Development of Computational Fluid Dynamic Model for Calculating Flow Through a Complex Stormwater Green Infrastructure Inlet

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ABSTRACT

NYC has built thousands of bioswales to retain and detain stormwater in a sustainable way. Only a few of these are monitored to evaluate their effectiveness due to various reasons such as funding and other practical difficulties in monitoring. Thus, modeling is a widely adopted option to scale up these monitoring results to inform design changes. This poster presents the method and the initial results of a three-dimensional computational fluid dynamics (CFD) model developed replicating physical and boundary conditions of a constructed bioswales inlet in New York City. The inlet with the catch basin is connected to the bioswale using a horizontal pipe attached to a riser pipe that is open at both ends. The top of the riser pipe is open to the atmosphere and the bottom is inserted into the soil. The outflow from bottom is restricted by the infiltration rate of the engineered soil. The flow through this connection is difficult to measure as the horizontal pipe is submerged on upstream as well as downstream. Thus, a weir cannot be used to measure inflow. The model was validated using data collected through a field experiment conducted to study the hydraulics of stormwater flow. We are working on analyzing the effect of the inlet pipe diameter on the modeled flow rate into the bioswale. The computational results showed that the larger connection diameter significantly increased the flow through the top outlet increasing distribution of flow over the bioswale area.

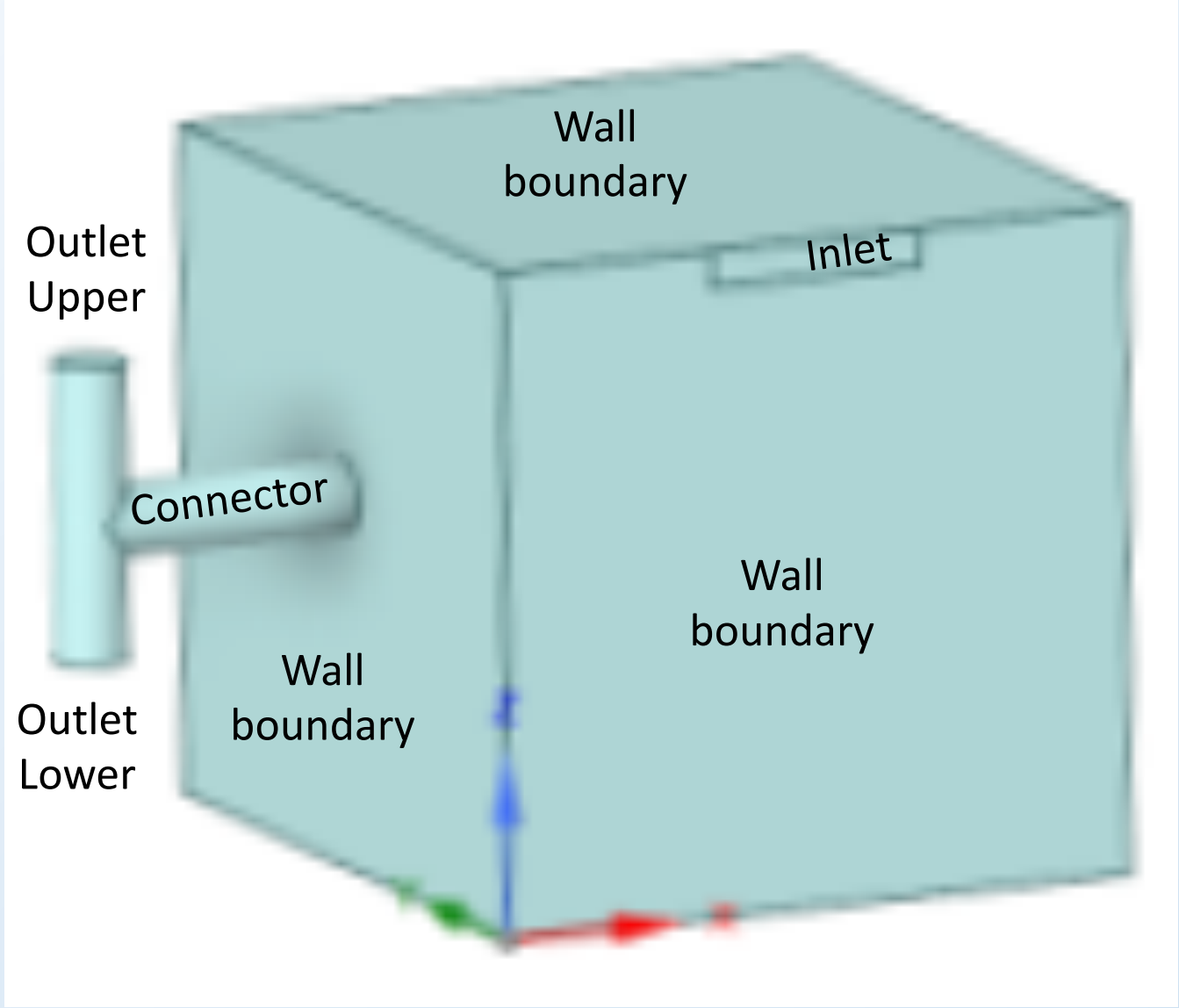
INTRODUCTION

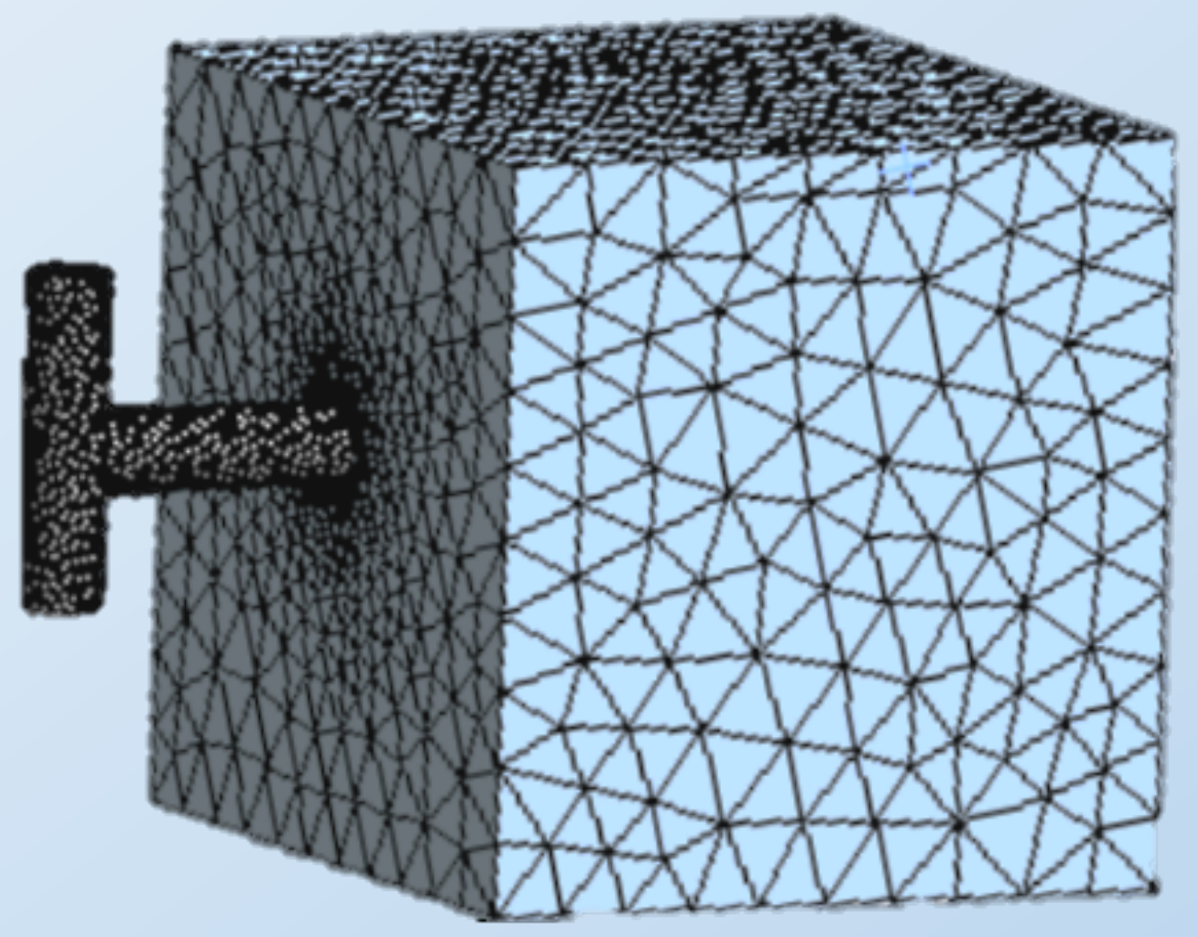
- Hydraulics of Green Infrastructure (GI) inlets are understudied. New inlets designs were tested.
- Flow through connector pipe attached to riser pipe open at both end is complex and to generalize the results, more data is required
- Either field, lab, or models are developed
- Computer based hydrodynamic models replicate field conditions but reduce uncertainty of field experiments and more cost effective.

METHODOLOGY

Field data –
- Dimensions of tank, inlet, connector pipe, and riser pipe
- Infiltration rate, velocity, and flowrate were collected during hydrant test conducted at bioswale in 2019.

Model development –
- Model Selection - ANSYS fluent model with a mixture of air and water therefore volume of fluid method (VOF) was selected
- Meshing – autogenerated polyhedral mesh
- Boundary Conditions – velocity inlet, open to atmosphere upper outlet, and lower outlet constrained by infiltration rate



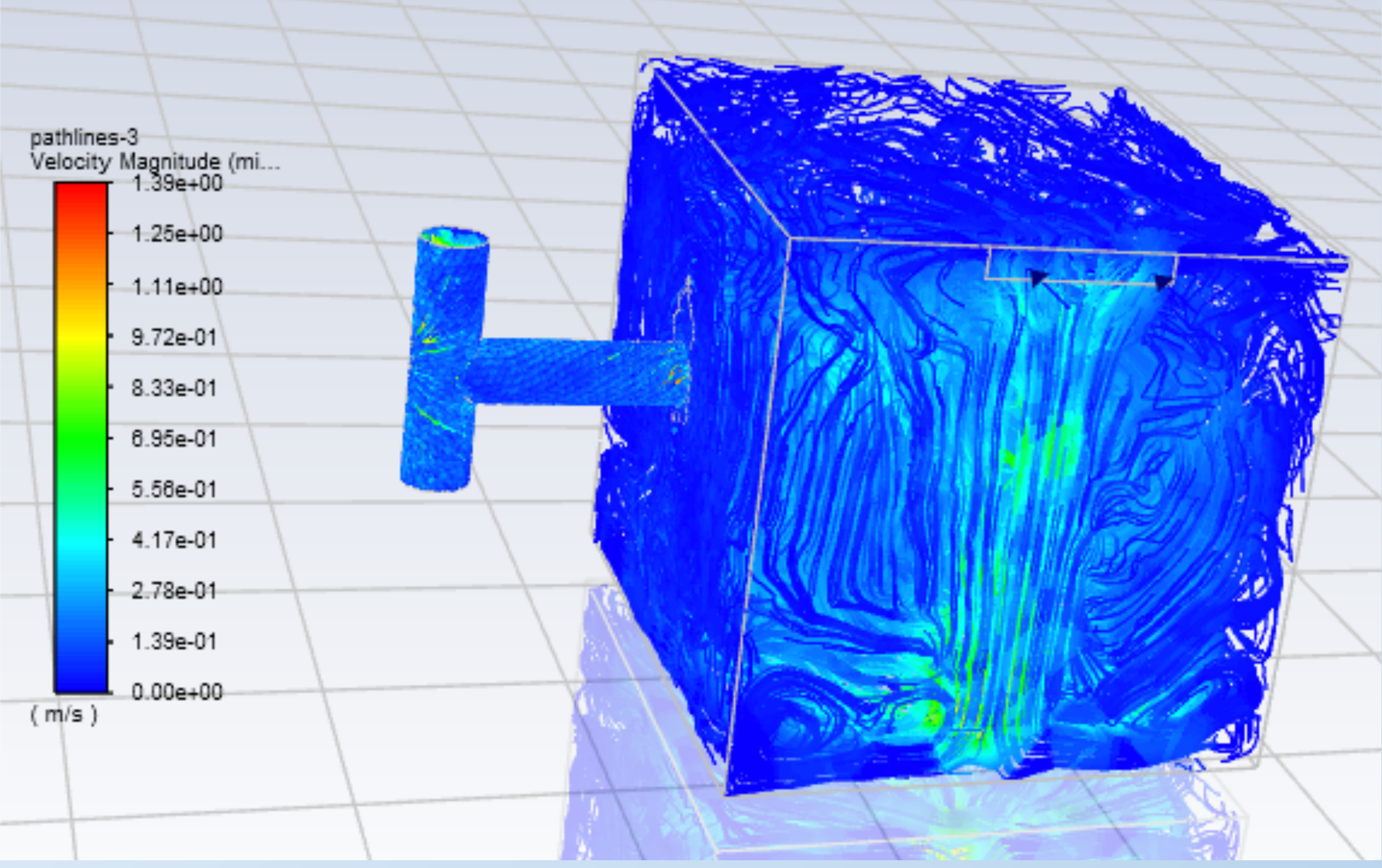


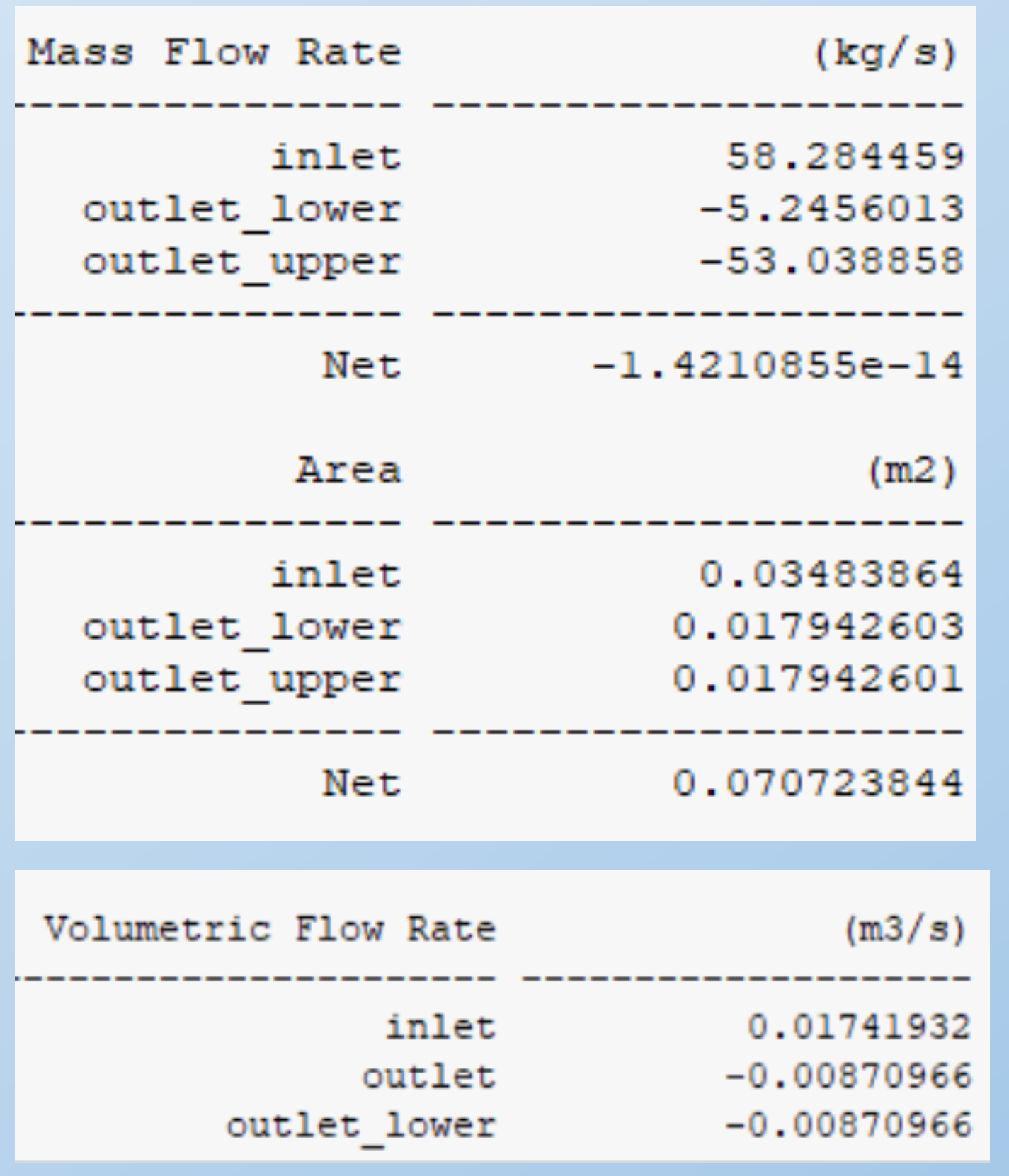
Multiphase Model	Volume of Fluid
Eulerian Phases	2
Body Force Formation	Implicit Body Force
Standard Initialization	Fraction Variable

Cμ	0.0845
C1ε	1.42
C2ε	1.68
σk	0.7194
σε	0.7194

LAFAYETTE ENGINEERING

RESULTS





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Mass Flow Rate                    (kg/s)
-------------------- --------------------
           inlet               58.284459
    outlet_lower              -5.2456013
    outlet_upper              -53.038858
-------------------- --------------------
             Net          -1.4210855e-14

            Area                    (m2)
-------------------- --------------------
           inlet              0.03483864
    outlet_lower             0.017942603
    outlet_upper             0.017942601
-------------------- --------------------
             Net             0.070723844
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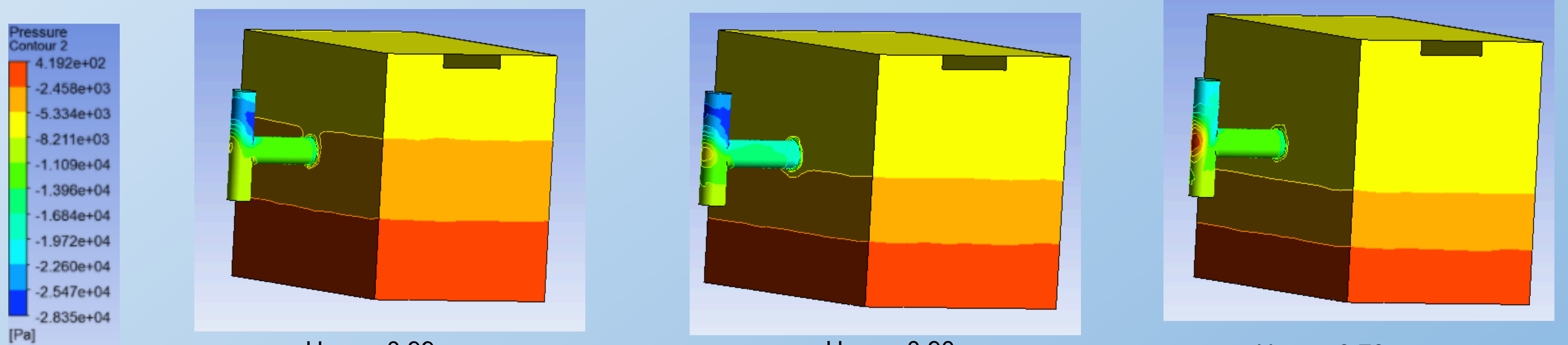
 Volumetric Flow Rate                (m3/s)
------------------------ --------------------
                   inlet          0.01741932
                  outlet         -0.00870966
            outlet_lower         -0.00870966
```

- The model has continuity – $Q_{Inlet}=Q_{Outlet\ lower}+Q_{Outlet\ Upper}$,
- The water can be seen with lighter blue color, indicating higher velocity along the front face.
- Flow was diverted accordingly as predicted through the weighted fraction outlet.

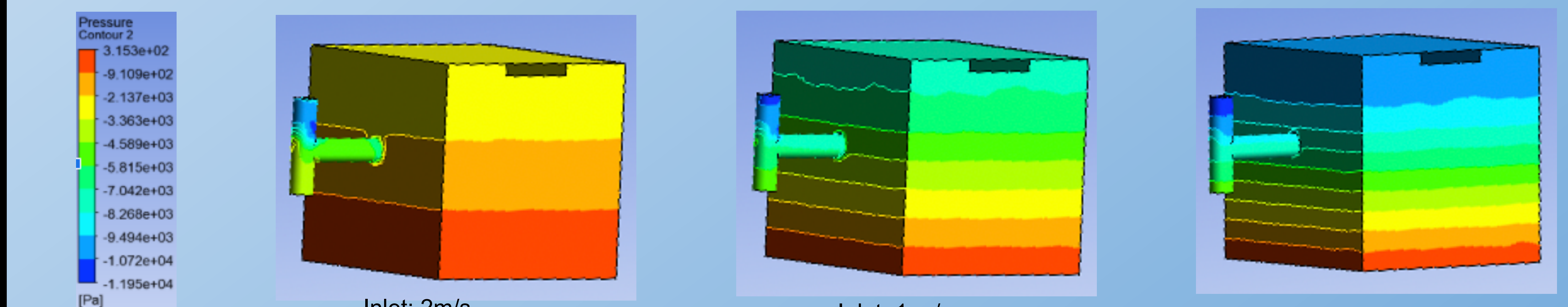


Upper: 0.99
Lower: 0.01

Upper: 0.90
Lower: 0.10

Upper: 0.70
Lower: 0.30

- Fraction of fluid leaving the upper and lower outlet were changed to see the effects that different infiltration would have on the bioswale.



Inlet: 2m/s

Inlet: 1 m/s

Inlet: 0.5 m/s

- Inlet velocities were changed to see the effects different six storms would have on the bioswale.

FURTHER RESEARCH

- Sensitivity analysis of different diameters and materials of the riser pipe and connector pipes on the bioswale
- Modeling debris in riser pipe

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