

Controlled Drainage Beyond Flat Fields

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1. Overview of controlled drainage

Controlled drainage, also known as drainage water management, is a conservation drainage practice that improves water retention for crops and reduces nitrate loss from tile-drained fields. The practice works by placing a weir inside a control structure to raise the outlet elevation of the subsurface drainage system. Weir settings can be tailored to the crop and season, keeping more nutrients for the crop and allowing only the excess water to leave the field (Figure 1, Bottom graph).

This bulletin shares results from a paired-field study (Ghane et al. 2025) that evaluated controlled drainage on a field in Michigan. Findings challenge the traditional belief that controlled drainage is only effective on relatively flat fields.



2. Rethinking the slope requirement of controlled drainage

Controlled drainage is typically recommended for relatively flat fields with slopes less than 1%, largely due to the perceived economic advantage that fewer control structures are needed to maximize the managed area. This *managed area* refers to the portion of the field where the raised outlet elevation from a control structure has a measurable effect on the water table. On steeper fields, this area tends to be much smaller.

However, recent field research has shown that controlled drainage can still significantly reduce nitrate loss even when only a small portion of the field is water managed. In one study by Ghane et al. (2025), a field with 1.1% slope and just 6.6% of its area under water management achieved a 48% reduction in nitrate load (Figure 1, Top graph).

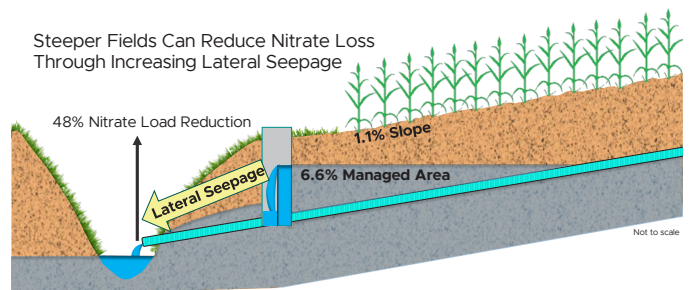
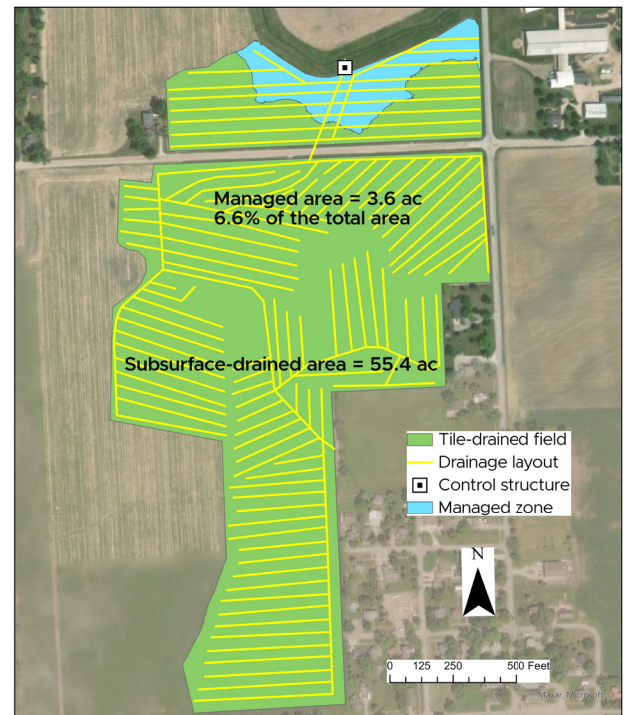


Figure 1- Top graph: Shows the top view of the field with a small managed area. Bottom graph: A controlled drainage system can reduce nitrate loss in steep fields.



3. Controlled drainage has two key functions

Controlled drainage serves two key functions depending on the field's slope and design goal (Figure 2):

(1) Crop yield-focused: On flatter fields, controlled drainage retains water across a larger area to support crop growth.

(2) Water quality-focused: On both flat and steeper fields, controlled drainage can reduce nitrate loss.

While steeper fields may gain less from water retention, controlled drainage can still improve water quality. In these fields, raising the outlet elevation increases the hydraulic gradient. This causes water to move out of the perforated pipes near the edge of the field and into the surrounding soil. The water then moves laterally toward adjacent low areas. This lateral seepage acts as a natural filtration process, creating additional opportunities for nitrate removal through denitrification.

Both flat and steep fields can generate lateral seepage under controlled drainage, especially when they are next to ditches or freely draining fields. Although lateral seepage also occurs in flat fields, it is generally less substantial than in steep fields because of the lower hydraulic gradient. Also, sandy soils have more lateral seepage than clay soils. Still, both field types can receive water quality benefits from controlled drainage.

Different functions of controlled drainage

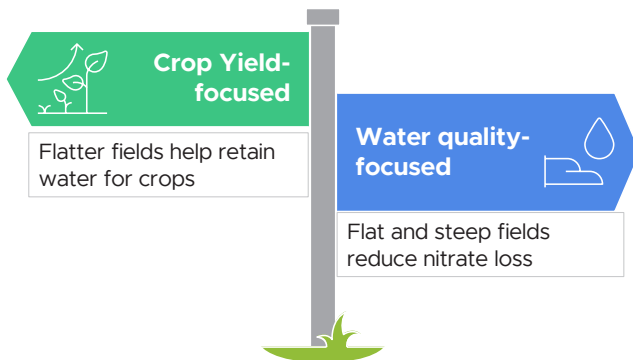


Figure 2- In crop yield-focused controlled drainage, flatter fields help retain water for crops. In water quality-focused controlled drainage, both flat and steeper fields reduce nitrate loss.



4. Recommendation for controlled drainage implementation

Controlled drainage is not limited to flat fields. When water quality is the primary goal, fields with slopes greater than 1%, even those with a small managed area, should not be excluded from implementation. Our findings show that even a small managed area (e.g., 3.6 out of 55.4 acres) can yield measurable nitrate load reductions.

5. Summary

- Controlled drainage improves water quality on both flat and sloped fields.
- Even with a minimal managed area, nitrate load reduction is possible with controlled drainage.
- Broader adoption of controlled drainage on steeper fields is supported by recent research.

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Expert Reviewed

This Extension bulletin has been peer reviewed by external experts.

References

- Ghane, E., AbdalAal, Y., Tehrani, A. (2025). Paired-field evaluation of a saturated buffer reveals significant water-quality benefit through upstream weir management. *Agricultural Water Management*. 318, 109664. <https://doi.org/10.1016/j.agwat.2025.109664>

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