MoDOT Pavement Preservation Research Program
Volume II, Data Collection for Pavement Management: Historical Data Mining and Production of Data

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16. Abstract

The objective of Task 1 was to develop data for use in MoDOT's pavement preservation program based primarily on historical information available throughout MoDOT as well as climate data from the National Oceanic and Atmospheric Administration (NOAA) and AASHTOWare (AASHTO), and subgrade soils data from the US Department of Agriculture (USDA). The purpose of Task 1 was to develop a framework for data collection and management that uses a methodology that can subsequently be implemented by MoDOT in the future across the state as it fully develops its pavement management system. Data integration from divisions within MoDOT (Planning, Construction and Materials, and Maintenance) will be necessary for a complete system. A pilot database was developed to demonstrate the methodology for future use by MoDOT and for initial use by investigators in Tasks 2 through 6. Numerous databases maintained by MoDOT residing in the above three divisions as well as climate and soils data from other sources were located, collected, supplemented, verified, and summarized. Recommendations for changes to present data collection procedures and repositories were developed.

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MoDOT PAVEMENT PRESERVATION RESEARCH PROGRAM
MoDOT TRyy1141

FINAL REPORT

VOLUME II
DATA COLLECTION FOR PAVEMENT MANAGEMENT: HISTORICAL DATA MINING AND PRODUCTION OF DATA

July 29, 2015

Prepared for the
Missouri Department of Transportation

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EXECUTIVE SUMMARY

The research reported in this document was performed by researchers from the Missouri University of Science and Technology and the University of Missouri-Columbia. The objective of Task 1 was to develop data for use in MoDOT's pavement preservation program based primarily on historical information available throughout MoDOT as well as climate data from the National Oceanic and Atmospheric Administration (NOAA) and AASHTOWare (AASHTO), and subgrade soils data from the US Department of Agriculture (USDA). The purpose of Task 1 was to develop a framework for data collection and management that uses a methodology that can subsequently be implemented by MoDOT in the future across the state as it fully develops its pavement management system. Data integration from divisions within MoDOT (Planning, Construction and Materials, and Maintenance) will be necessary for a complete system. A pilot database was developed to demonstrate the methodology for future use by MoDOT and for initial use by investigators in Tasks 2 through 6. Numerous databases maintained by MoDOT residing in the above three divisions as well as climate and soils data from other sources were located, collected, supplemented, verified, and summarized. Recommendations for changes to present data collection procedures and repositories were developed.

AUTHOR ACKNOWLEDGEMENTS

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1 INTRODUCTION

Effective and efficient data collection is essential to pavement management. Task 1 of the MoDOT Pavement Preservation Research Program was to establish data collection methodologies and produce useful data for the research program. This chapter describes the motivation for the work and outlines the work in the rest of this report. This report serves as both a summary of procedures and findings from Task 1 as well as a guidance document for future pavement management data collection efforts.

1.1 Goal

The principal goal of the MoDOT Pavement Preservation Research Program Task 1: *Data Collection for Pavement Management: Historical Data Collection and Production of Data* was to collect data for use in MoDOT's pavement preservation program based on historical information available from MoDOT and other sources. The data collection efforts focused on present needs (for this project) and the need for long-term pavement data collection efforts.

1.2 Objectives

The primary objectives of this task were to:

- Identify data needs for development of a pavement management system
- Locate the required data sources within MoDOT's organization
- Locate the required data sources from other sources
- Collect a sufficient amount of pavement data to support efforts by other tasks within the Pavement Preservation Research program
- Provide Guidance Documents for MoDOT's future efforts

1.3 Scope of Work

The following work was performed in this task:

- Types of data recommended for collection were identified from the AASHTO guide for pavement management (AASHTO 2012) and from other states' efforts
- Required data for development of a pavement management system were located within MoDOT's organization and from other sources
- Pavement data were collected and summarized to provide input for other Pavement Preservation Research Program tasks
- Methods of data collection were summarized and recommendations for improvements to data collection procedures were developed
- Two Guide Documents were produced

1.4 Organization of the Report

Chapter 1 presents the goal, objectives, and scope of this task. Chapter 2 presents background information from national sources as well as from other states. Chapter 3 describes the MoDOT and other data sources consulted and methods of accessing each of them. Chapter 4 describes how data were collected for use by other Tasks in the Pavement Preservation Research program. Chapter 5 contains a summary, conclusions, and recommendations for improvements to the pavement management data collection methods. Appendix 1A is a MoDOT document that defines fields used in the SS Pavement and ARAN Inventory databases. Appendix 1B is the Guidance Document for use by MoDOT pavement specialists, pavement engineers, and others involved with maintenance decisions. Appendix 1C is the Guidance Document for accessing data for the purposes of augmenting or creating new treatment models. In Appendix 1D are directions for accessing the ASU and the USDA websites for subgrade soils data. Appendix 1E has directions for obtaining NOAA and AASHTOWare climate data.

2 BACKGROUND AND LITERATURE REVIEW

Previous MoDOT work regarding pavement management, national guidance, and the practices of other states were consulted before developing the data collection methodology of Task 1. The emphasis of this literature review was to identify the types of data that should be collected and, to a lesser extent, to identify data collection techniques. Data collection techniques developed for other states, while helpful, were of limited use because the collection techniques developed for Task 1 were constrained by the availability and organization of MoDOT's data.

2.1 MoDOT Publications

The MoDOT Pavement Maintenance Direction (MoDOT 2010) guide was the primary MoDOT document utilized at the very beginning of the project. It summarized policy changes due to the major reduction in the overall MoDOT budget, and introduced the 10-point Pavement Surface Evaluation and Rating (PASER) system of visually rating the condition of a pavement surface. Prior to 2010, MoDOT used a 20-point condition index that was a mathematical combination of ride and distress indices. The Direction document, along with earlier MoDOT publications (Donahue 2002; Noble et al. 2003), informed the research team of the recent history of MoDOT's efforts to improve its transportation management system and maintenance/rehabilitation program.

Other MoDOT publications that were useful in providing background and current policy included the "Pavement Design and Type Selection Process" report (2004), the "Geology and Soils Manual" (1962), the final report of "Implementing the AASHTO Mechanistic-Empirical Pavement Design Guide in Missouri - Volumes I and II" (2009), the Missouri Standard Specifications for Highway Construction, the MoDOT Engineering Policy Guide, and the MoDOT Pavement Design Manual.

The MEPDG implementation report reported on a sensitivity analysis and validation/re-calibration of the models contained in the MEPDG (ARA 2004) as those relate to Missouri. For Hot Mix Asphalt (HMA) pavements, the sensitivity analysis revealed that the factors that were moderately to highly significant to prediction of alligator cracking/transverse cracking/rutting and International Roughness Index (IRI) were: HMA thickness, HMA mix characteristics, base characteristics, subgrade characteristics, and initial IRI. The validation/recalibration studies also included the factors of thickness, HMA material characteristics, base characteristics, initial IRI, subgrade characteristics (plasticity index [PI]), climate (annual average precipitation and annual average Freezing Index [FI]), and also included pavement age and truck traffic characteristics.

For concrete pavements, the list was similar with concrete material characteristics instead of HMA; other somewhat different specific factors were soil percent minus #200 [P200] instead of PI, number of wet days instead of annual precipitation, and number of freeze-thaw cycles. A variety of structural factors was also significant: joint spacing, slab width, and shoulder type.

2.2 AASHTO Pavement Management Manual

The American Association of State Highway and Transportation Officials (AASHTO) published an interim guide to pavement management in 2011 (Zimmerman, et al. 2011). This document provided the basis for much of the work performed under the MoDOT Pavement Preservation Research program.

Chapter 3 of the AASHTO guide describes the types of inventory data typically collected to support a pavement management system. These include all relevant data not associated with the condition assessment (pavement performance). The guide lists basic inventory data including location, route classification, and geometry of the pavement segment as well as structural information for the pavement (e.g. layer types, thicknesses, and history). The other major class of data needed for the inventory is traffic data. Chapter 3 also includes discussion of data integration, noting that the inventory information sources are often housed in different departments within an agency (i.e. pavement history data from a maintenance division, traffic from a planning division, etc.). Chapter 3 also includes discussion of data segmentation, which is pertinent because the different data types are collected at different spatial frequencies. The Guide states that “bringing the information from these disparate systems into a common decision-making framework exponentially increases the value of the information collected.”

Condition assessment is addressed in Chapter 4 of the AASHTO guide. Condition assessment for pavement is either *functional* or *structural*. Functional measures focus on performance from a user perspective, often by measuring roughness; structural measures are tied to pavement distress, often measured with deflection methods. The guide summarizes a survey performed by the Federal Highway Administration (FHWA) that shows roughness is the most commonly collected type of pavement condition data for all surface types, but other measures (rutting, cracking, etc.) are also commonly collected. The chapter also presents methods of developing pavement condition indices from various pavement measurements. Also discussed are various methods of network-level pavement condition assessment. Emerging technology is making network-level assessment of structural measures feasible.

2.3 State DOTs

2.3.1 General

Numerous state DOT Pavement Management Systems (PMS) were reviewed in an effort to discover the types of data necessary for creating pavement performance models and treatment trigger tables. The DOTs were Mississippi, Louisiana, Colorado, Virginia, South Dakota, Nebraska, North Carolina, Arizona, Pennsylvania, Minnesota, North Dakota, Oklahoma, Oregon, Washington, and Texas. Several are discussed below. Others are presented in the Task 2 and 5 reports.

Common features of various DOT PMS included division of the systems into pavement families by pavement type and traffic level, producing performance models that predict IRI and/or condition indices, collection of detailed distress data, using an Automatic Road Analyzer (ARAN) van for data collection, and creation of “homogeneous sections” (uniform structural, geometric characteristics, traffic, etc. along the length) for each model based on traffic, thickness, material types, and other parameters.

Data collected by other DOTs for their PMS include pavement types, traffic, truck traffic, pavement thickness, subgrade type, intervals of maintenance, climate, IRI, and extent and severity of pavement distress types. Thus, knowledge of these types of data guided the project researchers in seeking similar information from MoDOT and other data sources.

2.3.2 Mississippi DOT

George (2000) authored a report about the prediction models used by the Mississippi DOT's PMS, which were initiated in 1986. The report describes the PMS database and modeling data, particularly the partitioning of roadways into homogenous sections. Data collected for each section in the database were consistent with the discussion from the AASHTO guide (2012). The 26 pavement models in the report were based on a composite condition index that included IRI, and various distress measures. The models included subgrade characteristics. Pavement types were divided into five families. Data collected included pavement types, thicknesses, joint and reinforcement information, percent trucks, age, maintenance type, IRI, and 11 types of distress, along with severity and extent of those distresses.

2.3.3 Louisiana DOT

In 2009, Khattak et al. issued a report addressing performance models used in Louisiana's PMS. Phase I of the accompanying project assessed the data collection for the PMS. The authors noted good pavement distress data were available beginning in 1995, and that data were collected continuously for 0.1-mile long segments. The study also found that maintenance and rehabilitation data were recorded but not accessible through the PMS. In addition, various location-referencing systems were used by Louisiana's DOT. The authors noted that various types of distress indices were collected, and recommended expanding the types of distress to be more specific (e.g. alligator cracking, block cracking, etc.) rather than use the term "random cracking." IRI and 11 types of distress data were collected, along with distress severity and extent.

2.3.4 Colorado DOT

Colorado's system (Colorado 2011; 2012), initiated in the late 1980's, had families that were comprised of four pavement types and five traffic levels. Climate was included as a variable in partitioning of homogenous sections as well as pavement thickness. Types of models (curves) were both of the site-specific and family varieties. Models predicted distress and performance. Data collected included pavement types, thicknesses, IRI, and four types of distress, along with severity and extent.

2.3.5 Virginia DOT

Virginia's system (McGhee et al. 1991) initiated in the early 1980's, included five pavement families. Data collected included roughness, rut depth, patching, various crack measurements (distress severity and extent was included), truck traffic, and age since last treatment.

2.3.6 South Dakota DOT

South Dakota's system (South Dakota 2012), begun in 1977, had 12 pavement families. IRI and 11 types of distress data were collected, along with distress severity and extent. Distress and performance models numbered 168.

3 DATA REQUIREMENTS AND SOURCES

This chapter defines the requirements for the data collection efforts of Task 1 before providing detailed explanations of the MoDOT data sources used to address the requirements. The MoDOT data sources are organized by pavement performance data (primarily IRI) and pavement family data (primarily pavement history but also additional ancillary data). The range of data sources involves several divisions of MoDOT, including Construction and Materials, Maintenance, Transportation Planning, and Traffic and Safety. This chapter provides some historical and agency context on each data source, but the emphasis is on providing useful descriptions and retrieval guidance for each. Besides MoDOT data sources, U.S Department of Agriculture (USDA) and several National Oceanic and Atmospheric Administration (NOAA) [also known as National Climate Data Center (NCDC)] resources are presented.

3.1 Data Requirements

It has been shown that the longevity of pavement maintenance treatments depends upon:

- Original pavement type
- Layer thicknesses
- Base characteristics, including internal drainage
- Specific design features
- Subgrade type
- Condition prior to treatment
- Initial condition after treatment
- Quality of treatment
- Climate
- Accumulated traffic, especially truck traffic
- Interim maintenance procedures

Some additional descriptions can represent some of the above factors. As an example, “pavement functional classification” may be able to be used as a surrogate for thickness, base characteristics, design features, and quality of treatment. “Surface age” could represent traffic and environmental effects.

Data source delineation and data collection activities in Task 1 were two-fold: 1) provide information for model-building in Task 2 and for later model-updating by MoDOT, and 2) provide a method of data collection for day-to-day pavement selection in the normal course of MoDOT business. The first activity is more involved in that it is providing many different kinds of data that *may* be used in present and future models. All types of data pursued may not be in any given model at any given time. The data has *potential* use. The second activity, routine pavement selection, will need a much smaller variety of data types.

The primary purpose of data collection efforts for pavement management is to provide input for the decision processes. For the Pavement Preservation Research Program which involves developing one aspect of MoDOT’s pavement management system, data collection efforts are primarily intended for Tasks 2 and 5. Task 2 uses Task 1 data to establish pavement family and treatment models. The decision rationales established in Task 5 are closely related to Task 2 and therefore use data from Task 1 in a similar manner. Tasks 3 and 4 also use data from Task 1, but to a much lesser extent. Task 3 considers Task 1 data sources in its analysis of new collection methods, and Task 4 occasionally considered Task 1 data in selecting and analyzing specific sites.

The critical inputs for pavement management decision processes are pavement performance data and historical pavement family data. Performance data for pavements are generally categorized as *functional* or *structural*. The efforts for this project focused on functional measures from the ARAN van video, IRI, and from condition distress indices, although some consideration was given to structural measures from the falling weight deflectometer (FWD).

In the introductory document of the Pavement Preservation Research Program report, nine steps were presented which outlined the pavement treatment decision process. The first three steps involved data retrieval, which is the focus of Task 1:

Step 1 - Retrieve annual road condition surveys (IRI, condition indices, etc.)[and location]
Step 2 - Retrieve site (historical) data: pavement cross-section materials and thicknesses, subgrade soil information, coring data, non-destructive testing information, drainage conditions, construction records, and climate data
Step 3 - Retrieve traffic data: Average Daily Traffic (ADT) and some measure of truck traffic (percentage trucks or Annual Average Daily Truck Traffic [AADTT])

One issue that arose as the project progressed was the fact that MoDOT's databases are works-in-progress. Not only is information continually being updated, but new databases are being developed/populated, and old ones phased out, or no longer being updated. Thus, to capture historic information (both older and more recent), the user may have to access several databases to get a continuum of data. So, in this project it was necessary to find a variety of types of data from numerous sources of information.

3.2 MoDOT Data Organization

MoDOT data are organized into several distinct and separate sources, mostly (but not all) in electronic form, but not necessarily directly connected:

- Transportation Management System (TMS) (MoDOT intranet):
  - ARAN Viewer
  - TMS Maps (Map Viewer)
  - Statewide Transportation Improvement Program (STIP)
  - TR50 Reports
  - Project History Maps ("rag maps")
  - SharePoint
  - Pavement Tool
- Special files created by Planning for using Microsoft Access for:
  - ARAN Inventory Tables ("survey" ≥2001 and "history" 1988-2000, inclusive)
  - SS Pavement ("current" and "history")

- Historical Information:
    - Asphalt Summaries (on J-Drive)
    - Concrete 2-AA Sheets (on J-Drive)
    - Historic State Highway Maps (MoDOT's internet website)
    - Archived Project Plan Sheets (Z-drive)
    - J-Drive
    - ProjectWise
    - CDs and microfilm
- dTIMS dBase
- Site Manager
- Maintenance Data:
    - District Maintenance Spreadsheets/SharePoint
- Soils & Geology Section files:
    - Project Investigations
    - Soils Association files
- Pavement Section (Construction & Materials Division) files:
    - Coring data
    - FWD data

3.3 Matching Desired Data with Data Sources

Table 3.1 summarizes the desired data types and the sources (both MoDOT and non-MoDOT) where they can be accessed. The sources will be discussed in detail in the following sections.

Table 3.1 Data types and sources

Data Types	**Data Sources**
Pavement Condition:	
IRI, segment averages	ARAN Viewer: accesses ARAN tables and SS Pavement databases back to 2003, and, possibly, a project (Job) plan file recently associated with the segment of interest
IRI, "raw" data, 0.02 miles	ARAN Inventory Tables
Condition Indices	ARAN Inventory , SS Pavement
Distress Indices	ARAN Inventory , SS Pavement
PASER ratings	ARAN Inventory , SS Pavement
Road segment images	ARAN Viewer
Pavement Site Data:	
Pavement materials, original (Pavement Types)	Ragmaps; STIP; Asphalt Summary Sheets; Concrete 2-AA Sheets; Archived Project Plan Sheets (Z-Drive); contract plans and final plans (As-Builts) on ProjectWise and on CDs and microfilm
Pavement materials, maintenance (Surface Type)	Ragmaps; ARAN Viewer (most recent treatment); SS Pavement; STIP; Asphalt Summary Sheets; Concrete 2-AA Sheets; Pavement Tool; Site Manager; Historic State Highway Maps; SAM II; J-Drive; ProjectWise; District maintenance spreadsheets; SharePoint; personal recollection
Layer thicknesses, original	Ragmaps; STIP; Concrete 2-AA Sheets; Asphalt Summary Sheets; Archived Project Plan Sheets (Z-drive); contract plans and final plans

	(As-Builts) on ProjectWise and on CDs and microfiche
Layer thicknesses, maintenance	Ragmaps; Asphalt Summary Sheets; STIP; J-Drive; ProjectWise; Pavement Tool; SharePoint; Site Manager; District spreadsheets
Layer ages (project dates)	Ragmaps; Asphalt Summary Sheets; ARAN Viewer (surface date); STIP; Concrete 2-AA Sheets; contract plans and final plans (As-Builts) on ProjectWise and on CDs and microfiche
Subgrade soils	USDA county soils maps; ASU soils maps; Concrete 2-AA Sheets
Drainage features	STIP; Concrete 2-AA Sheets; contract plans and final plans (As-Builts) on ProjectWise and on CDs and microfiche
Climate data	NOAA data; AASHTOWare
Coring data	Construction & Materials Division databases; J-Drive; ProjectWise
Reinforcement cover data	SharePoint
NDE (FWD, etc.) data	Construction & Materials Division databases
Traffic Data:	
AADT (by direction)	ARAN Viewer; SS Pavement; TR 50 reports
COMM_VOL_BY_DIR (i.e. AADTT by direction)	ARAN Viewer; SS Pavement; TR 50 reports
Maintenance Cost Data:	
Contract	District maintenance spreadsheets; Pavement Tool; SharePoint; SAM II
In-House	District maintenance spreadsheets; Pavement Tool; SharePoint; SAM II
Ancillary data:	
Segment location:	
General location	SS Pavement with ArcMap; TMS Maps
County	ARAN Viewer; SS Pavement; ARAN Inventory Tables
Beginning logmile	ARAN Viewer; SS Pavement; ARAN Inventory Tables
Ending logmile	ARAN Viewer; SS Pavement; ARAN Inventory Tables
Segment Travelway ID	TMS Maps; SS Pavement
Functional Classification	SS Pavement
Roadway type	SS Pavement
ARAN year	SS Pavement; ARAN Inventory
Segment length	Calculated using beginning and ending logmile values; SS Pavement; ARAN Inventory Tables
Route name	SS Pavement; ARAN Inventory

The organization of pavement historical families is described in the report for Task 2, but was generally delineated by pavement type, traffic level, and possibly by functional classification. Additional pavement family data such as subgrade, total pavement thickness, and climate were also considered.

3.4 Data Source Ages/Changes (Current Understanding)

1. ARAN data (back to 1988)
2. PSR in SS Pavement (1988-2009)
3. IRI data (1993) replacing Pavement Roughness

4. Out-of-synch IRI/PSR data 1997 or 1998 through 2001 (~20 points high)
5. SS Pavement (1999)
6. ProjectWise (back to 2007)
7. As-Builts on CD's (back to 1950's)
8. Asphalt Summaries (back to 1936)
9. Concrete 2-AA sheets

3.5 Pavement Performance Data

As with other transportation agencies, MoDOT's use of pavement performance data has evolved significantly over the last 25 years, primarily as a result of technology related to pavement performance measurement devices but also because of shifting ideas about pavement management. Current practice emphasizes IRI, a functional measure that increases with decreasing ride quality, and the Pavement Surface Evaluation and Rating (PASER), a visual rating standard that assigns integers from 1 to 10 for failed roads to new construction, respectively. Visual ratings are assigned manually by MoDOT personnel using images captured by the ARAN van. Previous performance measures include the Present Serviceability Rating (PSR), calculated from Ride Index and a visual distress rating, Condition Index, (calculated from several Distress Indices) consistent with the Long Term Pavement Performance Distress Identification Manual (FHWA 2003).

The research team primarily used ARAN video data and IRI data in its consideration of pavement performance, and condition indices to a lesser extent. ARAN video data were accessed via MoDOT's TMS. IRI data was accessed via MoDOT's ARAN Viewer and ARAN inventory database, which contained other useful data as well.

3.6 Getting Started

To get started, several types of information are required about a given road segment. First, the segment's route identification, location, and functional classification are necessary to begin using the available information software. The Functional Classifications listed in SS Pavement are shown in Table 3.2.

Table 3.2 Roadway Functional Classifications

Functional Classification	
Rural	**Urban**
Interstate	Interstate
Primary Arterial	Other Freeway & Expressway
Minor Arterial	Other Principal Arterial
Major Collector	Minor Arterial
Minor Collector	Collector
Local	Local

3.7 MoDOT Databases

3.7.1 MoDOT TMS, TMS Maps, and ARAN Video

Many MoDOT personnel likely appreciate the usefulness of the ARAN video, which captures a visual record of MoDOT's roadways on an annual, biennial, or triennial basis. An example of an ARAN video/photograph is shown in Fig. 3.1.

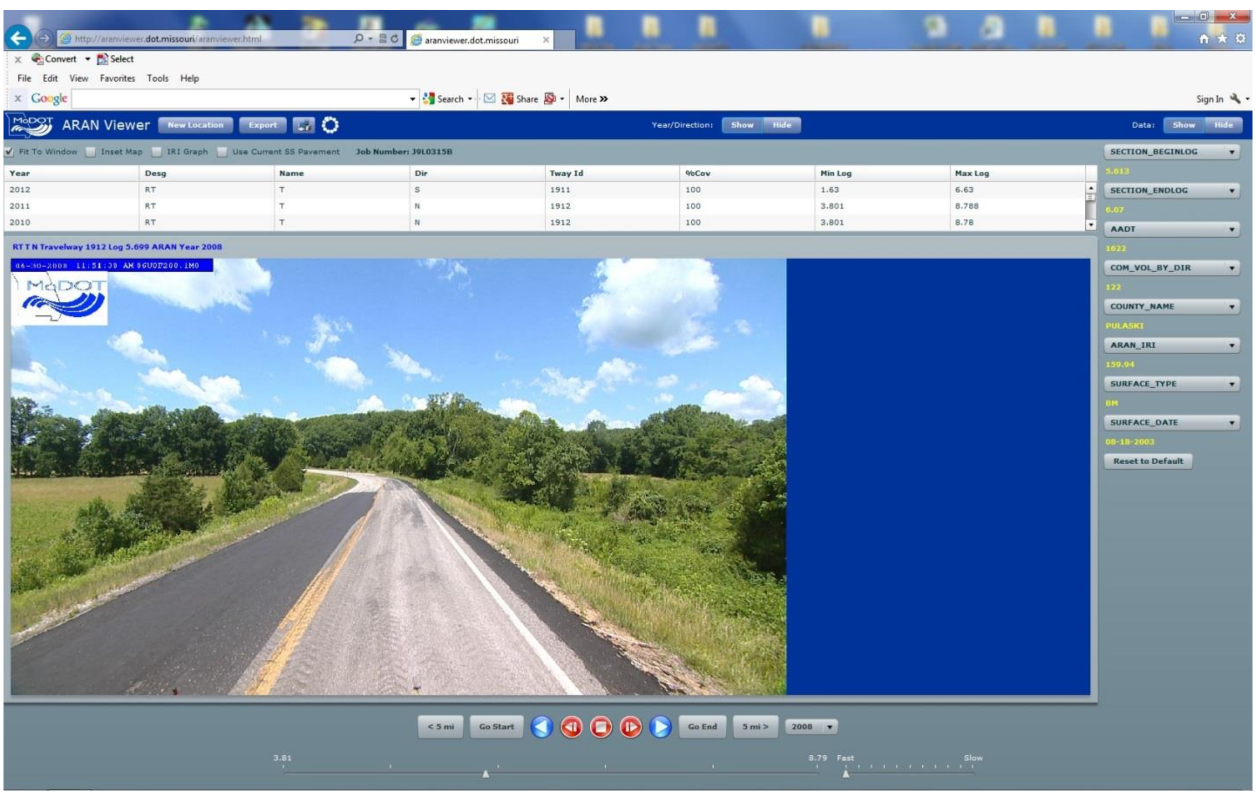

Fig 3.1 – Example of ARAN video viewed via MoDOT's TMS homepage.

Images from the ARAN van can be accessed from MoDOT's TMS webpage on MoDOT's Intranet. MoDOT's TMS contains many other useful data sources related to pavements. Therefore, three sets of access instructions are included in the Guidance Document. The first addresses general TMS access. The second addresses TMS Maps, which is useful for obtaining general information for any roadway, including Travelway ID numbers, which differ from route numbers and which are used throughout TMS. The final set of instructions addresses ARAN video data.

3.7.2 SS Pavement Database and ARAN Inventory Tables

The TMS webpage is a convenient interface by which MoDOT users can access data stored in TMS databases. However, instead of going through TMS, much of the data for Task 1 was collected directly from two databases: the SS Pavement database, and the ARAN inventory tables (both are Oracle tables). Accessing the databases directly allowed for more efficient data collection and allowed data to be filtered according to user criteria. The Microsoft Access files were necessary to query and retrieve data from the TMS database files. The Microsoft Access files were provided to the research team by MoDOT's planning division, which oversees TMS. By using Microsoft Access, users can query the databases by route, traffic, surface type, or any of the other fields in the SS Pavement and ARAN table's databases. Definitions for the database fields were provided by MoDOT and are included as Appendix 1A.

Another way to view the data contained in the SS Pavement database is through Geographic Information System (GIS) software such as ESRI ArcMap. Using GIS to view the data is advantageous when location is of primary interest, and GIS provides a convenient means for visualizing data.

A pair of important notes on using ARAN inventory and SS Pavement data:

- The 20-point condition index data dates back to 1988 and was discontinued in 2009. Raw IRI data (i.e. a record every 0.02 miles) dates back to 1993. However, the 1997 to 2001 (inclusive) IRI data were not used due to an algorithm error during these years.
- The SS Pavement databases are "dynamically segmented," which refers to the way the locations of each data point are referenced. Practically speaking, this means the logmiles of each data segment in the databases could differ from year to year because any change to the roadway information (i.e. not just re-alignment but also any addition of traffic data, speed limit data, functional information, etc.) results in a new segmentation. This necessitates flexibility and some creativity (e.g. averaging) for purposes of data analysis.

3.8 dTIMS dBase

The dTIMS dBase files are select files from MoDOT's previous pavement management system. The dTIMS data includes route names, locations, traffic, and of greatest interest, structural information (e.g. base and surface thicknesses at a particular date, and material types). The research team was advised to not use this database because the database has been discontinued and is not current.

3.9 Pavement History Data

The pavement performance data are interpreted through the framework of pavement families in order to develop useful models for the pavement management system. The families and models are described in more detail in the Task 2 report. Pavement history is a critical input for explaining pavement performance and developing performance prediction models. This section describes data sources used to establish pavement history for a given roadway segment.

3.9.1 Project History Maps

Project history maps, also known as "rag maps," are useful tools for establishing the early history of a roadway segment. An example portion of a rag map is shown in Fig. 3.2. The maps contain a plan view of major routes in the county with notes showing the extents and a listing of the general summary of projects and major maintenance along the route. The original maps were maintained in paper form but have since been digitized (scanned). The project history starts as early as the 1920s and typically ends in the 1990s. There is one map per county, and the maps can be accessed through the MoDOT internet:

http://www.modot.org/business/contractor_resources/ProjectHistoryMaps.htm

As is evident from Fig. 3.2, the maps contain a considerable number of project records. More recent projects often include project numbers, which can be used to obtain project plans as described in the next section.

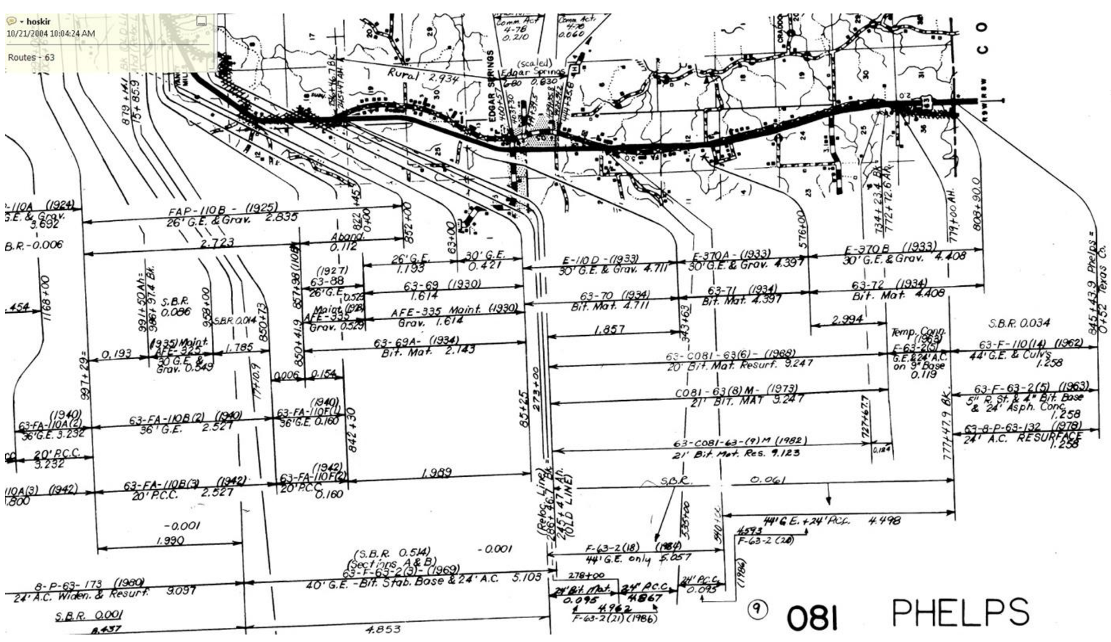

Fig. 3.2 – Example of a MoDOT project history map ("rag map") for Phelps County.

3.9.2 STIP Project Database

Another database that can be accessed through TMS is the Statewide Transportation Improvement Program (STIP). The STIP Management database contains information about projects that have been completed as part of MoDOT's STIP. The STIP is MoDOT's five-year plan for transportation construction and is updated annually. The projects listed in the STIP database are mostly larger projects that tend toward contract work, as opposed to in-house work. The database goes back to 1998. The STIP database is accessed from the TMS homepage on MoDOT's Intranet by clicking a link on the navigation bar on the left side of the page. The STIP project database can be searched by job number, route, district, and county. Job numbers, dates, and project descriptions are included in the table resulting from the search. The dropdown menu above the table (initially says "Navigate To…") can be used to locate the project on a map (select "Location Map") and potentially to find stored documents, including contract plans and as-built plans. Construction plans are one of the most useful aspects of the STIP, but the availability of as-built plans is limited.

3.9.3 Asphalt Summaries

MoDOT's pavement group has kept records of all asphalt work done for major routes across the state on "asphalt summaries," an example of which is shown in Fig. 3.3. These were compiled from As-Builts and Plant Inspector Daily Reports. One set of asphalt summaries comprises a table of asphalt work for the year. The tables are organized by route. The routes are listed by district, and one entry (row) is included for any asphalt project completed in the year of the table. The table lists a MoDOT project number and log miles for the project, as well as the treatment type and history of other asphalt work for the route. The history of previous work usually correlates to the Project History maps. Prior to the commencement of the Preservation Research Project, Asphalt Summaries existed only in hard-copy format located at the Field Office. The research team scanned all asphalt summary tables to Adobe PDF; these are now available on J-Drive:

J:\Pavement Group\Asphalt Summaries

Route	County	Project	Contract	Location Description	Log Mile:	Treatment	History
71	Nodaway	J1P2187	100514-102	NBL from Rte A to Bus. 71	556+79.41 to 176+90.22 7.2 miles	Type 3 Micro	2004 – 1.75" SP125C on top of 4" C.I.R. 1974 – 4" asphalt 1956 – 9" PCCP 1956 – 4" Type 3 Agg. Base

Fig. 3.3 – Example of an asphalt summary sheet listing, for Route 71 in District 1, 2010.

3.9.4 Concrete 2-AA Sheets

Similar to asphalt summary sheets, concrete "2-AA" sheets provide a record of construction for concrete projects. These were compiled from As-Builts and Plant Inspector Daily Reports for concrete paving projects, and they provide more detailed information than the asphalt summary sheets, with a single project spanning multiple large sheets, an example of which is shown in Fig. 3.4. Information contained on the Concrete 2-AA sheets includes the typical section of the pavement, the materials used and their source (i.e. the quarry name), subgrade type and preparation method, weather on the day of concrete placement, concrete mix proportions, reinforcement, and joints, among other useful information. The entire set of Concrete 2-AA sheets is quite large and is organized by district and then by county. Prior to the commencement of the Preservation Research Project, Concrete 2-AA sheets existed only in hard-copy format located at the Field Office. The research team scanned all Concrete 2-AA sheets to Adobe PDF; these are now available on J-Drive:

J:\Pavement Group\2-AA Sheets Historical

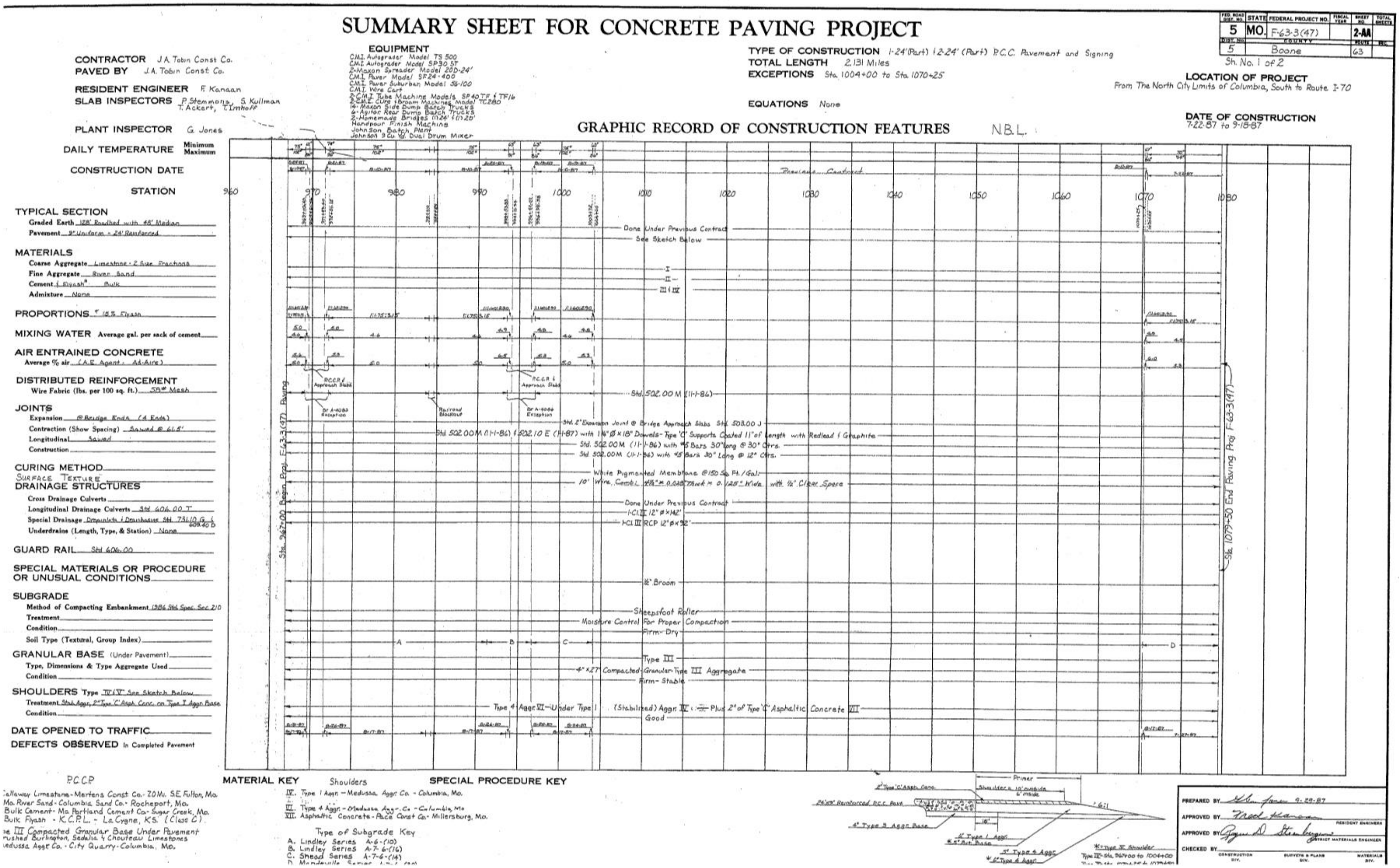

Fig. 3.4 – Example Concrete 2-AA sheet, for U.S. 63 in Boone County.

3.9.5 CDs and microfilm

Prior to 2007, contract plans and final plans (As-Builts) were stored on CDs or microfilm at the district offices. The CDs are also available from the Central Office.

3.9.6 Historical State Highway Maps

These maps show year-to-year roadway surface types thus showing changes in surface types; they are available on:

http://www.modot.gov/historic maps/

3.9.7 Archived Project Plan Sheets (Z-drive)

MoDOT archives the older project (Job) plan sheets on a separate server labeled as the Z-drive. The research team was given access to this drive to search for plan drawings for projects (jobs) referenced in the asphalt summaries or ragmaps, for example. The plan drawings sometimes give typical cross-sections that show layer thicknesses.

3.10 Site Manager

Site Manager is an AASHTO software used for construction and materials management from contract award through finalization. Among many other things, material types and project sampling and testing are recorded, and is available back to 2002.

3.11 J-Drive

There is a separate J-Drive for each district and division, located on MoDOT's internal servers. The J-Drive is a repository for previous recommendations and email correspondence and the now-scanned Asphalt Summaries and concrete 2-AA sheets. Using previous job numbers, core and condition information can be found.

3.12 ProjectWise

Projectwise is Bentley software used as a repository for project plans, specifications, estimates, previous recommendations and email correspondence, dating back to June 2007. Using previous job numbers, core and condition information can be found.

3.13 SAM II

State Accounting Management Software (SAM II) is accessible through SharePoint under Financial Services. SAM II was found to be of limited use in regard to thickness determination, even by estimation of thickness via tonnage and assumed lane width and length, because details of the linear extent of actual treatment was lacking.

3.14 SharePoint

SharePoint is a newly-developed departmental-wide repository of a variety of types of information within TMS, and is taking on more of a role as the primary portal for many applications. Among other things, districts can post their maintenance planning spreadsheets and contract work summaries. As another example, emails and notes about thickness of cover over mesh prior to diamond grinding may be archived in SharePoint. Fig. 3.5 shows an example of SharePoint/Maintenance/Pavement. Fig. 3.6 shows a screen for contract work.

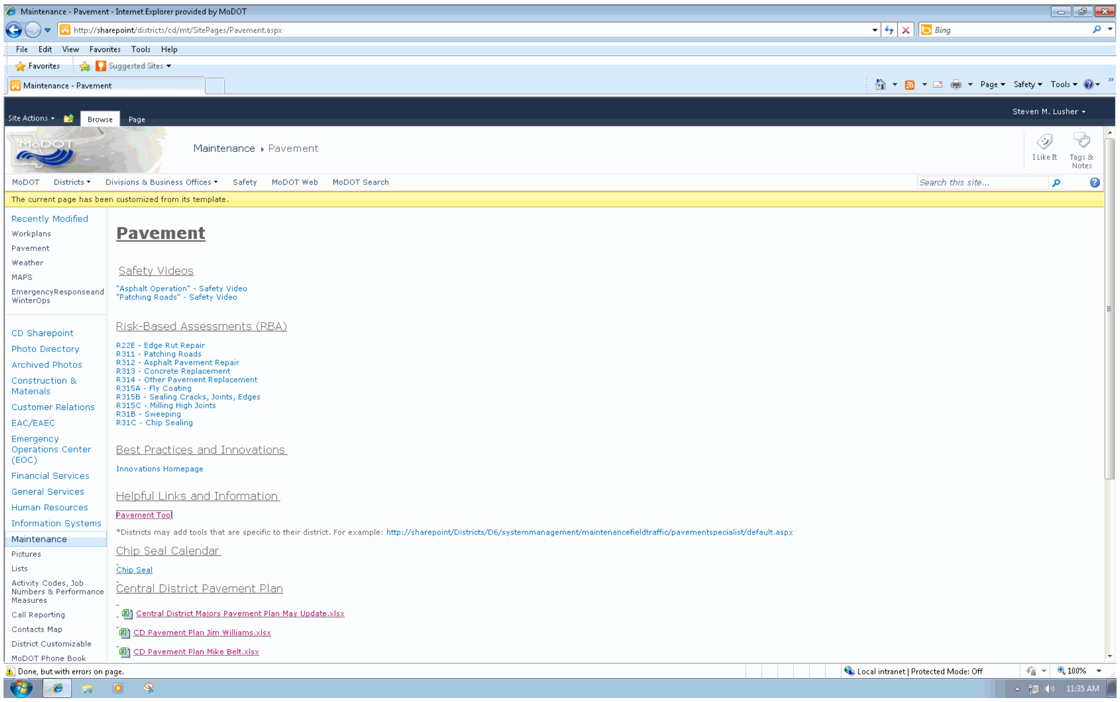

Fig. 3.5 – SharePoint/Maintenance/Pavement site.

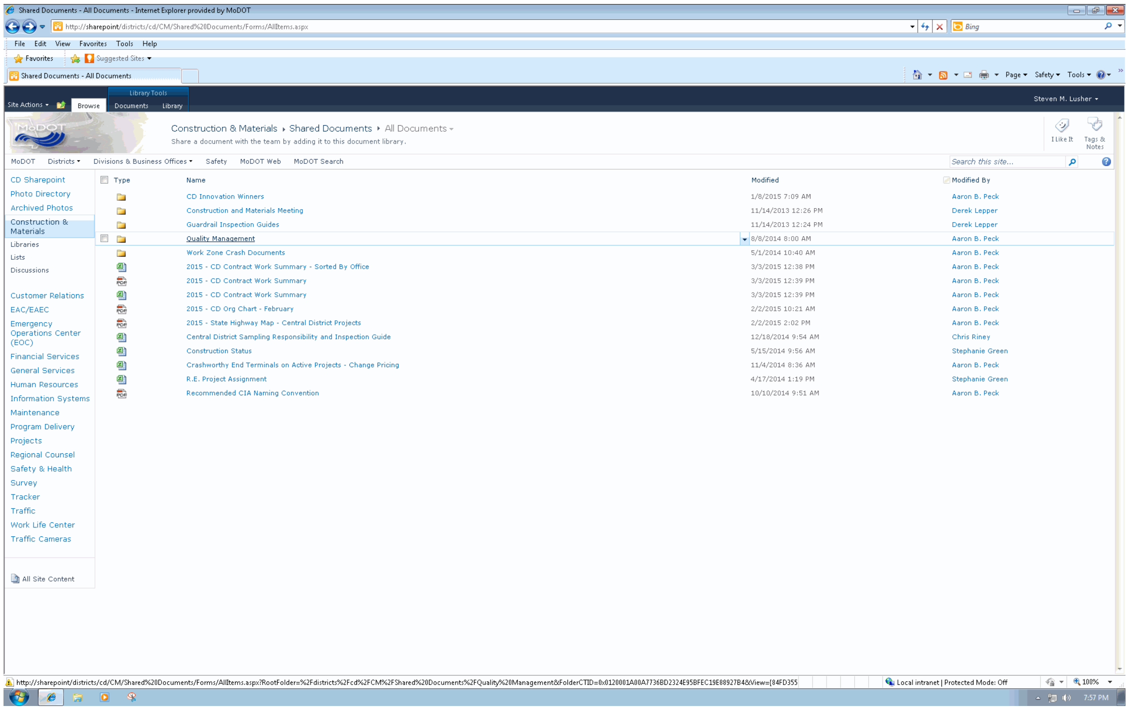

Fig. 3.6 – SharePoint/Construction & Materials/Shared Documents/All Documents/ 2015 CD Construction Work Summary.

Fig. 3.7 shows an example of a Contract Work Summary, which contains treatment types and thicknesses date of completion.

Contract ID	Job#	Route	County	Location Description	Length (Mi)	Project Office	Contractor	MS	Treatment	Notice to Proceed	Contract Completion	Semi-Final Inspection	Striping	Pilot-Car?
Asphalt Pavement Treatment, High Type, Superpave/SMA														
150320-D07	J5P3005	50	Osage	Rte 100 to Rte 89 in Linn	2.0	Jefferson City	???	Strube	1.75" SP125 Mill/Fill, Shoulders and ADA Improvements	5/4/2015	11/1/2015		Contractor	Yes
Asphalt Pavement Treatment, Low Type, Bit Base/Pavement														
140822-D01	J5I3005	I-70	Cooper	W/O Rte 87 to Missouri River Bridge	15.6	Columbia	APAC	Baumhoer	3/4" Type C UBAWS and Shoulder Sealing	10/14/2014	10/1/2015		Contractor	No
141017-D02	J5L1500D	Y/J/D	Camden/Laclede	Various Routes	30.1	Camdenton	Magruder	Bohon	1" Surface Leveling and Shoulder Improvements	1/5/2015	11/1/2015		Contractor	Yes
141017-D03	J5L1500E	68	Maries/Phelps	Rte 63 to St. James	11.7	St. James	Rolla Asphalt	Buscher	1 1/4" BP1 Overlay and Shoulder Improvements	12/8/2014	10/1/2015		Contractor	Yes
141017-D05	J5P2187	5	Camden	Jet Ski Rd. to Signing Oaks Dr. in Sunrise Beach	1.1	Camdenton	Magruder	Bohon	Grading, Opt. Pavement and Resurfacing	1/5/2015	11/2/2015		Contractor	No
	J5S3007F	135	Morgan	Rte 52 to Rte 5 near Laurie	20.6	Camdenton		Williams	1" Surface Leveling and Shoulder Improvements	1/5/2015	11/2/2015		Contractor	Yes
141121-D01	J5S3035	E	Gasconade	Rte 19 to Rte H	5.1	St. James	Rolla Asphalt	Strube	1" Surface Leveling	1/5/2015	10/1/2015		Contractor	Yes
150123-D02	J5P3010C	63	Maries	South of Vichy to North of Vichy	6.7	St. James	NB West	Buscher	Diamond Grind and Shoulder Improvements	3/9/2015	10/1/2015		Contractor	Yes
150220-D03	J5S3046	185	Washington	Rte 8 near Potosi to Rte AA	1.5	St. James	Iron Belt Materials	Schroyer	1" Surface Leveling and Shoulder Improvements	4/6/2015	10/1/2015		MoDOT	Yes
150320-D04	J5L1500C	Y	Miller/Morgan	Rte 52 to End of State Maintenance	12.6	Camdenton	???	Bohon	1" Surface Leveling and Shoulder Improvements	5/4/2015	11/1/2015		Contractor	Yes
150320-D10	J5S3007B	P	Miller	Rte 87 to End of State Maintenance	1.1	Camdenton	???	Bohon	1" Surface Leveling	6/1/2015	11/1/2015		Contractor	Yes
	J5S3088	87	Miller/Moniteau	Rte 50 to Rte 54 East of Eldon	19.9	Camdenton		Baumhoer	1" Surface Leveling and Shoulder Improvements	6/1/2015	11/1/2015		Contractor	Yes
150320-D11	J5S3007E	179	Cooper/Moniteau	Rte. 98 to Rte. 87	12.8	Columbia	???	Baumhoer	1" Surface Leveling with Culvert Replacements	5/4/2015	7/1/2016		Contractor	Yes
Seal Coat Treatment														
131122-D02	J5S3072	V/H/O/K/C/F	Phelps/Crawford/Dent	Various Routes in Various Counties	80.4	St. James	Blevins	Schroyer	Grade A Seal Coat	1/6/2014	10/1/2014		MoDOT	Yes
140919-D04	J5S3009B	T/M/D/N	Osage/Gasconade/Maries	Various Routes in Various Counties	49.8	Jefferson City	Hutchens Construction	Strube	Grade A1 Seal Coat	11/3/2014	10/1/2015		MoDOT	Yes
140919-D05	J5S3009C	42 & 134	Miller/Maries	Various Routes in Various Counties	37.5	Camdenton	Vance Brothers	Bohon	Misc. Sealing Treatment	11/3/2014	10/1/2015		MoDOT	Yes
140919-D06	J5S3009D	A/T/7	Camden	Various Routes in Various Counties	56.1	Camdenton	Hutchens Construction	Bohon	Seal Coat/Misc. Sealing Treatment	11/3/2014	10/1/2015		MoDOT	Yes
Expansion/Realignment/Misc. Construction														
140919-D01	J5P0820D	50	Cole	Rte 50 from Monroe St to Clark Ave	0.7	Jefferson City	Emery Sapp	Belt	Grading, Pavement and Bridge	12/1/2014	10/1/2016		Contractor	No
	J5P3015B	50	Cole	Rte 50 and Clark Ave Intersection	0.1	Jefferson City		Belt	Latex Modified Bridge Surfacing, Pavement and Sidewalk	12/1/2014	10/1/2016		Contractor	No
141017-D01	J5I3097	I44	Phelps	WB Lane Exit, East of Martin Springs	0.1	St. James	Lehman Construction	Buscher	Slide Repair	12/8/2014	5/2/2015		MoDOT	No
150320-D08	J5P3032	Various	Various	Various Locations	0.0	St. James	???	Various	Chevron Additions and Guardrail Replacement	5/4/2015	11/1/2015		N/A	No
Bridge Construction														
140919-D03	J5P3096	Various	Camden/Maries/Miller	13 Various Bridge Locations	0.0	Camdenton	Leavenworth Excavating	Bohon	Scour Repair	10/8/2014	3/1/2015		N/A	N/A
141017-D04	J5M0265	V	Camden	North of Rte 7 over Dry Auglaize Creek	0.1	Camdenton	Lehman Construction	Bohon	Bridge Removal	12/8/2014	5/1/2015		N/A	N/A
141113-D01	J5M0267	50	Cole	Over Big Horn Drive near Jefferson City	0.1	Jefferson City	L.F. Krupp Construction	Belt	Bridge Repair Resulting From Collision	11/14/2014	1/16/2015		Contractor	N/A
141121-D02	J9P2221	8	Phelps	Over Dry Fork Creek	0.5	St. James	Robertson Contractors	Buscher	Grading, Paving and Bridge Replacement	1/5/2015	10/1/2015		Contractor	N/A
150123-D01	J2S0430	E	Howard	Over Adams Fork, 0.6 Mi W of Rte 5	0.1	Columbia	APAC	Williams	Bridge Replacement	3/9/2015	9/11/2015		Contractor	N/A
	J2S2206	A	Howard	Over Moniteau Creek, near Fayette	0.1	Columbia	APAC	Williams	Bridge Deck Replacement	3/9/2015	9/11/2015		Contractor	N/A
150220-D01	J5S2182	E	Boone	2.5 Mi North of I-70 near Columbia	0.1	Columbia	Lehman Construction	Belt	Bridge Deck Replacement	3/12/2015	8/14/2015		Contractor	N/A
150220-D02	J5S2226	OO	Boone	Over Hinkson Creek near Hallsville	0.1	Columbia	Don Schnieders	Belt	Bridge Replacement	4/6/2015	10/2/2015		Contractor	N/A
	J5S2227	UU	Boone	Over Sugar Branch Creek near Columbia	0.1	Columbia		Belt	Bridge Replacement	4/6/2015	10/2/2015		Contractor	N/A
150320-D09	J5S2200	A	Camden	Over Boer Creek near Richland	0.1	Camdenton	???	Bohon	Bridge Deck Replacement	5/4/2015	8/7/2015		MoDOT	N/A

Fig. 3.7 – Example of a Contract Work Summary.

Unfortunately, information such as final plan sheets only go back about a year at the time of writing of this report.

3.15 Pavement Tool

The Pavement Tool is a website within TMS, currently accessible from SharePoint, created to track, analyze, update, and predict pavement condition. Completed and planned maintenance work information can be entered into the Pavement Tool by district maintenance forces and others. Specific types of data include year (2009-2030), treatment/repair type (23 choices with some specific, others more general), overlay thicknesses (eight choices from 1 to 5¾ in.), funding category (five sources), roadway classification (major, minor, low volume), centerline miles, lane miles, district, route, cost, etc.). However, some categories of treatment materials are not specific as to mix type, and seal type. Hopefully, present and future users will avail themselves of the specific choices available when entering data, and that newer material categories will be added as the need arises. Fig. 3.8 shows the Tool main menu.

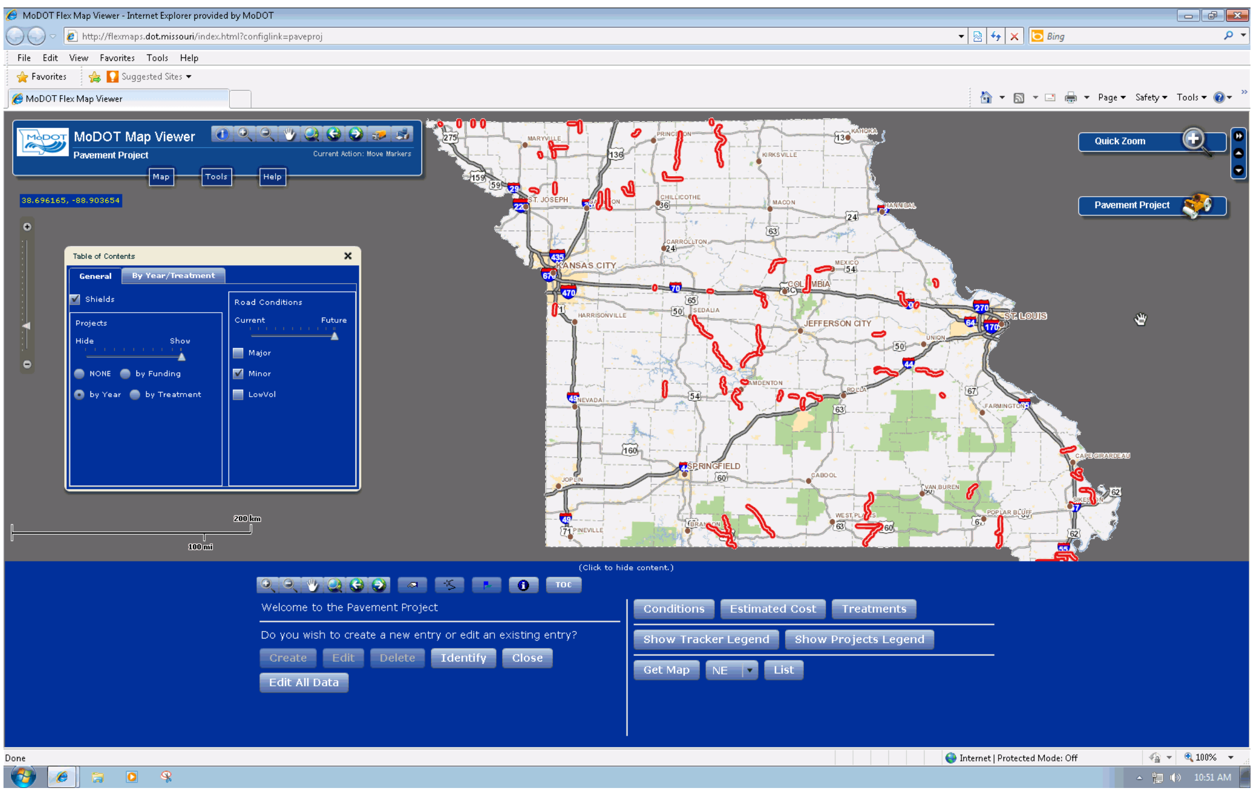

Fig. 3.8 – Pavement Tool main menu.

Fig. 3.9 shows the types of treatments available for searching, as well as the years of interest, going back to 2009.

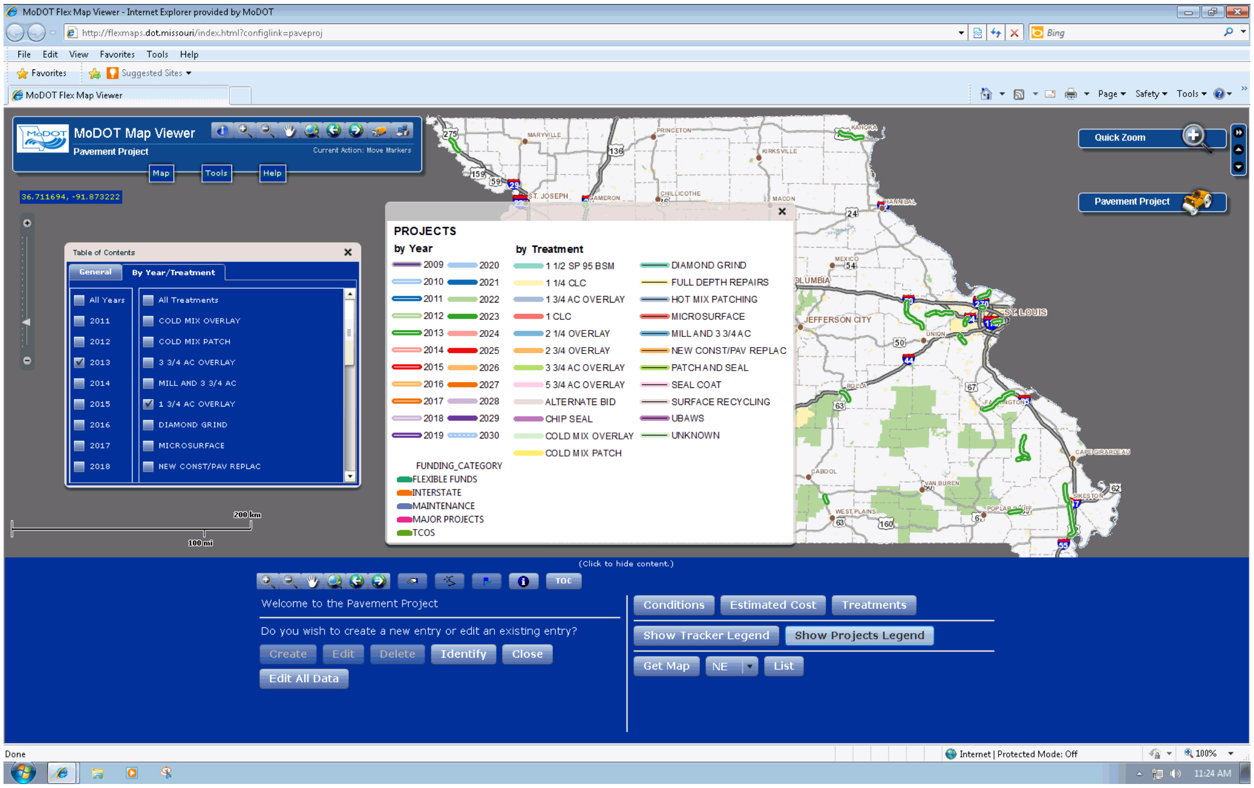

Fig. 3.9 – Pavement Tool treatment types and years.

For a specific segment of a specific route, one can find the specific type of treatment and its cost in a given year, going back to 2009. An example is shown in Fig. 3.10, where the query was for chip seals on low volume roads in the Central District using Maintenance funds in 2011. However, if one wanted a complete history of different treatments for a given route, separate queries would have to be made for each plausible treatment types (narrowed from 23 choices) for every year and possibly for each plausible funding category. The main issue with the Pavement Tool is that it is a relatively new site and only goes back to 2009.

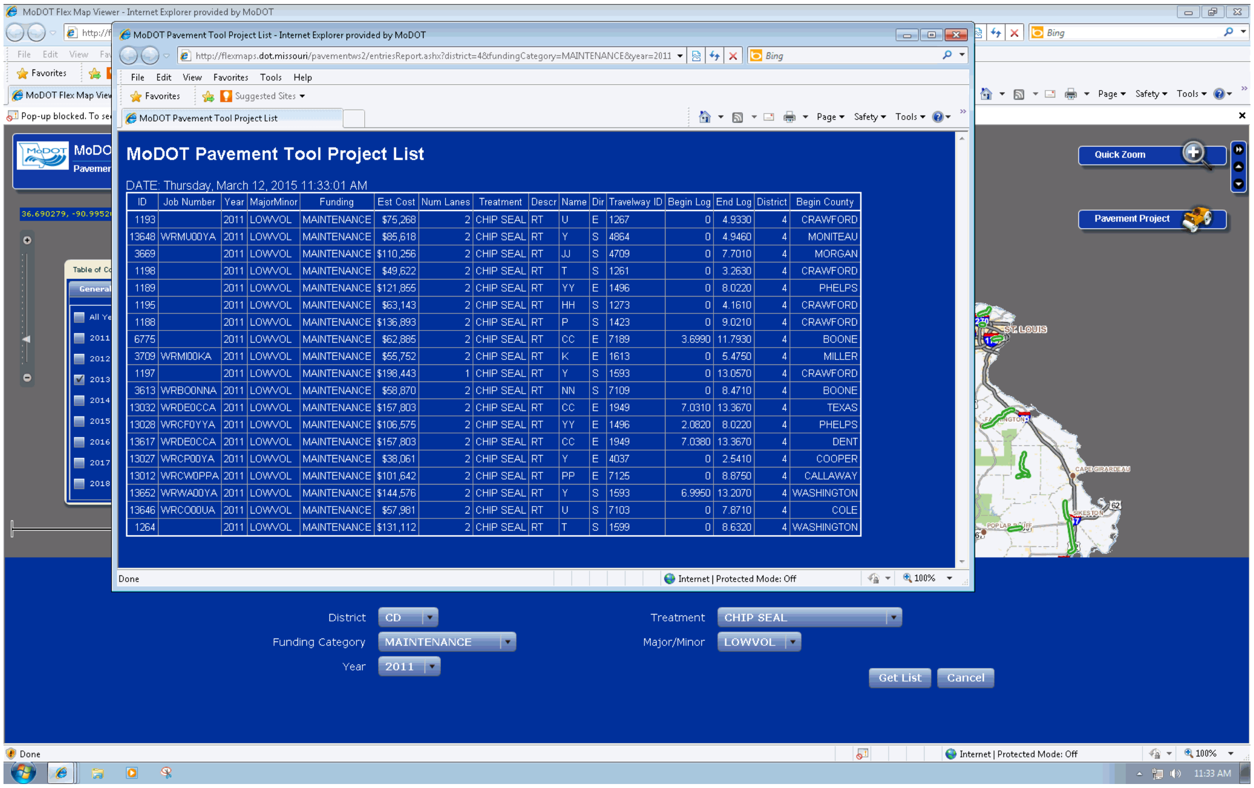

Fig. 3.10 – Pavement Tool chip seal projects in Central District in 2011.

The Tool records 5 years of pavement planning for each district with a minimum of three years of operating budget projects included.

3.16 Traffic

Traffic data, especially truck (commercial vehicle) traffic, is an important predictor of pavement performance because it describes the most significant loading history of a pavement. Commercial vehicles are defined as six-tire and larger trucks. Unfortunately, the relative concentrations of types of trucks (and hence axle loads) are not included in the commercial count, and could result in less accurate cause-and-effect analysis in regard to the influence of truck traffic on pavement performance modeling. There are several ways to access traffic data throughout MoDOT's TMS databases. Traffic data (Annual Average Daily Traffic [AADT] and commercial volume [trucks]) are included as fields in the SS Pavement database, and traffic data are also shown as a user views ARAN video data (both described in Section 3.3). Another, slightly more comprehensive way to view traffic data is to generate reports of traffic data ("TR 50" reports).

Typically, all three sources for traffic data were consistent, though the dynamic segmentation issues associated with the SS Pavement database made the ARAN video values slightly more reliable, so these were primarily used for data collection. For higher volume roads, traffic data could differ between the two directions (e.g. northbound vs. southbound), but for smaller volume roads, both directions were assumed to be the same.

3.17 Pavement Layer Thickness

Pavement thickness includes the original constructed thickness, plus all subsequent treatment layer thicknesses. Original designed/constructed thicknesses can be found in Concrete 2-AA sheets, ragmaps (occasionally), asphalt summaries, and project plan sheets (the STIP project database, ARAN Viewer, or in the archived files on the Z-drive). Treatment thicknesses can be found in the project plan sheets, Asphalt Summaries, the Pavement Tool, and district maintenance files, either at the district offices or on SharePoint. Unfortunately, detailed records for full depth asphalt original construction for minor roads is incomplete, and maintenance/rehabilitation data is spotty. Routes with less than 750 AADT that were inherited from the counties typically will not have any available information. In most cases, the only data available are treatment thicknesses subsequent to original cross-section design, which makes selection of thickness for modeling purposes difficult.

3.18 Quality of Treatment

The quality of a treatment can be the controlling factor in regard to the longevity of the treatment, overpowering the effect of most other variables. A poor quality treatment may fail pre-maturely. In discussions with maintenance personnel, it was brought out that a major proportion of variability in data will be due to construction quality. In recent years, there have been a number of premature failures (within one year) of both overlays and chip seals. This makes modeling very difficult. The three major components of treatment quality are materials, construction practices (MoDOT, 2010), and prevailing weather at the time of construction.

The category of “materials” includes material type and quality. “Material type” means specific treatment materials, such as type of overlay mix (surface leveling, plant mix type [BP-1, etc.), type of seal (chip seal [and subtype], onyx seal, scrub seal, etc.), microsurfacing, Ultrathin Bonded Asphalt Wearing Surface (UBAWS), etc. “Quality” of the material refers to mix design (including volumetrics, binder content, choice of specific gravity value, etc.), and the quality (source) of the materials used (primarily aggregate).

“Construction quality” refers to how well the material meets the specifications in regard to material preparation at the plant (temperature, screening, etc), tacking operation, compaction, and constructed thickness interaction with actual aggregate nominal maximum size (NMS). Construction records are somewhat available through Site Manager, but this typically does not cover many of the various desired types of information for most of the maintenance types of treatments. For instance, some types of construction control do not lend themselves to the type of material combined with design thickness of many maintenance treatments, and so the control is not specified nor recorded. So, these types of variables are not directly available for modeling purposes. Construction quality also includes preparation, e.g. milling some existing material prior to treatment to remove rutted, cracked, and age-hardened material. Bad weather during construction can also result in a low level of construction quality.

To address the problems for modeling purposes, Functional Classification has been used as a surrogate for quality (assumption: higher FC, greater quality)(Khattak et al. 2013).

In the future it would be of great help but would take little effort if someone, perhaps from the Field Office in the Construction and Materials Division, would maintain a running commentary, construction season-to-construction season very brief description of what changes were made in the specifications, the reasons for making them, and the resulting successes and failures. The commentary should be easily available somewhere for all MoDOT personnel to access. In this way, a judgment could be made as to predicting how long a given treatment with a given material constructed during a given season would last.

3.19 Existing Condition

The longevity of a given treatment is somewhat dependent upon the support to be given by the existing structure: subgrade, granular base, original pavement, and treatment layers as they interact with each other and the climate. IRI and condition indices just prior to treatment are indicative of the "existing condition" as well as condition after the treatment is applied. A poorer before-treatment condition will be more difficult to recover from, and a poorer-after-treatment will start a treatment in a more disadvantageous position. Other conditions, such as moisture content/drainage issues, will affect performance.

3.20 Pavement Maintenance Data

The collection of data associated with in-house MoDOT pavement maintenance work has been one of the most challenging processes in Task 1. Full-surface preservation treatments such as chip seals, scrub seals, fog seals, etc. are sometimes performed by MoDOT maintenance personnel but details of the work (e.g. specific location, date of the work, material quantities, thickness, and type) are not documented in a complete and consistent manner. This type of information usually resides with district pavement specialists and/or maintenance personnel in electronic form and/or on a personal experiential basis. Thus, all the data is not available on a system-wide basis. However, in recent years, some maintenance operations have begun to be incorporated into the newer sites such as Pavement Tool and SharePoint.

Researchers made personal visits to various District Pavement Specialists and Maintenance Supervisors to review the information for each of the study's project segments in order to: 1) verify the data that the researchers have found (see above discussions), 2) add any treatments that were missing in the MoDOT databases, and 3) review the pavement selection and maintenance planning procedures in-place at the district level. District pavement specialists have indicated that historical pavement data (e.g. new construction and maintenance activities), and future planning information (e.g. treatment types and when to be applied) based on the history is sometimes available on an individual route segment basis. District maintenance supervisors have indicated that information similar to that collected/created by pavement specialists may be available on a more local maintenance jurisdiction basis.

Descriptions of materials and construction procedures can be found in MoDOT's Engineering Policy Guide (EPG) (MoDOT 2014).

3.20.1 District Maintenance/Treatment Selection Operations

Maintenance operations for two districts were explored: the Southwest District (SW), and the Central District (CD). The primary source of information for the SW district was the Senior District Pavement Specialist. For the Central District, the Senior District Pavement Specialist, his predecessor, the Assistant District Maintenance Engineer, and all six Maintenance Superintendents were interviewed. From that, the various procedures for treatment selection and programming for both districts were reviewed, as well as the spreadsheets maintained by the above individuals.

Maintenance funding is divided into two types: Contract and In-House. Discussions with district personnel centered on “Minor” roads (less than 5000 AADT). The minor road system is sub-divided by AADT (see Table 3.3).

3.20.2 Materials

The typical maintenance scenario for a given route involved programmed “Treatments”, with intermediate “Preventive Treatments” done in between “Treatments”. A third type of maintenance, “Reactive/Corrective Treatments”, was not necessarily programmed, but was done on an as-needed basis to keep roads drivable and safe. The Treatment types were hot mix (bituminous material [BM]) or cold mix (oil asphalt = OA) overlays. Sometimes microsurfacing and UBAWS were used, although UBAWS is usually reserved for more major roadways. The Preventive Treatments were chip seals, scrub seals, “onyx” seals, fog seals, scratch seals, spot seal coating, and crack sealing/filling. “Reactive/Corrective Treatments” included partial patching and sometimes crack sealing/filling as a pre-treatment prior to a programmed treatment.

3.20.2.1 Programmed Treatments

3.20.2.1.1 HMA Overlays

The HMA overlays were section 401 mixes (BP-1 and BP-2), section 402 mixes (surface leveling course [SLC]) mixes, and for greater traffic roadways, section 403 (Superpave [SP]) mixes.

3.20.2.1.2 Cold Mix Overlays

Cold mix is generally limited to roadways with less than 2000 AADT.

3.20.2.2 Programmed Preventive Treatments

3.20.2.2.1 UBAWS

UBAWS is used mostly for major routes and on Portland Cement Concrete (PCC) where there are friction problems and added structure is not required. UBAWS is costly (about the same as a 1-¼ in. overlay); another negative involves the need to mill the old UBAWS off before overlaying with a new mix, so as not to leave a porous layer that would be filled with dirt over the years.

3.20.2.2.2 Microsurfacing

Basically a slurry seal, the cost of microsurfacing is considered a little too high compared to chip sealing, and there is a need for a little more ductility on the minor roads than a microsurface provides (microsurfaces seem to reflect cracks fairly quickly; they are believed to be more brittle).

3.20.2.2.3 Scratch Seals

Scratch sealing is a fairly new procedure to MoDOT. The roadway receives a ½ in. deep hot mix overlay to correct the road profile, then a chip seal is placed on top. The ½ in. depth is measured from the high points in the road cross section.

3.20.2.2.4 Chip Seals

Chip seals are a mainstay of surface treatments. It is unusual for treatments other than chip seals or 1-in. SLCs to be performed on roadways with AADTs less than 3500.

3.20.2.2.5 Onyx Seals

An onyx seal is basically a high quality slurry seal that is starting to be used more. A slurry seal is a mixture of aggregate, mineral filler (if necessary), emulsified asphalt, and water.

3.20.2.2.6 Scrub Seals

Scrub seals are similar to chip seals, but with additional scrubbing action to embed the liquefied asphalt and fine aggregate into the cracks.

3.20.2.2.7 Fog Seals (Fly Coating)

Fog seals are applied on cold mix routes, cold mix patches, and shoulders of major and some minor routes. The 409 standard specification requires limestone/dolomite chip seals to be fly coated (fog sealed) if the chips were not pre-coated; however, the Pavement Maintenance Direction (MoDOT 2010) states that fog sealing in this case is not required for < 400 AADT. Sand or cinders may be applied as a blotter at intersections and entrances.

3.20.2.3 Reactive/Corrective Treatments

3.20.2.3.1 Partial Patching

Partial cold mix patching is done on an as-needed basis, but is not included in a programmed cycle.

3.20.2.3.2 Crack Sealing/Filling

Crack sealing/filling should be considered as a both a preventive treatment and as pre-treatment prior to certain other treatments that do not fulfill a crack sealing function.

3.20.3 Costs

In the SW District, unit costs are assumed as follows: High Volume (> 5000 AADT) [SP overlay thickness]: $75,000 per centerline mile; Medium Volume (> 3500 AADT) [1-¾ in. BP-1 overlay (15-year cycle)]: $70,000, $74,000, $78,000, or $80,000/mile, depending on location in the district. There are permanent plants in/around Springfield, Joplin and Branson, so MoDOT gets better prices if the projects are located closer to town; for distant counties, haul distance or set-up of a portable plant (if the job is large enough) costs more. Medium Volume (1750-3500 AADT) [1-¼ in. BP-2 overlay (25-year cycle)] costs are: $55,000, $58,000, $60,000, or $63,000/mile, depending on the county. Low Volume (1000-1750 AADT)[1-in. SLC overlay (25-year cycle)] costs are: $50,000, $53,000, $55,000, or $58,000/mile, depending on the county. Preventive maintenance is $18,000/mile, for all counties (chip seal or onyx seal).

In the Central District, the total cost per mile of trap rock chip seals is estimated as $14-16,000 for in-house and $18,000-21,000 for contract seals, all depending on whether the surface is flycoated. One-in. CLCs cost about $45-55,000 per mile (total cost). There is not a perceived significant difference in costs depending on which county the project is located.

3.20.4 Longevity of Treatments

For the SW District, design life ("Overlay Cycle") is set at 10 years (SP), 15 years (1-¾ in. BP-1), or 25 years (1¼-in. BP-2 or 1-in. SL)-this is for what is considered "Treatments" (overlays). The treatment cycles (~life expectancies = STIP budget / Centerline miles@ unit cost) are a function of treatment (material type-plus- thickness), ADT (less traffic = longer lasting), and what it takes to balance the STIP annual budget. "Preventive Treatments" (usually chip seals or onyx seals) are programmed at 8 years (for 15-year treatments); and at 10 and 18 years (for 25-year treatments). The real trigger for preventive maintenance is appearance of cracking and raveling; there is no formalized PMS program of preventive maintenance.

3.20.5 Programming Treatments

3.20.5.1 Southwest District

Planning (when to put a segment into a given cycle) is a function of when the segment is scheduled for some type of treatment, modified by condition (10 point scale)—essentially worst first, e.g. when the Condition Index (not IRI) is nearing the Good/Poor threshold. One spreadsheet is for planning; what is actually done is on other spreadsheets—e.g. Treatment Year comes from TMS, ARAN video, and in-house spreadsheets ("District 8" and others spreadsheets-these are just for chip seals).The high volume minor road category has no Preventive Treatment because the SW District treats these like it treats major routes, e.g. chip seals are avoided. Planning continues for up to 12 more years beyond the initial three years to get the routes on a timeline order to match the yearly dollar amount available.

The following is a table used for SW District programming at the time of this report's data-collection. As an example, the first column first row refers to conversion of the surface from PCC to Superpave (SP).

Table 3.3 SW District treatment types

Existing Surface Type-to-Proposed Treatment	ADT	Overlay and Preventative Cycle (Years)
PCC to Superpave	> ±5000	
SP, BM, AC to Superpave	>± 5000	Overlay @ 15 years w/ preventive @ 8 years
BM, LC, AC to 1 ¾" BP-1	3500-5000	Overlay @ 15 years w/ preventive @ 8 years
PCC to 1 ¾" BP-1	3500-5000	
BM, LC, AC to 1 ¼" BP-2	1750-3500	Overlay @ 25 years w/ preventive @ 10 & 18 years
BM, LC, AC to 1" SL	1000-1750	Overlay @ 25 years w/ preventive @ 10 & 18 years
BM, LC to OA	< 1000	
OA to OA	< 1000	

Centerline miles are calculated from the planned sections, multiplied by unit costs, and then summed. The whole planning amount cannot exceed the Annual Budget, thus the Prioritized list of segments is adjusted to meet the budget. Programmed sections and life expectancies (10, 15, 25 years, etc.) are varied until proposed expenditures equals the budget allowed.

The SW district calculated a weighted average of %Good for each of the eight traffic/facility levels by calculating an individual segment weighting factor (segment length in miles * %Good rating for that segment) for each segment, summing the weighting factors for a given traffic level, and dividing by the total centerline miles. For example, for the Medium (3500-5000) category, Greene County, Rt M, segment Rt 60 to Rt FF, (3.7433 centerline miles * 44% Good [from SS Pavement ratings]) = 164.69; sum of all segments' weighting factors in the Medium (3500-5000) category = 45,170 and sum of all segment's miles = 483.9; so, the "Weighted %Good" = 45,170/483.9 = ~ 94%.

In-house treatment types and tonnages (not thicknesses) are chosen by Field Maintenance Superintendents based on experience and budget constraints, not on Condition Index or IRI. Treatments are chip seals, fog seals, and partial overlay patching. In the SW District, all overlays are now by contract.

3.20.5.2 Central District

Three things are kept in mind by Central District Maintenance personnel when planning: traffic (the primary consideration), IRI, and customer service concerns.

1) Routes above 150 IRI will be considered for treatment.
2) Routes above 200 IRI will be a priority.
3) When selecting routes the following factors will be considered:
   a) Type of business located on route
   b) Length of route
   c) Additional CLC in the area
4) The Central District uses an IRI Map that identifies routes within the Central District that carry at least 1000 AADT and have IRI values from 150 to 200 and over 200.

5) Working closely with Maintenance Superintendents and Supervisors, the planners track the amount of repair work completed on routes and log them into the Pavement Tool. This information provides when a route has been repaired and may be ready for a CLC.
6) Costumer Concerns: all costumer concerns are taken seriously, and repair is attempted with Maintenance budget, or if it qualifies for a CLC, the planners will try to see if it fits within the CLC budget.

Chip Seals:

1) Chip seals will be considered on all routes.
2) The Central District will select routes based on age of CLC
3) Location of routes: CD tries to get 25-30 miles of chip seals within a geographical area for better pricing.
4) Central District Maintenance will try to chip seal 100 miles per year in-house.
5) Chip seals are programmed by North and South areas:
   a) MoDOT chip seals are in the North area 1 year and in the South area the following.
   b) Contract chip seals will follow the same pattern but just opposite of MoDOT.
6) Just like CLC programming chip seals are selected by maintenance activities and patching completed.
7) Central District attempts to follow the CLC 20 year cycle. With current budget issues they select the higher AADT Routes first.

Table 3.4 shows the Central District's match up of material type and traffic level.

Table 3.4 Central District treatment types

Traffic	Material	Thickness
Minors: AADTT ≥ 600	Superpave	
> 3500, AADTT < 600	BP-1	
< 3500, AADTT < 600	BP-1 or BP-2	
1750-3500	CLC	1 ¼"
1500-1750	CLC	1"

3.20.6 District Maintenance Spreadsheets

There are a number of spreadsheets used for maintenance activities that the various districts have developed for their own use. These reside and are maintained on individual maintenance district personnel's desktop computers; some are posted on SharePoint (see section 3.13). Most of the spreadsheets are used primarily for programming future longer-term maintenance activities out 20 years or more. They are also used for fine-tuning short term planning as the programmed year is finally approached. An example from the Central District is shown in Fig.

3.11. Unfortunately for model-building, there is not much detail in terms of material types, overlay thickness, and so forth. Additionally the spreadsheets do not go back very far.

Washington County Central District											Continuous Log			2012 Data				Previous		4	12	20
County	County	District	Class	TWAY ID	Desig	Name	Direction	Divided	Lanes	Description	Begin	End	Length	AADT	Truck Vol	AVG IRI	% Good		Future Treatments - CLC Cycle			
																		CLC	CLC	CS1	CS2	CLC
Washington	Wa	CD	Minor	16	MO	21	S	U	2	Jefferson Co. to MO 47 N Jct	42.672	47.341	4.669	4,333		100	99%	2009				
Washington	Wa	CD	Minor	16	MO	21	S	U	2	MO 8 to Schroer Rd/CRD 643	58.439	60.150	1.711	4,333		100	99%					
Washington	Wa	CD	Minor	16	MO	21	S	U	2	Schroer Rd/CRD 643 to MO 32	60.150	70.680	10.530	4,333		100	99%	2009				
Washington	Wa	SE	Minor	16	MO	21	S	U	2	MO 32 to Iron Co	70.680	72.742	2.062	4,333		100	99%					
Washington	Wa	SE	Minor	1056	MO	32	E	U	2	MO 21 North/East to St Francois Co.	228.710	238.551	9.841	1,284		141	99%	2006		2012	2020	
Washington	Wa	CD	Minor	50	MO	47	S	U	2	Franklin Co. to MO 21 N Jct	87.626	98.736	11.110	1,592		154	63%	2014		2018	2026	
Washington	Wa	CD	Minor	50	MO	47	S	U	2	MO 21 S Jct to St Francois Co.	103.662	112.175	8.513	2,471		223	0%	2014		2018	2025	
Washington	Wa	CD	LowVol	100	MO	104	E	U	2	MO 21 W Jct to MO 21 E Jct	0.000	3.203	3.203	167		221	0%					
Washington	Wa	CD	Minor	20	MO	185	S	U	2	Franklin Co to Rt T	38.533	55.381	16.848	771		103	100%	2011				
Washington	Wa	CD	Minor	20	MO	185	S	U	2	Rt T to Rt AA	55.381	64.685	9.304	771		103	100%	2010				
Washington	Wa	CD	Minor	20	MO	185	S	U	2	Rt AA to MO 8	64.685	66.128	1.443	771		103	100%	2010				
Washington	Wa	CD	Minor	1601	RT	A	E	U	2	MO 185 to MO 47	0.000	15.885	15.885	445		204	6%					
Washington	Wa	CD	LowVol	1603	RT	AA	E			MO 8 to MO 185	0.000	11.486	11.486	340		198	99%					
Washington	Wa	CD	LowVol	1589	RT	BB	S	U	2	Rt C to SME	0.000	3.324	3.324	266		174	42%			2010	2018	
Washington	Wa	CD	Minor	1587	RT	C	E	U	2	Rt Y to Rt DD	0.000	14.381	14.381	582		163	62%			2012	2020	
Washington	Wa	CD	Minor	1587	RT	C	E	U	2	Rt DD to MO 21	14.381	22.367	7.986	582		163	62%			2009		
Washington	Wa	CD	Minor	880	RT	CC	E	U	2	MO 21 to St Francois Co	0.000	3.255	3.255	789		174	0%					
Washington	Wa	CD	LowVol	1591	RT	DD	S	U	2	Rt C to Iron Co.	0.000	6.302	6.302	222		111	100%	2004		2012	2020	
Washington	Wa	CD	Minor	882	RT	E	S	U	2	Rt CC to MO 47	0.000	6.147	6.147	1,937		123	92%	2012		2016	2024	
Washington	Wa	CD	Minor	882	RT	E	S	U	2	MO 47 to MO 21	6.147	11.243	5.096	1,937		123	92%	2002		2012	2020	
Washington	Wa	CD	Minor	882	RT	E	S	U	2	MO 21 to MO 8	11.243	12.760	1.517	1,937		123	92%	2010				
Washington	Wa	CD	Minor	1605	RT	EE	S	U	2	SME to MO 185	0.000	1.202	1.202	400		177	3%					
Washington	Wa	CD	Minor	1597	RT	F	S	U	2	SME to Sunset Ln	0.000	8.362	8.362	890		112	100%	2012		2016	2024	
Washington	Wa	cty	Minor	1597	RT	F	S	U	2	Sunset Ln to MO 8	8.362	9.029										
Washington	Wa	CD	Minor	888	RT	H	E	U	2	MO 47 to Jefferson Co	0.000	4.137	4.137	1,036		128	100%	2011		2012	2020	
Washington	Wa	CD	LowVol	1580	RT	JJ	S	U	2	Rt C to SME	0.000	2.822	2.822	320		197	0%			2014	2022	
Washington	Wa	CD	Minor	868	RT	M	E	U	2	MO 21 to St Francois Co	0.000	9.247	9.247	785		105	99%	2012		2016	2024	
Washington	Wa	CD	Minor	1609	RT	N	E	U	2	Crawford Co to MO 185	11.926	18.099	6.173	98		218	2%	2001		2010	2018	
Washington	Wa	CD	Minor	1595	RT	O	E	U	2	MO 8 to SME	0.000	2.580	2.580	1,427		109	100%	2011		2015	2023	
Washington	Wa	CD	Minor	1582	RT	P	S	U	2	MO 8 to Rt C	0.000	14.039	14.039	928		110	100%	2011		2015	2023	
Washington	Wa	CD	LowVol	1599	RT	T	S	U	2	Rt A to MO 185	0.000	8.632	8.632	182		215	62%			2011	2019	
Washington	Wa	CD	Minor	870	RT	U	S	U	2	MO 8 to Rt M	0.000	9.907	9.907	894		215	2%			2010	2018	
Washington	Wa	CD	Minor	870	RT	U	S	U	2	Rt M to St Francois Co	10.072	13.655	3.583	396		154	1%			2010	2018	
Washington	Wa	CD	Minor	1607	RT	W	S	U	2	Rt N to SME	0.000	8.650	8.650	98		217	86%			2014	2022	
Washington	Wa	SL	Minor	40	RT	WW	S	U	2	Jefferson Co to Jefferson Co	8.938	9.125	0.187	626		129	100%					
Washington	Wa	CD	Minor	1593	RT	Y	S	U	2	Crawford Co Rt W. N Jct to Crawford Co. S Jct	6.082	13.211	7.129	178		209	73%			2011	2019	
Washington	Wa	CD	Minor	1584	RT	Z	E	U	2	SME (Crd Palmer Rd) to Rt C	0.000	2.143	2.143	46		204	72%			2014	2022	

Fig. 3.11 – Example Central District "Pavement Plan Spreadsheet".

Some historical data are accumulated over time, but not much at this point. Other spreadsheets are more of a historical nature. For instance, the SW district keeps a chip seal historical file, and produces chip seal annual historical maps, as shown in Fig. 3.12.

SW District Chip Seal History
2002-2012

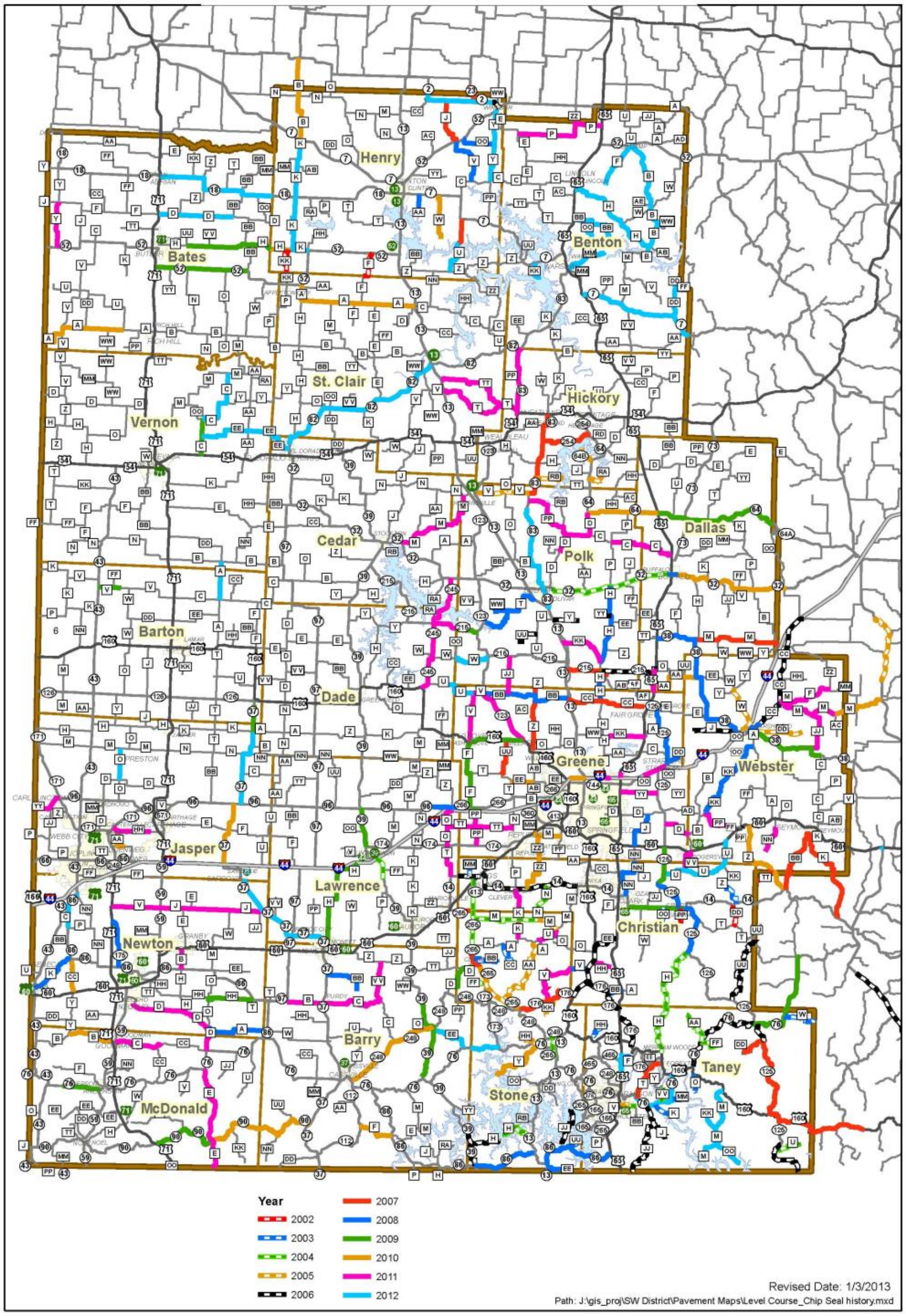

Fig. 3.12 – SW District chip seal history map.

Other spreadsheets contain older data, such as shown in Fig 3.13. This is an example of chip seal data from the SW district going back to 2002. Fig. 3.14 is an historical treatment file (all types) for the Central District, which includes treatment types but lacks thicknesses and most material type information.

ID	Year	Rte	County	Section	Length	LogBegin	LogEnd	TWAY_ID			
1	2013	76	Barry	112 to Stone Co.	20.614	54.815	75.429	1923			Contract
2	2013	86	Barry	76 to E	8.509	64.581	73.09	3143			Contract
3	2013	YY	Barry	39 to end	2.760	0	2.76	2927			Contract
4	2013	Z	Barry	60 to 39	8.464	0	8.464	2405			Contract
5	2013	J	Barry	End to 86	3.741	0	3.741	2461			Contract
6	2013	73	Camden	54 to Dallas Co.	2.183	0	2.183	2061			Contract
7	2013	73	Dallas	Camden to Maple St.	17.249	2.183	19.432	2061			Contract
8	2013	JJ	Christian	125 to 14	4.517	0	4.517	2080			Contract
9	2013	14	Christian Douglas	125 to BB	15.278	39.25	54.528	1977			Contract
10	2013	T	Greene	F to I-44	9.942	0	9.942	2248			Contract
11	2013	AA	Greene	H to 65	5.091	0	5.091	2567			Contract
12	2013	AD	Greene Webster	125 to B	5.105	0	5.105	2839			Contract
13	2013	I-44 OR	Lawrence	FR 1010 to H	7.898	0	7.898	278127			Contract
14	2013	M	Lawrence	96 to I-44	5.134	14.967	20.101	3215			Contract
15	2013	Bu 60	Lawrence	Chapell Dr. Monett to Conc. (	2.878	1.916	4.794	2315			Contract
16	2013	97	Lawrence	44OR to 37	11.347	53.871	65.218	3151			Contract
17	2013	H	Newton	86 to D	6.126	0	6.126	3364			Contract
18	2013	86	Newton	P to 71	9.952	6.261	16.213	3143			Contract
19	2013	A	Stone	2654 to K	6.592	0.009	6.601	2893			Contract
20	2013	Y	Taney	160 to end	3.367	0	3.367	2485			Contract
21	2013	O	Taney	160 to end	2.547	0	2.547	2503			Contract
22	2013	B	Webster	I-44 to AD	9.937	0.05	9.987	2819			Contract
23	2013	59	McDonald	EE to Arkansas	8.975	37.52	46.495	3487			Contract
24	2013	F	McDonald	End to 59	8.26	0	8.26	3428			Contract
25	2013	52	ates/St. Clair/Hen	BB north to 13	25.21	30.8	56.01	52			Maint.
26	2013	82	St. Clair/Benton	13 to 83	12.76	25.99	38.75	2250			Maint.
27	2013	Y	Bates	18 to J	4.65	1.39	6.04	2027			Maint.
28	2013	18	Bates	A to RR @ Adrian	19.76	0.35	20.11	4428			Surface

Fig. 3.13 – Chip Seal Historical File SW District 2002-2013.

id	YEAR	JOB_NO	TWAY_I	BEG_LOG	END_LOG	LENGTH	DES	ROUT	BEGINNING_COU	ENDING_CO	LOCATION	TYPE	Material	STATUS	COMPLETED_D	RoadRank	COMMENTS
344	1994		1054	18.004	35.244	17.24	MO	8	Crawford		MO 19 To Crawford Co. Line	CLC		COMPLETED		3	na
259	1997		1054	9.26	17.341	8.081	MO	8	Crawford		1.8 mi. e/o Craw. CL To MO 19	CLC		COMPLETED		3	na
71	2002	PM044	1054	22.959	33.303	10.344	MO	8	Crawford		BB to Y	CHIP SEAL		COMPLETED		3	na
442	2007	J9L0600Q	1054	9.3	17.341	8.041	MO	8	Crawford		1.9 Mi. E/O Rte 68 To 0.5 Mi. N/O Rte 19	CLC		AWARDED		3	na
689	2007	J9P0567	1054	18.26	43.96	25.7	MO	8	Crawford	Washington	STEELVILLE TO RT AA	THIN-LIFT		COMPLETED		3	na
690	2007	J9P0567	1054	55.52	63.23	7.7	MO	8	Crawford	Washington	EAST OF RT O TO COUNTY LINE	THIN-LIFT		COMPLETED		3	na
942	2010	J9P0010B	1054	17.38	18.73	1.35	MO	8	CRAWFORD		MO 19 to MO 19	CLC	BP-3	PROGRAMMED			ECONOMIC RECOVERY
226	1995		54	112.27	122.75	10.48	MO	19	Crawford		Crawford Co. Line To IS 44 W	CLC		COMPLETED		4	na
290	1999		54	131.275	141.337	10.062	MO	19	Crawford		MO 8 To MO 49	CLC		COMPLETED		4	na
299	2001	J9L0122A	54	141.337	151.212	9.875	MO	19	Crawford	Dent	MO 49 To RT TT	CLC		COMPLETED		4	na
1164	2002	J6P0571	54	126.47	130.673	4.203	MO	19	Crawford		1.4 MILES SOUTH OF ROUTE O TO MO 8	GE		COMPLETED			
389	2003	J9L0306G	54	112.33	122.73	10.4	MO	19	Crawford		Gasconade Co. Line To S/O Rte. P	CLC		COMPLETED		4	na
390	2003	J9L0306H	54	124.24	126.44	2.2	MO	19	Crawford		0.8 Mi. N/O Rte. O To 1.4 Mi. S/O Rte. O	CLC		COMPLETED		4	na
525	2005	J9M0053	54	122.74	124.29	1.55	MO	19	Crawford		I-44 to 0.5 mile south of Route PP near Cuba City Limits	MICROSURFACING		COMPLETED		4	na
152	2007	PM264	54	131.275	141.337	10.062	MO	19	Crawford		MO 8 to MO 49	CHIP SEAL	Chip 4A	COMPLETED		4	na
723	2008		54	141.34	164.88	23.54	MO	19	CRAWFORD	DENT	49 TO SALEM CITY	CHIP SEAL	Chip 4A	COMPLETED	7/17/2008	4	na
753	2009	J9P0565	54	112.365	122.75	10.48	MO	19	Crawford		Crawford Co. Line To IS 44 W	THIN-LIFT		COMPLETED		4	na
870	2009	WRCF019A	54	126.4	130.671	4.27	MO	19	Crawford		CRD Lindburg Rd to MO 8	CHIP SEAL		COMPLETED	8/24/2009	4	na
965	2011	J9P0515	54	123.849	127.088	2.19	MO	19	Crawford		Cuba CityLimits south 2.19 miles	GE		PROGRAMMED			THIN LIFT OVERLAY AND FLATTEN CURVES
967	2012	J9P2189	54	122.832	123.849	1	MO	19	Crawford		I-44 to RT PP	THIN-LIFT		PROGRAMMED			
1159	1992		277993	0	2.276	2.276	SOR	44	CRAWFORD		RT KK to RT ZZ	CLC		COMPLETED			
625	2002	J9I0508	9	213.94	219.142	5.202	IS	44	CRAWFORD		Route H to Route N	THIN-LIFT		COMPLETED		1	na
600	2003	J9M0035	9	219.17	224.17	5	IS	44	CRAWFORD		East of Route J to Franklin County Line	Ultra-thin bonded wearing course		COMPLETED		1	na
607	2005	J9I0509	9	204.78	213.94	9.16	IS	44	Crawford			R&R		COMPLETED		1	na
585	2005	J9D0500C	9	219.17	224.17	5	IS	44	Crawford		W/O Rte. J to Franklin County line	THIN-LIFT		COMPLETED		1	na
464	2005	J9M0054	277730	0	5.546	5.546	OR	44	Crawford		Frontage Road/Hobby Hut Road to Route C	CLC		COMPLETED		0	na
418	2005	J9L0500B	277730	5.55	10.43	4.88	NOR	44	Crawford		Rte C To Rte WW	CLC		COMPLETED		0	na
616	2006	J9D0500B	10	66.293	76.64	10.347	IS	44	CRAWFORD		County line to Route H	DIAMOND GRINDING		COMPLETED		1	na
615	2006	J9I0514	10	76.64	89.12	12.48	IS	44	CRAWFORD		Route H to County line	R&R		COMPLETED		1	na
891	2009	J9I2168	10	76.579	89.086	12.507	IS	44	Crawford		Rte H to Phelps Coutny	R&R		AWARDED			ECONOMIC RECOVERY
872	2010		277999	0	2.428	2.428	OR	44	Crawford		END to RT FF	CHIP SEAL	1	COMPLETED	8/11/2010	5	na
890	2011	J9I2153	9	213.7	223	9.3	IS	44	Crawford		Rte H to Franklin County	THIN-LIFT		FUTURE			na
304	1994		1052	0	20.13	20.13	MO	49	Crawford	Iron	MO 19 To MO 32	CLC		COMPLETED		4	na
307	2006	J9L0600P	1052	5.24	15.4	10.16	MO	49	Crawford	Iron	Rte V in Crawford County To Rte Y in Iron County	CLC		REJECTED		4	na
729	2007		1052	0	15.401	15.401	MO	49	Crawford		MO 19 To Iron Y	CHIP SEAL	Chip 4A	COMPLETED		4	na
1044	2011	J9M0094	1052	0	20.066999	20.06699	MO	49	CRAWFORD	IRON	MO 19 to MO 32	CLC		FUTURE			WORST FIRST PLAN
728	2008		1271	0	10.215	10.215	RT	AA	CRAWFORD		19 TO END	CHIP SEAL	Chip 4A	COMPLETED	7/2/2008	0	na
445	2007	J9L0700D	1275	0	5.23	5.23	RT	BB	Crawford		MO 8 To Westover Rd	CHIP SEAL	Chip 4A	COMPLETED		6	na
1143	1991		1424	0	12.583	12.583	RT	C	CRAWFORD		MO 19 to I-44	CLC		COMPLETED			
243	1996		1424	0	12.31	12.31	RT	C	Crawford		MO 19 To IS 44 W	CLC		COMPLETED		0	na
126	2004	PM099	1424	0	12.59	12.59	RT	C	Crawford		19 to 44	CHIP SEAL		COMPLETED		0	na
843	2009	WRCF00CA	1424	0	12.324	12.324	RT	C	Crawford		MO 19 to IS 44	CHIP SEAL		COMPLETED	9/2/2009	6	na

Fig. 3.14 – Treatment (All Types) Historical File Central District 1991-2013.

The bottom line in regard to district spreadsheet information is that there is a lot of information somewhere, some of it is on SharePoint, and there is an increasing amount being posted on the Pavement Tool. However, for pavement selection and modeling purposes, the data is lacking in thicknesses, material types, and sometime treatment types information.

3.21 Subgrade

3.21.1 MoDOT Sources

Specific subgrade data is available from some project documents (e.g. Concrete 2-AA sheets as described in Section 3.8.4). Additionally, specific data can be obtained from Preliminary Geotechnical Reports for a given project. An example is shown in Fig. 3.15. The reports are discussed in the EPG Section 320.1 and can be obtained from the Soils and Geology section of the Construction and Materials Division. Unfortunately, soil investigations for minor routes typically do not exist, unless there was a re-alignment or a bridge or other structure had been built. More generalized data can be found in the 1962 Geology & Soils Manual (Fig. 3.16) and updated soil association files (Fig. 3.17) and soil map (Fig. 3.18) in the Soils and Geology section of the Construction and Materials Division. Fig. 3.19 shows the five geologic regions in Missouri.

MEMORA JUM

Missouri Department of Transportation

District 6 - Materials

TO: Michael Fritz -po

CC: Michael Fritz -po (2)
Ahmad Lesani -pm6
Construction -po6 (2)

FROM: Phil Ruffus PR
Senior Geotechnical Specialist

DATE: January 5, 2004

SUBJECT: Preliminary Geotechnical Report
Job No. J6I0977
I-44, Franklin County

The preliminary geotechnical report for the above job has been completed. This 1.76-mile length of road extends from east of St. Louis Inn Road, Sta. 562+00, to west of Route WW, Sta. 650+37. The proposed improvement includes realigning the eastbound and westbound acceleration and deceleration lanes at the St. Clair rest area. Additional improvements include removing several concrete islands, relocating existing parking spaces, and restriping the rest area.

This preliminary geotechnical report was prepared in accordance with plans and cross sections furnished on October 6, 2003.

Logs of subsurface information are attached along with a preliminary geotechnical report summary sheet showing descriptions and typical properties of the materials encountered.

Soil Types and Geologic Formations:

Soils to be encountered are the Gladden Series and the Lily-Holstein-Ramsey Complex. The Gladden series soils are alluvial in nature and are found in the channel and small floodplain of Dry Creek. These soils will not be involved in excavation. The primary soils to be encountered are the residual Lily-Holstein-Ramsey Complex. This Complex consists of shallow, somewhat excessively drained, rapidly permeable soils on slopes and uplands. They formed in material weathered from acid sandstone. The content of coarse fragments of sandstone or chert ranges from 5 to 35 percent throughout the soil profile. They are primarily lean clays (CL) by ASTM standards. However, pockets of essentially rock free fat clay (CH) are present near an identified collapse structure

The Roubidoux Formation comprises the bedrock in this area. The Roubidoux Formation

Our mission is to provide the St. Louis metro area with a quality transportation network meeting today's demands and tomorrow's expectations.

P.02/18

Fig. 3.15 Example of a MoDOT Preliminary Geotechnical Report.

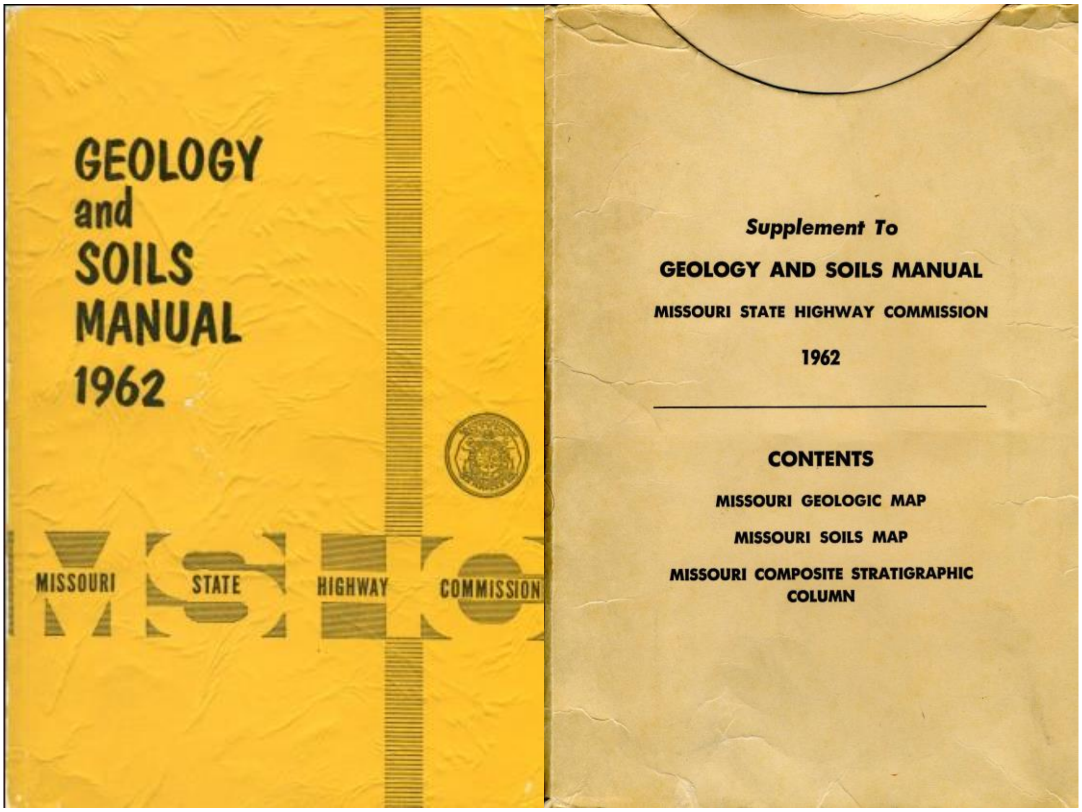

Fig. 3.16 MoDOT Geology & Soils Manual and Maps.

GEOLOGY AND SOILS MANUAL—1962 39

ASHE

Primary Area—St. Francois Mts.—Ozarks

Derivation—Chiefly residual from granite, but the character of the soil on lower slopes suggests the possibility that cherty limestone may have contributed to its formation.

Topography—The stony loam occupies land that ranges from hilly to mountainous with long and steep slopes in country that is thoroughly dissected. The silt loam is found in level to gently sloping areas within the mountainous areas of stony loam. It occupies the broad irregular valley-like areas between the peaks and the flat tops of the large hills or mountains.

Associated Soils—Clarksville—Tilsit

Average Laboratory Test Results:

	Horizon		
	A	B	C
Liquid Limit	27	24	32
Plastic Index	0	0	7
Group Index	2	7	0
Silt and Clay	40	62	22
Optimum Moisture	11	13	10
Maximum Density	117	116	126
Shrinkage Factor-Composite		1.15	

Description

Horizon A—Yellowish brown to gray floury silt loam—considerable content of stone fragments.

Horizon B—Yellow silty clay which becomes heavier and more plastic with an increase in depth and has very few or no rock fragments.

Horizon C—Yellow or yellowish brown, moderately friable, silty clay which becomes lighter in color and heavier in texture with increasing depth—rock content quite high in lower part of the subsoil — usually mottled with yellow and rather crumbly—often this zone is entirely lacking, with only a thin mantle of soil lying on the bedrock.

Fig. 3.17 – Example of Soil Association data.

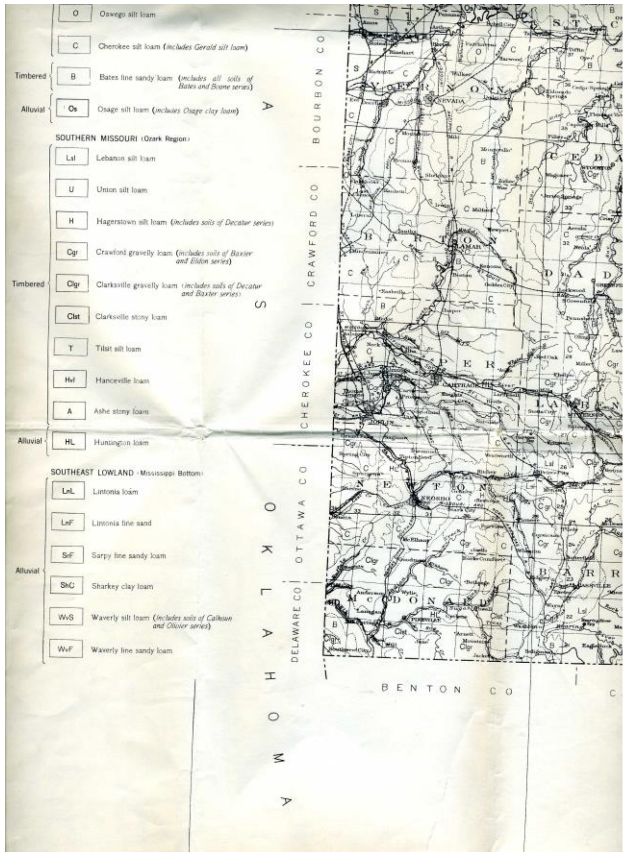

Fig. 3.18- Soil Association soils map.

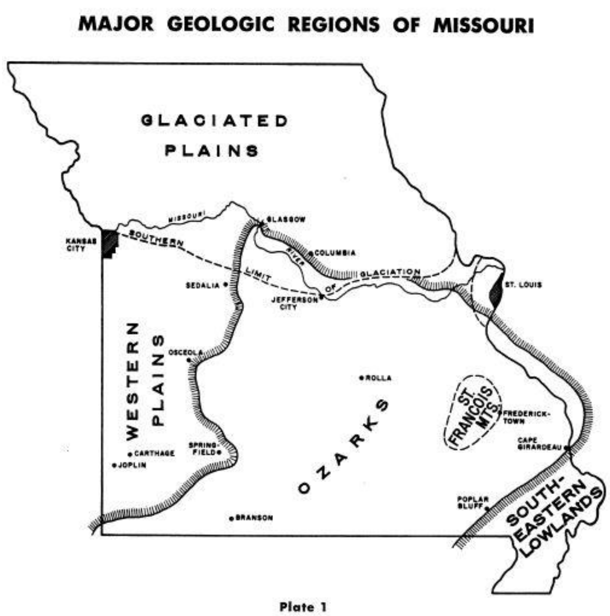

Fig. 3.19 – Missouri geologic regions.

3.21.2 Arizona State University Web Portal

For specific minor routes, data will probably not be available from MoDOT sources, so two other non-MoDOT sources can be used: Arizona State University (ASU) and U.S. Department of Agriculture (USDA) soils maps.

A first-pass, fairly simple but less detailed, source of soil condition parameters for the selected pavement segments can be obtained through an online tool available through the ASU Soil Unit Map Application portal as discussed in NCHRP Project 9-23B (Zapata and Carey 2012). The data are derived from USDA soils maps. The ASU information uses a different hierarchy of soil delineation than does the USDA maps that are typically available to the user. USDA information is divided into three soil geographic databases that are chiefly differentiated by the scale that is used for mapping the soil units:

1. Soil Survey Geographic (SSURGO) database
2. State Soil Geographic (STATSGO) database
3. National Soil Geographic (NATSGO) database

SSURGO is the most detailed. The ASU web is based on NATSGO.

Fig. 3.20 shows the home page for the ASU Soil Map Unit Application

(http://nchrp923b.lab.asu.edu/index.html)

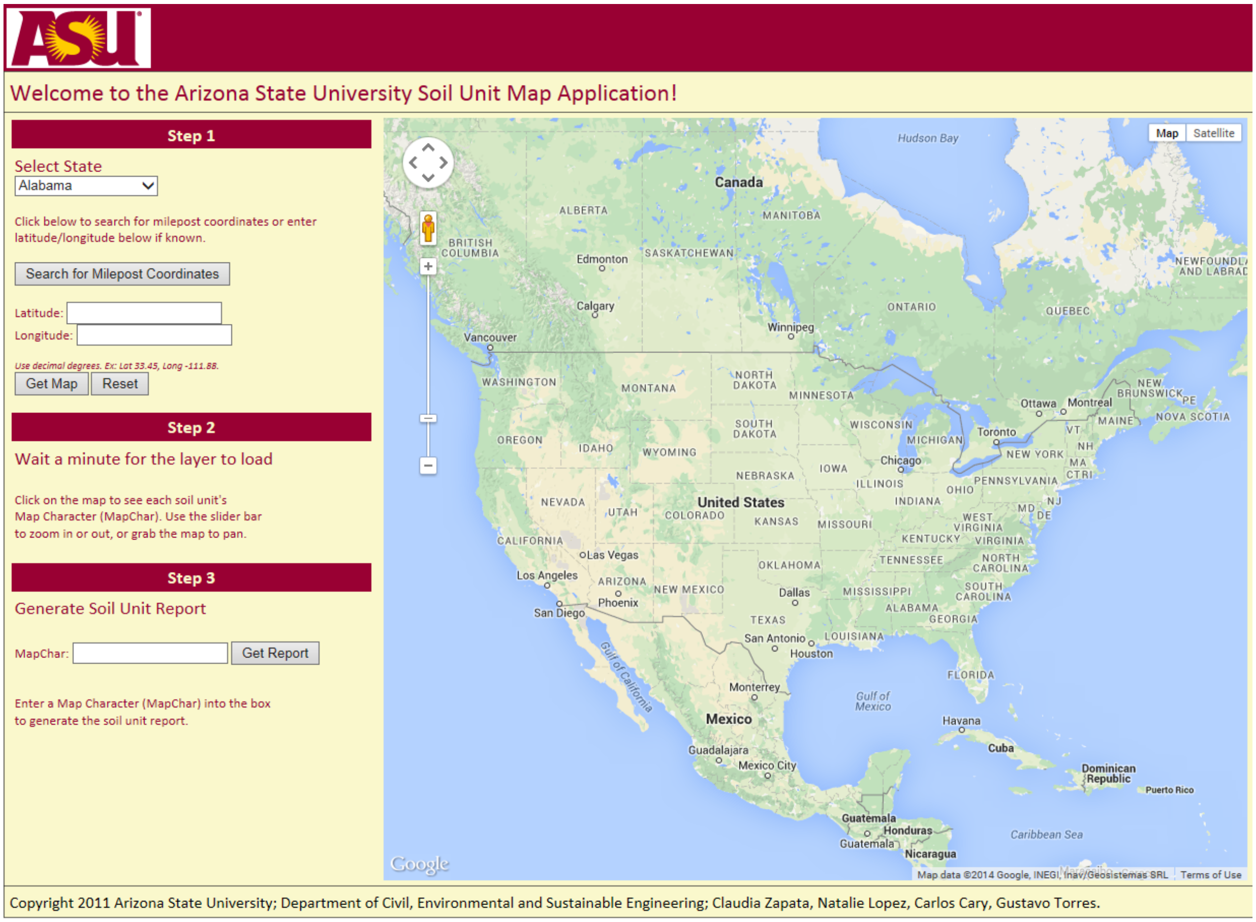

Fig. 3.20 - ASU Soil Unit Map Application webpage.

An example of a specific project site is shown in Fig. 3.21. It should be noted that the number of soil types is fairly small, usually one or two. The dataset associated with one of the soil types is shown in Fig. 3.22. Data are delineated by depth and test results. The small number of soil types and extent both horizontally and vertically of each soil type is simplified from actual USDA reports, which will be presented next. To arrive at one overall description of the soil for a given roadway segment, the user has to manually do a weighted average calculation of soil characteristics from layer thicknesses and horizontal extent of each soil classification.

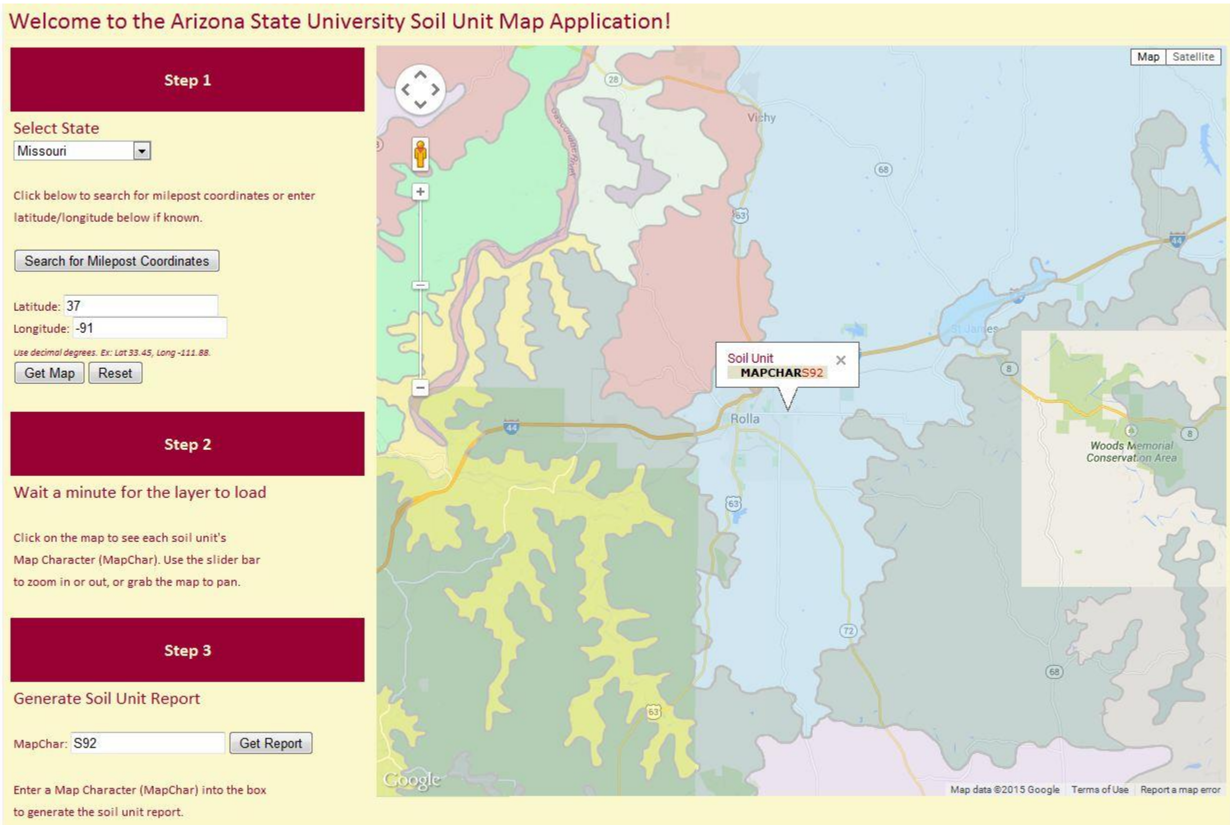

Fig 3.21 - ASU Soil Unit Map Application webpage for Route BB, Phelps County.

Properties of Soil Unit S92

Map Character	Map Unit Key	Map Unit Name	Component Name
S92	663302	Union-Swiss-Beemont (s3801)	Union

AASHTO Classification	AASHTO Group Index	Top Depth (in)	Bottom Depth (in)	Thickness (in)	% Component	Water Table Depth Annual Min (ft)	Depth to Bedrock (ft)
A-4	7	0	9.1	9.1	34	1.57	N/A
A-7-6	18	9.1	29.9	20.9	34	1.57	N/A
A-2-6	0	29.9	53.1	23.2	34	1.57	N/A
A-7-6	26	53.1	79.9	26.8	34	1.57	N/A

CBR from Index Properties	Resilient Modulus from Index Properties (psi)	Passing #4 (%)	Passing #10 (%)	Passing #40 (%)	Passing #200 (%)	Passing 0.002 mm (%)	Liquid Limit (%)
11	11848	100	95	90	80	21	30
5.4	7545	95	90	85	80	37.4	44
41.6	27793	25	20	15	10	19	30
3.3	5502	75	65	60	55	73	79

Plasticity Index (%)	Saturated Volumetric Water Content (%)	Saturated Hydraulic Conductivity (ft/hr)	Parameter af (psi)	Parameter bf	Parameter cf	Parameter hr (psi)
10	43	0.1063	7.691	0.8514	0.7202	3000
22	44	0.1063	4.2065	0.8844	0.4141	3000.03
11	N/A	0.01181	N/A	N/A	N/A	N/A
54	33	0.03543	0.0001	44.189	0.0059	3005.16

1 record found matching your criteria

Print Report Close

Fig. 3.22 - ASU Soil Unit Map Physical Data for Route BB, Phelps County.

Instructions for using the ASU tool are given in the NCHRP 9-23B report (http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP09-23B_FR.pdf) and are detailed in Appendix 1D of this report. Tables 3.5 and 3.6 show the soils data derived from the ASU site for model-building, sorted by percent minus #200 sieve (P200).

Table 3.5 – ASU soils data for model-building sorted by P200, Full-depth segments

County	Travelway Designation/Name	Travel Direction	BegLog (mile)	EndLog (mile)	Length (miles)	AADT	Geologic Areas	P200 (%)	PI	LL (%)	GI	%clay	%Swell
Phelps	RT F	East	9.10	13.30	4.20	400-750	Ozarks	18	6	20	0	12	0.1
Crawford	RT M	South	1.10	5.90	4.80	<400	Ozarks	18	6	20	0	12	0.1
Dent	MO 32	East	176.90	179.90	3.00	750-1700	Ozarks	28	16	40	0	33	1.5
Dent	RT K	South	5.30	13.30	8.00	<400	Ozarks	28	16	40	0	33	1.5
Phelps	RT BB	East	4.00	11.00	7.00	1700-3500	Ozarks	34	17	35	6	27	1.6
Washington	MO 47	South	91.00	96.00	5.00	750-1700	Ozarks	34	23	45	2	38	4.1
Washington	MO 21	South	60.00	66.00	6.00	1700-3500	Ozarks	35	18	39	1	33	2.1
Washington	MO 185	South	39.70	45.70	6.00	400-750	Ozarks	35	18	39	1	33	2.1
Laclede	MO 64	East	41.00	46.90	5.90	750-1700	Ozarks	44	22	44	8	44	4.0
Camden	MO 7	South	134.00	138.60	4.60	750-1700	Ozarks	46	17	40	4	37	1.9
Laclede	MO 32	East	93.80	97.10	3.30	1700-3500	Ozarks	47	0	0	6	39	0.0
Gasconade	RT Y	East	0.10	5.70	5.60	<400	Ozarks	49	25	47	9	40	5.1
Gasconade	MO 19	South	107.80	111.20	3.40	750-1700	Ozarks	51	28	50	11	42	7.0
Pulaski	RT T	South	0.60	4.60	4.00	1700-3500	Ozarks	53	22	45	10	46	4.1
Camden	RT J	South	4.10	8.10	4.00	<400	Ozarks	53	22	45	10	45	4.1
Miller	MO 17	South	8.70	11.70	3.00	400-750	Ozarks	60	28	50	15	55	8.5
Osage	RT T	South	1.90	6.90	5.00	400-750	Ozarks	61	30	53	16	45	8.7
Osage	MO 133	South	6.00	12.40	6.40	<400	Ozarks	61	30	53	16	45	8.7
Cole	RT E	East	1.30	5.50	4.20	<400	Ozarks	61	30	53	16	45	8.7
Morgan	MO 52	East	129.10	137.10	8.00	1700-3500	Ozarks	62	29	53	16	45	8.0
Moniteau	MO 5	South	175.00	178.50	3.50	1700-3500	Ozarks	62	29	53	16	45	8.0
Gasconade	MO 28	East	57.70	63.70	6.00	1700-3500	Ozarks	62	29	53	16	32	6.5
Morgan	RT W	South	1.50	10.50	9.00	400-750	Ozarks	63	33	56	20	49	11.6
Boone	RT E	South	0.00	10.00	10.00	750-1700	GlacPlains	64	29	52	16	42	7.6
Pulaski	MO 17	South	31.70	35.20	3.50	750-1700	Ozarks	66	20	46	12	45	3.2
Pulaski	MO 133	South	45.80	50.20	4.40	400-750	Ozarks	66	20	46	12	45	3.2
Laclede	RT J	East	1.80	9.10	7.30	400-750	Ozarks	66	20	46	12	45	3.2
Callaway	RT D	South	4.30	12.20	7.90	<400	GlacPlains	68	25	45	15	41	5.2
Howard	MO 3	South	69.70	73.50	3.80	400-750	GlacPlains	71	28	47	18	40	6.8
Cole	RT C	East	28.10	33.10	5.00	1700-3500	Ozarks	74	25	49	19	47	5.7
Howard	MO 87	South	5.40	10.40	5.00	<400	GlacPlains	82	21	41	17	33	3.0
Callaway	RT B	East	3.30	6.70	3.40	400-750	GlacPlains	84	27	50	24	41	6.3
Boone	RT HH	East	1.80	5.30	3.50	<400	GlacPlains	84	27	48	22	40	6.2
Boone	MO 124	East	27.20	31.20	4.00	1700-3500	GlacPlains	91	28	52	28	40	6.8
Callaway	RT F	East	6.70	8.80	2.10	1700-3500	GlacPlains	91	28	52	28	40	6.8
Callaway	RT C	South	1.94	6.34	4.40	750-1700	GlacPlains	91	28	52	28	40	6.8
Howard	MO 240	East	43.80	47.40	3.60	750-1700	GlacPlains	95	30	50	31	32	7.0
Boone	RT N	South	0.20	5.60	5.40	400-750	GlacPlains	96	18	36	18	25	1.8
Cooper	MO 135	South	0.82	5.82	5.00	750-1700	GlacPlains	98	25	46	27	36	4.8
Cooper	RT J	East	6.70	15.50	8.80	<400	GlacPlains	98	25	46	27	36	4.8

Table 3.6 - ASU soils data for model-building sorted by P200, Composite segments

County	Travelway Designation/Name	Travel Direction	BegLog (mile)	EndLog (mile)	Length (miles)	AADT	Geologic Areas	P200 (%)	PI	LL (%)	GI	%clay	%Swell
Phelps	US 63	South	233.00	237.50	4.50	1732 to 2023	Ozarks	42	13	33	6	28	0.9
Lawrence	MO 174	East	4.05	6.25	2.20	1308	WestPlains	45	21	43	6	38	3.2
Butler	US 67	South	186.64	191.84	5.20	2203 to 2489	SE Lowlands	53	5	17	0	20	0.1
Phelps	US 63	South	204.60	207.40	2.80	2609	Ozarks	61	30	53	16	45	8.7
Grundy	US 65	South	23.53	26.53	3.00	777 to 984	GlacPlains	65	20	36	10	31	2.6
Grundy	MO 6	East	70.90	76.20	5.30	1060 to 2324	GlacPlains	72	22	34	14	34	3.4
Cooper	RT M	South	0.06	3.97	3.91	184	GlacPlains	90	16	34	17	23	1.3
Monroe	US 24	East	160.10	162.80	2.70	843 to 1052	GlacPlains	91	28	52	28	40	6.8
St. Francois	MO 8	East	63.60	68.35	4.75	3019 to 6657	St.Francis	92	13	35	12	30	0.9
St. Francois	MO 32	East	242.20	244.30	2.10	890 to 1024	St.Francis	92	13	35	12	30	0.9
Schuyler	US 63	South	13.70	15.80	2.10	2224 to 2381	GlacPlains	95	32	55	34	40	9.4
Cooper	MO 87	South	22.63	24.70	2.07	2074 to 2357	GlacPlains	96	18	36	18	25	1.8
Pettis	US 50	East	85.65	88.95	3.30	2194 to 3737	GlacPlains	98	25	46	24	36	4.8

3.21.3 US Department of Agriculture

A more detailed source of data regarding subgrade can be found from the USDA soil surveys, which are organized by county. The website URL is as follows:

http://websoilsurvey.nrcs.usda.gov/app/

Very detailed information can be obtained from this website about any given segment of roadway. Sometimes, there is more detail then what the reader desires, and it may be too cumbersome with which to deal, thus the previously-discussed ASU website can be used. Using the USDA website, looking at Route BB in Phelps County, Fig. 3.23 shows the horizontal extent of various soil units.

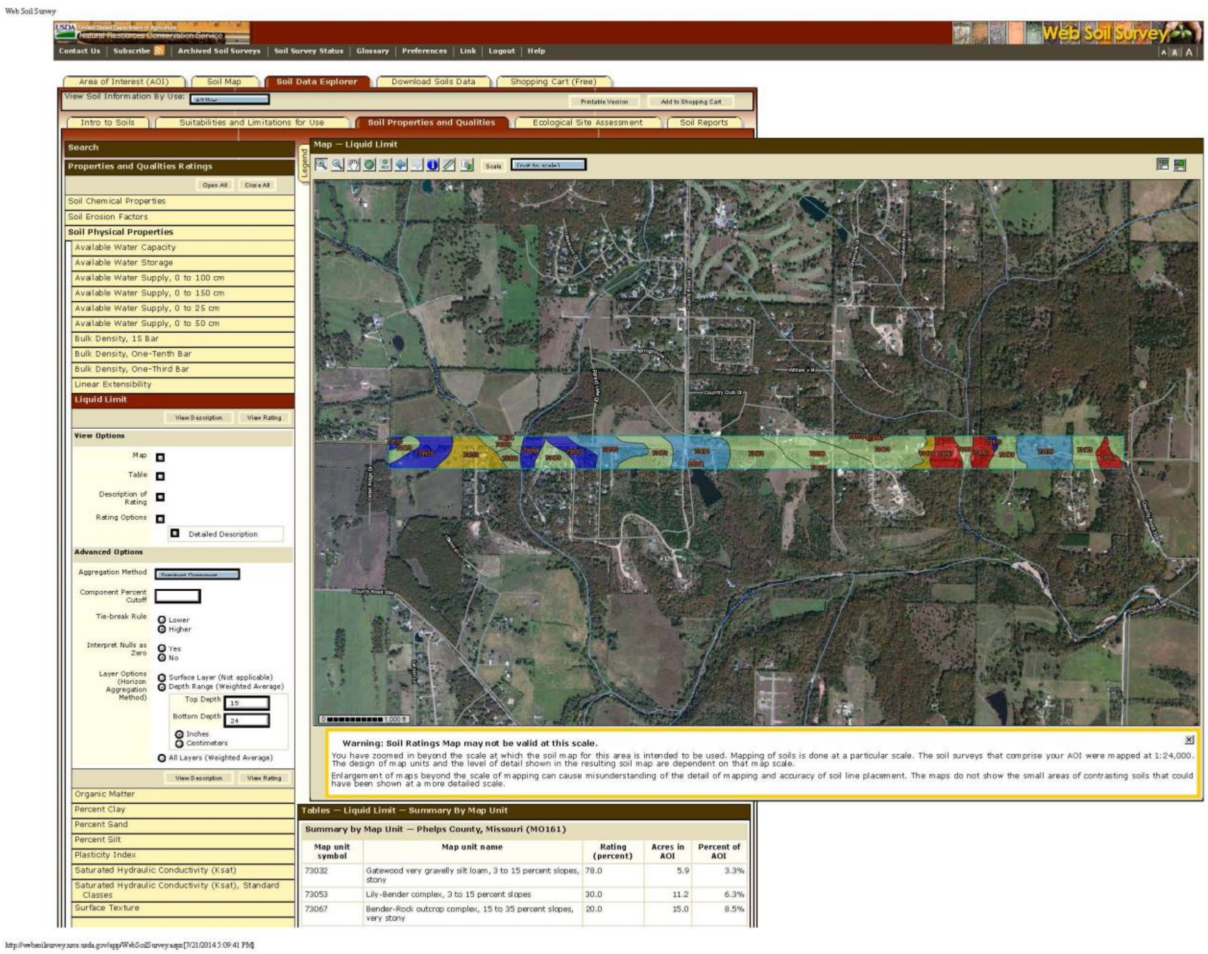

Fig. 3.23 – USDA "Soil Physical Properties" view of a delineated roadbed with Liquid Limit displayed.

Working through a series of drop down menus, the "Map Unit" soil numbers are contoured on the maps, as shown in Fig. 3.23. The "Percent AOI" (Area of Interest) is displayed and is the percent of the roadway delineated as that Map Unit. Map Units may be made up of several Soil Names. These are shown in Fig. 3.24 (just the first one "73032" is showing). Not shown in Fig 3.24 but on the actual screen display are each Soil Name within each Map Unit, and the Soil Name percents within the Map Unit. Thus, to obtain the percent of an association within the delineated roadway, the % Map Unit would be multiplied by the % Soil Name within that Map Unit.

It is useful to classify soils as to potential behavior, including potential soil support and problems they may cause, such as swell and frost-heave potential. To classify each fine-grained layer in each association as to the AASHTO method and to calculate Group Index (GI), the LL, PI, and % minus #200 sieve are required. To estimate swell potential by the Seed method, PI and % clay (< 0.002 mm) are required. To classify soil as to frost susceptibility by the U.S. Corps of Engineers method, PI and % silt and % sand are required. Unfortunately, the USDA and AASHTO do not agree on what constitutes the particle size boundaries between clay, silt, and sand. To confound the issue, the USDA clay, silt, and sand percents are based on the minus 0.02 mm (#10 sieve) rather than total soil. And, there is no #200 sieve value shown for individual associations. USDA defines Rock Fragments as greater than 2 mm.

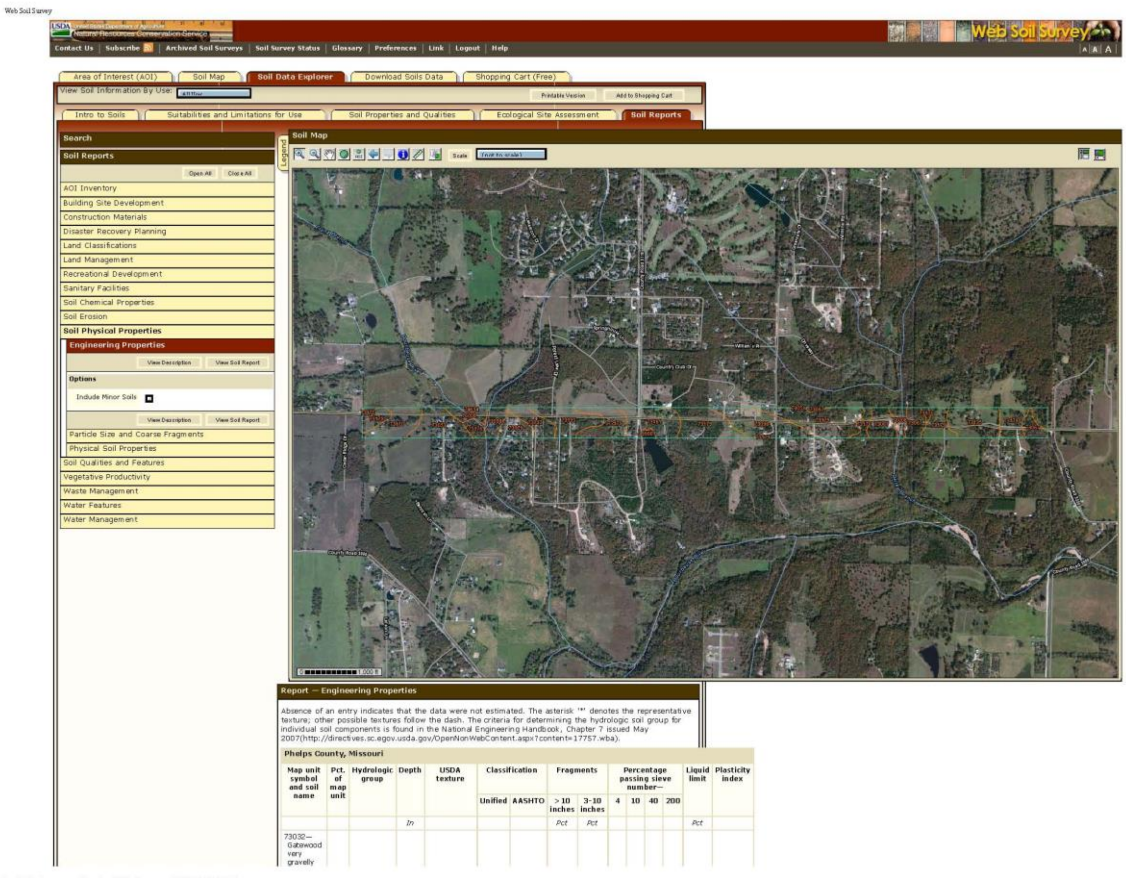

Fig. 3.24 – USDA "Soil Reports" view of a delineated roadbed with all soil Map Unit contours displayed.

So, to navigate through all this, the following steps are recommended:

1. Set up a spreadsheet and enter LL, PI, % clay, % silt, % sand, and average % Rock Fragments.
2. Calculate the % finer-than (<) 2mm material by: (100 - %total Rock Fragments).
3. Adjust the %s from < 2mm-basis to total soil-basis by multiplying each % by the %< 2mm:

% clay, total = (% <2mm)(% clay from website)/100
% silt, total = (% <2mm)(% silt from website)/100
% sand, total = (% <2mm)(% sand from website)/100

4. Calculate an approximate % minus #200 by: (% silt, total + % clay, total).

Now the soils can be classified, GI calculated, % swell calculated, and frost susceptibility level can be judged. Weighted averages of each soil's % swell, GI, and frost susceptibility can be calculated for the entire roadway using the percents discussed above. An example spreadsheet is shown in Appendix 1D. MoDOT does not have any hard-and-fast rules about what constitutes a problematic swelling soil and frost susceptible soil for roadway subgrades.

3.21.4 District Impressions

District personnel were informally asked about areas of problem soils. Several sources from the Central District agreed that soils north of the Missouri River were worse, such as Route N in Boone County. Likewise, in the SW district, the western parts of Bates County, specifically Routes C, F, J, U, and V were mentioned as having problem subgrade soils.

3.22 Climate

Climate data is available from the National Climatic Data Center (NCDC) of the National Oceanic and Atmospheric Administration (NOAA). Wang et al. (2012) investigated the effect of climate on various pavement preservation treatments applied to select asphalt segments in the Long-Term Pavement Performance (LTPP) program database. The pavement condition measure used to evaluate this effect was IRI. The researchers found that the effectiveness of the treatment procedures varied with climate to a significant degree. Precipitation (the number of days/year that precipitation was greater than 0.1 in. [2.5 mm]) and temperature (the number of days/year that the minimum air temperature was below 32° F [0°C]) were used together to define six climate zones. These zones were then used in a statistical analysis per pavement treatment to evaluate the change in IRI relative to control pavement segments. In the present report, number of days below freezing per year will be referred to as "DT32" and number of days with greater than 0.1 in. precipitation per year will be "DP01".

Data from weather stations across Missouri and adjacent states that was fairly recent and as complete as possible (i.e. continuously collected over time) was averaged and associated with the appropriate station. This resulted in data from 87 weather stations being used to create the isolines. The maximum, minimum, and average number of months used to create average DT32 and DP01 values for each weather station was 287, 227, and 276, respectively. Figs. 3.25, and 3.26 show plots of DP01 and DT32 isolines, respectively, on the state map.

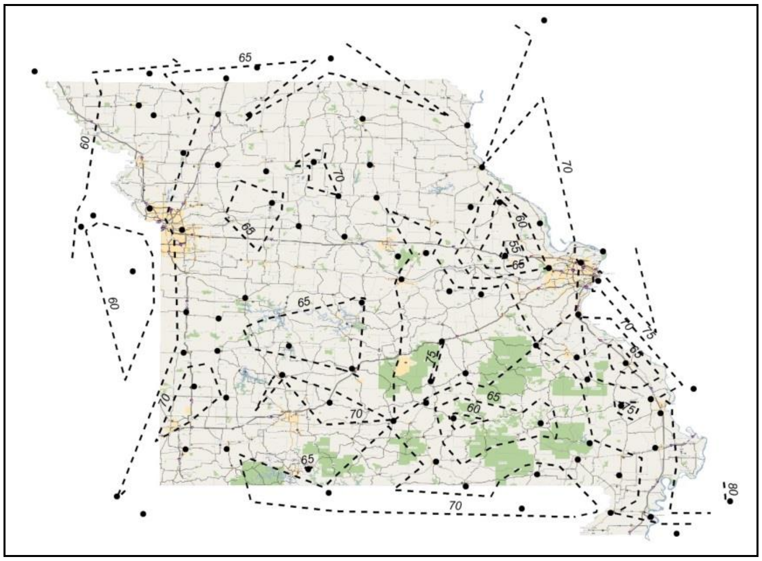

Fig.3.25 – Number of wet days per year (>0.1 in. precipitation) DP01 isolines.

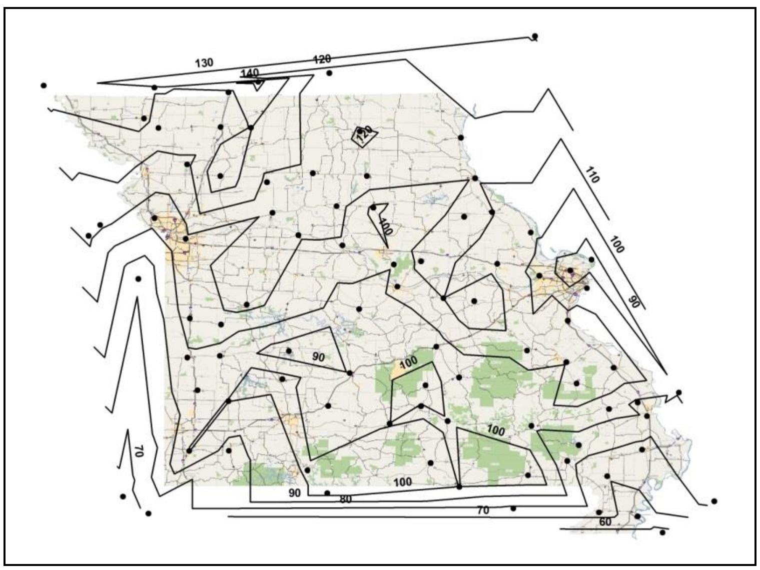

Fig.3.26 – Number of days per year below freezing DT32 isolines.

For directions for extracting climate data from NOAA NCDC website, go to this website:

http://www.ncdc.noaa.gov/cdo-web/

Other agencies have used the Air Freezing Index (AFI) as a predictor of behavior (FAA 1978; UFC 2004). The AFI is a well-established climate parameter used primarily for design of frost protected shallow foundations (FPSF). AFI can be calculated using several methods, but the most commonly specified for FPSF applications is the 100-year return value, AFI (100), that is associated with a 99% probability. However, the Federal Aviation Administration (FAA) has used a "design" AFI value for pavement design, based on work by the US Army Corps of Engineers.

The design AFI is defined as the average freezing index for the three coldest winters over the last 30 years of record. Using seasonal AFI data obtained through the NCDC for the years 1951 through 1980, the design AFI was calculated for weather stations in Missouri and those in the bordering states as near the Missouri border as possible. These calculated design AFI values were compared to the probabilistic values given in tables on the NCDC website. They compared very closely with the 50-year return AFI values, AFI (50), which are associated with a 98% probability. Therefore, the decision was made to use the AFI (50) value as an additional climate parameter of interest in this study. Figure 3.27 shows the plot of the weather stations and generated isolines for AFI (50) on the state map.

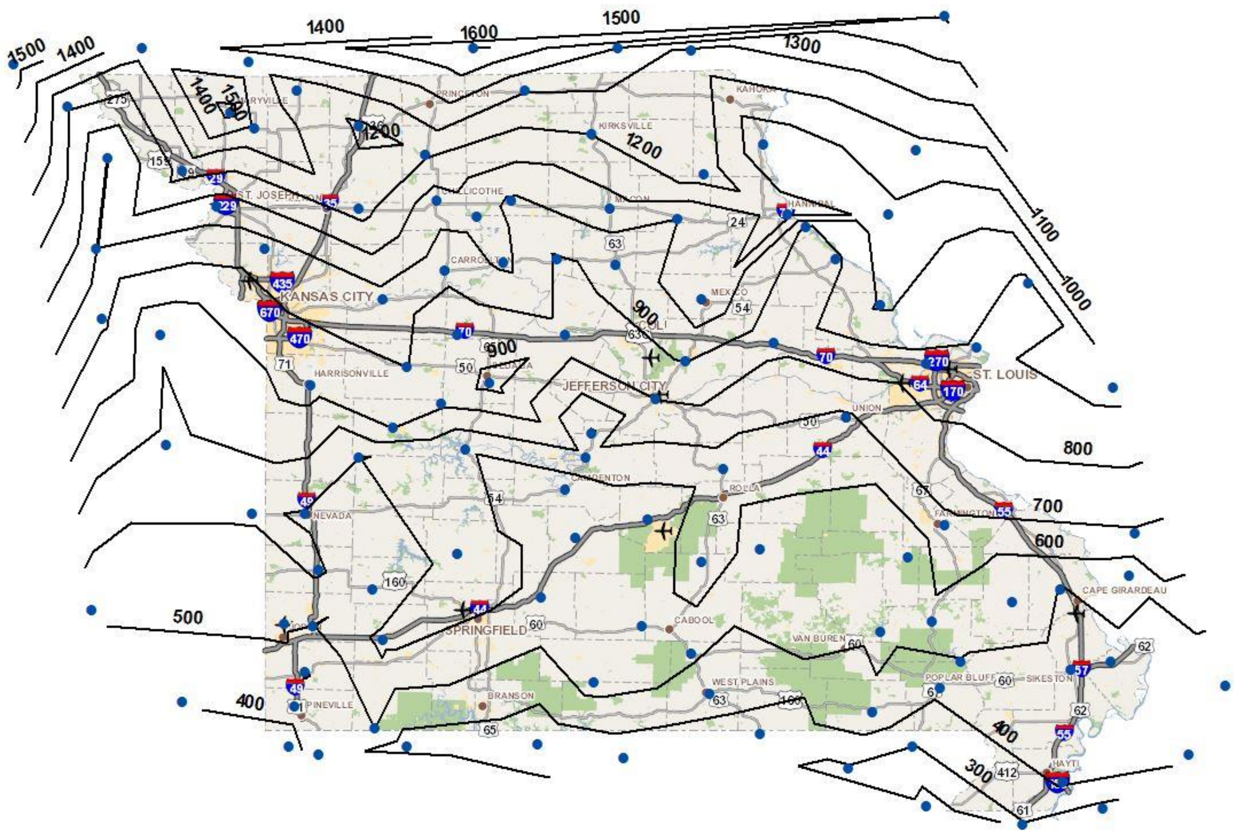

Fig. 3.27 – AFI (50) isolines.

Finally, the number of freeze/thaw cycles was also investigated as a predictor of behavior. Freeze/thaw cycles were obtained from AASHTOWare in the Climate portion of the program. The average latitude and longitude of each study roadway segment was calculated, then used in AASHTOWare to create a virtual weather station from three or more actual stations for each roadway segment, which displayed the number of freeze/thaw cycles for each segment. It is recommended that when creating a virtual station, the choice of actual weather stations be in a consistent manner, e.g. place the roadway location near the apex of a triangle of actual stations. Table 3.7 contains the climate data used in this study.

Table 3.7 Climate data used in Task 2 report

County	Travelway Designation/Name	Travel Direction	BegLog (mile)	EndLog (mile)	Length (miles)	AADT	Climate Data DP01 (days/yr)	DT32 (days/yr)	AFI(50) (°F-days)	F/T (cycles/yr)
Asphalt Pavement Sections										
Washington	MO 21	South	60.00	66.00	6.00	1700-3500	69.9	102.1	563	69.6
Morgan	MO 52	East	129.10	137.10	8.00	1700-3500	65.2	97.1	682	59.4
Laclede	MO 32	East	93.80	97.10	3.30	1700-3500	65.4	92.3	554	57.8
Phelps	RT BB	East	4.00	11.00	7.00	1700-3500	74.3	98.3	611	69.3
Pulaski	RT T	South	0.60	4.60	4.00	1700-3500	68.6	92.8	536	58.8
Moniteau	MO 5	South	175.00	178.50	3.50	1700-3500	66.0	99.5	752	63.3
Cole	RT C	East	28.10	33.10	5.00	1700-3500	69.5	100.6	770	74.4
Boone	MO 124	East	27.20	31.20	4.00	1700-3500	70.5	105.2	939	66.8
Callaway	RT F	East	6.70	8.80	2.10	1700-3500	71.0	111.0	928	67.1
Gasconade	MO 28	East	57.70	63.70	6.00	1700-3500	73.3	110.8	685	66.0
Washington	MO 47	South	91.00	96.00	5.00	750-1700	68.8	101.3	649	65.0
Gasconade	MO 19	South	107.80	111.20	3.40	750-1700	73.2	112.3	664	68.5
Pulaski	MO 17	South	31.70	35.20	3.50	750-1700	69.0	93.5	583	61.3
Camden	MO 7	South	134.00	138.60	4.60	750-1700	63.5	89.1	576	60.1
Cooper	MO 135	South	0.82	5.82	5.00	750-1700	68.0	106.2	877	61.6
Laclede	MO 64	East	41.00	46.90	5.90	750-1700	64.2	90.2	574	58.8
Boone	RT E	South	0.00	10.00	10.00	750-1700	69.0	101.8	897	64.6
Howard	MO 240	East	43.80	47.40	3.60	750-1700	69.2	105.8	882	64.9
Callaway	RT C	South	1.94	6.34	4.40	750-1700	71.6	111.7	888	72.0
Dent	MO 32	East	176.90	179.90	3.00	750-1700	72.3	92.0	538	62.4
Washington	MO 185	South	39.70	45.70	6.00	400-750	70.9	109.2	629	68.9
Osage	RT T	South	1.90	6.90	5.00	400-750	72.5	100.8	736	65.9
Miller	MO 17	South	8.70	11.70	3.00	400-750	66.6	94.1	695	62.9
Pulaski	MO 133	South	45.80	50.20	4.40	400-750	69.5	93.6	576	61.5
Phelps	RT F	East	9.10	13.30	4.20	400-750	73.5	96.5	585	67.6
Morgan	RT W	South	1.50	10.50	9.00	400-750	65.2	97.4	725	58.5
Laclede	RT J	East	1.80	9.10	7.30	400-750	68.0	91.3	572	59.6
Howard	MO 3	South	69.70	73.50	3.80	400-750	69.6	108.3	886	65.0
Boone	RT N	South	0.20	5.60	5.40	400-750	68.3	102.1	873	66.4
Callaway	RT B	East	3.30	6.70	3.40	400-750	70.2	112.7	967	66.3
Osage	MO 133	South	6.00	12.40	6.40	<400	71.5	99.6	734	69.5
Crawford	RT M	South	1.10	5.90	4.80	<400	72.6	101.7	593	66.6
Dent	RT K	South	5.30	13.30	8.00	<400	67.9	94.0	527	61.1
Camden	RT J	South	4.10	8.10	4.00	<400	63.6	89.3	553	57.9
Cooper	RT J	East	6.70	15.50	8.80	<400	67.8	103.7	798	55.3
Howard	MO 87	South	5.40	10.40	5.00	<400	69.3	110.2	903	64.9
Cole	RT E	East	1.30	5.50	4.20	<400	69.6	99.3	759	73.0
Boone	RT HH	East	1.80	5.30	3.50	<400	69.7	103.4	908	65.9
Callaway	RT D	South	4.30	12.20	7.90	<400	67.3	111.4	864	68.3
Gasconade	RT Y	East	0.10	5.70	5.60	<400	72.8	111.8	702	67.4
Composite Pavement Sections										
Grundy	MO 6	East	70.90	76.20	5.30	1060 to 2324	66.1	128.3	1210	69.3
St. Francois	MO 8	East	63.60	68.35	4.75	3019 to 6657	71.0	101.7	627	65.9
Lawrence	MO 174	East	4.05	6.25	2.20	1308	69.8	92.5	622	60.4
Cooper	RT M	South	0.06	3.97	3.91	184	68.1	106.9	857	64.4
Schuyler	US 63	South	13.70	15.80	2.10	2224 to 2381	66.2	118.2	1265	78.1
Grundy	US 65	South	23.53	26.53	3.00	777 to 984	65.4	127.7	1290	69.6
Butler	US 67	South	186.64	191.84	5.20	2203 to 2489	70.1	92.3	372	67.0
St. Francois	MO 32	East	242.20	244.30	2.10	890 to 1024	70.6	101.0	603	67.0
Cooper	MO 87	South	22.63	24.70	2.07	2074 to 2357	68.8	107.1	866	62.9
Monroe	US 24	East	160.10	162.80	2.70	843 to 1052	69.5	103.9	1030	65.8
Pettis	US 50	East	85.65	88.95	3.30	2194 to 3737	66.9	105.3	904	53.3
Phelps	US 63	South	204.60	207.40	2.80	2609	74.7	97.2	652	66.1
Phelps	US 63	South	233.00	237.50	4.50	1732 to 2023	75.0	104.3	675	66.1

3.23 Coring Data

Core data that is collected for project-scoping purposes (non-construction acceptance) is archived electronically in the specific project folder-of-interest by the Construction and Materials division on its J-Drive. Coring information can also be found in ProjectWise and may be on plan sheets where bridge replacement has occurred.

3.24 Non-Destructive Evaluation Data

Falling Weight Deflectometer (FWD) data that is collected for project-specific purposes is archived electronically by the Construction and Materials division.

3.25 Summary and Conclusions

Data sources for MoDOT's pavement management system are summarized in Table 3.8. The table describes the information presented in each data source, how to access each data source, and provides additional comments on the data sources as necessary.

Table 3.8 – Summary of certain select data sources

Data Source	Description of Data	How to Access	Other Comments
ARAN Viewer	Still images of all roadways from the video records of MoDOT's ARAN van	Link on TMS homepage.	
ARAN Inventory Tables	Raw IRI data; a record every 0.02 mile or about 105 feet. Other pavement data similar to that in the SS Pavement database is also available	A pass-through query system within MoDOT Planning Division created Microsoft Access database files	A specialized process not generally available.
SS Pavement	Database of pavement data, including route information, pavement performance (IRI, condition index, cracking, rutting), and traffic	Database files are available through MoDOT Planning Division. The files can be used with database software (e.g. Microsoft Access) for searching or with GIS software (e.g. ESRI ArcMap) for visualization	
Rag Maps	Plan view of routes in a county with notes showing the extents and listing the general summary of projects and major maintenance along the route	http://wwwi/intranet/tp/products/projecthistory/projecthistorymaps.htm	History dates back to the 1920s and typically continues until the 1990s.

STIP Management	Database of projects completed through MoDOT's STIP. Projects can be searched by job number, route, district, and county	Link on TMS homepage	Project records on the STIP database often include construction plans.
Asphalt Summary Sheets	One set of asphalt summary sheets comprises a table of asphalt work for the table year. The table lists a project number, log miles, treatment type, and treatment history for each project	Research team scanned all asphalt summary sheets and provided files to MoDOT	
Concrete 2-AA Sheets	As-built summary sheets for concrete paving projects, including detailed information on the pavement (typical cross-section, materials used and their source, subgrade, concrete mix proportions, reinforcement, joints, etc.)	Research team scanned all concrete 2-AA sheets and provided files to MoDOT	
District Maintenance Data	In-house pavement maintenance data such as surface treatment type, location, and date; e.g. chip seals, scrub seals, fog seals, as well as contract overlays	District pavement specialists and/or maintenance superintendents: electronic spreadsheets or personal interview	
Traffic	AADT counts and commercial volume data are presented on ARAN Viewer page and in SS Pavement database. Additional traffic data is available through TR 50 reports.	See above for ARAN Viewer and SS Pavement info. TR 50 reports are generated on the TMS webpage. From the homepage, select Reports link and then Traffic Reports.	Traffic data from SS Pavement was primary source for Task 1 collection efforts.
Subgrade	Project-specific data may be available (e.g. Concrete 2-AA sheets).Specific data related to subgrade can be found in Preliminary Geotechnical Reports. More general data can be found in the Geology & Soils Manual and updated files.	Preliminary Geotech Reports can be obtained from the Soils & Geology section. County soil surveys can be downloaded from http://websoilsurvey.nrcs.usda.gov/app/	
Climate	Climate data is available through NOAA.	http://www.ncdc.noaa.gov/	
Pavement Cores	Pavement material and thickness	Archived electronically by Construction & Materials in project-specific files	
Non-Destructive Evaluation	FWD data	Archived electronically by Construction & Materials in project-specific files	

Other Construction Data	Construction of other assets (e.g. culverts) often results in incidental data about pavement cross-sections.	Data not collected at present	

4 PROCEDURE FOR PAVEMENT DATA RETRIEVAL AND RESULTS

The data sources described in Chapter 3 were used to collect data for use in other tasks, primarily Tasks 2 and 5, and for routine use by MoDOT pavement selection specialists. Task 2 used the data collected from Task 1 to develop pavement family and treatment models. Task 5, in turn, used the Task 2 models to develop decision processes. Chapter 4 describes the Task 1 data collection efforts and presents example results.

Out of the 22 desired types of information shown in the literature to be relevant to pavement treatment performance, as presented in Chapters 2 and 3, only 12 were able to be elicited with any success from the data sources, and of these 12, only eight with regularity. It should be noted that all routes were minor, and many were letter routes. A summary of this comparison is shown in Table 4.1.

Table 4.1 – Information desired vs. successfully collected in this study

Significant Data Collected/Desired in the Literature	**Significant Data Collected in This Study**	**Frequency of Success**	**Used in Models**
Roadway Segment:			
Original pavement type	Original pavement type	Always	yes
Layer thicknesses	Layer thicknesses	Sometimes	yes
Base characteristics		Seldom	
Subgrade type	Subgrade type	Estimate-only	yes
Condition prior to treatment	Condition prior to treatment	Sometimes	yes
Condition after treatment	Condition after treatment	Sometimes	yes
Quality of treatment materials		Seldom	
Treatment construction quality		Seldom	
Interim maintenance types	Interim maintenance types	Usually	yes
Interim maintenance intervals	Interim maintenance intervals	Usually	yes
AADT	AADT	Always	yes
Accumulated truck traffic	Accumulated truck traffic	Estimate-only	yes
Axle load distribution		Never	
Layer ages	Layer ages	Sometimes	yes
Climate	Climate	Always	yes
Functional classification	Functional classification	Always	
Performance Data:			
IRI, segment average	IRI, segment average	Always	
IRI, raw	IRI, raw	Always	
Composite Condition Index		PASER too new; old CI phased out	
Individual distress Indices		Old indices phased out	
Individual distress extent		Old data phased out	
Individual distress severity		Old data phased out	

4.1 Procedure

The procedure for mining pavement data from the MoDOT and non-MoDOT data sources described in Chapter 3 involved identifying candidate roadways, collecting raw data for those roadways, processing the data to improve its usefulness for subsequent tasks, and preparing it for use. These steps are described in further detail in the sections below.

4.1.1 Select Roadway Segments

The Pavement Preservation Research program study scope was limited to “minor” roads. Table 4.2 shows the different roadway classifications that MoDOT uses. It is somewhat difficult to determine exactly what the definition of “minor” roads is in terms of AADT. This is an important distinction because of the way the pavement families were determined for model-building. For this study, the cut-off of less than 3500 AADT was used.

Table 4.2 MoDOT road classification systems

Functional Classification		**State System Classification**	**Design Pavement Name**		**Major-Minor**	**Pavement Direction Manual**	**Roadway Types**	**EPG Section VII**
Rural	Urban		Duty	ADT				
Interstate	Interstate	Interstate	Heavy Duty		Major	Interstate	Freeway	Interstate 3500 AADTT
Principal Arterial	Other Freeway & Expressway	Primary	Medium Duty		Major	Major	Expressway	
Principal Arterial	Other Principal Arterial	Primary	Light Duty LA	3500-12,000	Major	Major	Multi-lane	
Minor Arterial	Minor Arterial	Primary/ Supplementary	Light Duty LA	3500-12,000	Minor	Regionally Significant Minor	Shared 4 lane	Minor Arterial 1750-3500 AADTT
Major Collector	Collector	Supplementary	Light Duty LB/LC/LD	1700-3500	Minor	Minor >400 ADT	5 Lane	Major Collector 450-1750 AADTT
				750-1700				
				400-750				
Minor Collector		Supplementary	Light Duty LC/LD/LE	750-1700	LowVol	Minor <400 ADT	3 Lane	Minor Collector <450 AADTT
				400-750				
				<400				
Local	Local	Supplementary	Light Duty LE	<400	LowVol	Minor <400 ADT	Super 2 Lane	
Local	Local	Supplementary	Light Duty LE	<400	LowVol	Minor <400 ADT	2 Lane	

Note: Caution: Alignment across columns may not be accurate because of differing definitions

Selection of roadway segments was conducted in close coordination with Task 2, which developed pavement family and treatment models. Originally, roads were classified as to “Design Pavement Name” because it is the best system for delineating design features: traffic levels, internal drainage, widened travelways, and type of shoulders. However, this effort was abandoned because of so many missing records in SS Pavement. Ultimately, pavement families were comprised of two-lane, undivided highways, and further defined by pavement type (full-depth asphalt, concrete, or composite) and traffic level (for the full-depth asphalt family, there were four traffic levels based on AADT: less than 400, 400-750, 750-1700, 1700-3500). “Full-depth” was defined as an asphalt pavement with no concrete in the cross-section. Very few “Full-Depth” asphalt pavements were truly full-depth, but actually had some unbound granular base beneath the asphalt.

Ten candidate full-depth asphalt routes for data collection were identified for each of the four traffic levels using ArcMap with SS Pavement data. At the recommendation of the MoDOT Research leadership, for most pavement families, all full-depth routes were selected from the Central District to serve as a model of how the rest of the state pavement system should eventually be modeled. Routes for each traffic level were selected from across the district, usually three north of the Missouri River and seven south of the Missouri River, to provide some geographic, subgrade, and climate variability.

Additionally, 13 composite segments at up to 12,000 AADT were evaluated over a larger geographic area to garner a sufficient number of segments. There were no concrete-only segments that satisfied the above requirements for a separate dataset. Ultimately, routes in 24 counties across six districts (Central, NE, NW, Kansas City, SE, and SW) were sampled. Fig 4.1 shows an example of the use of ArcMap.

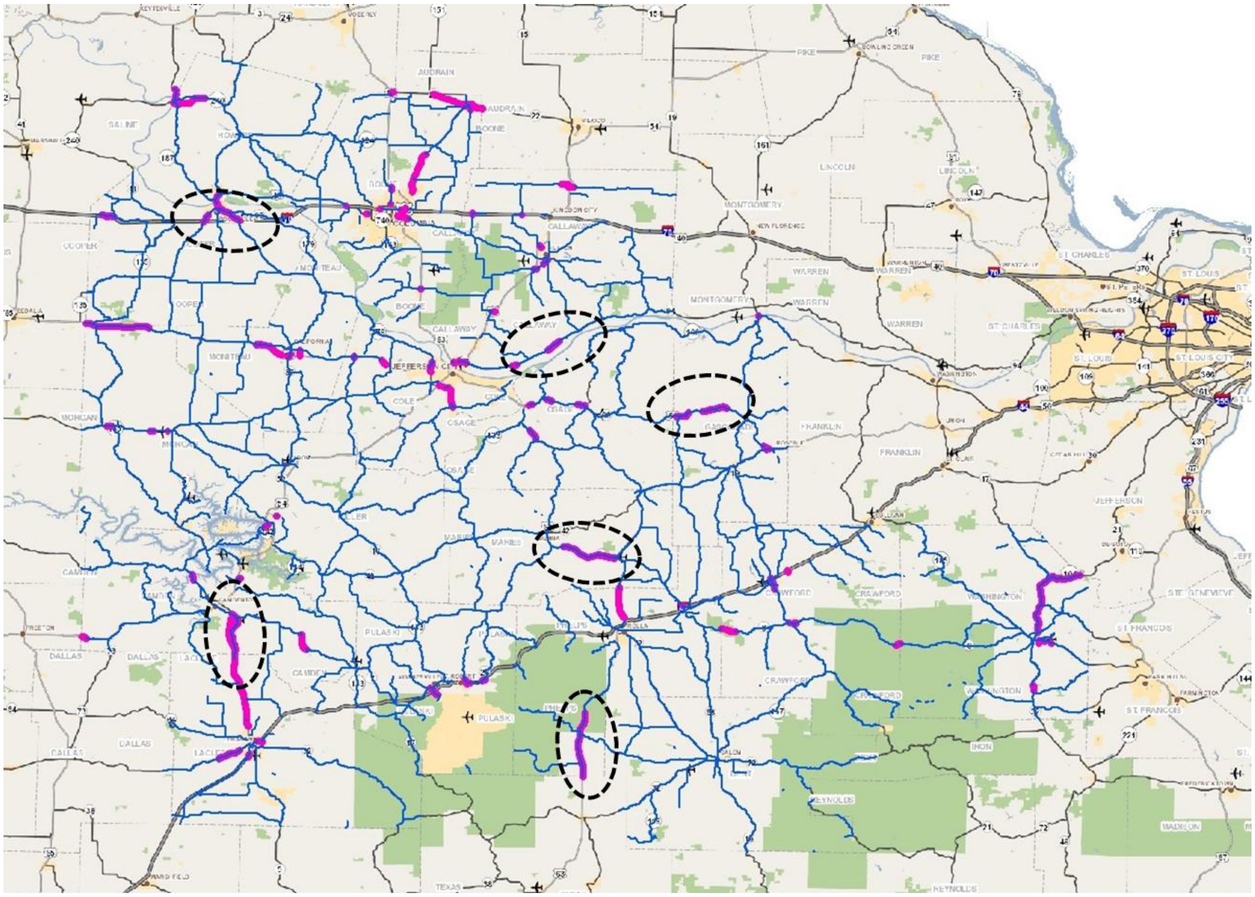

Fig. 4.1 – Example of using ArcMap to find study routes. Highlighted routes are composite pavement segments in the Central District with AADT less than 12,000 on a two-lane undivided roadway.

After the potential routes were identified, they were screened with ARAN Viewer to delineate continuous and homogenous segments of at least 1 mile in length. Homogeneity was defined as having no change in surface type (e.g. overlays or chip seals, bridges, etc.) and no change in speed (speed limits, stop signs, etc.). This step resulted in a total of 40 full-depth asphalt segments and 13 composite pavement segments. Because each route segment was two-lane, undivided, the actual number of "traveled lane" segments for modeling purposes was 80 full-depth (20 per traffic level) and 26 composite routes.

4.1.2 Extract Raw Data from ARAN Inventory and SS Pavement Databases

Data for the pavement segments were collected by querying the ARAN Inventory tables (for raw IRI, condition index, etc.) and SS Pavement (traffic data) databases using Microsoft Access. The query specified the travelway ID (based on route and direction) and logmiles identified from the previous step of delineating homogenous segments. The queried portion of the database was copied to a spreadsheet for further processing as described in the next step. The results copied to the spreadsheet included IRI, AADT (which is directional by definition), and commercial traffic volume (also by direction), among other fields as described in more detail later.

4.1.3 Data Processing

Processing the data queried from the ARAN Inventory tables and SS Pavement involved verifying records and supplementing them with additional pavement history data. Pavement history was gathered from the sources described in Section 3:

- Rag maps were used to develop an initial summary of pavement history dating back to a road's initial construction.
- Asphalt Summary Sheets were consulted to supplement and confirm the rag map history. The summary sheets were consistent with rag map data and sometimes provided some supplementary information regarding pavement thickness.
- Similarly, Concrete-2-AA sheets were consulted for concrete segments. All relevant details from the sheets were recorded.
- The STIP Management Database was searched to find plan sets from the last 20 years. Any relevant plan sets were saved and details related to pavement structure, like those from the example typical section shown in Fig. 4.2 were recorded. Often the typical sections encountered were less detailed, such as the example of Fig. 4.3.
- District Maintenance Spreadsheets: researchers made personal visits to various District Pavement Specialists and Maintenance Supervisors to review the information for each project section in order to: 1) verify the data that the researchers have found (see above discussions), 2) add any treatments that were missing in the MoDOT central databases, and 3) review the pavement selection and maintenance planning procedures in-place at the district level. The data are either in spreadsheet form on personal computers, or in individual memories. Some spreadsheet information is presently being placed on SharePoint.

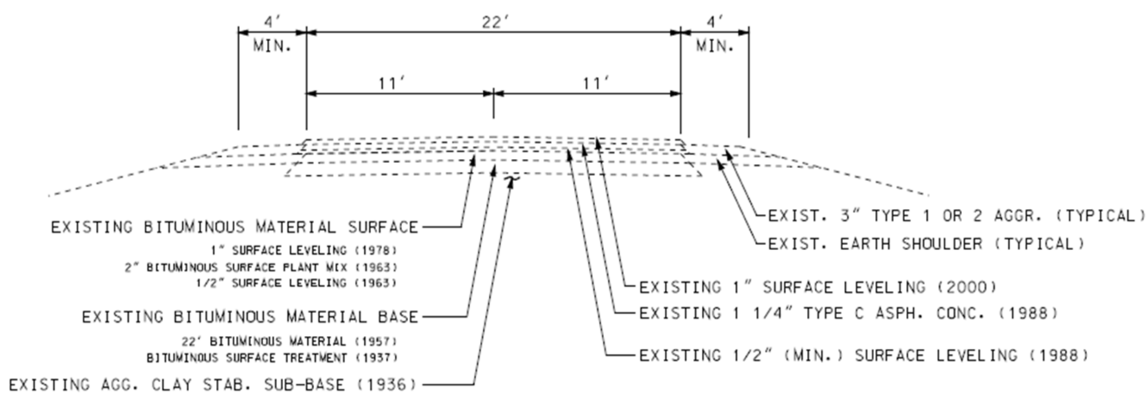

Fig. 4.2 – Example typical detail from project plans.

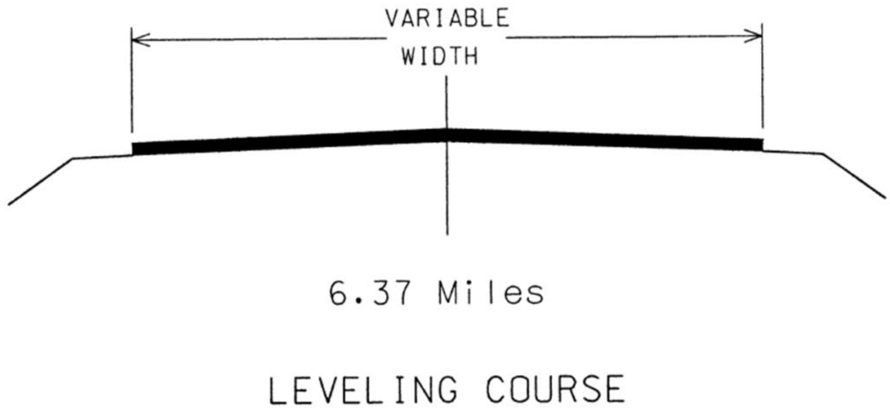

Fig. 4.3 – Example typical section with minimal detail.

Traffic data were also summarized and verified. SS Pavement includes fields (column headings in spreadsheet) for directional AADT and commercial vehicle volume. These were verified along the route for the last five years using traffic data listed on the ARAN Viewer site. A table of traffic counts from both SS Pavement and ARAN Viewer for the past five years was created, as in the example of Table 4.3. Typically, both data sources were consistent, but not always.

Table 4.3- Example of traffic counts

		ARAN		SS Pavement	
Year	**Direction**	**AADT**	**ComVol-by-dir**	**AADT**	**ComVol-by-dir**
2008	South	1711	147	1470	236
2009	South	1708	146	1708	146
2010	South	2177	278	2177	278
2011	South	2155	277	2155	277
2012	North	1833	241	2133	274
"Current"		1833	241		

Finally, a detailed review of all ARAN Viewer records for each route was conducted. The review included all video records available with the TMS viewer; typically, the review included about 10 years of data. For each year, detailed notes such as the example in Fig. 4.4 were recorded to note any observations related to pavement condition and/or surface changes.

ARAN NOTES

…

2007
-Road in same condition as previous year, but showing significantly more wear.

2008
-Small Intermittent patching, spaced every 20' (Pot holes, shoulder reinforcement, center filling) 175S-178S

-Northbound Patch at 175.091S for 5' (Center of lane)
-Northbound Patch at 175.122S for 5' (Center of lane)
-Northbound Patch at 175.138S for 5' (Center of lane)
-Southbound Patch at 175.169S for 2' (edge Patch)

…omitting 100 lines…

-Northbound patch at 177.936 for 10' (median)
-Northbound patch at 177.998 for 10' (Median)
-Northbound patch at 178.013 for 10' (median)
-Northbound patch (median)
-178.029
-178.06
-178.076

Fig. 4.4 – Example of notes of observations from ARAN Viewer records.

4.1.4 Data Presentation

The results for each study route were compiled in the spreadsheet file originally extracted from the ARAN Inventory tables and SS Pavement. Pavement history was indicated in additional columns regarding treatment types and thicknesses, with color highlighting used to indicate changes. Traffic tables (e.g. Table 4.4) were added to each spreadsheet file, and graphics related to pavement history were also pasted into the spreadsheet file (e.g. ragmaps Fig. 3.2 and cross-sections Fig. 4.2). Finally, a summary of ARAN Viewer notes was included in a textbox (e.g. Fig. 4.4) in the spreadsheet file.

4.2 Results

The procedure outlined in Section 4.1 was implemented for each family, most of which had 10 study routes. This section summarizes the work completed, references, and explains how the work has been communicated with other tasks from the Pavement Preservation Research program.

4.2.1 Summary of Study Routes

Table 4.4 shows the selected composite pavement segments for analysis. A range of AADT values indicates changes in traffic counts due to the travelway segments encountering an intersection but without a reduction in travel speed. The SS Pavement query parameter was set to less than or equal to 12,000 AADT. The AADT range was increased from that used for asphalt segments (<400-3500) to garner more sections. It should be noted that the Current AADT values extracted from the Current SS Pavement tables were used and reported.

Table 4.4 –Composite segments for analysis

Location				Current AADT
County	Travelway Designation/Name	Travel Direction	Beginning/Ending Logmile (current)	
Grundy	MO 6	East	70.9/76.2	1060 to 2324
St. Francois	MO 8	East	63.6/68.35	3019 to 6657
Lawrence	MO 174	East	4.05/6.25	1308
Cooper	RT M	South	0.06/3.97	184
Schuyler	US 63	South	13.7/15.8	2224 to 2381
Grundy	US 65	South	23.53/26.53	777 to 984
Butler	US 67	South	186.64/191.84	2203 to 2489
St. Francois	MO 32	East	242.2/244.3	890 to 1024
Cooper	MO 87	South	22.63/24.7	2074 to 2357
Monroe	US 24	East	160.1/162.8	843 to 1052
Pettis	US 50	East	173.4/176.7	2194 to 3737
Phelps	US 63	South	204.6/207.4	2609
Phelps	US 63	South	233/237.5	1732 to 2023

Table 4.5 shows the selected full-depth asphalt pavement segments for analysis. The AADT range was the one of the SS Pavement query parameters and was used to assign a particular segment to a pavement family.

Table 4.5 – Full-depth asphalt sections for analysis

Location				AADT Range
County	Travelway Designation/Name	Travel Direction	Beginning/Ending Logmile (current)	
Washington	MO 21	South	60/66	1700 to 3500
Morgan	MO 52	East	129.1/137.1	
Laclede	MO 32	East	93.8/97.1	
Phelps	RT BB	East	4/11	
Pulaski	RT T	South	0.6/4.6	
Moniteau	MO 5	South	175/178.5	
Cole	RT C	East	28.1/33.1	
Boone	MO 124	East	27.2/31.2	
Callaway	RT F	East	6.7/8.8	
Gasconade	MO 28	East	57.7/63.7	
Washington	MO 47	South	91/96	750 to 1700
Gasconade	MO 19	South	107.8/111.2	
Pulaski	MO 17	South	31.7/35.2	
Camden	MO 7	South	134/138.6	
Cooper	MO 135	South	0.82/5.82	
Laclede	MO 64	East	41/46.9	
Boone	RT E	South	0/10	
Howard	MO 240	East	43.8/47.4	
Callaway	RT C	South	1.94/6.34	
Dent	MO 32	East	176.9/179.9	
Washington	MO 185	South	39.7/45.7	400 to 750
Osage	RT T	South	1.9/6.9	
Miller	MO 17	South	8.7/11.7	
Pulaski	MO 133	South	45.8/50.2	
Phelps	RT F	East	9.1/13.3	
Morgan	RT W	South	1.5/10.5	
Laclede	RT J	East	1.8/9.1	
Howard	MO 3	South	69.7/73.5	
Boone	RT N	South	0.2/5.6	
Callaway	RT B	East	3.3/6.7	
Osage	MO 133	South	6/12.4	<400
Crawford	RT M	South	1.1/5.9	
Dent	RT K	South	5.3/13.3	
Camden	RT J	South	4.1/8.1	
Cooper	RT J	East	6.7/15.5	
Howard	MO 87	South	5.4/10.4	
Cole	RT E	East	1.3/5.5	
Boone	RT HH	East	1.8/5.3	
Callaway	RT D	South	4.3/12.2	
Gasconade	RT Y	East	0.1/5.7	

4.2.2 Coordination with Other Tasks

Coordination between Tasks 1, 2, and 5 was relatively seamless because several of the various Task team members were on all three teams.

5 CONCLUSIONS AND RECOMMENDATIONS

This report has detailed the MoDOT, NOAA, ASU, USDA, and AASHTOWare data sources pertinent to pavement management and the data collection efforts undertaken to assist in development of MoDOT's pavement management system. Included in this chapter is a summary of these efforts and recommendations for improvements to the data collection methodology.

5.1 Pavement Data Sources

MoDOT data sources useful for the development of a pavement management system were described in Chapter 3. Table 3.1 summarized the data types and data sources.

5.2 Data Collection Procedure

The MoDOT pavement data sources were used for collection of sufficient data for use by other tasks within the Pavement Preservation Research program, primarily by Task 2 (pavement family and treatment performance modeling) and Task 5 (treatment trigger and decision method development). The procedure for collecting data involved identifying homogenous sections meeting the criteria for each family (i.e. pavement type and traffic level), querying databases to collect raw data, verifying the raw data and supplementing it with pavement history (e.g. 2-AA sheets, asphalt summaries, STIP, etc.) and ARAN video observational data, and preparing the data for presentation to other tasks. This procedure was sufficient for the Pavement Preservation Research program data needs, but it is rather labor intensive, and efficiency improvements would result in major savings in time for an implemented pavement management system. Recommendations related to these efficiency improvements are presented below.

5.3 Data Sources

The following data sources have been successfully accessed. Included in the list is basic information about the data gathered from them.

- SS Pavement databases: Current (active) and Historic (1999 up to active)
    - Dynamically segmented records; i.e. pavement segment lengths per record are variable
    - Data includes ARAN year, roadway name and travelway ID, locations (e.g. county, beginning and ending logmiles), roadway type and functional classifications, condition parameters (e.g. IRI, condition index, individual distress indices), traffic (AADT and commercial volume), most recent surface type and date
- ARAN databases: Survey (2001 to present, inclusive) and Historic (1988 to 2000, inclusive)
    - Raw ARAN data; i.e. each record represents approximately 0.02 miles (~105 feet) of pavement

    - Data includes ARAN year, date that the data was collected (mm/dd/yyyy), roadway name and travelway ID, locations (e.g. county, beginning logmile), same condition parameters as SS Pavement
- Project History Maps, a.k.a. Ragmaps (MoDOT Intranet)
    - Construction history: location, date, type of pavement surface, project job numbers
- 2-AA Sheets and Asphalt Summaries (hard copy scans)
    - Historic as-built information
        - 2-AA sheets: concrete pavement projects; data can be very comprehensive and includes location (stationing), concrete mix design, structural thicknesses, base and subgrade information
        - Asphalt summaries: much of the data corresponds to that on the ragmaps; route, county, date construction completed, project job number and approximate location, existing base/subsurface (historic), surface being constructed (depending on the year, mix type and thickness, tons/mile, begin-end logs)
- Archived Project Plan Sheets (MoDOT Z-drive)
    - Project plan drawings in PDF file format: typical section drawings, geometries, quantities, etc.
- STIP Management (MoDOT Intranet: TMS)
    - An additional portal for finding more recently archived project plan files
- ARAN Viewer (MoDOT Intranet: TMS)
    - Primary method for visual verification of information already gathered, and determining if a treatment occurred that was not documented in databases
        - SS Pavement data can be accessed (back to and including 2003)
        - Most recent project plan drawings associated with segment of interest may be available
- TR50 Reports (MoDOT Intranet: TMS)
    - Primarily traffic data (AADT and commercial)
- Historic State Highway Maps (MoDOT internet and intranet)
    - Annually published maps that indicate roadway surface type; can help determine when a pavement segment was originally paved
- Pavement Tool
- SharePoint
- ProjectWise
- J-Drive
- CDs and microfilm
- Site Manager
- District Maintenance Spreadsheets
- ASU and USDA county soils maps
    - County maps that indicate soil properties, extent, depth, and position
- NOAA and AASHTOWare climate data

    - Various types of precipitation and temperature data

5.4 Pavement Data Recommendations

5.4.1 "Ideal Situation"

The primary purpose of the project was to outline a *process* that would allow MoDOT to do more selective planning, better engineering, and more effective maintenance in order to minimize costs while maintaining adequate safety and performance of Missouri's pavements. The project researchers envisioned developing a *user-friendly, single online portal* that would allow pavement engineers, district pavement specialists, and district maintenance supervisors to access *all data* pertinent to their particular tasks, *without leaving their desks or requesting special access methodology*.

Developing and implementing the scenario outlined above will require considerable effort. Some of the details involved with enhancing the current system and processes that will continually update any future system are discussed below.

5.4.2 Immediate Improvements

All of the MoDOT stakeholders should be called together to discuss their needs and expectations for going forward, and develop a plan for doing so. Stakeholders will probably include personnel from divisions of Design, Planning, Construction and Materials, and Maintenance at both the district and central levels. It is imperative that the stakeholders are quickly educated about any shortcomings of the current system, from all perspectives.

5.4.3 Short-term Improvements

District pavement specialists that have been contacted have indicated that efforts are underway to find missing historical data in the various data repositories. These efforts should be moved up the priority list. Subsequently, existing data should be subjected to intense quality control inspections. One of the consequences of the Task 1 (and corresponding Task 2) activities has been identification of missing data, data entry errors, placeholder entries, redundancies and terminology inconsistencies across databases. The following is a list of some of those findings:

- Fields of interest in SS Pavement, etc., are incomplete; i.e. a significant amount of historical data needs to be recovered, checked for accuracy, and added to existing databases. Some such fields of interest are Design Pavement Name, SURFACE DATE, FUNCTIONAL CLASSIFICATION, SURFACE TYPE, TRF SEG INFO SED ID, Divided_Undivided.
- Some of the Surface Type and Surface Date records in SS pavement are not accurate in that they do not always reflect the traveled lane associated with a specific record. For example, it was discovered that data in these fields sometimes actually referred to work recently performed on the shoulder or left/right turn lanes rather than the traveled way. Creating fields for more specific roadway features would be helpful.
- In some cases, the Surface Type recorded did not correlate with the distress indices for the same segment of roadway. This may be connected to the previous bullet-point.

- SS Pavement location description errors; intersecting routes are shown in wrong counties
- SS Pavement irrational concrete surface type changes; PCN for many years then designated as PCR for 2010 and 2011
- The ARAN tables also contained some problematic entries. For example, IRI values of 999 or entire ARAN years where the condition index or IRI was non-changing across the length of a roadway segment.
- Although it may be impossible to rectify, the IRI values during the ARAN years of 1997 to 2001, inclusive were reportedly incorrect due to an algorithm error. This data was disregarded during modeling.
- In the ARAN tables, the driver and passenger IRI are recorded every 0.02 mile. It was found, fairly regularly, that errors in one or the other (usually the passenger IRI) existed which would have adversely skewed the average or raw (Unit) IRI value. The understanding is that mechanical issues in the ARAN van (e.g. bad accelerometers, calibration, etc.) were most likely the cause of this error.

5.4.4 Recommendations for Future Work

To review, good modeling requires existing pavement layer thickness and material types, granular base data, subgrade soil and drainage information, quality of treatments, all types of vehicle traffic data, and a variety of pavement condition indicators.

1. Regarding future data collection and storage, standardization of the various database fields and record entry descriptions (and codes) across *all* stakeholder departments would be extremely beneficial. The language and terminology used by the maintenance personnel should translate effortlessly with the pavement engineers, materials technicians, construction inspectors, etc.

2. In addition to all of the databases and other data sources outlined in section 5.3, the Pavement Tool (maintenance-oriented) should be incorporated into the single portal. The Tool could be improved by adding features such as the following, thereby allowing more input flexibility for district maintenance personnel:

- More treatment type choices and details (e.g. limestone or trap rock chip seals)
- Milling details such as depth of cut and transverse location of milling-machine passes
- Bituminous treatment thickness data whether input directly or estimated based on tonnage, design mix density, project width and length
- Specific bituminous mix types

3. It would be beneficial to pavement engineers to be able to access construction data from SiteManager through the single portal. Because material sampling and testing data collected during a project is entered into SiteManager, detailed information such as core data (as-built density and layer thickness [especially if full-depth coring information is available as recommended elsewhere in this document]) and mix characteristics (which may raise red flags

and prompt requests for more detailed data, such as coring), may help fine-tune the decisions made by planners on a future treatment selection for that project segment. If the ProjectWise (engineering) application and the SAM II (maintenance costs) database supply valuable, pertinent capabilities, they, too, should be easily accessible through the single portal.

Characterizing the structural configuration of existing roadways would be extremely helpful in improving the treatment selection process and the upgrading of performance models. It is evident that coring is the most reliable method for determining structural layer thickness, material makeup, and current condition. It is understood that this is an expensive recommendation, but it may be economically feasible to incorporate random coring during construction projects. For example, take one full-depth core (including sufficient subgrade) at some optimum frequency as part of the QC/QA process during projects involving Sections 401 and 403 mixes when cores are being cut anyway. The thing is that this full-depth coring would only have to be done once on any given segment of Missouri's roadways. Once documented, those existing structures would remain as such unless significant rehabilitation/reconstruction occurred. Over time, a considerable amount of full-depth core data could be accumulated with a minimal amount of effort.

4. Traffic data in terms of AADT is useful, but uniform and plentiful information for heavier axle load distributions is not now readily available in the databases commonly used. Truck data is only in terms of commercial truck counts, and data is not necessarily even tied to the purported roadway segment, nor in the same direction.

5. Quality of treatments is so important, yet is not well documented. For instance, it is difficult to determine the combination of mix type, specification year, and construction records for any given treatment on any given segment of a route. It should be understood that the full-depth asphalt pavement models are built from data from the Central District; treatments using aggregate from another district may not last as long.

It is recommended that records be kept as to what materials are going into the treatments. In the future it would be of great help but would take little effort if someone, perhaps from the Field Office in Construction and Materials Division, would maintain a running commentary, construction season-to-construction season very brief description of what changes were made in the specifications, the reasons for making them, and the resulting successes and failures. The commentary should be easily available somewhere for all MoDOT personnel to access. In this way, a judgment could be made as to predicting how well a given treatment with a given material constructed during a given season would last.

In some manner, treatment decision-makers should be able to find out what specification edition was in-force for a given job. In this way, when predicting longevity of a particular treatment for planning, specification-change induced quality could be taken under consideration, i.e., say a given route is being programmed for treatment, if it was known what mix specification was in-force, the programmed treatment date could be delayed or brought forward in consideration of the particular mix's reputation.

6. Any other activity that may lend itself to documenting the existing pavement structure characteristics should be considered. For example, culvert inspection and/or construction, or utility work may be conducive to evaluating the state of the pavement structure, e.g. thickness and type of layers, granular base thickness, and subgrade soil type. Again, some sort of centralized documentation procedure would be necessary.

7. The technology exists at this time to augment the ARAN capabilities with more objective methods of evaluating different pavement distress measures, e.g. video-based evaluation and analysis of crack severity and extent. Consideration of moving to this new technology should be in any plan going forward.

8. The issue of continuing to use logmiles has been ongoing. Fields for longitude and latitude are currently in the ARAN tables and partially populated. Adopting a GPS approach to locations of state assets should be in any future plan.

5.4.5 Summary of Future Augmentation of Treatment Models and Trigger Tables

1. Add more non-IRI distress data: old Condition/Distress Indices were phased out, replacement PASER system not in place long enough at the time of the study (i.e. keep accumulating PASER data)

2. Augment the ARAN with more automated method of distress evaluation, thus enabling the re-establishment of some form of Distress Indices, if found necessary in the Task 5 report.

3. Collect/generate more complete/accurate original pavement thickness data

4. Collect/generate more complete/accurate treatment pavement thickness data

5. Collect/generate more complete/accurate/timely pavement condition prior and after treatment

6. Collect/generate more complete/accurate treatment pavement material type data

7. Collect/generate more complete/accurate treatment pavement material and construction quality data

8. Continue adding subgrade data as it becomes available (see section 5.5.4)

9. Continue adding pavement base data as it becomes available (see section 5.5.4)

10. Continue adding treatment dates

11. Continue adding pavement core data as it becomes available (see section 5.5.4)

12. Make more detailed axle load/truck data available (e.g. TTCs)

13. Actually measure truck traffic for all routes

14. Develop NDE database (FWD and other NDE methods)

15. Develop models for other pavement families and treatment methods

16. Eventually have most routes set up for individual Remaining Service Life models

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APPENDIX 1A – SS PAVEMENT AND ARAN INVENTORY DATABASE DEFINITIONS

The following text defines fields used to populate the SS Pavement database. It was prepared by MoDOT.

DATE CREATED: 10/23/2002

DATE MODIFIED: 08/20/2013

SS_PAVEMENT

Description

Each SS_PAVEMENT record represents pavement breaks on a Traffic Information Segment. A pavement break may be caused by a change in surface type, surface width, city limits, etc. This is one of the tables used to generate our yearly State of the System report.

NAME	*DESCRIPTION*
AADT	Annual Average Daily Traffic. The estimate of typical daily traffic on a road segment for all days of the week, Sunday through Saturday, over a period of one year.
ACCESS_CAT_NAME	Describes the accessibility of a SS_PAVEMENT route.

NAME	*DESCRIPTION*
FULL	FULL ACCESS CONTROL
LIMITED	PARTIAL ACCESS CONTROL
NONE	NO ACCESS CONTROL

ARAN_YEAR	Year the ARAN data was collected.
ARC_ID_BEGIN	The unique identifier of the arc where the segment begins.
ARC_ID_END	The unique identifier of the arc where the segment ends.
ARC_REF_BEGIN	The direction on the arc where the segment begins.
ARC_REF_END	The direction on the arc where the segment ends.
AREA_DESG_NAME	The name of the area designation for this range.

NAME	DESCRIPTION
METROPOLITAN	OVER 200,000 POP.
RURAL	LESS THAN 5,000 POP.
UNDESIGNATED	UNDESIGNATED
URBAN	5,000 - 50,000 POP.
URBANIZED	OVER 50,000 - 200,000 POP.

AREA_ENGINEER — Name of the area engineer where the segment falls in.

AVERAGE_IRI — Average of driver and passenger wheel path (International Roughness Index)

BEG_CONTINUOUS_LOG — The begin continuous log unit defines the beginning of a travelway range or segment. Continuous log units increase throughout the entire length of the travelway and do not change when crossing county lines.

CENTERLINE — Centerline mileage for each SS_PAVEMENT record. Centerline mileage is calculated for travelways with directions of South and East.

CITY_ID — Unique identifier for a City.

CITY_NAME — The city in the City's official mailing address.

CNTL_BEG_CONT_LOG — The begin continuous log unit defines the beginning of a controlling travelway range or segment.

CNTL_END_CONT_LOG — The end continuous log unit defines the ending point of a controlling travelway range or segment.

CNTL_TW_DESG — Route designation for the controlling route.

CODE	DESCRIPTION	HIERARCHY
AL	ALTERNATE ROUTE	4
ALY	ALLEY	22
BU	BUSINESS	7
CO	CONNECTOR FOR WYE LEG	14
COE	CORP OF ENGINEERS	20
CRD	COUNTY ROAD	12
CST	CITY STREET	11
DOD	DEPARTMENT OF DEFENSE	21
FWS	FISH WILDLIFE SERVICE	19
IS	INTERSTATE	1

LP	LOOP (INTERSTATE ONLY)	6
MO	MISSOURI NUMBERED ROAD	3
NFS	NATIONAL FOREST SERVICE	17
NPS	NATIONAL PARKS SERVICE	18
OR	OUTER ROAD	10
PED	PEDESTRIAN	25
PK	PARK	26
PVT	PRIVATE	23
RA	REST AREA	15
RP	RAMP	13
RR	RAILROAD	24
RT	MISSOURI LETTERED ROUTE	5
RV	REVERSIBLE	9
SP	SPUR	8
US	US NUMBERED ROUTE	2
WS	WEIGHT STATION	16

CNTL_TW_DIRECTION Direction of the controlling route.

CODE	DESCRIPTION
E	EAST
N	NORTH
S	SOUTH
W	WEST

CNTL_TW_ID Unique route identifier for the controlling route.

CNTL_TW_NAME Name of the controlling route.

CNTL_TW_OFFSET Offset direction for the controlling route. It is used in conjunction with outer roads.

COMM_VOL_BY_DIR The total commercial volume for a specific travelway segment by directions.

CONDITION_INDEX The sum of distresses that apply to a pavement. For asphalt it is the sum of F Cracking, F Patching, Raveling, and Rut Index. For Concrete, it is the sum of Joint Condition, C Cracking, C Patching, D Cracking, and Spalling.

COUNTY_NAME Official name of the county that the SS_PAVEMENT record falls in. ***Joins with*** **COUNTY**.

COUNTY_NUMBER	Unique identifier for the Counties within the state that the SS_PAVEMENT record falls in.
CRACK_INDEX_FLEX	Rating assigned to the amount of cracking on asphaltic concrete.
CRACK_INDEX_RIGID	Rating assigned to amount of cracking on PCC (Portland Cement Concrete). Ratings are derived from a visual analysis of severity and extent with 0.0 (worst) to 5.0 (best).
DESG_BYWAY_CLS_NM	Names and identifies a Designated Scenic Byway Classification.
DESG_TRUCK_RTE_NM	Classification for the travelways for Federal or State designated truck routes.
DIRECTIONAL	Indicates the direction of the inventory route.
DISTRICT	The MoDOT District (1-7) number that the SS_PAVEMENT record falls in.
DISTRICT_ABBR	Two-letter abbreviation for the seven districts. Valid values are: NW, NE, KC, CD, SL, SW and SE.
DIVIDED_UNDIVIDED	Indicates if the travelway is divided or undivided. A divided travelway is a travelway with any type of barrier or four-foot or greater flush median.
END_CONTINUOUS_LOG	The end continuous log unit defines the ending point of a travelway range or segment.
FED_CLS_NFS	Federal System Classification name - 'National Forest System.'
FED_CLS_NHS	Federal System Classification name – 'National Highway System.'
FED_CLS_PRIORITY	Federal System Classification name – 'Congressional Priority.'
FED_CLS_STRAHCON	Federal System Classification name – 'Strategic Highway Network Connector.'
FED_CLS_STRAHNET	Federal System Classification name – 'Strategic Highway Network' that is assigned to truck routes.

FED_CLS_UNCLASS Federal System Classification name - 'Intermodal Connector.'

FED_SYS_CLS_NAME A unique identifier for the Federal System Classification.

NAME	ABBR	DESCRIPTION
CONGRESSIONAL PRIORITY	CHP	CONGRESSIONAL HIGH PRIORITY ROUTE
CORPS OF ENGINEER	CORP	CORPS OF ENGINEER
FEDERAL AID INTERSATE	FAI	HISTORY – NOT ACTIVE
FEDERAL AID PRIMARY	FAP	HISTORY – NOT ACTIVE
FEDERAL AID SUPPLEMENTARY	FAS	HISTORY – NOT ACTIVE
FEDERAL AND URBAN	FAU	HISTORY – NOT ACTIVE
INTERMODAL CONNECTOR	IC	INTERMODAL CONNECTOR
NATIONAL FOREST SYSTEM	NFS	FOREST ROAD
NATIONAL HIGHWAY SYSTEM	NHS	NATIONAL HIGHWAY SYSTEM
STRAHNET	STR	STRATEGIC HIGHWAY NETWORK STRAHNET
CONNECTOR	STR-C	STRATEGIC HIGHWAY NETWORK CONNECTOR

FUNC_CLASS_NAME This table names and describes the type of functional classification used to categorize a travelway.

Rural

1 Interstate – The interstate Highway System provides service for long distance trips. These trips may begin and end in Missouri, travel through Missouri, or begin or end in another state. All cities with a population of 50,000 or more are served by an Interstate route. Interstate highway standards are such that speeds are high. Access is fully controlled on Interstates, which means entering and leaving the Interstate can only be done at an interchange.

2 Principal Arterial – Principal Arterials serve long distance through trips within a state or from state to state. Together with the Interstate System they serve nearly all cities with a population of 5,000 or more. They also serve major recreational areas. These routes should be two-lane, limited access or fully controlled access divided highways. Provisions should be made to limit traffic interruptions on principal arterials.

6 Minor Arterial – Minor Arterials serve moderate length trips within or between counties. They connect almost all the remaining cities with population over 1,000, and provide access to the Principal Arterial or Interstate Principal Arterials, most of the Minor Arterials are two-lane routes.

7 Major Collectors – Major Collectors primarily serve trips within a county. They link the county seat and any larger towns, if not on an arterial, to the arterial system. In addition, the Major Collectors provide service to traffic generators of countywide importance, such as; consolidated schools, shipping points, other modes of transportation, important mining or agricultural areas, state parks and recreational areas.

8 Minor Collectors – The Minor Collectors link the remaining communities and locally important traffic generators to a Major Collector or arterial route.

9 Local – The local road system provides access to adjacent land along its entire length. Trips are relatively short and at low speeds. The Local functional classification accounts for all mileage not included in the collector or arterial systems.

URBAN

11 Interstate – The urban Interstate routes provide "cut through" the urban area or travel around the urban area on or near its perimeter. As with the rural Interstate System, these routes are fully access controlled to encounter as little traffic interruption as possible.

12 Other Freeway and Expressway – These routes serve relatively long trips within an urban area. The speeds are not as fast as on the Interstate System but are generally high. Because the emphasis of the Other Freeway and Expressways is on traffic mobility, these routes should be fully or partially access controlled.

14 Other Principal Arterial – The Other Principal Arterials provide relatively direct routes to major urban attractions, not on the Interstate or Other Freeway and Expressway system. These trips are also relatively long. The Other Principal Arterials also provide continuity to rural arterials, which intercept the urban boundary. Any direct access to adjacent land is purely incidental.

16 Minor Arterial – The Minor Arterial system should connect and supplement the principal arterials and provide service to trips of moderate length at a lower degree of mobility than the principal arterials.

17 Collector – The Collector channel traffic from residential, industrial, or commercial areas to the arterial system. Conversely, they channel traffic from the arterials into such areas. Because they provide a higher degree of land access than the arterial system, speeds are lower than on the arterials.

19 Local – Local streets provide access to abutting land along their length, and to the collector and arterial systems. The local functional classification includes all urban mileage that is not on a higher system.

INTERCHANGE_ID	Unique identifier of the interchange if the SS_PAVEMENT record falls within an interchange.
INTERSECTION_NO	Unique identifier for a Travelway Intersection.
JOINT_INDEX_RIGID	Rating assigned to amount of joints on PCC (Portland Cement Concrete). Ratings are derived from a visual analysis of severity and extent, and a range from 0.0 (worst) to 5.0 (best).

LANE_COLLECTED	Visual lane number of the lane for which the ARAN data were collected.
LANE_MILES	The number of lane miles the project will cover.
LANE_WIDTH	Width in feet of individual driving lanes.
LAST_CHANGE_DATE	The date that the data was last changed in the system.
LAST_CHANGE_USER	The user ID of the individual who made the change to the data
LENGTH	Length of travelway segment for which the SS_PAVEMENT is calculated
LRPT	Long Range Planning Transportation. Values are 'NHS'. 'OTHER Arterial', 'COLLECTOR' or 'NOS'.
MAINT_DATE	The date of a maintenance pavement treatment.
MAINT_LOCATION	The maintenance building that is responsible for the road.
MAINT_OWNER_NAME	Describes the owner who maintains the SS_PAVEMENT record. ***Description*** CALLAWAY COLE COOPER ELDON JEFFERSON CITY MODOT NEW BLOOMFIELD OSAGE BEACH ST. LOUIS
MAINT_TYPE	The type of maintenance pavement treatment.
MAJOR_MINOR	Major is established by functional class of Principal Arterial and above. The lower classes are considered “Minor”.
MSHP_TROOP	Unique identifier for a HP Troop.
NUMBER_OF_LANES	Number of lanes per SS_PAVEMENT record.
OVERLAPPING_IND	Used to indicate if a route is controlling on an overlapping situation. Primary (P), Secondary (S), or Null.

PATCH_INDEX_FLEX — Rating assigned to the amount of patching on Asphaltic concrete.

PATCH_INDEX_RIGID — Rating assigned to the amount of patching on PCC (Portland Cement Concrete). Ratings are derived from a visual analysis of severity and extent, and a range from 0.0 (worst) to 5.0 (best).

PLANNING_ORG — Name of the planning organization that the SS_PAVEMENT record falls in.

NAME	TYPE
BOONSLICK REG PLAN COM	RPC
BOOTHEEL REG PLAN & ECON DEV	RPC
CAMPO MPO	MPO
CATSO MPO	MPO
EWGCC MPO	MPO
EWGCC RPC	RPC
GREEN HILL REG PLAN COMM	RPC
HARRY S. TRUMAN COORD COUN	RPC
JATSO MPO	MPO
KAYSINGER BASIN REG PLAN COMM	RPC
LAKE OZARK COUN OF LOCAL GOVT	RPC
MARC MPO	MPO
MARC RPC	RPC
MARK TWAIN REG COUN OF GOVT	RPC
MERAMEC REG PLAN COMM	RPC
MID-MO REG PLAN COMM	RPC
MO-KAN REGIONAL COUNCIL	RPC
NE MO REG PLAN COMM	RPC
NW MO REG COUN OF GOVTS	RPC
OTO MPO	MPO
OZARK FOOTHILLS REG PLAN COMM	RPC
PIONEER TRAILS REGIONAL COUN	RPC
SE REG PLAN & ECON DEV COMM	RPC
SJATSO	MPO
SO CENTRAL OZARK COUN OF GOVTS	RPC
SW MO ADIVISORY COUN OF GOVTS	RPC

PLANNING_ORG_NO — Unique identifier for a Planning Organization.

PLANNING_ORG_TYPE — Type of planning organization such as MPO (Metropolitan Planning Organization) or RPC (Regional Planning Commission).

POS_BEGIN — The position on the arc where the segment begins. A percentage from 0 – 100.

POS_END — The position on the arc where the segment ends. A percentage from 0 – 100.

PRIOR_COUNTY — Previous county name.

PSR — A 40-point scale representing overall pavement condition. PSR is developed from ratings of individual distresses and roughness, weighted and combined to form a single value.

RAVEL_INDEX_FLEX — Rating assigned to the amount of raveling on asphaltic concrete.

ROADWAY_TYPE_NAME — Name of the Roadway Type. ***Joins with*** **ROADWAY TYPE.**

NAME	***NUMBER OF LANES***
3 LANE SECTION	3 Lanes
5 LANE SECTION	5 Lanes
EXPRESSWAY	2 or More Lanes
FREEWAY	2 or More Lanes
MULTI-LANE	2 or More Lanes
ONE-WAY	1 or More Lanes
RAMP	1 or More Lanes
SUPER 2-LANE	2 Lanes
TWO-LANE	2 Lanes
SUPER 4 LANE (PASSING LANE 2+1)	2 or More Lanes

Freeway: A divided travelway with full control of access and two or more lanes for through traffic in each direction. All intersections are grade separated (interchanges).

Expressway: A divided travelway with limited/partial control of access and two or more lanes for through traffic in each direction. Intersections are normally at-grade, although isolated interchanges are possible.

Multi-lane: An undivided travelway with two or more lanes for through traffic in each direction. The access control can be either limited/partial or none.

3 lane section: An undivided travelway with one lane for through traffic in each direction and a Two-Way Left-Turn-Lane (TWLTL) as a median.

5 Lane Section: A travelway with two lanes for through traffic in each direction and a TWLTL as a median.

Two-Lane: An undivided travelway with one lane for through traffic in each direction and is not classified as a Super 2-Lane. May include three lane sections which the third lane maybe either a climbing lane or passing.

Super 2-Lane: A travelway with one lane for through traffic in each direction. Lane width is a minimum of 12 feet and has stabilized shoulders with a width greater than 8 feet. May include three lane sections which the third lane is a climbing lane.

One-Way: A travelway with one or more lanes for through traffic in one direction only.

Ramp: A travelway with limited/partial or no access control which allows movement from one travelway to another travelway. Ramps are usually found at interchanges; however, some at grade intersections may have ramps to reduce turning movements.

Shared 4 Lane (passing lane 2 + 1): A travelway with one lane for through traffic in each direction and an additional continuous lane that can be used for passing that will alternate between travelway directions (this does not include climbing lanes).

RUT_DEPTH	Displacement of material in a wheel path measured as the difference in elevation of both sides less the elevation of the displaced area with 0.0 (worst) to 5.0 (best).
RUT_INDEX	Number assigned to average rutting based on average rut depth.
SHOULDER_TYPE	Name of the type of material from which the shoulder is constructed.

CODE	DESCRIPTION
AC	ASPHALTIC CONCRETE
AG	AGGREGATE
BM	BITUMINOUS MAT
BRK	BRICK
CG	CURB AND GUTTER
ERT	EARTH
LC	ASPHALT LEVELING COURSE
MS	MICROSURFACING
OA	OIL AGGREGATE
PC	CONCRETE UNKNOWN REINFORCEMENT
PCN	CONCRETE NON-REINFORCED
PCR	CONCRETE REINFORCED
SLC	SUPERPAVE LEVELING COURSE
SM	STONE MASTIC
SP	SUPERPAVE
SA	SAND

SS	STABILIZED SHOULDERS
TYP1	TYPE 1 AGGREGATE
TYP2	TYPE 2 AGGREGATE
TYP3	TYPE 3 AGGREGATE
TYP4	TYPE 4 AGGREGATE
TYP5	TYPE 5 AGGREGATE
UTA	ULTRA THIN BONDED A
UTB	ULTRA THIN BONDED B
UTC	ULTRA THIN BONDED C

SHOULDER_WIDTH — The width of the shoulder surface measured in feet.

SPALL_INDEX_RIGID — Rating assigned to amount of spalling on PCC (Portland Cement Concrete). Ratings are derived from a visual analysis of severity and extent, and range from 0.0 (worst) to 5.0 (best). Spalling is the loss of pieces of concrete pavement from the surface or along the edges of cracks and joints.

SS_PAVEMENT_ID — Unique identifier for an SS_PAVEMENT record.

STATE_BRIDGE_ID — Unique identifier for State Bridges.

STATE_SYSTEM_CLASS — Describes how a travelway is classified by the Missouri Dept. of Transportation. Values are INTERSTATE, PRIMARY, SUPPLEMENTARY, or NOT ON SYSTEM.

SUBAREA_LOCATION — The maintenance subarea where the SS_PAVEMENT record is located.

SURFACE_DATE — Date that the pavement surface was laid.

SURFACE_TYPE — The name of the type of material from which the pavement surface is constructed.

CODE	DESCRIPTION
AC	ASPHALTIC CONCRETE
AG	AGGREGATE
BM	BITUMINOUS MAT
BRK	BRICK
CG	CURB AND GUTTER
ERT	EARTH
LC	ASPHALT LEVELING COURSE
MS	MICROSURFACING
OA	OIL AGGREGATE

PC	CONCRETE UNKNOWN REINFORCEMENT
PCN	CONCRETE NON-REINFORCED
PCR	CONCRETE REINFORCED
SLC	SUPERPAVE LEVELING COURSE
SM	STONE MASTIC
SP	SUPERPAVE
SA	SAND
SS	STABILIZED SHOULDERS
TYP1	TYPE 1 AGGREGATE
TYP2	TYPE 2 AGGREGATE
TYP3	TYPE 3 AGGREGATE
TYP4	TYPE 4 AGGREGATE
TYP5	TYPE 5 AGGREGATE
UTA	ULTRA THIN BONDED A
UTB	ULTRA THIN BONDED B
UTC	ULTRA THIN BONDED C

THROUGH_LANES — A lane that continues to the next segment without any right or left handed turns.

TMA_NON_TMA — Transportation Management Area (area with population over 250,000 e.g. St. Louis or Kansas City).

TOTAL_AADT — The volume for both sides of a travelway added together (divided and undivided).

TRACKER_CONDITION — The three tracker measures are GOOD, NOT GOOD, and NA. This represents whether the segment of road is considered good for the tracker.

TRAVELWAY_DESG — Describes the designation of the route that the SS_PAVEMENT record resides on.

CODE	DESCRIPTION	HIERARCHY
AL	ALTERNATE ROUTE	4
ALY	ALLEY	22
BU	BUSINESS	7
CO	CONNECTOR FOR WYE LEG	14
COE	CORP OF ENGINEERS	20
CRD	COUNTY ROAD	12
CST	CITY STREET	11
DOD	DEPARTMENT OF DEFENSE	21
FWS	FISH WILDLIFE SERVICE	19

IS	INTERSTATE	1
LP	LOOP (INTERSTATE ONLY)	6
MO	MISSOURI NUMBERED ROAD	3
NFS	NATIONAL FOREST SERVICE	17
NPS	NATIONAL PARKS SERVICE	18
OR	OUTER ROAD	10
PED	PEDESTRIAN	25
PK	PARK	26
PVT	PRIVATE	23
RA	REST AREA	15
RP	RAMP	13
RR	RAILROAD	24
RT	MISSOURI LETTERED ROUTE	5
RV	REVERSIBLE	9
SP	SPUR	8
US	US NUMBERED ROUTE	2
WS	WEIGHT STATION	16

TRAVELWAY_DIR — The direction of the route that the SS_PAVEMENT record resides on.

CODE	DESCRIPTION
E	EAST
N	NORTH
S	SOUTH
W	WEST

TRAVELWAY_ID — Unique sequence number for the route that each SS_PAVEMENT record resides on.

TRAVELWAY_NAME — The name of the route that the SS_PAVEMENT record resides on.

TRAVELWAY_OFST_DIR — Offset direction is used in conjunction with outer roads. If an outer road runs east/west, the offset will be north/south.

TRF_INFO_SEG_DESC — Describes the intersecting street of each traffic segment.

TRF_INFO_SEG_ID — Unique sequence number for the traffic segment that each SS_PAVEMENT resides on.

TRF_INFO_SEG_SEQ — Unique system generated identifier behind TRF_INFO_SEG_ID.

TW_ALIAS_NAME	A commonly used name for a given Travelway or section of travelway.

NAME

1. GREAT RIVER ROAD
3. LEWIS AND CLARK TRAIL
7. ALEXANDER DONIPHAN MEMORIAL HIGHWAY
8. BRUCE R. WATKINS FREEWAY
9. CORPORAL M.E. WEBSTER MEMORIAL PARKWAY
10. GEORGE BRETT BRIDGE
11. GEORGE BRETT SUPER HIGHWAY
13. JAY B. DILLINGHAM FREEWAY
14. TOM WATSON PARKWAY
15. C.F. "RED" WHALEY FREEWAY
17. MARK TWAIN EXPRESSWAY
18. OZARK EXPRESSWAY
19. GENE TAYLOR HIGHWAY
20. PAYNE STEWART HIGHWAY
21. VETERAN'S BRIDGE
22. V.F.W. MEMORIAL HIGHWAY
23. BOB WARD HIGHWAY
24. KOREAN WAR MEMORIAL HIGHWAY
25. ROSA PARKS HIGHWAY
26. PEARL HARBOR MEMORIAL HIGHWAY
27. GEORGE WASHINGTON CARVER MEMORIAL HIGHWAY
28. KOREAN WAR VETERAN'S MEMORIAL HIGHWAY 29. BUTTERFIELD RANCH ROAD
30. AMERICAN LEGION MEMORIAL HIGHWAY
31. TROOPER CHARLES P. CORBIN MEMORIAL HIGHWAY
32. WILLIAM "BILL" LARK MEMORIAL HIGHWAY
33. TROOPER JIMMIE LINEGAR MEMORIAL HIGHWAY
34. CORPORAL BOBBIE J. HARPER MEMORIAL HIGHWAY
35. SHORT LINE SPUR HISTORICAL TRAIL
36. AVENUE OF THE SAINTS
37. SERGEANT ROBERT KIMBERLING MEMORIAL HIGHWAY
38. PONY EXPRESS BRIDGE
39. DAVID RICE ATCHISON MEMORIAL HIGHWAY
40. ZACH WHEAT MEMORIAL HIGHWAY
41. BABE ADAMS HIGHWAY
42. BRIGGS DRIVE
43. U.S. SUBMARINE VETERANS MEMORIAL HIGHWAY
44. WW II EXERCISE TIGER EXPRESSWAY
45. SMART MEMORIAL HIGHWAY
46. TROOPER WAYNE W. ALLMAN MEMORIAL BRIDGE

47. RICHARD L. HARRIMAN HIGHWAY
48. VETERANS MEMORIAL PARKWAY
49. CITY MARSHAL JOHN HENRY BRENDEL MEMORIAL HIGHWAY
50. CONGRESSMAN IKE SKELTON BRIDGE
51. HARRY DARBY MEMORIAL HIGHWAY
52. TROOPER ROSS S. CREACH MEMORIAL HIGHWAY
53. REX WHITTON EXPRESSWAY
54. TROOPER DENNIS H. MARRIOTT MEMORIAL HIGHWAY
55. SENATOR CHRISTOPHER S. BOND BRIDGE
56. HENRY SHAW OZARK CORRIDOR
57. BROWN-STINSON MEMORIAL BRIDGE
58. BERNARD F. DICKMAN BRIDGE
59. JOE R. NICHOLS OVERPASS
60. BLANCHETTE MEMORIAL BRIDGE
61. DISCOVERY BRIDGE
62. DANIEL BOONE EXPRESSWAY
63. LEWIS & CLARK BOULEVARD/EXPRESSWAY
64. MARK MCGWIRE HIGHWAY
65. GOVERNOR MEL CARNAHAN MEMORIAL BRIDGE
66. BUZZ WESTFALL MEMORIAL HIGHWAY
67. OFFICER SCOTT ARMSTRONG MEMORIAL HIGHWAY
68. CHIEF JERRY BUEHNE MEMORIAL ROAD
69. JOHNSON HIGHWAY
70. ALBERT E. BRUMLEY PARKWAY
71. CARVER PRAIRIE DRIVE
72. TROOPER RUSSELL HARPER MEMORIAL HIGHWAY
73. CONGRESSMAN MEL HANCOCK FREEWAY
74. JARRETT ROBERTSON MEMORIAL BRIDGE
76. ED BROWN BRIDGE
77. GLEN SHARP BRIDGE
78. RICK HARMON MEMORIAL HIGHWAY
79. EDWIN P. HUBBLE MEMORIAL HIGHWAY
80. LAURA INGALLS WILDER MEMORIAL HIGHWAY
81. JAMES GRASSHAM & ORVILLE WILLIAMS WALKWAY
82. SERGEANT RANDY SULLIVAN MEMORIAL HIGHWAY
83. TROOPER MIKE L. NEWTON MEMORIAL HIGHWAY
84. DANNY STAPLES BRIDGE
85. TROOPER KELLY L. POYNTER MEMORIAL HIGHWAY
86. TROOPER ROBERT KOLILIS MEMORIAL HIGHWAY
87. BILL EMERSON MEMORIAL BRIDGE
88. GOVENOR JOHN M. DALTON MEMORIAL HIGHWAY
89. SERGEANT RANDY SULLIVAN MEMORIAL HIGHWAY
91. TROOPER JAMES FROEMSDORF MEMORIAL HIGHWAY
92. THOMAS G. TUCKER, JR. MEMORIAL HIGHWAY
93. DEPUTY STEVEN R. ZIEGLER MEMORIAL HIGHWAY

94. TROOPER JESSE R. JENKINS MEMORIAL HIGHWAY
95. VETERANS MEMORIAL HIGHWAY
96. VETERANS MEMORIAL BRIDGE
97. INNERBELT EXPRESSWAY
98. AMERICAN VETERANS MEMORIAL HIGHWAY
99. KOREAN WAR VETERANS MEMORIAL FREEWAY
100. TROOPER MIKE L. NEWTON MEMORIAL BRIDGE
101. KOREAN WAR VETERANS ASSOCIATION MEMORIAL HIGHWAY
102. BOB WARD PARKWAY

TW_CNTL_STAT_NAME Describes the status of a route.

NAME	***DESCRIPTION***
CONTINUOUS OPERATIONS RT	Priority routes defined for winter snow removal.
OPEN TO TRAFFIC	used by driving public

TW_DSGN_PVMT_NAME Indicates the pavement design based on the number of trucks on the roadway. **Click here for codes**

NAME	***DESCRIPTION***
Heavy Duty	DESIGN MAN. CH. VI 6-03.1 (1)
Medium Duty	DESIGN MAN. CH. VI 6-03.1 (2)
Light Duty LA	>3,500 ADT
Light Duty LB	1,700-3,500 ADT
Light Duty LC	750 - 1,700 ADT
Light Duty LD	400 - 700
Light Duty LE	<400 ADT

TW_LANE_JOB_NUMBER Unique identifier for the lane job.

TW_OWNER_ID Describes who owns the travelway.

NAME	**DESCRIPTION**
CITY	CITY
COUNTY	COUNTY
FEDERAL	FEDERAL
PRIVATE	PRIVATE
SPEC ROAD DIST	SPECIAL ROAD DISTRICT
STATE	STATE

TW_SPEED_LIMIT_CD Speed Limit that the SS_PAVEMENT record falls on.

CODES	**DESCRIPTION**

15	15 MPH
20	20 MPH
25	25 MPH
30	30 MPH
35	35 MPH
40	40 MPH
45	45 MPH
50	50 MPH
55	55 MPH
60	60 MPH
65	65 MPH
70	70 MPH
99	99 NOT STATED OR UNKNOWN

URBAN_AREA_NAME Rural (area with population less than 5,000) Urban (area with population 5,000 – 50,000).

NAME	DESCRIPTION
METROPOLITAN	OVER 200,000 POP.
RURAL	LESS THAN 5,000 POP.
UNDESIGNATED	UNDESIGNATED
URBAN	5,000 - 50,000 POP.
URBANIZED	OVER 50,000 - 200,000 POP.

YEAR Calendar year the data represents.

The following text defines fields used to populate the ARAN inventory database. It was prepared by MoDOT.

DATE CREATED: 01/14/2004

DATE MODIFIED: 08/13/2010

AUTO_COND_SURV_VW

Description

This table contains automated condition survey (ARAN) data.

NOTE: *This table contains information that is protected from disclosure by federal law, 23 USC Section 409 and the Missouri Open Records Law (Sunshine Act), Section 610.021 RSMo. Please review MoDOT's policy and procedure manual on the Sunshine Act before releasing any of the information contained herein.*

NAME	*DESCRIPTION*
AUTO_COND_SURV_ID	Unique identifier for an Automated Condition Survey record.
AVERAGE_RUT	The average of the driver and passenger rut depth.
AVERAGE_RUT_SI	The metric equivalent of the average of the driver and passenger rut depth.
C_CRACKING_RATING	The rating of cracks for concrete pavement. Ratings are derived from a visual analysis of severity and extent, and range from0.0 (worst) to 5.0 (best).
C_PATCHING_RATING	The rating of patching for concrete pavement. Ratings are derived from visual analysis of severity and extent, and range from 0.0 (worst) to 5.0 (best).
CNTY_LOG	County Log unit measures the distance from where the travelway begins in the given county to location.
CONDITION_INDEX	The sum of distresses that apply to a pavement. For asphalt it is the sum of F Cracking, F Patching, Raveling, and Rut Index. For Concrete, it is the sum of Joint Condition, C Cracking, C Patching, D Cracking, and Spalling.

COUNTY_NAME	The official name of the county where the AutomatedCondition Survey record resides.
CROSSFALL	Slope of the road.
CURR_SURVEY_FLAG	Identifies a record as the most current. (Y = Current; N= Not Current).
D_CRACKING_RATING	The rating of D Cracking for a pavement. Ratings are derived from a visual analysis of severity and extent, and range from 5.0 (worst) to 0.0 (no D Cracking). **Note: that the value is negative.**
DATE0	Date the automated condition (ARAN) survey was completed.
DESIGNATION	Unique identifier for each route in TMS. **Click here for codes**
DIRECTION	Refers to the direction of the travelway. **Click here for codes**
DISTRICT_NUMBER	The district number where the Automated Condition Survey record resides.
DRIVER_IRI	International Roughness Index Number indicating roughness statistics in the left wheel path.
DRIVER_RUT_DEPTH	Maximum rut depth measured in the left wheel path of a particular lane of a flexible pavement. (Measured to the nearest tenth of an inch).
DRIVER_RUT_DPTH_SI	The metric value of the Driver Rut
Depth. ELEVATION	The height of a given level.
EVENT_NUMBER	Number of events within an interval for the Automate Condition Survey.
F_CRACKING_RATING	The rating of cracks for flexible pavement. Ratings are

	derived from a visual analysis of severity and extent, and range from 0.0 (worst) to 5.0 (best).
F_PATCHING_RATING	The rating of patching for flexible pavement. Ratings are derived from a visual analysis of severity and extent, and range from 0.0 (worst) to 5.0 (best).
GRADE	The incline or decline of a roadway.
IMAGE_NUMBER	Original image file from ARAN computer.
JOINT_COND_RTNG	The rating of joints. Ratings are derived from a visual analysis of severity and extent, and range from 0.0 (worst) to 5.0 (best).
LAST_CHANGED_DATE	The date the data was last changed in the system.
LAST_CHANGED_USER	The user ID of the individual who made the last change to the data.
LATITUDE	Geographical latitude of coordinates running north and south and measured in decimal degrees.
LOG	Continuous Log Unit measures the distance from the beginning of the travelway to the given location.
LONGITUDE	Geographical longitude of coordinates running east and west and measured in decimal degrees.
OBJECT_ID	Is an auto-number index field in a table that contains route events.
OFFSET_DIRECTION	A secondary travelway identity that is perpendicular to the referencing travelway.
PASS_RUT_DEPTH_SI	The metric value for Passenger Rut Depth.
PASS_RUT_DPTH	Maximum rut depth measured in the right wheel path of a particular lane of flexible pavement. (Measured to the nearest tenth of an inch.)
PASSENGER_IRI	International Roughness Index Number indicating roughness statistics in the right wheel.

PAVEMENT_ID	Identifies the type of pavement. Values are AC = Asphaltic Concrete; PCC = Portland Cement Concrete
PAVEMENT_ROUGH	The rating of pavement smoothness derived from the Automated Condition Survey axel acceleration (ride). Ratings range from 0.0 (worst) to 10.0 (best).
PRES_SVC_RATING	A 40 point scale representing relative pavement condition. PSR is developed from ratings of individual distresses and roughness, weighted and combined to form a single value.
PRIMARY_IND	Used to indicate if a route is controlling on an overlapping situation. Y = Route is controlling; N = Route is secondary
RAVELING_RATING	The rating of raveling for a pavement. Raveling is the progressive loss of pavement materials from the surface. Ratings are derived from a visual analysis of severity and extent, and range from 0.0 (worst) to 5.0 (best).
RUNFILE	Unique ARAN file name.
RUT_DEPTH_SI_UOM	The metric unit of measure for Driver and Passenger Rut Depth
RUT_DEPTH_UOM	Unit of measure for Driver and Passenger Rut Depth.
RUT_RATING	The rating of measured rut depth ranging from 0.0 (worst) to 5.0 (best), using the deepest of either the left or right wheel path. Rutting is the displacement of materials in a wheel path measured as the difference in elevation of both sides less the elevation of the displaced area.
SAT_BEGLOG	A GIS calculated identifier for the beginning log point.
SAT_ENDLOG	A GIS calculated identifier for the ending log point.
SEALING_INDICATOR	Indicates whether or not the cracks are sealed.
SHAPE	Contains geometry of the location of a data record used for mapping.
SPALLING_RATING	A rating of spalling at joints and cracks. Spalling is the loss

	pieces of concrete pavement from the surface or along the edges of cracks and joints. Ratings are derived from a visual analysis of severity and extent, and range from 0.0 (worst) to 5.0 (best)
TRAVELWAY_ID	The unique identifier for the travelway from which this segment was originally referenced. ***Joins with*** **Travelway.**
TRAVELWAY_NAME	Refers to the name of the travelway. TW_LANE_ID Unique identifier for a Travelway Lane record.
TW_LANE_TYPE_NAME	Names and identifies a Travelway Lane Type.
VISUAL_LANE_NO	Number assigned to the lane (visibly how the lanes "stack up" horizontally). This number begins with one from the left most to the right of the travelway (following the direction of travel). **Click here for codes**
YEAR	Calendar year the data represents.

APPENDIX 1B – PAVEMENT MAINTENANCE DATA RETRIEVAL GUIDANCE DOCUMENT FOR PAVEMENT TREATMENT SELECTION ENDEAVORS

Two basic kinds of information are necessary when selecting a pavement treatment: existing condition and existing pavement cross-section. Pavement condition can be determined from actual site visitation, or remotely through electronic files. Ideally, coring data for a proposed treatment/rehabilitation project is extremely helpful in determining what is already in-place. However, core data are not always available, and even if available, it is important to be able to determine the condition of the in-place layers, and causes of deterioration. The following is the step-by-step process for gathering data for a prospective pavement maintenance project. Not all data sources will need to be accessed for every situation. The entire list is presented for completeness. The resources utilized would depend in part on the type of proposed treatment (structural overlay vs. thin overlay vs. chip seal, etc.), the individual involved (field office pavement engineer vs. district pavement specialist), and the type of roadway. The list of steps could include:

Step 1: Access TMS, TMS Maps, and ARAN Viewer.

Step 2: In *ARAN Viewer*, look for visual view of pavement section of interest and for the year of interest. Drop-down menus on the right side of the window directly access SS Pavement (Current or History) and the ARAN Survey Inventory databases. Eight different database fields (some created especially for ARAN Viewer) can be viewed simultaneously for the dynamically-segmented section (DSS) being viewed. Possible fields of interest are as follows: Section Beginlog and Endlog, Section IRI (DSS average), Section Tracker (DSS average), Section Condition Index (DSS average), ARAN IRI (the IRI for the particular video frame being viewed) AADT, commercial truck volume, Surface Type and Date, and County. One can also view a plot of raw (0.02 mile) or running average IRI for the DSS by using the IRI graph option above the visual view screen.

Step 3: (Optional) If ARAN IRI (again, the IRI value for the video frame being viewed) or DSS IRI is questionable, one could extract and process raw data from *ARAN Inventory tables* and/or DSS data from *SS Pavement*.

Step 4: Gather historical data—pavement cross-section for thicknesses, materials, age, etc. These are not necessarily in a strict order; sequence depends on the situation.

- Step 4A: STIP Plans
- Step 4B: Project History Maps (Ragmaps)
- Step 4C: J-Drive
- Step 4D: ProjectWise
- Step 4E: Asphalt Summaries
- Step 4F: Concrete 2-AA Sheets
- Step 4G: Archived Project Plan Sheets (Z-Drive)

Step 4H: CDs and microfilm
Step 4I: Historic State Highway maps
Step 4J: Pavement Tool
Step 4K: District Maintenance spreadsheets (on SharePoint or at Districts)
Step 4L: Construction & Materials Coring Data
Step 4M: Construction & Materials FWD data

Step 5: Query for Traffic data:
Step 5A: ARAN Viewer (SS Pavement)
Step 5B: TR50 Reports

Step 6: Query subgrade data, if desired
Step 6A: Soils & Geology preliminary investigations
Step 6B: S&G soil association files
Step 6C: ASU and USDA websites

Step 7: Obtain maintenance longevity estimates from Trigger Table Guidance Document

Step 1: Access TMS, TMS Maps, and ARAN Viewer

"TMS maps" should be accessed in order to delineate the project segment in terms of obtaining Travelway ID, logmiles, and Functional Classification.

To access the TMS homepage:

1. From the homepage of MoDOT's Intranet, click the "Division/Business Offices" link on the top/horizontal navigation bar.
2. Click on the last link to go to "Transportation Planning".
3. Click the "TMS Web Homepage" link on the left/vertical navigation bar.
4. Enter the general access MoDOT credentials.
5. NOTE: Very recently, a new portal into TMS has been made available and is called MoDOT's Virtual Desktop Secure Gateway (via Quest Workspace). Some aspects are still under construction. Contact MoDOT IS for details. Figs. B.1 through B.3 show some screenshots of the sequential login webpages.

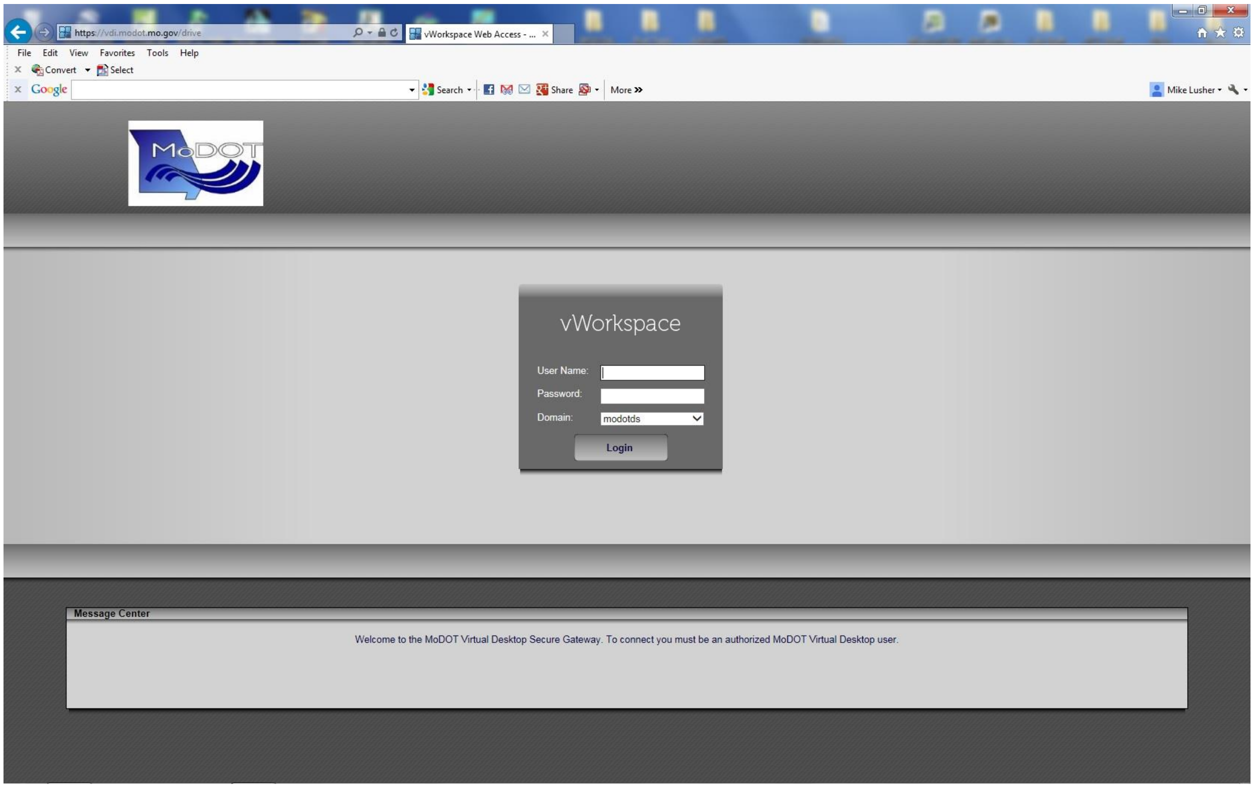
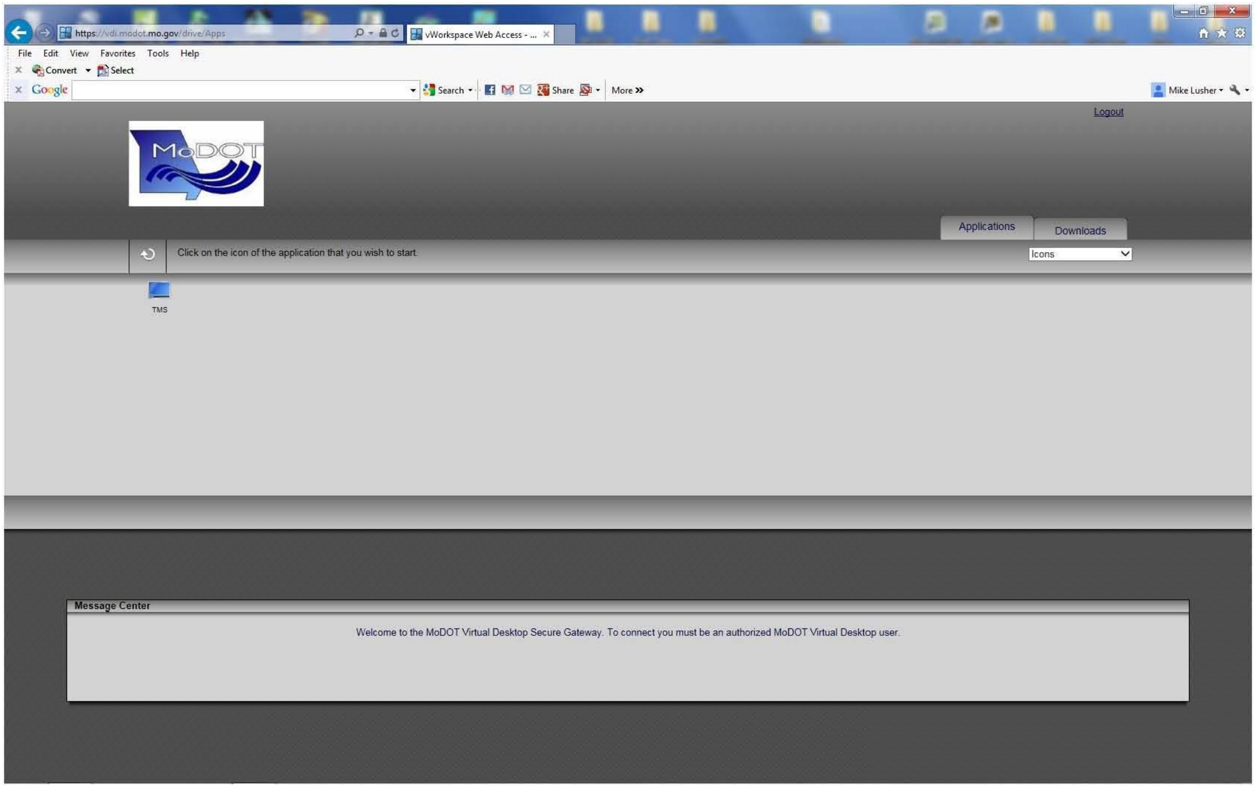


Fig. B.1- Sequential log-in webpage.



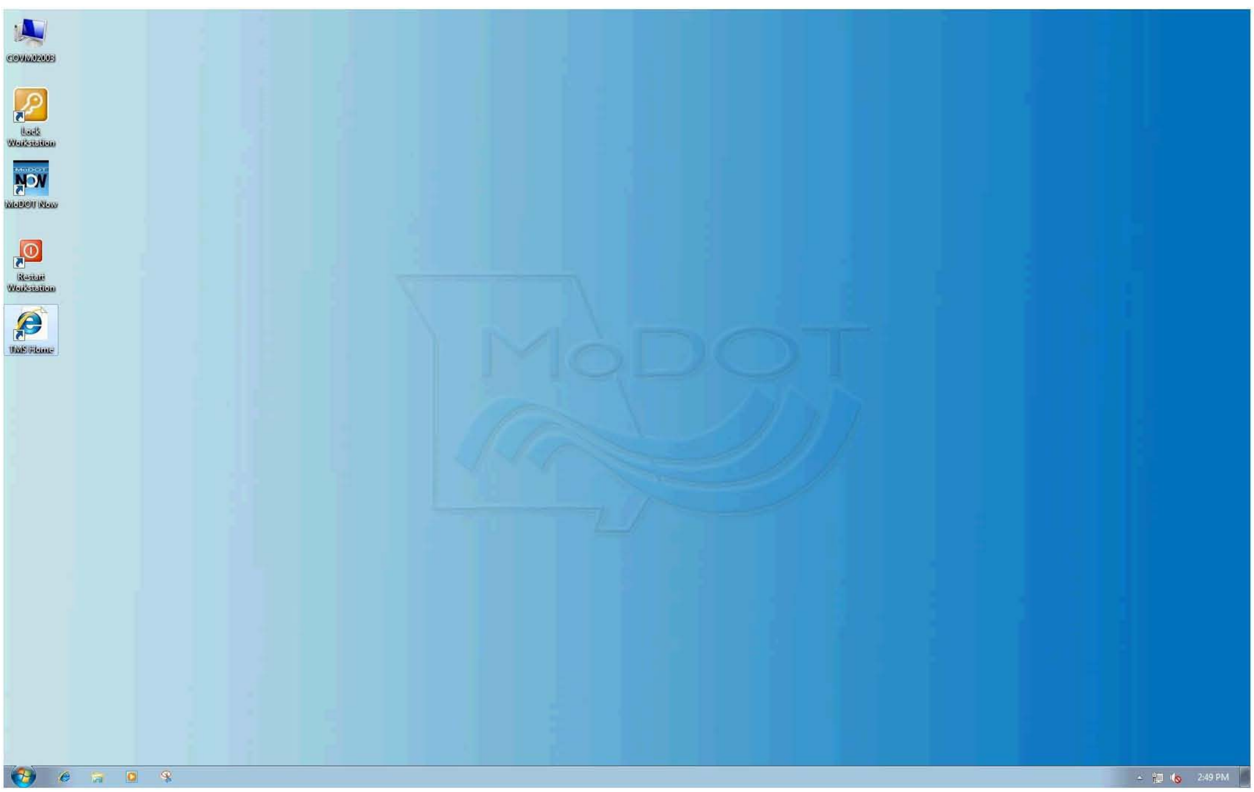


Fig. B.2- Sequential log-in webpages.

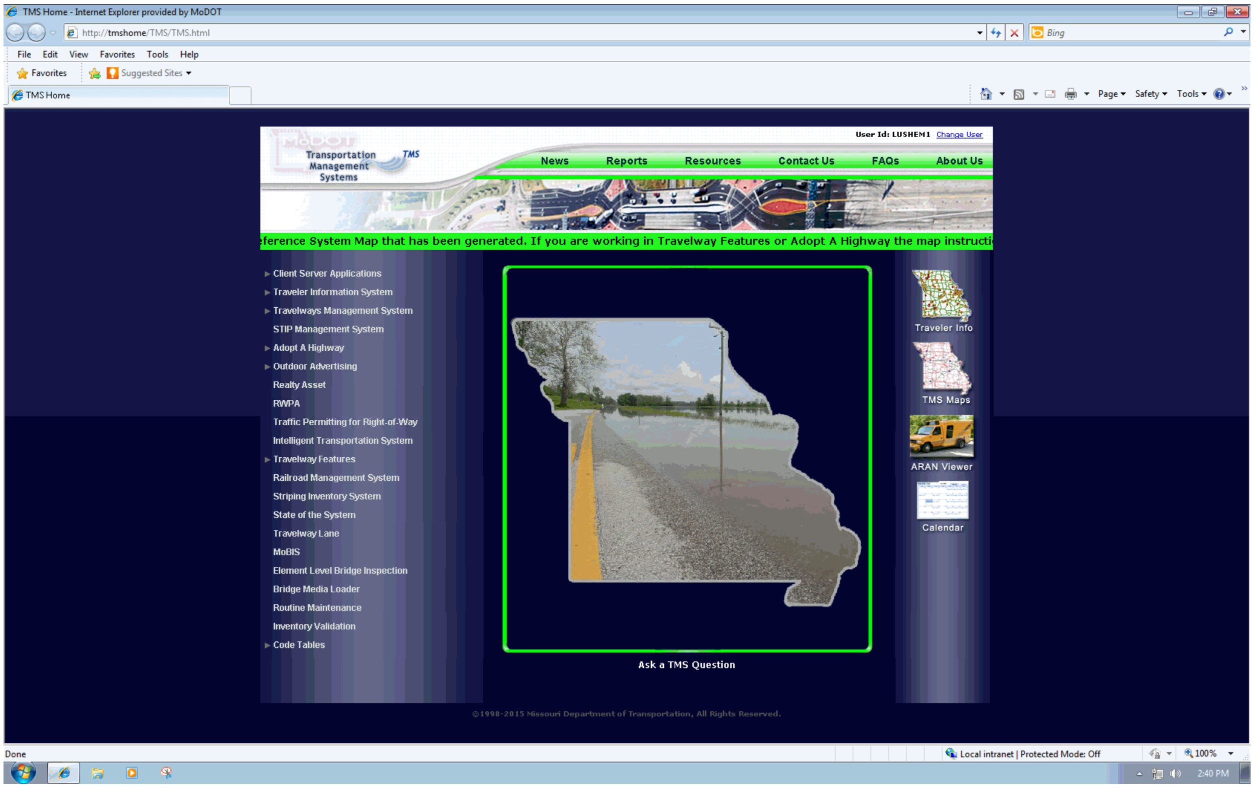


Fig.B.3- Sequential log-in webpage.

To access TMS maps:

1. From the TMS homepage (Fig. B.3 above), click on the graphical “TMS Maps” link on the right side of the page.
2. The map should show up via Microsoft Silverlight. It might be helpful to click the upper rightmost icon to enlarge to full screen.
3. Click on the “layers” button, which is top center just under the heading. Clicking on any of the options that appear will bring up a legend. Clicking different headings on each legend will display different data on the map. Many different types of data are available through these maps.
4. Clicking the button with a blue circle and an “i” on the left side of the screen near the top will bring up the “Identify” box that provides detailed information based on the route that you click on. This can be used, among many other things, to pull up travelway ID numbers for various routes. For example, the Travelway ID for I-44 is 10. This was accessed by loading the “Travelway_Data” legend, then selecting “Functional Class” on the legend, and then clicking on I-44 after clicking the “Identify” button.
5. For loading speed, it is helpful to zoom into the area of interest before loading the layers of interest.

To access ARAN Video:

1. From the TMS homepage, click on the graphic “ARAN Viewer” link on the right side of the page.

Step 2: Utilize ARAN Viewer

1. The video/photograph from the ARAN van is displayed as shown in Fig. B.4, with SS Pavement/ARAN Inventory data shown in the eight drop-down menus on the right side of the screen. Field names are listed alphabetically in the drop-down menus and Fig. B.5 shows the first of the field names available (beginning with AADT) when a drop-down menu is engaged. The buttons below the ARAN video image are used to progress from one image to the next (or to the previous).
2. To move to a different route, click the “New Location” button on the top of the screen. As mentioned above, the Travelway ID can be ascertained from the TMS Maps. Fig. B.6 shows the interface for input of Travelway ID and Start (begin) Log.
3. A plot of IRI (raw, 1/10, or ¼ mile running average) and an aerial view map of the location can be shown by using the “IRI Graph” and “Inset Map” checkboxes (respectively) near the top of the page (see Figs. B.7 through B.10).
4. If there has been a recent project associated with the section of interest, the “Job Number” button will have an actual job number displayed. Clicking on the button will open a new window displaying the plan sheets for that project. Fig. B.11 shows an example.

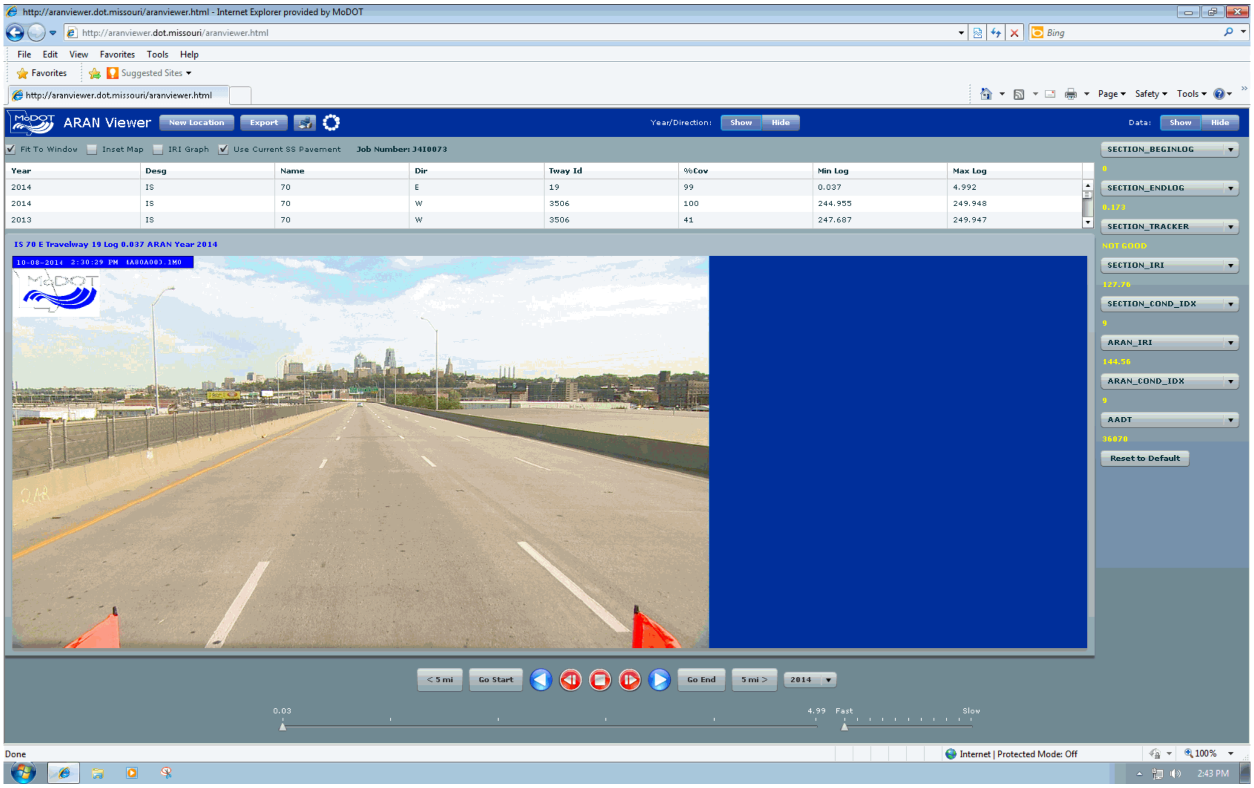


Fig. B.4 – Example of ARAN video viewed via MoDOT's TMS homepage.

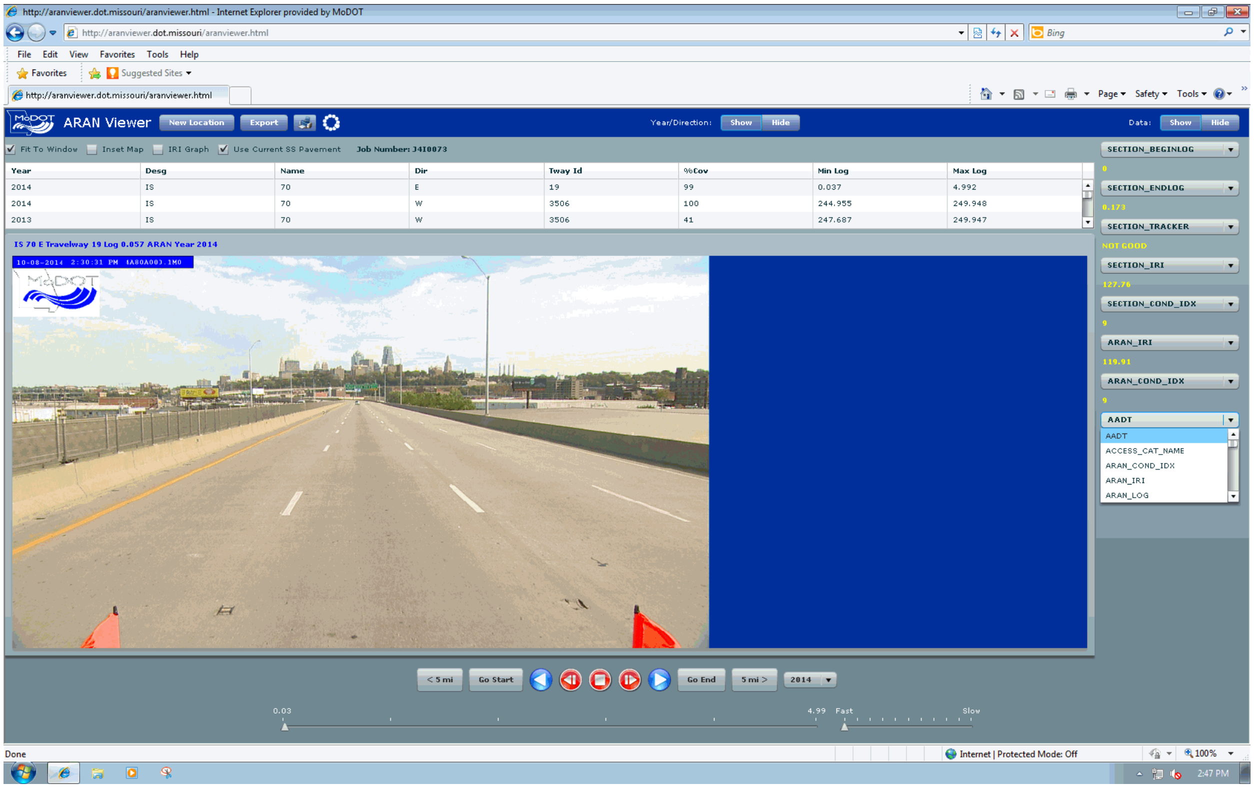


Fig. B.5 - Example of ARAN video with field names available shown.

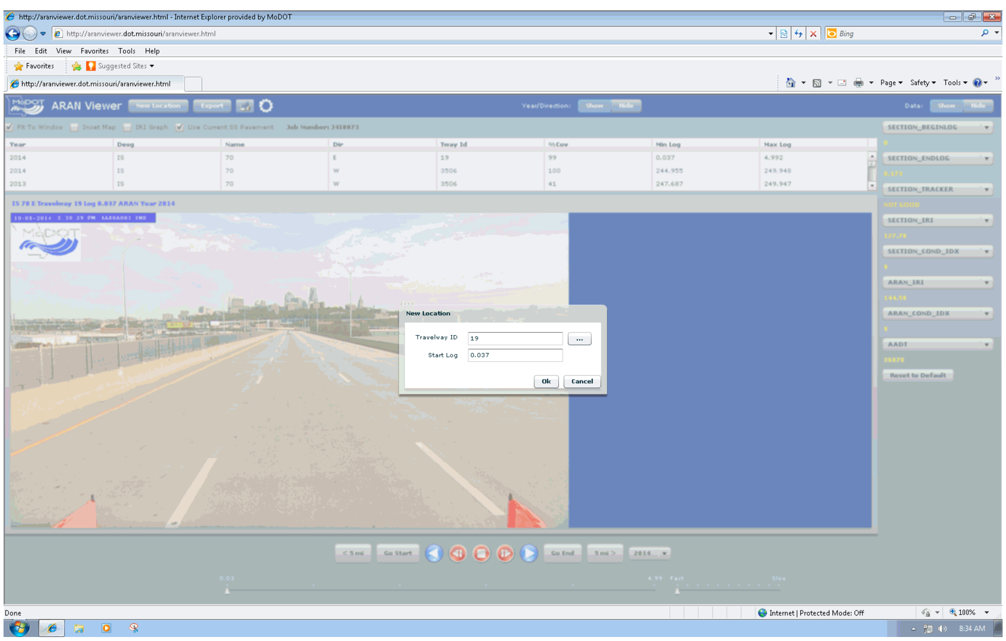


Fig.B.6 - ARAN video with interface for Travelway ID and begin log.

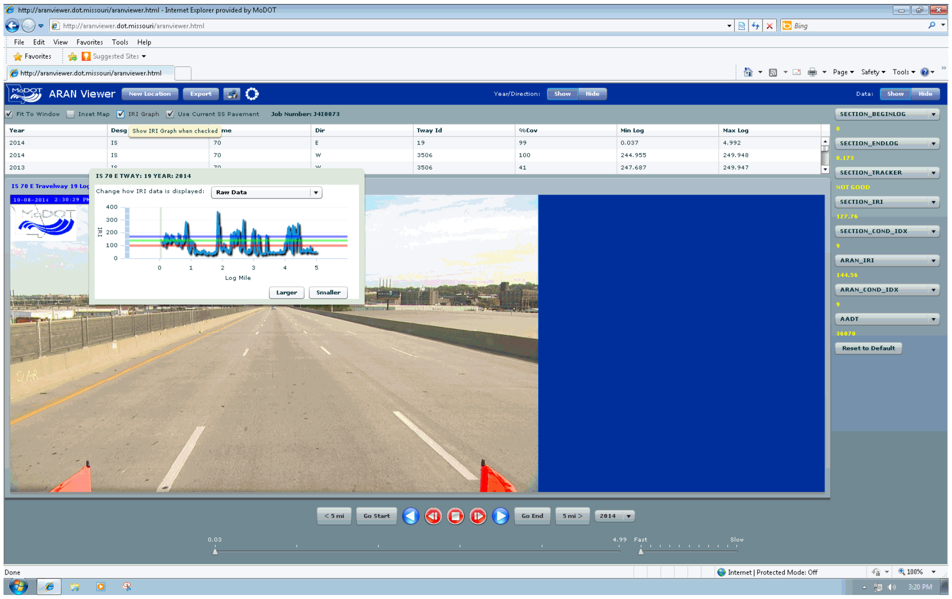


Fig. B.7 – ARAN video with IRI running data.

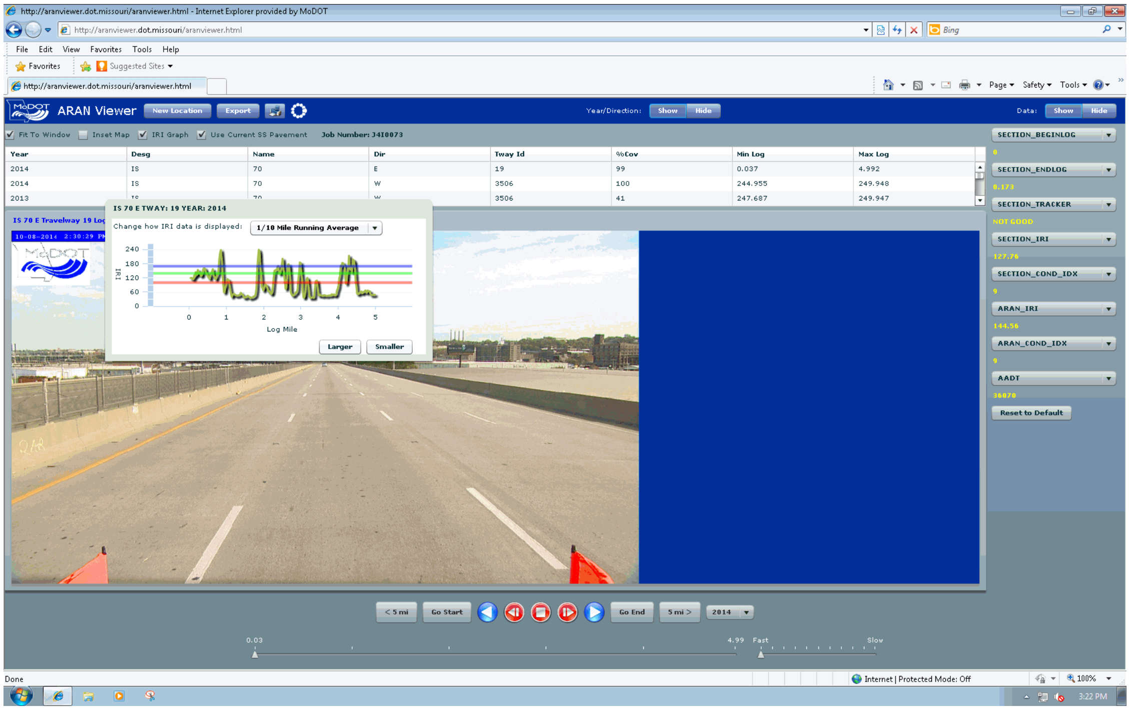


Fig. B.8 - ARAN video with IRI running data.

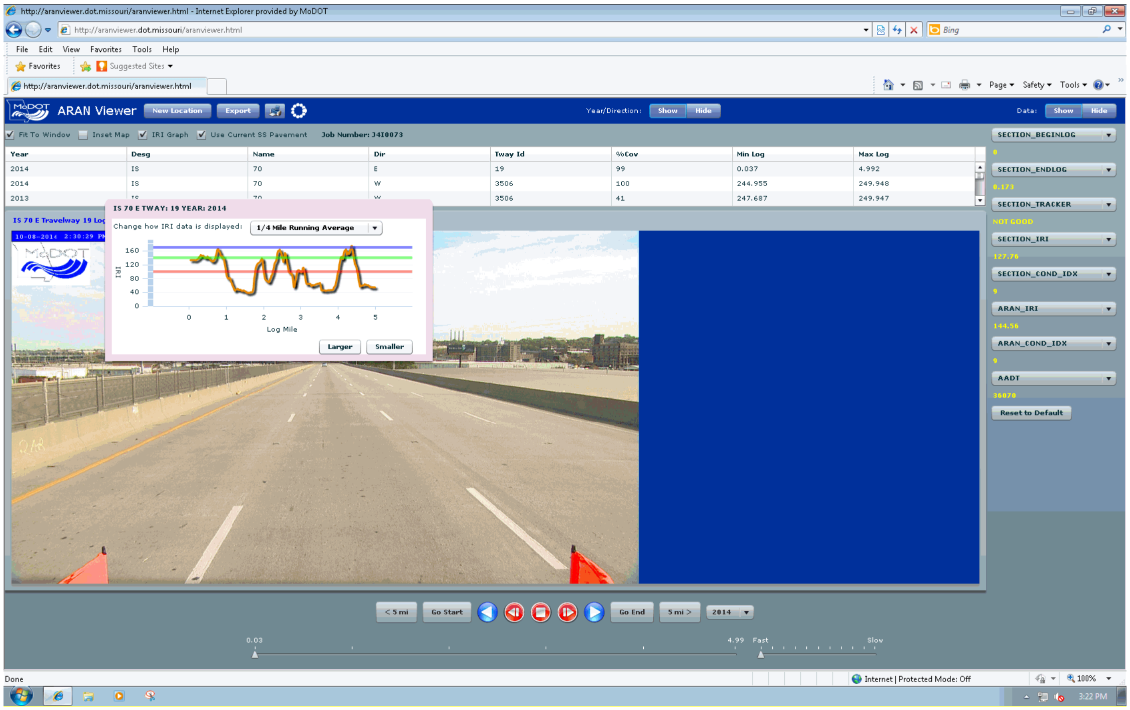


Fig. -B.9 – ARAN video with IRI running data.

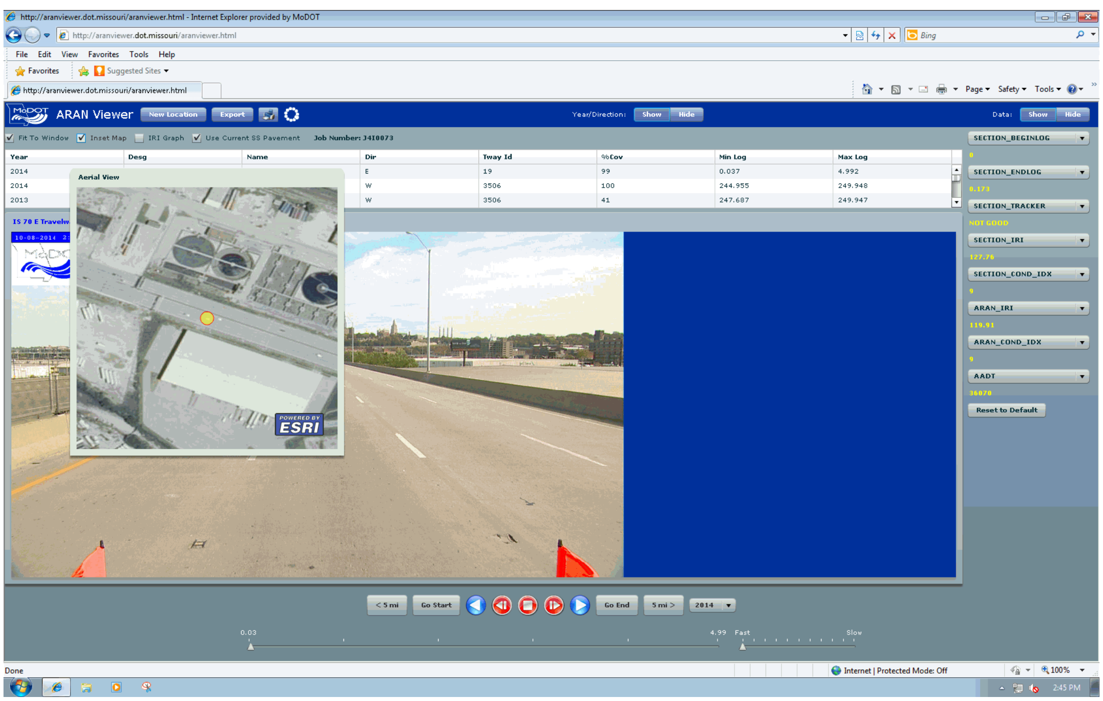


Fig. B.10 - ARAN video with inset map.

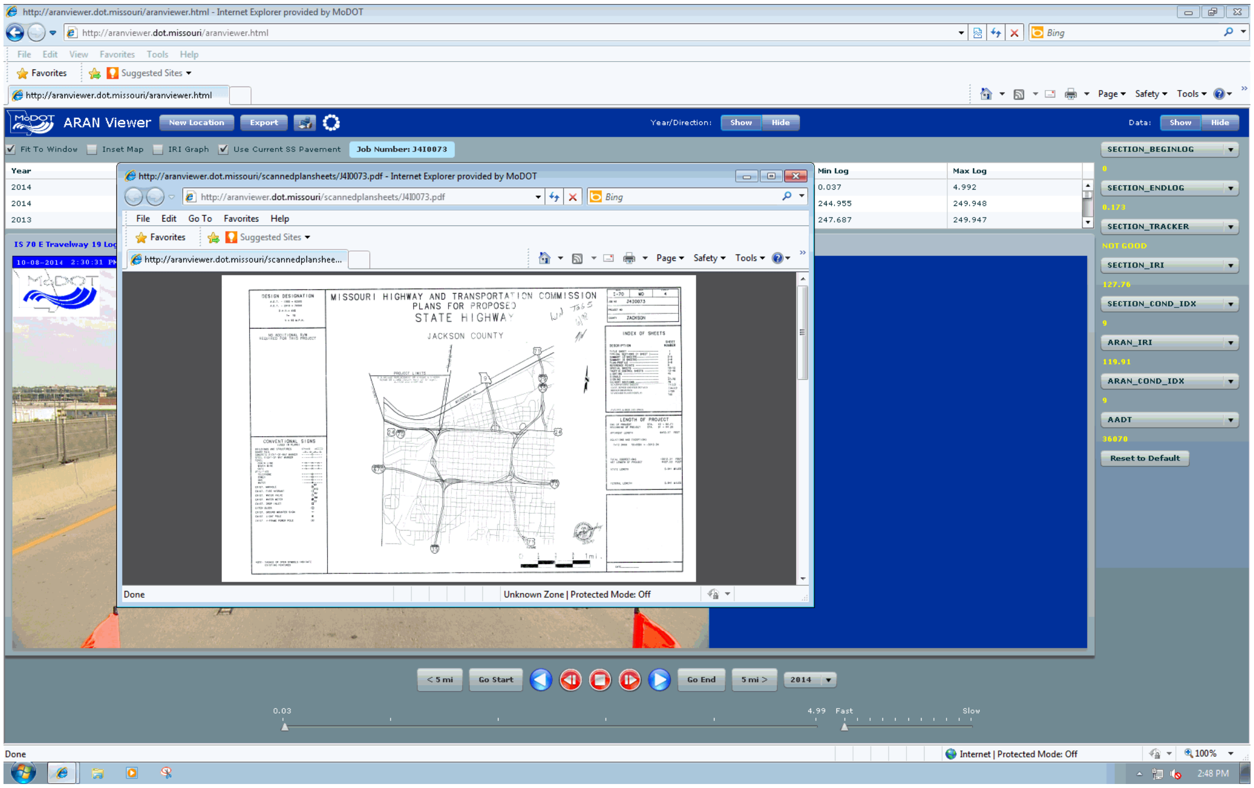


Fig. B.11 - ARAN video with plan sheets.

Step 3: (Optional) Extract and Process Data from ARAN Inventory Tables and/or SS Pavement Using Microsoft Access and SQL routine

Extract data from ARAN Inventory (raw data corresponding to 0.02 mile long pavement segments) and SS Pavement (DSS data): A routine used for much of the model-building work in this study is shown in Fig. B.12.

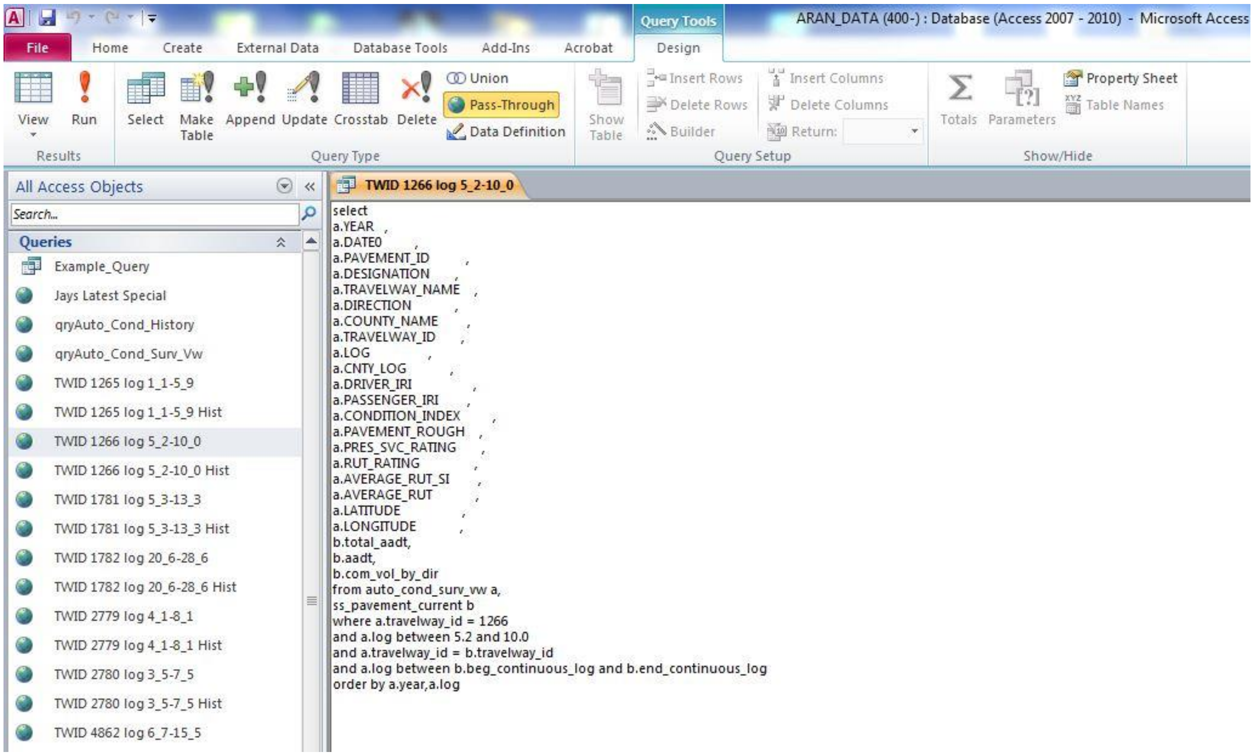


Fig. B.12 – Fields of interest for ARAN inventory tables.

Fields of interest from the ARAN inventory tables are identified in Fig. B.12 as “a”, meaning they are associated with the “a” database, i.e. the “auto_cond_surv_vw a” database (≥2001), specifically. The same logic applies to the fields in the Current SS Pavement database “ss_pavement_current b”. The only parameters changed for model-building purposes were the travelway_id value (which identified the roadway and direction), and the logmile values for the beginning and end of the section of interest. It should be noted that ARAN Viewer was used extensively to obtain the travelway ID and the beginning and end logmile values for the same roadway going in the other direction across the centerline. Also, if ARAN data prior to 2001 was desired, the “a” database parameter was changed from “auto_cond_surv_vw a” to “auto_cond_hist_vw a”.

Once the routine parameters are set, the “Run” button in the top right of the screen is clicked and the data is simultaneously extracted from the two databases. The routine shown in Fig. B.12 would extract raw ARAN data for all specified fields, and all years, in the specified database, and the most recent (current) data for AADT (directional traffic), the Total AADT (usually twice the AADT for two-lane, undivided, low-volume roadways), and the Commercial Volume (truck traffic) by direction.

The data extraction results can be exported in Excel format for further data manipulation. For example, Surface Age has to be calculated; it is not a field in any of the databases. To calculate Surface Age, one can take the difference between the date the ARAN data was collected (field DATE0 in Fig. B.12) and the date of the last surface treatment (to be determined using historical data sources), and express that difference in years. Also, the raw (or "unit") IRI value for each ~0.02 mile length of roadway has to be calculated as the average of the driver and passenger IRI values.

The MoDOT Transportation Planning (e.g. Jay Whaley) should be contacted for more details on using Access and SQL for data extraction.

Step 4: Gather historical data—pavement cross-section for thicknesses, materials, etc.

Gather pavement segment history from appropriate sources; this can include pavement thickness, material types, ages, and condition.

Step 4A: STIP plans

The STIP database is accessed from the TMS homepage by clicking a link on the navigation bar on the left side of the page. The STIP project database can be searched by job number, route, district, and county. Job numbers, dates, and project descriptions are included in the table resulting from the search. The dropdown menu above the table (initially says "Navigate To…") can be used to locate the project on a map (select "Location Map") and potentially to find stored documents, including contract plans.

Step 4B: Ragmaps (Project History maps)

There is one map per county, and the maps can be accessed through the MoDOT internet: http://www.modot.org/business/contractor_resources/ProjectHistoryMaps.htm

As is evident from Fig. 3.2, the maps contain a considerable number of project records. More recent projects often include project numbers, which can be used to obtain project plans.

Step 4C: J-Drive

There is a separate J-Drive for each district and division, located on MoDOT's internal servers. The J-Drive is a repository for previous recommendations and email correspondence and the now-scanned Asphalt Summaries and concrete 2-AA sheets. Using previous job numbers, core and condition information can be found.

Step 4D: ProjectWise

ProjectWise is Bentley software used as a repository for project plans, specifications, estimates, previous recommendations and email correspondence, dating back to June 2007. Using previous job numbers, core and condition information can be found. Special permission/setup is required to access ProjectWise.

Step 4E: Asphalt Summaries

All asphalt summary sheet tables were scanned to Adobe PDF format by the research team and are available on the J-Drive; the originals are located in the Field Office. Asphalt summaries can now be accessed at :

J:\Pavement Group\2-AA Sheets Historical

Step 4F: Concrete 2-AA sheets
The entire set of Concrete 2-AA sheets is quite large and is organized by district and then by county. The research team scanned all Concrete 2-AA sheets to Adobe PDF and are available on the J-Drive; the originals are located in the Field Office. Concrete 2-AA sheets can now be accessed at :

J:\Pavement Group\2-AA Sheets Historical

Step 4G: Archived Project Plan Sheets
A large collection of archived project (Job) plan sheet files is stored on the Z-drive in Construction and Materials. Not all projects identified on the rag maps and asphalt summaries are necessarily in the archive.

Step 4H: CDs and microfilm
Prior to 2007, contract plans and final plans (As-Builts) were stored on CDs or microfilm at the districts. The CDs are also available from the Central Office.

Step 4I: Historic State Highway Maps
These maps show year-to-year roadway surface types; they can be found on MoDOT's internet website:

http://www.modot.org/historicmaps/

Step 4J: Pavement Tool
The link for the Pavement Tool can be found within SharePoint (see bottom of Fig. B.13 under "Helpful Links and Information"):

[http://sharePoint/systemdelivery/MT/SitePages/Pavement.aspx] and within district maintenance websites (see Fig. B.13):

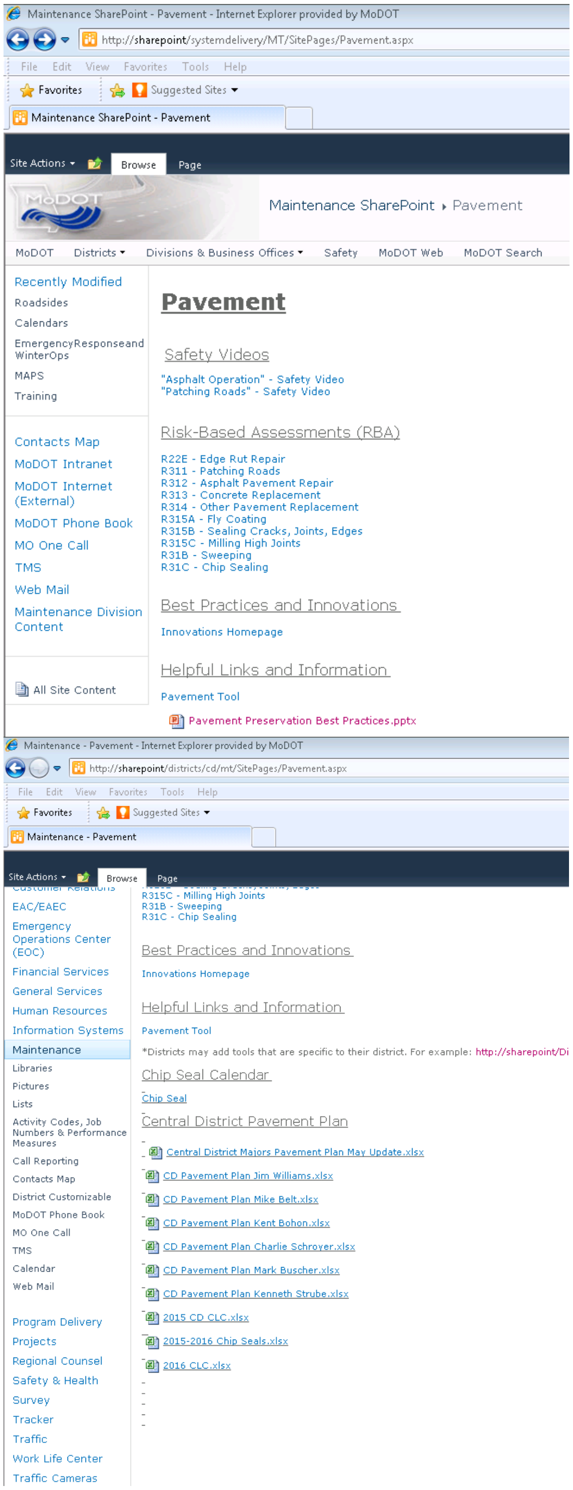


Fig. B.13 – Link to Pavement Tool.

Step 4K: District maintenance spreadsheets
These may be found on each district maintenance website (for examples, see Fig. 3.11-3.14 in Section 3.20.7). Currently, each District's Pavement Specialist would have to be consulted to locate the specific information sought.

Step 4L: SharePoint
SharePoint is a newly-developed departmental-wide repository of a variety of types of information within TMS, and is taking on more of a role as the primary portal for many applications. Among other things, districts can post their maintenance planning spreadsheets and contract work summaries, which is a source of pavement treatment types and thicknesses. As another example, emails and notes about thickness of cover over mesh prior to diamond grinding may be archived in SharePoint.

Step 4M: Construction & Materials coring data
Core data that is collected for project-scoping purposes (non-construction acceptance) is archived electronically in the specific project folder-of-interest by the Construction and Materials division on the J-Drive. Coring information can also be found in ProjectWise and may also be on plan sheets where bridge replacement has occurred.

Step 4N: Construction & Materials FWD data
Falling Weight Deflectometer (FWD) data that is collected for project-specific purposes is archived electronically by the Construction and Materials division.

Step 5: Query for traffic data

There are several ways to access traffic data throughout MoDOT's TMS databases. Traffic data (Annual Average Daily Traffic [AADT] and commercial volume [trucks]) are included as fields in the ARAN Viewer (SS Pavement database). Another slightly more comprehensive way to view traffic data is to generate reports of traffic data ("TR 50" reports):

1. From the TMS homepage, click the "TMS Reports" link on the top/horizontal navigation bar.
2. Enter MoDOT login credentials.
3. Click "Traffic/Congestion Reports" on the folder listing that comes up, then click "Traffic Information TR50."
4. Enter data for the desired year(s), district ("CD" = central district), county, designation, and travelway, then click "Travelways" under "Navigation" to select the locations.
    a. In the page that comes up, click the radio button next to the travelway. A list of reference points should then appear.
    b. Click on the radio button next to the desired beginning location in the list that comes up, then click, "Update Begin Log."

c. Click on the radio button next to the desired ending location in the list that comes up, then click, “Update End Log.”
d. Click the “OK” button near the top of the page.
e. This should return you to the original TR50 page with the log miles filled in.

5. Under “Traffic Info Types”, select both “AADT” and “Total Commercial Volume” by holding the control button while clicking.
6. Click the “Submit Report” button under “Navigation”.
7. A pop-up window with the results will appear. Clicking the quantity values (blue links) will pull up a map of the data.

Step 6: Query subgrade data (if desired)

Step 6A: Soils & Geology preliminary investigations:
Contact the MoDOT Soils and Geology section for pertinent available geotechnical investigations

Step 6B: S&G soil association files:
Contact the MoDOT Soils and Geology section for most recent version of the soils association map and association files.

Step 6C: ASU and USDA websites:
See Appendix 1D for specific directions in accessing both the ASU and USDA websites.

Step 7: Obtain maintenance longevity estimates from Trigger Table Guidance Document

The Task 5 report (Volume VI) should be consulted to retrieve various maintenance treatment service lives and cost information. At this point, the user should start following the Guidance Document for treatment selection contained in Volume VI.

APPENDIX 1C –GUIDANCE DOCUMENT FOR CREATING AND/OR UPDATING PAVEMENT FAMILY/TREATMENT MODELS

Basic Methodology Used in This Study for Creating Models:

1. Identify Routes/Pavement Types of interest (some of the query parameter field names used in this study are in parenthesis): For simple visual assessment of query results, query SS Pavement through ArcMap using parameters such as location (county name), traffic level (AADT), roadway type (two-lane), divided/undivided (undivided), surface type (BM or bituminous material, PCN or concrete non-reinforced), etc.
2. After the potential routes/pavement sections of interest are identified in ArcMap, perform screening with the ARAN viewer to delineate continuous and homogenous segments of at least 1 mile in length (if possible). Homogeneity was defined as having no change in roadway type/configuration, no change in surface type (e.g. overlays or chip seals, bridges, etc.), no significant change in traffic level, and no change in vehicle speed (speed limits, stop signs, etc.). Delineation requires viewing the latest videos (*travel in both directions*) for the section of interest so that the latest beginning and ending logmile values for said section can be recorded in both directions. The latest logmile values are needed for raw ARAN data extraction.
3. Simultaneously extract all recent and historic data from the appropriate ARAN tables (contains raw IRI, etc., for 0.02 mile-long sections) and SS Pavement (in this study, Current AADT and Com Vol by Dir). NOTE: assistance from Planning may be necessary to customize the SQL query for desired data.
4. Export extracted data files to Excel being cognizant of file size limits.
5. Combine all Excel files in chronological order for each section of interest. This will mean that, for two-lane undivided roadways, there may be interspersing of yearly ARAN data from the other side of the centerline, when the ARAN van was traveling in the opposite direction. This fact effectively results in twice the number of "traveled lane" pavement sections than originally identified in Step 1; i.e. there are two "traveled lane" sections per two-lane, undivided route section. This is an important concept to understand because pavement performance on each side of the centerline could be somewhat different based on different traffic levels (as observed in the data during this study), drainage behavior, etc., even though the cross-section is essentially the same and the surface treatments are applied to both sides at essentially the same time.
6. Augment extracted/exported data with additional historic pavement data (e.g. treatment date, type, and thickness [e.g. chip seals = 0.375 in.], asphalt mix type,

original concrete pavement thicknesses, etc.) via ARAN Viewer, project plan sheets (ARAN Viewer, STIP, archives), 2-AA sheets, asphalt summaries, J-Drive, ProjectWise, maintenance databases, Sharepoint, Pavement Tool, ragmaps, historical highway maps, district maintenance spreadsheets, etc. Plotting the 20-point Condition Index (1988 to 2009, inclusive) as a function of year can help determine if a treatment has occurred but is not showing up in the hard documentation.

7. Augment the Excel file for each section with columns for average or "unit" IRI and Surface Age. "Unit IRI" is the average of the passenger and driver raw IRI values per 0.02 mile-long record. Surface Age is taken as the difference between the date the ARAN data was collected (field name = DATE0) and the last treatment date. It may be necessary to assume a full month/day/year date for the last treatment to properly calculate Surface Age in terms of decimal years (e.g. 4.235 years).
8. Perform quality check on the data.
    a. If negative Surface Ages have been calculated, the treatment date needs adjusting and this means a deeper investigation into the maintenance history of the section of interest. This investigation can start by reviewing the ARAN video and/or may very well mean making personal contact with local maintenance personnel to verify the actual treatment date.
    b. For IRI predictive models:
        i. Remove all pre-1993 data (IRI collection did not start until 1993) and 1997 – 2001 (inclusive) data due to an error in the ARAN algorithm during these years.
        ii. Remove any year of data in which all passenger and driver IRI values are the same for all records in a given year. Beginning in 2002, some recorded IRI data was not collected via the ARAN van but was entered manually.
        iii. Remove all records with passenger and/or driver IRI values of 999.
        iv. Perform an analysis on the percent difference (PDiff) between the passenger and driver IRI. PDiff = (passenger IRI – driver IRI)/Unit IRI. For this study, Minitab Interval Plot and Quality Tools – Run Chart methods were used to determine the yearly mean PDiff ($PDiff_{mean}$), and if it was ≈40% or more, the data was usually removed. However, a 40% or greater $PDiff_{mean}$ did not always result in removal of data because the median PDiff across all years for that section was sometimes very near 40%; i.e. relative closeness of the mean and median yearly PDiff was taken into account when culling data. The Minitab Interval Plot was also used to

make judgments about the data based on time-line trends in between treatments.

9. OPTIONAL: Develop IRI models for the upper 25th percentile of the data (i.e. the worst 25% of the yearly Unit IRI data per section of interest): Determine the 75th percentile value for each year of data for sections of interest. Using routines in Excel, remove all data below the 75th percentile value for each year of data for those sections. These files can now be treated the same as the full dataset files in creating models.
10. Combine into one file, all of the individual database files for each section that belongs to a particular pavement family; e.g. full-depth asphalt, concrete, or composite. These combined “pavement family” database files are used for Pavement Family Model development. Note that each of these pavement family database files will most likely have different types of pavement information in them; e.g. original concrete pavement thickness will be in the concrete and composite databases but not the full-depth asphalt database.
11. Starting with each pavement family database file, sub-divide them into separate files based on treatment type; e.g. 1 in. asphalt overlay on composite, chip seal on asphalt, etc. These files are used for Treatment Model development.
12. Using a software program such as Minitab, convert each database file (where every record or row represents 0.02 miles of pavement) to an “Averages” file that is grouped by County Name, Travelway Name, and Year. In Minitab, for example, one can choose to output and save all sorts of different statistics, including the mean, median, 75th percentile, etc., grouped by any desired parameter. In this study, County Name, Travelway Name, and Year were the grouping parameters, and averaged data included Unit IRI, AADT, and Com Vol by Dir. These three data parameters were, essentially, the only ones that had varying values through the entire length of the section of interest, especially Unit IRI. Data parameters such as Surface Age, Last Treatment Thickness, etc., were constant within each year of data for the section of interest.
13. Augment averages database files with additional pavement information parameters such as climate data (NOAA-NCDC data sources), subgrade soil properties (USDA, ASU, etc. data sources), or any other parameters that apply to the entire length of section of interest. Note that this step could have also been done during Step 6, but adding these full-section length parameters to the averages database files requires less time and effort.
14. RECOMMENDED IF DATABASE IS SUFFICIENTLY LARGE: Although not performed in this study, randomly extract some significant percentage of the averages database files (e.g. 75%) for model-building. The remaining percentage (25%) of the data should be used to validate any model(s) that are developed.

15. Now that the averages database files are configured and randomly reduced for importation into statistical software packages for regression analyses, use model selection procedures and appropriate predictor variable pools to screen for the best model based on standard model-building criteria. NOTE: Because data parameters were averages, the length of the section of interest (SecLength in miles) was used as a weighting factor in all regression procedures that allowed a weighting factor.
    a. Model selection procedures used in this study were stepwise (JMP software), best subsets (Minitab software), and minimum R^2 improvement (SAS).
    b. To avoid any issues with multicollinearity between predictor variables, each model selection (screening) analysis should use a predictor variable pool that includes only those predictor variables that are independent of one another based on the best *a priori* knowledge. For example, the Group Index (GI) is a function of the percent passing the #200 sieve (P200), liquid limit (LL) and plasticity index (PI). PI is a function of the LL. Percent Clay (%Clay) is a function of P200, and percent swell (%Swell) is a function of %Clay and PI (and LL). Thus one must be careful to perform model selection using those soil parameters in the predictor variable pool that are not related mathematically. Traffic parameters may also cause multicollinearity issues during model selection if not handled properly. Since Com Vol by Dir is usually some percentage of AADT, it may not be wise to include them both in the predictor variable pool for individual model selection procedures. However, collinearity diagnostic statistics such as the Variance Inflation Factor (VIF) or the condition number (CN) are useful to help determine which predictor variables can and cannot be used together in a model.
    c. Criteria for a good model are a reasonably high goodness-of-fit statistic such as R^2 (or adjusted-R^2 if comparing models with differing numbers of predictor variables), statistically significant and independent predictor variables (p-values less than 0.05, and VIFs < 3, respectively), and signs on the regression coefficients (i.e. parameter estimates) that make sense. Regarding the sign on a regression coefficient in an IRI prediction model, for example, if the Surface Age term coefficient has a negative sign on it, something is wrong because that means that as the pavement surface gets older (Surface Age goes up), the pavement gets smoother (IRI goes down).
16. Once a model is developed, validate the model by fitting it to an independent set of data to see how well it predicts said data.

Updating Existing Models:

To update an existing model, which means keeping the same variables in the model, one would simply append newly acquired data onto the database file previously used to develop and validate the existing model (i.e. enlarge the database created just prior to Step 14 above), then fit the existing model to the enlarged database. Do not forget to use the SecLength parameter as a weighting factor. Check the regression results using criteria discussed in Step 15c above. If the regression analysis is not satisfactory, meaning one's confidence in the predictive ability of the model is diminished, it may help to remove the oldest data in the database and re-run the regression. It seems logical that confidence in the model's predictive ability would increase by removing the oldest data in the database as newer data is added. Adding newer data and discarding older data would better reflect changes in material properties, data collection protocols, and the quality of construction/maintenance methods, to mention a few. If, however, keeping the database approximately the same size as during the previous model development while simultaneously improving the quality of the data does not produce a model of equivalent predictive ability, one should consider developing new models using the upgraded data.

Creating New Models:

To create new models, one would follow the basic methodology outlined above but one would (hopefully) begin with more, complete, reliable, and up-to-date data. Also, there could be a greater variety of potential predictor variables to evaluate in the model selection process. Fig. C.1 is a flowchart of the model-building and updating process.

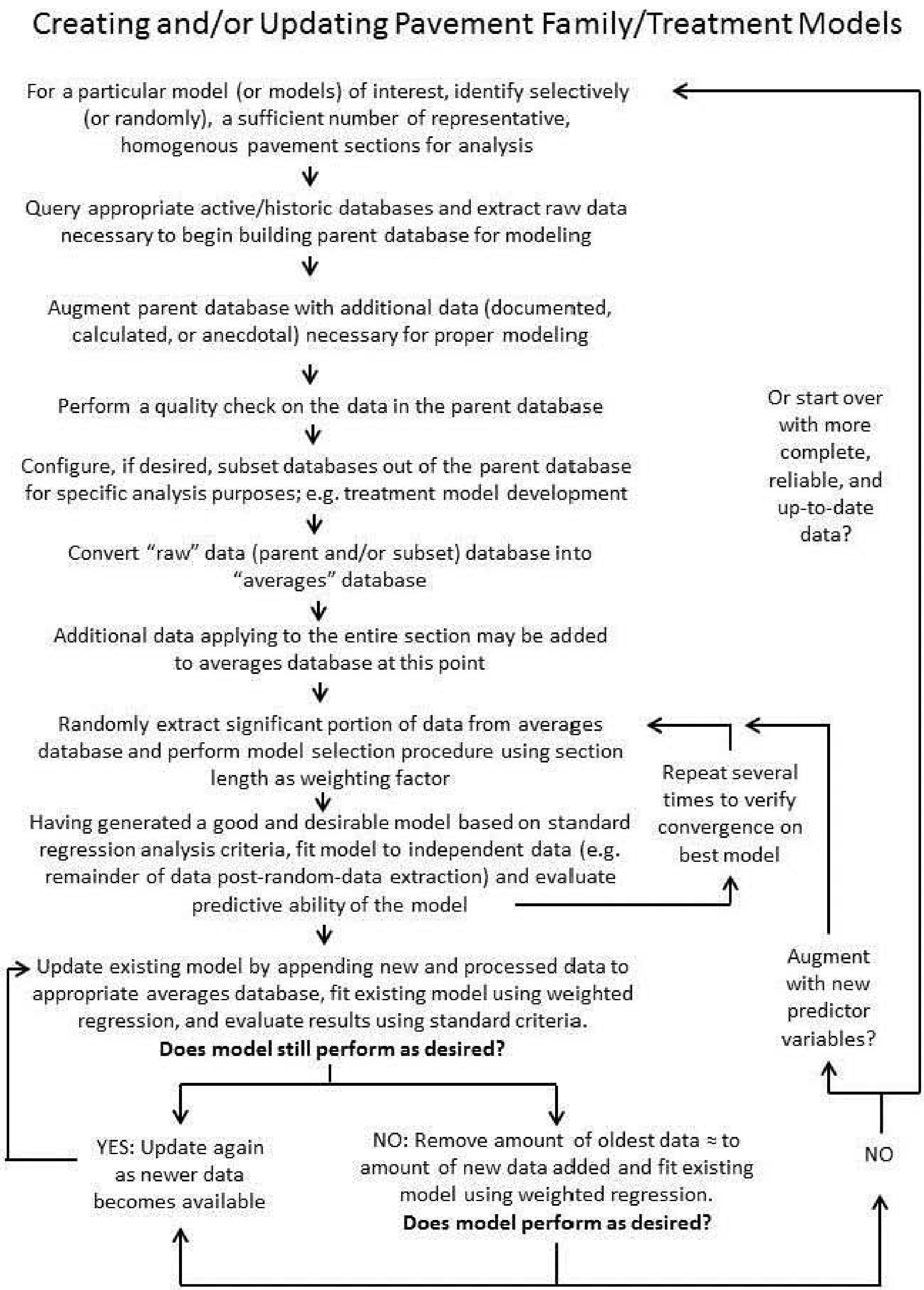


Fig. C.1 – Flowchart for model-building and updating.

APPENDIX 1D – SUBGRADE SOILS DATA PROCUREMENT: ASU and USDA WEBSITES

For specific minor routes, data will probably not be available from MoDOT sources, so two other non-MoDOT sources can be used: Arizona State University (ASU) and U.S. Department of Agriculture (USDA) soils maps.

A first-pass, fairly simple but less detailed, source of soil condition parameters for the selected pavement segments can be obtained through an online tool available through the ASU Soil Unit Map Application portal as discussed in NCHRP Project 9-23B (Zapata and Carey, 2012). The data are derived from USDA soils maps.

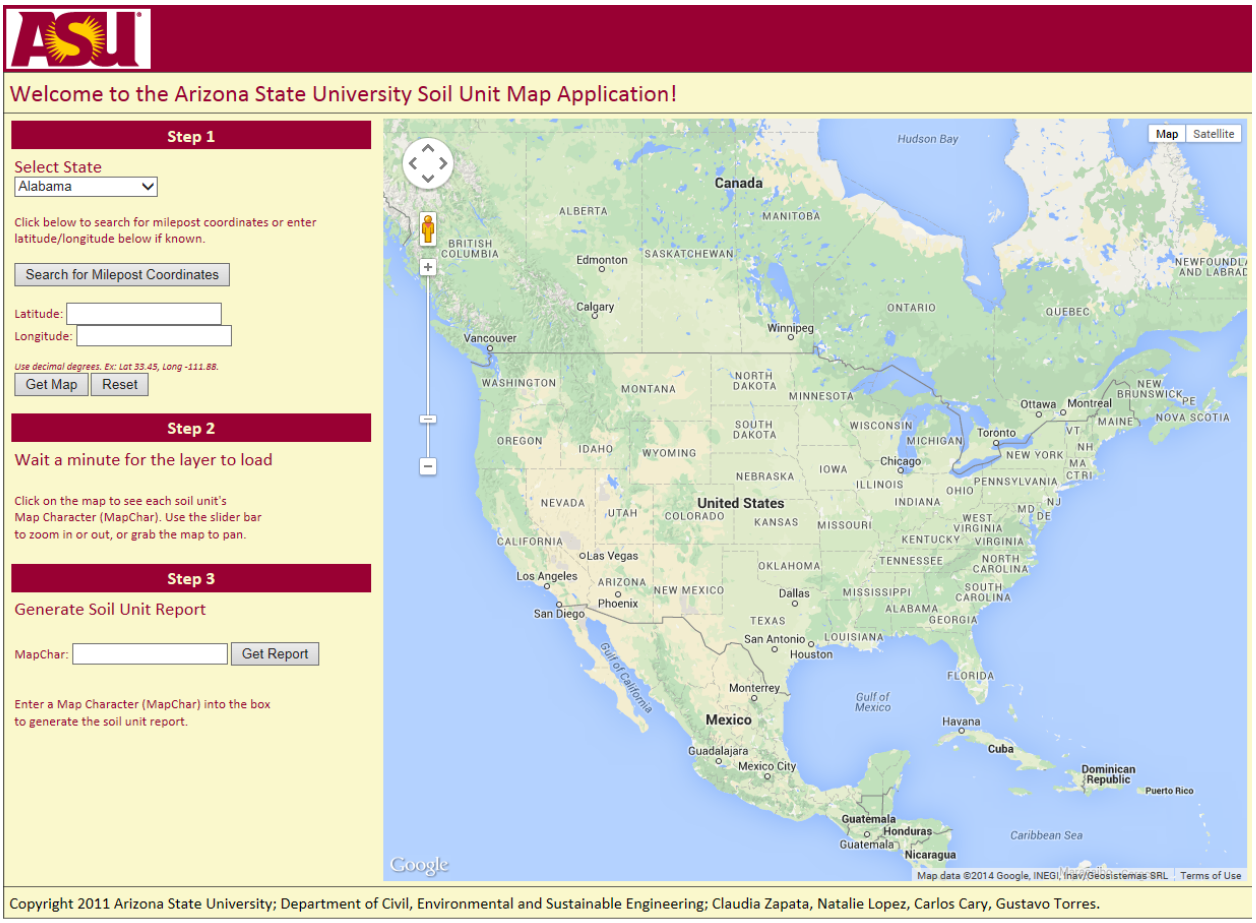


Fig. D.1 - ASU Soil Unit Map Application webpage.

An example of a specific project site is shown in Fig. D.2. It should be noted that the number of soil types is fairly small, usually one or two. The dataset associated with one of the soil types is shown in Fig. D.3. Data are delineated by depth and test results. The small number of soil types and extent both horizontally and vertically of each soil type is simplified from actual USDA reports, which will be presented next. To arrive at one overall description of the soil for a given roadway segment, the user has to manually do a weighted average calculation of soil characteristics from layer thicknesses and horizontal extent of each soil classification, as estimated from the figure.

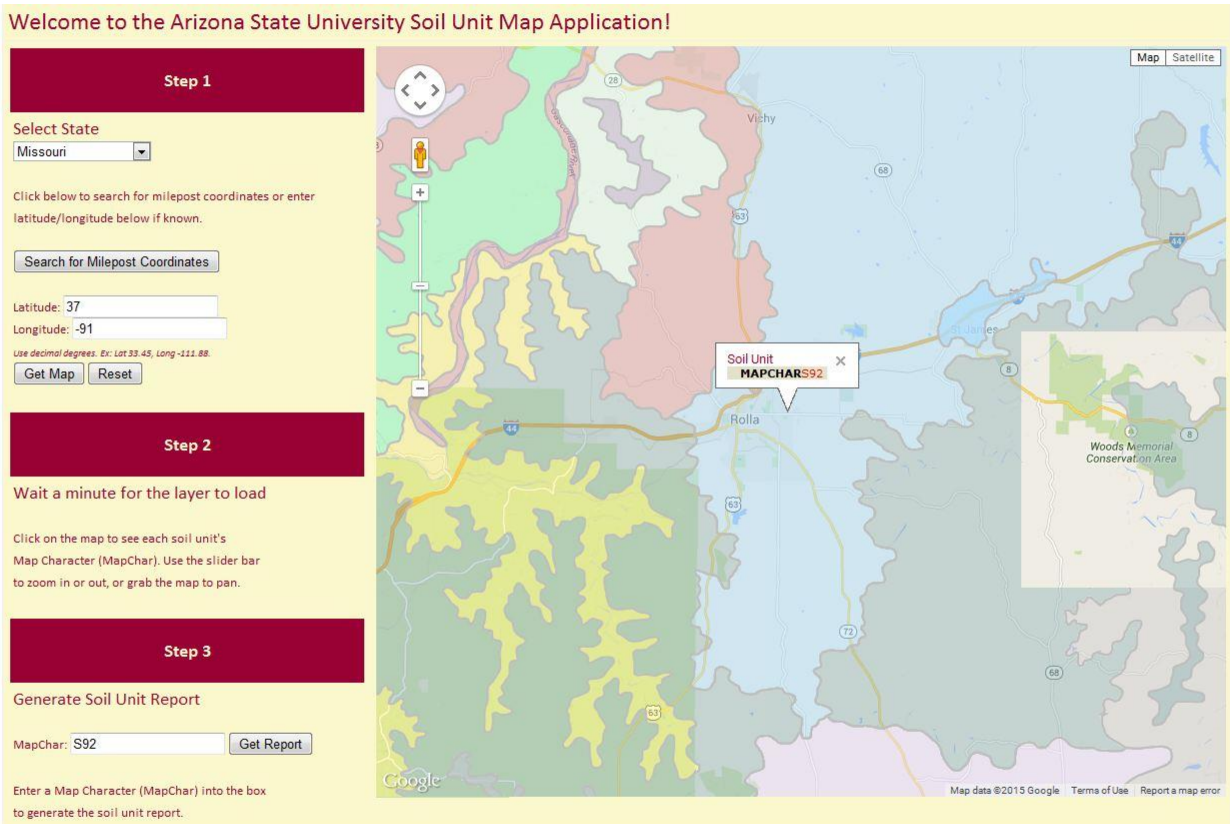


Fig D.2 - ASU Soil Unit Map Application webpage for Route BB, Phelps County.

Properties of Soil Unit S92

Map Character	Map Unit Key	Map Unit Name	Component Name
S92	663302	Union-Swiss-Beemont (s3801)	Union

AASHTO Classification	AASHTO Group Index	Top Depth (in)	Bottom Depth (in)	Thickness (in)	% Component	Water Table Depth Annual Min (ft)	Depth to Bedrock (ft)
A-4	7	0	9.1	9.1	34	1.57	N/A
A-7-6	18	9.1	29.9	20.9	34	1.57	N/A
A-2-6	0	29.9	53.1	23.2	34	1.57	N/A
A-7-6	26	53.1	79.9	26.8	34	1.57	N/A

CBR from Index Properties	Resilient Modulus from Index Properties (psi)	Passing #4 (%)	Passing #10 (%)	Passing #40 (%)	Passing #200 (%)	Passing 0.002 mm (%)	Liquid Limit (%)
11	11848	100	95	90	80	21	30
5.4	7545	95	90	85	80	37.4	44
41.6	27793	25	20	15	10	19	30
3.3	5502	75	65	60	55	73	79

Plasticity Index (%)	Saturated Volumetric Water Content (%)	Saturated Hydraulic Conductivity (ft/hr)	Parameter af (psi)	Parameter bf	Parameter cf	Parameter hr (psi)
10	43	0.1063	7.691	0.8514	0.7202	3000
22	44	0.1063	4.2065	0.8844	0.4141	3000.03
11	N/A	0.01181	N/A	N/A	N/A	N/A
54	33	0.03543	0.0001	44.189	0.0059	3005.16

1 record found matching your criteria

Print Report Close

Fig. D.3 - ASU Soil Unit Map Physical Data for Route BB, Phelps County.

USDA Website

A more detailed source of data regarding subgrade can be found from the USDA soil surveys, which are organized by county. The website URL is as follows:

http://websoilsurvey.nrcs.usda.gov/app/

To retrieve data for a given roadway segment:

1. Access the USDA website.
2. Left-click on the “START WSS” button.
3. Left-click on “State and County” on the menu on the left side of the screen
4. Select state and county of interest from drop down menus.
5. Left-click on the “View” button.
6. Left-click on the “Zoom In” magnifying glass icon located on the top/horizontal toolbar and delineate the area of interest on the map by clicking and holding down the cursor, drawing a perimeter around the desired area. It is recommended that at this stage to delineate a fairly large area.
7. Left-click on the polygon icon on the AOI Interactive Map/horizontal toolbar, then left-click points around the roadway to delineate the “Area of Interest” (AOI). It is recommended to keep the area as tight to the roadway as possible. When finished, double left-click.
8. To set up for printing, left-click on “Preferences” on the top/horizontal toolbar.
9. Left-click on “Remember Preferences…”
10. De-select the “Open Links and PDFs…”. Left-click on the “Save Preferences” button. Steps 8-10 should not have to be repeated during the session.
11. Left-click on the “Soils Data Explorer” tab on the top/ horizontal tab selection area, as shown in Fig. D.4.

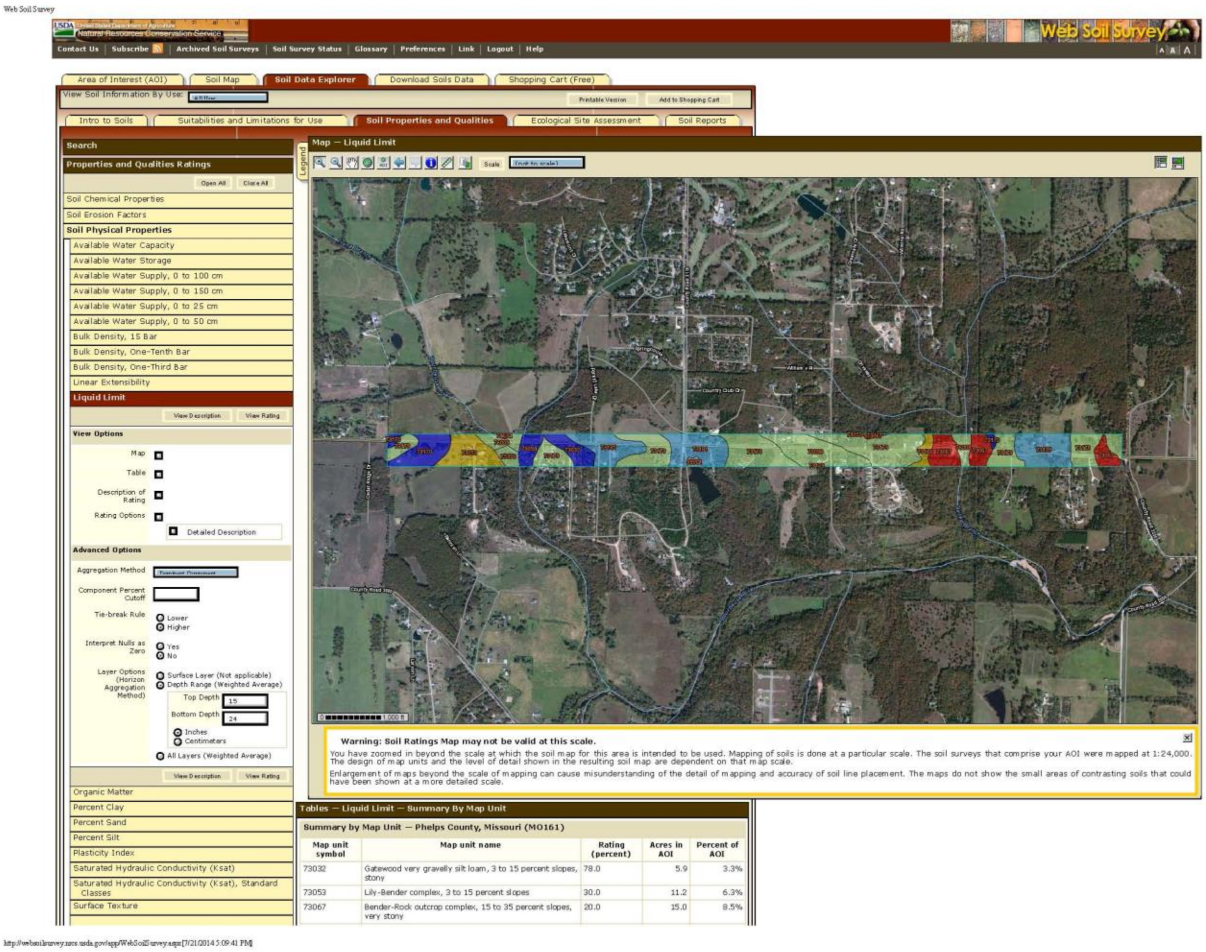


Fig. D.4 – USDA "Soil Physical Properties" view of a delineated roadbed with Liquid Limit displayed.

12. Left-click on the "Soil Properties and Qualities" tab on the top/ horizontal tab selection area.
13. Left-click on the "Soil Physical Properties" choice on the left side of the screen.
14. Choose the soil property of interest (such as "Liquid Limit" [LL]) for all Map Units by left-clicking the property listed.
15. Left-click on the "All Layers" radio button.
16. Choose the "Aggregation Method" by clicking on the choice. This deals with what values will be displayed, depending on the rules governing the choice. For an overall description of what is in the soil units, choose "Dominant Condition".
17. Left-click on the "View Rating" button. The soil properties of interest (e.g. LL) is in the "Rating (Percent)" column. Also of interest is the "Percent AOI" column.
18. Left-click on "Printable Version" on the top/horizontal toolbar.
19. Left-click on "View".
20. Left-click on the print icon. Select pages to print. Select "OK".

21.Left-click on the previous page arrow.
22. Repeat steps 14-20 for other soil properties such as Plasticity Index (PI), Percent Clay, Percent Silt, and Percent Sand to be able to classify the soil and predict swell potential and frost susceptibility.
23. To determine details of the soils in each soil unit at depth, and to determine % Rock Fragments, left-click on "Soil Reports" in the top/horizontal tab selection area.
24. Left-click on "Soil Physical Properties" on the left side of the screen.
25. Left-click on "Engineering Properties" on the left side of the screen.
26. Left-click on "Include Minor Soils" if displaying all soils is desired
27. Left-click on "View Soil Report". This will display each Map Unit and subsets of Soil Names (e.g. associations), percent of each Soil Name, different soil layers at various depths, soil classification, and ranges of properties.
28. Print as in steps 18-20.
29. Left-click on "Particle Size and Coarse Fragments" on the left side of the screen.
30. Left-click on "View Soil Report".
31. Print as in steps 18-20.

The "Map Unit" soil numbers are contoured on the maps, as shown in Fig. D.4. The "Percent AOI" is displayed and is the percent of the roadway delineated as that Map Unit. Map Units may be made up of several Soil Names. These are shown in Fig. D.5 (just the first one "70302" is showing). Not shown in Fig D.5 but on the actual screen display are each Soil Name within each Map Unit, and the Soil Name percents within the Map Unit. Thus, to obtain the percent of an association within the delineated roadway, the % Map Unit would be multiplied by the % Soil Name within that Map Unit.

To classify each fine-grained layer in each association as to the AASHTO method and to calculate Group Index (GI), the LL, PI, and % minus #200 sieve are required. To estimate swell potential by the Seed method, PI and % clay (< 0.002 mm) are required. To classify soil as to frost susceptibility by the U.S. Corps of Engineers method, PI, % silt, and % sand are required. Unfortunately, the USDA and AASHTO do not agree on what constitutes the particle size boundaries between clay, silt, and sand. To confound the issue, the USDA clay, silt, and sand percents displayed are of the minus 0.02 mm (#10 sieve) rather than total soil. And, there is no #200 sieve value shown for individual associations. USDA defines Rock Fragments as greater than 2 mm.

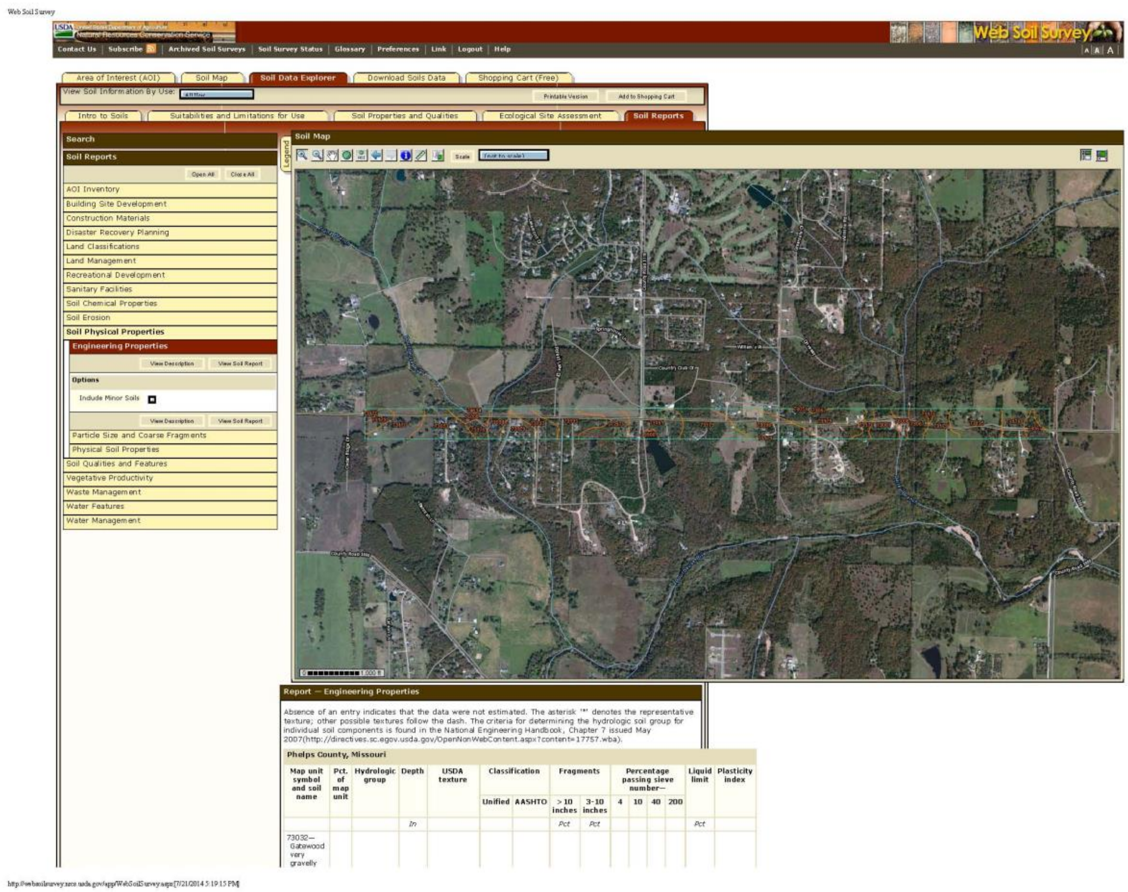


Fig. D.5 – USDA "Soil Reports" view of a delineated roadbed with all soil Map Unit contours displayed.

To navigate through all this, the following is recommended:

1. Set up a spreadsheet and enter LL, PI, % clay, % silt, % sand, and average % Rock Fragments.
2. Calculate the % finer-than (<) 2mm material by: (100-%total Rock Fragments).
3. Adjust the %'s from < 2mm-basis to total soil-basis by multiplying each % by the %< 2mm:

% clay, total = (% <2mm)(% clay from website)/100
% silt, total = (% <2mm)(% silt from website)/100
% sand, total = (% <2mm)(% sand from website)/100

4. Calculate an approximate % minus #200 by: (% silt, total + % clay, total).

Now the soils can be classified, GI calculated, % swell calculated, and frost susceptibility adjudged. Weighted averages of each soil's % swell, GI, and frost susceptibility can be calculated for the entire roadway using the percents discussed above. An example is shown below. MoDOT does not have any hard-and-fast rules about what constitutes a problematic swelling soil and frost susceptible soil for subgrades.

Swell potential by the Seed method is a function of PI and % clay size. Frost potential is evaluated by two methods: 1) extent of soil that is classified as A-4 and A-6 (PI less than 12), or 2) extent of soil that is classified as silty-sand. Weighted percent areas for swell and frost susceptibility are shown in the bottom row. This analysis indicates that a certain segment of Highway U in Bates County has 38% subgrade of its area at greater than 10% swell (high potential) and 13% is frost susceptible. This was a route identified by district maintenance personnel as having persistent subgrade issues.

Table D.1- Example of soil classification

									>2mm		%fine-medsand			
Rt	soil unit s	%AOI	Depth	LL	PI	%clay	%silt	%sand	%Fragmen	<2mm	0.05-2mm	%silt	%clay	%~ #200
U	40051	3.6		24.0	6.8	19.8	28.7	52	10	90	47	26	18	44
Bates Co.	40054	1.4		41.1	19.3	29.7	62.9	8	2	98	8	62	29	91
Western F	40065	3.2		46.0	21.0	38.5	35.4	26	9	91	24	32	35	67
	40066	11.5		39.3	20.3	37.8	49.2	9	1	99	9	49	37	86
	40072	38.2		58.7	33.7	46.3	49.0	4	3	97	4	48	45	92
	40113	1.3		56.0	31.4	43.9	50.2	6	2	98	6	49	43	92
	46002	8.5		32.3	12.1	28.5	65.2	8	0	100	8	65	29	94
	46005	9.6		29.7	10.5	24.4	66.4	4	0	100	4	66	24	91
	46011	1.7		38.9	17.5	30.7	61.5	10	0	100	10	62	31	92
	99011	21.0		39.8	17.7	25.7	36.3	38	47	53	20	19	14	33
	sum	100.0												

			Swelling prone= >10, 25% Swell						Frost-prone= A-4 and A-6 PI<12					Frost prone=Silty Sand				either
Rt	soil unit s	%AOI	%Swell	Swell	WtedSwe	%>10%	%>25%	#200> 35	LL < 41	PI < 12	GI < 9	frost susc?	frost area	0.05-2mm	%silt>15	frost susc	frost area	
U	40051	3.6	0.2	LOW	0.0	0.0	0.0	1	1	1	1	YES	3.6	1	1	YES	3.6	YES
Bates Co.	40054	1.4	2.3	MEDIUM	0.0	0.0	0.0	1	0	0	0	NO	0.0	0	1	NO	0.0	NO
Western F	40065	3.2	3.1	MEDIUM	0.1	0.0	0.0	1	0	0	0	NO	0.0	0	1	NO	0.0	NO
	40066	11.5	3.0	MEDIUM	0.3	0.0	0.0	1	1	0	0	NO	0.0	0	1	NO	0.0	NO
	40072	38.2	11.5	HIGH	4.4	38.2	0.0	1	0	0	0	NO	0.0	0	1	NO	0.0	NO
	40113	1.3	9.4	HIGH	0.1	0.0	0.0	1	0	0	0	NO	0.0	0	1	NO	0.0	NO
	46002	8.5	0.7	LOW	0.1	0.0	0.0	1	1	0	0	NO	0.0	0	1	NO	0.0	NO
	46005	9.6	0.5	LOW	0.0	0.0	0.0	1	1	1	1	YES	9.6	0	1	NO	0.0	YES
	46011	1.7	1.8	MEDIUM	0.0	0.0	0.0	1	1	0	0	NO	0.0	0	1	NO	0.0	NO
	99011	21.0	1.7	MEDIUM	0.3	0.0	0.0	0	1	0	1	NO	0.0	0	1	NO	0.0	NO
	sum	100.0			5.5	38.2	0.0						13.2				3.6	13.2

APPENDIX 1E – CLIMATE DATA PROCUREMENT

Three climate-related factors have been linked to maintenance treatment performance: 1) the number of days/year that precipitation was greater than 0.1 in. [2.5 mm]), 2) the number of days/year that the minimum air temperature was below 32° F [0°C], and 3) the number of freeze-thaw days per year. The first two can be obtained from the NOAA website, while the third from AASHTOWare.

NOAA
Directions for extracting climate data from NOAA NCDC website:
Go to this website
http://www.ncdc.noaa.gov/cdo-web/

Fig. E.1 – NCDC Climate Data Online (CDO) homepage.

Click on "Search Tool" link (bottom left, blue box)
This is the first screen visible.

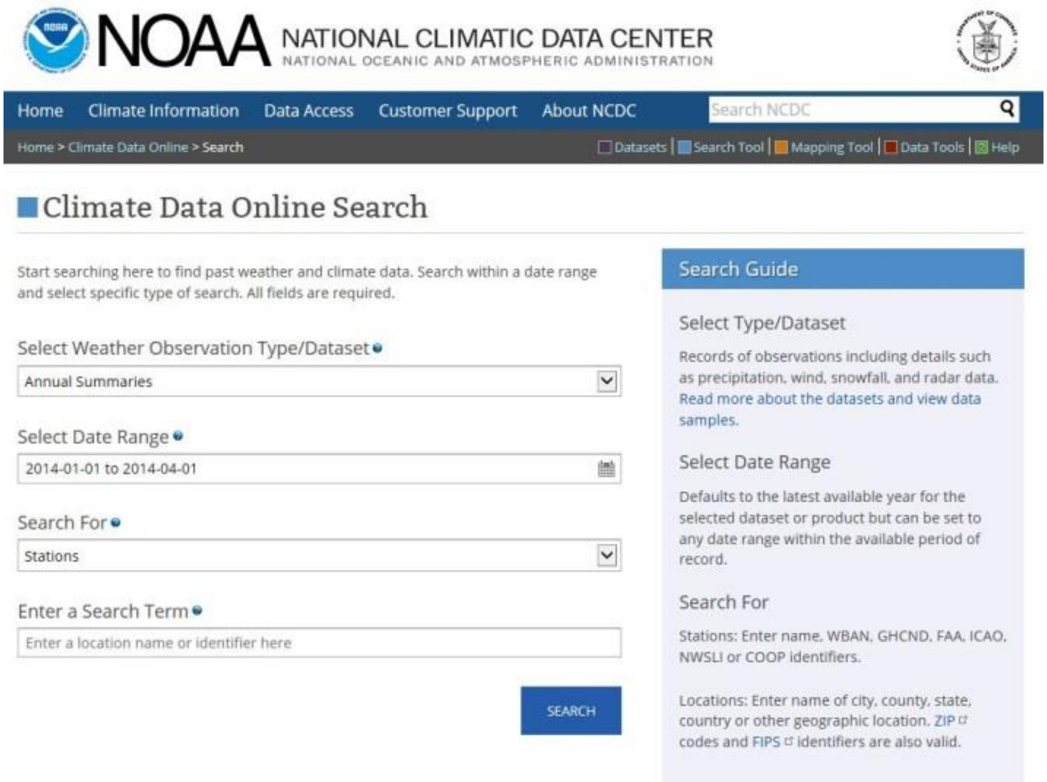


Fig. E.2 – NCDC CDO Search Tool default first page.

Annual Summaries is the default choice for “Select Weather Observation Type/Dataset.” Do not change this selection.
“Select Date Range” is an option one will have to select. Click on the little calendar to the far right in the “Select Date Range” box.

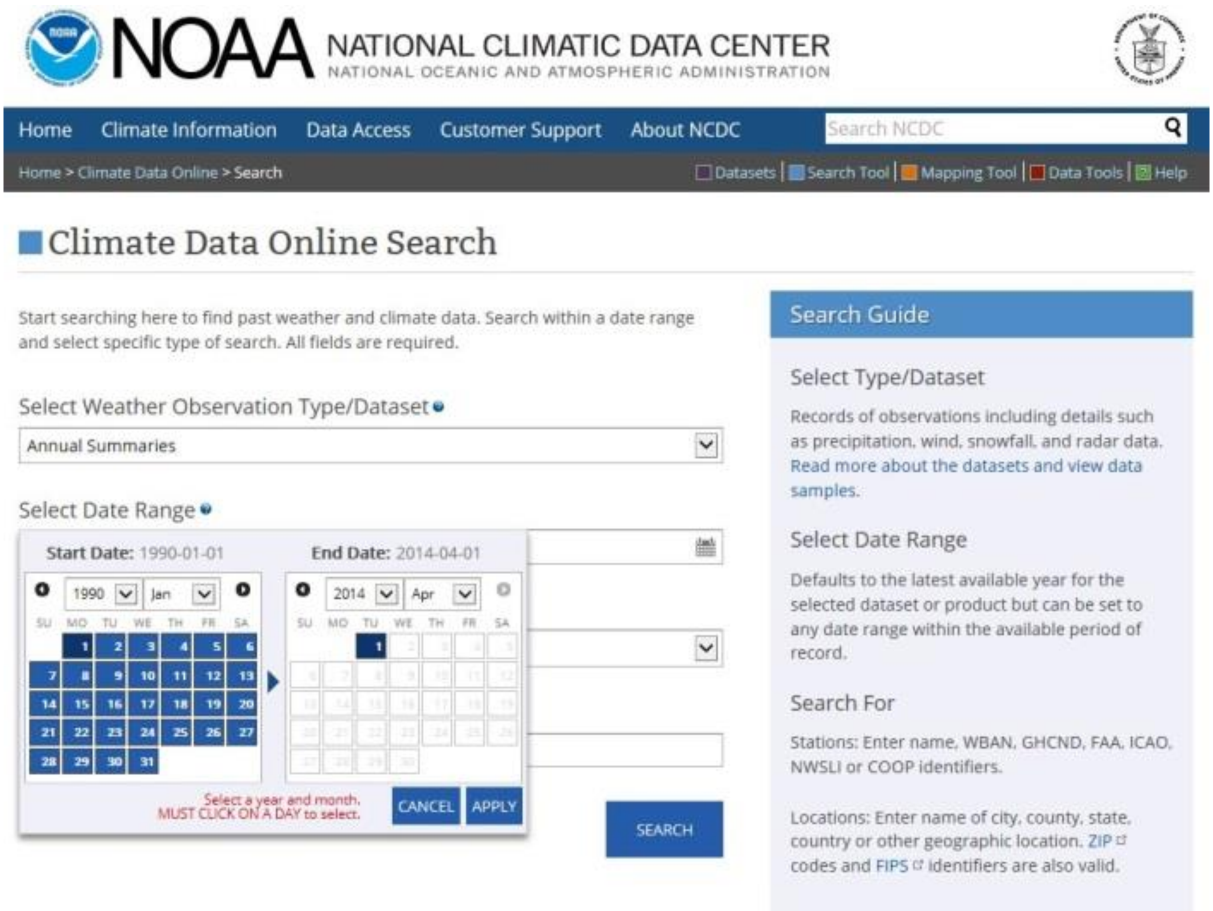


Fig.E.3 – NCDC CDO Search Tool, Select Data Range calendars.

In the left calendar, select a beginning date for data (in this example, January 1, 1990 was chosen). The right calendar has the most recent date that data is available (in this example, April 1, 2014 is left as-is). Click on the "Apply" button. You will see that the dates chosen are now in the "Select Date Range" box. Leave the "Search For" default selection of "Stations" as-is. In the "Enter Search Term" box, one can enter several different search terms but in this example, all weather stations in Missouri, US are searched for by typing "MO US" in the box. Click on the "Search" button.

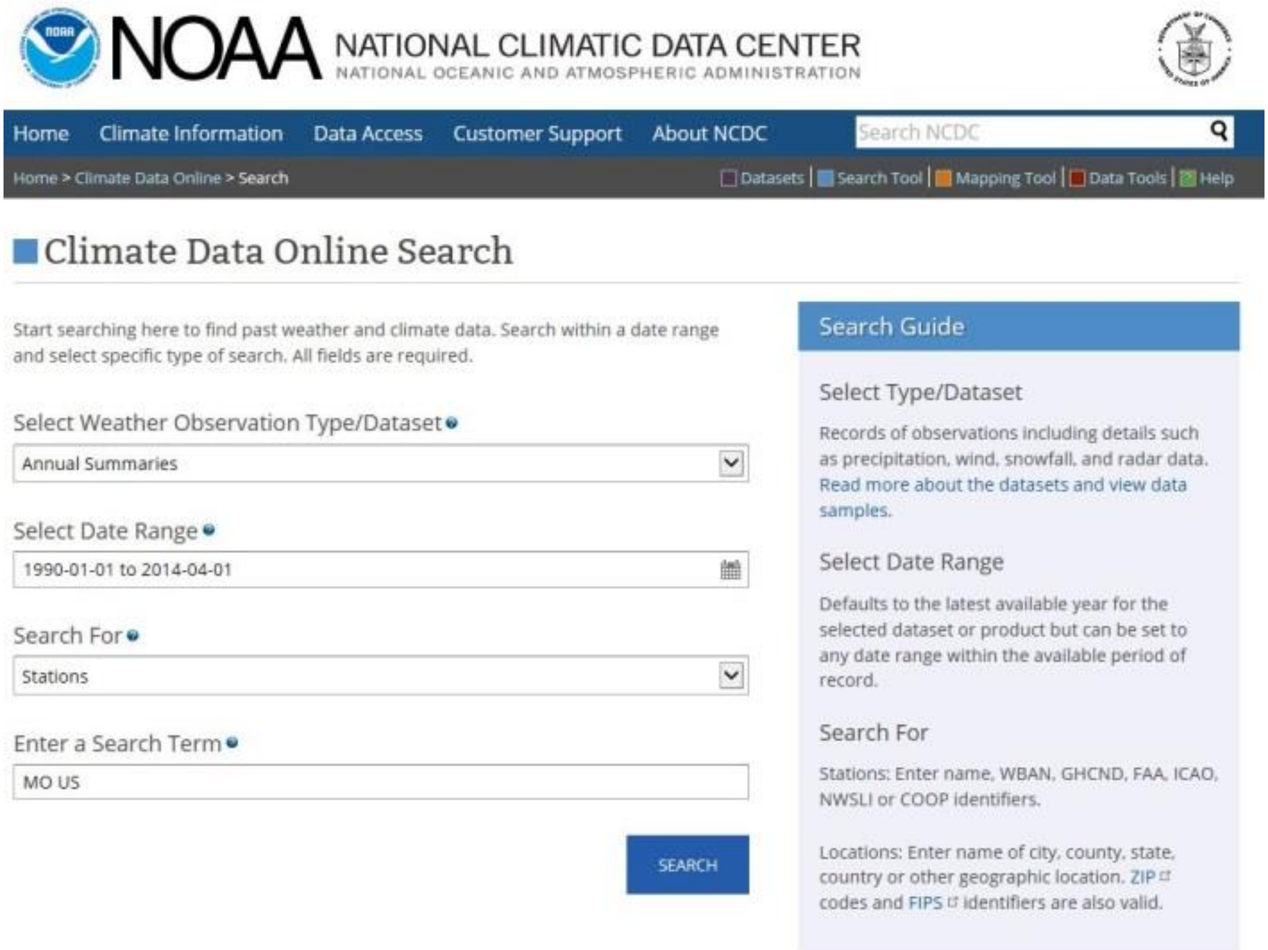


Fig. E.4 – NCDC CDO Search Tool, Enter Search Term page.

Below is the next window that will appear.

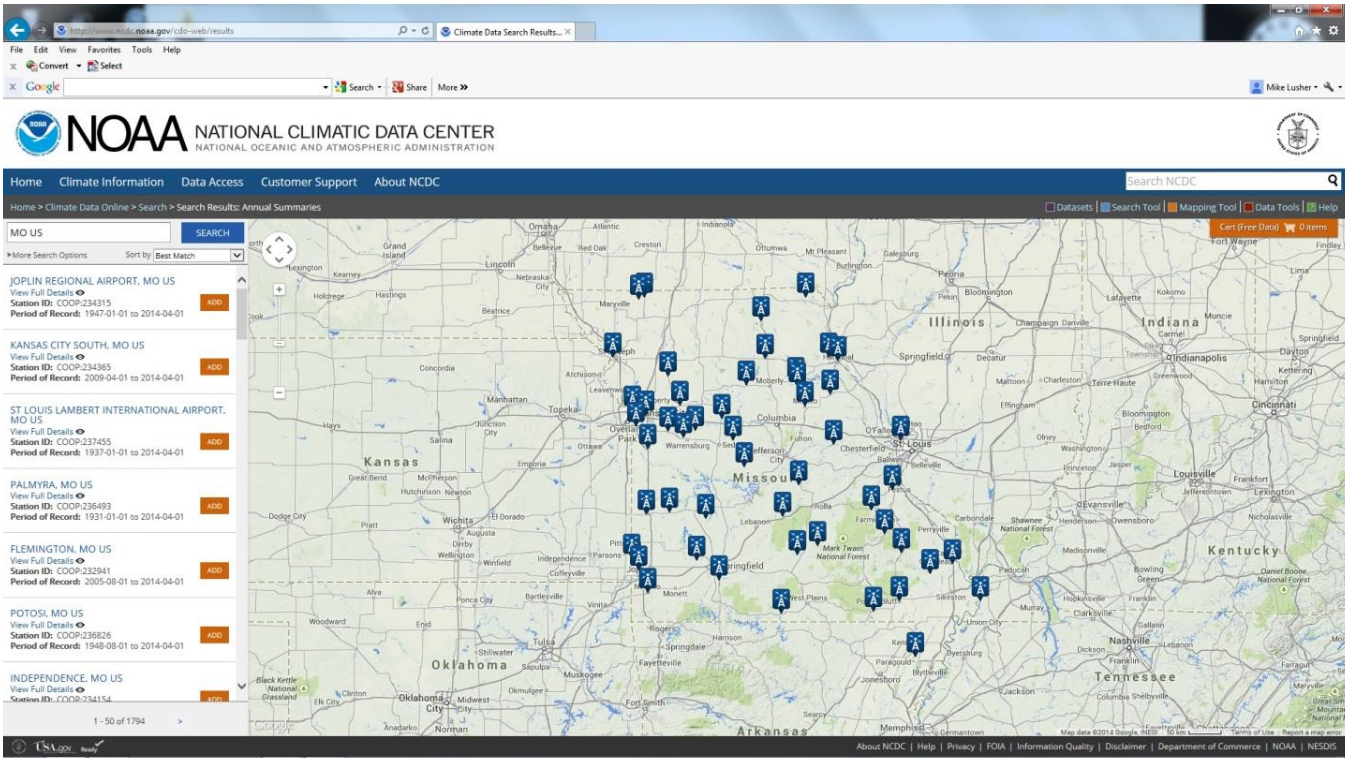


Fig. E.5 – NCDC CDO Search Tool, search results.

The next step is to add the desired “Stations” to your ‘shopping’ cart (see upper right corner of screen). One still has to use some judgment when selecting stations because of the “Period of Record” date for each station, although one selected a “Date Range” previously in the process. In this example, only those Missouri stations that had a “Period of Record” that encompassed the desire “Date Range” are ‘added’ to the cart. The next image shows what happens when certain stations are added.

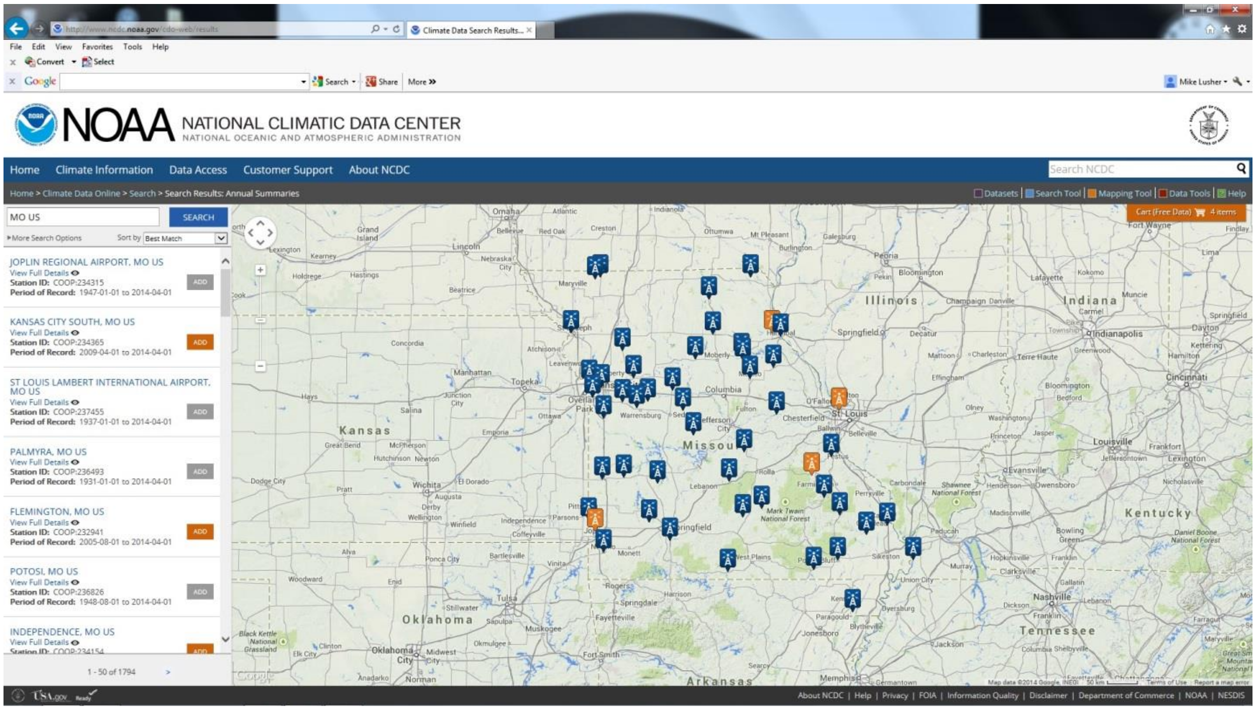


Fig.E.6 – NCDC CDO Search Tool, add select search results to data cart (part 1).

In this example, the Joplin, St. Louis Lambert Airport, Palmyra, and Potosi stations were added (note that the add buttons become grayed-out and the selected station icon towers change color from blue to orange). For this example, a few more stations were selected/added by scrolling down.

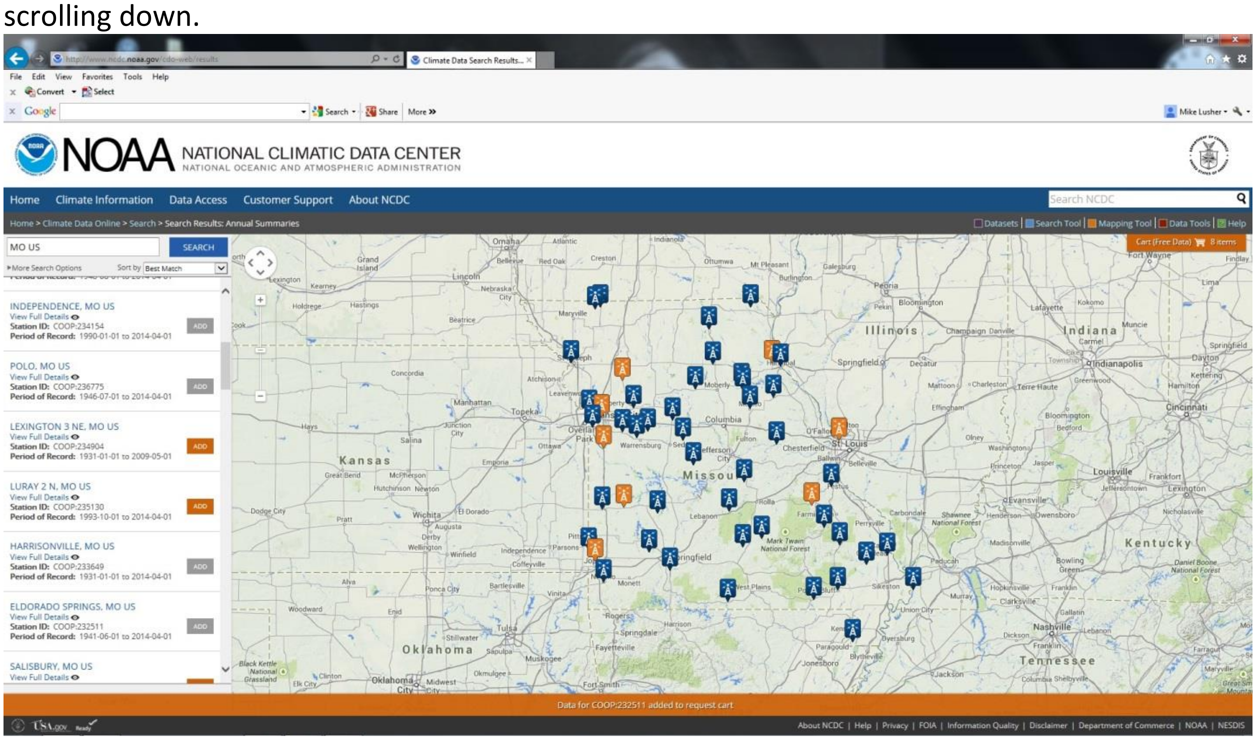


Fig. E.7 – NCDC CDO Search Tool, add select search results to data cart (part 2).

Four more stations were added: Independence, Polo, Harrisonville, and El Dorado Springs. Note the change in colors again. Assuming one has chosen all stations desired, click on the "Cart (Free Data) – 8 items" link in the upper right corner of the page.

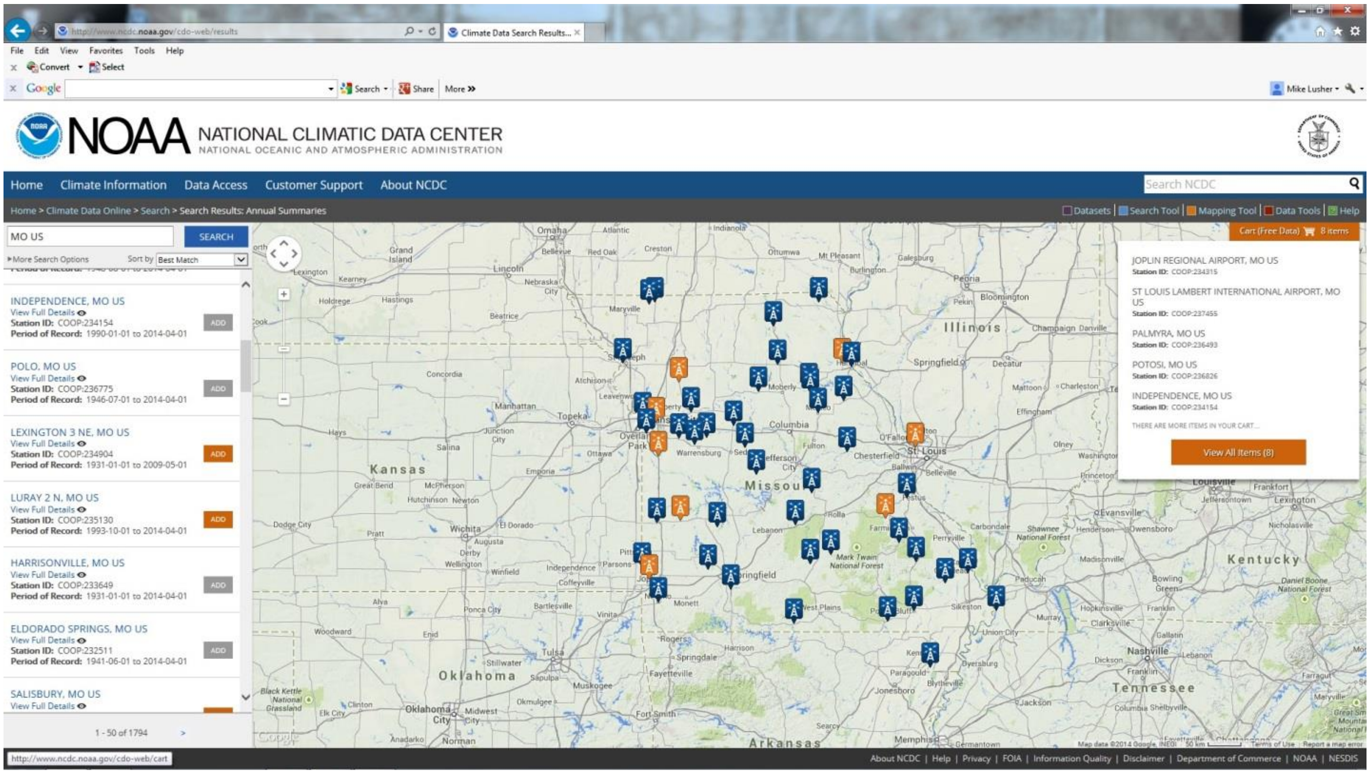


Fig. E.8– NCDC CDO Search Tool, view data cart contents drop-down.

Next, click on the "View All Items (8)" button in the drop down menu (upper right corner of page). Below is the next page that will appear.

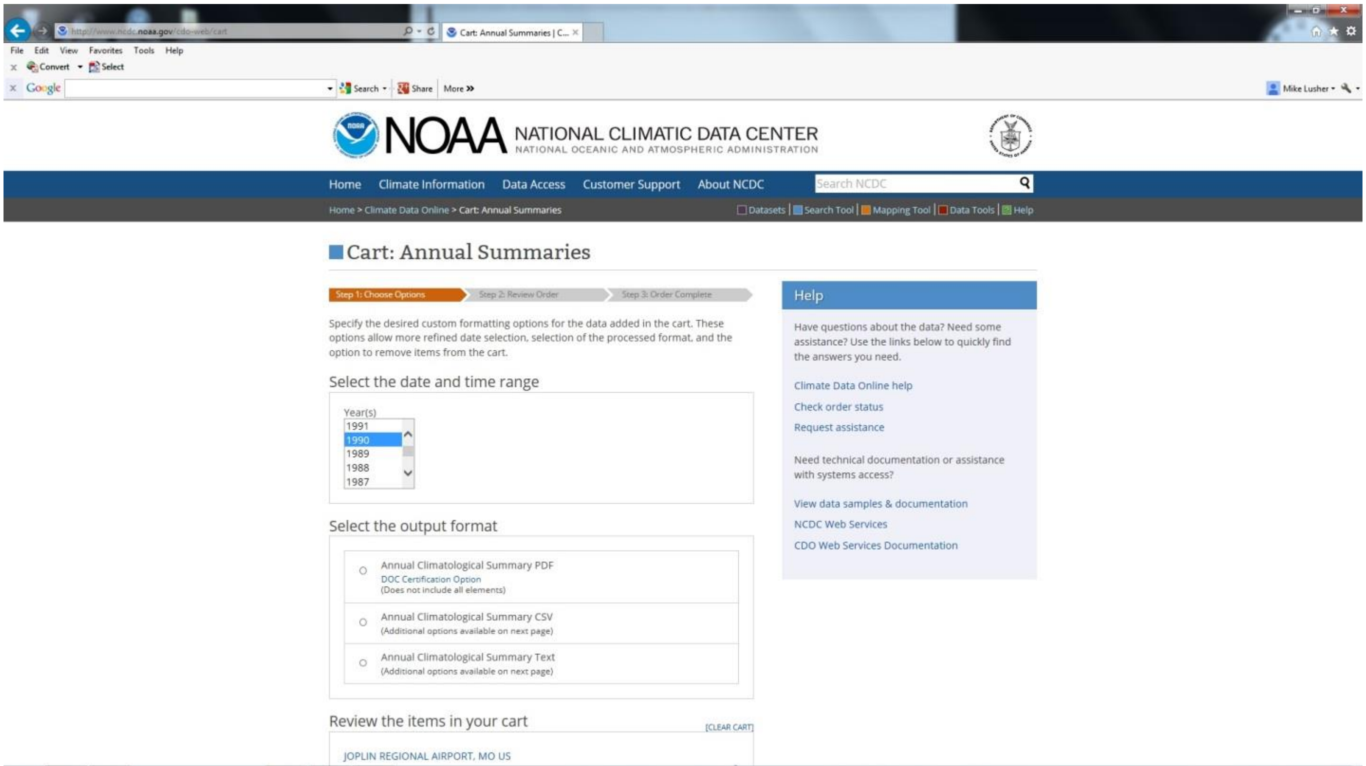


Fig. E.9– NCDC CDO Search Tool, requested data formatting options selection page.

One will note that there is another requirement for choosing a date range in the "Select the date and time range." In this example, the same range of years was selected by, first, scrolling down and highlighting the year "1990." The yearly range originally desired was 1990 to 2014, so scroll up until 2014 is visible, hold down the "shift" key, and click on the year "2014." Below is the next view.

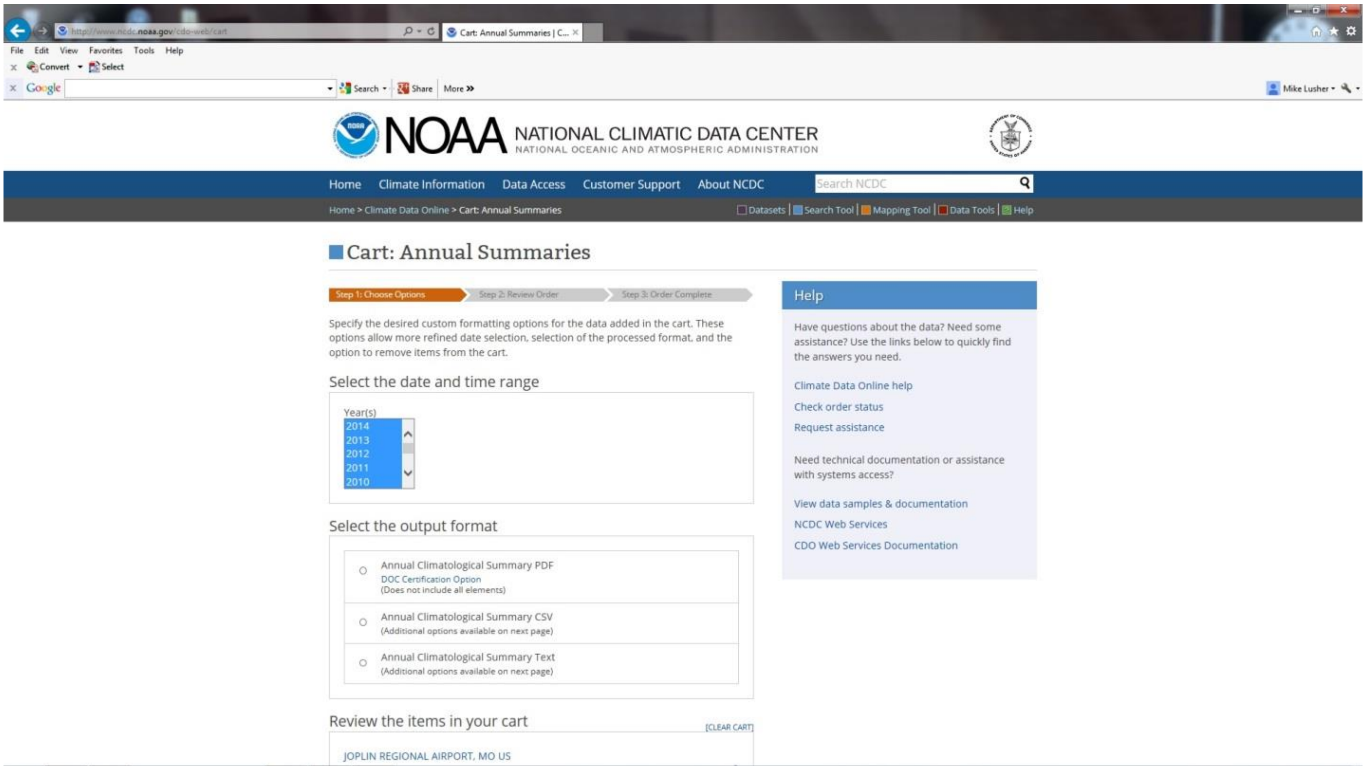


Fig. E.10 – NCDC CDO Search Tool, requested data Time Range selection.

One can see that all years from 2014 down to 1990 are highlighted blue meaning they are selected. Next, select “Annual Climatological Summary CSV” by clicking on the radio button to the left of that box. Below shows the next view.

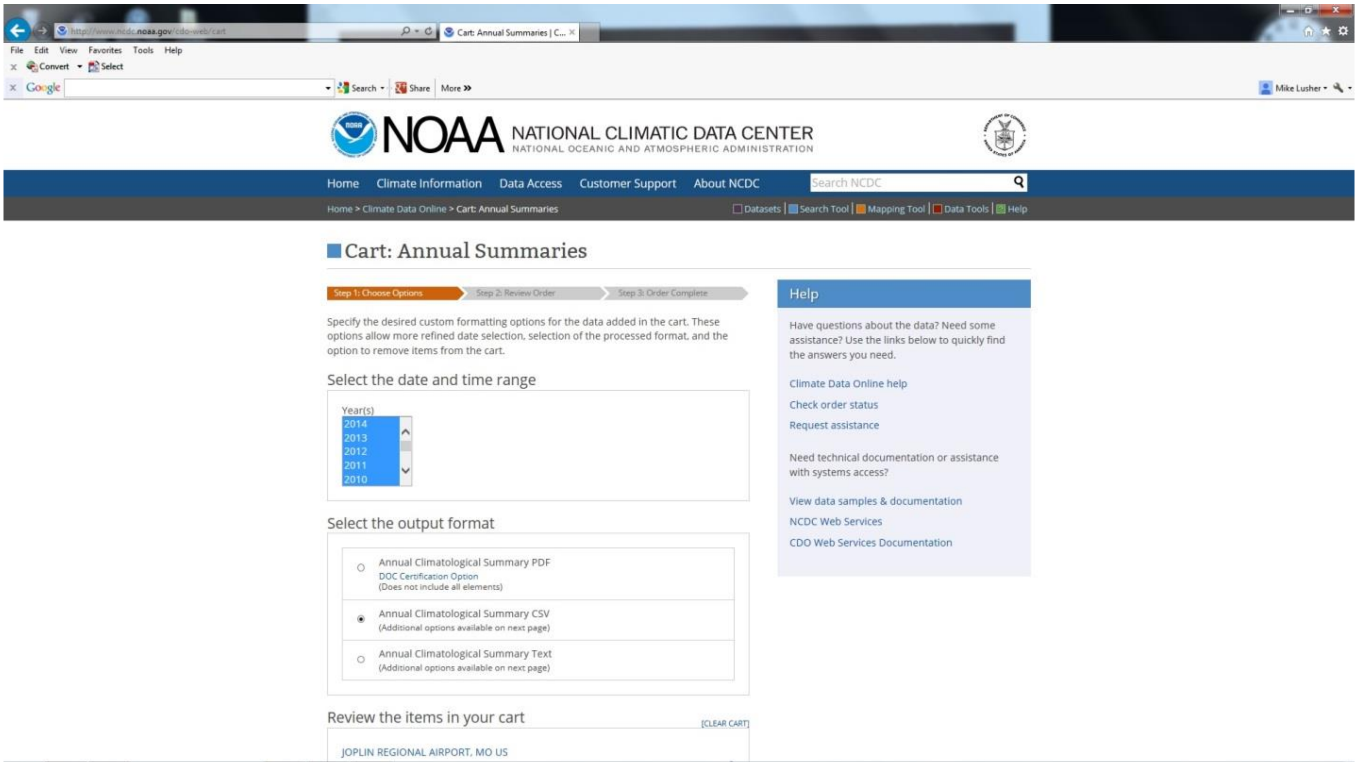


Fig. E.11– NCDC CDO Search Tool, requested data Output Format selection.

The image below shows the bottom half of the page view shown above.

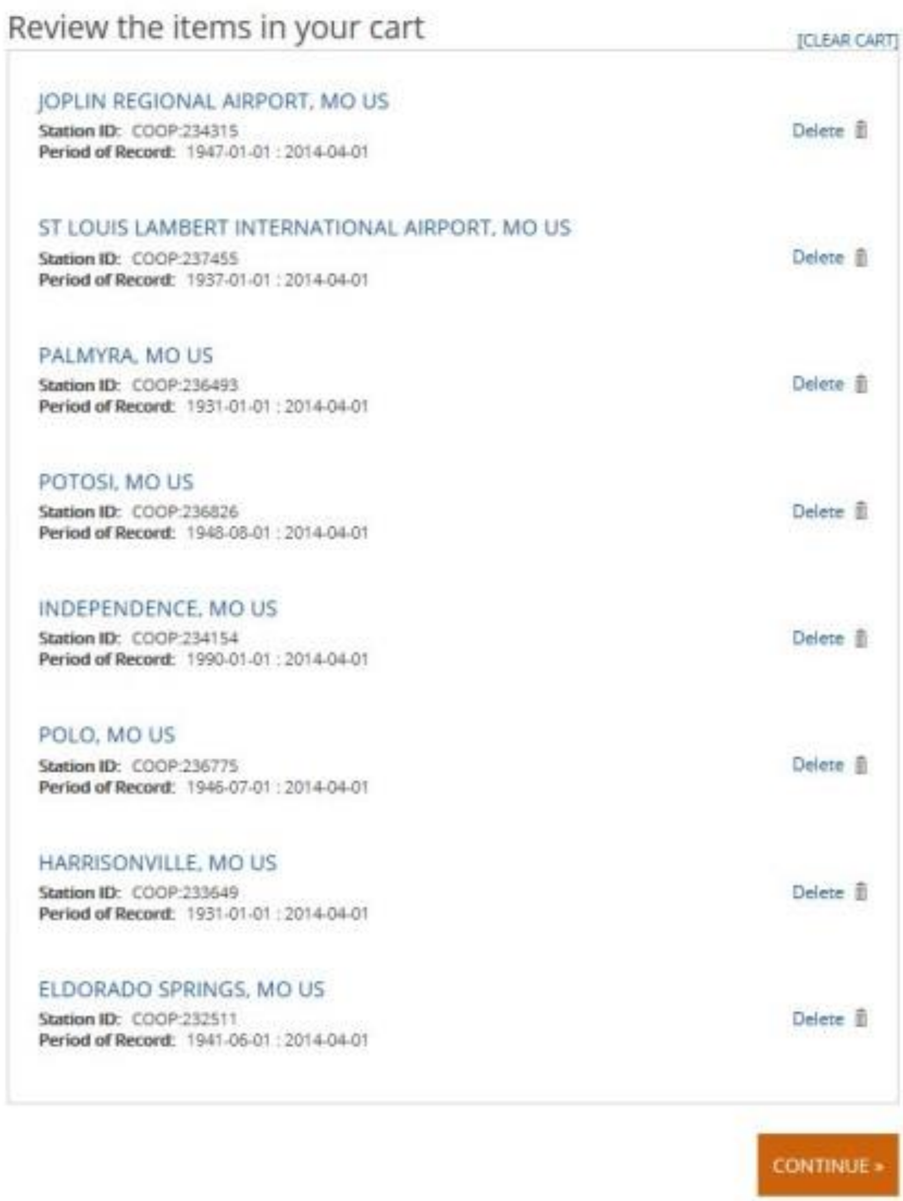


Fig.E.12 – NCDC CDO Search Tool, bottom half of page in Fig E.11.

Click on the “Continue” button at the bottom of the page. The next page gives one “Custom Options” on the type of data requested for the selected stations. The image below shows that the default “Station Detail & Data Flag Options” is “Station Name” (see the check in the box to the left of the title.

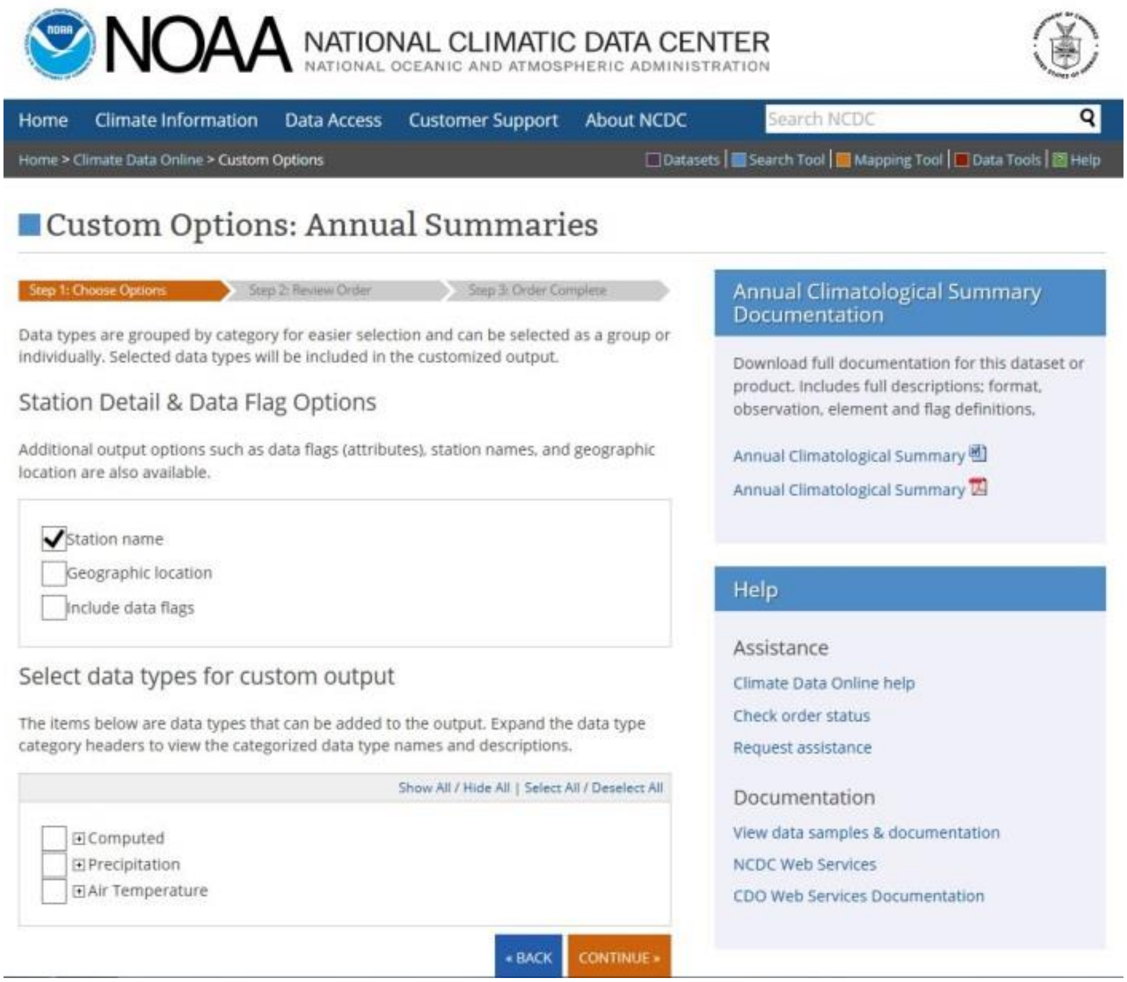


Fig.E.13 – NCDC CDO Search Tool, Custom Options output selection default page.

For this example, all six boxes were checked.

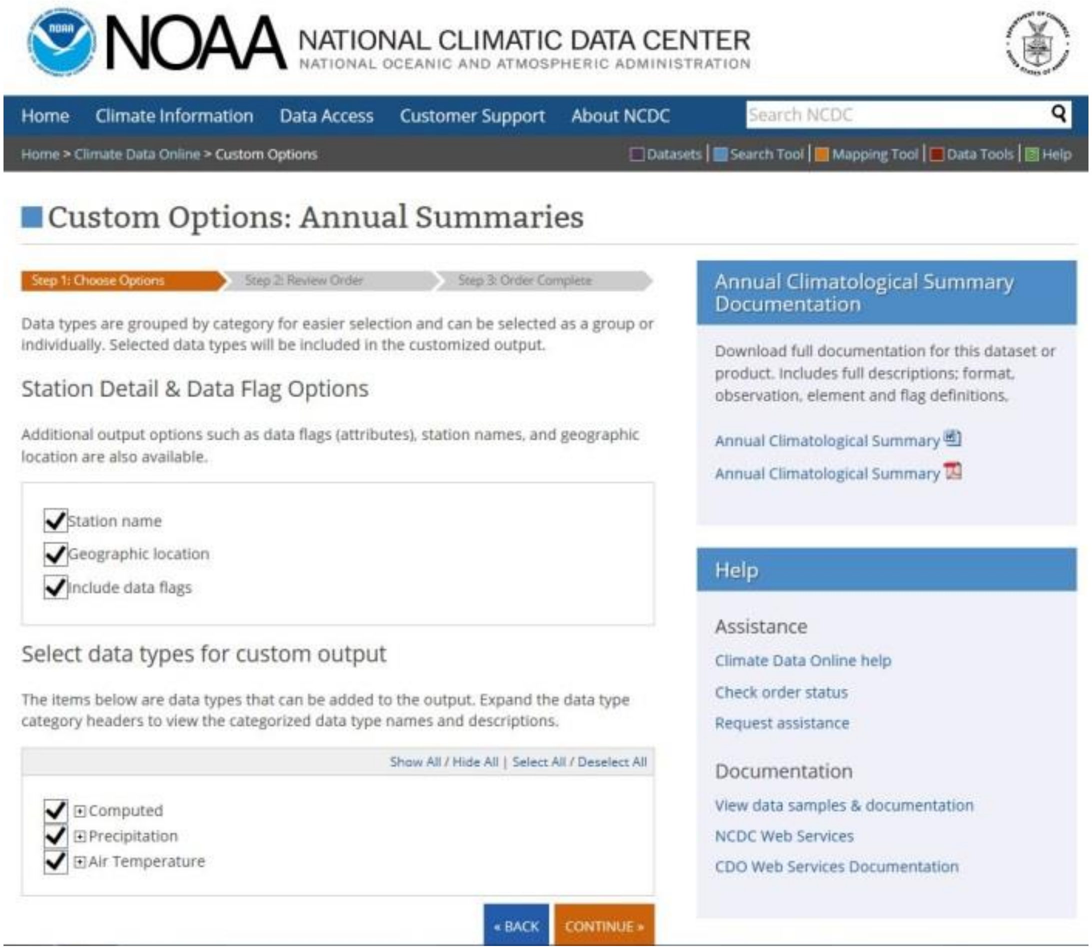


Fig.E.14 – NCDC CDO Search Tool, Custom Options additional output selection.

Next, click on the “Continue” button (bottom right). The next screen will let one “Review Order.”

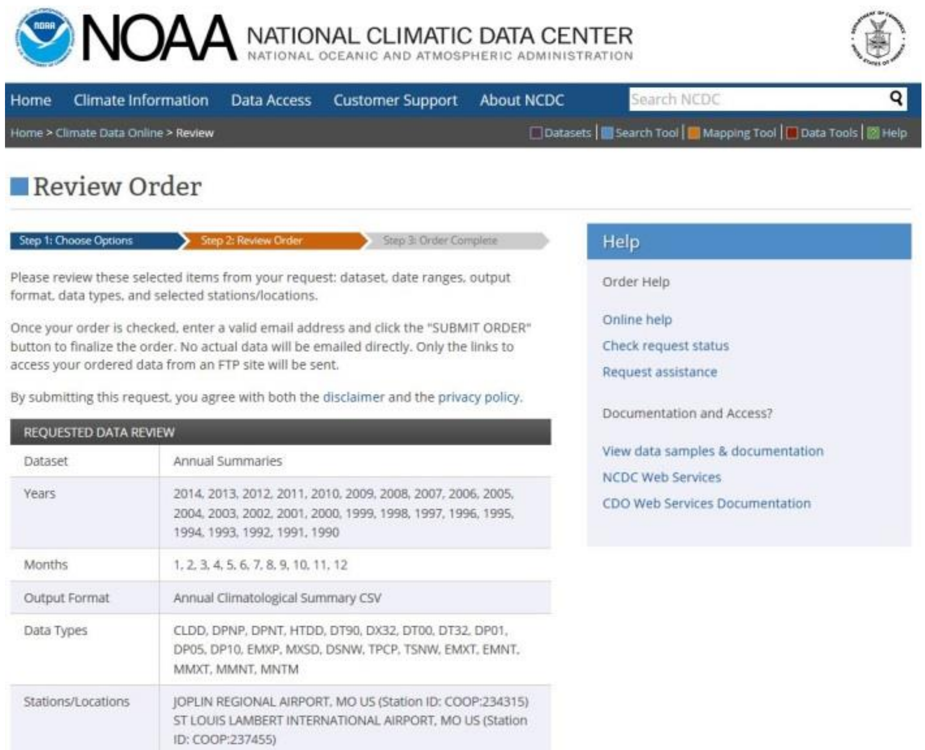
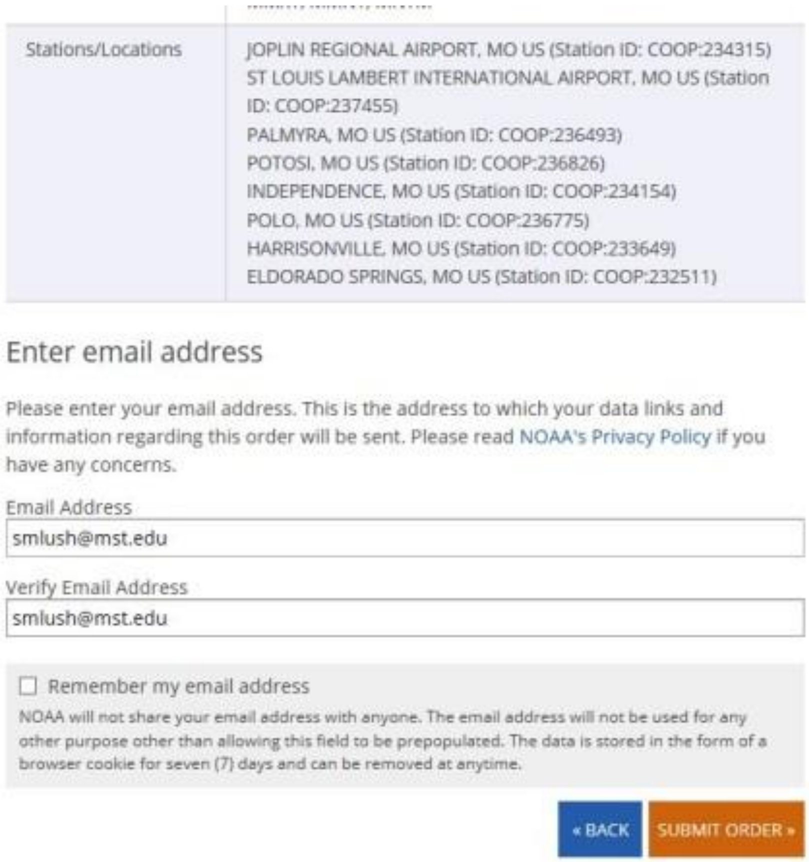


Fig. E.15 – NCDC CDO Search Tool, Review Order screen.

The image below shows the bottom half of the page shown above. Enter and re-enter the e-mail address that the requested (in the shopping cart) data will be delivered. One can choose to have the website remember your e-mail address, or not. Click on “Submit Order.”



Stations/Locations	JOPLIN REGIONAL AIRPORT, MO US (Station ID: COOP:234315) ST LOUIS LAMBERT INTERNATIONAL AIRPORT, MO US (Station ID: COOP:237455) PALMYRA, MO US (Station ID: COOP:236493) POTOSI, MO US (Station ID: COOP:236826) INDEPENDENCE, MO US (Station ID: COOP:234154) POLO, MO US (Station ID: COOP:236775) HARRISONVILLE, MO US (Station ID: COOP:233649) ELDORADO SPRINGS, MO US (Station ID: COOP:232511)

Enter email address

Please enter your email address. This is the address to which your data links and information regarding this order will be sent. Please read NOAA's Privacy Policy if you have any concerns.

Email Address

smlush@mst.edu

Verify Email Address

smlush@mst.edu

☐ Remember my email address

NOAA will not share your email address with anyone. The email address will not be used for any other purpose other than allowing this field to be prepopulated. The data is stored in the form of a browser cookie for seven (7) days and can be removed at anytime.

« BACK SUBMIT ORDER »

Fig. E.16 – NCDC CDO Search Tool, bottom half of page in Fig. E.15.

Once the “Submit Order” is clicked, the next screen indicates “Request Submitted.”

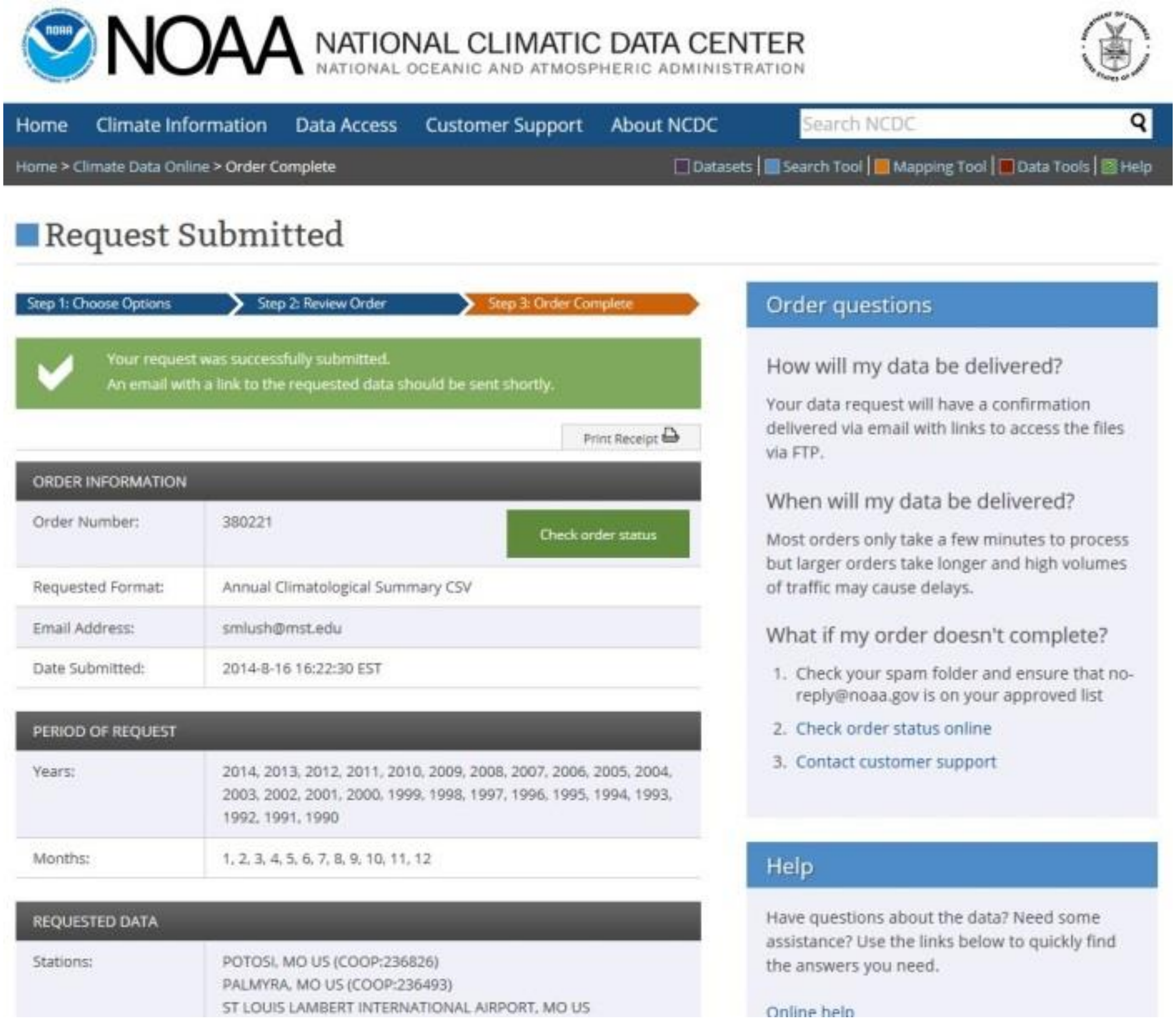


Fig.E.17 – NCDC CDO Search Tool, Request Submitted confirmation.

The image below shows the bottom half of the page shown above.

REQUESTED DATA	
Stations:	POTOSI, MO US (COOP:236826) PALMYRA, MO US (COOP:236493) ST LOUIS LAMBERT INTERNATIONAL AIRPORT, MO US (COOP:237455) ELDORADO SPRINGS, MO US (COOP:232511) INDEPENDENCE, MO US (COOP:234154) POLO, MO US (COOP:236775) HARRISONVILLE, MO US (COOP:233649) JOPLIN REGIONAL AIRPORT, MO US (COOP:234315)
Custom Flag(s):	Station name, Geographic location, Include data flags
Data Types:	**DSNW** - Number days with snow depth > 1 inch. **HTDD** - Heating degree days **DP10** - Number of days with greater than or equal to 1.0 inch of precipitation **MXSD** - Maximum snow depth **EMXT** - Extreme maximum daily temperature **DPNP** - Departure from normal monthly precipitation. **DP01** - Number of days with greater than or equal to 0.1 inch of precipitation **MMNT** - Monthly Mean minimum temperature **TPCP** - Total precipitation **EMXP** - Extreme maximum daily precipitation **DT00** - Number days with minimum temperature less than or equal to 0.0 F **MMXT** - Monthly Mean maximum temperature **DT90** - Number days with maximum temperature greater than or equal 90.0 F **DT32** - Number days with minimum temperature less than or equal to 32.0 F **CLDD** - Cooling degree days **EMNT** - Extreme minimum daily temperature **TSNW** - Total snow fall **MNTM** - Monthly mean temperature **DP05** - Number of days with greater than or equal to 0.5 inch of precipitation **DX32** - Number days with maximum temperature less than or equal to 32.0 F **DPNT** - Departure from normal monthly temperature.

Have questions about the data? Need some assistance? Use the links below to quickly find the answers you need.

Online help

Check request status

Request assistance

Fig. E.18 – NCDC CDO Search Tool, bottom half of page in Fig. E.17.

It usually does not take long for one to receive an e-mail confirming that the request was "submitted."

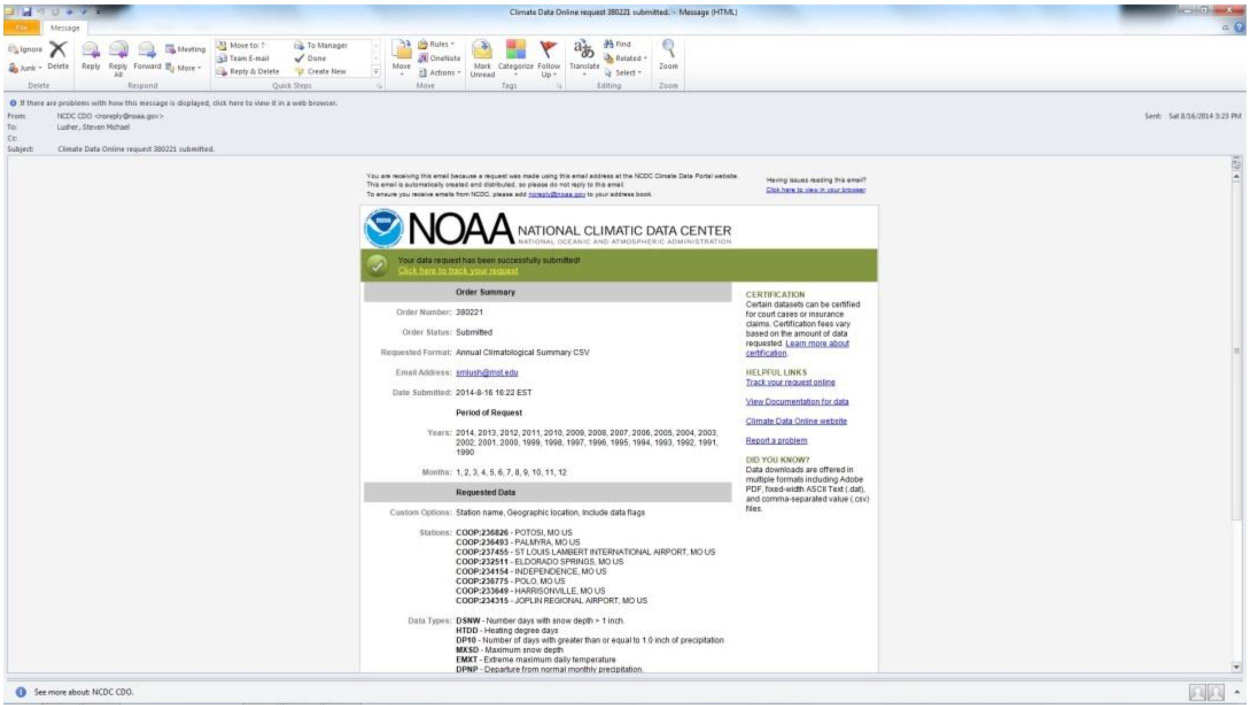


Fig. E.19 – NCDC CDO data request submittal e-mail confirmation screenshot.

Depending on the size of the data request, the following e-mail will contain “download” links to access the data file. The image below shows the “Download Data” link and another link to “Download Documentation” (if desired-these are explanatory pdf or Word documents that describe the NCDC data, etc.).

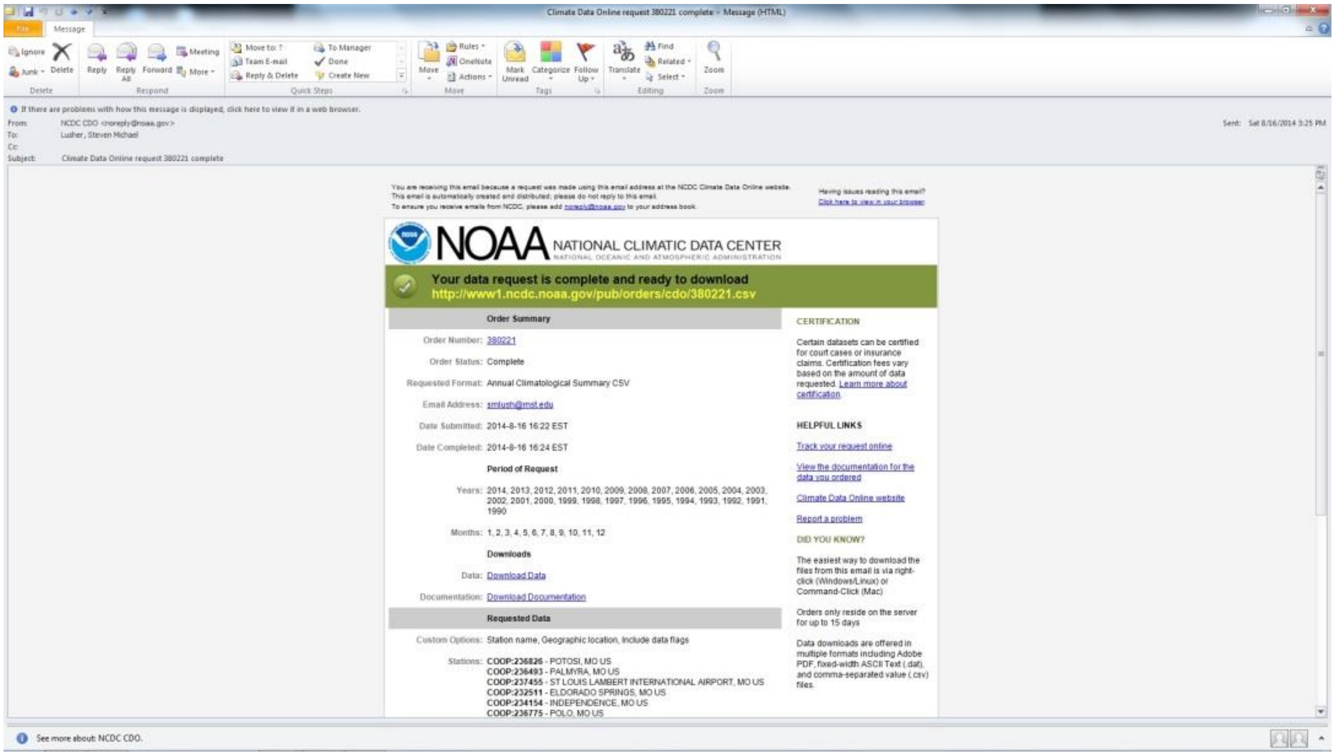


Fig. E.20 – NCDC CDO data available (download links) e-mail screenshot.

When one clicks on the “Download Data” link, your internet browser will open allowing for downloading capability. The next image shows what may happen, depending on your setting, if one uses Internet Explorer.

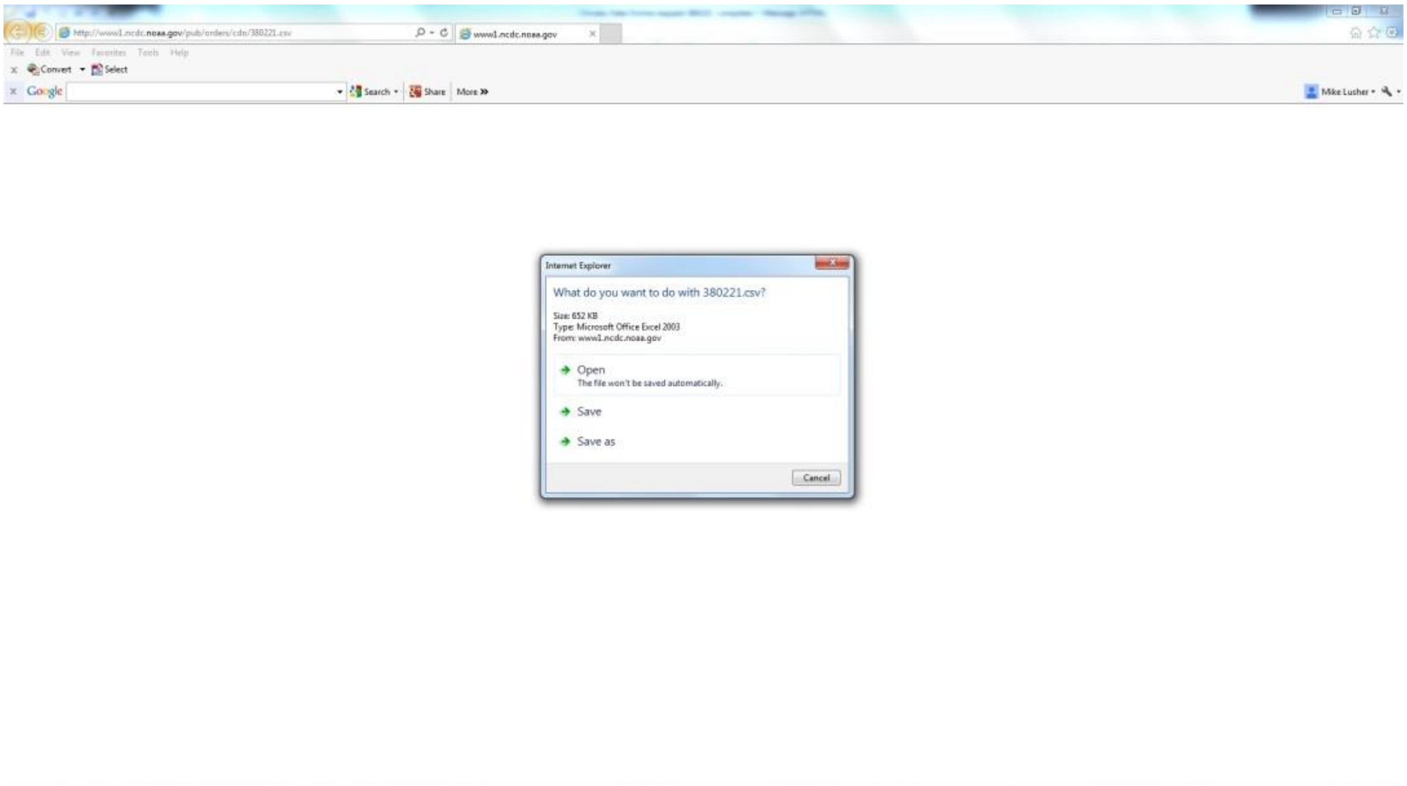


Fig. E.21 –Internet Explorer file download “save as” screenshot.

For this example, the file was “Saved As” to a location of one’s choosing.

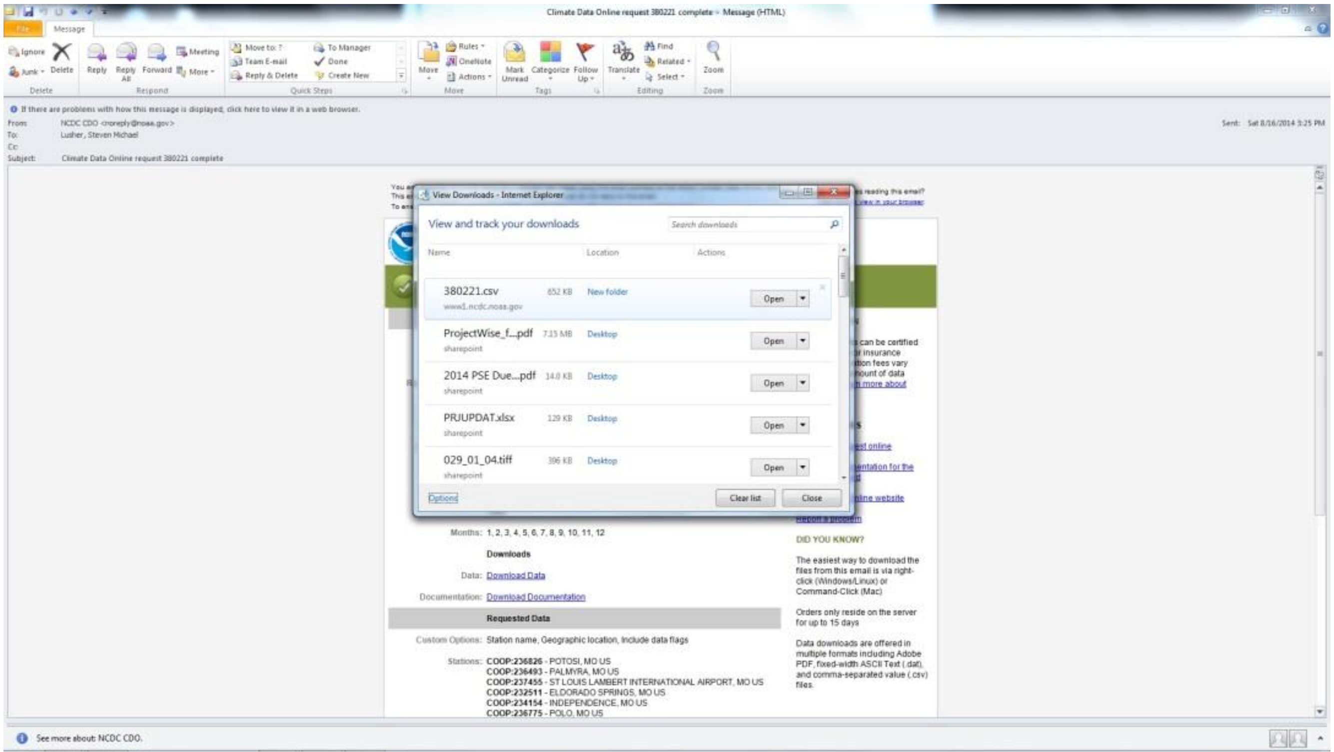


Fig. E.22 –Internet Explorer file download "complete" screenshot.

Each downloaded file has its own unique filename. In this example, it is "380221.csv" and can be opened in Excel.

AASHTOWare

AAHTOWare can be used to generate the number of freeze-thaw days per year for a given site. Once the user has opened the AASHTOWare software, to access the Climate interface, expand the Project tree and double-click on the Climate node. At the Climate Station section, one can choose to select a single weather station or create a virtual weather station. Enter the site of interest required information: latitude/longitude. Selection of the virtual weather station option activates a table that displays nearby actual weather stations, with distances from the site of interest and elevations of each station. It is recommended that a virtual weather station be created with at least three weather stations, forming a geographic polygon with the site of interest in the middle. More weather stations may be required. If possible, select stations with similar elevations. Once the virtual station has been created, the number of freeze-thaw days per year will be displayed for the site of interest.