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DEVELOPMENT OF SELF-CLEANING BOX CULVERT DESIGNS

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Self-cleaning culvert designs can prevent formation of sediment deposits at multi-box culverts using the hydraulic power of the stream.

BACKGROUND

Site visits of multi-barrel culverts in three Iowa counties showed a common feature: sediment deposits developed in the upstream vicinity of the culvert. Severe sedimentation situations were encountered at several culverts. The deposits were partially blocking the culvert active area and usually were covered by vegetation. Cleanup operations are costly and for some of the visited culverts were needed just two years after a previous cleanup.

OBJECTIVES

The main objective of this research is to understand and conceptualize the mechanics of sedimentation process at multi-box culverts and develop self-cleaning systems that flush out sediment deposits using the power of drainage flows.

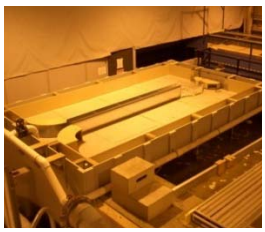
DESIGN CONCEPT

The driving criterion for designing the self-cleaning culvert geometry was to make modifications in the upstream area of the culvert that would restore the shape and functionality of the original (undisturbed) stream. For this purpose, the lateral expansion areas were filled in with sloping volumes of material to both reduce the depth and to direct the flow and sediment toward the central barrel, where the original stream was located prior to the culvert construction.

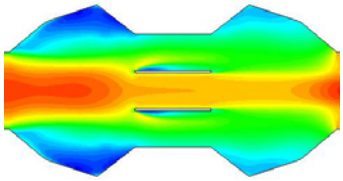
INVESTIGATIVE TOOLS

A triple set of tests was used to find a working self-cleaning multi-box design:

- A 1:20 scale three-box culvert model was used to replicate the baseline tests and screen the self-cleaning culvert configurations for their effectiveness to mitigate sedimentation problems for a range of flow conditions. The tests were run using clear-water scour and continuous sediment feeding.



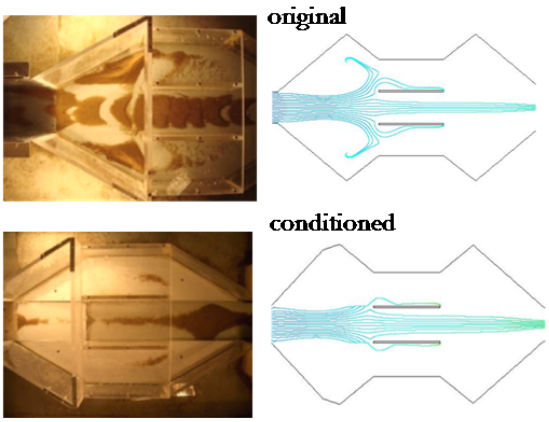
- Numerical simulations were used to refine the self-cleaning culvert geometry and test it for a range of flow conditions complementary to that tested in the laboratory experiments. Passive scalar visualizations were used to simulate the sediment transport.



- A 1:5 scale three-box culver model was used to assess the performance of the designed self-cleaning culvert configuration. The tests were run using live-bed scour and sediment recirculation. Extensive running times were used to achieve equilibrium for both flow and sediment transport.

OUTCOMES

The fillet-based self-cleaning design developed through this study proved their reliability and efficiency through a variety of tests. The conditioned culverts (with fillets set in) displayed favorable flow behavior compared with the original ones. Among the fillets' main effects are:



- direct the sediment through the central barrel of the multi-box culvert
- maintain the effectiveness over a range of flows (even for the highest flows where small deposits are created, they do not obstruct the active area of the lateral culvert boxes)
- maintain the overall sediment transport rates within the boxes of the conditioned culverts at levels comparable with those in the original culverts

IMPLEMENTATION NOTES

The design is simple to implement in any stage of the culvert lifetime, i.e., at the time of construction or later on by retrofitting the area in the vicinity of the structure at the time of a cleanup. In the latter situation, the fillets can be mainly constructed with local material, i.e., the sediment deposited at the culvert is relocated in the area of fillets during the cleaning. The retrofitting using the actual sediment deposits are obviously the most efficient means from cost perspective. The such obtained fillets can be "rip-rap"- ed and, possibly, grouted to roughen their surface for enhanced resistance to flow action. The grouting is also recommended for creating a vegetation barrier.