# Dancing with the Models. SWMM and Physical Models used to Optimize Design of the Cemetery Brook Drain Tunnel

City of Manchester, New Hampshire

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# Integrating Physical Model Testing with SWMM Analysis

# Agenda

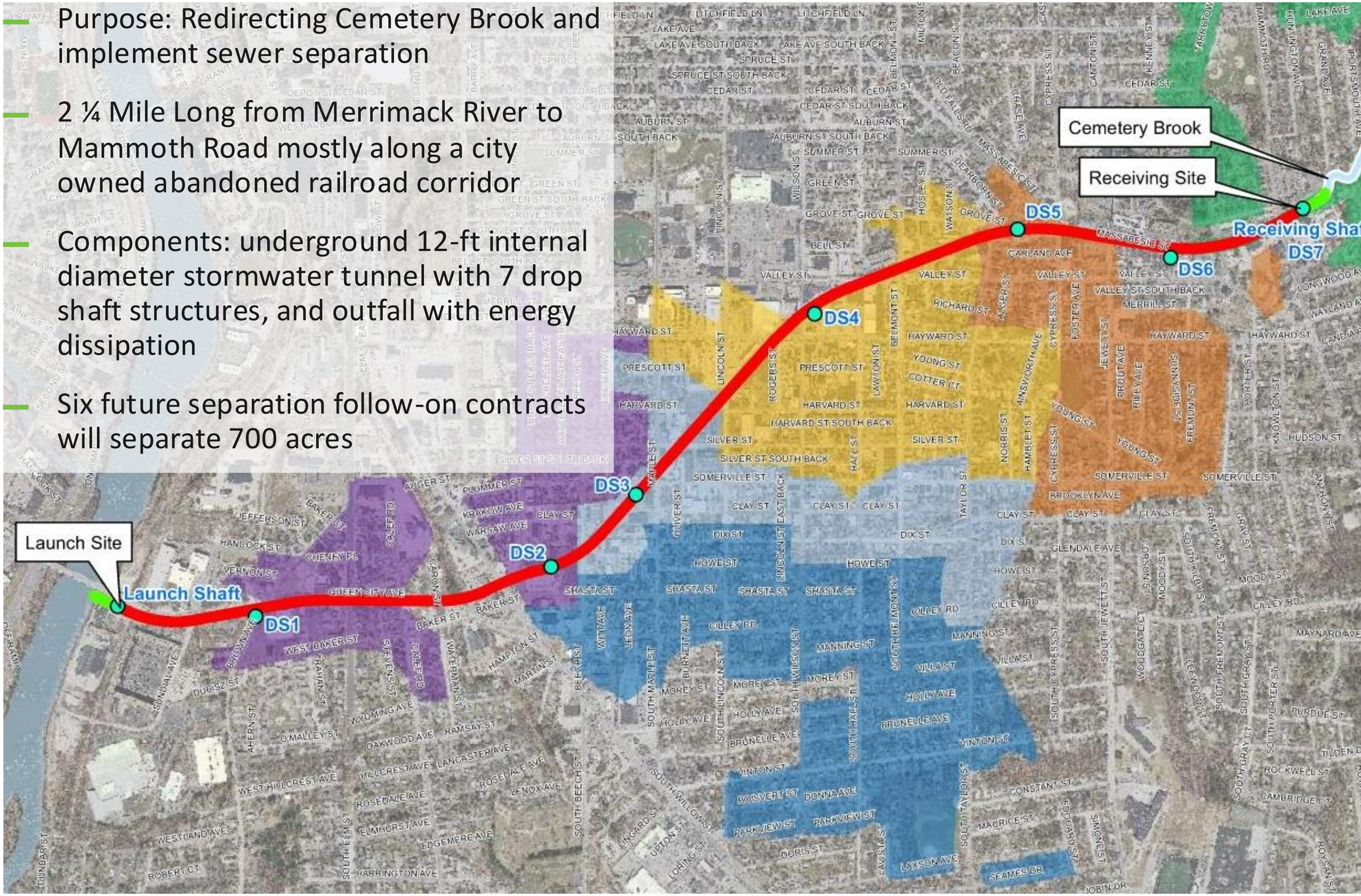
1. Introduction
2. Project Overview
3. SWMM Modeling Analysis
4. Physical Model Testing and Results
5. Conclusion
6. Acknowledgements

# Introduction

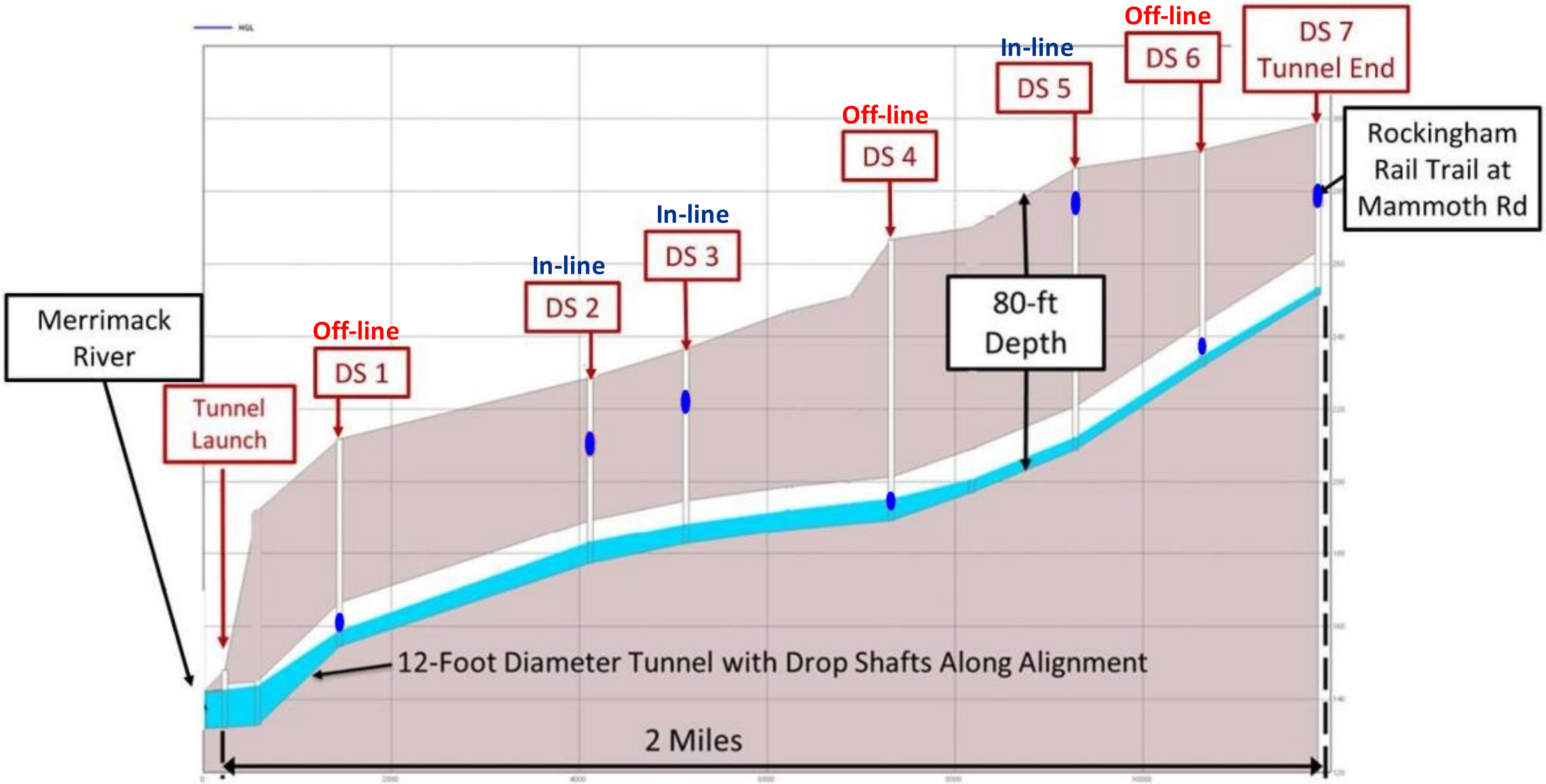
- Manchester Wastewater Treatment Facility: 72 MGD
- Existing Combined Sewer System
  - 385 miles of sewer
  - 50% “combined” system
  - 5 brooks feed into sewer system
- Cemetery Brook is the largest of five brooks that contribute to combined sewer overflow discharges to Merrimack River.
- Removal of the Cemetery Brook, along with sewer separation, is one of the primary objectives of the city’s Long-Term Control Plan
- Recommended construction of a new Cemetery Brook Drain Tunnel (CBD)

# Project Overview

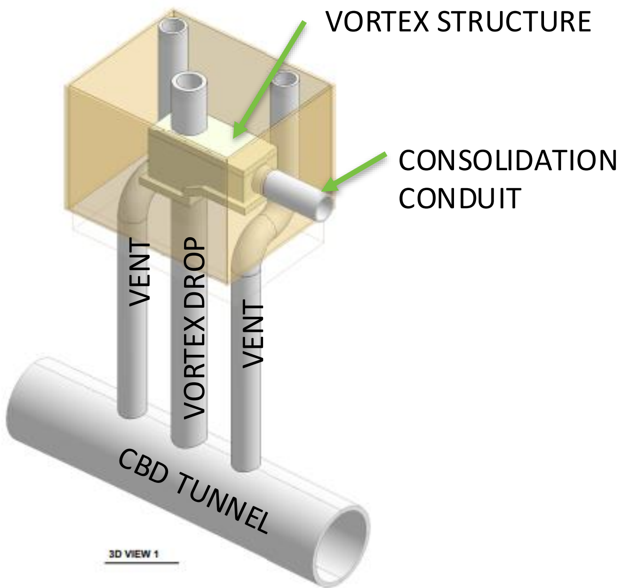
- Purpose: Redirecting Cemetery Brook and implement sewer separation
- 2 ¼ Mile Long from Merrimack River to Mammoth Road mostly along a city owned abandoned railroad corridor
- Components: underground 12-ft internal diameter stormwater tunnel with 7 drop shaft structures, and outfall with energy dissipation
- Six future separation follow-on contracts will separate 700 acres



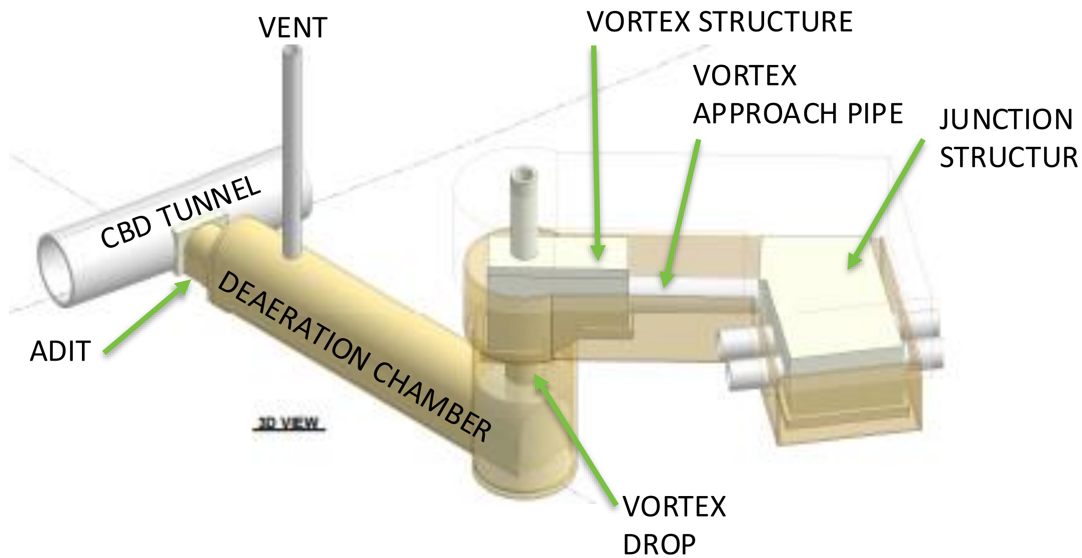
# Proposed Tunnel Profile in the 25-yr Design Storm



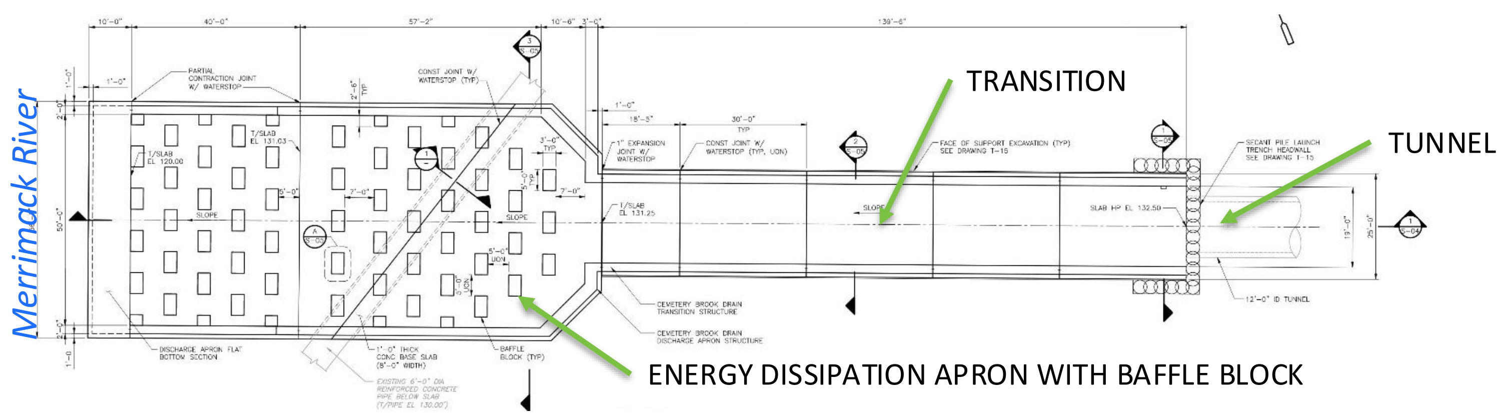
# Modeled Design Elements




In-line Drop Shaft




Off-line Drop Shaft



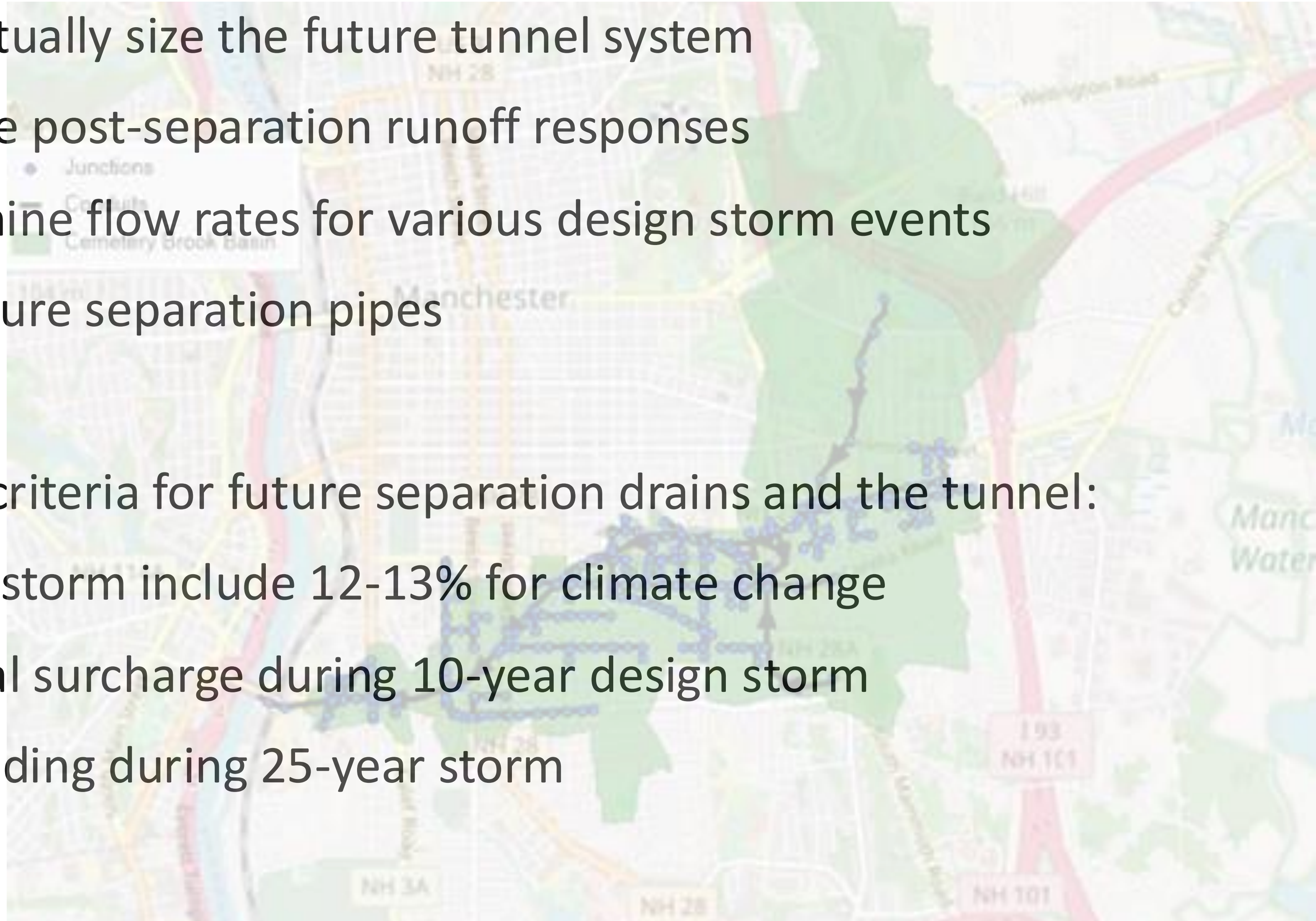

Outfall Structure

# SWMM Modeling Analysis

- ✓ Conceptually size the future tunnel system
- ✓ Simulate post-separation runoff responses
- ✓ Determine flow rates for various design storm events
- ✓ Size future separation pipes

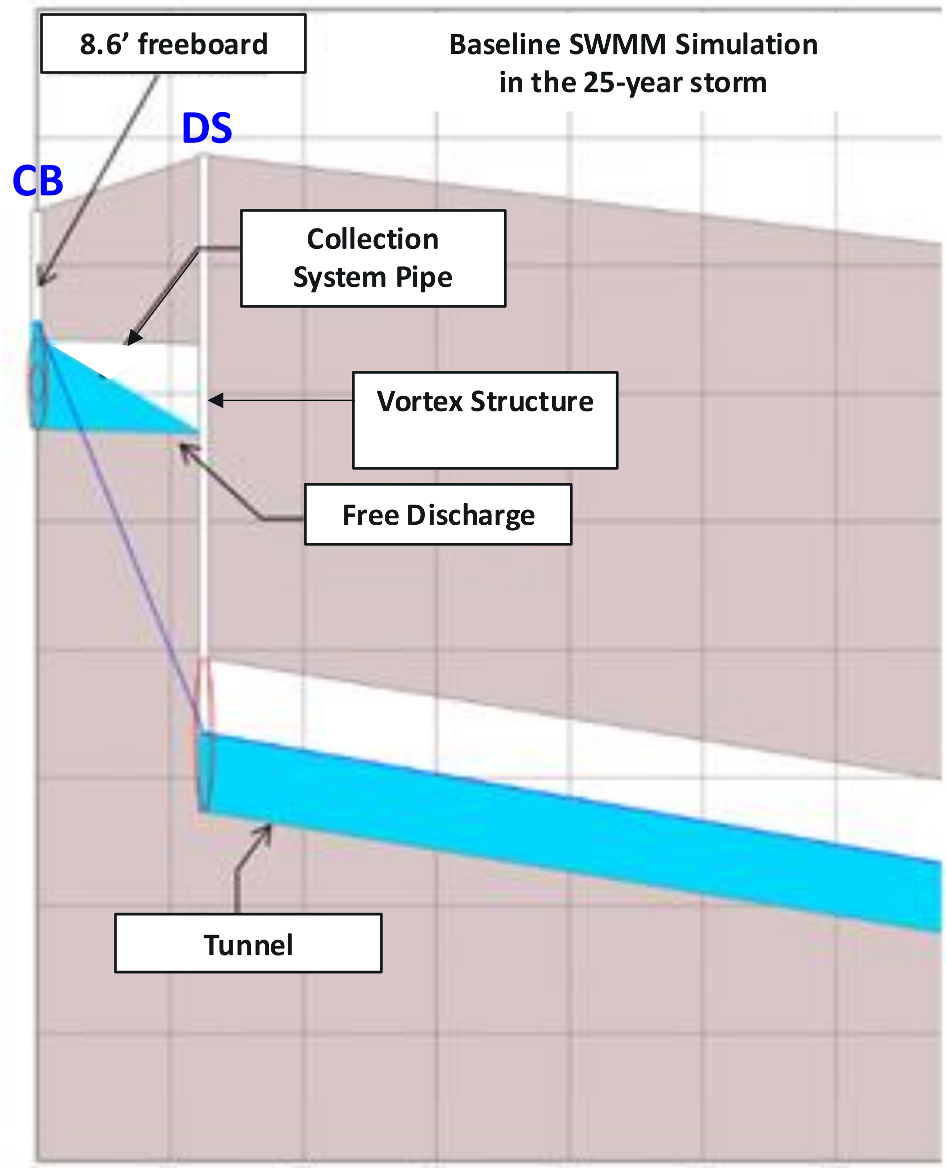
Hydraulic criteria for future separation drains and the tunnel:

- ✓ Design storm include 12-13% for climate change
- ✓ Minimal surcharge during 10-year design storm
- ✓ No flooding during 25-year storm



# SWMM Modeling Limitation

- SWMM model has limitations on complex structures and the interaction of tunnel flows with these drops
- SWMM simulates free pipe discharge at the connection of collection system piping to the drop shaft vortex inlet structure
- In real life vortex structures can generate backwater effects
- To verify concept pipe sizes and investigate complex behavior within structures during various design storm events, a scaled physical model was built in the lab by Clemson Engineering Hydraulics, Inc. (CEH)



# What is a physical model of hydraulic structures?

Laboratory based reduced scale hydraulic model

## Why to build a physical model?

- Design and validate performance of hydraulic structures
- Reduce risk and project cost
- Visualize hydraulic behavior in otherwise unobservable locations

# Physical Model Testing Lab Overview
# Clemson Engineering Hydraulics, Inc. (CEH)

# Physical Model Testing

Clemson Engineering Hydraulics constructed a physical model at a 1:9.3 scale

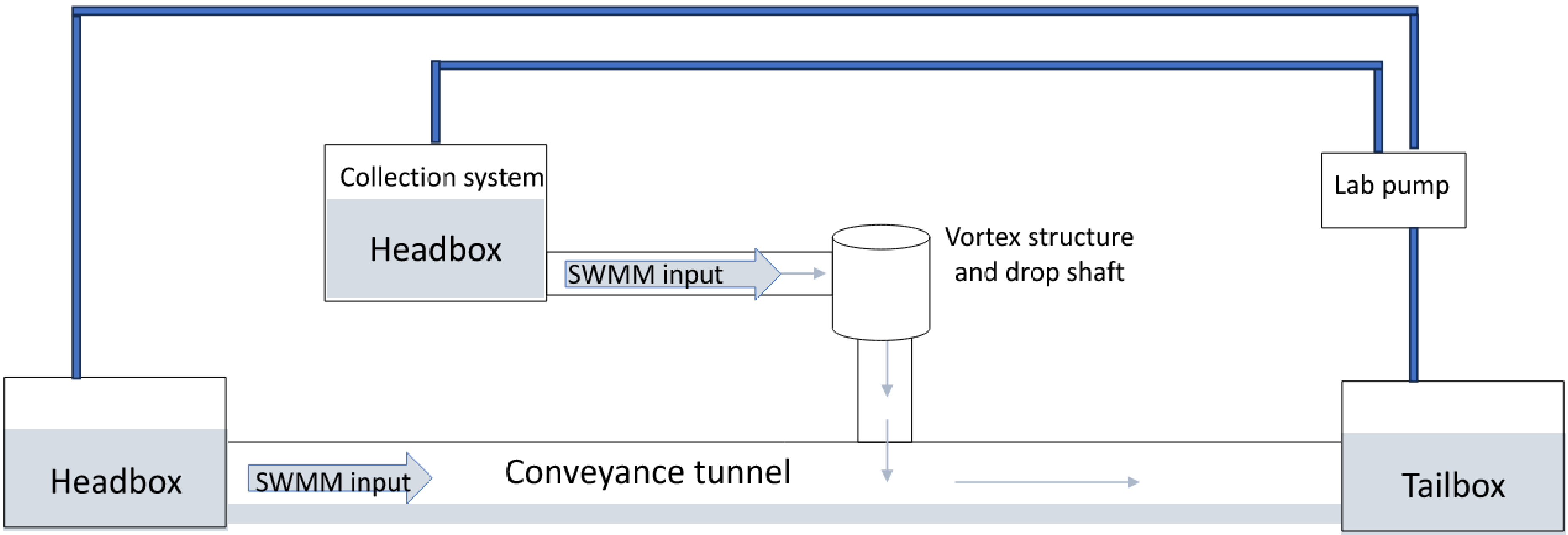
Key components of the prototype:

- ✓ 200 feet of tunnel upstream and 300 feet (prototype) downstream of the drop shaft connections
- ✓ In-line and off-line drop shaft lines
- ✓ De-aeration chamber
- ✓ Outfall

Purpose:

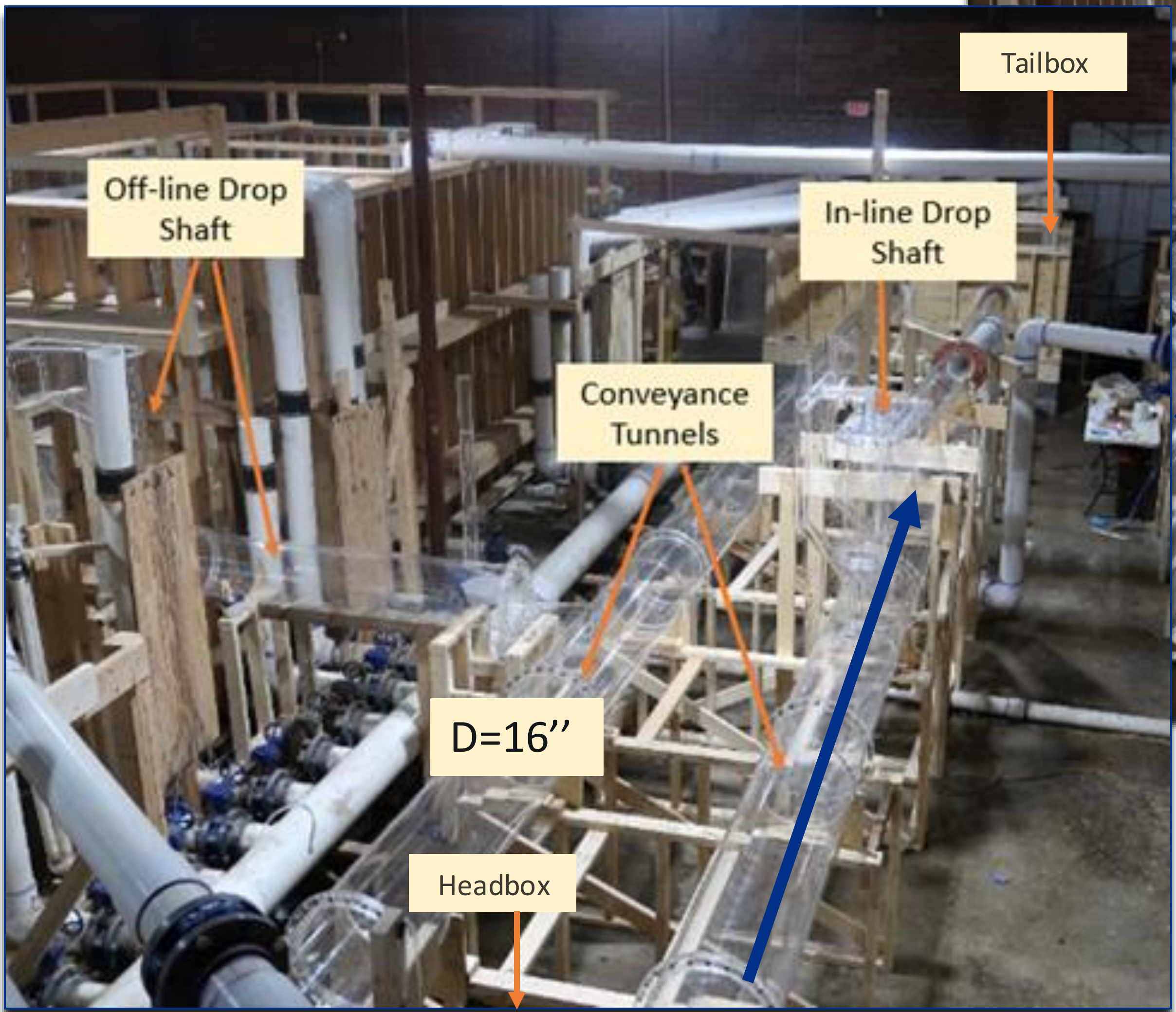
- ✓ Validate modeled tunnel and collection system pipe sizes
- ✓ Assess hydraulic performance under different conditions
- ✓ Analyze the vortex structure efficiency to get flow into the tunnel
- ✓ Investigate corrective adjustments to the tunnel design

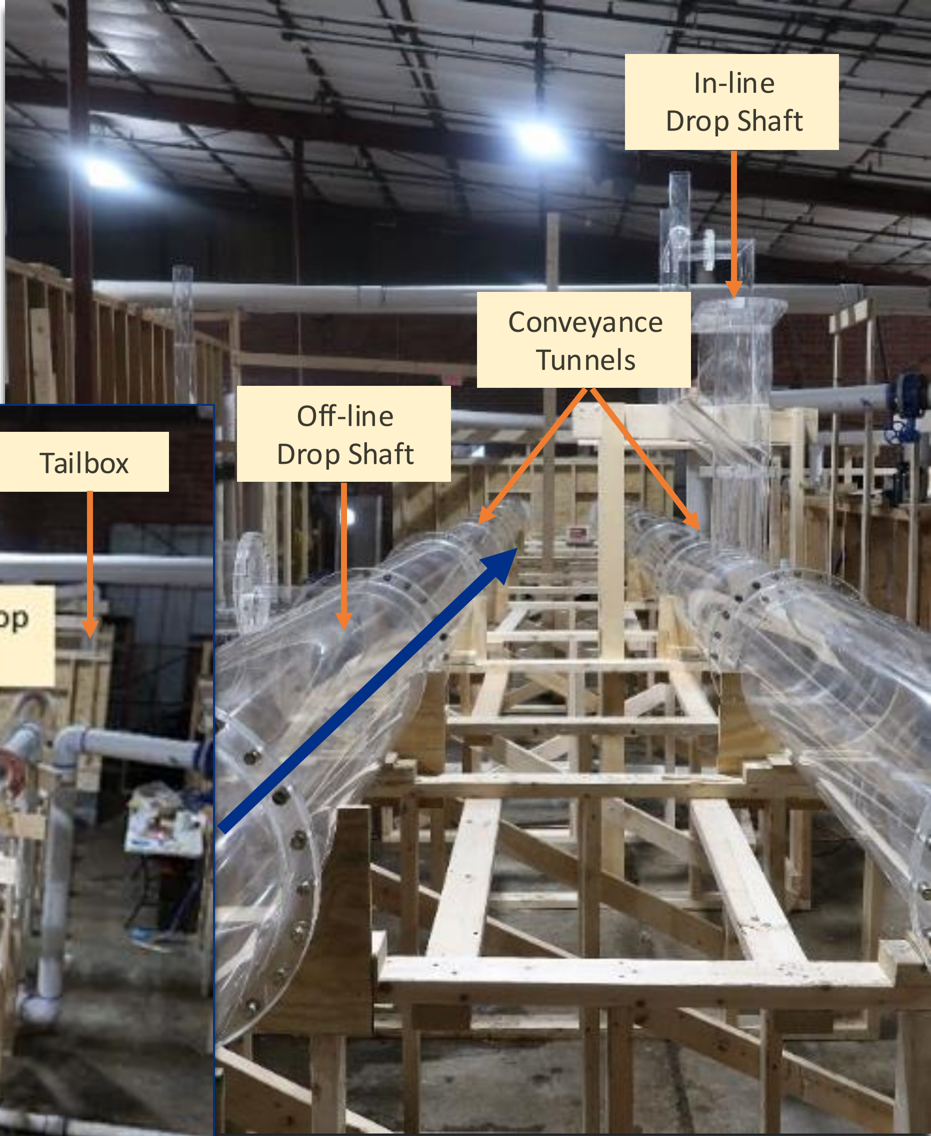
# Drop Shaft Schematics



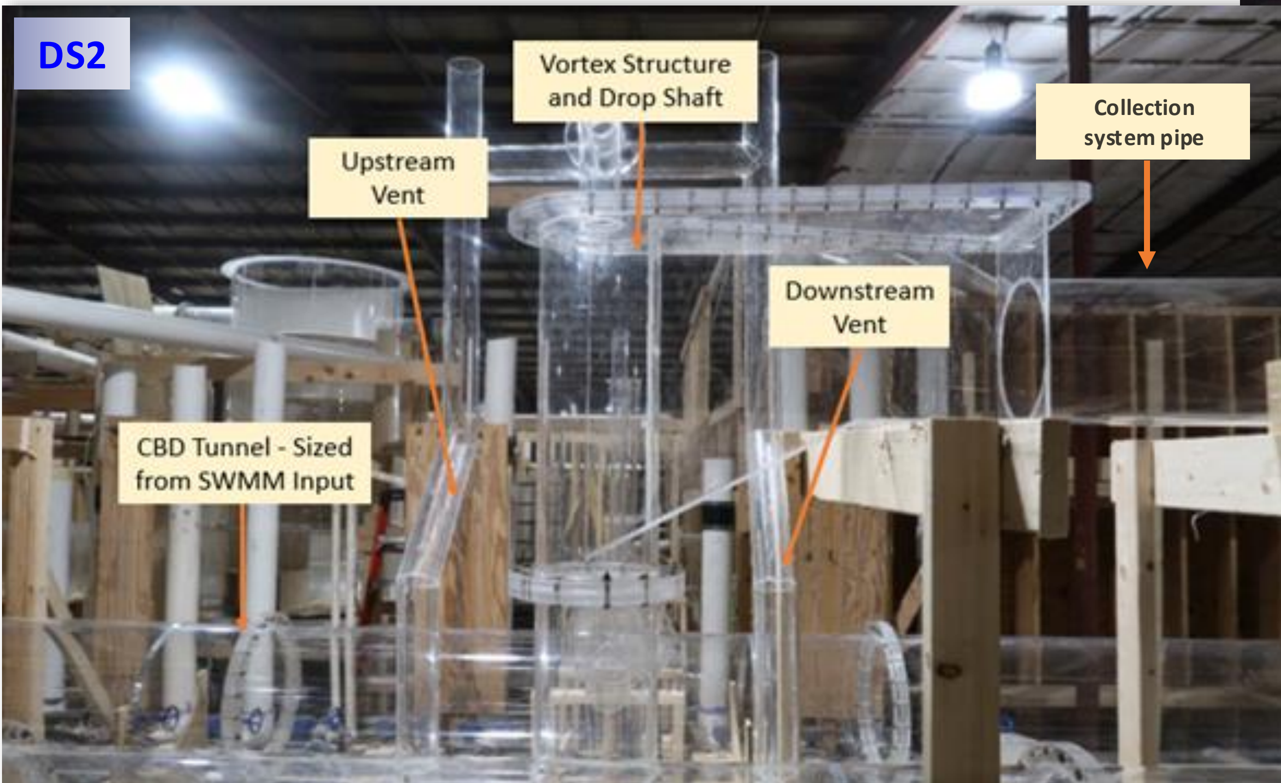

- 10-yr storm with min surcharge
- 25-yr no street flooding
- Included climate change volume
- Checked tunnel performance under up to 100-yr storm conditions

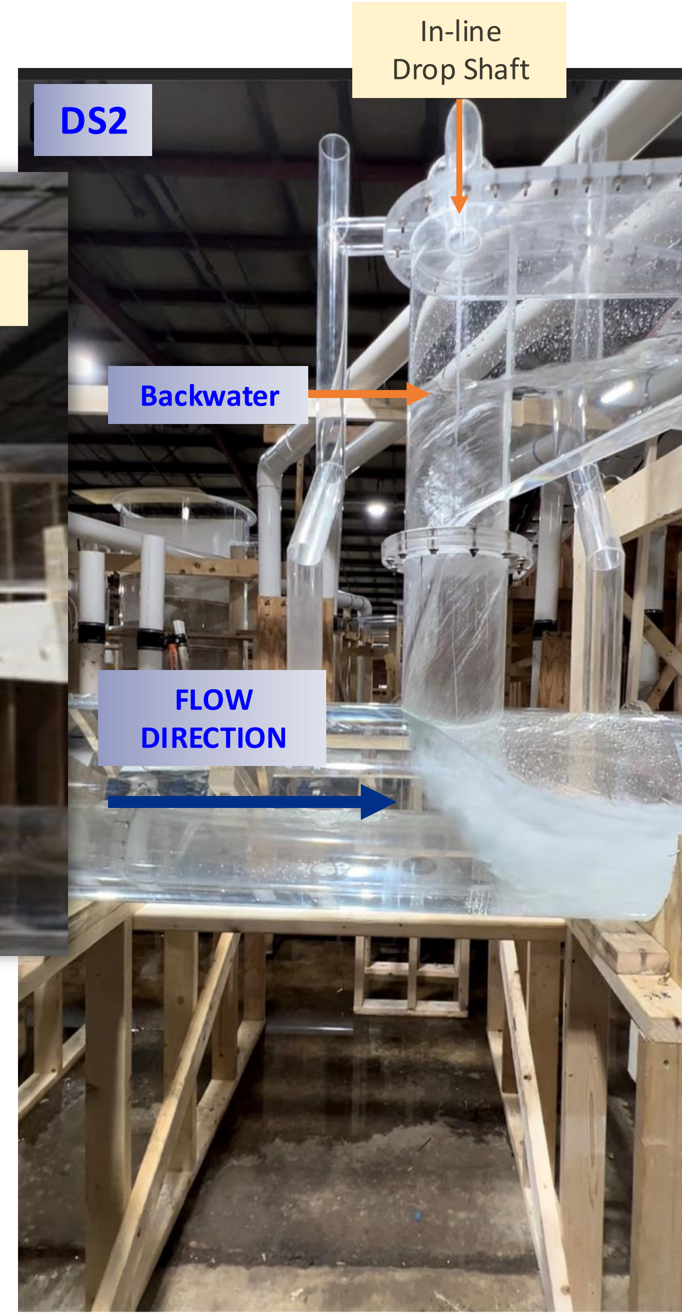
# Overview of Drop Shafts



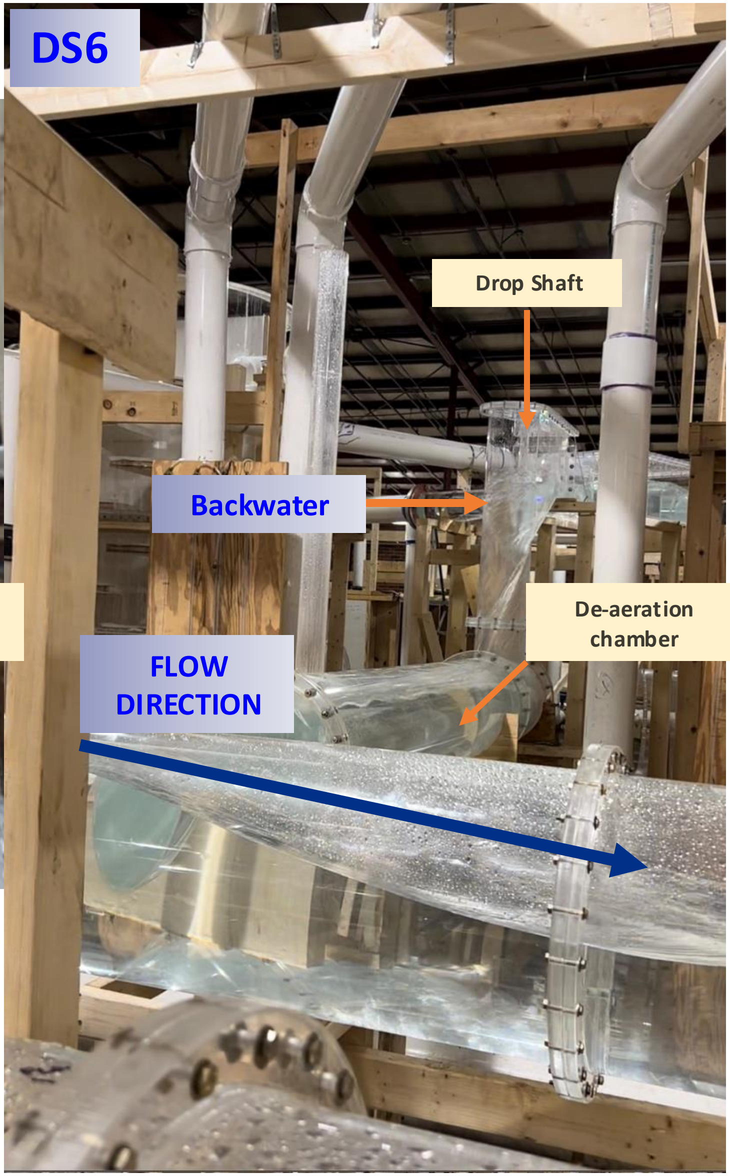



# In-line Drop Shaft

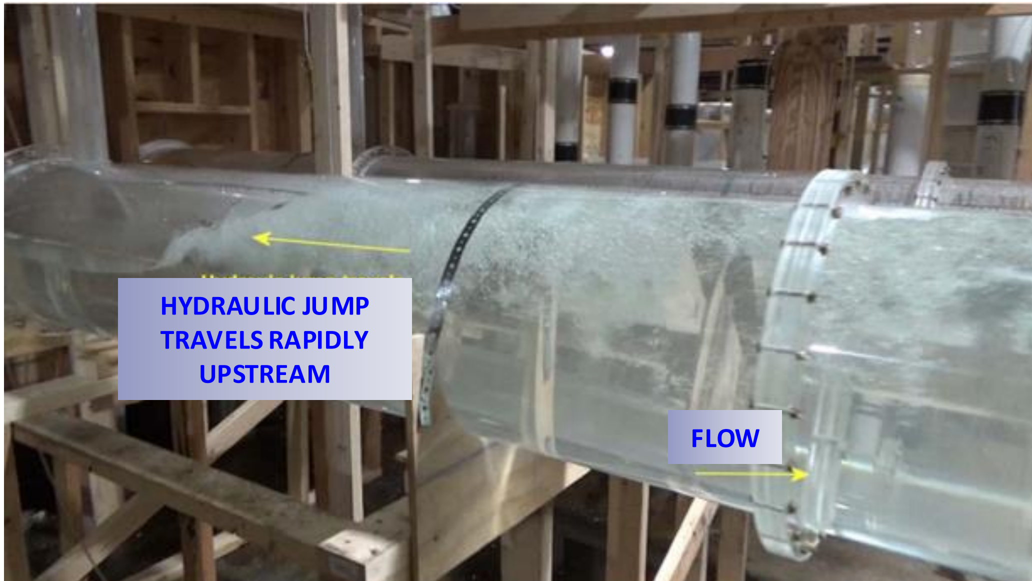


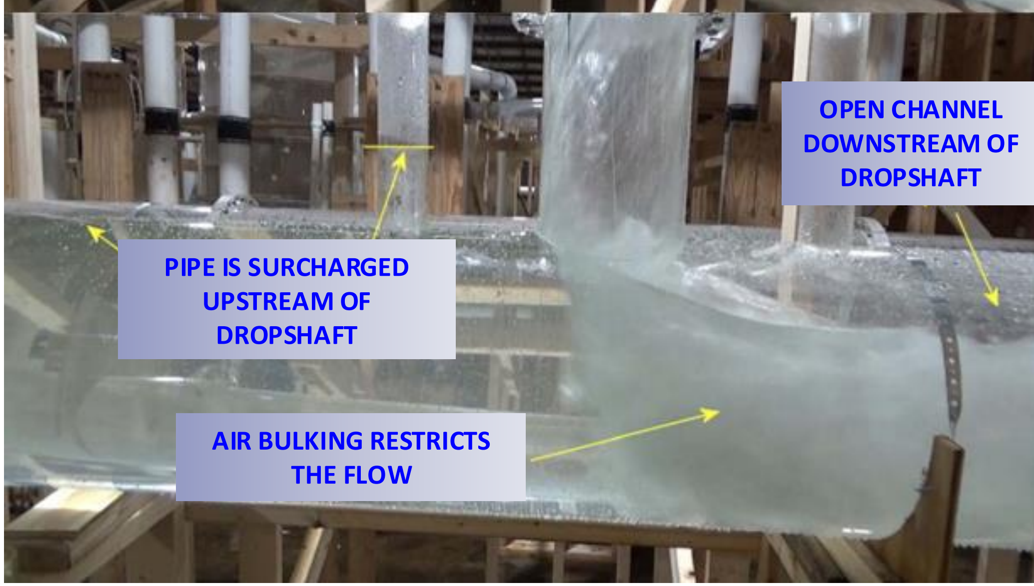



# Off-line Drop Shaft

# Hydraulic Jump



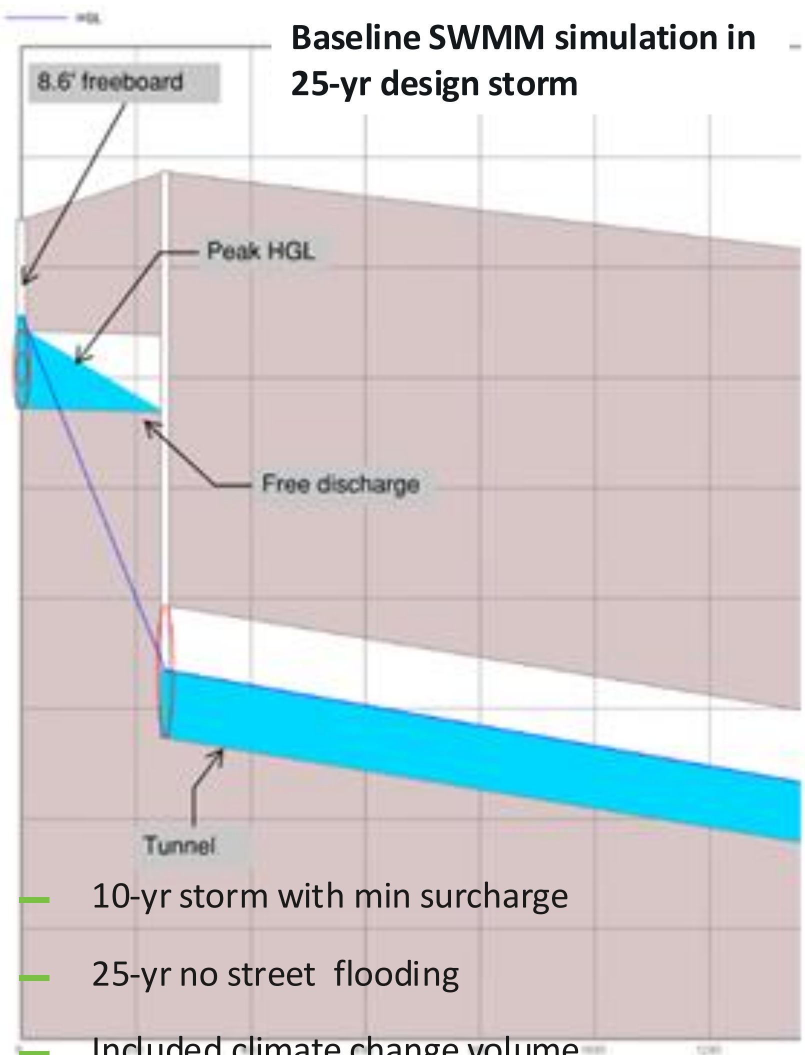




# Physical Modeling Testing Results

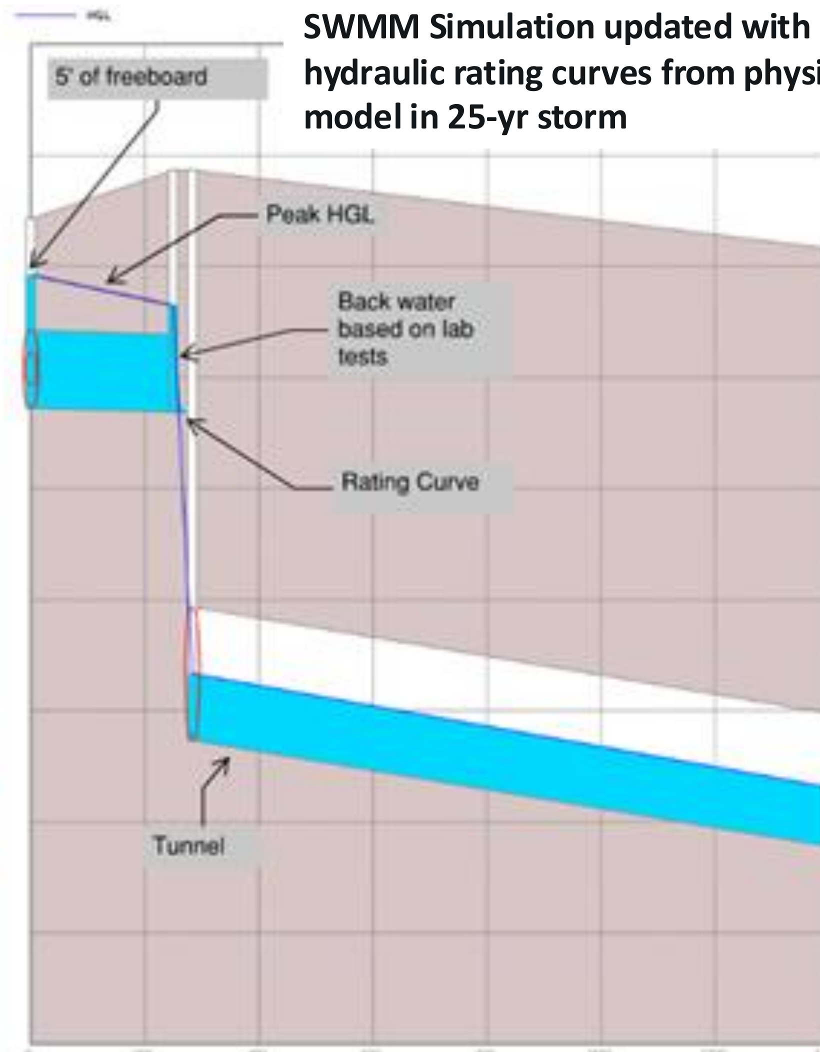
- Validated the SWMM model's predictions and confirmed key parameters such as peak flows, depths, and pipe sizes
- Identified hydraulic phenomena, the formation of hydraulic jumps, which prompted design modifications
- Developed hydraulic rating curves to improve SWMM drain model
- Enhanced the overall reliability of the project's design

# Mutual exchange of information between physical and computational models

**Baseline SWMM simulation in 25-yr design storm**

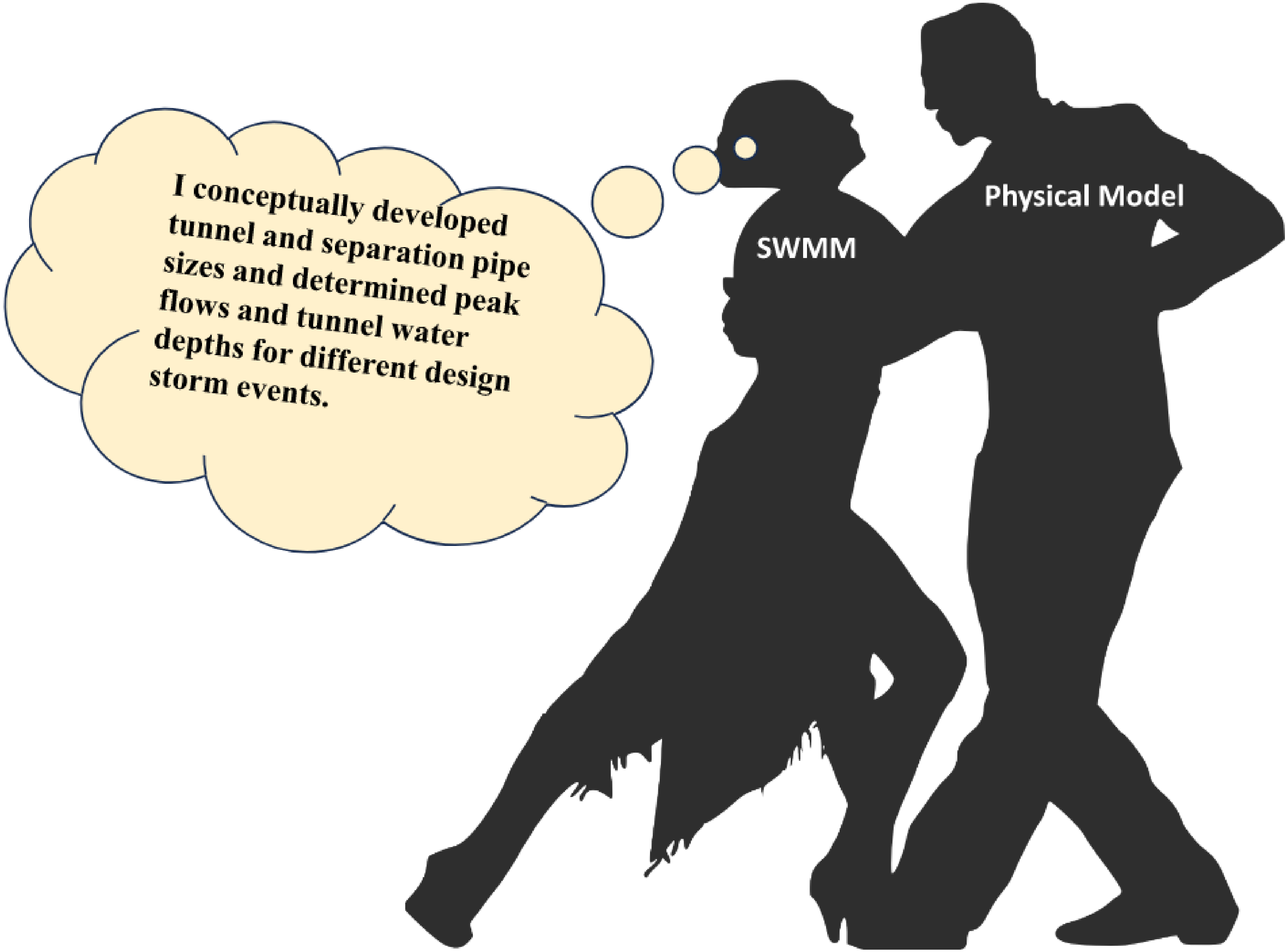


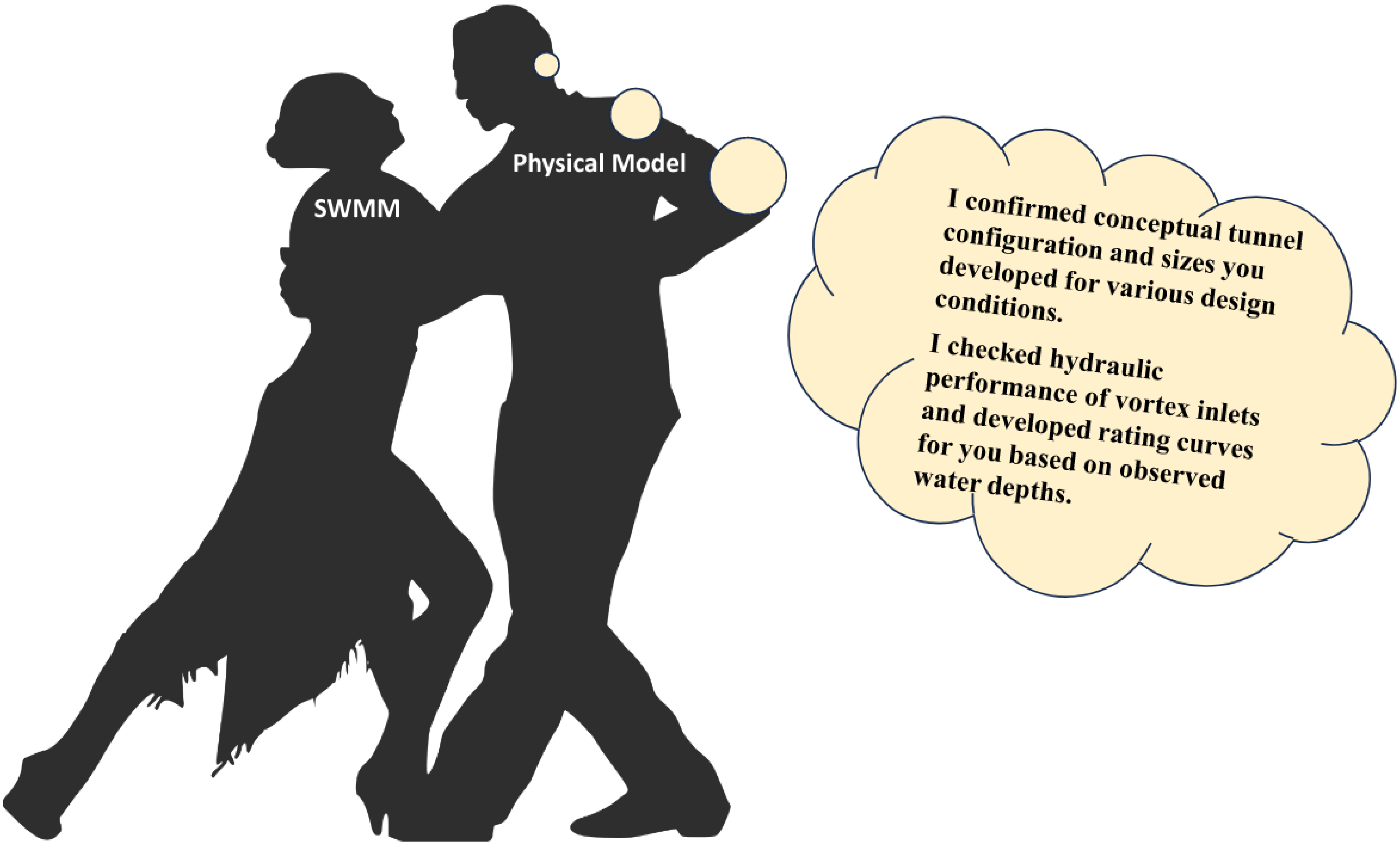

**SWMM Simulation updated with hydraulic rating curves from physical model in 25-yr storm**

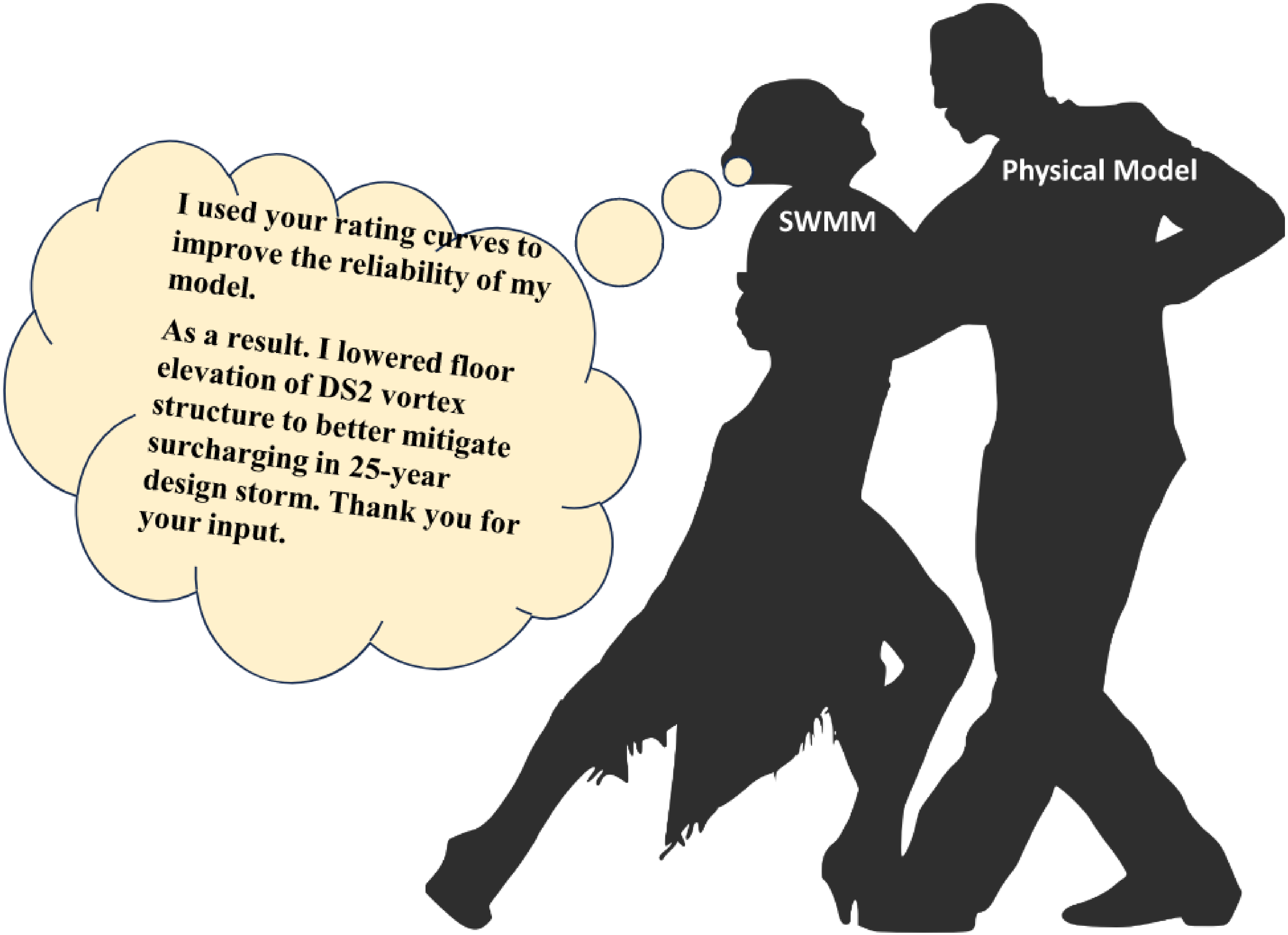



- 10-yr storm with min surcharge
- 25-yr no street flooding
- Included climate change volume

Checked tunnel performance under up to 100-yr storm conditions


I conceptually developed tunnel and separation pipe sizes and determined peak flows and tunnel water depths for different design storm events.
SWMM
Physical Model


Physical Model
SWMM
I confirmed conceptual tunnel configuration and sizes you developed for various design conditions.
I checked hydraulic performance of vortex inlets and developed rating curves for you based on observed water depths.


I used your rating curves to improve the reliability of my model.
As a result. I lowered floor elevation of DS2 vortex structure to better mitigate surcharging in 25-year design storm. Thank you for your input.
SWMM
Physical Model

# Conclusion

- The tunnel project will improve stormwater management and reduce CSO events
- The integration of SWMM and physical models enhanced reliability of the tunnel design and increased confidence in the long-term success of the City’s infrastructure
- Our goal is to ensure the effectiveness and sustainability of City’s infrastructure for years to come

# Acknowledgements and Thank You

City of Manchester, New Hampshire

- Clemson Engineering Hydraulics Lab team

Presenters:

- Tatyana Dudiac, P.E. CDM Smith

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- Shawn Lavoie, P.E. CDM Smith

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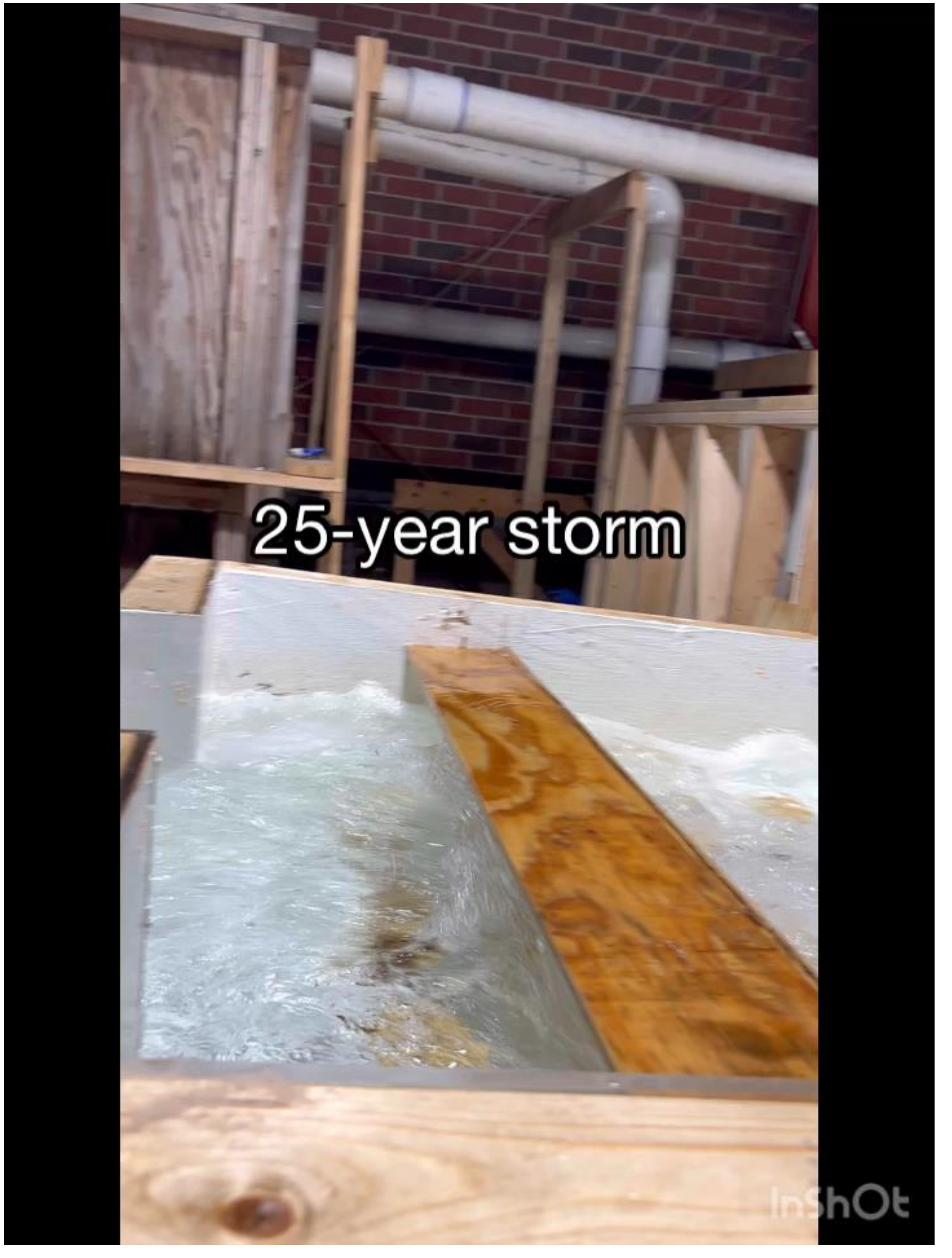
- Baseline test – the off-line de-aeration chamber enters the tunnel at 90 degree.
- As a result, air bulking and surcharge in the tunnel

- One of the tests – the collection pipes enters the tunnel via in-line drop shaft at a 45-degree angle with a metal plate placed inside the tunnel (not a final design configuration!).
- As a result, less air and surcharge in the tunnel

- Outfall performance in the 25-year and 100-year storms with baffled block for energy dissipation to reduce bank erosion



- Hydraulic jump in the outfall pipe when Merrimack River is at a 100-year water level.
- Hydraulic jump is in the opposite direction of the flow