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Evaluating a Two-Stage Roadside Ditch Design to Improve Environmental Performance

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Sponsors

Iowa Department of Transportation
&
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About
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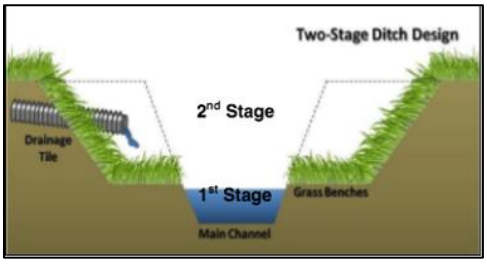
IIHR's mission is to advance science and technology, providing innovative solutions for fluids-related problems while building upon its long tradition of excellence in laboratory, field, and simulation-based research and education.

BACKGROUND

Conventional trapezoidal roadside ditches are designed to rapidly and efficiently deliver runoff, sediment and nutrients to downstream surface water system. Overapplication of this principal design criterion often compromises ditch sustainability by increasing the risk of erosional downcutting and excessive sedimentation. Erosion contributes to roadway and shoulder instability, whereas sediment accumulation reduces ditch capacity and limits effective runoff drainage over time. These processes require continual maintenance to ensure long-term functionality. Recent work on single Iowa watershed has highlighted the potential role that roadside ditches can play in nutrient reduction efforts. This finding has provided compelling motivation to further investigate the multi-functional role of the roadside ditches and how can they be improved to better serve Iowa landscapes.

OBJECTIVES

Proof-of-concept projects conducted on drainage channels in agricultural regions in other states have demonstrated that two-stage ditch designs can enhance sediment conveyance and promote the retention of transported dissolved constituents through increased infiltration. A two-stage ditch is an alternative to the conventional trapezoidal ditch, in which floodplain benches are constructed along the main channel to mimic the morphology and hydraulic function of natural stream systems.



This project evaluated the efficacy of the two-stage design for roadside ditches located in Iowa from multiple perspectives. For this purpose, the project team set forth the following research objectives:

1. Evaluation of the performance of two-stage roadside ditches for their ability to improve water quality by efficiently processing sediment and nutrients:
2. Evaluation of hydrology of two-stage ditches constructed in roadsides to mitigate flooding; and,
3. Evaluation of potential for expanding the 2-stage ditch implementation at other landscape locations throughout Iowa.

Attaining these evaluations has been accomplished through a set of complementary tasks that included: a) retrofitting a conventional 1-stage ditch with a 2-stage configuration; b) executing a multi-variable field monitoring program: and c) conducting associated numerical simulations.

CONCLUSION

Converting the conventional roadside ditch to a two-stage design is a novel application of a Best Management Practice tested only on agricultural drainage ditches in the US Midwest. The test site used for the 2-stage ditch design evaluation entailed a 450-m-long two-stage ditch draining 194-ha tributary catchment (see photo series).

Original 1-stage ditch

The 2-stage ditch under construction

The finalized 2-stage ditch

The pre-construction design and monitoring could be straightforwardly implemented but the post-construction monitoring was compromised by several unforeseen reasons: active construction on the road adjacent to the ditch that resulted in introducing sediment into the observation test site, unauthorized excavations in the vicinity of the monitored ditch; and flow diversion into an unknown drainage tile. Ensuing from the above-mentioned considerations, an important lesson learned for other studies considering roadside ditch applications, is that careful consideration that should be given to building and monitoring the ditch independent of any roadway construction. More broadly, to ensure that the study variables are appropriately managed and controlled without unplanned complications, there is a need for close collaboration with state, local, and private stakeholders in areas where road ditches are being retrofitted.

Despite these experimental challenges the team considers an achievement that monitoring data garnered through the project could be collected and analyzed to produce meaningful results. The most substantial inferences are summarized below:

- A vegetation survey conducted after two-stage construction using a native seed mix showed a marked improvement in vegetation composition and an increase in plant diversity.
- Upstream-downstream monitoring during both the pre- and post-construction periods revealed a statistically significant impact of the two-stage ditch on turbidity. The difference in turbidity between the upstream and downstream monitoring sites suggests a reduction in particulate phosphorus and organic nitrogen concentrations. No statistical differences in dissolved constituents were observed.
- A hydraulic model of the ditch constructed for 1-year, 2-year, 5-year, and 10-year storms to compare single stage to a two-stage configuration showed that peak flow rates were reduced by 22%, 21%, 7.5%, and 4.3%, respectively, while water volume reductions were near 6%. Maximum velocities throughout the ditch corridor also decreased, with reductions spanning 32% (1-year) – 45% (10-year). Reducing maximum velocities reduces the potential for bank erosion.
- A GIS evaluation identified 314 potential roadside 2-stage ditch sites along state highways and county roads in Iowa, with a mean length of 515 m and totaling approximately 162,000 m across the state. Assuming a nutrient removal rate of 0.027 kg per meter of ditch per year (kg/m/yr) for particulate phosphorus and 0.196 kg/m/yr for organic nitrogen, potential two-stage ditch projects have the capacity to remove 4,290 kg/yr and 31,700 kg/yr, respectively.

RECOMMENDATIONS

The outcomes of this first-of-its-kind research project on the performance of the two-stage roadside ditches show promising results for adopting this innovative design. However, more sites in similar and other landscapes along with acquisition monitored datasets are needed to properly quantify the design performance and suggest modifications.

Project results are sufficiently promising to recommend that DOT construct a new roadside two-stage ditch at another site to conduct additional performance testing. Although not a focus in this study, the two-stage design of roadside ditches should be investigated for potential highway safety improvements. Many ditches along primary and secondary roads in Iowa trapezoidal in shape with rather steep sides that present a roll-over risk for vehicles. The first stage the two-stage ditch can act as main outlet for draining the shoulder while the gentler-slopes of the second stage can lessen the rollover risk while providing additional flood reduction and water quality benefits.