



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

*Quarter 1, January - March 2020*

prepared by  
M. Sitek, S. Lottes, 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.*

<b>Transportation Pooled Fund Program Project #</b> <i>(i.e., SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX))</i>  <p style="font-size: 1.2em;">TPF-5(446)</p>	<b>Transportation Pooled Fund Program - Report Period:</b> <input checked="" type="checkbox"/> Quarter 1 (January 1 – March 31)  <input type="checkbox"/> Quarter 2 (April 1 – June 30)  <input type="checkbox"/> Quarter 3 (July 1 – September 30)  <input type="checkbox"/> Quarter 4 (October 1 – December 31)	
<b>Project Title:</b> <b>High Performance Computational Fluid Dynamics (CFD) Modeling Services for Highway Hydraulics</b>		
<b>Name of Project Manager(s):</b> <i>Kornel Kerenyi</i>	<b>Phone Number:</b> <i>(202) 493-3142</i>	<b>E-Mail</b> <i>kornel.kerenyi@fhwa.dot.gov</i>
<b>Lead Agency Project ID:</b>	<b>Other Project ID (i.e., contract #):</b>	<b>Project Start Date:</b>
<b>Original Project End Date:</b>	<b>Current Project End Date:</b>	<b>Number of Extensions:</b>

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**

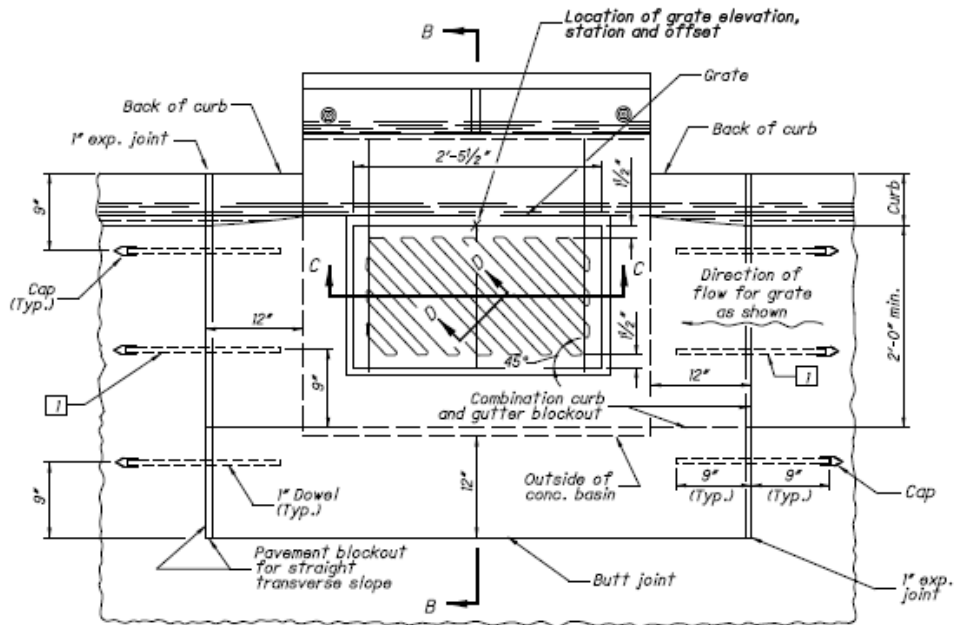
#### **1.1: Computational Fluid Dynamics Modelling of Hydraulic Capacity of Ohio DOT Drainage Structures**

Highway drainage systems need to handle higher volumes of runoff during rain events than they have in the past. To handle higher volumes of traffic, modern roads are being built, and old roads are being expanded with more lanes giving a larger rainfall collection area. In addition, more frequent and extreme rain events can overwhelm existing drainage systems and new systems need to be designed to handle the higher rates of runoff. State Departments of Transportation are developing new designs of drainage structures including more accurate functions of efficiency under a variety of conditions. They are also assessing old designs to determine if they are capable of draining higher flow rates off the roads.

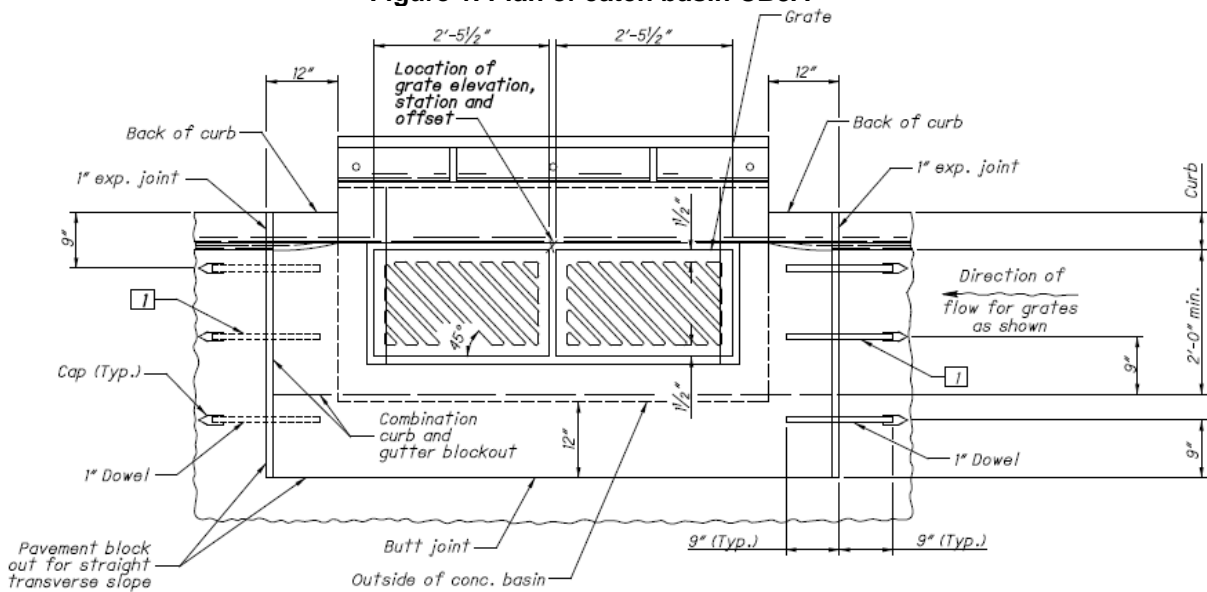
Three-dimensional computational fluid dynamics analysis can determine flow and efficiency through drains with complex geometry and catch basins at field scale over a broad range of conditions. Argonne researchers were approached by Ohio DOT to perform an evaluation of inlet types CB3 and CB3A with the use of computational fluid dynamics on a high-performance computing cluster. These drainage structures consist of a grate and window, with the window being considered a factor of safety against grate clogging.

Geometric parameters in the test case matrix include varying cross-slopes and longitudinal slopes of the road surface, shoulder/gutter width, as well as a range of flow rates. On-grade and sump conditions are accounted for in the study. The computational analysis yields the hydraulic efficiency of the inlets, the split of the flow rate between front, side, and backflow of the grate, flow through the curb opening when present, as well as the bypass flow.

The hydraulic capacity of catch basin 3A is analyzed in on-grade conditions and the double catch basin CB3 in sump conditions. Figure 1 and 2 show plan views of both catch basins.

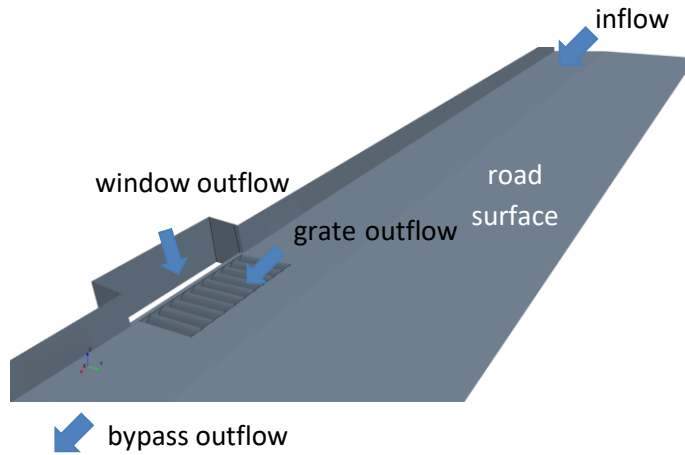


**Figure 1. Plan of catch basin CB3A**



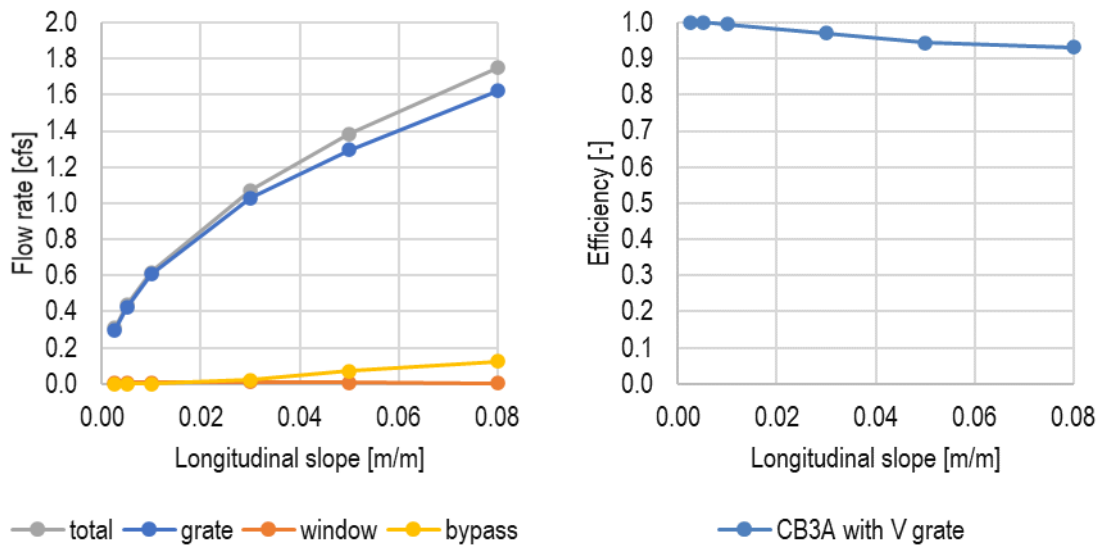
**Figure 2. Plan of catch basin CB3**

The computational domain developed for this study covers the space right above the road, gutter, and grate surface, see Figure 3. The length of the section of the road upstream and downstream of the grate is big enough so that the boundary conditions have no influence on the flow pattern in the vicinity of the grate. The width and height of the domain depends on the spread of the pool of water. The flow rate through the grate, window, and the bypass is computed during the simulation and compared to the inlet flow rate. As a result, the hydraulic capacity of the window-grate combination can be calculated.



**Figure 3. Perspective view of the CFD domain with inflow and outflow surfaces**

Example results of the CFD simulations are presented in Figure 4. For a constant gutter width (2 ft), and flow spread (4 ft), the longitudinal slope was varied from 0.3% to 8%. The plots show the split of the flow rate between the grate, window, and bypass flow (left), and the efficiency curve (right).



**Figure 4. Flow rate vs. longitudinal slope, and efficiency curve**

## 2: Computational Mechanics Research Support

Argonne Transportation Research and Analysis Computing Center (TRACC) computational mechanics staff ran nationwide videoconferences every other Thursday that were open to state Department of Transportation staff and university researchers supported by the Federal Highway Administration or state DOTs. The videoconferences provide a venue to discuss approaches and issues related to hydraulics modeling projects. Topics during this reporting period included, but were not limited to:

- new methodologies of scour modeling,
- approaches to modeling and mitigating hydroplaning risk,
- hydraulic analysis of catch basins.

## 3: Computing Support

Routine cluster maintenance including software and hardware upgrades, security patching against cyber threats, and development of custom tools to increase users' productivity. TRACC staff is currently working on upgrading the TRACC clusters to support the latest scientific and engineering software utilizing industry's best practice guidelines in Open Source software and virtualization.

## **Anticipated work next quarter:**

### **1: Computational Mechanics Research on a Variety of Projects**

- development of a new methodology for riverbed scour
- hydraulic analysis of a catch basins
- analysis of water film thickness on pavements

### **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, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

**None.**