



## Computational modeling to improve chlorinator design in a Haitian drinking water system

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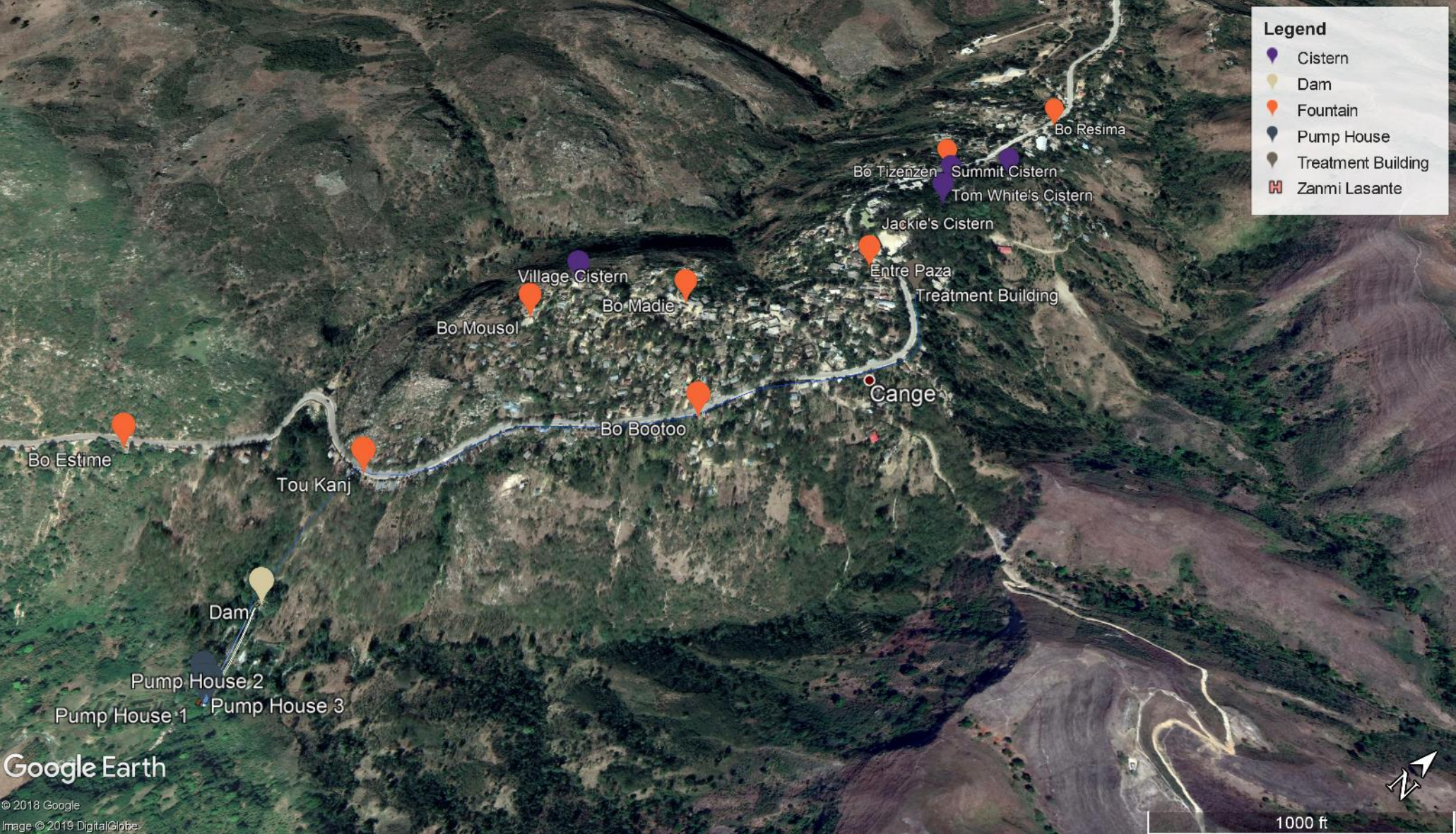
AEESP Conference, Tempe, Arizona. May 16, 2019



Clemson Engineers for Developing Countries (CEDC) has worked in Cange, Haiti, since 2009.

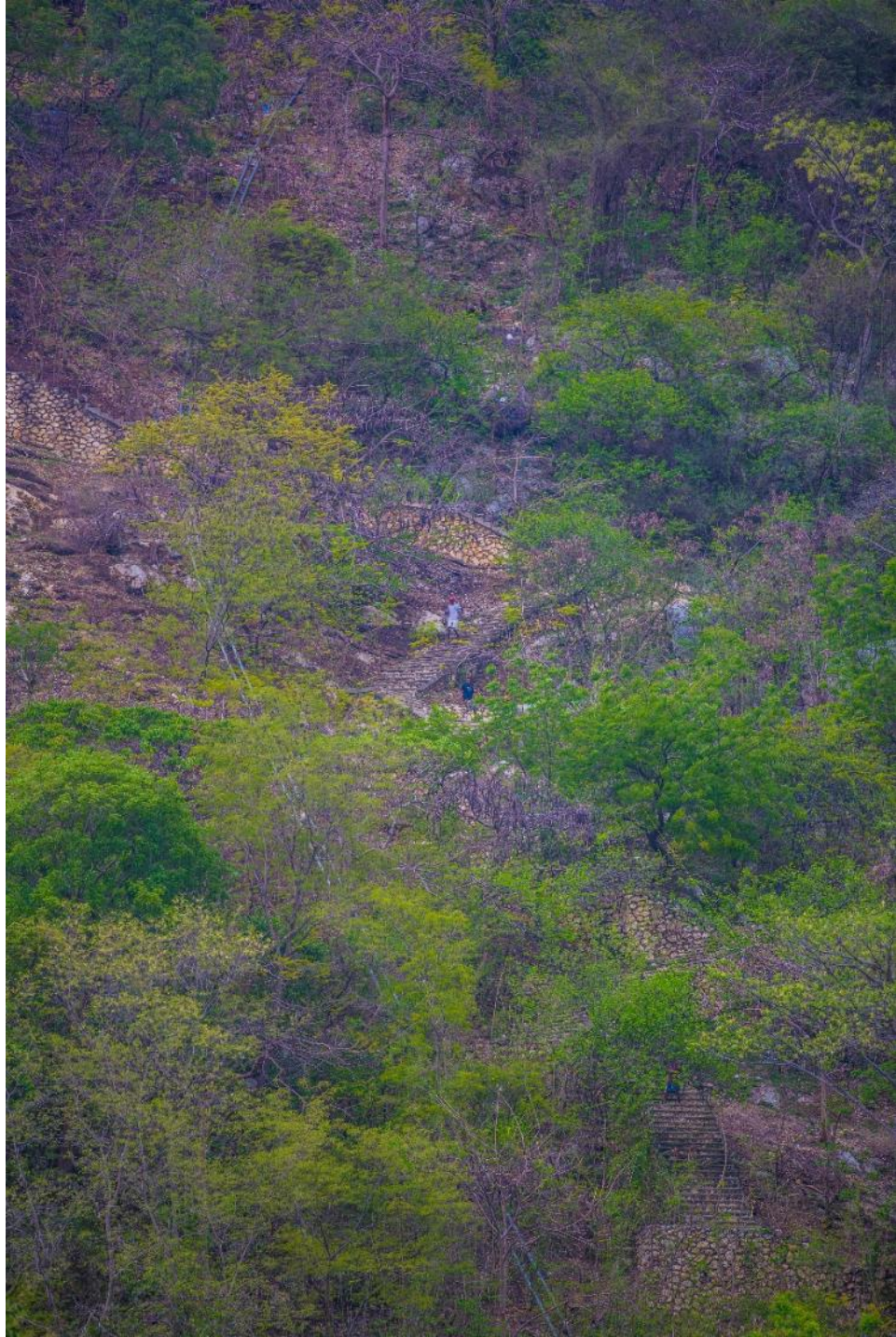


A hydraulic pump sends water up the canyon and through a treatment system.















REFERENCE  
BER SHOP  
KY & JHONSON  
3187 4806  
62 49 3216 0410

Brothers

A NEU LIMANES NIU PAP BLIVEVA





EN MEMOIRE ET HONNEUR DE PIERCE ET JACKIE WILLIAMS

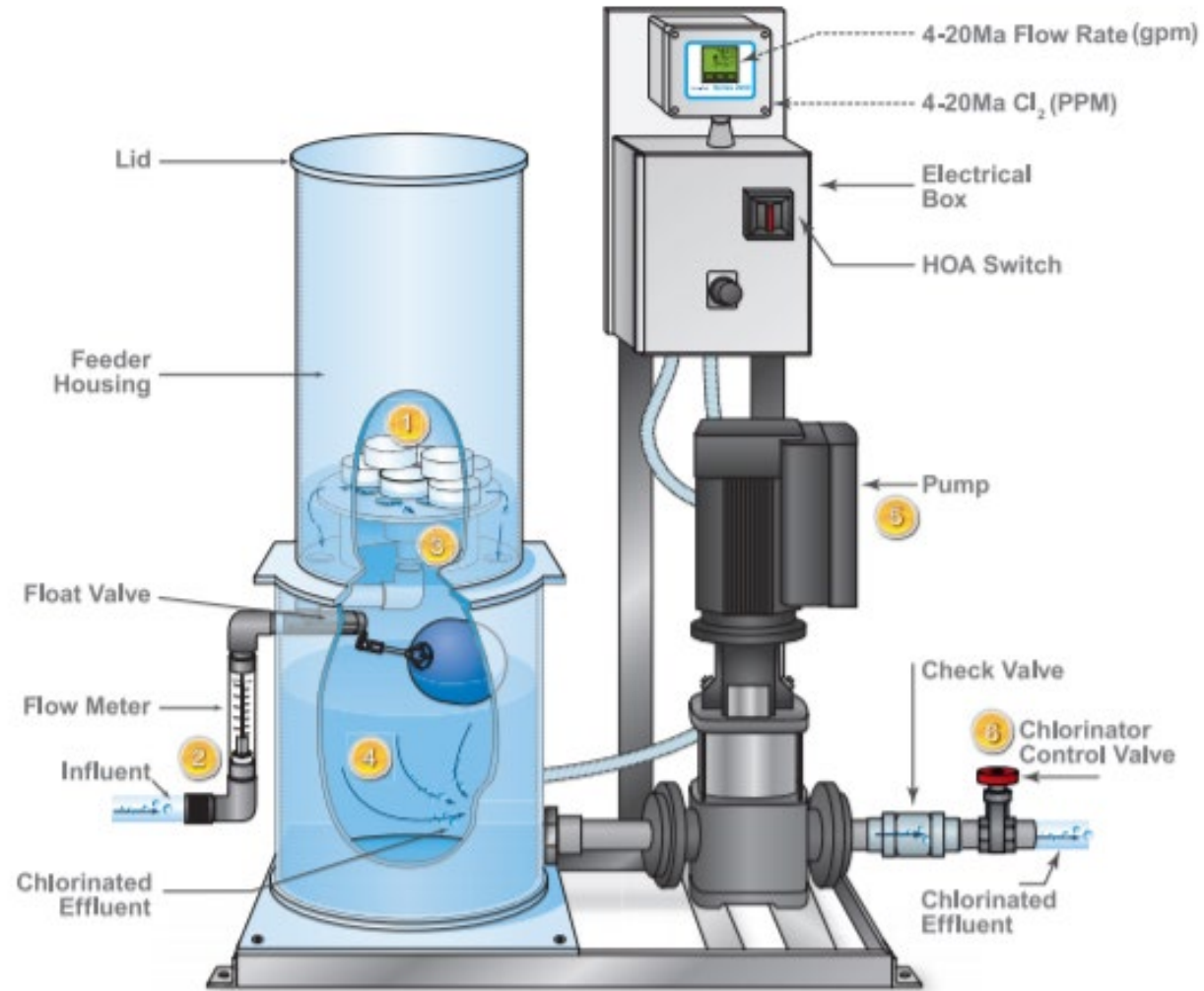
E K I P S O L I D O

E D U S C C A F E



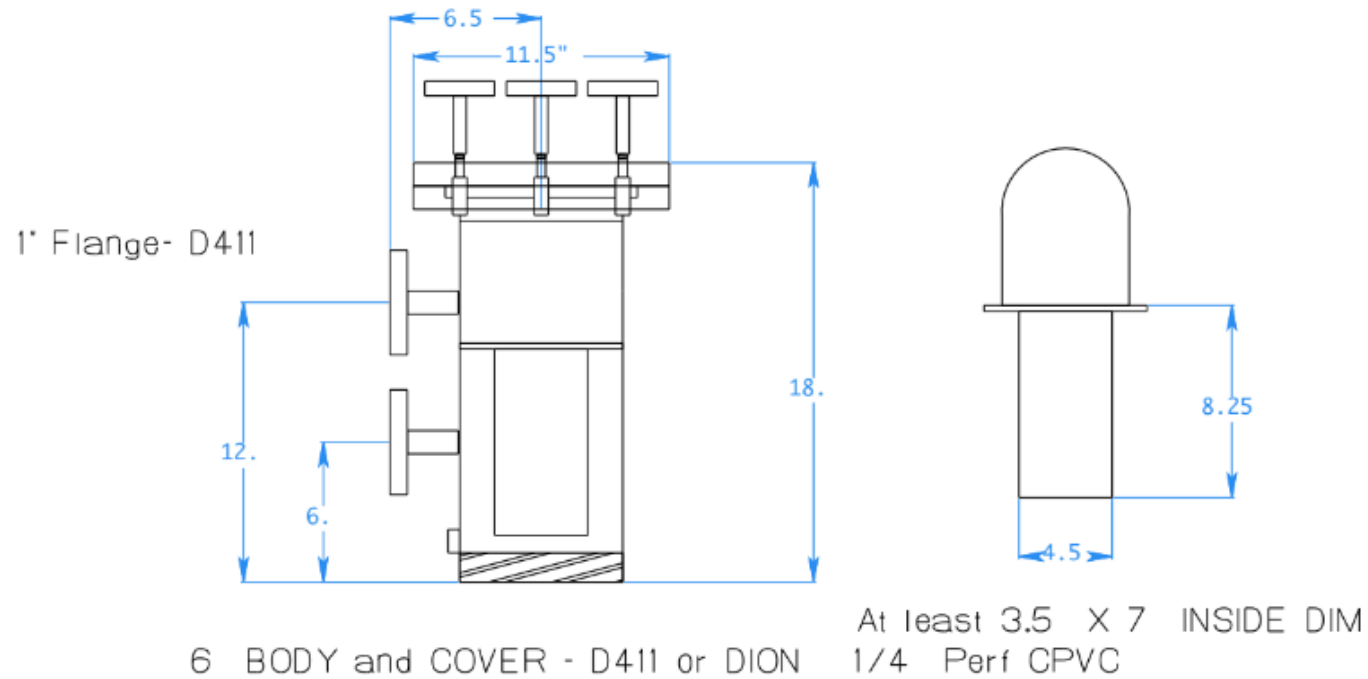


# Chlorination has taken several forms at different times.





The most recently installed chlorinator is a tablet feeder built to handle the high system pressure (>100 psi).



Residual chlorine measurements are taken every other day.





Date: \_\_\_\_\_

Time: \_\_\_\_\_

1.)

Avan Tretman	
TDS [mg/L]:	
Turbidity [NTU]:	
pH [-]:	

2.)

Aprè Tretman	
TDS [mg/L]:	
Turbidity [NTU]:	
pH [-]:	

3.)

Klowoks		
Deskripsyon	Ki Kote	[mg/L]
Fontén	Entre Paza	
Fontén	Bo Madie	
Fontén	Bo Mousol	
Fontén	Tou Kanj	
Fontén	Bo Estime	
Fontén	Bo Bootoo	
Fontén	Bo Tizenzen	
Fontén	Bo Rezima	
Fontén	Cité Platon	
Kay Filtrasyon	Liy Jean Claude	
Kay Filtrasyon	Liy Chen Jape	
L'opital	Andedan	
Kanaran	Andedan	

4.)

Machin Klowoks	
Èske ou pral ajoute klowoks jodi a? [wi/non]	
Konbyen tablet ou ajoute?	
Klowoks apre filtrasyon avan ou chanje [mg/L]:	
Pwa nan klowoks avan ou chanje [lb]:	
Pwa nan klowoks apre ou chanje [lb]:	
Klowoks apre filtrasyon apre ou chanje [mg/L]:	

5.)

Konbyen Dlo Pase [gpm]	
Machin Klowoks	
Sistèm	

6.)

Meter Dlo [gal]	
Liy Jean Claude	
Liy Chen Jape	

7.)

Presyon [psi]		
Ki Kote	Premye Presyon	Dezyèm Presyon
Avan Filtrasyon		
Primye Liy Filte		
Dezyèm Liy Filte		
Liy Jean Claude		
Liy Chen Jape		

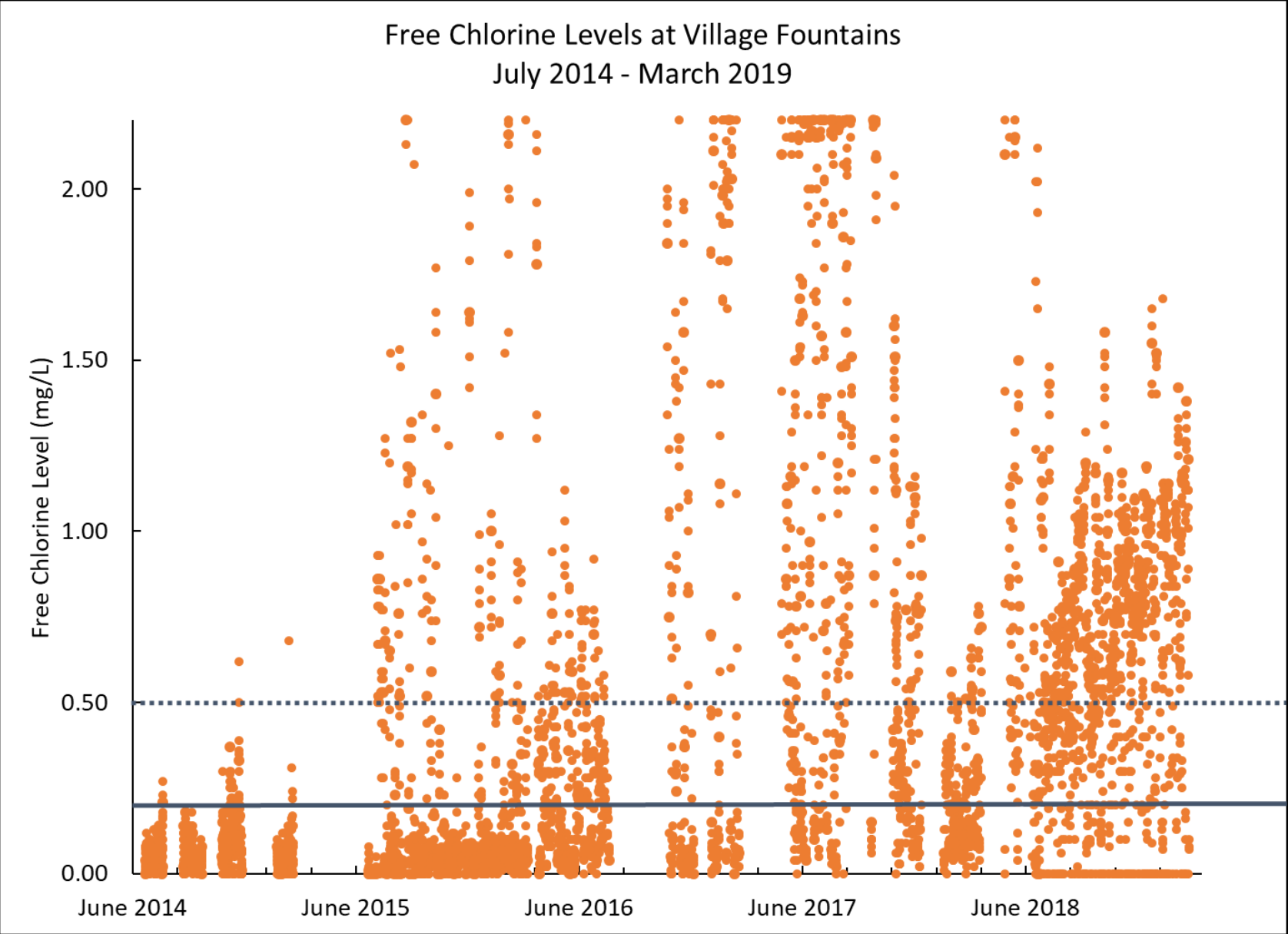
8.)

Si Baypass Ouvri	
Ki Kote	[wi/non]
Primye Liy Filte	
Dezyèm Liy Filte	
Dezyèm Machin Klowoks	
Machin Klowoks	
Liy Jean Claude	
Liy Chen Jape	

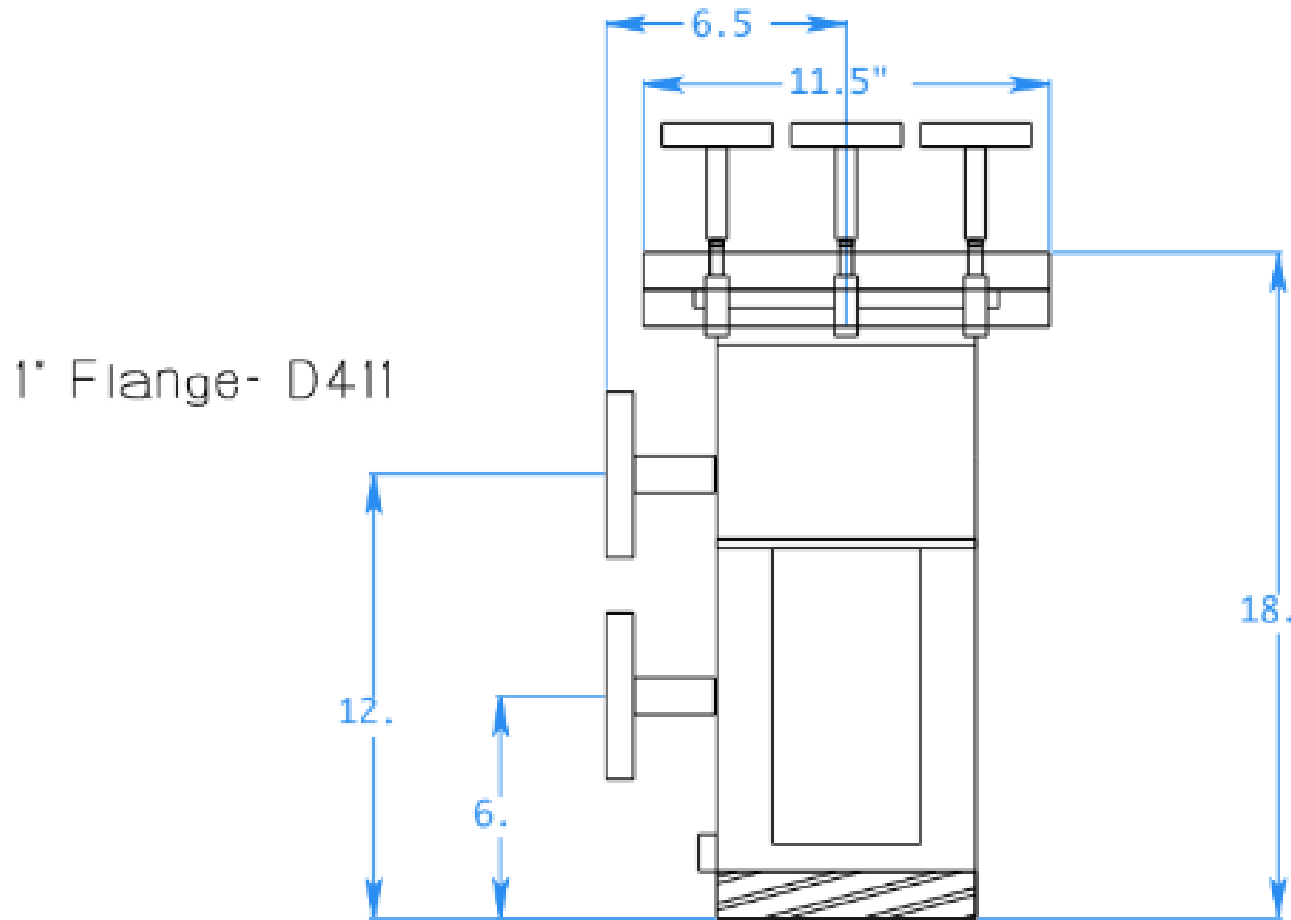
Pwoblem nou genyen avèk fontén sa yo:

Fontén [#wobiné/#douch]	Konbyen Bouch Tio Kraze/Gaspiye	Konbyen Douch Kraze / Gaspiye	Materyo nou bezwen pou ranje li
Entre Paza --- [6/3]			
Bo Madie --- [5/3]			
Bo Mousol --- [3/2]			
Tou Kanj --- [4/3]			
Bo Estime -- [3/2]			
Bo Bootoo --- [5/3]			
Bo Tizenzen --- [6/3]			
Bo Rezima --- [5/3]			
Cité Platon --- [3/2]			

# Achieving stable chlorine concentrations has been challenging.



We are investigating mass transport within the tablet feeder to achieve consistent chlorine doses.



- Flow through the chlorinator
- Dissolution of chlorine tablets
- Transport of free chlorine

6 BODY and COVER - D411 or DION

# Mathematical Model

- Conservation of Mass

$$\nabla \cdot (\rho \mathbf{q}) + \frac{\partial \rho}{\partial t} = M$$

- Conservation of Momentum

$$\mathbf{F} - \nabla P + \mu \nabla^2 \mathbf{v} = \rho (\nabla \cdot \mathbf{v}) \mathbf{v} + \rho \frac{\partial \mathbf{v}}{\partial t}$$

- Dissolved Mass in Fluid

$$\frac{\partial C}{\partial t} + \nabla \cdot (\mathbf{q}C - D\nabla C) - R = 0$$

- Important Boundary Conditions
  - Higher initial concentration at tablet surface
  - Inlet
  - Outlet
- Initial Conditions
  - No initial concentration in chlorinator

# COMSOL Model

- Laminar Flow Physics

- $\rho(u \cdot \nabla)u = \nabla \cdot [-PI + \mu(\nabla u + (\nabla u)^T)]$
- $\rho \nabla \cdot (u) = 0$

- Transport of Diluted Species Physics

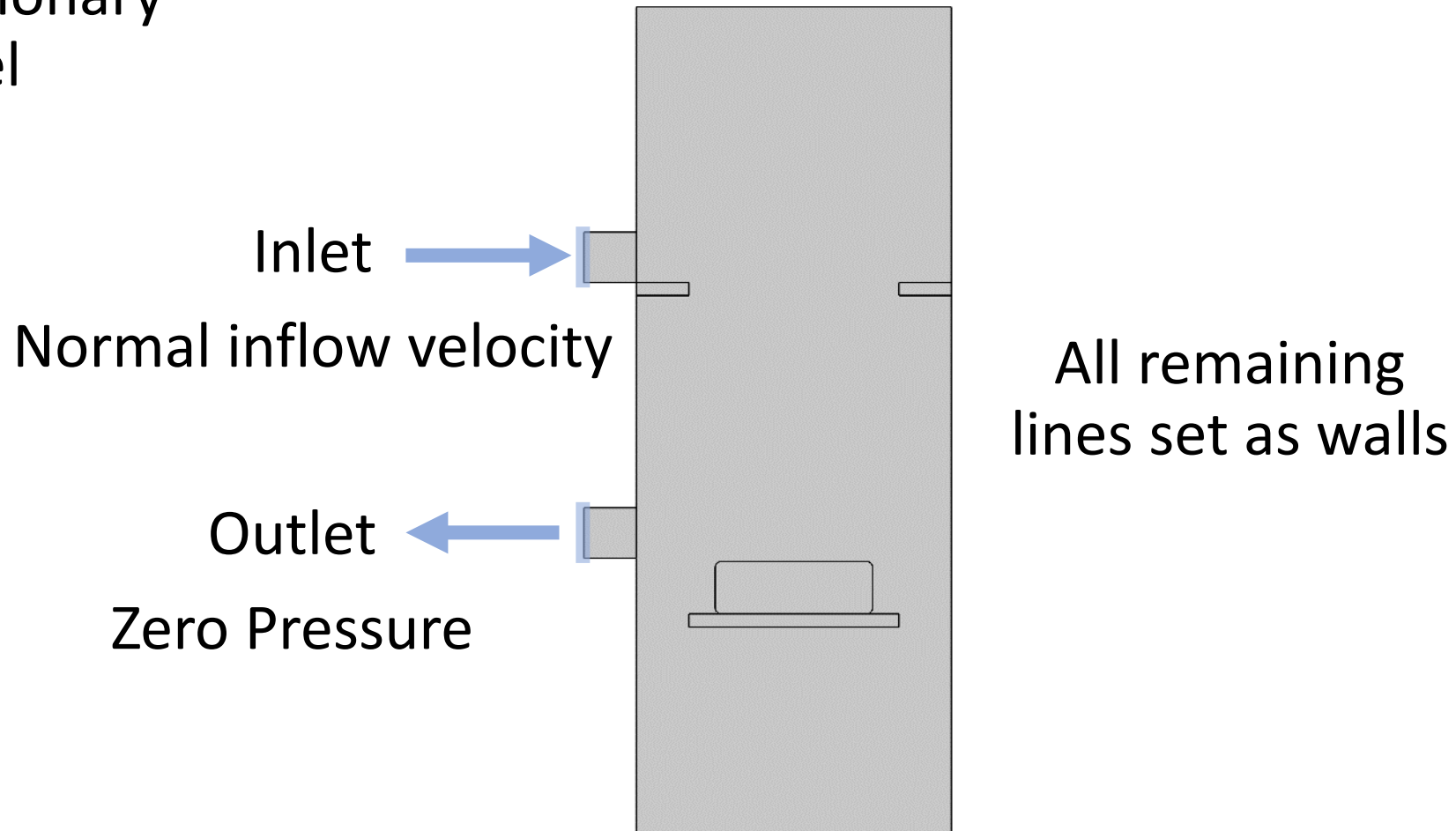
- $\frac{\partial c_i}{\partial t} + \nabla \cdot J_i = R_i$
- $J_i = -D_i \nabla c_i$

- Moving Mesh

# COMSOL Model

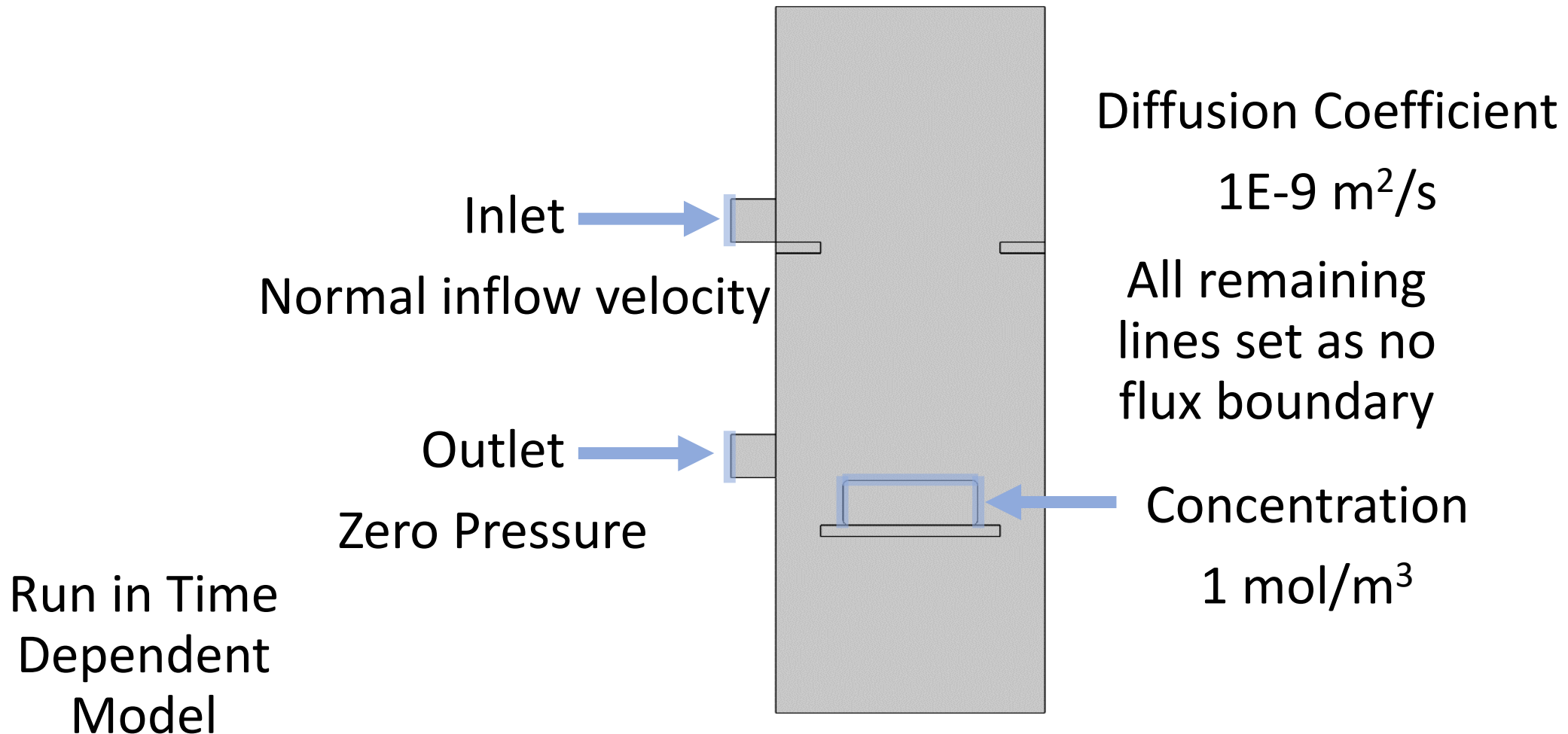
## Laminar Flow

Run in Stationary  
Model

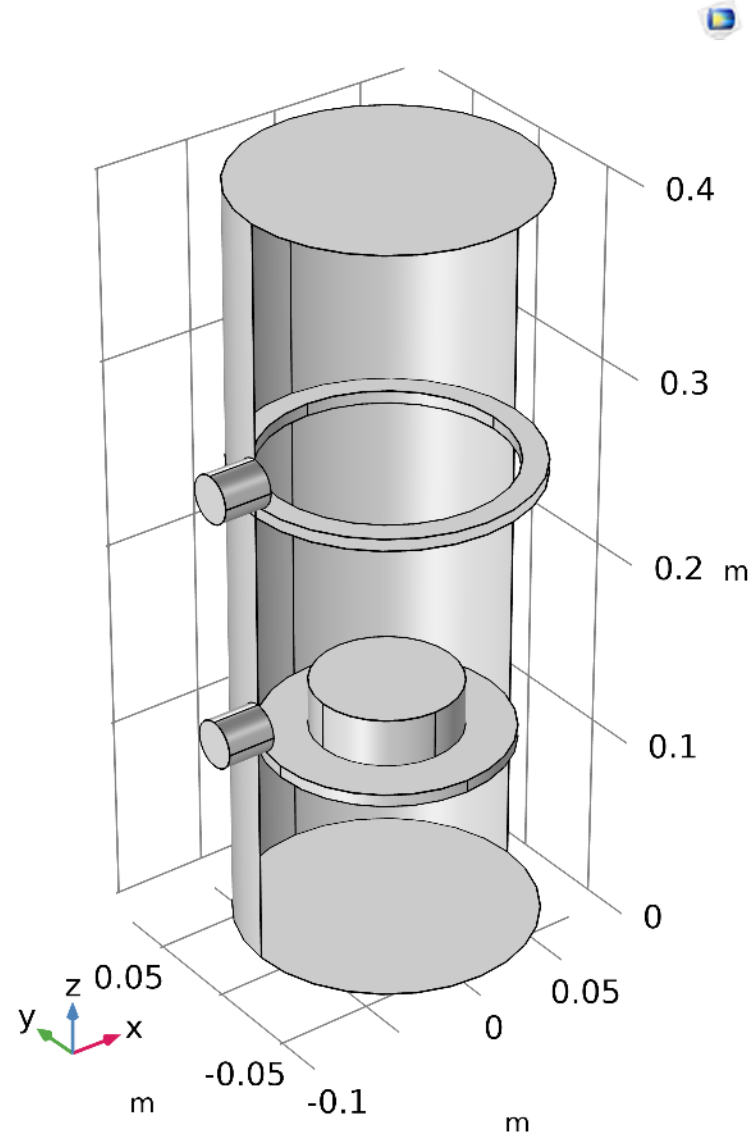
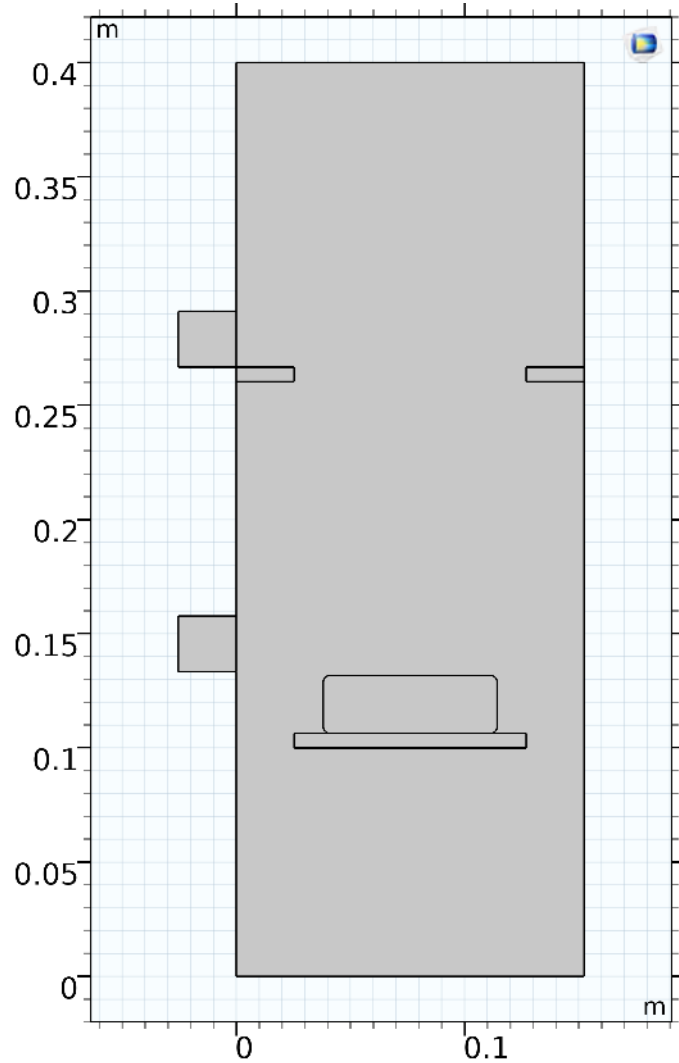


# COMSOL Model

## Transport of Diluted Species

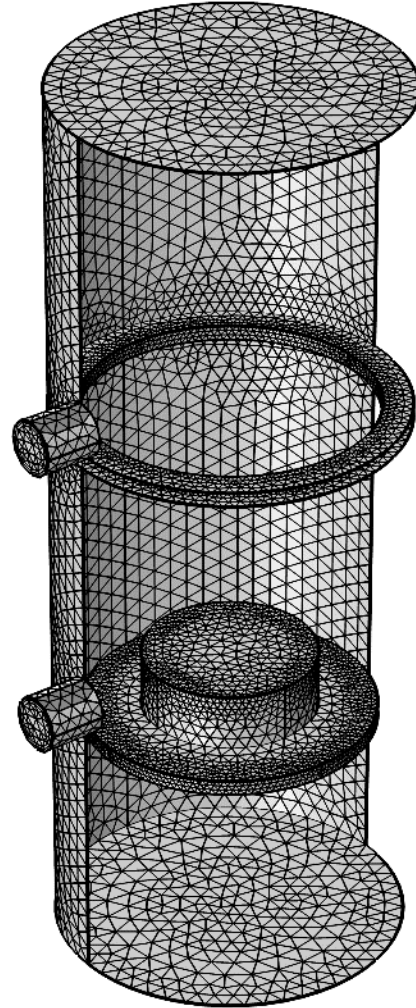
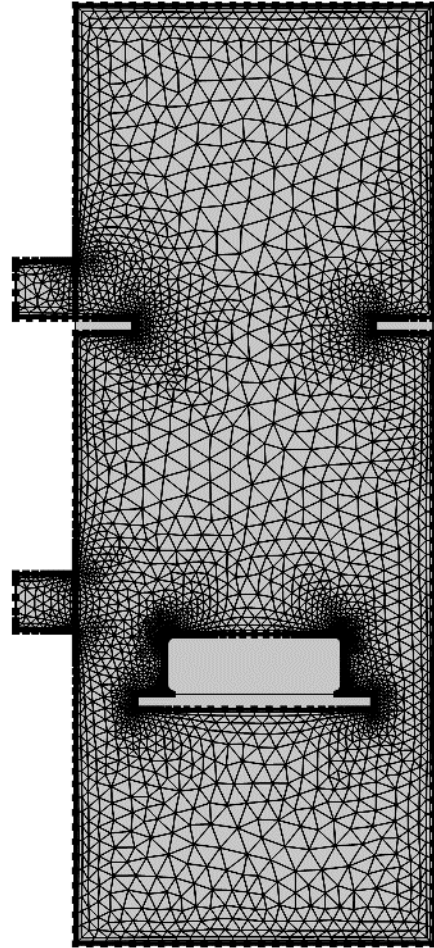


# COMSOL Model

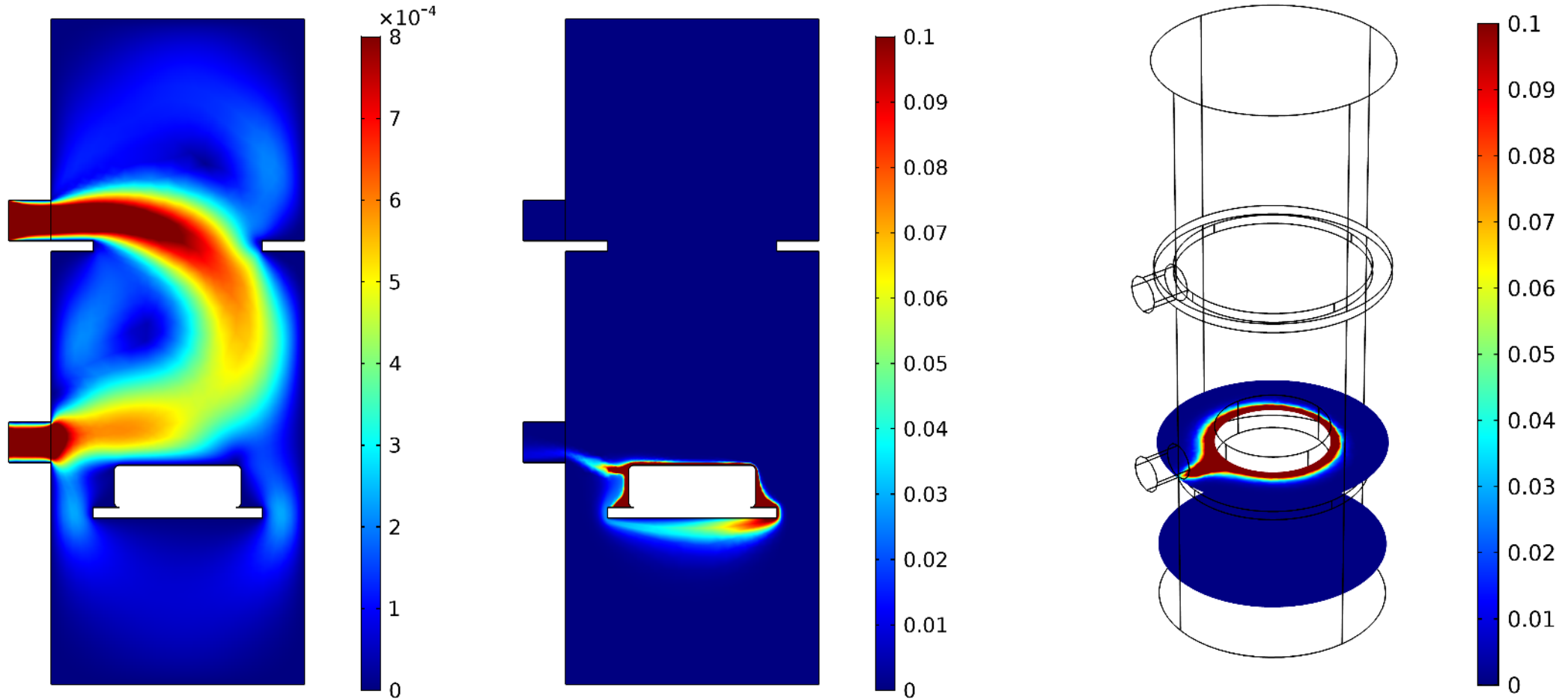




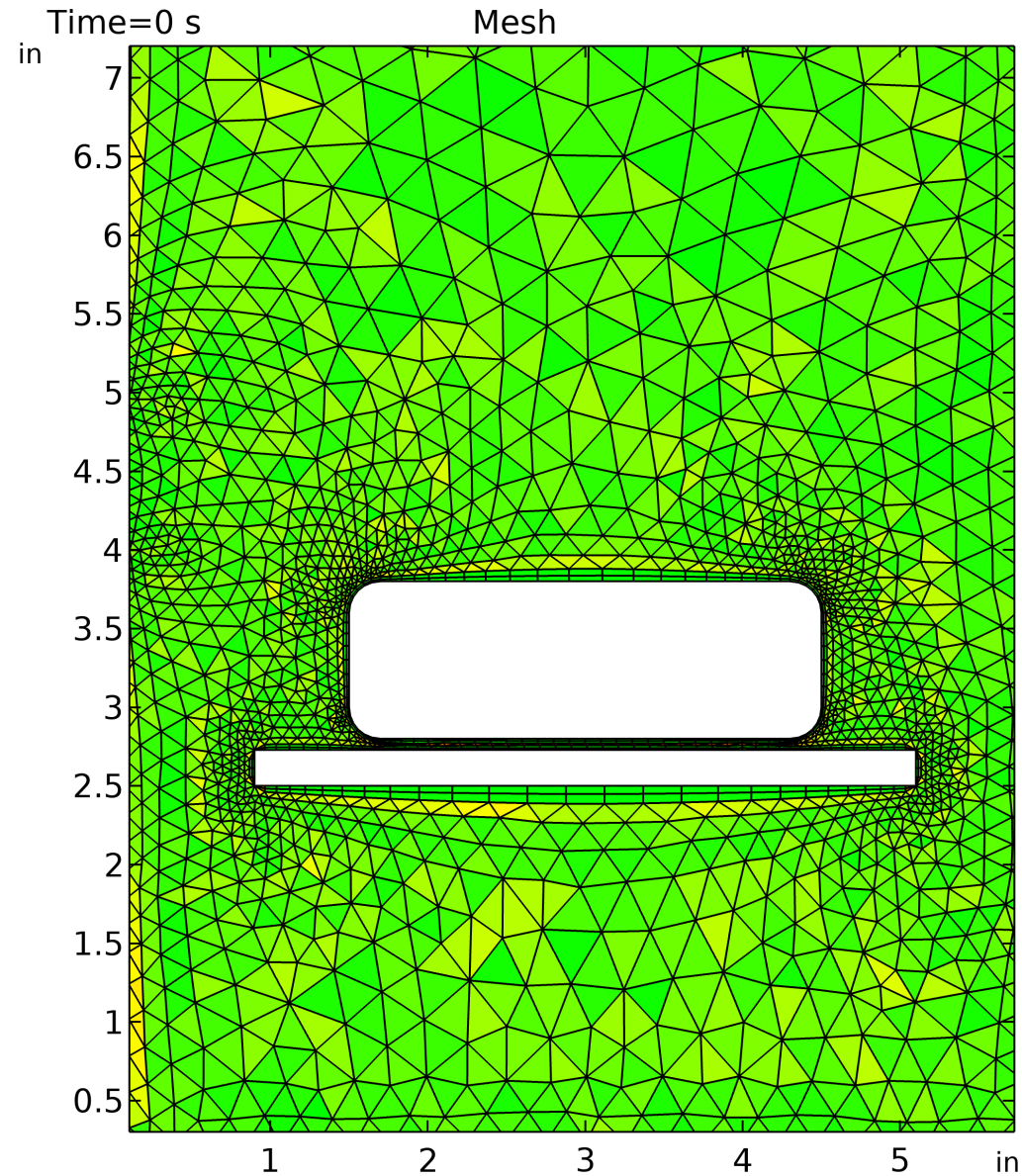
# COMSOL Model



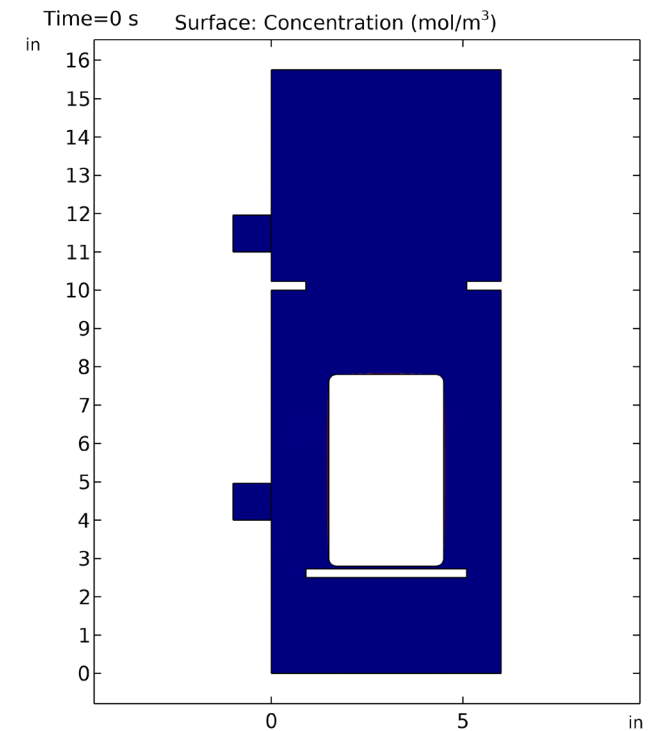
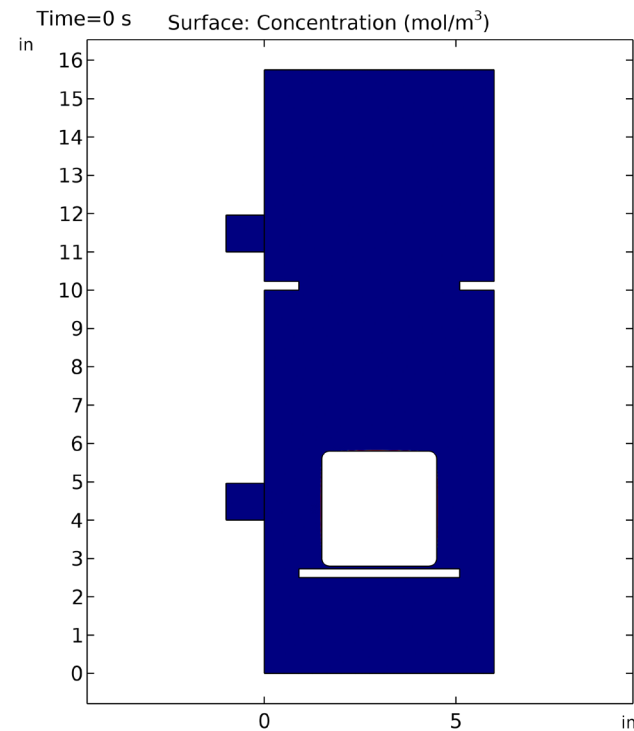
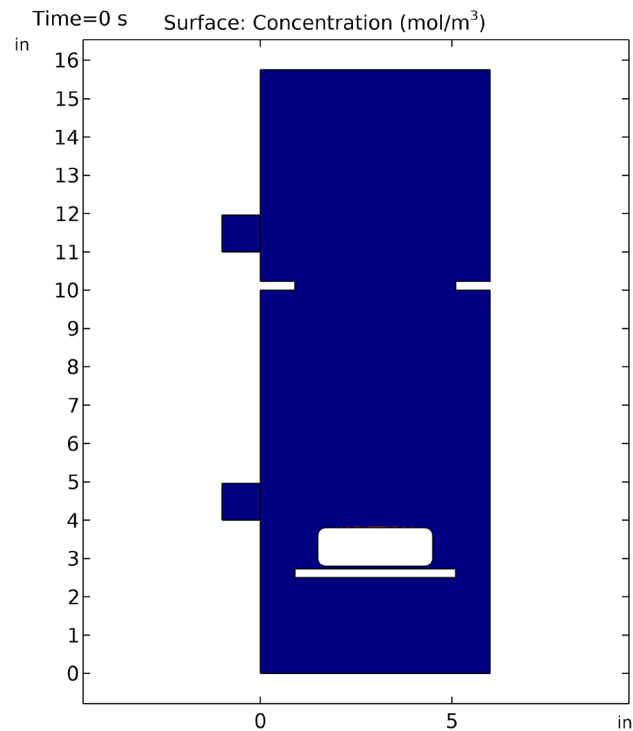
2D and 3D give similar results, though 2D has fewer degrees of freedom for chlorine flow.



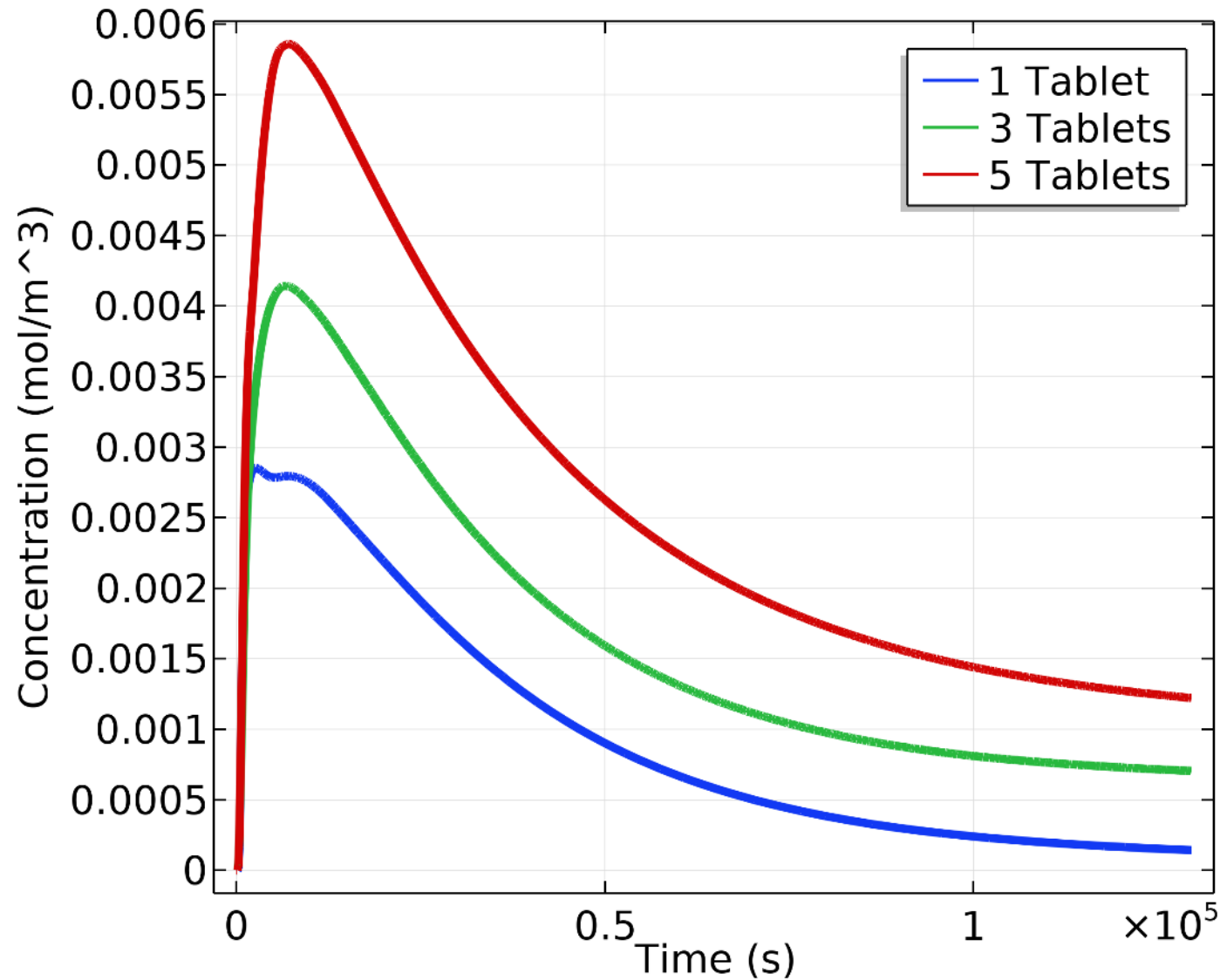
# Tablet dissolution is modelled with a moving mesh.



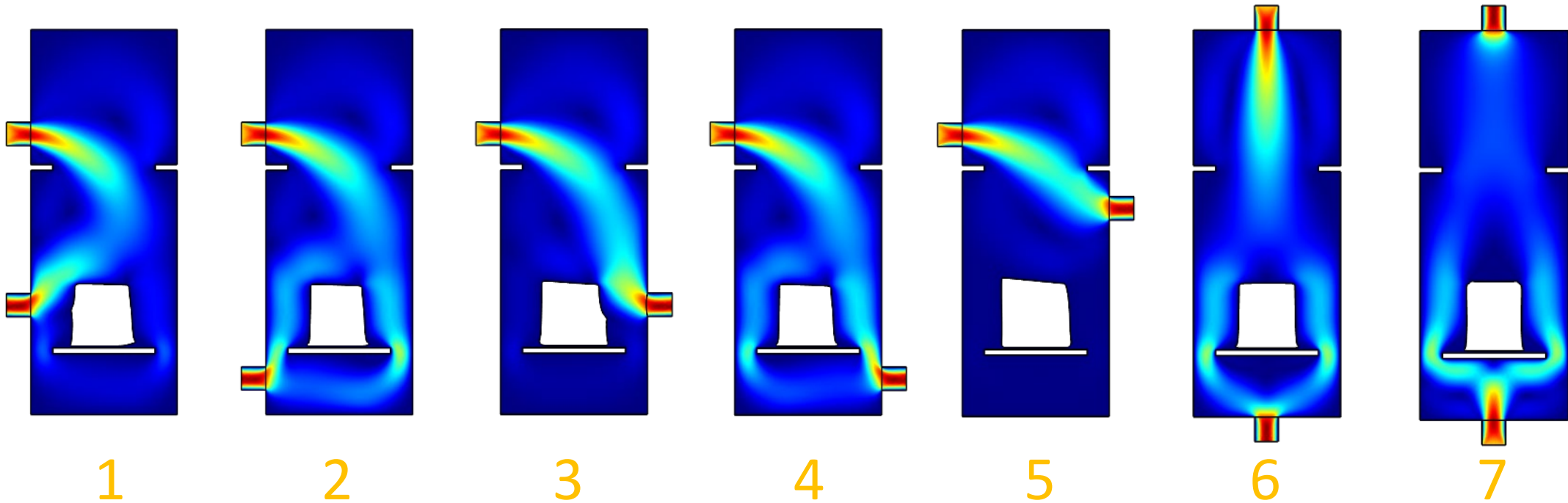
# We compared simulations with 1, 3, and 5 tablets.



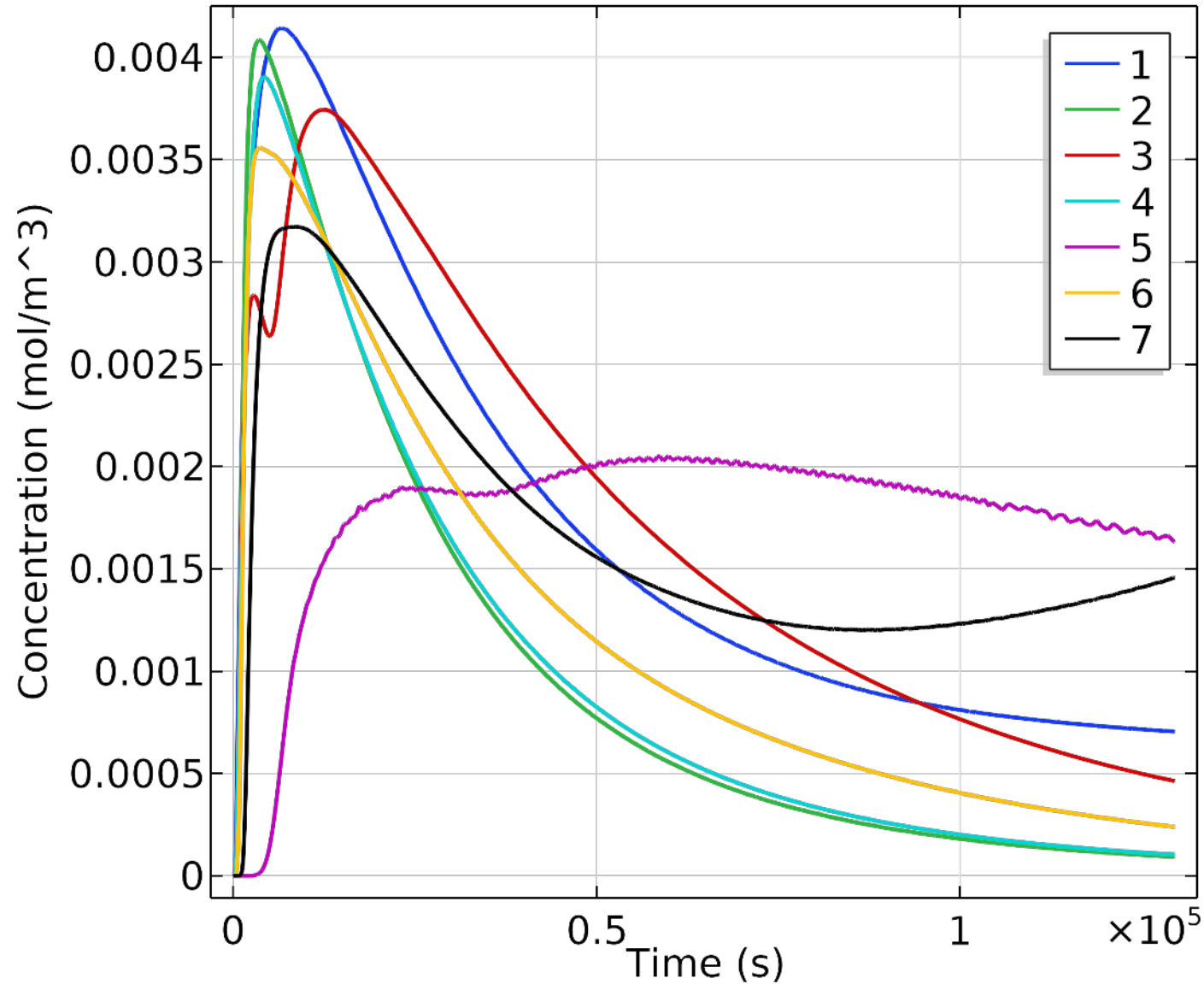
Chlorine concentrations peak early then taper off over time.



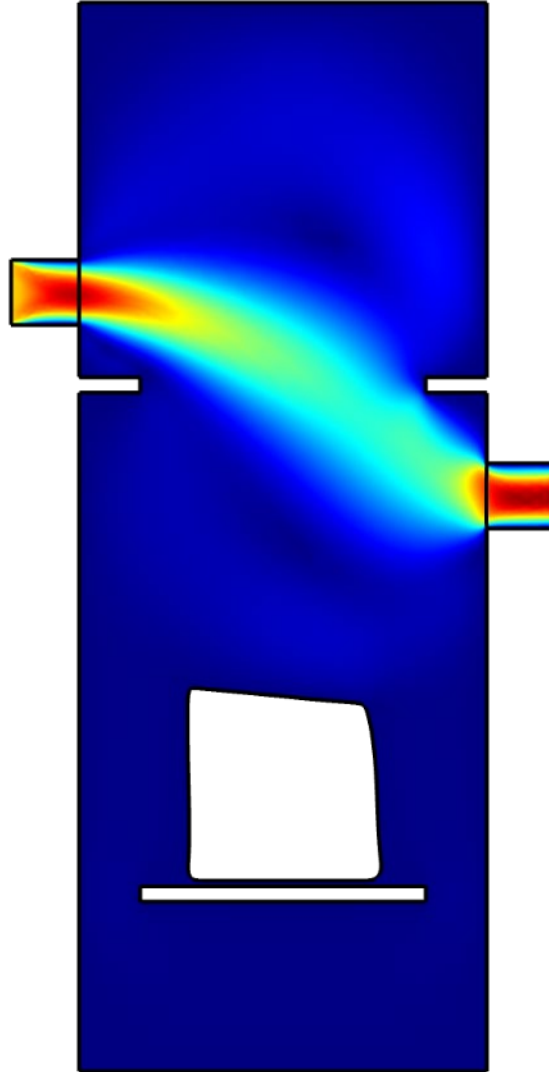
We changed the inlet and outlet locations to explore benefits to chlorine dose stability.



Scenario 5 (inlet and outlet above tablets) gave most consistent chlorine levels.



With less fluid flow directed at the tablets, convection plays a smaller role than diffusion. Tablet surface area is less important.





# Acknowledgements

- Clemson Engineers for Developing Countries (CEDDC)
  - David Vaughn
  - Paris Stringfellow
  - Jeff Plumbley
- Larry Murdoch

