Transportation Pooled Fund Program TPF-5(446) Quarterly Progress Report

Quarter 1, January - March 2022

prepared by
S. Lottes, M. Sitek, H. Ley

Nuclear Science & Engineering Division, Argonne National Laboratory

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TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): _FHWA_______________________________________

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e., SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* *TPF-5(446)*	**Transportation Pooled Fund Program - Report Period:** ☒Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 1 – December 31)

Project Title:
High Performance Computational Fluid Dynamics (CFD) Modeling Services for Highway Hydraulics

Name of Project Manager(s): *Kornel Kerenyi*	**Phone Number:** *(202) 493-3142*	**E-Mail** *kornel.kerenyi@fhwa.dot.gov*
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**

Project schedule status:

☒ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date

Project Description:

The Federal Highway Administration established an Inter-Agency Agreement (IAA) with the Department of Energy's (DOE) Argonne National Laboratory (ANL) Transportation Analysis Research Computing Center (TRACC) to get access and support for High Performance Computational Fluid Dynamics (CFD) modeling for highway hydraulics research conducted at the Turner-Fairbank Highway Research Center (TFHRC) Hydraulics Laboratory. TRACC was established in October 2006 to serve as a high-performance computing center for use by U.S. Department of Transportation (USDOT) research teams, including those from Argonne and their university partners. The objective of this cooperative project is to:

- Provide research and analysis for a variety of highway hydraulics projects managed or coordinated by State DOTs.
- Provide and maintain a high-performance Computational Fluid Dynamics (CFD) computing environment for application to highway hydraulics infrastructure and related projects.
- Support and seek to broaden the use of CFD among State Department of Transportation employees.

The work includes:

- Computational Mechanics Research on a Variety of Projects: The TRACC scientific staff in the computational mechanics focus area will perform research, analysis, and parametric computations as required for projects managed or coordinated by State DOTs.
- Computational Mechanics Research Support: The TRACC support team consisting of highly qualified engineers in the CFD focus areas will provide guidance to users of CFD software on an as needed or periodic basis determined by the State DOTs.
- Computing Support: The TRACC team will use the TRACC clusters for work done on projects; The TRACC system administrator will maintain the clusters and work closely with the Argonne system administrator's community; The TRACC system administrator will also install the latest versions of the STAR-CCM+ and OpenFOAM CFD software and other software that may be required for accomplishing projects.

Progress this Quarter:

(Includes meetings, work plan status, contract status, significant progress, etc.)

1: Computational Mechanics Research on a Variety of Projects

1.1: Computational Study of Hydraulic Performance of South Carolina DOT Catch Basins Type CB 1, CB 16, and CB 17

Proper design of surface drainage of roadways is essential to minimize flooding and provide for traffic safety. Inlets collect the excess storm water from the drainage area of a roadway and discharge it to storm drains. Knowing the hydraulic efficiency of inlets, defined as the percentage of intercepted flow to the total street flow, is necessary in drainage design to determine inlet spacing such that the system can transport all or the majority of the road surface flow during rain events off of the road into the catch basins.

The CB-1 catch basin is a combination grate and curb opening inlet used by SCDOT. It is characterized by a grate covering part of the inlet and a fully open portion on the curb edge, protected with a hood. Figure 1 shows a cross section through the inlet and Figure 2 presents a top view of the inlet. A 2-feet-long transition between the gutter and the drain directs the flow into a depressed grate that is wider than the gutter by 3/8".

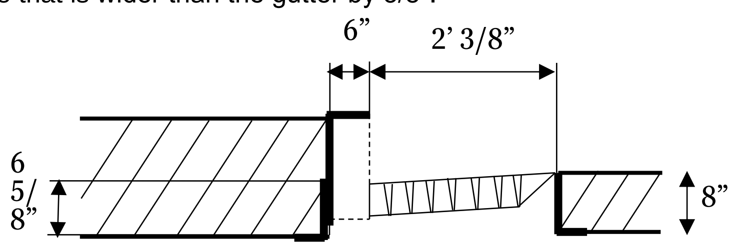

Figure 1: Cross-section through the inlet Type 1

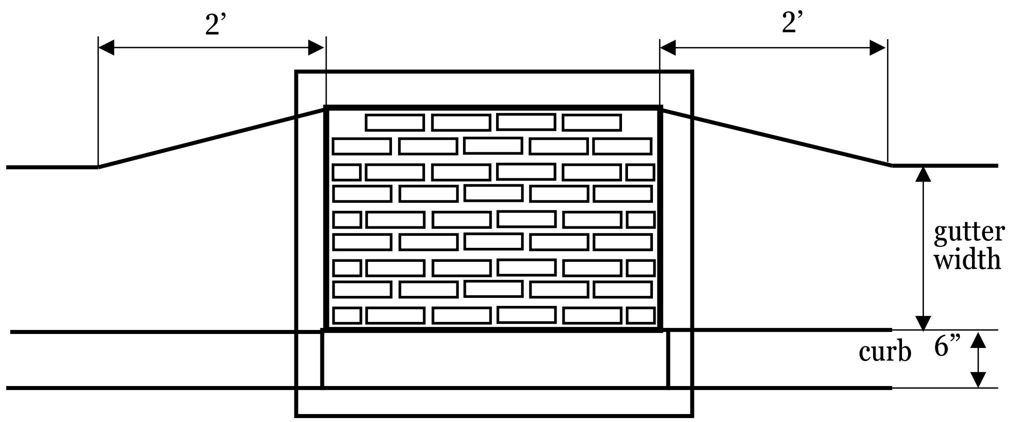

Figure 2: Top view of the catch basin Type 1.

A CFD analysis of the hydraulic efficiency of this grate was performed for a variety of conditions for travel lane cross slopes of 0.5% and 2.0%, longitudinal slopes varying from 0.3% to 16%, and flow rates varying from 0.12 cfs to 24 cfs.

The CFD results for efficiency as a function of flow rate for the range of analyzed longitudinal slopes are plotted in Figure 3 for cases with a street cross slope of 0.5% and 2%. The efficiency is a decreasing function of flow rate and longitudinal slope, but an increasing function of cross slope. The plots in these two figures also include the HEC 22 predictions of efficiency for the geometry and flow conditions. At a travel lane cross slope of 0.5%, the CFD and HEC 22 predictions are very close for all of the different longitudinal slopes with the CFD predicting slightly higher efficiencies at higher flow rates as shown in Figure 3. At a travel lane cross slope of 2%, the CFD and HEC 22 predictions of efficiency also match closely over most of the longitudinal slopes and flow conditions. At 2% travel lane cross slope, however, the CFD predicts a slightly lower efficiency with efficiency decreasing more rapidly with flow rate at longitudinal slopes greater than 10%.

A comparison of all case data points between HEC 22 prediction and CFD is shown in Figure 4 with 20% variation dashed lines plotted above and below the diagonal exact match line. The red dots are for the 2% travel lane cross slope results and blue dots are for the 0.5% travel lane cross slope results. Nearly all of the data points above an efficiency of 50% are within 10% of the HEC 22 prediction and slightly above it, meaning the HEC 22 prediction is slightly more conservative. For the 2% travel lane cross slope and efficiency less than 50%, about half of the red dots showing CFD results fall below the HEC 22 prediction, although they are, with one exception, still within a 20% deviation.

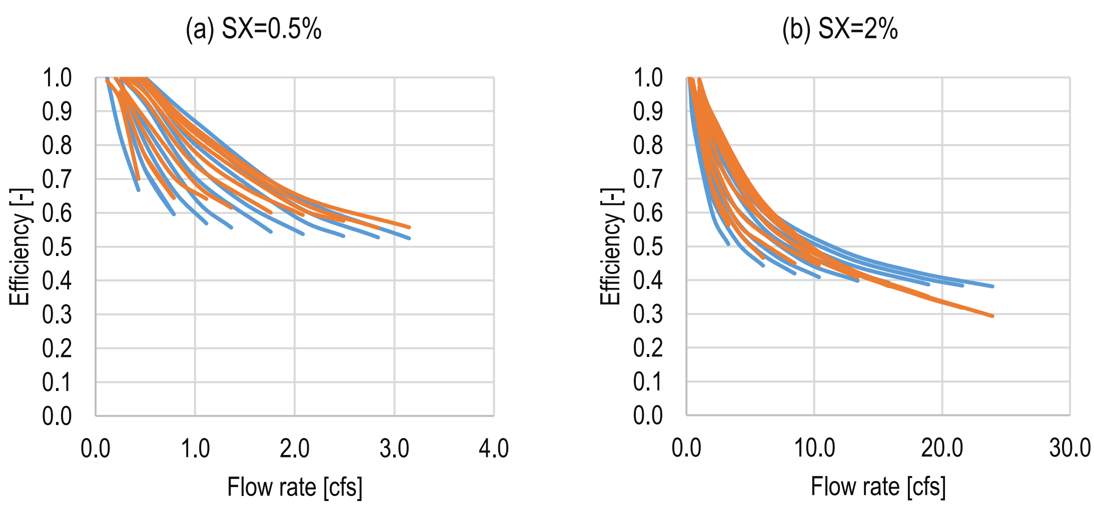

Figure 3: Efficiency as a function of the design flow rate for CB-1 catch basin at (a) 0.5%, (b) 2% travel lane cross-slope. Blue – HEC-22, Orange – CFD.

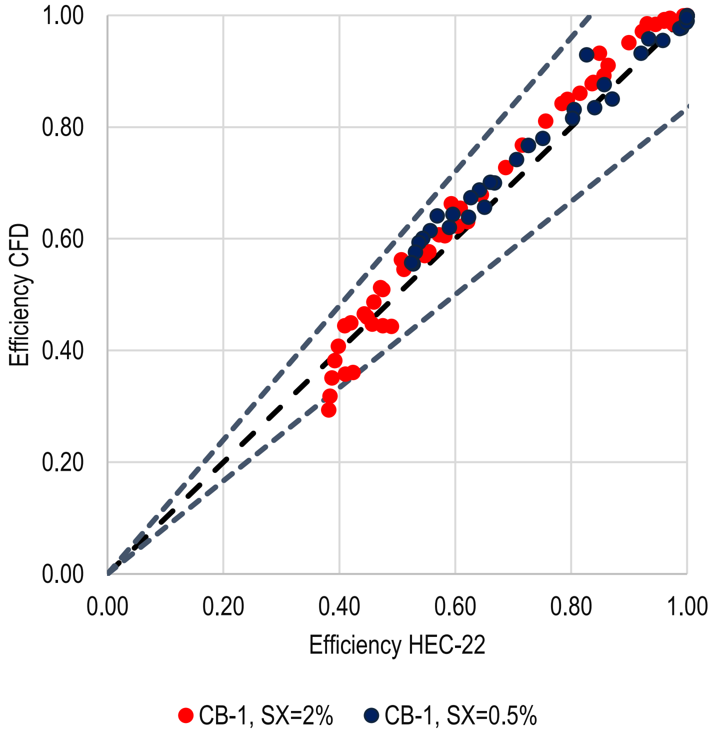

Figure 4: Comparison of CB-1 catch basin efficiency computed in simulations and calculated from HEC-22 design equations. Dashed black line is the unity line, and dashed grey lines represent a ±20% difference between estimates

Anticipated work next quarter:

1: Computational Mechanics Research on a Variety of Projects

- hydraulic analysis of catch basins on grade and in sump
- analysis of water film thickness on pavements (hydroplaning water film thickness and speed)

2: Computational Mechanics Research Support

This work will continue.

Task 3: Computing Support

This work will continue.

Circumstance affecting project or budget.

(Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.