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NCHRP 15-55 Guidance to Predict and Mitigate Dynamic Hydroplaning on Roadways - Project Update

https://www.wikihow.com/Stop-Hydroplaning#/Image:Stop-Hydroplaning-Step-7-Version-2.jpg

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30th RPUG Conference
Best Western Ramkota, Rapid City, SD
Sep 19 to 21, 2018

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- ✓ Background
- ✓ Integrated Hydroplaning Model
- ✓ Hydroplaning & Hydroplaning Potential
- ✓ Outcomes
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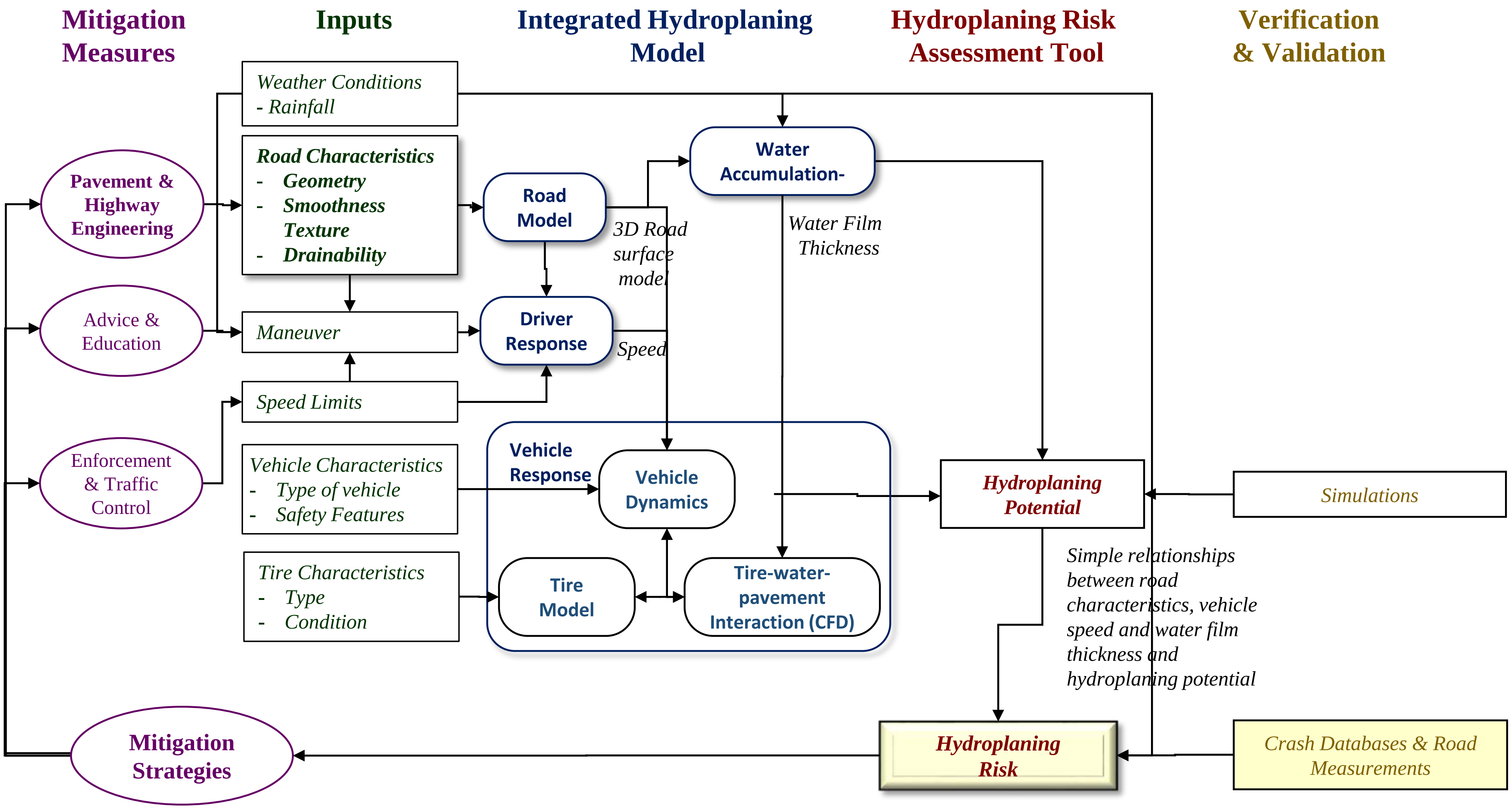
NCHRP 15-55 Objective

- ✓ To develop a comprehensive hydroplaning risk assessment tool that can be used by transportation agencies to help reduce the potential of hydroplaning.
  - – Treating hydroplaning as a multidisciplinary and multi-scale problem
  - – Solutions for areas with a high potential of hydroplaning based on a fundamental and meaningful understanding of the problem.

NCHRP 15-55 Objective (Cont.)

- ✓ Final Product: ***Guidance and tools to predict and mitigate hydroplaning on roadways***
  - – Applicable to all types of roadways
  - – Site-specific factors such as geometric design, etc.
  - – Appropriate for new construction, reconstruction, and maintenance/ retrofit projects.
- ✓ Two Supporting products:
  - – A *Hydroplaning Risk Assessment Tool*
  - – An *Integrated Hydroplaning Model*

Research Approach Overview

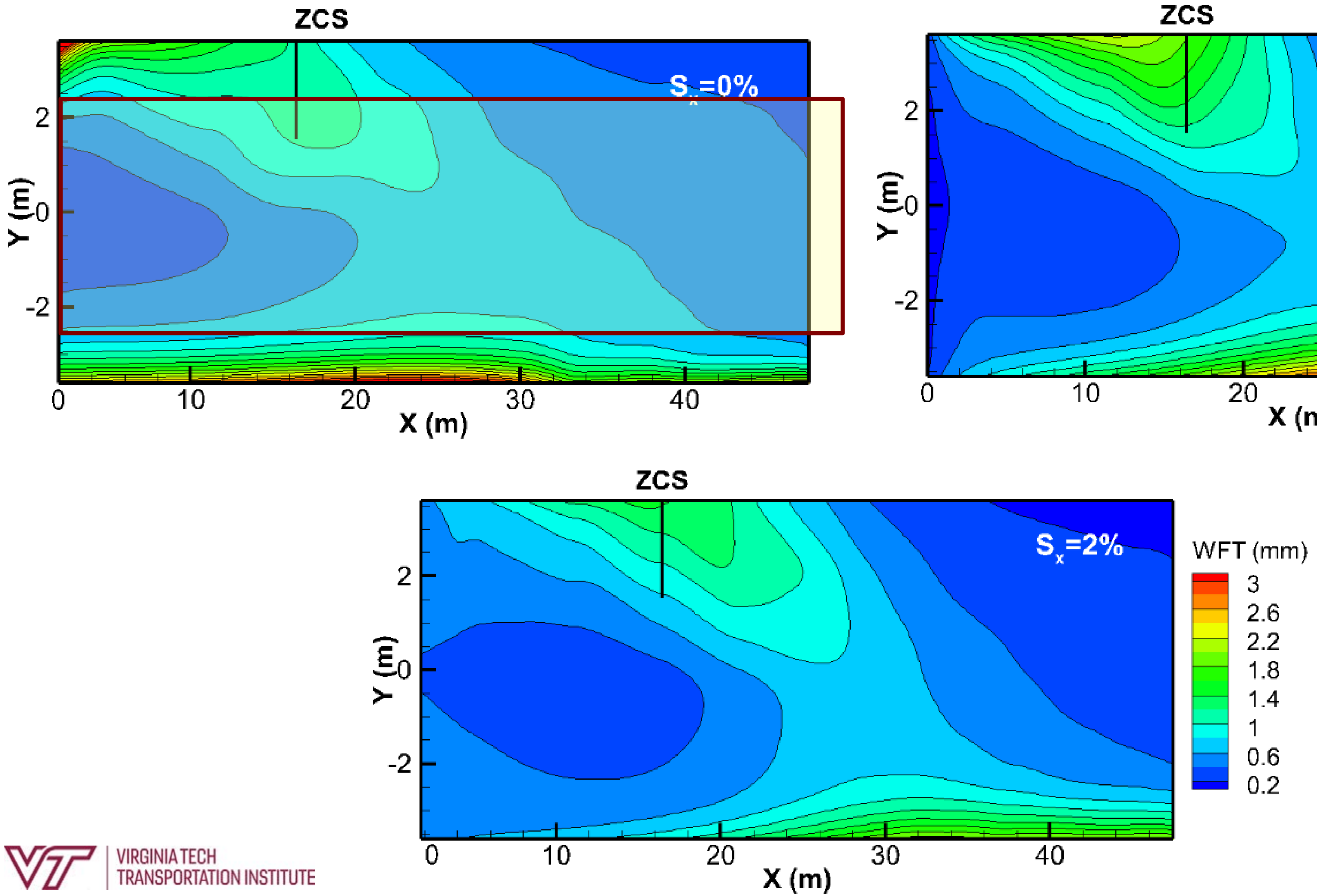


Integrated Hydroplaning Model (*IHM*)
Water Film Model

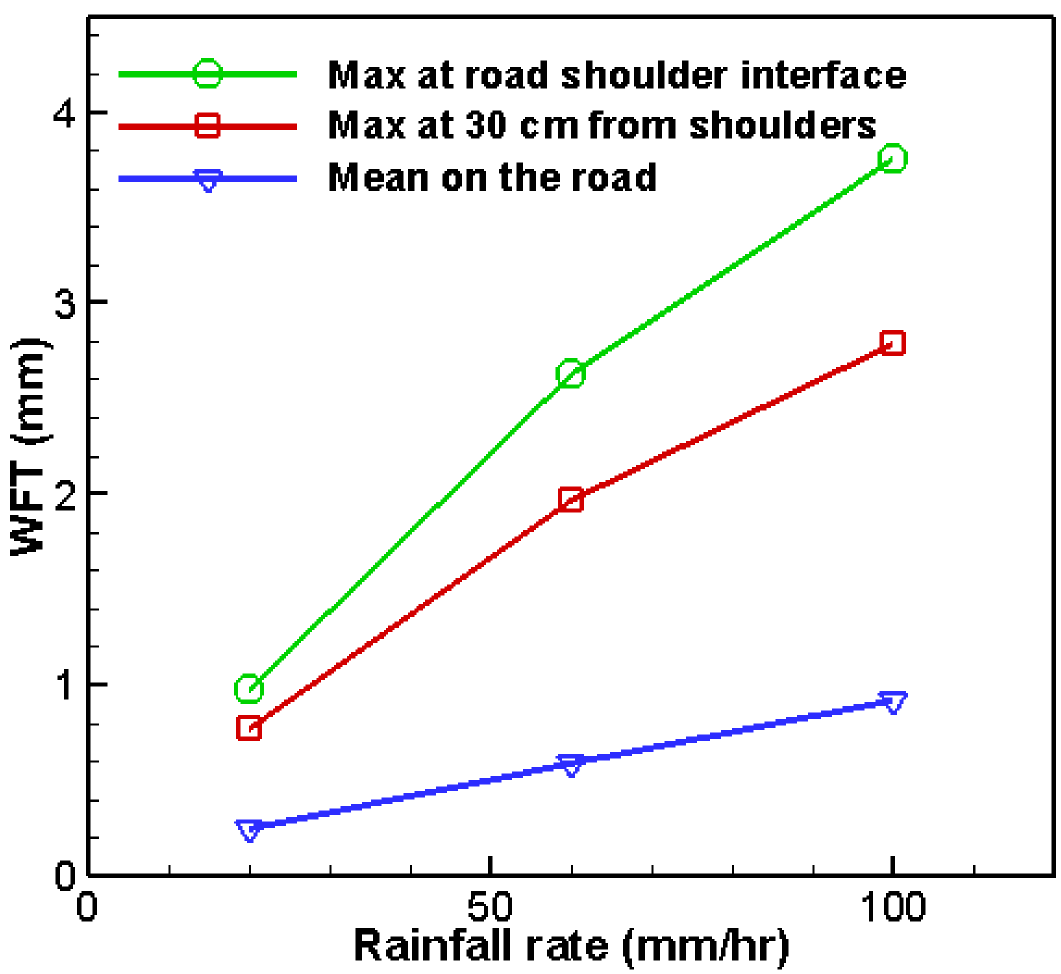
- ✓ Three conditions
  1. Straight segment
  2. Curve
  3. Transition

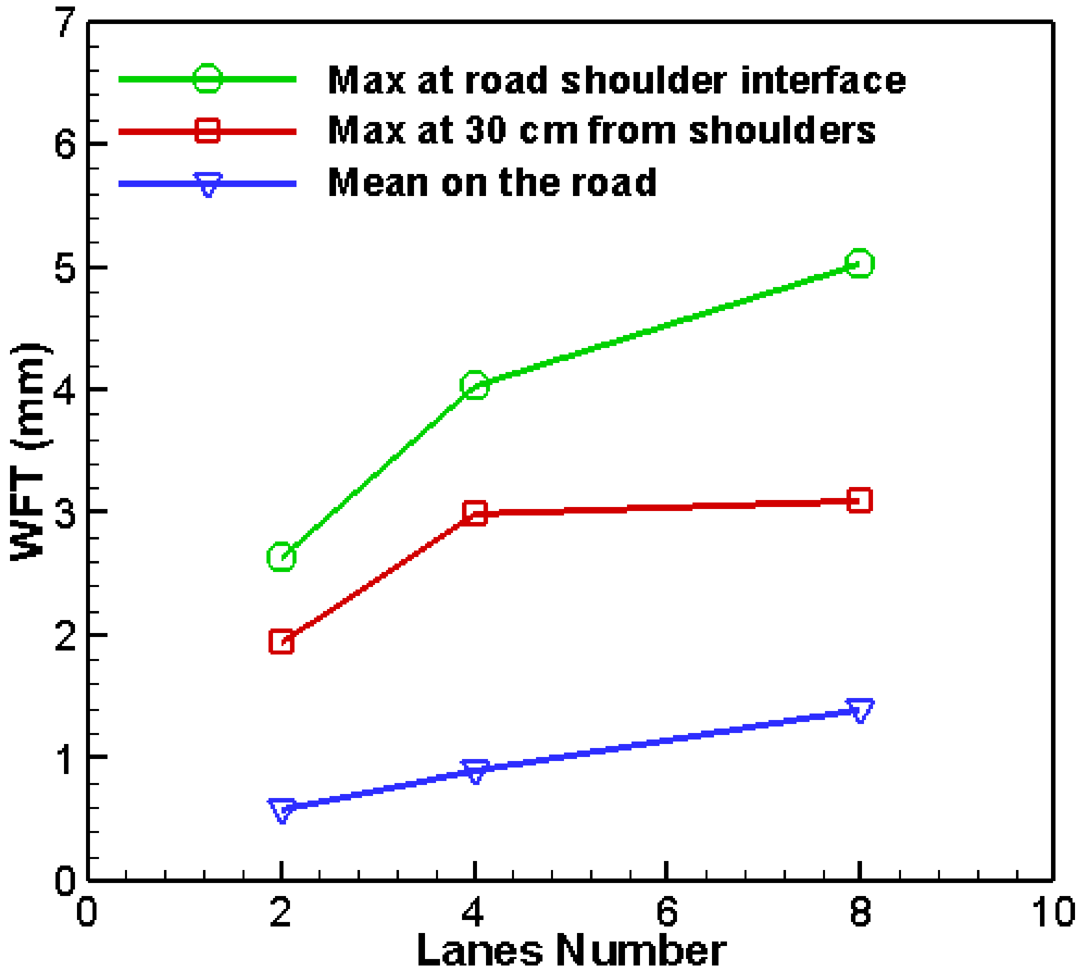
Horizontal Alignment	Grade	Cross-slope	Number of lanes	Macrotexture	Drainability
Straight	0%	0%	2 undivided	Low	Non-permeable
Curve	1%	1%	4 undivided	Medium	Permeable
Transition	2%	2%	4 divided	High	
	4%		6 divided		
			8 divided		

Transition Results



Example of Results





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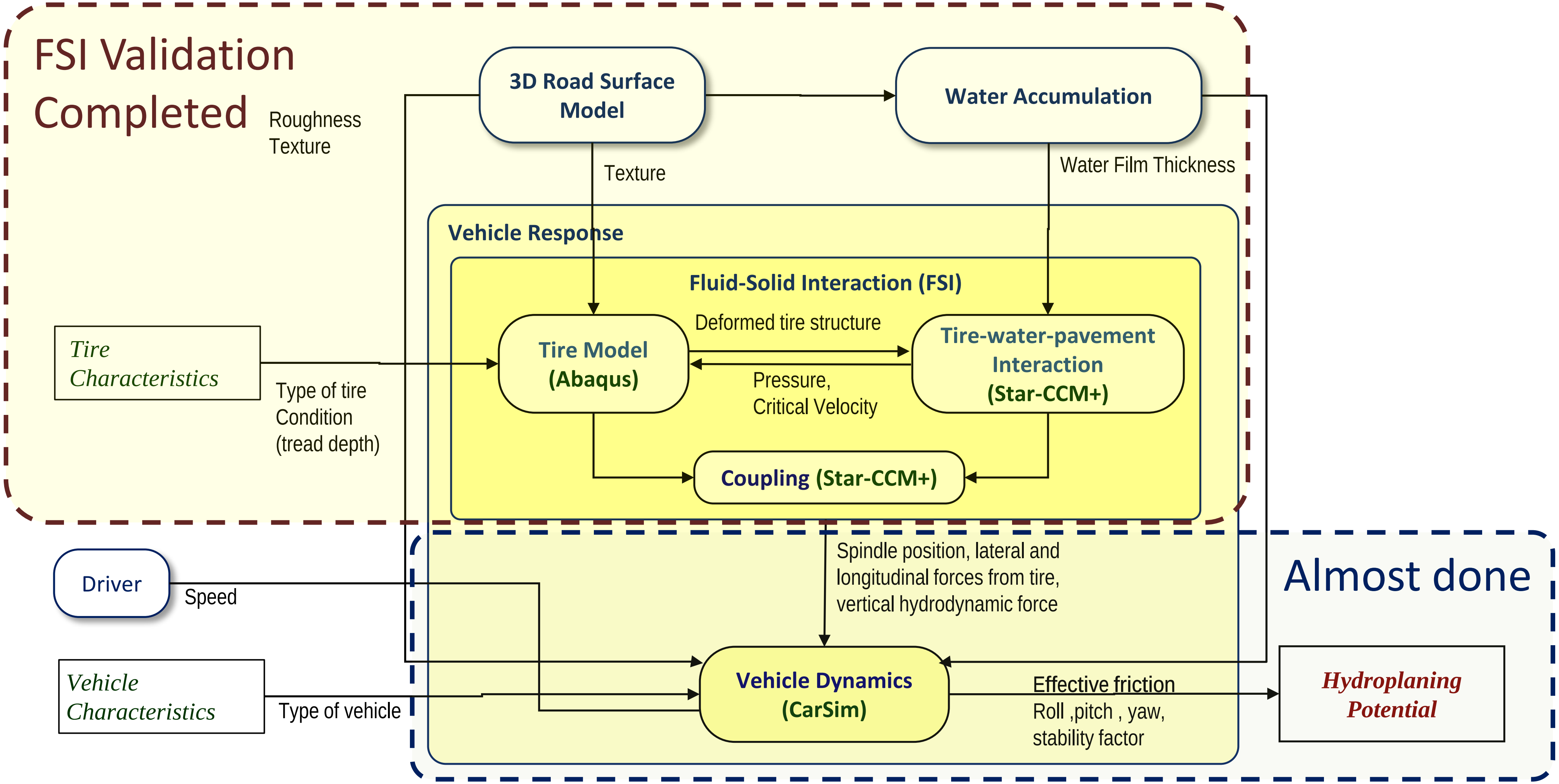
Integrated Hydroplaning Model (*IHM*)
Vehicle Model



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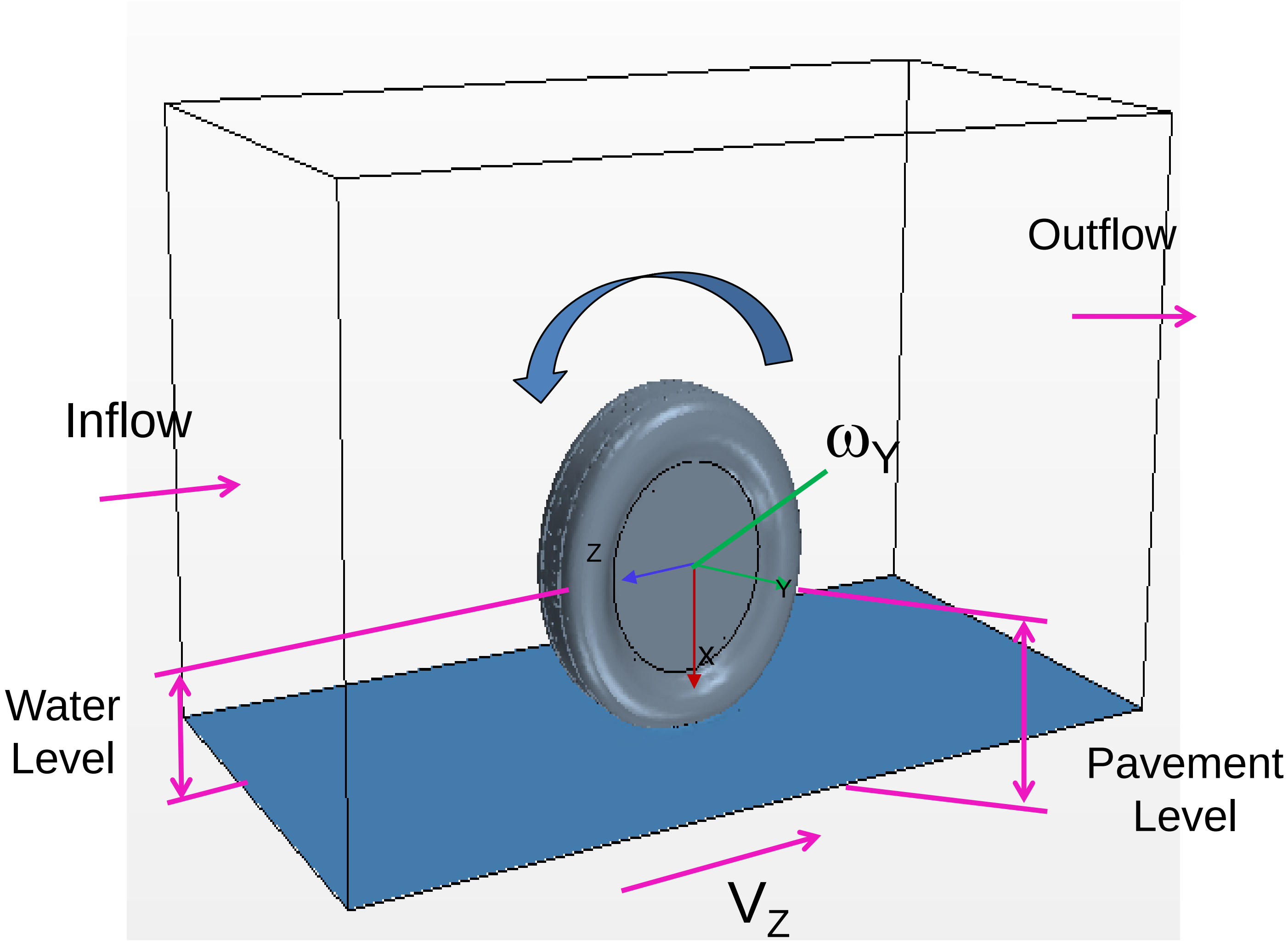
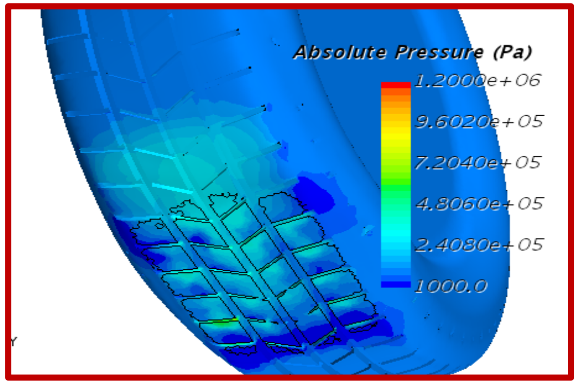
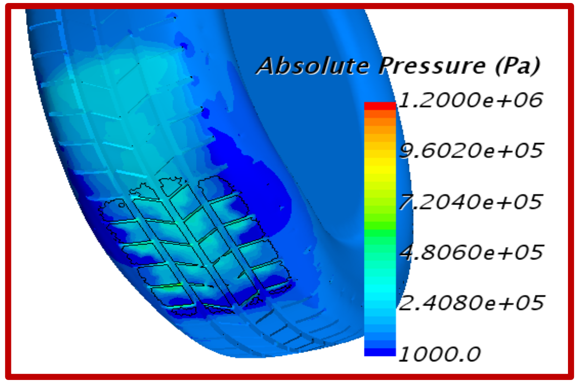
FSI Model



Water 5 mm

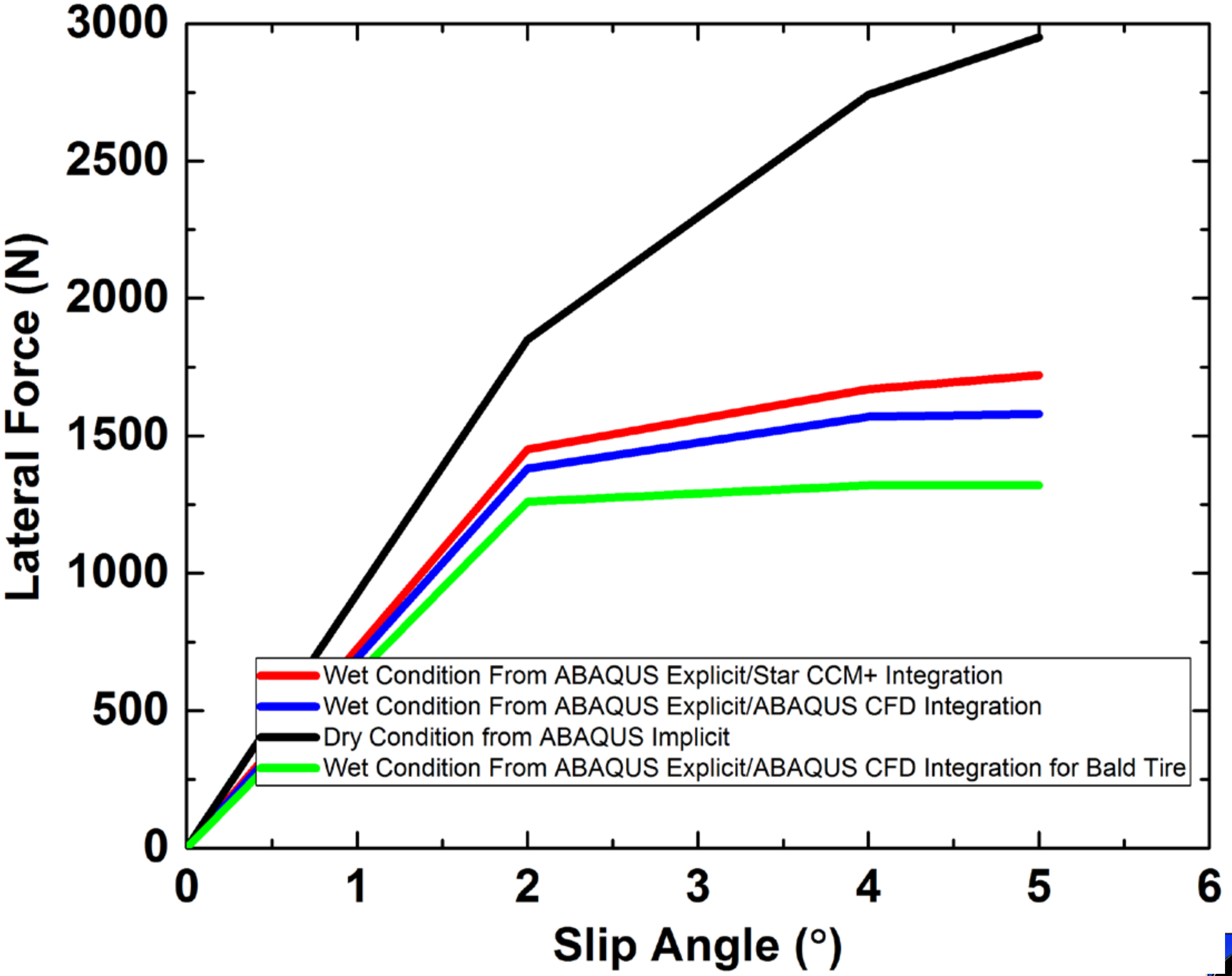


Water 30 mm



Lateral Forces

FSI Simulation Results: Lateral Force for the Case Study of 4100N, 50 mph



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FSI simulation results for lift and lateral forces under different conditions.

Vertical Fz (N)	Speed (mph)	Tire Pressure (psi)	Slip Angle (degree)	Tire Tread[2]	WFT (mm)	Lift Force by water (N)	Lateral Force (N)
4100	40	32	2	New tread	2	1050	1650
4100 [1]	40	32	2	New tread	5	1676	1490
4100	40	32	2	New tread	10	2205	1250
4100	60	32	2	New tread	5	2876	720
4100	40	32	5	New tread	0	X	2870
4100	40	32	5	New tread	5	1550	2210
4100	60	32	5	New tread	0	X	2980
4100	40	32	10	New tread	0	X	3566
5300	40	25	5	Bald	0	X	2376
2100	80	32	5	Bald	2	1250	1270
2100	60	32	10	Bald	10	815	2596
2100	40	25	5	Half Tread	0	X	1260

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"Magic" Tire Model

✓ $F_y(\alpha, B, C, D, F_z) = D \times F_z \times \sin\big(C \times \mathrm{atan}(atan(B\alpha))\big)$

Where,

$B \approx B_O + B_1 \times \Delta speed + B_2 \times \Delta pre$

$C \approx C_O + C_1 \times \Delta speed + C_2 \times \Delta pres$

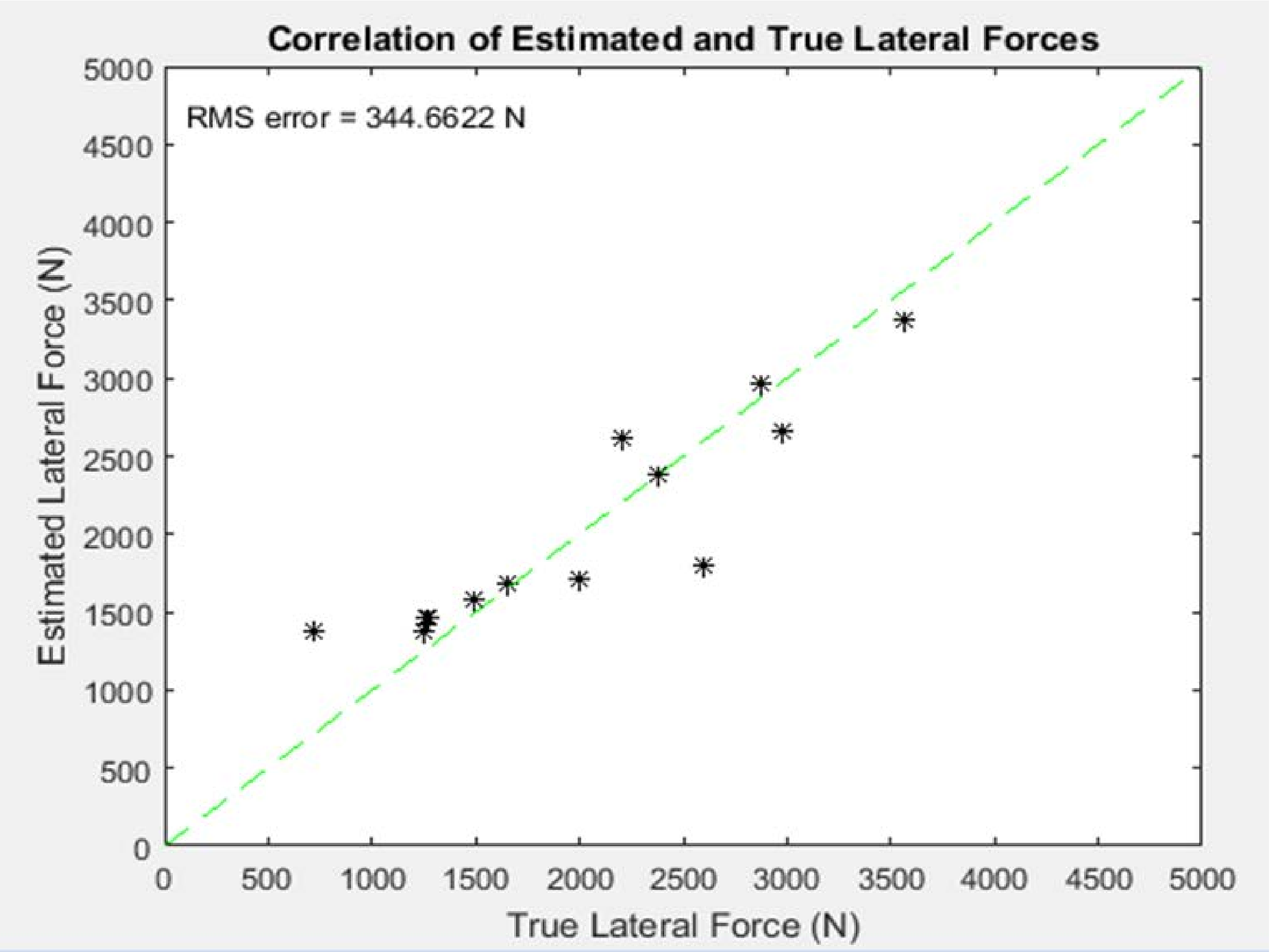
$D \approx D_O + D_1 \times \Delta speed + D_2 \times \Delta pre$

$B_1 = \left.\frac{\partial B}{\partial speed}\right|_{S_0}$

$B_1 = \left.\frac{\partial B}{\partial pressure}\right|_{S_0}$

$C_1 = \left.\frac{\partial C}{\partial speed}\right|_{S_0}$

...



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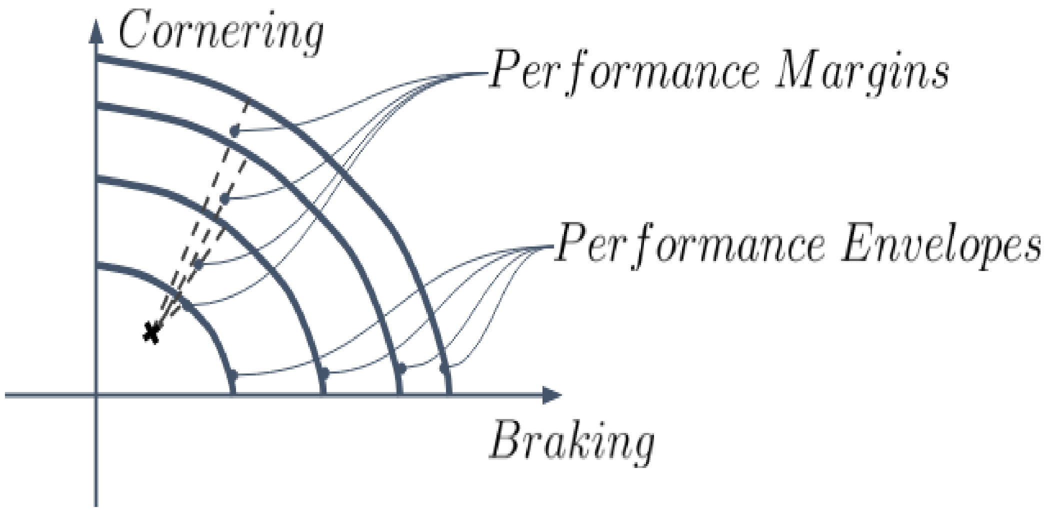
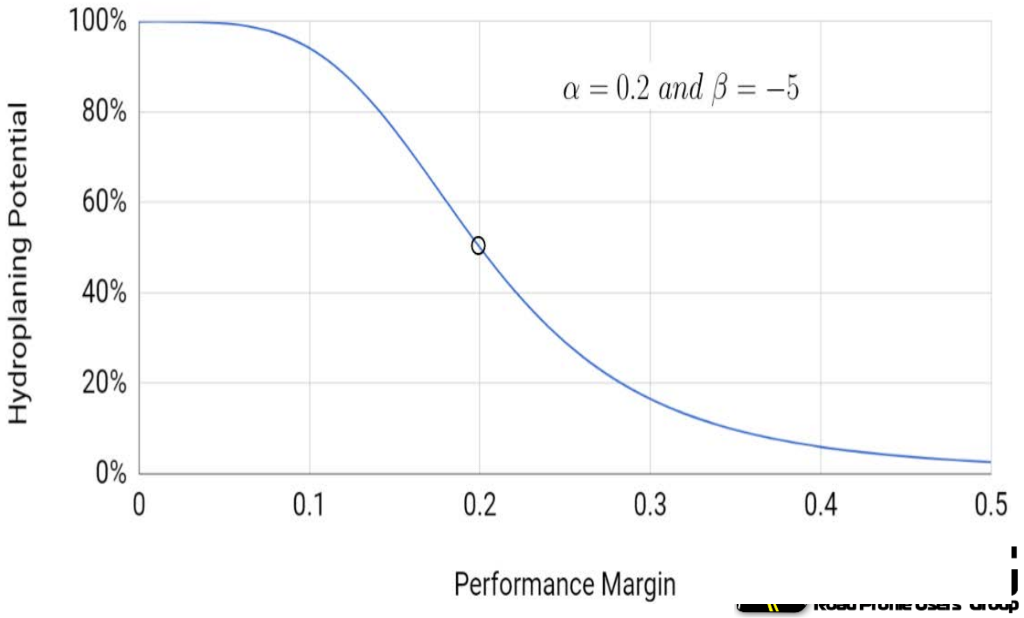
Hydroplaning Definition

- ✓ Hydroplaning potential

$$H_P = P(\mathrm{H}/\,V\;S\;W) = \left(1 + \left(\frac{PM}{\alpha}\right)^{-4\alpha\beta}\right)^{-1}$$





Hydroplaning Definition (cont.)

✓ Hydroplaning risk

$$H_R = P(H/S) = \sum_V \sum_W P(H / V W S))(P\, P(W)\, P(W/S))$$

Vehicle/tire combinations (e.g., sedan with new tires);

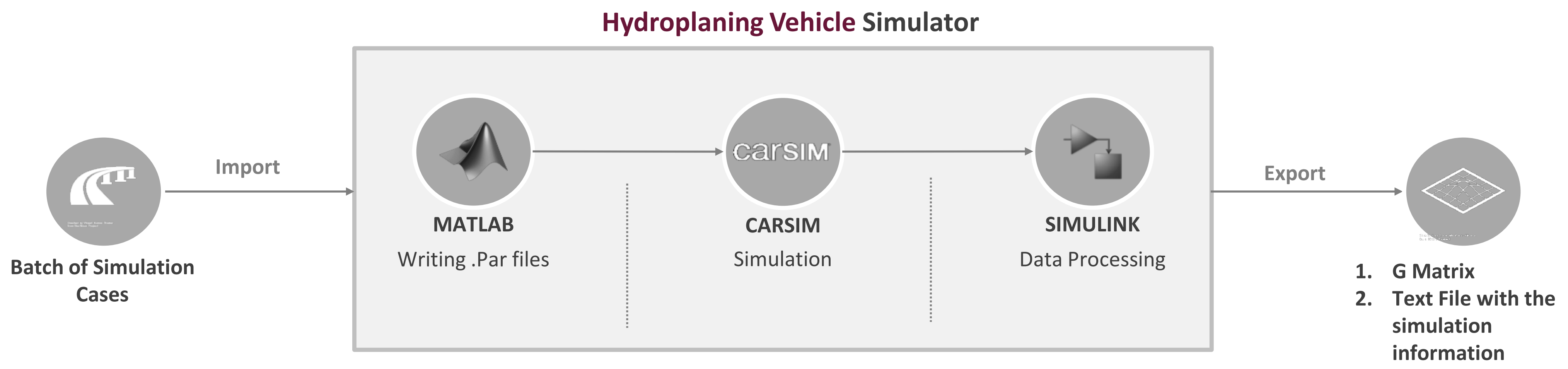
Water Film Thicknesses

Pavement surfaces, including many discrete levels of grade, cross-slope, roughness, and texture

Vehicle Dynamic Simulation

Hydroplaning Vehicle Simulator

Hydroplaning Vehicle Simulator allows the user to do a batch simulation by changing the CarSim simulation factors (vehicle type, road characteristic, maneuver, and tire models) automatically by writing CarSim own code file (.par file)



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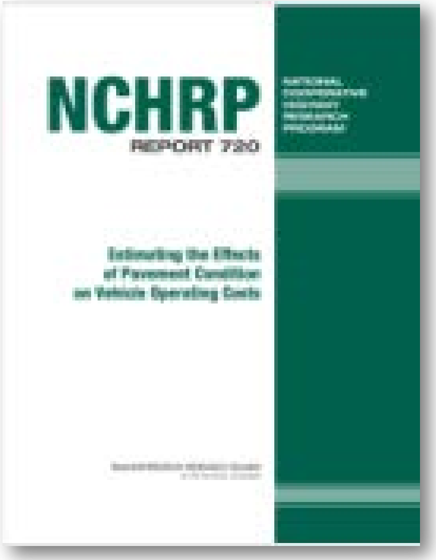
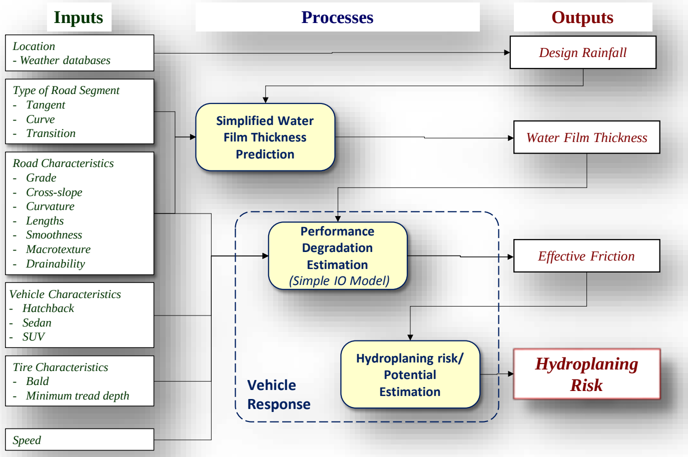
Final Outcomes

(Still under development)



- ✓ **Guide for Assessing and Mitigating Hydroplaning Potential**

- ✓ *Hydroplaning Risk Assessment Tool*



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Guide for Assessing and Mitigating Hydroplaning Potential

1. Introduction

2. Understanding Hydroplaning

2.1. Definitions

2.2. Accumulation of Water on the Pavement

2.3. Vehicle Response to Driver Behavior and Road Conditions

2.5. Integrated Hydroplaning Model

3. Assessment of Hydroplaning Risk

3.1. Hydroplaning Risk Assessment Tool

3.2. Evaluation of Pavement Surface Properties

3.3. Precipitation Estimations

3.4. Prediction of Hydroplaning Potential and Risk

4. Hydroplaning Mitigation Strategies

4.1. New Roadways

4.2. Existing Roadways

4.3. Case Studies

5. Implementation Recommendations

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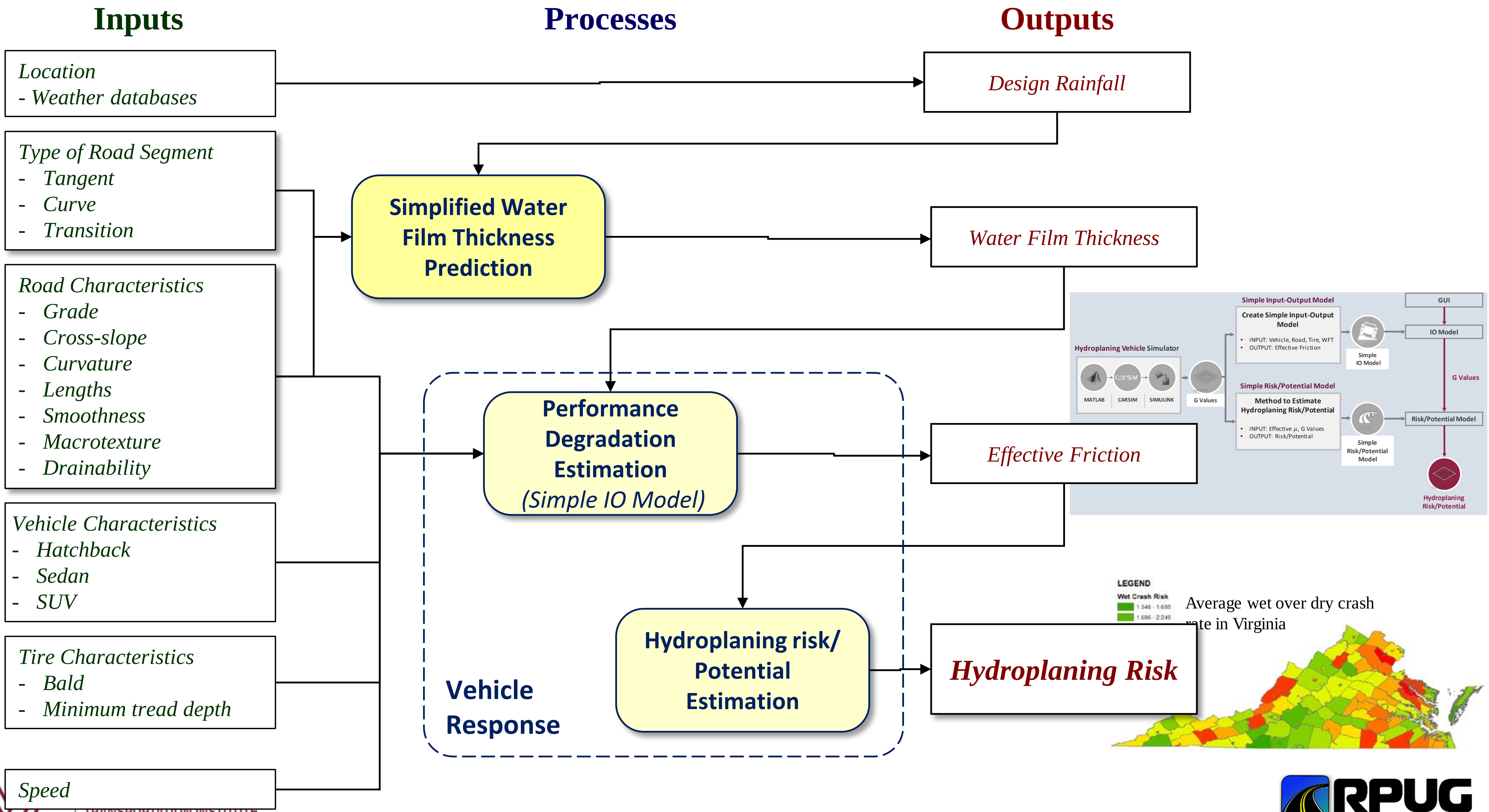
Hydroplaning Risk Assessment Tool



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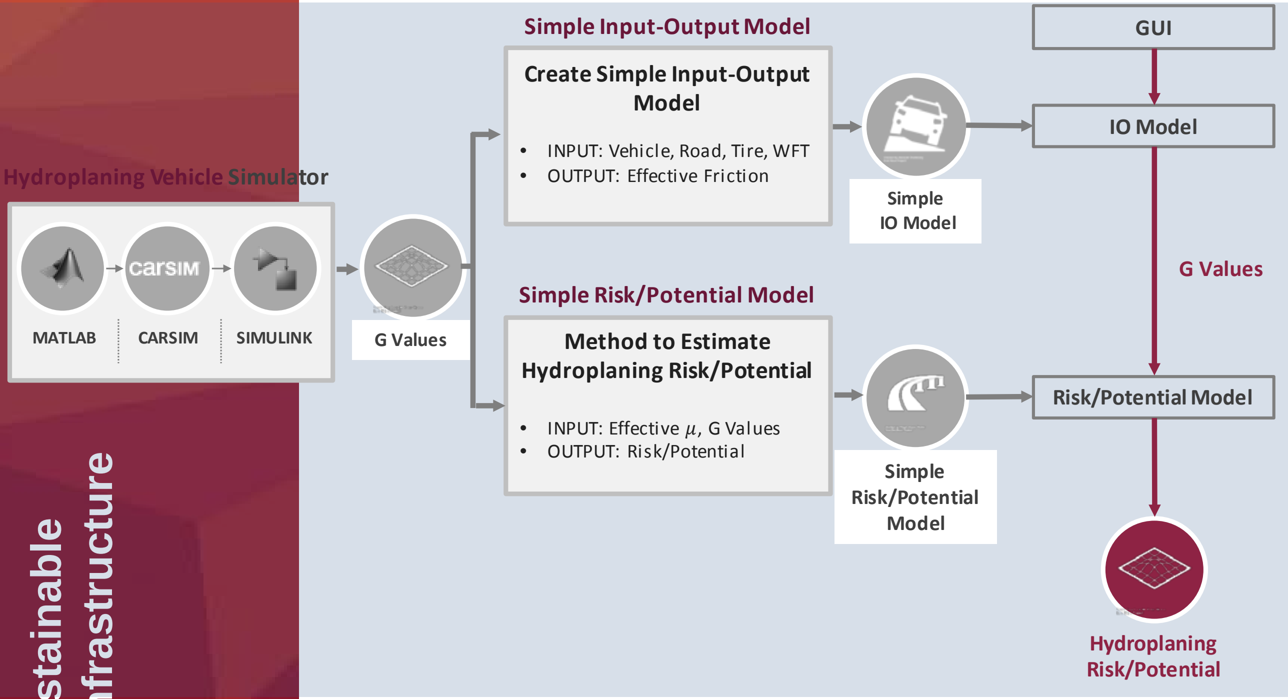
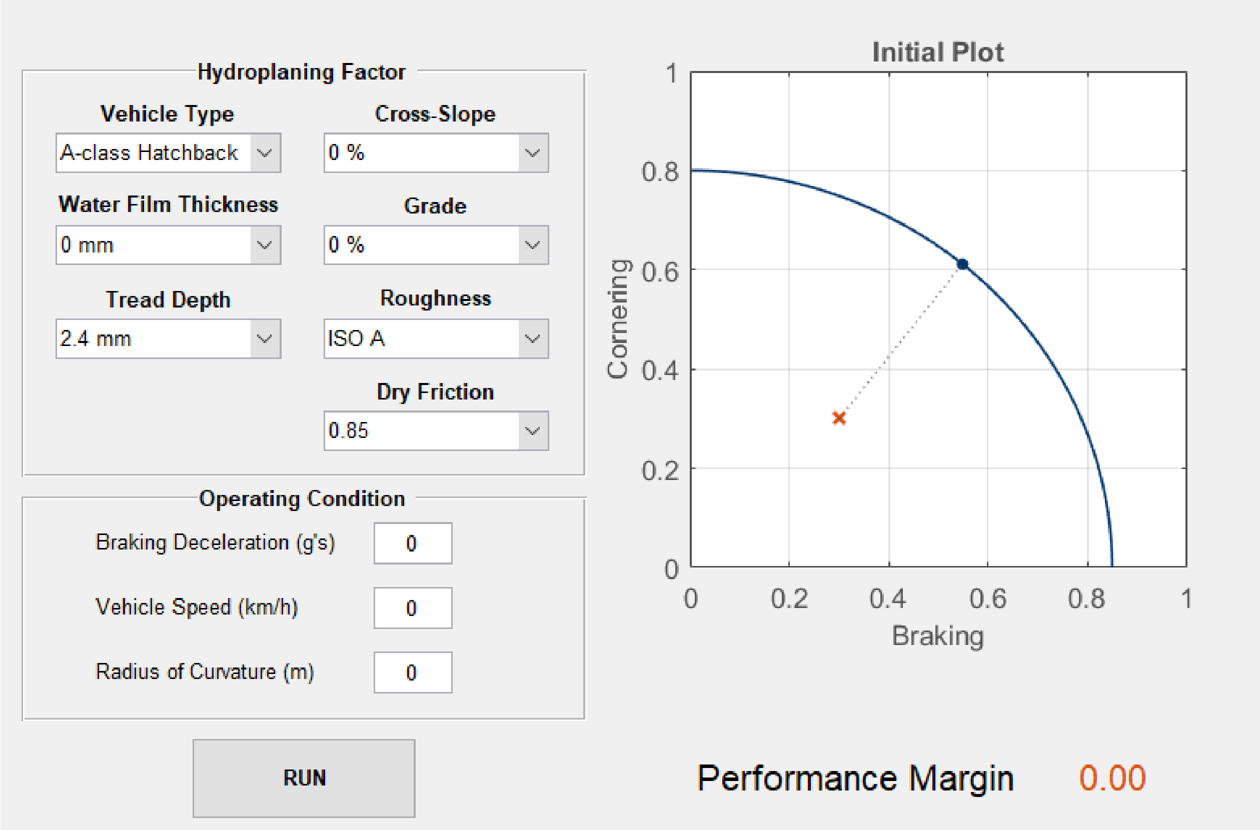
Hydroplaning Potential (Effective Friction) Calculation and Verification





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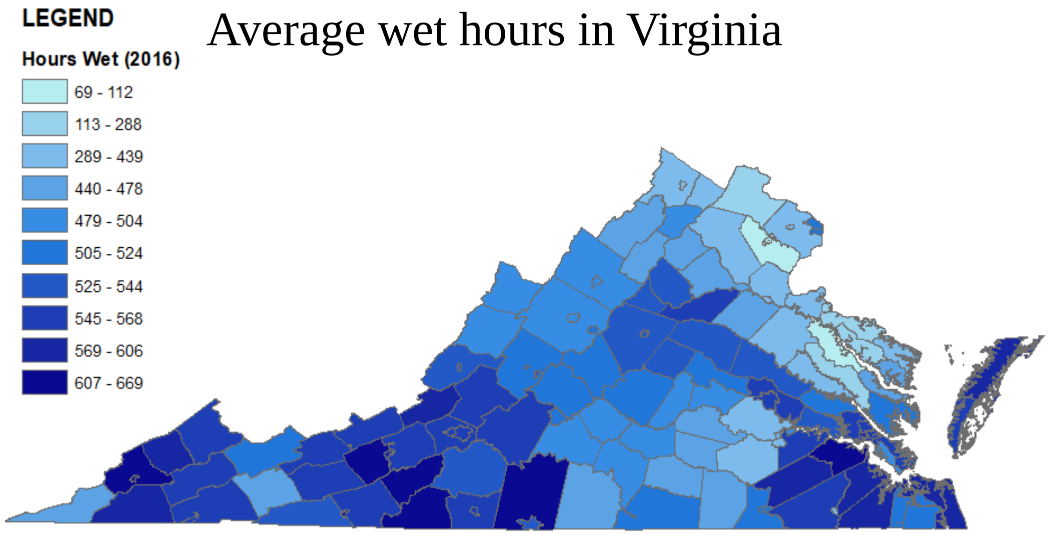
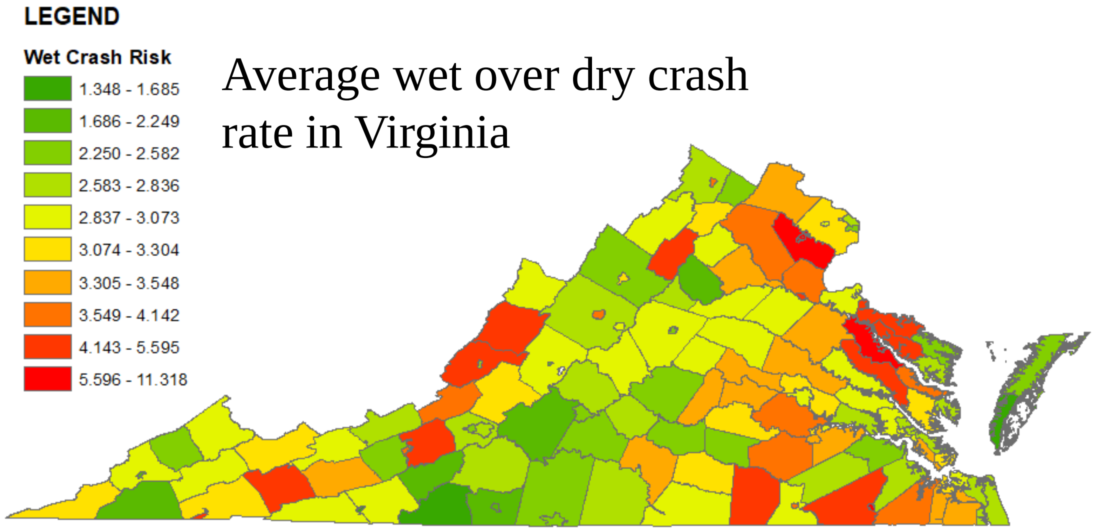
Hydroplaning Risk Validation

- ✓ “Network-level” verification



Average wet hours in Virginia

- ✓ $$Wet\ Crash\ Ratio = \frac{C_{wet}/H_{wet}}{C_{dry}/H_{dry}}$$



Average wet over dry crash rate in Virginia

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Sept.
17-21
2019

Pavement Evaluation 2019

Virginia Tech

Roanoke, VA

September 17-21, 2019