

## Hydroplaning Analysis



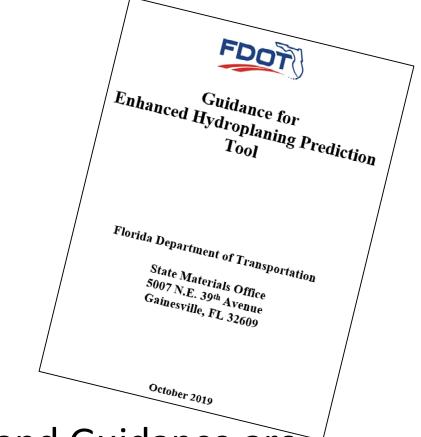
#### **Computer Based Training Course**

## Outline

- Introduction
- Learning Objectives
- Hydroplaning Fundamentals
- Factors Affecting Hydroplaning
- Hydroplaning Prediction
- FDOT Hydroplaning Prediction Tool

## **FDOT Hydroplaning Guidance**

 Quick reference document for those that will be using FDOT's new Hydroplaning Prediction Tool

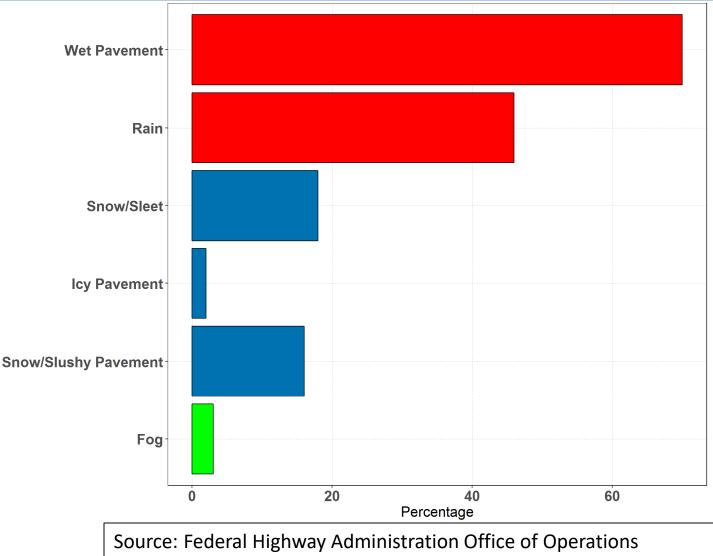


 The Hydroplaning Tool and Guidance are available at <u>FDOT's Roadway Drainage Office</u> <u>Website</u>

#### Introduction

- Weather Related Crashes
  - Crashes that occur in the presence of adverse weather and/or slick pavement conditions
- National Highway Traffic Safety Administration Data (2007-2016)
  - Over 1.2M weather related crashes per year
  - Over 410K injuries per year
  - Over 5,000 fatalities per year

#### **Weather Related Crashes**



https://ops.fhwa.dot.gov/weather/q1\_roadimpact.htm



#### Water on Pavement Surface

- Slippery When Wet!
  - Water reduces friction between tire & pavement
  - Tire treads are designed to drain water
- Hydroplaning!
  - Under Severe Circumstances (More water than treads can handle)
  - Water pressure lifts the tire up from the pavement
  - Little to no traction
  - Affects driver's control of the vehicle



## **Learning Objectives**

#### **Objective 1**

 Understand Different Types of Hydroplaning and their Causes

#### **Objective 2**

• Understand the Factors Affecting Hydroplaning

#### **Objective 3**

- Understand the Features of FDOT's Hydroplaning Tool
- Understand the Inputs for Hydroplaning prediction

## **Hydroplaning Fundamentals**

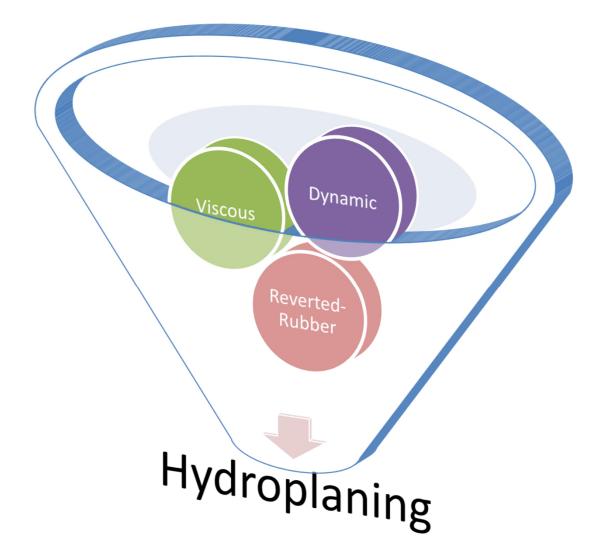
Definition

#### What is Hydroplaning?

 Condition that exists when a film of water or other contaminant is present at the tire/pavement interface and completely separates the tire from the pavement surface



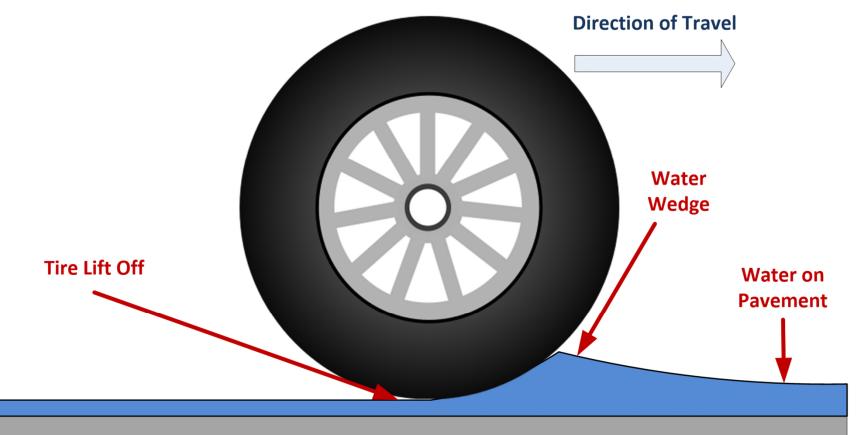
## **Hydroplaning Types**





### **Dynamic Hydroplaning**

 Occurs when there is more water than a tire can push away





## **Dynamic Hydroplaning**

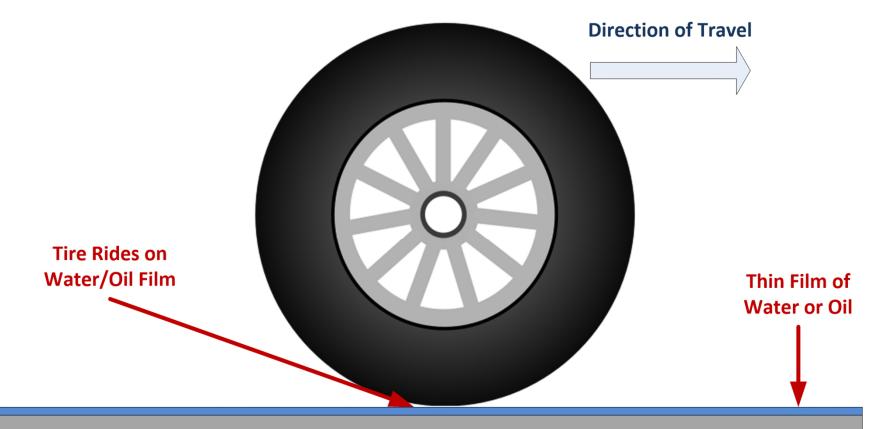
- Most frequent type
- FDOT's Hydroplaning Prediction Tool





#### **Viscous Hydroplaning**

Occurs on pavements with little or no micro texture



#### **Viscous Hydroplaning**

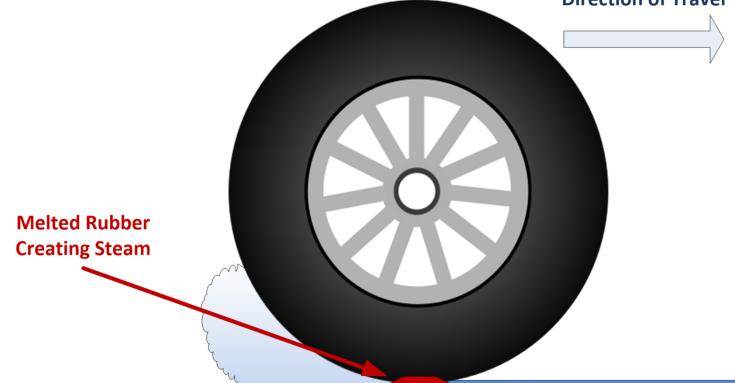
Even a very thin film of water (less than 0.001 inch) may cause hydroplaning





## **Reverted-Rubber Hydroplaning**

 Occurs when friction between tire and pavement generates excessive heat to the point where the tire rubber has melted





### **Reverted-Rubber Hydroplaning**

- Typically does not occur on roadways
- Rarely on runways with high speed aircrafts



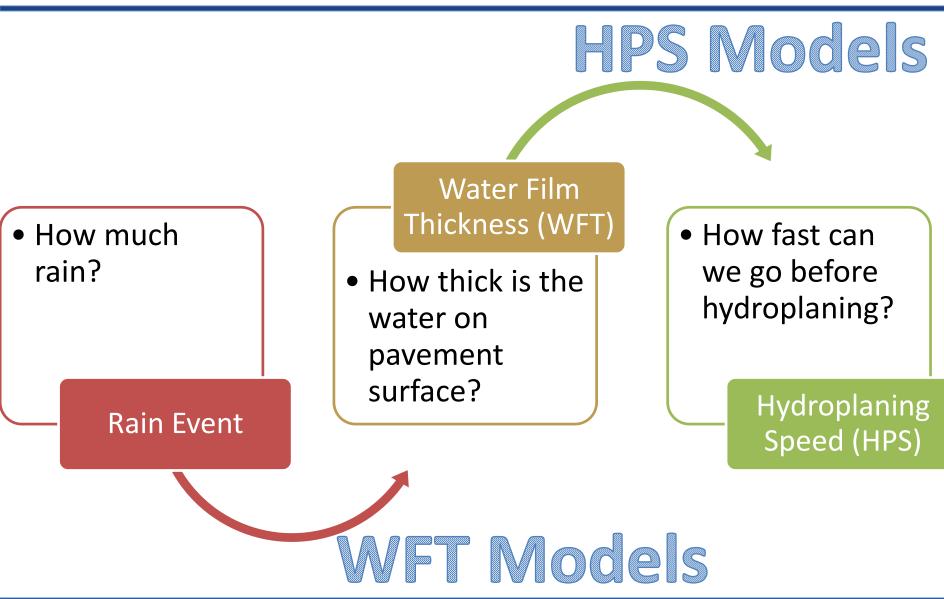


## What Affects Hydroplaning?

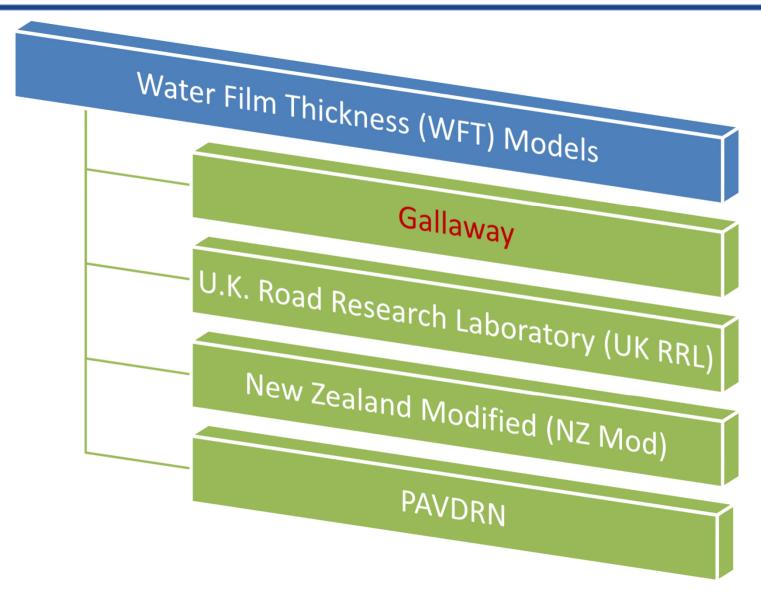
- Hydroplaning is a complicated phenomenon
- Improving Roadway and Pavement factors may help reduce hydroplaning

Roadway and Pavement	Environmental	Driver	Vehicle
Surface Type	Rainfall Intensity	Speed	Tire Tread Design
🔲 Rut Depth	Rainfall Duration	Accelerating or Braking	Tire Tread Depth
Micro and Macro Texture	Temperature	Steering Maneuvers	Tire Pressure
Permeability			🔲 Vehicle Type
Cross Slope			Uehicle Weight
Longitudinal Grade			
Pavement Width			
Roadway Curvature			
Pavement Depressions			

#### **Hydroplaning Prediction**



#### Water Film Thickness (WFT) Models



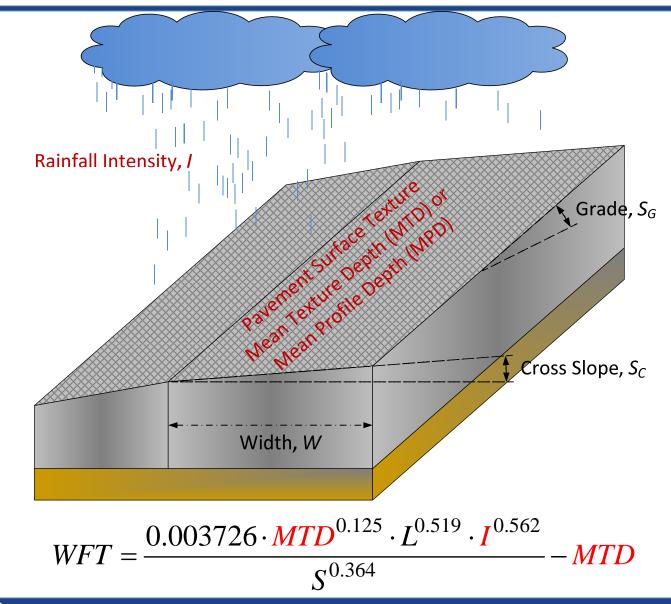


## Gallaway WFT Model

$$WFT = \frac{0.003726 \cdot MTD^{0.125} \cdot L^{0.519} \cdot I^{0.562}}{S^{0.364}} - MTD$$

- WFT: Water Film Thickness (in.)
- MTD: Mean Texture Depth (in.)
- L: Drainage Path Length (ft.)
- I: Rainfall Intensity (in./hr.)
- S: Total Slope (dimensionless)
- You do NOT need to memorize the equation — Know the INPUTS and their importance

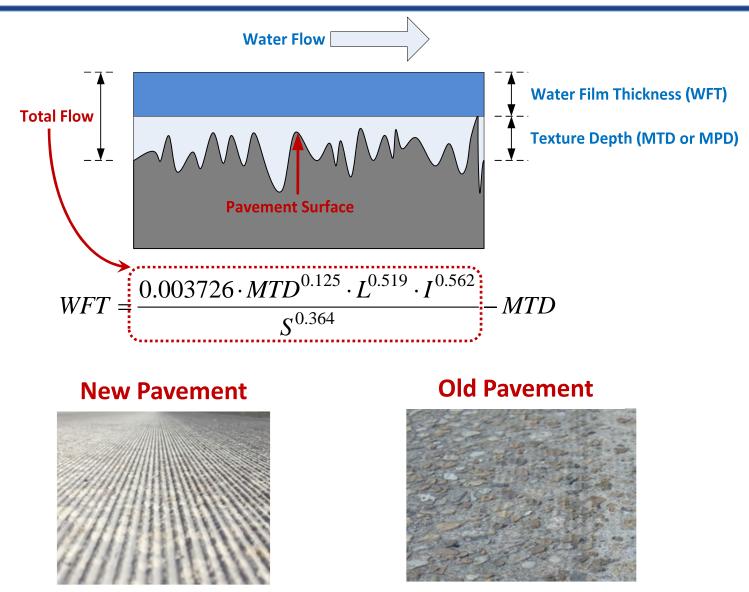
#### **Inputs for WFT Equation**



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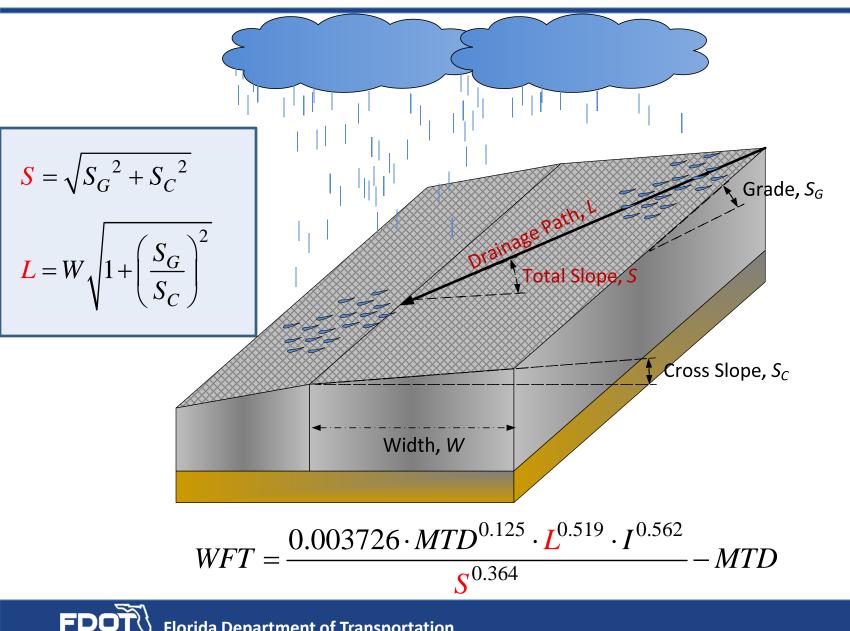
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#### Why is Texture Important?



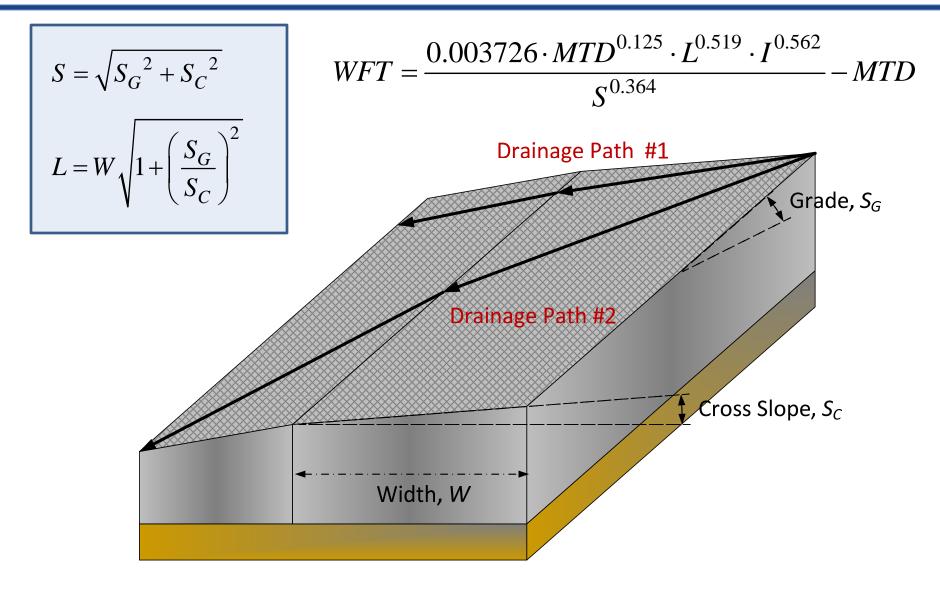


#### **Intermediate Variables**



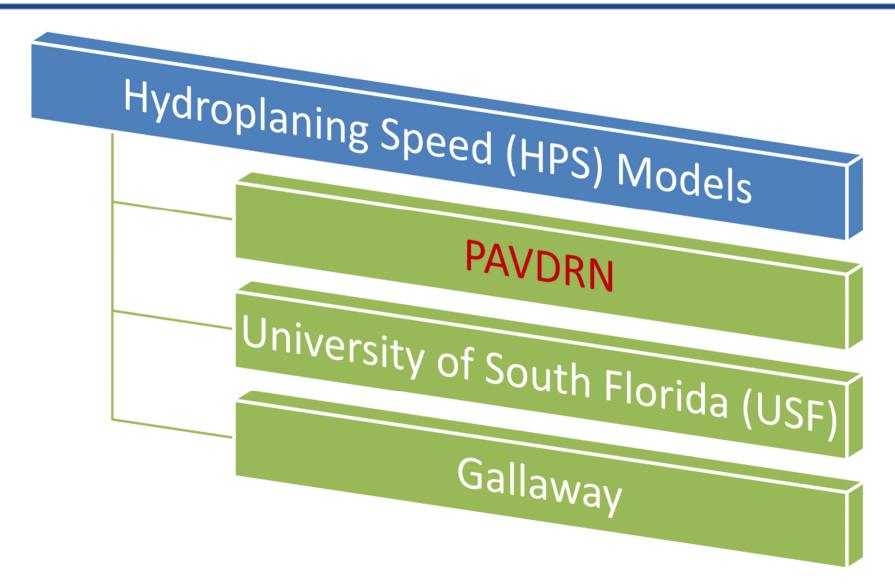
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## Why Slope and Width of Pavement?





## Hydroplaning Speed (HPS) Models





#### **PAVDRN HPS Model**

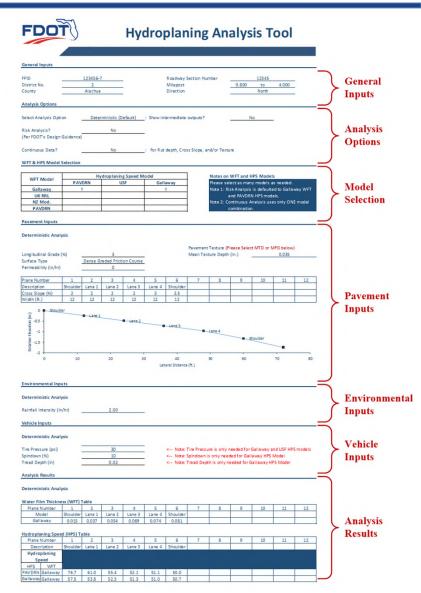
$$HPS = \begin{cases} 26.04 \cdot WFT^{-0.259} & \text{if } WFT < 0.094 \text{ in.} \\ 3.09 \cdot Max \left( \frac{10.409}{WFT^{0.06}} + 3.507, \left[ \frac{28.952}{WFT^{0.06}} - 7.817 \right] \cdot MTD^{0.14} \right) & \text{if } WFT \ge 0.094 \text{ in.} \end{cases}$$

– HPS: Hydroplaning Speed

- You do NOT need to memorize the equation
- FDOT's Hydroplaning Prediction (HP) Tool will do all the calculations for you

# **FDOT's Hydroplaning Prediction Tool**

- Macro-enabled Excel (.xlsm file)
- User-Friendly
  - Select analysis option
  - Fill in the inputs
  - Get the outputs





# **FDOT's Hydroplaning Prediction Tool**

- Analysis Options
  - Deterministic
    - Risk Analysis
    - Basic Analysis
    - Continuous Analysis
  - Sensitivity
  - Probabilistic

FDOT Hydroplaning Ana	
General Inputs           FPD         1233567         Roadway Section Number           District No.         2         Milepost           County         Alschua         Direction	General North Account
Analysis Options	
Select Analysis Option <u>Deterministic (Default)</u> : Show intermediate outputs? Risk Analysis? <u>No</u> (Per FDOT's Design Guidance) Continuous Data? <u>No</u> : For Rut depth, Cross Slope, and/or Textun	Analysis Options
WFT & HPS Model Selection	₹
WFT Nodel         PAXDRN         USF         Gallaway         Prase sele           Galaway         Y         Y         Y         Note 1: Ris         Note 2: Ris           UK RRL         ar         ar         Note 2: Cor         Note 2: Cor         Note 2: Cor	IFT and HPS Models tas many models as needed. Analysis is defaueted followed WFT PAVORN HPS models. Instance Analysis uses only ONE model mbination.
Description Security in Security Lane 1 Const Stope (N) 2 Virther (N) 2 2 2 2 2 2 2 2 2 2 2 2 2 2	Pavement Inputs
Deterministic Analysis           Rainfail Intensity (in/hr)         2.00	Environme Inputs
Vehicle Inputs Deterministic Analysis	ī
Time Pressume (psi)         30         < Note: Time Pressum is only needly           Spindown (%)         20         < Note: Time Depth (in)	
Analysis Results	ī
Deterministic Analysis           Water Film Thickness (WFT) Table           Films Number         1         2         3         4         5         6         7         8           Model         Shoulder         Lane 1         Lane 2         Lane 4         Shoulder         1           Gallaway         0.051         0.051         0.054         0.069         0.074         0.081	Analysis
Hydroplaning Speed (HPS) Table           Plane Number         1         2         3         4         5         6         7         8           Description         Shoulder         Lane 1         Lane 2         Lane 3         Lane 4         Shoulder	9 10 11 12 Results
Speed	



# **FDOT's Hydroplaning Prediction Tool**

- Analysis Options
  - Deterministic
    - Risk Analysis
    - Basic Analysis
    - Continuous Analysis
  - Sensitivity
  - Probabilistic

		lydroplani		,		6
General Inputs FPID District No. County	123456-7 2 Alachua	Roadway Sec Milepost Direction	ction Number	12345 0.800 to North	4.000	General Inputs
Analysis Options						$\prec$
Select Analysis Option Risk Analysis? (Per FDOT's Design Guidar Continuous Data?	No	t) : Show intermediate ou		No		Analysis Options
WFT & HP5 Model Selecti	on					$\prec$
WFT Model Gallaway UK RRL NZ Mod. PAVDRN Pavement Inputs	Hydroplaning Spe AVDRN USF Y	eed Model Gallaway Y	Please sel Note 1: Ri Note 2: Co	WFT and HPS Models ect as many models as sk Analysis is defaulte and PAVDRN HPS mode ontinuous Analysis use combination.	s needed. d to Gallaway WFT els.	Model Selection
	2 2	une         Lane         4 Shoulder           2         3         5.5           12         12         12	• Lare 4	• Shoulder	70 50	Pavement Inputs
Environmental Inputs						- <b>-</b>
Deterministic Analysis	2.00					Environment
Rainfall Intensity (in/hr) Vehicle Inputs	2.00					<b>Inputs</b>
Deterministic Analysis Tire Pressure (psi) Spindown (%) Tread Depth (in)	30 10 0.02	< Note: Spi	indown is only need	needed for Gallaway ar ded for Gallaway HPS M seded for Gallaway HP	Vodel	Vehicle Inputs
Analysis Results						
Deterministic Analysis Water Film Thickness (Wi Plane Number 1 Model Shoul Gallaway 0.01	2 3 der Lane 1 Lane 2 Las 5 0.037 0.054 0.0	4 5 6 he 3 Lane 4 Shoulder 069 0.074 0.081	7 8	9 10	11 12	Analysis
Hydroplaning Speed (HPS	2 3	4 5 6	7 8	9 10	11 12	Results
Plane Number 1	der Lane 1 Lane 2 Lan	ne 3 Lane 4 Shoulder				

#### **Deterministic Analysis Options**

- Risk Analysis
- Basic Analysis
  - Select "No" for both "Risk" and "Continuous" analysis options
- Continuous Analysis

	Analysis Options			
	Select Analysis Option	Deterministic (Default)	: Show intermediate outputs?	No
$\int$	Risk Analysis? (Per FDOT's Design Guidance)	No	-	
	Continuous Data?	No	: For Rut depth, Cross Slope, and/or Texture	



#### **Deterministic** → **Risk Analysis**

- Based on FDOT's Design Guidance
- Expected driver speed vs. Hydroplaning speed
- Gallaway WFT & PAVDRN HPS models

Analysis Options				
Select Analysis Option	Deterministic (Default)	: Show intermediate outputs?	No	
Risk Analysis? (Per FDOT's Design Guidance)	No Yes No	~		
Continuous Data?	No	: For Rut depth, Cross Slope, and/or Textu	re	



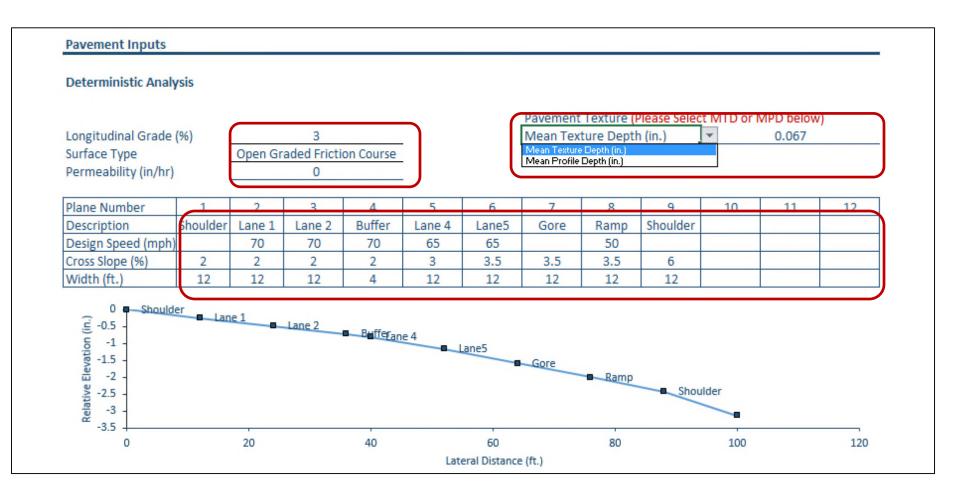
# Deterministic → Risk Analysis: Predicted Driver Speed

- Depends on Rainfall Intensity
- Minimum speed for Hydroplaning Analysis = 45 mph

Rainfall Intensity	Predicted Driver Speed
(in/hr)	(mph)
0.1	Design Speed – 0
0.25	Design Speed – 0
0.5	Design Speed – 6
1	Design Speed – 8
2	Design Speed – 12
3	15 mph
4	45 mph



#### **Deterministic** → **Risk Analysis Inputs**





#### **Deterministic** → **Risk Analysis Results**

• Lane 2, Buffer Area, and Lane 5

#### – Not passing FDOT's Design Criteria

						ver Speed	(					
Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Intensity (in/hr)	Shoulder	Lane 1	Lane 2	Buffer	Lane 4	Lane5	Gore	Ramp	Shoulder			
0.1		70.0	70.0	70.0	65.0	65.0		50.0				
0.25		70.0	70.0	70.0	65.0	65.0		50.0				
0.5		64.0	64.0	64.0	59.0	59.0		45.0				
1		62.0	62.0	62.0	57.0	57.0		45.0				
2		58.0	58.0	58.0	53.0	53.0		45.0				
3		45.0	45.0	45.0	45.0	45.0		45.0				
4		45.0	45.0	45.0	45.0	45.0		45.0				

#### Predicted Hydroplaning Speed (mph)

						0 - 1						
Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Intensity (in/hr)	Shoulder	Lane 1	Lane 2	Buffer	Lane 4	Lane5	Gore	Ramp	Shoulder			
0.1		999.0	999.0	999.0	999.0	999.0		999.0				
0.25		999.0	999.0	999.0	999.0	999.0		999.0				
0.5		999.0	999.0	999.0	999.0	999.0		110.5				
1		999.0	84.4	77.2	72.4	68.3		61.0				
2		67.1	57.3	55.4	53.9	52.3		49.0				
3		56.7	50.6	49.3	48.2	53.7		52.8				
4		51.8	53.7	53.3	53.0	52.7		51.8				



#### Deterministic → Basic Hydroplaning Analysis

 Select "No" for both Risk and Continuous options

Analysis Options			
Select Analysis Option	Deterministic (Default)	: Show intermediate outputs?	No
Risk Analysis?	No		
(Per FDOT's Design Guidance)		-	
Continuous Data?	No	: For Rut depth, Cross Slope, and/or Texture	

#### • Up to 12 model combinations

WFT Model	Hyd	roplaning Speed I	Vodel	Notes on WFT and HPS Models
WFI Wodel	PAVDRN	USF	Gallaway	Please select as many models as needed.
Gallaway	Y	Y	Y	Note 1: Risk Analysis is defaulted to Gallaway WFT
UK RRL	Y	Y	Y	and PAVDRN HPS models.
NZ Mod.	Y	Y	Y	Note 2: Continuous Analysis uses only ONE model
PAVDRN	Y	Y	Y	combination.



#### **Deterministic** → **Basic** Analysis Inputs

- Similar to Risk Analysis
- No Design Speed

Deterministic Ana	lysis											
							Pavement	Texture (P	lease Select	t MTD or N	1PD below)	
Longitudinal Grade	(%)		3				Mean Text				0.067	
Surface Type		Open Gra	aded Frictic	on Course								
Permeability (in/hr)	) –		0									
Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Bernsteller		Lano 1	Lane 2	Buffer	Lane 3	Lane 4	Gore	Ramp	Shoulder			
Description	Shoulder	Lane 1	Latte Z	Durici	Lune 5	Euric 4	0010		Shoulder			
	2	2	2	2	3	3.5	3.5	3.5	6			
Cross Slope (%) Width (ft.)	2 12							1				
Description Cross Slope (%) Width (ft.) 0 Should (iii) -0.5 - iiii -0.5 - iiii -1.5 - iiiii -2 - strate -1.5 - iiii -2.5 - ere -3 - -3.5 -	2 12	2 12	2	2 4	3 12 e 3	3.5 12 ane 4	3.5	3.5	6	lder		



#### **Deterministic** → **Basic** Analysis Inputs

Additional Inputs (Depending on Models)
 – Environmental & Vehicle Inputs

Deterministic Analysis		
Rainfall Intensity (in/hr)	2.00	
Temperature (deg. F)	70.0	< Note: Temperature is only needed for PAVDRN WFT Model
Vehicle Inputs		
Deterministic Analysis		
	472.1	< Note: Axle Weight is only needed for USF HPS Model
Deterministic Analysis Axle Weight (lbs) Tire Pressure (psi)	472.1 30	<ul> <li>Note: Axle Weight is only needed for USF HPS Model</li> <li>Note: Tire Pressure is only needed for Gallaway and USF HPS models</li> </ul>
Axle Weight (lbs)		

 If you do NOT see these inputs, do NOT worry about them

## Deterministic → Basic Analysis Output

Plane Number	1	2	3	VVC		ilm Th	ickne	22 KG	suits	10	11	12
Model	Shoulder	Lane 1	Lane 2	Buffer	Lane 4	Lane5	Gore	Ramp	Shoulder			
Gallaway	0.025	0.051	0.071	0.077	0.082	0.089	0.098	0.106	0.094			
UK RRL	0.029	0.056	0.077	0.083	0.092	0.100	0.109	0.117	0.113			
NZ Mod.	0.018	0.037	0.050	0.054	0.056	0.060	0.065	0.070	0.058			
PAVDRN	0.019	0.032	0.040	0.043	0.044	0.046	0.052	0.055	0.048			

#### Hydroplaning Speed (HPS) Table (Units: mph)

	annig Spee		-			_	-	_	_				
Plane	Number	1	2	3	4	5	6	7	8	9	10	11	12
Desc	ription	Shoulder	Lane 1	Lane 2	Buffer	Lane 4	Lane5	Gore	Ramp	Shoulder			
A Par	ameter												
	Gallaway	17.72	16.77	16.34	16.23	16.14	16.05	15.93	15.83	15.98			
WFT	UK RRL	17.48	16.63	16.24	16.14	16.01	15.90	15.79	15.70	15.75			
VVFI	NZ Mod.	18.14	17.19	16.77	16.68	16.63	16.56	16.45	16.35	16.58			
	PAVDRN	18.05	17.38	17.06	16.98	16.95	16.89	16.73	16.65	16.83			
Hydro	planing							-					
Sp	eed				Hy	dropla	aning	Speed	d Resi	ılts			
HPS	WFT					· · ·		•					
	Gallaway	67.8	56.4	51.7	50.6	49.7	48.7	49.2	48.9	48.1			
PAVDRN	UK RRL	64.9	54.9	50.7	49.7	48.4	49.1	48.8	48.5	48.7			
PAVDRIN	NZ Mod.	73.5	61.3	56.5	55.4	54.9	54.1	52.9	51.9	54.3			
	PAVDRN	72.3	63.6	59.7	58.9	58.5	57.8	56.0	55.1	57.1			
	Gallaway	55.0	53.6	52.9	52.7	52.6	52.4	52.3	52.1	52.3			
LICE	UK RRL	54.7	53.3	52.7	52.6	52.4	52.2	52.1	51.9	52.0			
USF	NZ Mod.	55.7	54.2	53.6	53.4	53.3	53.2	53.1	52.9	53.3			
	PAVDRN	55.5	54.5	54.0	53.9	53.8	53.7	53.5	53.4	53.7			
	Gallaway	55.5	52.5	51.2	50.9	50.6	50.3	49.9	49.6	50.1			
Callaway	UK RRL	54.8	52.1	50.9	50.6	50.2	49.8	49.5	49.2	49.3			
Gallaway	NZ Mod.	56.8	53.9	52.6	52.3	52.1	51.9	51.5	51.2	52.0			
	PAVDRN	56.6	54.4	53.5	53.2	53.1	52.9	52.4	52.2	52.8			



### **Deterministic** → **Continuous** Analysis

• Pavement Cross-Slope, Grade, and Texture change from one location to another

Analysis Options			
Select Analysis Option	Deterministic (Default)	: Show intermediate outputs?	No
Risk Analysis? (Per FDOT's Design Guidance)	No	_	
Continuous Data?	No Yes No	For Rut depth, Cross Slope, and/or Texture	

• Can be used only if continuous measurements are available

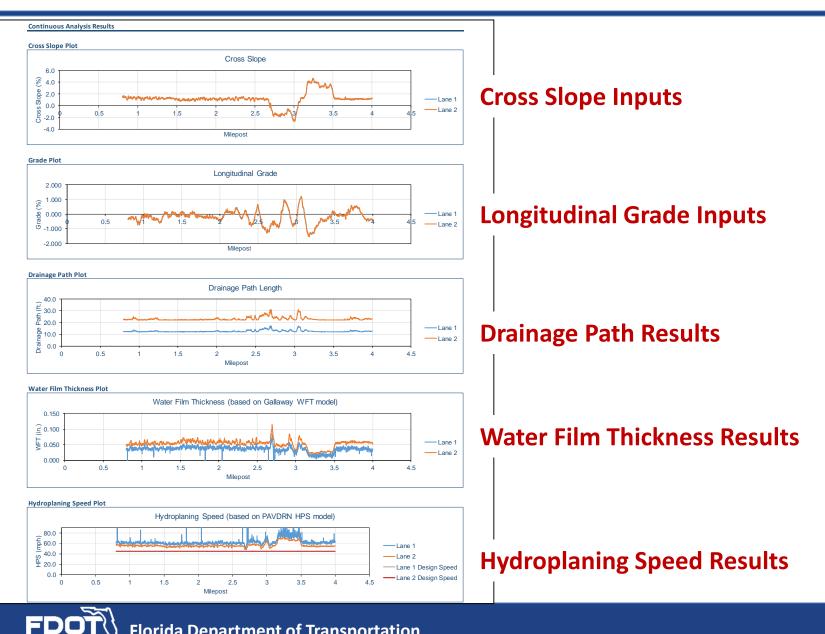
#### **Deterministic** → **Continuous** Analysis Inputs

Analysis	options					
Select An	alysis Optio	n Deter	ministic (Default)	: Sho	w intermediate outputs?	No
Risk Anal			No	_		
(Per FDO	T's Design G	Guidance)				
Continuo	us Data?		Yes	_: For	Rut depth, Cross Slope, and/or Text	ture
Input Ta	ble for Con	tinuous Data Analy	ysis (Provide Value	es or Rig	ht-Click to Select Continuous File)	
Plane	Design Speed (mph)	Description	Width (ft.)		libri - 12 - A A \$ - %	
1	45	Lane 1	12	T\ B	I ≡ 🏠 - 🗛 - 🛄 - €.0 .00	MPD (in.) Rut Depth (in.)
2	45	Lane 2	10	TVAVO	roplanning\TasT\Hvdroplanning\Ta	
3					Cut	$ ac{1}{T}$ Right Click to impo
4				E B		
5						1 Continuous Data F
6				Ê	Paste Options:	
7					Ê.	
8					Paste Special	
9					Paste <u>opecial</u>	
10				_	Insert	
11					Delete	
12				_	Clear Co <u>n</u> tents	
	Click Her	re to Run Conti	inuous Analysi	is.		to Export KML File!
					Filter	
Note: On	lly One moo	del (Leftmost Colur	nn & Top Row in t	ne N	Sort >	Iontinuous Analysis
	PS Model S	alastian			-	
WFI&H	PS Model S	election		- Č	Insert Co <u>m</u> ment	
		Lb.	draplaning Coord	No =	Eormat Cells	/FT and HPS Models
WFT	Model	PAVDRN	droplaning Speed USF	WU	Pick From Drop-down List	of as many models as needed.
Gall	away	Y	031	<b>H</b>	-	Analysis is defaulted to Gallaway WFT
	RRL	1			Define N <u>a</u> me	C PAVDRN HPS models.
	Mod.			- 8	Hyperlink	r tinuous Analysis uses only ONE model
	/DRN				Select Cross Slope and Grade File	mbination.

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#### Deterministic $\rightarrow$ Continuous Analysis Results



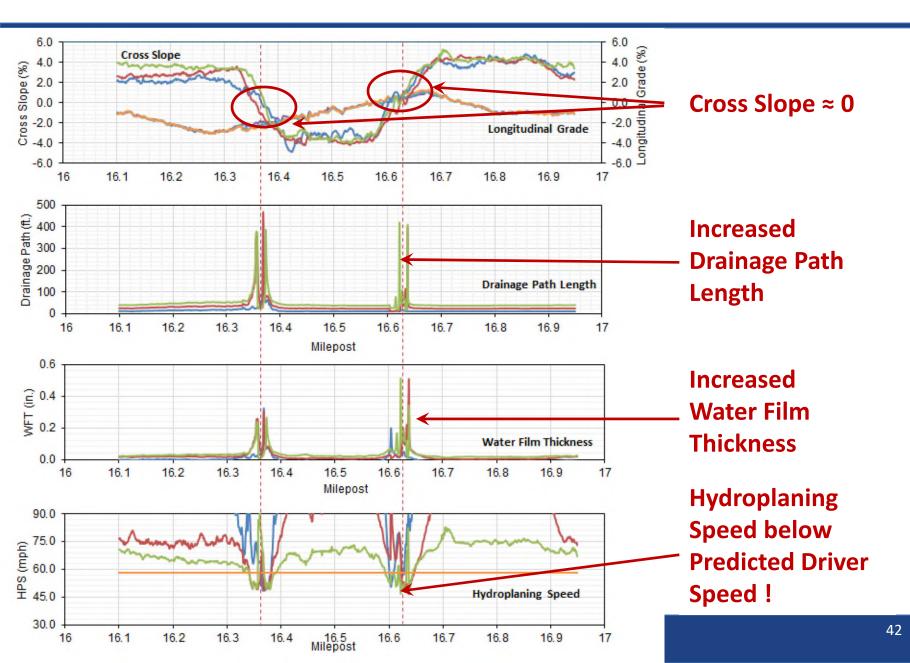
#### Deterministic → Continuous Analysis Example

- Problem Statement
  - Increased number of crashes between mileposts
     16.0 and 17.0 , especially under wet conditions
- Available Data
  - Continuous Cross Slope and Grade





#### Deterministic → Continuous Analysis Example Results



# **FDOT's Hydroplaning Prediction Tool**

- Analysis Options
  - Deterministic
    - Risk Analysis
    - Basic Analysis
    - Continuous Analysis
  - Sensitivity
  - Probabilistic

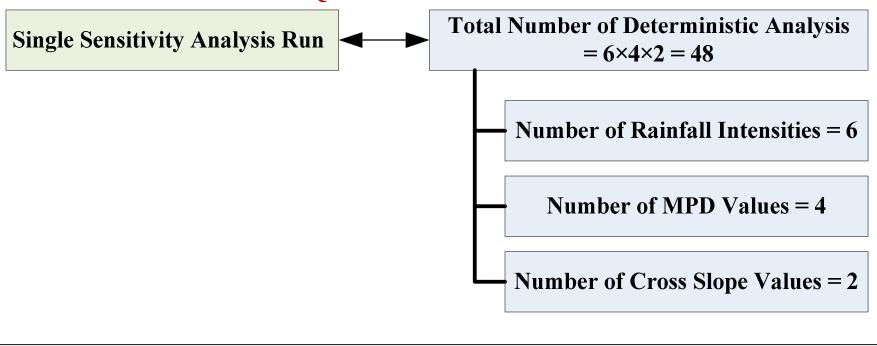
General Inputs FPID District No. County Analysis Options	123456-7				
District No.					
Analysis Options	2 Alachua	Roadway Section Milepost Direction	0.800	1345 to 4.000 orth	General Inputs
					$\exists$ .
Select Analysis Option Risk Analysis? (Per FDOT's Design Guidanc Continuous Data? WFT & HPS Model Selectio	No	Show intermediate output		_	Analysis Options
	Hydroplaning Speed Mo	del	Notes on WFT and HPS N	Vodeis	5
Gallaway UK RRL NZ Mod.	AVDRN USF Y	Gallaway Y	Please select as many mo Note 1: Risk Analysis is de and PAVDRN HP Note 2: Continuous Analys	idels as needed. afaulted to Gallaway WFT Smodels.	Model Selection
PAVDRN Pavement Inputs			combination.	-	
Surface Type Permeability (in/hr) Plane Number 1 Description Shoulder (Coss Stoge (V) 2 Width (ft.) 22 Width (ft.) 22 Width (ft.) 32 Environmental Inputs	2 2 2 2 12 12 12 12	5         6         7         7           Lane 4         Shoulder         3         3.5         12           12         12         12         12         12           - Lane 3         - Lane 4         - Lane 5         - Lane 5         - Lane 5	• 14064 • 50 60	20 21 22 	Pavement Inputs
Deterministic Analysis Rainfall Intensity (in/hr)	2,00				Environment Inputs
Vehicle Inputs				=	ゴ
Deterministic Analysis Tire Pressure (psi) Spindown (%) Tread Depth (in)	30 10 0.02	< Note: Spindov	essure is only needed for Galla wn is only needed for Gallaway Depth is only needed for Gallaw	y HPS Model	Vehicle Inputs
Analysis Results				=	う しょうしょう
Gallaway 0.015 Hydroplaning Speed (HPS) Plane Number 1	2         3         4           er         Lane 1         Lane 2         Lane 3           i         0.037         0.054         0.069             Table         2         3         4	5         6         7           Lane 4         Shoulder         0.074           0.074         0.081         0.081           5         6         7           Lane 4         Shoulder         7		10 11 12 10 11 12	Analysis Results



### **Sensitivity Analysis**

• Batch run for Basic Analysis

#### **EQUIVALENT !!**



Analysis Options				
Select Analysis Option		how intermediate outputs?	No	
	Deterministic (Default) Sensitivity			
WFT & HPS Model Selection	Probabilistic			



### **Sensitivity Analysis Inputs**

#### • Minimum, Maximum, and Increment

Sensitivit	y Analysis										Min	Max	Inc.
Select Su	rface Type	(Y/N)						Longitudin	al Grade (%)		1	2	
	aded Frictio		1	(	]			Permeabil	ity (in/hr)		0		
Open gra	ded Frictio	n Course			1			Mean Prof	ile Depth (in	.)	0.02	0.05	0.01
	PCC (LGD)				1			(Please Se	lect MTD or	MPD from	m above Ce	ll)	
PC	C (LGD+TG	V)			1								
	Number	1	2	3	4	5	6	7	8	9	10	11	12
Desc	ription	Lane 1	Lane 2										
Cross	Min	1	1										
Slope	Max	2	2										
(%)	Inc.	1											
Width	Min	12	12										
(ft.)	Max	14	14										
(10.)	Inc.	)											
Sensitivit	nental Inpu ay Analysis	٢	Min	Max	Inc.	ī)		Click He	ere to Ru	n Sensi	itivity Ar	nalysis!	
<b>Sensitivit</b> Rainfall Ir	y Analysis	/hr)	0.5	3			< Note:						
<b>Sensitivit</b> Rainfall Ir	y Analysis	/hr)					< Note:		ere to Rui				
<b>Sensitivit</b> Rainfall Ir Temperat	<b>y Analysis</b> ntensity (in, ure (deg. F)	/hr)	0.5	3			< Note:						
<b>Sensitivit</b> Rainfall Ir Temperat	<b>y Analysis</b> ntensity (in, ure (deg. F)	/hr)	0.5	3			< Note:						
Sensitivit Rainfall Ir Temperat Vehicle Ir	<b>y Analysis</b> ntensity (in, ure (deg. F)	/hr)	0.5	3 80	0.5		< Note:						
Sensitivit Rainfall Ir Temperat Vehicle Ir Sensitivit	ntensity (in, nure (deg. F) nputs ny Analysis	/hr)	0 5 70 Min	3 80 Max				Temperatu	re is only nee	eded for	PAVDRN W	FT Model	
Sensitivit Rainfall Ir Temperat Vehicle Ir Sensitivit Axle Weig	y Analysis ntensity (in, rure (deg. F) nputs y Analysis ght (lbs)	/hr)	0.5 70 Min 450	3 80 Max 550	0.5		< Note:	Temperatu Axle Weigh	re is only nee	eded for	PAVDRN W	FT Model	models
Sensitivit Rainfall Ir Temperat Vehicle Ir Sensitivit	y Analysis ntensity (in, uure (deg. F) nputs y Analysis ght (lbs) sure (psi)	/hr)	0 5 70 Min	3 80 Max	0.5		< Note: < Note:	Temperatu Axle Weigh Tire Pressu	re is only nee	eded for eded for U eded for U	PAVDRN W JSF HPS Mo Gallaway a	FT Model del nd USF HPS	i models



FD

## **Sensitivity Analysis Inputs**

- Rainfall Intensity
  - Minimum: 0.5 in/hr
  - Maximum: 3.0 in/hr
  - Increment: 0.5 in/hr

Equivalent to running Basic Analysis 6 times

 With 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 in/hr rainfall intensities

### **Sensitivity Analysis Results**

EG8	3			* :	XV	fx										
4	A	В	с	D	0	P	AA	AB	AC	AD	AE	AK	AL	AW	AX EF	
T			Wate	Film	Hydroph	aning_Sp					mental					
1			Thickne		100000000000000000000000000000000000000	ed		Pavement	Inputs		Inputs	Cross	Slope	wi	dth	
				1				Longitud		Mean						
	WFT	HPS	Lana 1	Lane 2	Lang 1	Lane 2	Surface	inal	ermeab	Profile	Rainfall	12/21	Lana 2	Lane 1	I Loo F	
	Model	Model	Lane 1	Lane Z	Lane 1	Lane 2	Туре	Grade	ility	Depth	Intensity	Leve I		Lone 1	Use t	Excel filters to sort
2	*	*	-	7	7	-	*	(%) -	(in/hr <sup>v</sup> ∓	(in.) -	(in/hr)			-		
3 (		PAVDRN	0.007	0.020	94.6	71.9	DGFC 2	• -	st to Large	est		0	1.0	120	throu	igh the needed output
-		PAVDRN	0.001	0.019	163.5	73.0	DGFC Z	Sort Larges	t to Small	est		2.0	1.0	12.0	unou	ugh the needed outpu
		PAVDRN	0.021	0.040	70.7	59.8	DGFC	Sort by Col	or			1.0	1.0	12.0	100	•
	Gallaway		0.012	0.039	81.5	60.5	DGFC	Clear Filter	From "Ra	infall Intensi	t"	2.0	1.0	12.0	12.0 12.0	
-	Gallaway Gallaway	PAVDRN	0.032	0.056	63.3 70.6	54.8 55.4	DGFC DGFC	Filter by Co				1.0	1.0	12.0 12.0	12.0	
	Gallaway		0.021	0.034	59.1	51.8	DGFC	Number Fil				1.0	1.0	12.0	12.0	
		PAVDRN	0.029	0.068	65.1	52.3	DGFC	Number <u>r</u> i	ters			2.0	1.0	12.0	12.0	
-	Gallaway		0.051	0.083	56.3	49.6	DGFC	Search			Q	1.0	1.0	12.0	12.0	
		PAVDRN	0.036	0.080	61.6	50.1	DGFC	🖌 (Sele	ect All)			2.0	1.0	12.0	12.0	
	Gallaway		0.059	0.094	54.2	47.9	DGFC	✓ 0.50				1.0	1.0	12.0	12.0	
	Gallaway		0.042	0.091	59.0	48.4	DGFC	1.50			- 11	2.0	1.0	12.0	12.0	
5	Gallaway	PAVDRN	0.000	0.013	999.0	79.5	DGFC	2.00				1.0	1.0	12.0	12.0	
6	Gallaway	PAVDRN	-0.006	0.012	999.0	81.6	DGFC	- 🗹 2.50 - 🗹 3.00				2.0	1.0	12.0	12.0	
7	Gallaway	PAVDRN	0.015	0.035	77.6	62.2	DGFC	- 2 3.00				1.0	1.0	12.0	12.0	
8	Gallaway	PAVDRN	0.006	0.033	100.1	63.1	DGFC					2.0	1.0	12.0	12.0	
9 1	Gallaway	PAVDRN	0.027	0.051	66.7	56.1	DGFC					1.0	1.0	12.0	12.0	
20	Gallaway	PAVDRN	0.015	0.049	77.4	56.8	DGFC		_			2.0	1.0	12.0	12.0	
21 (	Gallaway	PAVDRN	0.037	0.066	61.3	52.7	DGFC		0	ĸ	Cancel	1.0	1.0	12.0	12.0	
	Gallaway		0.023	0.063	69.2	53.2	DGFC				4	2.0	1.0	12.0	12.0	
23 (	Gallaway	PAVDRN	0.046	0.079	57.9	50.3	DGFC	1	0	0.030	2.50	1.0	1.0	12.0	12.0	
										130	2.50	2.0	1.0	12.0	12.0	
	oto	e of	roc	• • • • • • •		rou	ida	ed in		130	3.00	1.0	1.0	12.0	12.0	
	.Uts		163	uit	Э. Г		luc			40	3.00	2.0	1.0	12.0 12.0	12.0	
										40	0.50	2.0	1.0	12.0	12.0	
C	en	arat	te v	vor	·kch	lee	-			40	1.00	1.0	1.0	12.0	12.0	
9	CP	ulu			NJI					40	1.00	2.0	1.0	12.0	12.0	
1	Gallaway	PAVDRN	0.020	0.046	71.6	57.9	DGFC	1	0	0.040	1.50	1.0	1.0	12.0	12.0	
_		PAVDRN	0.008	.043	90.4	58.7	DGFC	1	0	0.040	1.50	2.0	1.0	12.0	12.0	
3	Gallaway	PAVDRN	0.031	.061	64.3	53.8	DGFC	1	0	0.040	2.00	1.0	1.0	12.0	12.0	
4	Gallaway	PAVDRN	0.017	0.058	75.4	54.4	DGFC	1	0	0.040	2.00	2.0	1.0	12.0	12.0	
5 (	Gallaway	PAVDRN	0.040	.074	60.0	51.1	DGFC	1	0	0.040	2.50	1.0	1.0	12.0	12.0	
6	Gallaway	PAVDRN	0.024	.071	68.4	51.7	DGFC	1	0	0.040	2.50	2.0	1.0	12.0	12.0	
7 (	Gallaway	PAVDRN	0.048	.086	57.0	49.1	DGFC	1	0	0.040	3.00	1.0	1.0	12.0	12.0	
-		PAVDRN	0.031	0.083	64.1	49.6	DGFC	1	0	0.040	3.00	2.0	1.0	12.0	12.0	
-		PAVDRN	-0.014	0,000	999.0	999.0	DGFC	1	0	0.050	0.50	1.0	1.0	12.0	12.0	
0	Gallaway	PAVDRN	-0.0.1	0.002	999.0	999.0	DGFC	1	0	0.050	0.50	2.0	1.0	12.0	12.0 12.0	

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# **FDOT's Hydroplaning Prediction Tool**

- Analysis Options
  - Deterministic
    - Risk Analysis
    - Basic Analysis
    - Continuous Analysis
  - Sensitivity

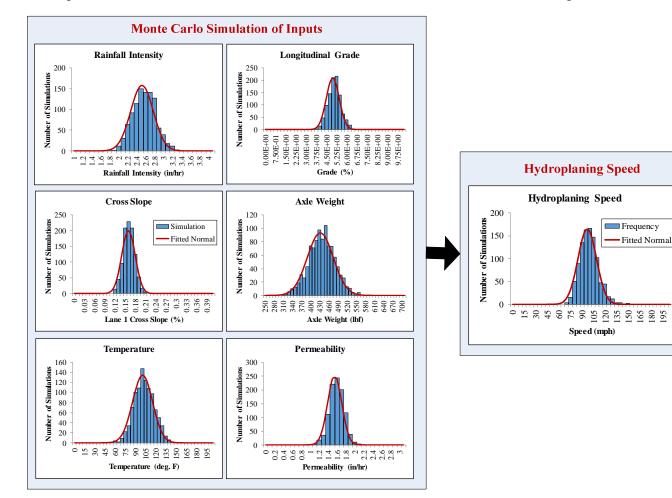
Probabilistic

				opi			nal	ysi	5 1				
General Inputs													
FPID District No. County	123456- 2 Alachua			Mile	dway Section post ction	on Number	0.	.800	to North	4.000		$\left.\right\}$	General Inputs
Analysis Options												$\leq$	
Select Analysis Opti	on Dete	rministic (Def	ault) : Si	how interme	diate outp	uts?	_	No					
Risk Analysis? (PerFDOT's Design	Guidance	No										5	Analysis
Continuous Data?		No	: F	or Rut dept	h. Cross Sid	pe, and/or T	Texture					ſ	Options
WFT & HPS Model	Selection												
		droplaning	Speed Mode	1	_	Note	s on WFT	and HP	5 Model				
WFT Model	PAVDRN	USF		Gallaway	_	Please	e select a 1- Risk Ar	as many i	models a	s needed. d to Galla	way WFT		Model
UK RRL				_			and P	AVDRN	IPS mode			<u>۲</u>	Selection
NZ Mod. PAVDRN						Note :		uous Ana ination:	iysis use	s only ON	E model		Selection
Pavement Inputs					-								
Deterministic Anal	ysis												
Longitudinal Grade (	(96)	3				n Texture De			ATD or N	0.035	)		
Surface Type		raded Friction	Course					_					
Permeability (in/hr)		0		_									
Plane Number Description	1 2 Shoulder Lane 1	3 Lane 2	4 Lane 3 La		6 ulder	7 8		9	10	11	12		
Cross Slope (%) Width (ft.)	2 2 12 12	2 12	2 12	3 3	3.5				_				Pavement
eration (in)	er D Lane (		Lane 2	e Lan	a.3	• Lane 4							Inputs
-0.5 -			Lane 2	- LLO	40	• Lane 4		• 520	lder	70	80		
Relative (fevation (in)	• Lane 1 , 10	•		- LLO	e3			,	ider	-	80		
Relative flywardow (in)	• Line ; ,0 10	•		- LLO	40			,	ider	-	50		
(ii) ustative (iii) ustative (ii	<ul> <li>Lace 1</li> <li>10</li> <li>uts</li> <li>pis</li> </ul>	•		- LLO	40			,	sider	-	50		Inputs Environmen
(a) of the second secon	<ul> <li>Lace 1</li> <li>10</li> <li>uts</li> <li>pis</li> </ul>	20		- LLO	40			,	sider	-	50		Inputs
(a) of the second secon	10 10 10 /hri	20		- LLO	40			,	elder	-	50		Inputs Environmen
Call of the second seco	10 10 10 /hri	20		Lan	e3 20 istance (ft.)	50		60		70			Inputs Environmen
Environmental Inpr Deterministic Analy Rainfall Intensity (in Vehicle Inputs Deterministic Analy Tire Pressure (psi) Spindown (%)	10 10 10 /hri	2.00 2.00 30 20		Lateral D	e 3 40 istance (ft.) Note: Tire I Note: Spinc	50 Pressure is o	nly needs needed fr	ed for Ga	llaway ar	nd USF HP			Inputs Environmen Inputs Vehicle
Environmental Inpu 2 - 2 - 0 Environmental Inpu Peterministic Analy Rainfall Intensity (in Vehicle Inputs Deterministic Analy	10 10 10 /hri	2.00		Lateral D	e 3 40 istance (ft.) Note: Tire I Note: Spinc	50 Pressure is o	nly needs needed fr	ed for Ga	llaway ar	nd USF HP			Inputs Environmen Inputs
Environmental Inpr Deterministic Analy Rainfall Intensity (in Vehicle Inputs Deterministic Analy Tire Pressure (psi) Spindown (%)	10 10 10 /hri	2.00 2.00 30 20		Lateral D	e 3 40 istance (ft.) Note: Tire I Note: Spinc	50 Pressure is o	nly needs needed fr	ed for Ga	llaway ar	nd USF HP			Inputs Environmen Inputs Vehicle
Gill         OS         -1           -1         -2         -1         -1           -1         -2         -0         -1         -1           Environment al Ingo         -2         -0         -1         -1           Deterministic Anah         Rainfail Intensity (in Webicle Inputs)         -1         -1         -1           Deterministic Anah         Tim Pressure (psi)         Spindown (%)         Spindown (%)         -1 <td></td> <td>2.00 2.00 30 20</td> <td></td> <td>Lateral D</td> <td>e 3 40 istance (ft.) Note: Tire I Note: Spinc</td> <td>50 Pressure is o</td> <td>nly needs needed fr</td> <td>ed for Ga</td> <td>llaway ar</td> <td>nd USF HP</td> <td></td> <td></td> <td>Inputs Environmen Inputs Vehicle</td>		2.00 2.00 30 20		Lateral D	e 3 40 istance (ft.) Note: Tire I Note: Spinc	50 Pressure is o	nly needs needed fr	ed for Ga	llaway ar	nd USF HP			Inputs Environmen Inputs Vehicle
Environment al Inpu Environment al Inpu Deterministic Analy Rainfal Intensity (in Tran Presse (sci) Byteministic Analy Tran Desterministic Analy Tran Desterministic Analy Tran Desterministic Analy Tran Desterministic Analy Tran Desterministic Analy		2.00 2.00 30 20		Lateral D	e 3 40 istance (ft.) Note: Tire I Note: Spinc	50 Pressure is o	nly needs needed fr	ed for Ga	llaway ar	nd USF HP			Inputs Environmen Inputs Vehicle
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Environmental Inge Environmental Inge Control	- Lane J     - Lane J	20 2.00 30 10 0.02	30 30		a 3 40 sistance (ft.) Note: Time Note: Time Spinc	50 Pressure is o	nly needed needed fily needed	so ad for Gal ad for Gallav	llaway ar way MS Iaway HPS	70 nd USF HP Vodel 'S Model	Smodels		Inputs Environmen Inputs Vehicle
G 00 00 00 00 00 00 00 00 00 00	- Lane, J     10	2.00 2.00 30 10 0.02 31 2.00	4 Lane 3 Lane 3 0.069 0	Lateni D     Lateni D     Lateni D     S     C     C     C     S     S     S     C-	A A Note: Time Note: Time Solider Solider	50 Pressure is o	nly needed needed fily needed	so ad for Gal ad for Gallav	llaway ar way HPS laway HPS 20	nd USF HP USF HP USF Hodel IS Model	S models		Inputs Environmen Inputs Vehicle Inputs
Environment al Ingo Environment al Ingo Environment al Ingo Deterministic Anah Rainfal Intensity (in Vehicle Inguts Deterministic Anah Tire Pressure (psi) gandons (is) Tend Depth (in) Anahyb Results Deterministic Anah Piane Number Wedrichen and Status Status Status Model Gallaway		20 2.00 30 0.02 30 0.02 3 1.120 0.02 3	30 4 1 Lane 3 Lu 0.069 0	Lateral D     Lateral D     S     S     S     S	ation of the second sec	50 Pressure is o	nly needed needed fily needed	so ad for Gal ad for Gallav	llaway ar way MS Iaway HPS	70 nd USF HP Vodel 'S Model	Smodels		Inputs Environmen Inputs Vehicle Inputs Analysis
Environmental Inge Environmental Inge Deterministic Anah Rainfal Intensity (in Vehicle Inguts Deterministic Anah Tise Pressure (psi) Johdon (N) Trand Depth (in) Anahyb Results Deterministic Anah Piane Number Model Gallaway Vehicle Inguts	10 10 11 10 12 13 10 10 10 10 10 10 10 10 10 10	20 2.00 30 0.02 30 0.02 3 1.120 0.02 3	30 4 1 Lane 3 Lu 0.069 0	Lateral D     Lateral D     S     S     S     S	ation of the second sec	50 Pressure is o	nly needed needed fily needed	so ad for Gal ad for Gallav	llaway ar way HPS laway HPS 20	nd USF HP USF HP USF Hodel IS Model	S models		Inputs Environmen Inputs Vehicle Inputs Analysis
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### **Probabilistic Analysis**

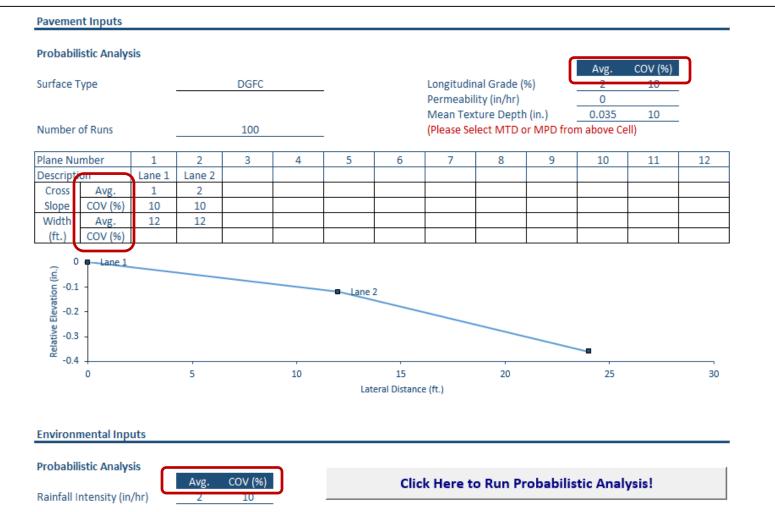
• Are you sure the Rainfall is exactly 2.0 in/hr?





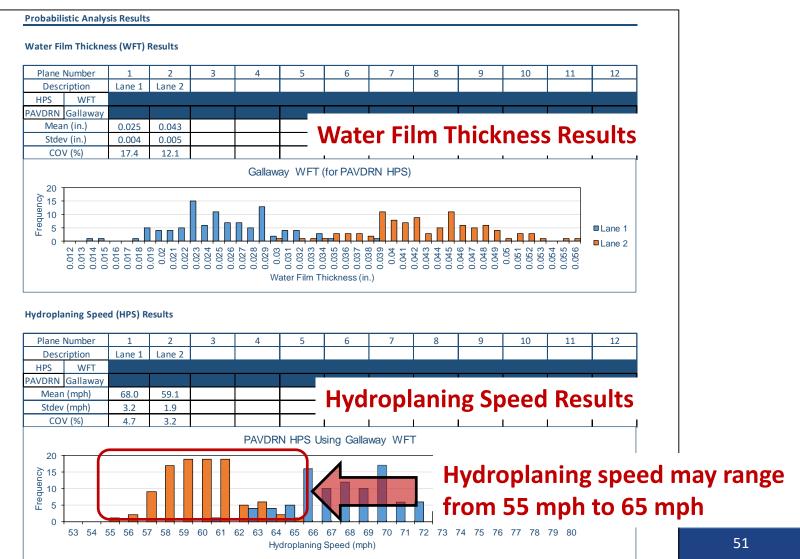
### **Probabilistic Analysis Inputs**

- In terms of Distribution
  - Average (or Mean) & Coefficient of Variation (COV)



### **Probabilistic Analysis Results**

#### • Also in terms of Distribution



### **Summary**

### Dynamic Hydroplaning

- Occurs when there is more water than a tire can push away
- Tire is NOT in contact with pavement
- Most frequent on Roadways

### What Affects Hydroplaning?

- Pavement / Roadway Geometry (e.g., Lane Width, Slopes)
- Environmental Conditions (e.g., Rainfall)
- Driver Behavior (e.g., Speed)
- Vehicle Condition (e.g., Tire Pressure, Weight, Tread)

## **Summary**

#### FDOT's Hydroplaning Prediction Tool

- Built in MS Excel
- User-Friendly
  - Select Analysis Option
  - Fill in the Inputs
  - Obtain the Results
- Different Analysis Options
  - Understand what you need when you need it
- Consult FDOT's Hydroplaning Guidance for detailed information and Step-by-Step procedures
- Refer to FDOT's Design Manual (Section 210.2.4.2) and Drainage Manual (Section 3.9.4) for additional information regarding FDOT's criteria on calculating hydroplaning risk
- The Hydroplaning Tool and Guidance are available at <u>FDOT's Roadway</u> <u>Drainage Office Website</u>





# **Hydroplaning Analysis**

#### **Computer Based Training Course**

Quiz

Q: When hydroplaning occurs, the tire is in contact with the pavement.

a) True b) False



Q: \_\_\_\_\_ hydroplaning is the most frequent type of hydroplaning on roadways.

- a) Dynamic
- b) Viscous
- c) Reverted-Rubber



Q: Which of the following factors affect Hydroplaning Speed?

a) Pavement / Roadway Geometry

- b) Environmental Conditions
- c) Driver Behavior
- d) Vehicle Condition
- e) All of the above

Q: FDOT's recommended model for Water Film Thickness is:

a) U.K. Road Research Laboratory Modelb) New Zealand Modified Modelc) Gallaway Model



Q: FDOT's recommended model for Hydroplaning Speed is:

a) University of South Florida Model
b) PAVDRN Model
c) U.K. Road Research Laboratory Model



Q: Based on FDOT's Design Guidance, Hydroplaning Risk Analysis compares the Hydroplaning Speed against the \_\_\_\_\_

a) Design Speedb) Speed Limitc) Predicted Driver Speed

Q: You are running FDOT's Hydroplaning Risk Analysis. The results show that the Predicted Driver Speed 60 mph. The Hydroplaning Speed is found to be 50 mph. According to FDOT's Design Guidance, this pavement is safe and hence accepted.

> a) True b) False

Q: Which of the following is NOT an input into the Hydroplaning Prediction tool?

- a) Rainfall Intensity
- b) Pavement Width
- c) Pavement Cross-Slope
- d) Speed Limit

Q: Which of the following is NOT an output from the Hydroplaning Prediction tool?

a) Rainfall Intensity

- b) Water Film Thickness
- c) Hydroplaning Speed
- d) Both (b) and (c)

Q: Which Analysis Option in the Hydroplaning Prediction tool should you choose when you want to run a batch of Deterministic Inputs?

a) No Options availableb) Sensitivity Analysis Optionc) Probabilistic Analysis Option



# **End of CBT**