



PaveSafe v1.0.4

**Mechanistic Load Restriction Decision Platform for Pavement Systems Prone
to Moisture Variations**

5/17/2021

User Manual

Majid Ghayoomi

majid.ghayoomi@unh.edu

Eshan Dave

eshan.dave@unh.edu

The software development was sponsored by National Road Research Alliance (NRRRA) under MnDOT Contract# 1034192 and supported by the University of New Hampshire.

For updates please visit <http://mypages.unh.edu/pavesafe/>

TABLE OF CONTENTS

Requirements and Installation Procedure.....	1
Introduction	5
Password Protection Menu	6
SI Units vs Us customary units selection stage.....	8
Project Information Panel	9
Pavement Structure Panel.....	10
Subgrade Properties Panel	11
Hydrological Information Panel.....	13
Results Panel.....	18
Menu Tab.....	21

REQUIREMENTS AND INSTALLATION PROCEDURE

The toolkit “PaveSafe” is currently at version v1.0.4. The toolkit requires MATLAB Compiler Runtime (MCR) to be installed on the host system.

MCR inherits identical system requirements as of the MATLAB version used to build the toolkit. MATLAB 2019b Update 3 has been used for toolkit development.

General MCR requirements are listed below:

1. For Macintosh systems: <https://www.mathworks.com/content/dam/mathworks/mathworks-dot-com/support/sysreq/files/system-requirements-release-2019b-macintosh.pdf>
2. For Windows systems: <https://www.mathworks.com/content/dam/mathworks/mathworks-dot-com/support/sysreq/files/system-requirements-release-2019b-windows.pdf>
3. For Linux systems: <https://www.mathworks.com/content/dam/mathworks/mathworks-dot-com/support/sysreq/files/system-requirements-release-2019b-linux.pdf>

Installation Procedure:

Step 1: The toolkit package is provided in two folders:

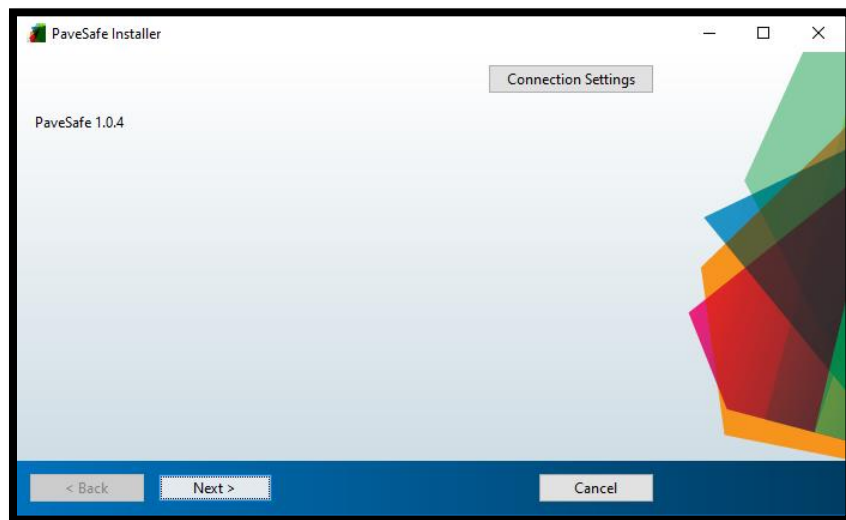
- PaveSafe Application
- MyAppInstaller

Users can choose to use the PaveSafe Application folder which contains the toolkit to run the application, given, MCR already configured in the host system.

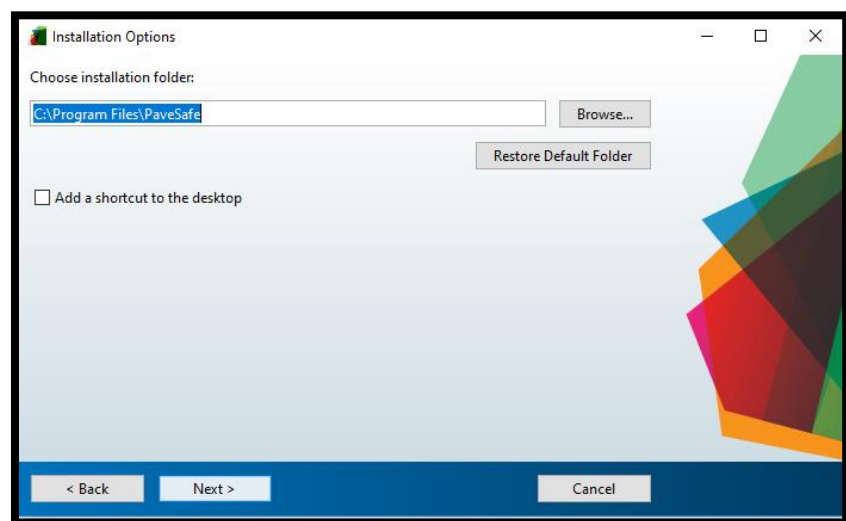
If MCR is not configured on the host system, users may need to use the MyAppInstaller folder and launch the contained installer file “MyAppInstaller_web”. Detailed installation procedure using the installer is mentioned in the following steps

 MyAppInstaller	5/21/2021 8:14 AM	File folder
 PaveSafe Application	5/21/2021 9:07 AM	File folder

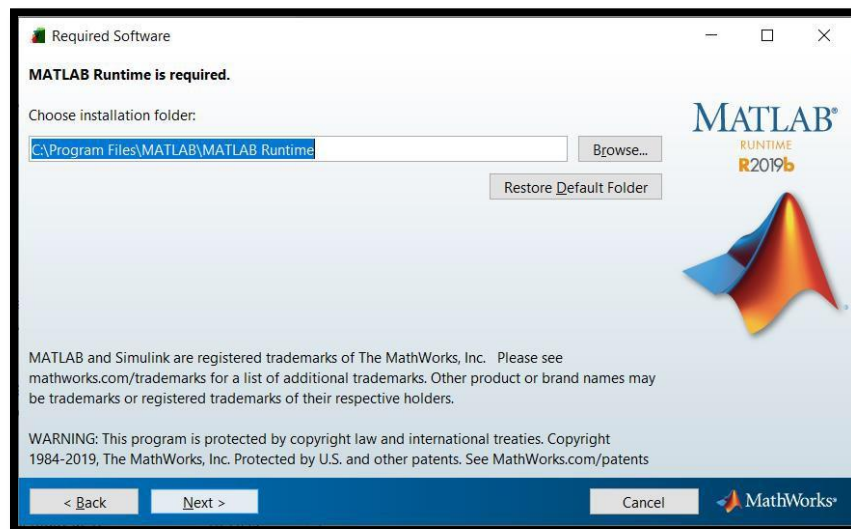
Step 2: Open the MyAppInstaller_web installer.



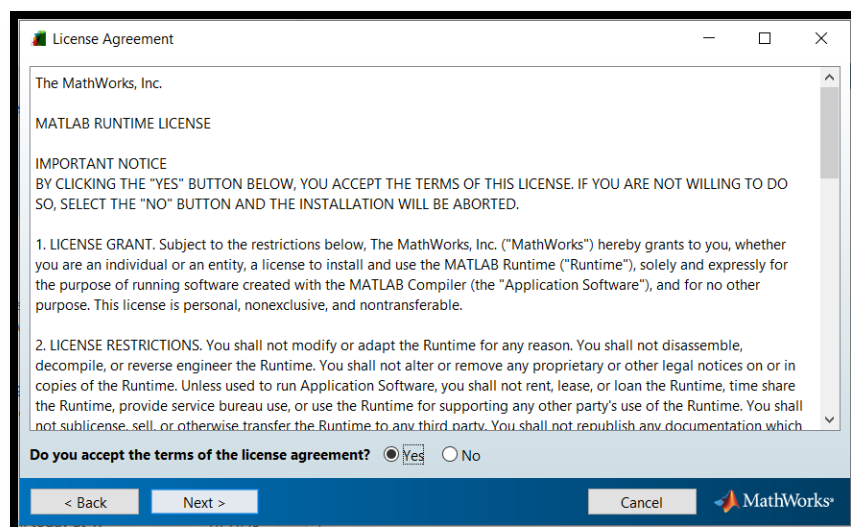
Step 3: Select the application installation folder.

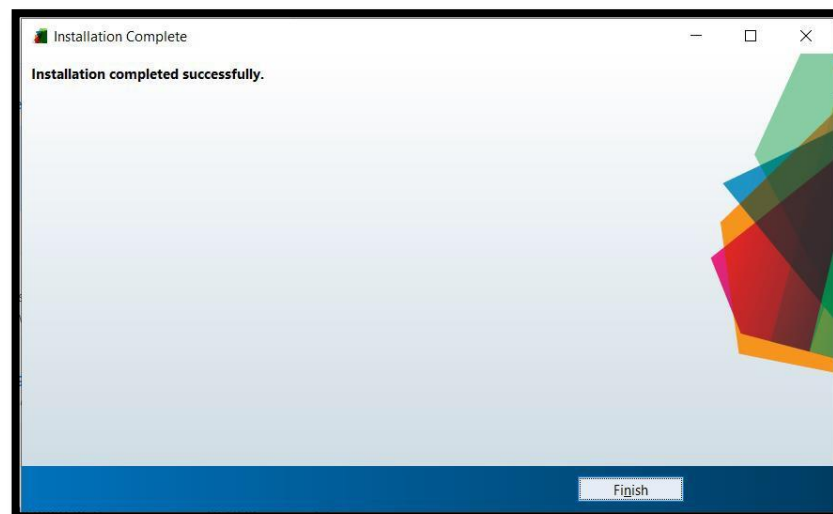
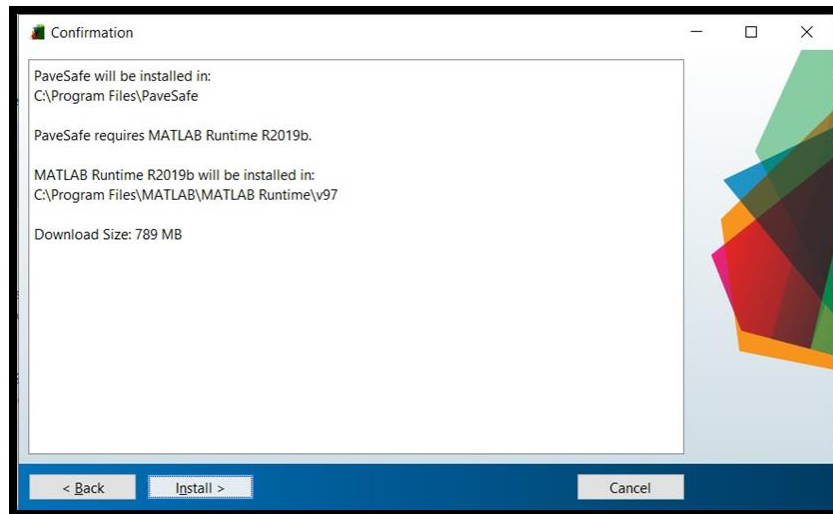


Step 4: Installer will detect if the MRC is installed on the host computer. If it is not already configured, a prompt for choosing the installation folder appears.



Step 5: Accept the license agreement, confirm and wait until installation is completed.





INTRODUCTION

The toolkit PaveSafe v1.0.4 is password protected via password protected window and requires the user to provide inputs across 5 panels after correct password has been provided. In addition to these sections, the toolkit offers the Menu Tab on top of the PaveSafe application window. In the version PaveSafe v1.0.4 we have added the flexibility for user to select SI Units or use US Customary instead.

The application collectively contains the following sections:

- Password Protection Window
- SI Units vs US Customary Selection Stage
- Project Information Panel
- Pavement Structure Panel
- Subgrade Properties Panel
- Hydrological Information Panel
- Results Panel
- Menu Tab

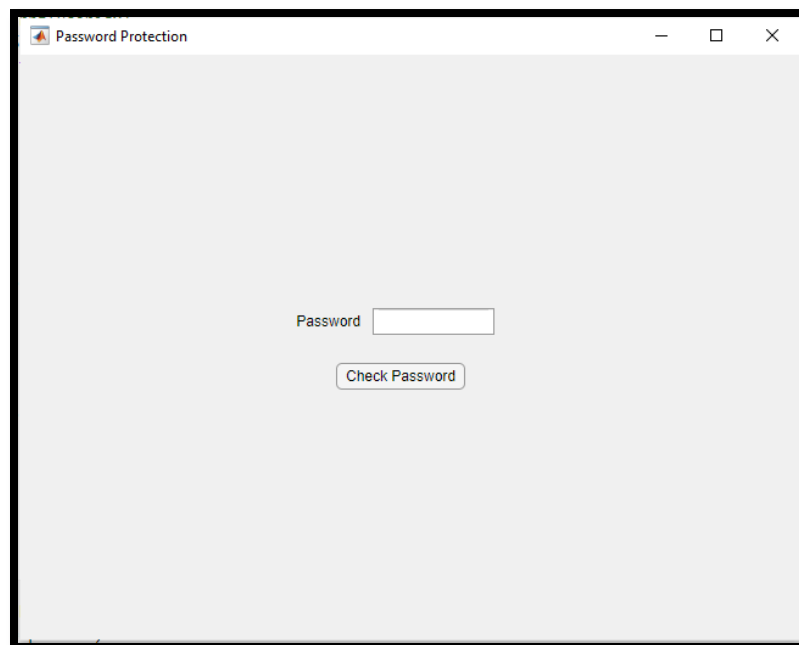
These panels and windows are described in more detail in the upcoming sections.

PASSWORD PROTECTION MENU

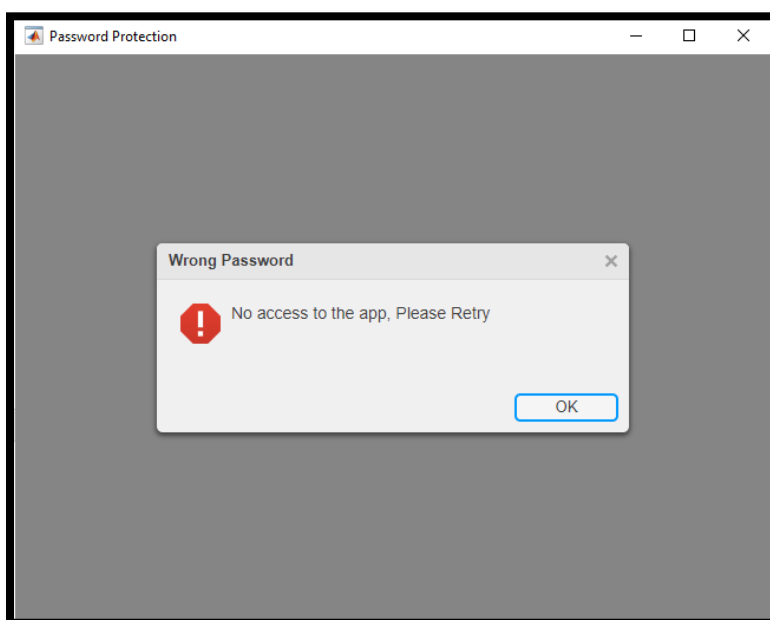
Inherently, MATLAB does not provide a password protection for the generated applications. A password protection window that secures the app from unauthorized access is prepared as first line of defense.

Disclaimer: Please note that there is no underlying encryption mechanism which protects the application from people who have intentions to misuse the application. Simple methods such as brute force (example – John the Ripper password cracking software) can still break the password. It is advised to share the application with the intended users only. In workspaces, users should be trained to be aware of attacks such as Shoulder Surfing, Tailgating, Phishing and other forms of Social Engineering attacks. The host systems can be secured by using anti-virus and setting up appropriate firewall settings. These preventive measures along with provided password protection can reduce the risk of misuse. We do not guarantee complete protection against hackers or take accountability for any misuse of the application. It is the responsibility of the intended users to keep the application secure.

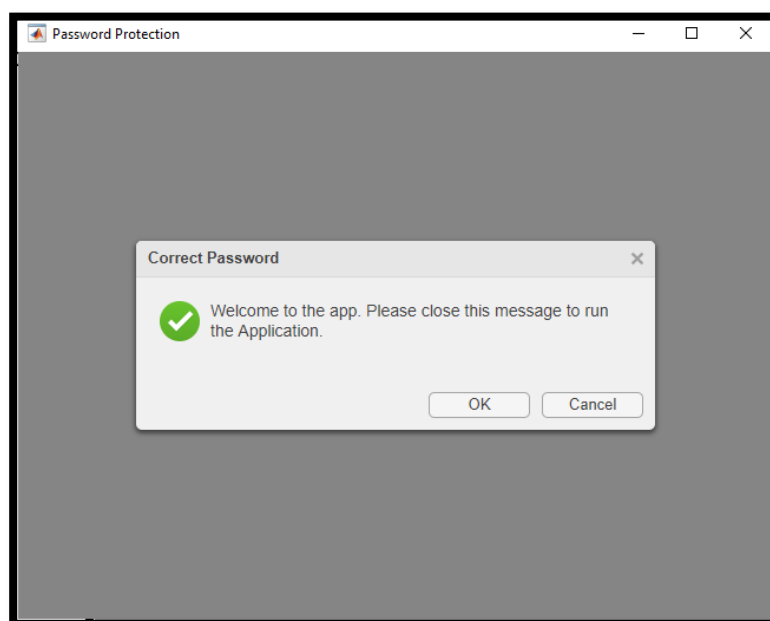
On launch, a password protection screen pops out and requires the users to enter the password. After providing the password it is required to press the “Check Password” button in order to proceed.



In the event of providing an incorrect password, a wrong password alert box appears on the screen. You may choose to close the alert box or press “OK” to proceed.



In the event of providing a correct password, a correct password alert box appears on the screen. You must choose to close the alert box by pressing “OK”, “Cancel” or closing the alert box by clicking the “X” on top right side of the alert box to proceed working with the PaveSafe application.



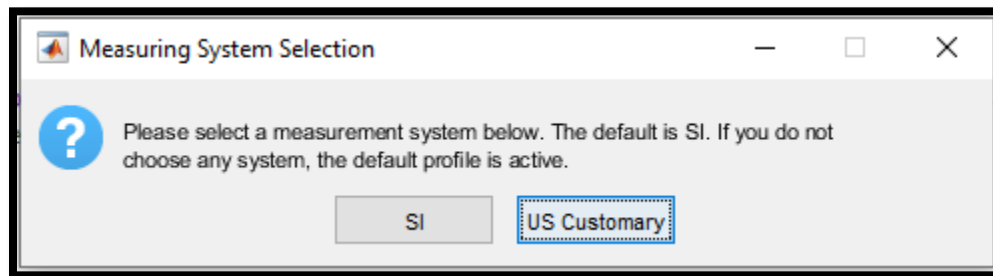
SI UNITS VS US CUSTOMARY UNITS SELECTION STAGE

In this stage, user is required to select the units of measurement.

We have the following units of measurements in place:

- SI Units
- US Customary

A dialogue box will appear requiring the user to select the desired units of measurement. If user chooses to close the dialogue box without selection, SI Units will be default.



PROJECT INFORMATION PANEL

On launch of the application post selecting the desired units of measurement, Project Information panel appears in the application which has the following optional inputs to be provided by the user:

- Project Name:
- Engineer Name:
- Route:
- City:
- Date:
- Notes: Any additional notes to be saved for future reference.

The screenshot displays the PavSafe v1.0.4 application window. The title bar shows the application name and version, along with standard window controls. The menu bar includes 'About', 'Help', and 'Export Data'. The left sidebar contains four buttons: 'Pavement Structure' (highlighted with an orange background), 'Subgrade Properties', 'Hydrological Information', and 'Results'. The main area is titled 'Project Information' and contains a form with the following fields: 'Project Name', 'Engineer Name', 'Route', 'City', 'Date', and 'Notes'. At the bottom of the main area, there are logos for the 'NRRA National Road Research Alliance' and the 'University of New Hampshire'.

The Pavement Structure, Subgrade Properties, Hydrological Information and Results Panels can be accessed by pressing the individual buttons on the left-hand side of the application screen. If these buttons are pressed again then the button is de-selected, and it brings the users back to the Project Information Panel.

PAVEMENT STRUCTURE PANEL

The Pavement Structure panel requires the user to input thickness (in units of cm or inch), resilient modulus (in units of MPa or ksi) and saturated hydraulic conductivity (in units of m/hour or ft/s) for Asphalt Concrete, Base and Subbase layers. Please note that it is not required to provide saturated hydraulic conductivity for the Asphalt Concrete layer. The users may choose to use the default values provided. The field “Type” was added in PaveSafe v1.0.4 and it provides the user 2 dropdowns to choose default values for AASHTO or MnDOT Class with respect to Base and Subbase selection (if other agencies provide us with their default materials and corresponding properties, those will be added to the selection drop-box). Note that, the units will change when US Customary is selected.

Type	Selection	Layers	Thickness (cm)	Modulus (MPa)	Ks,sat (m/hour)
		Asphalt Concrete	10	3000	
Base Selection	☒	Base	15	275.8	10
Subbase Selection	☒	Subbase	25	275.8	5

Base Selection: AASHTO A-1-a
Subbase Selection: AASHTO A-1-b

Logos: NRR, University of New Hampshire

In order to remove Base and Subbase layers from calculations in case those layers do not exist, users may opt to uncheck the respective selection check boxes. By default, these layers are selected for calculations.

SUBGRADE PROPERTIES PANEL

The default screen for the Subgrade Properties Panel has the following appearance:

PavSafe v1.0.4
About Help Export Data

Subgrade Properties

Pavement Structure
Asphalt Concrete
Base
subbase

Subgrade Properties
subgrade
GW

Hydrological Information

Results

Soil Type: Coarse Grained
Soil Category: A-2-4

Resilient Modulus at OMC (MPa): 65

van Genuchten's SWRC parameters
avG (1/m): 90
nvG (-): 3

Saturated Hydraulic Conductivity
☐ Input Value ☒ Estimate

Void Ratio, e: 0.6
Effective Grain Size, D10 (mm): 0.02
Ks saturated (m/hour): 0.002

Estimate Ks

NRRRA National Road Research Alliance
University of New Hampshire

PavSafe v1.0.4
About Help Export Data

Subgrade Properties

Pavement Structure
Asphalt Concrete
Base
subbase

Subgrade Properties
subgrade
GW

Hydrological Information

Results

Soil Type: Fine Grained
Soil Category: A-4

Resilient Modulus at OMC (MPa): 40

van Genuchten's SWRC parameters
avG (1/m): 1.6
nvG (-): 1.4

Saturated Hydraulic Conductivity
☐ Input Value ☒ Estimate

Void Ratio, e: 0.8
Liquid Limit (%): 10
Ks saturated (m/hour): 0.0002

Estimate Ks

NRRRA National Road Research Alliance
University of New Hampshire

The Soil Type dropdown menu controls the Soil Category dropdown and default values of other inputs appearing on the screen. The default value of Soil Type dropdown menu is “Coarse Grained” and can be changed to “Fine Grained”.

After the selection of the Soil Type, Soil Category based on AASHTO soil classification system must be selected. Based on the Soil Category default values of other inputs on the screen are populated. Users always have an option to change these values including resilient modulus at optimum moisture content (in units of MPa or ksi), van Genuchten’s SWRC fitting parameters, void ratio, effective grain size (D10) (in units of mm or inch).

The saturated hydraulic conductivity will be estimated based on either the default soil parameters or the input values, by pressing “Estimate Ks” button. If this button is not pressed, then a default value will be assigned, which may not exactly reflect the Soil Category.

Also, there is an option provided for the user to directly input saturated hydraulic conductivity via selecting the “Input value” radio button under the Saturated Hydraulic Conductivity box, if such value is available (in units of m/hour or ft/s).

The screenshot displays the PaveSafe v1.0.4 software interface. On the left is a vertical sidebar with four icons: 'Asphalt Concrete' (with sub-labels 'Base' and 'subbase'), 'Pavement Structure', 'Subgrade Properties' (highlighted with a sub-label 'GW'), 'Hydrological Information', and 'Results'. The main window is titled 'Subgrade Properties'. It contains several input fields and dropdown menus. 'Soil Type' is set to 'Fine Grained' and 'Soil Category' is set to 'A-4'. 'Resilient Modulus at OMC (MPa)' is set to 40. Under 'van Genuchten's SWRC parameters', αvG (1/m) is 1.6 and nvG (-) is 1.4. The 'Saturated Hydraulic Conductivity' section has two radio buttons: 'Input Value' (selected) and 'Estimate'. Below this, 'Ks saturated (m/hour)' is set to 0.0002. At the bottom right, there are logos for 'NRRRA National Road Research Alliance' and 'University of New Hampshire'.

HYDROLOGICAL INFORMATION PANEL

Hydrological Information Panel has the following required inputs:

- Period of Analysis (in hour): By default, this value is set to be for 10 days of analysis i.e. 240 hours.
- Input Climatic Data: The precipitation events can be provided as input to the application by first selecting the “Precipitation Event” checkbox and then providing the starting and ending hour values with the rate of precipitation (in units of cm/hour or inch/hour). However, if the box assigned for each precipitation event is not checked, that event would not be considered in the analysis.
- Initial Pondered Water Height (in units of m or ft): By default, we assume there is no ponded water above the ground hence default value is 0.
- Evaporation Rate (in units of m/hour or ft/hour): The default value set inside the application is 0.005 m/hour; however, if there is no ponded water above the ground, there will be no evaporation in the calculations.
- Water Runoff (as % of precipitation): This input is the percentage of precipitation water that runs off from the ground.
- Initial Ground Water Depth (in units of m or ft): This is the depth at which ground water table exists. By default, 3 meters is taken as input value.
- Initial Saturation Condition: The users can select the initial saturation condition of the ground above the water table to be hydrostatic or fully saturated. The default value set is hydrostatic condition above the water table, meaning linear suction profile with depth.

The default screen appears as below:

PavSafe v1.0.4
About Help Export Data

Hydrological Input

Period of Analysis (hour)

Precipitation Data Method Selection
☒ Input Climatic Data ☐ Import Climatic Data

Precipitation Event	Start (hour)	End (hour)	Rate (cm/hour)
☐	0	0	0
☐	0	0	0
☐	0	0	0
☐	0	0	0
☐	0	0	0

Initial Pondered Water Height (m)

Evaporation Rate (m/hour)

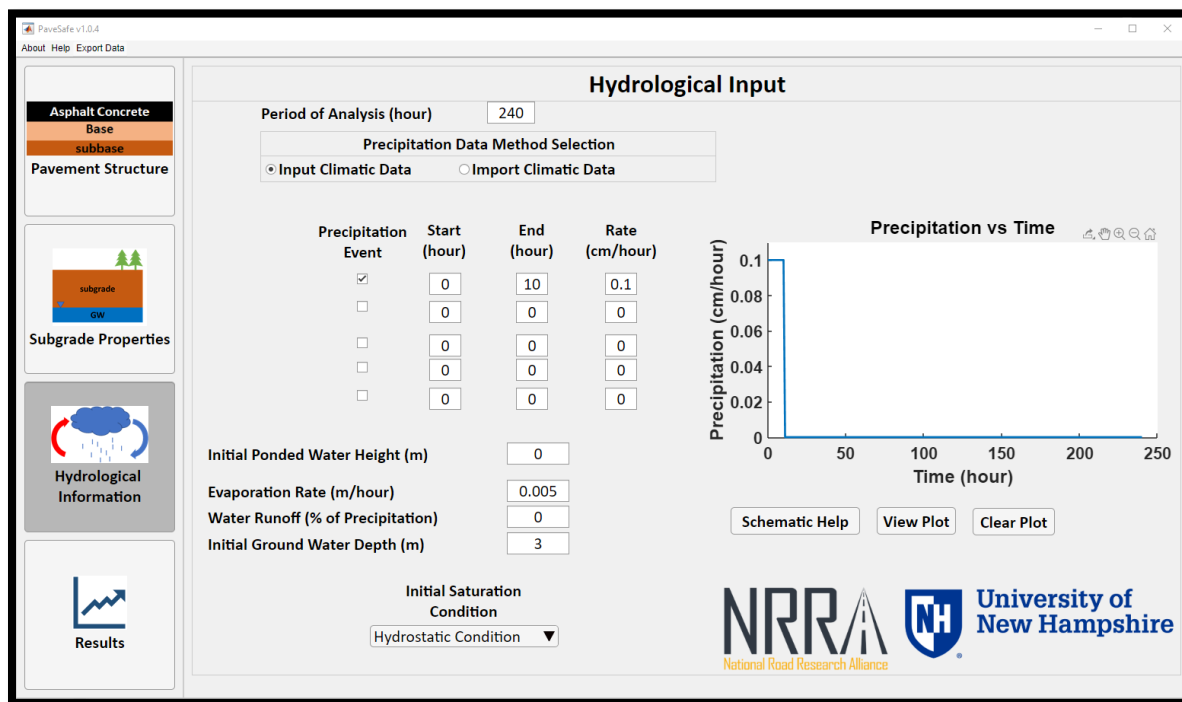
Water Runoff (% of Precipitation)

Initial Ground Water Depth (m)

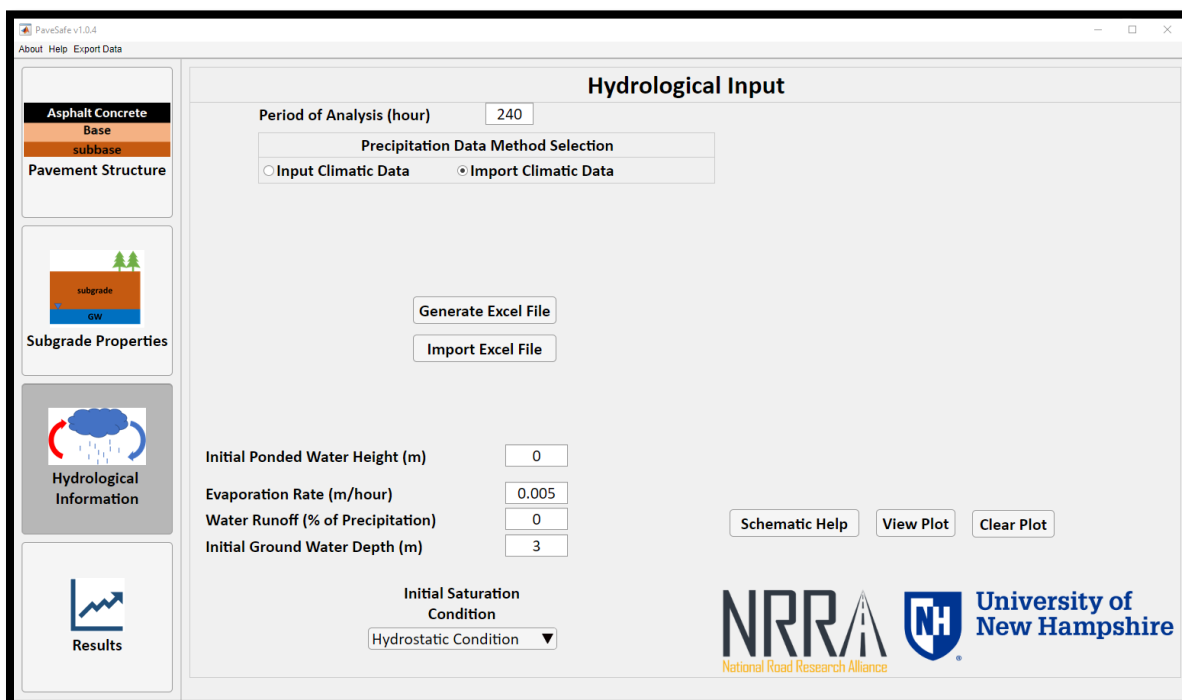
Initial Saturation Condition

NRRRA **University of New Hampshire**
 National Road Research Alliance

After providing the precipitation event data, the user can view the plot of precipitation data by clicking “View Plot” button and “Clear Plot” to clear the plot from the screen. A view plot example is as shown below:



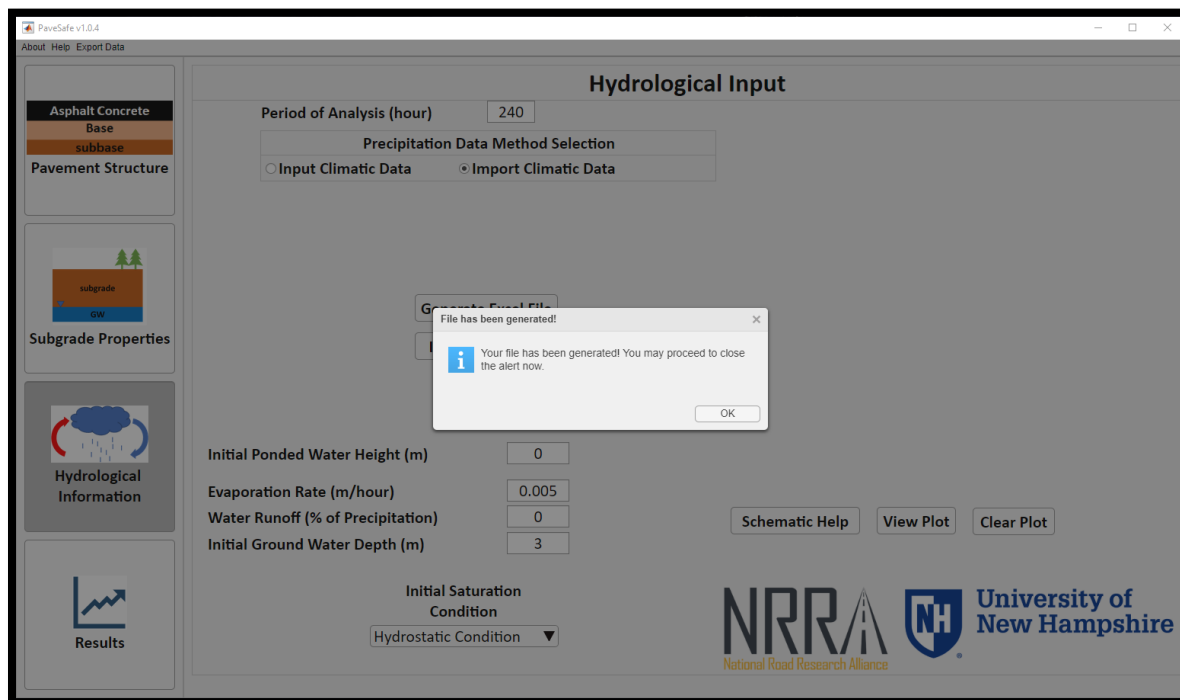
The other option is “Import Climatic Data”. The default screen that appears when selecting this option is shown below:



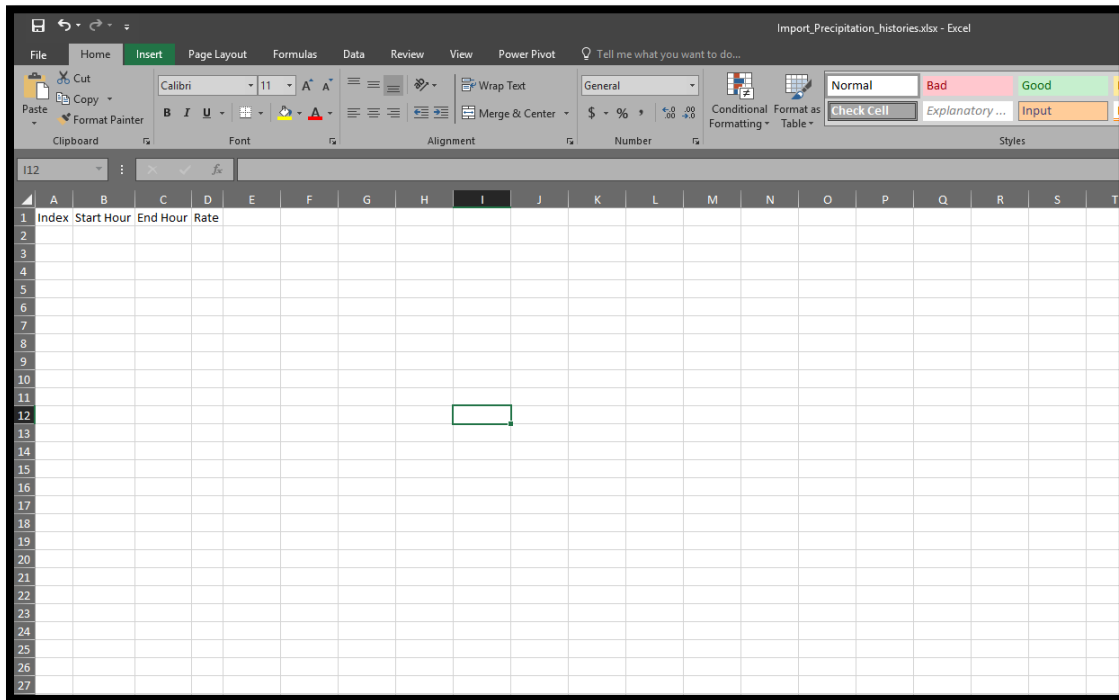
When clicking on “Generate Excel File” a window named “Select Folder to Open” will pop up. Simply clicking on “Select Folder” without need to select any specific folder, an excel file named “Import_Precipitation_histories.xlsx” is going to be generated in the PaveSafe Application Folder as shown below:

	Import_Precipitation_histories.xlsx	5/21/2021 8:44 AM	Microsoft Excel W...	6 KB
	PaveSafe.exe	5/21/2021 8:14 AM	Application	3,035 KB
	readme.txt	5/21/2021 8:14 AM	Text Document	2 KB
	splash.png	5/21/2021 8:14 AM	PNG File	226 KB

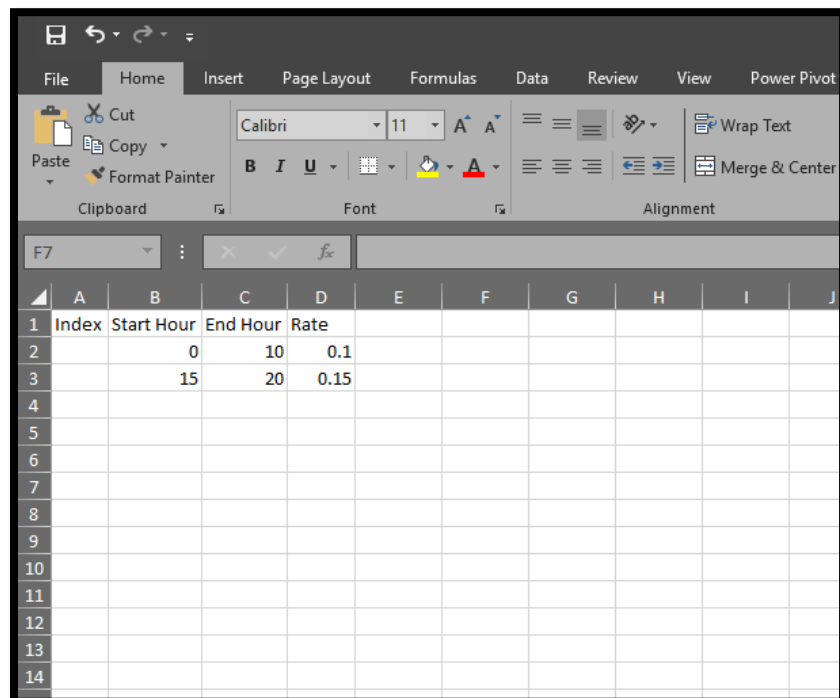
When the Excel file is generated and ready to use the App will show the notification shown below:



When opening the Excel file, its format is going to be as shown in the screenshot below:

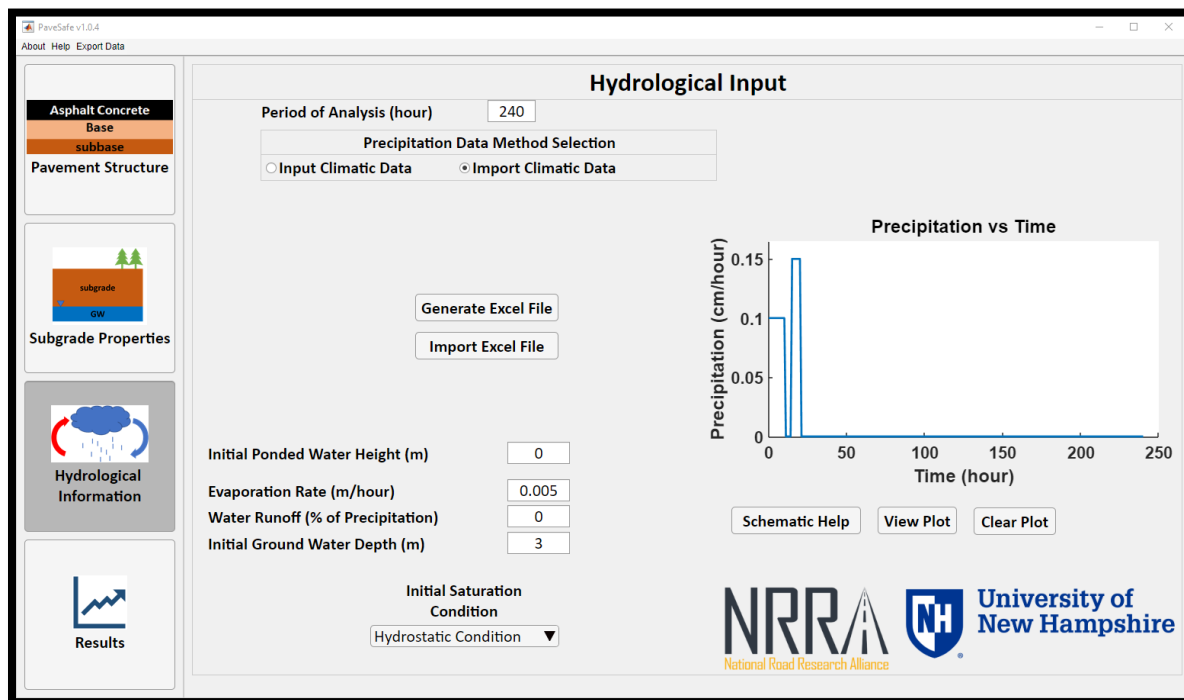


At this point the Start Hour, End Hour and Rate for the precipitation events can be inputted as shown below:

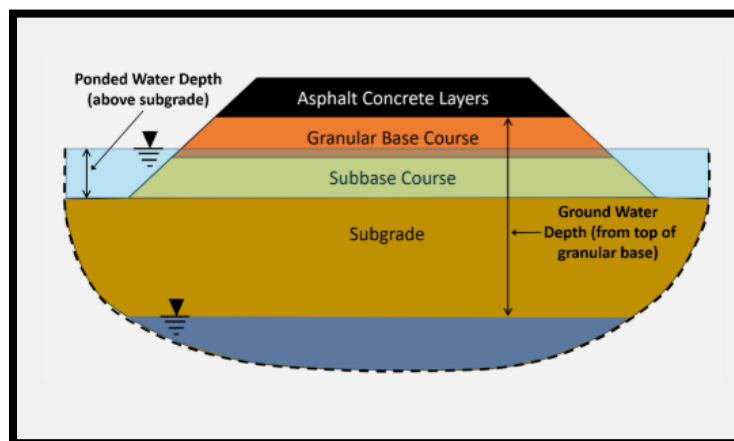


The user can also insert the ID or # of the precipitation event in the index column but it is not necessary for the input Excel file to work.

After saving the Excel file, the user can go back to the PaveSafe App and click on “Import Excel File” and select the Excel file from the PaveSafe Application folder. At this point, the user can click on “View Plot” to see a plot of the inputted precipitation events as shown below:

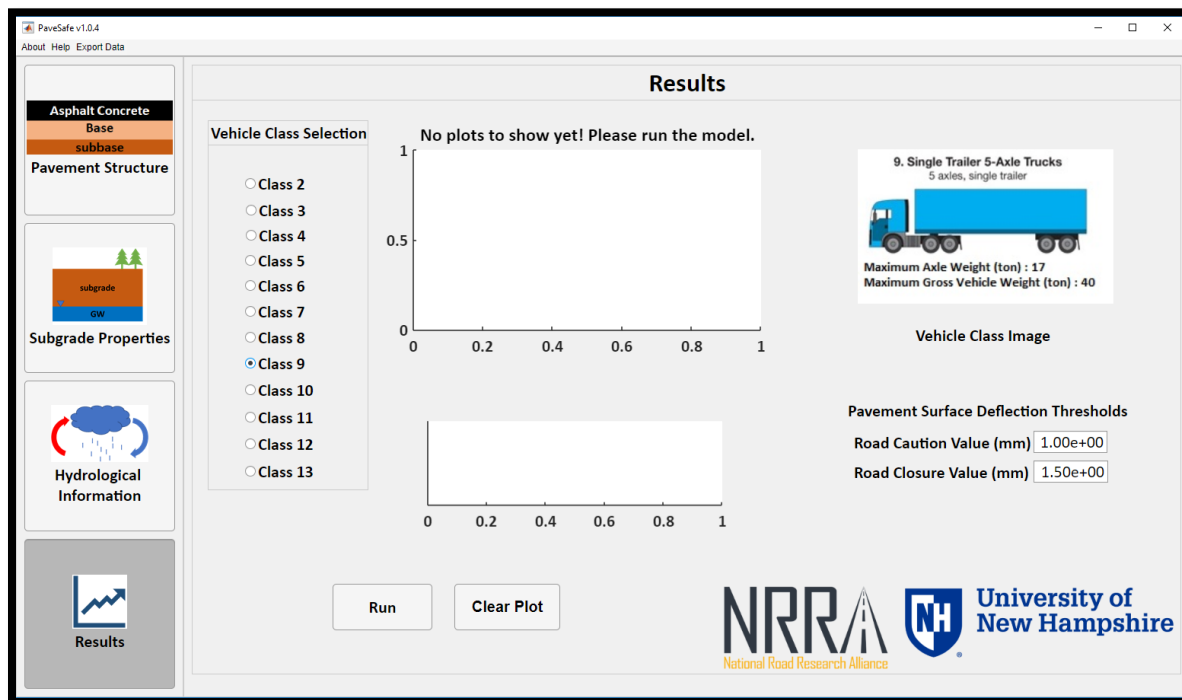


Also, in PaveSafe v1.0.4, a “Schematic Help” button was introduced explaining the underlying model. The schematic help is mentioned below for reference.



RESULTS PANEL

By default, the results panel has the following appearance:

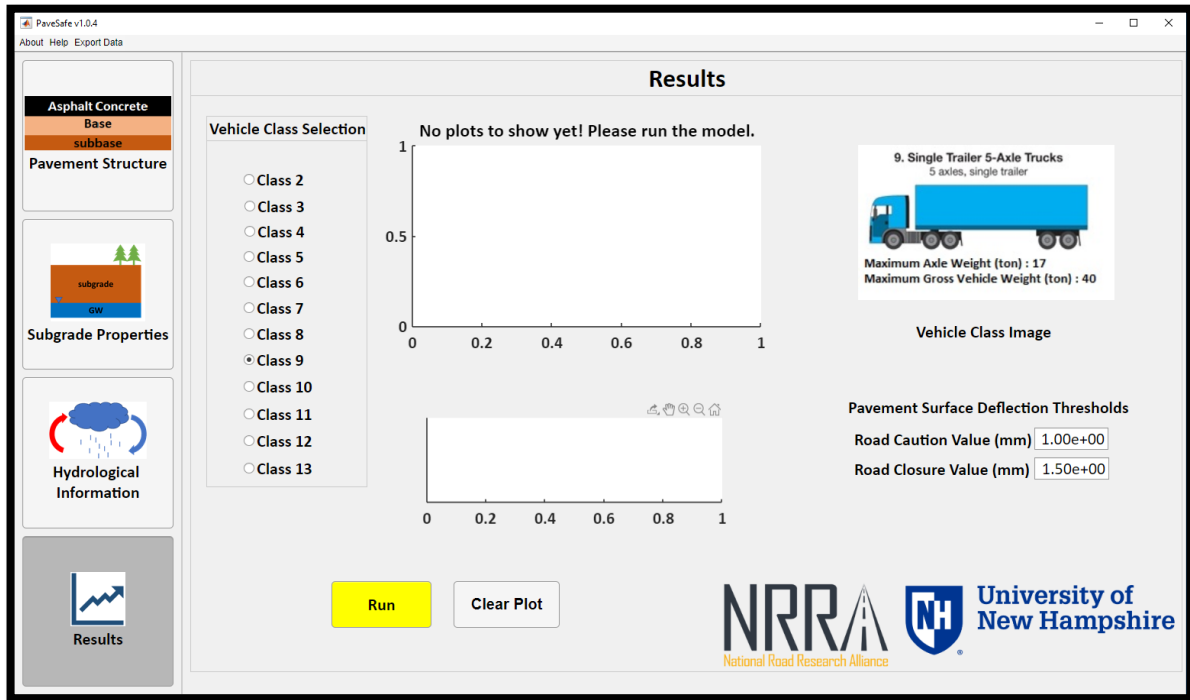


The users can opt to select the desired vehicle class and a representative image of that vehicle class will appear on the screen.

As input to the application, users can set the Pavement Surface Deflection Threshold for Road Caution and Road Closure (in mm or inch). By default, these values are set to 1 mm (0.04 inch) and 1.5 mm (0.06 inch) for Road Caution and Road Closure, respectively.

After the inputs are provided or retained, the application is ready to run. To run the application please press the “Run” button appearing on the screen.

While the model is running the “Run” button turns **Yellow** in color and users must wait until the model has completed the run cycle. The running state appears as below:



Once the model has finished its run cycle, the “Run” button turns **Green** and the deflection results are displayed on the figure at the top as a graph. A bell sound alerts the user of completed run. Also, safe passage information is visible at the bottom of the graph giving information about the condition of the road with respect to the selected vehicle class. **Green** Passage means the vehicle is safe to pass, **Yellow** means it is a caution zone and **Red** means completely unsafe. After the run cycle the Results Panel appears as below:



The users are provided the freedom to change the Road Caution and Road Closure values to view the effect on safe passage with the new values. Users must keep in mind that it is required to change the vehicle class to reflect changes with new Road Caution and Road Closure values. Also, any change in the application inputs (excluding changes to Project Information Panel) turns the “Run” button to **Gray**, which means a new analysis and run are needed.

Note that, users are also provided with a feature to export the analysis data. This feature is available in the Menu Tab and will be explained in detail in the following section.

MENU TAB

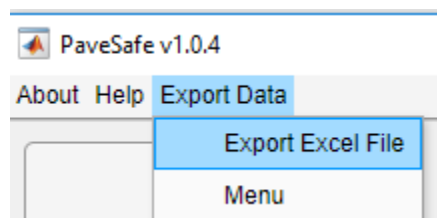
The Menu Tab appears at the top of the application and contains the following options:

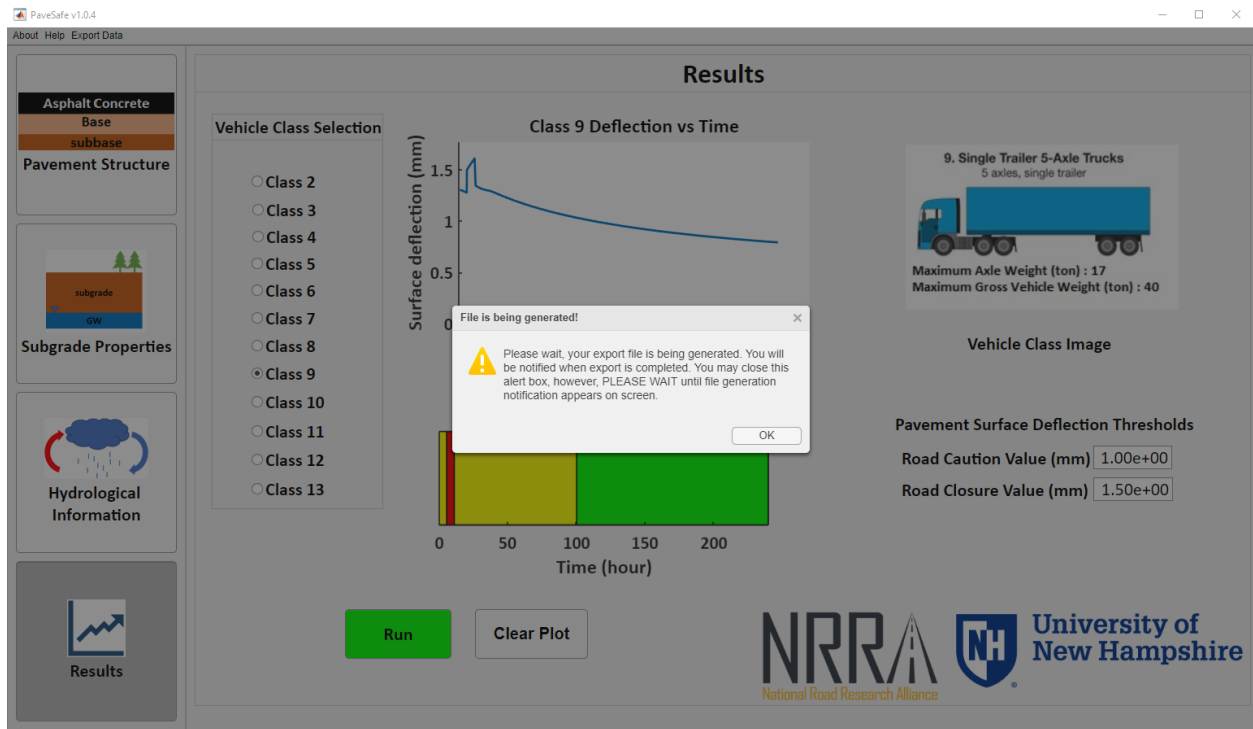
- About
- Help
- Export Data

The About menu brings up details about the application in the default browser. It is a pdf file and it has a possibility to be opened within the default pdf viewer on the system.

The Help menu brings up the User Manual for detailed information about the application.

The Export Data menu brings down “Export Excel File” dropdown. When this dropdown is clicked, it asks the users to provide the location where the generated file would be saved. Also, an alert box appears on the screen informing the user about the file generation process. Users may close this alert box, but they must wait until “File Generated” alert appears on the screen before they continue to interact with the application. The output file generated is a Microsoft Excel Worksheet with name “PaveSafe_ExportData”.





An example of the “PaveSafe_ExportData.xlsx” Excel file is shown below:

PaveSafe_ExportData.xlsx - Excel													
File Home Insert Page Layout Formulas Data Review View Power Pivot Tell me what you want to do...													
Clipboard Font Alignment Number Styles													
Q12													
	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Time (hour) ↓ / Deflection Value (mm) →	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
2	0	0.070199474	0.185714791	0.71726502	0.774632007	1.1508043	1.420161171	1.08132828	1.302403341	1.347541389	0.866366203	1.116096045	1.494820892
3	0.01	0.070178729	0.185708377	0.71723985	0.774604807	1.150770191	1.420119785	1.081296135	1.302361635	1.347507331	0.866335792	1.116062916	1.494777189
4	0.02	0.070176314	0.185701396	0.717214667	0.774577591	1.150738601	1.42007831	1.081263923	1.302319863	1.347473173	0.86630536	1.116029718	1.494733391
5	0.03	0.070173893	0.185695525	0.71718941	0.774550296	1.150701708	1.420036684	1.081231596	1.302277952	1.347438879	0.866274837	1.115996401	1.494689436
6	0.04	0.070171463	0.185689707	0.717164075	0.774522916	1.150667281	1.419995907	1.081199153	1.302235896	1.347404451	0.866244217	1.115962964	1.494645332
7	0.05	0.070169027	0.185682595	0.71713866	0.77449545	1.150632731	1.419952978	1.081166594	1.302193695	1.34736989	0.866213501	1.115929407	1.494601045
8	0.06	0.070166582	0.1856761	0.717113166	0.774467898	1.150598059	1.4199109	1.08113392	1.302151352	1.347335199	0.866182687	1.115895732	1.494556612
9	0.07	0.070164128	0.185669579	0.717087567	0.774440233	1.150563227	1.419868627	1.081101095	1.302108821	1.347300338	0.866151745	1.115861902	1.494511974
10	0.08	0.070161664	0.185663031	0.717061866	0.774412458	1.150528237	1.419826516	1.081068123	1.302066104	1.347265307	0.866120678	1.115827919	1.494467132
11	0.09	0.070159198	0.185656479	0.717036143	0.774384659	1.150493217	1.419783656	1.08103512	1.302023351	1.347230245	0.866089585	1.115793905	1.49442225
12	0.1	0.070156724	0.185649905	0.717010339	0.774356772	1.150458073	1.419741002	1.081002003	1.301980452	1.347195052	0.866058392	1.115759773	1.494377209
13	0.11	0.070154238	0.185643286	0.716984402	0.774328743	1.150422729	1.419698102	1.080968996	1.301937318	1.347159644	0.86602704	1.115725445	1.494333191
14	0.12	0.070151756	0.185636702	0.716958511	0.77430076	1.150387458	1.41965529	1.080935458	1.301894267	1.347124233	0.865995729	1.115691189	1.494288707
15	0.13	0.070149261	0.185630073	0.716932486	0.774272633	1.150351982	1.419612232	1.080902027	1.301850974	1.347088778	0.865964276	1.115656733	1.4942441237
16	0.14	0.070146759	0.185623425	0.716906388	0.774244428	1.1503164	1.419569043	1.080868497	1.301807577	1.347053125	0.865932725	1.115622175	1.494199533
17	0.15	0.070144251	0.18561676	0.716880222	0.77421615	1.150280713	1.419525725	1.080834868	1.301764016	1.347017358	0.86590109	1.115587515	1.494149893
18	0.16	0.070141741	0.18561009	0.716854039	0.774187853	1.15024501	1.419482388	1.080801223	1.301720452	1.346981582	0.865869436	1.115552839	1.494104133
19	0.17	0.070139215	0.185603377	0.716827685	0.774159371	1.150209039	1.419438722	1.080767326	1.301676575	1.346945511	0.865837572	1.115517902	1.494058025
20	0.18	0.070136693	0.185596675	0.716801373	0.774130935	1.150173144	1.419395152	1.080733501	1.301632784	1.346909534	0.86580576	1.115483041	1.494012019
21	0.19	0.070134158	0.18558994	0.716774929	0.774102356	1.150137064	1.419351329	1.080699462	1.301588753	1.346873332	0.865773787	1.115447979	1.493966346
22	0.2	0.070131618	0.18558319	0.716748429	0.774073716	1.150100961	1.419307406	1.080665387	1.301544623	1.346837046	0.865741744	1.115412838	1.493921968
23	0.21	0.070129072	0.185576404	0.716721865	0.774045007	1.150064584	1.419263368	1.080631202	1.301500382	1.34680066	0.865709625	1.115377605	1.493877568
24	0.22	0.070126519	0.185569641	0.716695236	0.774016228	1.150028213	1.419219215	1.080596928	1.301456028	1.346764176	0.865677427	1.11534228	1.493832646
25	0.23	0.07012396	0.185562842	0.71666854	0.773987377	1.149991738	1.419174935	1.080562557	1.301411553	1.346727582	0.865645146	1.115306855	1.493779492
26	0.24	0.070121396	0.185556028	0.716641787	0.773958463	1.149955181	1.419130554	1.080528108	1.301366978	1.346690902	0.865612796	1.11527135	1.493732631
27	0.25	0.070118826	0.185549197	0.716614966	0.773929477	1.14991852	1.419088048	1.080493562	1.301322282	1.346654112	0.865580363	1.115235744	1.493685637
28	0.26	0.07011625	0.185542353	0.716588094	0.773900434	1.14988176	1.41904452	1.080458947	1.301277698	1.346617247	0.865547868	1.115200066	1.493638549
29	0.27	0.070113668	0.185535492	0.716561157	0.773871322	1.149844954	1.418996737	1.08042424	1.301232599	1.346580278	0.865515293	1.115164296	1.493591335
30	0.28	0.070111081	0.185528616	0.71653416	0.773842144	1.149808032	1.418953111	1.080389448	1.301187593	1.346543214	0.865482645	1.115128437	1.493544004
31	0.29	0.070108488	0.185521726	0.716507107	0.773812907	1.14977103	1.418909877	1.08035458	1.301142491	1.346506065	0.86544993	1.1150925	1.49349657
32	0.3	0.07010589	0.185514822	0.716479996	0.773783607	1.14973394	1.418861956	1.08031963	1.301097285	1.346468825	0.865417143	1.115056477	1.493449023
33	0.31	0.070103286	0.185507902	0.716452825	0.773754242	1.149696759	1.418816815	1.080284595	1.301052172	1.346431488	0.865384283	1.115020367	1.49340136
34	0.32	0.070100677	0.185500969	0.716425603	0.773724821	1.149659504	1.418771583	1.080249489	1.301006571	1.346394075	0.865351361	1.114984185	1.49335336
35	0.33	0.070098062	0.185494021	0.716398318	0.773695333	1.149622155	1.418726236	1.080214295	1.300961058	1.346356596	0.865318363	1.114947911	1.493305729
36	0.34	0.070095442	0.185487076	0.716370965	0.773665792	1.149584735	1.418680802	1.080179034	1.300915461	1.346318973	0.865285306	1.114911560	1.493257748
37	0.35	0.070092817	0.185480084	0.716343596	0.773636319	1.14954723	1.418635266	1.080143694	1.300869764	1.346281296	0.865252179	1.114875144	1.493209667
38	0.36	0.070090187	0.185473095	0.71631615	0.773606528	1.149509642	1.418589626	1.080108274	1.300823968	1.346243531	0.865218985	1.114838637	1.493161479
39	0.37	0.070087563	0.185466092	0.716288743	0.773576915	1.149472051	1.418543889	1.080072787	1.300778085	1.346205666	0.865185729	1.114802063	1.493113287

The file is organized in 13 columns. The first column represents all the times at which the deflection on top of the pavement surface was calculated, and all of the other columns show deflection values for all the different vehicle classes (Class 2 to 13).