Integrated Modeling for Road Conditions Prediction: System User Guide

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Draft

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Federal Highway Administration

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1,000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2,000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	2.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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LIST OF ABBREVIATIONS

ADCIRC	Advanced Circulation model for oceanic, coastal, and estuarine waters
AHPS	Advanced Hydrologic Prediction Service
ASOS	Automated Surface Observing System
CAP	Common Alerting Protocol
ConOps	Concept of operations
CV	Connected vehicle
DMS	Dynamic message sign
EOC	Emergency operations center
FHWA	Federal Highway Administration
GFS	Global Forecast System
IMRCP	Integrated Model for Road Condition Prediction
METRo	Model of the Environment and Temperature of Roads
NDFD	National Digital Forecast Database
NHC	National Hurricane Center
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
RAP	Rapid Refresh weather model
RTMA	Real-Time Mesoscale Analysis
SLOSH	Sea Lake and Overland Surges from Hurricanes model
TMC	Transportation management center
TSMO	Transportation systems management and operations
USDOT	United States Department of Transportation

CHAPTER 1. INTRODUCTION

BACKGROUND

Transportation agencies face many challenges when working toward effective transportation systems management and operations (TSMO). Weather, incidents, and events outside the knowledge and control of transportation agencies and travelers can reduce a free flow of traffic to a snarled mess in minutes or seconds. Whether the focus is on traffic incident management, work zones, active traffic management, or emergency evacuation routing, the intent of TSMO is to minimize and mitigate the impact of disruptions and to enable travelers to make better choices for safe and reliable travel.

The breadth of information available to support TSMO strategies fortunately has been expanding to meet the needs. Views of traffic conditions, road weather, incidents and work zones, and flooding and extreme events have been expanded by augmenting an agency's own data with other private and crowdsourced data. The views of conditions that might affect safety and mobility across the transportation network has grown both broader and more detailed. These views have, however, still been somewhat limited by their lack of integration and by being limited to current and past conditions. The next level of decision support for TSMO needs to be integrated across the technical disciplines and provide a view into likely future conditions.

The Federal Highway Administration (FHWA) Road Weather Management Program[1] began developing Integrated Modeling for Road Condition Prediction (IMRCP) in 2015 to provide data and decision support for these kinds of events. IMRCP is a tool that incorporates real-time and archived weather and traffic conditions data and results from forecast and probabilistic models to predict current and future road and travel conditions. It provides tools for what-if analyses; views of the data from archives; and views of the data from near-past, present, and future operational time horizons. IMRCP supports transportation system and emergency operations in decisionmaking and after-action reviews.

Previous phases of IMRCP developed the foundational traffic and weather data system components, including a machine learning-based traffic model. Previous phases also deployed the system at the scale of a metropolitan area, operated the system for five winter seasons, evaluated the operational results, and updated the system documentation. IMRCP phase 5 improved and demonstrated IMRCP capabilities as an agency-deployable system with multiple contiguous States managing evacuations and responses to adverse weather conditions. IMRCP's improvements have included traffic forecasting for tropical storm conditions, a dashboard for user-configurable event alerts, data management and processing speed to accommodate multiple large road networks, and data sharing across deployments. IMRCP capabilities have been demonstrated in a regional deployment over Louisiana, Mississippi, and Alabama to support analysis and management of evacuation, response, and recovery from adverse weather

[1] "Road Weather Management Program," FHWA, USDOT, last accessed April 3, 2025, https://ops.fhwa.dot.gov/weather/.

conditions. The improved IMRCP capabilities, updated technical documentation, and training materials are packaged for future deployments in an open-source repository.[2]

PURPOSE

The purpose of this System User Guide is to provide a description of the IMRCP system user interface, its functions, and features. This document includes instructions for using the interface, a sample set of practical use cases, and definitions of the map interface layers, data types, and alerts.

DOCUMENT OVERVIEW

Chapter 1 provides background information as context for the rest of the document.

Chapter 2 describes the system architecture to provide context for the user instructions.

Chapter 3 presents information on using the IMRCP user interface, including the map interface, scenario creation and viewing, and creating and accessing reports and subscriptions.

Chapter 4 outlines possible uses of the IMRCP system and provides example applications for actual events.

Appendix A describes the layers on the map interface.

Appendix B describes the observation types available in the system.

Appendix C describes alerts provided by the system.

Appendix D provides an example for loading user-specific content as overlays to the IMRCP maps.

[2] "OSADP/IMRCP," IMRCP GitHub repository, last accessed April 3, 2025, https://github.com/OSADP/IMRCP.

CHAPTER 2. SYSTEM OVERVIEW

The IMRCP system provides a framework for the integration of road condition monitoring and forecast data to support tactical and strategic decisions by travelers, transportation operators, and maintenance providers. The system collects and integrates environmental observations and transportation operations data; collects forecast environmental and operations data when available; initiates road weather and traffic forecasts based on the collected data; generates travel and operational advisories and warnings from the collected real-time and forecast data; and provides the road condition data, forecasts, advisories, and warnings to other applications and systems. Road condition and operations data and forecasts to be integrated into the prediction include atmospheric weather; road (surface) weather; small stream, river, and coastal water levels; road network capacity; road network demand; traffic conditions and forecasts; traffic control states; work zones; maintenance activities and plans; and emergency preparedness and operations.

The IMRCP system performs six major functions:

- Collecting weather, traffic, operations, and hydrological data for use in predicting road and weather conditions.
- Storing the collected and system-generated data.
- Generating forecasts of traffic and road conditions.
- Mapping the forecasts, current conditions, alert notifications, and archive data for system users;
- Reporting on forecasts, current conditions, alerts, and archive data.
- Enabling “what-if” analyses of operational and maintenance strategies for traffic and road weather conditions.

Data sources and the road network model are specific to particular geographic areas. Observations from these data sources are stored in the IMRCP data store as sets of specific observation types. These data types are classed according to the model objects—like roadways, sensors, or atmospheric weather—to which they apply. All observation types and their sources are described in Appendix B.

The IMRCP system forecasts road weather, traffic, and hydrological conditions using data from the data store. The forecasted data is then written to the data store as additional sets of observation types, also described in Appendix B.

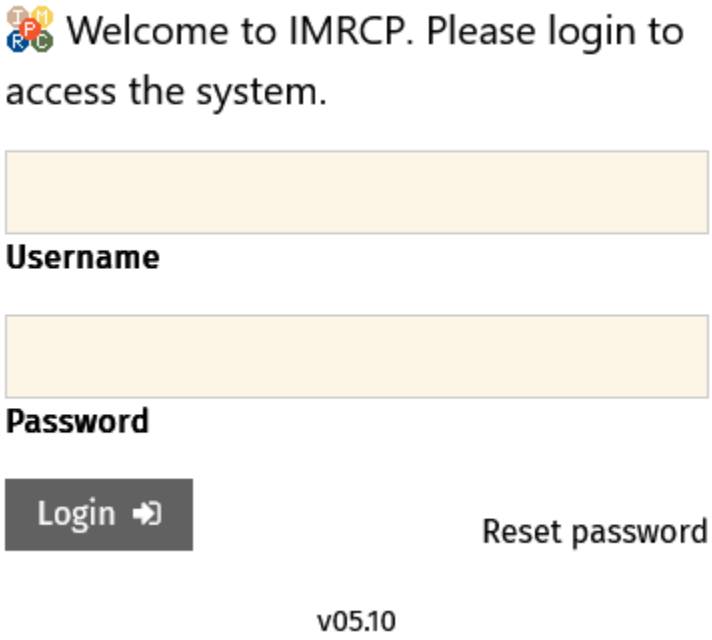
Data from the data store is presented to the user through the IMRCP user interface. The data populates layers on the map interface and is used to create alerts. Users may also view the data through reports and subscriptions.

CHAPTER 3. USER INSTRUCTIONS

LOGIN

The IMRCP user interface is accessed at through a web browser[3] at the site address provided by the system administrator.[4] User accounts are set up by the system administrators. A prospective user provides a contact email address to the administrators, who assign a password for the account. Administrators then send the account name and password back to the prospective user.

As shown in Figure 1, users input their username and password and click "Login" on the IMRCP landing page to access the IMRCP user interface. Users who have previously been provided with passwords but have lost their password can get a new password by clicking the "Reset password" link.



Source: FHWA.

Figure 1. Screen capture. IMRCP login dialog.

A successful login presents the IMRCP user interface, which may at the user's discretion default to a map or a dashboard.

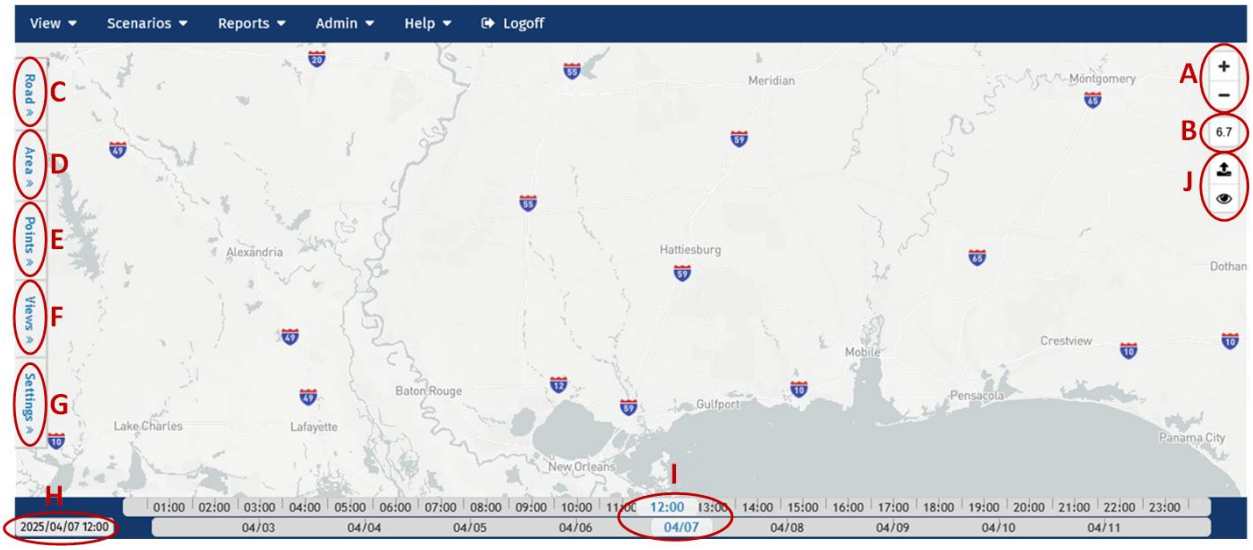
[3] The instructions and examples in this manual presume that the user is accessing the system with a typical personal computer browser.

[4] For example, the site used in the IMRCP phase 5 deployment for Louisiana and Mississippi is https://imrcp.data-env.com/ .

MAP

The IMRCP map is the view when first logging into the system. It provides views of road conditions, weather conditions, and alerts in the immediate past, present, and near future.

The map view is available from the leftmost pulldown "View" tab at the top of the IMRCP window. Map controls as shown in figure 2 are described in the following sections.



Source: FHWA.

Figure 2. Screen capture. Map User Controls.

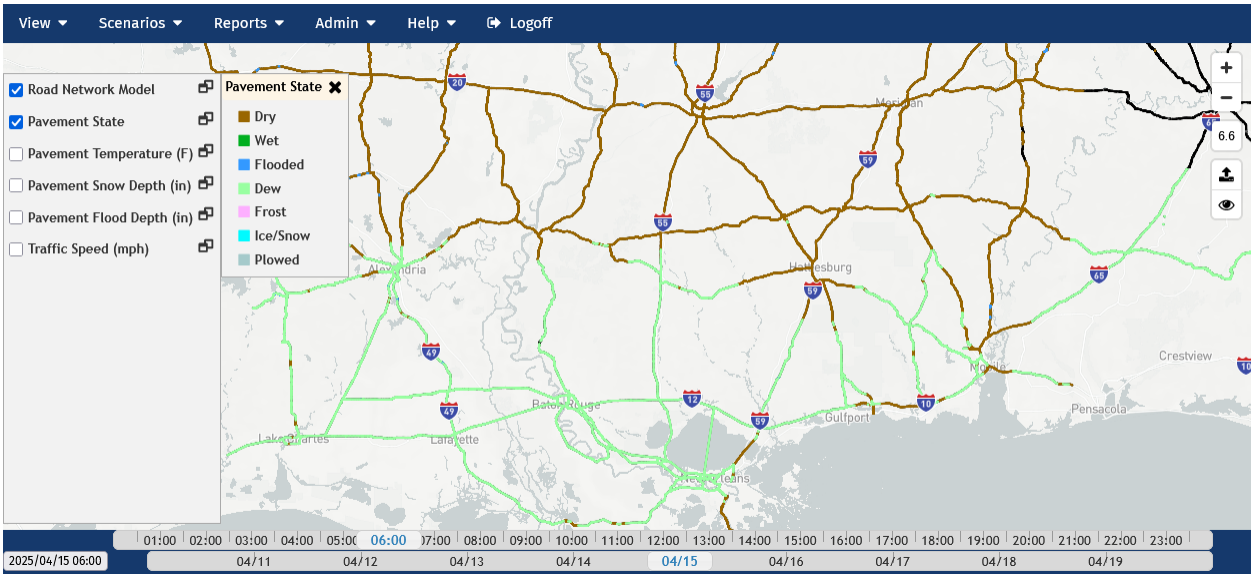
Using Map Tools

1. To zoom into and out of the map, use the zoom controls (A in figure 2) in the top right corner of the map or use the mouse's scroll wheel while the cursor is positioned over the map. Some map layers (for example, roads) may appear only when zoomed in to sufficient detail. The zoom level indicator (B) provides a reference.

2. To move the map, left-click on the map and drag the cursor.

Viewing Road Condition Data

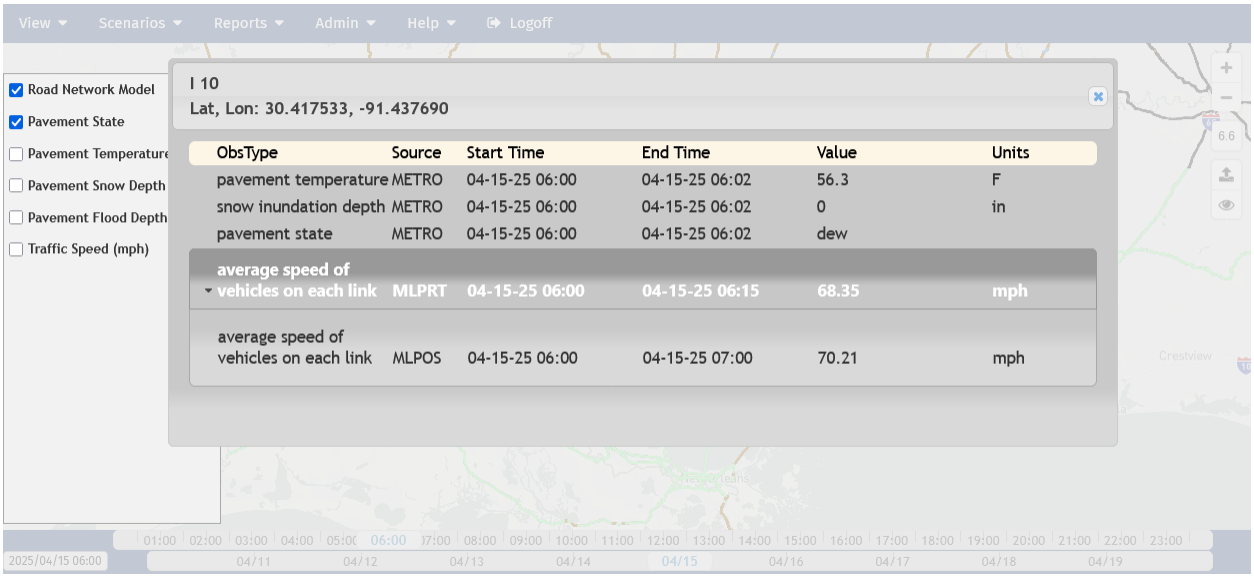
3. As shown in figure 3, users select a road data layer from the "Road" tab and panel (C in figure 2) on the left side of the page. Left-click the tab to open the panel. Select the type of data to be displayed by left-clicking the checkbox to the left of the layer label. Users can select multiple layers to be displayed, with the last layer selected on top. Left-clicking the icon to the right of a layer label opens the map legend for that layer. Left-click the ✖ icon on the legend or the icon to the right of the layer label to close the legend panel. Left-click the "Road" tab to close list of layers. The layer definitions can be found in appendix B.



Source: FHWA.

Figure 3. Screen capture. Viewing road condition data.

4. Left-click on a road segment on the map to view detailed data (figure 4) for that road segment at the date and time indicated on the time controls (H in Figure 2). Left-click the icon to close the details dialog.

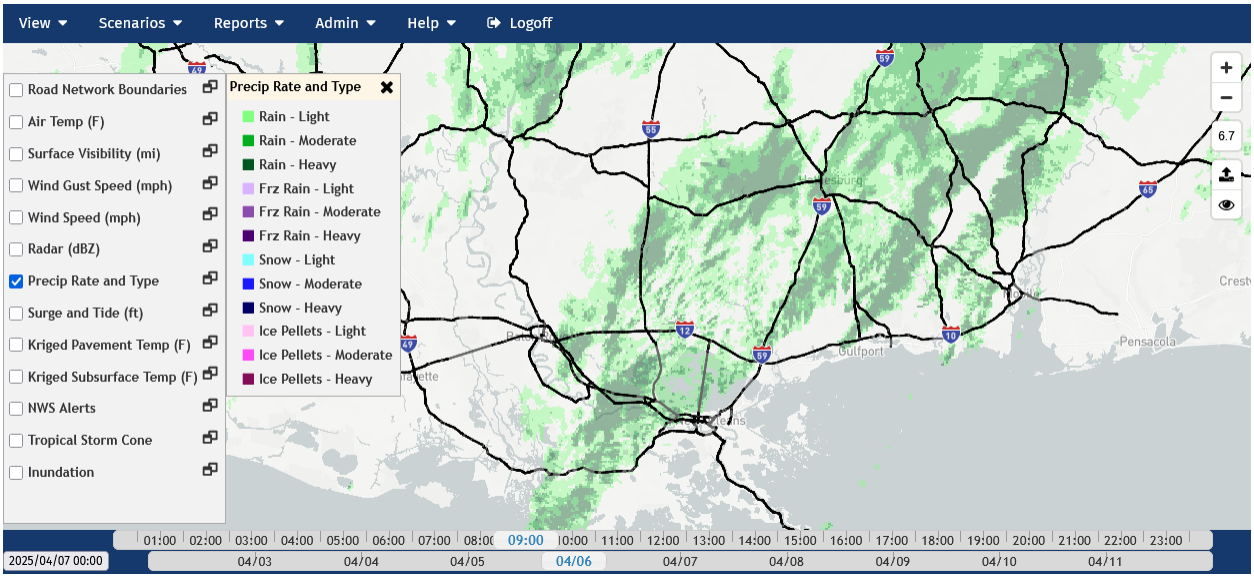


Source: FHWA.

Figure 4. Screen capture. Viewing road condition data details.

Viewing Area and Weather Condition Data

5. Users select an area data layer from the “Area” tab and panel (D on figure 2) on the left side of the page. Left-click the tab to open the panel. Select the type of data to be displayed by left-clicking the checkbox to the left of the layer label (figure 5). Users can select multiple layers to be displayed, with the last layer selected on top. Left-clicking the icon to the right of a layer label opens the map legend for that layer. Left-click the ✖ icon on the legend or the icon to the right of the layer label to close the legend panel. Left-click the “Area” tab to close list of layers. The layer definitions can be found in appendix B.



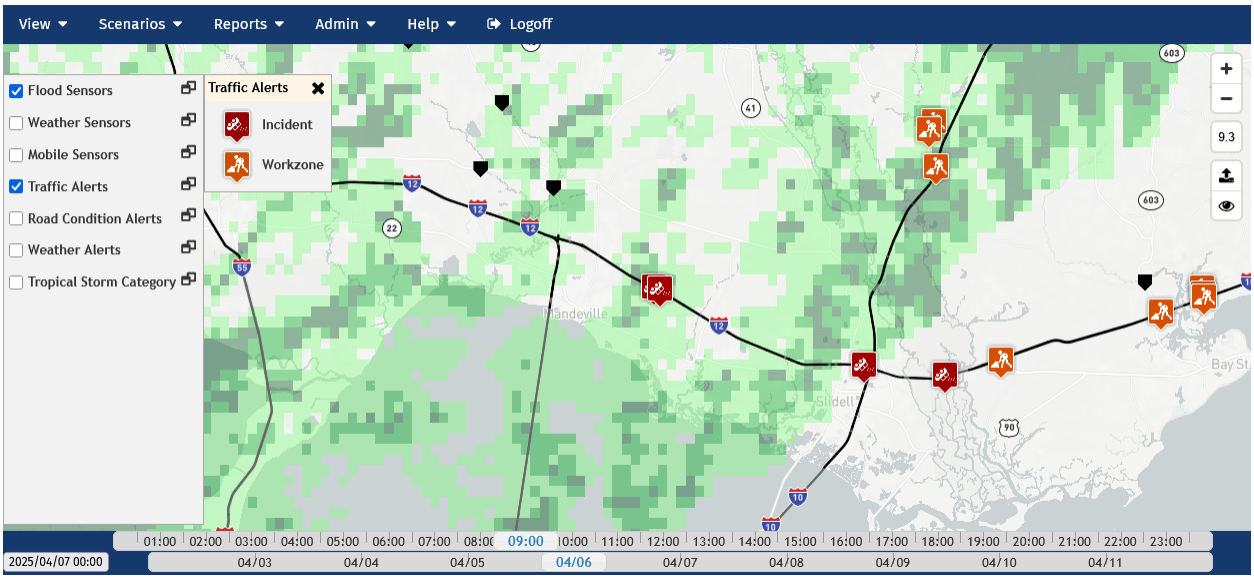
Source: FHWA.

Figure 5. Screen capture. Viewing area and weather condition data.

6. Left-click on a location with data for the selected layer on the map to view detailed data for that location at the date and time indicated on the time controls (I on figure 2). Left-click the icon to close the details dialog.

Viewing Alerts and Field Sensor (Points) Data

1. Users select a points data layer from the “Points” tab and panel (E on figure 2) on the left side of the page. Left-click the tab to open the panel. Select the type of data to be displayed by left-clicking the checkbox to the left of the layer label (figure 6). Users can select multiple layers to be displayed, with the last layer selected on top. Left-clicking the icon to the right of a layer label opens the map legend for that layer. Left-click the ✖ icon on the legend or the icon to the right of the layer label to close the legend panel. Left-click the “Points” tab to close list of layers. The layer definitions can be found in appendix B.



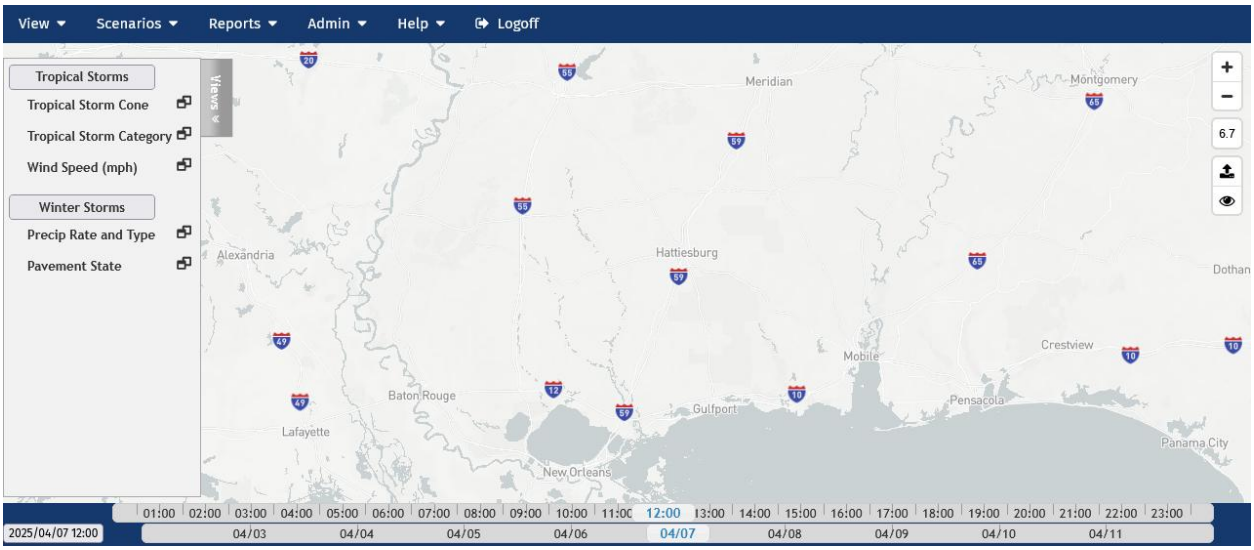
Source: FHWA.

Figure 6. Screen capture. Viewing alerts and field sensor data.

2. Left-click on a point layer icon on the map to view detailed data for that location at the date and time indicated on the time controls (H on figure 2). Left-click the icon to close the details dialog. Alert definitions can be found in appendix C.

Viewing Tropical Storms or Winter Storms with the Views Tab

1. Users can quickly select a view of tropical storm or winter storm data layers from the "Views" tab and panel (F on figure 2) on the left side of the page. Left-click the tab to open the panel. Select the type of storm to be displayed by left-clicking the button for the type of storm. (figure 7). Left-clicking the icon to the right of a layer label opens the map legend for that layer. Left-click the icon on the legend or the icon to the right of the layer label to close the legend panel. Left-click the "Views" tab to close the list of layers. Users can select additional layers to be displayed, with the last layer(s) selected on top, from the other tabs. The data layer definitions can be found in appendix B.

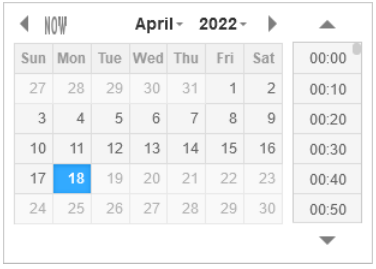


Source: FHWA.

Figure 7. Screen capture. Viewing tropical or winter storm data.

Using the Time Selector

1. To view the map data layers for the immediate past, current, or future time frames, select a date and time on the time controls at the bottom of the map **(**I on figure 2).
2. The reference time frame can be set further into the past by left-clicking on the reference date-time display indicator (H in figure 2). A small calendar dialog will pop up over the map (figure 7). Select a date on the calendar using the year and month pulldown arrows or the left and right arrows at the top of the dialog to change the month and the calendar to select the day. Select the reference time on that day from the list on the right of the dialog. The dialog disappears when a time is selected. The date and time in the box and on the slider are changed to the new reference time for the view. Moving the time control sliders to the left will display data for that time. Moving the sliders to the right of the reference date and time will display forecasts as seen from that reference time.
3. To go back to the current time, click on the date display (H on figure 2) and then click on "NOW" in the upper left-hand corner of the pop-up dialog.



Source: FHWA.

Figure 8. Screen capture. Reference time selection control.

Changing Settings for the Map View

Users can change and save map view settings as account defaults using the "Settings" tab and panel (G on figure 2) on the left side of the page.

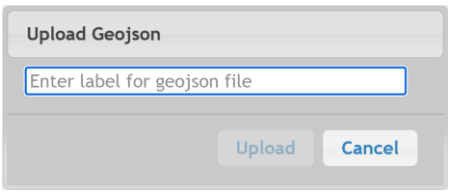
1. Set the map zoom level, location, and time frame.
2. Click on the "Settings" tab.
3. A selection box enables users to show or not show the latitude and longitude at the cursor location on the map.
4. Map Behaviors can be configured to refresh the map view with no refresh, 2-minute, or 5-minute intervals."
5. Users can adjust the area layer opacity from 10 to 100 per cent. Higher opacity will obscure the underlying map detail.
6. Users can select either the dashboard or the map as their default view.
7. The current settings can be saved as defaults and will become active when the "Settings" tab is clicked to close the panel.

Adding and Viewing User-specified Map Layers

Users can add custom data layers over the IMRCP data layers using the upload and view GeoJSON controls on the upper left of map interface (J on figure 2). The map layers to be uploaded and viewed must be described in a standard GeoJSON file. A sample file is provided in Appendix D.

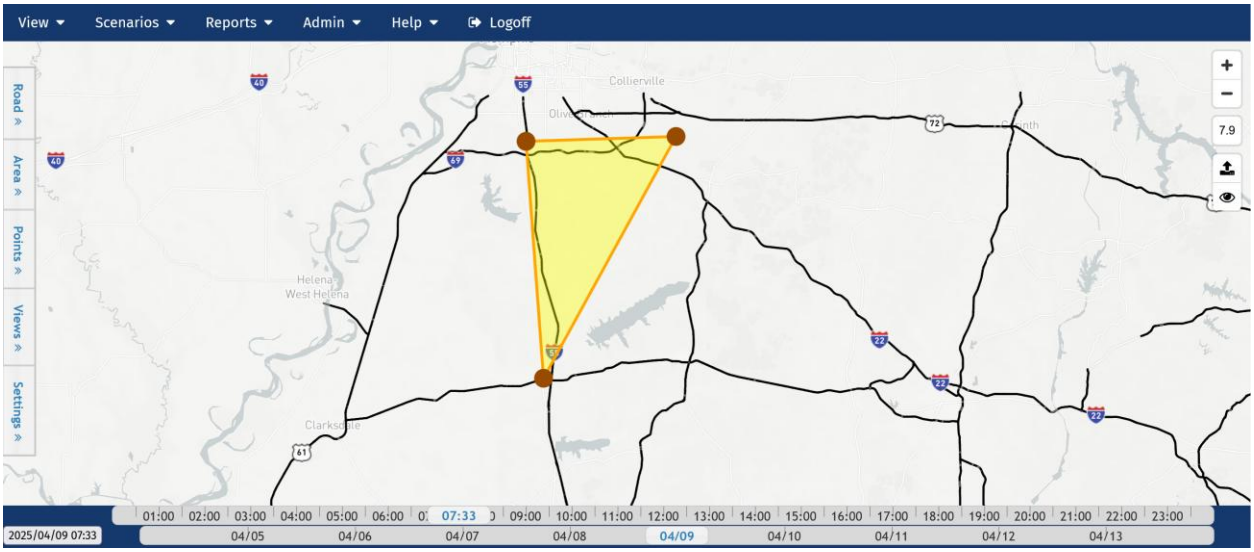
1. To load a GeoJSON file, click the upload button . A File Upload dialog will open for file selection. Select and open the file containing the GeoJSON.

2. A dialog for creating a label for the map layer content opens (figure Figure). Enter a label (without spaces or special characters other than a hyphen or underscore) and click the Upload button. The file is uploaded and the view is returned to the map with the GeoJSON file content visible on the map (figureFigure 10).



Source: FHWA.

Figure 9. Screen capture. Upload GeoJSON dialog.

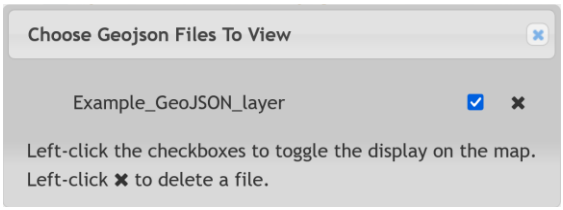


Source: FHWA.

Figure 10. Screen capture. Example GeoJSON layer displayed on map.

3. Uploaded layers remain available for future IMRCP sessions and are selectable. To select which custom layers to view, click on the view control .

4. A dialog for selecting layers is displayed. Select and deselect the desired layers by clicking the checkbox(es). A file can be removed from the list by clicking the ✖ icon to the right of the checkbox. Click the blue close button in the upper right of the dialog to close it. The view is returned to the map.



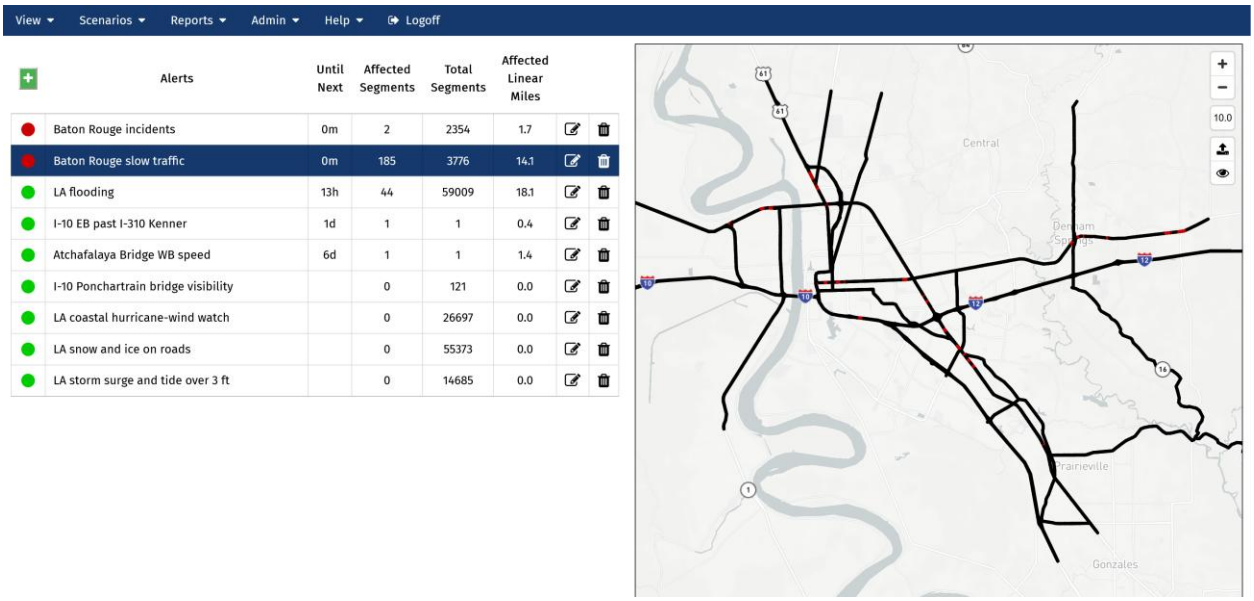
Source: FHWA.

Figure 11. Screen capture. Choosing GeoJSON layers dialog.

DASHBOARD

The IMRCP dashboard provides a list of realtime and forecast alerts and localized views of road conditions, weather conditions, and events. Eash user specifies a list of alerts for their applications.

The dashboard is selected from the leftmost pulldown “View” tab at the top of the IMRCP window. As shown in Figure 12, the lefthand panel displays a table of user-configured alerts and their current status. The righthand panel displays a map of the alert conditions selected from the lefthand table. The available upper righthand map controls work as described in the Map section.



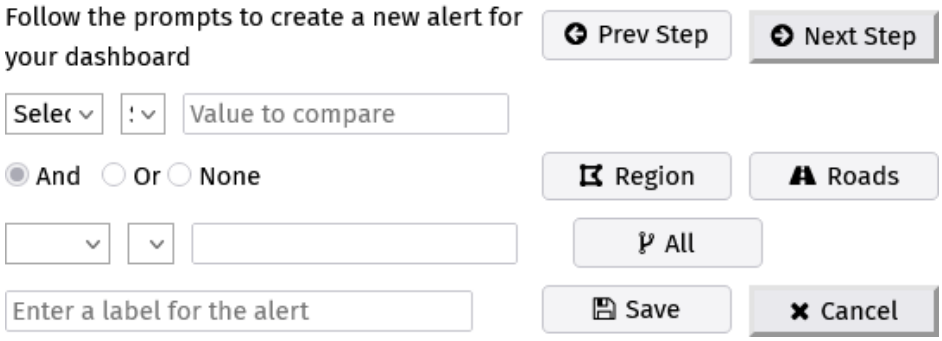
Source: FHWA.

Figure 12. Screen capture. Dashboard view.

Adding a user-specified alert

The list of alerts for each user account is empty until the user creates the alerts needed for their applications.

1. To create an alert, click the green plus icon in the upper left of the dashboard view. A new panel as shown in will appear in the lower left corner of the dashboard view.



Source: FHWA.

Figure 13. Screen capture. Prompts for adding an alert to the dashboard view.

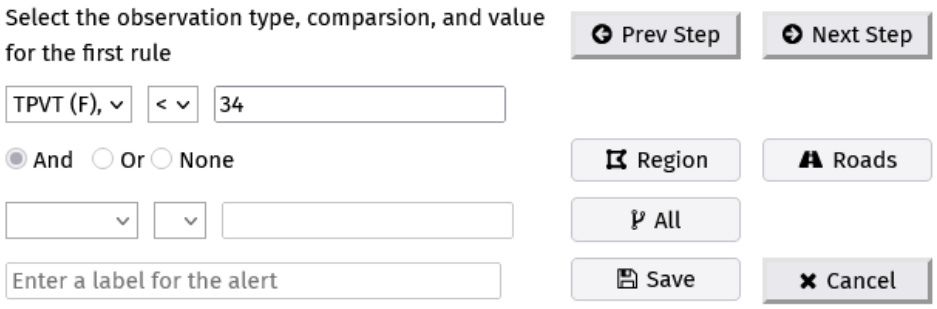
2. As indicated in the panel, follow the prompts by clicking the “Next Step” button.

3. If the user has access to more than one IMRCP road network, the user is prompted to select the network on the righthand map for which the alert is to be created. Click on the appropriate road network map outline. The prompt will indicate that the user has to wait for the road network data to load for the next step.

4. Continue to follow the prompts to draw a region on the map, by clicking the Region button Region, or select roads, by clicking the Roads button Roads, for which to be alerted.

5. For selecting a region, click on the righthand map to create a polygon representing the area for which alerts are to generated. For roads, click on one or more road segments. Click the Next Steps button to proceed.

6. As instructed by the prompt, select the observation type, comparison operator, and value for the first alerting rule. For example, setting an alarm for pavement temperature below 34 Fahrenheit (1 Celsius) on a segment would look like the settings in Figure 14. Click the Next Step button to proceed.

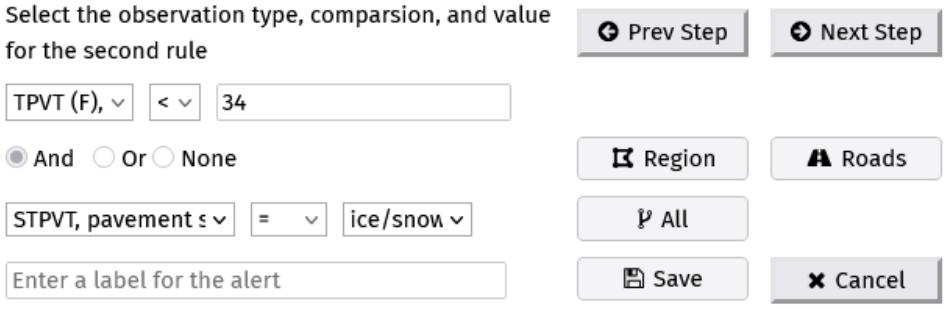


Source: FHWA.

Figure 14. Screen capture. Prompts for specifying alert rule parameters.

7. Each alert can have 1 or 2 conditions. If a second condition is appropriate, select either "And" or "Or". Click the Next Step button to proceed.

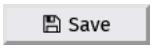
8. Select the observation type, comparison operator, and value for the second alerting rule. For example, setting a second alarm condition for pavement state being ice or snow on a segment would look like the settings in Figure 15. Click the Next Step button to proceed.



Source: FHWA.

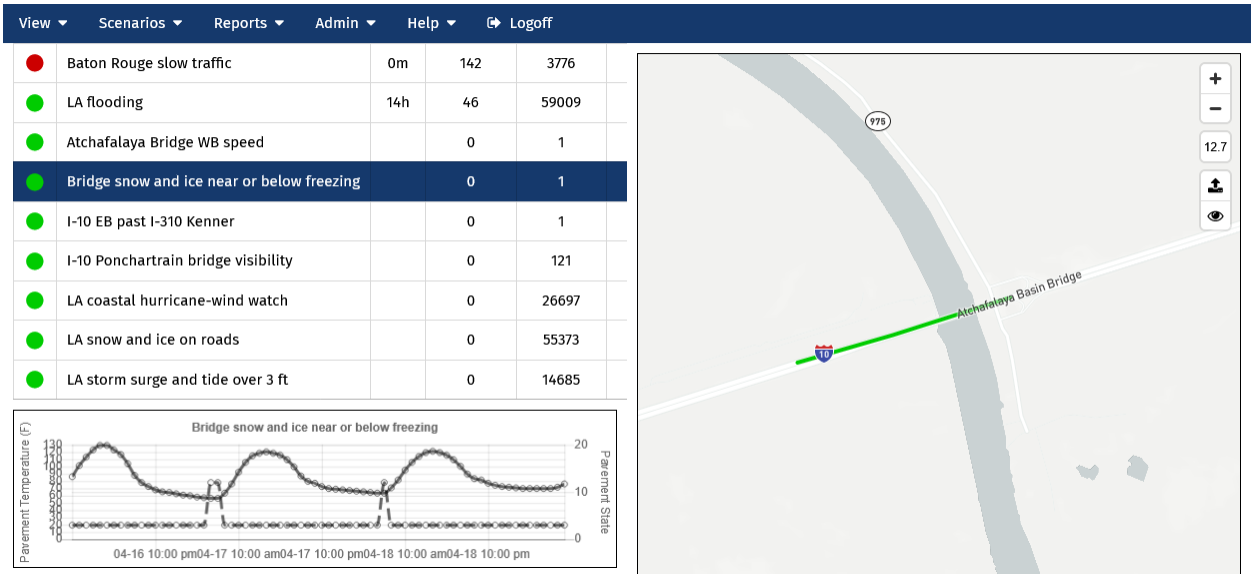
Figure 15. Screen capture. Prompts for specifying a second set of alert rule parameters.

9. As prompted, enter a label to be displayed on the dashboard for this alert. Click the Next Step button to proceed.

10. Click the save button  to save the alert configuration. The alert specification panel disappear and the new alert is added to the list on the upper left panel of dashboard.

Viewing Alert Details

Details for each alert and its status can be viewed by clicking on the alert in the list on the dashboard view. Figure 16, for example shows the results of an alert configured to examine pavement temperature and state on a bridge. The location and status of the alert is shown on the map to the right. If the alert is generated for a single road segment, a graph of the alert parameter(s) over the previous 72 hours is displayed on the lower left of the dashboard.



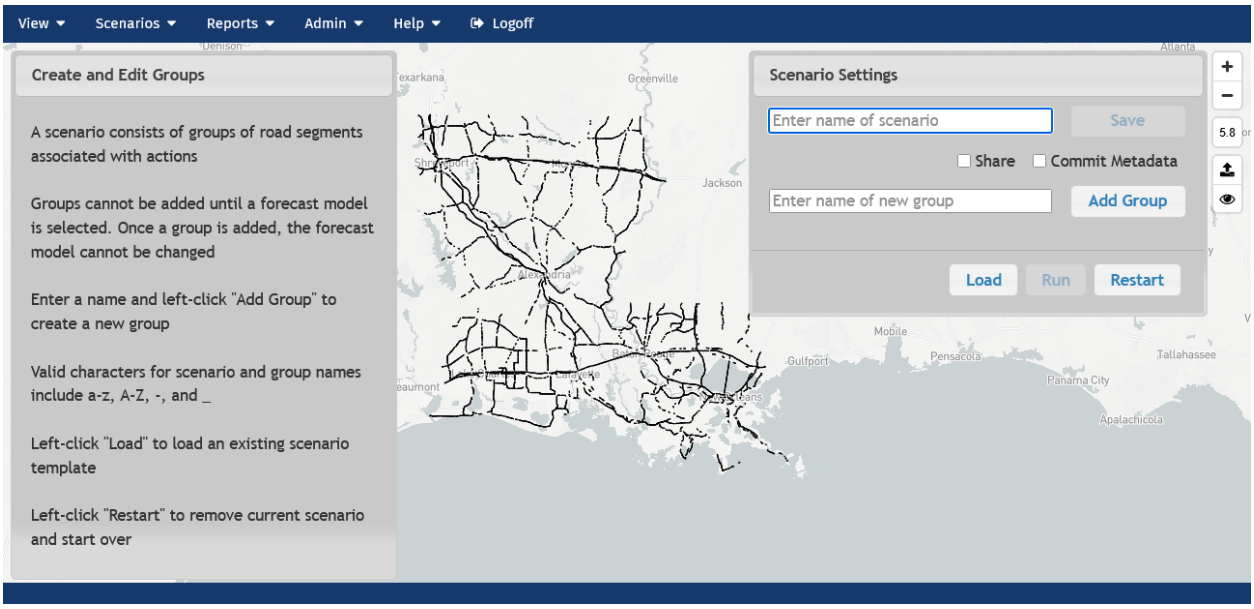
Source: FHWA.

Figure 16. Screen capture. Dashboard view of alert details.

CREATING A SCENARIO

Scenario modeling enables IMRCP users to postulate and evaluate the impact of operations and maintenance strategies on road conditions during challenging environmental and incident conditions. Users create models of operations and maintenance interactions with specific road segments that are saved for execution and evaluation under at particular times and varying conditions.

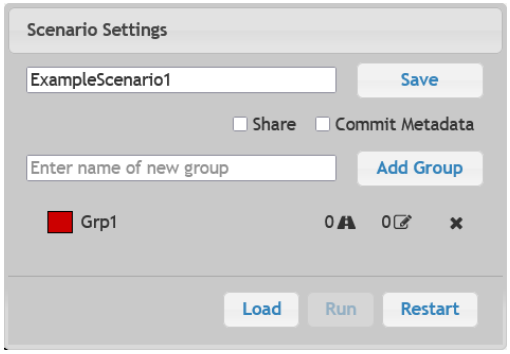
1. Select “Create Scenario” from the “Scenarios” tab at the top of the page. A map and dialogs for defining scenarios appears as shown in figure 8. The “Create and Edit Groups” dialog provides descriptions of the controls in the “Scenario Settings” dialog on the right.



Source: FHWA.

Figure 17. Screen capture. Dialogs for creating a scenario.

2. Enter a scenario name in the “Scenario Settings” dialog.
3. Enter a name for a new group of segments on which the scenario will take place and left-click "Add Group" to create a new group. The scenario and group names cannot contain spaces.
4. Use the map controls to zoom into an area for which the scenario is being created. Left-click the icon to add segments to the group. The “Scenario Settings” dialog appears as shown in the figure 9 example. A group of segments will share the same set of actions in the scenario. Some segment groups may be selected for evaluation of conditions upstream or downstream of a set of actions, even though there are no actions applied to those segments.



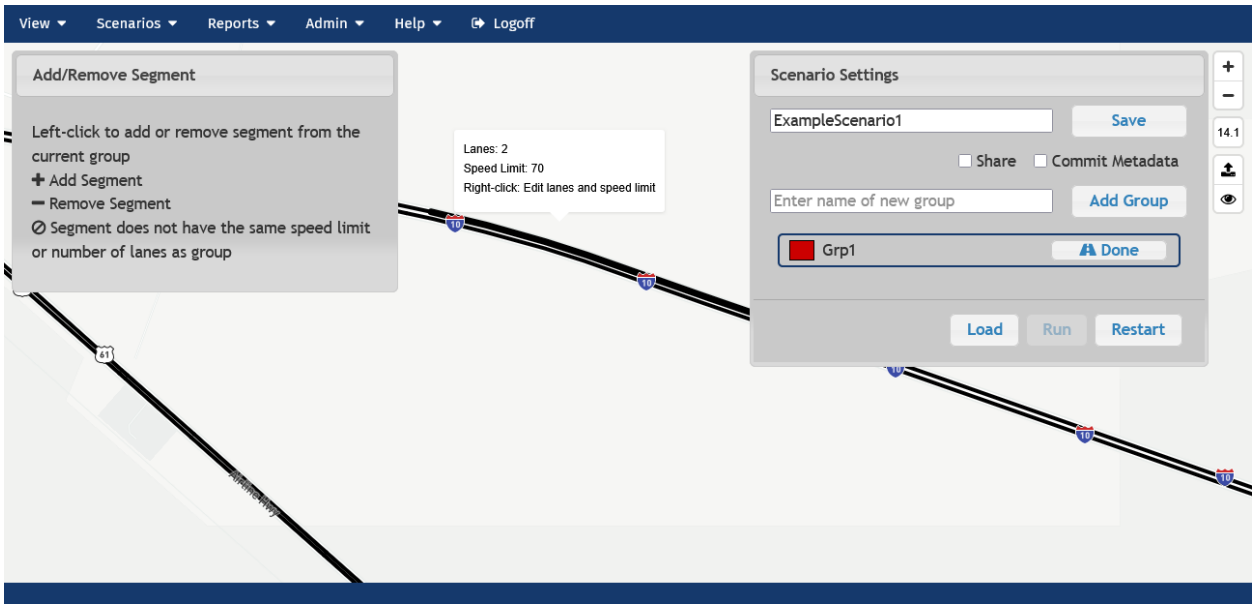
Source: FHWA.

Figure 18. Screen capture. Scenario settings dialog.

5. Left-click to select the first segment for the first group. It may be necessary to zoom further in to distinguish segments that closely parallel each other on the map. The segment is

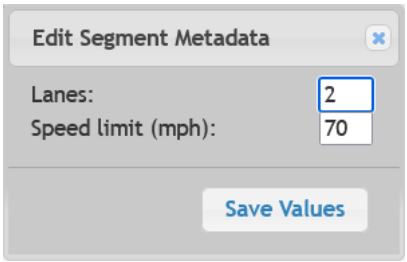
highlighted as a thicker line than non-selected segments and in the group color. A green plus sign will be displayed when the mouse is hovered over a segment that can be selected. A red minus sign will be displayed when the mouse is hovered over a selected segment.

6. Left click to add/remove segments to/from the selection set. All segments in a group must share the same number of lanes and speed limit. The number of lanes and speed limit on a segment can be changed by right-clicking on the segment prior to selecting and adding the segment to a group, as shown in Figure 19. The dialog for changing the number of lanes and speed limit is shown in Figure 20.The cursor will change to a "null" ⊘ icon if a segment with different properties is attempted for inclusion in a group. There is no hard limit on the number of segments that can be selected, but more segments will increase the time needed to process the report.



Source: FHWA.

Figure 19. Screen capture. Segment selection and properties for creating a scenario.

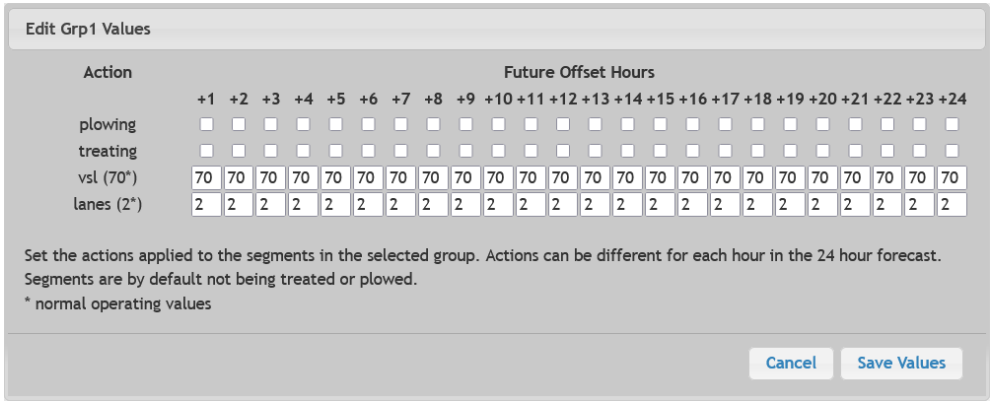


Source: FHWA.

Figure 20. Screen capture. Dialog for editing number of lanes and speed limit.

7. Left-click the Done button in the "Scenario Settings" dialog (Figure 19) to save the set of segments. The segments selected for the group will be highlighted in the color shown in the corresponding row in the Scenario Settings dialog. The count of segments selected will appear next to the segment icon.

8. Left-click the icon to associate actions with the group. A group of segments will share the same set of actions in the scenario. An "Edit [group name] Values" dialog pops up (figure 10).



Source: FHWA.

Figure 21. Screen capture. Scenario actions dialog.

9. Set the actions applied to the segments in the selected group. Actions can be different for each hour in the 24-hour forecast. Segments are by default not plowed for snow and ice and not treated to prevent freezing of precipitation. Variable speed limits ("vsl") model speed limit reductions that might be used to reduce the impacts of inclement weather or traffic congestion. Reducing the number of lanes can be used to simulate work zone or incident closure. Increasing the number of lanes models strategies like hard shoulder running or contraflow lanes. Normal operating values for are specific to the segments to which the actions are being applied. A value of "-1 for the vsl or lanes indicates that the normal operation value is unknown.

10. Left-click "Save Values" to save the action plan for the selected group. Left-clicking "Cancel" clears any changes. In either case, the dialog closes and the interface returns to the "Scenario Settings" dialog.

11. Add other groups as described in Steps 3 through 9 to complete the settings for the scenario.

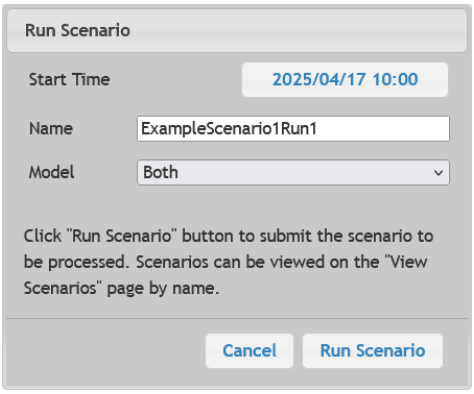
12. When all groups are set, checking the "Share" checkbox on the "Scenario Setting" dialog enables the scenario to be shared with other users who have access to this road network model. Checking the "Commit metadata" checkbox saves the default number of lanes and speed limit (potentially changed in step 6) for all users of the road network model.

13. Left-click the "Save" button on the "Scenario Settings" dialog to save the segment groups and actions. A "Save Succeeded" dialog will appear. Left-click the icon to close the dialog. The "Scenario Settings" dialog reappears with "Load" and "Run" buttons enabled for selection.

14. If additional changes need to be made to a saved scenario model, click "Load" to return to the "Scenario Settings" with the saved groups and actions.

15. Left-click "Run" to submit a scenario for analysis. A "Run Scenario" dialog will appear as shown in figure 11. Left-click in the "Start Time" box to select a date and time at which

the scenario forecast should start. Left-click in the "Name" box to provide a label for the scenario forecast results report. Click in the "Model" box to select "Road Weather Model," "Traffic Model," or "Both." As instructed in the dialog, left-click the "Run Scenario" button to submit the scenario to be processed. The scenario may take an hour or more to process, depending on the number of road segments and actions included in the scenario. Scenario results are listed and accessed by selecting "View Scenarios" on the "Scenarios" tab at the top of the IMRCP page.



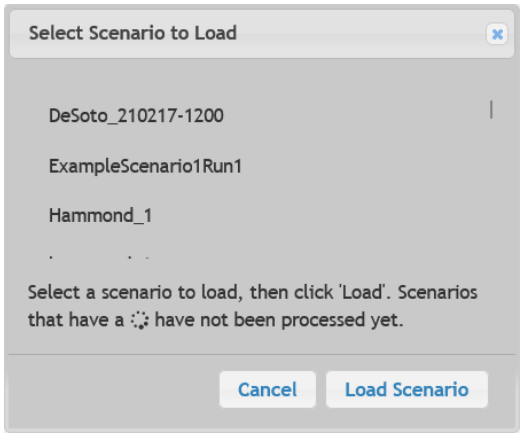
Source: FHWA.

Figure 22. Screen capture. Run Scenario dialog.

VIEWING SCENARIO RESULTS

Scenario modeling enables IMRCP users to postulate and evaluate the impact of operations and maintenance strategies on road conditions during challenging environmental and incident conditions. Users create models of operations and maintenance interactions with specific road segments that are saved for execution and evaluation under at particular times and varying conditions. Those scenario models are run to create result that are then viewed in IMRCP.

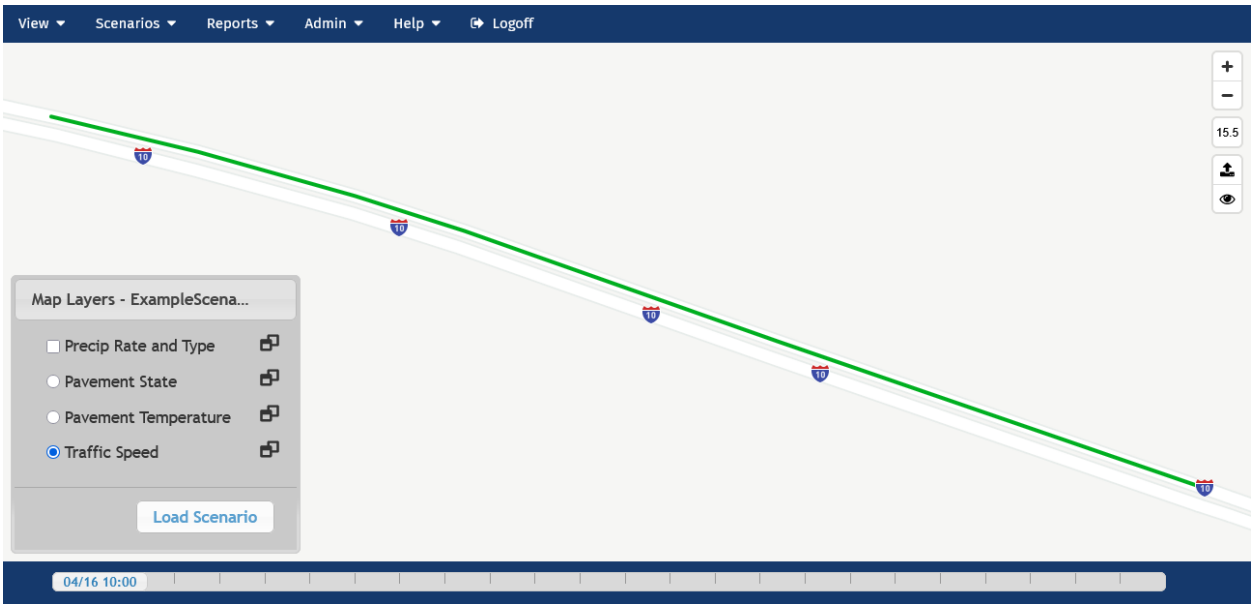
1. Select "View Scenarios" from the "Scenarios" tab at the top of the IMRCP page. A "Select Scenario to Load" dialog appears as shown in figure 12. All scenarios that have been queued to run or completed for the logged-in user will appear in the list.



Source: FHWA.

Figure 23. Screen capture. Scenario selection dialog.

2. Find the scenario run name in which you are interested. If the scenario was just recently submitted to run, it may still be in process as indicated by a rotating icon to the right of the scenario name. If so, come back to this page later. Scenarios that are complete and available for viewing have no icon to the right of the scenario name. When the run is complete, left click on the scenario run name to highlight that case. Left-click Load Scenario. The IMRCP window will show a map with the focus on the segment selections associated with the scenario that was run (figure 13). The specific time interval within the scenario time frame is selectable with the scale under the map.

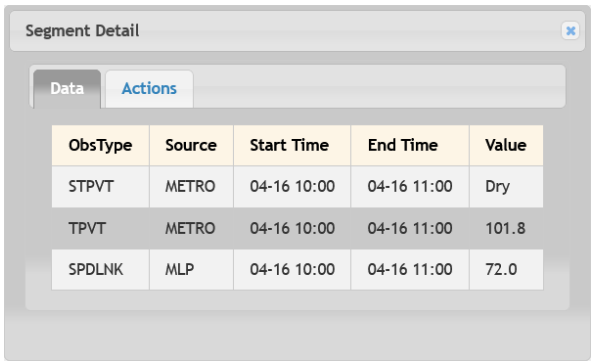


Source: FHWA.

Figure 24. Screen capture. Scenario map view.

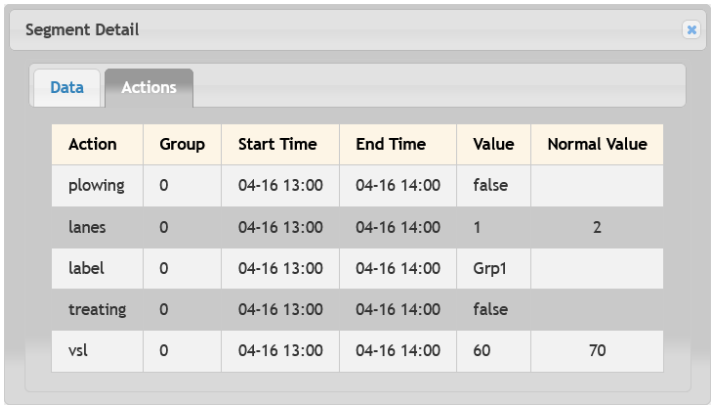
3. Users can select the layers available on the scenario results map in the dialog on the left. The precipitation rate and type can be displayed with any of the other roadway layers, only one of which can be displayed at a time.

4. Left-clicking on a segment brings up a dialog with the detailed results for that segment on a "Data" tab (figure 14). Left-clicking on the "Actions" tab displays the actions applied to the segment at the time being viewed on the scenario results map (figure 15). The rows in the table describe the actions for the selected segment at the time shown on the slide when the segment was selected for viewing.



Source: FHWA.

Figure 25. Screen capture. Data detail for segments in scenarios.



Source: FHWA.

Figure 26. Screen capture. Action detail for segments in scenarios.

CREATING A REPORT OR SUBSCRIPTION

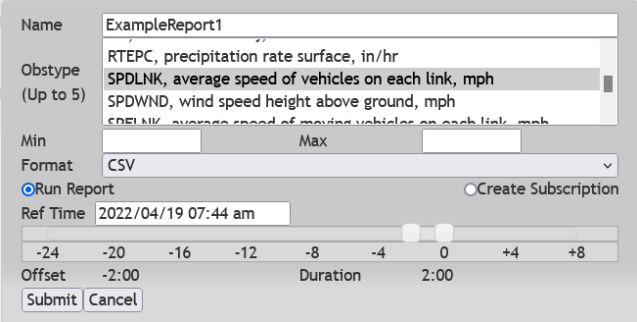
Reports provide extracts of road and weather conditions collected or forecast by the IMRCP system at locations within the road network for specific time periods. A subscription is a report run on a recurring basis, typically to provide a series of similar reports for further analysis or automation.

1. Select “Create Report” from the “Reports” tab at the top of the IMRCP interface. The system will display a map of the road network with an instruction dialog.

2. Use the map controls to locate a set of segments for which the report is to be run. It may be necessary to zoom further in to distinguish segments that closely parallel each other on the map. A green plus sign will be displayed when the mouse is hovered over a selectable segment. Left-click to select a segment for a report.

3. Left click to add/remove segments to/from the selection set. A red minus sign will be displayed when the mouse is hovered over a selected segment. Clicking on a selected segment removes it from the selection set. There is no hard limit on the number of segments that can be selected, but more segments will increase the time needed to process the report.

4. Press the enter key to finish the selection of segments for the report. A pop-up dialog for entering detailed report parameters will appear (figure 16).



Source: FHWA.

Figure 27. Screen capture. Report settings dialog.

5. Type a name in the name field.

6. Select the observation types (obstype) to be listed in the report/subscription. Observation type definitions and units are found in appendix A. Hold down the control key to select multiple individual types, or use the shift key to select a range of types.

7. If only selecting one observation type, optionally type a minimum and/or maximum value for that observation type in the "Min" and "Max" fields. Values less than the minimum or greater than the maximum constraints will be filtered from the report.

8. Select the format for the report/subscription from the dropdown menu. Comma-separated value (CSV) is the only option currently supported in IMRCP.

To run a report:

9. Select the "Run Report" radio button on the Report/Subscription wizard.

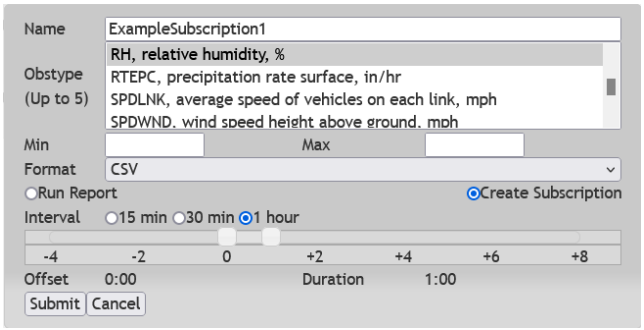
10. Select a reference date and time by clicking on the "Ref Time" input box.

11. Set the time range for the report relative to the reference time using the left and right slide controls. Note that time to the left of the reference time will yield measured and estimated values at those times; time to the right of the reference will yield values as they were forecast at that time.

12. Select the "Submit" button.

Creating a subscription involves defining the report parameters and a recurrence interval at which the report will be run. To create a subscription, complete the top part of the dialog and then:

13. Select the "Create Subscription" radio button on the Report/Subscription wizard (figure 17).



Source: FHWA.

Figure 28. Screen capture. Subscription Settings Dialog.

14. Select an interval radio button.

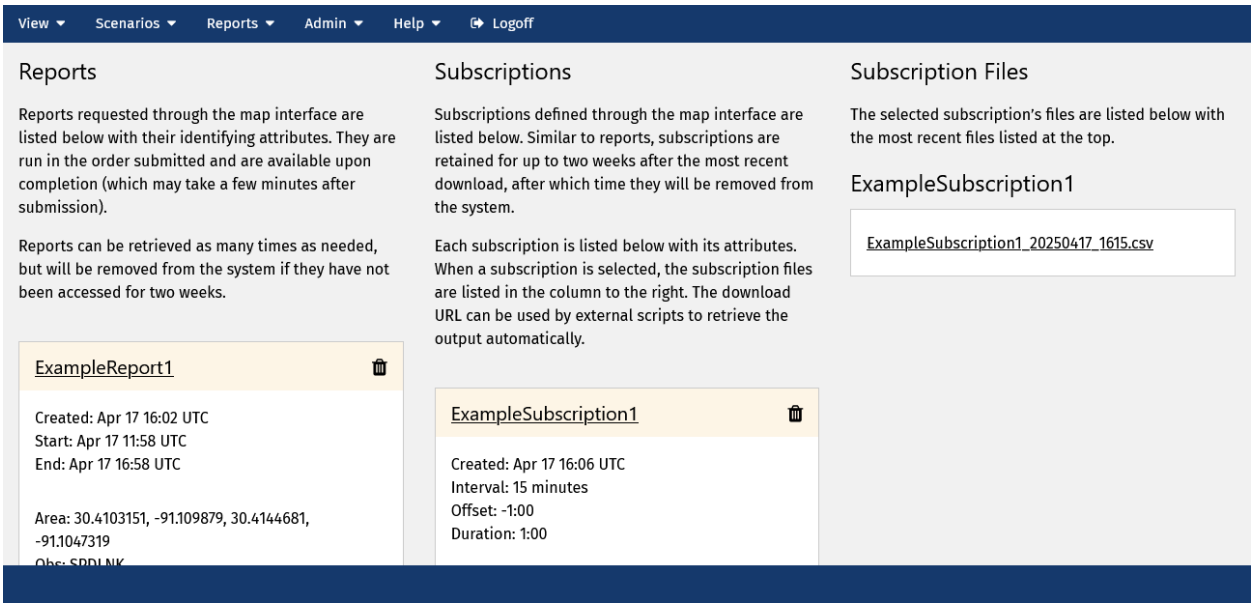
15. Set the time range for the report relative to the reference time using the left and right slide controls. Note that time to the left of the reference time will yield measured and estimated values at those times; time to the right of the reference will yield values as they were forecast at that time.

16. Select the "Submit" button.

VIEW REPORTS

Reports and subscriptions created are accessed through the "View Reports" selection from the "Reports" tab at the top of the IMRCP page.

1. Select "View Reports" from the "Reports" tab at the top of the IMRCP page. Reports submitted by the user are listed in the left panel and the subscriptions submitted by the user are listed in the center panel (figure18). The creation date and filter criteria for each report and subscription is listed below its name. Each report and subscription is retained for two weeks after it has been downloaded and will then be removed from the system.



Source: FHWA.

Figure 29. Screen capture. Reports and Subscription Listings.

Viewing a Report

2. To view a report, click on the report name on the left panel of the page. The page may need to be refreshed if a report is pending fulfillment as reports may not be generated for several minutes after they have been requested.

Viewing a Subscription

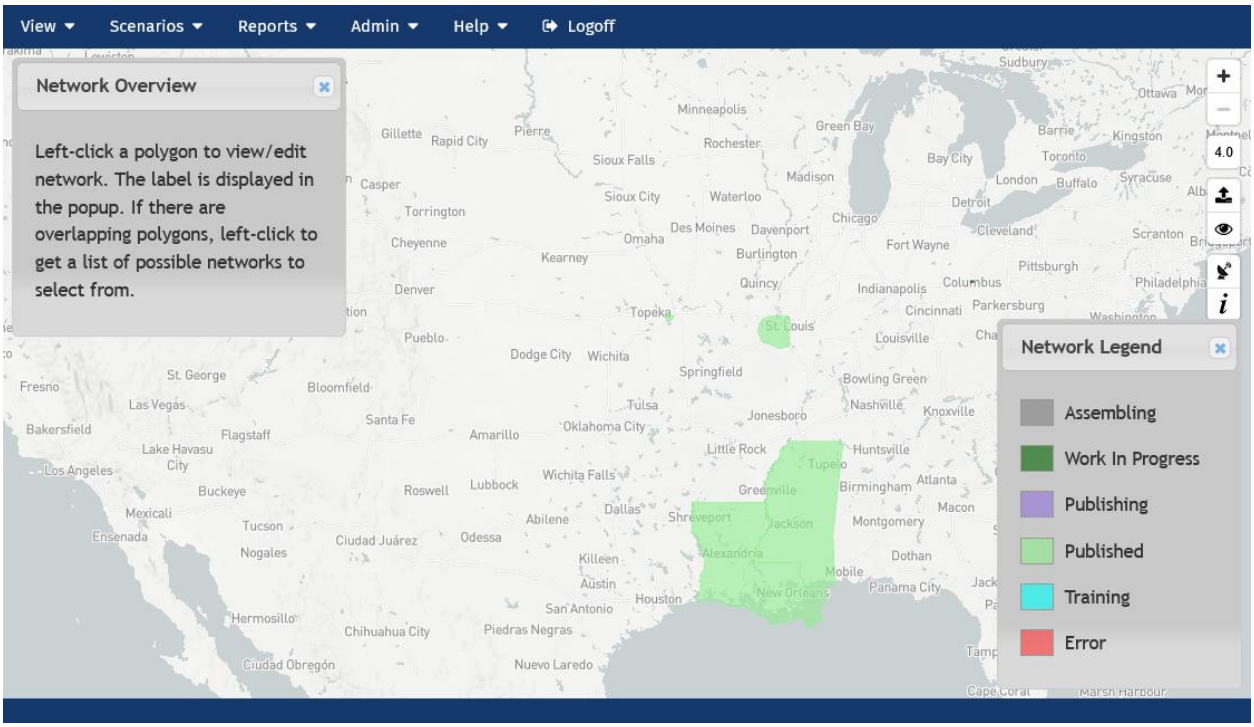
3. To view a subscription, click on the subscription's name in the center panel of the page. The files generated for that subscription will appear in the right panel of the page.

4. Click on the subscription file you would like to open. The subscription files are named based on the time they are generated in a "YYYYMMDD_HHMM" format.

MANAGE ROADS

IMRCP administrators have access to the "Manage Roads" selection from the "Admin" tab at the top of the IMRCP page.

1. Select the "Manage Roads" tab at the top of the IMRCP page. The browser window will open a new Network Overview of the road networks (Figure 30). Networks being assembled from map databases are shown in gray and those being edited are dark green. Networks submitted for the publishing process are purple. Available "published" networks are shown as light green polygons. Networks for which traffic models are training are cyan. Networks in an "error" state are red. To edit an existing road network, skip to the "Edit Road Network" instructions below. If no network polygons appear on the map, continue to the "Create Road Network" instructions.



Source: FHWA.

Figure 30. Screen capture. Manage Roads Network Overview.

Create Road Network

IMRCP road network creation consists of drawing a boundary polygon for roads to be included in the network and submitting the polygon to IMRCP for rendering the network map from the OpenStreetMap (OSM) database. The polygon does not need to be precise. Roads outside the original polygon can be added in subsequent edits. Roads within the polygon that are not needed in the final network can be removed in subsequent edits.

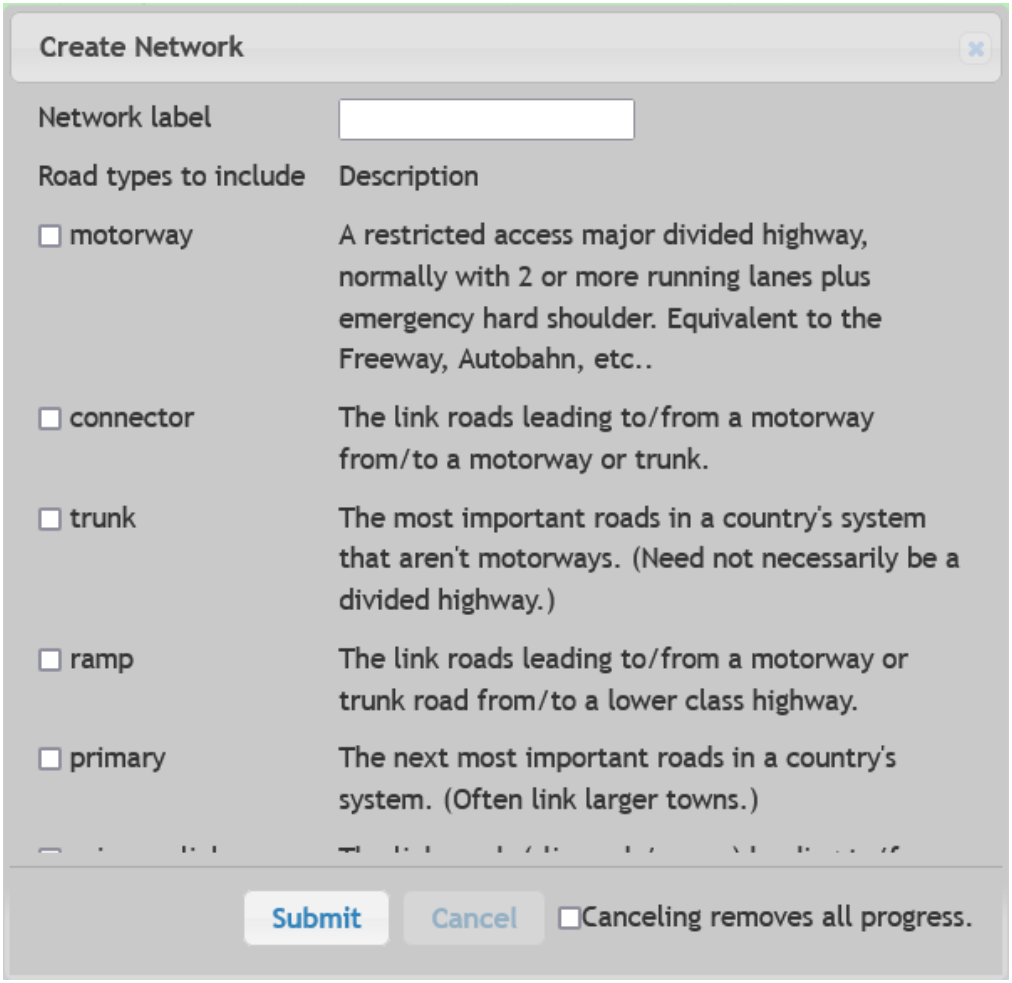
1. To start a new polygon, left-click the polygon tool icon on the righthand menu. (You may need to close the "Network Legend" dialog to see the polygon tool.) The instructions dialog in the upper left of the window will update.

2. Select a start point (vertex) for the polygon by left-clicking on the map. The map will display a blue line from the start point to the next cursor location, indicating the potential next segment of the polygon. The cursor with change to a black plus sign. If needed, press the escape key to cancel the selection and reselect the start point.

3. Select the second point (vertex) by moving the cursor to the desired location and left-clicking the point. The segment (side) of the polygon between the selected points will remain as a blue line over the map.

4. Proceed to select subsequent points (vertices) for the polygon.

5. To close the polygon, move the cursor near the first point of the polygon. The cursor will change to a green checkmark when close enough. Left-click to close the polygon. A new dialog (Figure 31) will appear.



Source: FHWA.

Figure 31. Screen capture. Create Network dialog.

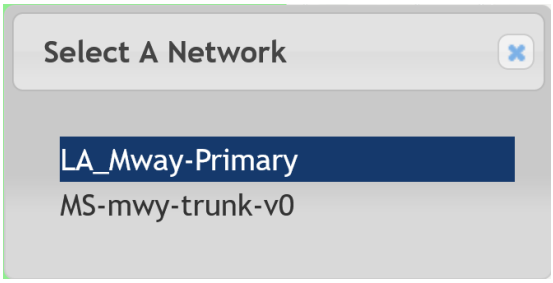
6. Enter a network label in the text box of the "Create Network" dialog. The Labels should be unique for all networks you are administering.

7. Select the types of roads to be included in the road network within the bounding polygon by left-clicking the checkbox next to the road types. The listed types are the categories assigned to roads in the OSM database. Generally, you will want to select the road types from the top of the list down to the lowest level for which you want to include all roads of that type. You may need to scroll down in the dialog to find the lowest types of roads. Roads included in the initial selections can be added to or removed from the network in subsequent road network edits.

8. Left-click the “Submit” button to submit the selected network parameter for processing. If you want to restart the road network creation process, left-click the checkbox next to “Canceling removes all progress” to enable the “Cancel” button, and then left-click the “Cancel” button. In either case, the dialog will close and the map will return to the main “Manage Roads” view.

Edit Road Network

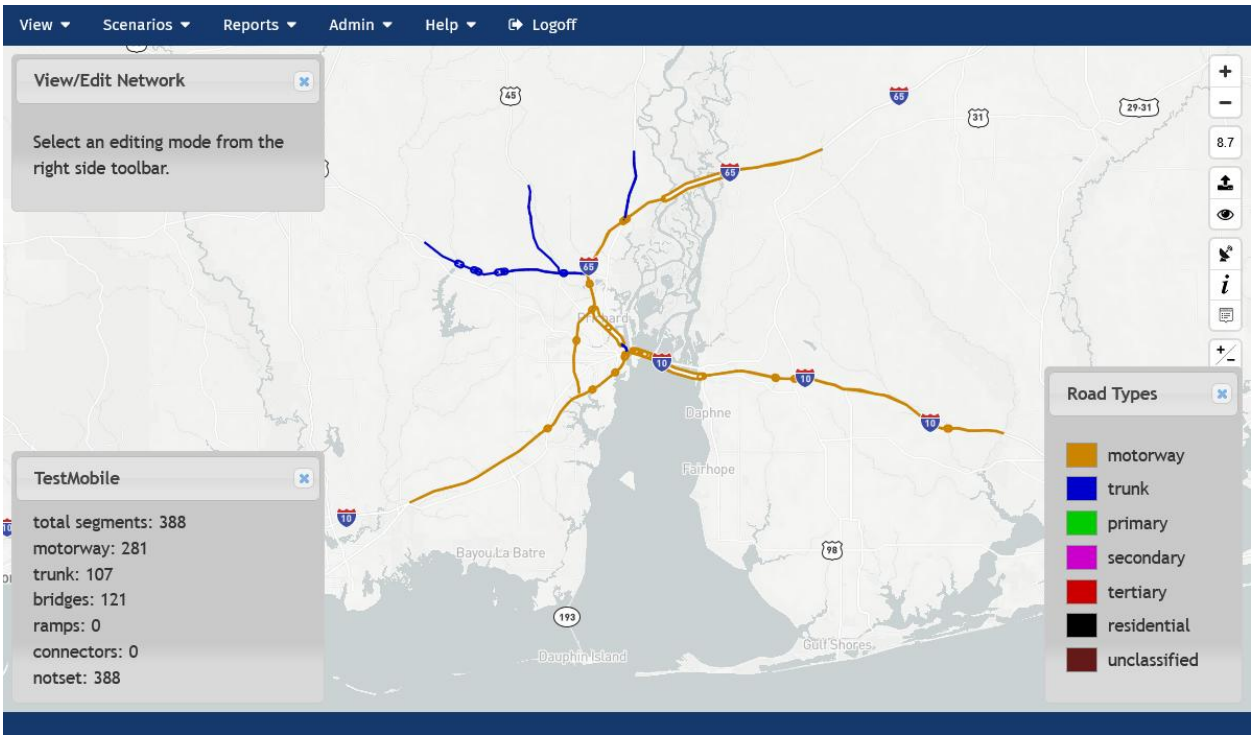
To select a road network for editing, hover over a green polygon on the “Manage Roads” map. A label for that network will appear in a popup. If two or more networks are available at the hover location, the popup will suggest left-clicking to select from list of available networks (Figure 32).



Source: FHWA.

Figure 32. Screen capture. Select a Network dialog.

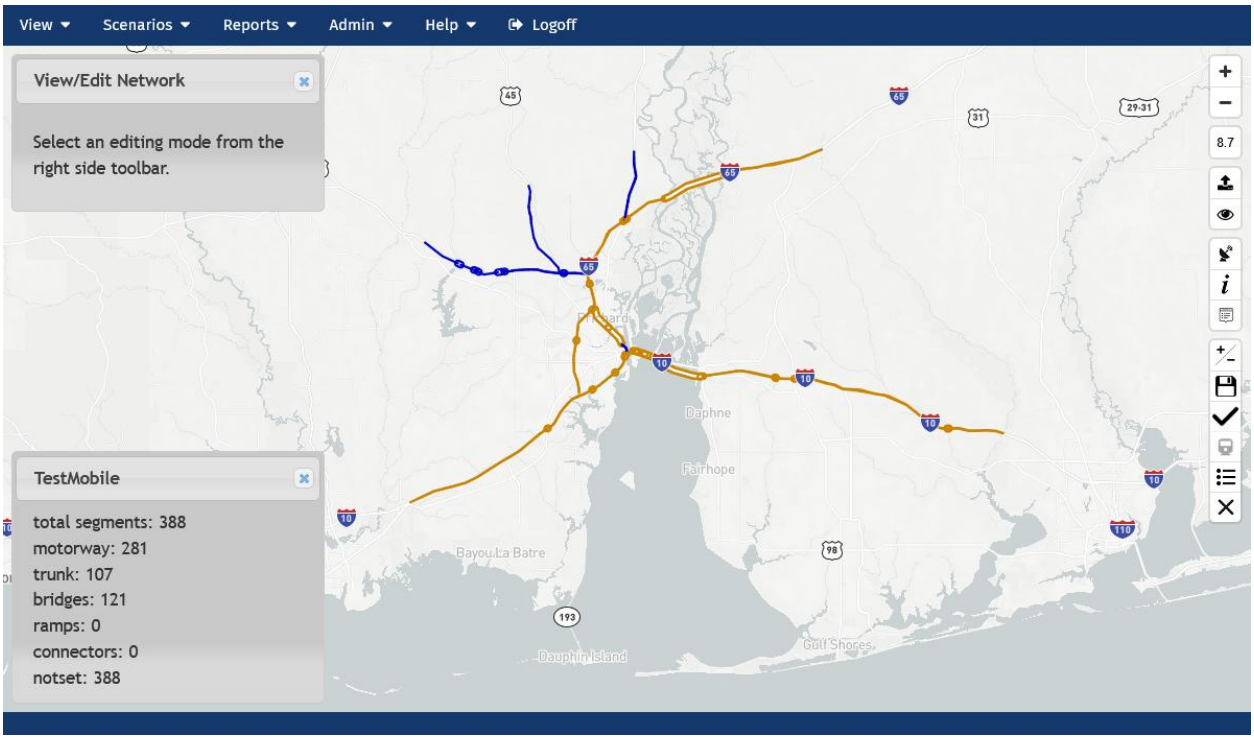
1. Left-click to make a network selection. The map view will zoom to display the selected network (Figure 33). General instructions for editing the map are shown in the dialog in the upper left of the map. The “Instructions” dialog can be closed by left-clicking the blue x icon in its upper right. The Instructions dialog can be restored by left-clicking the *i* tool icon.



Source: FHWA.

Figure 33. Screen capture. Network map to be edited.

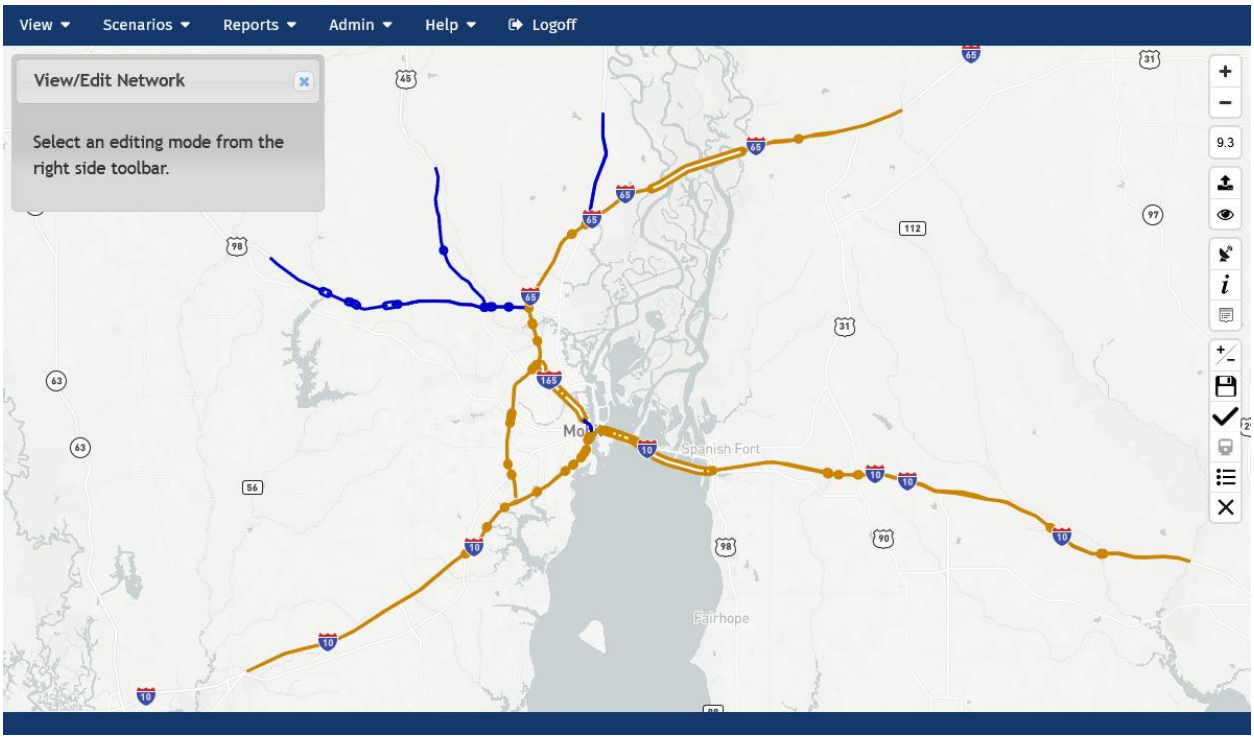
2. It may be necessary to close the "Road Types" dialog by left-clicking the blue x icon in its upper right to see all of the road network editing tools on the right side of the map. The Road Types legend can be restored by left-clicking the tool icon (Figure 34).



Source: FHWA.

Figure 34. Screen capture. Network map without road type legend.

3. The road network statistics dialog can also be closed to create a larger visible map by left-clicking the blue x icon in its upper right. The statistics dialog can be restored by left-clicking the  tool icon on the right side of the map view (Figure 35).

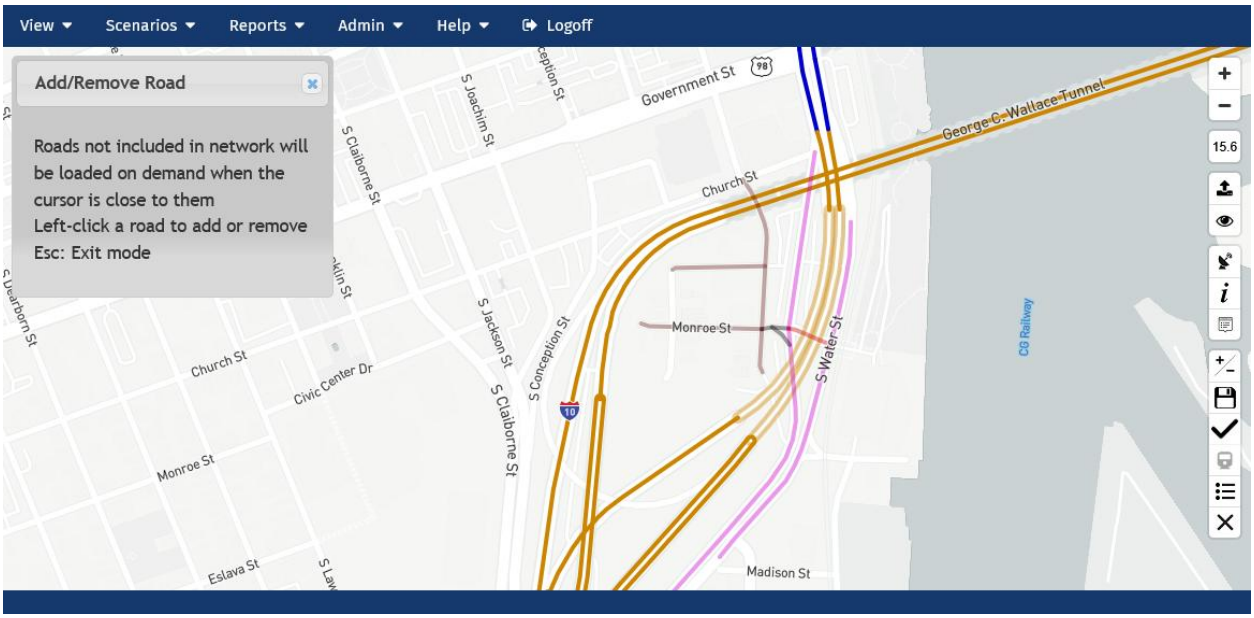


Source: FHWA.

Figure 35. Screen capture. Network map without network statistics dialog.

4. The background image behind the roads in the network can be toggled between default map view and a satellite view by left-clicking the icon on the right side of the map view.

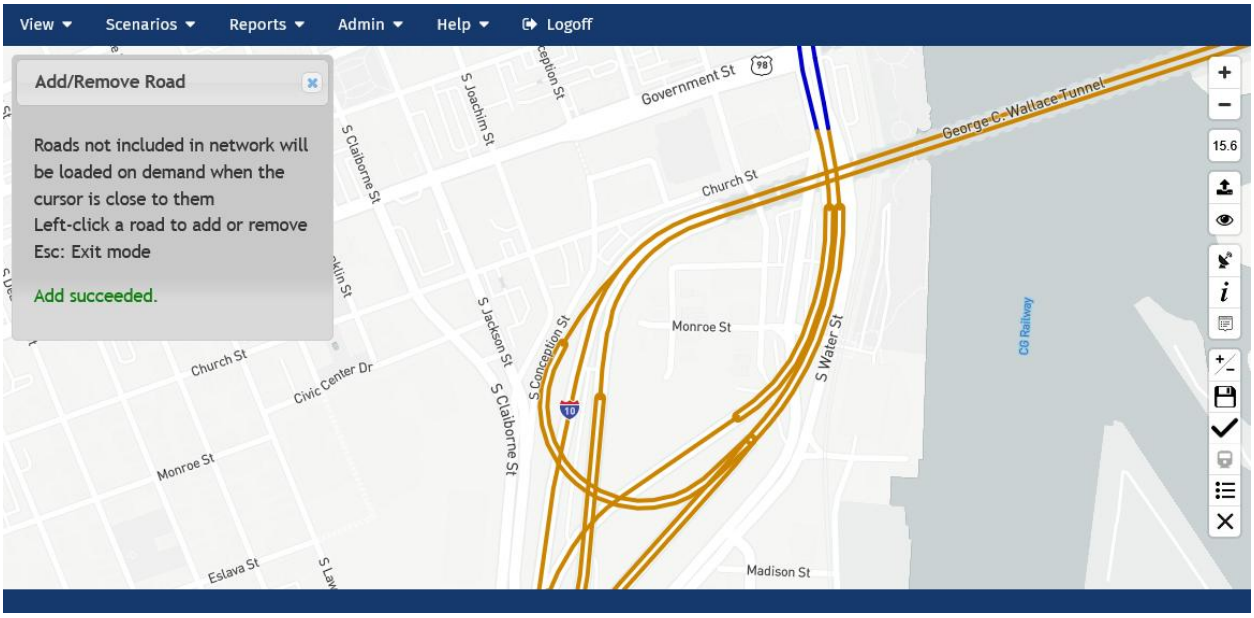
5. To add or delete road segments, view the map area of interest at a zoom level of 13 or greater (displayed in the upper right of the map, below the zoom tools). Left-click the "Add/Remove Road" icon to enter the editing mode. Hovering the cursor in an area displays road that can be selected in that area of the map (Figure 36). Left-clicking on an existing segment removes it from the network. Left-clicking a new segment adds it to the network.



Source: FHWA.

Figure 36. Screen capture. Network map with potential road segment additions.

6. Left-click the "Add/Remove Road" icon to exit the editing mode. The view retains the added segments and loses the removed segments (Figure 37).



Source: FHWA.

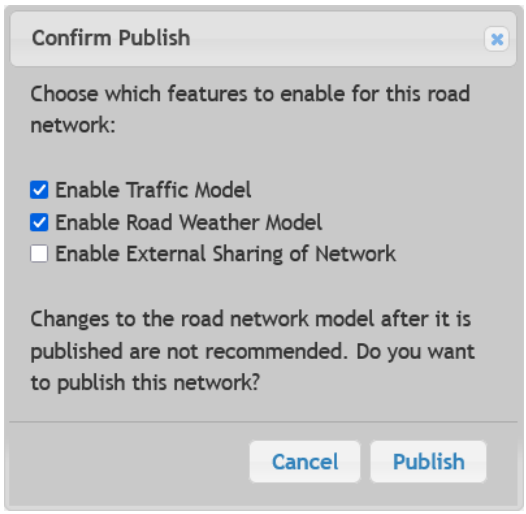
Figure 37. Screen capture. Network map with road segment additions.

7. Left-click the Save icon to save changes made to the road network. This action exits the Add/Remove roads editing mode.

Publish Road Network

A road network created and edited from the OSM database retains the pavement-based view of roads and does not distinguish directions of travel on undivided roadways. IMRCP needs to separate the directions of travel for computation and display of traffic data.

1. After all segments have been added to and deleted from the network, left-click the Publish Network icon to separate directions of travel and complete the segmentation of the road network model. A confirmation dialog for setting publication options will appear over the map (Figure 38).



Source: FHWA.

Figure 38. Screen capture. Road network publication process confirmation.

2. Select the options checkboxes appropriate to the network.

    a. Enabling the traffic model will initiate traffic modeling for the network. This should be set only for networks for which traffic data collection has been enabled by a system administrator as part of installation and administration.[5]

    b. Enabling the road weather model will initiate road weather condition modeling and forecasts for the network. This modeling works for any road models within the continental U.S. and does not require additional installation or administrative steps within that geography.

[5] Refer to the *Integrated Modeling for Road Condition Prediction Installation and Administration Guide*, available on the IMRCP GitHub site.

c. Enabling the external sharing of the network enables other IMRCP instances to see the outputs of this network modeling, if they are configured in their installation and administration to do so. This option enables, for example, IMRCP instances in adjacent states to see each other's view of the neighboring states.

3. Left-click the Publish button to close the dialog. Left-click the Cancel button to go back for more changes without publishing (finalizing) the network.

4. The map returns to the view/edit tools with the network state indicated by its color on the map. A network in the process of publishing will be shown as purple, and then as light green when the publishing process is finished.

Train Road Network for Hurricane Modeling

Road network models for areas subject to tropical storms and associated traffic impacts may want to train IMRCP hurricane traffic models for those events. Although IMRCP directly accesses hurricane landfall and path records from the National Hurricane Center, the training needs access to regional traffic speed archives for the area being modeled, so requires that the system administrator load those archives as part of the IMRCP installation and administration.[6] Hurricane model training is available only after the network model has been published, as indicated in Figure 39 by the train icon being available among the edit controls on the View/Edit Network page.

Source: FHWA.

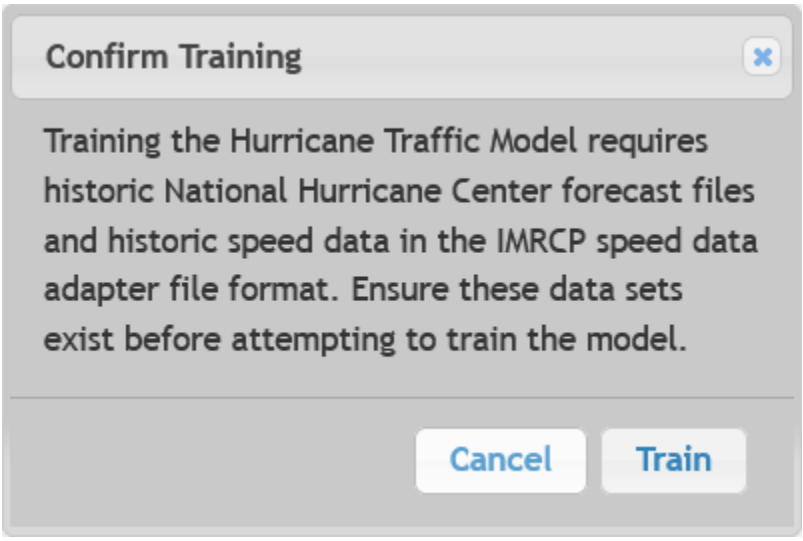
Figure 39. Screen capture. Road network View/Edit mode with training icon enabled.

2. Click the train icon to start the hurricane traffic model training. IMRPC presents a dialog to confirm the training process (Figure 40).

[6] Refer to the *Integrated Modeling for Road Condition Prediction Installation and Administration Guide*, available on the IMRCP GitHub site.

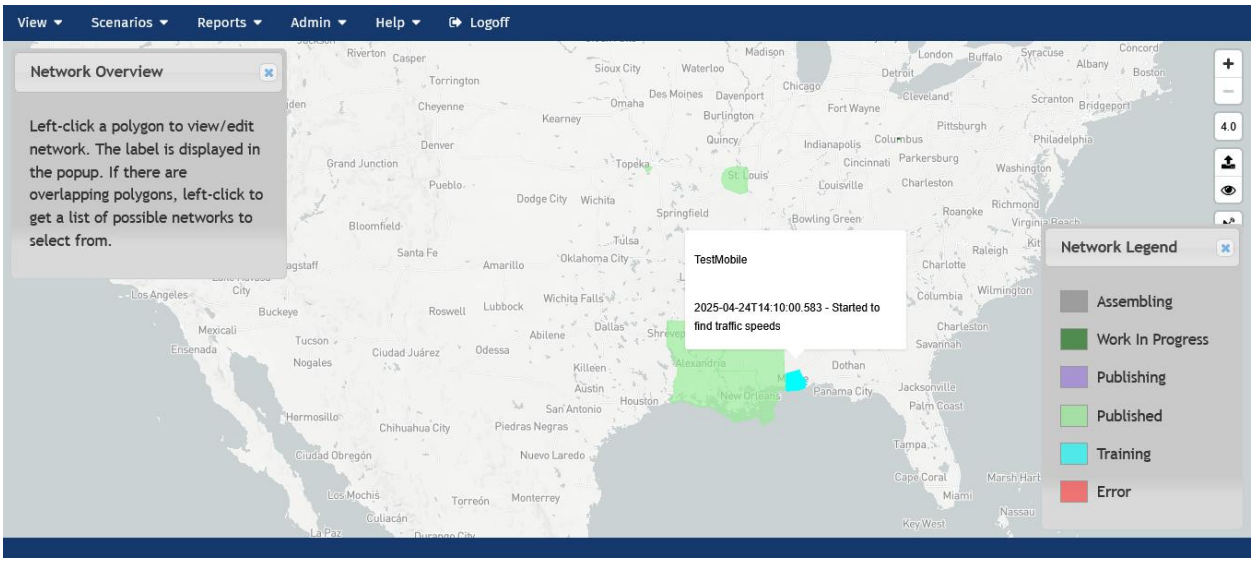
3. Click the “Train” button to start the training process or “Cancel” to cancel the request. The dialog will close and the view will return to the View/Edit map and show the network being trained in cyan (Figure 41).

4. The training will result in a trained network shown as published (light green).



Source: FHWA.

Figure 40. Screen capture. Confirmation dialog for hurricane traffic model training.



Source: FHWA.

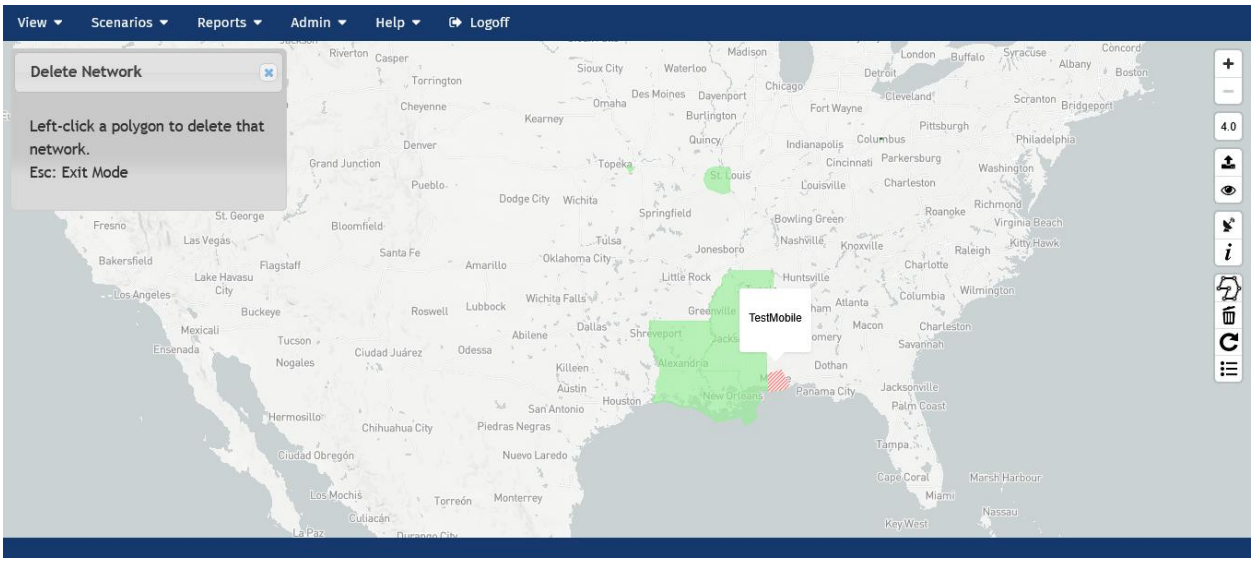
Figure 41. Screen capture. Road network View/Edit mode indicating hurricane traffic model in training.

Delete Network

Saved road networks can be deleted from the system. You may want to delete a network that has been edited and saved, for example, if it did not include enough road classifications to cover the intended detail or scope.

CAUTION: you can also delete a published model for which data and forecasts are being created saved. This deletion is not reversible and the data for the network will not be accessible from the View Map tab.

1. To delete a network, left-click the Delete Network icon from the tools on the right side of the Manage Roads view. Hovering the cursor over a network will change the network to a hashed red. Press the ESC key to cancel the deletion, or (**CAUTION**) left-click to delete the network.



Source: FHWA.

Figure 42. Screen capture. Road network selected for deletion.

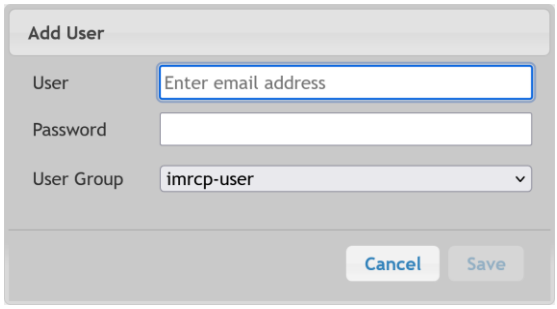
MANAGE USERS

IMRCP administrators have access to the "Manage Users" tab at the top of the IMRCP page.

1. Select "Manage Users" from the "Admin" tab at the top of the IMRCP page. The browser window will open a new page with a list of registered system users. The list shows the user's email address, user group, and date the user was disabled in the system (if any).

2. To add a new user, click the "Add User" button +Add User at the bottom of the page. A dialog will open. Enter the new user's email address as their user name. Administrators can set the user's password, or leave it blank for the user to reset later. The user group is either "imrcp-user" or "imrcp-admin." CAUTION: Assigning users to the imrcp-admin group gives them full privileges to add and delete road networks and users. Left-click the

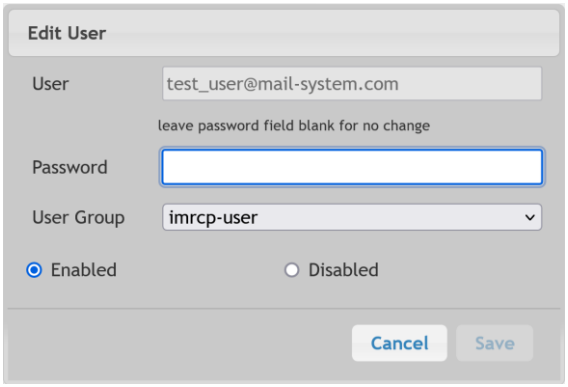
"Cancel" button to cancel the user addition, or "Save" to save the new user in the system. Left-clicking the "Cancel" or "Save" button closes the dialog.



Source: FHWA.

Figure 43. Screen capture. Add user dialog.

3. To modify an existing user profile, double-click a user email address to change their group or enable/disable their account. Administrators can assign a new password, change the user's group, and disable or enable the user account. Left-click the "Cancel" button to cancel the user edits, or "Save" to save the user in the system. Left-clicking the "Cancel" or "Save" button closes the dialog.



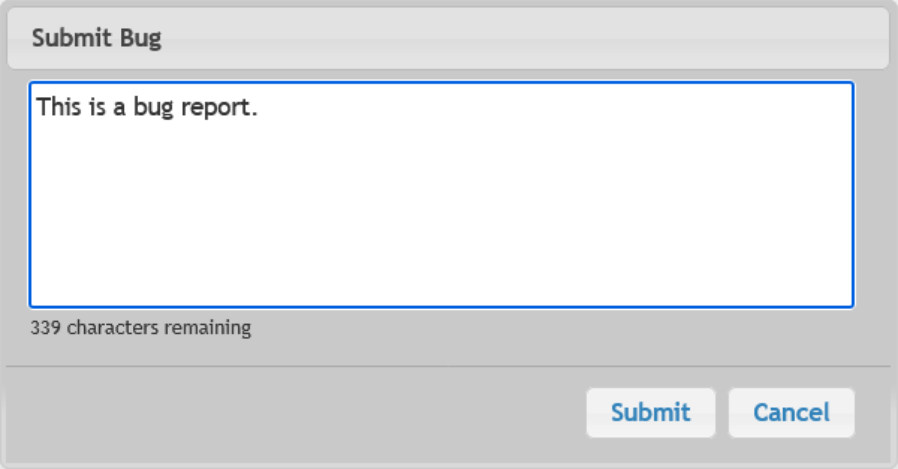
Source: FHWA.

Figure 44. Screen capture. Edit user dialog.

SUBMIT BUG

Any IMRCP user can submit a bug report when the system is not behaving as expected.

1. Select "Submit Bug" from the "Help" tab at the top of the IMRCP page. The browser window will open a dialog for briefly describing the bug or situation you encountered (Figure 45). Left-click the "Submit" button to submit the bug description to the system administrator for resolution, or left-click "Cancel" to close the window and return to the prior display.



Source: FHWA.

Figure 45. Screen capture. Submit Bug user dialog.

USER GUIDE

This user guide is available as a PDF document through the online IMRCP application.

1. Select “User Guide” from the “Help” tab at the top of the IRMCP page. The PDF User Guide document will open in another Web browser window.

LOGOFF

Left-clicking “Logoff” tab at the top of the IMRCP page logs the user out of IMRCP and returns to the IMRCP login dialog.

CHAPTER 4. EXAMPLE EVENTS

WINTER STORMS AND ROAD CONDITIONS

Winter weather conditions present complex operational challenges for the transportation system and its stakeholders. For example, travelers want information about conditions along their planned route and, as a group, create the aggregate traffic conditions as they drive along their routes. Winter maintenance crews plan for reducing the impact of storms on roadway conditions based on weather forecasts and may use a maintenance decision support system (MDSS), but also adapt to conditions on the roadway as they execute those plans. Operators in a transportation management center (TMC) monitor roadway conditions and implement weather responsive management strategies that may including using variable speed limits (VSL), limiting access to roadways through lane or road closures, and providing traveler information online, on roadside dynamic message signs, on smartphone apps, and through the media.

IMRCP Use Cases

IMRCP provides information and tools to support many of the needs driven by winter weather impacts on the transportation system. It enhances situational awareness by gathering, synthesizing, and integrating information about current and forecast traffic, weather, and hydrological conditions across the road network. It provides web interfaces, reports, and data subscriptions for operations stakeholders and for other systems that might benefit from the data integration. IMRCP can assist in planning and operations decision support with scenario analysis of weather-responsive management strategies like implementing VSL. Table 1 identifies potential operator uses for IMRCP in winter storms.

Table 1. Potential operator uses for IMRCP in winter storms.

Time relative to onset of storm	Operations/maintenance activities and potential uses for IMRCP
-5 days / -120 hours	Forecasts show approach of storm and extent of precipitation in IMRCP
-4 days / -96 hours	Continue to monitor storm forecast. Notify management and NWS office of intent to mobilize
-3 days / -72 hours	Continue to monitor storm forecast. IMRCP provides first look at pavement conditions during the storm, supplementing any other forecast resources. First response planning session for approaching storm with maintenance, operations, and NWS.
-2 days / -48 hours	Continue to monitor storm forecast. IMRCP updating pavement condition forecasts. Second planning session.
-1 day / -24 hours	Continue to monitor storm forecast. IMRCP updating pavement condition forecasts. Run IMRCP treatment/plowing scenario. Plan set and resources committed for storm response.
-18, -12, -6 hours	Continue to monitor storm forecast. IMRCP updating pavement condition forecasts. Update treatment and plowing scenarios.

Time relative to onset of storm	Operations/maintenance activities and potential uses for IMRCP
-3 hours	Continue to monitor storm forecast. IMRCP updating pavement condition forecasts. Update treatment and plowing scenarios. IMRCP forecasts traffic response to storm conditions. Run operations VSL/treatment/plowing scenarios. Maintenance and operations resources mobilized.
0 hours	Execute maintenance and operations plan. Collect AVL and mobile sensor data.
3, 6, 9, 12 hours	Continue to monitor storm, including pavement conditions updates from RWIS and maintenance operations. IMRCP updating pavement condition forecasts. Update operations scenarios to confirm ongoing operations plans.
12 hours	Storm passes.
24 hours	After action review. IMRCP event records used to review weather conditions and response. May perform scenario analysis of different treatment/plowing options or operational strategies.

Source: FHWA.

Agencies may already be using other winter weather and decision support tools. Many agencies, for example, have established relationships with local National Weather Service offices to exchange information on developing storms. Agencies may also have access to commercial weather information services, in some cases providing pavement condition information and forecasts similar to those provided by IMRCP. Agencies with access to a winter maintenance decision support system (MDSS) may use its treatment and plowing recommendations to guide maintenance planning and decisions. IMRCP can supplement those resources with additional information on traffic and operations, particularly traffic predictions.

As a winter storm approaches, IMRCP will collect atmospheric weather condition information and forecasts. Those weather data will be used with data from road weather information systems (RWIS) to model current and forecast pavement conditions across the road network. IMRCP's scenario tools can be used to investigate the road condition impacts of pre-treatment and plowing, although it does not provide treatment or plowing plans that can be generated by an MDSS.

As winter storm conditions are affecting the road network, IMRCP integrates traffic and weather views of current road conditions. This enables operators and maintenance staff to see the network-wide impact of actual weather conditions as they develop. TMCs can get views of conditions beyond specific locations seen through traffic cameras. Maintenance supervisors can monitor conditions in real time beyond reports from plow vehicles or RWIS. Road weather condition forecasts reflect the accumulated real-time weather conditions. Traffic predictions include the impacts of road weather conditions and incidents that may have occurred as a result of those conditions.

After the storm has passed, IMRCP provides a record of weather and traffic conditions and forecasts throughout the storm. This record provides operations and maintenance staff with a

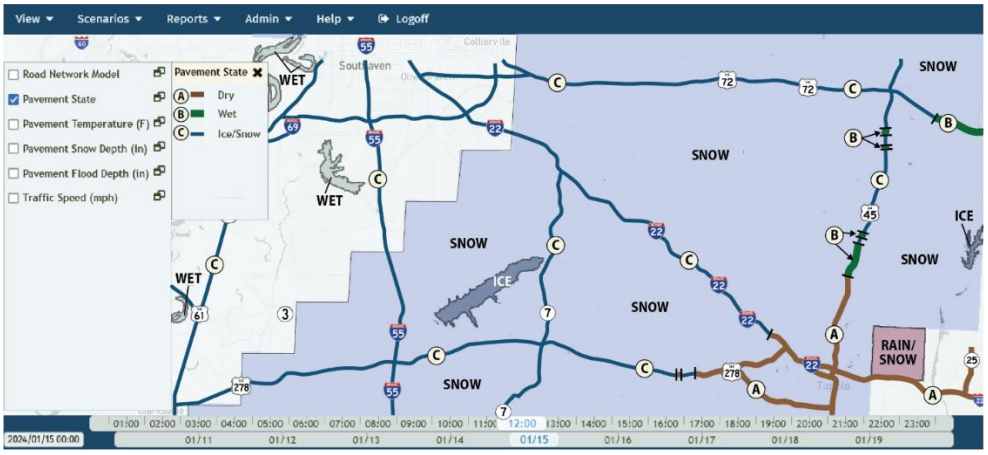
richer and more integrated view of events for after-action reviews. The data might also be used to feed storm indices or performance measures.

Example Ohio Winter Storm – January 16-17, 2022

Southern States Snow and Ice, January 2024

A severe winter storm impacted travel conditions across much of the United States in mid-January 2024 with snow, ice, and record cold temperatures. The mass of cold air pushed through the southern States as far south as New Orleans, Louisiana. Memphis, Tennessee, and northern Mississippi saw record snowfalls on Sunday, Jan. 14, and continued to receive snow showers throughout the day on Monday. Snow fell as far south as Biloxi, Mississippi, and Mobile, Alabama, on the gulf coast overnight and into Tuesday morning.

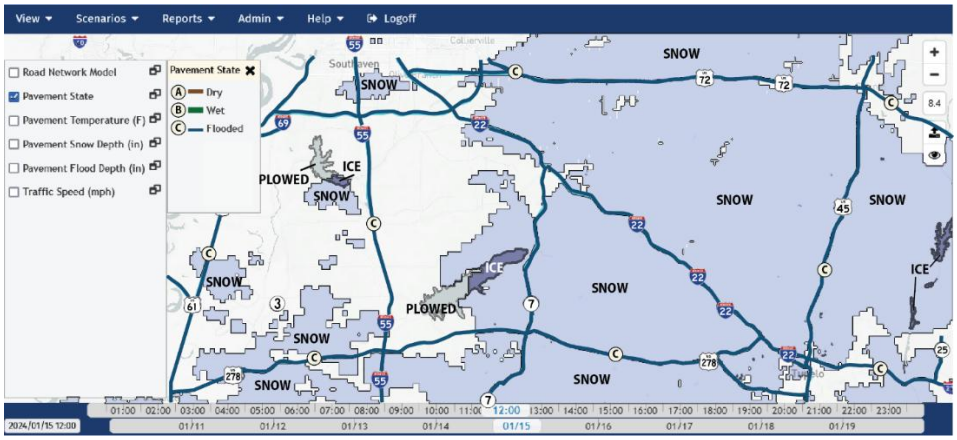
IMRCP provides views of weather and traffic conditions to support planning, operations, and evaluation. Forecasts of pavement condition and traffic can assist event response planning. Figure 46 shows the IMRCP forecasted precipitation conditions and pavement state as predicted at midnight on Jan. 15 as of noon that day. Operators would anticipate needing to provide winter maintenance crews to be widely deployed across northern Mississippi to deal with the snow and ice, and that travelers would benefit from advisories of the extent of the potentially hazardous conditions.



Source: FHWA.

Figure 46. Screenshot. IMRCP precipitation and pavement state across northern Mississippi, forecast for 12 noon central time, as of 12 midnight on Jan. 15, 2024.

Figure 47 shows the IMRCP-indicated precipitation conditions and pavement state as of noon on Jan. 15, 2024, as might be seen by operators in realtime or in an after-action review. The forecast was generally confirmed by observed conditions as to the extent and timing of the ice and snow on pavement. The differences between the images (in this instance, in the precise extent of the areas over which it is snowing and in the pavement state on specific roadways) might be useful in understanding, for example, the local operational responses to conditions.



Source: FHWA.

Figure 47. Screenshot. IMRCP precipitation and pavement state across northern Mississippi as of 12 noon central time on Jan. 15, 2024.

TROPICAL STORMS

Tropical storms create an ongoing series of threats to transportation system operations, as well as to life and property, as they approach land and move onshore. Emergency guidelines focus on planning for evacuation and preparedness for the storm's landfall and are dependent on the increasingly more precise forecasts of expected storm conditions and potential consequences. Operations as the storm moves onshore are somewhat limited to monitoring conditions and receiving damage reports. The post-storm recovery stage focuses on assessing damages and moving as quickly as possible to restore access and essential services to affected areas.

Transportation agencies play a support role throughout the storm planning, event, and response phases. While roadways are essential to preparing for and responding to tropical storms, emergency operations and public safety agencies manage most of the storm-related activities on the road network. The transportation agencies continue to maintain normal operations throughout, participate in emergency operations center (EOC) decisions and public information dissemination, support evacuations and contraflow, and provide resources to extraordinary operations in flood control, response, and service restoration.

IMRCP use cases

IMRCP provides information and tools to support transportation agencies in tropical storm conditions. It enhances situational awareness by gathering, synthesizing, and integrating information about current and forecast traffic, weather, and hydrological conditions across the road network. It provides web interfaces, reports, and data subscriptions for operations stakeholders and for other systems that might benefit from the data integration. IMRCP can assist in planning and operations decision support with scenario analysis of weather-responsive management strategies like implementing VSL. Table 2 identifies potential operator uses for IMRCP in tropical storms.

Table 2. Potential operator uses for IMRCP in tropical storms.

Time relative to onset of storm	Operations/maintenance activities and potential uses for IMRCP
-5 days / -120 hours	Forecasts show tropical storm cones and extent of precipitation in IMRCP.
-4 days / -96 hours	Continue to monitor storm path and development. State and parish emergency operations typically activated. IMRCP hurricane traffic models activated to predict evacuation conditions.
-3 days / -72 hours	Continue to monitor storm forecast. Public notifications prepared, depending on forecast path and strength of storm. Contraflow decisions need to be made with sufficient time for deployment of traffic control. IMRCP hurricane traffic models predicting evacuation conditions. IMRCP scenario analysis tools available for evacuation operations support.
-2 days / -48 hours	Continue to monitor storm forecast. Implementation of action statements and public advisories. State of Emergency declared (48 to 45 hours), if appropriate. Public advisory of specific areas to be affected. Mandatory evacuation areas and curfews announced along with times of commencement (48 to 45 hours), if appropriate. Evacuations proceeding. IMRCP monitoring conditions and available for scenario analysis.
-1 day / -24 hours	Continue to monitor storm forecast and traffic conditions.
0-24 hours	Continue to monitor storm conditions. Focus shifts to awareness of hydrological and asset conditions. Remote sensors may become unavailable from communications, power, and physical failures.
24 hours	Storm passes.
Beyond 24 hours	Recovery phase. Information from field devices may be unavailable or incomplete. IMRCP event records used to review weather conditions and response as part of after action reviews. May perform scenario analysis of different traffic management strategies.

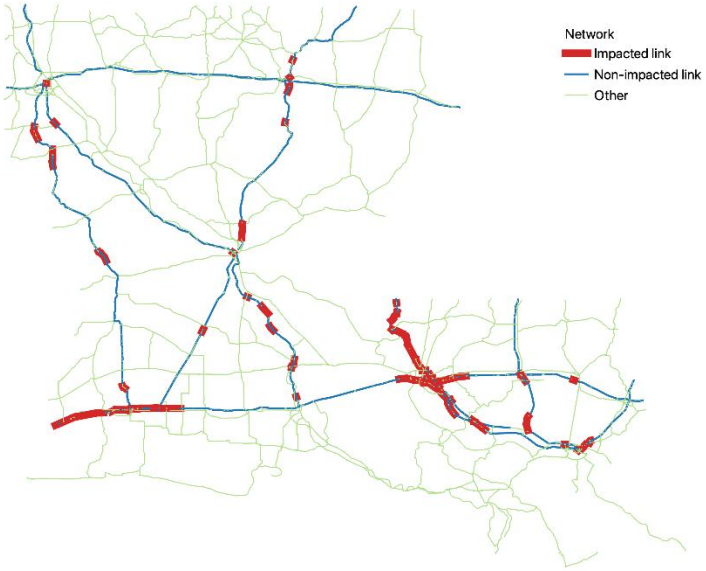
Source: FHWA.

Tropical storms are closely monitored and modeled by the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) and National Hurricane Center (NHC). State EOCs and transportation agencies similarly monitor the NHC and NWS forecasts for potential impacts on their states. IMRCP collects NHC and NWS data products for integration with its own traffic and pavement condition models. Forecast data sets collected by IMRCP include:

- Tropical storm path forecast cones.
- Wind and precipitation forecasts.
- Storm tide surge.
- NWS watches and warnings.
- River and stream levels.

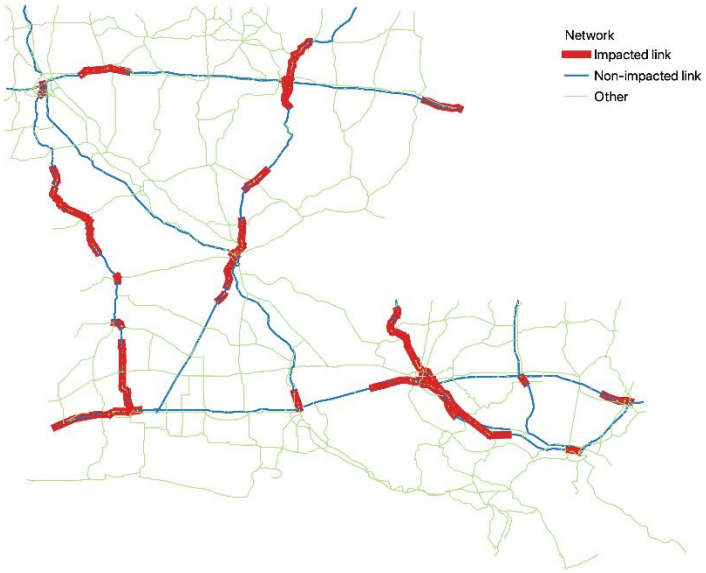
IMRCP uses these data to forecast potential road flooding and traffic based on the particular storm path and intensity. IMRCP can then be used by transportation agencies and their emergency operations partners in situation monitoring, evacuation planning, and operations during evacuations.

For tropical storms, setting up the traffic model involved getting data for as many storms as possible that had previously affected Louisiana road conditions. 2020 was a very busy tropical storm season in the Atlantic and Gulf of Mexico, and traffic and weather data records from 2020 in Louisiana were collected and processed into machine learning algorithms to build tropical storm traffic predictions for IMRCP. The resulting traffic speed model consists of three machine learning components models for predicting whether traffic on a link will be influenced by the approaching storm in a given day, predicting speeds on affected links within a given period, and predicting near-term speed based on real-time observed traffic speeds. Figure 48 shows the affected links observed for comparison to the affected links predicted as shown in Figure 49, one day before landfall for 2020 Hurricane Delta.



Source: FHWA.

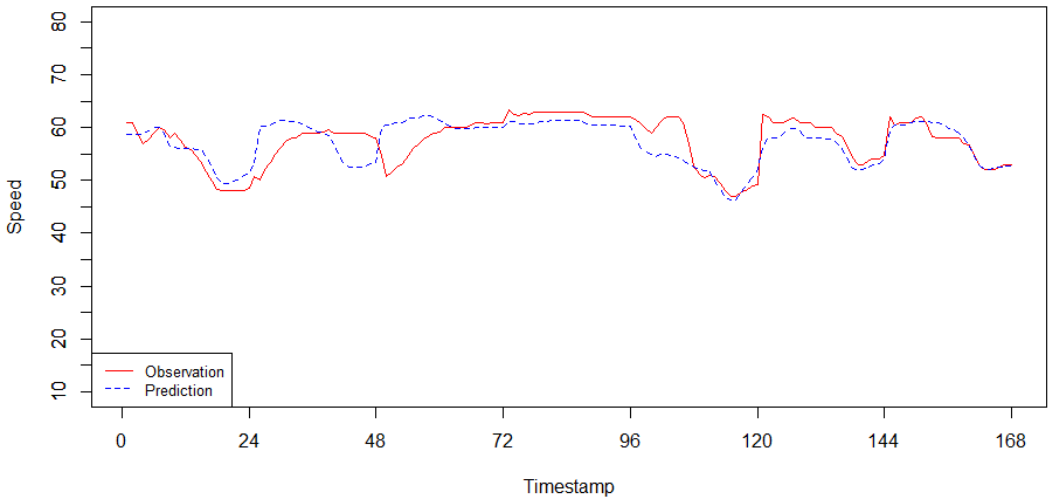
Figure 48. Graphic. Hurricane Delta congestion observations, one day before landfall.



Source: FHWA.

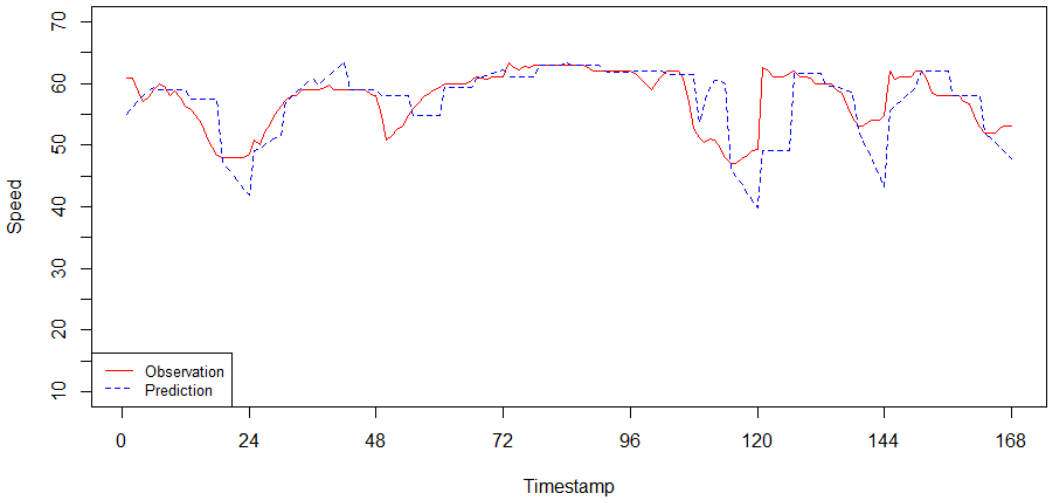
Figure 49. Graphic. Hurricane Delta congestions predictions, one day before landfall.

The three-part machine learning model also predicted traffic speeds at particular locations along evacuations for validated against observations for Hurricane Delta. In the example shown, traffic on I-10 eastbound approaching Baton Rouge was predicted based just on the training model and forecast landfall location in Figure 50, and as updated based on the hurricane path and local traffic conditions in Figure 51. Both results show excellent agreement with observations.



Source: FHWA.

Figure 50. Graphic. Speed prediction based on forecast Hurricane Delta path.



Source: FHWA.

Figure 51. Graphic. On-line speed prediction based on 6-hour real-time updates.

Transportation operations as a tropical storm moves through an area are limited by necessity and practice to those essential to safety. IMRCP in this phase of a storm's life cycle monitors wind, storm surge tide, and precipitation for potential impacts on the roadway and collects incident and event data as it becomes available to the TMC. Data collections and monitoring may be limited during the storm by power and communications outages and infrastructure damage from the storm.

The focus of transportation operations after a tropical storm has moved across a state turns to potential ongoing flooding and to recovery of infrastructure services. TMCs monitor roadway closures and other service outages in power and communications from wind and water damage. Roadways and bridges may be damaged and need emergency repairs or routing around longer closures. Storm debris may need to be removed from roadways over large areas. IMRCP can assist in monitoring weather conditions and, to the extent that road condition data is available from agencies, support post-event traffic analysis.

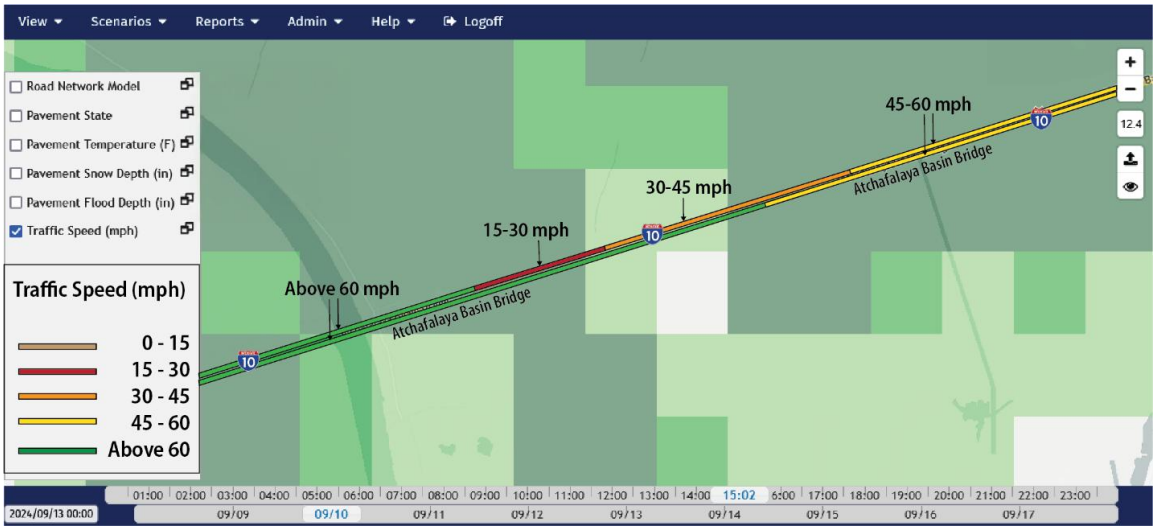
Tropical Storms, 2024

Tropical storms create an ongoing series of threats to life, property, and transportation system operations as they track from warm ocean waters to landfall and then move inland. Planning and preparations for operations in response to tropical storms starts as soon as the storm forecast indicates a landfall. Transportation agencies play a support role throughout the storm planning, response, and recovery phases. Emergency operations and public safety agencies manage most of the storm-related activities on the road network. The transportation agencies maintain system operations throughout the evolution of the storm; participate in emergency operations center decisions and public information dissemination; support evacuations and contraflow; and provide resources to extraordinary operations in flood control, response, and service restoration.

The 2024 tropical storm season produced an above average number of storms, with several impacting the United States mainland, but with only one storm landfalling in areas monitored

with IMRCP. Hurricane Francine made landfall near the St. Mary and Terrebonne Parishes about 30 miles south-southwest of Morgan City, Louisiana, at 5 p.m. central time on Sept. 11, 2024, with maximum sustained winds of 100 miles per hour. Storm surge and tide also affected the Mississippi coast. The Louisiana Governor's Office of Homeland Security and Emergency Preparedness, Mississippi Emergency Management Agency, and parish and county emergency departments closely monitored forecasts from NOAA's National Hurricane Center. Local parishes issued mandatory or voluntary evacuations for small areas near the coast; however, there were no large-scale regional evacuations for this event.

Congestion during the typical evacuation period in the day prior to Francine's landfall was intermittent and localized. As shown in Figure 52, traffic speeds were reduced to as low as 15 miles per hour at 3 p.m. local time on the westbound approach to the Louisiana Atchafalaya Basin Bridge on I-10. Showers and thunderstorms from the outer bands of precipitation were present in the area.



Source: FHWA.

Figure 52. Screenshot. Localized congestion on I-10 westbound Atchafalaya Basin Bridge approach at 3 p.m. on Sept. 10, 2024.

IMRCP provides information and tools to support transportation agencies in tropical storm planning, response, recovery, and review. Its alerts dashboard and situational awareness capabilities support environmental and forecast monitoring as a storm progresses. IMRCP traffic models predict conditions to help agencies with evacuation planning and operations decision support. The scenario analysis tool assists agencies in assessing weather-responsive management strategies such as implementing variable speed limits and hard-shoulder running. The IMRCP framework could be used in the recovery phase to provide asset and operations monitoring, particularly if and when information on road conditions, debris, and closures become available.

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APPENDIX A. OBSERVATION TYPE DEFINITIONS

Table 3. Observation type descriptions.

Name	Description
COVCLD	total cloud cover
DIRWND	wind direction
DPHLIQ	liquid inundation depth
DPHLNK	link depth
DPHSN	snow inundation depth
EVT	event
GSTWND	wind speed gust
MPLOW	MAC main plow
PCCAT	precipitation category
PRSUR	surface pressure
RH	relative humidity
RTEPC	precipitation rate
RTLIQM	liquid material rate
RTPREM	prewet material rate
RTSLDM	solid material rate
SPDLNK	average speed of vehicles on each link
SPDWND	wind speed
SSCST	extra tropical storm surge combined surge and tide
STG	flood stage
STPVT	pavement state
TAIR	air temperature
TDEW	dew point
TPLIQM	liquid material type
TPLOW	MAC tow plow
TPPREM	prewet material type
TPSLDM	solid material type
TPVT	pavement temperature
TRFLNK	traffic
TRSCAT	tropical storm category
TRSCNE	tropical storm cone
TRSTRK	tropical storm track
TSSRF	subsurface temperature
TYPPC	precipitation type
VIS	surface visibility
WPLOW	MAC wing plow

Source: FHWA.

Table 4. Observation types enumeration.

Name	Enumeration	Description
EVT	101	light-winter-precip
	102	moderate-winter-precip
	103	heavy-winter-precip
	104	light-precip
	105	moderate-precip
	106	heavy-precip
	107	low-visibility
	108	flood-stage-action
	109	flood-stage-flood
	201	dew-on-roadway
	202	frost-on-roadway
	203	blowing-snow
	204	icy-roadway
	301	incident
	302	workzone
	303	slow-traffic
	304	very-slow-traffic
	305	flooded-road
	306	lengthy-queue
	307	unusual-congestion
	399	test
	512	accident
	513	serious-accident
	514	injury-accident
	515	minor-accident
	516	multi-vehicle-accident
	517	numerous-accidents
	518	accident-involving-a-bicycle
	519	accident-involving-a-bus
	520	accident-involving-a-motorcycle
	521	accident-involving-a-pedestrian
	522	accident-involving-a-train
	523	accident-involving-a-truck
	524	accident-involving-a-semi-trailer
	525	accident-involving-a-hazardous-materials
	526	earlier-accident
	527	medical-emergency
	528	secondary-accident
	529	rescue-and-recovery-work-removed
	530	accident-investigation-work
	531	incident
	532	stalled-vehicle
	533	abandoned-vehicle
	534	disabled-vehicle

Name	Enumeration	Description
	535	disabled-truck
	536	disabled-semi-trailer
	537	disabled-bus
	538	disabled-train
	539	vehicle-spun-out
	540	vehicle-on-fire
	541	vehicle-in-water
	542	vehicles-slowing-to-look-at-accident
	543	jackknifed-semi-trailer
	544	jackknifed-trailer-home
	545	jackknifed-trailer
	546	spillage-occurring-from-moving-vehicle
	547	acid-spill
	548	chemical-spill
	549	fuel-spill
	550	hazardous-materials-spill
	551	oil-spill
	552	spilled-load
	553	toxic-spill
	554	overturned-vehicle
	555	overturned-truck
	556	overturned-semi-trailer
	557	overturned-bus
	558	derailed-train
	559	stuck-vehicle
	560	truck-stuck-under-bridge
	561	bus-stuck-under-bridge
	562	accident-cleared
	563	incident-cleared
	1000	Extreme Fire Danger
	1001	Fire Warning
	1002	Fire Weather Watch
	1003	Red Flag Warning
	1004	Heat Advisory
	1005	Excessive Heat Warning
	1006	Excessive Heat Watch
	1007	Severe Thunderstorm Warning
	1008	Severe Thunderstorm Watch
	1009	Storm Warning
	1010	Storm Watch
	1011	Tornado Warning
	1012	Tornado Watch
	1013	Severe Weather Statement
	1014	High Wind Warning
	1015	High Wind Watch

Name	Enumeration	Description
	1016	Wind Advisory
	1017	Extreme Wind Warning
	1018	Brisk Wind Advisory
	1019	Blowing Dust Advisory
	1020	Dust Storm Warning
	1021	Dense Fog Advisory
	1022	Dense Smoke Advisory
	1023	Air Quality Alert
	1024	Air Stagnation Advisory
	1025	Ashfall Advisory
	1026	Ashfall Warning
	1027	Earthquake Warning
	1028	Volcano Warning
	1029	Winter Storm Warning
	1030	Winter Storm Watch
	1031	Winter Weather Advisory
	1032	Ice Storm Warning
	1033	Blizzard Warning
	1034	Blizzard Watch
	1035	Avalanche Warning
	1036	Avalanche Watch
	1037	Blowing Snow Advisory
	1038	Snow and Blowing Snow Advisory
	1039	Heavy Snow Warning
	1040	Sleet Advisory
	1041	Sleet Warning
	1042	Snow Advisory
	1043	Freeze Warning
	1044	Freeze Watch
	1045	Freezing Drizzle Advisory
	1046	Freezing Fog Advisory
	1047	Freezing Rain Advisory
	1048	Freezing Spray Advisory
	1049	Frost Advisory
	1050	Hard Freeze Warning
	1051	Hard Freeze Watch
	1052	Wind Chill Advisory
	1053	Wind Chill Warning
	1054	Wind Chill Watch
	1055	Extreme Cold Warning
	1056	Extreme Cold Watch
	1057	Flash Flood Statement
	1058	Flash Flood Warning
	1059	Flash Flood Watch
	1060	Flood Advisory

Name	Enumeration	Description
	1061	Flood Statement
	1062	Flood Warning
	1063	Flood Watch
	1064	Hydrologic Advisory
	1065	Hydrologic Outlook
	1066	Beach Hazards Statement
	1067	Coastal Flood Advisory
	1068	Coastal Flood Statement
	1069	Coastal Flood Warning
	1070	Coastal Flood Watch
	1071	Gale Warning
	1072	Gale Watch
	1073	Hazardous Seas Warning
	1074	Hazardous Seas Watch
	1075	Heavy Freezing Spray Warning
	1076	Heavy Freezing Spray Watch
	1077	High Surf Advisory
	1078	High Surf Warning
	1079	Lake Effect Snow Advisory
	1080	Lake Effect Snow and Blowing Snow Advisory
	1081	Lake Effect Snow Warning
	1082	Lake Effect Snow Watch
	1083	Lakeshore Flood Advisory
	1084	Lakeshore Flood Statement
	1085	Lakeshore Flood Warning
	1086	Lakeshore Flood Watch
	1087	Lake Wind Advisory
	1088	Low Water Advisory
	1089	Marine Weather Statement
	1090	Rip Current Statement
	1091	Small Craft Advisory
	1092	Special Marine Warning
	1093	Tsunami Advisory
	1094	Tsunami Warning
	1095	Tsunami Watch
	1096	Hurricane Force Wind Warning
	1097	Hurricane Force Wind Watch
	1098	Hurricane Statement
	1099	Hurricane Warning
	1100	Hurricane Watch
	1101	Hurricane Wind Warning
	1102	Hurricane Wind Watch
	1103	Tropical Storm Warning
	1104	Tropical Storm Watch
	1105	Tropical Storm Wind Warning

Name	Enumeration	Description
	1106	Tropical Storm Wind Watch
	1107	Typhoon Statement
	1108	Typhoon Warning
	1109	Typhoon Watch
	1110	Hazardous Weather Outlook
	1111	Special Weather Statement
	1112	911 Telephone Outage
	1113	Administrative Message
	1114	Child Abduction Emergency
	1115	Civil Danger Warning
	1116	Civil Emergency Message
	1117	Evacuation Immediate
	1118	Hazardous Materials Warning
	1119	Law Enforcement Warning
	1120	Local Area Emergency
	1121	Nuclear Power Plant Warning
	1122	Radiological Hazard Warning
	1123	Shelter In Place Warning
	1124	Test
	5888	impassable
	5889	almost-impassable
	5890	passable-with-care
	5891	passable
	5892	surface-water-hazard
	5893	danger-of-hydroplaning
	5894	wet-pavement
	5895	treated-pavement
	5896	slippery
	5897	low-ground-clearance
	5898	at-grade-level-crossing
	5899	mud-on-roadway
	5900	leaves-on-roadway
	5901	loose-sand-on-roadway
	5902	loose-gravel
	5903	fuel-on-roadway
	5904	oil-on-roadway
	5905	road-surface-in-poor-condition
	5906	melting-tar
	5907	uneven-lanes
	5908	rough-road
	5909	rough-crossing
	5910	ice
	5911	icy-patches
	5912	black-ice
	5913	ice-pellets-on-roadway

Name	Enumeration	Description
	5914	ice-build-up
	5915	freezing-rain
	5916	wet-and-icy-roads
	5917	melting-snow
	5918	slush
	5919	frozen-slush
	5920	snow-on-roadway
	5921	packed-snow
	5922	packed-snow-patches
	5923	plowed-snow
	5924	wet-snow
	5925	fresh-snow
	5926	powder-snow
	5927	granular-snow
	5928	froazen-snow
	5929	crusted-snow
	5930	deep-snow
	5931	snow-drifts
	5932	drifting-snow
	5933	expected-snow-accumulation
	5934	current-snow-accumulation
	5935	sand
	5936	gravel
	5937	paved
	5938	dry-pavement
	5939	snow-cleared
	5940	pavement-conditions-improved
	5941	skid-hazard-reduced
	5942	pavement-conditions-cleared
MPLOW	0	Plow up
	1	Plow down

Name	Enumeration	Description
PCCAT	0	no-precipitation
	1	light-rain
	2	moderate-rain
	3	heavy-rain
	4	light-freezing-rain
	5	moderate-freezing-rain
	6	heavy-freezing-rain
	7	light-snow
	8	moderate-snow
	9	heavy-snow
	10	light-ice
	11	moderate-ice
	12	heavy-ice
	101	other
	102	unknown
	104	light-unidentified
	105	moderate-unidentified
	106	heavy-unidentified
STG	0	not-defined
	1	no-action
	2	action
	3	flood
	4	moderate
	5	major
STPVT	1	other
	2	error
	3	dry
	4	trace-moisture
	5	wet
	6	chemically-wet
	7	ice-warning
	8	ice-watch
	9	snow-warning
	10	snow-watch
	11	absorption
	12	dew
	13	frost
	14	absorption-at-dewpoint
	20	ice/snow
	21	slush
	22	melting-snow
	23	icing-rain
	30	flooded
TPLOW	0	Plow up
	1	Plow down

Name	Enumeration	Description
TRSCAT	479	Tropical Depression
	642	Hurricane
	809	Major Hurricane
	1057	Tropical Depression
	1072	Tropical Storm
	37345	Subtropical Depression
	37360	Subtropical Storm
TRSCNE	479	Tropical Depression
	642	Hurricane
	809	Major Hurricane
	1057	Tropical Depression
	1072	Tropical Storm
	37345	Subtropical Depression
	37360	Subtropical Storm
TRSTRK	479	Tropical Depression
	642	Hurricane
	809	Major Hurricane
	1057	Tropical Depression
	1072	Tropical Storm
	37345	Subtropical Depression
	37360	Subtropical Storm
TYPPC	0	none
	1	rain
	2	snow
	3	ice-pellets
	4	freezing-rain
	5	other
	6	unknown
WPLOW	0	Plow up
	1	Plow down

Source: FHWA.

Table 5. Observation type source descriptions.

Source	Forecast/ Observation	Spatial Extent	Temporal Extent	Observation Types
ADCIRC	forecasts	2.5 km x 2.5 km grid for CONUS	1 hour forecasts for 120 hours starting 6 hours after collection	SSCST
CAP	observations and forecasts	County and custom polygons	Varies	EVT
GFS	forecasts	25 km x 25 km grid for entire world	3 hour forecasts for 168 hours starting 54 hours after collection	DPHSN, GSTWND, PCCAT, PRSUR, RH, RTEPC, SPDWND, TAIR, TDEW, TYPPC, VIS
IMRCP	observations	Area surrounding individual stations	Observations valid for 1 hour	TPVT, SSRF
IMRCP	forecasts	2.5 km x 2.5 km grid for CONUS	1 hour forecasts for 72 hours starting 1 hour after collection	PCCAT
IMRCP	observations	1 km x 1 km grid for CONUS	Observations valid for 4 minutes	PCCAT
METRo	forecasts	Individual segments	2 minute forecasts for 1 hour, then 20 minute forecasts for 11 hours	DPHLIQ, DPHSN, STPVT, TPVT, TSSRF
MLP	forecasts	Individual segments	15 minute forecasts for 2 hours, or 1 hour forecasts for 24 hours	SPDLNK
MRMS	observations	1 km x 1 km grid for CONUS	Observations valid for 4 minutes	RDR0, RTEPC
NDFD	forecasts	2.5 km x 2.5 km grid for CONUS	1to 3 hour forecasts for 72 hours starting 1 hour after collection	COVCLD, RTEPC, SPDWND, TAIR, TDEW
NHC	forecasts	Tropical storm cones of probability	6 hour forecasts for 120 hours	TRSCAT, TRSCNE, TRSTRK
NWM	forecasts	Inundation polygons	120 hour forecasts every hour	STG
NWPS	observations and forecasts	Individual stations	Most recent observed values	EVT, STG, STPVT

Source	Forecast/ Observation	Spatial Extent	Temporal Extent	Observation Types
			and 24 hour forecast	
RTMA	forecasts	2.5 km x 2.5 km grid for CONUS	1 hour forecast	COVCLD, DIRWND, GSTWND, PRSUR, SPDWND, TAIR, TDEW, VIS
WxDE	observations	Individual stations	Observations valid for 1 hour	DIRWND, DPHLNK, GSTWND, PCCAT, PRSUR, RH, RTEPC, SPDWND, STPVT, TAIR, TDEW, TPVT, TSSRF, TYPPC, VIS

Source: FHWA.

Table 6. Observation type synthesis algorithms.

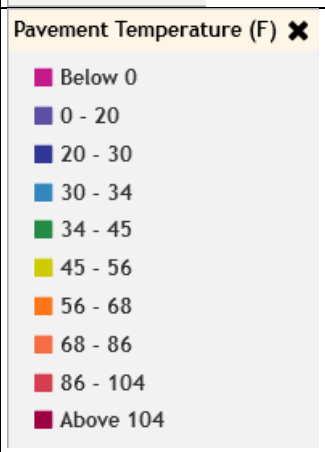
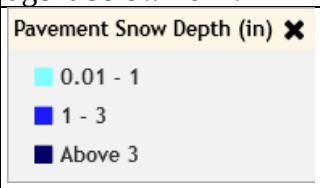
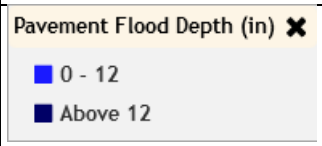
Name	Description	Source – Observations	Source – Predictions
dphliq	liquid inundation depth	Model of the Environment and Temperature of Roads (METRo) is run for each link in the road network model to determine liquid inundation depth estimations.	METRo is run for each link in the road network model to determine liquid inundation depth predictions.
dphlnk	link depth	AHPS stage observations at select locations in the road network model are collected when new values are available. These values are used to determine the flood depth on links based on inundation mapping provided by NOAA/NWS.	AHPS stage predictions at three locations in the road network model are collected when new values are available. These values are used to determine the flood depth on links based on inundation mapping provided by NOAA.
dphsn	snow inundation depth	METRo is run for each link in the road network model to determine pavement snow depth estimations. The snow inventory is tracked from previous runs.	METRo is run for each link in the road network model to determine pavement snow depth predictions. The snow inventory is tracked from each run to the next, accounting for new accumulation and melting.
evt	event	Workzone and Incident event details are collected from contributing transportation management centers. National Weather Service (NWS) Common Alerting Protocol (CAP) alert events are collected from NWS. CAP alerts affecting counties use previously stored county defintions to display on the map. CAP alerts affecting areas other than counties use the area definition provided in the CAP alert to display on the map.	Workzone and Incident event details are collected from contributing transportation management centers. NWS CAP alert events are collected from NWS. CAP alerts affecting counties use previously stored county defintions to display on the map. CAP alerts affecting areas other than counties use the area definition provided in the CAP alert to display on the map.

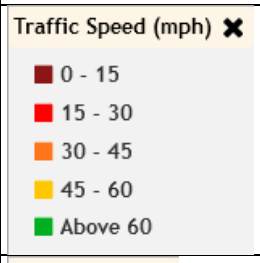
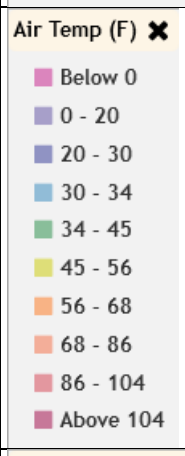
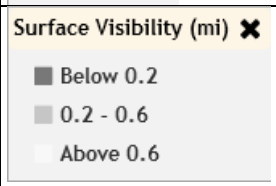
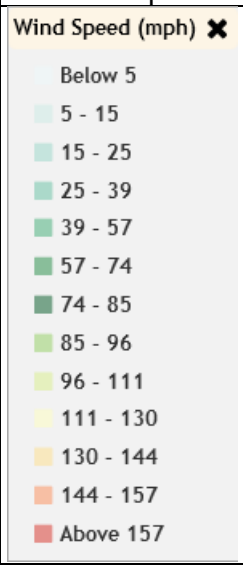
Name	Description	Source – Observations	Source – Predictions
pccat	precipitation category	The precipitation category is determined based on observation TYPPC and RTEPC. • Light Freezing Rain: RTEPC <= 7.056x10-5 kg/m2-s and TYPPC = [freezing rain] • Medium Freezing Rain: 7.056x10-5 < RTEPC <= 7.056x10-4 kg/m2-s and TYPPC = [freezing rain] • Heavy Freezing Rain: 7.056x10-4 < RTEPC kg/m2-s and TYPPC = [freezing rain] • Light Snow: RTEPC <= 7.056x10-5 kg/m2-s and TYPPC = [snow] • Medium Snow: 7.056x10-5 < RTEPC <= 7.056x10-4 kg/m2-s and TYPPC = [snow] • Heavy Snow: 7.056x10-4 < RTEPC kg/m2-s and TYPPC = [snow] • Light Ice Pellets: RTEPC <= 7.056x10-5 kg/m2-s and TYPPC = [ice pellets,] • Medium Ice Pellets: 7.056x10-5 < RTEPC <= 7.056x10-4 kg/m2-s and TYPPC = [ice pellets,] • Heavy Ice Pellets: 7.056x10-4 < RTEPC kg/m2-s and TYPPC = [ice pellets] • Light Rain: RTEPC <= 7.056x10-4 kg/m2-s and TYPPC = [rain]	The precipitation category is determined based on predicted TYPPC and RTEPC. • Light Freezing Rain: RTEPC <= 7.056x10-5 kg/m2-s and TYPPC = [freezing rain] • Medium Freezing Rain: 7.056x10-5 < RTEPC <= 7.056x10-4 kg/m2-s and TYPPC = [freezing rain] • Heavy Freezing Rain: 7.056x10-4 < RTEPC kg/m2-s and TYPPC = [freezing rain] • Light Snow: RTEPC <= 7.056x10-5 kg/m2-s and TYPPC = [snow] • Medium Snow: 7.056x10-5 < RTEPC <= 7.056x10-4 kg/m2-s and TYPPC = [snow] • Heavy Snow: 7.056x10-4 < RTEPC kg/m2-s and TYPPC = [snow] • Light Ice Pellets: RTEPC <= 7.056x10-5 kg/m2-s and TYPPC = [ice pellets,] • Medium Ice Pellets: 7.056x10-5 < RTEPC <= 7.056x10-4 kg/m2-s and TYPPC = [ice pellets,] • Heavy Ice Pellets: 7.056x10-4 < RTEPC kg/m2-s and TYPPC = [ice pellets] • Light Rain: RTEPC <= 7.056x10-4 kg/m2-s and TYPPC = [rain]

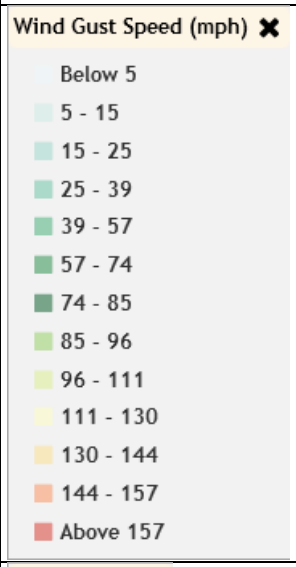
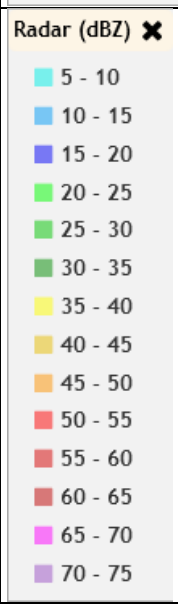
Name	Description	Source – Observations	Source – Predictions
		• Medium Rain: $7.056x10^{-4}$ < RTEPC <= $2.117x10^{-3}$ kg/m^2-s and TYPPC = [rain] • Heavy Rain: $2.117x10^{-3}$ < RTEPC kg/m^2 and TYPPC = [rain]	• Medium Rain: $7.056x10^{-4}$ < RTEPC <= $2.117x10^{-3}$ kg/m^2-s and TYPPC = [rain] • Heavy Rain: $2.117x10^{-3}$ < RTEPC kg/m^2 and TYPPC = [rain]
stpvt	pavement state	METRo is run for each link in the road network model to determine pavement state estimations. • Dry Road: The water reservoir contains less than 0.01 mm and the ice/snow reservoir contains less than .2 mm of water equivalent. • Wet road: The water reservoir contains more than 0.01 mm of water. • Ice/Snow: The ice/snow reservoir contains more than 0.2 mm of water equivalent. • Water/Snow: Both of the reservoirs (water and ice/snow) contain more than 0.2 mm of water equivalent. • Dew: Condensation on the road when the temperature of the surface of the road is above the freezing point. • Frost: Condensation on the road when the temperature of the surface of the road is below the freezing point or water already present on the road is turning into ice.	METRo is run for each link in the road network model to determine pavement state predictions. • Dry Road: Each reservoir (water and ice/snow) contains less than 0.01 mm of liquid water equivalent. • Wet road: The water reservoir contains more than 0.01 mm of water. • Ice/Snow: The ice/snow reservoir contains more than 0.2 mm of water equivalent. • Water/Snow: Both of the reservoirs (water and ice/snow) contain more than 0.2 mm of water equivalent. • Dew: Condensation on the road when the temperature of the surface of the road is above the freezing point. • Frost: Condensation on the road when the temperature of the surface of the road is below the freezing point or water already present on the road is turning into ice.
trflnk	traffic	The estimated speed value for each link is divided by the speed limit for that link.	The predicted speed value for each link is divided by the speed limit for that link.

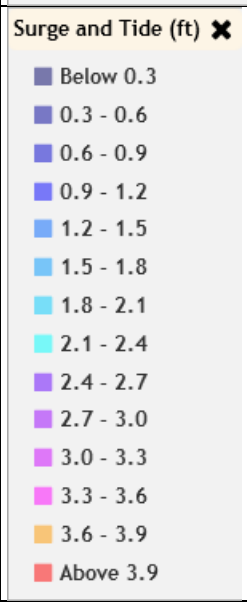
APPENDIX B. MAP LAYER LEGENDS

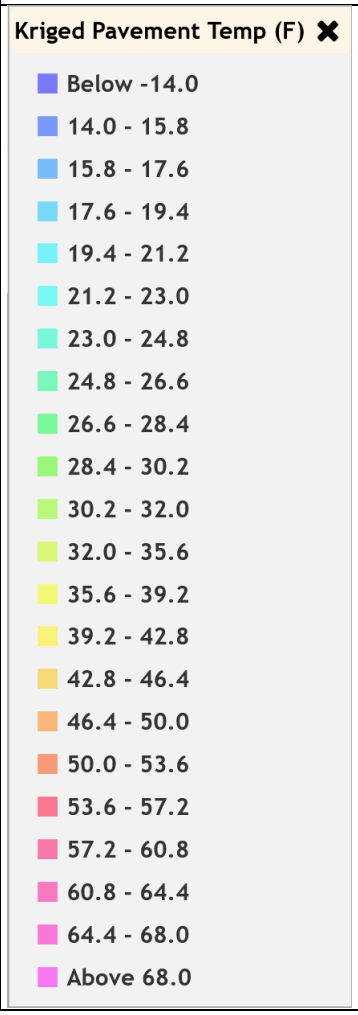
Table 7. Layer Definitions.

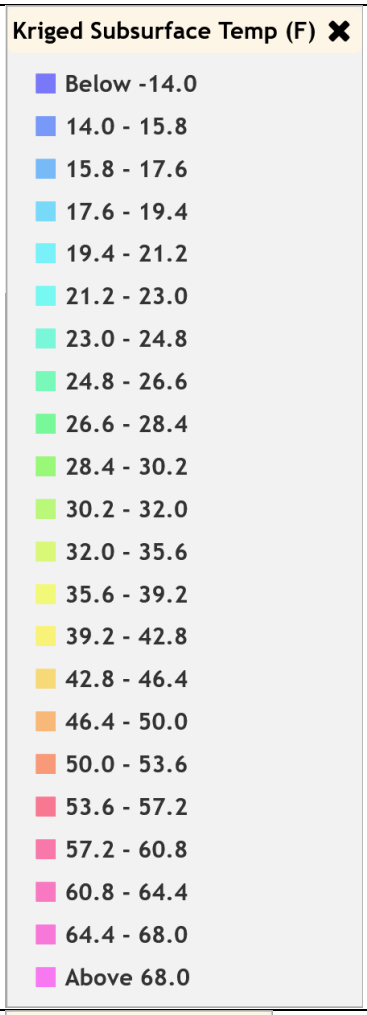
Layer	Observation Type	Legend
Pavement State	STPVT	 The Pavement State layer categories are consistent with the METRo model pavement state categories. A flooded state is projected from local inundation calculations, where available.
Pavement Temperature	TPVT	 The Pavement Temperature map layer is divided into levels based on pavement behaviors at temperature intervals. Pavement temperatures between 30°F and 34°F indicate a transition to freezing conditions. Salt treatment may be effective on pavement at temperatures between 20°F and 29°F. Salt loses its effectiveness as an anti-icing agent below 20°F.
Pavement Snow Depth	DPHSN	 The Pavement Snow Depth layer is represented in bands for noticeable, actionable, and significant impacts on travel conditions.
Pavement Flood Depth	DPHLNK	 The flood depth calculation is available only at specific locations, and an absence of a flood depth indication is not necessarily evidence of an absence of flooding.

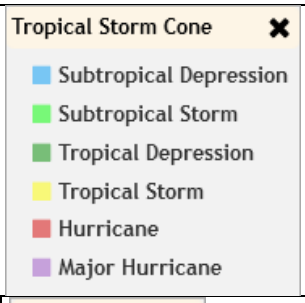
Layer	Observation Type	Legend
Traffic Speed	SPDLNK	 The Traffic Speed layer is divided into five equal bands ranging from 0 to 75 mph.
Air Temperature	TAIR	 The Air Temperature layer is divided into layers based on typical temperature behaviors. The narrow band at 32 F highlights the precipitation freezing point.
Surface Visibility	VIS	 The Surface Visibility layer remains white until the visibility is below 0.6 mi (1 km). Travelers can be significantly affected by visibility below this point.
Wind Speed	SPDWND	 The Wind Speed bands mark increasing intensity up to and through the tropical storm and hurricane levels.

Layer	Observation Type	Legend
Wind Gust Speed	GSTWND	 The Wind Gust Speed bands use the same levels as Wind Speed.
Radar	RDR0	 The Radar layer is divided into levels based on those used by the NWS.

Layer	Observation Type	Legend
Precipitation Rate & Type	PCCAT	 The Precipitation Rate & Type layer is divided into categories based on the observation returned by PCCAT. PCCAT categories are described in Appendix A.
Surge and Tide	DPHLIQ	 The surge and tide layer presents the depth of water from storm surge and tide over the coastal landform, provided by the NWS from its Advanced Circulation model for oceanic, coastal, and estuarine waters (ADCIRC).

Layer	Observation Type	Legend
Kriged Pavement Temp	KRTPVT	 Spatial estimates of pavement temperature are computed by IMRCP from measurements at environmental sensor stations (ESS) using Kriging statistical methods.

Layer	Observation Type	Legend
Kriged Subsurface Temp	KTSSRF	 Spatial estimates of subsurface temperature are computed by IMRCP from measurements at environmental sensor stations (ESS) using Kriging statistical methods.
NWS Alerts	EVT	 The NWS Alerts Layer is categorized based on the type of alert issued by the NWS.

Layer	Observation Type	Legend
Tropical Storm Cone	n/a	 Tropical storm cones are represented from National Hurricane Center (NHC) data to show the potential path and current category of tropical storms.
Inundation	STG	 The NWPS inundation polygons show locations that would be flooded at the current or predicted flood stage.

Source: FHWA.

APPENDIX C. ALERT DEFINITIONS

Table 8.Traffic Alert Definitions

Type	Algorithm	Extent	Reference	Notify	Icon
Incident	EVT=Incident	point	TMC	n/a	
Work Zone	EVT=Workzone	link	TMC	n/a	

Source: FHWA.

Table 9. Weather Alert Definitions.

Type	Algorithm	geoExtent	Reference	Notify	Icon
Medium Winter Precip	PCCAT= [Medium Freezing Rain, Medium Snow, Medium Ice Pellets]	area	RAP	Y	
Heavy Winter Precip	PCCAT= [Heavy Freezing Rain, Heavy Snow, Heavy Ice Pellets]	area	RAP	Y	
Medium Precip	PCCAT= [Medium Rain]	area	RAP	N	
Heavy Precip	PCCAT= [Heavy Rain]	area	RAP	Y	
Flood Stage Action	n/a	point	NWM	n/a	
Flood Stage Flood	n/a	point	NWM	n/a	
Low Visibility	VIS < 0.2 mi	area	RAP	Y	

Source: FHWA.

Table 10. Road Condition Alert Definitions.

Type	Algorithm	Extent	Reference	Notify	Icon
Low Visibility	VIS < 0.2 mi	area	RAP	n/a	
Ice on Bridge	STPVT= [ice]	segment	METRo	n/a	
Flooded Road	DPHLNK > 0 in.	segment	NWM	n/a	

Source: FHWA.

Table 11. Tropical Storm Categories.

Type	Algorithm	Extent	Reference	Notify	Icon
Subtropical Depression	From NHC	point	NHC	n/a	
Subtropical Storm	From NHC	point	NHC	n/a	
Tropical Depression	From NHC	point	NHC	n/a	
Tropical Storm	From NHC	point	NHC	n/a	
Hurricane	From NHC	point	NHC	n/a	
Major Hurricane	From NHC	point	NHC	n/a	

Source: FHWA.

APPENDIX D. EXAMPLE GEOJSON MAP LAYER FILE

Figure 53 illustrates example content for a GeoJSON file that could be uploaded and displayed as a layer on the IMRCP map. The file structure conforms to the RFC 7946 GeoJSON standard.[7] Not all geometry types within the standard are available in IMRCP, but features and tags within the example file are specifically recognized by IMRCP for display.

[7] Internet Engineering Task Force (IETF). "RFC 7946 – The GeoJSON Format"(website). August 2016. https://datatracker.ietf.org/doc/html/rfc7946. Accessed April 9, 2025.

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			"geometry": {"type": "LineString", "coordinates":
			[[-89.994133, 34.894754],[-89.547436, 34.906460],[-89.941924,
34.315270],[-89.994133, 34.894754]]}
	},
	{
			"type": "Feature",
			"properties": {"opacity": 0.4, "label": "1", "color": "yellow"},
			"geometry": {"type": "Polygon", "coordinates":
			[[[-89.994133, 34.894754],[-89.547436, 34.906460],[-89.941924,
34.315270],[-89.994133, 34.894754]]]}
	},
	]
}
```


Source: FHWA.

Figure 53. Textbox. Example GeoJSON Map Layer File Content.