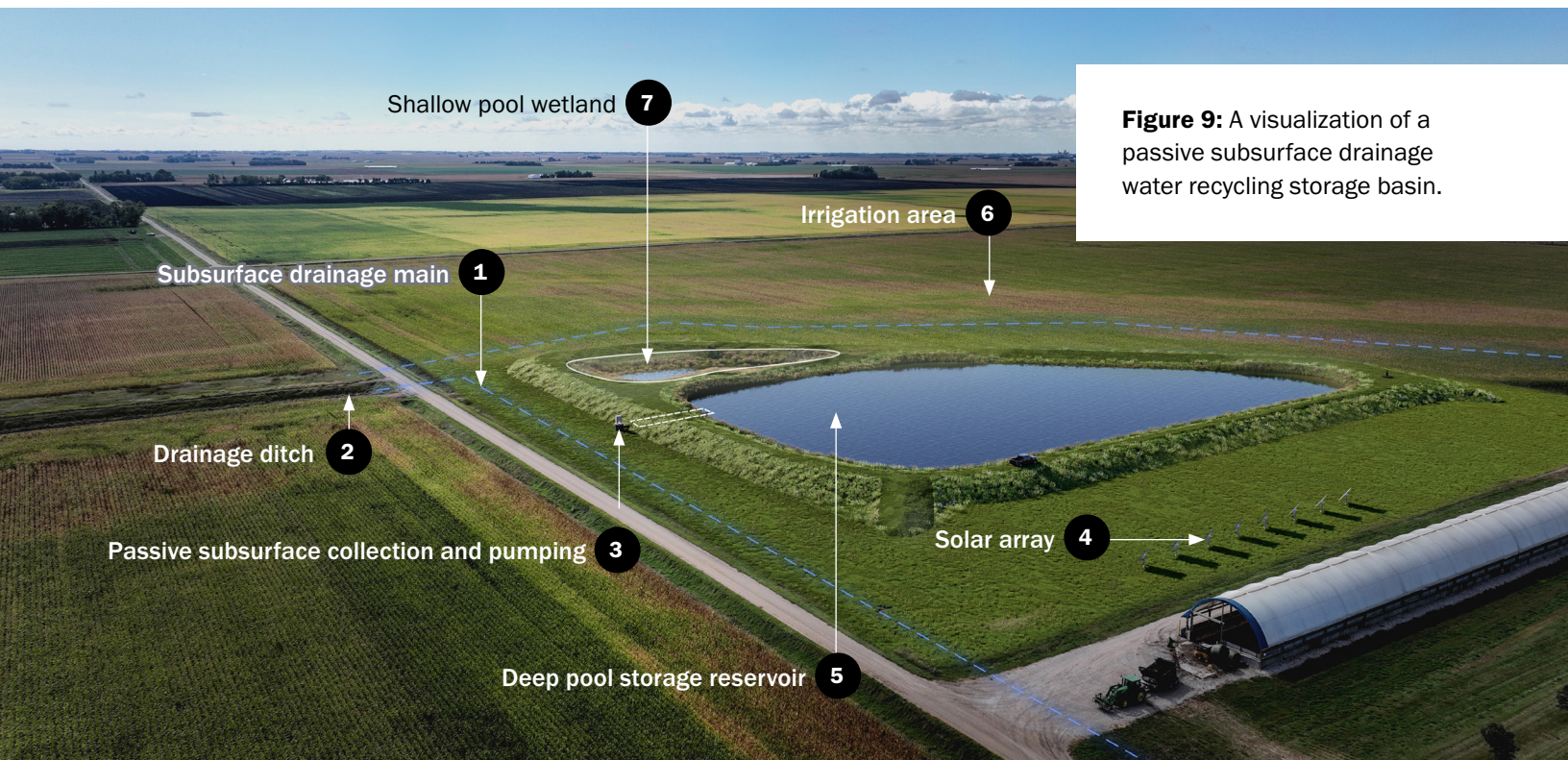


Figure 9: A visualization of a passive subsurface drainage water recycling storage basin.



Figure 10: An active surface water storage basin.

Water collection

The second classification of storage basins is based on whether the water collected or received is surface or subsurface water. Surface water is subdivided into field-scale and watershed-scale categories based on drainage area. In general, field-scale surface water is water captured from overland flows from storm events, while watershed-scale surface water is captured from larger channels, such as drainage ditches, rivers, streams, and other waterways. Surface flows can also include natural subsurface water discharging into the stream, river, or channel.

Subsurface water is typically captured from subsurface tile drainage through a tile main, tile outfall, or drainage ditch where its primary purpose is to transport subsurface drainage discharge. The water source, surface or subsurface, can influence nutrient concentrations and loads. In tile-drained landscapes suitable for drainage water recycling, surface runoff generally has low nitrate concentrations but higher total phosphorus concentrations from sediment-bound phosphorus. Subsurface water generally has higher nitrate concentrations but less total phosphorus. However, in some conditions, subsurface drainage water can be a significant source of more biologically available dissolved phosphorus, so even small amounts of dissolved phosphorus can trigger algal blooms in sensitive water bodies.



SURFACE WATER

Field-scale: water captured from overland flows from storm events.

Watershed-scale: water captured from larger channels, such as drainage ditches, rivers, streams, and other waterways.



SUBSURFACE WATER

Water captured from subsurface tile drainage where its primary purpose is to transport subsurface drainage discharge.



Figure 11: An active subsurface storage basin.



SURFACE WATER

Surface water storage basins typically require a larger contributing watershed to ensure adequate basin recharge, especially when they are passive. If active, these basins could provide flood reduction benefits. In most cases for surface water storage basins, the nitrate capture and removal capacity are low, but the phosphorus and sediment removal capacity are high, especially for active surface basins. Surface basins do not require tile main replacement as part of construction, but may incur costs from requiring a larger water outlet. Active surface basins are better suited for small-drainage-area surface water and require a sediment capture component and regular cleaning. Passive surface basins typically draw water from a stream or river with a larger drainage area, which may require a water use permit.



SUBSURFACE WATER

Subsurface tile drainage water

Subsurface basins generally have a more consistent incoming flow from tile drainage and could be constructed with a smaller contributing watershed. They also provide high nitrate capture and removal capacity, as well as drainage outlet relief and benefits. However, they capture minimal sediments and phosphorus. Construction costs can be higher, especially if significant tile replacement or pumping infrastructure is required to direct flows into the basin. Some flood reduction benefits are possible, depending on the scale of the contributing watershed.



Figure 12: A shallow wetland storage basin that receives both surface and subsurface drainage.



BOTH SURFACE AND SUBSURFACE

Typically, active storage basins, especially within smaller watersheds, collect both subsurface and surface water, showcasing characteristics of each described above. The cost of a storage basin that collects both types of water varies based on site characteristics and design.

IRRIGATION METHODS

There are four main categories of agricultural irrigation systems: surface irrigation, sprinkler irrigation, microirrigation, and subirrigation, each with unique advantages and applications.



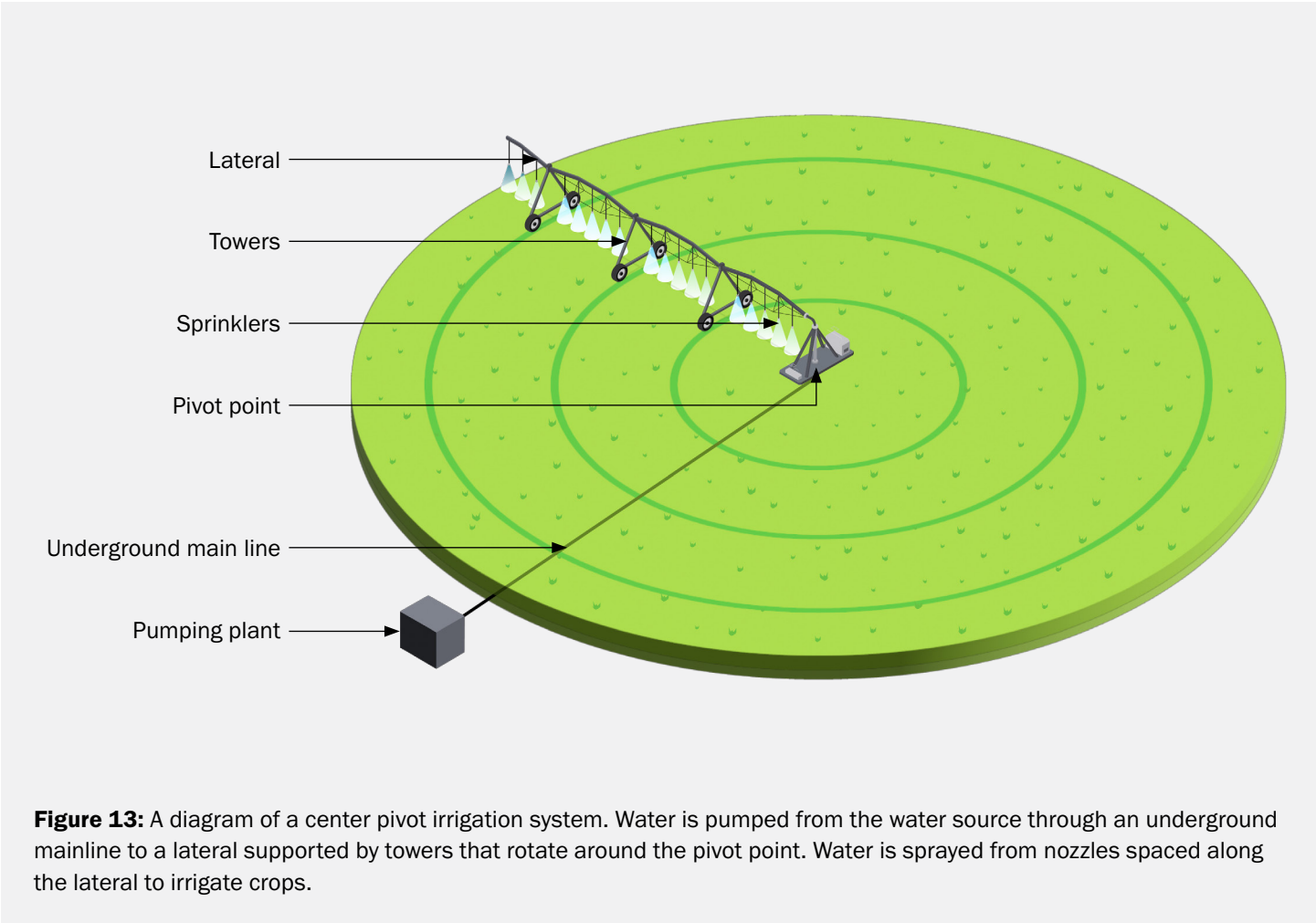
SURFACE IRRIGATION

Surface irrigation uses gravity to deliver water across the soil surface using overland flow. It is a traditional method used in many areas throughout the U.S., including the west and mid-south. However, due to land leveling and labor requirements, surface irrigation is not ideal for drainage water recycling.



SPRINKLER IRRIGATION

Sprinkler irrigation uses pressurized pipes to distribute water to the soil in the form of a spray. It is the predominant form of irrigation in the U.S. Center pivot irrigation, a specialized form of sprinkler irrigation, uses a rotating lateral supported by towers to distribute water in a circular pattern, making the method ideal for large fields.





MICROIRRIGATION

Microirrigation systems deliver frequent small quantities of water through emitters or applicators placed along a delivery line. Subsurface drip irrigation is a form of microirrigation using driplines permanently buried beneath the soil surface. This method is becoming more popular for irrigating row crops, particularly for smaller or odd-shaped fields that are less suited for center pivots.

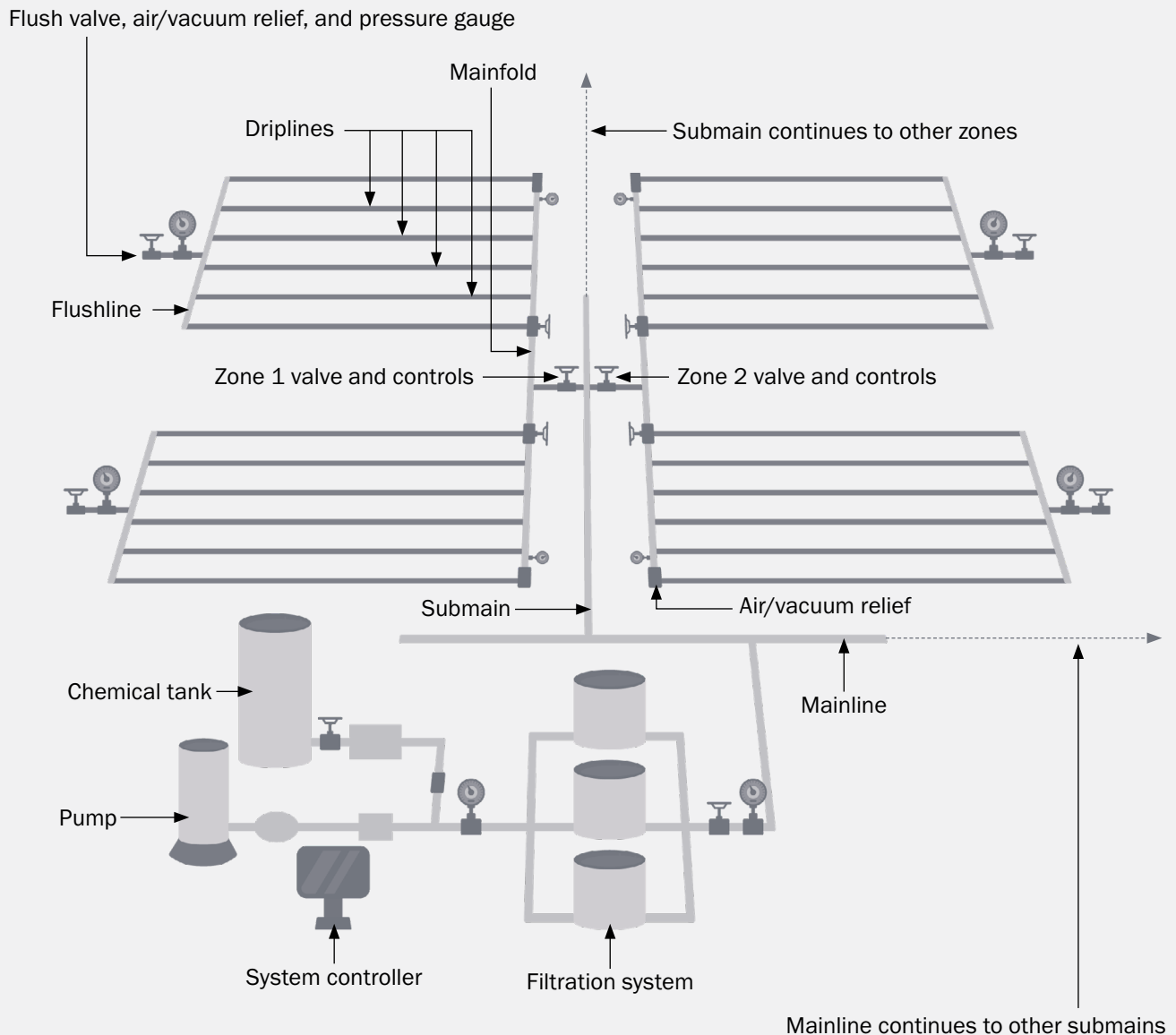
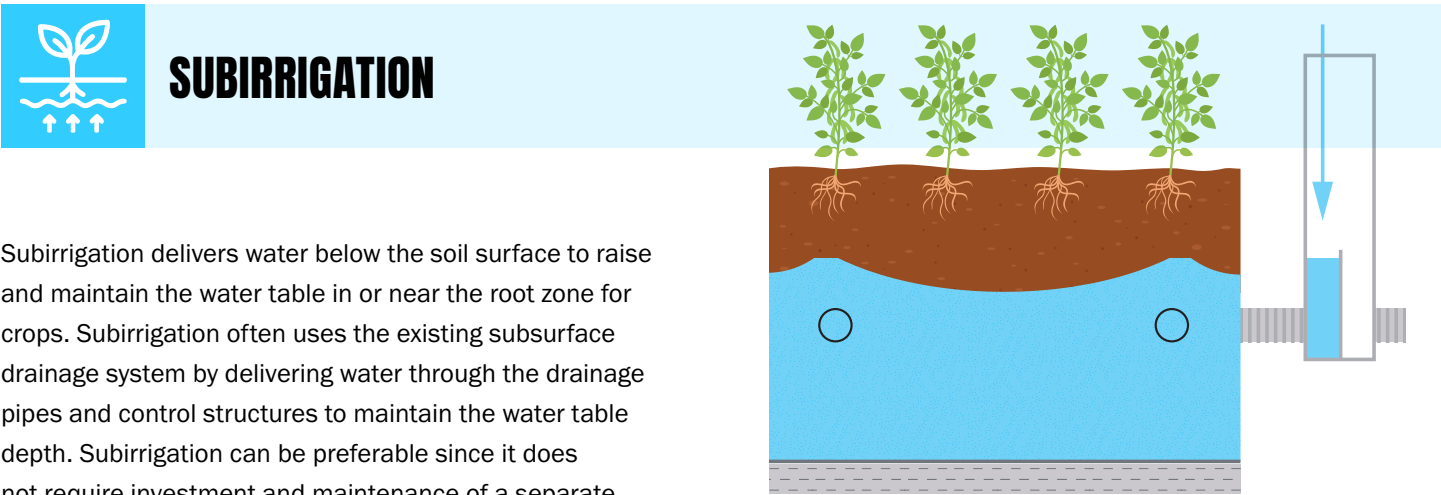


Figure 14: A schematic diagram of a subsurface drip irrigation system. Water is delivered directly to the root zone via emitters on polyethylene tubes buried below the soil surface.



Figure 15: A surface intake into a drainage system with a bar guard to prevent debris from entering the system.



Subirrigation delivers water below the soil surface to raise and maintain the water table in or near the root zone for crops. Subirrigation often uses the existing subsurface drainage system by delivering water through the drainage pipes and control structures to maintain the water table depth. Subirrigation can be preferable since it does not require investment and maintenance of a separate irrigation system. However, it does require greater drainage intensity with more closely spaced laterals and control structures. It is also limited to relatively flat fields with suitable and uniform soils.

Figure 16: A graphic profile view of subirrigation. Water is introduced back into the drainage system. Water control structures are used to raise and maintain the water table in or near the crop root zone.

STAKEHOLDER ROLES IN FACILITATING DRAINAGE WATER RECYCLING IMPLEMENTATION

Although some existing drainage water recycling sites are designed and installed entirely through landowner funding, the size and complexity for implementing the practice generally requires involvement from outside stakeholders, especially when water quality and other complementary benefits are a priority. End users such as producers, landowners, and drainage districts provide essential input to ensure systems fit into farm operations.



Planning

Planners identify suitable sites, engage landowners, and coordinate funding and outreach with support from agencies and organizations such as the Iowa Department of Agriculture and Land Stewardship (IDALS), the Minnesota Board of Soil and Water Resources (BSWR), and the Iowa Soybean Association (ISA).

Funding

Funders, including public agencies, provide cost share and other programs that may eventually support market-based or alternative approaches for drainage water recycling funding, to cover major costs and support projects from planning through post-construction monitoring. Technical and design experts, such as engineers and Natural Resources Conservation Service (NRCS) staff, guide system design and ensure technical and economic feasibility throughout the project lifecycle.

Other indirect beneficiaries include downstream users and recreational groups who may benefit from reduced nutrient loads in water, storm water control, or habitat improvement. Whether or not each of these groups are involved with a specific drainage water recycling project, they all play a role in efficient and effective adoption of this practice. Engaging them will help build public support for drainage water recycling and help define the economics of the practice as it advances.

Permitting

Permitting agencies such as the U.S. Army Corps of Engineers (USACE) and state department of natural resources (DNRs) help identify permitting challenges early and guide project implementation.

Research

Researchers from universities and government agencies, such as Iowa State University and the U.S. Department of Agriculture (USDA), provide data and insights to support adoption and inform funding decisions.

Industry

Industry members, including manufacturers and suppliers, provide necessary equipment and may innovate new technologies as the practice expands.



SECTION 2

ANALYSIS SCOPE AND STRUCTURE

This study includes three analysis categories: costs, benefits, and financial returns based on a model site.

MODEL SITE

Due to the wide range of potential drainage water recycling project types, a base set of assumptions were made to guide cost, benefit, and financial return analyses. These analyses are based on a model site built to provide supplemental irrigation to a common agricultural field size of 160 acres with an idealized corresponding storage and contributing watershed. The idealized watershed and storage areas were sized to provide the best outcomes and value for the model site without being larger than necessary or unrealistic. The assumed actual irrigated area varies by irrigation method and ranges from 125 acres to 155 acres. For subirrigation cost estimation purposes, the field was assumed to have a constant 0.5% slope in one direction. The storage basin costs and benefits are reflective of storing 4 to 6 inches of water⁽⁴⁾ for the irrigated acres, which ranges from 41.7 to 77.5 acre-feet for the model site. The model site was assumed to have a contributing watershed of 1,500 acres. Sites with smaller storage, irrigation, or watershed areas may not perform as well as the model site. All drainage water recycling sites were assumed to be in agricultural production and artificially drained with subsurface drain tile and/or surface ditches prior to drainage water recycling development.

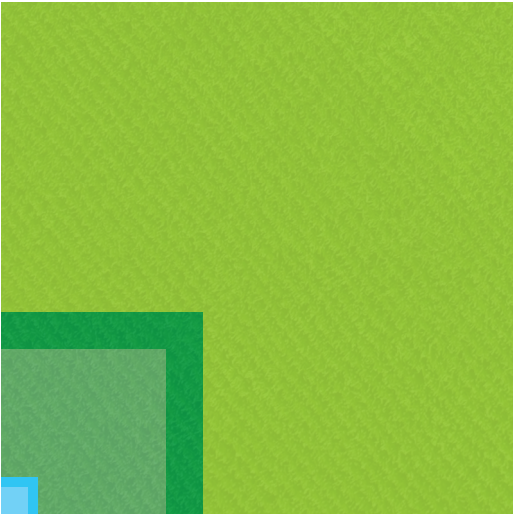


Figure 17: Model site.

- 1,500-acre drainage area
- 125–155 irrigated acres
- 42–78 acre-feet reservoir storage area

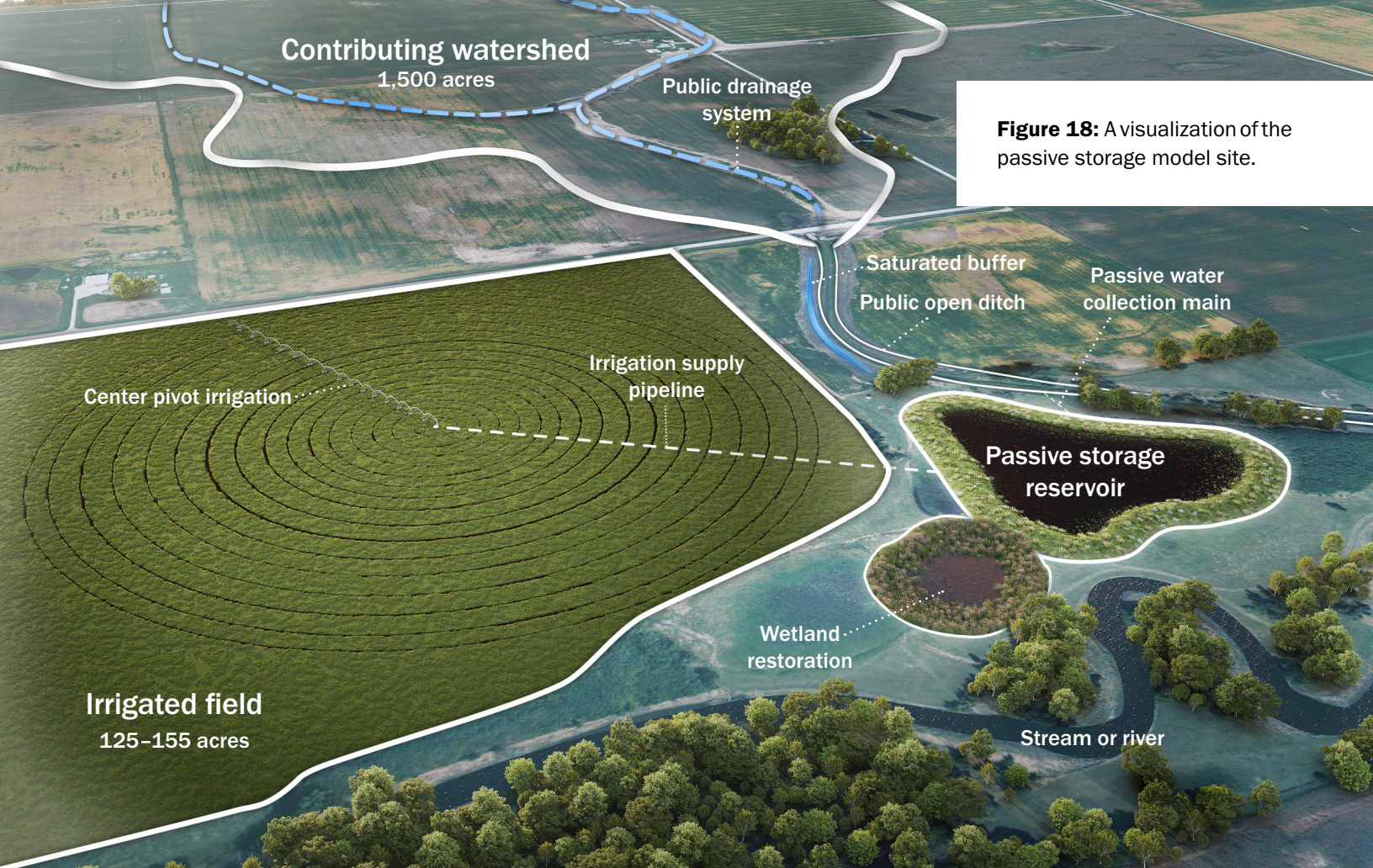


Figure 18: A visualization of the passive storage model site.

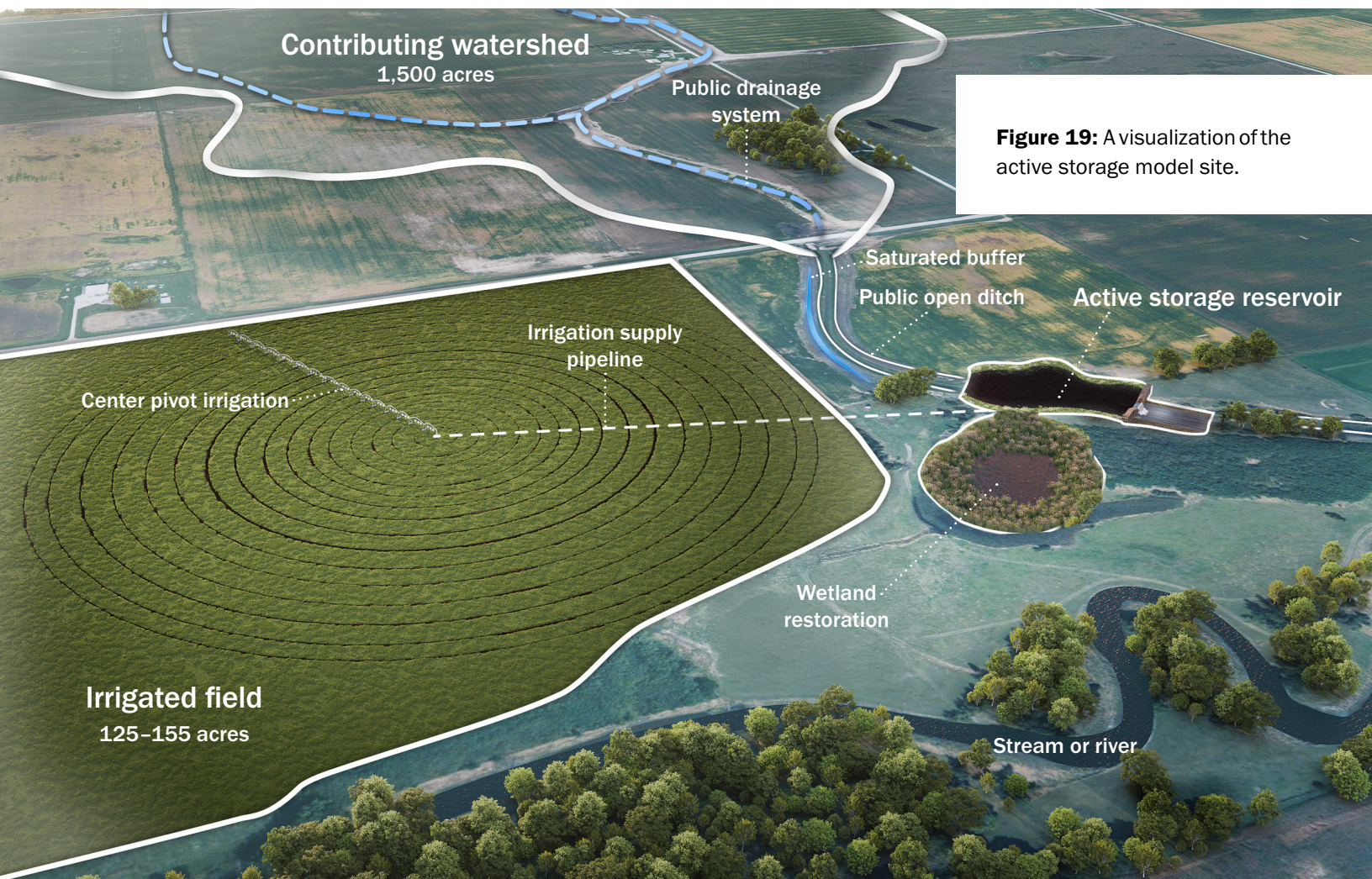


Figure 19: A visualization of the active storage model site.

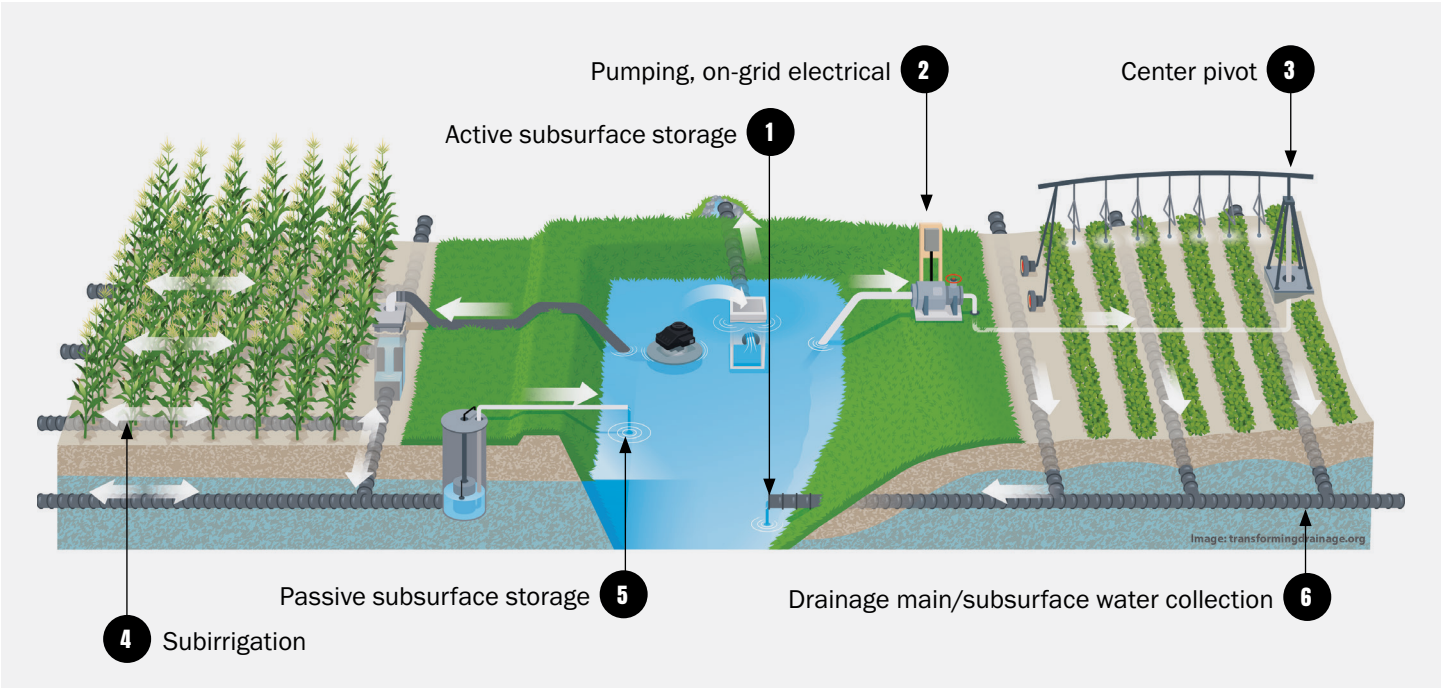


Figure 21: Elements of a drainage water recycling site; Image courtesy of transformingdrainage.org.

DRAINAGE WATER RECYCLING PROJECT COSTS

The cost analysis focuses on gathering and summarizing costs of implementing drainage water recycling using multiple, though limited, project types, scenarios, and real-life examples. Cost estimates are provided as a range for the different scenarios. Although costs may not directly be scaled with size, these scenarios provide a framework that can be used to inform cost estimates of projects of different sizes.

Table 2: Elements of a drainage water recycling site.

Category	Details
Design and planning	• Standalone projects • Joint projects with drainage or other infrastructure improvements
Storage construction	1 Active storage 5 Passive storage • Surface water collection 6 Subsurface water collection
Irrigation types	3 Center pivot irrigation 4 Subirrigation • Subsurface drip irrigation
Power supply options	• Solar 2 On-grid electrical • Diesel
Operations and maintenance	• Storage cleanout and maintenance • Irrigation operation • Monitoring and management • Smart irrigation • Smart storage options



DRAINAGE WATER RECYCLING BENEFITS

The benefits analysis focuses on gathering and assessing potential drainage water recycling benefits to row crop producers and other stakeholders. Benefits to producers for implementing drainage water recycling are compiled, estimated, and summarized for each project type and scenario. This includes measured and modeled yield benefits; production efficiency benefits; drainage outlet relief benefits; potential cost share from state agencies; potential NRCS Environmental Quality Incentives Program (EQIP) payments; and potential water quality outcome payments.

DRAINAGE WATER RECYCLING FINANCIAL RETURN ANALYSIS

For this analysis, investment scenarios are modeled with possible funding contributions from various funders. These investment scenarios include a recommended breakdown of funding sources and as percentages for each project type. Privately funded options include landowners and producers. Public drainage includes the cost share for watershed-scale storage on a public drainage system. Community irrigation cost share includes watershed-scale storage and multiple landowner irrigation. Public water quality investment is not specified, other than water quality is prioritized in design. Each of these scenarios were compared to determine expected success. A financial return analysis was then completed on multiple potential drainage, irrigation, and storage scenarios of the model site, with the resulting return on investment, net present value, and payback period calculated.



SECTION 3

COSTS OF IMPLEMENTING DRAINAGE WATER RECYCLING

The cost estimates were calculated based on the 160-acre model site. However, the costs can be scaled with project size and can vary with several site-specific factors. Where possible, unit pricing of various costs was provided to allow for extrapolation and adjustment for varying project sizes. Some costs are fixed and change less based on size. Caution should be taken when extrapolating.

In addition to presenting costs for new traditional drainage water recycling sites, estimates were also prepared for storage retrofit drainage water recycling projects, for which there is an existing storage basin that can be modified for drainage water recycling. Many of the costs and benefits included within the cost estimates are subject to the impacts of inflation and other economic trends. Since drainage water recycling projects typically take multiple years to implement, inflation and expected price increases are included within the economic analysis. Unless otherwise noted, prices included within this analysis are representative of 2025 pricing.

Cost estimates included a 10% contingency. The pricing included within this section is based on the implementation of drainage water recycling in the Upper Mississippi River Basin. Most pricing is based on previous projects in Iowa and Minnesota. However, regional pricing variations within the Upper Midwest are minor and should fall within the ranges provided. The permitting costs included within this report are representative of a drainage water recycling project in Iowa. Design and planning costs may vary due to regional permitting differences. Wherever applicable, itemized cost estimates are included in the Appendix and the scope of cost estimates are outlined in the relevant sections.

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SUMMARY OF DRAINAGE WATER RECYCLING COSTS

Table 3: Summary of drainage water recycling costs.

Cost categories		Cost ranges	Average cost estimates for model site*	Recommended primary funders
1	Private drainage system	\$600–\$1,200 per acre drained	\$112,500–\$139,500	Landowners and/or producers
2	Public drainage system	\$750–\$1,500 per acre drained	\$1,125,000–\$1,800,000	Drainage districts
3	Design and planning	Standard: \$128,500–\$195,000	\$155,500	Public water quality funding and drainage districts
		Storage retrofit: \$102,500		
4	Site investigation	\$14,750–\$24,250	\$19,500	Public water quality funding and drainage districts
5	Storage land easement/acquisition	\$10,000–\$15,000 per acre	\$120,000	Drainage districts, public water quality funding, and landowners providing the land for storage at low or no cost
6	Storage construction	Retrofit: \$225,000	\$497,000	Public water quality funding and drainage districts
		New Construction: \$430,000–\$706,000 or \$10,000–\$20,000 per acre-foot of storage		
7	Irrigation construction	\$1,150–\$2,000 per irrigated acre	Center pivot: \$144,000	Landowner and/or producers
			Subirrigation and subsurface drip: \$310,000	
8	Operation and maintenance (annual)	Storage: \$1,500–\$2,500	Storage: \$2,000	Landowner and/or producers
		Irrigation: \$2,500–\$4,000	Irrigation: \$3,500	
9	Monitoring and management (annual)	\$3,300 –\$5,000	\$4,500	Landowner and/or producers

*The model site is based on 1,500-acre contributing drainage area, 125–155-acre irrigated acres, and 41.7–77.5 acre-feet storage reservoir. Storage estimates reflect an average for active and passive storage reservoirs.

- 1. Private drainage system:** Field-scale construction cost of improving or replacing existing field-scale drainage systems, specific to the 160-acre field that the site is built on. Drainage systems will exist prior to drainage water recycling project

2. Public drainage system: Additional watershed scale drainage replacements and improvements

3. Design and planning: Inclusive of all project planning, design, and non-construction implementation costs for drainage water recycling storage and irrigation, including the design of accompanying natural infrastructure or best management practices (BMPs) such as wetlands, saturated buffers, or bioreactors

4. Site investigation: Site investigation costs such as tile and soils investigation and survey
- 5. Storage land easement/acquisition:** Value of land taken for the construction of the storage, either by purchase, conservation easement, or other means

6. Storage construction: Inclusive of all construction costs associated with the storage basin

7. Irrigation construction: Inclusive of all construction costs associated with the irrigation equipment

8. Operation and maintenance (annual): Average expected annual costs for upkeep and operation, including fuel or power for pumping

9. Monitoring and management (annual): Upfront costs for irrigation monitoring equipment

DRAINAGE SYSTEM COSTS

Drainage system costs for both field-scale drainage adjacent to the drainage water recycling site and for potential watershed-scale drainage associated with the adjacent drainage district are estimated for reference. The design cost of drainage replacements or improvements are not included, as they would either be provided at no additional cost by the drainage contractor on a field scale or be paid directly by the drainage district on a watershed scale. It is expected that construction costs will be paid by the private landowner or drainage district outside of the drainage water recycling project, except for minor existing drainage modifications to accommodate the system. Cost estimates for drainage water recycling storage construction include estimates for minor, local drainage modifications.

The operation and maintenance of drainage systems are minimal; yet, when necessary, are considered paid directly by the landowner or drainage district. In the case of subirrigation, the costs of installing additional drainage laterals for effective subirrigation would still typically be the responsibility of the landowner for the private irrigation and drainage benefits. Valves, control structures, and mains enabling the system to function could be funded externally due to water quality benefits created from controlled drainage and subirrigation. The construction cost of improving or replacing existing field-scale drainage systems will vary greatly based on the extent and condition of the existing drainage system and the intensity of proposed drainage, but can be estimated at \$600 to \$1,200 per acre drained. In addition to field-scale drainage costs, watershed-scale drainage replacements and improvements, where applicable, will cost an additional \$750 to \$1,500 per acre drained, depending on the scope of work. These costs have long been taken on by landowners and are not expected to change with the addition of a drainage water recycling project.



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DESIGN, PLANNING, AND SITE DEVELOPMENT

Based on previous project experience and input from IDALS, probable costs of the model site for varying drainage water recycling implementation are evaluated and estimated. This is inclusive of all project planning, design, and non-construction implementation costs for drainage water recycling storage and irrigation, including site conservation easement acquisition.

Design and planning

Design and planning costs are estimated at \$102,500 for storage retrofit projects, but may range from \$128,500 to \$195,000 for new or non-retrofit drainage water recycling projects. Factors impacting cost include site topography, soils, permitting, and design complexity. Projects on sites with multiple landowners, a larger contributing watershed, or public drainage infrastructure are expected to be on the upper end of the cost range. A detailed summary of these estimates is listed within the Appendix. Included within these costs is the design of accompanying natural infrastructure and implementation of BMPs, such as wetlands, saturated buffers, or bioreactors. The design cost of adding these natural infrastructure components is estimated as minimal, as the designer is likely already working on the site for drainage water recycling. Last, because site planning and development can take years, these costs will be incurred beginning one to three years prior to construction and through project commissioning.

Site investigation

Site investigation costs include drain tile or geotechnical soils investigation, which is essential information to guide site design. In addition to the project planning and design costs, project site investigation costs vary from \$14,750 for a retrofit site to \$24,250 for a complex traditional site.

Storage land easement/acquisition

Storage reservoir construction for drainage water recycling often requires agricultural land to be taken out of production. In most cases, the landowner will be compensated for the land used for the storage reservoir, either through the purchase of this land or through a conservation easement. These costs will vary depending on the land value and are estimated at \$120,000 for the model site. Land acquisition costs can be minimized by selecting nonproductive or undesirable land for the storage reservoir, such as areas with poor soil fertility and irregular-shaped fields. Landowners may also be willing to provide the land at little or no cost to facilitate the project given the increased benefit to their remaining land through the repurposed irrigation.

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STORAGE CONSTRUCTION

Evaluation and cost estimates of multiple drainage water recycling storage construction scenarios were considered for the model site. These scenarios include retrofit projects; varying water supplies for surface, subsurface or combination water types; and active or passive water collection systems. Estimates include earthwork, drainage modifications, intakes, structures, pumps, erosion control, and seeding. Each storage basin type provides unique benefits to the surrounding and downstream watershed. Therefore, classifying costs in this manner will allow the unique characteristics and benefits of each storage basin to be considered in the economic analysis.

A base construction scenario with common construction components was developed with an estimated construction cost of \$497,000 for the model site. Retrofit projects can greatly reduce construction costs, with an estimated cost of \$225,000 for construction.

The estimated construction costs for all other drainage water recycling storage types are summarized below. For this analysis, storage costs for a project of this size are estimated at \$10,000 to \$20,000 per acre-foot of water stored.

Table 4: Estimated construction costs for drainage water recycling storage types.

Storage type	Estimated construction cost
Retrofit	\$225,000
Active surface	\$430,000
Passive surface	\$450,000
Baseline	\$497,000
Passive tile	\$546,000
Active both	\$666,000
Active tile	\$706,000

Storage construction costs will vary depending on several site-specific factors, including topography, soils, or existing drainage infrastructure. However, these estimates provide an expected range for almost all drainage water recycling sites of the assumed size. Sites with favorable conditions for storage will be significantly less expensive to construct. A detailed summary of the cost estimates is in the Appendix.



NATURAL INFRASTRUCTURE

Wherever possible, natural infrastructure components and supplemental BMPs, such as wetlands, saturated buffers, and denitrifying bioreactors, should be incorporated into the design of a drainage water recycling site to maximize water quality benefits. Since the drainage water recycling site and storage basin will already include earthwork, drainage modifications, pumps, structures, and mobilization, the marginal cost of adding supplemental BMPs is minor in comparison with standalone BMPs and the drainage water recycling system. For example, a recently designed drainage water recycling site included a 0.61-acre shallow wetland adjacent to the drainage water recycling reservoir at little to no additional construction cost, since the area was already being graded for the drainage water recycling reservoir and water was already being pumped from a tile main.

The most suitable supplemental BMPs will vary by drainage water recycling site characteristics and basin type. Where sufficient area is available, an associated wetland pool could provide additional water treatment along with other wetland benefits. Similarly, where a suitable riparian buffer or waterway is present, diverting some of the basin outflows through a saturated buffer or waterway system would add treatment capacity. Denitrifying bioreactors may also make sense in some locations. A saturated buffer could be added for additional costs of \$2,500 to \$7,500, and bioreactors or supplemental wetlands could be added for as little as \$20,000 in additional costs when site characteristics are favorable. With less favorable site conditions, supplemental wetland costs could increase to \$100,000 or more.

Saturated buffer: A BMP to redirect tile drainage water from fields into riparian buffer zones.

Wetland: An area of water saturated soil, either permanently or seasonally.

Denitrifying bioreactor: A subsurface structure filled with a carbon source, typically woodchips, designed to treat drainage water.



Credit: NRCS/SWCS Photo by Lynn Betts



Credit: SWCS/IDALS Photo by Lynn Betts



Credit: SWCS/IDALS Photo by Lynn Betts



IRRIGATION CONSTRUCTION

Irrigation system costs for the model site were estimated based on 2024 USDA NRCS practice scenarios from Iowa and Nebraska, as well as past project experience and complementary references. Three different irrigation systems were evaluated:

- Center pivot
- Subsurface drip
- Subirrigation

Center pivot irrigation systems will often be the most effective, especially if the site can accommodate a full-circle center pivot. The estimated cost was \$144,000 for a center pivot for the assumed 125-acre irrigation area, which is the area irrigated by a 1,320-foot center pivot without an end gun or corner arm.

Costs for subsurface drip and subirrigation systems both exceeded \$300,000. For subirrigation, the subsurface infrastructure will be used for drainage and irrigation. This means field-scale drainage would not incur any additional costs beyond the subirrigation cost.

Each of the irrigation system costs were estimated assuming three-phase electrical power would be available to the site, as electrical power will generally be the most cost-effective unless electric service must be brought in over a long distance. The costs of bringing in offsite electrical service were not included. Estimated costs for other power sources were calculated based on the center pivot example.

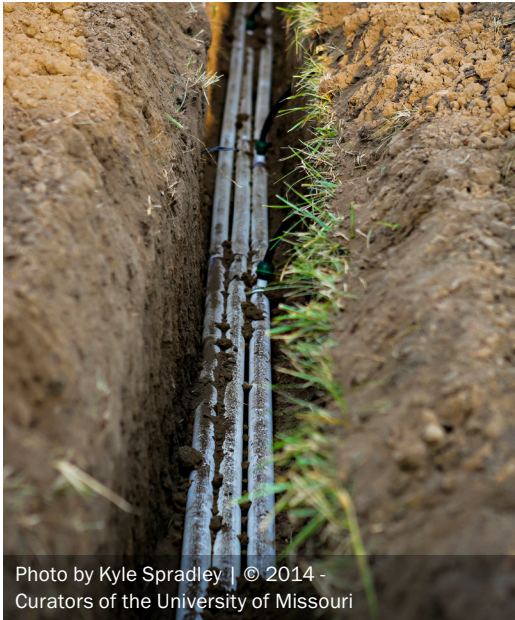


Photo by Kyle Spradley | © 2014 - Curators of the University of Missouri





OPERATION AND MAINTENANCE

Storage basins within drainage water recycling sites will require regular cleaning and sediment removal, as well as pump maintenance and replacement, as applicable. Based on previous projects, pond cleaning intervals vary by site, but should be planned for at least every 10 to 20 years at an approximate cost of \$15,000 to \$25,000 per cleaning^[5]. Pump maintenance and replacement will also vary by site. Other storage basin components are typically designed with a 100-year lifespan. Depending on the storage basin type, some outlet structures may require replacement halfway through the pond’s useful life.

When considering maintenance over the life of storage basins, including all design, implementation, operation and maintenance costs, the equivalent annual cost (EAC) of the active and passive storage basins was \$41,000 per year and \$26,100 per year, respectively, based on a 100-year useful life. Detailed calculations of the storage basin life cycle analysis are included in the Appendix.

The annual operating costs of power and labor for the irrigation systems range from approximately \$1,300 to \$2,500 for electrical power. Subsurface drip has the lowest annual operating costs since it is more efficient, as less water is applied, with lower pumping costs. Subirrigation has the highest annual operating costs because more manual labor is required, some of which could be automated at an additional cost. Power costs for other fuels were also estimated for a center pivot. Irrigation system repair and maintenance cost estimates range from approximately \$2,800 to \$7,600 per year. Useful life will vary by irrigation method. A life cycle analysis was completed to determine the EAC for the three primary irrigation methods. The inputs and results of the irrigation system life cycle analysis are summarized in the table below.

Table 5: Summary of equivalent annual cost calculation inputs and results by irrigation method

Irrigation method	Initial cost	Irrigated acres	Annual o&m cost	Expected useful life (years)	Equivalent annual cost (\$/irrigated acre/year)
Center pivot	\$150,000	125	\$4,000	25	\$122
Subirrigation	\$310,000	155	\$3,500	40	\$148
Subsurface drip	\$315,000	155	\$2,500	25	\$153



MONITORING AND MANAGEMENT

Unique opportunities exist for monitoring and managing drainage water recycling sites within both the storage and irrigation systems. To maximize all benefits of storage, such as water quality, crop yield, and drainage capacity, drainage water recycling storage basins can be designed with automated outlet control structures or a continuous monitoring and adaptive control (CMAC) system. Further research should be completed to understand the cost and benefits of storage management systems. Utilization of a CMAC system or another reservoir management strategy may reduce basin excavation and construction costs, while maximizing storage benefits.

Supplemental irrigation will be most effective when irrigations are scheduled to provide the correct amount of water at the right time. The use of soil moisture sensors or a water table level for subirrigation may be most effective for drainage water recycling systems due to their ability to account for shallow water table contributions to meet crop water demand. A basic soil moisture sensor setup is estimated to be approximately \$3,300, whereas a more advanced system is approximately \$5,000. Subscription-based services from irrigation manufacturers and third-party providers are another option for irrigation management.

Automated outlet control structures: A system used to regulate the flow of water from subsurface drainage networks.

Continuous monitoring and adaptive control (CMAC) system: A water management technology using real-time data and automation to optimize performance of drainage infrastructure.

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SECTION 4

BENEFITS OF DRAINAGE WATER RECYCLING

The benefits of drainage water recycling are summarized in the table below based on existing research and previously implemented projects. The financial benefit values are provided as either a per acre or per pound of nutrient unit value. These unit values were then applied to the model site to estimate its total possible financial benefit.

SUMMARY OF DRAINAGE WATER RECYCLING BENEFITS

Table 6: Summary of drainage water recycling benefits.

Category		Benefit ranges	Average benefit estimates for model site (active storage)*	Main beneficiaries
1	Yield improvement from irrigation	\$130.22–\$146.20 per acre per year	\$16,250 per year \$130/acre × 125 irrigated acres	Producers and landowners through rent and land value
2	Operating cost savings	\$10–\$20 per acre per year	\$1,875 per year \$15/acre × 125 irrigated acres	Producers
3	Yield improvement from drainage	\$100 per acre drained per year	\$150,000 per year for entire watershed \$100/acre × 1,500-acre contributing watershed area	Landowners across entire contributing watershed
4	Storage and outlet relief within the drainage area	One-time benefit of \$100–\$180 per acre for the entire public drainage watershed	\$225,000 one-time savings at construction \$150/acre × 1,500-acre contributing watershed area	Drainage districts
5	Potential water quality benefits	Nitrogen: \$0.0005–\$4.54 per pound	Nitrogen: \$4–\$40,277 per year**	Downstream communities and recreational water users. Producers and landowners could benefit if outcomes-based payment programs are developed
		Phosphorus: \$8–\$25.58 per pound	Phosphorus: \$4,720–\$15,092 per year**	

*The model site is based on 1,500-acre contributing drainage area, 125–155-acre irrigation area and 41.7–77.5 acre-feet active storage reservoir.

** Average of annual estimated nutrient removal range for model site scenarios calculated in the following section of this report (Nitrogen ranges from 1,363–16,38 per pound, for an average of 8,871.5 pounds) (Phosphorus ranges from 62–1,119 pounds for an average of 590 pounds) × \$/lb for each nutrient.

- 1. Yield improvement from irrigation:** Based on measured yield improvements from supplemental irrigation at a drainage water recycling site near Story City, Iowa
- 2. Operating cost savings:** Producers with drainage water recycling sites and center pivots can use the irrigation system for fertigation and/or chemigation, saving on equipment and fuel costs that would otherwise be required to apply fertilizer or fungicide to the irrigated area
- 3. Yield improvement from drainage:** Expected yield improvement from replacement of failing drainage infrastructure with new, properly sized infrastructure for the upstream contributing watershed

- 4. Storage and outlet relief within the drainage area:** Due to the improved storage, tile main capacity and/or pipe size required to ensure proper drainage within the drainage area is reduced, translating to savings on construction and maintenance. Estimates are based on drainage systems in Iowa and Minnesota
- 5. Potential water quality benefits:** Potential water quality benefits based on different valuations, including estimates of the social costs of nutrients, outcomes payments for other practices, and nutrient trading examples. Since water quality markets are still emerging and none have been applied to drainage water recycling, these values are speculative but present a range of possible values

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PRODUCTION BENEFITS

Irrigation

A monitored drainage water recycling site near Story City, Iowa, measured yield improvements from supplemental irrigation, which have resulted in an average of 34 bushels of corn per acre with a range of –7 bushels per acre in a wet year when no irrigation water was applied, to 119 bushels per acre in a year with 32% less precipitation than average between May and September^[6]. Using an average corn price of \$3.83 per bushel from a price model results in an average annual benefit of \$130.22 per acre. The model accounts for corn pricing as a deviation function from the increasing trend in yield with time to account for weather variations for corn prices since 2000^[4]. The USDA projects corn prices to climb incrementally to \$4.30 per bushel over the next decade^[7]. At \$4.30 per bushel, the average annual benefit increases to \$146.20 per acre. Given that the Story City site is the only drainage water recycling site in Iowa with multiple years of data on crop yield impacts, this is an area for additional research. Research on drainage water recycling using subirrigation in Ohio, Missouri, and Minnesota showed an average yield increase of 19 bushels of corn per acre with 28% less yield variability than free drainage^[8]. The production of higher value crops, such as popcorn, seed corn, vegetables, and others, will result in a greater financial benefit from drainage water recycling.

Another supplemental irrigation benefit to consider is the added agronomic management ability. For example, producers with drainage water recycling sites and center pivots can use the irrigation system for fertigation and/or chemigation, saving on equipment and fuel costs that would otherwise be required to apply fertilizer or fungicide to the irrigated area. Savings on application costs range from \$10 to \$20 per acre^[9]. Fertigation allows nitrogen applications during the entire growing season, enabling producers to fine-tune nitrogen rates to crop uptake and removes weather-related risks of traditional nitrogen sidedress applications. Stored in reservoirs, the water containing nitrate provides supplemental fertilization value when irrigated. While the exact value of these added fertilization benefits is not well defined, they may be helpful in justifying the investment in a drainage water recycling site by a landowner.

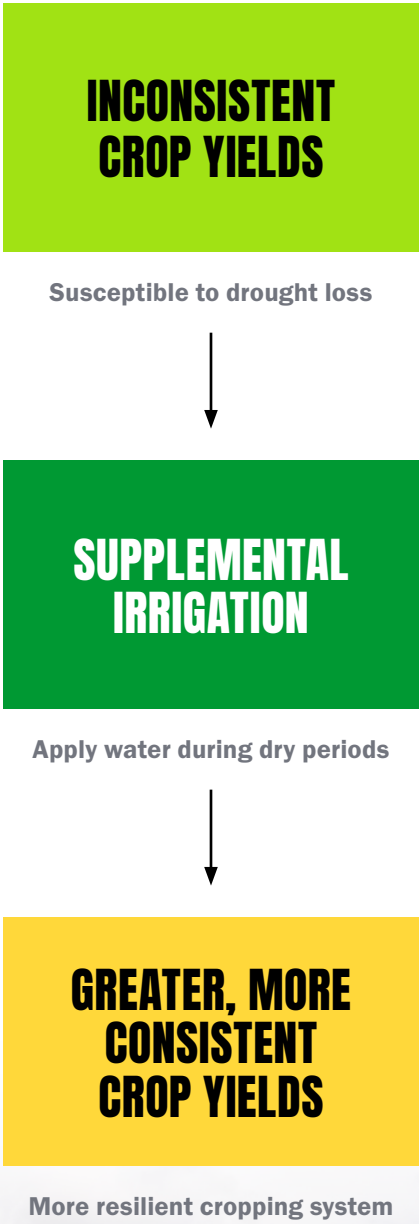


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Drainage

The implementation of drainage water recycling sites and storage is most effective when combined with drainage capacity improvements to the site and all lands within the project watershed. Drainage system improvements, which are necessary to satisfy drainage coefficient recommendations, can result in an average yield improvement of 8% to 15%. Based on ISG’s previous experience of drainage system improvements in lands where the existing system did not satisfy recommended drainage coefficients, an economic benefit of \$300 to \$500 per acre was estimated in wet years. Averaged across all years, the benefit is estimated at \$100 per acre. The benefits of improving or replacing drainage have traditionally justified the costs for private landowner investment.



**DRAINAGE SYSTEM
IMPROVEMENTS RESULT
IN AN AVERAGE YIELD
IMPROVEMENT OF
8% TO 15%**

PUBLIC DRAINAGE SYSTEM BENEFITS

Impact of drainage water recycling on public drainage systems and crop production

Many drainage systems in the Midwest were originally installed in the early 1900s and have outdated and/or failing infrastructure, rendering them unable to provide the capacity necessary to meet the drainage coefficient required for crop production. The entities responsible for the maintenance and improvement of these systems often experience economic challenges when exploring options to address the failing drainage infrastructure.

Implementation of drainage water recycling projects within public drainage districts can provide significant savings, as well as storage and outlet relief within the drainage area. As a result of the improved storage, the tile main capacity, or pipe size, required to ensure proper drainage within the drainage area is reduced, translating to savings on construction and maintenance. Based on ISG’s previous project experience with implementation of storage in drainage systems in Iowa and Minnesota, this cost savings benefit may range from \$100 per acre to \$180 per acre for the entire public drainage watershed.

Impact of drainage water recycling on sediment capture

Active storage basins can capture sediment. While active storage will require more regular maintenance and cleaning to ensure continued performance, the sediment capture of active storage provides a benefit to public drainage systems since it centralizes the location of sedimentation into a silt trap or forebay, which can be cleaned in a more cost-effective and less invasive manner than large scale ditch cleaning. Klein Pond, located on Blue Earth County Ditch 57 in Minnesota, is an active storage basin that receives both surface and subsurface water from approximately 1,700 acres. ISG’s monitoring of sediment capture rates found a capture of approximately 721 tons of sediment per five years. Life cycle construction and maintenance costs result in an estimated cost of \$44.57 per ton of sediment captured and removed^[5]. While sediment capture itself is not a driving force behind storage construction, it can justify public drainage investment in storage maintenance and cleaning.

GOVERNMENT PAYMENTS

There are a few known drainage water recycling sites in the Midwest that have been installed with no public assistance. As initial interest in DWR is growing in the Midwest, states such as Indiana, Iowa, Minnesota, and Ohio are exploring the use of public resources to advance conservation, water quality, and flood storage benefits, linking the potential for adding irrigation to increase acceptance and potential economic return for landowners/farmers for scaling implementation. Some recent sites in Iowa have used project assistance from IDALS to cover some of the costs of installing drainage water recycling systems. Storage grants are also available in Minnesota through the Minnesota BWSR, funding up to 90% of storage construction costs. Other state programs, such as H2Ohio in Ohio, may also be an avenue for project cost share. As the practice and programs evolve, there may be additional or alternative programs to support drainage water recycling.

NRCS could be well positioned to advance and support drainage water recycling. However, interpretation of their programs and resource concerns has been limited. Federal funding through NRCS EQIP is theoretically possible to cost share drainage water recycling systems, but there are no known drainage water recycling systems that have used EQIP funding. The NRCS Conservation Practice Standard Irrigation and Drainage Tailwater Recovery (Code 447) was modified to include drainage water recycling and has been adopted at the national level and by several Midwest states. It has not yet been adopted in Iowa. However, individual component practices could be covered alone or in combination by cost share for a drainage water recycling system. One known challenge with EQIP funding is that irrigation-related practices where water quantity has been the primary resource concern, require a previous history of irrigation. If NRCS’s interpretation were to be changed to allow irrigation-related practices to address a water quality resource concern without a previous irrigation history, this could make an EQIP cost share for drainage water recycling more feasible. EQIP payments typically cover 50% to 75% of implementation cost, but that percentage may be higher for priority practices or areas and could be combined with funding from state or other sources to increase the cost share up to 100%.



Credit: USDA Photo by Lance Cheung.

OUTCOMES PAYMENTS

Water quality outcomes payments are another potential future funding mechanism for a drainage water recycling system. Historically, outcomes programs have favored annually renewable conservation practices such as no-till farming and the use of cover crops, compared with longer-term structural practices. Current outcomes payments could inform potential programs that would pay for outcomes from structural practices. An example of water quality outcomes payments in Iowa are those from the Soil and Water Outcomes Fund, which currently pays \$3 per pound for nitrogen and \$8 per pound for phosphorus (A. Kiel, personal communication, January 8, 2025). Outcomes payments would likely be higher in states with more active water quality trading (WQT) markets.

Water quality trading: Water quality trading is a collaborative, market-based approach that allows regulated entities to meet pollution limits more cost-effectively by purchasing pollution reduction credits from others. It promotes economic efficiency, environmental improvement, and cooperation among stakeholders like municipalities, farmers, and regulators.

WATER QUALITY IMPROVEMENTS FROM DRAINAGE WATER RECYCLING

Drainage water recycling benefits water quality via storage treatment and nitrogen and phosphorus recycling through the drained water back to the cropland, reducing the amount released downstream. However, water quality monitoring of drainage water recycling systems at a level sufficient of assessing true nutrient load reductions has been limited. More research is needed to better quantify nutrient load reductions.

Of the existing research, four site-years of water quality monitoring for Iowa drainage water recycling sites have shown substantial nitrogen load reductions, whereas the results for phosphorus have been mixed^[6, 10]. Nutrient load reductions, calculated via inflows minus outflows and seepage, were influenced by the reservoir type; active or passive. With one exception, the active storage site removed greater nutrient loads as it captured greater inflows.

Conversely, passive storage generally had greater percentage removals since there were no outflows other than seepage. Nitrogen load reductions ranged from 421 to 2,707 pounds per year, or 63% to 92%, respectively. Phosphorus load reductions ranged from -44 pounds to 15 pounds per year, or -122% to 90%, respectively. Both extremes were seen at the active storage site.

It was hypothesized that at the active storage site, the high phosphorus loss in the first year was due to phosphorus release from newly disturbed sediments in the waterway where the reservoir was constructed, along with stream bank erosion in the outlet channel upstream of the monitoring location. In the second year, phosphorus loss was reduced due to phosphorus recycling through irrigation. The passive storage sites had positive but small phosphorus load reductions because of smaller inflows. The two years monitored to date were both drier years, so additional monitoring is necessary to assess nutrient reduction potential over a range of climate conditions.

In other studies, a small drainage water recycling reservoir in North Carolina had average load reductions of 391 pounds, or 47%, for nitrogen, and 16 pounds, or 30%, for phosphorus over two years of monitoring^[11]. An additional modeling study was referenced based on drainage data from sites in Indiana and Iowa^[12]. At the Indiana site, average load reductions were 10 pounds per acre, or 37%, for nitrate-nitrogen and 0.04 pounds per acre, or 39%, for soluble reactive phosphorus. At the Iowa site, modeled average load reductions were 8 pounds per acre, or 24%, for nitrate-nitrogen and 0.02 pounds per acre, or 21%, for soluble reactive phosphorus. The study assumed passive storage and did not account for nutrient reductions within the reservoir, so nutrient reductions were a function of how much water could be stored.

Table 7: Summary of nutrient load reductions from four site-years of drainage water recycling monitoring in Iowa.

Site year	Reservoir type	Nitrogen		Phosphorus	
		Load reduction (lbs)	Removal efficiency	Load reduction (lbs)	Removal efficiency
Lake City 2022	Active	2,707	63%	-44	-122%
Lake City 2023	Active	1,709	92%	15	32%
Story City 2022	Passive	421	90%	4	63%
Dayton 2023	Passive	930	92%	5	90%



SCENARIO ANALYSIS BASED ON REPORTED RESEARCH AND EXPECTED OUTCOMES

To assess the potential drainage water recycling water quality benefits for the scenarios evaluated in this report, a synthesis of nutrient removal data from almost 600 wetland, lake, and reservoir water bodies was used^[13]. Based on that data, average nutrient removals from reservoirs are 31.8% for total nitrogen and 47.8% for total phosphorus. In addition to nutrient removal from the reservoir, it is assumed that 100% of nutrients in irrigation water are removed, meaning they did not return to the stream, by plant uptake or other processes, and that 50% of nitrogen in seepage water is removed from passing through a denitrification zone.

For the 1,500-acre catchment area scenario of the model site, it assumes an average nitrogen yield of 31.5 pounds per acre^{[14][15]} and total phosphorus yield of 1.5 pounds per acre^[16]. Using assumed evaporation and seepage rates of 15% and 10% per year, respectively, water and nutrient balances were calculated for active and passive storage reservoirs of 41.7 acre-feet, which is 4 inches of storage for 125 acres and 62.5 acre-feet, which is 6 inches of storage for 125 acres. Based on the above parameters, the analysis showed estimated average annual load reductions ranged from 1,363 pounds to 16,380 pounds for nitrogen and 62 pounds to 1,119 pounds for phosphorus.

Similar to the monitored Iowa sites, the active reservoirs had greater load reductions in the mass of nutrients removed. The passive reservoirs, with no assumed outflows, had greater percentage reductions of inflows into the reservoirs. However, percentage reductions relative to the total yield from the upstream catchment area were much smaller because reservoir inflows were a small component of the overall water yield. The greatest source of load reduction was from treatment in the reservoir, but irrigation increases the load reduction and is critical for passive reservoirs because it determines the amount of water that can be stored and treated. These analyses only considered the nutrient reductions from the reservoir and recycled drainage water. Additional water quality benefits could be achieved by incorporating other water quality practices such as wetlands, saturated buffers, and denitrifying bioreactors into the system.

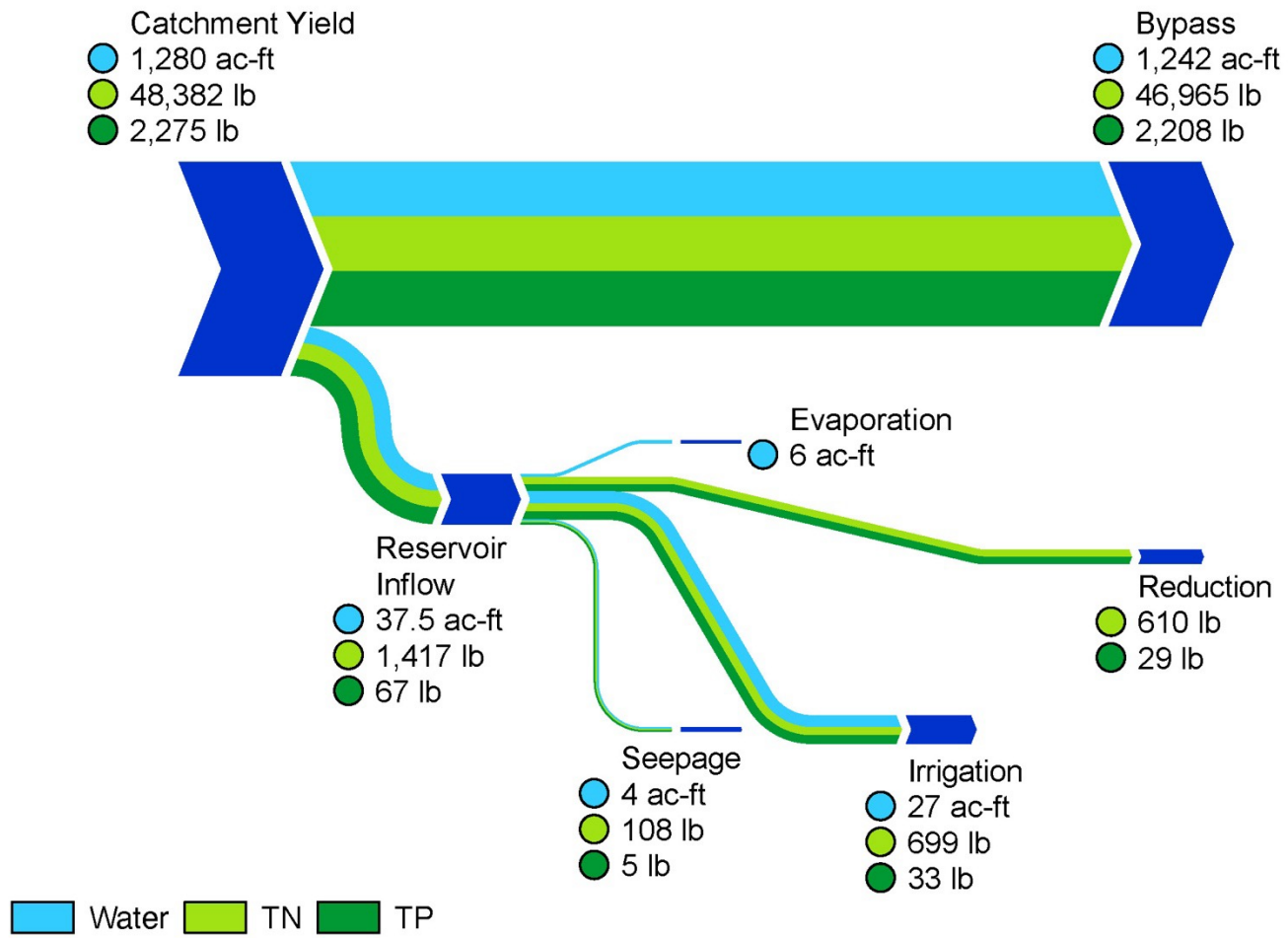


Figure 22: Water, total nitrogen (TN), and total phosphorus (TP) quantities. A diagram of average annual water and nutrient flows for a 41.7 acre-feet passive reservoir with 4 inches of storage receiving water from a 1,500-acre catchment area. The width of the bars is proportional to flow. Bypass flows are to scale, but all other flows are exaggerated by a factor of 10 to improve their visibility.

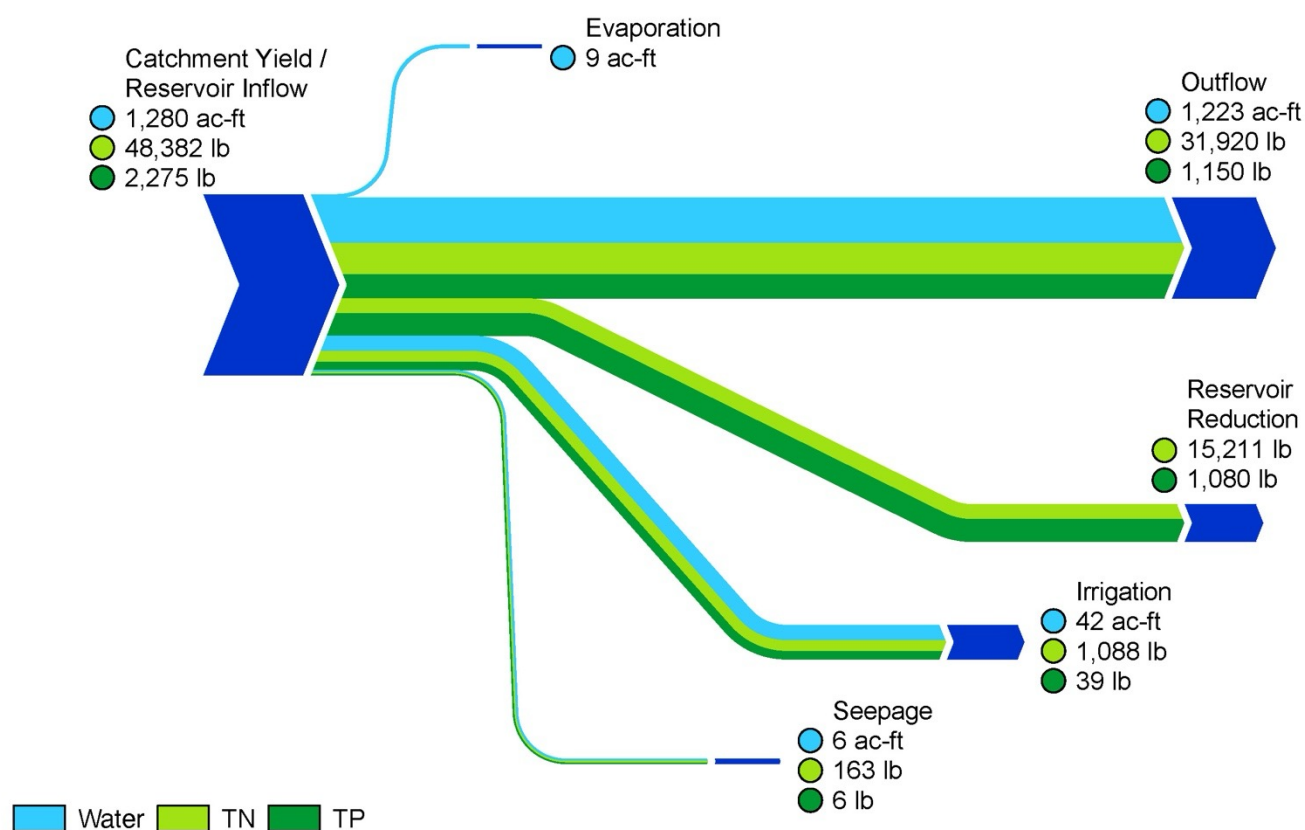


Figure 23: A diagram of average annual water and nutrient flows for a 62.5-acre feet active reservoir with 6 inches of storage receiving water from a 1,500-acre catchment area. The width of the bars is proportional to flow. Outflows and reservoir reductions are to scale, but evaporation, irrigation, and seepage are exaggerated by a factor of 10 to enhance visibility.

Table 8: Summary of estimated water, nitrogen, and phosphorus flows for drainage water recycling systems with active and passive reservoirs with 4 and 6 inches of storage. Nutrient load reductions are a combination of reductions from storage in the reservoir and nutrients recycled back to the field in the irrigation water. In addition, 50% of the nitrogen in seepage water was assumed to be removed from travel through a denitrification zone.

		Passive		Active	
Component		4 inches	6 inches	4 inches	6 inches
Inflows					
Reservoir inflow					
Water (ac-ft)		38	57	1,280	1,280
Total N (lbs)		1,417	2,166	48,382	48,382
Total P (lbs)		67	102	2275	2,275
Outflows					
Evaporation					
Water (ac-ft)		6	9	6	9
Seepage					
Water (ac-ft)		4	6	4	6
Total N (lbs)		108	161	108	163
Total P (lbs)		5	8	4	6
Irrigation					
Water (ac-ft)		27	42	27	42
Total N (lbs)		699	1,076	705	1,088
Total P (lbs)		33	51	26	39
Reservoir reduction					
Total N (lbs)		610	929	15,277	15,211
Total P (lbs)		29	44	1,079	1,080
Reservoir outflow					
Water (ac-ft)		--	--	1,242	1,223
Total N (lbs)		--	--	32,292	31,920
Total P (lbs)		--	--	1,167	1,150
Bypass flow					
Water (ac-ft)		1,242	1,223	--	--
Total N (lbs)		46,965	46,216	--	--
Total P (lbs)		2,208	2,173	--	--
Overall load reduction					
Total N (lbs)		1,363	2,085	16,036	16,380
Total P (lbs)		62	94	1,104	1,119

ESTIMATION OF THE SOCIAL COST OF NUTRIENT REDUCTION BASED ON EXISTING LITERATURE

Recent studies have estimated the social cost of nitrogen, or the present value of the monetary damage caused by an incremental increase in nitrogen, as a method to account for the externalities of nutrient loss from agricultural production. A 2016 report from estimated the social cost of nitrogen per pound of nitrogen fertilizer applied in Minnesota ranges over several orders of magnitude, from less than \$0.0005 per pound of nitrogen to greater than \$4.54 per pound of nitrogen, with an average of \$1.19^[17]. Using the social cost of nitrogen could be one way to estimate the broader economic benefits of water quality improvement from drainage water recycling. Using the average, the social benefits of nitrogen reduction for the scenarios above (1,363–16,380 pounds of nitrogen) would range from \$1,620 to \$19,466 per year.

DOWNSTREAM FLOW IMPACTS

By modulating runoff from storm events, storage basins in tile-drained landscapes, such as those constructed in a drainage water recycling system, can play a role in flood control strategies^[18]. Unless done at a large enough scale, downstream flood control benefits from drainage water recycling are likely to be localized. The practice may have potential positive impacts for mitigating high flows. Conversely, there may also be some potential negative impacts on low flows that may affect aquatic ecosystems, particularly in small headwater areas. The impact of drainage water recycling on watershed hydrology is an area of research needed to understand the effects on stream flows across the range of flow regimes. This will help inform both the design and management of drainage water recycling sites to maximize potential flood reduction impacts, as well as strategies to enhance environmental flows and minimize negative impacts.

NUTRIENT REMOVAL AND WASTEWATER TREATMENT

Cost offsets for wastewater nutrient removal

WQT is a mechanism by which entities, such as producers, may trade credits to NPDES permit holding facilities, such as wastewater treatment plants, for implementing BMPs that offset the nutrient discharges of the NPDES facility. This approach provides an alternative to nutrient management that is flexible, economically efficient, and environmentally co-beneficial—as opposed to making costly investments in facility and technology improvements. A 2018 report from HDR^[19], provided by the City of Ames, Iowa, estimated the costs of removing nitrogen and phosphorus through wastewater improvements at ranges of \$2.55 to \$3.64 per pound and \$17.96 to \$25.58 per pound, respectively. Efforts are underway to update these prices to the 2025 price equivalent.

Credit prices vary based on factors such as geography and/or watershed, BMP type, nutrient type, and supply and demand. The City of Ames partners with local farmers to implement BMPs to offset nitrogen and phosphorus discharges from their municipal wastewater treatment plant. Ames is in the process of registering their BMPs and valuing the credits. Depending on the site type, a drainage water recycling project could create nitrogen and/or phosphorus credits that could be sold to a municipality.



SECTION 5

DRAINAGE WATER RECYCLING INVESTMENT ANALYSIS

ANALYSIS METHODOLOGY AND ASSUMPTIONS

The drainage water recycling investment analysis was completed for four different model site scenarios. For each scenario, the anticipated investments into a drainage water recycling site made by each stakeholder were calculated based on their expected benefit. Once the funding framework was developed for each site, an investment analysis of the site was completed to determine the financial outcomes and profitability for the landowner and producer. Producers are assumed to own the land and thus be the landowner for the purposes of this analysis. Alternatively, if they are separate entities it is assumed that costs and benefits are shared between the two, since it would not be feasible for producers to invest in DWR on rented land without the landowner’s support.



The results of the analysis are presented as net present value (NPV), return on investment (ROI), and payback period. NPV provides a present-day dollar amount that represents the value of the drainage water recycling system to the landowner and producer, considering the monetary value of time. ROI expresses the efficiency of the landowner or producer's investment into the drainage water recycling system as a percentage, showing the return relative to the investment cost. The payback period represents the amount of time required to recoup the original investment into the system made by the landowner or producer. Each of these values were calculated based on the initial investment, annual costs, and annual benefits to the landowner or producer for the drainage water recycling site. Detailed calculations are in the Appendix. The following is a list of assumptions made when creating the funding scenarios and calculating the financial outcomes.

- Investments into the drainage systems were not included in the analysis, as these are expected to be made by landowners or drainage districts prior to or outside of the DWR project in all circumstances.
- Public water quality funding investments into the drainage water recycling storage were based on the previously estimated value of nutrient removal made by the system. If the value of water quality benefits of the storage exceeded the storage costs, it was assumed that 100% of the storage would be publicly funded.
- All modeled scenarios utilized center pivot irrigation, as this was the most cost-efficient irrigation method.
- Annual site operation and maintenance costs were assumed to increase at 3% with inflation, while annual crop yield benefits of irrigation were assumed to slightly outpace costs at 3.5% due to increased drought frequency.
- The irrigation yield benefits were modeled using the low-end, conservative yield improvement estimate of \$130 per acre and this benefit is shared between the landowner and producer, if they are separate entities.
- The cost and benefit analyses were completed based on the anticipated useful lifespan of the irrigation system, which is 25 years for center pivot. The storage component has an anticipated useful lifespan of 100 years, but future re-investments into new irrigation systems were not modeled. It was assumed that storage and drainage would continue to operate and provide the expected outcomes in the future independent of irrigation.



STAKEHOLDER INVESTMENTS

The components of a drainage water recycling site are expected to be funded by a variety of sources since they provide both private and public benefits. Estimated investment from each source was modeled using expected costs and benefits. The result provides a framework for future funding of drainage water recycling sites at scale.



LANDOWNER AND PRODUCER INVESTMENTS

Drainage

If existing private field-scale drainage infrastructure is to be replaced or improved as part of a drainage water recycling project, it is expected that the landowner and/or producer would pay for the costs of this replacement or improvement since the benefits are realized by the landowner and producer. Artificial drainage enables earlier planting, improves the timeliness of field work and crop yields, and aids in the adoption of other conservation practices, such as no-till farming and cover crops. Therefore, the expected returns of field-scale private drainage improvement have traditionally justified a 100% investment by the landowner. With some minor exceptions, such as additional mains or submains necessary to make the site suitable, the private drainage portions of a drainage water recycling site are expected to continue to be supported by landowners. Some minor modifications to existing drainage infrastructure may be necessary to accommodate a drainage water recycling site, in which case those costs would be included within the storage construction. If subirrigation is selected, the drainage infrastructure will double as the irrigation infrastructure, in which case an alternative funding arrangement may be applicable for valves, control structures, and mains associated with the controlled drainage and subirrigation.

Storage

Private landowners are generally not likely to provide significant out-of-pocket funding for storage construction. **Although storage enables the ability to irrigate and offsets the need to develop a different water source, the high cost of constructing storage is not likely to be justified by the benefit received through supplemental irrigation.** Without additional financial incentives, landowners are not likely to implement drainage water recycling or may consider using other water supplies. However, other water supplies may not offer water quality and other benefits that drainage water recycling offers, potentially increasing strain on those alternate water sources from additional withdrawals. A potential investment scenario may be for the landowner providing the land for storage construction at low or no cost. Early implementation projects have included the operation and maintenance costs of storage as either a private landowner or drainage district responsibility.

Expected irrigation yield improvements

The analysis used an average expected corn yield benefit of 34 bushels per acre^[6] for center pivot and subsurface drip irrigation, and 19 bushels per acre for subirrigation^[20]. A corn price of \$3.83 per bushel was used to calculate the initial expected benefit per irrigated acre. The irrigation benefit was assumed to grow at a slightly greater rate than costs, approximately 3.5% per year, due to inflation and anticipated increased drought frequency^[21].

Appropriate yearly operation and maintenance costs were assigned to each irrigation method and assumed to grow at 3% with inflation. NPV measures the difference between the present value of cash inflows versus the outflows over the period. Net equivalent annual value is a method to compare investments with different lifespans by converting their NPVs into an equivalent cost or benefit. ROI determines the profitability of a cost. The investment analysis results for the three irrigation methods are summarized in the table below.

Table 9: Irrigation methods investment analysis.

Irrigation method	Net present value (NPV)	Return on investment (ROI)	Net equivalent annual value	Payback period (years)
Center pivot	\$143,400	95.6%	\$9,179	13
Subirrigation*	-\$43,800	-14.11%	-\$2,210	N/A
Subsurface drip	\$103,187	32.76%	\$6,605	19

**The negative NPV for subirrigation is a function of greater costs (based, in part, on an assumed 0.5% field slope requiring multiple control structures) and smaller observed yield increases. The subirrigation analysis also does not consider additional drainage benefit from the increased drainage intensity needed to enable subirrigation. A change in any of these factors: reduced costs for flatter, more suitable sites; larger yield increases; or a modest increase in drainage benefit results in a positive NPV.*

The irrigation infrastructure construction, operation, and maintenance costs will be covered at least in part by the landowner and/or producer due to expected value and crop yield benefits. Drainage water recycling irrigation benefits for the model site, as summarized in the table above, would justify a landowner investment of 75%–100% of the total irrigation infrastructure, and operation and maintenance costs. Unless a long-term lease is in place, drainage water recycling systems on rented cropland will likely be rare during early implementation phases given high investment costs. The most common arrangement for irrigated cropland rental is a crop share agreement, in which the producer and landlord share in the costs and benefits of the irrigation system. However, other rental arrangements are possible.



PUBLIC DRAINAGE INVESTMENT

In the case of drainage water recycling projects completed in combination with a public drainage repair, replacement, or improvement, it is expected the drainage district would pay the costs of replacing, repairing, or improving the public drainage infrastructure. Similar to private field-scale drainage investments, the return on watershed-scale improvements or repairs typically justifies a 100% investment by the drainage district. Implementing active storage into a watershed-scale drainage project has proven to decrease the overall project costs by providing outlet relief and reducing the necessary drainage coefficient and pipe sizing. These savings are variable and range from \$100 to \$180 per acre for the entire watershed and are a one-time benefit associated with construction.

In cases where the drainage water recycling project is sited and designed to provide these savings, it is expected that the drainage district would fund the storage construction costs up to or near the level of drainage construction cost savings. For the model site with active storage, these savings in drainage construction range from \$150,000 to \$270,000. Drainage districts also typically cover at least part of the costs of active storage regular maintenance and cleaning. It is not expected that the drainage district would cover any portion of the irrigation construction or associated operation and maintenance costs.



PUBLIC FUNDING OPTIONS

Drainage

It is not expected that external public funding would support field-scale or watershed-scale drainage repairs or improvements, except modifications to existing infrastructure necessary to accommodate a drainage water recycling site. If subirrigation is used, the cost of control structures, valves, pumps, or mains could be funded publicly because they facilitate water recycling and nutrient removal.

Irrigation

Some of the existing drainage water recycling sites in Iowa have received EPA grants through IDALS to fund a portion of the irrigation system costs, but this is not expected to be sustainable. It is possible the modification of existing NRCS EQIP programs may allow for partial funding of irrigation systems. However, significant public investment in irrigation equipment is not expected at this time.

Storage

Proven BMPs for nutrient reduction such as wetlands, saturated buffers, or in-field practices have traditionally been supported up to 100% for the design and construction costs by public water quality funding. To compare the nutrient removal efficiency of various BMPs, a removal efficiency value or cost per pound can be calculated by dividing the lifetime financial cost of the practice by the practice's estimated lifetime removal of the nutrient of interest.

The cost per pound of nitrogen and phosphorus removal for more widely accepted BMPs ranges from less than \$1 per pound of nitrogen and \$0.05 per pound of phosphorus to over \$26 per pound of nitrogen and \$870 per pound of phosphorus^[22]. Mean values for constructed wetlands are \$7 per pound of nitrogen and \$367 per pound of phosphorus. The nutrient removal costs for the active drainage water recycling model site in this report are designed to reduce nitrogen and phosphorus at an approximate price of \$2 per pound and \$30 per pound, respectively.

The passive site had a much lower modeled nutrient removal, with removal costs of \$14 per pound and \$316 per pound, respectively. While the efficiency of nutrient removal for drainage water recycling sites is highly dependent on storage type, sites with nutrient removal prioritized in design are expected to remove nutrients at a comparable cost to other BMPs such as saturated buffers, bioreactors, or wetlands. Based on previous experience and current conditions, it is reasonable to expect that public water quality funding would continue funding drainage water recycling design and storage construction. The level of support depends on storage type and expected nutrient removal. Sites with active storage and supplemental wetlands may be funded by up to 100% of construction costs, while passive storage may only be funded in part through public water quality initiatives.



COMMUNITY IRRIGATION COST SHARE

Community drainage water recycling sites have multiple landowners that can access and use stored drainage water. These sites are an opportunity to maximize the usage and efficiency of constructed storage. A community site allows for larger storage to be constructed, and economies of scale are likely to result in a lower overall cost for each landowner involved. While the entire cost of constructing a storage basin is typically too expensive for one landowner, the division of storage costs between multiple landowners and/or end users creates a more attractive private investment. Supplemented by public funding, community drainage water recycling sites are a promising opportunity to increase efficiency and adoption of drainage water recycling. Specific funding and water use arrangements need to be determined to ensure successful community site implementation.



RETURN ON INVESTMENT AND FINANCIAL FEASIBILITY

Return on Investment (ROI) analysis

Building on the irrigation cost-benefit analysis, a complete financial cost-benefit analysis was completed for four drainage water recycling site scenarios. Expected storage and irrigation costs and benefits were included for each scenario. Drainage system costs and benefits were not included, as they are expected to occur independently of drainage water recycling, except for upstream public drainage outlet benefit resulting from active storage construction, which was applied to storage costs where applicable. Center pivot irrigation was used for all analyses since center pivot costs are more consistent across sites, and it was the most cost-effective option among scenarios. Subirrigation may be a more desired option in some situations, but subirrigation costs will vary widely depending on soils and topography.

Table 10: Landowner investment scenarios

System type	Active storage with center pivot	Passive storage with center pivot	Retrofit system with center pivot	Community storage with three center pivots
25 year ROI	96%	5%	44%	68%
Payback period	13 years	24 years	18 years	15 years



Active storage drainage water recycling with center pivot

The active storage scenario included design, planning, and construction costs for an active storage basin. It also included future costs for regular sediment cleaning and maintenance. Three assumptions were made in this scenario. The first was that 100% of the storage basin design and construction costs were paid upfront through external public drainage and water quality funding due to cost effectiveness. The second was that future storage maintenance costs were paid externally by the drainage district. The third was that irrigation construction and operation and maintenance costs were all modeled as paid by the landowner. The resulting NPV of the landowner's investment was approximately \$144,000 with a 96% ROI and a payback period of 13 years.



Passive drainage water recycling with center pivot

The passive storage scenario included design, planning and construction costs for a passive, pumped storage basin. It also included future costs for pump replacement and other maintenance. The external public investment was estimated at approximately 75% of storage design and construction costs based on lower nutrient removal potential. Future storage maintenance costs were assumed to be paid externally due to the water quality benefit of pumping water into the storage basin. The irrigation construction and operation and maintenance costs were all modeled as paid by the landowner. The resulting NPV of the landowner's investment was approximately \$15,000 with a 5% ROI and a payback period of 24 years.



Retrofit drainage water recycling with center pivot

The retrofit storage scenario was modeled similarly to the passive storage scenario with partial storage retrofit funding, as modifying existing storage to accommodate drainage water recycling only provides a marginal increase in water quality benefit for the water being irrigated. The primary difference is the significantly lower storage construction costs for retrofitting, resulting in an NPV of the landowner's investment of approximately \$89,900 with a 44% ROI and a payback period of 18 years.



Community drainage water recycling site with three center pivots

A community storage drainage water recycling site was modeled using a large, complex storage basin with high construction costs and three adjacent landowners who each used the storage for their own irrigation. Four assumptions were made in this scenario. The first was that about 90% of storage construction costs were paid externally due to water quality or drainage benefits. The second was that landowners would pay for their own irrigation construction and operation and maintenance costs. The third was that external funding was used for storage operation and maintenance. The fourth assumption was that the site would have three separate center pivots for multiple landowners to use over approximately 350 irrigated acres. The modeled community site resulted in a total NPV of the landowners' investment of approximately \$343,000 with a 68% ROI and a payback period of 15 years.

An aerial photograph of a vast, green agricultural field, likely corn, with a small drone flying in the lower right portion of the frame. The field is divided into sections by rows of crops, and the background shows more greenery and some distant trees under a clear sky.

COMPARISON OF INVESTMENT SCENARIOS

The active storage basin site model resulted in the highest ROI primarily due to external storage funding. The storage construction costs played a significant role in the overall feasibility, as scenarios without 100% funding for storage were difficult to reach a positive NPV. The retrofit site performed much better than the passive site due to the significantly lower storage construction costs.

Other funding

Other non-traditional funding sources may be considered to supplement the core drainage water recycling site funding sources. Some of these may include outcomes-based nutrient reduction payment programs, nutrient credit trading markets, downstream flood mitigation funding, habitat restoration funding, and recreational funding. While the applicability of each of these types of supplemental funding is highly dependent on specific drainage water recycling site characteristics, they may serve to bridge funding gaps where the core funding sources are insufficient to cover drainage water recycling site costs.



SENSITIVITY ANALYSIS (ACTIVE STORAGE AND CENTER PIVOT)

The analysis and expected returns to the landowner or producer are highly sensitive to the irrigation system costs and benefits. To better understand the sensitivity to irrigation and the range of possible outcomes, a sensitivity analysis was completed for the active storage with center pivot scenario.

Irrigation benefits

The estimated annual irrigation yield benefit of \$130 per acre is based on the model site and known research for corn production, but actual returns on irrigation investment vary with several site-specific factors including soil type, production crop type, irrigation scheduling, and agronomic management. Sites with coarse texture soils that have a greater need for irrigation, or sites that produce higher value crops, could show a much greater annual irrigation benefit.

Conversely, sites with more poorly drained soils will likely show less response to the irrigation. Well managed and scheduled irrigation systems will maximize annual yield returns, while poorly managed systems could limit returns. This range of potential annual irrigation benefits was modeled with a 50% increase and a 50% decrease, summarized in the table below. The increased irrigation benefits scenario resulted in significantly improved ROI and NPV with a faster payback period. The decreased benefits scenario resulted in a negative ROI and NPV.

Table 11: Irrigation benefit sensitivity analysis summary

Landowner investment scenario (active storage with center pivot)	Return on investment	Payback period (years)	Net present value
Original (\$130 per acre per year)	96%	13	\$144,000
50% increase in annual yield benefit	223%	8	\$334,000
50% decrease in annual yield benefit	-32%	N/A	(\$48,000)



Irrigation Costs

Irrigation initial investment and annual operating costs per acre are more well defined and less variable. While there are some regional variations in pricing and limited irrigation cost-share opportunities available, the initial irrigation investment per acre is not expected to vary more than 25%. Annual irrigation operating costs will vary year-to-year depending on the amount of irrigation, but average annual irrigation costs per acre should not vary significantly across drainage water recycling sites or geographies. The range of irrigation costs was modeled with a 25% increase and 25% decrease in the initial investment for irrigation.

Table 12: Irrigation cost sensitivity analysis summary

Scenario (active storage with center pivot)	Return on investment	Payback period (years)	Net present value
Original (\$150,000 initial investment and \$4,000 annual O&M)	96%	13	\$144,000
25% Decrease in initial irrigation investment	161%	10	\$181,000
25% Increase in initial irrigation investment	56%	16	\$106,000

The sensitivity analysis showed variations in irrigation system cost and benefits play a significant role in landowner investment feasibility. Variation in irrigation yield benefit outweighed cost variation, as the decreased irrigation benefit scenario produced negative returns, while increased irrigation investment costs still showed positive, yet reduced, returns. The sensitivity analysis revealed annual irrigation yield benefit was the most important factor to drainage water recycling site financial success and positive return on landowner investment. **This emphasizes the importance of siting drainage water recycling in fields where irrigation will provide the most financial benefit, such as well drained soils or high value crops.** Additionally, this highlights the importance of educating landowners or operators on proper irrigation operation and scheduling, to maximize returns.

FINANCIAL FEASIBILITY

The investment return analysis of the three irrigation methods resulted in a positive NPV for center pivot and subsurface drip irrigation, but not subirrigation. The center pivot irrigation option gave the shortest payback period and highest ROI due to a lower initial investment.

While the subirrigation analysis showed a negative NPV and ROI, the initial investment in subirrigation includes a significant drainage system investment that is likely to provide additional benefit to the producer if the system is sized to take advantage of the increased drainage intensity.

Additional drainage benefits were not considered in this analysis. Drainage mains were assumed to be sized to maintain existing drainage rates. The marginal drainage benefit from subirrigation installation depends on several site-specific factors. Results from modeling similar soils in southern Minnesota indicate an additional drainage benefit from splitting the laterals for subirrigation of a 12.5% increase in yield (E. Ghane, personal communication, April 10, 2025). Assuming an average corn yield of 200 bushels per acre, the additional drainage benefit would be 25 bushels per acre, which at an assumed corn price of \$3.83 per bushel would be approximately \$96 per acre. Even a modest drainage benefit of \$10 per acre would provide a positive NPV for subirrigation.

While center pivot irrigation continues to be the most cost-effective option, subsurface drip and subirrigation are still viable options to be considered when drainage water recycling site constraints are not suitable for a center pivot. For example, subirrigation may be more suitable in a flat field that also requires drainage replacement and with soils well suited for subirrigation, while subsurface drip may be more suitable for smaller, irregular shaped fields and higher value crops with greater water needs.

The economic analysis shows the expected yield benefits justify the investment to the irrigation system on drainage water recycling sites by landowners. While the benefit justifies the investment into irrigation, excess benefit beyond irrigation costs is modest when compared with storage costs.

The economic model showed drainage water recycling sites require some external funding to be feasible and the level of external funding plays a vital role in project success. **Sites with water quality and drainage benefits prioritized during design will be much more attractive to external funding sources, and therefore more economically feasible.** Irrigation annual benefits should be maximized through proper siting and implementation to ensure positive returns. Passive drainage water recycling sites with lower water quality benefits and no ancillary benefits are unlikely to be economically feasible in the long-term unless a much lower storage construction cost is achieved. Retrofit sites are promising opportunities for future projects, especially if converting existing storage to drainage water recycling provides additional water quality benefits. The success of community drainage water recycling sites will depend on the economies of scale realized during implementation.



SECTION 6

CASE STUDY

M&M FARMS, LAKE CITY, IOWA

The M&M Farms drainage water recycling site located near Lake City in Calhoun County, Iowa, showcases an instance of how drainage water recycling may be funded or implemented by multiple stakeholders.



DRAINAGE



STORAGE



IRRIGATION

TABLE OF CONTENTS	EXECUTIVE SUMMARY	DWR OVERVIEW	ANALYSIS SCOPE AND STRUCTURE	COST OF IMPLEMENTING DWR	BENEFITS OF DWR	DWR INVESTMENT ANALYSIS	CASE STUDY	CONCLUSION
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DRAINAGE

Most of the upstream watershed is comprised of Calhoun County Drainage District No. 203 (DD203). DD203 had aging, undersized drainage mains that were petitioned for drainage improvements in 2014. In 2018, construction was completed to improve the capacity of multiple drainage mains within DD203. The drainage improvement was completed through the drainage district and was funded 100% by landowners of the district at approximately \$650 per acre. Since M&M Farms is a landowner within DD203, they paid a portion of the drainage improvement costs.

Figure 24: Installation of the DD203 improvements in 2018.



STORAGE

The active storage basin, downstream of the DD203 outfall, receives all surface and subsurface flow from the contributing DD203 watershed. Since the storage basin was sited downstream of DD203, the drainage district receives no direct benefit from the storage. However, M&M Farms benefits from increased water supply due to the upstream DD203 improvements. At the upper reach of the storage basin, a shallow pool was constructed to facilitate additional denitrification. The storage basin was built for approximately \$150,000. Construction costs were kept low due to minimal excavation, since the site had favorable topography. Additionally, the storage basin was constructed slightly smaller than recommended because the landowner knew the waterway has nearly continuous flows—except for very dry periods—due to drainage district discharge and groundwater seepage from the adjacent hillsides. Therefore, considerable in-season recharge of the reservoir was expected. The design and construction costs of the storage basin were paid for by IDALS.

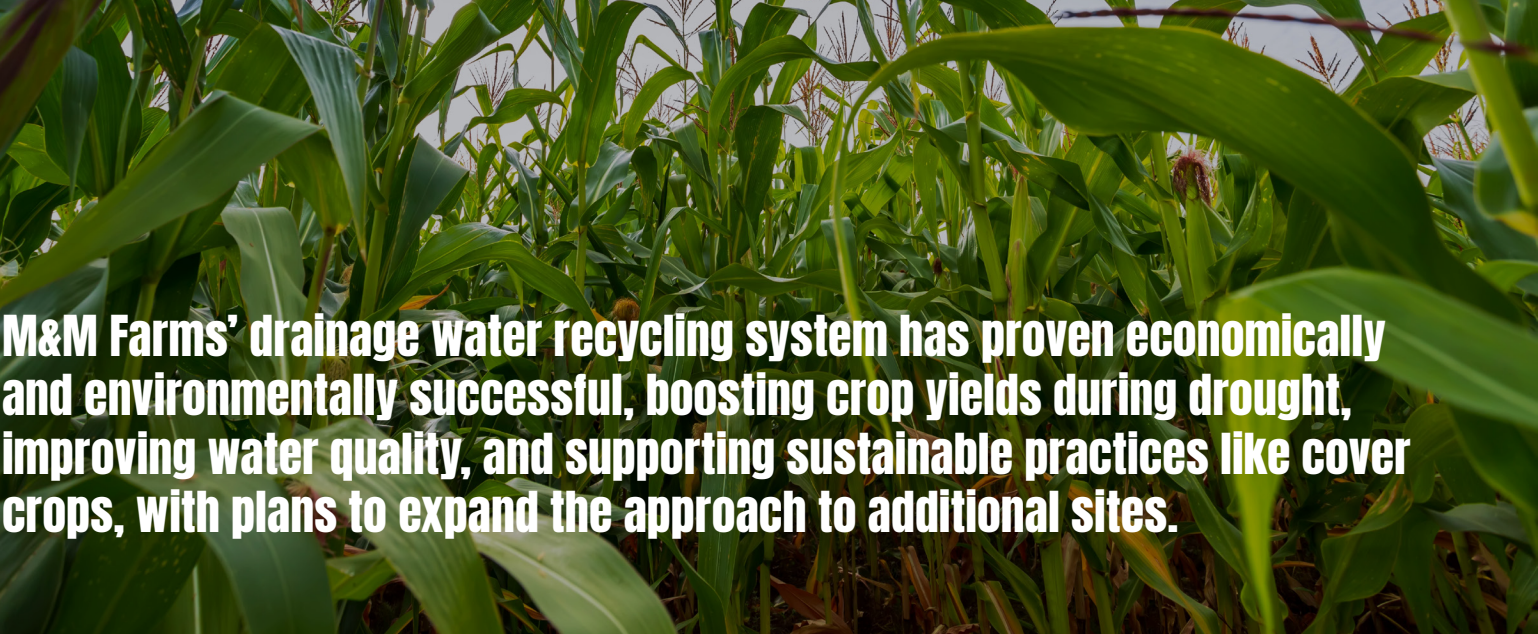
Figure 25: M&M Farms drainage water recycling storage basin shallow pool, facing upstream.



IRRIGATION

The M&M Farms site includes a center pivot that irrigates approximately 53 acres of land in row crop production for primarily corn silage and grain, popcorn, soybeans, and cover crops. The center pivot pumps water out of a wet well in the storage basin. The construction cost of the center pivot was approximately \$110,000. IDALS would not normally cost share the irrigation system, but this was part of a demonstration project, leading IDALS to provide a 50% cost share on the irrigation system using EPA Gulf of America Division's (GAD) Farmer-to-Farmer (F2F) program funding with the remainder paid by M&M Farms.

Figure 26: M&M farms drainage water recycling center pivot and storage basin.



M&M Farms’ drainage water recycling system has proven economically and environmentally successful, boosting crop yields during drought, improving water quality, and supporting sustainable practices like cover crops, with plans to expand the approach to additional sites.

KEY TAKEAWAYS

The M&M Farms site is a successful demonstration of drainage water recycling. The irrigated field is primarily sandy alluvial soils that benefit greatly from irrigation in the summer. The adjacent waterway provided an advantageous location to create a storage impoundment with minimal excavation. Discharge from the upstream drainage district provides a reliable water supply, making it a more attractive option for the landowner than creating another well. The landowner was already familiar with irrigation from previous work and has operated center pivots on other parts of his farm for many years.

In addition, M&M Farms has some higher value crops, such as popcorn for both seed and consumption, that more easily justify the irrigation investment. Unfortunately, there is not adequate space for a control area to directly compare crop yields, with and without supplemental irrigation. However, the irrigation came online just in time in 2021 to save the crop from drought conditions and produced good yields in the drier years of 2022 and 2023, which otherwise would have experienced reduced production. As an active storage basin, the reservoir has also produced positive water quality benefits, removing 2,707 pounds of nitrogen in 2022, a 63% reduction, and 1,709 pounds of nitrogen in 2023, a 92% reduction.

Phosphorus results have been mixed, with an increase downstream in 2022 presumably from the release of phosphorus due to sediments disturbed by reservoir construction and streambank erosion between the reservoir outflow and the monitoring point. Phosphorus recycled to the field through irrigation resulted in an overall phosphorus reduction in 2023.

With the success of their first drainage water recycling site, M&M Farms is in the process of implementing a second site with tentative plans for others. With a new understanding of drainage water recycling benefits, the owner said he would have used more sites to supply center pivots instead of the current groundwater wells. M&M Farms has also implemented saturated buffers and bioreactors at other sites as part of a watershed project. The landowner particularly likes the drainage water recycling project due to the economic benefits to his operation. Similarly, M&M Farms has also adopted cover crops throughout the operation due to the economic benefits of additional grazing opportunities for cattle, as well as the soil health and water quality benefits. M&M Farms has indicated that the drainage water recycling system has aided in cover crop production by providing supplemental water to support germination and establishment that would otherwise hinder cover crop effectiveness in dry years.



SECTION 7

CONCLUSIONS

Drainage water recycling represents a promising opportunity to build agricultural resilience for farmers with potential environmental and economic returns for a broad range of stakeholders. This is critical, as the upfront costs of drainage water recycling implementation may require a public-private funding approach that ensures costs are appropriately shared between public and private beneficiaries.

The report found the most effective funding scenarios maximize benefits to both landowners and public beneficiaries while distributing costs appropriately. For example, landowners and farmers could cover field drainage and irrigation costs, given that they will directly benefit financially from these investments. Storage may be supported by landowners providing land at low or no cost, while public funding is best suited to cover storage construction and in some cases conservation easement costs given the potential water quality benefits to the public.

Among the available methods for implementation, active storage with center pivot irrigation stands out as the most economical due to its relatively low, consistent irrigation costs and the potential for public funding for storage construction and maintenance. Under these assumptions, this scenario offers the highest ROI for landowners, followed by the community storage scenario with three center pivots and the retrofit system with a center pivot.

Continued research is needed to better understand nutrient removal, crop yield improvement, and the broader public benefits of drainage water recycling. Public and private sector stakeholders should invest in additional research, as well as test sites and financing mechanisms to determine the most effective approach to scale drainage water recycling implementation in ways that support farm resilience, water quality, and flood mitigation.

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The report utilizes publicly available information from the following organizations:

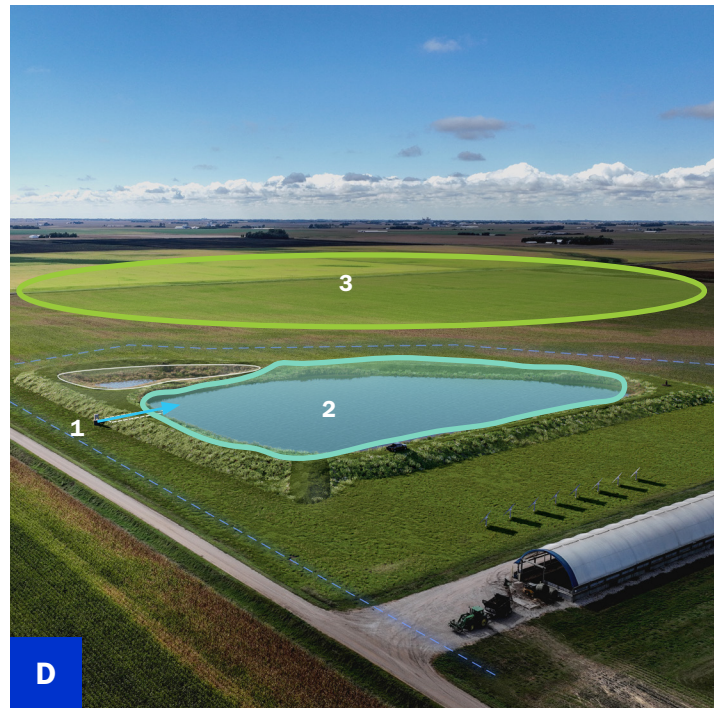
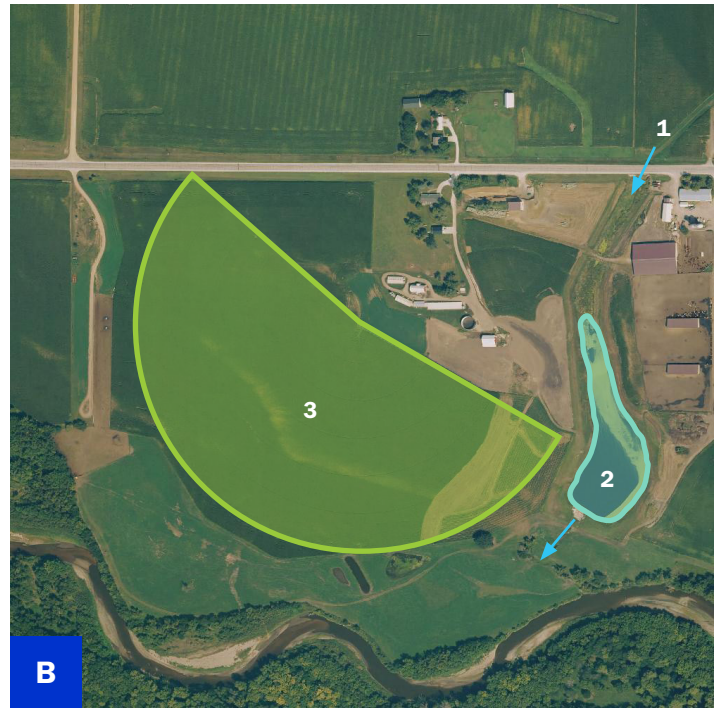
- Iowa Soybean Association
- Iowa Department of Agriculture and Land Stewardship
- Soil and Water Outcomes Fund
- City of Ames
- Iowa State University

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IOWA DRAINAGE WATER RECYCLING SITES

Primary data on drainage water recycling costs and benefits were derived from three existing and one planned drainage water recycling site in Iowa. The Story County site was the primary source of corn yield benefits. All three existing sites provided initial water quality results. Monitoring and data analysis for the three existing sites were completed by Iowa State University and the Iowa Soybean Association^[4,6,10]. The Kossuth County site was designed by ISG and is under construction in 2025. These sites provide a starting point for better understanding of the economics of drainage water recycling, but given the limited number of project sites and site-years of data, caution should be exercised in extrapolating beyond these sites.

	A	B	C	D
	Story County	Calhoun County	Webster County	Kossuth County
Storage type	Active capture of subsurface drainage water from field and passive capture from adjacent stream	Active	Passive	Passive
1 Inflows	Drainage from a 6-inch outlet supplemented with water pumped from an adjacent stream	Surface inlet channel receiving input through a 4 ft x 6 ft box culvert, 30-inch drainage outlet, and local surface runoff	Sump intercepting an 18-inch drainage main	Sump intercepting 18-inch and 24-inch drainage mains
Catchment area	20 acres of subsurface drainage and approximately 19,840 acres from stream	Approximately 1,417 acres	Approximately 245 acres	Approximately 630 acres
2 Reservoir area (full pool)	2.5 acres	3.7 acres	3.3 acres	3.77 acres
Reservoir volume (full pool)	12.2 acre-feet	15.3 acre-feet	37.0 acre-feet	47.9 acre-feet
Irrigation system	Center pivot	Center pivot	Center pivot	TBD
3 Irrigated area	60 acres	53 acres	106 acres	TBD (expected 100-120 acres)
Year established	2015	2021	2022	2025



PREVIOUS DRAINAGE AND STORAGE DESIGN EXPERIENCE

Knowledge of drainage and storage design and construction used in the development of this analysis was informed by extensive experience with water storage projects that were designed and constructed by ISG. ISG's water storage initiatives have consistently incorporated BMPs aimed at reducing flooding, enhancing field conditions for improved crop yields, and improving water quality through the reduction of sediment and nutrient loading. Collectively, these projects represent the modeling of over 4.6 million acres of watersheds, the creation of more than 1,300 acre-feet of storage volume, and over 1,000 drainage system designs.

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