3D printed culvert diffusers to improve rural transportation resiliency

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Introduction

The recent increase in stormwater discharge due to climate change and land-use changes, exacerbated by aging diffusers has resulted in culvert washouts. Such washouts have been observed in Route 186 in Gouldsboro and multiple roads in western Washington County, in June 2021, around Camden and Rockport in late October 2021, and Route 219 in Hartford in May 2023.

These washouts block vehicle movement for days or weeks, disrupting access to disaster relief and emergency services in rural Maine. 3D-printed diffusers, as a part of trenchless culvert rehabilitation technology, increase culvert discharge and prevent washouts during high-discharge rainstorms.

Fig: Rocky Hill Brook, NH 85/Newfields Rd, Exeter, NH.

Objectives

- Evaluate feasibility of 3D printed diffusers for highway culvert rehabilitation to improve resiliency of rural highways.
- Manufacture and deploy 3D printed diffusers.
- Evaluate effectiveness of diffusers for increasing discharge and reducing outlet velocity.

Methodology

Two culvert-outlet diffusers were installed as part of a project to enhance water flow management and reduce erosion at critical sites. A prototype was first tested and installed at Thorndike, while a full-scale diffuser was later implemented at Exeter, NH, offering a more permanent solution. Both diffusers were manufactured in segments, employing advanced 3D printing technology at the Advanced Structures and Composites Center (ASCC). The large-format additive manufacturing (LFAM) process enabled the precise fabrication of complex diffuser components. Once the segments were printed, they were transported to the respective sites for careful assembly. The installation involved detailed coordination between upstream and downstream works to ensure that water flow through the culvert would be effectively managed from both ends. This approach minimized environmental disruption during installation and helped stabilize the surrounding area. After assembly, monitoring systems were set up to track the water flow through the diffusers, allowing the team to assess their performance under a variety of flow conditions.

Fig: 3D printed culvert diffuser manufactured at ASCC, UMaine.

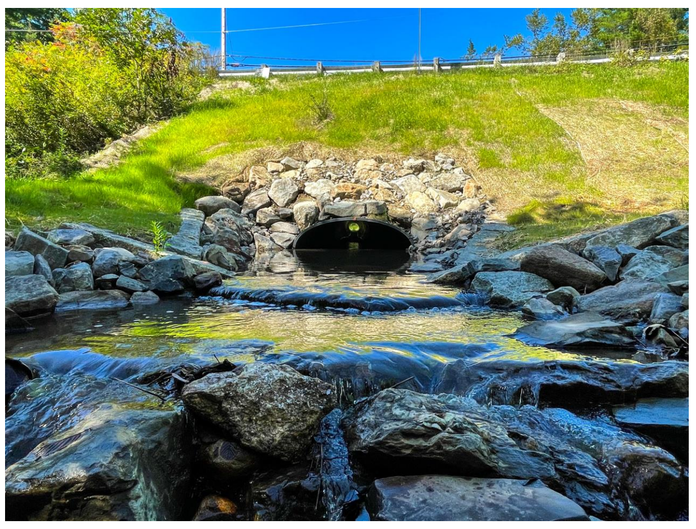


Fig: Culvert outlet diffusers installed at Exeter, NH.

Results

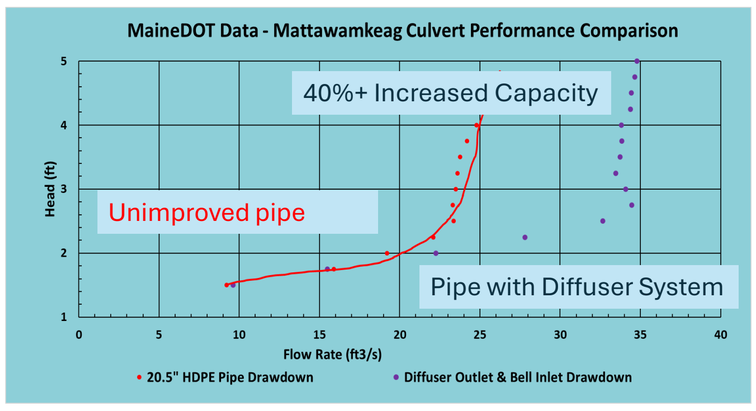
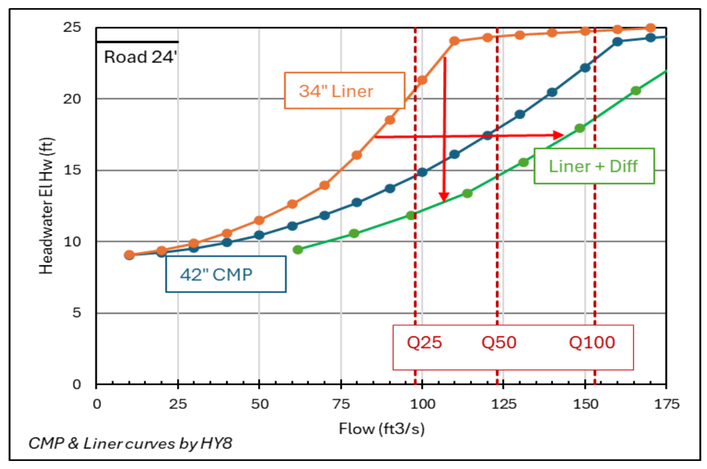


Fig: Mattawamkeag Culvert Diffuser performance [1].

The rehabilitation of highway culverts using liners can decrease flow by restricting the waterway's cross-sectional area. However, the use of 3D-printed diffusers counteracts this by increasing flow and reducing outlet velocity, leading to more controlled and efficient water discharge. The project aimed to assess the feasibility of using 3D-printed diffusers for highway culvert rehabilitation to enhance the resilience of rural highways. To achieve this, diffusers were manufactured using large-format 3D printing and deployed at various sites. Their effectiveness was evaluated by monitoring their ability to increase water discharge while significantly reducing outlet velocity, demonstrating their potential to improve culvert performance and reduce erosion.



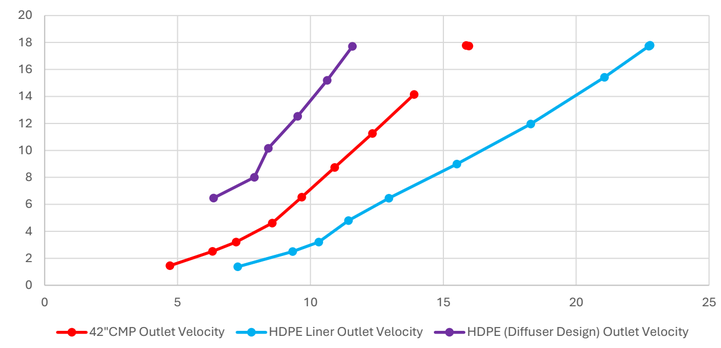


Fig: Calculated Diffuser performance at Exeter NH [1].

Conclusions

- LFAM can be used to manufacture diffusers that perform well.
- Rehabilitation of existing at-risk culverts and improving performance.
- The technology can be used to improve the resilience of rural highways.

Future work

Future work will focus on identifying culverts that are at risk of failure, which is crucial for prioritizing rehabilitation efforts. Additionally, there will be an emphasis on improving both the hydraulic and structural design of culverts to enhance their performance and longevity. This will involve optimizing flow management, increasing resilience to environmental stresses, and ensuring that culverts can better withstand the forces they encounter over time.

Acknowledgments

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