Pavement Health Track (PHT) Analysis Tool Graphical User Interface

User's Manual

Version 2.x

Federal Highway Administration
Office of Asset Management

June 2013

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Appendices

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Scope

This document provides the user's manual and general information for the Pavement Health Track (PHT) analysis software tool version 2.x.

Reference Documents

The following documents form a part of this manual to the extent referenced herein.

- Pavement Health Track RSL Forecasting Models Technical Information, latest version.
- HPMS Field Manual, September 2010.

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Introduction

The Federal Highway Administration (FHWA) Pavement Health Track (PHT) Analysis Tool is a computer-assisted decision-making tool designed to help state highway agencies (SHA), metropolitan planning organizations (MPO), cities, and counties characterize current and future pavement network health and manage pavement deficiencies through maintenance and rehabilitation planning in a timely, cost-effective manner.

Benefits of Using the PHT Analysis Tool

The benefits of using PHT Analysis Tool include the following:

- An effective tool for local jurisdictions to both manage pavement networks (repository of all pertinent highway inventory, traffic, maintenance and rehabilitation, and costs information
- Highway agencies can characterize current and future pavement network health.
- Highway agencies can estimate current and future maintenance and rehabilitation needs to achieve predetermine levels of performance.
- Highway agencies can determine pavement network health for different levels of maintenance and rehabilitation funding.

Software Installation

The PHT Analysis tool is a software application designed for use with the Microsoft Windows® operating system.

- Insert the PHT Analysis Tool CD into the CD drive
- The installation should automatically start. If this does not occur, browse to the drive where the CD is located and double-click `Setup.exe`
- Follow the instructions on the InstallShield® Wizard to complete installation.
- Upon completion of the installation, a new Start Menu group, Pavement Health Track, will be created in the Windows Start menu. Also an icon will be placed on the Windows desktop.

Uninstall the PHT Analysis tool software from the Windows Control Panel.

Support Services

Information on all support services can be obtained from:

http://www.fhwa.dot.gov/pavement/healthtrack

Source Data

The default source data for the PHT Analysis Tool is based on the HPMS 2010 format comma-delimited text file shown in Table 20 or other state maintained Pavement Management System (PMS) electronic source data. The PHT tool acquires data from the external data sources and compiles a set of highway data made up of the data fields required for the PHT analysis. Each record in the highway data represents a highway section. The compiled highway data are permanently stored in the database for subsequent use in the PHT analysis.

PHT Analysis Procedure

The general procedure for characterizing a pavement networks health using the PHT Analysis Tool is comprised of the following steps:

1. Importing the highway data into the analysis tool.
2. Performing data quality checks.
3. Defining analysis type and what-if scenarios.
4. Running the PHT analysis.
5. Reviewing of results.
6. Presentation and documentation of results.

Estimating RSL

Pavement RSL at the project level typically is defined as life of a pavement from the present time until application of the first significant rehabilitation treatment or reconstruction, which would be the first significant cost expenditure for the pavement after its original construction. The placement of a structural overlay or reconstruction signals the end of a pavement's serviceable life; the application of minor maintenance treatments or thin overlays is not considered significant enough to indicate the end of pavements service life.

Significant rehabilitation occurs due to some form of pavement failure. Failure typically is described as the pavement attaining first terminal distress as shown in Figure 1. Thus, RSL is simply the time in years or remaining equivalent single axle loads (ESALs) that it would take a given pavement to attain the first terminal distress.

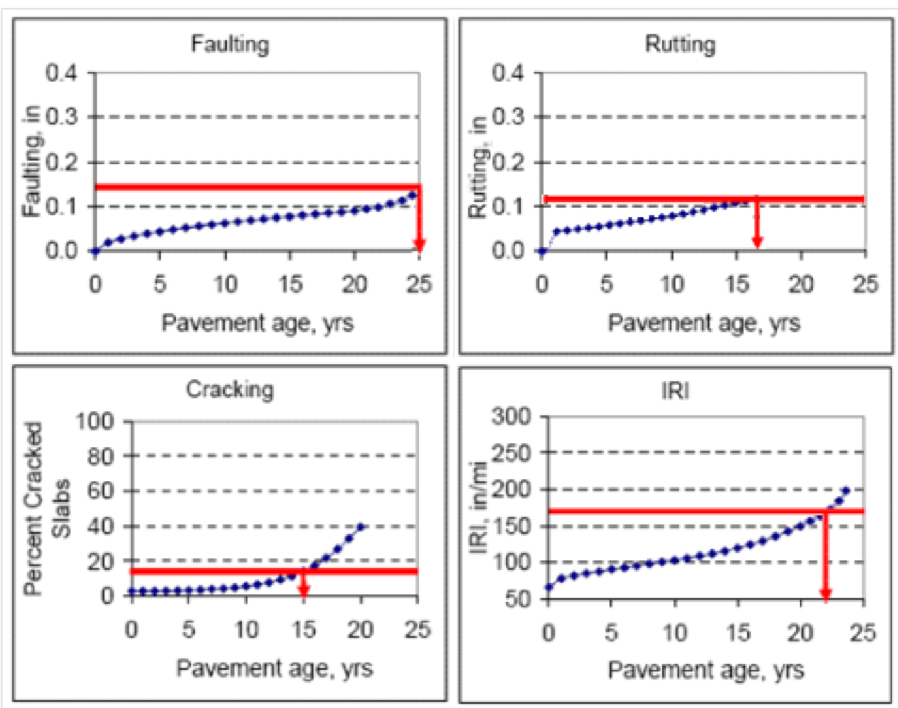

Figure 1. Predicted Pavement Distress and Estimated RSL

Critical RSL

The critical RSL is the estimated time until the first terminal distress occurs. Using the example illustrated in Figure 1 for jointed plain concrete pavement (JPCP), the critical RSL is estimated as shown in Table 1. In this example, the first terminal distress is cracking, which occurs at 15 years. Since the pavement's current age is 10 years, the RSL is the difference of 5 years.

Table 1. Estimation of Critical RSL

JPCP Distress/IRI	Predicted Life, yrs	Current Pavement Age, yrs	RSL, yrs	Critical RSL
Faulting	25	10	15	5
Rutting	20	10	10	
Cracking	15	10	5	
IRI	22	10	12	

Weighted Average RSL

The weighted average RSL is the estimated time until each terminal distress occurs averaged together using a user-defined weight for each distress type. Using the example illustrated in Figure 1, the weighted average RSL is estimated as shown in Table 2. In this example, each distress type is assigned an equal weight in the average calculation, resulting in an average RSL of 10.5 years.

Table 2. Estimation of Weighted Average RSL

JPCP Distress/IRI	Predicted Life, yrs	Current Pavement Age, yrs	RSL, yrs	Weight	Average RSL
Faulting	25	10	15	1	10.5
Rutting	20	10	10	1	
Cracking	15	10	5	1	
IRI	22	10	12	1	

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Application GUI

The following sections describe the PHT Analysis Tool Graphical User Interface (GUI).

Welcome Window

When the application starts, the welcome window shown in Figure 2 will appear. This window allows you to quickly select what action you would like to take to begin working. You may create a new Study, open an existing Study, return to the last Study that you were working in, or begin working without an active Study.

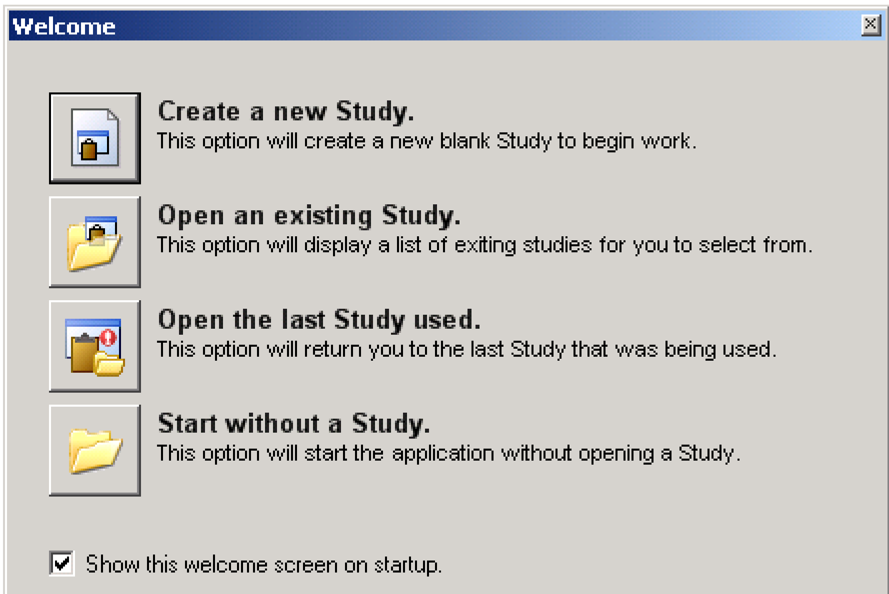


Figure 2. Application Welcome Window

The welcome window may be disabled, in which case the application will always begin without an active study being opened. If the welcome window is disabled, you may re-enable it from the applications options window available under the **Tools/Options** menu item on the main application window as shown in Figure 4.

Main Application Window

The Pavement Health Track Analysis Tool serves as an add-in analysis module for the Battelle Multi-Faceted Analysis Tool (BMFAT) environment. The main application window hosting the PHT analysis tool is shown in Figure 3.

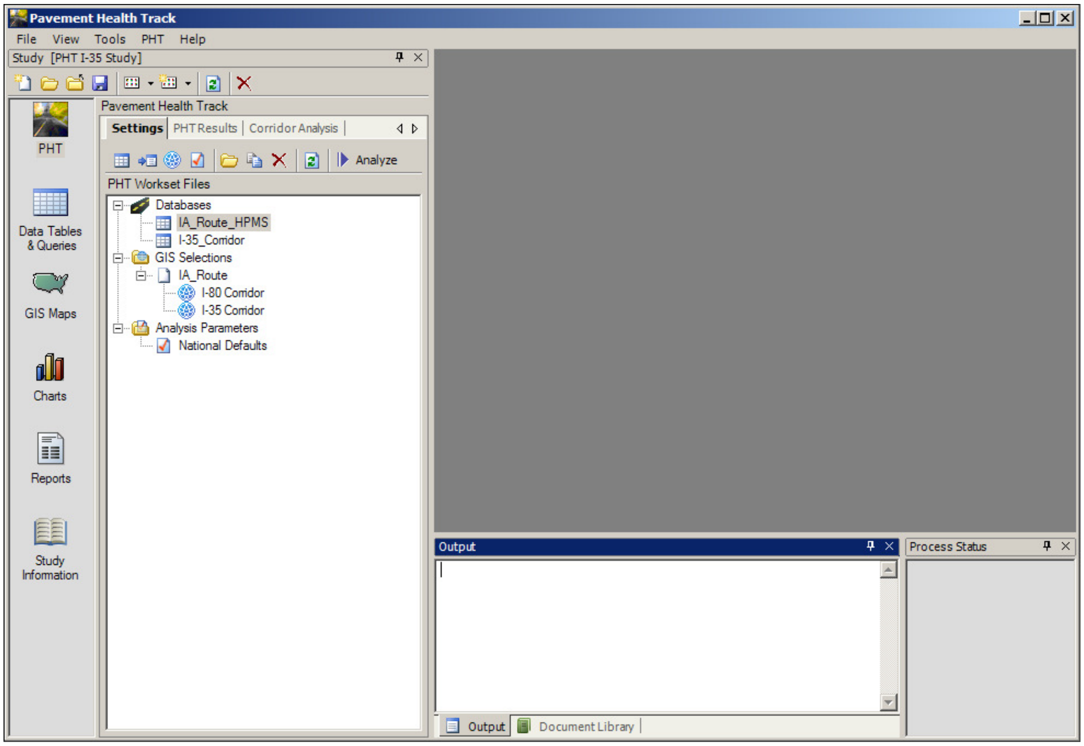


Figure 3. Main Application Window

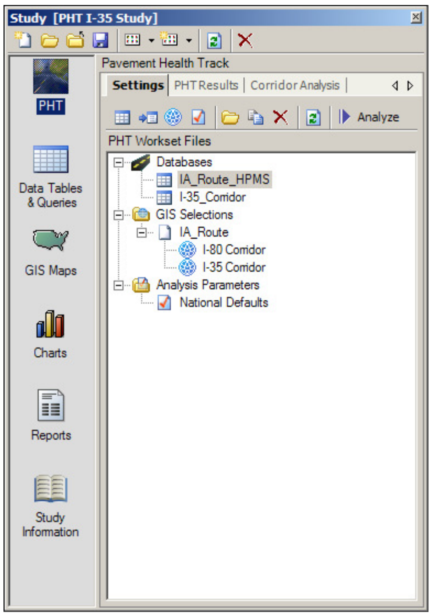
The main application window provides four panels and a main workspace area. The panels can be arranged, hidden, or displayed as desired. If any panel is not visible in the application workspace, you may activate it by selecting it under the **View** menu from the applications main menu.

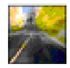
- Study. This panel provides access to the PHT analysis module and serves to organize your efforts to study a particular issue. You can create any number of Studies and make their scope as broad or specific as you deem useful.
- Document Library. This panel provides access to the complete library of documents that are produced by the PHT analysis tool. All documents in the library are available here regardless of the Study that produced them.
- Output. This panel provides a communication platform for messages produced by the PHT analysis module to be displayed.
- Process Status. This panel provides status and progress bars to provide feedback.

The Study Window

The Study is displayed in the **Study** window shown in Figure 4. If it is not already visible in the application workspace, you may activate the Study window by clicking the **View/Study** menu item from the applications main menu. To create a new Study, click the **New**  button. To open a Study that has previously been created, click the **Open**  button and select a Study from the list.

Note that only one Study can be open at a time.





The **PHT** icon displays the user interface for the PHT analysis tool.

The **Data Tables & Queries** icon displays a list of data tables that are part of the Study. These tables contain the raw analysis data that has been stored in the data warehouse.

The **GIS Maps** icon displays a list of GIS documents that are part of the Study.

The **Charts** icon displays a list of chart documents that are part of the Study.

The **Reports** icon displays a list of report documents that are part of the Study.

The **Study Information** icon displays general information about the Study such as its name, description, status, etc.

Figure 4. Study Window

The Study window toolbar provides the following functions:

 **Create a New Study.** Create a new blank Study.

 **Open an Existing Study.** Display a dialog to select an existing Study.

 **Close.** Close the current Study.

 **Save.** Save all changes to the current Study.

 **Add Existing Items.** Display a dialog window that allows you to select an existing chart, map, report, table, or query and add it to the Study.

 **Create New Item.** Create a new blank chart, map, report, or query and add it to the current Study.

 **Refresh.** Refresh the display.

 **Remove.** Remove the currently selected item(s) from the Study.

Document Library

The document library window shown in Figure 5 stores all of the reports produced automatically by the PHT Analysis Tool. There are two types of reports available: GIS Maps and Charts. This window is the global library of all reports that have been created at any time. When a report is created from within a Study, the report is placed in the global library and is also automatically referenced by the Study.

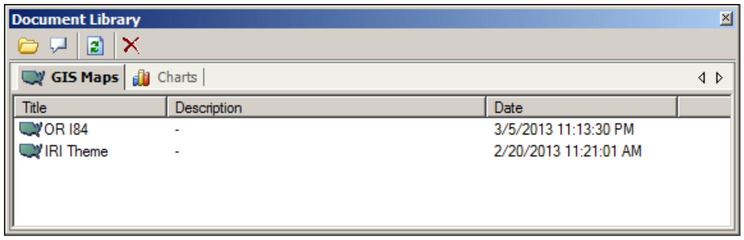


Figure 5. Document Library Window

When deleting a map or chart report from the library, any Study referencing the deleted report will identify it as missing in the Study window. References to missing reports must be deleted from individual studies.

Output Window

The output window shown in Figure 6 provides a messaging center for the PHT analysis tool to communicate status and other information with the user.

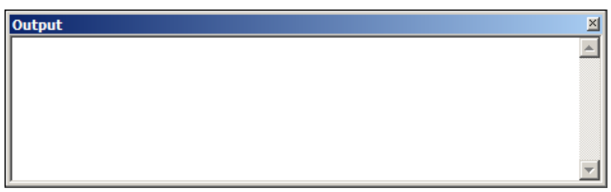


Figure 6. Output Window

Process Status Window

The process status window shown in Figure 7 provides a progress bar for process that are being performed by the PHT analysis tool. When a cancelable process is running, the user my cancel it by clinking the **Cancel** button. Other information about the process such as the elapsed time can be obtained by clicking the **Information** button.

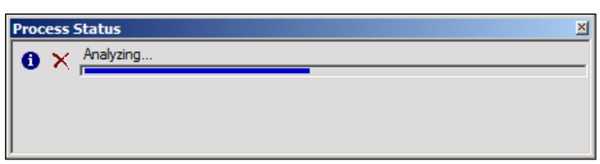


Figure 7. Process Status Window

PHT Application Windows

PHT Analysis Window

SETTINGS

The first tab, shown in Figure 8, is the **Settings** tab, which provides the user interface for working with highway data, GIS selections, and PHT analysis parameters and for running the PHT analysis. A hierarchical tree displays and organizes these items and a toolbar and various RIGHT-click popup menus are provided to work with them.

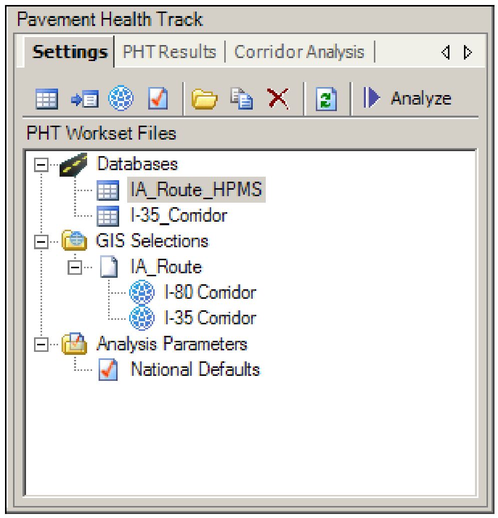


Figure 8. PHT Analysis Tool – Model Settings

The toolbar at the top of the window provides for the following functions:

 **Read HPMS Data.** Open an HPMS 2010 formatted comma-delimited text file and read its contents into a PHT database.

 **Read Non-HPMS Data.** Connect to a Microsoft® Access, dBase, comma-delimited file, or other ODBC (open database connectivity) data source and import its contents into a PHT database using the import wizard.

 **Create a new GIS Selection.** Create a new GIS selection based on an existing GIS shape file.

 **Create a new set of Parameter Metrics.** Create a new set of parameter metrics that is used to control the PHT analysis.

 **Open.** Open the item currently selected in the tree.

 **Copy.** Create a copy of the item currently selected in the tree.

 **Delete.** Delete the item currently selected in the tree.

 **Refresh.** Refresh the display.

Run PHT Analysis. Display the PHT run dialog window to initiate the PHT analysis process.

In addition to the functions provided by the toolbar, individual items in the tree structure have unique operations that can be performed. Access to these functions is provided by the popup menu that appears when you RIGHT-click on a specific item in the tree structure. The popup menu for each item type is shown in Figure 9.

PHT Databases Menu **GIS Selections Menu** **Analysis Parameters Menu**

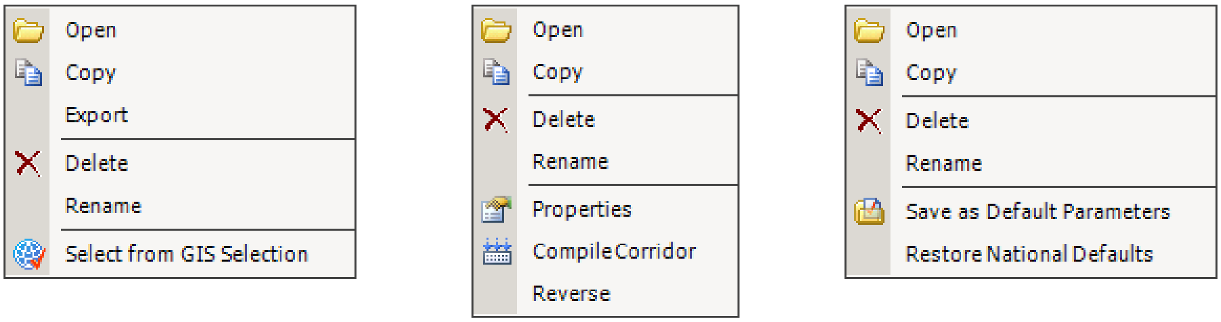


Figure 9. PHT Settings – RIGHT-Click Popup Menus

The items in the popup menus provide the following functions:

Open. Open the item currently selected in the tree.

Copy. Create a copy of the item currently selected in the tree.

Export. Export the contents of the currently selected PHT database to an external comma-delimited file in the HPMS 2010 format.

Delete. Delete the item currently selected in the tree.

Rename. Rename the currently selected item.

Select from GIS Selection. Select highway sections to be evaluated by the PHT analysis using an existing GIS selection.

Properties. Display the properties dialog of a GIS selection.

Compile Corridor. Evaluate the highway sections that make up a GIS selection and determine if they form a continuous corridor.

Reverse. Reverse the direction of a corridor.

Save as Default Parameters. Save the currently selected set of parameter metrics as the default values to be automatically applied to new sets of parameters.

Restore National Defaults. Restore the original national default values to the currently selected set of parameter metrics.

PHT RESULTS

The second tab in the PHT analysis window, shown in Figure 10, is the **PHT Results** tab, which provides the user interface for working with results data for the PHT analysis and allows you to generate automated reports. A hierarchical tree displays and organizes each set of results, and a toolbar and RIGHT-click popup menus are provided to work with them.

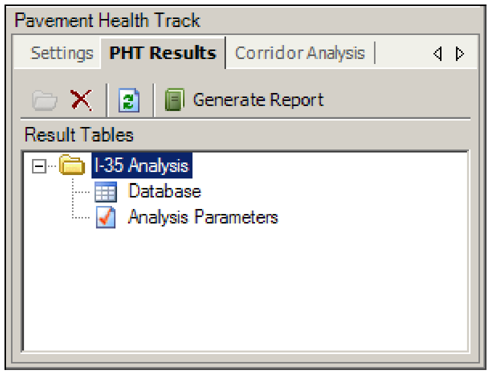


Figure 10. PHT Analysis Tool – PHT Results

The toolbar at the top of the window provides for the following functions:

 **Open.** Open the item currently selected in the tree.

 **Delete.** Delete the currently selected set of PHT results.

 **Refresh.** Refresh the display.

Generate Report. Display the PHT report wizard dialog window to automatically generate a report based on a selected set of PHT results and a report template.

In addition to the functions provided by the toolbar, individual items also provide a popup menu that appears when you RIGHT-click on a specific item in the tree structure. The menu for each item type is shown in Figure 11.

PHT Result Root **Database / Analysis Parameters**

Figure 11. PHT Results – RIGHT-Click Popup Menus

The items in the popup menus provide the following functions:

 **Open.** Open the item currently selected in the tree.

 **Delete.** Delete the item currently selected in the tree.

Rename. Rename the currently selected item.

CORRIDOR ANALYSIS

The third tab in the PHT analysis window, shown in Figure 12, is the **Corridor Analysis** tab, which provides the user interface for evaluating the PHT results for any given corridor. The top pane displays a list of existing corridor profiles for you to select from, while the bottom pane displays the options for the selected corridor profile. You must select a set of PHT analysis results, a GIS selection that represents the continuous corridor, and up to four data items to profile.

Once you have selected the profile options, click the **Display** 

button in the toolbar to view the corridor profile as shown in Figure 13. If you make any changes to the options for the profile, you must then click the **Display** button again to refresh the display window.

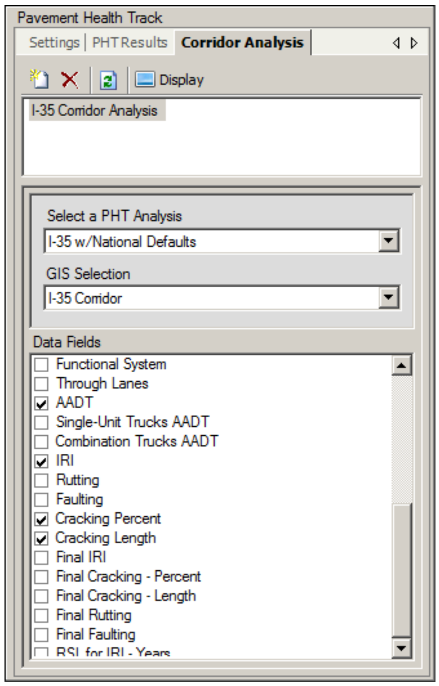


Figure 12. PHT Analysis Tool – Corridor Analysis

The toolbar at the top of the window provides for the following functions:

 **Create New.** Create a new profile analysis.

 **Delete.** Delete the currently selected profile analysis.

 **Refresh.** Refresh the display.

Display. Display the results of the currently selected profile. After making any changes, click this button to refresh the display of the corridor profile.

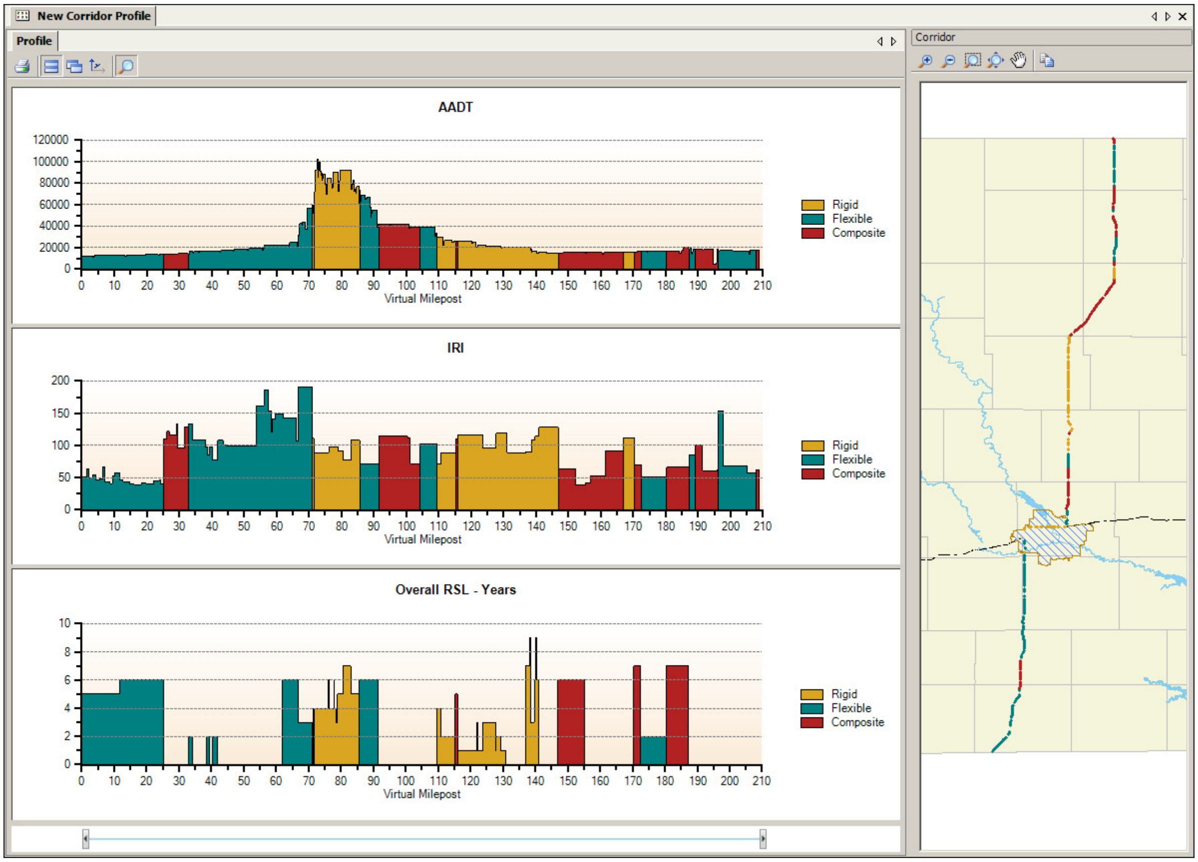


Figure 13. Corridor Profile Display

The corridor profile identifies the pavement type of each highway section as a color code depicting rigid, flexible, and composite pavements for those regions of the corridor that have sample PHT data. Regions without sample data appear gray. Corridors are characterized by virtual mileposts beginning at zero and incrementing based on the lengths of the highway sections that make up the corridor.

A GIS map of the corridor is displayed with color highlighting identical to the profile charts. The GIS map window will initially appear at the right or bottom of the window depending on the general orientation of the highlighted route, and you can resize and move the window as desired.

The toolbars provide for the following functions:

 **Print.** Display the print dialog to print the charts to a file, printer, or clipboard.

 **Stack Charts.** Display the chart windows stacked vertically.

 **Tab Charts.** Display each chart as an individual tabbed window.

 **Synchronize Y Axis.** Synchronize the Y Axis of all the charts to a single scale.

 **Zoom.** Activate chart zooming.

 **Copy.** Copy the GIS map image to the clipboard.

 **Zoom and Pan.** Zoom in or out, and pan through the GIS map.

ZOOM

To zoom into an area of the corridor, click the **Zoom** button on the toolbar. The zoom control will appear at the bottom of the window. Drag the beginning and ending markers left or right to adjust the zoom region. The GIS map will automatically track with the zoom region of the corridor and will highlight only those highway sections that appear in the profile charts. Click the zoom button on the toolbar again to remove all zooming from the charts and restore the profile to its original scale.

SYNCHRONIZE Y-AXIS

The synchronize Y-axis button will cause all of the charts in the display to use the same scale for their vertical axis. This can be useful when comparing similar data on multiple charts.

MAINTENANCE DATA FIELDS

The data fields for the maintenance analysis can be profiled also. Before the maintenance analysis results can be profiled you must first open the PHT analysis result window from the **Results** tab and apply a maintenance analysis to the PHT result data. The maintenance analysis results are not persisted or saved when the PHT result window is closed, so this window must remain open with a maintenance analysis applied for the maintenance analysis results to be available to be profiled.

When you select a set of PHT analysis results that has had a maintenance analysis applied, the additional results fields for the maintenance analysis will be appended to the list of data fields available for profiling, as shown in Figure 14. Simply select the maintenance data field(s) of interest as you would any other data field and click the **Display** button to display the profile chart.

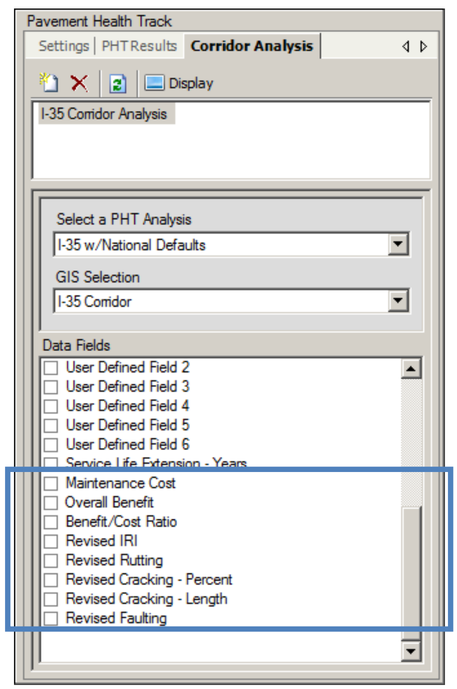


Figure 14. Corridor Analysis with Maintenance Fields

PHT Properties

The PHT properties window is displayed by clicking the **PHTv2/Properties** menu item in the application main menu. The PHT properties window has six tabs as follows.

PHT DATABASE

The PHT Database tab (shown in Figure 15) allows you to specify the database file used by the PHT analysis tool to store local information unique to the PHT tool. The user name and password requirements are not implemented at this time. The location of the PHT database file is set up during installation and will generally not need to be modified.

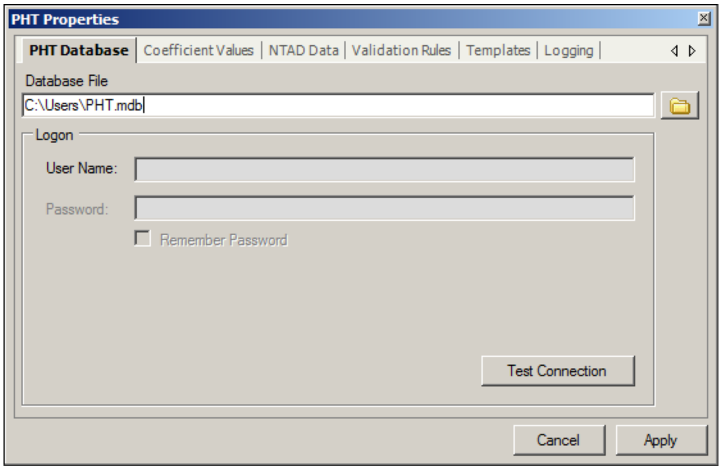


Figure 15. PHT Properties – PHT Database

COEFFICIENT VALUES

The PHT coefficient values tab (shown in Figure 16) are used by the analytical models employed by the analysis engine and are not editable without authorization.

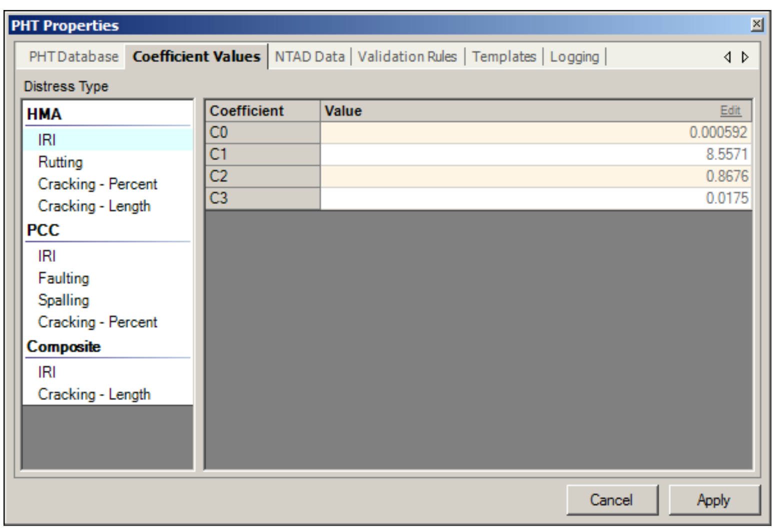


Figure 16. PHT Properties – Coefficient Values

The coefficient values apply to the model equations defined in the *Pavement Health Track RSL Forecasting Models Technical Information document, version 2.x, March 2013*. A cross-reference between the coefficient values and the analysis model equations is provided in Table 3.

Table 3. Coefficient Reference Equations

Distress Type	Coefficients	Reference Equations (Technical Information Document)
HMA IRI	C0 – C3	Equation 31
HMA Rutting	C0 – C3	Equations 25, 26, 27, 28
HMA Cracking Percent	C0 – C1	Equation 24
HMA Cracking Length	C0 – C5	Equation 29
PCC IRI	C0 – C3	Equation 8
PCC Faulting	C0 – C7	Equations 6, 7
PCC Spalling	NA	
PCC Cracking Percent	C0 – C9	Equations 4, 5
Composite IRI	C0	Equation 34
Composite Cracking Length	C0 – C2	Equation 33

NTAD DATA

The National Transportation Atlas Database (NTAD) data tab, shown in Figure 17, provides background images for the GIS maps used by the GIS selections. The NTAD backgrounds are useful to provide you with additional references when viewing the GIS maps but are otherwise optional. You can select which backgrounds that you would like to appear in the GIS maps.

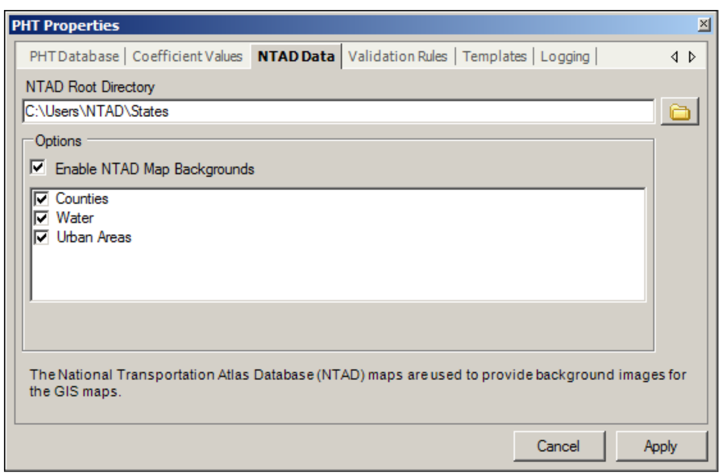


Figure 17. PHT Properties – NTAD Data

VALIDATION RULES

The validation rules tab, shown in Figure 18, is used to selectively enable individual highway data validation rules that are applied to the input PHT database. Each validation rule is displayed along with a checkbox to enable or disable it. If a rule is checked, it is enabled and will be enforced. The validation rules are defined in detail in Appendix A.

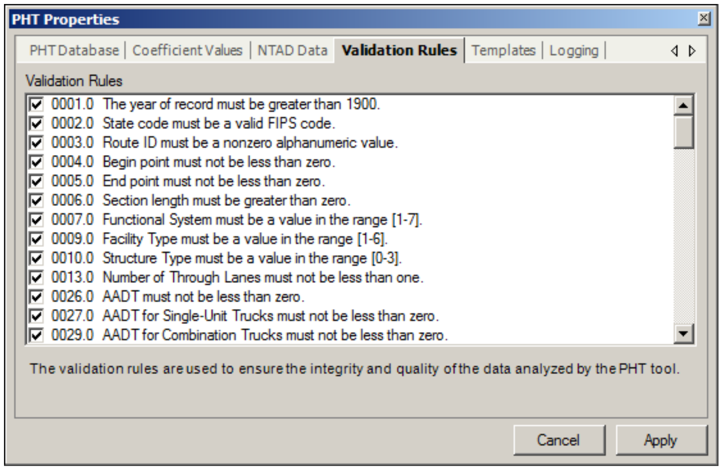


Figure 18. PHT Properties – Validation Rules

TEMPLATE LIBRARY

The template library tab shown in Figure 19 provides management of the template library. The templates provide the format for predefined charts used to generate reports. Once a template is selected from the list, it can be deleted or exported to an XML file. In XML form, the template file can be shared with other PHT users who can import it into their own template library.

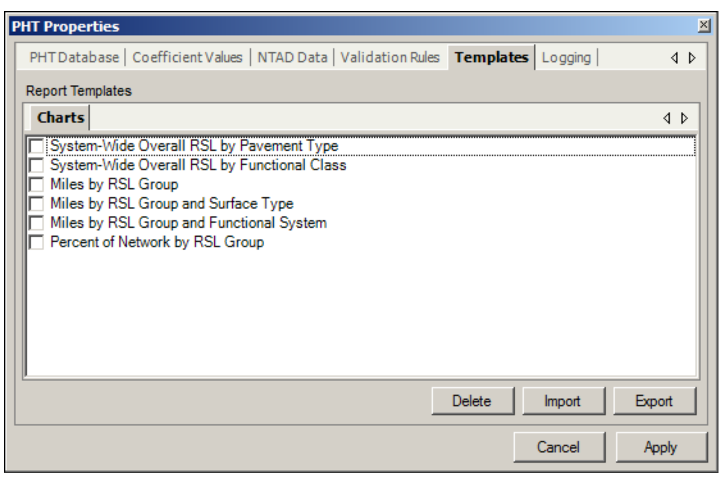


Figure 19. PHT Properties – Template Library

You can easily create chart templates by first using the Report Wizard to produce a chart report, and then modifying the report to meet your unique needs. You can save the report as a template to the library as described in section discussing the PHT Report Wizard.

LOGGING

The analysis logging tab shown in Figure 20 is used to enable the PHT analysis logging capability and to specify the level of logging to be captured. The PHT analysis log can be used to track the analysis process to aid in understanding the results. When an analysis log has been captured, the logging for the analysis for each individual highway section is available on the **Log** tab of the PHT results window; however, logging can significantly increase the analysis runtime and should be disabled when the log is not of interest.

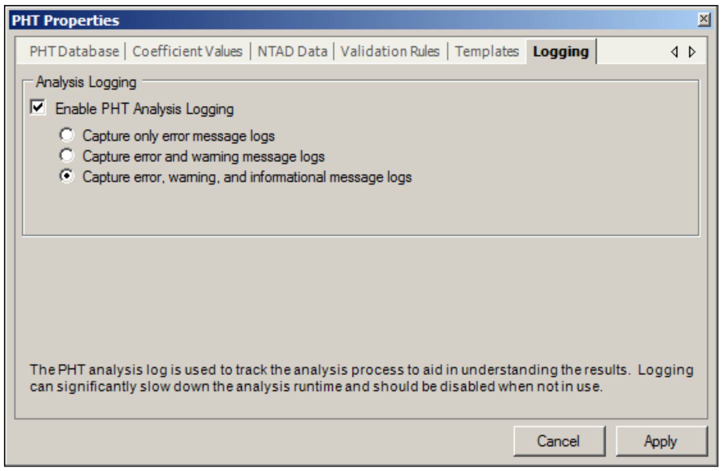


Figure 20. PHT Properties – Logging

PHT Database Window

The PHT database window is displayed by selecting a database on the **Settings** tab of the PHT analysis window and clicking the **Open** button on the toolbar.

The PHT database is the source data for the RSL analysis. It contains the data fields that describe the condition of each highway section. Each record in the database represents a highway section. The PHT database is displayed in the data table window shown in Figure 21.

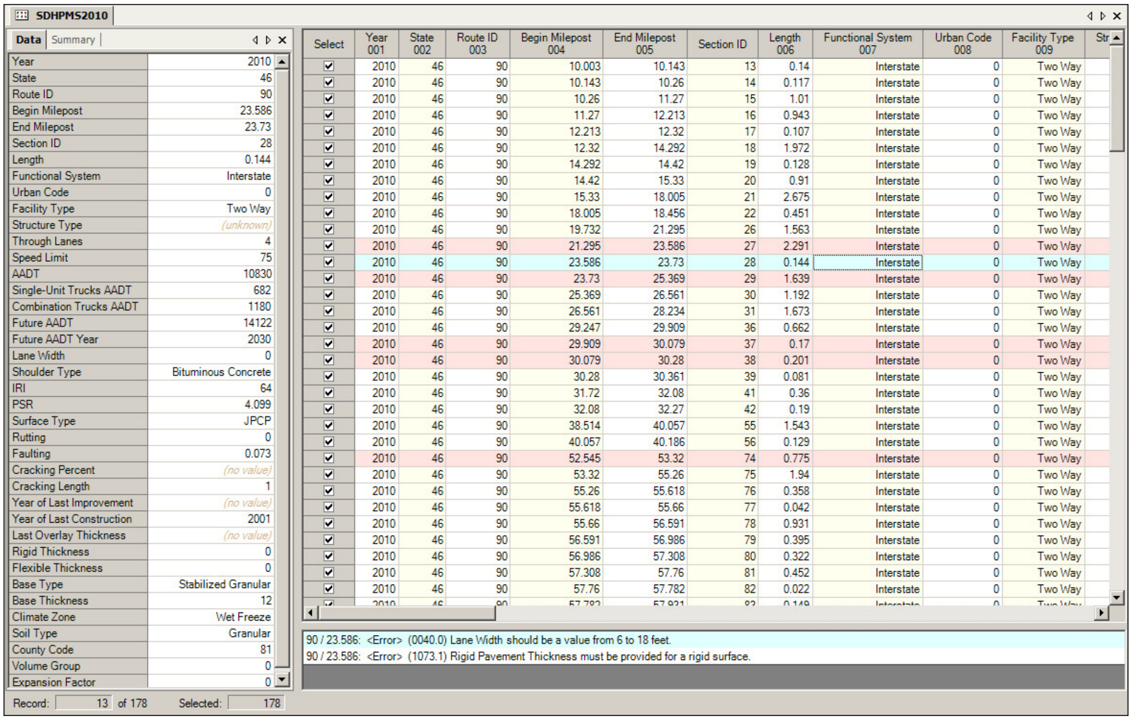


Figure 21. PHT Database Window

This window provides layout formatting, editing, and validation testing through popup menus. The menus are activated by RIGHT-clicking on individual records or on the column headers. Each menu is described in the following paragraphs.

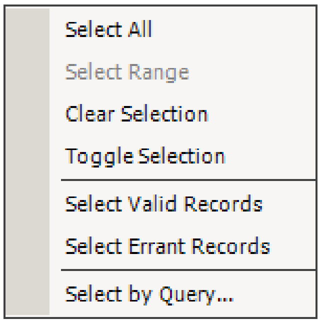
A vertical oriented panel is available that displays the data items of the selected highway section in a convent format that allows all of the data items to be seen at once. The vertical panel is located on the left of the window and can be expanded by dragging the slider bar to the right.

When validation testing has been performed, individual highway sections that have violated one or more validation tests are highlighted with a red shaded background. When one of these errant records is selected, a list of its validation errors is displayed in the panel at the bottom of the window. DOUBLE-clicking on an error message entry will cause the application to jump focus to the specific record and data item that has caused the error. Individual validation rules can be enabled or disabled from the PHT properties window.

The error message panel for the validation rules normally displays the validation errors for the selected highway section; however it can also show all the validation errors of the entire dataset or a list of each unique error message in that dataset. To change how the validation errors are displayed, RIGHT-click on the panel to display its popup menu and select an option under the **View** menu item.

SELECTION MENU

The first column in the table (**Select**) determines if a highway section will be included in the PHT analysis. If this field is checked, the record will be analyzed by the PHT tool when the analysis is run; otherwise the record will be ignored. To select or unselect a highway section, you can manually click on its checkbox or use the selection commands available from the menu shown in Figure 22. This popup menu is activated by RIGHT-clicking on the **Select** column header.



Select All. Select all highway sections.

Select Range. Select the highway sections in the highlighted range, and unselect all others.

Clear Selection. Unselect all highway sections.

Toggle Selection. Toggle the selection state of all highway sections.

Select Valid Records. Select only highway sections that do not have validation errors.

Select Errant Records. Select only highway sections that have violated one or more validation tests.

Select by Query. Display a query wizard to select highway sections based on their attributes.

Figure 22. Selection Popup Menu

When selecting highway sections by Query, the query builder shown in Figure 23 is displayed. On the **Filter Wizard** tab, select the data fields you want to use as the selection criteria and then click the **Apply** button to select the records that meet the criteria. To add to the current selection rather than replace it, check the option to append the selection results at the bottom of the window.

Users that are comfortable working directly with the SQL language may enter the SQL text using the SQL text window. The SQL text represents the WHERE clause of a SQL statement and must comply with all SQL syntax rules. This window provides a list of available data fields, operators, built-in functions, and a list of unique values for the selected field.

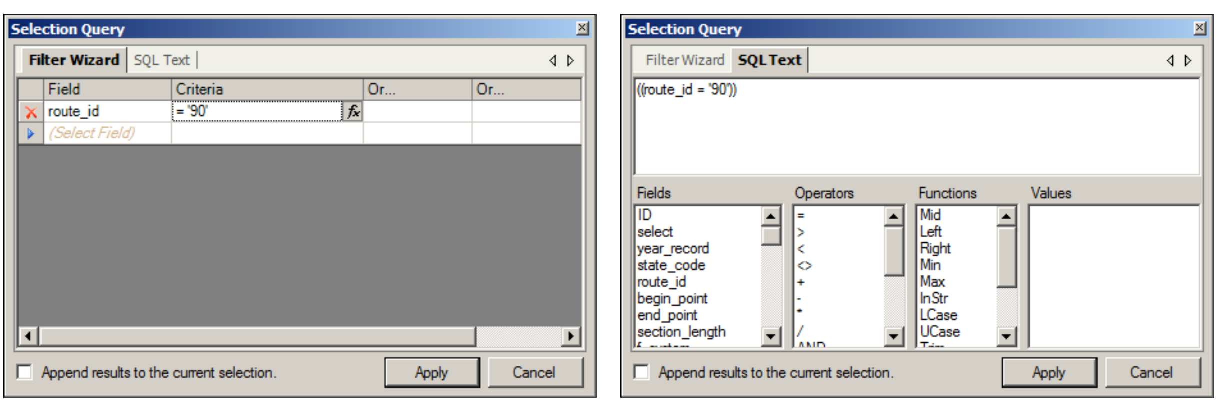
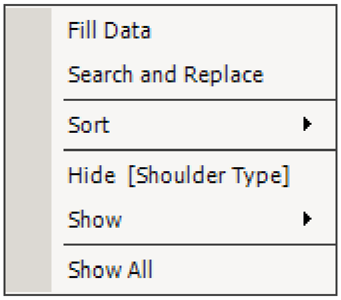


Figure 23. Selection Query Builder

COLUMN MENU

The column for each data item provides a popup menu, shown in Figure 24, that appears when you RIGHT-click on the column header. Items in this menu apply only to the column that was clicked.



Fill Data. Display a dialog window that allows you to fill the selected column with a new value, overwriting all previously existing values in the column.

Search and Replace. Display a dialog window that allows search the selected column for a particular value and replace it with a new value.

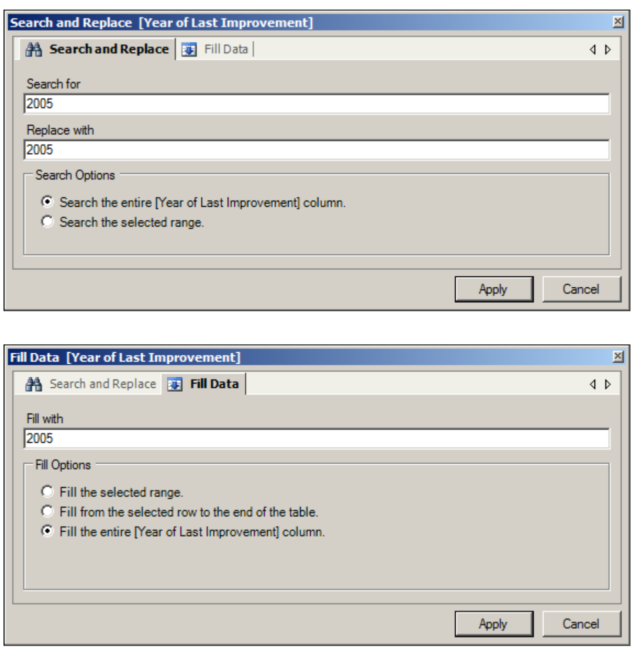
Sort. Sort the selected column in ascending or descending order, or remove any applied sorting.

Hide. Hide the selected column.

Show. List hidden columns so that individual columns can be re-shown.

Show All. Show all hidden columns.

Figure 24. Column Popup Menu



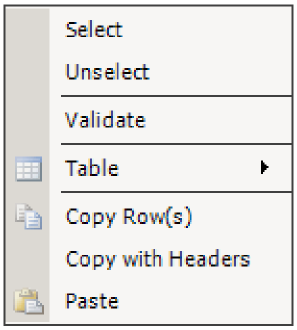
The **Search and Replace** window (Figure 23) allows you to search a column of data for a particular value and replace it with a new value. The search operation can apply to a selected range or to the entire column.

The **Fill Data** window (Figure 23) allows you to fill a column of data with a new value overwriting all previously existing values in the column. The fill operation can apply to a selected range, from the current record to the end of the table, or the entire column.

Figure 25. Mass Edit Dialog Window

RECORD/TABLE MENUS

Each highway data record provides a popup menu that appears when you RIGHT click on a record as shown in Figure 26. The items in the record menu (top) apply to the selected record, while the items in the table sub-menu (bottom) apply to the entire table.



Select. Select the record for analysis.

Unselect. Unselect the record so it will not be included in the PHT analysis.

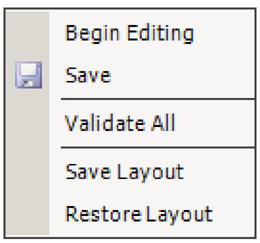
Validate. Perform validation testing on the selected record

Table. Displays the Table sub-menu.

Copy Row(s). Copy the selected row(s) to the clipboard.

Copy with Headers. Copy the selected row(s) along with the column headers to the clipboard.

Paste. Paste the contents of the clipboard to the table.



Begin Editing. Place the PHT database window in edit mode to allow user editing of the highway data table. If already in edit mode, this item will labeled **End Editing** and will terminate the PHT database window edit mode.

Save. Save all changes to the highway data table.

Validate All. Validate all records in the highway data table.

Save Layout. Save the current layout of the table.

Restore Layout. Restore the default layout of the table.

Figure 26. Record/Table Popup Menus

SUMMARY

The **Summary** tab in the vertical panel shown in Figure 27 summarizes the percentage of highway sections that already have a failing measured distress or have exceed their maximum service life as well as the minimum, maximum, and average distress values and surface age for the rigid, flexible, and composite pavement types. This summary is useful to help you assess your highway data set prior to running the PHT analysis.

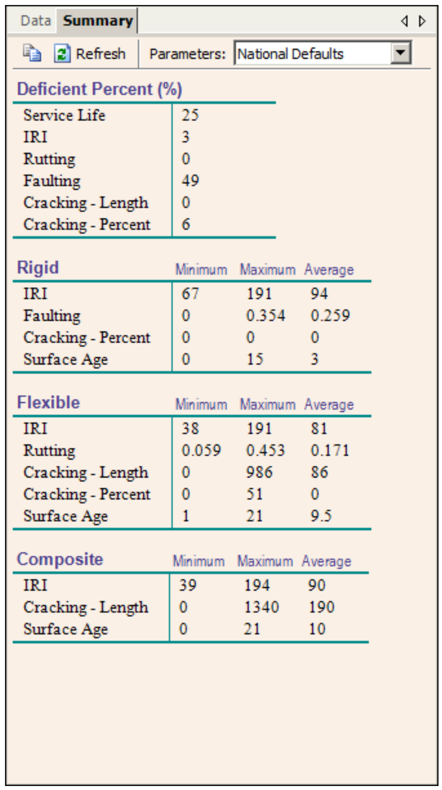


Figure 27. PHT Database Summary Window

The distress thresholds and maximum service life durations are defined as part of the PHT analysis parameters. To perform a summary analysis you must first select the parameters for the analysis from the drop-down list at the top of the window. Click the **Refresh** button to perform the summary analysis and display the results in the window.

Only the highway sections that are selected in the data set are used when performing the summary analysis. This allows summaries of different subsets of highway sections, by first selecting only the sections of interest and then clicking the **Refresh** button.

The **Copy** button on the toolbar will copy the summary analysis results to the Windows clipboard in a format that is compatible with Microsoft® Word or Excel.

GIS Selections

The GIS Selections are based on a GIS shape file that contains the geographical information about the highway sections associated with your PHT database. You can use the **GIS Selections** window shown in Figure 28 to select a group of highway sections to work with. The GIS selection has multiple uses in the PHT analysis tool including selecting highway sections for analysis, defining a continuous corridor for corridor profiling, and providing GIS information to generate thematic maps by the report wizard.

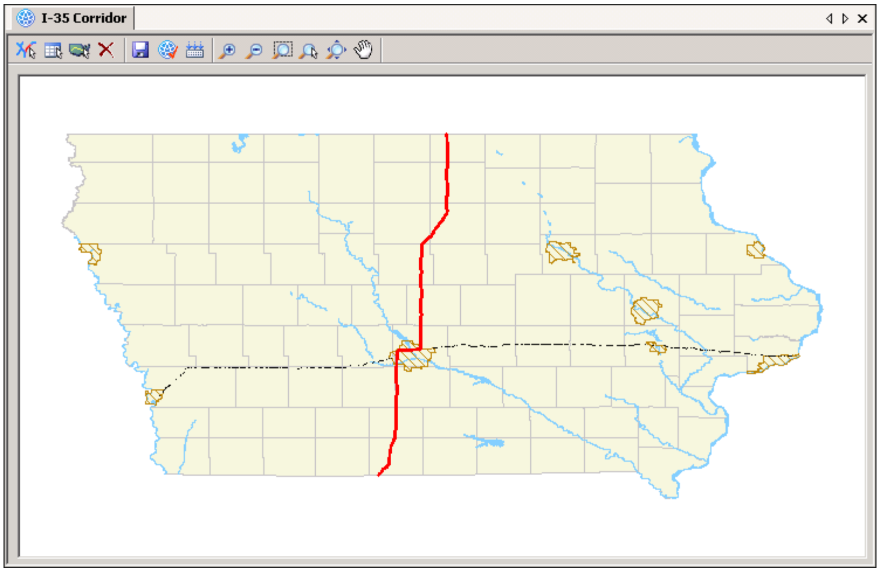


Figure 28. GIS Selection Window

The toolbar at the top of the window provides for the following functions:

 **Manual Selection.** Select highway sections by manually clicking on them in the GIS map. Clicking a highway section will toggle it between selected and non-selected.

 **Select by Attributes.** Select highway sections by querying the attributes of the GIS map records. The GIS query builder dialog window will be displayed to write the SQL selection query.

 **Select by Shortest Path.** Select highway sections by finding the shortest path between two points. You must click on two highway sections to serve as the beginning point and end point of the path.

 **Remove.** Remove the current selection.

 **Save.** Save the current selection of highway sections.

 **Select Highway Sections.** Use the GIS selection to select highway sections to be evaluated by the PHT analysis.

 **Compile Corridor.** Evaluate the highway sections that make up a GIS selection and determine if they form a continuous corridor.

 **Zoom and Pan.** Zoom and pan through the GIS map.

GIS SELECTION PROPERTIES

When a GIS selection is first created, its properties window, shown in Figure 29, is displayed. For the GIS selection to work with the PHT database, you must specify the data fields that will be used to link the PHT database with the GIS information. There are five fields to specify:

- **State FIPS.** This item identifies the field that contains the state FIPS (Federal Information Processing Standard) code.
- **Route ID.** This item identifies the field that contains the route identifier. Route identifiers must be a non-zero alphanumeric value.
- **Beginning Milepost.** This item identifies the field that contains the beginning milepost along the route where the highway section begins. To uniquely identify a highway section, route mileposts must be state-based and must increment continuously along the route.
- **Section ID.** This item identifies the field that contains a state-wide unique highway section identifier. A section identifier is an alphanumeric value. The section identifier field is optional, but if provided it will be used in lieu of the route identifier and beginning milepost combination when linking the PHT database with the GIS information.
- **Section Length.** This item identifies the field that contains section length information. This field is required when working with corridor profiles to provide length information for highway sections that are included in the GIS corridor, but for which there is no corresponding record in the PHT database.

The properties window for the GIS Selection can also be activated by clicking the **Properties**  option in the GIS selection RIGHT-click popup menu.

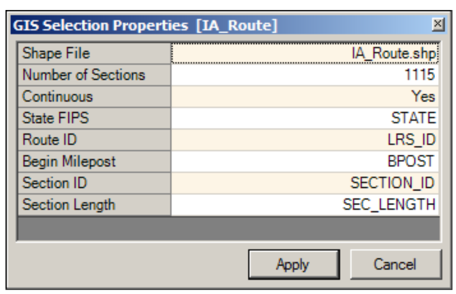


Figure 29. GIS Selection Properties

If a GIS selection is intended to be used for corridor profiling, all the highway sections in the selection must form a single continuous corridor. The properties window indicates if the GIS selection is or is not a continuous corridor, or if its state is unknown. You can determine if the GIS selection is a continuous corridor using the **Compile Corridor** option in the GIS selection RIGHT-click popup menu. After a GIS selection has been created or edited, its continuous state is defined as **Unknown** until it is compiled, after which it will be **Yes** or **No**.

However, use of the GIS selection by the report wizard to simply generate thematic maps does not require it to define a continuous corridor. For this use, it may define a corridor or any other sub-section of the map such as a type of functional class, or geographical region such as a county or urban area.

Analysis Parameters

The PHT analysis parameters provide many settings that affect the results of the PHT analysis. The PHT tool provides a complete set of national default values for each metric; however, you can modify the metrics to customize the PHT analysis as desired. Once modified, the customized parameters can be saved as the default values, overriding the original national defaults. You can restore any set of parameters to their original national defaults from the Analysis Parameters popup menu.

The analysis parameters are organized on four tabs. The first tab, shown in Figure 30, provides the settings for the pavement maximum service life. The maximum service life is specified in years for each type of surface treatment.

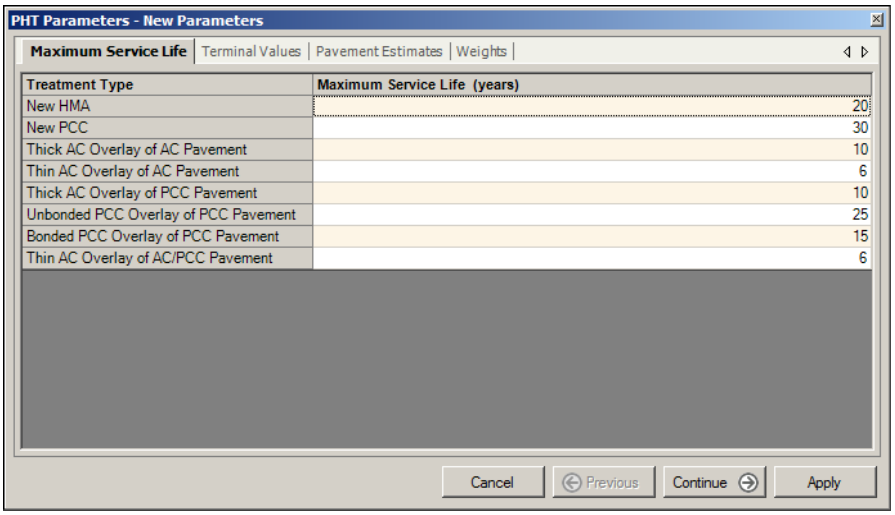


Figure 30. Parameters – Maximum Service Life

The next tab, shown in Figure 31, provides the settings for the terminal values for each type of distress associated with rigid, flexible, and composite surfaces. These values are the deficiency thresholds at which point the surface is considered to have reached the end of its service life.

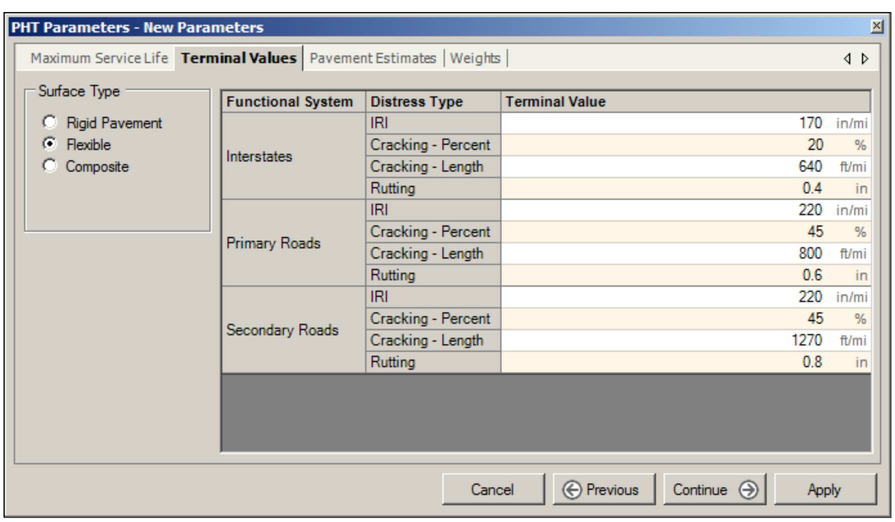


Figure 31. Parameters – Terminal Values

The next tab, shown in Figure 32, provides the pavement estimate settings that are used by the PHT analysis to estimate values that are missing from the PHT source data. Values are provided for each individual state for interstates and for primary and secondary roads.

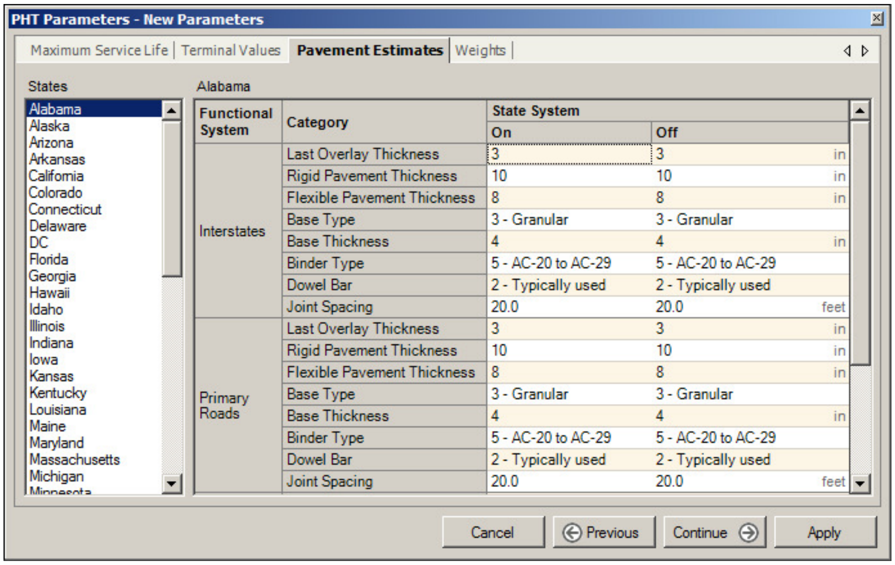


Figure 32. Parameters – Pavement Estimates

The last tab, shown in Figure 33, provides options on how the RSL is calculated. You can use the critical RSL or a weighted average. The distress weights are used to set the relative effect of each distress type on the RSL calculation when using weighted averages. Setting all weights to an equal percentage will cause each distress type to have an equal effect. The sum of the weight percentage of all distresses for each surface type must add up to 100%.

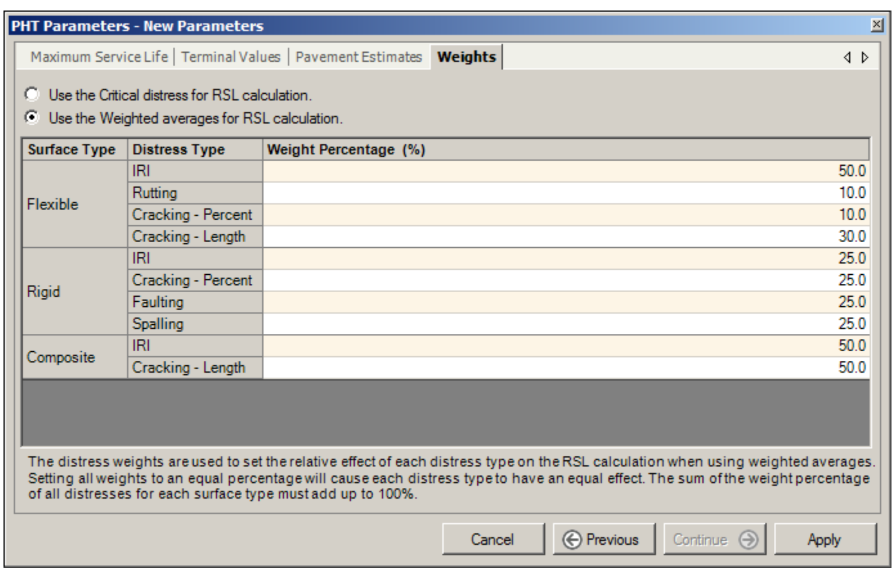


Figure 33. Parameters – Weights

Running the PHT Analysis

To run the PHT analysis, select a PHT database and click the **Analyze** 

button in the toolbar of the **Settings** tab of the PHT analysis window. The run dialog window shown in Figure 34 will appear.

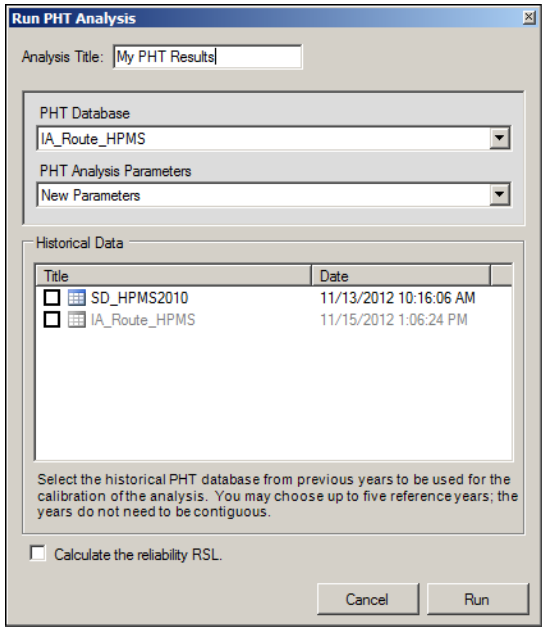


Figure 34. PHT Run Window

The PHT run dialog window allows you to select options that affect how the analysis is performed.

- The first option is to enter a descriptive title for the PHT analysis results. This is the title that will appear in the Results tree in the user interface. To avoid confusion with other PHT analysis runs you may perform, you should take time to enter a title that is both descriptive and unique.
- The second option is to select the PHT database and PHT analysis parameters that you want to use for the analysis. Select the desired PHT database and parameters from the drop-down lists.
- Finally you may select historical PHT databases from previous years to be used for the calibration of the analysis based on measured values. The records in historical databases must be for the same set of highway samples that are being analyzed. You may choose up to five historical reference years; the years do not need to be contiguous. The historical data are optional, but providing the actual measured distresses will improve the accuracy of the RSL predictions.
- The final checkbox at the bottom of the window instructs the PHT analysis to calculate the reliability RSL value.

Click the **Run** button to start the PHT analysis.

During the processing of the PHT analysis, a progress indicator is displayed in the **Process Status** panel shown in Figure 35 (top) to provide you with feedback about the analysis progress. You can cancel the PHT analysis from this window by clicking on the **Cancel** button. Textual messages are periodically displayed in the **Output** window, shown in Figure 35 (bottom), to give more detailed information about the status of the analysis. When logging is enabled, any records that generate an analysis error will display the error message in this window to provide a real-time feedback to the user as an indicator of any problems with the analysis.

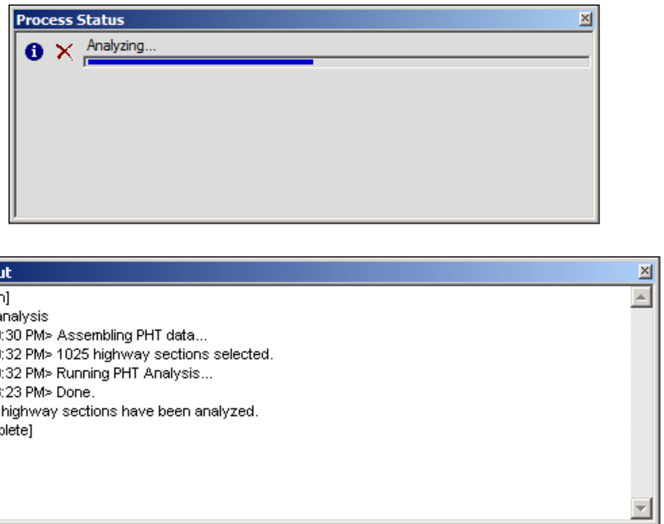


Figure 35. PHT Output Window

After the PHT analysis is complete, a message dialog window will display to inform you about the results of the PHT analysis, as shown in Figure 36.

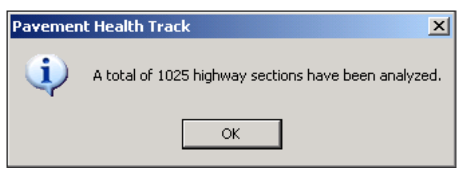


Figure 36. PHT Analysis Result

The PHT results are displayed in the tree on the **PHT Results** tab of the PHT analysis window. A result set includes a copy of the parameter metrics used during the analysis and a copy of the original PHT database with the fields that contain the analysis results appended to the database table.

If there are no successfully analyzed records, then no result set will be displayed.

PHT Results

The PHT results are displayed in the tree on the **PHT Results** tab of the PHT analysis window. A result set includes a copy of the parameter metrics used during the analysis and a copy of the original PHT database with the fields that contain the analysis results appended to the database table. The PHT results window is displayed by selecting a result database and clicking the **Open** button on the toolbar.

The PHT results are displayed in the data table window shown in Figure 37.

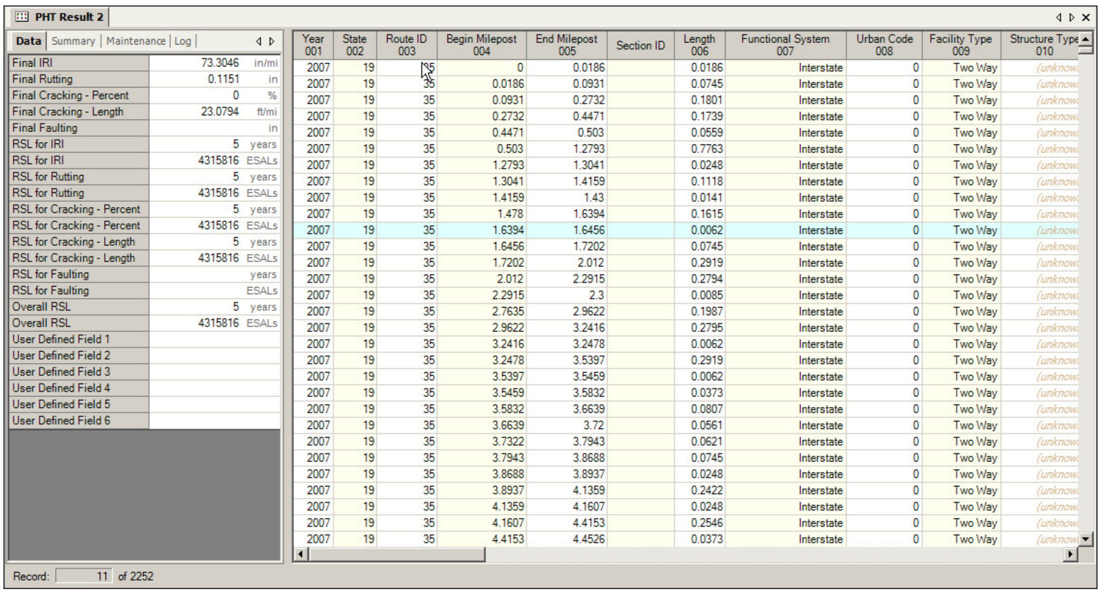


Figure 37. PHT Results Window

The data table displays the original highway data that were analyzed by the PHT tool. A vertical oriented panel on the left of the window provides information about the analysis for the highway data record selected in the table including the RSL estimates, a summary report, and an analysis log. All data items in this window are read-only and cannot be modified.

POPUP MENUS

The PHT results window provides popup menus similar to those in the PHT database window. The column menu appears when RIGHT-clicking on a column header and allows for ascending or descending sorting of the selected column or to remove any applied sorting. The table menu appears when RIGHT-clicking on the table body and provides options to copy the contents of the table to the clipboard. When copying the data to the clipboard, all data items are copied including the PHT results data items.

DATA

The **Data** tab in the vertical panel provides a view of the PHT analysis results for the highway data record selected in the table. All the RSL data items can be displayed, or you can filter the display into categories using a popup menu that appears when you RIGHT-click anywhere on the data list. The filtering options include RSL by years, by ESALs, and user-defined fields.

SUMMARY

The **Summary** tab in the vertical panel provides a user-friendly readable summary of the analysis results for the highway data record selected in the table as shown in Figure 38. The summary highlights the estimated RSL for the pavement surface and illustrates the distresses and service life limits that contributed to the RSL estimate. It also annotates the analysis with notes that describe the pavement construction and any unusual conditions in the data.

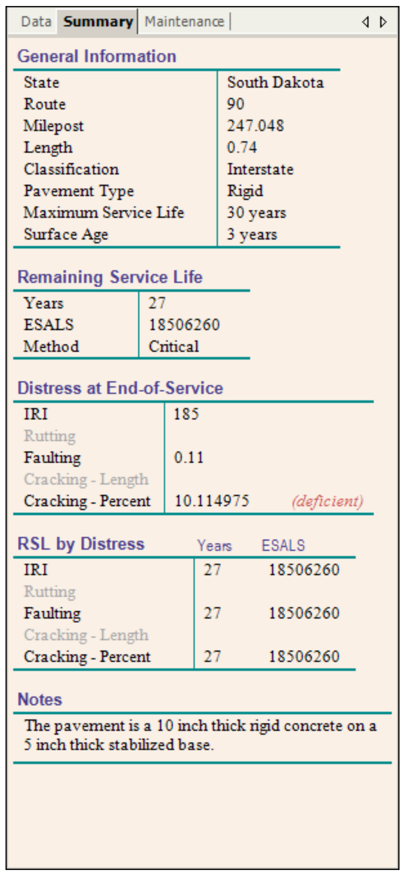


Figure 38. PHT Result Summary Window

MAINTENANCE

The **Maintenance** tab in the vertical panel provides access to the PHT maintenance model. The maintenance model uses the forecasted distress levels to select highway sections that have a feasible maintenance treatment available that will extend their RSL. The model also calculates the cost and estimates the monetary benefits of the maintenance treatment for each section.

The maintenance model window is shown in Figure 39.

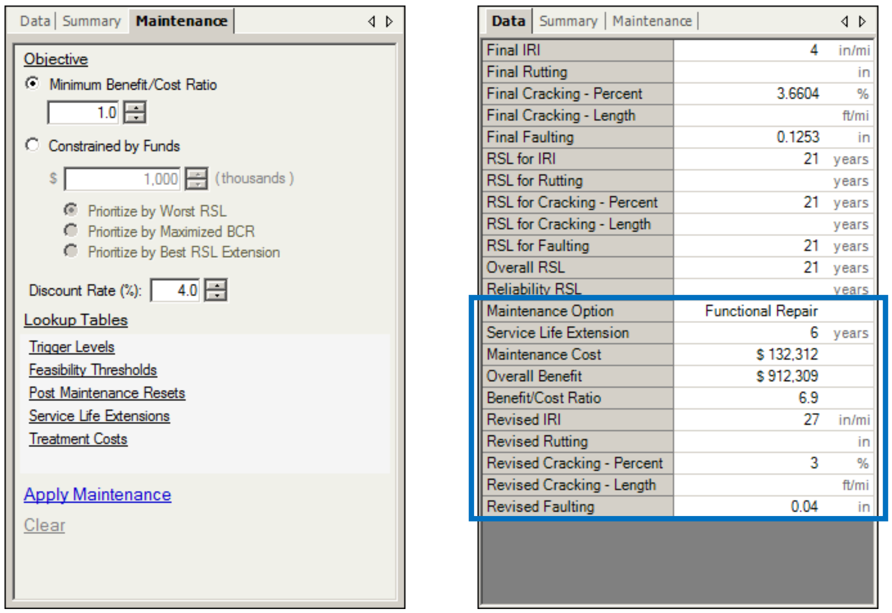


Figure 39. PHT Maintenance Model Window and Results

There are two objectives for the maintenance model:

- **Minimum Benefit/Cost Ratio (BCR).** This objective will identify all highway sections that have a feasible maintenance treatment option available that will produce a benefit/cost ratio greater than some specified level regardless of cost.
- **Constrained by Funds.** This objective will identify all highway sections that have a feasible maintenance treatment option available and prioritize each until some specified level of funding has been exhausted. Prioritization is performed using one of three selection methods:
  - **Worst RSL.** This method selects as the first to be treated those highway sections that have the lowest RSL as forecasted by the PHT analysis.
  - **Maximized BCR.** This method selects as the first to be treated those highway sections that have a maintenance treatment option that will produce the highest BCR.
  - **Best RSL Extension.** This method selects as the first to be treated those highway sections that have a maintenance treatment option that will produce the highest service life extension.

The **Discount Rate** percentage is used by the maintenance analysis for estimating the benefits associated with postponing reconstruction costs by performing a less expensive maintenance treatment to prolong the life of the existing pavement.

Click on **Apply Maintenance** to apply the maintenance model and see the results. After a maintenance model has been applied, the results will appear in the vertical oriented **Data** tab. A description of the data fields that make up the maintenance model results is provided in Table 7. Click on **Clear** to remove the maintenance model and display the original table of PHT results.

The PHT maintenance model feature is a run-time viewer utility. The results of the model are not saved when the PHT result window is closed. A detailed description of the maintenance model is provided in the Technical Information section of this document.

LOOKUP TABLES

The maintenance model uses five lookup tables when performing its analysis. The user can view and modify each of these tables by clicking on the title a table. The default values for each lookup table are provided in Table 9 through Table 13 in the Technical Information section of this document. The following tables are available:

- **Trigger Levels.** The trigger-level table provides the deficiency thresholds for each distress type that defines at what point a maintenance treatment is warranted. Any distress exceeding its threshold triggers the need for a maintenance action.
- **Feasibility Thresholds.** The feasibility thresholds provide the decision criteria for selecting the improvement option based on the pavement distress and RSL. The preferred improvement will be the lowest feasible improvement group that will address the pavement's conditions.
- **Post-Maintenance Resets.** The post-maintenance reset table provides the percentage of improvement for each distress type as a result of a maintenance treatment. The extent of the improvement is determined based on the existing distress level and the type of treatment applied. A value of 0% means no change to the distress while a value of 100% implies that the distress is reset to a like-new condition.
- **Service Life Extensions.** The service life extension table provides the post-improvement extension to the RSL (years) as a result of the application of a maintenance treatment. Additional extensions to the service life are provided to take into account the effect of climate and traffic conditions and pavement construction.
- **Treatment Costs.** The treatment cost table provides the estimated cost of applying a maintenance treatment as measured in current dollars per lane-mile.

RESULTS

The results of the PHT maintenance model analysis provide the following information:

- **Maintenance Option.** Recommended maintenance treatment for the highway section.
- **Service Life Extension.** The extension in service life of the pavement as a result of applying the recommended maintenance treatment.
- **Maintenance Cost.** Overall total cost of applying the recommended maintenance treatment taking into account the length of the highway section and the number of lanes treated.
- **Overall Benefit.** Benefit, quantified in terms of the value added to the pavement infrastructure due to the application of a given maintenance treatment.
- **Benefit/Cost Ratio.** Ratio of the overall benefit and total maintenance cost.
- **Revised Distresses.** The revised post-maintenance distress values for IRI, rutting, cracking, and faulting as a result of applying the recommended maintenance treatment.

LOG

The **Log** tab in the vertical panel is only available if a log file has been captured during the analysis and is available for display as shown in Figure 40. The content of the log file is determined by the logging properties that are set in the **Log** tab of the **Properties** window. It displays the log entries created in the log file for the highway data record selected in the table. The log entries are useful to track the analysis process to aid in understanding the results.

Each log entry is identified as an error, warning, or informational message.

Figure 40. PHT Log Window

PHT Report Wizard

To activate the Report Wizard, click the **Generate** 

button on the toolbar of the **PHT Results** tab of the analysis window. This wizard provides an automated process to generate statistical charts and thematic maps useful to visualize the results of the analysis.

The Report Wizard window is shown in Figure 41.

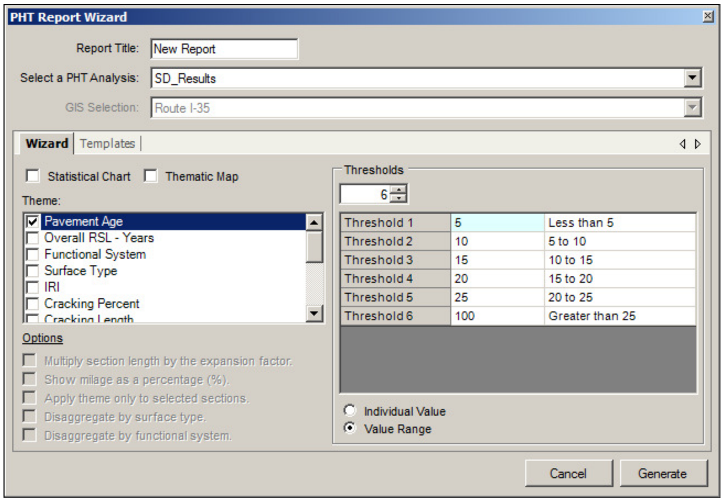


Figure 41. Report Wizard

A title must be provided for the report. To avoid confusion later, the report title should be both descriptive and unique. A set of PHT analysis results must also be selected to provide the basis for the report content.

A list of theme options is provided that determines the purpose of the report. When a theme option is selected, a suggested list of threshold values is automatically provided that defines groupings for the reports information. This is only a suggested list and can be edited by the user as necessary. Each threshold must specify a limit value for its range, followed by a textual description of the data group that the threshold is defining. The limit values can have two meanings as follows:

- **Individual Value.** The data in this grouping must equal the limit value. This setting is useful when the theme is based on an enumerated value, such as the function system.
- **Value Range.** The data in this grouping must lie within the range defined by the upper limit value inclusively and the previous threshold's upper limit value exclusively; for the first threshold, the range is defined as less-than limit value inclusively. When using this setting, the limit values for each subsequent threshold must always increment in value.

The Report Wizard can generate a statistical chart, a thematic map, or both together using the same settings. When the report is generated, it is automatically added to the document library and the current Study. Clicking the **GIS Maps** or **Charts** icon at the left of the Study window will display a list of reports that have been created by the report wizard and added to the Study.

CHARTS

Statistical charts are used to create complex graphs that illustrate quantitative information generated by the PHT analysis. Extensive formatting features are available to create many types and styles of charts that can be saved to a template library for reuse. Check the **Statistical Chart** checkbox to instruct the wizard to generate a chart report.

A number of options are available when generating a statistical chart report:

- **Multiply section length by the expansion factor.** This option will instruct the wizard to multiply the length of the highway section by its expansion factor when determining its overall total length. If no expansion factor is provided in the data, then the unmodified section length will be used. This option is useful when you have a small number of samples that represent a large number of miles and you want the report to more accurately represent the actual highway miles in the theme group.
- **Show mileage as a percent.** This option will instruct the wizard to determine the total number of miles in the data set and calculate the overall percent of miles included in the theme group to be used in the chart rather than actual miles.
- **Disaggregate by surface type.** This option will instruct the wizard to disaggregate the data for each theme group into sub-groups by the pavement surface type. This option in not available for thematic maps.
- **Disaggregate by function system.** This option will instruct the wizard to disaggregate the data for each theme group into sub-groups by the function system. This option in not available for thematic maps.

An example of a statistical chart is shown in Figure 42.

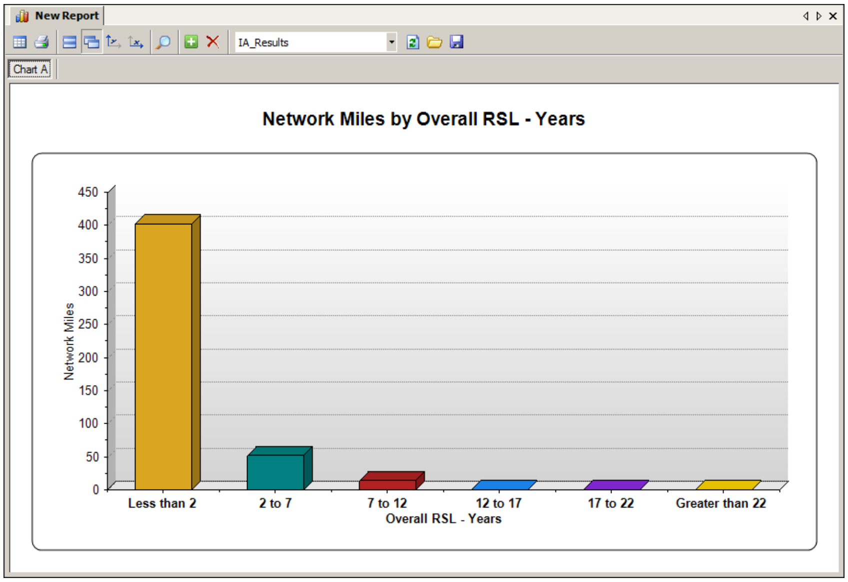


Figure 42. Statistical Chart

When displaying multiple charts you have the option to display them as **Tabbed** or **Stacked** by clicking the corresponding button on the toolbar. The tabbed feature has the advantage of maximizing the amount of screen space available to display each chart, but only displays one chart at a time. While the stacked feature allows you to view all the charts at once, it limits the amount of space available to display each chart.

The chart appearance can be customized using the chart's **Properties** window; simply RIGHT-click anywhere in the chart area window to activate the properties dialog for the chart. Settings include color and shading, 3D effects, chart types, legend appearance, plot types, grids, axis scales and annotations, and chart labels.

You can apply a common Y-axis scale for all the charts by clicking the **Synchronize Y-axis** button on the charts toolbar. This is useful to visualize the relative values among multiple charts that show similar information with a common unit of measurement.

The **Synchronize X-axis** button on the toolbar will visually align the axis positions of several charts together. This is required when using the Zoom feature while using the stacked page layout.

The **Zoom** button on the toolbar toggles the X-axis zoom mode for the chart. When zooming is active, a zoom bar appears at the bottom of the chart window. You can adjust the amount of zoom and pan by dragging the beginning and ending markers to the left or right as desired. When zooming is deactivated, all zooming will be removed from the charts.

You can use the **Add** and **Remove** buttons to manually add and remove charts from the display.

The **Print** button on the toolbar will activate a dialog window that provides printing options for the chart. The print destination can be a printer, Windows clipboard, or a bitmap file. You have options to set the position and scaling of the chart image as desired. A preview of the printed chart is provided.

The following four controls in the chart toolbar are exclusively for working with chart templates and the template library, and are only active immediately after the report wizard has generated the statistical chart. Once the chart window has been closed, the template controls will not be available the next time the chart window is opened from the document library.

IA_Results	**PHT Analysis Results.** Identify the analysis results displayed in the chart.
	Refresh. Refresh the chart after a different set of results are selected.
	Load. Load a chart from the chart template library.
	Save. Save the chart to the chart template library.

The **Chart Data** window, shown in Figure 43, is displayed by clicking the **Data Sheet** button on the toolbar. This window is where you enter or query the data that you want to display in the chart. All data that will be graphed in the chart are specified in this window. The table contains columns of data for the X and Y axis of the chart and is an active spreadsheet that allows for both manual data entry and formula calculations.

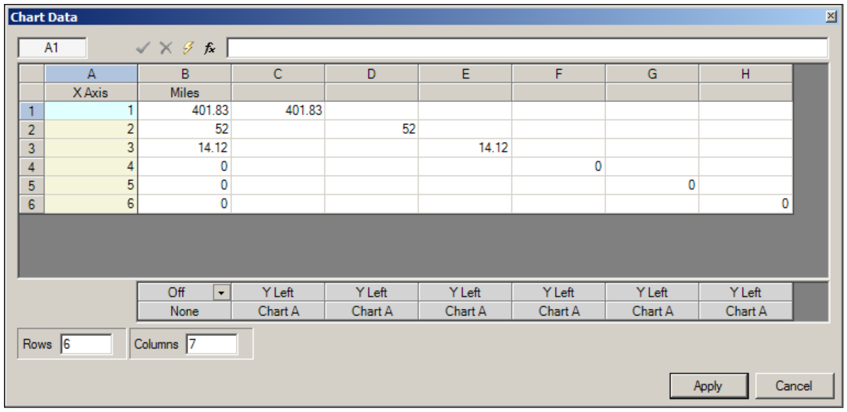


Figure 43. Chart Data Window

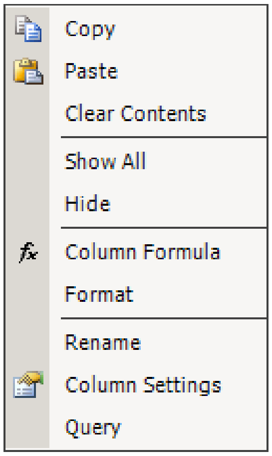
When you click on a cell, information about the selected cell is displayed and can be edited using the fields and toolbar above the table. Chart data can also be retrieved automatically from the database using the options available through a given chart's popup menus. The left most column of the table contains the data for the X-Axis while the other columns contain the Y-Axis data for each plot on the chart.

- X-Axis Column. All plots in the chart share a common X-axis. The chart table always has an X-Axis column displayed in its left-most position. No holes are permitted in the X-Axis, so every row of the X-Axis column must be provided with a value.
- Y-Axis Columns. There are two types of Y-Axis columns available, designated as the primary Y-Left axis and the secondary Y-Right axis. One or more columns can be added to the table with each column corresponding to a separate plot on the chart. Each data column for each plot is designated as a Y-Left or Y-Right plot. Holes are permitted in the plots if no data corresponding to the X-Axis are available. To create a hole, skip a row in a plot column, leaving the unwanted cell blank. The Y-axis columns can also be designated as OFF, in which case the data are still saved, but are not plotted in the chart.
- Other Columns. Not all columns in the table need to be plotted onto the chart. The data in columns that are not directly plotted can be used as source data or as intermediate steps for formula calculations. These columns can be hidden in the table for clarity.

You can add any number of Y-axis columns of data to the design grid and have each column correspond to a separate plot on the chart. To add a plot column, simply increase the number of columns in the table and select the axis that you want the data to be plotted on.

Though normally the design data will represent the information for a single chart, you also have the option to separate the data onto up to five different charts. Plots are arranged onto different charts by selecting the chart designator A, B, C, D, or E. You can also specify the ALL option to indicate that you want the plot to appear on all charts. When using multiple charts, they will each use a common X-axis scale.

By RIGHT-clicking on the column headers of the data table, you will activate a popup menu, shown in Figure 44, which allows you to manipulate the column data and properties.



Copy. Copy the contents of the selected column into the windows clipboard.

Paste. Paste the contents of the Windows clipboard into the selected column.

Clear Contents. Clear all data from the selected column.

Show All. Show any column that has been previously hidden from view in the table.

Hide. Hide the selected column.

Column Formula. Display the expression builder to write a mathematical formula to calculate the data for the column.

Format. Enter a formatting string that formats the numbers displayed in the column.

Rename. Rename the column. The column name is used in the legend of the chart when the data are plotted.

Column Settings. Display the property settings for the selected column that control the appearance of data in the chart and access trend-line options.

Query. Display the query wizard to retrieve PHT analysis result data from the database.

Figure 44. Chart Data Column Popup Menu

One of the features of the chart data window is the ability to use mathematical formulas to calculate the data for individual cells or for the entire column. Formulas are equations that perform calculations on values. A cell formula must always start with an equal sign followed by an equation as show in the example formula below. Formulas may contain numerical values, mathematical operators and functions, and references to other cells in the table. Cells are referenced by their address in the table, which is always their column letter (A-Z) followed by their row number.

```
=INT((B1/C1)*10000)/100
```

Column formulas apply to the entire column. The syntax used by column formulas is identical to that used by cell formulas except that in addition to cell references, column formulas may also use column references. Columns are referenced by their column letter (A-Z) only and are NOT followed by a row number. The column reference is essentially a partial cell address that is completed by the row number when it is applied. For example, a reference to column B would become B3 when applied to a cell in the third row of the table.

Cell formulas supersede column formulas and column formulas supersede manually entered data. Data retrieved from the database are treated by the data table as manually entered data. As such, data retrieved from the database will be superseded by both cell and column formulas.

The PHT analysis results can be queried directly from the result tables in the database using the query wizard to select a data table, data field, and filter clause. The data filter represents the WHERE clause of a SQL statement and must comply with all SQL syntax rules.

MAPS

Maps are used to create complex geographical information system (GIS) maps. Check the **Thematic Map** checkbox to instruct the wizard to generate a map report. To generate a thematic map, you must choose a GIS selection from the drop-down list for the wizard to use as the source for the map.

There is one option available when generating a thematic map report.

- **Apply theme only to selected sections.** This option will instruct the wizard to apply the map theme only to the highway sections that are selected in the GIS selection. This option is useful when you want the map theme to be highlighted only on a sub-section of the map such as a corridor, type of functional class, or a geographical region such as a county or urban area.

An example of a thematic map is shown in Figure 45.

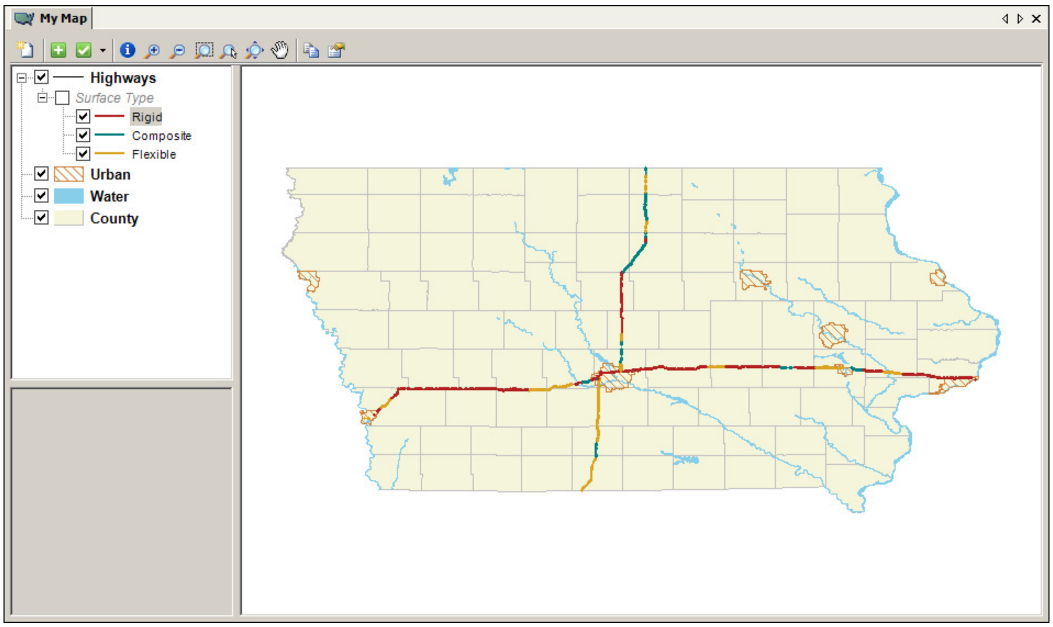


Figure 45. Thematic Map

The map layer is the basic component of a map. A map can have multiple layers with each layer displaying the contents of a different shape file. The order in which the layers are displayed is shown in the legend with the layer at the top appearing above all layers beneath it.

To add a new layer to the map, click the **Add Layer** button on the toolbar. Browse to the GIS file that you want to add to the map and select it. The new layer is added to the map and placed as the top layer. To delete a layer, select it in the legend and press the **Delete** key. The style properties of the layer define its appearance in the map including color, line weight, and line and fill styles. To view and edit a layer's style properties, double-click the layer entry in the legend.

To create a selection of items from the map, click the **Selection** button on the toolbar and a new selection is added to the currently selected layer and displayed in the legend. The selection is highlighted with a user-defined color, line thickness and style. The drop-down menu provides three methods available to add items to the selection.

- Select by Attributes. This option will display the Query Dialog where you can build a SQL query statement to select items based on their attributes. The query wizard allows you to define selection criteria to add items to the selection. The syntax of the selection criteria represents the WHERE clause of a SQL statement and must comply with all SQL syntax rules. To assist in building the selection criteria, the selection builder provides a list of attribute fields and their respective unique values.
- Manual Selection. This option allows you to manually add items to the selection by clicking on them in the GIS map. Only items that are in the currently selected map layer can be added.
- Select by Shortest Path. This option applies to line-layers only and allows you to automatically select a map corridor between two points. If no unbroken path between the two points can be found, then no items will be added to the selection.

To clear the entire map, click the **New Map**  button on the toolbar.

To view the attributes of any item in the map, click the **Identify**  button on the toolbar and then click the item on the map. Items on any layer of the GIS map may have many attributes that describe them. These attributes are useful to create map selections and themes. The attributes for the item appear in a table under the legend.

The legend of the map is displayed in a hierarchal tree. You can turn individual items in the map on and off using the check boxes on the left side of the legend pane. Double-click items in the legend to display a dialog window to edit the settings for that item.

TEMPLATES

Charts generated by the report wizard can be saved to a template library for reuse with other PHT analysis result sets. The report wizard can generate charts from templates stored in the template library as shown in Figure 46. To select a chart template, click the **Templates** tab in the report wizard window. All of the chart templates in the template library are displayed in the list. Click on a chart template in the list to select it and click the **Generate** button to create a new chart based on the selected template.

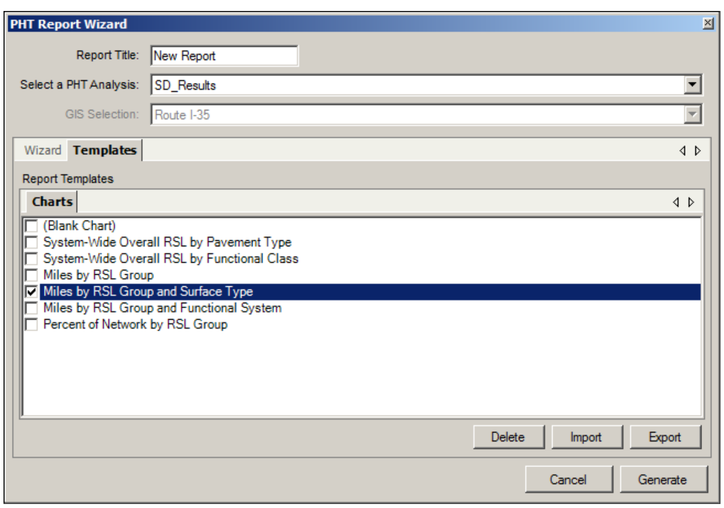


Figure 46. Report Wizard - Chart Templates

Non-HPMS Data Mapping

You can import highway data directly from a non-HPMS data source using a one-to-one field map to control how the data are loaded. Data can be read from an Access database, a flat comma-delimited file, a dBase file, or any predefined ODBC connected data source.

To activate the import wizard, click the **Open Non-HPMS** button on the **Settings** toolbar. The window shown in Figure 47 will appear. This first tab allows you to select the data source to read the highway data.

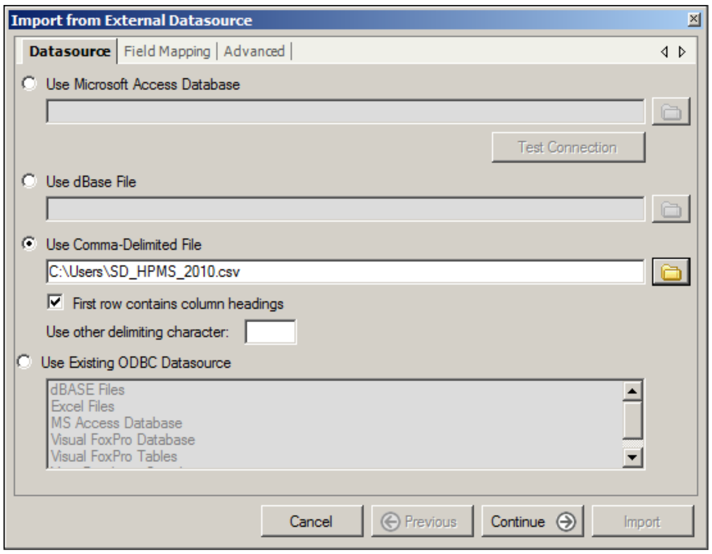


Figure 47. Import Wizard – Datasource

There are four options to select from when importing an external non-HPMS formatted data source:

- The first option is to import data stored in a Microsoft® Access database. Using this option will also require you to select a source table within the Access database. Data cannot be read from multiple tables; therefore if the data reside in multiple tables, it will be necessary to design a query to combine all the data into a single table prior to importing it into the PHT analysis tool.
- The second option is to import data from a dBase file.
- The third option is to import data from a comma-delimited text file. When using this option, you will need to indicate if the first line of the source file contains field names. It is easier to create the field map if descriptive field names are provided. An alternate delimiting character can also be specified if other than a comma.
- The fourth option is to import data from any defined ODBC data source such as Oracle, FoxPro, Paradox, or even spreadsheets such as Excel.

The next tab, shown in Figure 48, allows you to select the source table (if applicable) and define a field map between the data fields in the source data and those of the PHT data table. For each PHT field, select a matching field that provides the data. You can also directly enter a hard-coded value or choose to leave a field blank if the source table has no matching item. The mapped field must have a compatible data type with the PHT field.

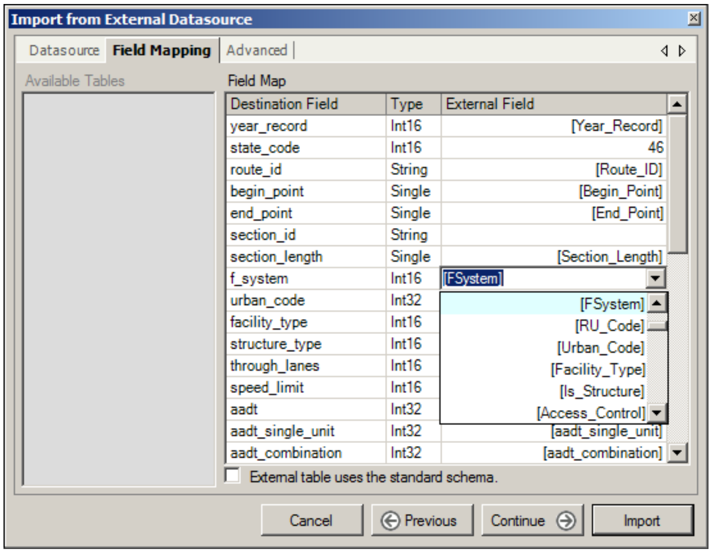


Figure 48. Import Wizard – Field Map

APPLYING FORMULAS IN THE FIELD MAP

In addition to one-to-one field mapping, the import wizard also provides formulas to calculate a required value when it is not directly available in the source data. To create a formula for a field, activate the formula wizard by selecting the field and then clicking the **Formula** option at the top of the dropdown list, as shown in Figure 49.

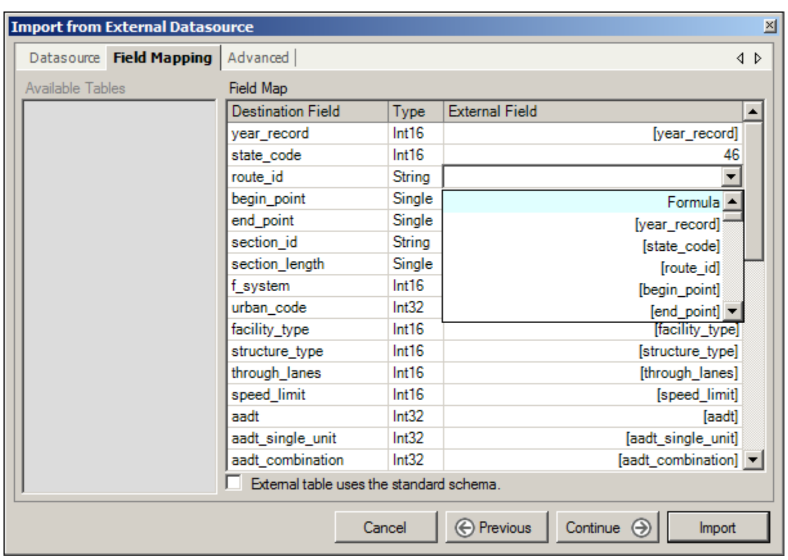


Figure 49. Import Wizard – Formulas

The formula wizard provides a list of all of the data fields that are available in the source data. The formula expression can use simple math, functions, and the values of the other fields in the record to calculate the new value as shown in Figure 50. The math and string function prototypes are available by clicking the **Functions** button in the formula builder.

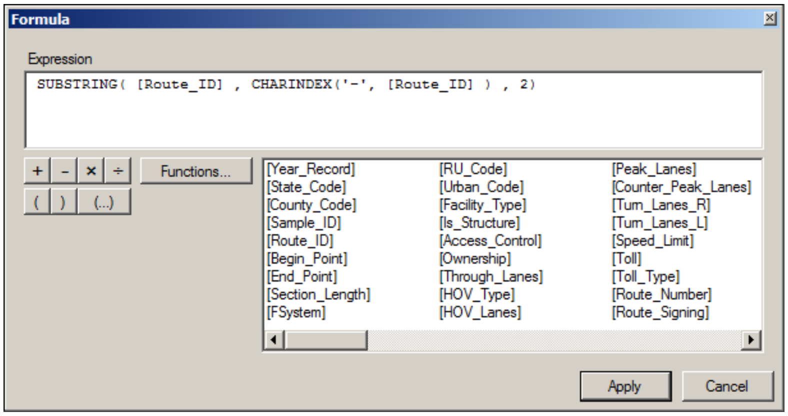


Figure 50. Formula Builder

<u>MATH AND STRING FUNCTIONS</u>

The supported math and string functions are described in Table 4.

Table 4. Math and String Functions

Math Functions	Trig Functions	String Functions	Decision Functions
ABS EXP LOG LOG10 CEILING RAND ROUND SIGN SQRT	SIN COS TAN ASIN ACOS ATAN SINH COSH TANH	LEFT RIGHT SUBSTRING CHARINDEX LEN	CASE

The final tab, shown in Figure 51, provides an advanced option to filter the records in the source table prior to importing the data to the PHT table. This is useful if you only want to read a sub-set of the records that are in the source table. Use the filter wizard to create the SQL clause to filter the data, or use the SQL Text window to enter the filter clause directly.

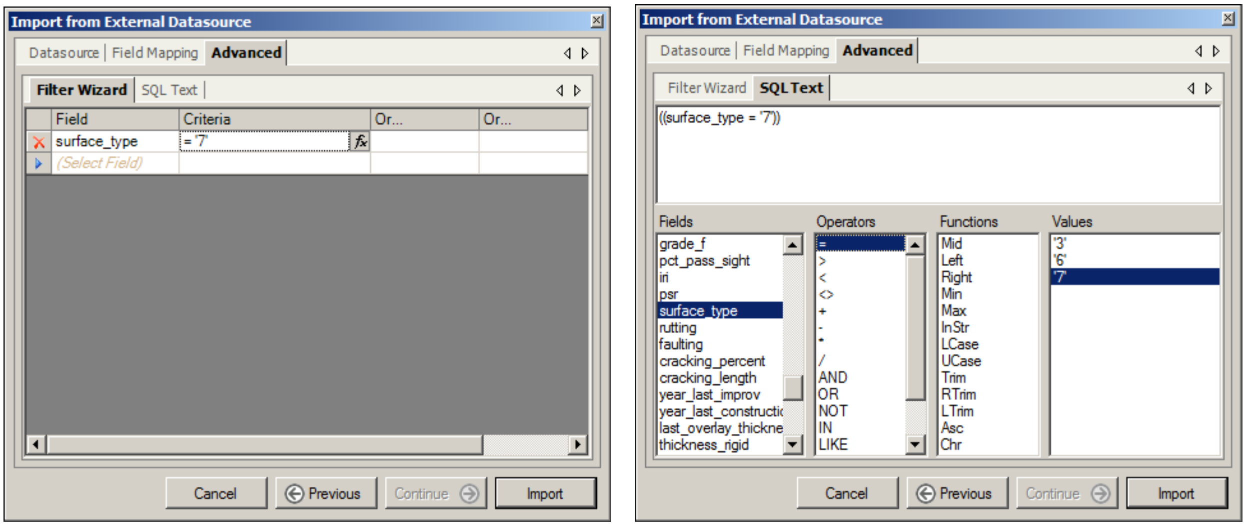


Figure 51. Import Wizard – Advanced Filtering

Click the **Import** button to import the source data into the PHT analysis tool. When you import data, the import wizard will remember all of your selections and field mapping design for reuse in the future. If you cancel the import wizard, any selections or field mapping changes will be lost.

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Technical Information

The PHT analysis engine quantifies the RSL of the pavement for each highway section using the simplified MEPDG-based pavement performance prediction models. The PHT analysis engine receives highway data and parameter metrics and determines the pavement RSL in accordance with its implementation process presented in Figure 52.

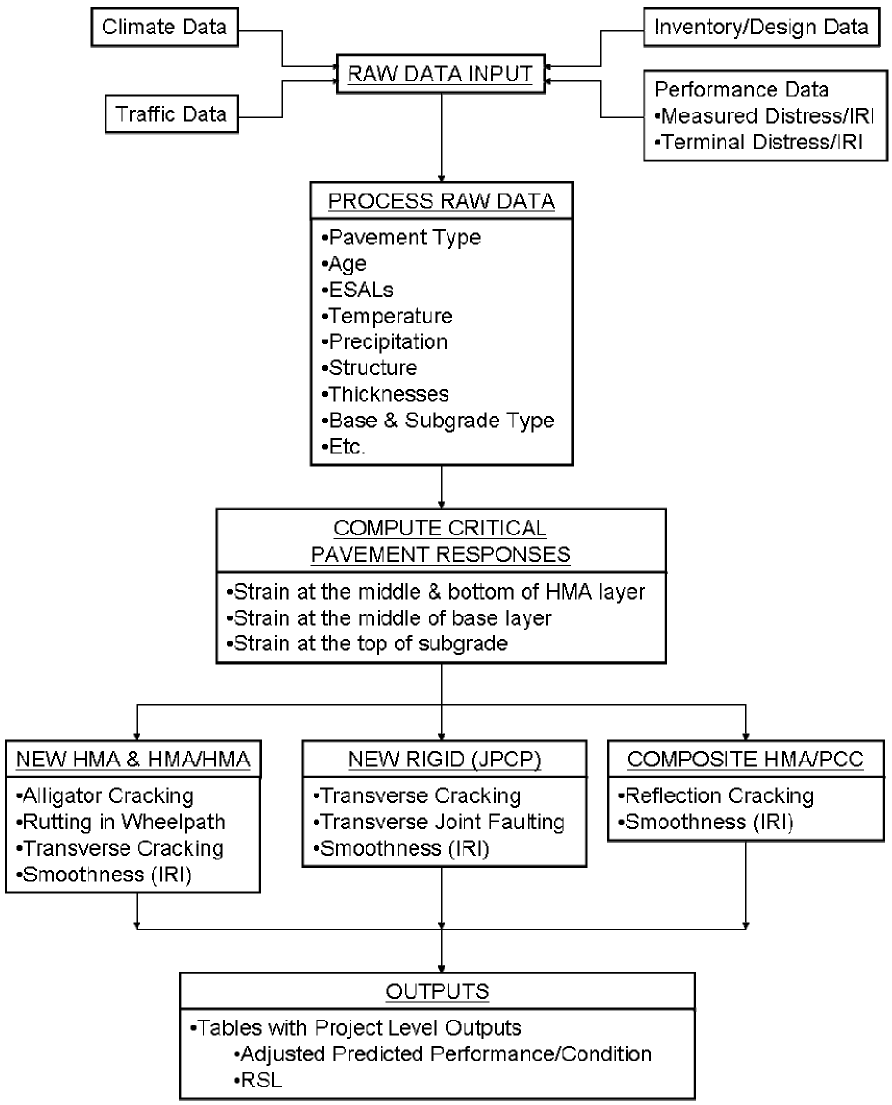

Figure 52. RSL Forecasting Process

PHT Data Schema

Table 5. PHT Data Fields

Field Name	Type	Description
ID	integer	Unique record identifier.
year_record	integer	Year of record.
state_code	integer	State FIPS code.
route_id	text	Route identifier.
begin_point	single	Beginning milepost.
end_point	single	Ending milepost.
section_id	text	State wide unique section identifier, 32 characters max.
section_length	single	Overall section length.
f_system	integer	The FHWA approved functional system classification.
urban_code	integer	Urbanized area code
facility_type	integer	Operational characteristics of the roadway.
structure_type	integer	Section is completely on a structure, tunnel, or causeway.
through_lanes	integer	Number of lanes of the entire facility.
speed_limit	integer	Posted speed limit.
aadt	integer	Annual average daily traffic.
aadt_single_unit	integer	AADT for single unit trucks.
aadt_combination	integer	AADT for combination trucks.
future_aadt	integer	Forecasted AADT.
future_aadt_year	integer	Year of forecasted AADT.
lane_width	Single	Measure of existing lane width.
shoulder_type	integer	Type of existing shoulder.
iri	integer	International roughness index.
psr	single	Present serviceability rating.
surface_type	integer	Surface type of the facility.
rutting	single	Estimate of average rutting.
faulting	single	Estimate of average vertical displacement between adjacent slabs.
cracking_percent	single	Estimate of total area with fatigue cracking or percent of cracked slabs.
cracking_length	single	Estimate of total feet/mile of cracking length.
year_last_improv	integer	Year in which the roadway surface was last improved.
year_last_construction	integer	Year the facility was last reconstructed.
last_overlay_thickness	single	Thickness of the most recent pavement overlay.
thickness_rigid	single	Thickness of the rigid pavement.
thickness_flexible	single	Thickness of the flexible pavement.
base_type	integer	The base pavement type.
base_thickness	single	Thickness of the base pavement.
climate_zone	integer	Climate zone for the facility.
soil_type	integer	Soil class type.
county_code	integer	County FIPS code.
volume_group	integer	The AADT volume group for the facility.
expansion_factor	single	Factor to expand sample data to represent the universe data.

The schema for the PHT result data fields shown in Table 6 are appended to the end of the original PHT source data schema when the PHT analysis is performed.

Table 6. PHT Result Fields

Field Name	Type	Description
n_RU_Code	integer	Auto-generated code used by the PHT analysis.
f_RSL_Final_IRI	single	Predicted IRI at the end of the overall service life.
f_RSL_Final_Rutting	single	Predicted Rutting at the end overall service life.
f_RSL_Final_Cracking_Percent	single	Predicted Percent Cracking at the end of the overall service life.
f_RSL_Final_Cracking_Length	single	Predicted Cracking Length at the end of the overall service life.
f_RSL_Final_Faulting	single	Predicted Faulting at the end of the overall service life.
f_RSL_Term_IRI_Years	single	Number of years until the terminal IRI is reached.
f_RSL_Term_IRI_ESALs	single	Remaining ESALs until the terminal IRI is reached.
f_RSL_Term_Rutting_Years	single	Number of years until the terminal Rutting is reached.
f_RSL_Term_Rutting_ESALs	single	Remaining ESALs until the terminal Rutting is reached.
f_RSL_Term_Cracking_Percent_Years	single	Number of years until the terminal Percent Cracking is reached.
f_RSL_Term_Cracking_Percent_ESALs	single	Remaining ESALs until the terminal Percent Cracking is reached.
f_RSL_Term_Cracking_Length_Years	single	Number of years until the terminal Cracking Length is reached.
f_RSL_Term_Cracking_Length_ESALs	single	Remaining ESALs until the terminal Cracking Length is reached.
f_RSL_Term_Faulting_Years	single	Number of years until the terminal Faulting is reached.
f_RSL_Term_Faulting_ESALs	single	Remaining ESALs until the terminal Faulting is reached.
f_Overall_RSL_Years	single	Overall number of years remaining in the service life.
f_Overall_RSL_ESALs	single	Overall number of ESALs remaining in the service life.
f_Reliability_RSL	single	Calculated Reliability RSL.
n_Analysis_Result_Code	integer	Code (1) indicating the record was successfully analyzed.
f_UDF1	single	User defined data field.
f_UDF2	single	User defined data field.
f_UDF3	single	User defined data field.
f_UDF4	single	User defined data field.
f_UDF5	single	User defined data field.
f_UDF6	single	User defined data field.

Maintenance Model

The schema for the Maintenance model result data fields shown in Table 7 are appended to the end of the PHT result data schema when the maintenance model analysis is performed.

Table 7. Maintenance Model Fields

Field Name	Type	Description
f_Treatment	integer	Code indicating the type of feasible maintenance treatment.
f_SLE	single	Estimated service life extension.
f_Cost	integer	Estimated cost of the maintenance treatment.
f_Benefit	single	Estimated monetary benefit.
f_BCR	single	Benefit/Cost ratio
f_Reset_IRI	single	Revised post-maintenance IRI value
f_Reset_Rutting	single	Revised post-maintenance Rutting value
f_Reset_Cracking_Percent	single	Revised post-maintenance Cracking Percent value
f_Reset_Cracking_Length	single	Revised post-maintenance Cracking Length value
f_Reset_Faulting	single	Revised post-maintenance Faulting value

The codes for the feasible maintenance treatments for asphalt concrete (AC)-surfaced (flexible & composite) and rigid pavements are described in Table 8.

Table 8. Maintenance Treatment Codes

Treatment Type	Code
None	0
AC – Surface Sealing	1
AC – Full Depth Patching	2
AC – Patching with Thin Overlay	3
AC – Major Rehabilitation	4
AC – Reconstruction	5
Rigid – Functional Repair	6
Rigid – Surface Seal with Thin Overlay	7
Rigid – Major Rehabilitation	8
Rigid – Reconstruction	9

The maintenance model uses five lookup tables as shown in Table 9 through Table 13. These tables describe the default values used by the PHT maintenance model including the trigger levels, post-maintenance resets, costs, service life extensions, and feasibility thresholds.

The model will select a preferred treatment strategy from the list in Table 12 and Table 13 based on each option's selection criteria. The model will select the lowest feasible improvement group by order of severity that will address the distress/IRI and RSL conditions.

Table 9. Default Maintenance Trigger Levels

Surface Type	Class	IRI	Cracking		Rutting	Faulting
			Percent	Length		
Flexible, Composite	Interstate	80	0 %	250 ft/mi	0.25 in.	
	Primary	100	0 %	1000 ft/mi	0.25 in.	
	Secondary	125	5 %	1000 ft/mi	0.25 in.	
Rigid	Interstate	100	0 %			0.10 in.
	Primary	100	0 %			0.10 in.
	Secondary	125	0 %			0.15 in.

Table 10. Default Post-Maintenance Resets (%) and Treatment Costs

Surface Type	Treatment	IRI	Cracking		Rutting	Faulting	Cost per Lane-Mile
			Percent	Length			
Flexible, Composite	Surface Sealing	0 %	40 %	15 %	10 %		$ 12,250
	Full-Depth Patching	0 %	40 %	15 %	25 %		$ 32,500
	Patching and Overlay	30 %	100 %	90 %	50 %		$ 42,000
	Rehabilitation	100 %	100 %	100 %	100 %		$ 92,000
	New / Reconstruction	100 %	100 %	100 %	100 %		$ 290,000
Rigid	Functional Repair	50 %	7 %			70 %	$ 27,750
	Seal and Overlay	0 %	0 %			0 %	$ 22,000
	Rehabilitation	0 %	0 %			0 %	$ 132,750
	New / Reconstruction	100 %	100 %			100 %	$ 450,000

Note: A value of 0% means no change while a value of 100% implies reset to like-new conditions.

Table 11. Default Service Life Extensions (Years)

Surface Type	Treatment	RSL Extension	Additive (+)				
			Climate (non-freeze)	Climate (dry)	Class (non-principal)	Pavement (composite)	Sub-Grade (fine)
Flexible, Composite	Surface Sealing	1.5					
	Full-Depth Patching	0.5	1		2	0	0
	Patching and Overlay	5.5	0		0	0	0
	Rehabilitation	10	2.5		2	5	3
	Reconstruction	20					
Rigid	Functional Repair	6	1	2	0		0
	Seal and Overlay	5.5					
	Rehabilitation	15					
	Reconstruction	30					

Table 12. Feasible Improvements for Flexible and Composite (AC) Pavements

	Interstate	Primary	Secondary
Surface sealing	N/A	N/A	RSL > 5 years Rutting < 0.35 in Cracking Length < 2500 Cracking Percent < 5 % IRI < 150 in/mi
Full depth patching with OR without grinding	RSL > 10 years Rutting < 0.25 in Cracking Length < 250 Cracking Percent < 5 % IRI < 125 in/mi	RSL > 5 years Rutting < 0.25 in Cracking Length < 1000 Cracking Percent < 5 % IRI < 150 in/mi	RSL > 5 years Rutting < 0.35 in Cracking Length < 1000 Cracking Percent < 5 % IRI < 125 in/mi
Full depth patching with thin AC overlay OR surface recycling	RSL > 10 years Rutting < 0.35 in Cracking Length < 1000 Cracking Percent < 10 % IRI < 125 in/mi	RSL > 5 years Rutting < 0. 5 in Cracking Length < 2000 Cracking Percent < 10 % IRI < 150 in/mi	N/A
Major rehabilitation	RSL > 3 years Rutting < 0.35 in Cracking Length < 2000 Cracking Percent < 15 % IRI < 150 in/mi	RSL > 3 years Rutting < 0.5 in Cracking Length < 2000 Cracking Percent < 15 % IRI < 150 in/mi	RSL > 3 years Rutting < 0.75 in Cracking Length < 2500 Cracking Percent < 15 % IRI < 175 in/mi
New or reconstruction	RSL < 3 years Rutting > 0.35 in Cracking Length > 2000 Cracking Percent > 15 % IRI > 150 in/mi	RSL < 3 years Rutting > 0.5 in Cracking Length > 2000 Cracking Percent > 15 % IRI > 150 in/mi	RSL < 3 years Rutting > 0.75 in Cracking Length > 2500 Cracking Percent > 15 % IRI > 175 in/mi

Table 13. Feasible Improvements for Rigid Pavements

	Interstate	Primary	Secondary
Functional repair	RSL > 10 yrs Cracking Percent < 10% Faulting < 0.15 in IRI < 125 in/mi	RSL > 10 yrs Cracking Percent < 10% Faulting < 0.15 in IRI < 125 in/mi	N/A
Surface seals & thin overlay	RSL > 10 yrs Cracking Percent < 1% Faulting < 0.1 in IRI < 150 in/mi	RSL > 10 yrs Cracking Percent < 1% Faulting < 0.1 in IRI < 150 in/mi	RSL > 10 yrs Cracking Percent < 1% Faulting < 0.1 in IRI < 150 in/mi
Major rehabilitation	RSL > 5 yrs Cracking Percent < 15% Faulting < 0.2 in IRI < 175 in/mi	RSL > 5 yrs Cracking Percent < 15% Faulting < 0.2 in IRI < 175 in/mi	RSL > 5 yrs Cracking Percent < 20% Faulting < 0.2 in IRI < 175 in/mi
Reconstruction	RSL < 5 yrs Cracking Percent > 15% Faulting > 0.2 in IRI > 175 in/mi	RSL < 5 yrs Cracking Percent > 15% Faulting > 0.2 in IRI > 175 in/mi	RSL < 5 yrs Cracking Percent > 20% Faulting > 0.2 in IRI > 175 in/mi

The PHT maintenance model estimates benefits of each pavement section improvement quantified in terms of the value added to the pavement infrastructure. Benefits are calculated based on the following assumptions:

- Straight-line depreciation is used to depreciate individual pavement assets over their service life.
- The post-treatment rate of depreciation remains the same.
- The initial service life of the pavement is the sum of the current pavement age and the RSL where the current pavement age is the difference between the current year of record and the original year of construction for new pavements; or the year of last improvement for rehabilitated pavements.

Straight-line depreciation, along with the effect of the application of a maintenance treatment on increasing the service life and asset value, is shown in Figure 53.

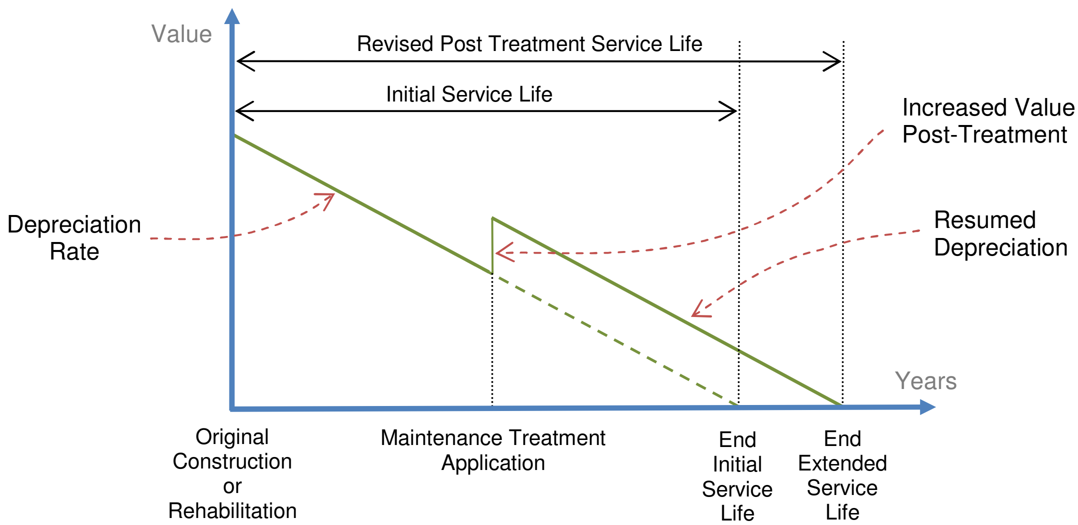

Figure 53. Straight-Line Depreciation with Maintenance Treatment

The initial value of the pavement at original construction or rehabilitation is determined by the new construction costs multiplied by the adjustment factors shown in Table 14.

Table 14. Initial Pavement Value Adjustment Factors

Pavement Type	Surface Type (Table 15)	Factor
New Pavement	2, 3, 4, 5	1.00
Rehabilitated Pavement, thin overlay	6, 7, 8, 9, 10, 11	0.60
Rehabilitated Pavement, thick overlay		0.60

The following equations described how the PHT maintenance model determines the overall cost and benefits of the application of a maintenance treatment.

Determine the initial service life of the pavement.

$$ISL = (CYR - OCYR) + RSL \qquad \text{(New Pavement)} \qquad (1)$$
$$ISL = (CYR - LIYR) + RSL \qquad \text{(Rehabilitated Pavement)}$$

Where:

ISL	=	Initial Service Life, years
CYR	=	Current Year, (field: `year_record`)
OCYR	=	Original Year of Construction, (field: `year_last_construction`)
LIYR	=	Year of Last Improvement, (field: `year_last_improv`)
RSL	=	Estimated Remaining Service Life, (field `f_Overall_RSL_Years`).

Estimate monetary benefit of the maintenance action for the highway section.

$$BENEFIT = SLE \times \left(\left(\frac{NPAC \times \beta}{ISL} \right) + \left((NPAC - COST) \times DR \right) \right) \times (LN \times LEN) \qquad (2)$$

Where:

BENEFIT	=	Estimated Monetary Benefit
SLE	=	Service Life Extension, (see Table 11)
NPAC	=	New Pavement Asset Cost, (see Table 10)
ISL	=	Initial Service Life, (see Equation 1)
COST	=	Maintenance Cost, (see Table 10)
DR	=	Discount Rate
LEN	=	Length of the Highway Section, miles, (field: `section_length`)
LN	=	Number of Lanes, (field: `through_lanes`)
β	=	Adjustment Factor, (see Table 14).

Calculate the total cost of the maintenance action for the highway section.

$$COST = UCOST \times (LEN \times LN) \qquad (3)$$

Where:

COST	=	Estimated Cost of Improvements
UCOST	=	Unit Cost of Improvement per Lane-Mile, (see Table 10)
LEN	=	Length of the Highway Section, miles, (field: `section_length`)
LN	=	Number of Lanes, (field: `through_lanes`).

Calculate the Benefit-to-Cost Ratio.

$$BCR = \left(\frac{BENEFIT}{COST} \right) \qquad (4)$$

Where:

BCR	=	Benefit to Cost Ratio
BENEFIT	=	Estimated Monetary Benefit, (see Equation 2)
COST	=	Estimated Cost of Improvements (see Equation 3).

Data Aggregations

The PHT tool classifies pavement types as Rigid, Flexible, and Composite. The aggregation of the standard HPMS 2010 surface types into these three classifications is shown in Table 15.

Table 15. Surface Type Classifications

Classification	RSL Analysis	HPMS Code	Description
none	No	0	Not Reported
none	No	1	Unpaved
Flexible	Yes	2	Bituminous
Rigid	Yes	3	JPCP – Jointed Plain Concrete Pavement
Rigid	No	4	JRCP – Jointed Reinforced Concrete Pavement
Rigid	No	5	CRCP – Continuously Reinforced Concrete Pavement
Flexible	Yes	6	Asphalt-Concrete (AC) Overlay over Existing AC Pavement
Composite	Yes	7	AC Overlay over Existing Jointed Concrete Pavement
Composite	No	8	AC (Bi Overlay over Existing CRCP)
Rigid	No	9	Unbounded Jointed Concrete Overlay on PCC Pavements
Rigid	No	10	Unbounded CRCP Overlay on PCC Pavements
Rigid	No	11	Bonded PCC Overlays on PCC Pavements
none	No	12	Other

The PHT tool aggregates the standard HPMS 2010 functional classifications for highway sections into three categories of Interstate, Primary, and Secondary roadways as shown in Table 16.

Table 16. Functional System Classifications

Classification	HPMS Code	Description
Interstate	1	Interstate
Interstate	2	Principal Arterial – Other Freeways and Expressways
Interstate	3	Principal Arterial – Other
Primary	4	Minor Arterial
Primary	5	Major Collector
Secondary	6	Minor Collector
Secondary	7	Local

Parameter Metrics

Table 17 through Table 19 describes the default values for the parameter metrics used by the PHT analysis tool including the terminal thresholds, maximum service life, and default pavement estimates. You may modify any of these values as needed.

Table 17. Default Terminal Values

Surface Type	Functional System	IRI	Cracking		Rutting	Faulting
			Percent	Length		
Rigid	Interstate	170	10 %			0.15 in.
	Primary	220	15 %			0.20 in.
	Secondary	220	20 %			0.20 in.
Flexible	Interstate	170	20 %	640 ft/mi	0.40 in.	
	Primary	220	45 %	800 ft/mi	0.60 in.	
	Secondary	220	45 %	1270 ft/mi	0.80 in.	
Composite	Interstate	170		100 ft/mi		
	Primary	220		60 ft/mi		
	Secondary	220		60 ft/mi		

Table 18. Default Maximum Service Life

Treatment Type	Years
New HMA	20
New PCC	30
Thick AC Overlay of AC Pavement	10
Thin AC Overlay of AC Pavement	6
Thick AC Overlay of PCC Pavement	10
Unbonded PCC Overlay of PCC Pavement	25
Bonded PCC Overlay of PXX Pavement	15
Thin AC Overlay of AC/PCC Pavement	6

Table 19. Default Pavement Estimates (All Functional Systems)

Pavement Estimate Category	State System	
	On	Off
Last overlay Thickness	3 in.	3 in.
Rigid Pavement Thickness	10 in.	10 in.
Flexible Pavement Thickness	8 in.	8 in.
Base Type	Granular	Granular
Base Thickness	4 in.	4 in.
Binder Type	AC-40 to AC-49	AC-40 to AC-49
Dowel Bar	Typically used	Typically used
Joint Space	20 feet	20 feet

HPMS 2010 File Format

The following table describes the data fields for the Comma Separated Value (CSV) file for the HPMS2010 formatted data that is used by the PHT analysis tool. This format is defined in the HPMS Field Manual Appendix G, September 2010. Data fields shown in gray are not used in the analysis and can be left blank; but a placeholder must remain in the CSV file for the unused fields for the PHT tool to properly read and import the file.

Table 20. PHT Data Fields

001	Year_Record	032	Dir_Factor	063	IRI
002	State_Code	033	Future_AADT	064	PSR
003	Route_ID	034	Future_AADT_Year	065	Surface_Type
004	Begin_Point	035	Type_Signal	066	Rutting
005	End_Point	036	Pct_Green_Time	067	Faulting
006	Section_Length	037	Number_Signals	068	Cracking_Percent
007	F_System	038	Stop_Signs	069	Cracking_Length
008	Urban_Code	039	At_Grade_Other	070	Year_Last_Improv
009	Facility_Type	040	Lane_Width	071	Year_Last_Construction
010	Structure_Type	041	Median_Type	072	Last_Overlay_Thickness
011	Access_Control	042	Median_Width	073	Thickness_Rigid
012	Ownership	043	Shoulder_Type	074	Thickness_Flexible
013	Through_Lanes	044	Shoulder_Width_R	075	Base_Type
014	HOV_Type	045	Shoulder_Width_L	076	Base_Thickness
015	HOV_Lanes	046	Peak_Parking	077	Climate_Zone
016	Peak_Lanes	047	Widening_Obstacle	078	Soil_Type
017	Counter_Peak_Lanes	048	Widening_Potential	079	County_Code
018	Turn_Lanes_R	049	Curves_A	080	NHS
019	Turn_Lanes_L	050	Curves_B	081	Future_Facility
020	Speed_Limit	051	Curves_C	082	STRAHNET_Type
021	Toll_Charged	052	Curves_D	083	Truck
022	Toll_Type	053	Curves_E	084	VSF
023	Route_Number	054	Curves_F	085	Capacity
024	Route_Signing	055	Terrain_Type	086	Design_Speed
025	Route_Qualifier	056	Grades_A	087	Vertical_Alignment
026	AADT	057	Grades_B	088	Horizontal_Alignment
027	AADT_Single_Unit	058	Grades_C	089	Volume_Group
028	Pct_Peak_Single	059	Grades_D	090	Expansion_Factor
029	AADT_Combination	060	Grades_E		
030	Pct_Peak_Combination	061	Grades_F		
031	K_Factor	062	Pct_Pass_Sight		

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APPENDIX A

PHT HIGHWAY DATA VALIDATION RULES

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PHT Highway Data Validation Rules – Range Validations

Number	Description
0001.0	The year of record must be greater than 1900. Condition: The **year_record** (1) field is less than 1900.
0002.0	State code must be a valid FIPS code. Condition: The **state_code** (2) field is not a valid state code.
0003.0	Route ID must be a nonzero alphanumeric value. Condition: The **route_id** (3) field blank or equal to 0.
0004.0	Begin point must not be less than zero. Condition: The **begin_point** (4) field is less than 0.
0005.0	End point must not be less than zero. Condition: The **end_point** (5) field is less than 0.
0006.0	Section length must be greater than zero. Condition: The **section_length** (6) field is not greater than 0.
0007.0	Functional System must be a value in the range [1-7]. Condition: The **f_system** (7) field is less than 1 or greater than 7.
0009.0	Facility Type must be a value in the range [1-6]. Condition: The **facility_type** (9) field is less than 1 or greater than 6.
0010.0	Structure Type must be a value in the range [0-3]. Condition: The **structure_type** (10) field is less than 0 or greater than 3.
0013.0	Number of Through Lanes must not be less than one. Condition: The **through_lanes** (13) field is less than 1.
0020.0	Speed Limit must be greater than zero and should be divisible by 5. Condition: The **speed_limit** (20) field is not greater than 0 and divisible by 5.
0026.0	AADT must not be less than zero. Condition: The **aadt** (26) field is less than 0.
0027.0	AADT for Single-Unit Trucks must not be less than zero. Condition: The **aadt_single_unit** (27) field is less than 0.
0029.0	AADT for Combination Trucks must not be less than zero. Condition: The **aadt_combination** (29) field is less than 0.

Number	Description
0033.0	Future AADT must be greater than zero. Condition: The **future_aadt** (33) field is not greater than 0.
0040.0	Lane Width should be a value from 6 to 18 feet. Condition: The **lane_width** (40) field is less than 6 or greater than 18.
0043.0	Shoulder Type must be a value in the range [1-7]. Condition: The **shoulder_type** (43) field is less than 1 or greater than 7.
0063.0	IRI must contain a value from 0 to 955. Condition: The **iri** (63) field is less than 0 or greater than 955.
0064.0	PSR must contain a value from 0.0 to 5.0. Condition: The **psr** (64) field is less than 0.0 or greater than 5.0.
0065.0	Surface Type must be a value in the range [1-11]. Condition: The **surface_type** (65) field is less than 1 or greater than 11.
0066.0	Rutting must not be less than zero. Condition: The **rutting** (66) field is less than 0.
0067.0	Faulting must not be less than zero. Condition: The **faulting** (67) field is less than 0.
0068.0	Cracking Percent must not be less than 0 or greater than 100. Condition: The **cracking_percent** (68) field is less than 0 or greater than 100.
0069.0	Cracking Length must not be less than zero. Condition: The **cracking_length** (69) field is less than 0.
0071.0	The year of construction must be greater than 1900. Condition: The **year_last_construction** (71) field is less than 1900.
0072.0	Last Overlay Thickness must not be less than zero. Condition: The **last_overlay_thickness** (72) field is less than 0.
0073.0	Rigid Pavement Thickness must not be less than zero. Condition: The **thickness_rigid** (73) field is less than 0.
0074.0	Flexible Pavement Thickness must not be less than zero. Condition: The **thickness_flexible** (74) field is less than 0.

Number	Description
0075.0	Base Type must be a value in the range [1-8]. Condition: The **base_type** (75) field is less than 1 or greater than 8.
0076.0	Base Pavement Thickness must not be less than zero. Condition: The **base_thickness** (76) field is less than 0.
0077.0	Climate Zone must be a value in the range [1-4]. Condition: The **climate_zone** (77) field is less than 1 or greater than 4.
0078.0	Soil Type must be a value in the range [1-2]. Condition: The **soil_type** (78) field is less than 1 or greater than 2.
0079.0	County code must be a valid FIPS code. Condition: The **county_code** (79) field is not a valid county code.
0089.0	Volume Group must be a value in the range [1-12]. Condition: The **volume_group** (89) field is less than 1 or greater than 12.
0090.0	Expansion Factor must not be less than one. Condition: The **expansion_factor** (90) field is less than 1.

PHT Highway Data Validation Rules – Cross Field Validations

Number	Description
1005.0	End point must be greater than the Begin point. Condition: The **end_point** (5) field is not greater than the **begin_point** (4) field.
1006.0	The Section Length must equal the distance between the begin and end points within 0.1 miles. Condition: The **end_point** (5) field minus the **begin_point** (4) field does not equal the **section_length** (6) filed plus or minus 0.1 miles.
1009.0	Interstate should not be a one-way facility. Condition: The **facility_type** (9) field equals 1 (one-way) AND The **f_system** (7) field equals 1 (interstate).
1013.0	Number of Through Lanes must not be zero when the functional system is less than [6]. Condition: The **through_lanes** (13) field equals 0 AND The **f_system** (7) field does NOT equal 6 (minor collector) or 7 (local).
1013.1	Number of Through Lanes should be two or more for a paved two-way facility. Condition: The **through_lanes** (13) field is less than 2 AND The **facility_type** (9) field equals 2 (two-way) AND The **surface_type** (65) field does NOT equal 1 (unpaved)
1020.1	Low Speed Limit of less than 50 MPH on an interstate. Condition: The **speed_limit** (20) field is less than 50 AND The **f_system** (7) field equals 1 (interstate).
1026.0	AADT must not be less than the sum of the single-unit and combination truck AADT. Condition: The **aadt** (26) is less than the sum of **aadt_single_unit** (27) and **aadt_combination** (29).
1026.1	AADT must not be zero when the facility is an interstate, freeway or principal arterial. Condition: The **aadt** (26) field equals to zero AND The **f_system** (7) field equals 1 or 2 (interstate or freeway) or 3 (principal arterial).
1026.2	Low AADT on interstate of less than 1000. Condition: The **aadt** (26) field is less than 1000 AND The **f_system** (7) field equals 1 (interstate).
1026.3	Low AADT of less than 500 per lane with more than 4 through lanes. Condition: The **aadt** (26) field divided by **through_lanes** (13) is less than 500 AND The **through_lanes** (13) is greater than 4.
1027.0	The sum of the single-unit and combination truck AADT must not be zero on an interstate. Condition: The sum of **aadt_single_unit** (27) and **aadt_combination** (29) equals zero AND The **f_system** (7) field equals 1 (interstate).

Number	Description
1033.0	Future AADT growth is more than 4 times or less than 0.4 times the AADT. Condition: The **future_aadt** (33) field is greater than **aadt** (26) times 4 or less than **aadt** (26) times 0.4.
1033.1	Future AADT has the same value as the AADT. Condition: The **future_aadt** (33) field equals the **aadt** (26) field.
1034.0	Future AADT year should be between 18 and 25 years beyond the Year-of-Record. Condition: The **future_aadt_year** (34) is less than the **year_record** (1) plus 18 OR The **future_aadt_year** (34) is greater than **year_record** (1) plus 25.
1043.0	Shoulder Type is none or earth on Interstate. Condition: The **shoulder_type** (43) field equals 1 (none) or 6 (earth) AND The **f_system** (7) equals 1 (interstate).
1063.0	IRI should not be zero when the facility is paved. Condition: The **iri** (63) equals zero AND The **surface_type** (65) is greater than 1 (paved).
1063.1	IRI should be zero when the facility is unpaved. Condition: The **iri** (63) is NOT zero AND The **surface_type** (65) field equals 1 (unpaved).
1063.2	Facility has an extremely low IRI of less than 30. Condition: The **iri** (63) field is less than 30 and NOT equal to zero.
1063.3	Facility has an extremely high IRI of greater than 400. Condition: The **iri** (63) field is greater than 400.
1064.0	PSR should not be zero when the facility is paved and IRI is zero. Condition: The **psr** (64) is zero AND The **surface_type** (65) is greater than 1 (paved) AND The **iri** (63) field is zero.
1064.1	PSR should be zero when the facility is unpaved. Condition: The **psr** (64) is does NOT equal zero AND The **surface_type** (65) field equals 1 (unpaved).
1065.0	Unpaved facility on an interstate, freeway or principal arterial. Condition: The **surface_type** (65) field equals 1 (unpaved) AND The **f_system** (7) field equals 1 or 2 (interstate or freeway) or 3 (principal arterial).
1066.0	Rutting is not a distress for a rigid surface. Condition: The **rutting** (66) field data is provided AND The **surface_type** (65) field equals 3, 4, 5, 9 or 10 (rigid).

Number	Description
1066.1	Rutting must be provided for a flexible or composite surface. Condition: The **rutting** (66) field data is NOT provided AND The **surface_type** (65) field equals 2, 6, 7 or 8 (flexible or composite).
1067.0	Faulting is not a distress for a flexible or composite surface. Condition: The **faulting** (67) field data is provided AND The **surface_type** (65) field equals 2, 6, 7 or 8 (flexible or composite).
1067.1	Faulting must be provided for a rigid surface. Condition: The **faulting** (67) field data is NOT provided AND The **surface_type** (65) field equals 3, 4, 5, 9 or 10 (rigid).
1068.0	Cracking percent must be provided for a rigid, flexible or composite surface. Condition: The **cracking_percent** (68) field data is NOT provided AND The **surface_type** (65) field equals 2, 3, 4, 5, 6, 7, 8, 9 or 10 (rigid, flexible and composite).
1069.0	Cracking length is not a distress for a rigid surface. Condition: The **cracking_length** (69) field data is provided AND The **surface_type** (65) field equals 3, 4, 5, 9 or 10 (rigid).
1069.1	Cracking length must be provided for a flexible or composite surface. Condition: The **cracking_length** (69) field data is NOT provided AND The **surface_type** (65) field equals 2, 6, 7 or 8 (flexible or composite).
1070.0	The year of last improvement must not be less than the year of last construction. Condition: The **year_last_improv** (70) field is greater than 0 AND The **year_last_improv** (70) field is less than the **year_last_construction** (71) field.
1070.1	The year of last improvement must not be greater than the year of record. Condition: The **year_last_improv** (70) field is greater than the **year_record** (1) field.
1070.2	The year of last improvement must be provided when an overlay exists. Condition: The **year_last_improv** (70) field is NOT greater than zero AND The **surface_type** (65) field equals 6, 7 or 8 (overlay).
1070.3	The year of last improvement must equal the year of construction when no overlay exists. Condition: The **year_last_improv** (70) field is greater than zero AND The **year_last_improv** (70) field does NOT equal the **year_last_construction** (71) field AND The **surface_type** (65) field 1, 2, 3, 4, 5, 9, 10 or 11 (no overlay).
1071.0	The year of last construction must not be greater than the year of record. Condition: The **year_last_construction** (71) field is greater than the **year_record** (1) field.

Number	Description
1072.0	The last overlay thickness must be greater than zero if an overlay has been applied. Condition: The **last_overlay_thickness** (72) field is NOT greater than 0 AND The **surface_type** (65) field equals 6, 7 or 8 (overlay).
1072.1	The last overlay thickness must be zero when no overlay has been applied. Condition: The **last_overlay_thickness** (72) field is greater than 0 AND The **surface_type** (65) field equals 1, 2, 3, 4, 5, 9, 10 or 11 (no overlay).
1072.2	Unusual last overlay thickness of less than 1 or greater than 8 inches. Condition: The **last_overlay_thickness** (72) field is less than 1 OR greater than 8 AND The **surface_type** (65) field equals 6, 7 or 8 (overlay).
1073.0	Rigid Pavement Thickness should not be provided for a flexible surface. Condition: The **thickness_rigid** (73) is greater than 0 AND The **surface_type** (65) field is 2 or 6 (flexible).
1073.1	Rigid Pavement Thickness must be provided for a rigid or composite surface. Condition: The **thickness_rigid** (73) is NOT greater than 0 AND The **surface_type** (65) field is 3, 4, 5, 7, 8, 9, or 10 (rigid or composite).
1073.2	Rigid Pavement Thickness should be between 6 and 16 inches for a rigid surface. Condition: The **thickness_rigid** (73) is less than 6 OR greater than 16 AND. The **surface_type** (65) field is 3, 4, 5, 9, or 10 (rigid).
1074.0	Flexible Pavement Thickness should not be specified for a rigid or composite surface. Condition: The **thickness_flexible** (74) is greater than 0 AND The **surface_type** (65) field is 3, 4, 5, 7, 8, 9, or 10 (rigid or composite).
1074.1	Flexible Pavement Thickness must be provided for a flexible surface. Condition: The **thickness_flexible** (74) is NOT greater than 0 AND The **surface_type** (65) field is 2 or 6 (flexible).
1074.2	Flexible Pavement Thickness should be between 2 and 24 inches for a flexible surface. Condition: The **thickness_flexible** (74) is less than 2 OR greater than 24 AND The **surface_type** (65) field is 2 or 6 (flexible).
1076.0	Base Thickness must not be specified when the base type is none. Condition: The **base_thickness** (76) field is greater than 0 AND The **base_type** (75) field equals 1 (none).
1076.1	Base Thickness must be specified when the when a pavement base is present. Condition: The **base_thickness** (76) field is NOT greater than 0 AND The **base_type** (75) field is greater than 1 (has base).