Oregon Department of Transportation

Stage 1 Research Problem Statement

Number*: 25-54*

Proposed Title: Advancing Sustainable and Resilient Culvert Infrastructure Assets: Design Guidelines for Pipe Zone Backfill Material

1. Concisely describe the **transportation issue** (including problems, improvements, or untested solutions) that Oregon needs to research.

A significant factor influencing the long-term durability of concrete and metal culverts is the physicochemical properties of the backfill materials used in the culvert backfill pipe zone and the culvert material. The backfill materials can be natural (e.g., in-situ soil) and any material (e.g., crushed granular material, soils) brought in for pipe zone backfill. The physicochemical factors of backfill materials affecting degradation include pH, electrical conductivity, moisture sensitivity, excessive settlement or heave from problematic soils (e.g., weak clayey soils), and mineralogical composition of the substrate and the culvert material. In addition, extreme weather conditions such as excessive rain or freezing conditions can enhance the degradation rate. Installing sensors at selected backfill locations will provide data on the varying physicochemical properties and enable the identification of critical factors driving the degradation. Therefore, monitoring and determining such physiochemical factors can help identify appropriate construction materials and subsequently improve the service life of the culverts. This approach promotes sustainable asset management by extending culvert lifespan and reducing the need for frequent replacements, thus conserving resources and minimizing negative environmental impact.

2. Document how this **transportation issue** is important to Oregon and will meet the Oregon Research Advisory Committee Priorities

In Oregon, a significant number of culverts are reaching the end of design life, and failure frequency is on the rise. The estimated asset replacement value of ODOT's culverts is over 25 billion dollars. Constructing new culverts and rehabilitating existing culverts are essential to ensure reliable performance. ODOT's culvert program has actively used advanced techniques for the repair and rehabilitation of deteriorated culverts. Monitoring culverts at different degradation stages can advance current evaluation methods and help develop material selection protocols. Furthermore, Oregon has a wide range of near-surface geology ranging from sandy silts to expansive clays. The physical structure and mineralogical composition of the soil around the zone of the culverts can have a significant impact on concrete and metal. For example, the presence of expansive clays with poor drainage can cause substantial volumetric change during extreme weather events such as heavy rain and excessive heat. We can determine the factors driving degradation by monitoring and analyzing the moisture, displacement, electrical conductivity, and pH using state-of-the-art soil sensors. The knowledge generated from this report can improve the durability and service life of the culverts. Additionally, this research aligns with sustainable infrastructure goals by fostering the development of long-lasting culverts that reduce the overall carbon footprint and resource usage. This research will contribute to the development of guidelines for designing and constructing culverts along Oregon's Highways.

3. What **final product or information** needs to be produced to enable this research to be implemented?

In this study, the factors driving the degradation of culverts will be determined using field instrumentation and laboratory investigation methods. The major research product will be improved evaluation and design guidelines, which will be implemented in both ODOT's Hydraulic Design Manual and the Geotechnical Design Manual. The guidelines will also focus on developing a testing protocol for identifying problematic backfill materials. It will provide an effective means to evaluate material brought from off-site for the pipe backfill zone. In addition,

corrosion mitigation using chemical soil stabilization (e.g., the addition of alkaline geopolymers to an acidic soil) will be investigated. The guidelines will specify the methodology to determine the optimum dosage of the stabilizer and the compaction methodology for maintaining a non-corrosive environment in the stabilized soil materials. These guidelines will not only enhance the structural integrity of culverts but also incorporate sustainable practices in material selection and construction methods, reinforcing asset reliance. Following review and approval by ODOT Research and the Hydraulic Engineering Section, this work will be used by ODOT engineers and engineering consultants. In addition, the laboratory investigation of this research will generate knowledge on the performance of soil around culverts under extreme weather conditions, which is critical to determining the long-term performance of the culverts. Additional research products include increased confidence in selecting appropriate pipe zone backfill materials and developing a pipe backfill and compaction standard drawing for larger culverts.

The proposed research tasks are:

1. *Literature review*: Perform a literature review on factors influencing the degradation of culverts. Review the locations of aggressive soils (e.g., organic soils) and environments (e.g., coastal, desert alkaline, and other electrochemical environment) in Oregon. Include a focus on sustainable materials and practices that contribute to longer-lasting infrastructure, aligning with the principles of asset reliance.
2. *DOT/ industry survey*: Perform a DOT/industry survey to identify the state of practice for the construction and repair of culverts.
3. *Field instrumentation*: Install sensors in selected culvert locations for the change in moisture, electrical conductivity, and pH. The preliminary proposal is to identify critical locations (at least two locations) and install sensors that can continuously monitor the physicochemical conditions for a period of two years of monitoring. The sites for installing instruments will be identified in collaboration with the ODOT research and culvert groups.
4. *Laboratory investigation*: Test soils before monitoring – what is the initial condition? This investigation focuses on developing pragmatic solutions to improve the long-term performance of the culvert. These studies will be complemented by electrochemical / corrosion studies in the OSU Corrosion and Coating Testing Laboratory. These electrochemical tests will be conducted to simulate soil-metal combinations in the field and will provide quantitative data that can be used to assess critical corrosion conditions and make recommendations on design guidelines. Chemical modification of soils with a sustainable material such as geopolymers will be considered a solution to reduce corrosion and evaluated in the laboratory.
5. *Revise existing guideline*s: Generate environmentally friendly recommendations regarding the selection of appropriate backfill material and propose revisions to both ODOT's Hydraulic Design Manual and Geotechnical Design Manual.
6. *Develop new guidelines*: Develop guidelines for developing a pipe backfill with chemically modified soils that have extreme pH limits and a pipe backfill/compaction standard drawing for culverts with an equivalent span greater than 72 inches.
7. *Report*: Document findings and submit a final report. In addition, highlight how the findings promote sustainable and asset-reliant approaches in the construction and maintenance of culverts.

4. (Optional) Are there any individuals in Oregon who will be instrumental to the success of implementing any solution that is identified by this research? If so, please list them below.

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5. Other comments:

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