THE EFFECT OF ENVIRONMENTAL FACTORS ON THE IMPLEMENTATION OF THE MECHANISTIC-EMPIRICAL PAVEMENT DESIGN GUIDE (MEPDG)

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July 2011

Acknowledgements

The authors would like to thank the Mountain-Plains Consortium (MPC) for providing funding for this research study and also the staff of the Water Resources Data System (WRDS) at the University of Wyoming for providing the available weather data. They also wish to thank the Wyoming Department of Transportation (WYDOT) for providing other input data for the study.

Disclaimer

ABSTRACT

Current pavement design based on the AASHTO Design Guide uses an empirical approach from the results of the AASHO Road Test conducted in 1958. To address some of the limitations of the original design guide, AASHTO developed a new guide: Mechanistic Empirical Pavement Design Guide (MEPDG). This guide combines the mechanistic and empirical methodology by making use of calculations of pavement responses such as stress, strains, and deformations using site specific inputs from climate, material, and traffic properties. With the new guide, various implementation challenges need to be overcome by agencies wanting to facilitate its use. In this respect, the MEPDG is currently undergoing several validation and calibration research studies, which are in the areas of materials, climate and traffic characteristics. It is anticipated that the findings from the various research studies will facilitate the implementaion of the MEPDG nationwide. This study summarizes the challenges that are likely to impede implementation of the MEPDG within the Northwest Region and how these can be overcome. The study also investigates the effects of climate variables on the predicted pavement performance indicators and, in addition, evaluates the adequacy of using interpolated climate data on pavement performance in the state of Wyoming.

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EXECUTIVE SUMMARY

The empirical pavement design methods available to pavement engineers have many limitations associated with them that have resulted in some pavements meeting design requirements and others not meeting the requirements. The new Mechanistic-Empirical Design Guide was then introduced to account for these limitations. This development was the result of research by the National Cooperative Highway Research Program (NCHRP) under sponsorship of AASHTO (Khazanovich, Yut, Husein, Turgeon, & Burnham 2008). The mechanistic-empirical design approach provides more information about the development of pavement distresses during the design life of the pavement. From this information, pavement engineers can decide on when and how to go about the maintenance of pavements while still meeting the requirements of its users (Petry, Han, & Ge 2007).

It is envisaged the Mechanistic-Empirical Pavement Design Guide (MEPDG) will provide significant benefits over the 1993 AASHTO Pavement Design Guide. Some of these benefits are: the implementation of performance prediction of transverse cracking, faulting and smoothness for jointed plain concrete pavements, the addition of climate inputs, better characterization of traffic loading inputs, more sophisticated structural modeling capabilities, and the ability to model real-world changes in material properties. These benefits will allow for achieving cost effective new and rehabilitated pavement designs (Coree 2005). The MEPDG utilizes a user friendly software interface that uses an integrated analysis approach to predict pavement behavior over the design life of the pavement. The MEPDG software accounts for the interaction between traffic, climate, and materials used in the pavement structure. The ultimate goal of an accurately predicted long-run evaluation of the pavement and determination of the subsequent pavement design can be achieved by using the MEPDG (Rabab'ah & Liang 2007).

With the new guide, various implementation challenges need to be overcome by agencies wanting to facilitate its use. In this respect, the MEPDG is currently undergoing several validation and calibration research studies in the areas of materials, climate, and traffic characteristics. It is anticipated that the findings from the various research studies will facilitate the implementaion of the MEPDG nationwide. This study summarizes the challenges that are likely to impede implementation of the MEPDG within the Northwest Region and how these can be overcome. The study also investigates the effects of climate variables on the predicted pavement performance indicators and, in addition, evaluates the adequacy of using interpolated climate data on pavement performance in the state of Wyoming.

1. INTRODUCTION

1.1 Background

The current design methodology of highway pavements carried out by most state departments of transportation is based on the empirical methodology. This methodology makes use of the statistical modeling of pavement performance (Dzotepe & Ksaibati 2010). In the future, it is envisaged that pavement design methodology guides will be based on a Mechanistic-Empirical approach. This methodology uses computations of pavement responses such as stresses, strains, and deformations and then adjusts accordingly based on performance models from the empirical approach. The ultimate goal for the future is to have pavement designed on a mechanistic approach only (AASHTO 2008).

The empirical design of pavements came about as a result of the AASHO Road Test in 1958 (AASHTO, 2008). Pavement design parameters created by AASHO from the road test included pavement serviceability, supporting value of the sub-grade, quantity of the predicted traffic, quality of the construction materials, and climate. The empirical design equations obtained by regression analysis were based on the conditions at the AASHO Road Test site in which multiple surfacing sections were tested with loaded trucks. By 1972, the AASHTO *Interim Guide for the Design of Pavement Structures* was published (AASHTO 2008). The design guide was rationally based on the experience of pavement engineers and their knowledge of how to avoid structural failures (AASHTO 2008). The equations contained in the AASHTO Guide predict a design pavement structural number for flexible pavements and design slab thickness for rigid pavements (Stires, 2009). But the Design Guide had several limitations because it was based on the AASHTO Road Test, which only included one climate, one sub-grade, two years duration, limited cross sections and 1950s materials, traffic volumes, specifications, and construction methods. As a result of the limitations posed by the guide, a dilemma on how to progress beyond the AASHTO Road Test limits came about (AASHTO 2008).

The AASHTO Guide, which was updated in 1986 and 1993, included improvements to the material input parameters and inclusion of additional input parameters that allowed for design reliability (AASHTO 2008). But the use of the updated design guide still produces conservative designs that are not optimally cost effective. A survey conducted in 2003 showed that three DOTs used the 1972 design guide, two used the 1986 guide, 26 used the 1993 guide, and 17 used their own agency's design guide or a combination of the AASHTO and agency's guides (Wagner 2007). In the mid 1990s, AASHTO initiated research for a new guide to pavement design with the objective to develop a design methodology that utilized mechanistic-based models and databases relevant to the current state of knowledge of highway performance. This became known as the Mechanistic-Empirical approach to pavement design, with the results documented in the NCHRP 1-37A project report (AASHTO 2008). Figure 1.1 shows the Mechanistic-Empirical design process in a basic flow chart. Further documentation of the new methodology appears in the *Mechanistic-Empirical Pavement Design Guide: A Manual of Practice, Interim Edition* (AASHTO 2008).

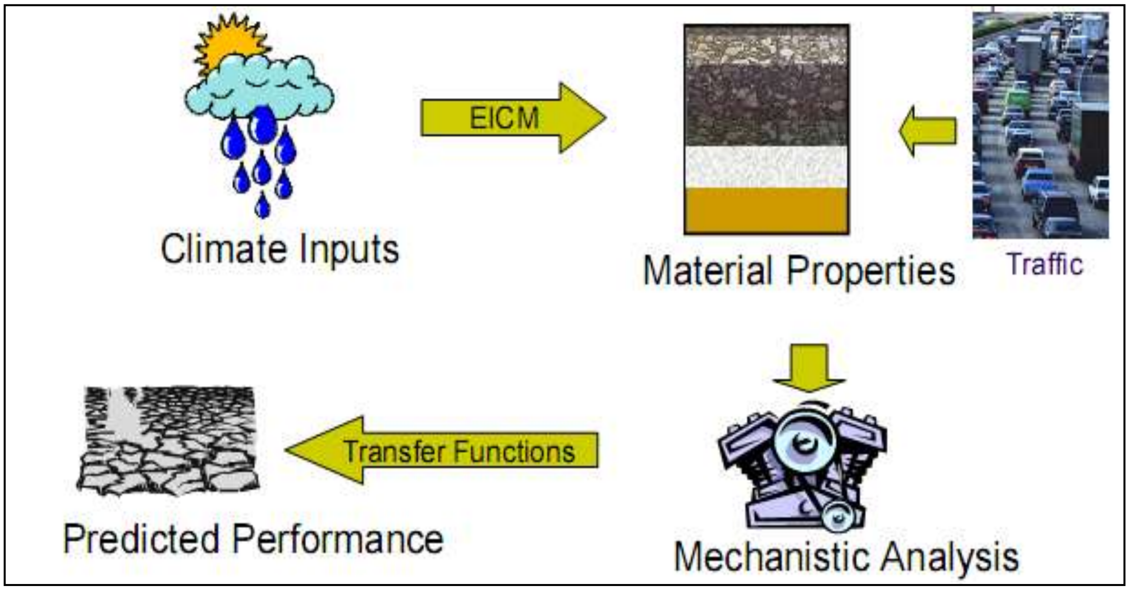

Figure 1.1 M-E Design Process (Wagner 2007).

The Mechanistic-Empirical design process contains more than 100 total inputs with 35 or more for flexible pavement and 25 or more for PCC. This can be compared with the 1993 AASHTO Guide, which contains 5 inputs for flexible pavement and 10 inputs for rigid pavements (AASHTO 2008). The MEPDG design methodology, which is based on software-generated pavement responses of stresses, strains, and deformations, are computed using detailed traffic loading, material properties, and environmental data, which are then used to compute incremental damage over time. Material factors come from modulus values and thermal properties of the specific materials while climate factors are based on site-specific climate considerations.

The Mechanistic-Empirical design process currently uses 800 or more weather sites incorporated into the software to narrow these factors to the specific site, while the AASHTO Guide uses extrapolation from the road test site in Ottawa, Illinois. Traffic inputs will come from locally collected data and will consist of the number of axles by type and weight as ESALs will no longer be used. With the MEPDG, the output of the analysis software is a prediction of the distresses and smoothness against set reliability targets and so it is anticipated that a more reliable design will be created and there will no longer be a dependence on extrapolation of empirical relationships. It will also allow for calibration nationally, regionally, or to local performance data for materials, climate, and traffic (Wagner 2007). Even though many DOTs are currently using the Mechanistic-Empirical design process, it is yet to be approved by AASHTO as a design guide.

The MEPDG is expected to come with its own peculiar problems due to its extensive data inputs. These problems are coming from the lack of ability to collect the desired input data and research. It is in these critical inputs in which the desired performance models are created; for example, the Integrated Climatic Model (ICM) for climate factors uses temperature and moisture inputs to run the model. For the Mechanistic-Empirical performance models of pavement materials, inputs come from modulus values, thermal properties, and strength properties (AASHTO 2008). It is in this regard that more time and equipment are needed by the various DOTs in order to collect the necessary data needed to create the required inputs.

Also, calibration and sensitivity efforts are an ongoing process. DOTs in the northwest states are currently looking at various ways of successfully implementing the MEPDG by which different levels of implementation have been reached. Some DOTs have documented various obstacles hindering this effort while others are undertaking research and calibration to local conditions. By consulting with the DOTs in the northwest states, the specific problems being encountered by different DOTs could be identified. These problems will then be summarized with the goal of determining the necessary equipment and/or research that is needed. In addition, where necessary, recommendations will be made for needed regional research. It is through these recommendations that the facilitation of the implementation of the MEPDG throughout the MPC region will be performed in order to fulfill the goal of complete implementation of the mechanistic-empirical pavement design process.

1.2 Problem Statement

Even though the survey conducted suggests that most DOTs use the current edition of the AASHTO Pavement Design Guide published in 1993, its reliability is still questionable. The guide is based on methodology from the AASHTO Road Test conducted from 1958 to 1961. Though a number of changes have been made to the guide from its initial publication as an interim guide in 1974 to later editions, the changes have not significantly altered the original methods of pavement design, which are based on empirical regression techniques relating to material and traffic characteristics and performance measures. Despite all these, the current AASHTO Pavement Design Guide does not provide performance of prediction of pavements. (Coree 2005).

The M-E Pavement Design Guide is envisaged to bring about a lot of improvement in pavement design, which makes it superior to the existing AASHTO Design Guide. Among the improvements that the new guide is likely to offer include the use of mechanistic-empirical pavement design procedures, the implementation of performance prediction of transverse cracking, faulting, and smoothness for jointed plain concrete pavements, the addition of climate inputs, better characterization of traffic loading inputs, more sophisticated structural modeling capabilities, and the ability to model real-world changes in material properties. For DOTs to transition to the M-E Design Guide, they need to have a detailed implementation and training strategy in place. Since the new guide lends itself to the use of local pavement design input parameters, these must also be determined based on their effects on pavement performance (Coree 2005). It is in this regard that, at the Mountain-Plains Consortium (MPC) Pavement Research Workshop in Denver, Colorado, in March 2008, a roadmap for future pavement-related research studies was laid out.

During the workshop, it was concluded that one of the top priorities for the region will be the implementation of the MEPDG. The represented agencies at the workshop included WYDOT, CDOT, SDDOT, NDDOT, SDLTAP, FHWA, Colorado State University, North Dakota State University, South Dakota State University, University of Utah, and University of Wyoming. It was determined that there were currently some issues regarding the smooth implementation of the new MEPDG. A follow-up to this meeting was a Northwest User Group meeting held at Oregon State University in Corvallis on March 9-10, 2009, to discuss participating states' implementation plans, and progress, as well as technical and other related issues with the implementation of the MEPDG. The attending states included Alaska, Idaho, Montana, North Dakota, Oregon, South Dakota, Washington, and Wyoming. Currently, as with any other state trying to implement the MEPDG, research is being undertaken in order to get the required level and reliability of inputs for the software.

Currently, the MEPDG has weather stations from all over the country embedded in the program. Sixteen of these are located in Wyoming. It is believed that these stations are not enough to carry out day-to-day pavement design activities, and so their effect and adequacy needs to be determined in addition to other factors that will facilitate the implementation of the MEPDG.

1.3 Objectives

There are three main objectives for this study. First, to study and determine the level of implementation of the MEPDG by DOTs in the northwest states and identify obstacles that are likely to impede these efforts. The second, investigate the effect of weather parameters on pavement performance in Wyoming. Third, determine whether the weather stations in the MEPDG are adequate for pavement design and performance.

1.4 Report Organization

Section 2 of this thesis is the literature review, which looks at a general overview of the MEPDG. Section 3 focuses on the national and regional implementation of the MEPDG, which looks at the efforts and changes being made at these levels by DOTs and other agencies to successfully implement the MEPDG. The section also discusses the challenges and limitations that are likely to impede implementation efforts. Section 4 describes the data collection process. Section 5 evaluates the output pavement performance distresses from the MEPDG runs and the statistical analysis used to evaluate the results. Section 6 presents the conclusions and recommendations of the study.

2. LITERATURE REVIEW

2.1 Background

Until recently, the empirical pavement design methods were the only pavement design choices available to pavement engineers. But there are many limitations associated with the empirical method that have resulted in some pavements meeting design requirements and others not meeting the requirements. The new Mechanistic-Empirical Design Guide was then introduced to account for the limitations. The development of the new pavement design procedure was the result of research by the National Cooperative Highway Research Program (NCHRP) under sponsorship of AASHTO (Khazanovich, Yut, Husein, Turgeon & Burnham 2008). The mechanistic-empirical design approach provides more information about the development of pavement distresses during the design life of the pavement. From this information, pavement engineers can decide on when and how to go about the maintenance of pavements while still meeting the requirements of its users (Petry, Han & Ge 2007).

The Mechanistic-Empirical Pavement Design Guide (MEPDG) provides significant benefits over the 1993 AASHTO Pavement Design Guide. Some of these benefits are: the implementation of performance prediction of transverse cracking, faulting, and smoothness for jointed plain concrete pavements, the addition of climate inputs, better characterization of traffic loading inputs, more sophisticated structural modeling capabilities, and the ability to model real-world changes in material properties. These benefits will allow for achieving cost effective new and rehabilitated pavement designs (Coree 2005). The MEPDG utilizes a user-friendly software interface that uses an integrated analysis approach to predict pavement behavior over the design life of the pavement. The MEPDG software accounts for the interaction among traffic, climate, and materials used in the pavement structure. The ultimate goal of an accurately predicted long-run evaluation of the pavement and determination of the subsequent pavement design can be achieved by using the MEPDG (Rabab'ah & Liang 2007).

The MEPDG is also a significant improvement in pavement performance prediction methodology. It is mechanistic because the model uses stresses, strains, and deformations in the pavement that have been calculated from real-world pavement response models to predict its performance. It is also empirical because pavement performance is predicted from lab-developed performance models that are adjusted according to observed performance in the field in order to reflect the differences between the predicted and actual field performance (Muthadi & Kim 2007). For Hot Mix Asphalt (HMA) pavements, the performance indicators are longitudinal cracking, alligator cracking, transverse cracking, and rutting. For Joint Plain Concrete Pavements (JPCP), the performance indicators are joints faulting and load-related transverse cracking. The functional performance for all pavements is defined by a measure of smoothness called the International Roughness Index (IRI). The performance models used are calibrated using limited national databases. As a result, it is necessary for these models to be calibrated locally by taking into account local materials, traffic, and environmental conditions (Muthadi & Kim 2007). A well-calibrated prediction model can result in reliable pavement designs and enable precise maintenance plans for agencies (Kang & Adams 2007).

The concept of mechanistic-empirical design is to employ the fundamental pavement responses under repeated traffic loadings. These calculations consist of stresses, strains, and deflections in a pavement structure. Pavement responses are related to distresses in the field as well as performance using existing empirical relationships. The design process starts with a trial design and through many iterations ends with predicted distresses that meet requirements based on the desired level of statistical reliability as defined by the user (Daniel & Chehab 2007). As it may be, the MEPDG is not at the point where this goal is achieved seamlessly, and its implementation is an ongoing endeavor (Dzotepe & Ksaibati 2010).

2.2 MEPDG Design Process

The general design process of highway pavement either being new or reconstructed, using the MEPDG requires an iterative approach with control in the hands of the pavement engineer. This procedure introduces a significant change from the previous pavement design methodologies as the process requires extensive information generation and collection. In this approach, the designer must first select and perform a trial design to determine if it meets the performance demands and criteria specified by the user. The process using the MEPDG for pavement design can thus be summarized in the following steps:

i. the trial design for the specified location based on traffic, climate, and material conditions.

ii. Define the pavement layer arrangement such as HMA and other underlying material properties.

iii. Establish the necessary criteria for acceptable performance at the end of the design period (acceptable levels of the different cracking types, rutting, International Roughness Index (IRI), etc.).

iv. Select the desired level of reliability for each of the performance criteria.

v. Process inputs to gather monthly data for traffic, material, and climate inputs needed in the design evaluations of the entire design life.

vi. Compute the structural responses (stress, strain, etc.) using the finite element or layered elastic analysis program for each damage calculation throughout the design period.

vii. Calculate the accumulated damages at each month for the entire design life.

viii. Predict vital distresses like cracking and rutting on a month-by-month basis of the design period using the calibrated mechanistic-empirical performance models provided in the MEPDG.

ix. Predict the smoothness as a function of the initial IRI, distresses over time, and site factors at the end of each month.

x. Evaluate the expected performance of the trial design at the given reliability level for adequacy.

xi. If trial design does not meet the performance criteria, modify the design and repeat steps 5 to 10 until the criteria are met. Options for adjustments to the design include modification to the layer thickness, adding layers, or altering the materials. The final decision lies in making engineering and lifecycle cost analysis for alternatives (NCHRP 2004).

2.3 MEPDG Performance Indicators

For Hot Mix Asphalt (HMA) pavements, the performance indicators are longitudinal cracking, alligator cracking, transverse cracking, and rutting. For JPCP structures, the performance indicators are mean joint faulting and load related transverse slab cracking. The IRI defines the smoothness measure of pavements.

2.3.1 Alligator Cracking (Bottom-Up Cracking)

Alligator cracking is computed as percent cracking of total lane in the MEPDG. This distress type is usually due to repeated loading causing cracks that begin at the bottom of the HMA layer and then spread up to the surface of the pavement. The bending of the HMA layer results in tensile stresses and strains developing cracks at the bottom of the layer (Stires 2009). A number of reasons have been associated with increase in alligator cracking; among these are higher wheel loads and tire pressures, inadequate HMA layers for the predicted magnitude and repetitions of the loading, or weaknesses in base layers resulting from high moisture contents, soft spots, or poor compaction issues (NCHRP 2004).

2.3.2 Longitudinal Cracking (Surface-down Fatigue Cracking)

Longitudinal cracking starts from the surface of the pavement due to stresses and strains developing at the surface of the pavement as a result of the tension generated from wheel loadings. These stresses and strains tend to create and spread longitudinal cracking in the HMA pavement. Due to this cracking phenomenon, it is also referred to as surface down fatigue cracking. In most instances, the aging of the HMA layer tends to create stiffness in the layer, which worsens the effect. A shearing effect is induced in the layer from the tire contact pressure which combines with the tension from the loading resulting in cracking. This distress is calculated as feet of cracking per mile in the MEPDG (NCHRP 2004).

2.3.3 Transverse Cracking (Thermal Cracking)

Transverse cracking is computed as feet of cracking per mile in the MEPDG and is a non-load-related cracking mechanism also referred to as thermal cracking. They tend to appear on the surface and are usually perpendicular to the pavement centerline. These cracks originate as a result of asphalt hardening, seasonal and daily temperature differences, or exposure to consistent cold weather conditions (NCHRP 2004).

2.3.4 Rutting

Rutting is computed in the MEPDG in inches and appears as a permanent deformation occurring along the wheel paths. It is caused by a vertical depression in any or all of the pavement layers. This depression could be as a result of traffic loading, poor compaction of any of the layers during construction stage, or the shearing of the pavement caused by the traffic wheel loading (AASHTO 2008).

2.3.5 International Roughness Index (IRI)

This pavement performance indictor is used to determine the functional serviceability of the pavement design. The MEPDG predicts the IRI by means of an empirical function combining the other performance indicators. It is usually used as an industry standard for pavement smoothness and measured in inches per mile (NCHRP 2004).

2.4 Performance Prediction Equations for Flexible Pavements

The MEPDG methodology for flexible pavement designs uses the Jacob Uzan Layered Elastic Analysis (JULEA) program, which involves the MEPDG dividing the layers of the pavement structure into sublayers where the JULEA program then calculates the critical responses in each sublayer (AASHTO 2008). The equations for predicting flexible performance distresses in the MEPDG are included in Appendix A1.

2.5 Design Criteria and Reliability

The results obtained for the MEPDG analysis for the performance indicators is checked against the user-specified design criteria or threshold limits. These threshold limits can be nationally or locally established by the state DOTs. The comparison is to help determine how well the particular pavement will perform throughout its design life. The general criteria set is that interstate projects require more stringent design or thresholds values when compared with secondary and primary roads. Evaluating the specified threshold limits against the performance prediction outputs from the design helps establish the acceptability or adjustment of the trial design. During the design analysis of the pavement, the point where the performance indicators exceed the specified ranges during the design life, the pavement would need reconstruction or rehabilitation. Table 2.1 shows the recommended design criteria limits provided by the MEPDG that are specified as defaults in the software. State DOTs can, however, adjust these values based on their local conditions.

Table 2.1 Recommended Threshold Design Values (AASHTO 2008)

Performance Criteria	Maximum Value at End of Design Life
Alligator Cracking (HMA)	Interstate: 10% lane area Secondary: 35% lane area Primary: 20% lane area
Rutting (HMA)	Interstate: 0.40 in Others: (<45mph): 0.65 in Primary: 0.50 in
Transverse Cracking (HMA)	Interstate: 500 ft/mi Secondary: 700 ft/mile Primary: 700 ft/mile
Mean Joint Faulting (JPCP)	Interstate: 0.15 in Secondary: 0.25 in Primary: 0.20 in
Percent Transverse Slab Cracking (JPCP)	Interstate: 10% Secondary: 20% Primary: 15%
IRI (All Pavements)	Interstate: 160 in/mi Secondary: 200 in/mi Primary: 200 in/mi

In order to account for the variability in the output performance indicators, the MEPDG uses statistical design reliability. The LTPP database was used for calibrating the reliability of the distress models. The definition of reliability within the MEPDG is the reliability of the design and it is the probability that the performance of the pavement predicted for that particular design will be satisfactory over the time period under consideration (Khazanovich, Wojtkiewicz & Velasquez 2007). In other words, the pavement performance indicators such as cracking and rutting will not exceed the design criteria established over the design analysis period. As with any process, to create and analyze the given design, there are many sources of variation that can occur in the prediction such as:

i. Traffic loading estimation errors.
ii. Climate fluctuation that the EICM (Enhanced Integrated Climate Model) may miss.
iii. Variation in layer thickness, material property, and subgrade characteristics throughout the project.
iv. Differences in the designed and actually built materials and other layer properties
v. Limitations and errors in the prediction models.
vi. Measurement errors.
vii. Human errors that may occur along the way (Khazanovich, Wojtkiewicz & Velasquez 2007).

The level of reliability for each of the performance indicators can be adjusted individually or can be the same value, and its computation is dependent on the standard error of the distress predicted for which the designer is free to adjust if the desired level of reliability is not reached after the design analysis. Designs that have strict criteria and reliability will attract higher cost. Continuous use and experience with the MEPDG will enable agencies to develop and calibrate design criteria and design reliability values for various pavement designs if not already in place. Table 2.2 is the design reliability for different roadway classifications recommended by AASHTO.

Table 2.2 Reliability Levels Roadway Classifications (AASHTO 2008)

Functional Classification	**Level of Reliability**	
	Urban	**Rural**
Interstate/Freeways	95	95
Principal Arterials	90	85
Collectors	80	75
Local	75	70

2.6 Calibration

The definition of the use of the word *calibration* in the MEPDG means to reduce the total error between the measured and predicted distresses by varying the appropriate model coefficients (Muthadi & Kim 2007). In general, there are three important steps involved in the process of calibrating the MEPDG to local materials and conditions. The first step is to perform verification runs on pavement sections using the calibration factors from the national calibration effort under the NCHRP 1-37A project. Step two involves the process of calibrating the model coefficients to eliminate bias and reduce standard error between the predicted and measured distresses. Once this is accomplished and the standard error is within the acceptable level set by the user, the third step is performed. Validation is the third step and it is used to check if the models are reasonable for performance predictions. The validation process determines if the factors are adequate and appropriate for the construction, materials, climate, traffic, and other conditions that may be encountered within the system. This is done by selecting a number of independent pavement sections that were not used in the local calibration effort and testing those (Muthadi & Kim 2007).

2.7 MEPDG Inputs

The main categories of the input variables for the MEPDG for the evaluation of pavement distresses are traffic, materials, and climate. These are based on a hierarchical input level that provides flexibility in determining which required inputs to use. The hierarchical level defines three levels of input for traffic and material. Climate is fixed and does not have a hierarchical input level. It is input from a climate database already installed in the software. Level 1 input provides the most accurate and least amount of uncertainty in data. They require site-specific and laboratory data or results of actual field testing. Level 2 inputs provide intermediate accuracy of data while level 3 inputs provide the lowest accuracy of data and are input as default values in the MEPDG.

2.7.1 Traffic Data

The MEPDG traffic input criteria does not incorporate equivalent single-axle loads (ESALs) as is the case in the current design guide, but instead were developed around axle load spectra. It is through axle load spectra that the unique traffic loadings of a given site are characterized. It is by means of these loading characteristics and pavement responses that the resulting damages can be computed. Full axle load spectra traffic inputs are used for estimating the magnitude, configuration, and frequency of traffic loads (Wang, Li, Hall, Nguyen, Gong & Hou 2007). The benefit of load distributions is that they provide a more direct and rational approach for the analysis and design of pavement structures. The approach estimates the effects of actual traffic on pavement response and distress. Until complete use of mechanistic-empirical design methods are fully implemented, it is anticipated that the use of ESALs will continue to be applied by pavement engineers in pavement design and rehabilitation for some time (Haider, Harichandran & Dwaikat 2007). The problem occurs in the transition between solely utilizing ESALs to only using axle load spectra. A possible solution is characterizing axle load spectra as a bimodal (two distinct peaks) mixture distribution and using its parameters to approximate ESALs. Dr. Haider and his colleagues have observed that axle load spectra can be reasonably described as a mix of two normal distributions. By developing closed-form solutions to estimate the parameters of the mixed distribution, traffic levels in terms of ESALs can then be estimated from the axle load spectra from a specific site (Haider, Harichandran & Dwaikat 2007). It is in the linkage between ESALs (empirical) and axle load spectra (mechanistic) in which the implementation of the MEPDG is being moved along. Type, weight, and number of axles are the criteria in which axle loads need to be estimated. The data gathered to follow the criteria should be site-specific and if that is not possible, site-related, regional, or agency-wide traffic data need to be substituted. The MEPDG software includes default axle load spectra and other traffic parameters if no other sources of traffic data can be obtained.

To fully benefit from the MEPDG it is important to characterize pavement traffic loads using detailed traffic data including axle load spectra. This traffic data should be specific to the project area, and if that is not possible, default data will have to be used. Generally, there is noticeable difference between the default traffic inputs included in the MEPDG and the regional traffic data collected in terms of axle load spectra. Volume and type of trucks along with axle load spectra are the main influences for predicting pavement performance. There are also main input factors that do not have significant influence on pavement performance predictions such as axle spacing and hourly volume adjustment factors (Swan, Tardif, Hajek & Hein 2007). The software used in the MEPDG looks at each axle load individually then estimates the stresses and strains imposed on the pavement structure by each axle load. The stresses and strains are related to pavement damage and the damage is then accumulated. Finally, a report of the total damage caused by all axle loads is created. Throughout the whole process, the calculations take into account the climatic conditions of the pavement structure. That is the temperature of the asphalt concrete layers along with the moisture content of the unbound material layers and subgrade. The calculations performed make up the mechanistic side of the guide, whereas the relation of the stresses and strains to pavement damage is the empirical part (Swan, Tardif, Hajek & Hein 2007). The data that are required to run the traffic analysis in the MEPDG are: Average Annual Daily Truck Traffic (AADTT) data, vehicle classification, axle load distribution and number of axles per truck. When weigh-in-motion (WIM) sites are close to the project site, these data can be used in a Level 1 analysis (Muthadi & Kim 2007).

Hierarchal Approach to Traffic Inputs

Based on the different pavement needs and the availability of traffic input data, the MEPDG accommodates three levels of input data that are progressively more reliable and accurate. The quality of the data in terms of reliability and accuracy, not detail, makes up the difference in the hierarchal input levels. In other words, the same amount and type of data are used in every level but level selection is based on the quality of the data. The hierarchal input levels are as follows:

i. Level 1 – The input data are gathered from direct and project-specific measurements. This level represents the greatest knowledge of the input parameters for the specific job. In particular, the input data are site-specific truck volumes for individual truck types and the axle load spectra is project site specific.

ii. Level 2 – The input data come from regional data such as measured regional values that encompass the project but are not site specific. For traffic data, estimated classified truck volumes are used. These estimations come from volumes gathered on sections with similar traffic characteristics to those of the current project.

iii. Level 3 – These data are based on best estimation data or default values. These data are based on global or agency-wide default values such as the median value from a group of similar projects. For example, this data may come from an agency-published look-up table of averages for classified truck volumes.

It is recommended by the MEPDG to use the best available data regardless of the overall input level. That is, it is possible for Level 1 inputs to be classified truck volumes and Level 2 data to be axle configuration and Level 3 inputs to be axle load. This is solely based on the quality of each individual piece of data and where it fits best in the hierarchal scheme (Swan, Tardif, Hajek & Hein 2007).

Traffic Elements

Traffic input data in the MEPDG are usually entered for the base year. The base year is the year the pavement is expected to open to traffic. Within the MEPDG software, there is a provision for future growth in truck volumes after the base year. Table 2.3 shows the input variables required to complete the traffic analysis in the MEPDG and are defined in the subsequent paragraph.

i. ***Truck Volume and Highway Parameters***. Truck volume is calculated by multiplying the Average Annual Daily Traffic (AADT) volume by the percent of heavy trucks of FHWA class 4 or higher. The result is the Average Annual Daily Truck Traffic (AADTT), but site-specific AADTT data are usually available through an agency.

ii. ***Monthly Traffic Volume Adjustment Factors***. These factors are used to distribute the AADTT volume over the 12 months in a year. Once the monthly traffic volume adjustment factors have been created, they are assumed to be the same for the design life. Monthly traffic volume adjustment factors are used if there is significant monthly variation in truck volumes that affect pavement performance. This variation is most likely due to seasonal traffic such as summer or winter traffic.

Table 2.3 MEPDG Traffic Inputs

Site-Specific Traffic Inputs	• Initial Two-Way Average Annual Daily Truck Traffic (AADTT) • Percent Trucks in Design Lane • Percent Trucks in Design Direction • Operational Speed • Truck Traffic Growth
WIM Traffic Data	• Axle Load Distribution • Normalized Truck Volume Distribution • Axle Load Configurations • Monthly Distribution Factors • Hourly Distribution Factors
Other Inputs	• Dual Tire Spacing • Tire Pressure • Lateral Wander of Axle Loads

iii. ***Vehicle Classification Distribution***. The MEPDG uses the FHWA scheme of classifying heavy vehicles as shown in Table 2.4. Ten different vehicle classes are used (classes 4 to 13). The subsequent three light vehicle classes (classes 1 to 3, motorcycle, passenger car and pick-up) are not used in the MEPDG.

iv. ***Hourly Traffic Volume Adjustment Factors***. Hourly traffic adjustment factors are expressed as a percentage of the AADT volumes during each hour of the day. These factors apply to all vehicle classes and are constant throughout the design life of the pavement system. These factors can be adjusted and customized by the user, but virtually no effect on the predicted pavement performance is seen with the current version of the MEPDG software.

v. ***Axle Load Distribution Factors***. The distribution of the number of axles by load range is the definition of axle load spectra. An axle load spectrum distribution is referred as axle load distribution factors in the MEPDG. The MEPDG software allows the user to put in a different set of axle load distribution factors for each vehicle class and each month.

vi. ***Traffic Growth Factors***. In anticipation of truck volume growth after a road has opened is expressed in traffic growth factors. These factors are applied to individual vehicle classes. Axle load distributions are assumed constant with time and no growth factors are applied to them. The MEPDG also had no provision for reduction in truck volume.

vii. ***Number of Axles per Truck***. For each class, the number of axles per truck by axle type is required. The axle type is single, tandem, tridem, and quad. The number of axles per truck has a significant influence on the predicted pavement performance.

viii. ***Lateral Traffic Wander***. Lateral traffic wander is defined as a lateral distribution of truck tire imprints across the pavement. Traffic wander plays an important role in the prediction of distresses associated with rutting. Default values for traffic wander are recommended unless quality data are available on a regional or local basis. Traffic wander data may be hard to gather and quantify so default values are highly recommended.

Table 2.4 FWHA System of Vehicle Classification (Source: www.fhwa.dot.gov)

Vehicle Class	**Vehicle Type**	**Description**
4	Buses	All vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This category includes only traditional buses (including school buses) functioning as passenger-carrying vehicles. Modified buses should be considered to be a truck and should be appropriately classified.
5	Two-Axle, Six-Tire, Single-Unit Trucks	All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., with two axles and dual rear wheels.
6	Three-Axle Single-Unit Trucks	All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., with three axles.
7	Four or More Axle Single-Unit Trucks	All trucks on a single frame with four or more axles.
8	Four or Fewer Axle Single-Trailer Trucks	All vehicles with four or fewer axles consisting of two units, one of which is a tractor or straight truck power unit.
9	Five-Axle Single-Trailer Trucks	All five-axle vehicles consisting of two units, one of which is a tractor or straight truck power unit.
10	Six or More Axle Single-Trailer Trucks	All vehicles with six or more axles consisting of two units, one of which is a tractor or straight truck power unit.
11	Five or fewer Axle Multi-Trailer Trucks	All vehicles with five or fewer axles consisting of three or more units, one of which is a tractor or straight truck power unit.
12	Six-Axle Multi-Trailer Trucks	All six-axle vehicles consisting of three or more units, one of which is a tractor or straight truck power unit.
13	Seven or More Axle Multi-Trailer Trucks	All vehicles with seven or more axles consisting of three or more units, one of which is a tractor or straight truck power unit.

ix. ***Axle Configuration***. The MEPDG software allows the user to enter two types of axle spacing. The first is axle spacing within the axle group and it is defined as the average spacing between individual axles within the axle group. For example, the average spacing for all tridem axles for all vehicle types. Separate entries for tandem, tridem, and quad axles are required. The second possibility is axle spacing between major axle groups. This is defined as the spacing between the steering axle and the first subsequent axle. Axle spacing between the major axle groups is required for short, medium, and long trucks. Axle configuration has a marginal effect on pavement performance predicted by the MEPDG and is at the discretion of the user to pick default values or use measured values.

Within the MEPDG there are several traffic input factors that may not have significant influence on the predicted pavement performance. As a result, sensitivity to these elements should be further investigated to gain a better understanding of their impact on predicted pavement performance (Swan, Tardif, Hajek & Hein 2007).

2.7.2 Climate/Environment and EICM

Climate and the surrounding environment (weather) play an important role in pavement performance. It can exert significant influences on the pavement structure, especially where seasonal changes are large. Changes in temperature, precipitation, and frost depth can drastically affect pavement performance. The MEPDG requires these inputs to be locally calibrated. As a result, these climate conditions are needed to be observed and correlated to pavement performance. One climatic factor that greatly influences pavement material properties is moisture, which can affect properties such as stiffness and strength and therefore needs to be examined. The MEPDG fully considers the influences of the climate and surrounding environment on pavement performance. This is achieved through a climatic modeling tool embedded into the MEPDG software called the Enhanced Integrated Climate Model (EICM), The EICM is a one-dimensional coupled heat and moisture flow model initially developed by the FHWA and adapted for use in the MEPDG, for which purpose is to predict and simulate the behavioral and characteristic changes in pavement and unbound materials related to environmental conditions over the service life of the pavement system (NCHRP 2008). The EICM requires two major types of input. Groundwater table depth is one input that is manually entered into the EICM. The other input is weather-related information, which is primarily obtained from weather stations close to the project. The five weather-related parameters used in the EICM include sunshine, rainfall, wind speed, air temperature, and relative humidity. These data are collected on an hourly basis from the designated weather stations (Wang, Li, Hall, Nguyen, Gong & Hou 2007). The data collected in the United States may come from the National Climatic Data Center (NCDC), National Oceanic and Atmospheric Association (NOAA) or other reliable sources. To simplify the input of such numerous data, the MEPDG software contains a climatic database that provides hourly data from 851 weather stations across the United States.

2.7.2.1 Virtual Weather Stations

For a specific location, where there are no weather data available, the Integrated Climatic Model (ICM) is able to create a virtual weather station by interpolating the climatic data from neighboring weather stations. To generate a virtual climate file for a project location, the user has to input the longitude and latitude of the project, the elevation, and the depth of the water table. (Velasquez, et al. 2009). The software will then automatically select six weather stations closest to the location of the project. The number of weather stations selected is used to create a virtual weather station for the project location. Multiple weather stations are recommended due to the possibility of missing data and errors in the database for a single station, which may cause the software to hang or crash in the climatic module. It is also recommended that the weather stations selected to create the virtual station have similar elevations, if possible, although temperatures are adjusted for elevation differences (AASHTO 2008). In areas of wide-range climatic differences, AASHTO recommends that highway agencies divide such areas into similar climatic zones (approximately the same ambient temperature and moisture) and then identify representative weather stations for each of these zones (AASHTO 2008). Virtual weather stations generation for the MEPDG is further discussed in Section 4.

2.7.3 Material Data

The MEPDG requires the use of material properties of the pavement layers to create a mechanistic analysis of the pavement responses. The parameters used in the MEPDG greatly outnumber those used by the 1993 AASHTO Guide. In fact, the 1993 AASHTO Guide material property factors only included structural layer coefficients, layer drainage coefficients and the subgrade resilient modulus. It has been found that these parameters are insufficient to portray the complex material behaviors that occur in pavement structures. Some of these complex behaviors include stress-dependent stiffness in unbound materials along with time- and temperature-dependent responses of asphalt mixes (Rabab'ah & Liang 2007). With the implementation of the MEPDG underway, it is important to understand the performance of pavement materials under differing conditions. Better and more accurate simulations of different pavement distress levels can be achieved when a complete spectrum of a material's performance under altering conditions are entered into the design method (Petry, Han & Ge 2007). In the MEPDG, a drainable base layer must be included in design. It is through this layer that water that has entered the pavement must be removed. The layer needs to maintain optimal thickness and structural capacity while having optimal permeability (Rabab'ah & Liang 2007). The effectiveness of permeable bases in actual service is an ongoing process and more field monitoring, evaluation, and research is needed to satisfy the needs of the MEPDG. In the design of pavements, the MEPDG requires the dynamic modulus for asphalt mixtures and the resilient modulus for unbound materials. These properties are dependent upon changes, seasonal or otherwise, in temperature and moisture content. The MEPDG considers these changes in the pavement structure and subgrade over the design life of the pavement and predicts them by use of the EICM and adjusts material properties according to that particular environmental condition (Rabab'ah & Liang 2007). The user has two options within the EICM for adjusting the resilient modulus for each design period. The first option is that the user can provide the resilient modulus for each design period. The second option is to provide the resilient modulus for the optimum moisture content. When choosing the second option, the EICM in the MEPDG software would predict the seasonal variation of the moisture content in any unbound layers (Rabab'ah & Liang 2007).

2.7.3.1 Resilient Modulus and Unbound Layers

One material characteristic used in the MEPDG is the resilient modulus, which provides a way for evaluating dynamic response and fatigue behavior of a pavement under vehicle loading. This material property and the test methods to obtain it have become an accepted standard approach for pavement engineers. The results of resilient modulus testing along with other properties of the materials are used to calibrate the design parameters used in the MEPDG (Petry, Han, & Ge, 2007). The resilient modulus of unbound materials is not a constant stiffness property. Rather, it is highly dependent on factors like state of stress, soil structures and water content (Rabab'ah & Liang, 2007). Generally, a soil with the same dry density that has higher water content yields a lower resilient modulus. One of the considerations found within the broad range MEPDG in the materials section is the characterization of unbound materials. Unbound materials consist of base, subbase(s) and subgrade. All play a vital role in a pavement system and the base layer is where the unbound materials start. The base layer is placed immediately under the surface course and above the subbase(s). The base layer is designed to distribute the load from the pavement course to the underlying subbase(s) and subgrade layers. In order to prevent failure in the layers below and handle the stresses in the base itself, the base layer thickness and quality must be sufficient. Proper characterization of the materials used in the base layer and subsequent layers used in pavement design is a very important task. By means of the MEPDG, these material properties can be adequately characterized (Hill, Yohannes, & Khazanovich, Toward A Unified Mechanistic Approach For Modeling Tests Of Unbound Materials, 2007).

2.7.3.2 Hierrchal Approach to Material Inputs

The MEPDG uses various models to estimate pavement performances from material properties that are measured or predicted. Depending on the available information and the desired reliability, different levels of analysis are available in the MEPDG's hierarchal approach. The MEPDG hierarchal levels are based off design and analysis options and are classified into three levels. The three levels are based on accuracy, reliability, state-of-knowledge, and available data. Level 3 is the lowest level of the hierarchy and uses predicted material properties and have the lowest degree of reliability. Level 1 is on top of the hierarchy and uses lab or field measured values for material properties, resulting in the highest extent of reliability in the design and analysis of a pavement (Daniel & Chehab 2007). The MEPDG also uses a hierarchal approach to characterize materials. The resilient modulus at optimum moisture content is a desired property found by the MEPDG. The MEPDG hierarchy consists of three levels with different inputs based on the data available to the user. The overall objective of the three levels is to calculate or estimate the resilient modulus depending on what data have been collected.

A Level 1 input requires the use of lab testing of the resilient modulus as an input. If no resilient modulus lab test data are available, the MEPDG will calculate the resilient modulus using other properties in a Level 2 approach. These properties generally are the California Bearing Ratio (CBR) and/or the Dynamic Cone Penetrometer indexes obtained through standard AASHTO or NCHRP testing methods. Finally, the Level 3 analysis will estimate the resilient modulus at optimum water content based on the material classification (Hill, Yohannes & Khazanovich 2007). The three levels in the hierarchal approach are expounded on in the following list:

i. Level 1 input requires the highest quality of data. The data is collected from direct testing of the actual material. The desired data for Level 1 designs are the resilient modulus. The resilient modulus values of base, subbase, subgrade, and bedrock are determined from direct testing. The recommended test to obtain the resilient modulus is through the repeated tri-axial test. The standard testing procedure can be followed by using the NCHRP 1-28 A method or the AASHTO T307 method (Rabab'ah & Liang 2007).

ii. Level 2 designs are used when direct lab test results are not available but other test results are. Although lab test results for the resilient modulus are the preferable source of data, the resilient modulus can be obtained using correlations. These correlations may be between the resilient modulus and physical properties of the material such as dry unit weight, Atterberg limits, and specific gravity or between resilient modulus and strength properties such as the CBR, DCP, or unconfined compressive strength. All of the physical and strength properties can be obtained by following standard NCHRP or AASHTO procedures (Rabab'ah & Liang 2007). As with any correlations, having them locally calibrated is desired.

iii. Level 3 design is typically used for lower volume roads because it uses the lowest level of data accuracy. In this level, the resilient modulus for the optimum moisture content of the material is estimated based on the classification of the material. The ICM then adjusts the resilient modulus for the seasonal effects of the climate (Rabab'ah & Liang, 2007).

Along with the hierarchal approach, the MEPDG recommends the use of available correlation relationships when using inputs to calculate or estimate the resilient modulus. It is highly encouraged that locally calibrated models be developed to make these calibrations more site-specific. This is where one of the problems is found. It is time consuming and expensive to develop locally calibrated correlation models. Whether it be lack of equipment, manpower, or money, locally calibrated models are hard to create. The other problem involves figuring out how to create these models. The answer is to create a unified model for tests of unbound materials. More time, money, and research are being applied to achieving this goal, and a unified approach to creating locally calibrated correlation models is underway (Hill, Yohannes & Khazanovich 2007). All the inputs required for the material side of the MEPDG are extensive and better shown in tabular form. Kelvin Wang and his colleagues have created a tabular summary of the material inputs, which can be seen in Table 2.5 (Wang, Li, Hall, Nguyen, Gong & Hou 2007).

2.8 Section Summary

The MEPDG provides a useful tool for pavement performance predictions by taking into account elements from traffic, climate, and material data. By doing so, a more extensive and complete view of pavement performance is created. Through the use of the Enhanced Integrated Climate Model, the needed environmental adjustments are made to the predictions. The use of the hierarchal approach method to pavement design allows the MEPDG to be customizable based on the available data and the desired needs of the designer. There are challenges and opportunities for the MEPDG due to its extensive data inputs. These would have to be overcome in order to derive the full benefits of the new guide while progress is made on its implementation.

Table 2.5 Major Material Input Considerations (Wang et al., 2007)

Materials Category	Material Inputs Required		
	Materials inputs required for critical response computations	**Additional materials inputs required for distress/transfer functions**	**Additional materials inputs required for climatic modeling**
Hot-Mix Asphalt Materials (this covers surface, binder, base and subbase courses)	• Time-temperature dependent dynamic modulus (E*) of HMA mixture. • Poisson's ratio.	• Tensile strength, creep compliance, coefficient of thermal expansion	• Surface shortwave absorptivity (only required for surface course), thermal conductivity, and heat capacity of HMA. • Asphalt binder viscosity (stiffness) characterization to account for aging.
PCC Materials (this covers surface layer only)	• Static modulus of elasticity (E) adjusted with time. • Poisson's Ratio • Unit Weight • Coefficient of thermal expansion	• Modulus of rupture, split tensile strength, compressive strength, cement type, cement content, water-to-cement (w/c) ratio, ultimate shrinkage, amount of reversible shrinkage.	• Surface shortwave absorptivity, thermal conductivity, and heat capacity of PCC.
Chemically Stabilized Materials (this covers lean concrete, cement treated, soil cement, lime-cement-fly ash, lime-fly ash, and lime stabilized layers)	• Elastic modulus (E) for high quality lean concrete, cement treated material, soil cement, and lime-cement-fly ash. • Resilient modulus (Mr) for lime stabilized soil. • Poisson's Ratio. • Unit weight.	• Minimum resilient modulus (used in flexible design), modulus of rupture (used in flexible design), base erodibility (for rigid design).	• Thermal conductivity and heat capacity of PCC.
Unbound Base/ Subbase and Subgrade Materials	• Seasonally adjusted resilient modulus (Mr). • Poisson's Ratio. • Unit weight. • Coefficient of lateral pressure.	• Gradation parameters and base erodibility (for rigid design).	• Plasticity index, gradation parameters, effective grain sizes, specific gravity, saturated hydraulic conductivity, optimum moisture contents, parameters to define the soil water characteristic curve.
Recycled Concrete Materials - Fractured PCC Slabs	• Resilient Modulus (Mr). • Poisson's Ratio.	•Base erodibility (for rigid design).	• Thermal conductivity and heat capacity.
Recycled hot asphalt mix (central plant processed)	Treated same as hot-mix asphalt surface course.		
Recycled cold asphalt mix (central plant or on-grade)	Treated same as hot-mix asphalt surface course.		
Cold recycled asphalt pavement (used as aggregate)	Treated same as granular materials with no moisture sensitivity		
Bedrock	• Elastic modulus (E) • Poisson's Ratio. • Unit weight.	None.	None.

3. REGIONAL IMPLEMENTATION OF MEPDG

3.1 Background

With the introduction of the new Mechanistic-Empirical Pavement Design, state DOTs' reaction to implementing it has been met with mixed reactions (Stires 2009). The large volume of input data required for the MEPDG, data collection, and testing will bring about a significant challenge and require an immense amount of time and resources from DOTs. It has been suggested that in order to take advantage of the huge benefits that the MEPDG brings, by way of local calibration and hierarchical input levels, a complete overhaul of current pavement design practices are necessary. While some DOTs seem to have taken immediate implementing steps, such as developing testing programs for material properties and traffic data, others claim they have already locally calibrated the current version of the software. Others suggest that it will be more prudent to wait for the release of the final version of the software before undertaking any implementation efforts. During the earlier stages of the release of the MEPDG, two groups were created to facilitate implementation efforts. One of the groups was the Design Guide Implementation Team (DGIT). This group was created by the FHWA to inform, educate, and assist all DOTs and other interested agencies and institutions about the new guide. Another group that was formed to promote the growth of the MEPDG and develop short- and long-term implementation plans was the Lead States Group. This group was formed in conjunction with AASHTO, NCHRP, and FHWA, and comprised of representatives from state DOTs that had early interest in the MEPDG (Stires 2009). In the Northwest Region, there are currently ongoing efforts to implement and put the MEPDG into full use for pavement design activities. As different DOTs will have different strategies for implementation, it will be useful to study some of the lead states' approach to implementation and what lessons can be learned. The Northwest Regions' implementation efforts have first been geared toward the formation of a user group attending various meetings to discuss the MEPDG. Implementation efforts of the various DOTs in the region are discussed in the subsequent sections.

3.2 User Group Meeting

A Northwest States' MEPDG User Group meeting held at Oregon State University in Corvallis, Oregon, on March 9-10, 2009, discussed participating states' implementation plans progress, technical issues related to the MEPDG, and the future direction of the MEPDG. The states in the region that attended the meeting included Alaska, Idaho, Montana, North Dakota, Oregon, South Dakota, Washington, and Wyoming. At least one representative from each participating state's department of transportation was present at the meeting. In order to allow for the participation of other interested groups in the meeting, a teleconference network was setup. Session one was a general overview and national update, along with state specific implementation plans and progress. The other session discussed general technical issues relating to the MEPDG and was presented by the states. In all, the meeting focused on the DOTs' implementation plans and some specific technical issues. It concluded with focused discussion on the future direction of the MEPDG. Each representative for the DOTs gave a presentation on behalf of the respective state's DOT about their implementation plans and progress so far on the MEPDG.

3.2.1 National Implementation Plan

At the national implementation level, plans are far advanced to release DARWin M-E version 2.0. This effort involved 19 states and the FHWA and was initiated in February 2009. The changes associated with this new MEPDG software are Computation Methodology, appearance (changes in data input screens) and distress transfer function and/or distress mechanism. It has been suggested that even though these changes are proposed, AASHTO will decide what final changes will be made. Presently, ongoing studies associated with version the DARWin-ME 2.0 include: NCHRP 9-30A – Calibration of Rutting Models for HMA Structural and Mix Design, NCHRP 9-41 – Reflection Cracking of HMA Overlays, NCHRP 9-42 – Top-Down Cracking of HMA, and NCHRP 9-38, 9-44, 9-44A – Application of the Endurance Limit for HMA mixes. It has been recommended that the implementation of the MEPDG should be an integral part of the day-to-day design practice as well as the validation and calibration of distress transfer functions to local conditions, materials, and policies. At the national implementation level, four critical elements have been identified as key steps to a successful implementation program: A champion to lead the implementation effort and program, communication, training, and adequate funding. It has also been recommended that, to integrate the MEPDG into daily pavement activities, the following should in addition to the above considered: set up implementation committee and communications plan, confirm default input values and set up input libraries (traffic and material inputs), complete concurrent designs with the MEPDG, verify reasonableness of final designs, and begin training in the use of MEPDG software. With a lot of unknowns associated with the MEPDG, one major issue that has been identified that may hinder implementation efforts is training. There are currently two National Highway Institute (NHI) training courses: NHI Course 131064 – Introduction to M-E Pavement Design and NHI Course 131109 – Analysis of New and Rehabilitated Pavement Performance with MEPDG Software. It is suggested that DOTs plan for future updates of the MEPDG since the guide is ongoing. To prepare for such updates it is useful to maintain a calibration-validation database along with input libraries; monitor the test sections, input parameters and update the database, and verify local calibration or agency-specific factors for future MEPDG versions. Currently, there is a calibration-validation database being developed under NCHRP Project 9-30 and enhanced under NCHRP 9-30A. This will provide features to store and manage data for calibrating M-E-based methods at the national level.

3.2.2 Regional Implementation Plan

Montana is the only state among the northwest states that has completed its implementation program at the moment while the rest are either in the process or will initiate their implementation plan in the near future (Dzotepe & Ksaibati 2010). In the subsequent sections are summary implementation plans and strategies for state DOTs within the region. These plans and strategies were presented during the user group meeting.

3.2.2.1 Washington DOT

Presently, the Washington Department of Transportation (WSDOT) uses the 1993 AASHTO Guide for Design of Pavement Structures as their design tool. It has been making many efforts on the MEPDG implementation. They have concentrated two of their main efforts on data preparation and calibration-validation. Areas in the data preparation have included traffic, material properties, and pavement performance. They have both concrete and flexible pavement sites constructed for calibration-validation efforts. During their implementation efforts of the MEPDG, WSDOT came out with some major findings. They concluded that the MEPDG was an advanced tool for pavement design and evaluation and that calibration was required prior to its implementation. The next concern was that the concrete pavement calibration results needed to be adjusted before use and that the calibration was a continual process along with implementation. WSDOT has already calibrated the distress models for new flexible pavement to its conditions, except the IRI model. They were also of the opinion that local agencies needed to balance the input accuracy and the costs and that they will continue to monitor future works related to the MEPDG. WSDOT has also created some future works that will begin soon. These include refining the calibration results for doweled JPCP slabs and Superpave, testing, and calibrating rehab models for HMA overlay on HMA and HMA overlay on PCCP; and preparing specific designs on high traffic roads, weak soil support, and mountain passes. Part of WSDOT's implementation plan is to develop a user guide, prepare sample files for typical designs, and train pavement designers (Dzotepe & Ksaibati 2010).

3.2.2.2 Oregon DOT

The Oregon Department of Transportation (ODOT) plans to have full implementation of the MEPDG by 2012. They are currently working closely with Oregon State University (OSU) researchers to help with the implementation process. In that respect, research was completed by OSU pertaining to back calculation software and it was recommended that EVERCALC be utilized for this process. OSU also performed research on AC Dynamic Modulus and Axle Load Spectra, and they are still researching traffic lane instrumentation. OSU, in addition, has an ongoing research project for perpetual pavement instrumentation as well as M-E pavement design inputs on I-5 and US-97. Design input research includes material characterization, climate data, and calibration. They have outlined some of their future research in the areas of HMA density, open-graded HMA, Recycled Asphalt Pavement (RAP) mixtures, Recycled Asphalt Shingle (RAS) mixtures, and the Asphalt Mixture Performance Tester (AMPT) pool fund study. As the current researches are going on, ODOT plans to start having staff use the MEPDG for pavement design on some of its interstate projects. They plan to use the interim guide of the MEPDG in addition to their own pavement design guide until full implementation is realized. It is their intention that, during this time, individual agreements with the contractors will be made to decide what guide will be utilized and how it will be used.

3.2.2.3 South Dakota DOT

The South Dakota Department of Transportation (SDDOT) started their implementation process in 2005 with their research project called SD2005-01. The objective of the project was to identify the requirements and resources that will be needed for SDDOT to implement the MEPDG and develop a plan. These objectives were met by means of:

i. Conducting sensitivity analysis
ii. Recommending input levels
iii. Determining resource requirements
iv. Identifying calibration requirements
v. Developing an implementation plan

SDDOT's current implementation plan is a result of the previous research. There are three main aspects of the current plan. First, create an MEPDG Implementation team called the SDDOT Transportation Implementation Group (SDDOT TIG). This team will consist of 12 SDDOT representatives, one FHWA representative, and two industry representatives. The industry representatives are from the South Dakota Concrete Pavement Association and the Dakota Asphalt Pavement Association. The second aspect is the development of a communication plan, which has been completed by SDDOT. Finally, the third aspect involves MEPDG training. This was completed in the fall of 2008. SDDOT wants to review and appraise the MEPDG software relative to its performance for South Dakota soils, materials, climate, traffic, and other considerations. This will be accomplished through the following active research projects:

i. SD2008-10, with Lance Roberts from the South Dakota School of Mines and Technology to determine resilient modulus and dynamic modulus values for soils and asphalt mixes typically used in South Dakota

ii. M-E/PDG design, validation testing, and monitoring through the Asphalt Research Consortium (ARC) with Peter Sebaaly from the University of Nevada Reno

iii. SD2008-03, with Peter Sebaaly from the University of Nevada Reno, to evaluate warm mix in South Dakota

iv. Evaluate Coefficient of Thermal Expansion in SDDOT's concrete lab and develop a database based on SDDOT's concrete mixes

SDDOT has created a short-term, mid-term, and long-term implementation plan. In these stages, they hope to move toward full implementation after the next four years. Table 3.1 displays these termed plans and the associated goals.

Table 3.6 SDOT Implementation Term Plans

Short-Term (1-3 years)	• Review inputs' significance using MEPDG Version 1.0 • Assess training needs and begin training • Begin database compilation using non-project specific data • Review recommendations for model calibration
Mid-Term (2-4 years)	• Conduct preliminary calibration of models • Acquire new equipment as needs define • Train personnel in new testing requirements • Begin using MEPDG alongside existing pavement design procedure • Develop MEPDG documentation and guidelines • Calibrate and validate models • Determine any further data collection needs
Long-Term (> 4 years)	• Move towards full implementation of MEPDG • Develop a design catalog for standard designs

3.2.2.4 Wyoming DOT

The Wyoming Department of Transportation's (WYDOT) pavement design is housed within the materials program and is centralized. This has enhanced effective communications between the pavement engineers who are also the materials engineers. As a result of the program being centralized, there is a small staff, which means training and implementation should be fairly easy. However, because of the small staff, difficulties arise in calibration and input development. That is, the centralized operation doesn't have district advice from the various regions in the state. WYDOT feels the MEPDG would be utilized well for high-volume roads in the state such as I-80, but the 1993 AASHTO guide is adequate for other roads. This has led to the desire to implement the MEPDG because the 1993 AASHTO guide just kept adding pavement thickness to I-80. The strategy WYDOT wants to adopt is to get a program that is implementable in a reasonable amount of time. In this respect, they started an implementation plan in 2006, but that was largely focused on the materials side of the MEPDG and was later shelved. It was found that this plan was too aggressive at the time and so

WYDOT created new implementation goals. These goals involved finding a good funding source and adopting a program that will be usable and implementable by 2011. WYDOT wants to use existing information wherever possible and reduce the level of inputs. They had begun working with Applied Research Associates (ARA) to get the experience desired to run the program. It was their desire to utilize ARA because they are also working with the neighboring states that have a more aggressive implementation plan. WYDOT narrowed things down to focus on primary design and rehab alternatives. They are going to utilize existing sites for calibration and focus on level 2 and level 3 inputs. One goal is to create a Wyoming Specific Design Manual that focuses on the inputs. Eventually, WYDOT wants to implement it for all pavement designs. WYDOT is in more of a rehabilitation mode rather than new construction mode. Most projects in Wyoming involve widening and/or overlays. This is a weaker area in the guide but it is where WYDOT wants to focus. Challenges faced by WYDOT are in climate data, traffic inputs, and materials inputs. For climate inputs, there are not enough existing weather stations, so interpolation is going to have to suffice. WYDOT has good count and classification data for the traffic inputs, but there is a limited number (only nine) of weigh in motion (WIM) sites in the state. The result is limited WIM coverage because most of them are on high traffic routes such as I-80 and I-25. In the materials area, correlation of the R-Value to M_R and back-calculations from FWD will pose a challenge. Furthermore, the properties of existing HMA layers are not sufficient and there is not much existing data for concrete inputs. Finally, the challenges with calibration-validation involve few granular base sites, no superpave mixture sites, and no dowelled PCCP sites.

3.2.3 Regional Research Needs

It is obvious that the future adoption of the MEPDG will have considerable effects on data collection, material testing, and pavement design procedures. The mechanistic-empirical procedures upon which the guide is based will require greater quantity and quality of input data in the following four major categories: traffic, material characterization, environmental variables, and historical pavement performance (Schwartz, Charles W. 2007). Input data requirements for the MEPDG are much more extensive than for the current AASHTO Design Guide procedure. Although some of the data for the MEPDG is similar to those for the AASHTO Guide (e.g., annual average daily truck traffic, vehicle class distributions, subgrade resilient modulus, concrete modulus of rupture and modulus), much is significantly different and/or much more detailed input information is required (e.g., axle load distributions by axle type, asphalt concrete dynamic modulus, thermo-hydraulic properties for unbound materials, etc.).

Due to the extensive data requirements for the MEPDG, there is currently a lot of ongoing research into different areas of the guide in order to facilitate the implementation of the MEPDG in the northwest states' DOTs. Most DOTs in the region are currently concentrating their research efforts in the areas of traffic, climate, materials, and pavement response and distress models (pavement performance). Calibration and validation of the MEPDG to local conditions, which are agency specific, are also areas most of the agencies are looking into. Research studies being undertaken at the national level are mostly associated with the prediction models of the MEPDG and with version 2.0 of DARWin-ME. These include NCHRP 9-30A – Calibration of Rutting Models for HMA Structural and Mix Design, NCHRP 9-41 – Reflection Cracking of HMA Overlays, NCHRP 9-42 – Top-Down Cracking of HMA, and NCHRP 9-44A – Application of the Endurance Limit for HMA mixes. This report classifies the MEPDG research needs into national and regional categories. These are discussed in detail in the following sections.

3.2.3.1 Traffic Data Characteristics

Traffic characteristics are one of the major inputs of the MEPDG and are expected to require significant attention. The current AASHTO Pavement Design Guide requires traffic data in ESALs as a major design input. The MEPDG traffic criteria have been developed around axle load spectra, which are a valuable dataset that can be used for traffic inputs within the MEPDG. It is through axle load spectra that the unique traffic loadings of a given site are characterized. By means of these loading characteristics, pavement responses and resulting damages can be computed. Full axle load spectra are used for estimating the magnitude, configuration, and frequency of traffic loads (Wang, Li, Hall, Nguyen, Gong & Hou 2007). The benefit of load distributions is that they provide a more direct and rational approach for the analysis and design of pavement structures. The approach estimates the effects of actual traffic on pavement response and distress.

Currently in the Northwest Region, ODOT, in collaboration with Oregon State University is concentrating its research efforts mostly in the area of the axle load spectra before going on to other areas. Consequently, OSU recently completed research on WIM sites throughout Oregon and is now working on traffic lane instrumentation. The other area of traffic characteristics is traffic data collection, which is being undertaken by WSDOT. As part of the research, WSDOT is working on traffic data preparation, axle load spectra development, and sensitivity analysis. The underlying objective for both WSDOT and OSU in undertaking this research is how best to collect realistic traffic data for use in the MEPDG. Data sources may include site-specific data from Average Vehicle Counts (AVC) and WIM stations and default data from the FHWA LTPP program and the MEPDG software. The traffic data should be made up of the following elements if possible: truck volume and highway parameters, monthly traffic volume adjustment factors, vehicle classification distribution, hourly traffic volume adjustment factors, axle load distribution factors, traffic growth factors, number of axles per truck, lateral traffic wander, and the axle configuration.

3.2.3.2 Climate/Environment Factors

Climate and the surrounding environment (weather) play an important role in pavement performance and thus have a major impact on the pavement's long term performance. It can exert significant influences on the pavement structure, especially where seasonal changes are large. These factors include precipitation, temperature, and free-thaw cycles together. Changes in temperature, precipitation and frost depth can drastically affect pavement performance. The behavior of layers in the pavement system is affected by climatic factors (Johanneck, Luke and Lev Khazanovich 2009) and the MEPDG requires these inputs to be locally calibrated. As a result, these climate conditions need to be observed and correlated to pavement performance. One climatic factor that greatly influences pavement material properties is moisture, which can affect properties such as stiffness and strength and therefore needs to be examined. A preliminary conclusion deduced from research conducted in Illinois on the effects of climate change on rigid pavements in that state indicate that this may change slab thickness by 1.5 inches. The Idaho Department of Transportation and the University of Idaho have also been researching the environmental variation effects in the MEPDG design. They are developing seasonal shift factors for various regions and are trying to implement these shift functions into the MEPDG process to predict the accumulated seasonal damage. From this research, they are developing a software package called WINFLEX, which is a mechanistic-empirical overlay design software for Idaho.

3.2.3.3 Materials Characterization

Material characterization for the mechanistic-empirical design procedure is significantly more fundamental and extensive than in the current empirically-based AASHTO Design Guide. The MEPDG requires the use of material properties of the pavement layers to create a mechanistic analysis of the pavement responses. It is therefore imperative that databases or libraries of typical material property inputs must be developed. Due to the extensive nature of the material inputs, a great deal of research is being performed on pavement materials' characterization of the MEPDG at the moment. One of the current researches in this area is how to run pavement rehabilitation using FWD back calculations. The Oregon DOT and OSU are undertaking this study for which their current recommendation for this research is to utilize EVERCALC as the software program for back calculations. ODOT is researching MEPDG modeling of composite pavements such as HMA overlays on top of CRCP, JPCP, or rubblized PCC. Other future research that OSU/ODOT plans to undertake includes HMA density, open graded HMA, RAP mixtures, RAS mixtures and AMPT pool fund study. SDDOT, on the other hand, is currently undertaking research on how to determine Resilient Modulus and Dynamic Modulus Values for soils and asphalt mixes typically used in South Dakota. Also, in collaboration with Peter Sebaaly from the University of Nevada Reno, SDDOT is undertaking validation testing and monitoring through the Asphalt Research Consortium (ARC). SDDOT is also seeking to evaluate the coefficient of thermal expansion and develop a database based on the DOT's concrete mixes. In addition to this, they are seeking to evaluate warm mixes as applied to the MEPDG. Other areas of research into pavement materials being undertaken include characterization of asphalt mixtures with RAP to see the influence of RAP on MEPDG models and how to how to characterize wearing surfaces such as SMA, OGFC, and rubber-modified surfaces. Alaska DOT is also currently studying how to characterize non-standard materials, soils, and unbound materials.

3.2.3.4 Pavement Performance

Pavement performance data are required for local calibration and validation of the MEPDG procedure and is mainly associated with pavement distresses. These include fatigue cracking (alligator and longitudinal), rutting, and roughness. Accurate records of historical pavement performance, which most cases is within an agency's PMS, is therefore a necessity. The MEPDG does not provide a design thickness but it uses mechanistic-empirical numerical models to analyze input data for traffic, climate, material, and proposed structure and then estimates the damage accumulation over the service life of the pavement. The pavement performance predictions within the MEPDG are made in terms of the distresses that are often evaluated to determine rehabilitation and reconstruction needs in HMA pavements (Hoegh, Khazanovich & Jensen 2009).

3.2.3.5 Calibration and Validation

Calibration and validation is a very significant step in the MEPDG. This will enable DOTs to adapt the software to the suit local environment. Currently, the MEPDG includes empirical distress models that have been calibrated using a national database. Most of the data used for the national calibration were obtained from the Long Term Pavement Performance (LTPP). It is therefore necessary that calibration of the MEPDG models be undertaken using local pavement condition data (Souliman, Manlouk & Zapata 2009). In order to successfully calibrate and validate the MEPDG procedure to local conditions, pavement performance data are required. The process involves the replacement of the national calibration coefficients in the empirical distress prediction models with values more suited to local conditions. The calibration process usually requires the selection and identification of a set of experimental pavement sections for which the MEPDG inputs such as traffic, environment, and material properties can be well quantified and for which a history of pavement performance data such as rutting, fatigue cracking, and roughness are available. All of the above mentioned pavement distresses need to be calibrated to local conditions. Studies have shown that local calibration of the MEPDG procedures can be very beneficial in improving pavement performance predictions for local conditions. A well calibrated prediction model results in a reliable pavement design and enables precise maintenance plans for state highway agencies. The process, however, requires a significant amount of effort to perform (Schwartz 2007).

3.2.4 Challenges and Limitations to Implementation Efforts

With the ongoing efforts of trying to adapt the MEPDG, there are many challenges and opportunities that have arisen in the implementation of the MEPDG. One of the major challenges is the participation or "buy-in" of the agencies to eventually make the MEPDG a tool for routine production work. This includes the agency as a whole to accept and embrace the change brought about by the MEPDG and also the staff, including but not limited to, administrators, regional officers, designers, engineers, material specialists, etc. Following the "buy-in" by agencies come effective implementation plans. These include responsibilities, timelines, and gathering and allocating resources such as people, equipment, training, etc. Also involved in an effective implementation plan is the calibration tasks and schedule to allow for more localized use of the MEPDG. Another challenge in the implementation of the MEPDG is developing the criteria to warrant implementation. This may include objectively based performance indicators (rutting, cracking, etc.), a committee to oversee and steer the use of the MEPDG, an audit process, and update and improvement assessments (Haas, Tighe, Dore & Hein 2007).

Although the above named challenges are important to the implementation of the MEPDG, they are still overlooked at the DOTs by the biggest challenge and opportunity facing many agencies, which are calibration and validation. There is a need for actual calibration and validation models for all aspects of the MEPDG. Calibration or adjustment factors for the IRI and distresses (rutting, cracking, etc) are needed. Two key aspects are critical to a successful rutting model calibration: data and method. Regarding data, existing in-field information only provides total rut depth, which could not meet the requirement of permanent deformation in each structural layer by the MEPDG. Concerning method, existing work either fails to address calibration factors from a holistic perspective by only focusing on individual sections separately or ignores variability inherent in those factors. In this study, layer-wise permanent deformation from instrumented pavement under accelerated pavement testing serves to accommodate the model's calibration. A systematic calibration procedure is established, which globally optimizes all available information across all test sections. Through simulation and numerical optimization, optimal calibration shift factors for three typical flexible pavement materials, asphalt mixture, unbound granular base, and fine grain soil are obtained as 0.60, 0.49, and 0.84, respectively (Hong & Chen 2008). This implies that the uncalibrated MEPDG is biased toward over prediction of rut depth. It is further suggested that a more rational result for each calibrated factor is to introduce an appropriate distribution to characterize its uncaptured variability (Hong & Chen 2008). Databases of local and regional material and subgrade properties along with climatic or environmental conditions are necessary. Moreover, guidelines for the calibration and validation procedures are going to be needed. Finally, data collection is a must for the calibration effort. This includes traffic data (axle load spectra, volume variations, lane distribution, etc.) and climate and moisture data for the EICM. With these challenges come opportunities, mainly the opportunity to create a new level of advanced pavement design that is based on the best science and engineering available. In other words, designing and constructing the most cost effective, longest lasting roadways that are of the highest level of reliability (Haas, Tighe, Dore & Hein 2007). During the Northwest MEPDG User Group Meeting, it was also evident that the challenges in implementing the MEPDG are numerous. As part of the challenges already enumerated, the following were also highlighted as some of the obstacles to implementation:

i. Cost of the software through AASHTO Darwin M-E is a big issue for the participating states. The states may be able to afford the software but consultants, city, and counties may not be able to purchase it.
ii. Acquiring field performance data to calibrate, e.g., top-down or bottom-up AC fatigue cracking identification.
iii. Lack of and the creation of a design catalog.
iv. Communicating to industry about MEPDG and future changes.
v. Posting or web hosting discussions and presentations from other regions.
vi. Sharing calibration information from other states in the region.

The user group also came up with the following limitations associated with the MEPDG:

i. Studded tire/mechanical wear and IRI prediction for PCC (WSDOT)
ii. Longitudinal cracking prediction on concrete pavement (WSDOT)
iii. Field definition of top-down and bottom-up fatigue cracking
iv. Rehabilitation and back calculation
v. Use of geotextiles (Wyoming)
vi. Low volume roads
vii. Aggregate base rutting is too high, which forces more AC (Idaho)
viii. Thermal cracking model prediction (SDDOT)
ix. Non-standard materials (FDR, foamed asphalt, RAP, OGFC)
x. Thin AC surfacing and predicted distresses

3.2.5 Benefits of Implementing the MEPDG

Ongoing research suggests that MEPDG, if successfully implemented, is anticipated to achieve a more reliable design (Wagner), which provides significant potential benefits over the 1993 AASHTO guide in achieving cost-effective pavement designs and rehabilitation strategies (Coree, Ceylan & Harrington 2005). A very important aspect of the MEPDG is its user-oriented computational software program, which uses an integrated approach for predicting pavement condition over the design life by accounting for the interaction of traffic, climate, and pavement structure, and also allows for evaluating design variability and reliability. The software will also serve as a forensic tool for analyzing the condition of existing pavements and pinpointing deficiencies in past designs (Coree, Ceylan & Harrington 2005). The MEPDG will allow pavement engineers and designers to make better-informed decisions and take cost-effective advantage of new materials and features. The adoption of the MEPDG will significantly improve pavement material testing, design procedures, and, most importantly, data collection (Schwartz 2007). The design guide will, in addition, allow for calibration to national, regional, or local performance data for materials, climate, and traffic (Wagner) thereby allowing agencies the greatest possible flexibility for applying and calibrating the design procedures to their local conditions (Schwartz 2007). Despite the significant benefits associated with the implementation of the MEPDG, its extensive data requirements from traffic, material, and climate inputs, however, pose some challenges. A number of further research areas have also been identified for the MEPDG at the national, regional, and local levels, which when successfully completed, will facilitate its implementation. It was therefore the objective of this study to identify further research needs that are considered very important and necessary to facilitate the implementation of the MEPDG. Consequently, at the Northwest States MEPDG User Group meeting, held March 9-10 in

Oregon, the main national research areas of the MEPDG identified included: NCHRP 9-30A – Calibration of Rutting Models for HMA Structural and Mix Design, NCHRP 9-41 – Reflection Cracking of HMA Overlays, NCHRP 9-42 – Top-Down Cracking of HMA, and NCHRP 9-38, 9-44, 9-44A – Application of the Endurance Limit for HMA mixes. Most of these research efforts are being undertaken under the National Cooperative Highway Research Program (NCHRP). Other research areas also being undertaken at the national level include the recommendation on the rehabilitation of both flexible and rigid pavements, the coefficient of thermal expansion, and the effects of geogrids and geotextiles, which can generate considerable cost savings in highway pavement construction. Further research areas at the regional level are concentrating on traffic, material and climate characteristics, and pavement performance. At the local level, the main area of research has to do with the calibration of the MEPDG models to local conditions. National and regional research studies and calibration efforts being undertaken by most DOTs in the northwest region are discussed in the subsequent sections. In the meantime, four critical elements have been identified as the key steps to a successful implementation of the MEPDG in the northwest states:

i. A champion to lead the implementation effort and program
ii. Communication
iii. Training
iv. Adequate funding

It is recommended that agencies seeking to implement the MEPDG should seriously consider these critical elements as well as monitor the progress of the above mentioned ongoing further researches (Northwest States User Group Meeting). Other activities also noted and recommended that were considered necessary for an effective integration of the MEPDG in practice included:

i. Setting up an implementation committee and communications plan
ii. Confirmation of default input values and set-up of input libraries (traffic and material inputs)
iii. Completion of concurrent designs with the MEPDG
iv. Verification of reasonableness of final designs
v. Training in the use of MEPDG software

Also noted, of particular importance to the application of the MEPDG to local conditions, was the calibration and validation of the guide, which is a continuous process. To assist in overcoming these challenges, it was recommended that agencies should:

i. Plan for and monitor future works related to updates and improvements of the MEPDG on a continuous basis.
ii. Maintain a calibration-validation database along with input libraries.
iii. Periodically monitor test sections, input parameters, and update the database.
iv. Verify local calibration or agency-specific factors for future MEPDG versions.

The current calibration-validation database being developed under NCHRP Project 9-30 and being enhanced under NCHRP 9-30A provides features to store and manage data for calibrating mechanistic-empirical-based methods at the national level (Northwest States User Group Meeting).

At the user group meeting, it was evident that training may be one of the major issues in the facilitation of the MEPDG at the moment. For this, two National Highway Institute (NHI) training courses are currently available in the MEPDG, and it is recommended that agencies assist and encourage not only their pavement designers but other personnel from the areas of traffic, materials, and Pavement Management Systems (PMS) to attend these courses (Dzotepe & Ksaibati 2010). These courses include:

i. NHI Course 131064 – Introduction to Mechanistic Empirical Pavement Design
ii. NHI Course 131109 – Analysis of New and Rehabilitated Pavement Performance with MEPDG Software

It is envisaged that the MEPDG will continue to be updated with new research areas being developed as time goes by, and that it will take considerable time before it becomes an accepted design guide, hence it is extremely important that agencies plan and monitor future works related to updates and improvements of the MEPDG on a continuous basis. The results will be that agencies can effectively calibrate and validate the MEPDG to suit their local conditions.

3.3 Section Summary

This section outlined the regional and the national implementation efforts of the MEPDG, which focused on some selected northwest states DOTs and the research areas these DOTs are concentrating on in order to facilitate implementation efforts. The section summarizes the various concerns and contributions raised by selected DOTs in the region during a presentation at the user group meeting.

4. DATA COLLECTION

4.1 Introduction

To simulate pavement performance distresses using the MEPDG software, it was necessary to use input parameters that reflected Wyoming local conditions as much as possible. Therefore, in this study the design input data required were obtained from the Wyoming Department of Transportation (WYDOT), where available. It was not possible to obtain project-specific design data for all the inputs and so in areas where actual data could not be obtained from WYDOT, default values embedded in the MEPDG software were used. As mentioned in Section 2, the user has the option of determining the level of analysis in the MEPDG. A level 3 analysis uses more default values while a level 2 analysis uses an intermediate level of accuracy. This level is recommended when appropriate tests are not available for a level 1 analysis. Inputs would typically be user defined from an agency database or derived values from a limited testing program. The level 1 analysis requires the highest level of accuracy and would usually be determined from laboratory testing or site data collection. This level would typically be used in heavy traffic areas or where early pavement failure would result in significant safety issues or economic consequences. The selection of the analysis level determines the required input values from the user. Generally, running the MEPDG requires data to be entered into four main sections of the software, as shown in Appendix A1, with other input data screens.

4.2 Design Inputs

Input data in the MPEDG is grouped into traffic, material, and climate. These are further sub-grouped into the different specific parameters that supplied by the user (See Appendix A2). For this research study, where project-specific input data were not available, defaults values embedded in the MEPDG have been used to run the simulations.

4.2.1 Traffic Input Data

The traffic input data in the MEPDG can be simplified, as shown in the Table 4.1. The AADTT used in this study can be said to be level 1, as this was obtained from the WYDOT Pavement Management System (PMS) included in Appendix B. This corresponded to the type of pavement selected from the PMS.

Table 4.7 Traffic Input Data

Site Specific Traffic Inputs	• Initial Two Way Average Annual Daily Truck Traffic (AADTT) • Percent Trucks in Design Lane • Percent Trucks in Design Direction • Operational Speed • Truck Traffic Growth
WIM Traffic Data	• Axle Load Distribution • Normalized Truck Volume Distribution • Axle Load Configurations • Monthly Distribution Factors • Hourly Distribution Factors
Other Inputs	• Dual Tire Spacing • Tire Pressure • Lateral Wander of Axle Loads

The other traffic parameter that can be considered as site specific is the operational speed. This has been selected based on the section and the location considered. All other input parameters for traffic have been left as default values in the MEPDG. This applies to all the different road classes considered for this research. The MEPDG allows for traffic input to be either entered directly as AADTT or can be calculated using the AADTT calculator shown in Appendix A2, where the Average Annual Daily Traffic (AADT) and percentage of heavy vehicles using class 4 and higher are multiplied. The traffic data in the PMS were that of an AADT and so had to be converted into AADTT as required by the MEPDG. Other traffic parameters, such as the traffic volume adjustment, axle load distribution factor, and general traffic inputs, can also be assessed from the traffic input screen or individually from the main MEPDG screen included in Appendix A2. The user may adjust the monthly truck distribution factors if such data are available; but for this study, no data were available from WYDOT and so the defaults in the MEPDG were used as the input data. The current default is set to 1.00 for all months and truck classes. The study also used default values for the axle load factors since this data could not be obtained from the DOT.

4.2.2 Pavement Material Data

The typical pavement cross sections for the different classes of road used for this study were derived from the WYDOT PMS. This study considered only flexible pavement structure. Information extracted from the PMS used in developing the typical cross sections included road classification system, route number, pavement type and depth, and base type and depth.

4.2.2.1 Primary System

For the primary road system, all the pavement types with designation G2 (standard PM pavement with plant mix wearing course) were extracted from the PMS. Pavement designations are included in Appendix B1. A graph of base type versus base and pavement depth shown in Appendix B2, was plotted. It was determined from the graph and also using highest occurring frequency (modal value) from the PMS that the most occurring pavement structure for primary system has a pavement depth

(HMA) layer of 4in and an aggregate base of 4in. In Wyoming, most of the aggregate base is crushed gravel and subgrades are typically A3 classification. Based on this information, a typical route (PR23) section located in Laramie on Third Street was selected from the PMS with its corresponding AADT and used for the MEPDG simulations. The typical cross section is shown in Figure 4.1.

2" Asphalt Concrete
2" Asphalt Concrete
4" Crushed Gravel
Subgrade (A-3)

Figure 4.1 Typical primary road cross section.

4.2.2.2 Secondary System

For the secondary system, the same procedure was followed to develop the typical cross section. It was determined using the modal value from the PMS that the most occurring pavement structure for secondary systems in Wyoming has a pavement depth (HMA) layer of 4 inches and an aggregate base of 6 inches. Using this information, a typical route (S109) section located at Bosler Junction, Wheatland, was selected from the PMS with its corresponding AADT. The cross section is shown in Figure 4.2. An extract of the secondary road classification is included in Appendix B3.

2" Asphalt Concrete
2" Asphalt Concrete
6" Crushed Gravel
Subgrade (A-3)

Figure 4.2 Typical secondary road cross section.

4.2.2.3 Interstate System

For the interstate system, a graph of base type versus base and pavement depth is shown in Appendix B4. This showed that most of the interstate flexible pavements have a 6-inch HMA layer and 6-inch asphalt permeable base layer (most common base layer). Based on this information, a typical route (I-80) section located at Table Rock was selected from the PMS with its corresponding AADT for the MEPDG analysis. The cross section is shown in Figure 4.3.

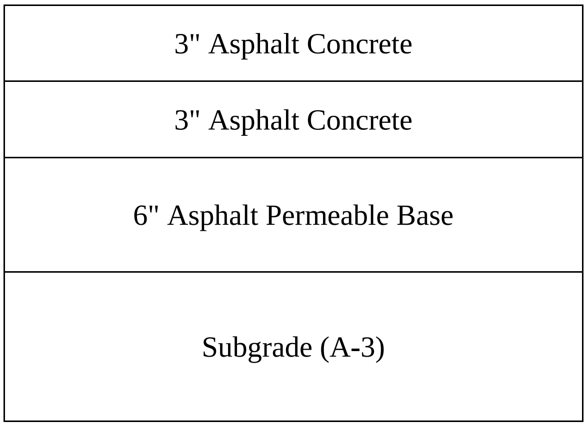

Figure 4.3 Typical Interstate 80 cross section.

4.2.2.4 Binder Grades

Data on the binder grades for the different classes of road was obtained from WYDOT. According to WYDOT, the binder grade selection for flexible pavements is based on the traffic, climate, depth of layer, and existing distresses, which results in PG58-28 for most secondary systems and lower lifts on primary systems. PG64-22 is mostly used on overlays for secondary systems and primary while PG64-28 is used on upper lifts of most primary roads and lower lifts of interstates. PG70-28 is used on some high truck primary routes and upper lifts of I-25 and I-90 and PG76-28 on upper lifts of I-80. Binder grades used by the DOT are included in Appendix B5. The MEPDG asphalt binder grade selection screen in Appendix A1 allows the user to select how the asphalt properties are determined. From the input screen, three methods are available, namely:

- Superpave binder grade
- Conventional viscosity grade
- Conventional penetration grade

For this study, the superpave binder grade method has been used. With the superpave grading, the user selects a PG grade from a list supplied by the MEPDG software. The superpave binder grades used in Wyoming as already discussed and, as such, used for this study include:

- PG58-28
- PG64-22
- PG64-28
- PG70-28
- PG76-28
- PG52-28 (not part of WYDOT binder date included in Appendix B4 but also considered for this study).

For the conventional viscosity grading, the user selects a viscosity grade (e.g., AC 10) from a list of six grades supplied by the software while the penetration grade requires the user to select from a list of five penetration grades (e.g., Pen 85-100) for the asphalt binder. The volumetric properties screen allows for the input of percent binder content, percent air voids, and total unit weight. In this screen, the thermal conductivity, heat capacity of the asphalt as well as the poisons ratio and reference temperature can all be edited. As no data were available on these parameters, they have been left as default values.

The strength properties input screen for the unbound materials allows for editing the R-value, CBR, modulus, and the layer coefficient. For this study, the R-values of unbound materials have been used where applicable. Since the strength of subgrade materials in Wyoming is known, the input of this value has been given a level 2. All other properties of unbound layer are the MEPDG default values. Depending on the R-value entered, the software calculates the modulus. The EICM input for the unbound layer has to do with the gradation of the material. The mean or the range can be selected whereby the material gradation data can be imported from a database or can be entered. Other properties of the unbound material are automatically calculated. The MEPDG allows for the input of the mix coefficient of thermal contraction (in/in/F) or allows the software to compute it automatically by providing the mixture VMA (%) and the aggregate coefficient of thermal expansion.

4.3 Climate Data

Information on the climate for this research has been collected from the Water Resource and Data System (WRDS) and compared to the ones already in the MEPDG. Table 4.8 shows all the weather stations with hourly data that are available in the MEPDG Version 1.1 software for the State of Wyoming.

Table 4.8 Weather Station Locations in Wyoming

	Weather Station	**Latitude (deg.mins)**	**Longitude (deg.mins)**	**Elevation (ft)**	**Months of Available Data**
A	Big Piney – Marbleton Airport	42.35	-110.07	6947	96
B	Buffalo, Johnson County Airport	44.23	-106.43	4913	91
C	Casper, Natrona County Int’l Airport	42.54	-106.28	5351	116
D	Cheyenne Airport	41.10	-104.49	6128	116
E	Douglas, Converse County Airport	42.48	-105.23	4921	80
F	Evanston, Evan-Uinta Co Burns FLD AP	41.16	-111.02	7143	79
G	Gillette-Campbell Co. Airport	44.20	-105.32	4332	92
H	Greybull, South Big Horn County Airport	44.31	-108.05	3910	89
I	Lander, Hunt Field Airport	42.49	-108.44	5560	111
J	Laramie Regional Airport	41.19	-105.40	7271	65
K	Rawlins Municipal Airport	41.49	-107.12	6739	65
L	Riverton Regional Airport	43.04	-108.28	5573	116
M	Rock Springs – Sweetwater Co Airport	41.35	-109.04	6763	58
N	Sheridan County Airport	44.46	-106.59	3945	111
O	Torrington Municipal Airport	42.04	-104.09	4193	**93 (M1)**
P	Worland Municipal Airport	43.58	-107.57	4174	63

Figure 4.4 shows the relative locations of these stations with respect to each other. Five additional weather stations were identified from the data collected that were not part of the ones already embedded in the MEPDG. These include Cody, Pinedale, Yellowstone Lake, Jackson Hole, and Torrington, as shown in Figure 4.5.

Figure 4.4 Weather station locations in MEPDG. (Source: Google Maps)

Figure 4.5 Weather station locations obtained from WRDS. (Source: Google Maps)

4.3.1 Virtual Weather Stations Generation

As noted in Section 2, in areas or locations where there are no weather station data, the MEPDG allows the user to create a virtual weather station of the location by means of the Integrated Climatic Model (ICM). The input screen for creating a virtual station is shown in Figure 4.6. The virtual station is created by interpolating climate data from neighboring climate stations.

As observed in Figure 4.6, the location (coordinates) of the weather station, the elevation, and the annual average depth of the water table should be provided to generate a new climatic file. The interpolation may be done based on all the available neighboring stations or by selecting only stations that have similar elevations.

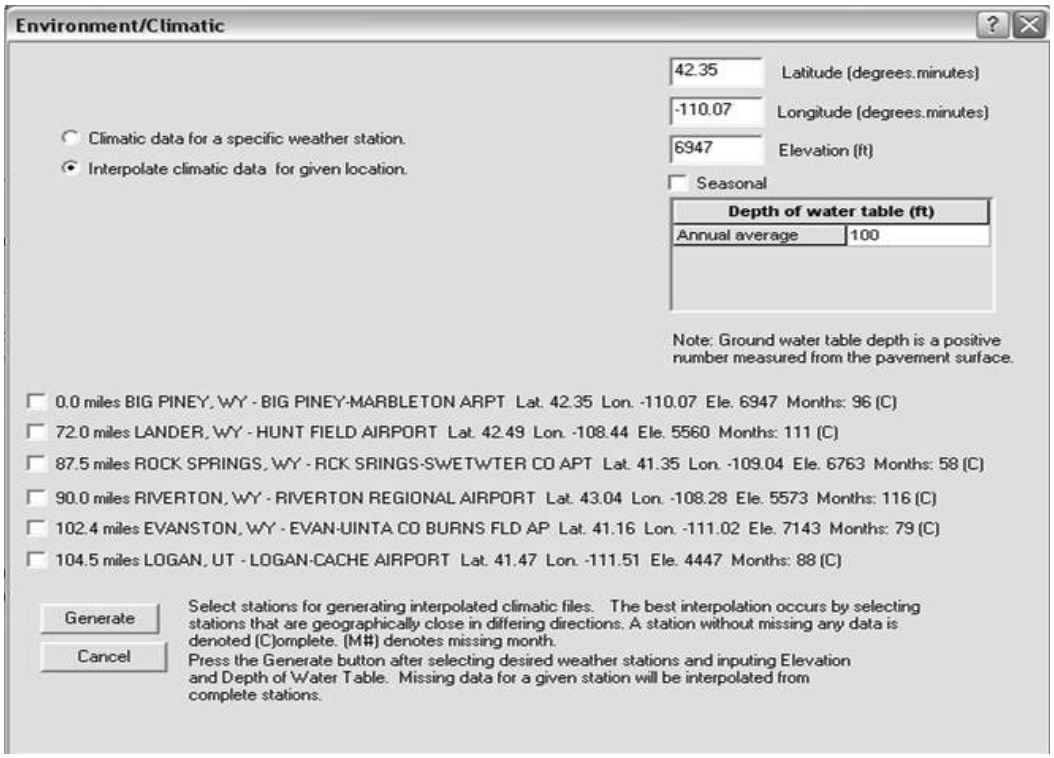

Figure 4.6 Virtual weather station interpolation screen.

4.3 Section Summary

This section presented the data collection and identified the different MEPDG inputs. The AADT, from which the AADTT was calculated, was obtained from the WYDOT Pavement Management System. The typical pavement cross sections for all the different road classes used were also developed from the PMS. Climate data obtained from WRDS identified four other stations that are not part of the ones already embedded within the MEPDG climate files. Where data could not be obtained or were unavailable, default values within the MEPDG were used to run the simulations.

5. DATA ANALYSIS

5.1 Introduction

The MEPDG makes use of all the input parameters of traffic, materials, and climate data to generate the pavement performance distresses for the selected design life of the pavement structure, as well as the annual climate statistics as output results. Both the performance distresses and the climate statistics output results have been generated for interstate, primary, and secondary road systems. Each of the output performance results have been analyzed using the actual weather stations, virtual stations generated from interpolation of all available neighboring stations, and also by interpolation using similar elevations of +/- 500 ft difference. The actual output results generated are compared with results generated by the virtual stations to determine how these values vary from the actual.

5.2 Annual Climate Statistics

The summary weather parameters generated are the mean annual temperature, rainfall, freezing index, and average annual number of freeze/thaw cycles.

Table **5.9** shows the annual climatic statistics for the actual weather stations in Wyoming.

Table 5.9 Annual Climate Statistics for Actual Stations

Weather Station Name	**Annual Climate Statistics**				**Elevation (ft)**
	Mean annual air temperature (ºF):	**Mean annual rainfall (in):**	**Freezing index (ºF-days):**	**Average Annual Number of Freeze/Thaw Cycles:**	
Big Piney	37.19	12.15	2439.19	149	6947
Buffalo	46.79	11.9	874.26	123	4913
Casper	46.26	10.4	986.09	118	5351
Cheyenne	46.86	13.26	793.33	117	6128
Douglas	46.61	11.86	1068.48	135	4921
Evanston	42.29	10.49	1325.58	98	7143
Gillette	47.11	12.85	949.71	124	4332
Greybull	46.2	5.27	1569.36	118	3910
Lander	45.8	11.42	1187.27	124	5560
Laramie	41.96	8.82	1314.61	146	7271
Rawlins	43.95	9.07	1162.02	120	6739
Riverton	45.2	8.46	1315.33	121	5573
Rock Springs	43.95	7.94	1253.8	111	6763
Sheridan	45.92	13.85	1110.34	140	3945
Worland	45.54	9.69	1452.64	127	4193

5.3 Performance Distresses

The MEPDG software's structural response model and transfer functions are able to compute the pavement distresses which are analyzed throughout the pavement's design life. For HMA pavements, the critical performance distresses evaluated are longitudinal cracking, alligator cracking, transverse cracking, rutting, and the International Roughness Index (IRI), which defines the overall smoothness measure of pavements. This research investigated the response performance distress of typical sections of three classes of road system: interstate, primary and secondary. The performance distresses of each system are presented in the subsequent sections.

5.3.1 Interstate System

For the interstate system, a section of I-80 was used with a typical cross section selected from the WYDOT PMS. Six different binder grade combinations were used to simulate pavement distresses to determine to what extent the particular climate used in the analysis would affect the distresses. In this analysis, only the weather station at Big Piney was used. A typical flexible pavement cross section that was derived from the PMS was assumed for the I-80 location at Table Rock at mile post 145.5 – 153.8 ft. and having a design life of 20 years. Tables 5.2 and 5.3 show the general traffic input and the limiting value for the distresses and reliabilities, respectively. It is against the limiting criteria and reliability in Table 5.3 that all the performance distress results have been measured.

Table 5.10 General Traffic Inputs

Initial two-way AADTT:	2738
Number of lanes in design direction:	2
Percent of trucks in design direction (%):	50
Percent of trucks in design lane (%):	95
Operational speed (mph):	75

Table 5.11 Design Limiting Values

Performance Criteria	Limit	Reliability
Initial IRI (in/mi)	75	
Terminal IRI (in/mi)	190	90
AC Surface Down Cracking (Long. Cracking) (ft/mile):	2000	90
AC Bottom Up Cracking (Alligator Cracking) (%):	25	90
AC Thermal Fracture (Transverse Cracking) (ft/mi):	1000	90
Permanent Deformation (AC Only) (in):	0.25	90
Permanent Deformation (Total Pavement) (in):	0.75	90

5.3.1.1 Performance Distresses for Different Binder Types

Table 5.4 shows a summary result of the performance distresses for different pavement binder grades using weather data for Big Piney Station. Detailed performance results for the different binder types are included in Appendix C1. The figures in bold italics indicate that the distress did not meet the design criteria specified in Table 5.4 and therefore failed. For the AC deformation, failure shown for Type 2 and 3 was a result of the design not meeting the reliability limit since the distress values did not exceed the design criteria.

Table 5.12 Predicted Pavement Distresses Using Different Binder Types at Big Piney

Pavement Composition	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
Layer 1 – Top Lift (3in)	PG76-28	PG52-28	PG52-22	PG58-22	PG64-22	PG70-22
Layer 2 – Bottom Lift (3in)	PG64-28	PG52-28	PG52-22	PG58-22	PG58-22	PG58-22
Layer 3 – ATB (6in)	PG64-28	PG52-28	PG52-22	PG58-22	PG58-22	PG58-22
Layer 4 – Subgrade (A3)						
Terminal IRI (in/mi)	123.3	124.8	127.2	126	125.5	125.2
Longitudinal Cracking (ft/mi)	0.1	4.1	2.6	0.6	0.2	0.1
Alligator Cracking (%)	0.1	0.1	0.1	0.1	0.1	0.1
Transverse Cracking (ft/mi)	***1595.1***	***1288.4***	***1696.9***	***1778.9***	***1791.3***	***1812***
AC Deformation (in)	0.1	***0.19***	***0.17***	0.13	0.12	0.11
Total Pavement Deformation (in)	0.24	0.34	0.32	0.28	0.26	0.25

Figure 5.7 to 5.4 indicate that the binder grade used in the pavement construction does play a significant part in the prediction of the pavement performance distresses except for the alligator cracking shown in Figure 5.4. As expected in Figure 5.1, the terminal rutting is lowest for PG76-28 and highest for PG52-22. These are the highest and lowest binder grades, respectively. It would have been expected that the IRI for PG52-28 would be higher for PG64-22 and PG70-22 as these are of a higher grade, but this is not the case. This gives the indication that the IRI may be dependent on the lower bound of the asphalt grade. Generally, the IRI is directly related to the initial IRI, SF (site factor), FC (fatigue cracking), TC (transverse cracking), and RD (average rut depth). Any of the binder properties that cause an increase in any of these parameters is highly likely to cause an increase in the IRI. The site factor (SF) is directly related to the age of the pavement, which is a function of PI (percent plasticity index of the soil), average annual precipitation, and the average annual freezing index.

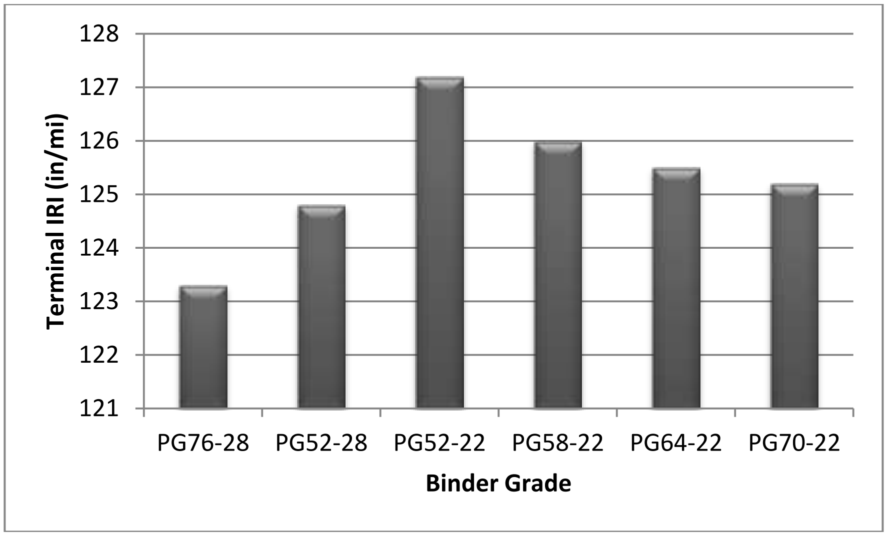

Figure 5.7 Binder grade vs. terminal IRI – Big Piney.

In the longitudinal cracking shown in Figure 5-2, it is expected that the lowest binder grade PG52-22 should show the most cracks, but the most longitudinal cracks tends to be associated with PG52-28. Since the upper bounds of the asphalts are the same, it therefore indicates that the difference in the longitudinal cracking must be due to the lower bounds in the binder grades. PG52-28, being a higher grade than PG52-22, may tend to be stiffer and so exhibits more cracks than PG52-22. But generally, the trend in the longitudinal cracking in considering the different grade is as expected.

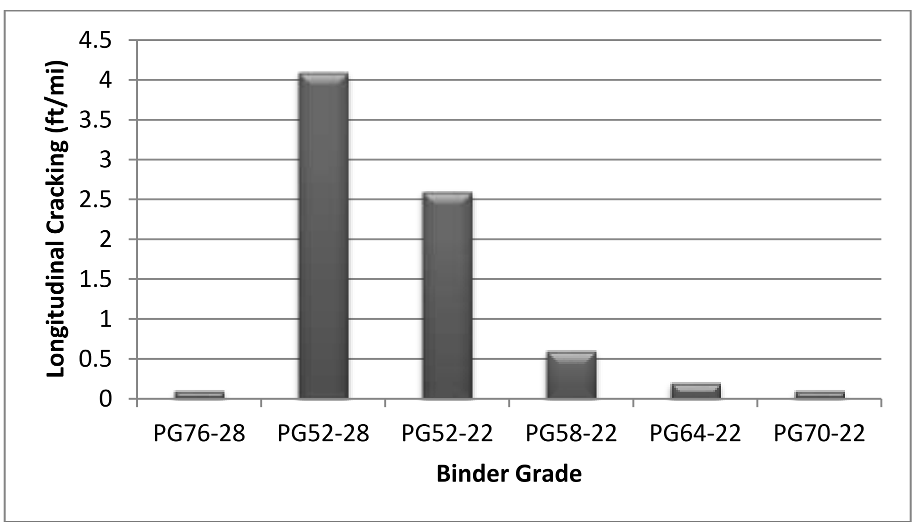

Figure 5.8 Binder grade vs. longitudinal cracking – Big Piney.

Figure 5.3 shows a plot of alligator cracking, AC rutting, and total rutting versus the different binder grades. The alligator cracking is unaffected by the binder grade as it can be observed that the extent of alligator cracking experienced by the pavement is unchanged irrespective of the binder type. This may be due to the fact that alligator cracking is a load-related cracking that is assumed to initiate at the bottom of the HMA layer and then propagate to the top with continued traffic. The alligator cracking model is also nationally calibrated and so it is essential that it be locally calibrated so as to exhibit reliable results. The trend shown for the AC and total pavement rutting are as expected with respect to the binder grades except for PG52-28 and PG52-22. The PG52-28 exhibits a higher AC and total pavement rutting than PG 52-22 even though this is of a lower grade of the two; being stiffer asphalt at the low end exhibits more cracks than PG52-22, which happens to be the lower grade.

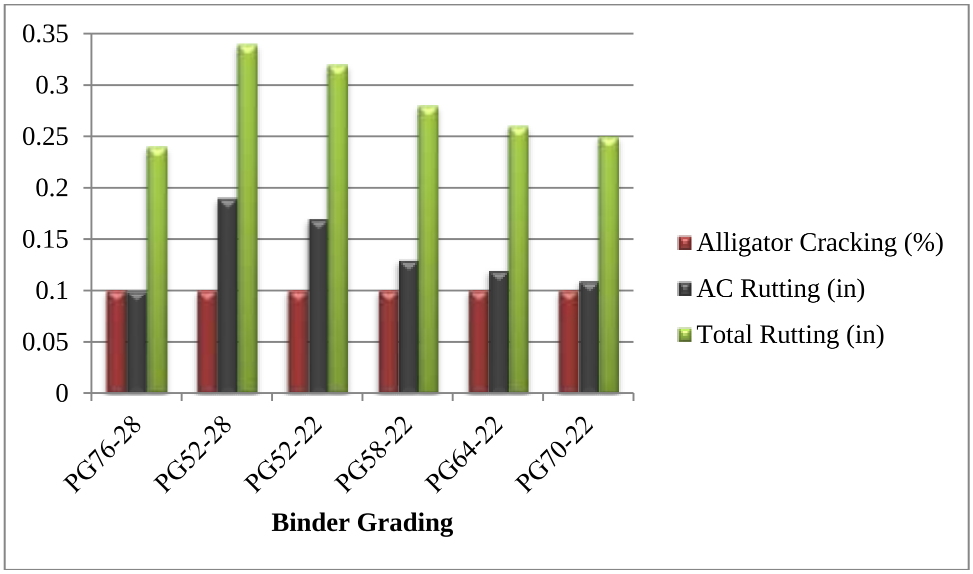

Figure 5.9 Binder grade vs. alligator cracking/rutting – Big Piney.

Figure 5.4 shows a plot of the transverse cracking model. Transverse cracking is a non-load related-cracking, which is highly dependent on the cooling cycle experienced by the pavement. PG52-28 and PG76-28 exhibit a lower transverse cracking than the other grades because these two grades have a higher low end range and so tend to resist this distress type better than the others. The PG76-28 exhibits a higher transverse cracking even though it is a higher grade than the PG52-28. This is due the fact that, as a higher grade binder, it is also a stiffer one and so may be more susceptible to transverse cracking. As observed, the other grades have a lower low end range and so exhibit higher transverse cracking. All the binder grades, however, did not pass for the transverse cracking analysis even though the PG52-28 performs better when compared with the other binders.

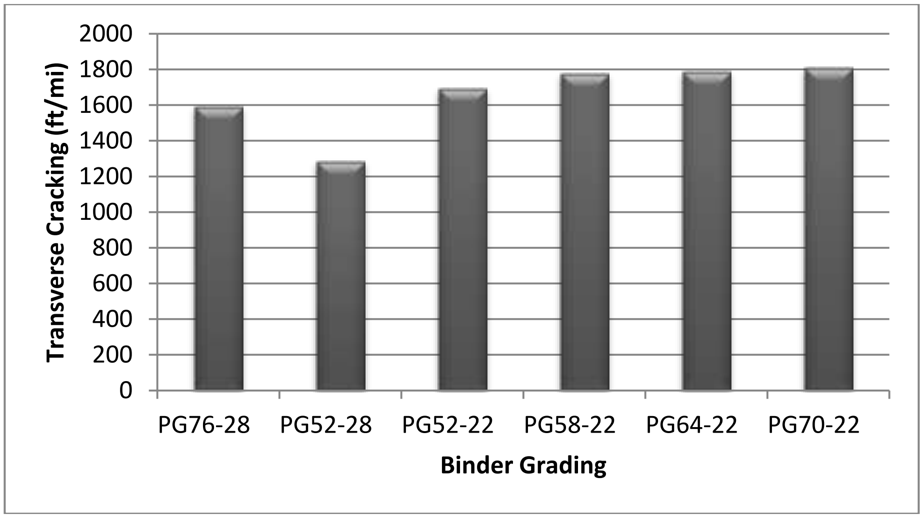

Figure 5.10 Binder grade vs. transverse cracking – Big Piney.

5.3.1.2 Climate Analysis

Two binder grades, PG52-28 and PG76-28, were used to run the MEPDG software for all the available weather stations in Wyoming. Tables 5.5 and 5.6 show the results obtained for the pavement performance distresses using PG52-28 and PG76-28, respectively, and Figures 5.5 to 5.10 show a graphical plot of the distresses. Clearly, it can be seen that the environment or climate in which the pavement structure is constructed has a significant impact on the future performance of the pavement. For the binder grade PG52-28, all the distresses passed for each climatic zone except for the transverse cracking and HMA permanent rutting. The transverse cracking passed for some weather stations and failed for others. It was significantly high for Big Piney, Greybull, and Worland. It was also observed to be too low for the Evanston and Rock Springs weather stations. The permanent rutting in the HMA layer failed for all the weather stations except for Laramie. For the terminal IRI, the differences are not too significant. For the longitudinal cracking, Greybull and Worland weather stations showed significantly high values.

Table 5.13 Summary of Performance Distresses Using PG52-28

Weather Station Name	Distress Predicted					
	Terminal IRI (in/mi)	AC Surface Down Cracking (Long. Cracking) (ft/mile):	AC Bottom Up Cracking (Alligator Cracking) (%):	AC Thermal Fracture (Transverse Cracking) (ft/mi):	Permanent Deformation (AC Only) (in):	Permanent Deformation (Total Pavement) (in):
Big Piney	124.8	4.1	0.1	1288.4	0.19	0.34
Buffalo	120.3	10.3	0.2	697.2	0.24	0.38
Casper	121.5	10	0.2	861	0.24	0.39
Cheyenne	114.3	2.3	0.1	154.8	0.19	0.34
Douglas	121.8	14.3	0.2	747.5	0.26	0.41
Evanston	112.5	3.5	0.1	3.1	0.18	0.32
Gillette	122.0	12	0.2	776.9	0.25	0.4
Greybull	126.0	81.5	0.2	1051	0.34	0.48
Lander	121.3	19.5	0.2	530.5	0.28	0.43
Laramie	117.7	3.1	0.1	780.5	0.17	0.31
Rawlins	117.5	7.3	0.1	588.1	0.2	0.34
Riverton	121.2	17.9	0.2	716.9	0.26	0.41
Rock Springs	113.6	11.1	0.1	57.7	0.22	0.36
Sheridan	123.4	15.4	0.2	740.1	0.28	0.43
Worland	129.9	72.2	0.2	1294.8	0.35	0.5
MAX	***129.9***	***81.5***	***0.2***	***1294.8***	***0.35***	***0.5***
MIN	***112.5***	***2.3***	***0.1***	***3.1***	***0.17***	***0.31***
Range	***17.4***	***79.2***	***0.1***	***1291.7***	***0.18***	***0.19***

For the binder grade PG76-28, all the distresses passed for each climatic zone except for the transverse cracking as noted in Table 5-6. The transverse cracking passed for only Evanston and Rock Springs and failed for all the other weather stations. In general, the number of stations failing the transverse cracking was higher in the PG76-28 than the PG 52-28. This may be attributed to polymers found in higher grade asphalts, which tended to stiffen higher grade asphalts, thereby making the mix susceptible to transverse cracking. The higher grade asphalts are also able to significantly resist HMA permanent rutting. The permanent rutting in the HMA layer failed for all the weather stations except for Laramie for the PG52-28, but passed for all stations for the PG76-28. It is noted that in as much as the climate affects the pavement performance, so also does the quality of the binder used. The alligator cracking shown for PG76-28, however, tends to be unaffected by the changes in the climatic conditions.

Table 5.14 Summary of Performance Distresses Using PG76-28

Weather Station Name	Distress Predicted					
	Terminal IRI (in/mi)	AC Surface Down Cracking (Long. Cracking) (ft/mile)	AC Bottom Up Cracking (Alligator Cracking) (%)	AC Thermal Fracture (Transverse Cracking) (ft/mi)	Permanent Deformation (AC Only) (in)	Permanent Deformation (Total Pavement) (in)
Big Piney	123.3	0.1	0.1	1595.1	0.1	0.24
Buffalo	118.3	0.3	0.1	1114	0.12	0.25
Casper	119.6	0.3	0.1	1289.9	0.12	0.25
Cheyenne	115.1	0.1	0.1	774.3	0.1	0.24
Douglas	118.9	0.4	0.1	1106.8	0.13	0.26
Evanston	109.1	0.1	0.1	45.3	0.1	0.23
Gillette	119.4	0.3	0.1	1164.1	0.12	0.26
Greybull	122.4	2.6	0.1	1567.9	0.16	0.29
Lander	119.4	0.5	0.1	1085.9	0.14	0.28
Laramie	117.3	0.1	0.1	1172.8	0.09	0.22
Rawlins	116.8	0.2	0.1	1049.7	0.1	0.23
Riverton	119.5	0.6	0.1	1231.2	0.13	0.27
Rock Springs	112.9	0.4	0.1	556.9	0.11	0.24
Sheridan	120.9	0.3	0.1	1220.7	0.13	0.28
Worland	124.7	1.8	0.1	1642.3	0.16	0.3
MAX	***124.7***	***2.6***	***0.1***	***1642.3***	***0.16***	***0.3***
MIN	***109.1***	***0.1***	***0.1***	***45.3***	***0.09***	***0.22***
Range	***15.6***	***2.5***	***0***	***1597***	***0.07***	***0.08***

The terminal IRI plot in Figure 5.5 is as expected with the lower grade binder showing more of the distress type than the higher grade. For both grades, Greybull and Worland exhibit the highest of the distress. The trend is also as expected for the longitudinal cracking shown in Figure 5.6 with Greybull and Worland again showing significantly high plots for the lower grade binder. Comparing the two binder grades, the difference in the longitudinal cracking between the two is highly observed. This is because the PG76-28 is a superior binder compared with the PG52-28.

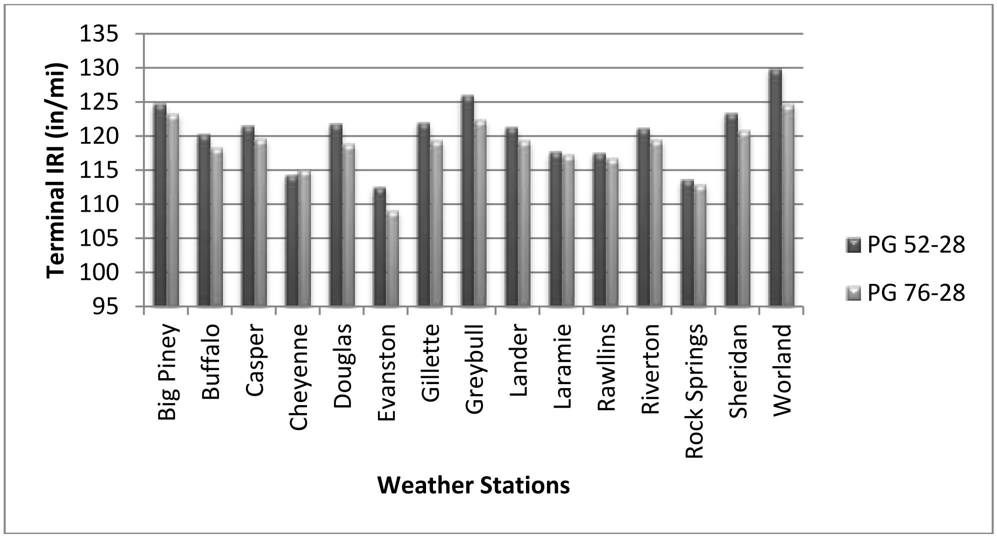

Figure 5.11 International roughness index values for various weather stations.

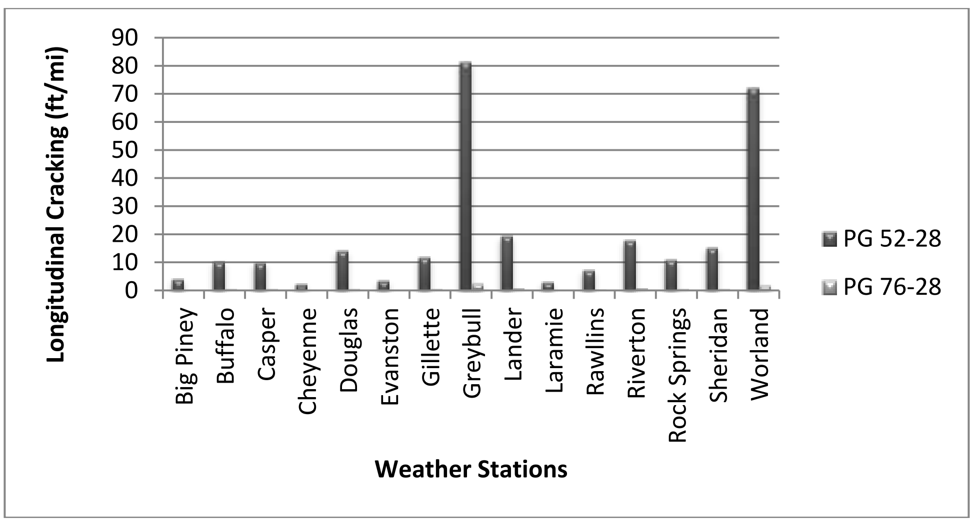

Figure 5.12 Longitudinal cracking values for various weather stations.

As noted previously, the PG76-28, being a superior grade, tends to contain polymers and so makes the asphalt mix stiffer. Figure 5.7 shows a plot of the transverse cracking. Due to the stiffness experienced in the higher grade, it is noted that this type of cracking is higher in the higher grade asphalt. This is the only pavement distress type where this trend tends to occur. As already noted, Evanston exhibits a significantly low transverse cracking for both asphalt grade types.

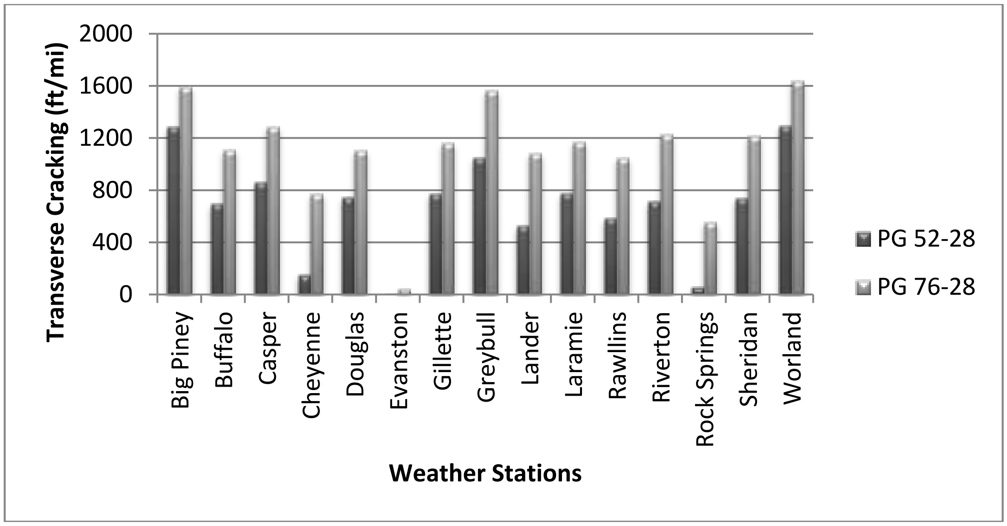

Figure 5.13 Transverse cracking values for various weather stations.

Figure 5.8 is a plot of the alligator cracking. The distress is unaffected by the higher grade asphalt irrespective of the climate but tends to show some changes for the lower grade. These changes are however insignificant as the values obtained for the PG52-28 range between 0.1 and 0.2% for all the available weather stations. Stations with relatively higher elevations indicated 0.1% and lower elevations exhibited 0.2%.

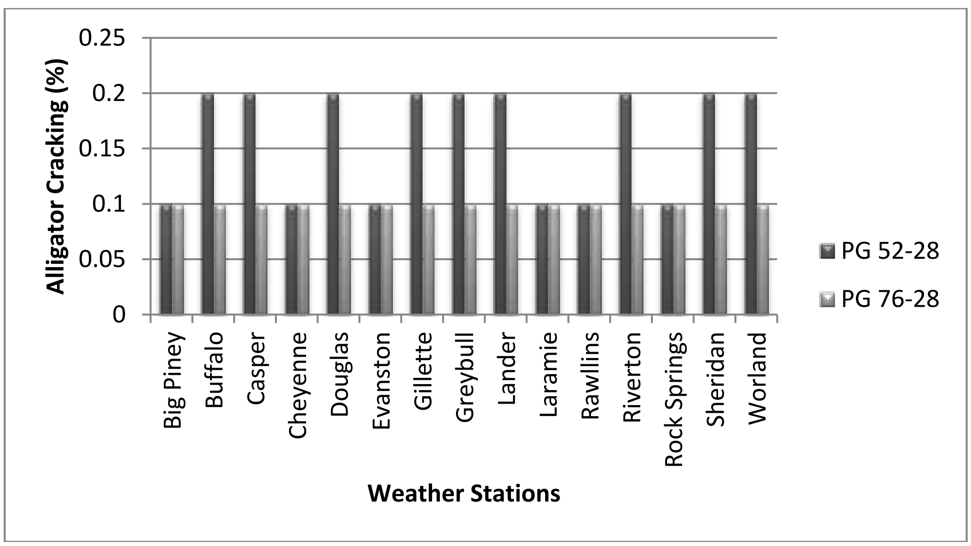

Figure 5.14 Alligator cracking values for various weather stations.

The trends shown for the HMA and total pavement rutting shown in Figures 5.9 and 5.10, respectively, are as expected with the higher grade asphalt exhibiting less of the distress type than the lower grade one. Greybull and Worland, however, show relatively higher distress values compared with the other stations. The differences in the two grades for both distresses are markedly observed. This may be because the stiffness in the higher grade is helping to prevent excessive rutting in the pavement layers.

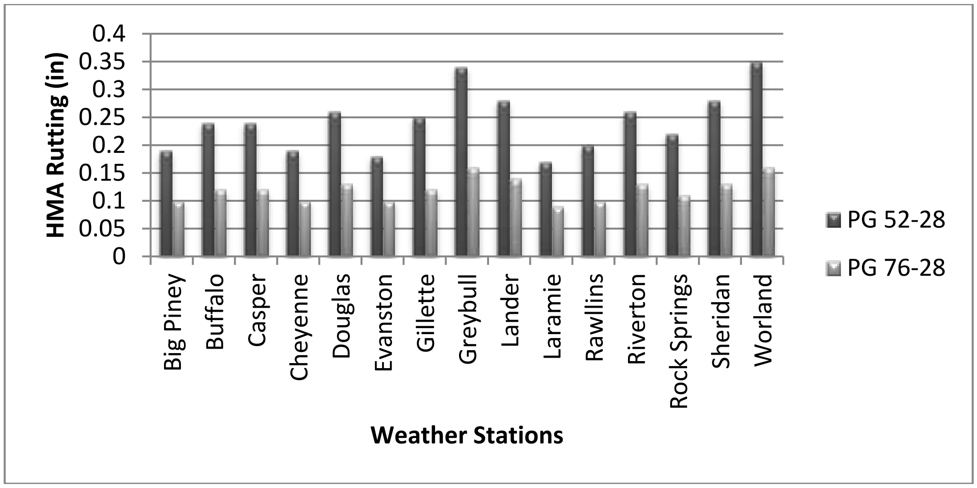

Figure 5.15 HMA rutting values for various weather stations.

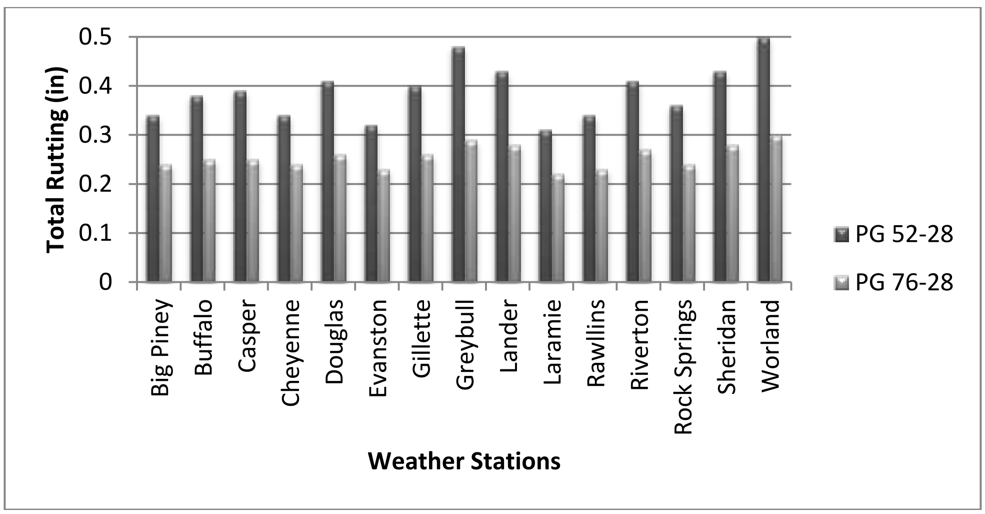

Figure 5.16 Total pavement feformation at various weather stations.

5.3.1.3 Virtual Climate Analysis

In areas where there is a deficiency in weather stations, the MEPDG allows for the creation of a virtual weather station to compensate for such. This is done by interpolation in the software from a group of known stations that are presented to the engineer, which are deemed to be in close proximity to the area in question. To create the virtual stations for the above known stations, the actual latitudes, longitude, and elevations were entered in the MEPDG Version 1.1. The software then presented a set of six known stations close to the known coordinates. All stations were selected except the one that showed the actual station data and coordinates for the interpolation as recommended by the MEPDG. This was classified as the first set of interpolation using all possible MEPDG stations. A second set of interpolation was carried out where only stations with similar elevations of +/- 500 ft were selected from the lot and used for the interpolation. The results of both interpolations were analyzed. Table 5.7 is the pavement performance values generated when using virtual stations. Comparing this table with that of the actual stations shown in Table 5.5, it was noted that all the distresses passed except for transverse cracking and the HMA layer rutting. The number of stations passing in both is similar except for some that passed for the actual failed, for the virtual, and vice versa. For the HMA rutting, only the Laramie station passed for both the actual and virtual. Detailed tables of the differences are included in Appendix D1.

Table 5.15 Pavement Performance –Virtual Station Using All Generated Stations (PG52-28)

Weather Station Name	Pavement Distress Predicted					
	Terminal IRI (in/mi)	AC Surface Down Cracking (Long. Cracking) (ft/mile)	AC Bottom Up Cracking (Alligator Cracking) (%)	AC Thermal Fracture (Transverse Cracking) (ft/mi)	Permanent Deformation (AC Only) (in)	Permanent Deformation (Total Pavement) (in)
Big Piney	121.1	4.6	0.1	826.7	0.21	0.36
Buffalo	127.1	5.7	0.1	1496.6	0.22	0.37
Casper	120.6	9.8	0.2	711.3	0.24	0.39
Cheyenne	122.1	1.8	0.1	1117.7	0.18	0.33
Douglas	119.4	7	0.2	649.9	0.23	0.37
Evanston	117.2	2.5	0.1	339.8	0.19	0.34
Gillette	119.1	7.6	0.2	516.8	0.24	0.39
Greybull	124.3	10.8	0.2	1032.1	0.26	0.41
Lander	120.6	15.6	0.2	672.4	0.25	0.4
Laramie	119.3	1	0.1	864	0.16	0.31
Rawlins	120.2	3.5	0.1	826	0.2	0.34
Riverton	121.2	16.3	0.2	584.8	0.27	0.42
Rock Springs	119.5	6.3	0.1	751.6	0.21	0.35
Sheridan	126.2	12.3	0.2	1405.7	0.25	0.4
Worland	119.6	20.5	0.2	401.6	0.28	0.43
MAX	***127.1***	***20.5***	***0.2***	***1496.6***	***0.28***	***0.43***
MIN	***117.2***	***1***	***0.1***	***339.8***	***0.16***	***0.31***
Range	***9.9***	***19.5***	***0.1***	***1156.8***	***0.12***	***0.12***

Table 5.8 shows the annual climate statistics for the virtual weather stations using interpolation of all the neighboring actual weather stations. No large significant difference was observed between this and the actual shown in Table 5.1 except for the freezing index where some considerable differences were noted. Detailed differences are highlighted in Appendix D2.

Table 5.16 Climate Statistics Using All Neighboring Stations

Weather Station Name	Annual Climate Statistics			
	Mean annual air temperature (ºF):	Mean annual rainfall (in):	Freezing index (ºF-days):	Average Annual Number of Freeze/Thaw Cycles:
Big Piney	40.9	11.68	1655.95	134
Buffalo	43.06	12.8	1459.03	154
Casper	45.47	10.7	1124.28	131
Cheyenne	43.7	13.32	1233.91	144
Douglas	47.04	11.33	887.24	121
Evanston	40.54	14.13	1676.79	116
Gillette	47.05	12.75	875.94	119
Greybull	47.26	12.46	1006.47	116
Lander	45.02	8.82	1312.4	131
Laramie	41.44	12.94	1398.28	146
Rawlins	41.73	10.94	1486.62	136
Riverton	45.13	11.28	1268.94	138
Rock Springs	41.31	9.25	1609.43	130
Sheridan	48.15	10.9	872.54	111
Worland	47.39	9.87	1080.04	114
MAX	***48.15***	***14.13***	***1676.79***	***154***
MIN	***40.9***	***8.82***	***872.54***	***111***
Range	***7.25***	***5.31***	***804.25***	***43***

Table 5.9 shows the pavement distresses generated using virtual stations generated by interpolation using neighboring stations that are similar in heights, considering a +/- 500 ft difference. This was also based on the input screen shown in Appendix A1 but selecting only the stations falling within the above elevation range. It can also be noted from the table that all the distresses passed except for transverse cracking and the HMA layer rutting. All the stations failed for the HMA rutting while there was equal proportion of pass and fail on the transverse cracking.

Table 5.17 Pavement Distresses Using Similar Elevations (PG52-28)

Weather Station Name	Distress Predicted					
	Terminal IRI (in/mi)	AC Surface Down Cracking (Long. Cracking) (ft/mile)	AC Bottom Up Cracking (Alligator Cracking) (%)	AC Thermal Fracture (Transverse Cracking) (ft/mi)	Permanent Deformation (AC Only) (in)	Permanent Deformation (Total Pavement) (in)
Big Piney	112	5.5	0.1	4.6	0.19	0.33
Buffalo	120.6	7.3	0.2	809.5	0.22	0.37
Casper	120.8	9.4	0.2	735.6	0.24	0.39
Cheyenne	115.5	1.9	0.1	382.1	0.18	0.32
Douglas	120.3	10.3	0.2	724.1	0.24	0.39
Evanston	122.2	9	0.1	1072.4	0.21	0.35
Gillette	119.4	9.6	0.2	530.2	0.24	0.39
Greybull	125.8	24.3	0.2	1024.3	0.29	0.45
Lander	121.2	18.2	0.2	702.7	0.26	0.41
Laramie	118.3	5.8	0.1	775.7	0.19	0.33
Rawlins	112.5	5.3	0.1	99.4	0.19	0.32
Riverton	121.3	19.3	0.2	537.5	0.28	0.43
Rock Springs	120.1	4.9	0.1	986.4	0.18	0.32
Sheridan	126.4	15.6	0.2	1411.4	0.25	0.4
Worland	125.2	32.5	0.2	1059.7	0.29	0.44
MAX	***126.4***	***32.5***	***0.2***	***1411.4***	***0.29***	***0.45***
MIN	***112***	***4.9***	***0.1***	***4.6***	***0.18***	***0.32***
Range	***14.4***	***27.6***	***0.1***	***1406.8***	***0.11***	***0.13***

The climate statistics shown in Table 5.10 have been generated for virtual weather stations interpolated using similar elevations. A detailed table of differences has been included in Appendix D2. Similar tables have been produced for the primary and secondary systems highlighting the significant differences between the data obtained using interpolation based on all the neighboring stations and that using similar elevations. These are included in Appendix D3 and D4, respectively. A statistical analysis of the data obtained for the different classes of road has been carried out and are presented in the subsequent sections. The variability in all the climate variables is minimal except for the freezing index.

Table 5.18 Climate Statistics Using Similar Elevations

Weather Station Name	Annual Climate Statistics			
	Mean annual air temperature (ºF):	Mean annual rainfall (in):	Freezing index (ºF-days):	Average Annual Number of Freeze/Thaw Cycles:
Big Piney	43.29	8.03	1238.36	117
Buffalo	45.98	10.98	1028.5	138
Casper	45.36	10.73	1146.45	138
Cheyenne	46.81	12.74	877.67	157
Douglas	47.26	10.56	885.43	128
Evanston	38.84	7.84	2098.26	144
Gillette	47.01	12.2	897.47	123
Greybull	46.13	11.78	1175.34	150
Lander	45.2	8.4	1315.33	121
Laramie	42.2	7.98	1390.44	152
Rawlins	43.92	7.91	1128.66	138
Riverton	45.8	11.36	1187.27	124
Rock Springs	40.77	8.04	1660.99	137
Sheridan	46.61	9.43	1180.55	116
Worland	45.27	8.15	1432.15	133
MAX	***47.26***	***10.56***	***2098.26***	***157***
MIN	***38.84***	***7.84***	***897.47***	***116***
Range	***8.42***	***2.72***	***1200.79***	***41***

5.4 Statistical Analysis

The statistical analysis performed on the output data sort to investigate two things:

1. To determine if there is a difference between the interpolated values and the actual values of the pavement distresses and annual climate statistics using bootstrapping.
2. Where there are observed differences between interpolated and actual values for the distresses, use p-values calculations to determine how they correlated with the annual climate factors as regressor variables. These regressor variables are further defined in the subsequent section.

For the bootstrap confidence intervals, when it was observed that zero was within the interval, it was concluded that there was no significant difference between interpolated and actual values, and for the p-values calculations, values less than 0.05 are deemed to be significant or important in predicting the pavement distress type. Since one of the objectives of this study was to investigate how climate impacted pavement performance, it was imperative that the annual climate variables be used as the regressor variables in the regression model for the p-values calculations. This analysis has been applied to all the different classes of road analyzed in this study. The following section explains the regression model and terms used in the p-values determination.

5.4.1 Regression Models for P-values Calculations

In all cases, the data set considered the actual, interpolated using all generated neighboring stations, and interpolated using stations that are similar in elevations. Two scenarios were analyzed using the bootstrap and p-values calculations. Scenario 1 was between the actual and interpolated using all neighboring stations and Scenario 2 was between actual values and interpolated values using similar heights. This was applied to the actual differences between interpolated and actual distress values and also on the percentage change between interpolated and actual.

The general model developed to explain observed differences from the bootstrapping:

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \beta_3 X_{i3} + \beta_4 X_{i4} + \varepsilon_i$$
$$E\{Y\} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4$$

Where:

Y = response variable (pavement performance distresses as defined in section below).
X_1, X_2, X_3, X_4 = predictor variables (annual climate variables as defined in section below).

5.4.1.1 Explanation of Regression terms

In this analysis, the response variables (Y) are the pavement distresses: International Roughness Index (IRI), Transverse Cracking (TC), Alligator Cracking (AC), Longitudinal Cracking (LC), AC Rutting (ACR), and Total Rutting (TR), the predictor variables (X) are Annual Rainfall (AR), Annual Temperature (AT), Freezing Index (FI), and Freeze/Thaw Cycle (FT). Based on the general regression model, a total of 12 regression models were developed:

<u>International Roughness Index (IRI)</u>

$$\Delta IRI_{1\text{-}2} = \beta_0 + \beta_1 \Delta AR_{1\text{-}2} + \beta_2 \Delta AT_{1\text{-}2} + \beta_3 \Delta FI_{1\text{-}2} + \beta_4 \Delta FT_{1\text{-}2}$$

$$\Delta IRI_{1\text{-}3} = \beta_0 + \beta_1 \Delta AR_{1\text{-}3} + \beta_2 \Delta AT_{1\text{-}3} + \beta_3 \Delta FI_{1\text{-}3} + \beta_4 \Delta FT_{1\text{-}3}$$

Where:

$\Delta IRI_{1\text{-}2}$ = Difference/Percent Change between virtual IRI-2 and actual IRI-1

$\Delta IRI_{1\text{-}3}$ = Difference/Percent Change between virtual IRI-3 and actual IRI-1

$\Delta AR_{1\text{-}2}$ = Difference/Percent Change between virtual AR-2 and actual AR-1

$\Delta AR_{1\text{-}3}$ = Difference/Percent Change between virtual AR-3 and actual AR-1

$\Delta AT_{1\text{-}2}$ = Difference/Percent Change between virtual AT-2 and actual AT-1

$\Delta AT_{1\text{-}3}$ = Difference/Percent Change between virtual AT-3 and actual AT-1

$\Delta FI_{1\text{-}2}$ = Difference/Percent Change between virtual FI-2 and actual FI-1

$\Delta FI_{1\text{-}3}$ = Difference/Percent Change between virtual FI-3 and actual FI-1

$\Delta FT_{1\text{-}2}$ = Difference/Percent Change between virtual FT-2 and actual FT-1

$\Delta FT_{1\text{-}3}$ = Difference/Percent Change between virtual FT-3 and actual FT-1

The designations 1, 2, and 3 represent actual, interpolated based on all stations and interpolated based on stations with similar elevations, respectively. (See tables in Appendix D).

Transverse Cracking (TC)

$$\Delta TC_{1\text{-}2} = \beta_0 + \beta_1 \Delta AR_{1\text{-}2} + \beta_2 \Delta AT_{1\text{-}2} + \beta_3 \Delta FI_{1\text{-}2} + \beta_4 \Delta FT_{1\text{-}2}$$

$$\Delta TC_{1\text{-}3} = \beta_0 + \beta_1 \Delta AR_{1\text{-}3} + \beta_2 \Delta AT_{1\text{-}3} + \beta_3 \Delta FI_{1\text{-}3} + \beta_4 \Delta FT_{1\text{-}3}$$

Where:

$\Delta TC_{1\text{-}2}$ = Difference/Percent Change virtual TC-2 and actual TC-1

$\Delta TC_{1\text{-}3}$ = Difference/Percent Change between virtual TC-3 and actual TC-1

All other terms as defined for the IRI.

Alligator Cracking (AC)

$$\Delta AC_{1\text{-}2} = \beta_0 + \beta_1 \Delta AR_{1\text{-}2} + \beta_2 \Delta AT_{1\text{-}2} + \beta_3 \Delta FI_{1\text{-}2} + \beta_4 \Delta FT_{1\text{-}2}$$

$$\Delta AC_{1\text{-}3} = \beta_0 + \beta_1 \Delta AR_{1\text{-}3} + \beta_2 \Delta AT_{1\text{-}3} + \beta_3 \Delta FI_{1\text{-}3} + \beta_4 \Delta FT_{1\text{-}3}$$

Where:

$\Delta AC_{1\text{-}2}$ = Difference/Percent Change between virtual AC-2 and actual AC-1

$\Delta AC_{1\text{-}3}$ = Difference/Percent Change between virtual AC-3 and actual AC-1

All other terms as defined for the IRI.

Longitudinal Cracking (LC)

$$\Delta LC_{1\text{-}2} = \beta_0 + \beta_1 \Delta AR_{1\text{-}2} + \beta_2 \Delta AT_{1\text{-}2} + \beta_3 \Delta FI_{1\text{-}2} + \beta_4 \Delta FT_{1\text{-}2}$$

$$\Delta LC_{1\text{-}3} = \beta_0 + \beta_1 \Delta AR_{1\text{-}3} + \beta_2 \Delta AT_{1\text{-}3} + \beta_3 \Delta FI_{1\text{-}3} + \beta_4 \Delta FT_{1\text{-}3}$$

Where:

$\Delta LC_{1\text{-}2}$ = Difference/Percent Change between virtual LC-2 and actual LC-1

$\Delta LC_{1\text{-}3}$ = Difference/Percent Change between virtual LC-3 and actual LC-1

All other terms as defined for the IRI.

AC Rutting (ACR)

$$\Delta ACR_{1\text{-}2} = \beta_0 + \beta_1 \Delta AR_{1\text{-}2} + \beta_2 \Delta AT_{1\text{-}2} + \beta_3 \Delta FI_{1\text{-}2} + \beta_4 \Delta FT_{1\text{-}2}$$

$$\Delta ACR_{1\text{-}3} = \beta_0 + \beta_1 \Delta AR_{1\text{-}3} + \beta_2 \Delta AT_{1\text{-}3} + \beta_3 \Delta FI_{1\text{-}3} + \beta_4 \Delta FT_{1\text{-}3}$$

Where:

$\Delta ACR_{1\text{-}2}$ = Difference/Percent Change between virtual ACR-2 and actual ACR-1

$\Delta ACR_{1\text{-}3}$ = Difference/Percent Change between virtual ACR-3 and actual ACR-1

All other terms as defined for the IRI.

Total Rutting (TR)

$$\Delta TR_{1-2} = \beta_0 + \beta_1 \Delta AR_{1-2} + \beta_2 \Delta AT_{1-2} + \beta_3 \Delta FI_{1-2} + \beta_4 \Delta FT_{1-2}$$

$$\Delta TR_{1-3} = \beta_0 + \beta_1 \Delta AR_{1-3} + \beta_2 \Delta AT_{1-3} + \beta_3 \Delta FI_{1-3} + \beta_4 \Delta FT_{1-3}$$

Where:

ΔTR_{1-2} = Difference/Percent Change between virtual TR-2 and actual TR-1

ΔTR_{1-3} = Difference/Percent Change between TR-3 and actual TR-1

All other terms as defined for the IRI.

5.4.1.2 Coefficient of Multiple Determination (R^2 and Adjusted R^2)

In analyzing the p-values calculations to determine the level of significance that the climate regressors have on the response distress variables, the coefficient of multiple determination (R^2) and the adjusted coefficient of multiple determination (Adjusted R^2) will also be analyzed for models that show significance in overall p-values but not for individual regressor p-values. The R^2 value for a regression analysis measures the proportionate reduction of the total variation in the response variable Y associated with the use of a set of predictor variables X. The value of the R^2 is between 0 and 1. The more the value approaches 1, the better the response Y observations tend to fall directly on the fitted regression model. However, a large value of R^2 does not necessarily imply that the fitted regression model is a useful one since large X variables will increase the R^2 value, hence the use of the adjusted R^2 value, which tends to adjust for the number of predictor X variables (Kutner, Nachtsheim & Neter 2004). The adjusted R^2 is always smaller than the R^2 as it tends to penalize for an excess number of predictor variables that do not contribute to the explanatory power of the regression model. For poorly fitting models, the adjusted R2 value could even become negative.

5.4.1.3 Coefficient of Correlation

The coefficient of correlation is a measure of the association between the response variable Y and the predictor variables X. It is given by the equation $r = +/- (R^2)^{1/2}$. The value of r is between -1 and 1 (Kutner, Nachtsheim & Neter 2004).

5.4.2 Interstate System

One data set considered the difference between the actual and the two methods of interpolation while the other used the percentage change between the actual and the interpolated values.

5.4.2.1 Confidence Intervals and P-values Calculations on Differences

Table 5.11 shows the bootstrap confidence intervals and the mean on the actual differences between virtual distresses and actual distresses. All the terms are as defined previously. Distresses that show no significant difference between the virtual and the actual are shown in bold and so are statistically equal. The IRI, AC, and TC all show no significant difference between the actual and virtual values. All the other distress types, however, show significant differences.

Table 5.19 Confidence Intervals for Performance Parameters using Differences

Performance Distress	Mean	95% Confidence Intervals	
		Lower Bound	Upper Bound
ΔIRI_{1-2}	**-0.6517**	**-2.9135**	**1.7868**
ΔIRI_{1-3}	**0.3984**	**-2.0667**	**2.9602**
ΔLC_{1-2}	10.7875	2.3532	22.2867
ΔLC_{1-3}	6.9787	0.0467	16.6338
ΔAC_{1-2}	**0.0067**	**0**	**0.02**
ΔAC_{1-3}	**0**	**0**	**0**
ΔTC_{1-2}	**-125.227**	**-362.04**	**116.2707**
ΔTC_{1-3}	**-38.8147**	**-318.838**	**249.5932**
ΔACR_{1-2}	0.0174	0.0047	0.032
ΔACR_{1-3}	0.0133	0.0007	0.0253
ΔTR_{1-2}	0.0154	0.0027	0.03
ΔTR_{1-3}	0.0133	0.002	0.0253

For the annual climate statistics shown in Table 5.12, it is noted that statistically, there is no significant difference between actual and virtual stations for all the annual climate parameters irrespective of the method of interpolation used. It was however observed that the range of confidence interval for the Freezing Index (FI) based on both methods of interpolation is significantly high as was also observed for the Transverse Cracking (TC) in Table 5.11 previously.

Table 5.20 Confidence Intervals for Climate Statistics using Differences

Climate Variable	Mean	95% Confidence Intervals	
		Lower Bound	Upper Bound
ΔAR_{1-2}	**-1.0537**	**-2.4248**	**0.1747**
ΔAR_{1-3}	**0.7607**	**-0.6861**	**1.9921**
ΔAT_{1-2}	**0.432**	**-0.6074**	**1.4147**
ΔAT_{1-3}	**0.069**	**-1.0428**	**0.9927**
ΔFI_{1-2}	**-11.3319**	**-191.232**	**176.0283**
ΔFI_{1-3}	**12.2038**	**-178.339**	**235.6568**
ΔFT_{1-2}	**-4.6217**	**-13.1333**	**4.0667**
ΔFT_{1-3}	**-9.6439**	**-20.3333**	**0.8000**

Table 5.13 shows the p-values calculation using the differences between interpolated and actual and based on the regression models from the previous section. Individual and overall p-values less than 0.05 are shown in bold and indicate importance or significance in predicting the pavement distress. All the terms in the table are as previously defined. As noted, only the Annual Temperature (ΔAT_{1-2}) is significant for predicting the Total Rutting (ΔTR_{1-2}). All the others do not show any significance in

predicting any of the distresses but the overall p-value for ΔIRI_{1-2} regression is marginally significant but it is very significant for the models of ΔIRI_{1-3} and ΔTC_{1-3}. These also show significant R^2 and adjusted R^2. The coefficient of correlation calculation for these two models is also significantly high implying some degree of correlation among the predictor climate variables. Further statistical analysis using the correlation matrix method confirms that there is a high degree of multi-collinearity among the regressor climate variables: freezing index, annual temperature and freeze/thaw cycle. The Annual Temperature ((ΔAT_{1-3}) and Freezing Index (ΔFI_{1-3}) are significant in predicting the AC Rutting (ΔACR_{1-3}). Results for interpolation using similar elevation show high significance in p-values than for that using all the available stations for interpolation.

Table 5.21 P-Values Calculations Using Differences

Performance Parameter	P-Values				Overall P-values	R^2	Adjusted R^2
	ΔAR_{1-2}	ΔAT_{1-2}	ΔFI_{1-2}	ΔFT_{1-2}			
ΔIRI_{1-2}	0.756	0.865	0.489	0.948	**0.0445**	0.5925	0.4295
ΔTC_{1-2}	0.796	0.437	0.867	0.476	0.0871	0.5257	0.336
ΔAC_{1-2}	0.632	0.682	0.787	0.772	0.6217	0.2137	-0.1008
ΔLC_{1-2}	0.2405	0.1364	0.0842	0.3323	0.0567	0.5699	0.3978
ΔACR_{1-2}	0.7829	0.0729	0.1239	0.0756	0.1955	0.4257	0.196
ΔTR_{1-2}	0.8076	**0.044**	0.0729	0.0579	0.1344	0.4752	0.2652
Performance Parameter	P-Values				Overall P-values	R^2	Adjusted R^2
	ΔAR_{1-3}	ΔAT_{1-3}	ΔFI_{1-3}	ΔFT_{1-3}			
ΔIRI_{1-3}	0.348	0.827	0.119	0.778	**0.0017**	0.7975	0.7165
ΔTC_{1-3}	0.945	0.564	0.446	0.624	**0.0043**	0.7535	0.6549
ΔAC_{1-3}	na	na	na	na	na	na	na
ΔLC_{1-3}	0.7234	0.079	0.0595	0.988	0.0584	0.5669	0.3937
ΔACR_{1-3}	0.3198	**0.0169**	**0.0225**	0.3698	0.1262	0.4829	0.2761
ΔTR_{1-3}	0.0664	0.1884	0.2598	0.3561	0.3304	0.344	0.0816

Table 5.14 was derived after further statistical analysis to eliminate the multi-collinearity in the predictor climate variables. And by using model selection method, further regression analysis was done to determine the significance in the p-values after the elimination of the multi-collinearity. Except the alligator cracking which is a load related distress, one or more of the climate variables showed high significance in predicting the pavement performance parameters. The major ones were the AT and the FI as noted in Table 5.14 for the interstate system.

Table 5.22 Significant Climate Variables for Interstate System

Performance Parameter	P-Values	Overall P-values	R^2	Adjusted R^2			
	ΔAR_{1-2}	ΔAT_{1-2}	ΔFI_{1-2}	ΔFT_{1-2}			
ΔIRI_{1-2}	-	-	0.00096	-	0.00096	0.5806	0.5484
ΔTC_{1-2}	-	0.00489	-	-	0.00489	0.4684	0.4275
ΔAC_{1-2}	*0.632*	*0.682*	*0.787*	*0.772*	*0.6217*	*0.2137*	*-0.1008*
ΔLC_{1-2}	-	0.0374	0.0127	-	0.0200	0.479	0.3921
ΔACR_{1-2}	-	0.0380	0.0464	0.0639	0.09946	0.4211	0.2632
ΔTR_{1-2}	-	0.0306	0.0420	0.0373	0.0625	0.4719	0.3279
Performance Parameter	P-Values	Overall P-values	R^2	Adjusted R^2			
	ΔAR_{1-3}	ΔAT_{1-3}	ΔFI_{1-3}	ΔFT_{1-3}			
ΔIRI_{1-3}	-	-	0.000018	-	0.000018	0.7683	0.7505
ΔTC_{1-3}	-	-	0.000039	-	0.000039	0.74	0.72
ΔAC_{1-3}	*na*	*na*	*na*	*na*	*na*	*na*	*na*
ΔLC_{1-3}	-	0.00283	0.00209	-	0.007239	0.5602	0.4869
ΔACR_{1-3}	0.1392	0.0183	0.0166	-	0.0862	0.4373	0.2839
ΔTR_{1-3}	0.0665	0.0236	0.0193	-	0.1128	0.4063	0.2444

5.4.2.2 Confidence Intervals and P-values Calculations Using Percentage Change

The same analysis was carried out based on the percentage change between the pavement performance parameters generated by actual weather stations and that by virtual stations to determine the mean and confidence intervals shown in Table 5.15. The values shown in bold indicate that there is no significant difference in mean between interpolated and actual values. This indication is, however, more prominent for values obtained by similar elevations. For the annual climate statistics shown in Table 5.16, all the climate parameters show no significant difference except for annual rainfall and freeze/thaw cycle.

Table 5.23 Confidence Intervals on Percentage Change

Performance Parameter	Mean	95% Confidence Intervals	
		Lower Bound	Upper Bound
ΔIRI_{1-2}	**0.0066**	**-0.0125**	**0.0254**
ΔIRI_{1-3}	**-0.0025**	**-0.0238**	**0.0186**
ΔLC_{1-2}	-0.363	-0.497	-0.2258
ΔLC_{1-3}	**-0.0198**	**-0.2734**	**0.2943**
ΔAC_{1-2}	**-0.0334**	**-0.1**	**0**
ΔAC_{1-3}	**0**	**0**	**0**
ΔTC_{1-2}	8.5862	0.1123	23.3871
ΔTC_{1-3}	**23.9423**	**-0.1283**	**71.108**
ΔACR_{1-2}	-0.0561	-0.10334	-0.0141
ΔACR_{1-3}	**-0.0415**	**-0.0888**	**0.0094**
ΔTR_{1-2}	-0.0324	-0.0639	-0.0027
ΔTR_{1-3}	**-0.0301**	**-0.0585**	**0.0002**

Table 5.24 Confidence Interval Using Percentage Change

Climate Statistics	Mean	95% Confidence Intervals	
		Lower Bound	Upper Bound
ΔAR_{1-2}	0.166	0.0049	0.3704
ΔAR_{1-3}	**-0.0143**	**-0.1662**	**0.1973**
ΔAT_{1-2}	**-0.0083**	**-0.0304**	**0.0163**
ΔAT_{1-3}	**-0.0005**	**-0.0238**	**0.0273**
ΔFI_{1-2}	**0.0637**	**-0.0847**	**0.2222**
ΔFI_{1-3}	**0.0315**	**-0.0905**	**0.1561**
ΔFT_{1-2}	**0.0473**	**-0.0218**	**0.1147**
ΔFT_{1-3}	0.0926	0.0035	0.1833

Table 5.17 is the p-values table based on using the percentage change of the mean between interpolated and actual values. The regression model for the ΔIRI_{1-2} shows a significant overall p-value with no individual p-value being significant. The model also indicates a large R^2 as well as a significant coefficient of correlation value. The ΔLC_{1-2} model, as noted, is highly influenced by the ΔAR_{1-2}, ΔAT_{1-2}, and ΔFT_{1-2}. This is also reflected in the overall p-values and R^2 value. The ΔIRI_{1-3} model indicates that the ΔAR_{1-3} and ΔFI_{1-3} are significant in predicting the IRI. The R^2 value for this model is larger than that for the ΔIRI_{1-2}, hence the model using the interpolation based on similar heights is highly correlated than the model based on the all, interpolation method.

Table 5.25 P-Values Calculations Using Percentage Change

Performance Parameter	P-Values				Overall P-values	R^2	Adjusted R^2
	ΔAR_{1-2}	ΔAT_{1-2}	ΔFI_{1-2}	ΔFT_{1-2}			
ΔIRI_{1-2}	0.1918	0.688	0.0535	0.3857	**0.0097**	0.7077	0.5907
ΔTC_{1-2}	0.893	0.934	0.951	0.59	0.8555	0.1148	-0.2393
ΔAC_{1-2}	0.2751	0.2682	0.0667	0.3833	0.1937	0.427	0.1978
ΔLC_{1-2}	**0.0099**	**0.0287**	0.843	**0.0112**	**0.0056**	0.7397	0.6356
ΔACR_{1-2}	0.229	0.1201	0.9509	0.0577	0.1152	0.4939	0.2915
ΔTR_{1-2}	0.6012	0.1063	0.5647	0.1323	0.1569	0.4555	0.2376
Performance Parameter	P-Values				Overall P-values	R^2	Adjusted R^2
	ΔAR_{1-3}	ΔAT_{1-3}	ΔFI_{1-3}	ΔFT_{1-3}			
ΔIRI_{1-3}	**0.0449**	0.7746	**0.0122**	0.2005	**0.0003**	0.8609	0.8052
ΔTC_{1-3}	0.995	0.295	0.251	0.275	0.0718	0.5461	0.3646
ΔAC_{1-3}	na	na	na	na	na	na	na
ΔLC_{1-3}	0.6785	**0.0491**	0.0659	0.8773	0.1022	0.5079	0.3110
ΔACR_{1-3}	0.6633	0.128	0.2034	0.7697	0.4246	0.2979	0.0171
ΔTR_{1-3}	0.2977	0.1213	0.1222	0.8332	0.472	0.2766	-0.0127

5.4.3 Primary System

Table 5.18 shows the confidence intervals calculated for the primary road using the differences between actual and interpolated stations. All the distresses show no significant difference using at least one of the two types of interpolation, except the rutting models that show significant difference using both methods of interpolation. For most of the models generated in Table 5.19, the significance in their overall p-values is also reflected in their respective high R^2 and adjusted R^2 values. It can also be noted that most of the results in Table 5.19 give significantly higher p-values for interpolation using similar elevations than for the one using all the neighboring stations.

Table 5.26 Confidence Intervals on Differences

Performance Parameter	**Mean**	**95% Confidence Intervals**	
		Lower Bound	**Upper Bound**
ΔIRI_{1-2}	**-1.6114**	**-4.1935**	**0.5467**
ΔIRI_{1-3}	**0.2738**	**-3.1335**	**3.7537**
ΔLC_{1-2}	**-1.233**	**-19.735**	**17.6017**
ΔLC_{1-3}	**12.2246**	**-7.8683**	**30.6683**
ΔAC_{1-2}	**0.4048**	**-0.0133**	**1.2267**
ΔAC_{1-3}	0.4435	0.0133	1.2468
ΔTC_{1-2}	-239.473	-508.4488	-30.7918
ΔTC_{1-3}	**-54.6112**	**-426.6638**	**332.022**
ΔACR_{1-2}	0.008	0.002	0.0147
ΔACR_{1-3}	0.006	0.0013	0.0107
ΔTR_{1-2}	0.0086	0.0013	0.016
ΔTR_{1-3}	0.0086	0.002	0.0154

Table 5.27 P-Values Calculations on Differences for Primary System

Performance Parameter	P-Values				Overall P-values	R^2	Adjusted R^2
	ΔAR_{1-2}	ΔAT_{1-2}	ΔFI_{1-2}	ΔFT_{1-2}			
ΔIRI_{1-2}	0.12	0.23	0.114	0.439	0.0721	0.5458	0.3641
ΔTC_{1-2}	0.328	0.516	0.283	0.849	0.3512	0.3333	0.0666
ΔAC_{1-2}	0.533	0.151	0.281	0.128	0.4201	0.3	0.02
ΔLC_{1-2}	**0.00006**	0.8958	0.4642	**0.0064**	**0.0003**	0.8595	0.8033
ΔACR_{1-2}	0.6204	**0.0256**	**0.0312**	0.0673	0.0794	0.5357	0.35
ΔTR_{1-2}	0.1791	**0.0015**	**0.008**	**0.0368**	**0.0031**	0.7711	0.6795
Performance Parameter	P-Values				Overall P-values	R^2	Adjusted R^2
	ΔAR_{1-3}	ΔAT_{1-3}	ΔFI_{1-3}	ΔFT_{1-3}			
ΔIRI_{1-3}	0.453	0.829	0.113	0.375	**0.00004**	0.9065	0.8691
ΔTC_{1-3}	0.815	0.368	0.428	0.59	**0.0002**	0.8762	0.8267
ΔAC_{1-3}	0.848	0.607	0.665	0.506	0.9115	0.0864	-0.2791
ΔLC_{1-3}	**0.0021**	0.6032	0.3071	0.2067	**0.0056**	0.74	0.636
ΔACR_{1-3}	0.9842	0.0518	0.0851	0.1086	0.1416	0.4687	0.2562
ΔTR_{1-3}	0.0857	**0.0097**	**0.0034**	0.4535	**0.0084**	0.7163	0.6029

Table 5.20 was derived by carrying out a model selection method to determine and drop variables as a result of high multi-collinearity. The table shows the climate variables that are of most significance or importance in predicting the pavement performance. None of the climate variables are significant in predicting the alligator cracking because it is a load-related distress. In the primary system also, the annual temperature and freezing index are the most common climate variables for predicting the pavement performance.

Table 5.28 Significant Climate Variables for Primary System

Performance Parameter	P-Values				Overall P-values	R^2	Adjusted R^2
	ΔAR_{1-2}	ΔAT_{1-2}	ΔFI_{1-2}	ΔFT_{1-2}			
ΔIRI_{1-2}	-	-	0.0218	-	0.02181	0.3429	0.2924
ΔTC_{1-2}	-	-	0.0582	-	0.05819	0.2492	0.1914
ΔAC_{1-2}	*0.533*	*0.151*	*0.281*	*0.128*	*0.4201*	*0.3*	*0.02*
ΔLC_{1-2}	0.00002	-	-	0.00104	0.00005	0.8076	0.7755
ΔACR_{1-2}	-	0.0205	0.0199	0.0410	0.03689	0.5236	0.3937
ΔTR_{1-2}	-	0.00255	0.00102	0.02071	0.002105	0.7233	0.6479
Performance Parameter	P-Values				Overall P-values	R^2	Adjusted R^2
	ΔAR_{1-3}	ΔAT_{1-3}	ΔFI_{1-3}	ΔFT_{1-3}			
ΔIRI_{1-3}	0.0295	-	0.000003	-	0.000002	0.8972	0.8801
ΔTC_{1-3}	-	0.000001	-	-	0.000001	0.8507	0.8392
ΔAC_{1-3}	*0.848*	*0.607*	*0.665*	*0.506*	*0.9115*	*0.0864*	*-0.2791*
ΔLC_{1-3}	0.0003	-	-	-	0.0003	0.6561	0.6296
ΔACR_{1-3}	-	0.01352	0.01542	0.0679	0.0645	0.4687	0.3238
ΔTR_{1-3}	0.02934	0.00904	0.00215	-	0.0033	0.6991	0.617

Table 5.21, on the other hand, is the bootstrap confidence interval based on the percentage change values. Here also many of the performance distress parameters indicate no significant difference. All values resulting from interpolation using similar heights show no difference except for the total pavement rutting that show significant differences for both methods of interpolation. Table 5.22 shows the results of the p-values calculation using the percentage change values. The overall p-values are large for ΔLC_{1-2}, ΔIRI_{1-3}, ΔTC_{1-3}, ΔLC_{1-3}, and ΔTR_{1-3}. The R^2 and adjusted R^2 values also reflect large values, indicating a significant relation between pavement performance and climate variables.

Table 5.29 Confidence Interval Using Percentage Change

Performance Parameter	**Mean**	**95% Confidence Intervals**	
		Lower Bound	**Upper Bound**
ΔIRI_{1-2}	**0.0143**	**-0.004**	**0.0377**
ΔIRI_{1-3}	**-0.0006**	**-0.0291**	**0.0289**
ΔLC_{1-2}	**0.0139**	**-0.0391**	**0.0741**
ΔLC_{1-3}	**-0.0281**	**-0.0816**	**0.0365**
ΔAC_{1-2}	**-0.0674**	**-0.193**	**0.0162**
ΔAC_{1-3}	**-0.0951**	**-0.2179**	**-0.0136**
ΔTC_{1-2}	0.7323	0.0188	2.0498
ΔTC_{1-3}	**0.6697**	**-0.138**	**2.1466**
ΔACR_{1-2}	-0.0464	-0.0852	-0.0039
ΔACR_{1-3}	**0.0197**	**0**	**-0.0404**
ΔTR_{1-2}	-0.0255	-0.0482	-0.0036
ΔTR_{1-3}	-0.0259	-0.0487	-0.0022

Table 5.30 P-Values Calculations Using Percentage Change

Performance Parameter	P-Values				Overall P-Values	R^2	Adjusted R^2
	ΔAR_{1-2}	ΔAT_{1-2}	ΔFI_{1-2}	ΔFT_{1-2}			
ΔIRI_{1-2}	0.652	0.896	0.818	0.454	0.2136	0.413	0.1782
ΔTC_{1-2}	0.891	0.928	0.946	0.589	0.8682	0.1087	-0.2478
ΔAC_{1-2}	0.2661	0.2433	0.3698	0.6077	0.3539	0.332	0.0647
ΔLC_{1-2}	**0.000154**	**0.009136**	0.067929	0.077858	**0.000016**	0.9223	0.8913
ΔACR_{1-2}	0.8234	0.262	0.6072	0.2951	0.3595	0.3292	0.0608
ΔTR_{1-2}	0.8081	0.4571	0.4731	0.6066	0.3139	0.3528	0.09387
Performance Parameter	P-Values				Overall P-values	R^2	Adjusted R^2
	ΔAR_{1-3}	ΔAT_{1-3}	ΔFI_{1-3}	ΔFT_{1-3}			
ΔIRI_{1-3}	0.0694	0.7722	**0.0107**	0.9431	**0.0000084**	0.9317	0.9043
ΔTC_{1-3}	0.976	0.361	0.241	0.294	**0.04853**	0.5846	0.4184
ΔAC_{1-3}	0.0582	0.0761	0.0577	0.7057	0.1877	0.4314	0.2039
ΔLC_{1-3}	**0.0283**	0.3755	0.8249	0.4897	**0.006292**	0.7333	0.6267
ΔACR_{1-3}	0.9644	0.0675	0.1851	0.1994	0.0887	0.5237	0.3331
ΔTR_{1-3}	0.1744	0.1342	**0.0333**	0.6092	**0.04899**	0.5837	0.4172

5.4.4 Secondary System

Table 5.23 shows the mean and confidence interval raw differences for performance distresses generated using actual weather stations and that use interpolations. Most of the distresses in the table show statistical equivalence, be it using all the neighboring stations for interpolation or selecting only stations that have similar elevations.

Table 5.31 Confidence Interval on Differences

Performance Parameter	Mean	95% Confidence Intervals	
		Lower Bound	Upper Bound
ΔIRI_{1-2}	-2.6096	-5.0467	-0.4532
ΔIRI_{1-3}	**-0.4464**	**-3.9668**	**3.274**
ΔLC_{1-2}	**-8.4634**	**-27.2733**	**1.6133**
ΔLC_{1-3}	**1.4914**	**-0.3002**	**3.2533**
ΔAC_{1-2}	**-0.0134**	**-0.04**	**0**
ΔAC_{1-3}	**0**	**0**	**0**
ΔTC_{1-2}	-243.029	-529.758	-6.5047
ΔTC_{1-3}	**-86.3897**	**-493.741**	**319.2743**
ΔACR_{1-2}	**0.004**	**0**	**0.08**
ΔACR_{1-3}	0.0033	0.0013	0.006
ΔTR_{1-2}	**-0.00002**	**-0.0093**	**0.0073**
ΔTR_{1-3}	**0.0033**	**-0.0007**	**0.0073**

Table 5.24 shows the p-values calculated from the regression analysis using the differences generated for the weather stations and pavement distresses for actual and interpolated weather stations for the secondary road system. Where overall p-values are observed to be significant but not in the individual regressor p-values, there exist high multi-collinearity among the regressor variables. Further statistical analysis was carried out to produce Table 5.25.

Table 5.32 P-values on Differences for Secondary System

Regression Analysis							
Performance Parameter	P-Values				Overall P-values	R^2	Adjusted R^2
	ΔAR_{1-2}	ΔAT_{1-2}	ΔFI_{1-2}	ΔFT_{1-2}			
ΔIRI_{1-2}	0.1764	0.4126	0.1741	0.6298	0.0688	0.5505	0.3708
ΔTC_{1-2}	0.366	0.814	0.428	0.883	0.3452	0.3364	0.0709
ΔAC_{1-2}	0.847	0.436	0.581	0.383	0.8815	0.1022	-0.257
ΔLC_{1-2}	0.99	0.436	0.568	0.435	0.9186	0.0824	-0.2846
ΔACR_{1-2}	0.3314	0.076	0.161	0.0629	0.1528	0.4589	0.2425
ΔTR_{1-2}	0.85	0.142	0.127	0.186	0.1845	0.4337	0.2072
Performance Parameter	P-Values				Overall P-values	R^2	Adjusted R^2
	ΔAR_{1-3}	ΔAT_{1-3}	ΔFI_{1-3}	ΔFT_{1-3}			
ΔIRI_{1-3}	0.739	0.402	0.323	0.642	**0.00008**	0.8914	0.848
ΔTC_{1-3}	0.691	0.265	0.544	0.645	**0.0001**	0.8782	0.8295
ΔAC_{1-3}	na	na	na	na	na	na	na
ΔLC_{1-3}	**0.0313**	0.4247	0.3009	0.6916	0.1203	0.4887	0.2842
ΔACR_{1-3}	0.3618	0.1604	0.0884	0.1036	0.1235	0.4856	0.2798
ΔTR_{1-3}	**0.0246**	**0.0008**	**0.0002**	0.4336	**0.0004**	0.8485	0.7878

Table 5.25 shows the variables that have the most effect in predicting the performance parameter. These variables were determined after multi-collinearity had been determined and removed. The resulting climate variables were obtained by using the method of model selection. As noted from the table, annual temperature and freezing index are the two climate parameters that are common in predicting the performance parameter, except for the alligator cracking. In Table 5.26, the mean and confidence intervals are based on the percentage change between distresses from actual stations and that based on interpolated stations. Distresses based on similar elevation interpolation show more statistical equivalence than those based on interpolation using all the neighboring stations.

Table 5.33 Significant Climate Variables for Secondary System

Performance Parameter	P-Values				Overall P-values	R^2	Adjusted R^2
	ΔAR_{1-2}	ΔAT_{1-2}	ΔFI_{1-2}	ΔFT_{1-2}			
ΔIRI_{1-2}	-	-	0.0093	-	0.0093	0.4169	0.3721
ΔTC_{1-2}	-	-	0.0455	-	0.04547	0.2735	0.2176
ΔAC_{1-2}	*0.847*	*0.436*	*0.581*	*0.383*	*0.8815*	*0.1022*	*-0.257*
ΔLC_{1-2}	*0.99*	*0.436*	*0.568*	*0.435*	*0.9186*	*0.0824*	*-0.2846*
ΔACR_{1-2}	-	0.0290	0.0351	0.0837	0.1164	0.4025	0.2396
ΔTR_{1-2}	-	-	0.0497	-	0.0497	0.2648	0.2082
Performance Parameter	P-Values				Overall P-values	R^2	Adjusted R^2
	ΔAR_{1-3}	ΔAT_{1-3}	ΔFI_{1-3}	ΔFT_{1-3}			
ΔIRI_{1-3}	-	0.0000003	-	-	0.0000003	0.8748	0.8652
ΔTC_{1-3}	-	0.0000008	-	-	0.0000008	0.8554	0.8443
ΔAC_{1-3}	*na*	*na*	*na*	*na*	*na*	*na*	*na*
ΔLC_{1-3}	0.0102	-	-	-	0.01024	0.4091	0.3637
ΔACR_{1-3}	-	-	-	0.0620	0.0620	0.2429	0.1846
ΔTR_{1-3}	0.0066	0.0006	0.0001	-	0.0001	0.8384	0.7943

Table 5.34 Confidence Interval on Percentage Change

Performance Parameter	**Mean**	**95% Confidence Intervals**	
		Lower Bound	**Upper Bound**
ΔIRI_{1-2}	0.0226	0.0039	0.0446
ΔIRI_{1-3}	**0.0051**	**-0.0242**	**0.0343**
ΔLC_{1-2}	**0.1719**	**-0.0294**	**0.5357**
ΔLC_{1-3}	**-0.0278**	**-0.0639**	**0.0107**
ΔAC_{1-2}	**0.0666**	**0**	**0.2**
ΔAC_{1-3}	**0**	**0**	**0**
ΔTC_{1-2}	0.9622	0.0188	2.7158
ΔTC_{1-3}	**1.0421**	**-0.1208**	**3.0841**
ΔACR_{1-2}	**-0.0521**	**-0.1156**	**0.0111**
ΔACR_{1-3}	-0.0568	-0.1017	-0.0167
ΔTR_{1-2}	**0.0018**	**-0.0275**	**0.0392**
ΔTR_{1-3}	**-0.0124**	**-0.0286**	**0.0039**

Table 5.27 shows p-values calculated from regression analysis using the percentage change generated for the weather stations and pavement distresses using actual and interpolated weather stations. Only the AT indicates significance in the prediction of the ACR. There is also a significant overall p-value with a high R^2 value, but the adjusted R^2 is marginal. The IRI in the second part of Table 5.27 has a high overall p-value, but none of the individual explanatory variables show any significance in predicting the IRI. The corresponding R^2 and adjusted R^2 values indicate a high degree of goodness of fit from the variables. As stated in the previous section, this may be due to the high degree of correlation among the explanatory variables.

Table 5.35 P-values Using Percentage Change

Performance Parameter	P-Values				Overall P-values	R^2	Adjusted R^2
	ΔAR_{1-2}	ΔAT_{1-2}	ΔFI_{1-2}	ΔFT_{1-2}			
ΔIRI_{1-2}	0.857	0.758	0.956	0.436	0.1681	0.4464	0.2249
ΔTC_{1-2}	0.884	0.939	0.947	0.599	0.8662	0.1097	-0.2464
ΔAC_{1-2}	0.538	1.000	0.654	0.459	0.9428	0.0677	-0.3053
ΔLC_{1-2}	0.621	0.917	0.59	0.47	0.96	0.0556	-0.3222
ΔACR_{1-2}	0.6361	**0.0056**	0.0918	0.2209	**0.025**	0.6411	0.4976
ΔTR_{1-2}	0.591	0.896	0.996	0.413	0.4573	0.2832	-0.0036
Performance Parameter	P-Values				Overall P-values	R^2	Adjusted R^2
	ΔAR_{1-3}	ΔAT_{1-3}	ΔFI_{1-3}	ΔFT_{1-3}			
ΔIRI_{1-3}	0.383	0.279	0.128	0.85	**0.00008**	0.8927	0.8498
ΔTC_{1-3}	0.987	0.343	0.241	0.287	0.0517	0.5787	0.4101
ΔAC_{1-3}	na	na	na	na	na	na	na
ΔLC_{1-3}	0.242	0.565	0.829	0.867	0.1656	0.4483	0.2277
ΔACR_{1-3}	0.1687	0.17	0.0731	**0.0334**	0.149	0.4622	0.247
ΔTR_{1-3}	0.507	0.482	0.149	0.735	0.1243	0.4848	0.2787

5.5 Summary of Statistical Analysis

Using the bootstrapping on the differences, it was observed that for the interstate system the IRI, alligator cracking and transverse cracking showed no significant difference using any of the interpolation methods. The other distresses did, however, show some differences even though the range was minimal. On using the percentage difference, all the distresses showed no significant change except for the transverse cracking, AC, and total rutting, which showed significant difference for the interpolation using all the stations. On the climate, no significant difference was noted for the climate variables for both data sets except for annual rainfall and freeze/thaw in the percentage change data set. For the p-values calculations based on the differences, only the models for the IRI and the transverse cracking were deemed to be a good fit having a significant R^2 and adjusted R^2 values. Using the percentage data set, the IRI for both methods of interpolation and the longitudinal cracking are good fits. The IRI using interpolation by similar elevations showed a better fit.

For the primary system, using bootstrapping, the IRI, longitudinal cracking, alligator cracking, and transverse cracking all showed no significant difference using the data set based on the differences. On using the percentage data set, the AC rutting was included in the above. All these were based on both methods of interpolation, but for the transverse cracking and AC rutting, these were based on interpolation based on the similar elevations. P-values calculations based on the differences and percentage change data showed more correlation in the distress models using similar elevations for the interpolation. For the secondary system, the bootstrapping for both data sets showed no significant difference between actual and interpolated distresses, except for the IRI, transverse cracking and the AC rutting, which showed significant difference based on the interpolation using all the stations. On examination for the p-values calculations, the distress models based on the interpolation using similar elevations showed significant correlation with regressors than based on the other interpolation. In all three classes of road system considered, more of the distress data from interpolation based on similar weather station elevation showed no significant difference and correlated better with regressors than for the ones based on interpolation using all the weather stations. The IRI is highly correlated with regressors than the other distresses irrespective of the dataset based on the interpolation by similar heights. The correlation is highest in the primary system than for the secondary and interstate. On the basis of the bootstrapping, the secondary system shows no significant difference for all the distresses based on the interpolation using similar elevations. It can be concluded that virtual stations based on similar elevations offer better results than for interpolation based on using all the weather stations.

5.6 Section Summary

In this section, the effect of different binder grade and climate factors on pavement performance was discussed. The results indicated that the binder grade used and the climate in which the pavement is constructed do play a significant role its performance. The section also discussed and analyzed the pavement performance distresses for the different classes of road system in Wyoming using actual weather data and virtual weather data from interpolation. A statistical analysis using a bootstrap sampling method was performed to investigate the adequacy of using interpolated weather data to determine pavement distresses. A regression model was developed using the performance distresses as response variables and the annual climate variables as regressors from which p-values calculation was also performed to determine how a specific annual climate variable affected the pavement distresses. Observations from the bootstrapping and p-values calculations indicated higher significance in using interpolated values by similar elevations than for using all the available neighboring weather stations. It should, however, be noted that in running the MEPDG analysis for the different classes of road, the interstate system kept indicating an on-screen error in the run analysis, which was not observed for the primary and secondary systems. This was attributed to the asphalt permeable base that was present in the interstate system but not in the primary and secondary.

6. CONCLUSIONS AND RECOMMENDATIONS

To satisfy the objectives of this research study, a general study of literature and presentations by various DOTs on the MEPDG was carried out to determine the level of implementation in the northwestern states. This literature search identified obstacles to the implementation efforts and how these could be overcome. Second, MEPDG simulations were conducted using MEPDG software version 1.1 to analyze how the different climate regions of Wyoming impacted MEPDG pavement performance. Finally, this study used virtual weather stations created by the MEPDG from interpolation using two different methods to investigate and statistically analyze its adequacy on pavement design and performance in the state of Wyoming. The analysis was carried out for interstate, primary, and secondary road classification systems.

6.1 Conclusions

Having reviewed current literature on the MEPDG, presentations by various states departments of transportation, and the observations from the climate analysis, the following conclusions can be drawn:

1. The implementation of the Mechanistic Empirical Pavement Design Guide (MEPDG) will create more reliable and cost-effective designs and rehabilitation strategies over the traditional AASHTO guide.

2. The user-oriented computational software program that comes with the MEPDG can predict pavement conditions over time and thereby help engineers make informed decisions.

3. Adoption of the MEPDG will significantly improve material testing, design procedures, and, most importantly, data collection.

4. Implementing the MEPDG will require significant amount of time and resources and so adequate resources should be made available for its implementation.

5. The MEPDG will allow DOTs flexibility to apply and calibrate design procedures to suit local conditions and thereby achieve more reliable designs.

6. Five additional weather stations with complete weather data were identified for inclusion into the MEPDG in the State of Wyoming.

7. The variability between actual and virtual climate information was minimal except for the freezing index where higher variations were observed.

8. The variability in performance parameters at the different locations was minimal except for transverse cracking. Transverse was therefore identified to be more sensitive to weather data.

9. The transverse cracking model showed failure for all locations except for Evanston and Rock Springs, which had the two lowest freeze/thaw cycles.

10. The alligator cracking was not affected by the binder grade nor the location. This is because this is a load-related distress and the load was held consistent in this study.

11. All the pavement performance parameters improved by improving the asphalt grade except for the transverse cracking. The transverse cracking model needs to be calibrated.

12. For all three functional classes of roads, there were higher correlations of performance parameters when using weather interpolated data based on similar elevations.

13. Performance parameters for the secondary classification were more statistically correlated than for the primary and interstate.

14. The MEPDG simulation runs on interstate continually indicated errors, which were attributed to the presence of the asphalt permeable base. Such error was not experienced in the primary and secondary systems.

6.2 Recommendations

1. Agencies should plan for and monitor future works related to updates and improvements of the MEPDG and the national and regional levels on a continuous basis.
2. It is important that the MEPDG software be calibrated and validated to suit local conditions, and so it is imperative that agencies develop and maintain a continuous calibration-validation database along with input libraries (traffic and material inputs).
3. Construct test sections and periodically monitor them for input parameters and update the database.
4. The five newly identified weather stations should be added to the MEPDG climate database in the State of Wyoming.
5. Climate data close to the proposed project site should be used for pavement design and analysis. Where no weather data is available and interpolations are required, this should be done based on using climate stations with similar elevations to the project site.

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APPENDIX A1: FLEXIBLE PAVEMENT PERFORMANCE PREDICTION EQUATIONS

The prediction equations for flexible pavement distresses have been taken from the *Mechanistic-Empirical Pavement Design Guide, A Manual of Practice, Interim Edition* (AASHTO July 2008) and show the computational steps used in the MEPDG to calculate the distresses. The equations have been nationally calibrated using field data from the LTPP data and indicate what calibration coefficients need to be changed to perform local calibration of the distress predictions. The procedure for computing rutting or plastic vertical deformation, in HMA layers is as shown in the equation. The total rutting of the pavement structure is summation of the permanent vertical deformation in each layer.

$$\Delta_{p(HMA)} = \varepsilon_{p(HMA)}\, h_{HMA} = \beta_{1r} k_z \varepsilon_{r(HMA)} 10^{k_{1r}} n^{k_{2r}\beta_{2r}} T^{k_{3r}\beta_{3r}}$$

Where:

$\Delta_{p(HMA)}$ = Accumulated permanent or plastic vertical deformation in the HMA layer, in

$\varepsilon_{p(HMA)}$ = Accumulated permanent or axial strain in the HMA layer/sublayer, in/in

h_{HMA} = Thickness of the HMA layer/sublayer, in.

ε_r = Resilient or elastic strain calculated by the structural response model at the mid-depth of each HMA sublayer, in/in.,

n = Number of axle load repetitions

T = Mix or pavement temperature, ^{o}F

k_z = Depth confinement factor,

$k_{1r, 2r, 3r}$ = Global field calibration parameters (from the NCHRP 1-40D recalibration;

$k_{1r} = -3.35412$, $k_{2r} = 0.4791$, $k_{3r} = 1.5606$)

$\beta_{1r, 2r, 3r}$ = Local or mixture field calibration constants; for the global calibration, These constants were all set to 1.0

$k_z = (C_1 + C_2 D)0.328196^D$

$C_1 = -0.1039(H_{HMA})^2 + 2.4868H_{HMA} - 17.342$

$C_2 = 0.0172(H_{HMA})^2 - 1.7330H_{HMA} + 27.428$

Where:

D = Depth below surface, in

H_{HMA} = Total HMA thickness, in

$$\Delta_{p(soil)} = \beta_{s1} k_{s1} \varepsilon_v h_{soil} \left\{\frac{\varepsilon_0}{\varepsilon_r}\right\} e^{-\left\{\frac{\rho}{n}\right\}^{\beta}}$$

Where:

$\Delta_{p(soil)}$ = permanent or plastic deformation for the layer/sublayer, in

n = number of axle load applications

ε_0 = Intercept determined from laboratory repeated load permanent deformation tests, in/in

ε_r = Resilient strain imposed in laboratory test to obtain material properties ε_0, ε, and ρ, in/in

ε_v = Average vertical resilient or elastic strain in the layer/sublayer and calculated by the structural response model, in/in

h_{soil} = Thickness of the unbound layer/sublayer, in

k_{s1}= Global calibration coefficients; ks1 = 1.673 for granular materials and 1.35 for fine grained materials

ε_{s1}= Local calibration constant for the rutting in the unbound layers; the local calibration constant was set to 1.0 for the global calibration effort.

$$\text{Log}\beta = -0.61119 - 0.017638(W_c)$$

$$\rho = 10^9 \left\{\frac{C_0}{(1-(10^9)^{\beta})}\right\}^{\frac{1}{\beta}}$$

$$C_0 = \text{Ln}\left\{\frac{a_1 M_r^{b1}}{a_9 M_r^{b9}}\right\} = 0.0075$$

W_c = Water content, %
M_r = Resilient modulus of the unbound later or sublayer, psi
$a_{1,9}$ = Regression constants; a_1 = 0.15 and a_9 = 20.0
$b_{1,9}$ = Regressions constants; b_1 = 0.0 and b_9 = 0.0

Load Related Cracking

There are two types of load related cracking predicted by the MEPDG; these are the alligator cracking and longitudinal cracking. It is assumed that alligator cracks are initiated at the bottom of the HMA layer and propagate to the surface with continued traffic, while the longitudinal cracks initiate at the surface of the pavement (AASHTO 2008). For both cracking models, the procedure for computing the allowable number of axle-load applications needed for the incremental damage index is shown using the following equations:

$$N_{f-HMA} = k_{f1}(C)(C_H)\beta_{f1}(\varepsilon_t)^{k_{f2}\beta_{f2}}(E_{HMA})^{k_{f3}\beta_{f3}}$$

Where:
N_{f-HMA} = Allowable number of axle load applications for a flexible pavement and HMA overlays
ε_t = Tensile strain at critical locations and calculated by the structural response model in/in
E_{HMA} = Dynamic modulus of the HMA measured in compression, psi
k_{f1}, k_{f2}, k_{f3} = Global field calibration parameters (from the NCHRP 1-40D recalibration; K_{f1}= 0.007566, k_{f2}= -3.9492, k_{f3}= - 1.281).
$\beta_{f1, f2, f3}$ = Local or mixture field calibration constants; for the global calibration, these constants were all set to 1.0.

$C = 10^M$

$$M = 4.84\left\{\frac{V_{be}}{V_a + V_{be}} - 0.69\right\}$$

Where:
V_{be} = Effective asphalt content by volume, %
V_a = Percent air voids in the HMA mixture
C_H = Thickness term, dependent on type of cracking
For bottom up or alligator cracking

$$C_H = \frac{1}{0.000398 + \frac{0.003602}{1+e^{(11.02-3.49H_{HMA})}}}$$

For top down or longitudinal cracking

$$C_H = \frac{1}{0.01 + \frac{12.00}{1+e^{(15.676-2.81H_{HMA})}}}$$

Where:
H_{HMA} = Total HMA thickness, in
The area of alligator cracking and length of longitudinal cracking are calculated from the total damage over time. The relationship used to predict the amount of alligator on the basis of area is as given in the equation below (AASHTO, 2008).

$$DI = \sum(\Delta DI)_{j,m,l,p,T} = \sum\left(\frac{n}{N_{f-HMA}}\right)_{j,m,l,p,T}$$

Where:
n = Actual number of axle load applications within a specific time period
j = Axle load interval
m = Axle load type (single, tandem, tridem, quad, or special axle configuration)
l = Truck type using the truck classification groups included in the MEPDG
p = Month
T = Median temperature for the five temperature intervals or quintiles used to subdivide each month, ^{o}F.

$$FC_{Bottom} = \left(\frac{1}{60}\right)\left(\frac{C_4}{1+e^{(C_1C_2^*+C_1C_2^*)Log(DI_{Bottom}*100)}}\right)$$

Where:
FC_{Bottom} = Area of alligator cracking that initiates at the bottom of the HMA layers, % of total lane area.
DI_{Bottom} = Cumulative damage index at the bottom of the HMA layers
$C_{1, 2, 4}$ = Transfer function regression constants; C_4 = 6,000; C_1 = 1.00 and C_2 = 1.00
$C^*_1 = -2C^*_2$
$C^*_2 = -2.40874 - 39.748(1+H_{HMA})^{-2.856}$
Where:
H_{HMA} = Total HMA thickness, in

$$FC_{Top} = (60)\left(\frac{C_4}{1+e^{(C_1 - C_2 log(DI_{Top}))}}\right)$$

Where:
FC_{Top} = Length of longitudinal cracks that initiate at the top of the HMA layer, ft/mi
DI_{Top} = Cumulative damage index near the top of the HMA surface
$C_{1, 2, 4}$ = Transfer function regression constants; $C_1 = 7.00$; $C_2 = 3.5$; $C_4 = 1{,}000$

Non-Load Related Cracking – Transverse Cracking

The transverse cracking is as a result of the cooling cycle experienced by the pavement. The amount of this type of crack propagation predicted in the MEPDG uses the Paris law of crack propagation (AASHTO 2008).

$$\Delta C = A(\Delta K)^n$$

Where:
ΔC = Change in the crack depth due to a cooling cycle
ΔK = Change in the stress intensity factor due to a cooling cycle
A, n = Fracture parameters for the HMA mixture

$$A = 10^{k_t \beta_t (4.389 - 2.52 Log(E_{HMA} \sigma_m n))}$$

Where:

$n = 0.8\left[1 + \frac{1}{m}\right]$

k_t = Coefficient determined through global calibration for each input level (Level 1 = 5.0; Level 2 = 1.5; and Level 3 = 3.0)

E_{HMA} – HMA indirect tensile modulus, psi

σ_m = Mixture tensile strength, psi

m = the m-value derived from the direct tensile creep compliance curve measured in the laboratory

β_t = Local or mixture calibration factor

The stress intensity factor K, is given by the equation

$K = \sigma_{tip}[0.45 + 1.99(C_0)^{0.56}]$

Where:

σ_{tip} = Far-field stress from pavement response model at the depth of crack tip, psi

C_0 = Current crack length, ft

The degree of transverse cracking is predicted by

$$TC = \beta_{t1} N\left[\frac{1}{\sigma_d} Log\left(\frac{C_d}{H_{HMA}}\right)\right]$$

Where;

TC = Observed amount of thermal cracking, ft/mi

β_{t1} = Regression coefficient determined through global calibration (400)

N[z] = Standard normal distribution evaluated at [z]

σ_d = Standard deviation of the log of the depth of cracks in the pavement (0.769), in

C_d = Crack depth, in

H_{HMA} = Thickness of HMA layers, in

IRI Computation

The equation embedded in the MEPDG for the prediction of IRI is as given below. The equation applies to new HMA pavements and HMA overlays of Flexible pavements.

$$IRI = IRI_0 + 0.0150(SF) + 0.400(FC_{Total}) + 0.0080(TC) + 40.0(RD)$$

Where:

IRI_0 = Initial IRI after construction, in/mi

SF = Site factor (equation given below)

FC_{Total} = Area of fatigue cracking (combined alligator, longitudinal and reflection cracking in the wheel path), percent of total lane area. All load related cracks are combined on an area basis – length of cracks is multiplied by 1ft to convert length into an area basis.

TC = Length of transverse cracking (including the reflection of transverse cracks in existing HMA pavements), ft/mi

RD = Average rut depth, in.

$$SF = Age\ [0.02003(PI + 1) + 0.007947(Precip + 1) + 0.000636(FI + 1)]$$

Where:

Age = Pavement age, yr

PI = Percent plasticity index of the soil

FI = Average annual freezing index, ^{o}F days

Precip = Average annual precipitation or rainfall, in

APPENDIX A2: MEPDG DATA INPUT SCREENS

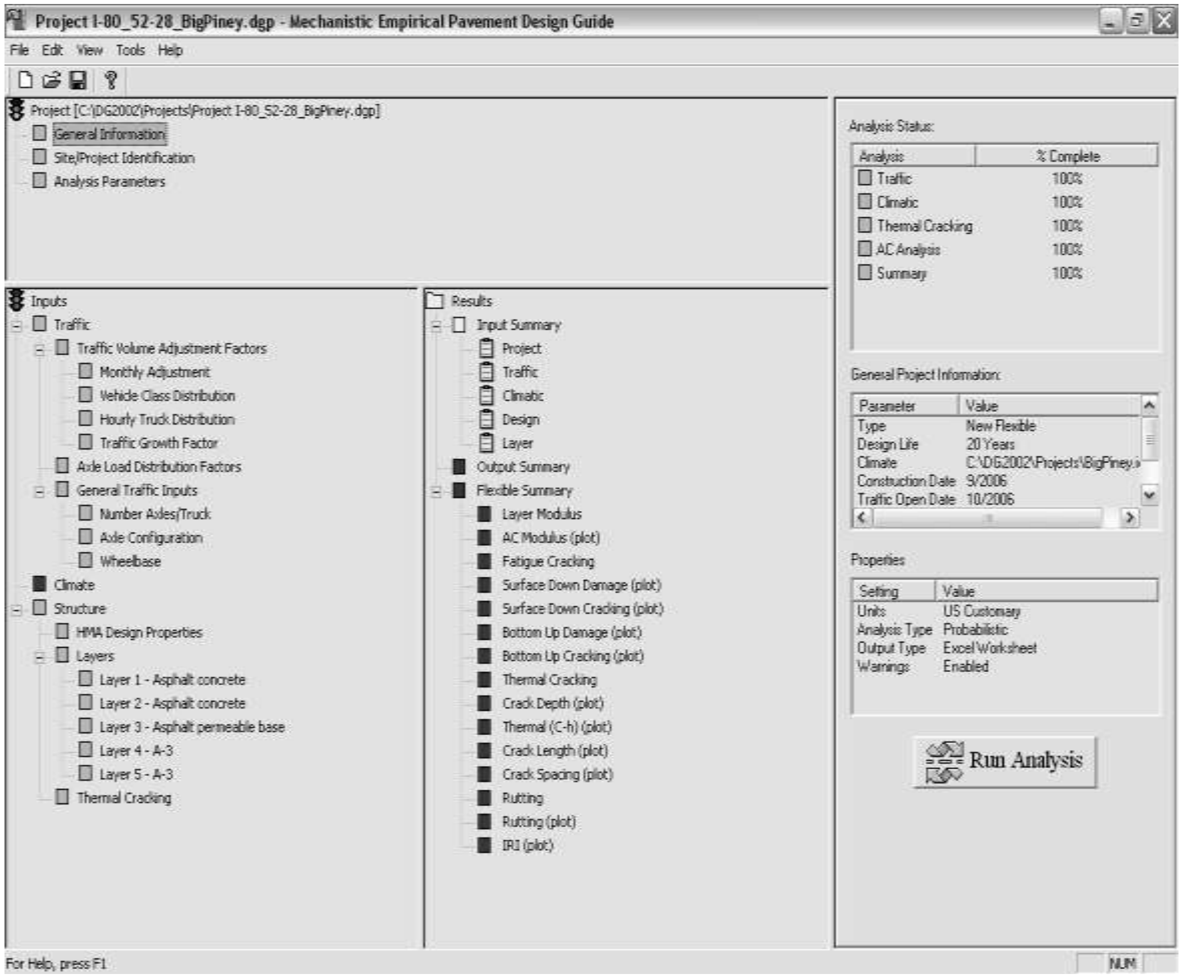


Figure A2.1 Main MEPDG Data Input Screen

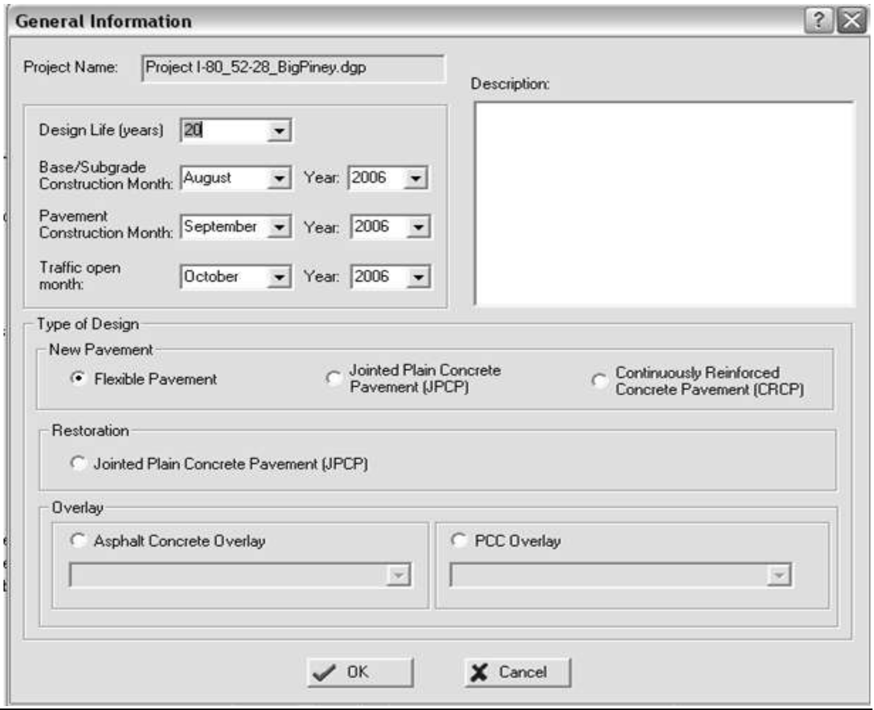


Figure A2.2 General Information Screen (I-80)

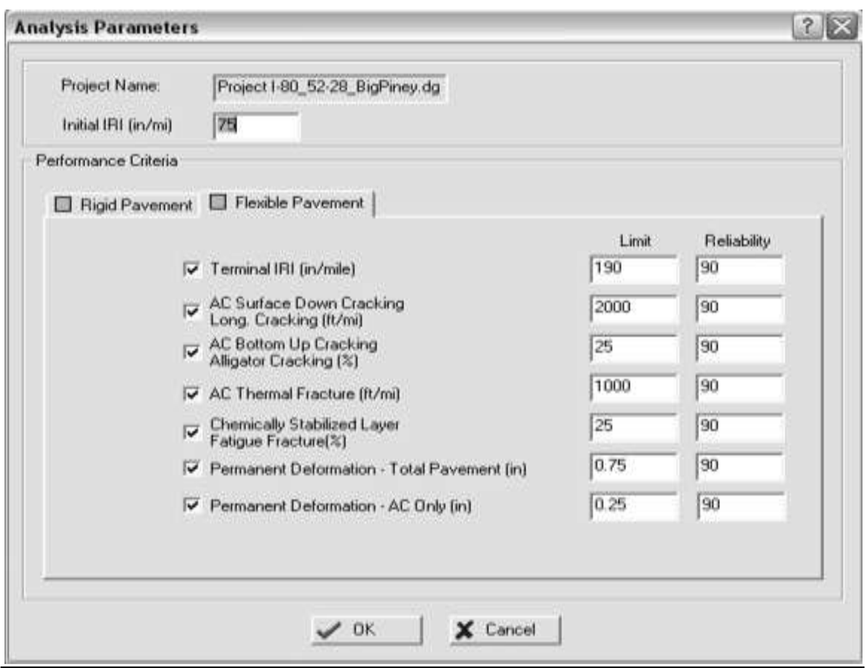


Figure A2.3 Analysis Parameter Screen (I-80)

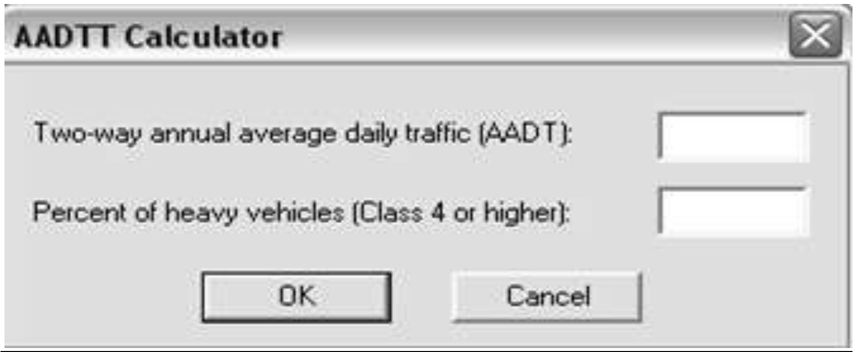


Figure A2.4 AADTT Calculator

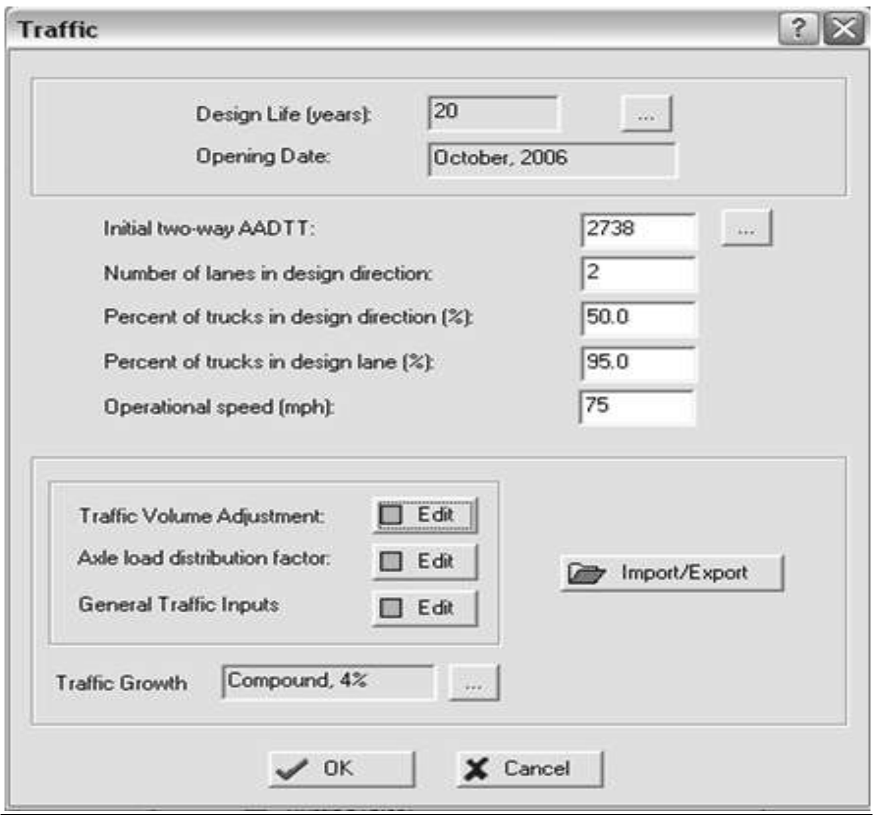


Figure A2.5 Traffic Input Screen (I-80)

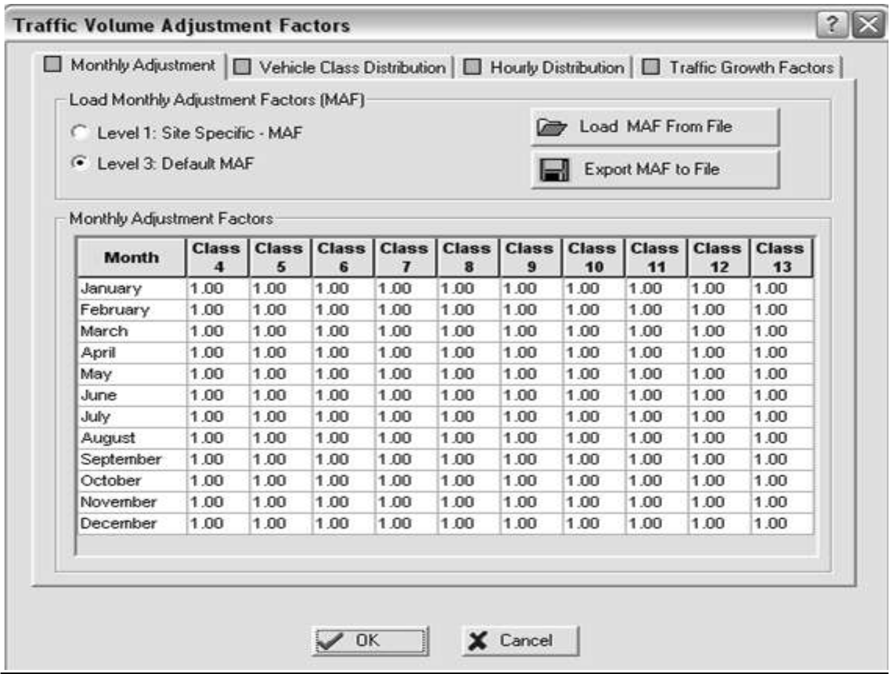


Figure A2.6 Truck Traffic monthly adjustment input screen (MEPDG default)

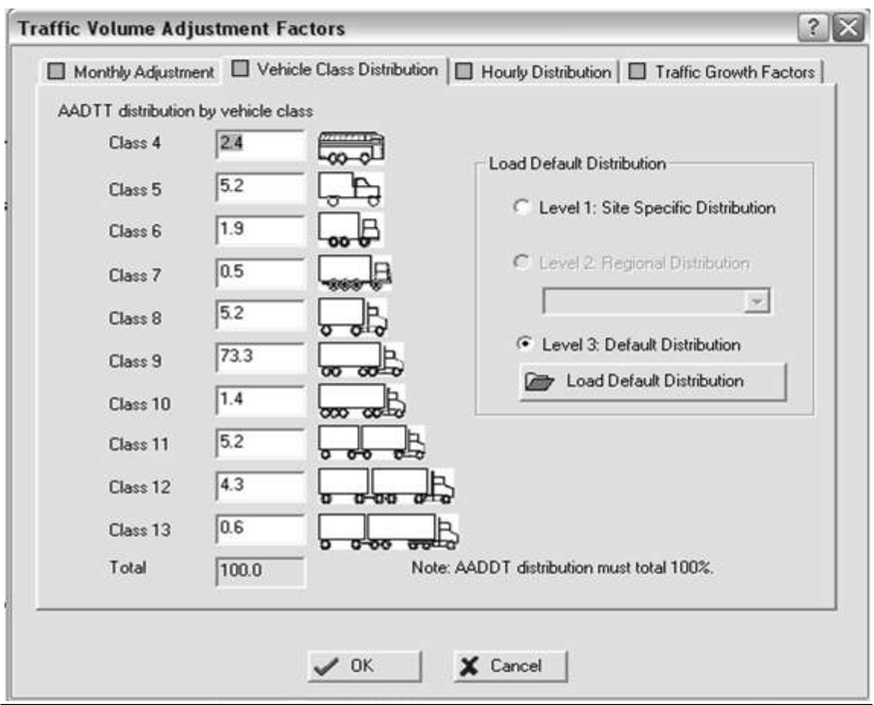


Figure A2.7 AADTT distribution by vehicle class screen (I-80)

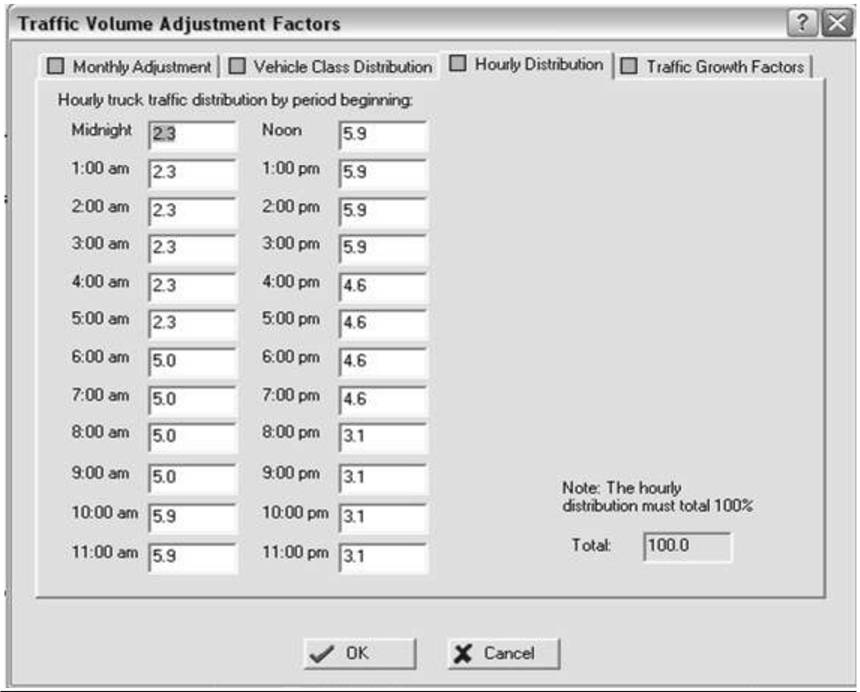


Figure A2.8 Hourly Truck Traffic Distribution Input Screen (MEPDG Defaults)

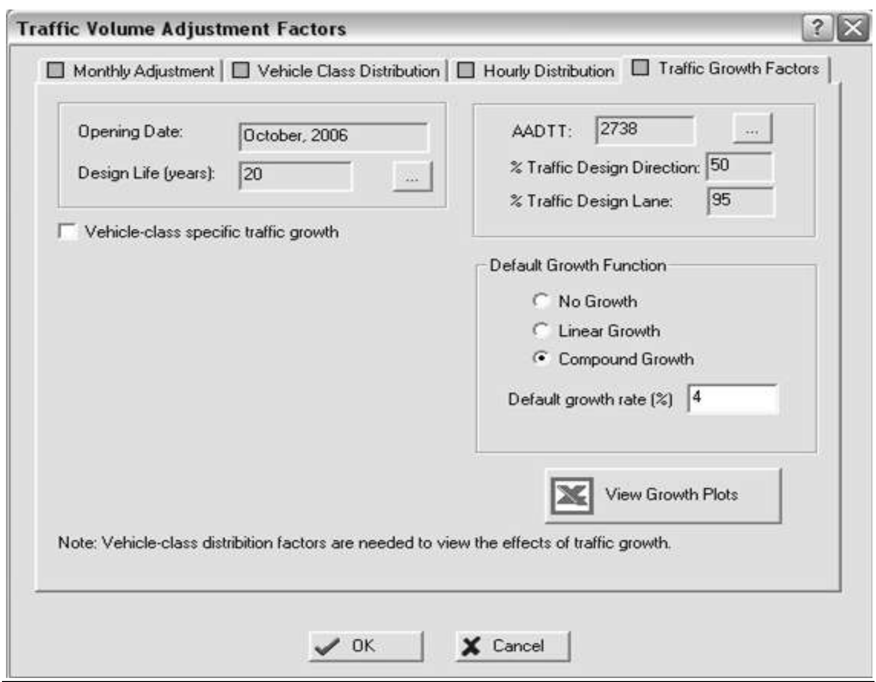


Figure A2.9 Traffic Growth Factor Input Screen (MEPDG Defaults)

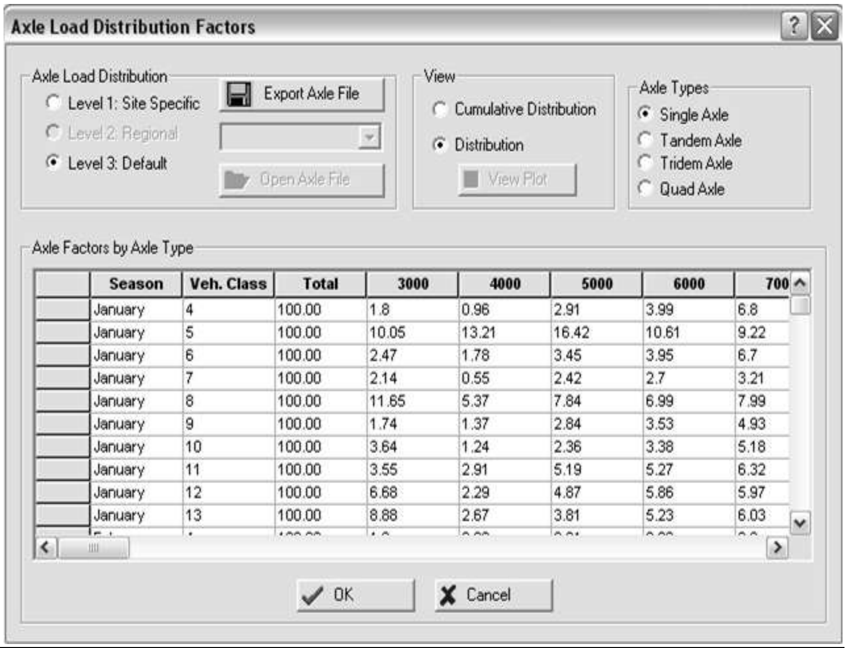


Figure A2.10 Axle Load Distribution Factors Input Screen (MEPDG Default)

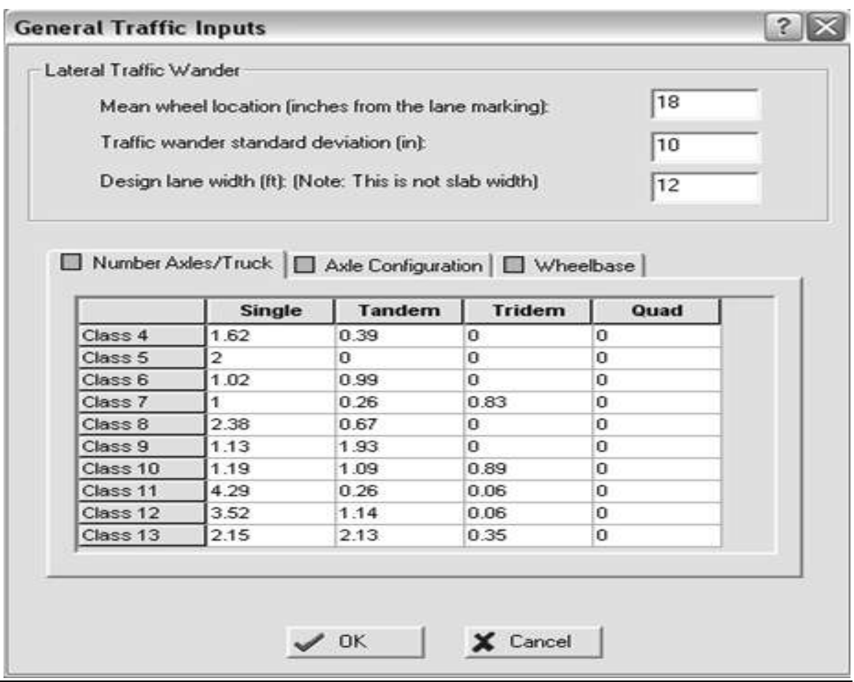


Figure A2.11 Number of Axles per Truck Input Screen (MEPDG Default)

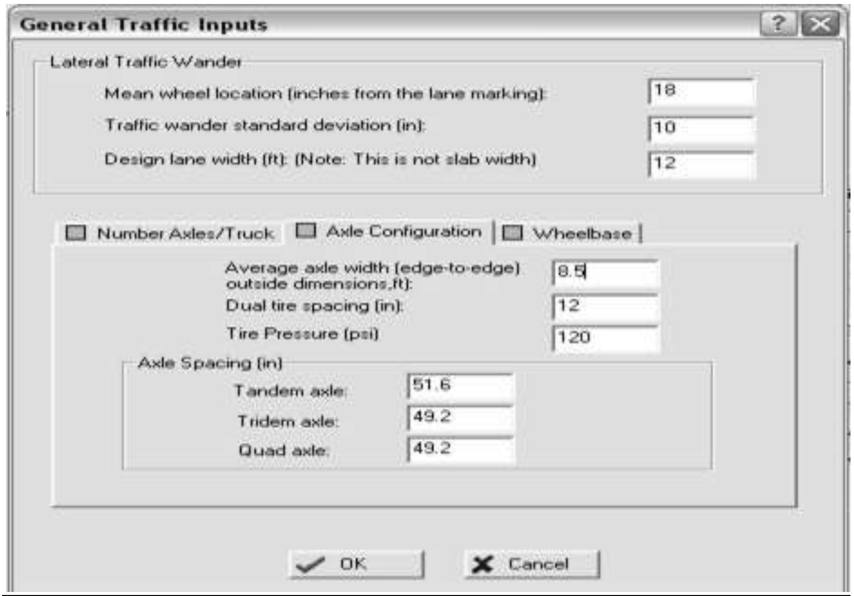


Figure A2.12 Axle Configuration Input Screen (MEPDG Defaults)

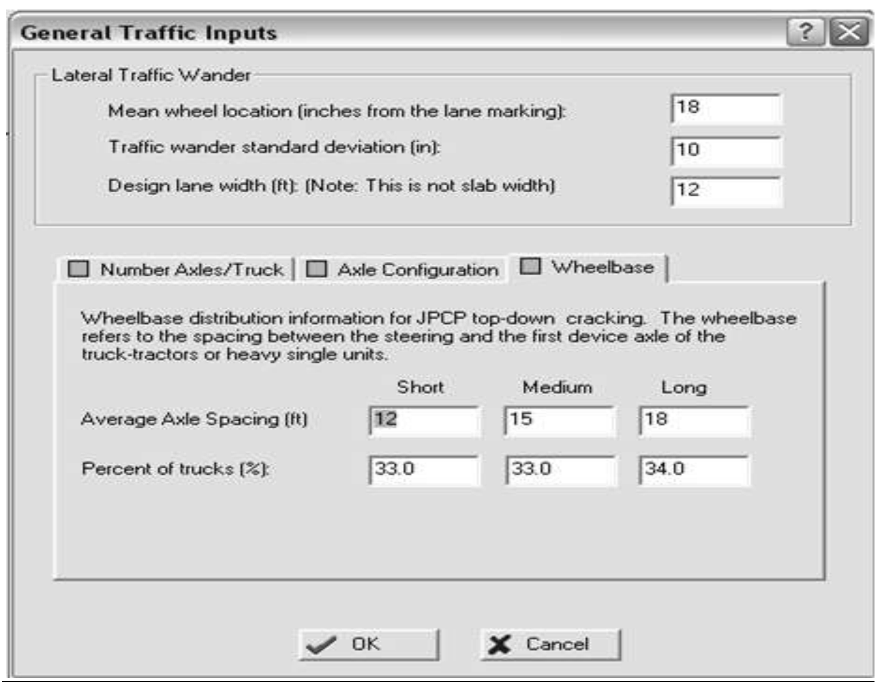


Figure A2.13 Truck Wheelbase Input Screen (MEPDG Defaults)

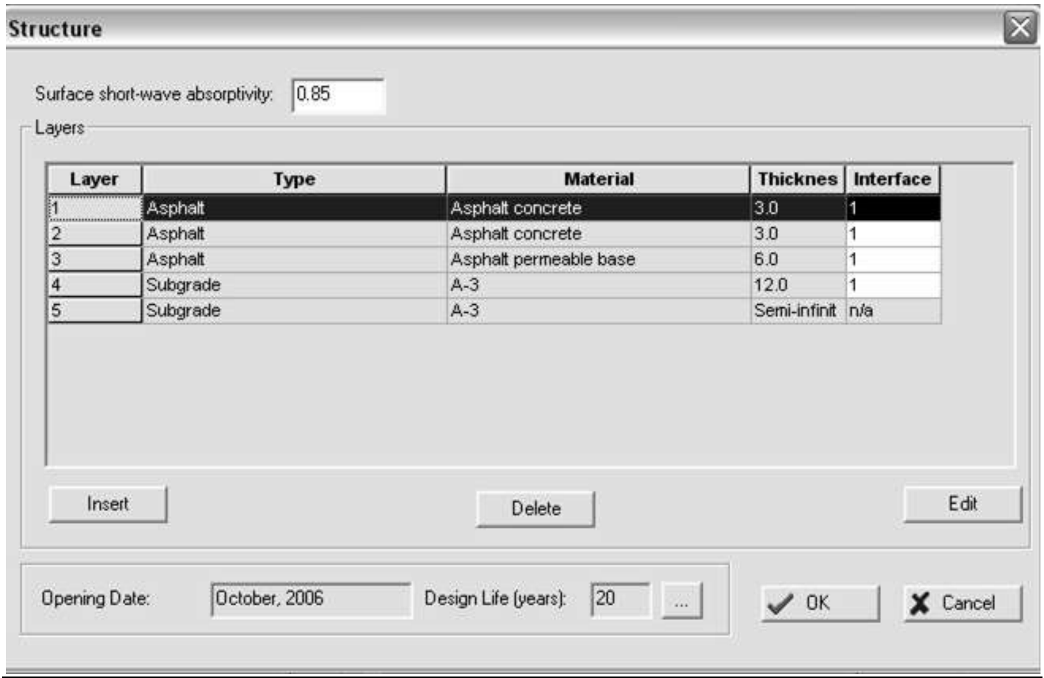


Figure A2.14 Pavement Structure Input Screen (I-80)

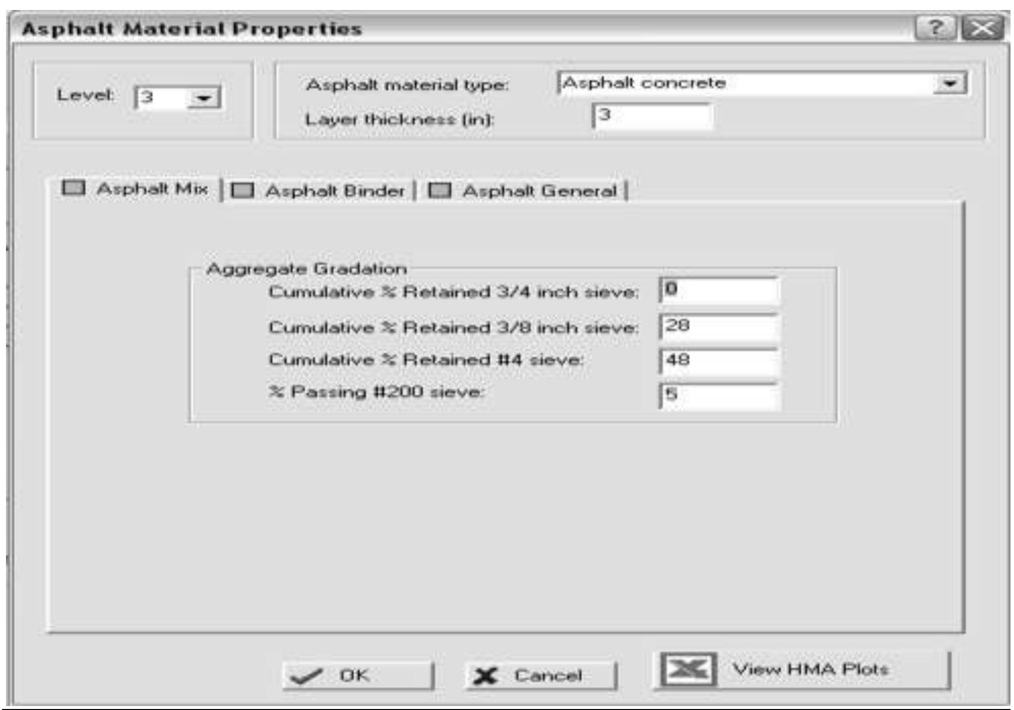


Figure A2.15 Asphalt Mix Input Screen (I-80)

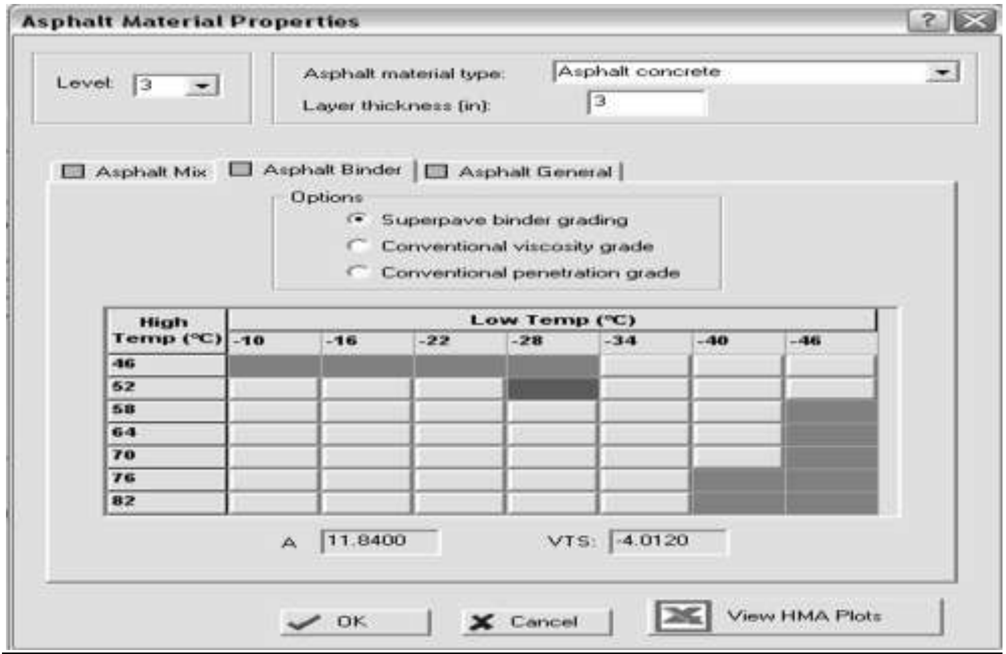


Figure A2.16 Asphalt Binder Selection Input Screen (I-80)

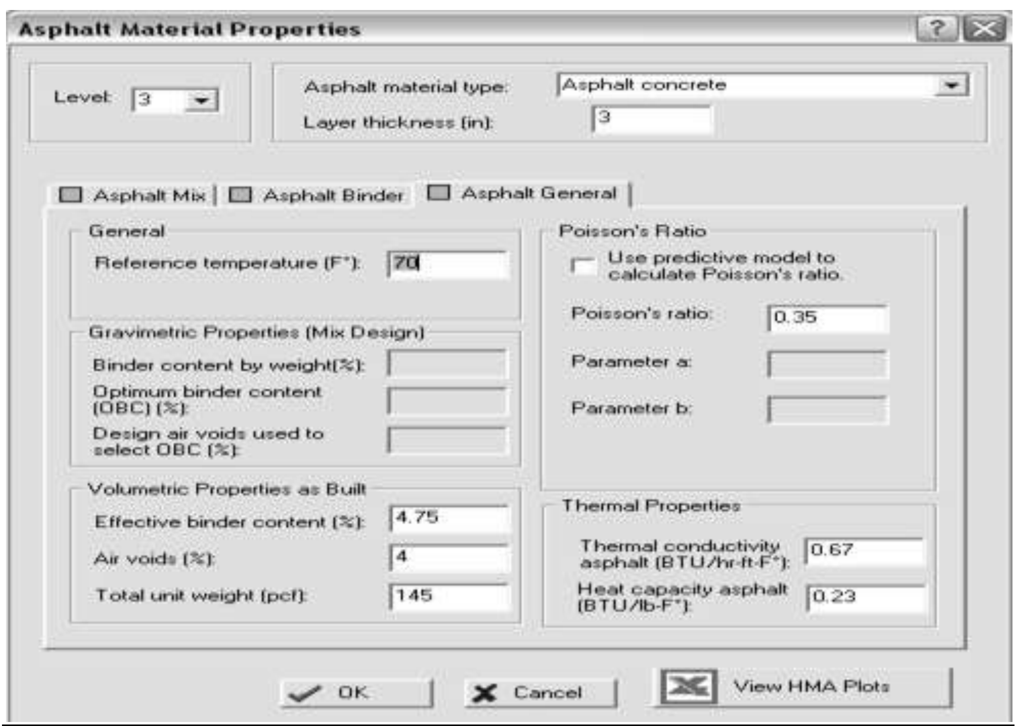


Figure A2.17 Asphalt General Properties Input Screen (I-80)

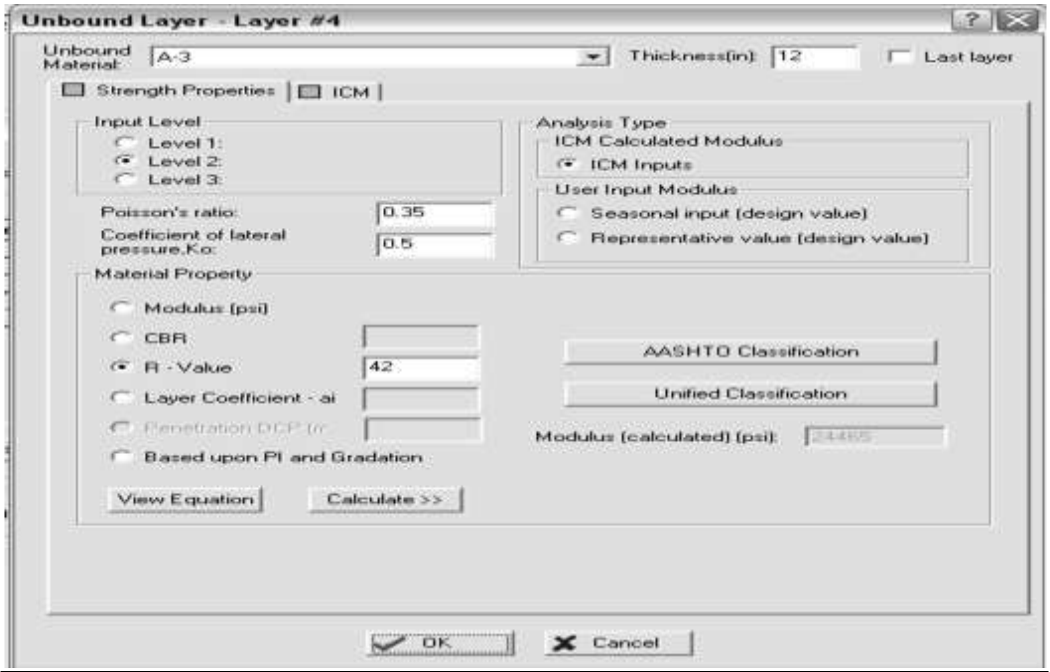


Figure A2.18 Strength Properties Input Screen for Unbound Materials

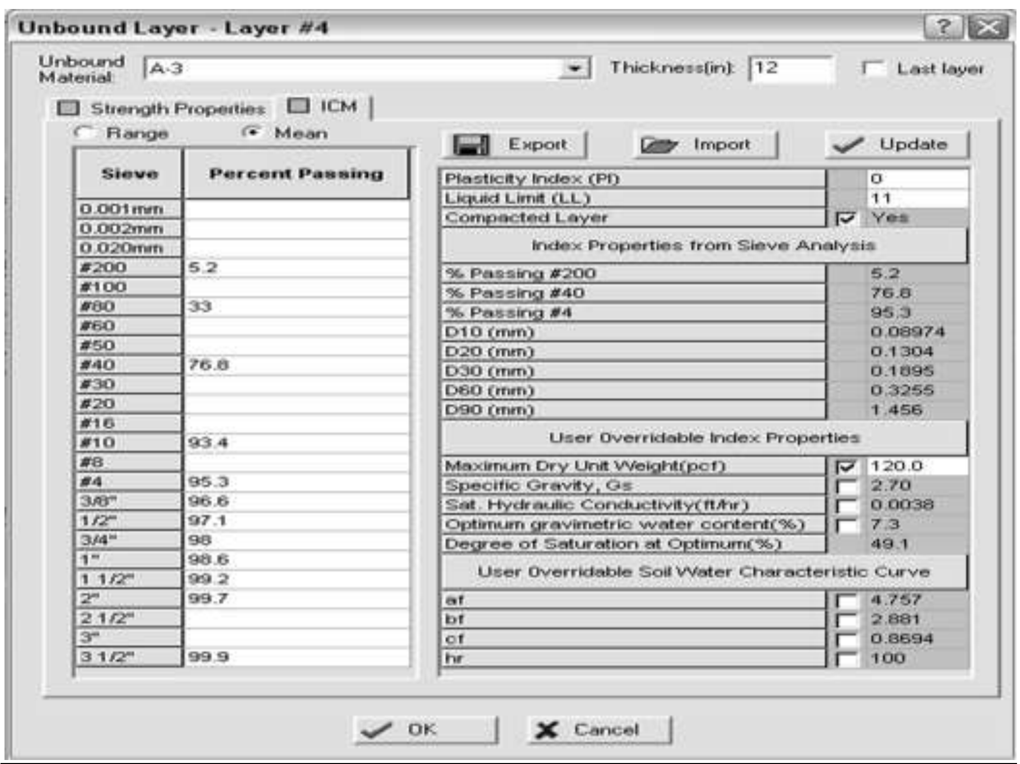
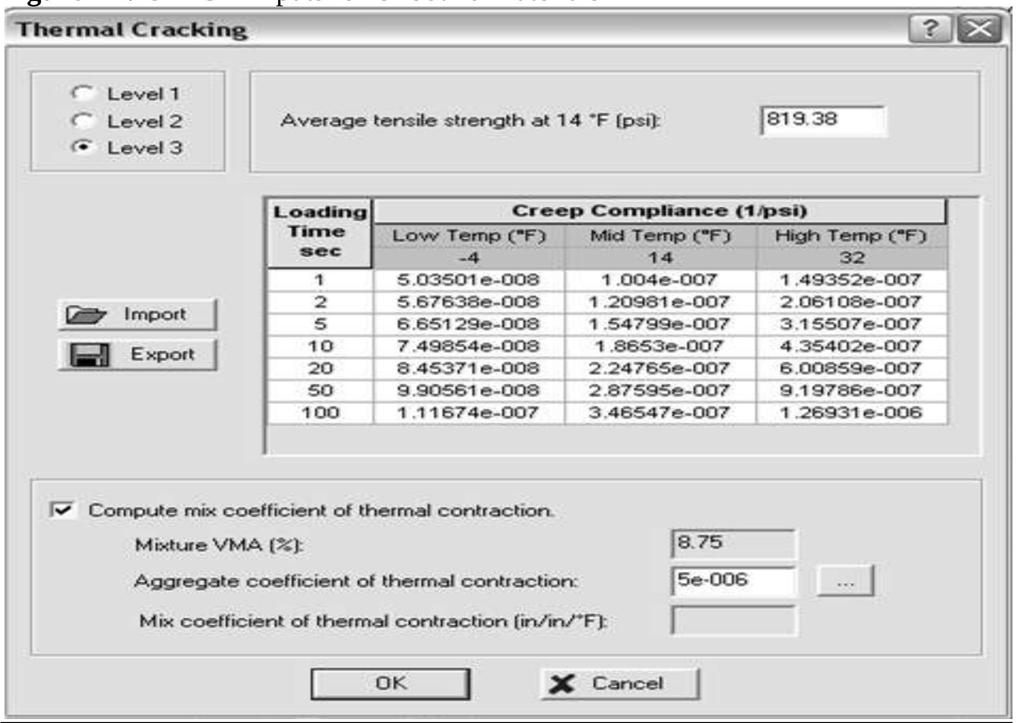


Figure A2.19 EICM Inputs for Unbound Materials



Loading Time sec	Creep Compliance (1/psi)		
	Low Temp (°F) -4	Mid Temp (°F) 14	High Temp (°F) 32
1	5.03501e-008	1.004e-007	1.49352e-007
2	5.67638e-008	1.20981e-007	2.06108e-007
5	6.65129e-008	1.54799e-007	3.15507e-007
10	7.49854e-008	1.8653e-007	4.35402e-007
20	8.45371e-008	2.24765e-007	6.00859e-007
50	9.90561e-008	2.87595e-007	9.19786e-007
100	1.11674e-007	3.46547e-007	1.26931e-006

Figure A2.20 Input Screen for Thermal Cracking (MEPDG Default)

APPENDIX B1: PAVEMENT DATABASE SURFACE/BASE TYPE DESIGNATIONS

Pavement Database Surface/Base Type Designations

The following designations were defined for use in the pavement management system.

Pavements:

G1: Standard PM Pavement with chip seal.
G2: Standard PM Pavement with plant mix wearing course.
G3: PM overlay of PCC pavement, no crack and seat.
G4: PM overlay of crack & seated PCC pavement.
G5: Plain jointed PCC pavement with PM inlay in driving lane.
G6: Standard PM Pavement with microsurfacing (DL or Full-width).
J1: Plain jointed full width PCC pavement.
J2: Dowel jointed full width PCC pavement.
J3: Plain jointed PCC pavement with PM pavement shoulders.
J4: Dowel jointed PCC pavement with PM pavement shoulders.
J5: PM pavement with PCC pavement inlay in driving lane.
J6: Dowel retrofitted Plain Jointed PCC pavement with PM pavement shoulders.
J7: Dowel retrofitted Plain Jointed full width PCC pavement.
K1: Plain jointed PCC pavement overlay (whitetop) over PM pavement
K2: Dowel jointed PCC pavement overlay (whitetop) over PM pavement

Bases:

AG: Aggregate base or rubblized cement treated base
PM: Plant mix treated base
CT: Cement treated base
AP: Asphalt treated permeable base
UP: Untreated permeable base
PC: Cracked and seated PCC pavement base
LT: Lime Stabilized Subgrade

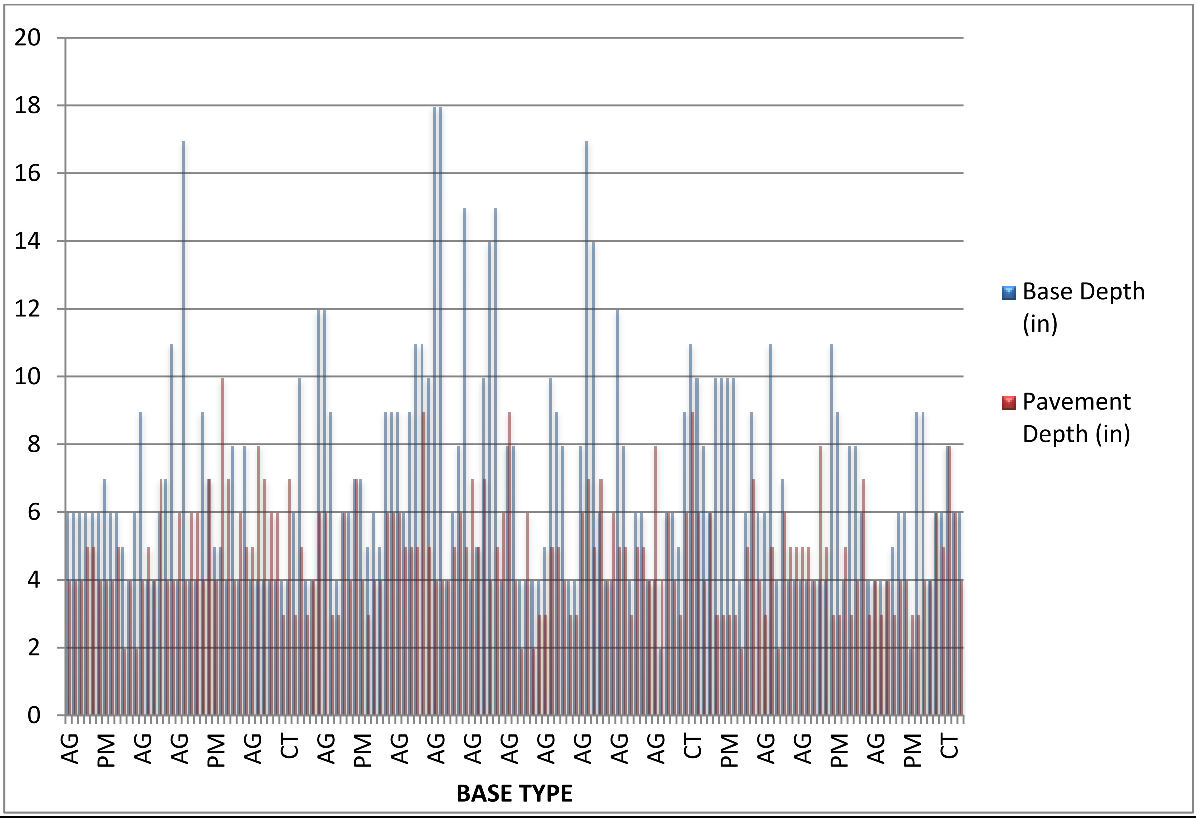
APPENDIX B2: EXTRACT FROM PRIMARY ROAD PMS

SYSTEM	ROUTE	BEG_MP	END_MP	PAVE_TYPE	LAST_REHAB	AADT	ESAL	PAVE_DEPTH	BASE_TYPE	BASE_DEPTH
P	10	0	2.37	G2	1987	1120	303	4	AG	6
P	10	1.122	11.59	G2	1989	1827	195	4	AG	6
P	10	84.93	85.59	G2	1988	3750	311	4	AG	6
P	10	85.59	87.16	G2	1987	4193	412	5	AG	6
P	10	118.3	120.9	G2	1999	1985	392	5	AG	6
P	10	120.9	127.2	G2	2001	1900	392	4	AG	6
P	10	127.2	132	G2	1998	1925	392	4	PM	7
P	10	132	136	G2	2002	1925	392	4	PM	6
P	10	136	139.3	G2	2000	1973	392	5	PM	6
P	10	139.3	142.5	G2	1986	2760	397	2	AG	5
P	10	142.5	146.8	G2	1982	3130	427	4	AG	4
P	10	146.8	148	G2	1977	3630	468	2	PM	6
P	10	148	151	G2	1998	4902	488	4	AG	9
P	10	151	154.3	G2	1989	9993	666	5	AG	4
P	10	155.1	158.8	G2	1973	4330	370	4	AG	4
P	13	0	1.147	G2	1983	7330	378	7	AG	6
P	13	1.618	2.867	G2	1995	3530	625	4	PM	7
P	13	2.867	4.71	G2	1995	1350	629	4	AG	11
P	13	111.3	115.3	G2	1987	995	191	6	AG	4
P	14	57.04	62.97	G2	1993	737	232	4	AG	17
P	16	96.96	99.02	G2	1990	2948	218	6	AG	4
P	20	47.22	54.37	G2	1990	360	150	6	AG	4
P	20	80.02	81.11	G2	1997	4513	305	4	PM	9
P	20	81.11	82.32	G2	2002	3170	337	7	AG	7
P	20	90.87	104.1	G2	1994	4381	465	4	PM	5
P	20	104.1	105.1	G2	2007	7418	459	10	AG	5
P	20	109.7	119.1	G2	1986	2018	540	7	AG	4
P	21	0.768	2.286	G2	1997	3003	442	4	AG	8
P	21	38.6	44.31	G2	2003	905	571	6	AG	4
P	21	79.6	88	G2	1989	1255	637	5	AG	8
P	21	88	94.08	G2	1990	1485	749	5	AG	4
P	21	94.08	98	G2	2000	1740	687	8	AG	4
P	21	98	101.1	G2	2000	1818	798	7	AG	4
P	21	101.1	106	G2	2000	2183	769	6	AG	4
P	21	106	107.9	G2	2000	2058	891	6	CT	4
P	21	107.9	111.7	G2	1995	4106	600	3	CT	4
P	21	111.7	113.2	G2	1992	11038	805	7	CT	4
P	21	114.8	115.3	G2	2005	6460	237	3	AG	6

SYSTEM	ROUTE	BEG_MP	END_MP	PAVE_TYPE	LAST_REHAB	AADT	ESAL	PAVE_DEPTH	BASE_TYPE	BASE_DEPTH
P	21	115.4	115.7	G2	1981	6607	245	5	AG	10
P	21	116.5	117.2	G2	1969	8927	637	3	AG	4
P	23	326.9	327.2	G2	1982	2730	143	4	AG	4
P	23	327.2	327.4	G2	1990	3670	156	6	AG	12
P	23	327.4	328.2	G2	1982	7750	271	6	AG	12
P	23	328.2	400.1	G2	1975	6675	278	3	AG	9
P	23	400.1	400.9	G2	1965	4895	660	3	AG	4
P	23	402.3	411.9	G2	1995	2380	545	6	PM	6
P	23	419.3	421.6	G2	1985	1585	621	4	CT	6
P	23	421.6	424.5	G2	1978	1585	621	7	PM	7
P	23	424.5	425.4	G2	1995	2069	660	4	PM	7
P	25	92.02	93.11	G2	1994	4478	393	3	AG	5
P	25	93.63	95.01	G2	1976	4775	472	4	AG	6
P	25	95.01	103.3	G2	1997	2353	569	4	PM	5
P	25	149	149.2	G2	2002	1700	186	6	AG	9
P	25	149.3	149.7	G2	2002	2748	407	6	AG	9
P	25	149.8	149.9	G2	2002	2510	377	6	AG	9
P	25	149.9	150.2	G2	1988	2200	375	5	AG	6
P	25	184.9	190.3	G2	1999	825	329	5	CT	9
P	25	190.3	192	G2	1999	689	285	5	CT	11
P	25	192	195.8	G2	1999	554	214	9	CT	11
P	25	195.8	202.6	G2	1995	413	123	5	CT	10
P	25	222.2	225.9	G2	1996	511	151	4	AG	18
P	25	225.9	229.3	G2	1996	708	159	4	AG	18
P	26	0	0.295	G2	1963	5865	195	4	AG	4
P	26	0.295	0.82	G2	1988	6099	218	5	AG	6
P	26	0.82	1.263	G2	1977	6006	181	6	AG	8
P	26	1.377	2.598	G2	1988	2905	180	5	AG	15
P	27	23.22	38.42	G2	2000	1157	424	7	AG	4
P	27	48.63	56.26	G2	1991	2712	379	5	PM	5
P	29	0.685	2.253	G2	2006	5455	360	7	AG	10
P	29	13.05	19.29	G2	2004	2407	385	4	AG	14
P	29	19.29	23.35	G2	2004	3130	275	5	CT	15
P	29	24.18	25.02	G2	2002	1710	190	6	AG	4
P	30	130.7	133.7	G2	1999	5712	186	9	AG	8
P	31	0	10	G2	1997	590	59	4	PM	8
P	31	27.47	36.41	G2	1975	698	69	2	AG	4
P	31	45.89	51.08	G2	2002	3093	202	6	AG	4

SYSTEM	ROUTE	BEG_MP	END_MP	PAVE_TYPE	LAST_REHAB	AADT	ESAL	PAVE_DEPTH	BASE_TYPE	BASE_DEPTH
P	31	51.08	51.78	G2	1994	4525	348	2	AG	4
P	31	52.96	54.8	G2	1994	3283	289	3	AG	4
P	33	0	0.674	G2	2003	1425	194	3	AG	5
P	33	38.18	43.12	G2	1994	550	170	5	CT	10
P	33	43.12	51.31	G2	1996	726	294	5	CT	9
P	33	72.91	81.21	G2	1991	1073	264	4	PM	8
P	34	0	2.89	G2	1990	4593	680	3	AG	4
P	34	0	1.1	G2	1999	4920	103	3	AG	4
P	34	3.874	10.37	G2	1990	5389	474	6	AG	8
P	34	10.36	21.24	G2	2002	1535	509	7	AG	17
P	34	164.1	164.6	G2	2006	1715	286	5	AG	14
P	34	164.7	165.4	G2	2000	2245	322	7	AG	6
P	34	165.8	166	G2	1985	4095	405	4	AG	4
P	34	186.3	197.7	G2	1991	1932	420	6	PM	4
P	34	202.6	203.6	G2	2005	2740	258	5	AG	12
P	34	203.6	205	G2	2007	3233	331	5	AG	8
P	34	205	205.3	G2	1962	2055	374	3	AG	4
P	36	80.09	87.16	G2	2003	620	87	5	AG	6
P	36	87.16	88.39	G2	2003	753	73	5	AG	6
P	36	90.83	91.96	G2	1990	3040	112	4	AG	4
P	36	100	100.7	G2	2003	3420	441	8	AG	4
P	37	20.36	20.55	G2	1992	310	48	4	AG	2
P	37	20.55	26.41	G2	1992	497	61	6	AG	6
P	37	61.6	66.3	G2	1999	453	56	4	AG	6
P	37	83.45	88.91	G2	2000	1235	100	3	PM	5
P	42	10.95	21.04	G2	1999	820	228	6	AG	9
P	43	8.662	18.21	G2	1997	1150	359	9	CT	11
P	43	107	111.2	G2	2000	8245	505	6	CT	10
P	43	111.2	112	G2	1994	19060	794	4	CT	8
P	43	113.1	114.9	G2	1979	7770	657	6	AG	6
P	43	114.9	115.2	G2	1981	8299	793	3	PM	10
P	43	115.3	115.4	G2	1981	3750	705	3	PM	10
P	43	115.4	115.4	G2	1984	3850	711	3	PM	10
P	43	115.5	118.8	G2	1981	1268	184	3	PM	10
P	44	0	0.252	G2	1963	1100	192	2	AG	4
P	49	0	0.381	G2	1988	1935	105	5	AG	6
P	49	1.084	1.764	G2	2004	1700	74	7	AG	9
P	51	4.324	4.646	G2	1996	4900	498	4	PM	6

SYSTEM	ROUTE	BEG_MP	END_MP	PAVE_TYPE	LAST_REHAB	AADT	ESAL	PAVE_DEPTH	BASE_TYPE	BASE_DEPTH
P	51	4.646	4.768	G2	1975	5760	311	3	AG	6
P	53	102.8	103.8	G2	1986	10035	464	5	PM	11
P	53	104.8	104.8	G2	1985	7316	324	2	CT	4
P	54	212	212	G2	1994	3885	319	6	AG	7
P	55	328.5	330.4	G2	1988	9085	169	5	AG	4
P	55	330.4	330.7	G2	1988	9544	224	5	AG	4
P	55	330.7	331	G2	1973	9402	219	5	AG	4
P	55	331	331.2	G2	1988	8572	214	5	AG	4
P	55	331.2	332.2	G2	1992	3073	224	4	AG	4
P	56	362.9	363.2	G2	1985	8310	229	8	AG	4
P	56	363.6	364.3	G2	1985	7888	205	5	AG	4
P	56	364.3	365.2	G2	1978	4100	152	3	PM	11
P	56	365.2	365.8	G2	1977	3830	174	3	PM	9
P	56	365.8	371.1	G2	1982	2233	116	5	AG	4
P	57	78.93	79	G2	1976	2570	150	3	AG	8
P	57	79.42	80.89	G2	1996	1545	100	4	AG	8
P	58	135.8	136.5	G2	1990	2565	208	7	AG	6
P	58	136.5	138	G2	1967	4025	236	3	AG	4
P	58	138	138.8	G2	1980	5403	228	4	AG	4
P	58	138.8	139.2	G2	1986	3550	104	3	PM	4
P	58	139.2	140	G2	1982	3895	138	4	AG	4
P	59	298.6	300.4	G2	1991	2829	146	3	PM	5
P	60	20.92	21.14	G2	1998	4925	350	4	CT	6
P	60	21.14	21.65	G2	1998	3940	190	4	CT	6
P	60	23.48	23.99	G2	1998	7289	274	3	PM	2
P	60	23.91	24.34	G2	1998	10070	213	3	PM	9
P	60	24.34	25.16	G2	1998	11182	324	4	PM	9
P	61	0.022	0.279	G2	1987	4750	181	4	AG	4
P	62	124.5	125.5	G2	1979	7589	336	6	AG	6
P	62	126.2	126.4	G2	2001	4325	392	5	CT	6
P	62	126.4	127.2	G2	2001	5569	255	8	CT	8
P	62	127.2	127.2	G2	2001	4423	317	6	CT	6
P	62	127.2	127.6	G2	2001	7589	336	4	CT	6



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BASE TYPE
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Pavement Depth (in)

APPENDIX B3: EXTRACT FROM SECONDARY ROAD PMS

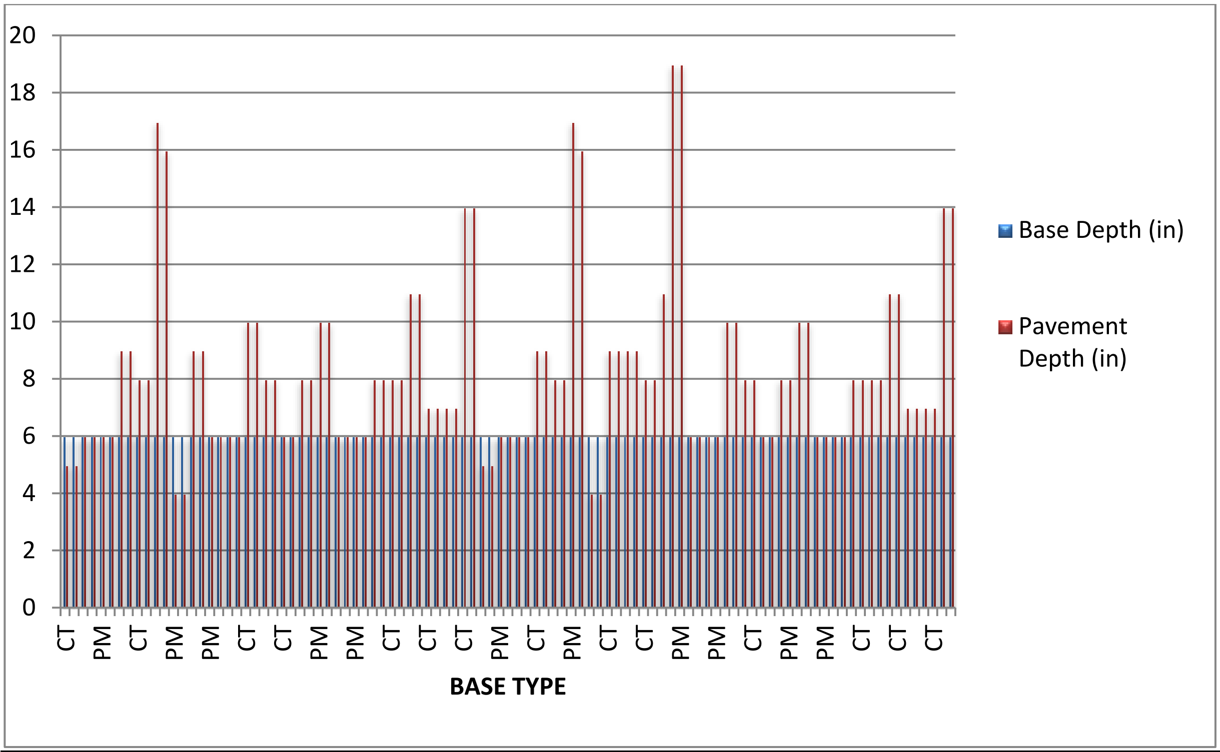
SYSTEM	ROUTE	BEG_MP	END_MP	PAVE_TYPE	LAST_REHAB	AADT	ESAL	PAVE_DEPTH	BASE_TYPE	BASE_DEPTH
S	107	3.92	10.4	G2	2004	1340	74	3	AG	12
S	109	28.5	30.6	G2	1997	274	30	4	AG	6
S	109	30.6	35.8	G2	1997	240	24	4	AG	6
S	109	35.8	45.1	G2	1995	335	40	4	AG	9
S	109	45.1	52.2	G2	1994	423	46	4	AG	6
S	302	89.3	99.3	G2	2002	880	114	2	AG	12
S	504	0	0.18	G2	2004	640	42	8	AG	8
S	504	0.18	1.38	G2	2004	746	24	8	AG	8
S	504	1.38	2.13	G2	2004	1033	61	10	AG	6
S	505	165	165	G2	1963	1419	83	3	AG	6
S	505	165	166	G2	2004	1668	82	6	AG	6
S	505	166	172	G2	1996	1150	89	5	AG	12
S	505	172	176	G2	1997	1260	89	5	AG	12
S	505	176	179	G2	1998	1260	89	7	AG	7
S	505	179	181	G2	1998	1260	89	7	AG	6
S	505	181	184	G2	1998	1450	108	7	AG	6
S	1501	1.66	2.74	G2	1979	1240	78	2	AG	6
S	1501	2.77	6.52	G2	1995	835	54	2	AG	6
S	1501	6.52	9.44	G2	1995	986	60	2	AG	6
S	1604	0.09	1.64	G2	1999	342	18	4	AG	8
S	1703	0	3.14	G2	2002	2190	78	5	AG	6
S	2000	0	3.67	G2	1984	8305	346	5	PM	7
S	2000	3.85	4.01	G2	1975	7095	264	6	AG	3
S	2000	4.01	6.58	G2	1984	3852	246	5	AG	6
S	2000	6.58	13.7	G2	2005	2100	83	2	AG	6
S	2000	13.7	17.5	G2	2005	1972	81	4	AG	4
S	2001	0	0.14	G2	1975	5335	226	4	AG	3
S	2001	0.14	6.63	G2	1971	4205	183	3	AG	4
S	2106	34.7	35.5	G2	2006	1015	66	8	AG	6
S	2106	35.4	42.3	G2	2006	1715	82	8	AG	6
S	2106	42.3	43.4	G2	1997	2053	76	3	AG	6
S	2303	27.3	28.1	G2	1995	883	111	4	AG	10

APPENDIX B4: EXTRACTS FROM I-80 PMS

SYSTEM	ROUTE	BEG_MP	END_MP	PAVE_TYPE	LAST_REHAB	AADT	ESAL	PAVE_DEPTH	BASE_TYPE	BASE_DEPTH
I	80	28.1	39	G2	1997	6453	5100	5	CT	6
I	80	39	28.1	G2	1997	6453	5100	5	CT	6
I	80	39	44	G2	1998	5855	4706	6	PM	6
I	80	44	39	G2	1998	5855	4706	6	PM	6
I	80	44	49	G2	1997	5800	4736	6	PM	6
I	80	49	44	G2	1997	5800	4736	6	PM	6
I	80	49	53	G2	2000	5800	4745	9	CT	6
I	80	53	49	G2	2000	5800	4745	9	CT	6
I	80	53	57	G2	2000	5800	4753	8	CT	6
I	80	57	53	G2	2000	5800	4753	8	CT	6
I	80	57	65.4	G2	2003	5758	4740	17	PM	6
I	80	65.4	57	G2	2003	5758	4740	16	PM	6
I	80	65.4	76	G2	1995	6545	5906	4	PM	6
I	80	76	65.4	G2	1995	6545	5906	4	PM	6
I	80	76	83	G2	1996	6695	5919	9	CT	6
I	80	83	76	G2	1996	6695	5919	9	CT	6
I	80	143	148.5	G2	1998	6090	5633	6	PM	6
I	80	149	143	G2	1998	6090	5633	6	PM	6
I	80	149	153.8	G2	1998	6085	5633	6	PM	6
I	80	154	148.5	G2	1998	6085	5633	6	PM	6
I	80	216	221.2	G2	2000	6455	6071	10	CT	6
I	80	221	216.2	G2	2000	6455	6071	10	CT	6
I	80	221	227.5	G2	1997	6355	6062	8	CT	6
I	80	228	221.2	G2	1997	6355	6062	8	CT	6
I	80	228	233.7	G2	2001	6215	5907	6	CT	6
I	80	234	227.5	G2	2001	6215	5907	6	CT	6
I	80	246	252	G2	1999	5975	5718	8	PM	6
I	80	252	245.9	G2	1999	5975	5718	8	PM	6
I	80	252	258.6	G2	1999	5975	5718	10	PM	6
I	80	259	252	G2	1999	5975	5718	10	PM	6
I	80	276	280.7	G2	2001	5490	5476	6	PM	6
I	80	281	275.6	G2	2001	5490	5476	6	PM	6
I	80	281	285	G2	2001	5430	5391	6	PM	6
I	80	285	280.7	G2	2001	5430	5391	6	PM	6
I	80	290	295	G2	2004	5430	5391	8	CT	6
I	80	295	289.9	G2	2004	5430	5391	8	CT	6
I	80	295	299.5	G2	2004	5430	5391	8	CT	6
I	80	300	295	G2	2004	5430	5391	8	CT	6

SYSTEM	ROUTE	BEG_MP	END_MP	PAVE_TYPE	LAST_REHAB	AADT	ESAL	PAVE_DEPTH	BASE_TYPE	BASE_DEPTH
I	80	300	310.5	G2	1991	5535	5191	11	CT	6
I	80	311	299.5	G2	1991	5535	5191	11	CT	6
I	80	324	329.6	G2	2005	6245	5233	7	CT	6
I	80	330	324	G2	2005	6245	5233	7	CT	6
I	80	330	336.6	G2	2006	6245	5233	7	CT	6
I	80	337	329.6	G2	2006	6245	5233	7	CT	6
I	80	337	348.5	G2	2004	6382	5278	14	CT	6
I	80	349	336.6	G2	2004	6382	5278	14	CT	6
I	80	28.1	39	G2	1997	6453	5100	5	CT	6
I	80	39	28.1	G2	1997	6453	5100	5	CT	6
I	80	39	44	G2	1998	5855	4706	6	PM	6
I	80	44	39	G2	1998	5855	4706	6	PM	6
I	80	44	49	G2	1997	5800	4736	6	PM	6
I	80	49	44	G2	1997	5800	4736	6	PM	6
I	80	49	53	G2	2000	5800	4745	9	CT	6
I	80	53	49	G2	2000	5800	4745	9	CT	6
I	80	53	57	G2	2000	5800	4753	8	CT	6
I	80	57	53	G2	2000	5800	4753	8	CT	6
I	80	57	65.4	G2	2003	5758	4740	17	PM	6
I	80	65.4	57	G2	2003	5758	4740	16	PM	6
I	80	65.4	76	G2	1995	6545	5906	4	PM	6
I	80	76	65.4	G2	1995	6545	5906	4	PM	6
I	80	76	83	G2	1996	6695	5919	9	CT	6
I	80	83	76	G2	1996	6695	5919	9	CT	6
I	80	108	120.3	G2	2003	6515	5747	9	CT	6
I	80	120	107.6	G2	2003	6515	5747	9	CT	6
I	80	120	130	G2	1996	6490	5550	8	CT	6
I	80	130	120.3	G2	2001	6490	5550	8	CT	6
I	80	138	130	G2	2001	6190	5208	11	CT	6
I	80	138	143	G2	1994	6040	5198	19	PM	6
I	80	143	138	G2	1994	6040	5198	19	PM	6
I	80	143	148.5	G2	1998	6090	5633	6	PM	6
I	80	149	143	G2	1998	6090	5633	6	PM	6
I	80	149	153.8	G2	1998	6085	5633	6	PM	6
I	80	154	148.5	G2	1998	6085	5633	6	PM	6
I	80	216	221.2	G2	2000	6455	6071	10	CT	6
I	80	221	216.2	G2	2000	6455	6071	10	CT	6
I	80	221	227.5	G2	1997	6355	6062	8	CT	6

SYSTEM	ROUTE	BEG_MP	END_MP	PAVE_TYPE	LAST_REHAB	AADT	ESAL	PAVE_DEPTH	BASE_TYPE	BASE_DEPTH
I	80	228	221.2	G2	1997	6355	6062	8	CT	6
I	80	228	233.7	G2	2001	6215	5907	6	CT	6
I	80	234	227.5	G2	2001	6215	5907	6	CT	6
I	80	246	252	G2	1999	5975	5718	8	PM	6
I	80	252	245.9	G2	1999	5975	5718	8	PM	6
I	80	252	258.6	G2	1999	5975	5718	10	PM	6
I	80	259	252	G2	1999	5975	5718	10	PM	6
I	80	276	280.7	G2	2001	5490	5476	6	PM	6
I	80	281	275.6	G2	2001	5490	5476	6	PM	6
I	80	281	285	G2	2001	5430	5391	6	PM	6
I	80	285	280.7	G2	2001	5430	5391	6	PM	6
I	80	290	295	G2	2004	5430	5391	8	CT	6
I	80	295	289.9	G2	2004	5430	5391	8	CT	6
I	80	295	299.5	G2	2004	5430	5391	8	CT	6
I	80	300	295	G2	2004	5430	5391	8	CT	6
I	80	300	310.5	G2	1991	5535	5191	11	CT	6
I	80	311	299.5	G2	1991	5535	5191	11	CT	6
I	80	324	329.6	G2	2005	6245	5233	7	CT	6
I	80	330	324	G2	2005	6245	5233	7	CT	6
I	80	330	336.6	G2	2006	6245	5233	7	CT	6
I	80	337	329.6	G2	2006	6245	5233	7	CT	6
I	80	337	348.5	G2	2004	6382	5278	14	CT	6
I	80	349	336.6	G2	2004	6382	5278	14	CT	6



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BASE TYPE
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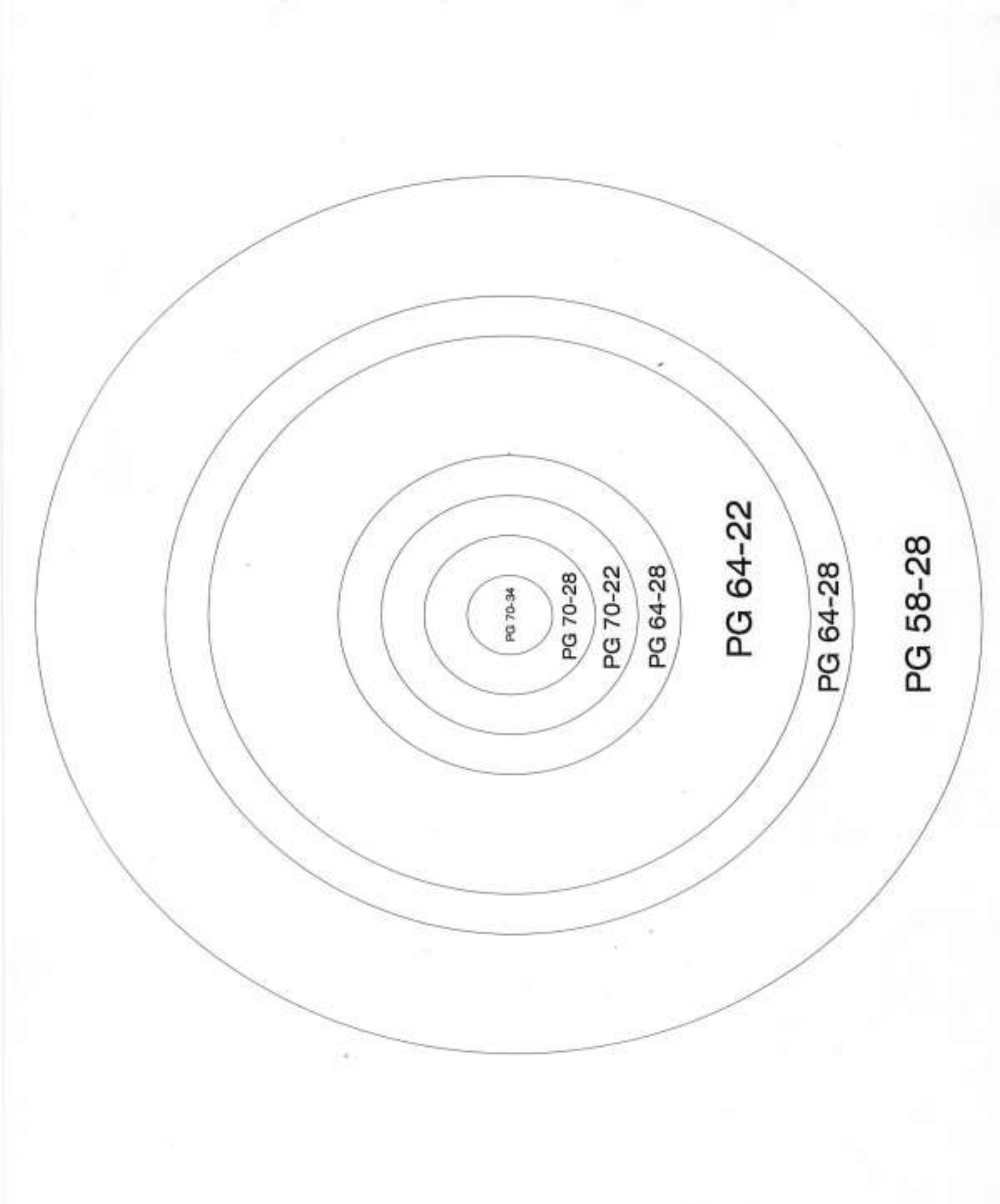
Pavement Depth (in)

APPENDIX B5: WYDOT BINDER GRADES



APPENDIX C1: PREDICTED DISTRESSES FOR DIFFERENT BINDER GRADES

Pavement #1 Structural Layers

Layer 1- 3in Asphalt Concrete - PG76-28
Layer 2- 3in Asphalt Concrete - PG64-28
Layer 3- 6in Asphalt Permeable Base - PG64-28
Layer 4- Subgrade (Classification A3; R-value – 42)

Table C1.1 Predicted Distresses for Pavement #1 at Big Piney

Performance Criteria	Distress Target	Reliability Target	Distress Predicted	Reliability Predicted	Acceptable
Terminal IRI (in/mi)	190	90	123.3	97.60	Pass
Longitudinal Cracking (ft/mi)	2000	90	0.1	99.99	Pass
Alligator Cracking (%)	25	90	0.1	99.99	Pass
Transverse Cracking (ft/mi)	***1000***	***90***	***1595.1***	***2.34***	***Fail***
AC Deformation (in)	0.25	90	0.1	99.99	Pass
Total Pavement Deformation (in)	0.75	90	0.24	99.99	Pass

Pavement #2 Structural Layers

Layer 1- 3in Asphalt Concrete - PG52-28
Layer 2- 3in Asphalt Concrete - PG52-28
Layer 3- 6in Asphalt Permeable Base - PG52-28
Layer 4- Subgrade (Classification A3; R-value – 42)

Table C1.2 Predicted Distresses for Pavement #2 at Big Piney

Performance Criteria	Distress Target	Reliability Target	Distress Predicted	Reliability Predicted	Acceptable
Terminal IRI (in/mi)	190	90	124.8	97.26	Pass
Longitudinal Cracking (ft/mi)	2000	90	4.1	99.97	Pass
Alligator Cracking (%)	25	90	0.1	99.99	Pass
Transverse Cracking (ft/mi)	***1000***	***90***	***1288.4***	***12.83***	***Fail***
AC Deformation (in)	0.25	90	***0.19***	***81.56***	***Fail***
Total Pavement Deformation (in)	0.75	90	0.34	99.99	Pass

Pavement #3 Structural Layers

Layer 1- 3in Asphalt Concrete - PG52-22
Layer 2- 3in Asphalt Concrete - PG52-22
Layer 3- 6in Asphalt Permeable Base - PG52-22
Layer 4- Subgrade (Classification A3; R-value – 42)

Table C1.3 Maximum values of Predicted Distresses for Pavement #3 at Big Piney

Performance Criteria	Distress Target	Reliability Target	Distress Predicted	Reliability Predicted	Acceptable
Terminal IRI (in/mi)	190	90	127.2	96.57	Pass
Longitudinal Cracking (ft/mi)	2000	90	2.6	99.99	Pass
Alligator Cracking (%)	25	90	0.1	99.99	Pass
Transverse Cracking (ft/mi)	***1000***	***90***	***1696.9***	***1.33***	***Fail***
AC Deformation (in)	***0.25***	***90***	***0.17***	***89.58***	***Fail***
Total Pavement Deformation (in)	0.75	90	0.32	99.99	Pass

Pavement #4 Structural Layers

Layer 1- 3in Asphalt Concrete - PG58-22
Layer 2- 3in Asphalt Concrete - PG58-22
Layer 3- 6in Asphalt Permeable Base - PG58-22
Layer 4- Subgrade (Classification A3; R-value – 42)

Table C1.4 Maximum Distresses of Predicted Distresses for Pavement #4 at Big Piney

Performance Criteria	Distress Target	Reliability Target	Distress Predicted	Reliability Predicted	Acceptable
Terminal IRI (in/mi)	190	90	126	96.89	Pass
Longitudinal Cracking (ft/mi)	2000	90	0.6	99.99	Pass
Alligator Cracking (%)	25	90	0.1	99.99	Pass
Transverse Cracking (ft/mi)	***1000***	***90***	***1778.9***	***0.85***	***Fail***
AC Deformation (in)	0.25	90	0.13	99.08	Pass
Total Pavement Deformation (in)	0.75	90	0.28	99.99	Pass

Pavement #5 Structural Layers

Layer 1- 3in Asphalt Concrete - PG64-22
Layer 2- 3in Asphalt Concrete - PG58-22
Layer 3- 6in Asphalt Permeable Base - PG58-22
Layer 4- Subgrade (Classification A3; R-value – 42)

Table C1.5 Maximum values of Predicted Distresses for Pavement #5 at Big Piney

Performance Criteria	Distress Target	Reliability Target	Distress Predicted	Reliability Predicted	Acceptable
Terminal IRI (in/mi)	190	90	125.5	97.04	Pass
Longitudinal Cracking (ft/mi)	2000	90	0.2	99.99	Pass
Alligator Cracking (%)	25	90	0.1	99.99	Pass
Transverse Cracking (ft/mi)	***1000***	***90***	***1791.3***	***0.79***	***Fail***
AC Deformation (in)	0.25	90	0.12	99.83	Pass
Total Pavement Deformation (in)	0.75	90	0.26	99.99	Pass

#6 Structural Layers (Big Piney Weather Station Only)

Layer 1- 3in Asphalt Concrete - PG70-22
Layer 2- 3in Asphalt Concrete - PG58-22
Layer 3- 6in Asphalt Permeable Base - PG58-22
Layer 4- Subgrade (Classification A3; R-value – 42)

Table C1.6 Maximum values of Predicted Distresses for Pavement #6 at Big Piney

Performance Criteria	Distress Target	Reliability Target	Distress Predicted	Reliability Predicted	Acceptable
Terminal IRI (in/mi)	190	90	125.2	97.12	Pass
Longitudinal Cracking (ft/mi)	2000	90	0.1	99.99	Pass
Alligator Cracking (%)	25	90	0.1	99.99	Pass
Transverse Cracking (ft/mi)	***1000***	***90***	***1812***	***0.71***	***Fail***
AC Deformation (in)	0.25	90	0.11	99.97	Pass
Total Pavement Deformation (in)	0.75	90	0.25	99.99	Pass

APPENDIX D1: PREDICTED DISTRESSES FOR INTERSTATE SYSTEM

TERMINAL IRI (in/mi)												
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	IRI-1	**IRI-2**	**IRI_{1-2}**		**IRI-1**	**IRI-3**	**IRI_{1-3}**		**IRI-2**	**IRI-3**	**IRI_{2-3}**
Big Piney	124.8	121.1	3.700		124.8	112	12.800		121.1	112	9.100
Buffalo	120.3	127.1	-6.800		120.3	120.6	-0.300		127.1	120.6	6.500
Casper Na	121.5	120.6	0.900		121.5	120.8	0.700		120.6	120.8	-0.200
Cheyenne	114.3	122.1	-7.800		114.3	115.5	-1.200		122.1	115.5	6.600
Doug. Avn	121.8	119.4	2.400		121.8	120.3	1.500		119.4	120.3	-0.900
Evanston	112.5	117.2	-4.700		112.5	122.2	-9.700		117.2	122.2	-5.000
Gillette	122.0	119.1	2.900		122.0	119.4	2.600		119.1	119.4	-0.300
Greybull	126.0	124.3	1.700		126.0	125.8	0.200		124.3	125.8	-1.500
Lander	121.3	120.6	0.700		121.3	121.2	0.100		120.6	121.2	-0.600
Laramie	117.7	119.3	-1.600		117.7	118.3	-0.600		119.3	118.3	1.000
Rawlins	117.5	120.2	-2.700		117.5	112.5	5.000		120.2	112.5	7.700
Riverton	121.2	121.2	0.000		121.2	121.3	-0.100		121.2	121.3	-0.100
Rock Springs	113.6	119.5	-5.900		113.6	120.1	-6.500		119.5	120.1	-0.600
Sheridan	123.4	126.2	-2.800		123.4	126.4	-3.000		126.2	126.4	-0.200
Worland	129.9	119.6	10.300		129.9	125.2	4.700		119.6	125.2	-5.600

IRI-1 International Roughness Index from Actual Weather Data.
IRI-2 International Roughness Index from Virtual Weather Data generated by interpolation using all neighboring stations.
IRI-3 International Roughness Index from Virtual Weather Data generated by interpolation using stations with similar elevation.

AC SURFACE DOWN CRACKING (LONGITUDINAL CRACKING) (ft/mile)											
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	LC-1	**LC-2**	**LC_{1-2}**		**LC-1**	**LC-3**	**LC_{1-3}**		**LC-2**	**LC-3**	**LC_{2-3}**
Big Piney	4.1	4.6	-0.500		4.1	5.5	-1.400		4.6	5.5	-0.900
Buffalo	10.3	5.7	4.600		10.3	7.3	3.000		5.7	7.3	-1.600
Casper Na	10.0	9.8	0.200		10.0	9.4	0.600		9.8	9.4	0.400
Cheyenne	2.3	1.8	0.500		2.3	1.9	0.400		1.8	1.9	-0.100
Doug. Avn	14.3	7.0	7.300		14.3	10.3	4.000		7.0	10.3	-3.300
Evanston	3.5	2.5	1.000		3.5	9	-5.500		2.5	9	-6.500
Gillette	12.0	7.6	4.400		12.0	9.6	2.400		7.6	9.6	-2.000
Greybull	81.5	10.8	70.700		81.5	24.3	57.200		10.8	24.3	-13.500
Lander	19.5	15.6	3.900		19.5	18.2	1.300		15.6	18.2	-2.600
Laramie	3.1	1.0	2.100		3.1	5.8	-2.700		1.0	5.8	-4.800
Rawlins	7.3	3.5	3.800		7.3	5.3	2.000		3.5	5.3	-1.800
Riverton	17.9	16.3	1.600		17.9	19.3	-1.400		16.3	19.3	-3.000
Rock Springs	11.1	6.3	4.800		11.1	4.9	6.200		6.3	4.9	1.400
Sheridan	15.4	12.3	3.100		15.4	15.6	-0.200		12.3	15.6	-3.300
Worland	72.2	20.5	51.700		72.2	32.5	39.700		20.5	32.5	-12.000

LC-1 Longitudinal Cracking from Actual Weather Data.
LC-2 Longitudinal Cracking from Virtual Weather Data generated by interpolation using all neighboring stations.
LC-3 Longitudinal Cracking from Virtual Weather Data generated by interpolation using stations with similar elevation.

AC BOTTOM UP CRACKING (ALLIGATOR CRACKING) (%)											
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	AC-1	**AC-2**	**AC_{1-2}**		**AC-1**	**AC-3**	**AC_{1-3}**		**AC-2**	**AC-3**	**AC_{2-3}**
Big Piney	0.1	0.1	0.000		0.1	0.1	0.000		0.1	0.1	0.000
Buffalo	0.2	0.1	0.100		0.2	0.2	0.000		0.1	0.2	-0.100
Casper Na	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Cheyenne	0.1	0.1	0.000		0.1	0.1	0.000		0.1	0.1	0.000
Doug. Avn	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Evanston	0.1	0.1	0.000		0.1	0.1	0.000		0.1	0.1	0.000
Gillette	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Greybull	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Lander	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Laramie	0.1	0.1	0.000		0.1	0.1	0.000		0.1	0.1	0.000
Rawlins	0.1	0.1	0.000		0.1	0.1	0.000		0.1	0.1	0.000
Riverton	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Rock Springs	0.1	0.1	0.000		0.1	0.1	0.000		0.1	0.1	0.000
Sheridan	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Worland	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000

AC-1 Alligator Cracking from Actual Weather Data.
AC-2 Alligator Cracking from Virtual Weather Data generated by interpolation using all neighboring stations.
AC-3 Alligator Cracking from Virtual Weather Data generated by interpolation using stations with similar elevation.

THERMAL FRACTURE (TRANSVERSE CRACKING) (ft/mi)											
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	TC-1	**TC-2**	**TC_{1-2}**		**TC-1**	**TC-3**	**TC_{1-3}**		**TC-2**	**TC-3**	**TC_{2-3}**
Big Piney	1289.2	826.7	462.500		1288.4	4.6	1283.800		826.7	4.6	822.100
Buffalo	697.2	1496.6	-799.400		697.2	809.5	-112.300		1496.6	809.5	687.100
Casper Na	861.0	711.3	149.700		861.0	735.6	125.400		711.3	735.6	-24.300
Cheyenne	154.8	1117.7	-962.900		154.8	382.1	-227.300		1117.7	382.1	735.600
Doug. Avn	747.5	649.9	97.600		747.5	724.1	23.400		649.9	724.1	-74.200
Evanston	3.1	339.8	-336.700		3.1	1072.4	-1069.300		339.8	1072.4	-732.600
Gillette	776.9	516.8	260.100		776.9	530.2	246.700		516.8	530.2	-13.400
Greybull	1051.0	1032.1	18.900		1051.0	1024.3	26.700		1032.1	1024.3	7.800
Lander	530.5	672.4	-141.900		530.5	702.7	-172.200		672.4	702.7	-30.300
Laramie	780.5	864	-83.500		780.5	775.7	4.800		864	775.7	88.300
Rawlins	588.1	826	-237.900		588.1	99.4	488.700		826	99.4	726.600
Riverton	716.9	584.8	132.100		716.9	537.5	179.400		584.8	537.5	47.300
Rock Springs	57.7	751.6	-693.900		57.7	986.4	-928.700		751.6	986.4	-234.800
Sheridan	740.1	1405.7	-665.600		740.1	1411.4	-671.300		1405.7	1411.4	-5.700
Worland	1294.8	401.6	893.200		1294.8	1059.7	235.100		401.6	1059.7	-658.100

TC-1 Transverse Cracking from Actual Weather Data.
TC-2 Transverse Cracking from Virtual Weather Data generated by interpolation using all neighboring stations.
TC-3 Transverse Cracking from Virtual Weather Data generated by interpolation using stations with similar elevation.

PERMANENT DEFORMATION (HMA LAYER) (in)											
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	ACR-1	**ACR-2**	**ACR_{1-2}**		**ACR-1**	**ACR-3**	**ACR_{1-3}**		**ACR-2**	**ACR-3**	**ACR_{2-3}**
Big Piney	0.19	0.21	-0.020		0.19	0.19	0.000		0.21	0.19	0.020
Buffalo	0.24	0.22	0.020		0.24	0.22	0.020		0.22	0.22	0.000
Casper Na	0.24	0.24	0.000		0.24	0.24	0.000		0.24	0.24	0.000
Cheyenne	0.19	0.18	0.010		0.19	0.18	0.010		0.18	0.18	0.000
Doug. Avn	0.26	0.23	0.030		0.26	0.24	0.020		0.23	0.24	-0.010
Evanston	0.18	0.19	-0.010		0.18	0.21	-0.030		0.19	0.21	-0.020
Gillette	0.25	0.24	0.010		0.25	0.24	0.010		0.24	0.24	0.000
Greybull	0.34	0.26	0.080		0.34	0.29	0.050		0.26	0.29	-0.030
Lander	0.28	0.25	0.030		0.28	0.26	0.020		0.25	0.26	-0.010
Laramie	0.17	0.16	0.010		0.17	0.19	-0.020		0.16	0.19	-0.030
Rawlins	0.20	0.20	0.000		0.20	0.19	0.010		0.20	0.19	0.010
Riverton	0.26	0.27	-0.010		0.26	0.28	-0.020		0.27	0.28	-0.010
Rock Springs	0.22	0.21	0.010		0.22	0.18	0.040		0.21	0.18	0.030
Sheridan	0.28	0.25	0.030		0.28	0.25	0.030		0.25	0.25	0.000
Worland	0.35	0.28	0.070		0.35	0.29	0.060		0.28	0.29	-0.010

ACR-1 AC Rutting from Actual Weather Data.
ACR-2 AC Rutting from Virtual Weather Data generated by interpolation using all neighboring stations.
ACR-3 AC Rutting from Virtual Weather Data generated by interpolation using stations with similar elevation.

TOTAL PAVEMENT DEFORMATION (in)											
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	TR-1	**TR-2**	**TR_{1-2}**		**TR-1**	**TR-3**	**TR_{1-3}**		**TR-2**	**TR-3**	**TR_{2-3}**
Big Piney	0.34	0.36	-0.020		0.34	0.33	0.010		0.36	0.33	0.030
Buffalo	0.38	0.37	0.010		0.38	0.37	0.010		0.37	0.37	0.000
Casper Na	0.39	0.39	0.000		0.39	0.39	0.000		0.39	0.39	0.000
Cheyenne	0.34	0.33	0.010		0.34	0.32	0.020		0.33	0.32	0.010
Doug. Avn	0.41	0.37	0.040		0.41	0.39	0.020		0.37	0.39	-0.020
Evanston	0.32	0.34	-0.020		0.32	0.35	-0.030		0.34	0.35	-0.010
Gillette	0.40	0.39	0.010		0.40	0.39	0.010		0.39	0.39	0.000
Greybull	0.48	0.41	0.070		0.48	0.45	0.030		0.41	0.45	-0.040
Lander	0.43	0.40	0.030		0.43	0.41	0.020		0.40	0.41	-0.010
Laramie	0.31	0.31	0.000		0.31	0.33	-0.020		0.31	0.33	-0.020
Rawlins	0.34	0.34	0.000		0.34	0.32	0.020		0.34	0.32	0.020
Riverton	0.41	0.42	-0.010		0.41	0.43	-0.020		0.42	0.43	-0.010
Rock Springs	0.36	0.35	0.010		0.36	0.32	0.040		0.35	0.32	0.030
Sheridan	0.43	0.40	0.030		0.43	0.4	0.030		0.40	0.4	0.000
Worland	0.50	0.43	0.070		0.50	0.44	0.060		0.43	0.44	-0.010

TR-1 Total Rutting from Actual Weather Data.
TR-2 Total Rutting from Virtual Weather Data generated by interpolation using all neighboring stations.
TR-3 Total Rutting from Virtual Weather Data generated by interpolation using stations with similar elevation.

	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	IRI-1	**IRI-2**	**IRI_{1-2}**		**IRI-1**	**IRI-3**	**IRI_{1-3}**		**IRI-2**	**IRI-3**	**IRI_{2-3}**
Big Piney	124.8	121.1	-0.030		124.8	112	-0.103		121.1	112	-0.075
Buffalo	120.3	127.1	0.057		120.3	120.6	0.002		127.1	120.6	-0.051
Casper Na	121.5	120.6	-0.007		121.5	120.8	-0.006		120.6	120.8	0.002
Cheyenne	114.3	122.1	0.068		114.3	115.5	0.010		122.1	115.5	-0.054
Doug. Avn	121.8	119.4	-0.020		121.8	120.3	-0.012		119.4	120.3	0.008
Evanston	112.5	117.2	0.042		112.5	122.2	0.086		117.2	122.2	0.043
Gillette	122.0	119.1	-0.024		122.0	119.4	-0.021		119.1	119.4	0.003
Greybull	126.0	124.3	-0.013		126.0	125.8	-0.002		124.3	125.8	0.012
Lander	121.3	120.6	-0.006		121.3	121.2	-0.001		120.6	121.2	0.005
Laramie	117.7	119.3	0.014		117.7	118.3	0.005		119.3	118.3	-0.008
Rawlins	117.5	120.2	0.023		117.5	112.5	-0.043		120.2	112.5	-0.064
Riverton	121.2	121.2	0.000		121.2	121.3	0.001		121.2	121.3	0.001
Rock Springs	113.6	119.5	0.052		113.6	120.1	0.057		119.5	120.1	0.005
Sheridan	123.4	126.2	0.023		123.4	126.4	0.024		126.2	126.4	0.002
Worland	129.9	119.6	-0.079		129.9	125.2	-0.036		119.6	125.2	0.047

	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	LC-1	**LC-2**	**LC_{1-2}**		**LC-1**	**LC-3**	**LC_{1-3}**		**LC-2**	**LC-3**	**LC_{2-3}**
Big Piney	4.1	4.6	0.122		4.1	5.5	0.341		4.6	5.5	0.196
Buffalo	10.3	5.7	-0.447		10.3	7.3	-0.291		5.7	7.3	0.281
Casper Na	10.0	9.8	-0.020		10.0	9.4	-0.060		9.8	9.4	-0.041
Cheyenne	2.3	1.8	-0.217		2.3	1.9	-0.174		1.8	1.9	0.056
Doug. Avn	14.3	7.0	-0.510		14.3	10.3	-0.280		7.0	10.3	0.471
Evanston	3.5	2.5	-0.286		3.5	9	1.571		2.5	9	2.600
Gillette	12.0	7.6	-0.367		12.0	9.6	-0.200		7.6	9.6	0.263
Greybull	81.5	10.8	-0.867		81.5	24.3	-0.702		10.8	24.3	1.250
Lander	19.5	15.6	-0.200		19.5	18.2	-0.067		15.6	18.2	0.167
Laramie	3.1	1.0	-0.677		3.1	5.8	0.871		1.0	5.8	4.800
Rawlins	7.3	3.5	-0.521		7.3	5.3	-0.274		3.5	5.3	0.514
Riverton	17.9	16.3	-0.089		17.9	19.3	0.078		16.3	19.3	0.184
Rock Springs	11.1	6.3	-0.432		11.1	4.9	-0.559		6.3	4.9	-0.222
Sheridan	15.4	12.3	-0.201		15.4	15.6	0.013		12.3	15.6	0.268
Worland	72.2	20.5	-0.716		72.2	32.5	-0.550		20.5	32.5	0.585

	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	AC-1	**AC-2**	**AC_{1-2}**		**AC-1**	**AC-3**	**AC_{1-3}**		**AC-2**	**AC-3**	**AC_{2-3}**
Big Piney	0.1	0.1	0.000		0.1	0.1	0.000		0.1	0.1	0.000
Buffalo	0.2	0.1	-0.500		0.2	0.2	0.000		0.1	0.2	1.000
Casper Na	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Cheyenne	0.1	0.1	0.000		0.1	0.1	0.000		0.1	0.1	0.000
Doug. Avn	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Evanston	0.1	0.1	0.000		0.1	0.1	0.000		0.1	0.1	0.000
Gillette	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Greybull	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Lander	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Laramie	0.1	0.1	0.000		0.1	0.1	0.000		0.1	0.1	0.000
Rawlins	0.1	0.1	0.000		0.1	0.1	0.000		0.1	0.1	0.000
Riverton	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Rock Springs	0.1	0.1	0.000		0.1	0.1	0.000		0.1	0.1	0.000
Sheridan	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Worland	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000

	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	TC-1	**TC-2**	**TC_{1-2}**		**TC-1**	**TC-3**	**TC_{1-3}**		**TC-2**	**TC-3**	**TC_{2-3}**
Big Piney	1289.2	826.7	-0.359		1288.4	4.6	-0.996		826.7	4.6	-0.994
Buffalo	697.2	1496.6	1.147		697.2	809.5	0.161		1496.6	809.5	-0.459
Casper Na	861.0	711.3	-0.174		861.0	735.6	-0.146		711.3	735.6	0.034
Cheyenne	154.8	1117.7	6.220		154.8	382.1	1.468		1117.7	382.1	-0.658
Doug. Avn	747.5	649.9	-0.131		747.5	724.1	-0.031		649.9	724.1	0.114
Evanston	3.1	339.8	108.613		3.1	1072.4	344.935		339.8	1072.4	2.156
Gillette	776.9	516.8	-0.335		776.9	530.2	-0.318		516.8	530.2	0.026
Greybull	1051.0	1032.1	-0.018		1051.0	1024.3	-0.025		1032.1	1024.3	-0.008
Lander	530.5	672.4	0.267		530.5	702.7	0.325		672.4	702.7	0.045
Laramie	780.5	864	0.107		780.5	775.7	-0.006		864	775.7	-0.102
Rawlins	588.1	826	0.405		588.1	99.4	-0.831		826	99.4	-0.880
Riverton	716.9	584.8	-0.184		716.9	537.5	-0.250		584.8	537.5	-0.081
Rock Springs	57.7	751.6	12.026		57.7	986.4	16.095		751.6	986.4	0.312
Sheridan	740.1	1405.7	0.899		740.1	1411.4	0.907		1405.7	1411.4	0.004
Worland	1294.8	401.6	-0.690		1294.8	1059.7	-0.182		401.6	1059.7	1.639

	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	ACR-1	**ACR-2**	**ACR_{1-2}**		**ACR-1**	**ACR-3**	**ACR_{1-3}**		**ACR-2**	**ACR-3**	**ACR_{2-3}**
Big Piney	0.19	0.21	0.105		0.19	0.19	0.000		0.21	0.19	-0.095
Buffalo	0.24	0.22	-0.083		0.24	0.22	-0.083		0.22	0.22	0.000
Casper Na	0.24	0.24	0.000		0.24	0.24	0.000		0.24	0.24	0.000
Cheyenne	0.19	0.18	-0.053		0.19	0.18	-0.053		0.18	0.18	0.000
Doug. Avn	0.26	0.23	-0.115		0.26	0.24	-0.077		0.23	0.24	0.043
Evanston	0.18	0.19	0.056		0.18	0.21	0.167		0.19	0.21	0.105
Gillette	0.25	0.24	-0.040		0.25	0.24	-0.040		0.24	0.24	0.000
Greybull	0.34	0.26	-0.235		0.34	0.29	-0.147		0.26	0.29	0.115
Lander	0.28	0.25	-0.107		0.28	0.26	-0.071		0.25	0.26	0.040
Laramie	0.17	0.16	-0.059		0.17	0.19	0.118		0.16	0.19	0.188
Rawlins	0.20	0.20	0.000		0.20	0.19	-0.050		0.20	0.19	-0.050
Riverton	0.26	0.27	0.038		0.26	0.28	0.077		0.27	0.28	0.037
Rock Springs	0.22	0.21	-0.045		0.22	0.18	-0.182		0.21	0.18	-0.143
Sheridan	0.28	0.25	-0.107		0.28	0.25	-0.107		0.25	0.25	0.000
Worland	0.35	0.28	-0.200		0.35	0.29	-0.171		0.28	0.29	0.036

	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	TR-1	**TR-2**	**TR_{1-2}**		**TR-1**	**TR-3**	**TR_{1-3}**		**TR-2**	**TR-3**	**TR_{2-3}**
Big Piney	0.34	0.36	0.059		0.34	0.33	-0.029		0.36	0.33	-0.083
Buffalo	0.38	0.37	-0.026		0.38	0.37	-0.026		0.37	0.37	0.000
Casper Na	0.39	0.39	0.000		0.39	0.39	0.000		0.39	0.39	0.000
Cheyenne	0.34	0.33	-0.029		0.34	0.32	-0.059		0.33	0.32	-0.030
Doug. Avn	0.41	0.37	-0.098		0.41	0.39	-0.049		0.37	0.39	0.054
Evanston	0.32	0.34	0.063		0.32	0.35	0.094		0.34	0.35	0.029
Gillette	0.40	0.39	-0.025		0.40	0.39	-0.025		0.39	0.39	0.000
Greybull	0.48	0.41	-0.146		0.48	0.45	-0.062		0.41	0.45	0.098
Lander	0.43	0.40	-0.070		0.43	0.41	-0.047		0.40	0.41	0.025
Laramie	0.31	0.31	0.000		0.31	0.33	0.065		0.31	0.33	0.065
Rawlins	0.34	0.34	0.000		0.34	0.32	-0.059		0.34	0.32	-0.059
Riverton	0.41	0.42	0.024		0.41	0.43	0.049		0.42	0.43	0.024
Rock Springs	0.36	0.35	-0.028		0.36	0.32	-0.111		0.35	0.32	-0.086
Sheridan	0.43	0.40	-0.070		0.43	0.4	-0.070		0.40	0.4	0.000
Worland	0.50	0.43	-0.140		0.50	0.44	-0.120		0.43	0.44	0.023

APPENDIX D2: ANNUAL CLIMATE STATISTICS

MEAN ANNUAL AIR TEMPERATURE (F)											
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	AT-1	**AT-2**	**AT_{1-2}**		**AT-1**	**AT-3**	**AT_{1-3}**		**AT-2**	**AT-3**	**AT_{2-3}**
Big Piney	37.19	40.90	-3.710		37.19	43.29	-6.100		40.90	43.29	-2.390
Buffalo	46.79	43.06	3.730		46.79	45.98	0.810		43.06	45.98	-2.920
Casper Na	46.26	45.47	0.790		46.26	45.36	0.900		45.47	45.36	0.110
Cheyenne	46.86	43.70	3.160		46.86	46.81	0.050		43.70	46.81	-3.110
Doug. Avn	46.61	47.04	-0.430		46.61	47.26	-0.650		47.04	47.26	-0.220
Evanston	42.29	40.54	1.750		42.29	38.84	3.450		40.54	38.84	1.700
Gillette	47.11	47.05	0.060		47.11	47.01	0.100		47.05	47.01	0.040
Greybull	46.20	47.26	-1.060		46.20	46.13	0.070		47.26	46.13	1.130
Lander	45.80	45.02	0.780		45.80	45.2	0.600		45.02	45.2	-0.180
Laramie	41.96	41.44	0.520		41.96	42.2	-0.240		41.44	42.2	-0.760
Rawlins	43.95	41.73	2.220		43.95	43.92	0.030		41.73	43.92	-2.190
Riverton	45.20	45.13	0.070		45.20	45.8	-0.600		45.13	45.8	-0.670
Rock Springs	43.95	41.31	2.640		43.95	40.77	3.180		41.31	40.77	0.540
Sheridan	45.92	48.15	-2.230		45.92	46.61	-0.690		48.15	46.61	1.540
Worland	45.54	47.39	-1.850		45.54	45.27	0.270		47.39	45.27	2.120

MEAN ANNUAL RAINFALL (in)											
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	AR-1	**AR-2**	**AR_{1-2}**		**AR-1**	**AR-3**	**AR_{1-3}**		**AR-2**	**AR-3**	**AR_{2-3}**
Big Piney	12.15	11.68	0.470		12.15	8.03	4.120		11.68	8.03	3.650
Buffalo	11.90	12.80	-0.900		11.90	10.98	0.920		12.80	10.98	1.820
Casper Na	10.40	10.70	-0.300		10.40	10.73	-0.330		10.70	10.73	-0.030
Cheyenne	13.26	13.32	-0.060		13.26	12.74	0.520		13.32	12.74	0.580
Doug. Avn	11.86	11.33	0.530		11.86	10.56	1.300		11.33	10.56	0.770
Evanston	10.49	14.13	-3.640		10.49	7.84	2.650		14.13	7.84	6.290
Gillette	12.85	12.75	0.100		12.85	12.2	0.650		12.75	12.2	0.550
Greybull	5.27	12.46	-7.190		5.27	11.78	-6.510		12.46	11.78	0.680
Lander	11.42	8.82	2.600		11.42	8.4	3.020		8.82	8.4	0.420
Laramie	8.82	12.94	-4.120		8.82	7.98	0.840		12.94	7.98	4.960
Rawlins	9.07	10.94	-1.870		9.07	7.91	1.160		10.94	7.91	3.030
Riverton	8.46	11.28	-2.820		8.46	11.36	-2.900		11.28	11.36	-0.080
Rock Springs	7.94	9.25	-1.310		7.94	8.04	-0.100		9.25	8.04	1.210
Sheridan	13.85	10.90	2.950		13.85	9.43	4.420		10.90	9.43	1.470
Worland	9.69	9.87	-0.180		9.69	8.15	1.540		9.87	8.15	1.720

FREEZING INDEX (F-days)											
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	FI-1	**FI-2**	**FI_{1-2}**		**FI-1**	**FI-3**	**FI_{1-3}**		**FI-2**	**FI-3**	**FI_{2-3}**
Big Piney	2439.19	1655.95	783.240		2439.19	1238.36	1200.830		1655.95	1238.36	417.590
Buffalo	874.26	1459.03	-584.770		874.26	1028.5	-154.240		1459.03	1028.5	430.530
Casper Na	986.09	1124.28	-138.190		986.09	1146.45	-160.360		1124.28	1146.45	-22.170
Cheyenne	793.33	1233.91	-440.580		793.33	877.67	-84.340		1233.91	877.67	356.240
Doug. Avn	1068.48	887.24	181.240		1068.48	885.43	183.050		887.24	885.43	1.810
Evanston	1325.58	1676.79	-351.210		1325.58	2098.26	-772.680		1676.79	2098.26	-421.470
Gillette	949.71	875.94	73.770		949.71	897.47	52.240		875.94	897.47	-21.530
Greybull	1569.36	1006.47	562.890		1569.36	1175.34	394.020		1006.47	1175.34	-168.870
Lander	1187.27	1312.40	-125.130		1187.27	1315.33	-128.060		1312.40	1315.33	-2.930
Laramie	1314.61	1398.28	-83.670		1314.61	1390.44	-75.830		1398.28	1390.44	7.840
Rawlins	1162.02	1486.62	-324.600		1162.02	1128.66	33.360		1486.62	1128.66	357.960
Riverton	1315.53	1268.94	46.590		1315.53	1187.27	128.260		1268.94	1187.27	81.670
Rock Springs	1253.80	1609.43	-355.630		1253.80	1660.99	-407.190		1609.43	1660.99	-51.560
Sheridan	1110.34	872.54	237.800		1110.34	1180.55	-70.210		872.54	1180.55	-308.010
Worland	1452.64	1080.04	372.600		1452.64	1432.15	20.490		1080.04	1432.15	-352.110

AVERAGE NUMBER OF FREEZE/THAW CYCLES											
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	FT-1	**FT-2**	**FT_{1-2}**		**FT-1**	**FT-3**	**FT_{1-3}**		**FT-2**	**FT-3**	**FT_{2-3}**
Big Piney	149	134	15.000		149	117	32.000		134	117	17.000
Buffalo	123	154	-31.000		123	138	-15.000		154	138	16.000
Casper Na	118	131	-13.000		118	138	-20.000		131	138	-7.000
Cheyenne	117	144	-27.000		117	157	-40.000		144	157	-13.000
Doug. Avn	135	121	14.000		135	128	7.000		121	128	-7.000
Evanston	98	116	-18.000		98	144	-46.000		116	144	-28.000
Gillette	124	119	5.000		124	123	1.000		119	123	-4.000
Greybull	118	116	2.000		118	150	-32.000		116	150	-34.000
Lander	124	131	-7.000		124	121	3.000		131	121	10.000
Laramie	146	146	0.000		146	152	-6.000		146	152	-6.000
Rawlins	120	136	-16.000		120	138	-18.000		136	138	-2.000
Riverton	121	138	-17.000		121	124	-3.000		138	124	14.000
Rock Springs	111	130	-19.000		111	137	-26.000		130	137	-7.000
Sheridan	140	111	29.000		140	116	24.000		111	116	-5.000
Worland	127	114	13.000		127	133	-6.000		114	133	-19.000

	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	AT-1	**AT-2**	**AT_{1-2}**		**AT-1**	**AT-3**	**AT_{1-3}**		**AT-2**	**AT-3**	**AT_{2-3}**
Big Piney	37.19	40.90	0.100		37.19	43.29	0.164		40.90	43.29	0.058
Buffalo	46.79	43.06	-0.080		46.79	45.98	-0.017		43.06	45.98	0.068
Casper Na	46.26	45.47	-0.017		46.26	45.36	-0.019		45.47	45.36	-0.002
Cheyenne	46.86	43.70	-0.067		46.86	46.81	-0.001		43.70	46.81	0.071
Doug. Avn	46.61	47.04	0.009		46.61	47.26	0.014		47.04	47.26	0.005
Evanston	42.29	40.54	-0.041		42.29	38.84	-0.082		40.54	38.84	-0.042
Gillette	47.11	47.05	-0.001		47.11	47.01	-0.002		47.05	47.01	-0.001
Greybull	46.20	47.26	0.023		46.20	46.13	-0.002		47.26	46.13	-0.024
Lander	45.80	45.02	-0.017		45.80	45.2	-0.013		45.02	45.2	0.004
Laramie	41.96	41.44	-0.012		41.96	42.2	0.006		41.44	42.2	0.018
Rawlins	43.95	41.73	-0.051		43.95	43.92	-0.001		41.73	43.92	0.052
Riverton	45.20	45.13	-0.002		45.20	45.8	0.013		45.13	45.8	0.015
Rock Springs	43.95	41.31	-0.060		43.95	40.77	-0.072		41.31	40.77	-0.013
Sheridan	45.92	48.15	0.049		45.92	46.61	0.015		48.15	46.61	-0.032
Worland	45.54	47.39	0.041		45.54	45.27	-0.006		47.39	45.27	-0.045

	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	AR-1	**AR-2**	**AR_{1-2}**		**AR-1**	**AR-3**	**AR_{1-3}**		**AR-2**	**AR-3**	**AR_{2-3}**
Big Piney	12.15	11.68	-0.039		12.15	8.03	-0.339		11.68	8.03	-0.313
Buffalo	11.90	12.80	0.076		11.90	10.98	-0.077		12.80	10.98	-0.142
Casper Na	10.40	10.70	0.029		10.40	10.73	0.032		10.70	10.73	0.003
Cheyenne	13.26	13.32	0.005		13.26	12.74	-0.039		13.32	12.74	-0.044
Doug. Avn	11.86	11.33	-0.045		11.86	10.56	-0.110		11.33	10.56	-0.068
Evanston	10.49	14.13	0.347		10.49	7.84	-0.253		14.13	7.84	-0.445
Gillette	12.85	12.75	-0.008		12.85	12.2	-0.051		12.75	12.2	-0.043
Greybull	5.27	12.46	1.364		5.27	11.78	1.235		12.46	11.78	-0.055
Lander	11.42	8.82	-0.228		11.42	8.4	-0.264		8.82	8.4	-0.048
Laramie	8.82	12.94	0.467		8.82	7.98	-0.095		12.94	7.98	-0.383
Rawlins	9.07	10.94	0.206		9.07	7.91	-0.128		10.94	7.91	-0.277
Riverton	8.46	11.28	0.333		8.46	11.36	0.343		11.28	11.36	0.007
Rock Springs	7.94	9.25	0.165		7.94	8.04	0.013		9.25	8.04	-0.131
Sheridan	13.85	10.90	-0.213		13.85	9.43	-0.319		10.90	9.43	-0.135
Worland	9.69	9.87	0.019		9.69	8.15	-0.159		9.87	8.15	-0.174

	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	FI-1	**FI-2**	**FI_{1-2}**		**FI-1**	**FI-3**	**FI_{1-3}**		**FI-2**	**FI-3**	**FI_{2-3}**
Big Piney	2439.19	1655.95	-0.321		2439.19	1238.36	-0.492		1655.95	1238.36	-0.252
Buffalo	874.26	1459.03	0.669		874.26	1028.5	0.176		1459.03	1028.5	-0.295
Casper Na	986.09	1124.28	0.140		986.09	1146.45	0.163		1124.28	1146.45	0.020
Cheyenne	793.33	1233.91	0.555		793.33	877.67	0.106		1233.91	877.67	-0.289
Doug. Avn	1068.48	887.24	-0.170		1068.48	885.43	-0.171		887.24	885.43	-0.002
Evanston	1325.58	1676.79	0.265		1325.58	2098.26	0.583		1676.79	2098.26	0.251
Gillette	949.71	875.94	-0.078		949.71	897.47	-0.055		875.94	897.47	0.025
Greybull	1569.36	1006.47	-0.359		1569.36	1175.34	-0.251		1006.47	1175.34	0.168
Lander	1187.27	1312.40	0.105		1187.27	1315.33	0.108		1312.40	1315.33	0.002
Laramie	1314.61	1398.28	0.064		1314.61	1390.44	0.058		1398.28	1390.44	-0.006
Rawlins	1162.02	1486.62	0.279		1162.02	1128.66	-0.029		1486.62	1128.66	-0.241
Riverton	1315.53	1268.94	-0.035		1315.53	1187.27	-0.097		1268.94	1187.27	-0.064
Rock Springs	1253.80	1609.43	0.284		1253.80	1660.99	0.325		1609.43	1660.99	0.032
Sheridan	1110.34	872.54	-0.214		1110.34	1180.55	0.063		872.54	1180.55	0.353
Worland	1452.64	1080.04	-0.256		1452.64	1432.15	-0.014		1080.04	1432.15	0.326

	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	FT-1	**FT-2**	**FT_{1-2}**		**FT-1**	**FT-3**	**FT_{1-3}**		**FT-2**	**FT-3**	**FT_{2-3}**
Big Piney	149	134	-0.101		149	117	-0.215		134	117	-0.127
Buffalo	123	154	0.252		123	138	0.122		154	138	-0.104
Casper Na	118	131	0.110		118	138	0.169		131	138	0.053
Cheyenne	117	144	0.231		117	157	0.342		144	157	0.090
Doug. Avn	135	121	-0.104		135	128	-0.052		121	128	0.058
Evanston	98	116	0.184		98	144	0.469		116	144	0.241
Gillette	124	119	-0.040		124	123	-0.008		119	123	0.034
Greybull	118	116	-0.017		118	150	0.271		116	150	0.293
Lander	124	131	0.056		124	121	-0.024		131	121	-0.076
Laramie	146	146	0.000		146	152	0.041		146	152	0.041
Rawlins	120	136	0.133		120	138	0.150		136	138	0.015
Riverton	121	138	0.140		121	124	0.025		138	124	-0.101
Rock Springs	111	130	0.171		111	137	0.234		130	137	0.054
Sheridan	140	111	-0.207		140	116	-0.171		111	116	0.045
Worland	127	114	-0.102		127	133	0.047		114	133	0.167

APPENDIX D3: PREDICTED DISTRESSES FOR PRIMARY SYSTEM

TERMINAL IRI (in/mi)											
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	IRI-1	**IRI-2**	**IRI_{1-2}**		**IRI-1**	**IRI-3**	**IRI_{1-3}**		**IRI-2**	**IRI-3**	**IRI_{2-3}**
Big Piney	131	129.8	1.200		131.0	112.8	18.200		129.8	112.8	17.000
Buffalo	128	130	-2.000		128.0	129.1	-1.100		130	129.1	0.900
Casper Na	129.1	129.1	0.000		129.1	129.3	-0.200		129.1	129.3	-0.200
Cheyenne	124.1	129.2	-5.100		124.1	125.3	-1.200		129.2	125.3	3.900
Doug. Avn	133.6	129	4.600		133.6	128.7	4.900		129	128.7	0.300
Evanston	113.1	128.9	-15.800		113.1	129.2	-16.100		128.9	129.2	-0.300
Gillette	129.3	127.8	1.500		129.3	127.9	1.400		127.8	127.9	-0.100
Greybull	129.9	129.9	0.000		129.9	130.6	-0.700		129.9	130.6	-0.700
Lander	129	129.4	-0.400		129.0	129.3	-0.300		129.4	129.3	0.100
Laramie	127.3	129.1	-1.800		127.3	128.8	-1.500		129.1	128.8	0.300
Rawlins	126.7	129.2	-2.500		126.7	121.7	5.000		129.2	121.7	7.500
Riverton	129.5	129.7	-0.200		129.5	129.1	0.400		129.7	129.1	0.600
Rock Springs	120.8	128.9	-8.100		120.8	128.3	-7.500		128.9	128.3	0.600
Sheridan	130.7	129.2	1.500		130.7	129.3	1.400		129.2	129.3	-0.100
Worland	131.5	128.8	2.700		131.5	129.9	1.600		128.8	129.9	-1.100

AC SURFACE DOWN CRACKING (LONGITUDINAL CRACKING) (ft/mi)											
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	LC-1	**LC-2**	**LC_{1-2}**		**LC-1**	**LC-3**	**LC_{1-3}**		**LC-2**	**LC-3**	**LC_{2-3}**
Big Piney	364	334	30.000		364.0	282	82.000		334.0	282	52.000
Buffalo	400	351	49.000		400.0	377	23.000		351.0	377	-26.000
Casper Na	378	369	9.000		378.0	368	10.000		369.0	368	1.000
Cheyenne	447	376	71.000		447.0	403	44.000		376.0	403	-27.000
Doug. Avn	378	397	-19.000		378.0	384	-6.000		397.0	384	13.000
Evanston	311	330	-19.000		311.0	286	25.000		330.0	286	44.000
Gillette	388	387	1.000		388.0	377	11.000		387.0	377	10.000
Greybull	282	369	-87.000		282.0	359	-77.000		369.0	359	10.000
Lander	364	336	28.000		364.0	333	31.000		336.0	333	3.000
Laramie	325	381	-56.000		325.0	372	-47.000		381.0	372	9.000
Rawlins	317	329	-12.000		317.0	308	9.000		329.0	308	21.000
Riverton	338	349	-11.000		338.0	360	-22.000		349.0	360	-11.000
Rock Springs	290	295	-5.000		290.0	276	14.000		295.0	276	19.000
Sheridan	390	384	6.000		390.0	343	47.000		384.0	343	41.000
Worland	338	340	-2.000		338.0	298	40.000		340.0	298	42.000

AC BOTTOM UP CRACKING (ALLIGATOR CRACKING) (%)											
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	AC-1	**AC-2**	**AC_{1-2}**		**AC-1**	**AC-3**	**AC_{1-3}**		**AC-2**	**AC-3**	**AC_{2-3}**
Big Piney	1.1	1	0.100		1.1	0.9	0.200		1.0	0.9	0.100
Buffalo	1	1	0.000		1	1	0.000		1.0	1.0	0.000
Casper Na	1	1	0.000		1	1	0.000		1.0	1.0	0.000
Cheyenne	1	1	0.000		1	1	0.000		1.0	1.0	0.000
Doug. Avn	7	1	6.000		7	1	6.000		1.0	1.0	0.000
Evanston	0.9	1	-0.100		0.9	0.9	0.000		1.0	0.9	0.100
Gillette	1	1	0.000		1	1	0.000		1.0	1.0	0.000
Greybull	1	1	0.000		1	1.1	-0.100		1.0	1.1	-0.100
Lander	1.1	1	0.100		1.1	1	0.100		1.0	1.0	0.000
Laramie	0.9	1	-0.100		0.9	0.9	0.000		1.0	0.9	0.100
Rawlins	0.9	0.9	0.000		0.9	0.8	0.100		0.9	0.8	0.100
Riverton	1.1	1.1	0.000		1.1	1.1	0.000		1.1	1.1	0.000
Rock Springs	0.9	0.9	0.000		0.9	0.8	0.100		0.9	0.8	0.100
Sheridan	1.1	1	0.100		1.1	1	0.100		1.0	1.0	0.000
Worland	1.1	1	0.100		1.1	1	0.100		1.0	1.0	0.000

AC THERMAL CRACKING (TRANSVERSE CRACKING) (ft/mi)											
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	TC-1	**TC-2**	**TC_{1-2}**		**TC-1**	**TC-3**	**TC_{1-3}**		**TC-2**	**TC-3**	**TC_{2-3}**
Big Piney	2112	2112	0.000		2112.0	240.9	1871.100		2112	240.9	1871.100
Buffalo	1972.2	2112	-139.800		1972.2	2112	-139.800		2112	2112	0.000
Casper Na	2112	2067.2	44.800		2112.0	2089.6	22.400		2067.2	2089.6	-22.400
Cheyenne	1538.4	2112	-573.600		1538.4	1723	-184.600		2112	1723	389.000
Doug. Avn	2025.7	2111.7	-86.000		2025.7	2081.8	-56.100		2111.7	2081.8	29.900
Evanston	183.8	1958.1	-1774.300		183.8	2112	-1928.200		1958.1	2112	-153.900
Gillette	2043.5	1917.3	126.200		2043.5	1927.4	116.100		1917.3	1927.4	-10.100
Greybull	2112	2112	0.000		2112.0	2112	0.000		2112	2112	0.000
Lander	1951.9	2112	-160.100		1951.9	2112	-160.100		2112	2112	0.000
Laramie	2050.5	2112	-61.500		2050.5	2112	-61.500		2112	2112	0.000
Rawlins	1927.3	2112	-184.700		1927.3	1392.1	535.200		2112	1392.1	719.900
Riverton	2112	2061.2	50.800		2112.0	1971	141.000		2061.2	1971	90.200
Rock Springs	1168.5	2112	-943.500		1168.5	2112	-943.500		2112	2112	0.000
Sheridan	2105	2112	-7.000		2105.0	2112	-7.000		2112	2112	0.000
Worland	2112	1984.6	127.400		2112.0	2112	0.000		1984.6	2112	-127.400

PERMANENT DEFORMATION (AC ONLY) (in)											
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	ACR-1	**ACR-2**	**ACR_{1-2}**		**ACR-1**	**ACR-3**	**ACR_{1-3}**		**ACR-2**	**ACR-3**	**ACR_{2-3}**
Big Piney	0.08	0.08	0.000		0.08	0.08	0.000		0.08	0.08	0.000
Buffalo	0.1	0.09	0.010		0.10	0.09	0.010		0.09	0.09	0.000
Casper Na	0.1	0.1	0.000		0.10	0.1	0.000		0.10	0.1	0.000
Cheyenne	0.08	0.08	0.000		0.08	0.08	0.000		0.08	0.08	0.000
Doug. Avn	0.12	0.09	0.030		0.12	0.1	0.020		0.09	0.1	-0.010
Evanston	0.07	0.08	-0.010		0.07	0.08	-0.010		0.08	0.08	0.000
Gillette	0.1	0.1	0.000		0.10	0.1	0.000		0.10	0.1	0.000
Greybull	0.14	0.11	0.030		0.14	0.12	0.020		0.11	0.12	-0.010
Lander	0.11	0.1	0.010		0.11	0.1	0.010		0.10	0.1	0.000
Laramie	0.07	0.07	0.000		0.07	0.07	0.000		0.07	0.07	0.000
Rawlins	0.08	0.08	0.000		0.08	0.08	0.000		0.08	0.08	0.000
Riverton	0.11	0.11	0.000		0.11	0.11	0.000		0.11	0.11	0.000
Rock Springs	0.09	0.08	0.010		0.09	0.08	0.010		0.08	0.08	0.000
Sheridan	0.11	0.1	0.010		0.11	0.1	0.010		0.10	0.1	0.000
Worland	0.14	0.11	0.030		0.14	0.12	0.020		0.11	0.12	-0.010

TOTAL PAVEMENT DEFORMATION (in)												
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolate d using similar elevations	Diff
	TR-1	**TR-2**	**TR_{1-2}**		**TR-1**	**TR-3**	**TR_{1-3}**		**TR-2**	**TR-3**	**TR_{2-3}**
Big Piney	0.31	0.3	0.010		0.31	0.28	0.030		0.30	0.28	0.020
Buffalo	0.3	0.3	0.000		0.30	0.3	0.000		0.30	0.3	0.000
Casper Na	0.3	0.31	-0.010		0.30	0.31	-0.010		0.31	0.31	0.000
Cheyenne	0.29	0.28	0.010		0.29	0.28	0.010		0.28	0.28	0.000
Doug. Avn	0.33	0.3	0.030		0.33	0.3	0.030		0.30	0.3	0.000
Evanston	0.28	0.29	-0.010		0.28	0.3	-0.020		0.29	0.3	-0.010
Gillette	0.31	0.3	0.010		0.31	0.3	0.010		0.30	0.3	0.000
Greybull	0.35	0.31	0.040		0.35	0.33	0.020		0.31	0.33	-0.020
Lander	0.32	0.31	0.010		0.32	0.31	0.010		0.31	0.31	0.000
Laramie	0.27	0.28	-0.010		0.27	0.28	-0.010		0.28	0.28	0.000
Rawlins	0.29	0.29	0.000		0.29	0.28	0.010		0.29	0.28	0.010
Riverton	0.32	0.32	0.000		0.32	0.32	0.000		0.32	0.32	0.000
Rock Springs	0.3	0.29	0.010		0.30	0.28	0.020		0.29	0.28	0.010
Sheridan	0.32	0.31	0.010		0.32	0.31	0.010		0.31	0.31	0.000
Worland	0.35	0.32	0.030		0.35	0.33	0.020		0.32	0.33	-0.010

	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	IRI-1	**IRI-2**	**IRI_{1-2}**		**IRI-1**	**IRI-3**	**IRI_{1-3}**		**IRI-2**	**IRI-3**	**IRI_{2-3}**
Big Piney	131	129.8	-0.009		131.0	112.8	-0.139		129.8	112.8	-0.131
Buffalo	128	130	0.016		128.0	129.1	0.009		130	129.1	-0.007
Casper Na	129.1	129.1	0.000		129.1	129.3	0.002		129.1	129.3	0.002
Cheyenne	124.1	129.2	0.041		124.1	125.3	0.010		129.2	125.3	-0.030
Doug. Avn	133.6	129	-0.034		133.6	128.7	-0.037		129	128.7	-0.002
Evanston	113.1	128.9	0.140		113.1	129.2	0.142		128.9	129.2	0.002
Gillette	129.3	127.8	-0.012		129.3	127.9	-0.011		127.8	127.9	0.001
Greybull	129.9	129.9	0.000		129.9	130.6	0.005		129.9	130.6	0.005
Lander	129	129.4	0.003		129.0	129.3	0.002		129.4	129.3	-0.001
Laramie	127.3	129.1	0.014		127.3	128.8	0.012		129.1	128.8	-0.002
Rawlins	126.7	129.2	0.020		126.7	121.7	-0.039		129.2	121.7	-0.058
Riverton	129.5	129.7	0.002		129.5	129.1	-0.003		129.7	129.1	-0.005
Rock Springs	120.8	128.9	0.067		120.8	128.3	0.062		128.9	128.3	-0.005
Sheridan	130.7	129.2	-0.011		130.7	129.3	-0.011		129.2	129.3	0.001
Worland	131.5	128.8	-0.021		131.5	129.9	-0.012		128.8	129.9	0.009

	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	LC-1	**LC-2**	**LC_{1-2}**		**LC-1**	**LC-3**	**LC_{1-3}**		**LC-2**	**LC-3**	**LC_{2-3}**
Big Piney	364	334	-0.082		364.0	282	-0.225		334.0	282	-0.156
Buffalo	400	351	-0.123		400.0	377	-0.058		351.0	377	0.074
Casper Na	378	369	-0.024		378.0	368	-0.026		369.0	368	-0.003
Cheyenne	447	376	-0.159		447.0	403	-0.098		376.0	403	0.072
Doug. Avn	378	397	0.050		378.0	384	0.016		397.0	384	-0.033
Evanston	311	330	0.061		311.0	286	-0.080		330.0	286	-0.133
Gillette	388	387	-0.003		388.0	377	-0.028		387.0	377	-0.026
Greybull	282	369	0.309		282.0	359	0.273		369.0	359	-0.027
Lander	364	336	-0.077		364.0	333	-0.085		336.0	333	-0.009
Laramie	325	381	0.172		325.0	372	0.145		381.0	372	-0.024
Rawlins	317	329	0.038		317.0	308	-0.028		329.0	308	-0.064
Riverton	338	349	0.033		338.0	360	0.065		349.0	360	0.032
Rock Springs	290	295	0.017		290.0	276	-0.048		295.0	276	-0.064
Sheridan	390	384	-0.015		390.0	343	-0.121		384.0	343	-0.107
Worland	338	340	0.006		338.0	298	-0.118		340.0	298	-0.124

	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	AC-1	**AC-2**	**AC_{1-2}**		**AC-1**	**AC-3**	**AC_{1-3}**		**AC-2**	**AC-3**	**AC_{2-3}**
Big Piney	1.1	1	-0.091		1.1	0.9	-0.182		1.0	0.9	-0.100
Buffalo	1	1	0.000		1	1	0.000		1.0	1.0	0.000
Casper Na	1	1	0.000		1	1	0.000		1.0	1.0	0.000
Cheyenne	1	1	0.000		1	1	0.000		1.0	1.0	0.000
Doug. Avn	7	1	-0.857		7	1	-0.857		1.0	1.0	0.000
Evanston	0.9	1	0.111		0.9	0.9	0.000		1.0	0.9	-0.100
Gillette	1	1	0.000		1	1	0.000		1.0	1.0	0.000
Greybull	1	1	0.000		1	1.1	0.100		1.0	1.1	0.100
Lander	1.1	1	-0.091		1.1	1	-0.091		1.0	1.0	0.000
Laramie	0.9	1	0.111		0.9	0.9	0.000		1.0	0.9	-0.100
Rawlins	0.9	0.9	0.000		0.9	0.8	-0.111		0.9	0.8	-0.111
Riverton	1.1	1.1	0.000		1.1	1.1	0.000		1.1	1.1	0.000
Rock Springs	0.9	0.9	0.000		0.9	0.8	-0.111		0.9	0.8	-0.111
Sheridan	1.1	1	-0.091		1.1	1	-0.091		1.0	1.0	0.000
Worland	1.1	1	-0.091		1.1	1	-0.091		1.0	1.0	0.000

	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	TC-1	**TC-2**	**TC_{1-2}**		**TC-1**	**TC-3**	**TC_{1-3}**		**TC-2**	**TC-3**	**TC_{2-3}**
Big Piney	2112	2112	0.000		2112.0	240.9	-0.886		2112	240.9	-0.886
Buffalo	1972.2	2112	0.071		1972.2	2112	0.071		2112	2112	0.000
Casper Na	2112	2067.2	-0.021		2112.0	2089.6	-0.011		2067.2	2089.6	0.011
Cheyenne	1538.4	2112	0.373		1538.4	1723	0.120		2112	1723	-0.184
Doug. Avn	2025.7	2111.7	0.042		2025.7	2081.8	0.028		2111.7	2081.8	-0.014
Evanston	183.8	1958.1	9.653		183.8	2112	10.491		1958.1	2112	0.079
Gillette	2043.5	1917.3	-0.062		2043.5	1927.4	-0.057		1917.3	1927.4	0.005
Greybull	2112	2112	0.000		2112.0	2112	0.000		2112	2112	0.000
Lander	1951.9	2112	0.082		1951.9	2112	0.082		2112	2112	0.000
Laramie	2050.5	2112	0.030		2050.5	2112	0.030		2112	2112	0.000
Rawlins	1927.3	2112	0.096		1927.3	1392.1	-0.278		2112	1392.1	-0.341
Riverton	2112	2061.2	-0.024		2112.0	1971	-0.067		2061.2	1971	-0.044
Rock Springs	1168.5	2112	0.807		1168.5	2112	0.807		2112	2112	0.000
Sheridan	2105	2112	0.003		2105.0	2112	0.003		2112	2112	0.000
Worland	2112	1984.6	-0.060		2112.0	2112	0.000		1984.6	2112	0.064

	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	ACR-1	**ACR-2**	**ACR_{1-2}**		**ACR-1**	**ACR-3**	**ACR_{1-3}**		**ACR-2**	**ACR-3**	**ACR_{2-3}**
Big Piney	0.08	0.08	0.000		0.08	0.08	0.000		0.08	0.08	0.000
Buffalo	0.1	0.09	-0.100		0.10	0.09	-0.100		0.09	0.09	0.000
Casper Na	0.1	0.1	0.000		0.10	0.1	0.000		0.10	0.1	0.000
Cheyenne	0.08	0.08	0.000		0.08	0.08	0.000		0.08	0.08	0.000
Doug. Avn	0.12	0.09	-0.250		0.12	0.1	-0.167		0.09	0.1	0.111
Evanston	0.07	0.08	0.143		0.07	0.08	0.143		0.08	0.08	0.000
Gillette	0.1	0.1	0.000		0.10	0.1	0.000		0.10	0.1	0.000
Greybull	0.14	0.11	-0.214		0.14	0.12	-0.143		0.11	0.12	0.091
Lander	0.11	0.1	-0.091		0.11	0.1	-0.091		0.10	0.1	0.000
Laramie	0.07	0.07	0.000		0.07	0.07	0.000		0.07	0.07	0.000
Rawlins	0.08	0.08	0.000		0.08	0.08	0.000		0.08	0.08	0.000
Riverton	0.11	0.11	0.000		0.11	0.11	0.000		0.11	0.11	0.000
Rock Springs	0.09	0.08	-0.111		0.09	0.08	-0.111		0.08	0.08	0.000
Sheridan	0.11	0.1	-0.091		0.11	0.1	-0.091		0.10	0.1	0.000
Worland	0.14	0.11	-0.214		0.14	0.12	-0.143		0.11	0.12	0.091

	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	TR-1	**TR-2**	**TR_{1-2}**		**TR-1**	**TR-3**	**TR_{1-3}**		**TR-2**	**TR-3**	**TR_{2-3}**
Big Piney	0.31	0.3	-0.032		0.31	0.28	-0.097		0.30	0.28	-0.067
Buffalo	0.3	0.3	0.000		0.30	0.3	0.000		0.30	0.3	0.000
Casper Na	0.3	0.31	0.033		0.30	0.31	0.033		0.31	0.31	0.000
Cheyenne	0.29	0.28	-0.034		0.29	0.28	-0.034		0.28	0.28	0.000
Doug. Avn	0.33	0.3	-0.091		0.33	0.3	-0.091		0.30	0.3	0.000
Evanston	0.28	0.29	0.036		0.28	0.3	0.071		0.29	0.3	0.034
Gillette	0.31	0.3	-0.032		0.31	0.3	-0.032		0.30	0.3	0.000
Greybull	0.35	0.31	-0.114		0.35	0.33	-0.057		0.31	0.33	0.065
Lander	0.32	0.31	-0.031		0.32	0.31	-0.031		0.31	0.31	0.000
Laramie	0.27	0.28	0.037		0.27	0.28	0.037		0.28	0.28	0.000
Rawlins	0.29	0.29	0.000		0.29	0.28	-0.034		0.29	0.28	-0.034
Riverton	0.32	0.32	0.000		0.32	0.32	0.000		0.32	0.32	0.000
Rock Springs	0.3	0.29	-0.033		0.30	0.28	-0.067		0.29	0.28	-0.034
Sheridan	0.32	0.31	-0.031		0.32	0.31	-0.031		0.31	0.31	0.000
Worland	0.35	0.32	-0.086		0.35	0.33	-0.057		0.32	0.33	0.031

APPENDIX D4: PREDICTED DISTRESSES FOR SECONDARY SYSTEM

TERMINAL IRI (in/mi)											
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	IRI-1	**IRI-2**	**IRI_{1-2}**		**IRI-1**	**IRI-3**	**IRI_{1-3}**		**IRI-2**	**IRI-3**	**IRI_{2-3}**
Big Piney	127.8	126.8	1.000		127.8	109.5	18.300		126.8	109.5	17.300
Buffalo	124.3	127	-2.700		124.3	125.8	-1.500		127	125.8	1.200
Casper Na	125.9	130.6	-4.700		125.9	125.6	0.300		130.6	125.6	5.000
Cheyenne	119.6	125	-5.400		119.6	121.5	-1.900		125	121.5	3.500
Doug. Avn	124.8	124.5	0.300		124.8	124.9	-0.100		124.5	124.9	-0.400
Evanston	109.9	124.9	-15.000		109.9	126.4	-16.500		124.9	126.4	-1.500
Gillette	125.2	124.2	1.000		125.2	124.3	0.900		124.2	124.3	-0.100
Greybull	126	126.6	-0.600		126.0	127.1	-1.100		126.6	127.1	-0.500
Lander	124.6	125.4	-0.800		124.6	125.6	-1.000		125.4	125.6	-0.200
Laramie	124.1	126.3	-2.200		124.1	126.1	-2.000		126.3	126.1	0.200
Rawlins	122.2	126.3	-4.100		122.2	117.4	4.800		126.3	117.4	8.900
Riverton	125.7	125.8	-0.100		125.7	124.9	0.800		125.8	124.9	0.900
Rock Springs	116	126	-10.000		116.0	125.6	-9.600		126	125.6	0.400
Sheridan	126.9	125.9	1.000		126.9	126.1	0.800		125.9	126.1	-0.200
Worland	127.5	124.3	3.200		127.5	126.4	1.100		124.3	126.4	-2.100

AC SURFACE DOWN CRACKING (LONGITUDINAL CRACKING) (ft/mi)											
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	LC-1	**LC-2**	**LC_{1-2}**		**LC-1**	**LC-3**	**LC_{1-3}**		**LC-2**	**LC-3**	**LC_{2-3}**
Big Piney	48.5	45.3	3.200		48.5	41.1	7.400		45.3	41.1	4.200
Buffalo	52.2	47.4	4.800		52.2	50.9	1.300		47.4	50.9	-3.500
Casper Na	51.5	186	-134.500		51.5	49.7	1.800		186.0	49.7	136.300
Cheyenne	56.6	49.4	7.200		56.6	53	3.600		49.4	53	-3.600
Doug. Avn	50.8	51.5	-0.700		50.8	51.6	-0.800		51.5	51.6	-0.100
Evanston	42.9	45.6	-2.700		42.9	42.1	0.800		45.6	42.1	3.500
Gillette	53.2	51.2	2.000		53.2	50	3.200		51.2	50	1.200
Greybull	42.9	50.4	-7.500		42.9	48.1	-5.200		50.4	48.1	2.300
Lander	45.7	47	-1.300		45.7	46.9	-1.200		47.0	46.9	0.100
Laramie	46.7	48.9	-2.200		46.7	49.8	-3.100		48.9	49.8	-0.900
Rawlins	44.3	45	-0.700		44.3	43.9	0.400		45.0	43.9	1.100
Riverton	47.4	47.2	0.200		47.4	49.2	-1.800		47.2	49.2	-2.000
Rock Springs	43.5	42.2	1.300		43.5	38.5	5.000		42.2	38.5	3.700
Sheridan	52.4	51.2	1.200		52.4	46.4	6.000		51.2	46.4	4.800
Worland	48.1	47.5	0.600		48.1	43.4	4.700		47.5	43.4	4.100

AC BOTTOM UP CRACKING (ALLIGATOR CRACKING) (%)											
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	AC-1	**AC-2**	**AC_{1-2}**		**AC-1**	**AC-3**	**AC_{1-3}**		**AC-2**	**AC-3**	**AC_{2-3}**
Big Piney	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Buffalo	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Casper Na	0.2	0.4	-0.200		0.2	0.2	0.000		0.4	0.2	0.200
Cheyenne	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Doug. Avn	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Evanston	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Gillette	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Greybull	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Lander	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Laramie	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Rawlins	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Riverton	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Rock Springs	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Sheridan	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Worland	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000

AC THERMAL FRACTURE (TRANSVERSE CRACKING) (ft/mi)											
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	TC-1	**TC-2**	**TC_{1-2}**		**TC-1**	**TC-3**	**TC_{1-3}**		**TC-2**	**TC-3**	**TC_{2-3}**
Big Piney	2112	2112	0.000		2112.0	163.8	1948.200		2112	163.8	1948.200
Buffalo	1899.1	2112	-212.900		1899.1	2096.1	-197.000		2112	2096.1	15.900
Casper Na	2112	1689.4	422.600		2112.0	2027.2	84.800		1689.4	2027.2	-337.800
Cheyenne	1344.7	1967.5	-622.800		1344.7	1600.6	-255.900		1967.5	1600.6	366.900
Doug. Avn	1897.4	1950.2	-52.800		1897.4	2003.8	-106.400		1950.2	2003.8	-53.600
Evanston	132.6	1813.3	-1680.700		132.6	2112	-1979.400		1813.3	2112	-298.700
Gillette	1944.6	1860.6	84.000		1944.6	1870.1	74.500		1860.6	1870.1	-9.500
Greybull	2112	2112	0.000		2112.0	2112	0.000		2112	2112	0.000
Lander	1848.4	2020.7	-172.300		1848.4	2054.3	-205.900		2020.7	2054.3	-33.600
Laramie	1976.1	2112	-135.900		1976.1	2112	-135.900		2112	2112	0.000
Rawlins	1723.1	2112	-388.900		1723.1	1186.6	536.500		2112	1186.6	925.400
Riverton	2059.5	1990.4	69.100		2059.5	1875.8	183.700		1990.4	1875.8	114.600
Rock Springs	952.5	2112	-1159.500		952.5	2112	-1159.500		2112	2112	0.000
Sheridan	2061.8	2112	-50.200		2061.8	2112	-50.200		2112	2112	0.000
Worland	2112	1866.3	245.700		2112.0	2112	0.000		1866.3	2112	-245.700

PERMANENT DEFORMATION (HMA LAYER) (in)											
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	ACR-1	**ACR-2**	**ACR_{1-2}**		**ACR-1**	**ACR-3**	**ACR_{1-3}**		**ACR-2**	**ACR-3**	**ACR_{2-3}**
Big Piney	0.04	0.05	-0.010		0.04	0.04	0.000		0.05	0.04	0.010
Buffalo	0.05	0.05	0.000		0.05	0.05	0.000		0.05	0.05	0.000
Casper Na	0.05	0.05	0.000		0.05	0.05	0.000		0.05	0.05	0.000
Cheyenne	0.05	0.05	0.000		0.05	0.04	0.010		0.05	0.04	0.010
Doug. Avn	0.06	0.05	0.010		0.06	0.06	0.000		0.05	0.06	-0.010
Evanston	0.04	0.04	0.000		0.04	0.04	0.000		0.04	0.04	0.000
Gillette	0.06	0.05	0.010		0.06	0.06	0.000		0.05	0.06	-0.010
Greybull	0.08	0.06	0.020		0.08	0.07	0.010		0.06	0.07	-0.010
Lander	0.06	0.06	0.000		0.06	0.06	0.000		0.06	0.06	0.000
Laramie	0.04	0.04	0.000		0.04	0.04	0.000		0.04	0.04	0.000
Rawlins	0.05	0.04	0.010		0.05	0.04	0.010		0.04	0.04	0.000
Riverton	0.06	0.06	0.000		0.06	0.06	0.000		0.06	0.06	0.000
Rock Springs	0.05	0.05	0.000		0.05	0.04	0.010		0.05	0.04	0.010
Sheridan	0.06	0.06	0.000		0.06	0.06	0.000		0.06	0.06	0.000
Worland	0.08	0.06	0.020		0.08	0.07	0.010		0.06	0.07	-0.010

TOTAL PAVEMENT DEFORMATION (in)											
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Diff		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Diff		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Diff
	TR-1	**TR-2**	**TR_{1-2}**		**TR-1**	**TR-3**	**TR_{1-3}**		**TR-2**	**TR-3**	**TR_{2-3}**
Big Piney	0.25	0.24	0.010		0.25	0.23	0.020		0.24	0.23	0.010
Buffalo	0.24	0.24	0.000		0.24	0.24	0.000		0.24	0.24	0.000
Casper Na	0.24	0.29	-0.050		0.24	0.24	0.000		0.29	0.24	0.050
Cheyenne	0.23	0.24	-0.010		0.23	0.23	0.000		0.24	0.23	0.010
Doug. Avn	0.25	0.24	0.010		0.25	0.24	0.010		0.24	0.24	0.000
Evanston	0.23	0.24	-0.010		0.23	0.24	-0.010		0.24	0.24	0.000
Gillette	0.25	0.24	0.010		0.25	0.24	0.010		0.24	0.24	0.000
Greybull	0.27	0.25	0.020		0.27	0.26	0.010		0.25	0.26	-0.010
Lander	0.25	0.25	0.000		0.25	0.25	0.000		0.25	0.25	0.000
Laramie	0.22	0.23	-0.010		0.22	0.23	-0.010		0.23	0.23	0.000
Rawlins	0.23	0.23	0.000		0.23	0.23	0.000		0.23	0.23	0.000
Riverton	0.25	0.25	0.000		0.25	0.25	0.000		0.25	0.25	0.000
Rock Springs	0.24	0.24	0.000		0.24	0.23	0.010		0.24	0.23	0.010
Sheridan	0.25	0.24	0.010		0.25	0.25	0.000		0.24	0.25	-0.010
Worland	0.27	0.25	0.020		0.27	0.26	0.010		0.25	0.26	-0.010

	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	IRI-1	**IRI-2**	**IRI_{1-2}**		**IRI-1**	**IRI-3**	**IRI_{1-3}**		**IRI-2**	**IRI-3**	**IRI_{2-3}**
Big Piney	127.8	126.8	-0.008		127.8	109.5	-0.143		126.8	109.5	-0.136
Buffalo	124.3	127	0.022		124.3	125.8	0.012		127	125.8	-0.009
Casper Na	125.9	130.6	0.037		125.9	125.6	-0.002		130.6	125.6	-0.038
Cheyenne	119.6	125	0.045		119.6	121.5	0.016		125	121.5	-0.028
Doug. Avn	124.8	124.5	-0.002		124.8	124.9	0.001		124.5	124.9	0.003
Evanston	109.9	124.9	0.136		109.9	126.4	0.150		124.9	126.4	0.012
Gillette	125.2	124.2	-0.008		125.2	124.3	-0.007		124.2	124.3	0.001
Greybull	126	126.6	0.005		126.0	127.1	0.009		126.6	127.1	0.004
Lander	124.6	125.4	0.006		124.6	125.6	0.008		125.4	125.6	0.002
Laramie	124.1	126.3	0.018		124.1	126.1	0.016		126.3	126.1	-0.002
Rawlins	122.2	126.3	0.034		122.2	117.4	-0.039		126.3	117.4	-0.070
Riverton	125.7	125.8	0.001		125.7	124.9	-0.006		125.8	124.9	-0.007
Rock Springs	116	126	0.086		116.0	125.6	0.083		126	125.6	-0.003
Sheridan	126.9	125.9	-0.008		126.9	126.1	-0.006		125.9	126.1	0.002
Worland	127.5	124.3	-0.025		127.5	126.4	-0.009		124.3	126.4	0.017

	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	LC-1	**LC-2**	**LC_{1-2}**		**LC-1**	**LC-3**	**LC_{1-3}**		**LC-2**	**LC-3**	**LC_{2-3}**
Big Piney	48.5	45.3	-0.066		48.5	41.1	-0.153		45.3	41.1	-0.093
Buffalo	52.2	47.4	-0.092		52.2	50.9	-0.025		47.4	50.9	0.074
Casper Na	51.5	186	2.612		51.5	49.7	-0.035		186.0	49.7	-0.733
Cheyenne	56.6	49.4	-0.127		56.6	53	-0.064		49.4	53	0.073
Doug. Avn	50.8	51.5	0.014		50.8	51.6	0.016		51.5	51.6	0.002
Evanston	42.9	45.6	0.063		42.9	42.1	-0.019		45.6	42.1	-0.077
Gillette	53.2	51.2	-0.038		53.2	50	-0.060		51.2	50	-0.023
Greybull	42.9	50.4	0.175		42.9	48.1	0.121		50.4	48.1	-0.046
Lander	45.7	47	0.028		45.7	46.9	0.026		47.0	46.9	-0.002
Laramie	46.7	48.9	0.047		46.7	49.8	0.066		48.9	49.8	0.018
Rawlins	44.3	45	0.016		44.3	43.9	-0.009		45.0	43.9	-0.024
Riverton	47.4	47.2	-0.004		47.4	49.2	0.038		47.2	49.2	0.042
Rock Springs	43.5	42.2	-0.030		43.5	38.5	-0.115		42.2	38.5	-0.088
Sheridan	52.4	51.2	-0.023		52.4	46.4	-0.115		51.2	46.4	-0.094
Worland	48.1	47.5	-0.012		48.1	43.4	-0.098		47.5	43.4	-0.086

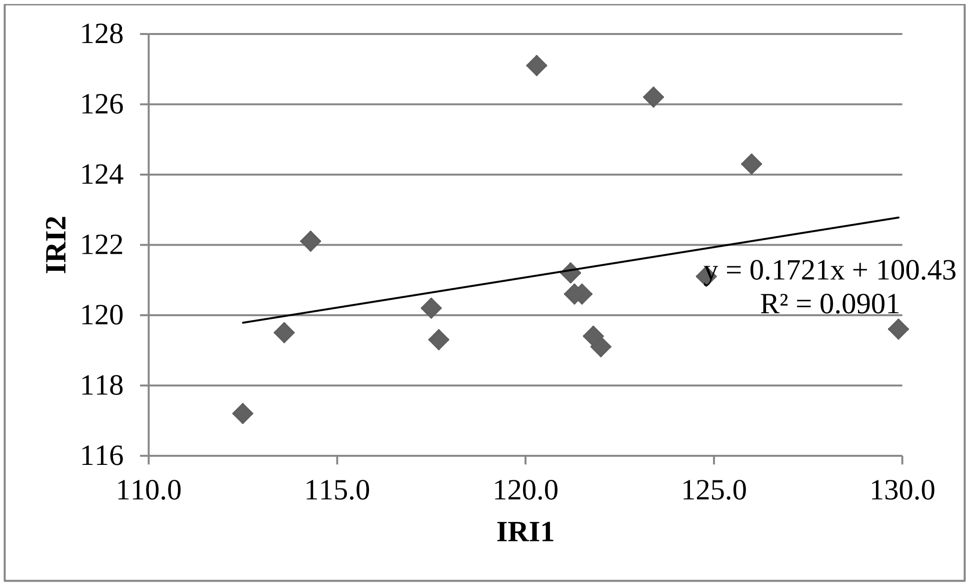
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	AC-1	**AC-2**	**AC_{1-2}**		**AC-1**	**AC-3**	**AC_{1-3}**		**AC-2**	**AC-3**	**AC_{2-3}**
Big Piney	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Buffalo	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Casper Na	0.2	0.4	1.000		0.2	0.2	0.000		0.4	0.2	-0.500
Cheyenne	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Doug. Avn	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Evanston	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Gillette	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Greybull	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Lander	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Laramie	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Rawlins	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Riverton	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Rock Springs	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Sheridan	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000
Worland	0.2	0.2	0.000		0.2	0.2	0.000		0.2	0.2	0.000

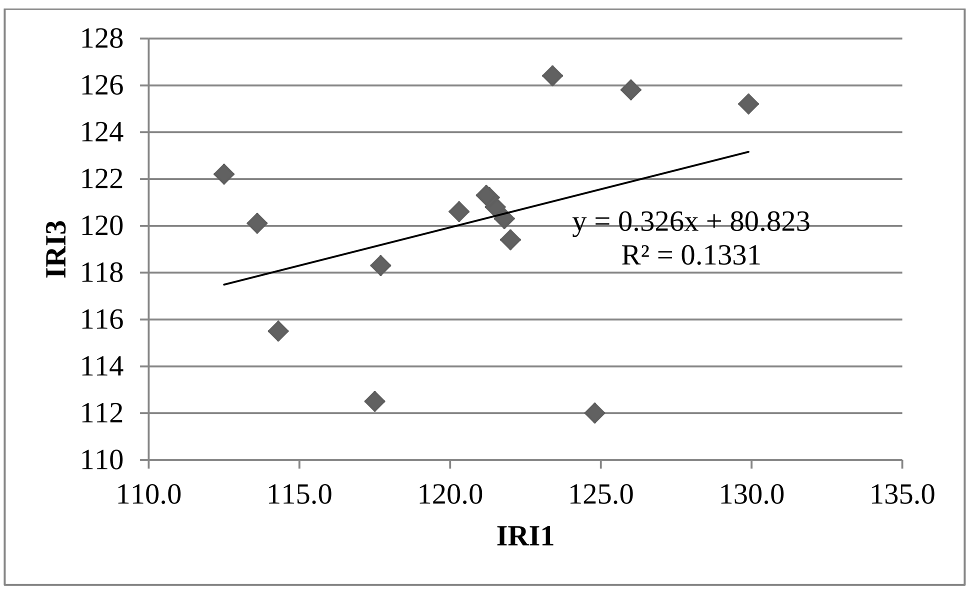
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	TC-1	**TC-2**	**TC_{1-2}**		**TC-1**	**TC-3**	**TC_{1-3}**		**TC-2**	**TC-3**	**TC_{2-3}**
Big Piney	2112	2112	0.000		2112.0	163.8	-0.922		2112	163.8	-0.922
Buffalo	1899.1	2112	0.112		1899.1	2096.1	0.104		2112	2096.1	-0.008
Casper Na	2112	1689.4	-0.200		2112.0	2027.2	-0.040		1689.4	2027.2	0.200
Cheyenne	1344.7	1967.5	0.463		1344.7	1600.6	0.190		1967.5	1600.6	-0.186
Doug. Avn	1897.4	1950.2	0.028		1897.4	2003.8	0.056		1950.2	2003.8	0.027
Evanston	132.6	1813.3	12.675		132.6	2112	14.928		1813.3	2112	0.165
Gillette	1944.6	1860.6	-0.043		1944.6	1870.1	-0.038		1860.6	1870.1	0.005
Greybull	2112	2112	0.000		2112.0	2112	0.000		2112	2112	0.000
Lander	1848.4	2020.7	0.093		1848.4	2054.3	0.111		2020.7	2054.3	0.017
Laramie	1976.1	2112	0.069		1976.1	2112	0.069		2112	2112	0.000
Rawlins	1723.1	2112	0.226		1723.1	1186.6	-0.311		2112	1186.6	-0.438
Riverton	2059.5	1990.4	-0.034		2059.5	1875.8	-0.089		1990.4	1875.8	-0.058
Rock Springs	952.5	2112	1.217		952.5	2112	1.217		2112	2112	0.000
Sheridan	2061.8	2112	0.024		2061.8	2112	0.024		2112	2112	0.000
Worland	2112	1866.3	-0.116		2112.0	2112	0.000		1866.3	2112	0.132

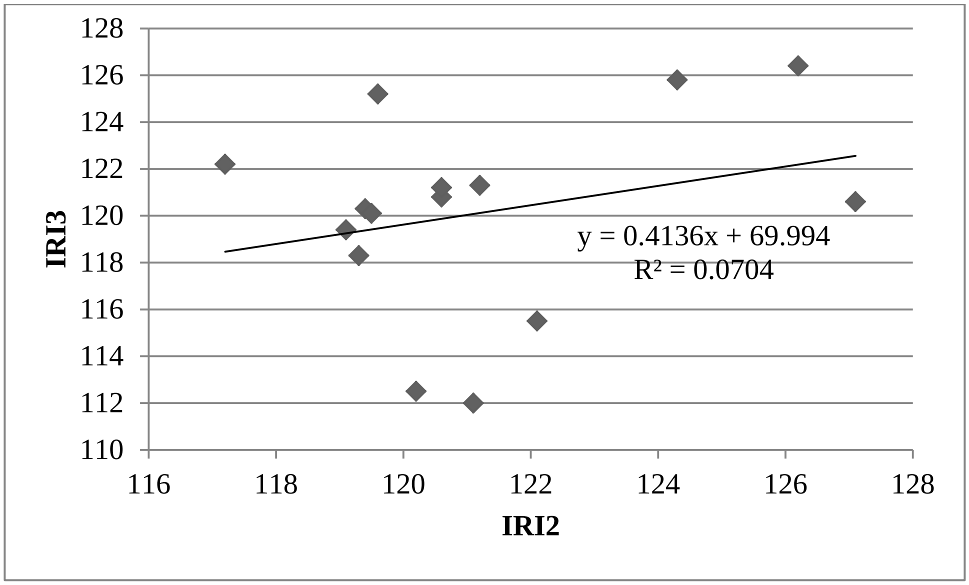
	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	ACR-1	**ACR-2**	**ACR_{1-2}**		**ACR-1**	**ACR-3**	**ACR_{1-3}**		**ACR-2**	**ACR-3**	**ACR_{2-3}**
Big Piney	0.04	0.05	0.250		0.04	0.04	0.000		0.05	0.04	-0.200
Buffalo	0.05	0.05	0.000		0.05	0.05	0.000		0.05	0.05	0.000
Casper Na	0.05	0.05	0.000		0.05	0.05	0.000		0.05	0.05	0.000
Cheyenne	0.05	0.05	0.000		0.05	0.04	-0.200		0.05	0.04	-0.200
Doug. Avn	0.06	0.05	-0.167		0.06	0.06	0.000		0.05	0.06	0.200
Evanston	0.04	0.04	0.000		0.04	0.04	0.000		0.04	0.04	0.000
Gillette	0.06	0.05	-0.167		0.06	0.06	0.000		0.05	0.06	0.200
Greybull	0.08	0.06	-0.250		0.08	0.07	-0.125		0.06	0.07	0.167
Lander	0.06	0.06	0.000		0.06	0.06	0.000		0.06	0.06	0.000
Laramie	0.04	0.04	0.000		0.04	0.04	0.000		0.04	0.04	0.000
Rawlins	0.05	0.04	-0.200		0.05	0.04	-0.200		0.04	0.04	0.000
Riverton	0.06	0.06	0.000		0.06	0.06	0.000		0.06	0.06	0.000
Rock Springs	0.05	0.05	0.000		0.05	0.04	-0.200		0.05	0.04	-0.200
Sheridan	0.06	0.06	0.000		0.06	0.06	0.000		0.06	0.06	0.000
Worland	0.08	0.06	-0.250		0.08	0.07	-0.125		0.06	0.07	0.167

	Actual Weather Data	Virtual Weather data interpolated from all generated stations	Change		Actual Weather Data	Virtual Weather data interpolated using similar elevations	Change		Virtual Weather data interpolated from all generated stations	Virtual Weather data interpolated using similar elevations	Change
	TR-1	**TR-2**	**TR_{1-2}**		**TR-1**	**TR-3**	**TR_{1-3}**		**TR-2**	**TR-3**	**TR_{2-3}**
Big Piney	0.25	0.24	-0.040		0.25	0.23	-0.080		0.24	0.23	-0.042
Buffalo	0.24	0.24	0.000		0.24	0.24	0.000		0.24	0.24	0.000
Casper Na	0.24	0.29	0.208		0.24	0.24	0.000		0.29	0.24	-0.172
Cheyenne	0.23	0.24	0.043		0.23	0.23	0.000		0.24	0.23	-0.042
Doug. Avn	0.25	0.24	-0.040		0.25	0.24	-0.040		0.24	0.24	0.000
Evanston	0.23	0.24	0.043		0.23	0.24	0.043		0.24	0.24	0.000
Gillette	0.25	0.24	-0.040		0.25	0.24	-0.040		0.24	0.24	0.000
Greybull	0.27	0.25	-0.074		0.27	0.26	-0.037		0.25	0.26	0.040
Lander	0.25	0.25	0.000		0.25	0.25	0.000		0.25	0.25	0.000
Laramie	0.22	0.23	0.045		0.22	0.23	0.045		0.23	0.23	0.000
Rawlins	0.23	0.23	0.000		0.23	0.23	0.000		0.23	0.23	0.000
Riverton	0.25	0.25	0.000		0.25	0.25	0.000		0.25	0.25	0.000
Rock Springs	0.24	0.24	0.000		0.24	0.23	-0.042		0.24	0.23	-0.042
Sheridan	0.25	0.24	-0.040		0.25	0.25	0.000		0.24	0.25	0.042
Worland	0.27	0.25	-0.074		0.27	0.26	-0.037		0.25	0.26	0.040

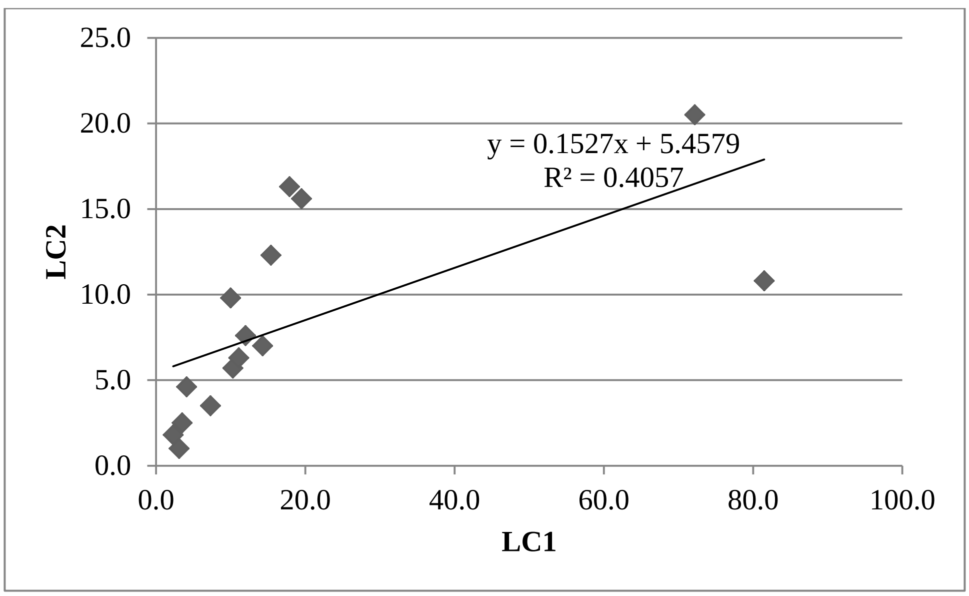
APPENDIX E1: INTERSTATE SCATTER PLOTS



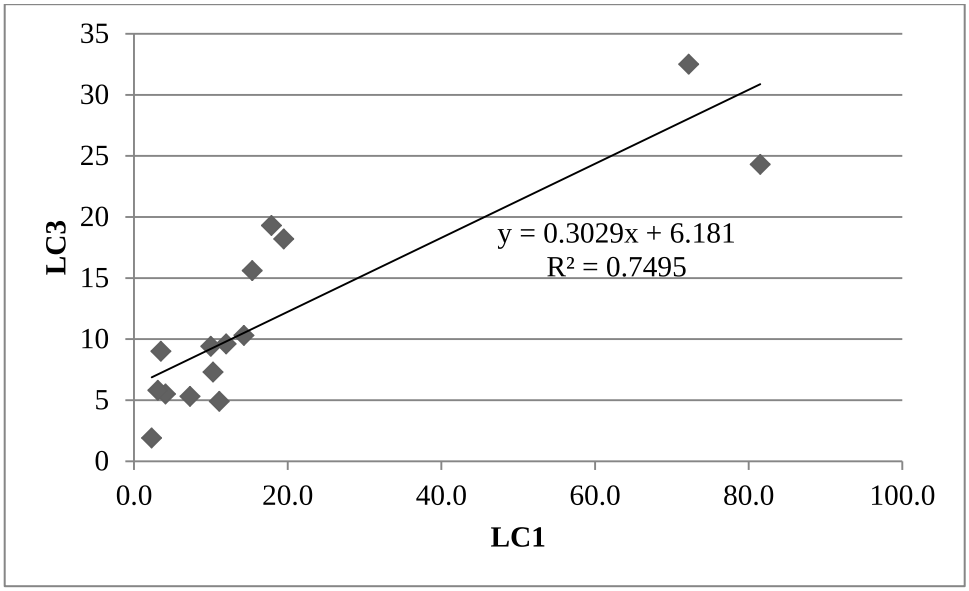


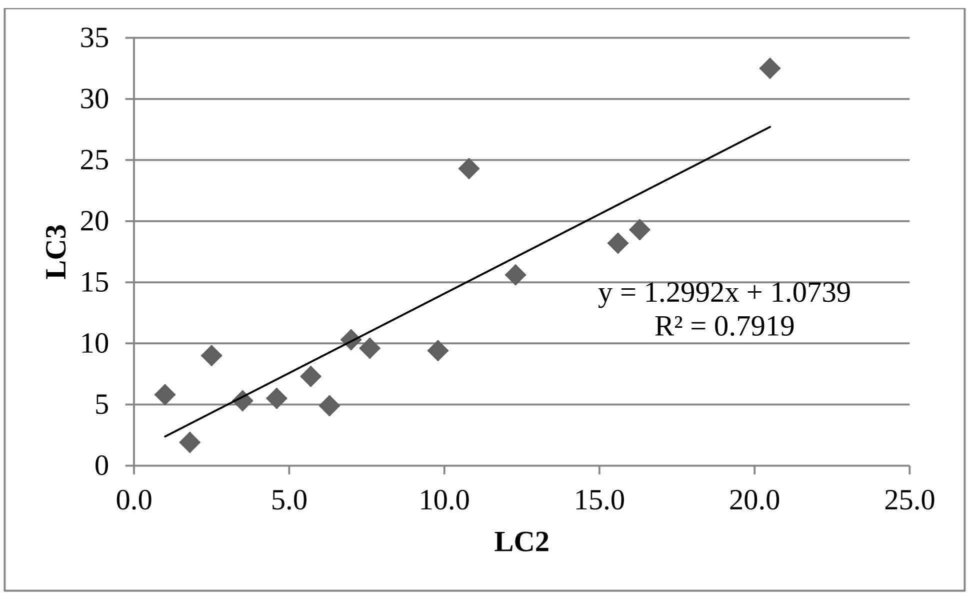


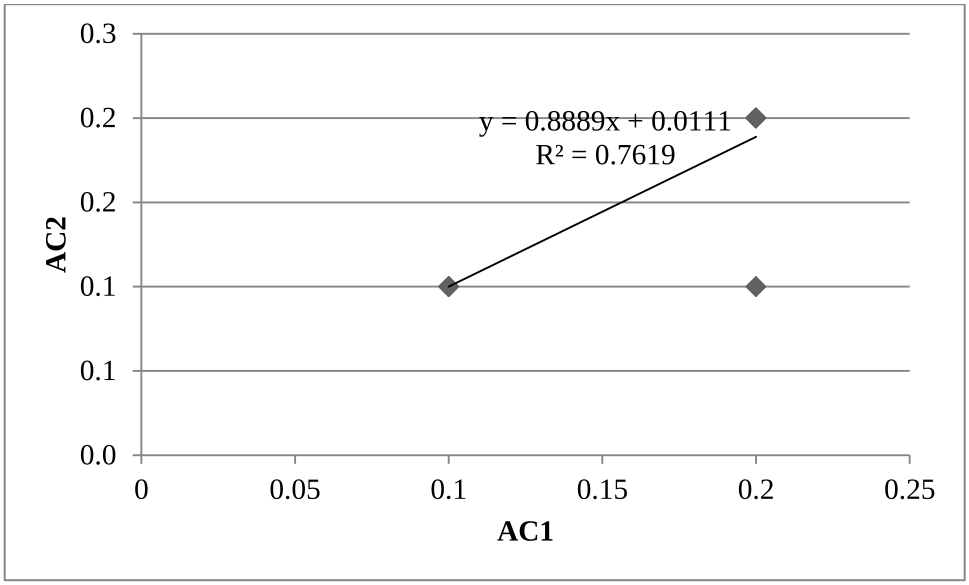
128
126
124
122
120
118
116
114
112
110
IRI3
116
118
120
122
124
126
128
IRI2
y = 0.4136x + 69.994
R² = 0.0704

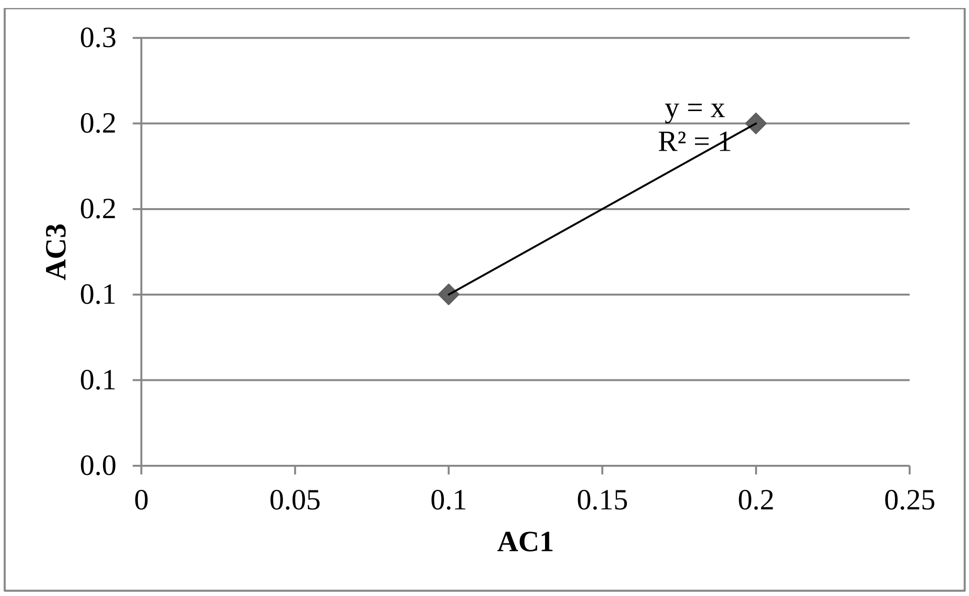


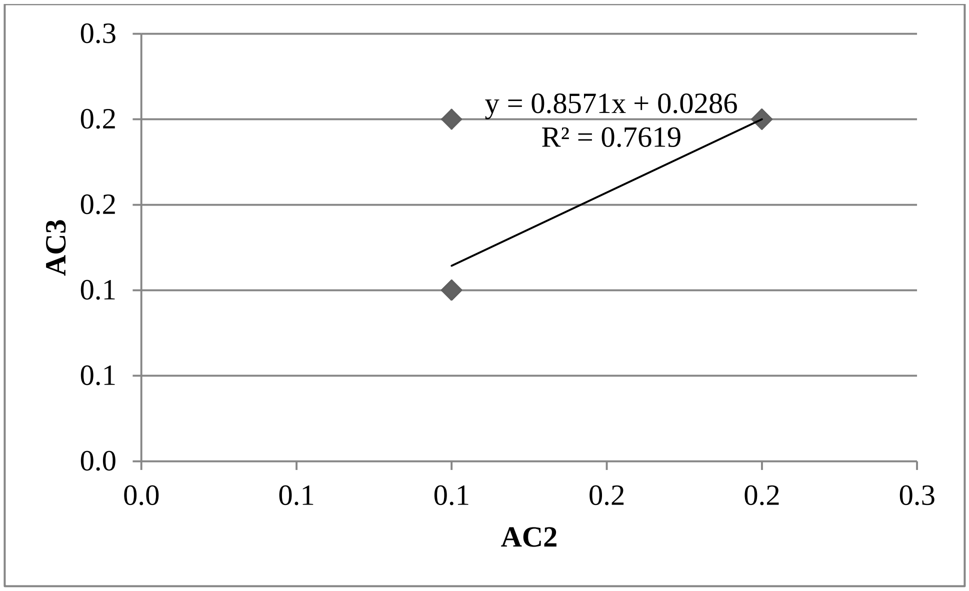
25.0
20.0
15.0
10.0
5.0
0.0
LC2
0.0
20.0
40.0
60.0
80.0
100.0
LC1
y = 0.1527x + 5.4579
R² = 0.4057

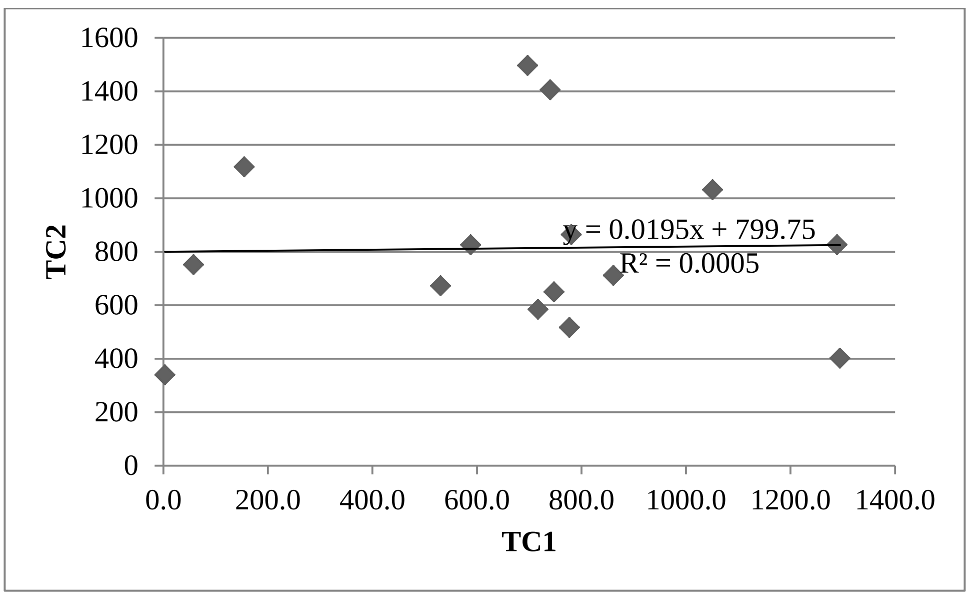

35
30
25
20
15
10
5
0
LC3
y = 0.3029x + 6.181
R² = 0.7495
0.0
20.0
40.0
60.0
80.0
100.0
LC1

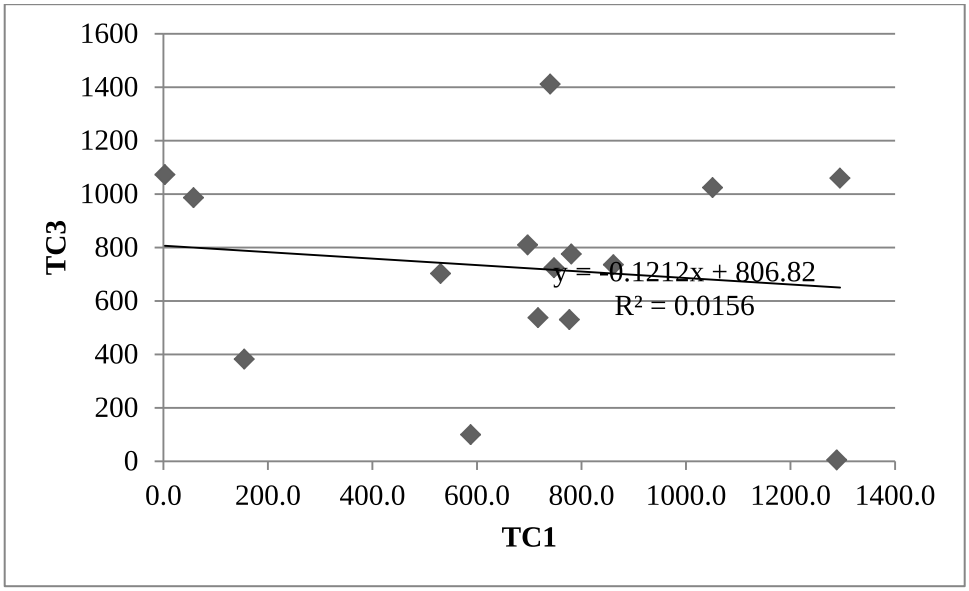

35
30
25
20
15
10
5
0
LC3
y = 1.2992x + 1.0739
R² = 0.7919
0.0
5.0
10.0
15.0
20.0
25.0
LC2


0.3
0.2
0.2
0.1
0.1
0.0
AC2
y = 0.8889x + 0.0111
R² = 0.7619
0
0.05
0.1
0.15
0.2
0.25
AC1

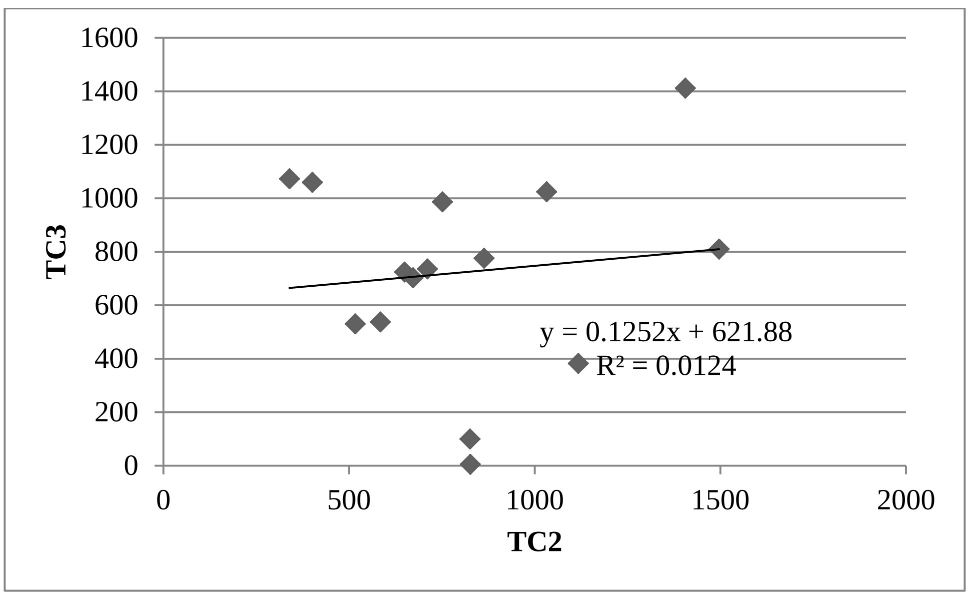

0.3
0.2
0.2
0.1
0.1
0.0
AC3
y = x
R² = 1
0
0.05
0.1
0.15
0.2
0.25
AC1


0.3
0.2
0.2
0.1
0.1
0.0
AC3
y = 0.8571x + 0.0286
R² = 0.7619
0.0
0.1
0.1
0.2
0.2
0.3
AC2

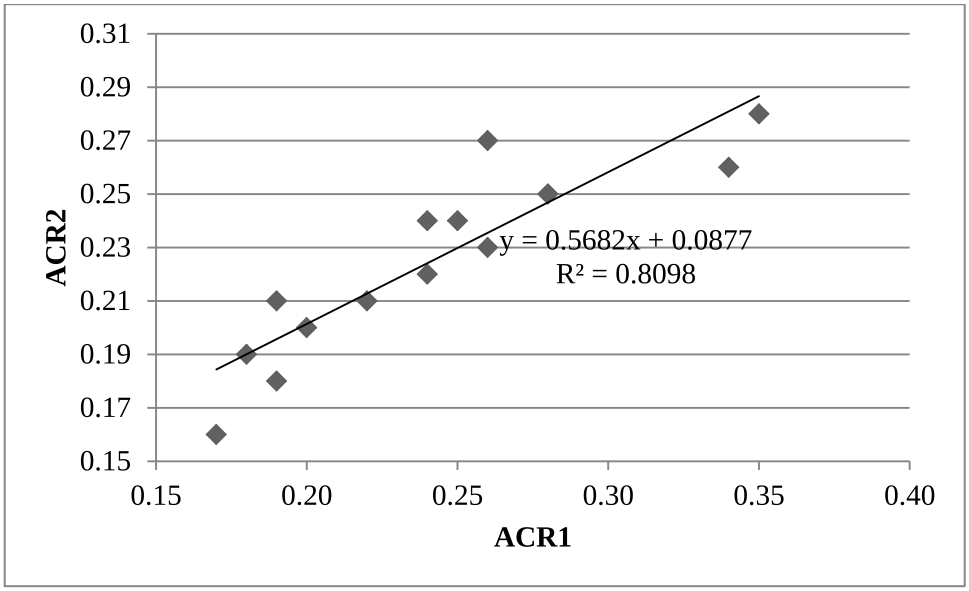

1600
1400
1200
1000
800
600
400
200
0
TC2
y = 0.0195x + 799.75
R² = 0.0005
0.0
200.0
400.0
600.0
800.0
1000.0
1200.0
1400.0
TC1

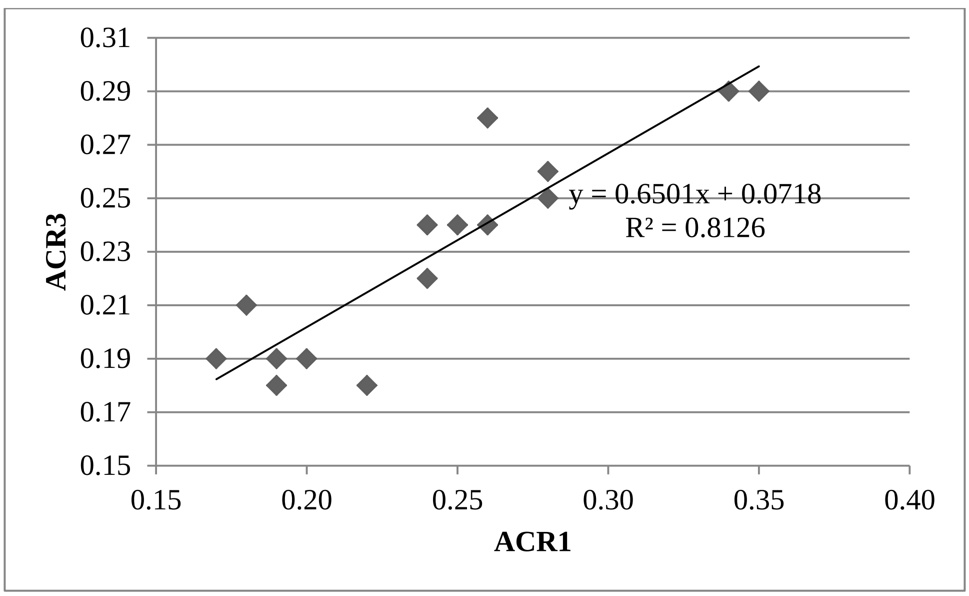


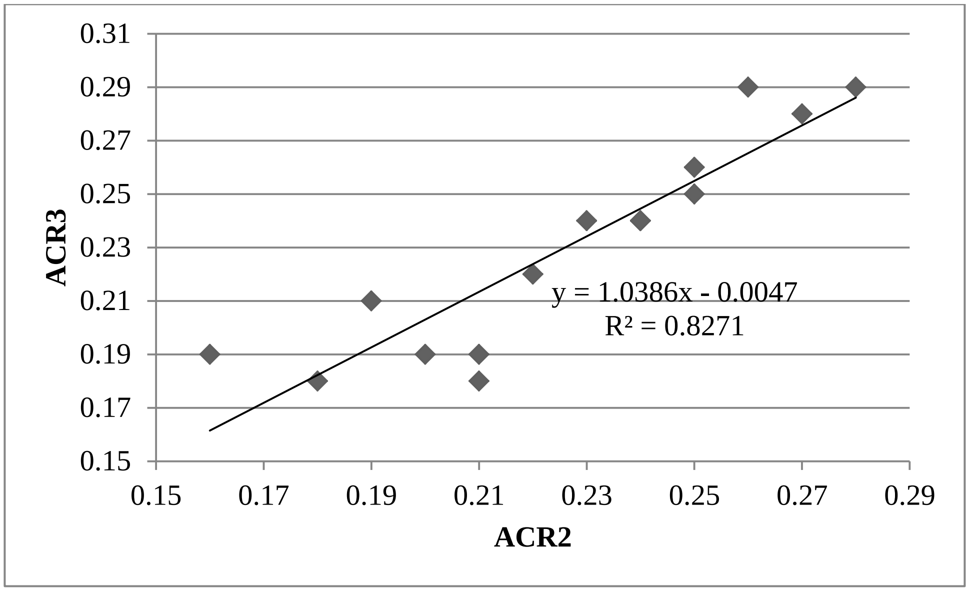
1600
1400
1200
1000
800
600
400
200
0
TC3
0.0
200.0
400.0
600.0
800.0
1000.0
1200.0
1400.0
TC1
y = -0.1212x + 806.82
R² = 0.0156

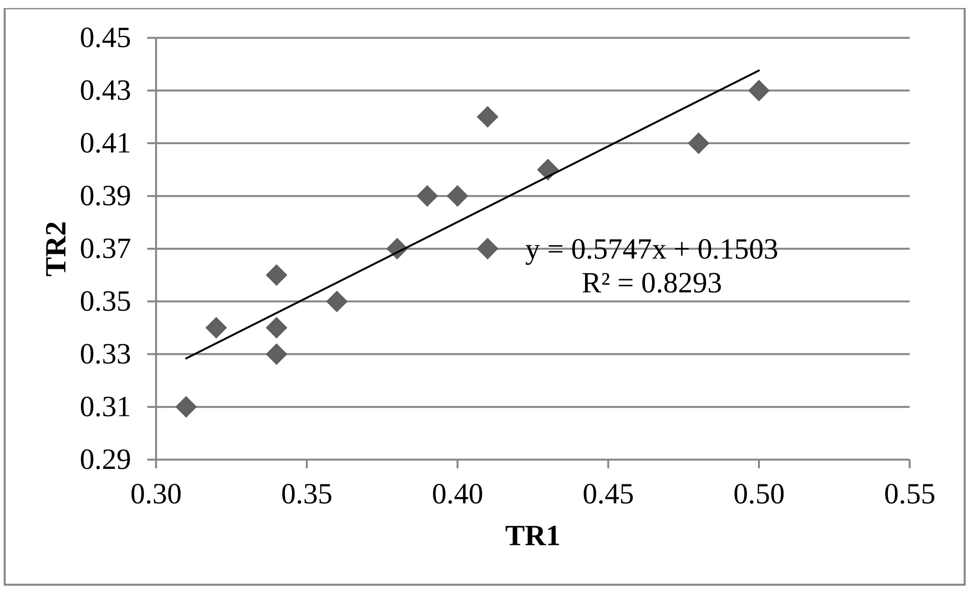


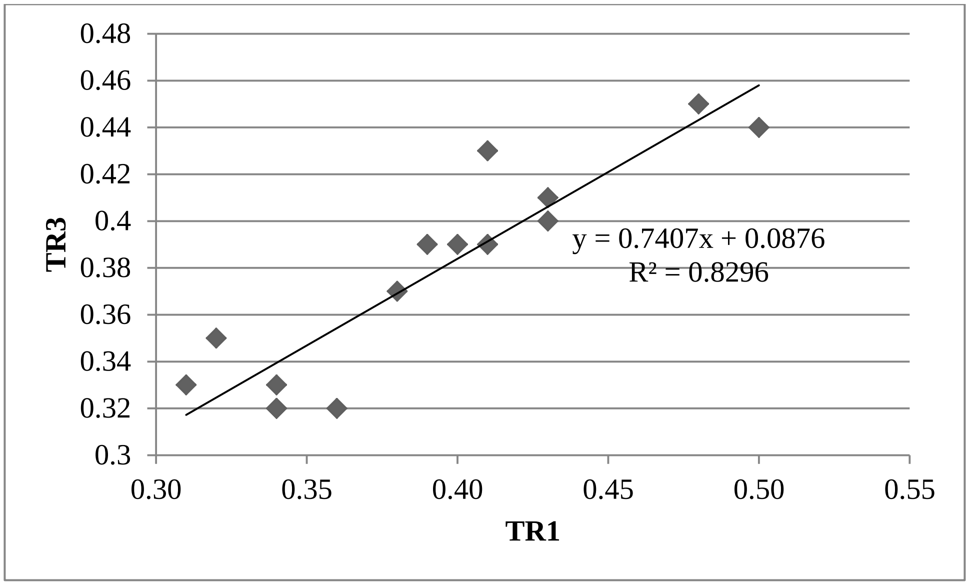
1600
1400
1200
1000
800
600
400
200
0
TC3
0
500
1000
1500
2000
TC2
y = 0.1252x + 621.88
R² = 0.0124

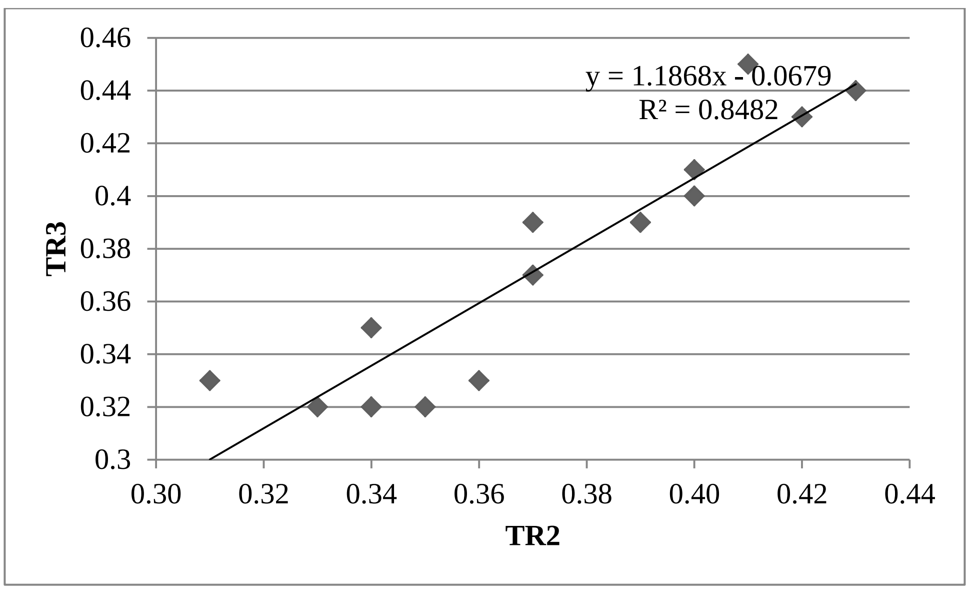

0.31
0.29
0.27
0.25
0.23
0.21
0.19
0.17
0.15
ACR2
y = 0.5682x + 0.0877
R² = 0.8098
0.15
0.20
0.25
0.30
0.35
0.40
ACR1

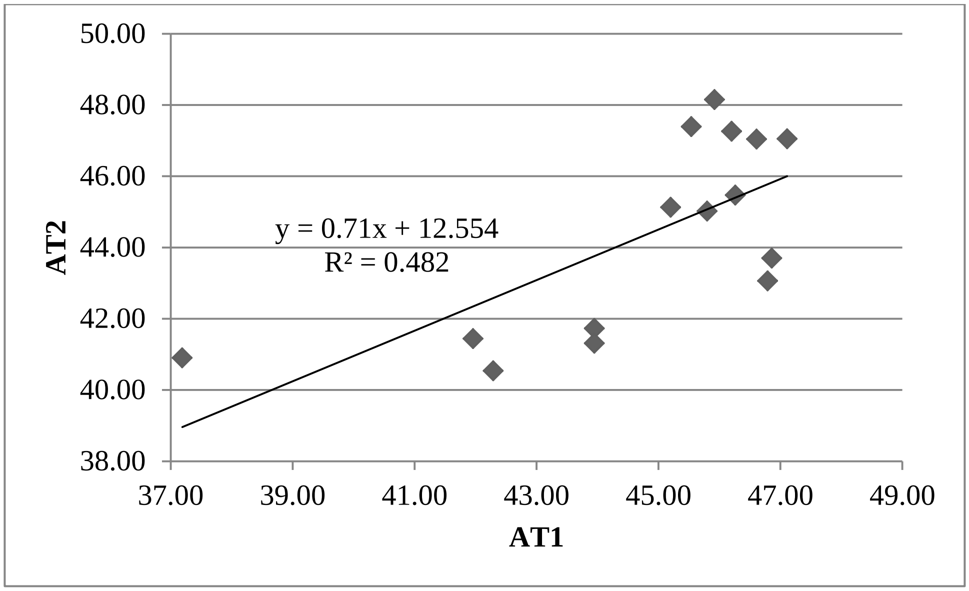

0.31
0.29
0.27
0.25
0.23
0.21
0.19
0.17
0.15
ACR3
y = 0.6501x + 0.0718
R² = 0.8126
0.15
0.20
0.25
0.30
0.35
0.40
ACR1

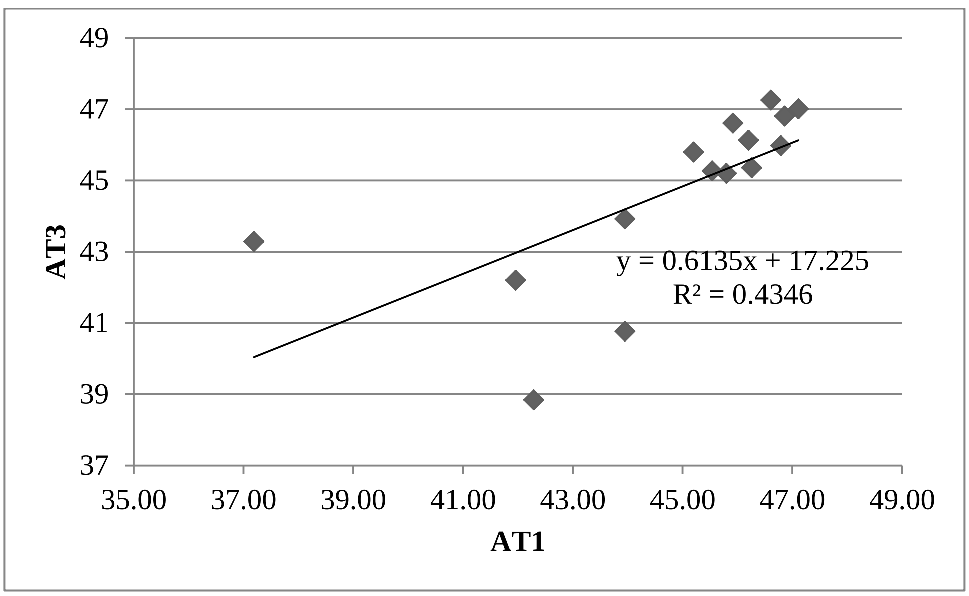

0.31
0.29
0.27
0.25
0.23
0.21
0.19
0.17
0.15
ACR3
0.15
0.17
0.19
0.21
0.23
0.25
0.27
0.29
ACR2
y = 1.0386x - 0.0047
R² = 0.8271

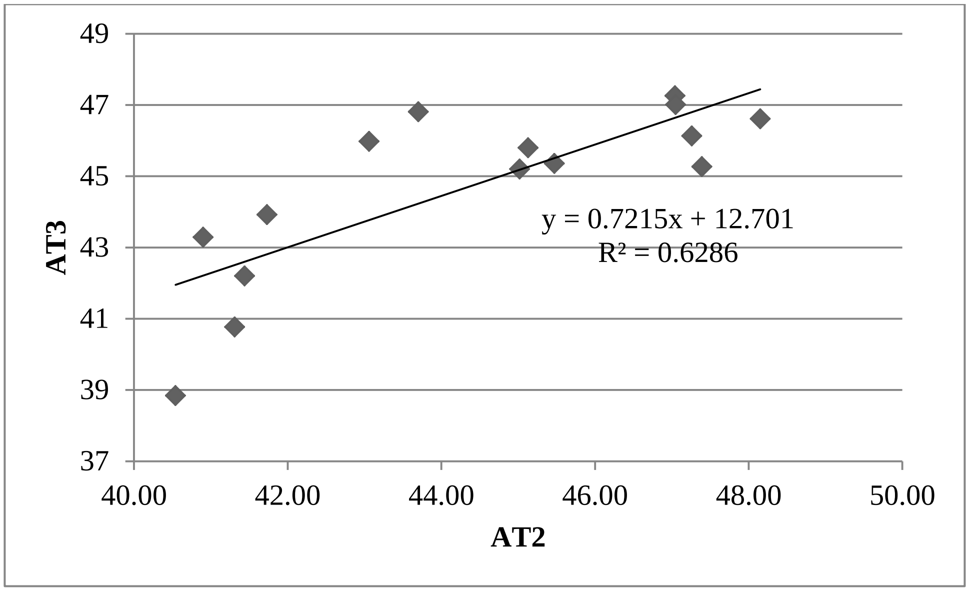

0.45
0.43
0.41
0.39
0.37
0.35
0.33
0.31
0.29
TR2
0.30
0.35
0.40
0.45
0.50
0.55
TR1
y = 0.5747x + 0.1503
R² = 0.8293

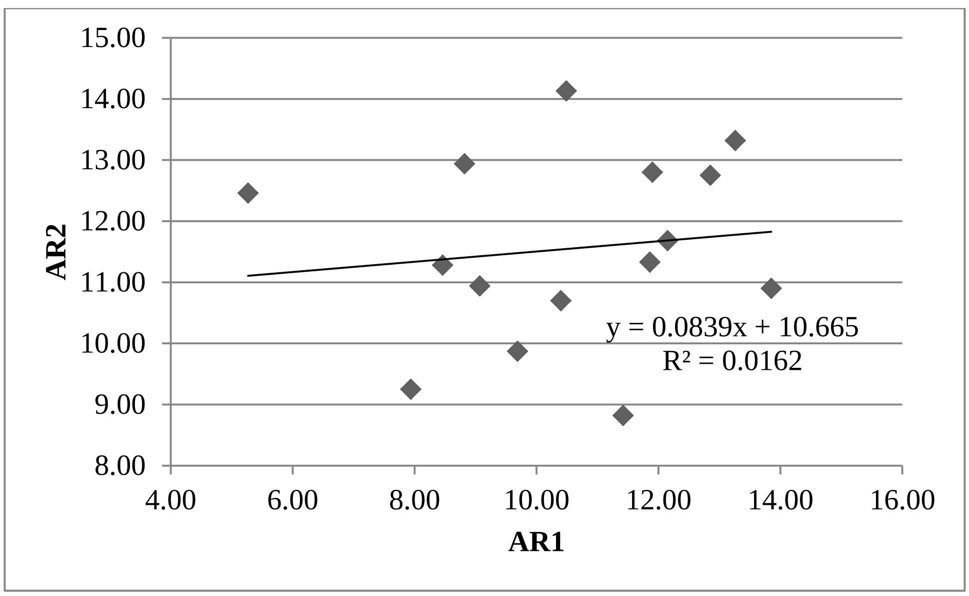

0.48
0.46
0.44
0.42
0.4
0.38
0.36
0.34
0.32
0.3
TR3
y = 0.7407x + 0.0876
R² = 0.8296
0.30
0.35
0.40
0.45
0.50
0.55
TR1

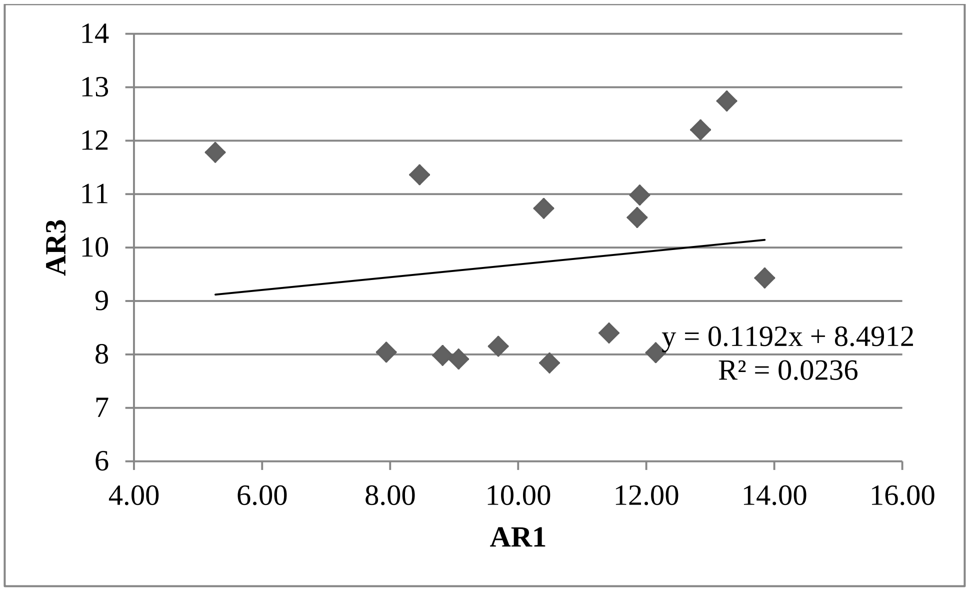

0.46
0.44
0.42
0.4
0.38
0.36
0.34
0.32
0.3
TR3
y = 1.1868x - 0.0679
R² = 0.8482
0.30
0.32
0.34
0.36
0.38
0.40
0.42
0.44
TR2


50.00
48.00
46.00
44.00
42.00
40.00
38.00
AT2
y = 0.71x + 12.554
R² = 0.482
37.00
39.00
41.00
43.00
45.00
47.00
49.00
AT1

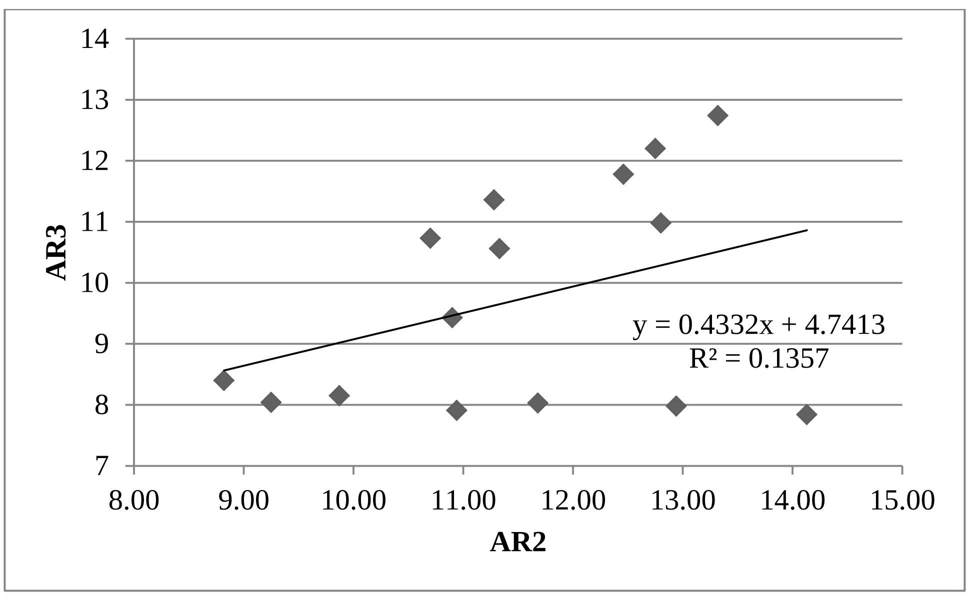

49
47
45
43
41
39
37
AT3
y = 0.6135x + 17.225
R² = 0.4346
35.00
37.00
39.00
41.00
43.00
45.00
47.00
49.00
AT1


49
47
45
43
41
39
37
AT3
y = 0.7215x + 12.701
R² = 0.6286
40.00
42.00
44.00
46.00
48.00
50.00
AT2

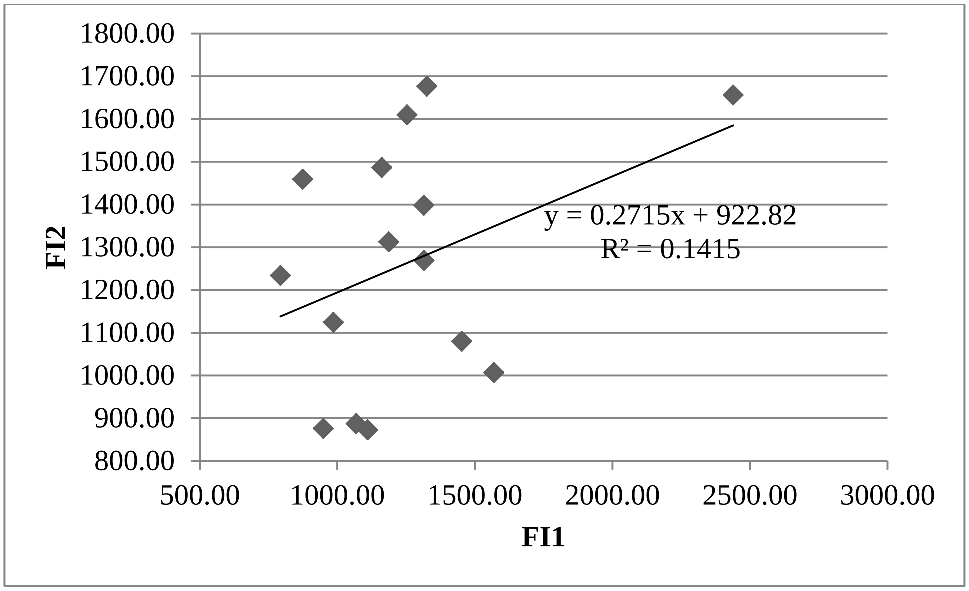

15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
AR2
y = 0.0839x + 10.665
R² = 0.0162
4.00
6.00
8.00
10.00
12.00
14.00
16.00
AR1

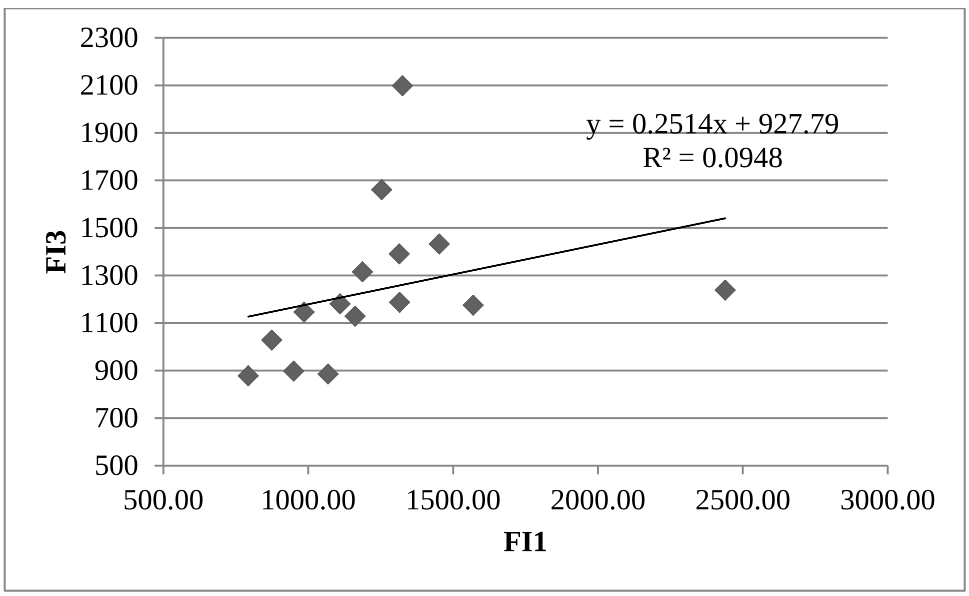


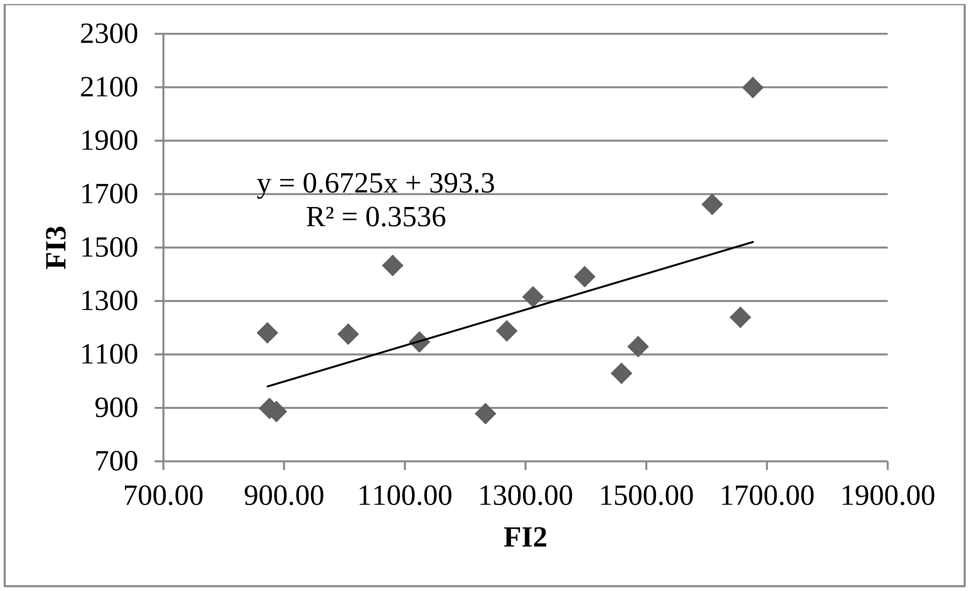
14
13
12
11
10
9
8
7
6
AR3
y = 0.1192x + 8.4912
R² = 0.0236
4.00
6.00
8.00
10.00
12.00
14.00
16.00
AR1

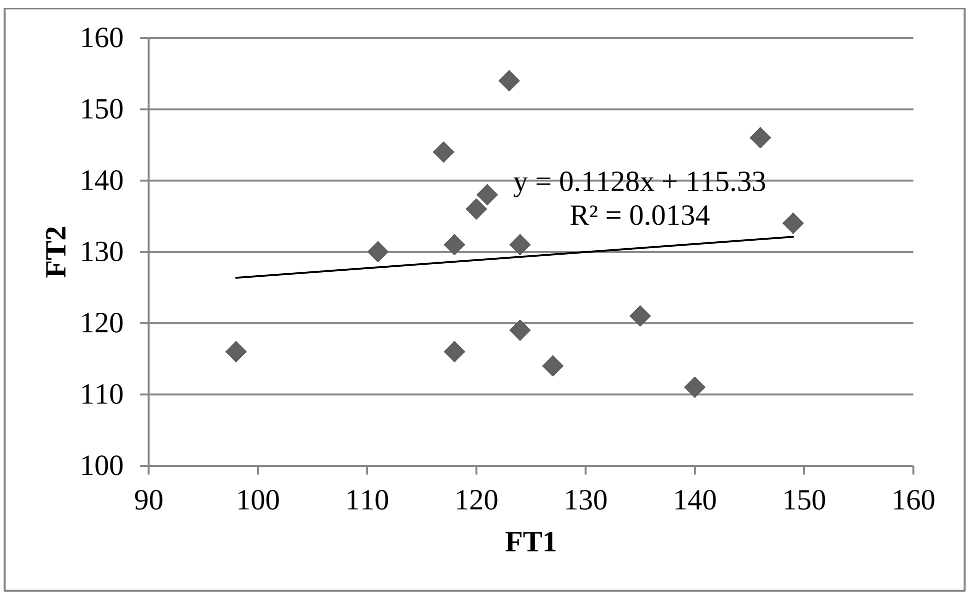


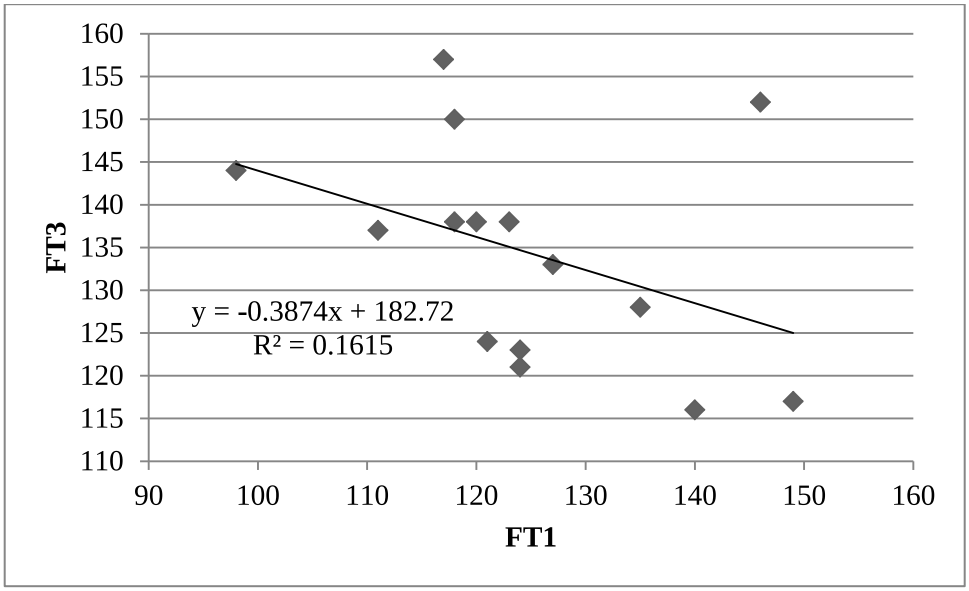
14
13
12
11
10
9
8
7
AR3
y = 0.4332x + 4.7413
R² = 0.1357
8.00
9.00
10.00
11.00
12.00
13.00
14.00
15.00
AR2

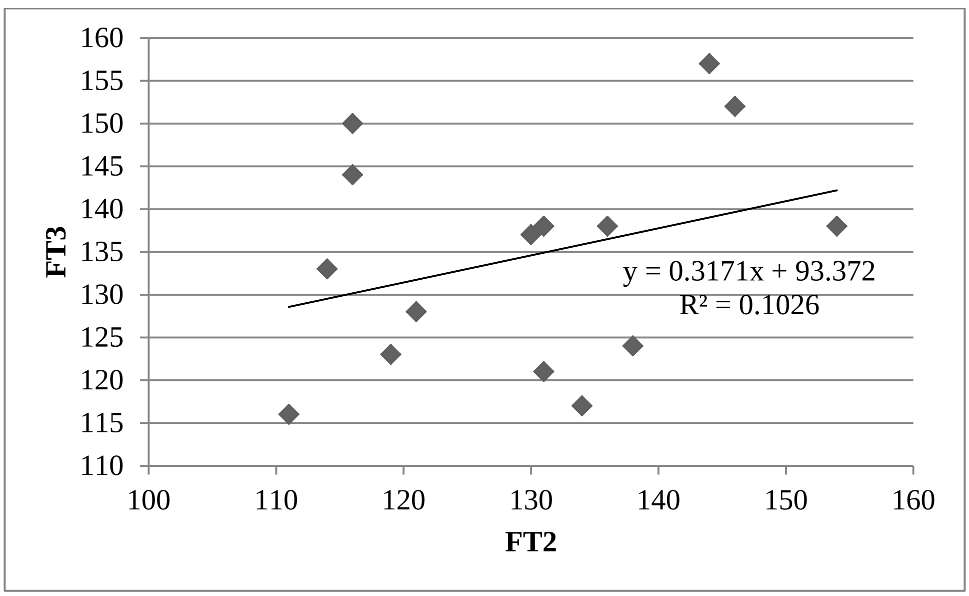

1800.00
1700.00
1600.00
1500.00
1400.00
1300.00
1200.00
1100.00
1000.00
900.00
800.00
FI2
y = 0.2715x + 922.82
R² = 0.1415
500.00
1000.00
1500.00
2000.00
2500.00
3000.00
FI1


2300
2100
1900
1700
1500
1300
1100
900
700
500
FI3
y = 0.2514x + 927.79
R² = 0.0948
500.00
1000.00
1500.00
2000.00
2500.00
3000.00
FI1


2300
2100
1900
1700
1500
1300
1100
900
700
y = 0.6725x + 393.3
R² = 0.3536
FI3
700.00
900.00
1100.00
1300.00
1500.00
1700.00
1900.00
FI2


160
150
140
130
120
110
100
y = 0.1128x + 115.33
R² = 0.0134
FT2
90
100
110
120
130
140
150
160
FT1


160
155
150
145
140
135
130
125
120
115
110
90
100
110
120
130
140
150
160
FT3
FT1
y = -0.3874x + 182.72
R² = 0.1615


160
155
150
145
140
135
130
125
120
115
110
100
110
120
130
140
150
160
FT3
FT2
y = 0.3171x + 93.372
R² = 0.1026