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16. Abstract The existing formulas used by the Texas Department of Transportation (TxDOT) to allocate the statewide maintenance budget rely heavily on inventory and pavement evaluation data. These formulas include regional factors and rainfall indices that vary by district to account for differences in environmental and soil factors across the state. The existing regional factors were developed in the 1990s and were intended to reflect differences in environmental and soil factors between districts. It is not known how these factors were calculated since no documentation is available that explains their development. Since the regional factors were introduced, the Texas Transportation Institute has completed a project in which a database of climatic and soil factors were compiled to characterize the variation of climatic and soil conditions across Texas. TxDOT's Maintenance Division realized the potential value of using this information and directed an implementation project to re-examine the existing regional and rainfall factors with the objective of revising the current factors to better reflect differences in climatic and soil conditions between districts. This report documents the evaluation of the existing rainfall and regional factors and the development of a revised set of factors for maintenance cost allocation.					
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# **INVESTIGATION OF RAINFALL AND REGIONAL FACTORS FOR MAINTENANCE COST ALLOCATION**

by

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Report 5-4519-01-1  
Project 5-4519-01

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Maintenance Budget Allocation

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## CHAPTER I. INTRODUCTION

The existing formulas used by the Texas Department of Transportation (TxDOT) to allocate the statewide maintenance budget rely heavily on inventory and pavement evaluation data. These formulas include regional factors and rainfall indices that vary by district to account for differences in environmental and soil factors across the state. Table 1 shows these factors based on TxDOT's FY2009 maintenance allocation spreadsheet. The existing regional factors were developed in the 1990s and were intended to reflect differences in environmental and soil factors between districts. It is not known how these factors were calculated since no documentation is available that explains their development. Since the regional factors were introduced, TxDOT has completed a project in which a database of climatic and soil factors were compiled to characterize the variation of climatic and soil conditions across Texas. Researchers from the Texas Transportation Institute (TTI) compiled this database in TxDOT Project 0-4519 to develop a procedure that provides pavement design engineers the option to consider moisture effects and differences in moisture susceptibilities between soils in the modified Texas triaxial design method. TxDOT's Maintenance Division realized the potential value of using the information from Project 0-4519 and directed an implementation project to re-examine the existing regional and rainfall factors with the objective of revising the current factors to better reflect differences in climatic and soil conditions between districts. To accomplish this objective, TTI researchers carried out the following tasks during this one-year implementation project:

- reviewed TxDOT's existing maintenance cost allocation formulas and regional factors to develop an understanding of the current cost allocation methodology;
- evaluated the regional and rainfall factors presently used for cost allocation against the observed yearly variations in rainfall and predicted variations in pavement load bearing capacity across the state; and
- established a revised set of regional and rainfall factors.

This report documents the development of the proposed regional and rainfall factors for maintenance cost allocation. Researchers note that the project focused on evaluating the existing regional and rainfall factors to establish a revised set of factors that better capture regional differences. No changes to the current cost allocation formulas were made.

**Table 1. Regional and Rainfall Factors by District.**

District	Regional Factor	30-year Average Rainfall (inches)	Rainfall Factor <sup>1</sup>
Paris (PAR)	1.0	47.82	1.48
Fort Worth (FTW)	1.1	34.06	1.05
Wichita Falls (WFS)	1.1	28.83	0.89
Amarillo (AMA)	1.1	19.71	0.61
Lubbock (LBB)	1.1	18.69	0.58
Odessa (ODA)	1.2	14.32	0.44
San Angelo (SJT)	1.1	20.91	0.65
Abilene (ABL)	1.1	23.78	0.73
Waco (WAC)	1.0	33.34	1.03
Tyler (TYL)	1.0	45.27	1.40
Lufkin (LFK)	1.0	46.62	1.44
Houston (HOU)	1.0	50.83	1.57
Yoakum (YKM)	1.1	40.96	1.26
Austin (AUS)	1.0	31.88	0.98
San Antonio (SAT)	1.1	32.92	1.02
Corpus Christi (CRP)	1.1	30.13	0.93
Bryan (BRY)	1.0	39.67	1.22
Dallas (DAL)	1.0	33.70	1.04
Atlanta (ATL)	1.0	48.83	1.51
Beaumont (BMT)	1.0	58.09	1.79
Pharr (PHR)	1.1	27.55	0.85
Laredo (LRD)	1.1	21.53	0.66
Brownwood (BWD)	1.1	28.32	0.87
El Paso (ELP)	1.2	9.43	0.29
Childress (CHS)	1.2	22.65	0.70

<sup>1</sup>District rainfall average/Statewide rainfall average

## CHAPTER II. REVIEW OF EXISTING COST ALLOCATION FORMULAS

Researchers reviewed an internal TxDOT report (*I*) provided by the project director that documents the original development of the cost allocation formulas in 1996. During that year, then Executive Director Mr. Bill Burnett commissioned a continuous improvement (CI) team to develop an allocation method that reduced reliance on the use of historical expenditures to distribute the routine maintenance budget. To accomplish this directive, the CI team took the approach of developing needs-based formulas to estimate levels of funding necessary to perform different maintenance functions that were grouped into the following five major areas:

- pavement maintenance,
- roadside maintenance,
- bridge maintenance,
- traffic operations, and
- extraordinary maintenance.

The formulas related to pavement maintenance, roadside maintenance, and traffic operations are functions of one or more of the following factors: inventory, traffic, pavement condition, and environment. Bridge maintenance allocations are generally determined based on bridge deck areas with the exception of movable span bridges where the allocation is determined based on expenditures incurred during the previous six years. The CI team noted the year-to-year fluctuations in cost associated with items falling under the extraordinary maintenance group. These items fall under TxDOT's 800 series function codes and are associated with services performed to maintain operation of the highway system during snow, ice, and flooding events. In view of the cost fluctuations and the difficulty in planning for these events, the CI team decided to base allocations on the last six years of expenditures (excluding the high and low years) for the extraordinary maintenance group.

Since this project is concerned with the rainfall and regional factors for maintenance allocation, researchers focused on those formulas where these factors are used. Table 2 identifies the maintenance functions where regional and rainfall factors are used in the existing formulas. The CI team report (*I*) describes these formulas as follows.

**Table 2. Maintenance Functions with Regional and Rainfall Adjustments.**

Maintenance Function (codes)	Regional Factor	Rainfall Factor
Base repair (110 & 120)	X	
Level-up/overlay (211, 212, & 213)	X	X
Crack sealing (225 & 325)		X
Seal coat (231)	X	
Spot or edge seal (232)	X	
Fog seal* (233)	X	
Blading shoulders (455)		X
Tree and brush control (552)		X
Slope repair/stabilization (563)		X
Culvert & storm drain maintenance (570)		X

\*Fog seal is a function of seal coat cost where a regional factor is applied.

## PAVEMENT MAINTENANCE ALLOCATION

### Base Repair

From TxDOT’s Pavement Management Information System (PMIS), the CI team considered the number of lane miles (LM) of intolerable pavement failures. The team decided that due to funding limitations, no more than 10 percent of the intolerable pavements could be repaired in any year, and that no more than 150 lane miles could be repaired per district per year. A district’s lane miles of intolerable pavements is multiplied by 7040 yd<sup>2</sup>/LM to get the total affected area. This figure is then divided by a regional factor to account for the effects of weather and soils. The resulting figure is then multiplied by the average statewide unit cost (\$/yd<sup>2</sup>) for base repair to get the allocation for the given district and fiscal year.

The CI team indicated in their report that the regional factor was obtained from a TxDOT document entitled “Maintenance and Operation Plan 1998–1999.” While this document might have provided an explanation regarding the development of the regional factors, no copy of the document was available for this review. However, as will be presented in the next chapter, this project did find a rationale for the existing regional factors. This finding is based on the strong agreement observed between the existing regional factors and district rankings determined from load bearing capacity predictions that considered the range of soil types and soil moisture conditions across the state.

## **Level-Up and Overlay**

The CI team considered PMIS ride quality data to determine the need for leveling and overlays. The team decided that 10 percent of the intolerable lane miles, 50 percent of the tolerable lane miles, and 25 percent of the acceptable lane miles could be leveled or overlaid (up to a maximum of 300 lane miles per district per year). In the team's formula, the LMs are multiplied by 7040 yd<sup>2</sup>/LM to get the total surface area for level-ups and overlays. The resulting quantity is then divided by the applicable regional factor and then multiplied by the average unit cost in \$/yd<sup>2</sup>. This figure is then multiplied by the applicable rainfall factor in TxDOT's maintenance allocation spreadsheets to get the budget estimate for the given district and fiscal year.

## **Crack Sealing**

The CI team considered lane miles of district roadways and rainfall to be the significant factors when determining the need for crack sealing. In the formula, 20 percent of each district's lane miles are multiplied by 200 ft of crack sealing per LM to get the total length of cracks to be sealed. This figure is multiplied by the applicable rainfall factor and by the statewide average unit cost (\$/ft) to get the budget estimate for the given district and fiscal year.

## **Seal Coat**

In the formula developed by the CI team, the allocation for seal coats is based on the lane miles of each district's roadways with less than 10,000 vehicles per day. This number of lane miles is divided by 20 since only 5 percent of the lane miles of seal coats statewide can be funded each year. The resulting number of lane miles is then multiplied by 7040 yd<sup>2</sup>/LM to get the total seal coat area and then divided by the applicable regional factor. Finally, the resulting figure is multiplied by the average unit cost (\$/yd<sup>2</sup>) to get the seal coat allocation for the given district and fiscal year.

## **Spot or Edge Seal**

The CI team's formula uses the center line miles (CLM) of roadways with widths less than or equal to 24 ft to estimate the spot seal budget. For this calculation, the CI team

assumed that each district's CLM will require a 2 ft edge seal on each side of the roadway. Based on this assumption, the total square footage of spot or edge seals can be estimated. This square footage is then converted to square yards and then divided by 5 since only 20 percent of the district CLM can be funded each year. The resulting figure is then divided by the applicable regional factor and then multiplied by the average price per square yard to get the allocation for the given district and fiscal year.

### **Fog Seal**

The CI team considered fog seals to be a function of the seal coat budget. Therefore, the number of lane miles allocated for fog seals equals the number of lane miles allocated for seal coats in the given district and fiscal year. This number of lane miles is multiplied by 7040 yd<sup>2</sup>/LM and then by the average unit fog seal cost in \$/yd<sup>2</sup> to get the fog seal budget for the given district and fiscal year.

### **Blading Shoulders**

The CI team considered blading shoulders to be a function of CLM of narrow roadways ( $\leq 24$  ft in width) and rainfall. The team also assumed that only 4 percent of the applicable CLM can be funded, statewide, each year. Thus, the CLM is divided by 25, and the resulting quantity is then multiplied by 5280 ft/mile  $\times$  2 roadway sides to get the total length of shoulders to be bladed. Finally, this figure is multiplied by the statewide average unit cost (\$/ft) to get the budget for this pavement maintenance function.

## **ROADSIDE MAINTENANCE ALLOCATION**

### **Tree and Brush Control**

While some of this work is sporadic, the CI team considered tree and brush control cost as a function of rainfall and roadway inventory. The allocation is based on the ratio of district CLM versus statewide CLM multiplied by the rainfall factor. This figure is then multiplied by the statewide average unit cost (\$/CLM) to get the budget for the given district and fiscal year.

Based on reviewing TxDOT's maintenance allocation spreadsheets from FY07 to FY09, the above estimate from the CI team's formula was further divided by 3 to arrive at the allocations for tree and brush control over these fiscal years.

### **Slope Repair/Stabilization**

The CI team's formula for estimating the slope repair/stabilization budget is the same as that for tree and brush control except that the applicable statewide average unit cost (\$/CLM) for slope repair/stabilization is used to estimate the budget.

### **Culvert and Storm Drain Maintenance**

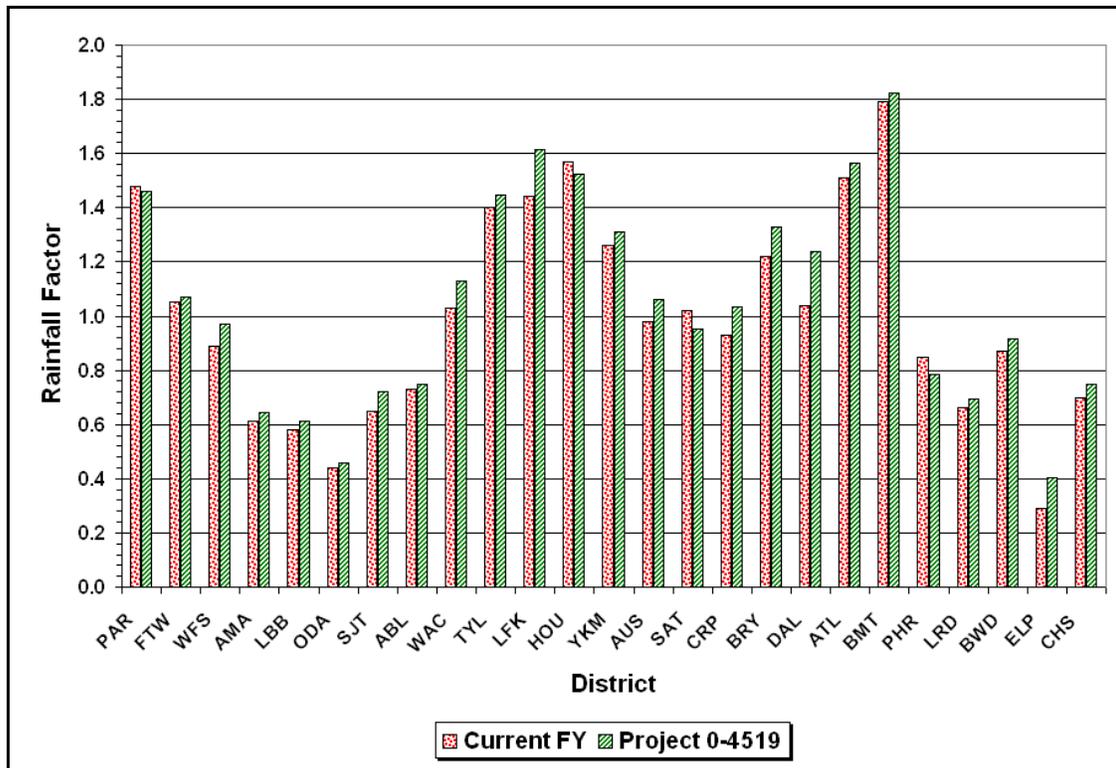
The CI team considered culvert and storm drain maintenance cost as a function of rainfall and urbanization. Given that daily vehicle miles (VM) traveled is an indicator of the level of urbanization, the CI team's allocation is based on the ratio of district VM versus statewide VM multiplied by the applicable rainfall factor. The resulting figure is then multiplied by the statewide average unit cost (\$/VM) to get the budget for culvert and storm drain maintenance for the given district and fiscal year.



## CHAPTER III. EVALUATION OF RAINFALL AND REGIONAL FACTORS FOR MAINTENANCE COST ALLOCATION

### RAINFALL FACTORS

The rainfall factors given in Table 1 are based on 30-year district and statewide rainfall averages with the most recent factors determined from rainfall data covering the years 1971 to 2000. Researchers initially compared the existing rainfall factors with corresponding values determined using the climatic data compiled in Project 0-4519. In that former project, TTI researchers (2) compiled available weather station data for all Texas counties and computed for each county 30-year averages of different climatic variables that included precipitation. Using these 30-year county rainfall averages, researchers computed the corresponding rainfall factors per district by averaging the values for the counties comprising a district; then averaging over all 254 Texas counties to get the statewide average; and finally determining the rainfall factors as the ratios of district to statewide rainfall averages. Figure 1 compares the existing rainfall factors with the corresponding values determined using Project 0-4519 data.



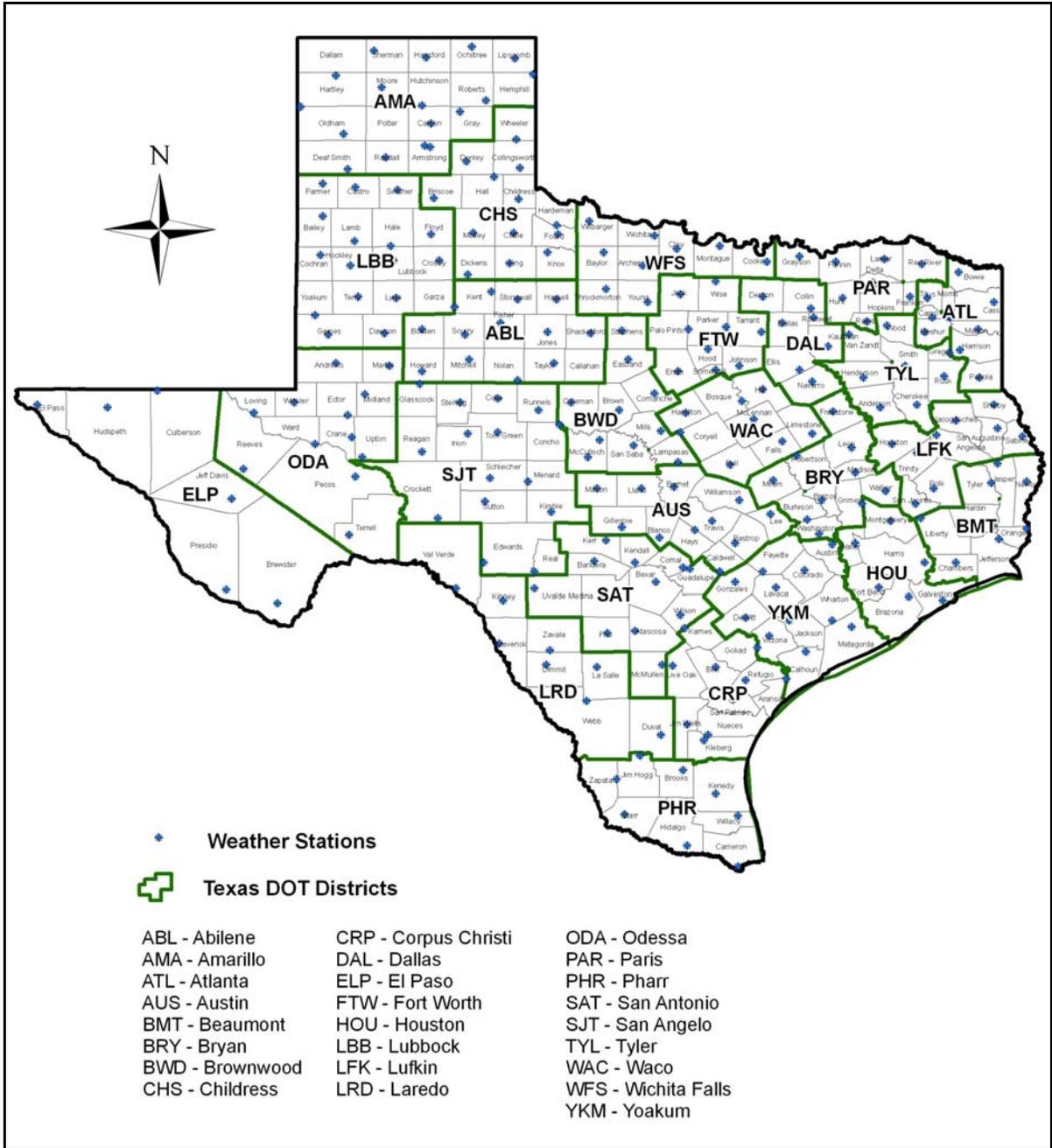
**Figure 1. Comparison of Current Fiscal Year Rainfall Factors with Values Determined from Project 0-4519 Precipitation Data.**

In general, Figure 1 shows good agreement between the existing rainfall factors and those determined from Project 0-4519 climatic data, with the magnitudes of the differences ranging from 0.02 to 0.20. Researchers also compared the maintenance cost allocations between the two sets of rainfall factors. For this comparison, researchers used the current TxDOT 2010 fiscal year (FY10) Excel® spreadsheet to determine the cost allocations using Project 0-4519 rainfall factors. Table 3 shows this comparison based on the maintenance functions where rainfall factors are applied. The cost allocations in the Project 0-4519 column are observed to be consistently higher than the corresponding cost allocations based on the existing FY10 rainfall factors. However, the differences are generally within 5 percent and are not considered to be significant.

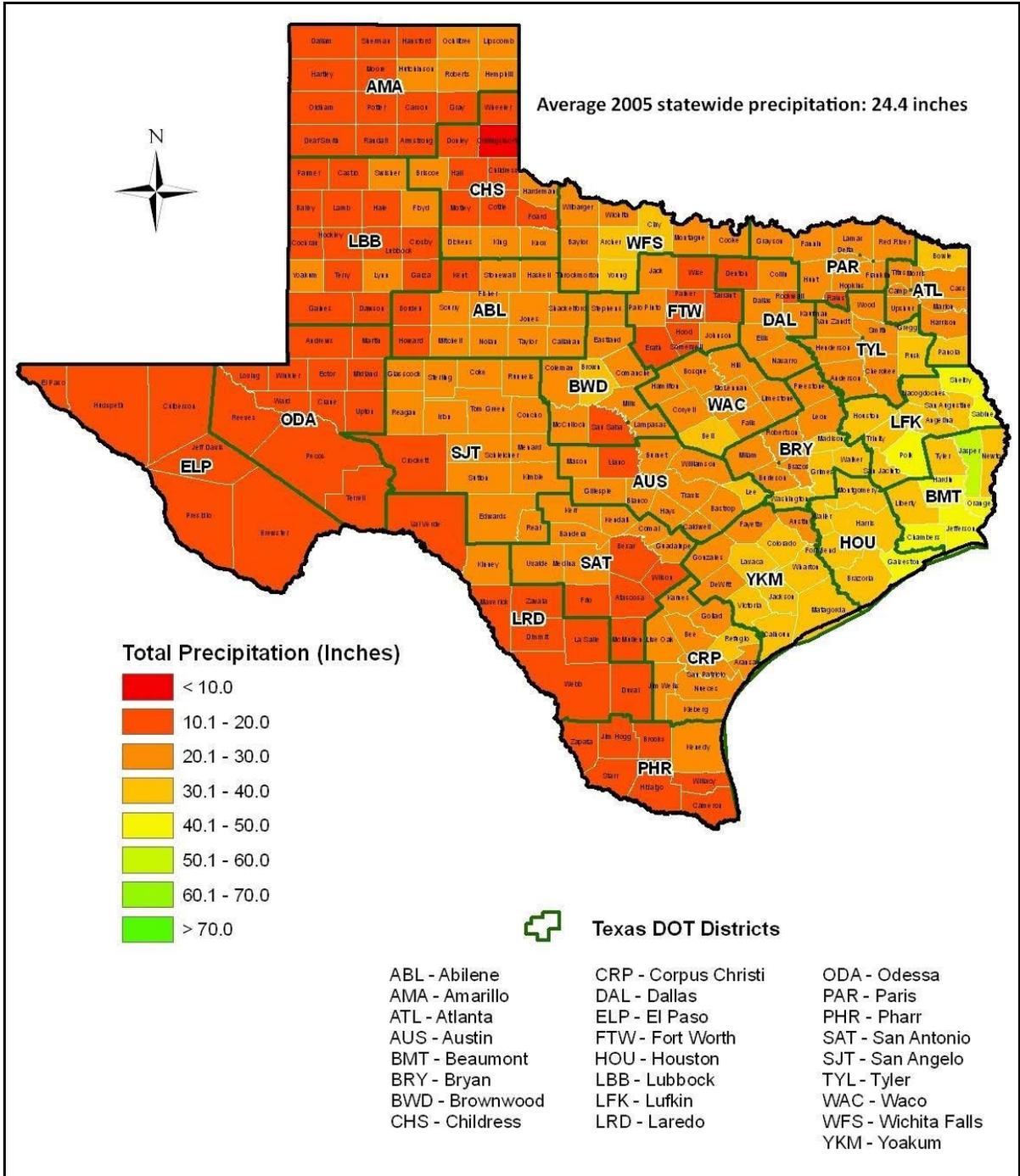
**Table 3. Comparison of FY10 Cost Allocations from Two Sets of Rainfall Factors.**

Maintenance Function	Rainfall Factor		Percent Difference
	FY10	Project 0-4519	
Level-up/Overlay	\$214,006,881	\$224,915,047	5.10
Crack sealing	\$25,445,017	\$26,684,120	4.87
Blading shoulders	\$6,933,062	\$7,284,580	5.07
Tree & brush control	\$10,326,042	\$10,838,684	4.96
Slope repair/stabilization	\$2,644,396	\$2,775,678	4.96
Culvert & storm drain maintenance	\$23,696,029	\$24,633,891	3.96

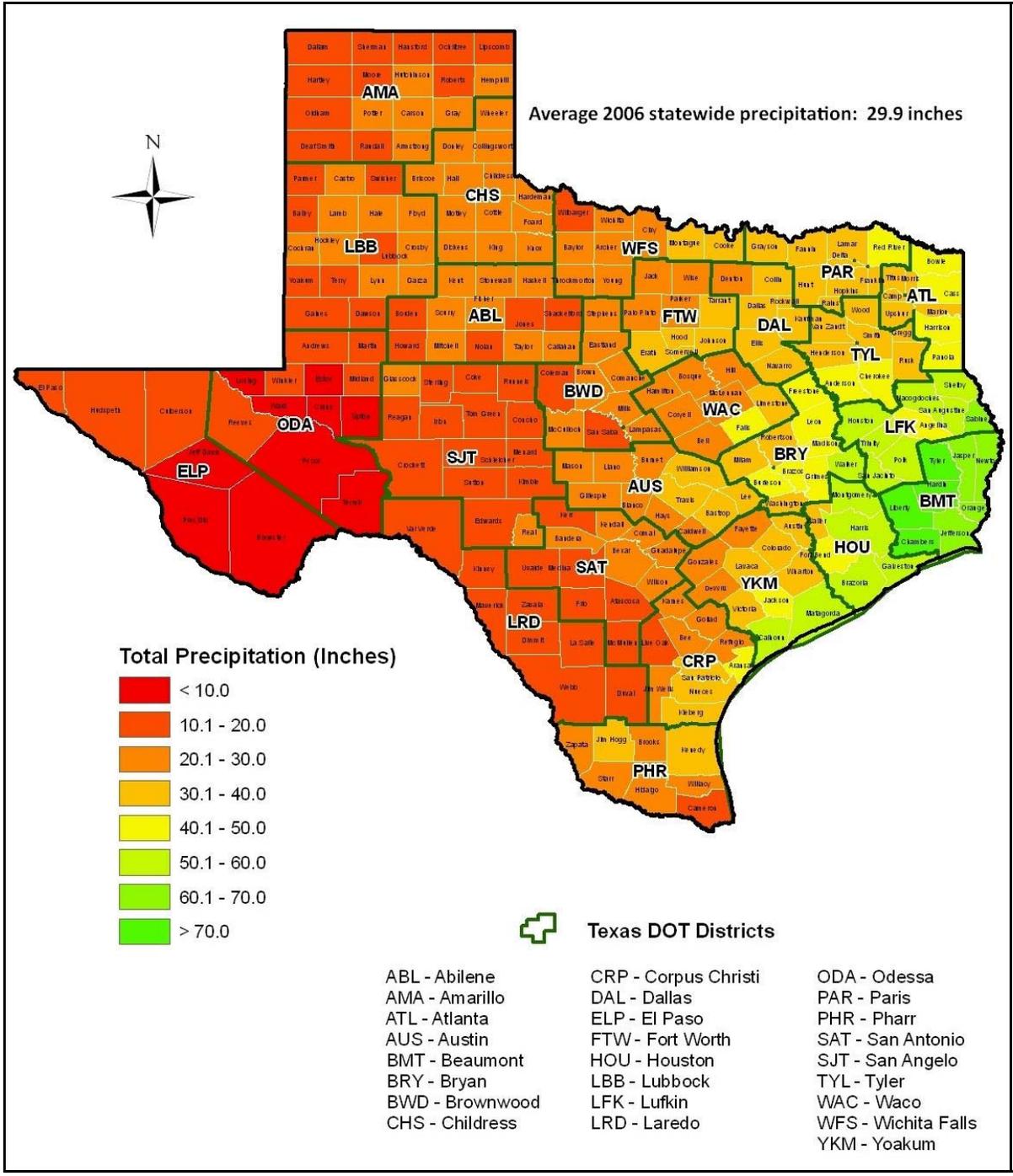
Researchers note that the above comparison is based on 30-year averages, which are not likely to produce significant differences since the averaging will tend to minimize the effect of yearly rainfall variations. From discussions with members of the project monitoring committee, there was general agreement that the rainfall factors should capture variations from the 30-year norm. Moving in this direction, researchers compiled precipitation data from Texas weather stations to characterize the yearly rainfall variations across the state. Figure 2 shows a map of these stations from which monthly rainfall data were obtained from the National Climatic Data Center (NCDC) website (3). Using this information, researchers prepared the maps shown in Figures 3 to 6 that illustrate rainfall variations across Texas over a 4-year period spanning 2005 to 2008. By comparing these maps, the temporal and spatial variations in rainfall become evident. Over the 4-year period, 2005 and 2007 may be described as dry and wet years, respectively. Since year-to-year variations could significantly impact maintenance needs, the importance of considering these variations in establishing rainfall factors becomes apparent.



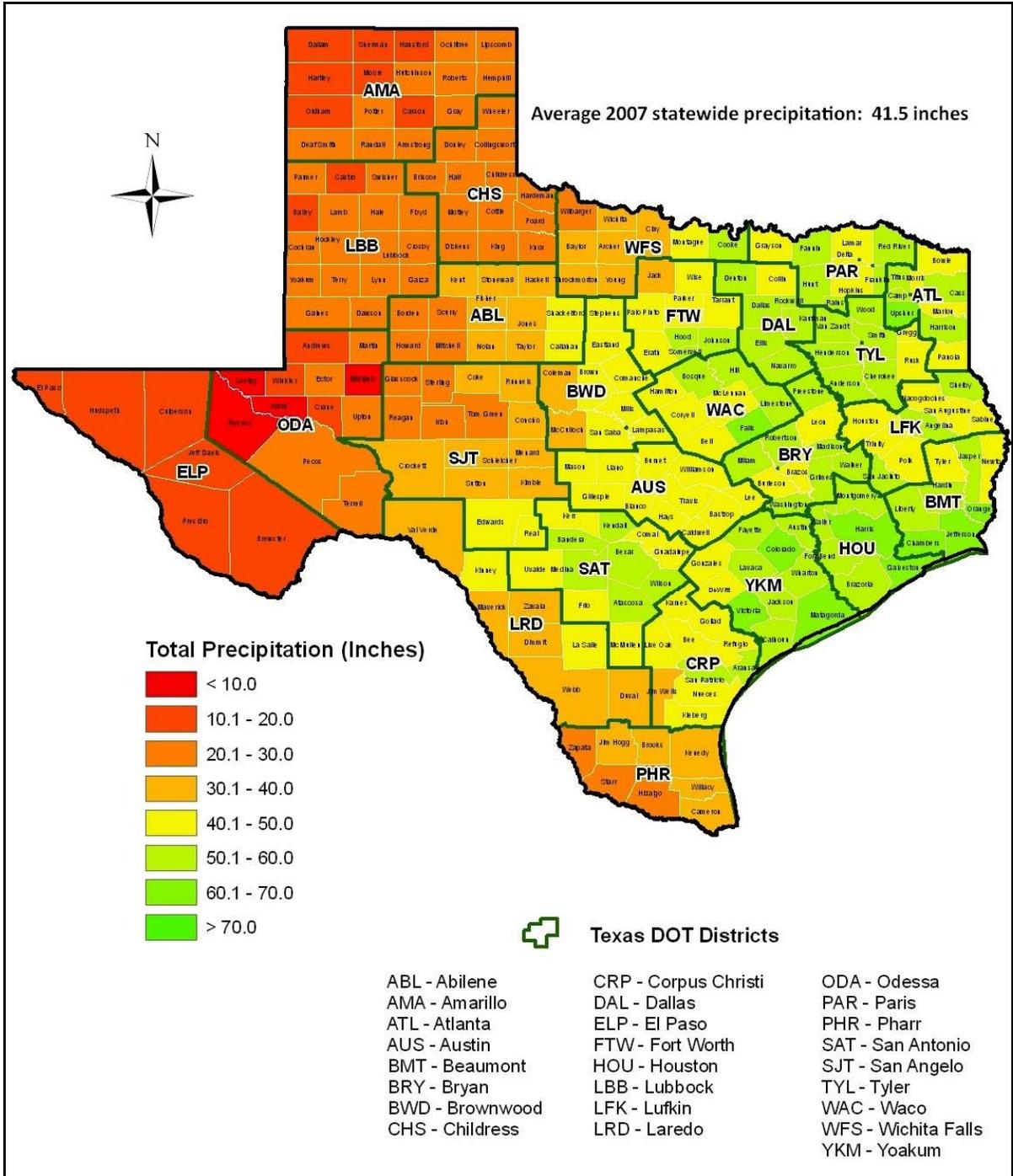
**Figure 2. Map of Texas Weather Stations.**



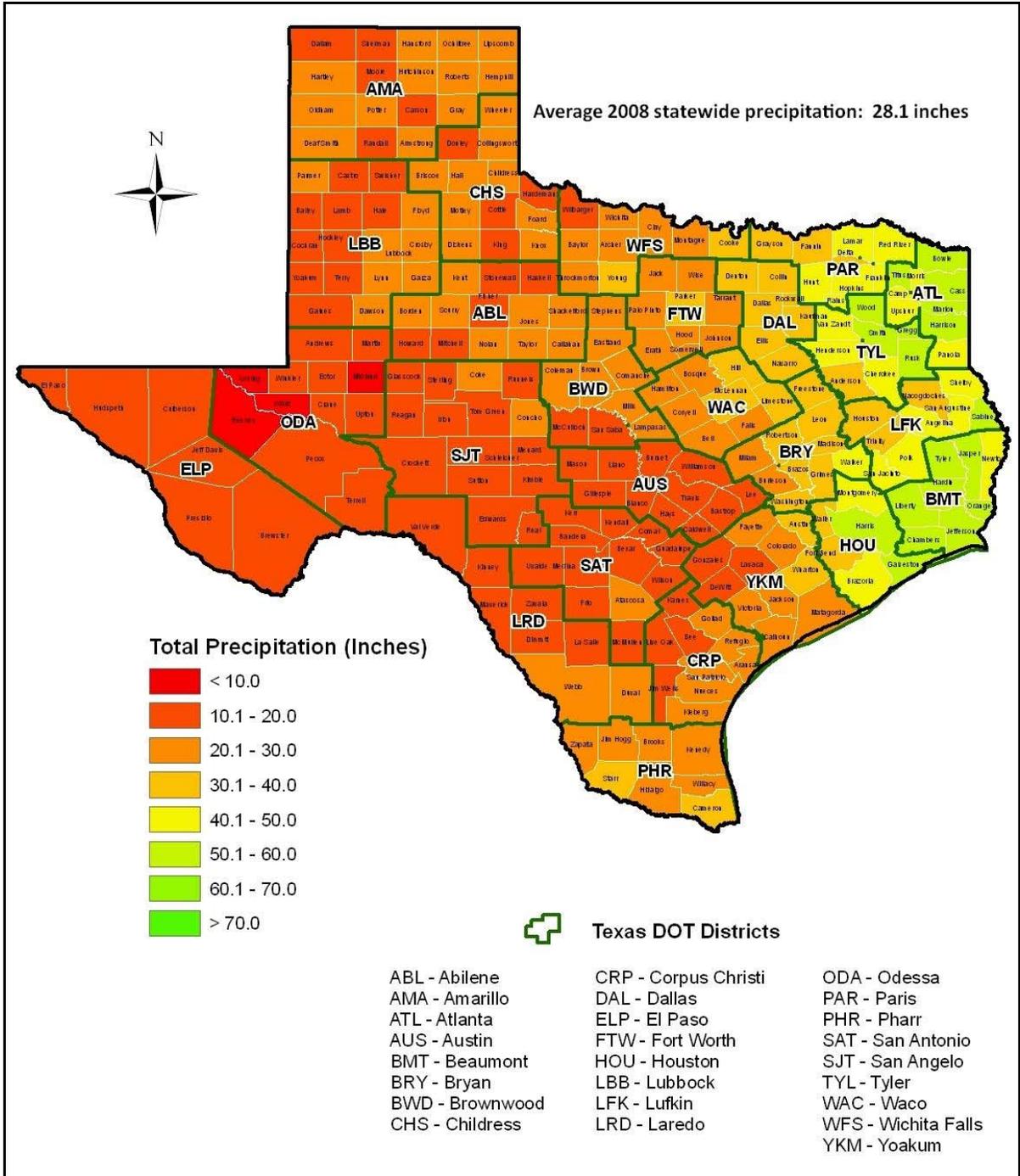
**Figure 3. 2005 Texas Precipitation Map.**



**Figure 4. 2006 Texas Precipitation Map.**

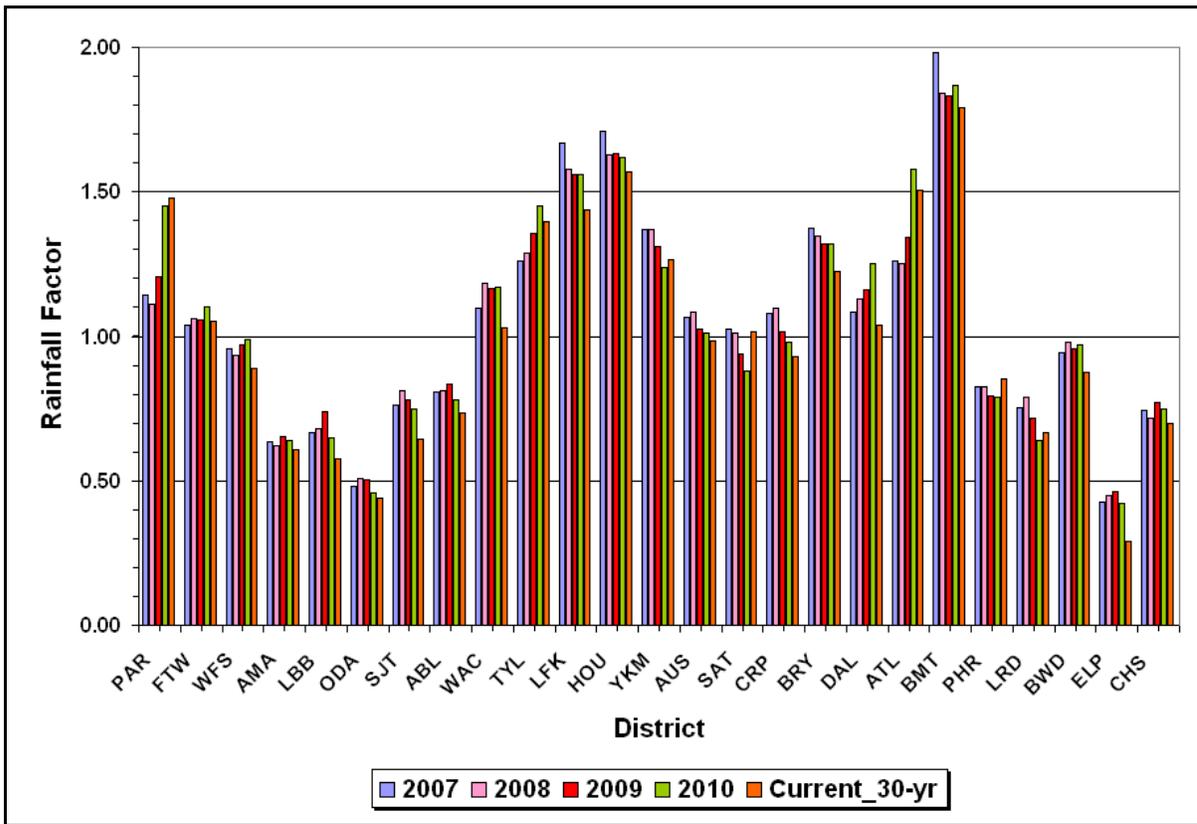


**Figure 5. 2007 Texas Precipitation Map.**



**Figure 6. 2008 Texas Precipitation Map.**

With respect to revising rainfall factors, the project monitoring committee recommended using a running 5-year rainfall average to determine rainfall factors that reflect variations from the corresponding 5-year statewide average. This recommendation was made during the May 2010 project close-out meeting held at the Riverside Maintenance Office in Austin. In line with this recommendation, researchers used the precipitation data from Texas weather stations to compute running 5-year rainfall averages and the corresponding rainfall factors. Figure 7 shows the calculated rainfall factors.



**Figure 7. Comparison of Rainfall Factors Based on Running 5-Year Averages with Existing Factors Based on 30-Year Averages.**

In the above figure, the rainfall factor for a given district and calendar year is determined by dividing the average rainfall for the prior five years by the 5-year statewide average over the same period. Thus, the 2007 rainfall factors are based on the averages of the rainfall values from 2002 to 2006. In like manner, the 2008 factors are based on the rainfall averages determined over the 5-year period from 2003 to 2007. Similar statements may be made regarding the rainfall factors for calendar years 2009 and 2010.

For comparison, Figure 7 also shows the current set of rainfall factors based on the 30-year district rainfall averages. From this figure one observes that, across districts, the

rainfall factors computed using running 5-year averages follow the trend of the existing factors based on 30-year averages. However, the calculated rainfall factors also show variations from the current 30-year values that can be attributed to the yearly rainfall variations within each district. Thus, the recommended rainfall factors capture both the regional differences between districts as well as variations from the 30-year norm. A comparison of the maintenance allocations determined using these factors with the corresponding allocations based on the existing factors is presented later in this chapter. The next section discusses the evaluation of regional factors for maintenance cost allocation.

## **REGIONAL FACTORS**

In reviewing the maintenance cost allocation formulas, researchers found no explanation on how the existing regional factors came about. The only statement found about their use came from the CI team who noted that the regional factors account for the effects of weather and soils. Recognizing that differences in soil properties and climate will impact maintenance needs particularly for low-volume roads, researchers used the *LoadGage* program (4) developed from Project 0-4519 to evaluate new weighting factors that account for regional differences in weather and soils on predicted load bearing capacity.

*LoadGage* is a computer program for checking flexible pavement designs based on the Mohr-Coulomb strength criterion used in the existing Texas modified triaxial design method. The program includes a moisture-correction procedure (to account for regional differences in weather and soils) that provides engineers the option of adjusting strength properties determined using TxDOT Test Method Tex-117E to the expected in-service soil moisture conditions. The moisture correction procedure considers the contribution of soil suction to the shear strength of unsaturated soils. As the soil dries, the soil suction component increases with an accompanying increase in shear strength. For pavement design, *LoadGage* uses the relationship between soil moisture content and soil suction to adjust failure envelope parameters determined from triaxial tests to corresponding values representative of expected in-service soil moisture conditions.

To implement *LoadGage*, researchers in Project 0-4519 compiled a database of soil properties covering each of the 254 Texas counties. This database was compiled from an extensive review of county soil survey reports, available NCDC climatic data from Texas weather stations and published data on soil suction properties. Using this database with the enhanced integrated climatic model (EICM; 5,6,7), Project 0-4519 researchers predicted the

expected in-service moisture contents based on 30-year average rainfall values for the different Texas counties to cover the range of climatic conditions and soil types found across the state. The EICM analyses were conducted on flexible pavements representative of low-volume Farm-to-Market (FM) roads, where the pavement design is typically governed by the modified triaxial design method. The expected in-service soil moisture contents are included in the soils database of the *LoadGage* program to facilitate its application for pavement design problems where site-specific data are not available.

To evaluate regional factors in the current implementation project, researchers used *LoadGage* to establish a ranking of the different districts based on predicted load bearing capacity. In this evaluation, researchers estimated the allowable wheel loads for the predominant soils found in each Texas county. Note that this application is the reverse of that for which the program was originally written. In practice, an engineer uses *LoadGage* to check the adequacy of a trial pavement design for the specified design load. Since this load had to be backcalculated for evaluating regional factors, researchers iteratively ran the *LoadGage* program to determine the allowable wheel load for a given set of conditions. Researchers note that this prediction of allowable loading is based on a stress analysis wherein a check is made to verify whether the shear stresses induced under a static load are within the Mohr-Coulomb failure envelope of the subgrade as defined by the material’s cohesion and friction angle. Chester McDowell (8) used this same approach in developing the Texas triaxial design method.

To evaluate regional factors, researchers assumed the thin-surfaced flexible pavement given in Table 4. The pavement shown is considered representative of a low-volume FM road where the pavement design is typically governed by the modified triaxial design method. This class of roads is also expected to be more susceptible to moisture effects because of the types of materials used and the relatively thinner pavement layers in comparison to Interstate, U.S., or state highways. Thus, regional differences are expected to be more pronounced for the purpose of ranking the different districts based on predicted load bearing capacity.

**Table 4. Thin Pavement Structure Used in *LoadGage* Analyses.**

Pavement Layer	Layer Thickness (in)	Modulus (ksi)	Poisson’s Ratio
Surface	2.0	200	0.4
Flexible base	8.0	40	0.4
Subgrade	Semi-infinite	variable <sup>1</sup>	0.4

<sup>1</sup>Subgrade modulus varied depending on soil type and moisture content.

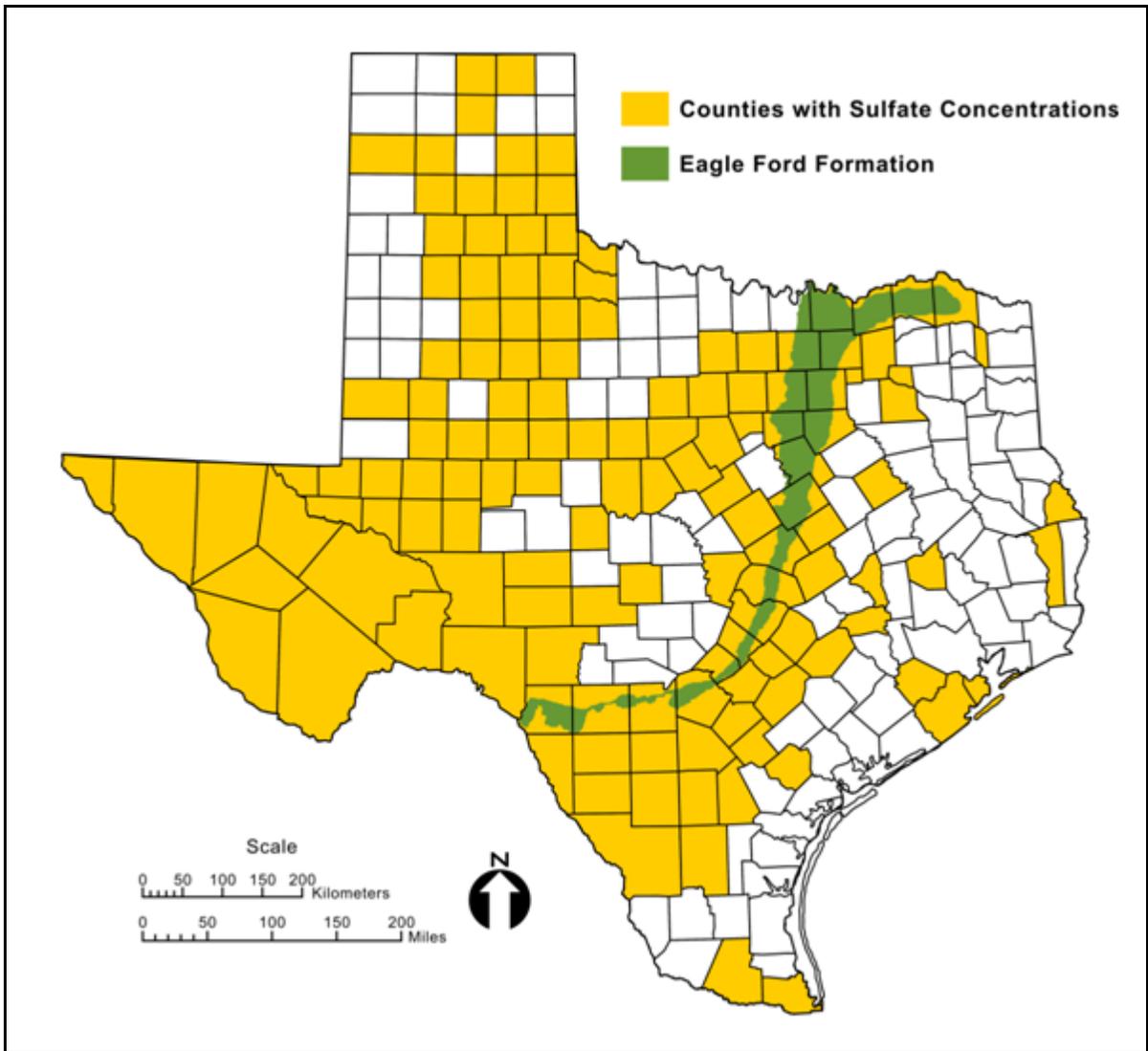
To evaluate regional factors, researchers considered two different cases. The first case involved running *LoadGage* assuming no moisture correction. This case mirrors the existing Texas modified triaxial design method, which is based on characterizing the strength properties of soils through laboratory triaxial tests of capillary saturated specimens following TxDOT Test Method Tex-117E. Thus, regional differences inferred from the results of this analysis can primarily be attributed to differences in soil types across the state.

The second case used the moisture correction procedure in *LoadGage* to estimate the allowable dual wheel loads. For this analysis, researchers used the *LoadGage* soils database to adjust the strength properties to the expected soil moisture content for the given soil type. Note that this database includes Texas triaxial classifications for the different soil types found in each county. Both cases used the Texas triaxial classification data to estimate allowable wheel loading except that, for the second case, the failure envelope is adjusted from the capillary saturated condition of Tex-117E to the expected soil moisture content. Thus, regional differences inferred from the Case II analysis can generally be attributed to differences in weather and soils across the state. However, exceptions were made for the following conditions:

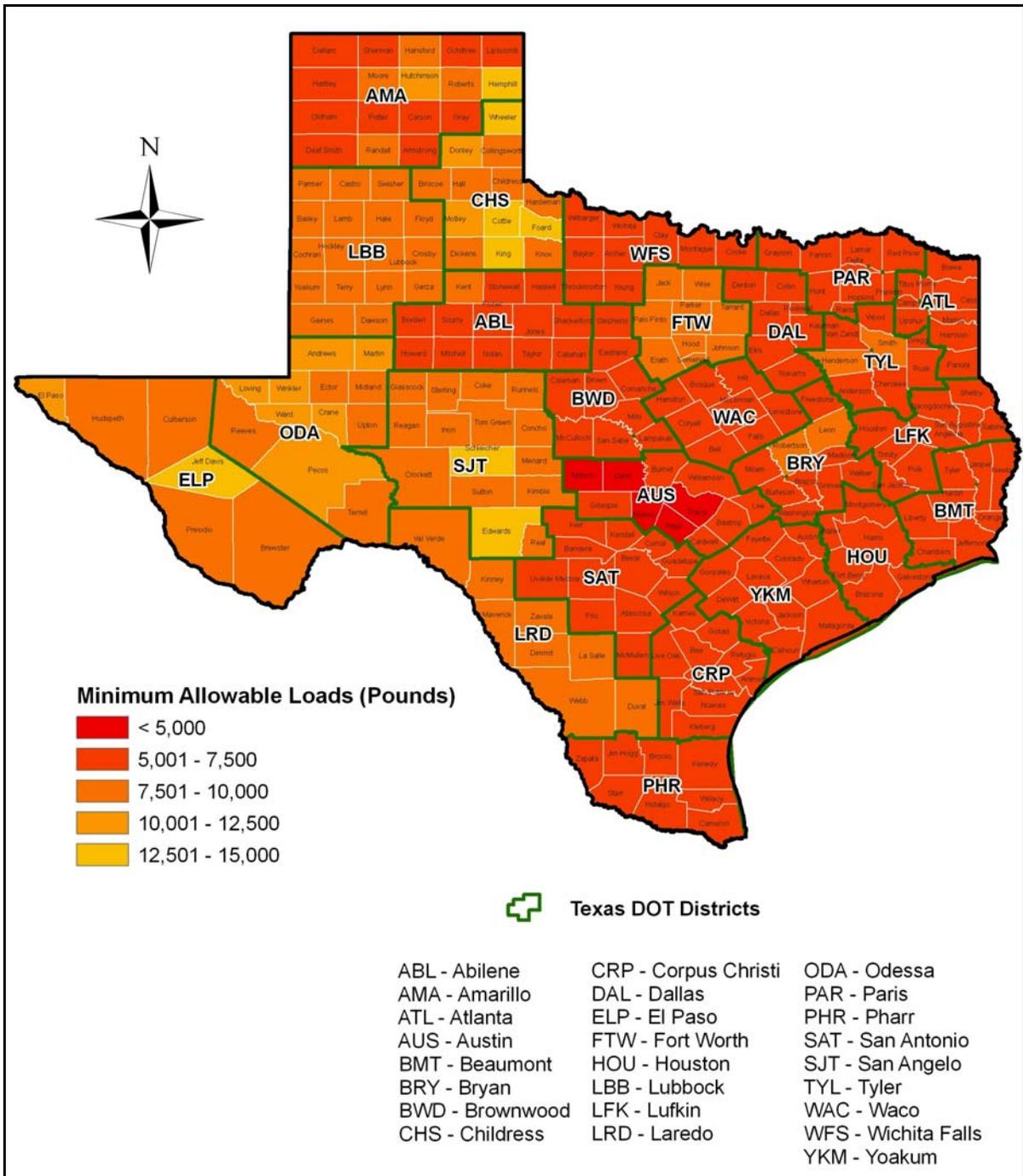
- high sulfate and high plasticity index (PI) soils found in counties located within the Eagle Ford formation (Figure 8) where swell problems have been observed and reported, and
- expansive soils located in counties within Texas river basins where increased maintenance due to such soils is a recurring problem.

For the above conditions, researchers used the more conservative estimates from Case I.

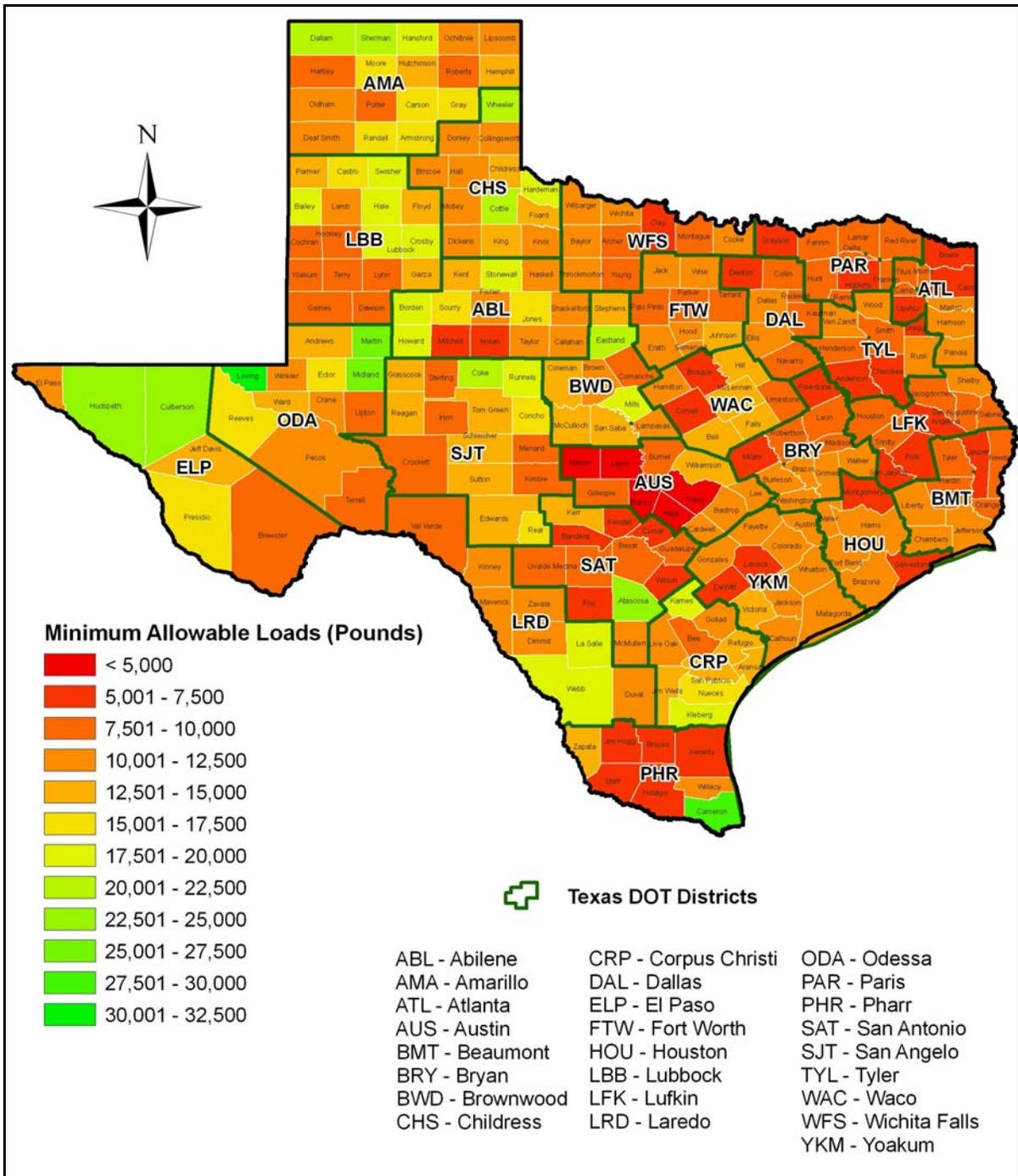
Figures 9 and 10 show the predicted load bearing capacities for the different Texas counties as determined from the Case I and Case II analyses, respectively. Since the analyses covered the different predominant soil types found in each county, researchers used the minimum of the predicted allowable wheel loads to generate the maps given in Figures 9 and 10. Comparing these figures, one observes less variation in the allowable load estimates plotted in Figure 9. This observation is expected since the Case I analysis is based on strength properties determined from tests on capillary saturated specimens, which correspond to the worst possible condition. In contrast, the Case II results given in Figure 10 exhibit more differentiation between districts, reflecting the effect of soil moisture variations across counties.



**Figure 8. Map of Counties Covered by the Eagle Ford Formation (9).**



**Figure 9. Map of Predicted Load Bearing Capacities from Case I Analysis.**



**Figure 10. Map of Predicted Load Bearing Capacities from Case II Analysis.**

The initial results from the evaluation of district rankings based on predicted load bearing capacity were presented during the February 2010 project meeting. From the discussions that took place, the project monitoring committee recommended using allowable load estimates from the Case II analysis to evaluate regional factors. The committee also recommended establishing finer categories of regional factors instead of the 1.0, 1.1, and 1.2 discrete levels that are presently used (as given in Table 1).

To evaluate new regional factors based on the Case II results, researchers computed the average of the estimated allowable wheel loads for the counties comprising each district. Researchers then used these averages to rank the districts based on predicted load bearing capacity. Figure 11 provides a bar chart of the predicted load bearing capacities for the different districts.

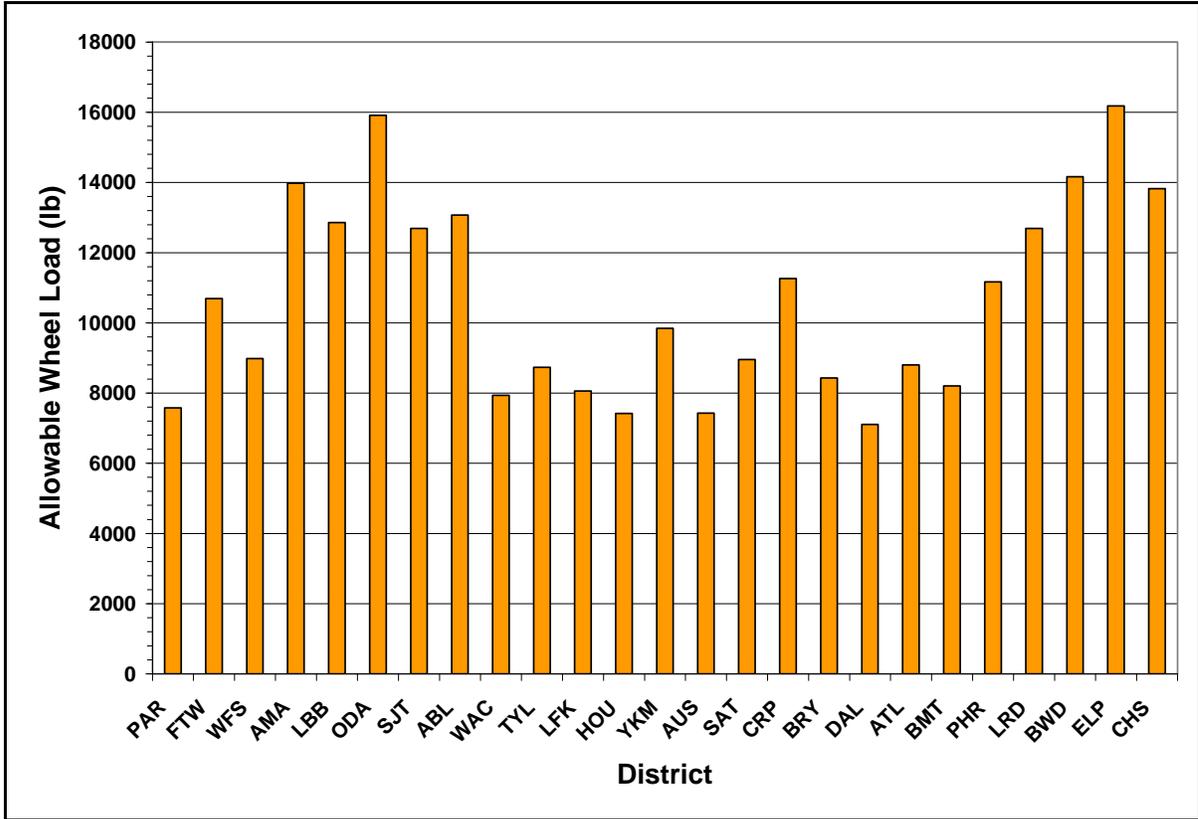


Figure 11. Estimates of Load Bearing Capacity by District.

To rank the districts, researchers scaled the load bearing capacity estimates in Figure 11 to the range of the existing regional factors (1.0 to 1.2). Specifically, the *LoadGage* estimates were mapped onto the existing limits according to the following equation:

$$LGRI = RF_{\min} + (P_i - P_{\min}) \times \frac{(RF_{\max} - RF_{\min})}{(P_{\max} - P_{\min})} \quad (1)$$

where,

- $LGRI$  = *LoadGage* regional index,
- $RF_{\min}$  = lower limit (1.0) of existing regional factors,
- $RF_{\max}$  = upper limit (1.2) of existing regional factors,
- $P_i$  = predicted load bearing capacity for district i,

$P_{\min}$  = minimum of predicted load bearing capacities from *LoadGage*, and  
 $P_{\max}$  = maximum of predicted load bearing capacities from *LoadGage*.

Table 5 shows the *LoadGage* regional indices determined from equation (1) along with the existing regional factors. It is interesting to note that in 20 of the 25 districts, the *LoadGage* regional indices equal the existing factors when rounded off to the nearest tenth. For three districts (Childress, San Antonio, and Wichita Falls), the LGRIs are lower than the existing factors, while in two other districts (Amarillo and Brownwood), the LGRIs are higher. However, for all five districts, the differences are within 0.1 of a point.

**Table 5. Regional Indices Determined from *LoadGage* Analyses.**

District	Existing Regional Factor	LGRI	LGRI after round-off to nearest tenth
Paris	1.0	1.010	1.0
Fort Worth	1.1	1.079	1.1
Wichita Falls	1.1	1.041	1.0
Amarillo	1.1	1.151	1.2
Lubbock	1.1	1.127	1.1
Odessa	1.2	1.194	1.2
San Angelo	1.1	1.123	1.1
Abilene	1.1	1.131	1.1
Waco	1.0	1.018	1.0
Tyler	1.0	1.036	1.0
Lufkin	1.0	1.021	1.0
Houston	1.0	1.007	1.0
Yoakum	1.1	1.060	1.1
Austin	1.0	1.007	1.0
San Antonio	1.1	1.041	1.0
Corpus Christi	1.1	1.092	1.1
Bryan	1.0	1.029	1.0
Dallas	1.0	1.000	1.0
Atlanta	1.0	1.037	1.0
Beaumont	1.0	1.024	1.0
Pharr	1.1	1.090	1.1
Laredo	1.1	1.123	1.1
Brownwood	1.1	1.156	1.2
El Paso	1.2	1.200	1.2
Childress	1.2	1.148	1.1

The good agreement shown above between the existing regional factors and the *LoadGage* regional indices provides a rationale for the existing factors used by TxDOT to allocate maintenance costs. This finding is significant since it shows a strong connection

between the existing factors and variations in predicted load bearing capacity due to regional differences in weather and soils. It thus provides a solid explanation of the existing regional factors that were not known prior to this implementation project.

**COMPARISON OF MAINTENANCE COST ALLOCATIONS BETWEEN PROPOSED AND EXISTING RAINFALL AND REGIONAL FACTORS**

Researchers used TxDOT’s maintenance allocation spreadsheets to do a comparative evaluation of the proposed rainfall and regional factors. This evaluation compared the allocations determined for those maintenance functions shown in Table 2 where rainfall and regional factors are used in the existing cost formulas. Table 6 compares the allocations based on FY09 inventory, traffic, and pavement condition data.

**Table 6. Comparison of FY09 Cost Allocations.**

Maintenance Function	Allocation ( $\times 10^6$ \$)		Percent change
	Current	Alternate <sup>1</sup>	
Base repair	61.33	60.98	-0.57
Level-up/Overlay	84.25	87.14	3.43
Crack sealing	30.26	31.61	4.46
Seal coats	31.87	31.65	-0.69
Spot or edge seals	24.65	24.50	-0.61
Fog seals	4.78	4.75	-0.63
Blading shoulders	6.40	6.68	4.38
Pavement maintenance subtotal	243.54	247.31	1.55
Tree/Brush control	6.81	7.11	4.41
Slope repair/Stabilization	1.28	1.34	4.69
Culvert/Storm drain maintenance	7.29	7.58	3.98
Roadside maintenance subtotal	15.38	16.03	4.23

<sup>1</sup> Using *LoadGage* regional indices in Table 5 and rainfall factors based on 5-year average precipitations.

For each maintenance function, Table 6 gives the allocations based on the current rainfall and regional factors, and based on the alternate set of factors presented earlier. On a statewide basis, it is observed that the cost allocations are comparable between the current and proposed rainfall and regional factors. It is also of interest to compare the allocations by district. These comparisons are given in Figures 12 to 21, which show the district allocations

for each of the maintenance functions given in Table 6. These figures show districts where the differences in cost allocations are more significant (larger than 5 percent) between the current and proposed rainfall and regional factors. This observation is particularly applicable for maintenance functions where rainfall factors are applied. For these functions, the differences in cost allocations reflect differences between the 30-year and 5-year average precipitations that are used to determine the rainfall factors. For maintenance functions where regional factors are used, the differences in allocations are expected to be smaller owing to the similarity (shown in Table 5) between the existing regional factors and the *LoadGage* regional indices.

The preceding results suggest that, while the statewide cost allocations are comparable, the allocations by district will vary under the alternative set of factors presented in this chapter. The district allocations will primarily be influenced by the rainfall factors, which will vary year-to-year depending on the average precipitation values for the prior five years.

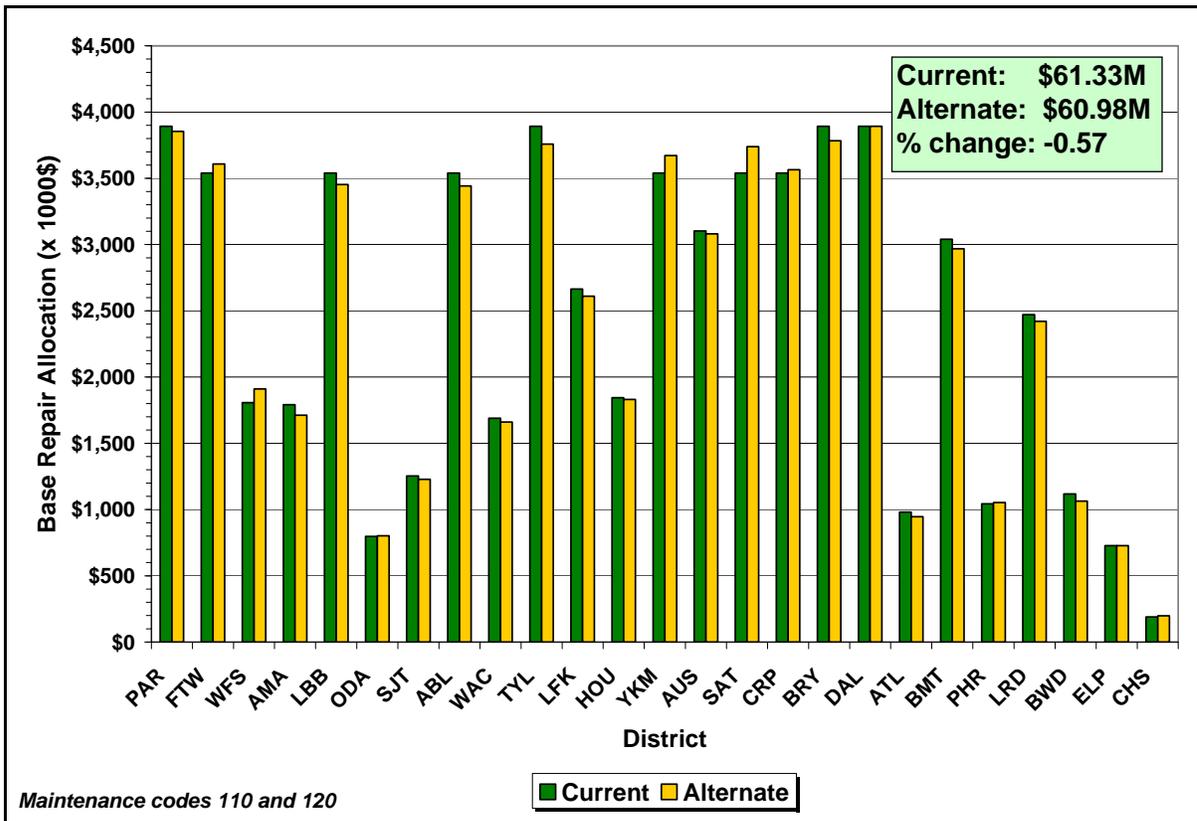


Figure 12. Comparison of Base Repair Allocations by District.

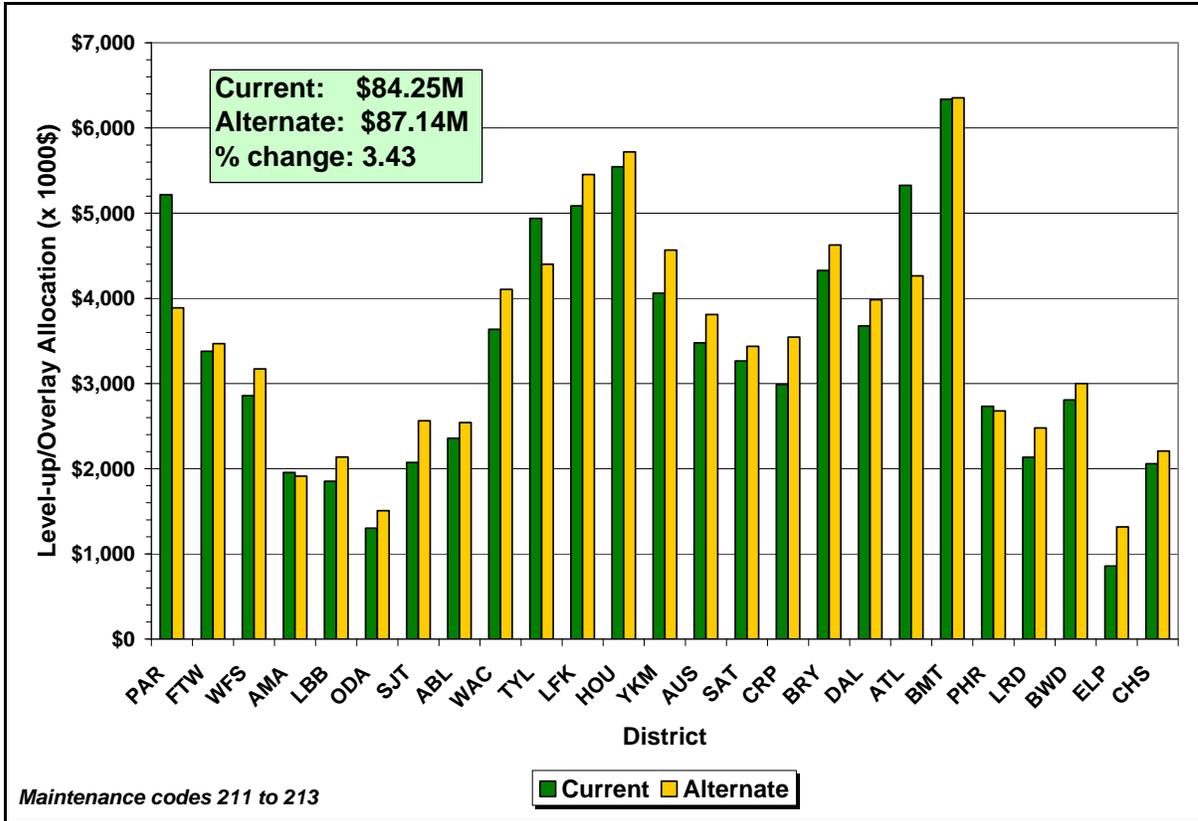


Figure 13. Comparison of Level-Up/Overlay Allocations by District.

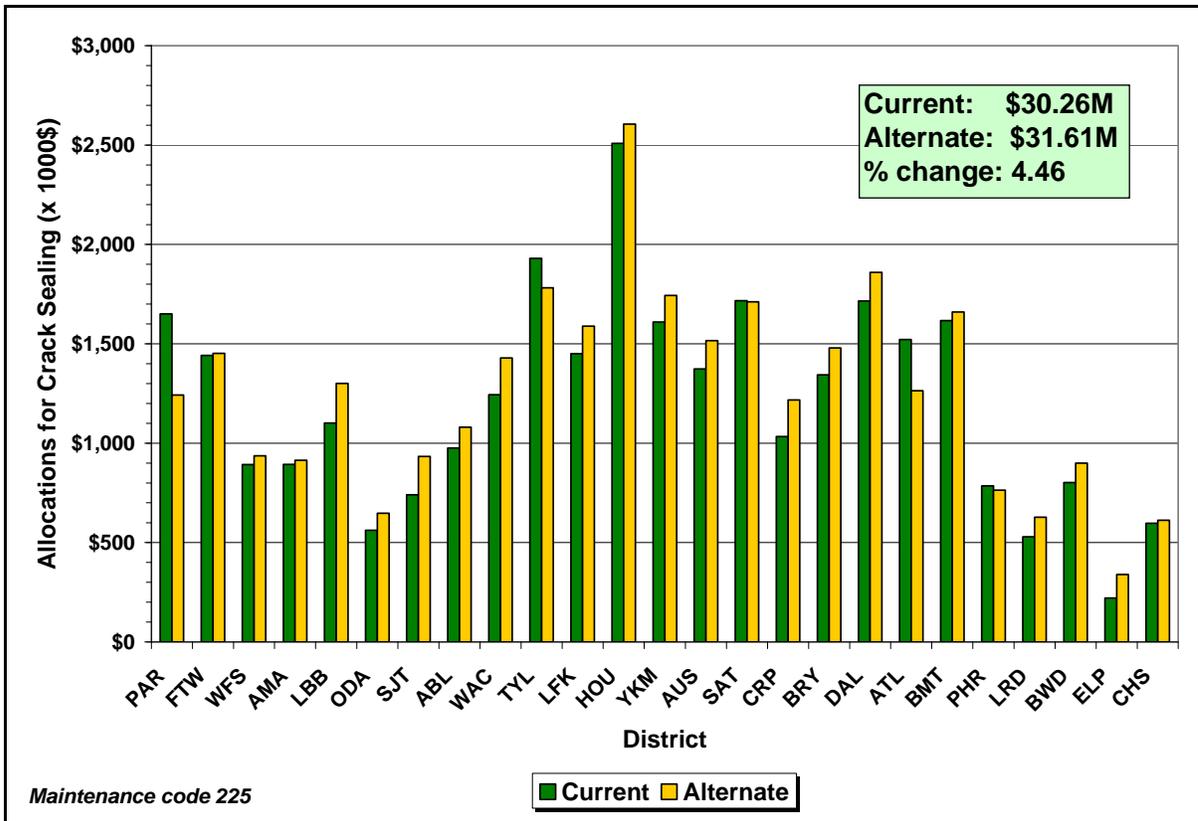


Figure 14. Comparison of District Allocations for Crack Sealing.

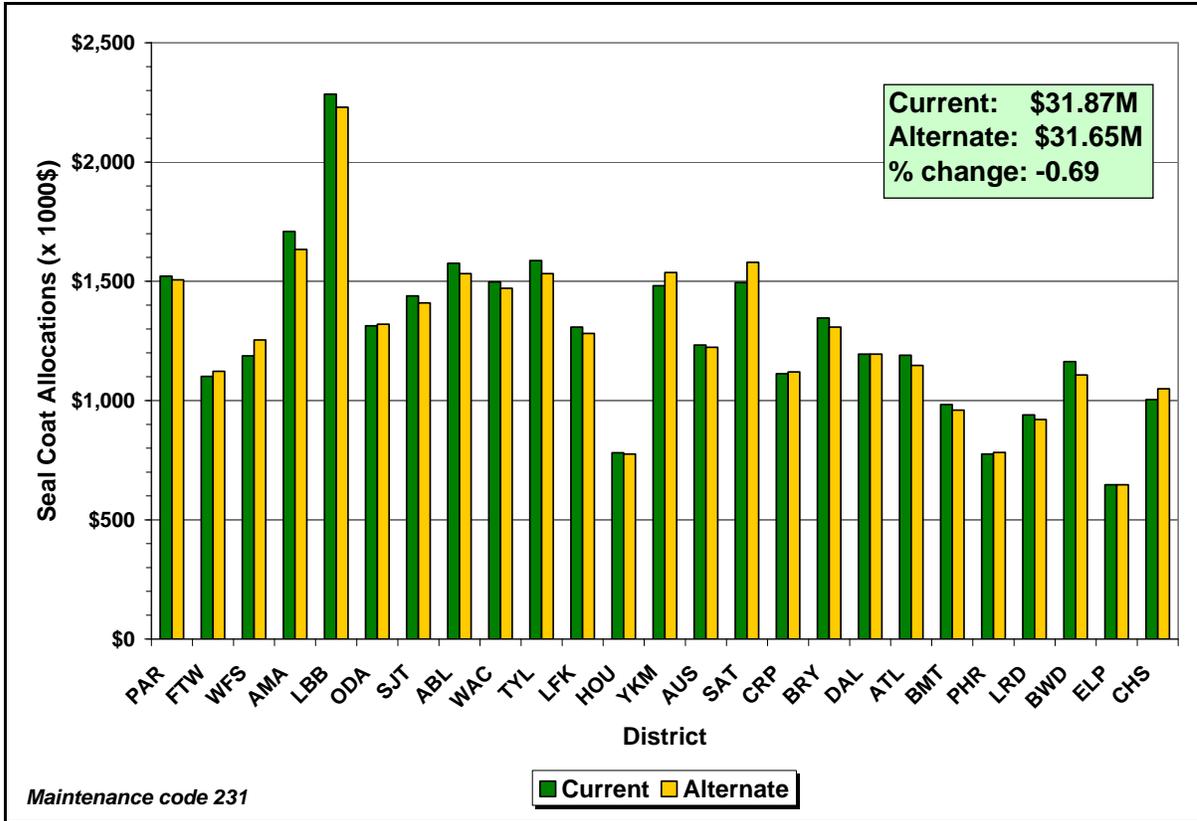


Figure 15. Comparison of Seal Coat Allocations by District.

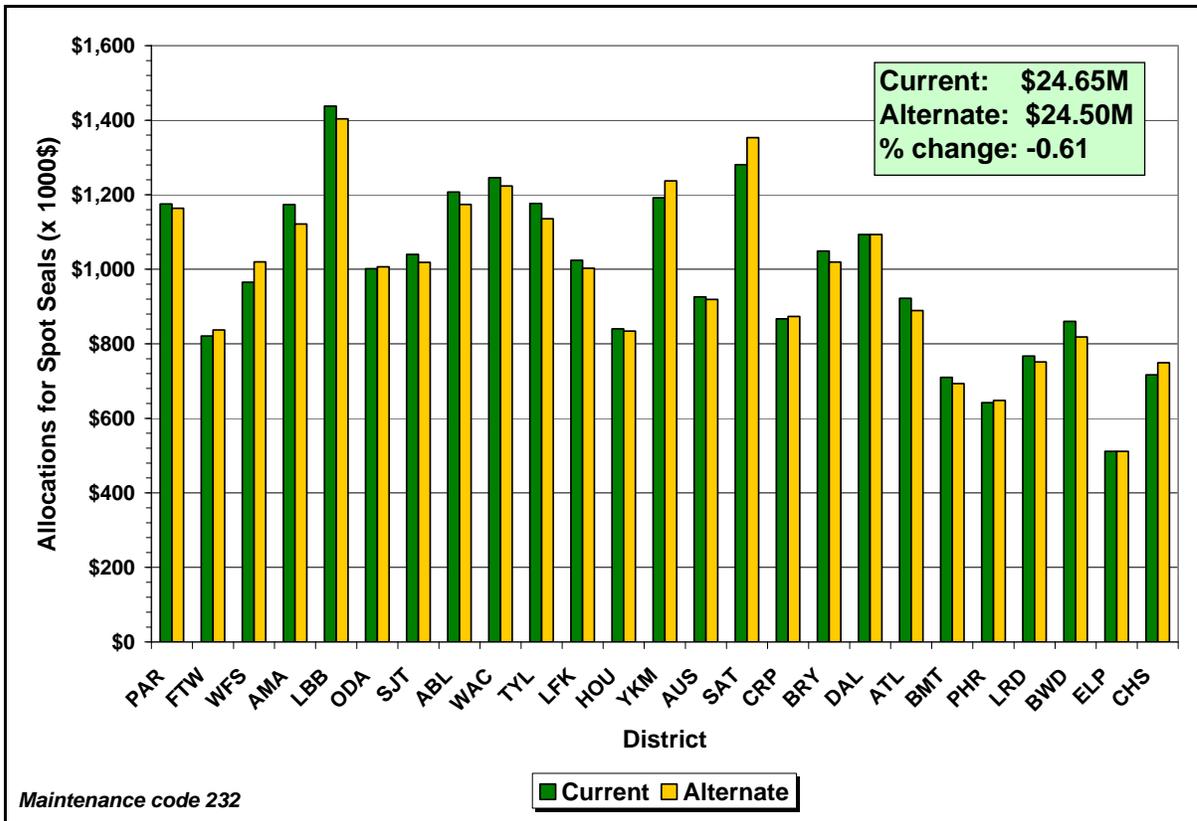


Figure 16. Comparison of District Allocations for Spot or Edge Seals.

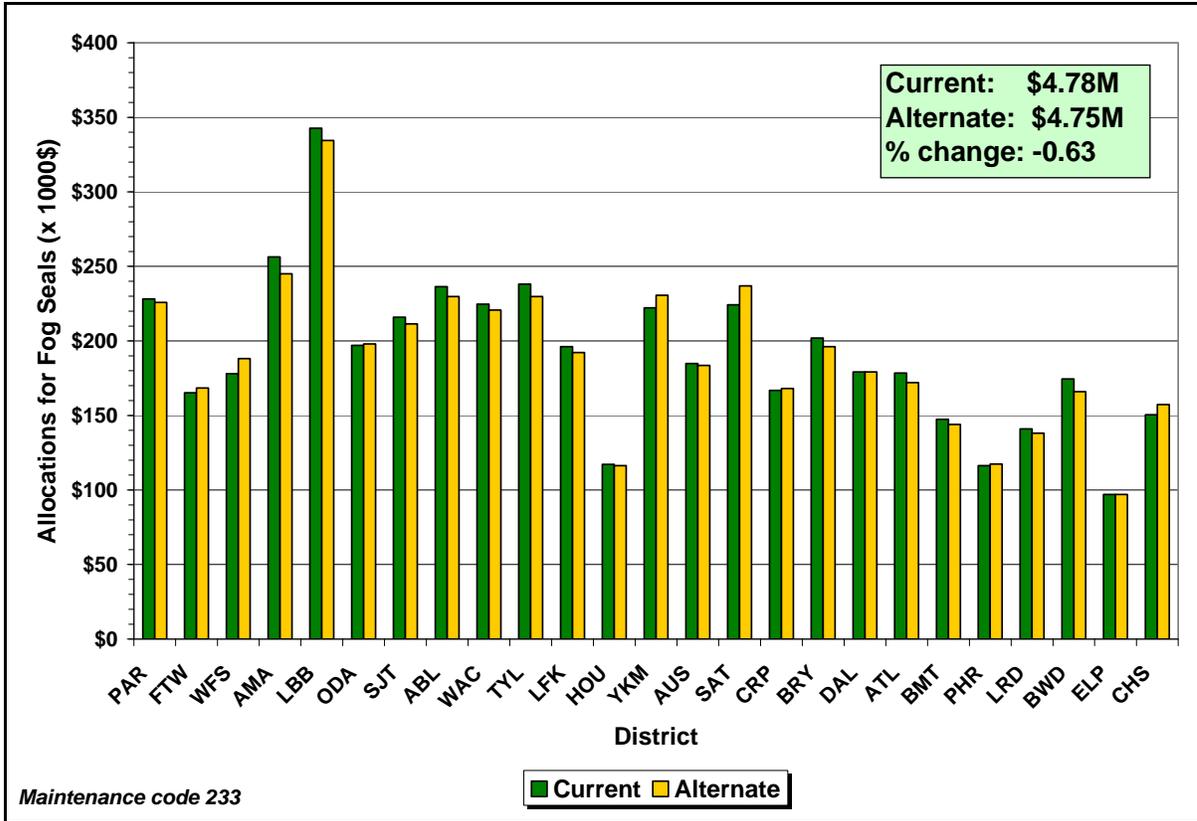


Figure 17. Comparison of District Allocations for Fog Seals.

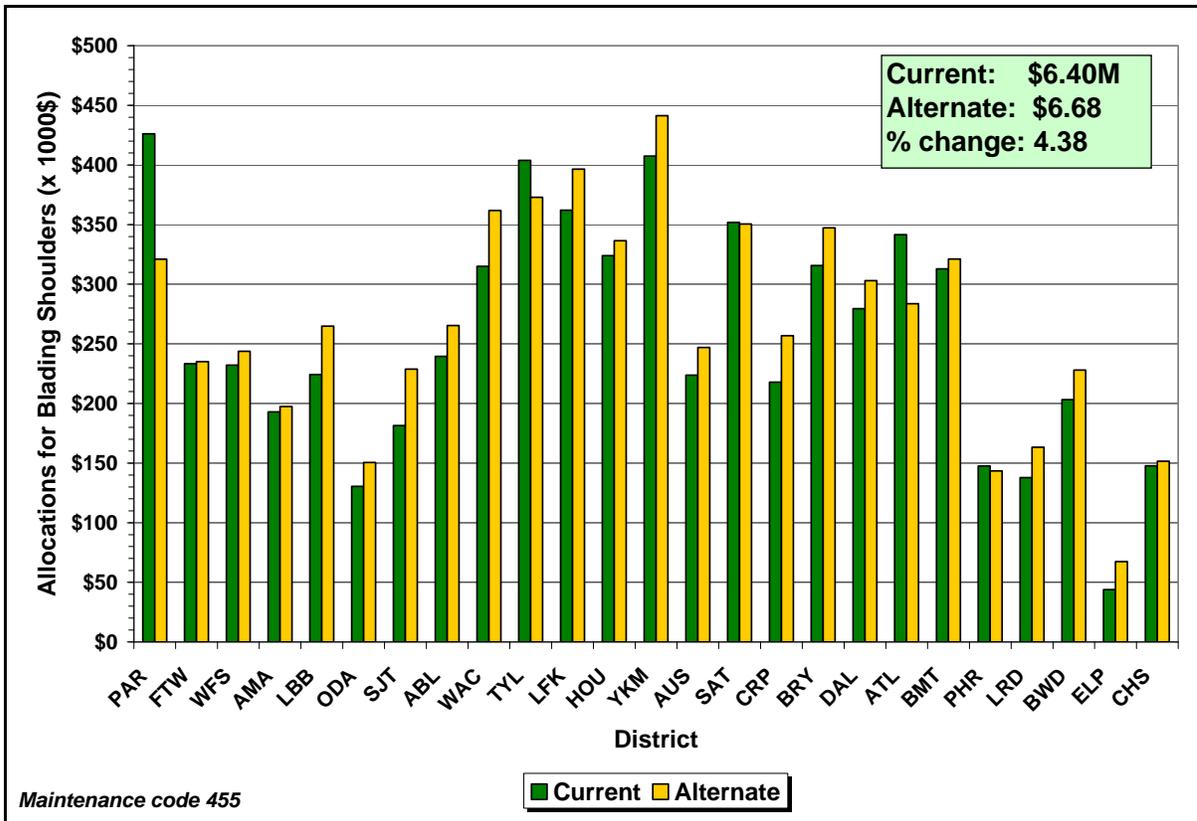
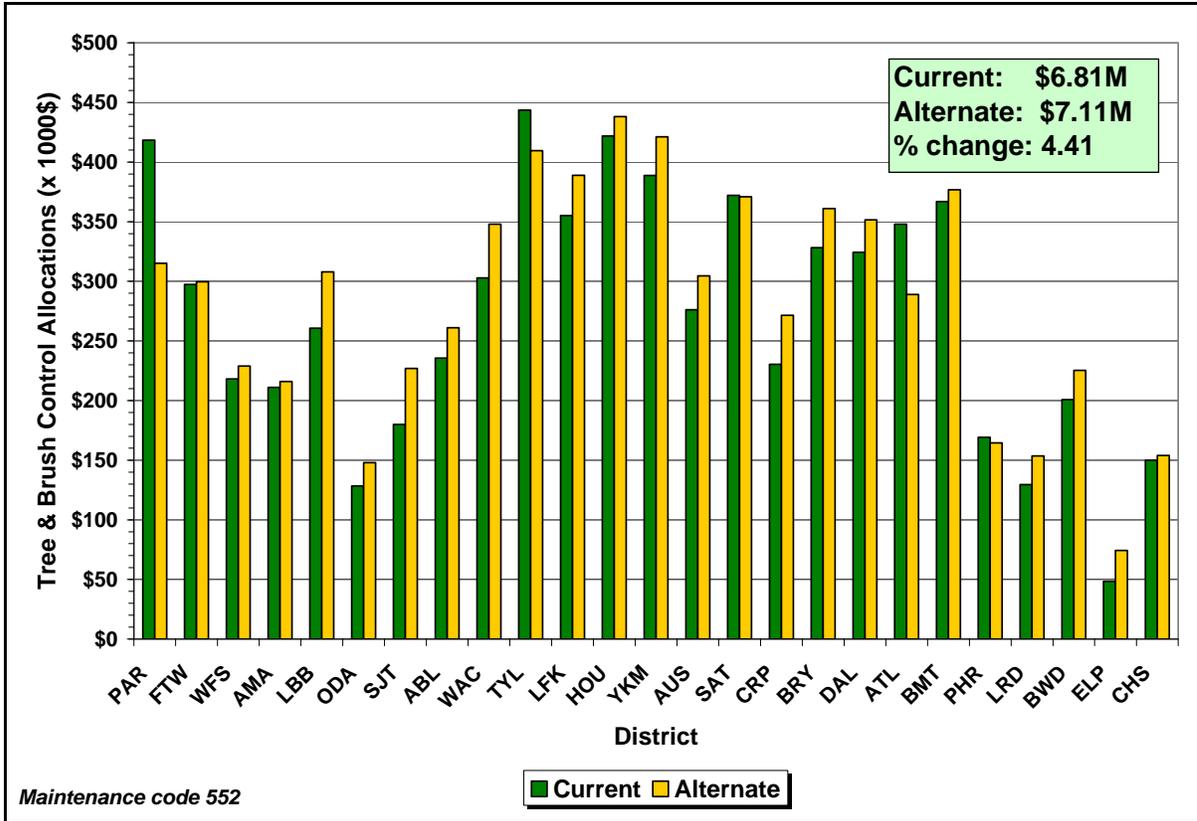
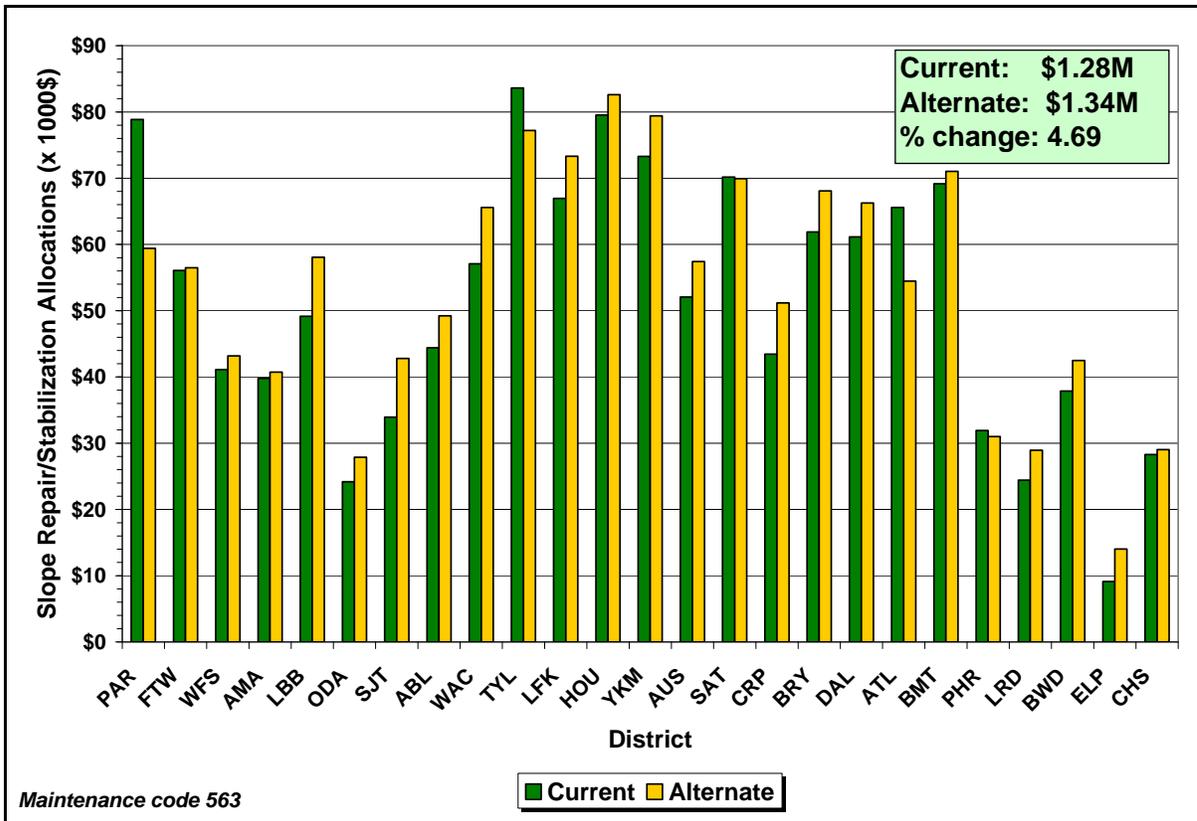


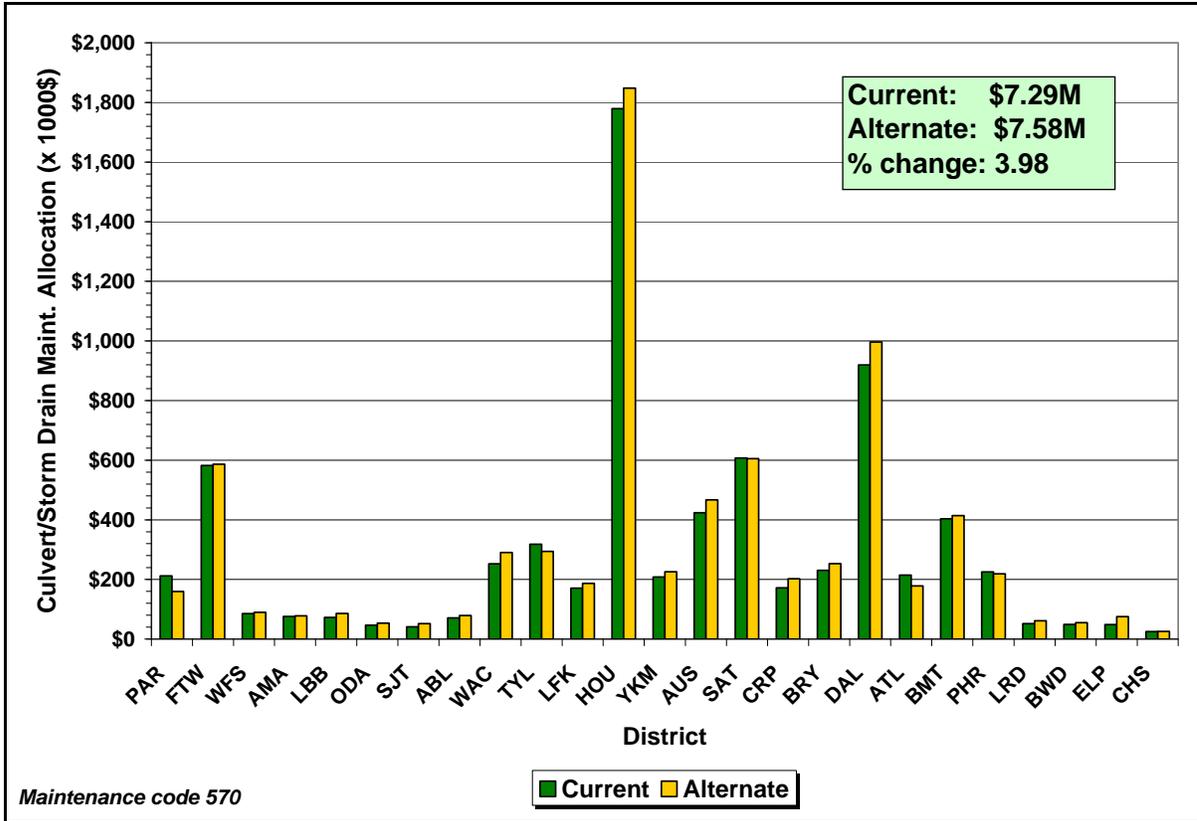
Figure 18. Comparison of District Allocations for Blading Shoulders.



**Figure 19. Comparison of District Allocations for Tree and Brush Control.**



**Figure 20. Comparison of District Allocations for Slope Repair/Stabilization.**



**Figure 21. Comparison of District Allocations for Culvert/Storm Drain Maintenance.**

Researchers also compared cost allocations across fiscal years. In this regard, Table 7 provides a summary of the statewide pavement and roadside maintenance cost allocations from FY08 to FY10. Again, researchers found the statewide cost allocations to be comparable between the existing and proposed rainfall and regional factors. More significant differences between the two sets of factors were observed in the district allocations for a given fiscal year, particularly with maintenance functions where rainfall factors are used in the existing cost formulas.

**Table 7. Comparison of FY08 to FY10 Maintenance Cost Allocations.**

Fiscal Year	Function	Allocation ( $\times 10^6$ \$) <sup>1</sup>		Percent change
		Current	Alternate <sup>2</sup>	
2008	Pavement maintenance	397.81	408.62	2.72
	Roadside maintenance	14.42	15.08	4.58
2009	Pavement maintenance	243.54	247.31	1.55
	Roadside maintenance	15.38	16.03	4.23
2010	Pavement maintenance	388.61	395.68	1.82
	Roadside maintenance	36.67	38.14	4.01

<sup>1</sup> Sum of district allocations for maintenance functions where regional and rainfall factors are applied.

<sup>2</sup> Using *LoadGage* regional indices in Table 5 and rainfall factors based on 5-year average precipitations.

### **REGIONAL FACTORS BASED ON LOWER LIMITS**

The *LoadGage* regional indices presented in Table 5 are based on scaling the predicted load bearing capacity for each district onto the current regional factor limits of 1.0 to 1.2 using equation (1). This same equation may be used to determine alternative regional factors based on a different set of lower and upper limits. For example, if the limits are changed to cover the range from 0.95 to 1.15, the resulting regional factors shown in Table 8 are obtained. This approach of determining the regional factors preserves the ranking of the districts based on the predicted load bearing capacities from *LoadGage*. However, the cost allocations will change depending on whether lower or higher limits are used. Regional factors calculated using lower limits, such as the factors given in Table 8, will result in higher allocations based on the existing maintenance cost formulas. To illustrate, if the regional factors based on lower and upper limits of 0.95 to 1.15 are used, the statewide cost allocations shown in Table 9 are obtained. The pavement maintenance cost allocations shown in Table 9 are observed to be higher than the corresponding allocations in Table 7, which are based on the 1.0 to 1.2 range of the existing regional factors. Note that the roadside maintenance allocations are unchanged since the allocations for tree and brush control, slope repair/stabilization, and culvert/storm drain maintenance do not depend on the regional factor.

**Table 8. Regional Factors Based on Two Sets of Lower and Upper Limits.**

District	LoadGage Regional Index	
	Limits of 1.0 to 1.2	Limits of 0.95 to 1.15
Paris	1.010	0.960
Fort Worth	1.079	1.029
Wichita Falls	1.041	0.991
Amarillo	1.151	1.101
Lubbock	1.127	1.077
Odessa	1.194	1.144
San Angelo	1.123	1.073
Abilene	1.131	1.081
Waco	1.018	0.968
Tyler	1.036	0.986
Lufkin	1.021	0.971
Houston	1.007	0.957
Yoakum	1.060	1.010
Austin	1.007	0.957
San Antonio	1.041	0.991
Corpus Christi	1.092	1.042
Bryan	1.029	0.979
Dallas	1.000	0.950
Atlanta	1.037	0.987
Beaumont	1.024	0.974
Pharr	1.090	1.040
Laredo	1.123	1.073
Brownwood	1.156	1.106
El Paso	1.200	1.150
Childress	1.148	1.098

**Table 9. Comparison of FY08 to FY10 Cost Allocations (0.95 to 1.15 Limits).**

Fiscal Year	Function	Allocation ( $\times 10^6$ \$) <sup>1</sup>		Percent change
		Current	Alternate <sup>2</sup>	
2008	Pavement maintenance	397.81	423.67	6.50
	Roadside maintenance	14.42	15.08	4.58
2009	Pavement maintenance	243.54	257.62	5.78
	Roadside maintenance	15.38	16.03	4.23
2010	Pavement maintenance	388.61	413.67	6.45
	Roadside maintenance	36.67	38.14	4.01

<sup>1</sup> Sum of district allocations for maintenance functions where regional and rainfall factors are applied.<sup>2</sup> Using regional factors scaled to 0.95 to 1.15 range and rainfall factors based on 5-year average precipitations.



## CHAPTER IV. SUMMARY OF FINDINGS AND RECOMMENDATIONS

This project evaluated the existing rainfall and regional factors TxDOT uses for maintenance cost allocations. Based on the results from this evaluation, the following findings are noted:

- Across districts, the rainfall factors computed using running 5-year average precipitations follow the trend of the existing factors based on 30-year averages. However, the calculated rainfall factors also show variations from the current 30-year values that can be attributed to the yearly rainfall variations within each district.
- Comparison of the existing regional factors with indices determined based on *LoadGage* estimates of allowable wheel loads showed that, in 20 of the 25 districts, the *LoadGage* regional indices equal the existing factors when these indices are rounded off to the nearest tenth. For the five districts where this level of agreement was not observed, the differences were within 0.1 of a point.
- The good agreement between the existing regional factors and the *LoadGage* regional indices provides a rationale for the existing factors used by TxDOT to allocate maintenance costs. Specifically, this implementation project demonstrated that the existing regional factors are strongly associated with variations in predicted load bearing capacity due to regional differences in weather and soils.
- Researchers compared the cost allocations determined using the existing rainfall and regional factors, and the alternative set of factors developed from this project. On a statewide basis, researchers observed the cost allocations to be comparable between the current and proposed rainfall and regional factors. However, researchers saw more significant differences between the two sets of factors when district allocations are compared, particularly on maintenance functions where rainfall factors are used in the existing cost formulas. For these functions, the differences in cost allocations reflect differences between the 30-year and 5-year average precipitations that are used to determine the existing and proposed rainfall factors, respectively. For maintenance functions where regional factors are used, researchers saw smaller differences in cost allocations owing to the good agreement between the existing regional factors and the *LoadGage* regional indices.

Given the above findings the author recommends that TxDOT implement the rainfall and regional factors established from this implementation project and provided to TxDOT as Product 5-4519-01-1 (10). To assist with this implementation, researchers developed a utility for calculating the applicable rainfall factors with which to establish the cost allocations for a given year. The appendix explains how this utility is used.

As described in this report, the *LoadGage* regional indices may be varied up or down by changing the lower and upper limits of the regional factors, providing an option for TxDOT to adjust the funding allocations according to district needs. The existing regional factors do not offer this flexibility. However, using the predicted load bearing capacities from *LoadGage*, this project showed that the same factors can closely be reproduced when the predicted load bearing capacities are scaled onto the range of the existing regional factors. The approach presented for varying the regional factors preserves the ranking of the districts based on the predicted load bearing capacities from *LoadGage*. Thus, the funding distribution among districts will always reflect this ranking but the statewide allocations will increase or decrease depending on whether the regional factors are adjusted down or up, respectively.

The author also recommends using the rainfall factors established from this project to allocate maintenance costs. The proposed rainfall factors vary between districts in a similar manner as the existing factors based on 30-year average values. However, the proposed factors are more sensitive to variations in annual precipitation than the existing rainfall factors. Thus, a district's funding allocation in any given fiscal year will vary depending on the yearly variations in precipitation over the prior five years.

With respect to further investigations of regional and rainfall factors for maintenance cost allocation, the author recommends that TxDOT consider funding a follow-up project to develop and investigate the application of a composite environmental index that combines both rainfall and regional factors for cost allocation. The author envisions that this investigation will use the enhanced integrated climatic model to simulate the variations in soil moisture content based on yearly rainfall variations (say for the prior five years) and to use the results from these simulations to evaluate load bearing capacity and determine the environmental index appropriate for a given county or region of the state. The proposed project can develop a computer program to provide for these calculations. Alternatively, this program can be used to develop tables of environmental indices for implementation purposes.

The proposed project will need to assess the impact of these indices on the maintenance cost allocations based on the existing cost formulas. In this regard, the author expects that the project scope will need to include evaluating and possibly modifying these existing formulas, where rainfall and regional factors are separately used.



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## APPENDIX. UTILITY FOR CALCULATING MAINTENANCE COST ALLOCATION FACTORS (MCAF)

### INSTRUCTIONS TO SETUP AND RUN THE PROGRAM

This appendix provides instructions for using a utility to calculate the applicable rainfall and regional factors for maintenance cost allocations. This utility is a Windows-based program written in C#. To install the program, simply run the setup file in Windows and follow the instructions displayed on screen. The setup program creates a shortcut on the user's desktop. Double-click on the MCAF utility's icon after installation to run the program. Figure A1 displays the input screen.

Maintenance Cost Allocation Factors

Input Log Factors

INPUT SECTION

Year: 2009

Data File: Data\9433954244327\_2009\_dat.txt

Station File: Data\9433954244327\_2009\_stn.txt

County List: Data\County\_mean\_monthly.csv

District List: Data\District\_Mean\_Precip\_Load.csv

District Avg. Data: Data\District\_Annual\_Precip.csv

Substitute County List: Data\Substitute\_County\_List.csv

Alternative Regional Factors based on User-Specified Limits

Edit County Substitution List Run Exit

Figure A1. MCAF Utility Input Screen.

In the *Input Section* of Figure A1, specify the year for which the program will calculate the average rainfall per Texas county using the weather station data for the same year downloaded from the National Climatic Data Center website (3). In the example shown, 2009 is the specified year. Instructions for downloading weather station data are given later in this appendix.

In the *Data File* field of Figure A1, specify the name of the rainfall data file downloaded from the NCDC. You may click on the button to the right of the *Data File* field to search your computer's directories for the applicable precipitation data file. In the example given in Figure A1, this file is named *Data\9433954244327\_2009\_dat.txt* where *Data\* is the default data subdirectory created during setup.

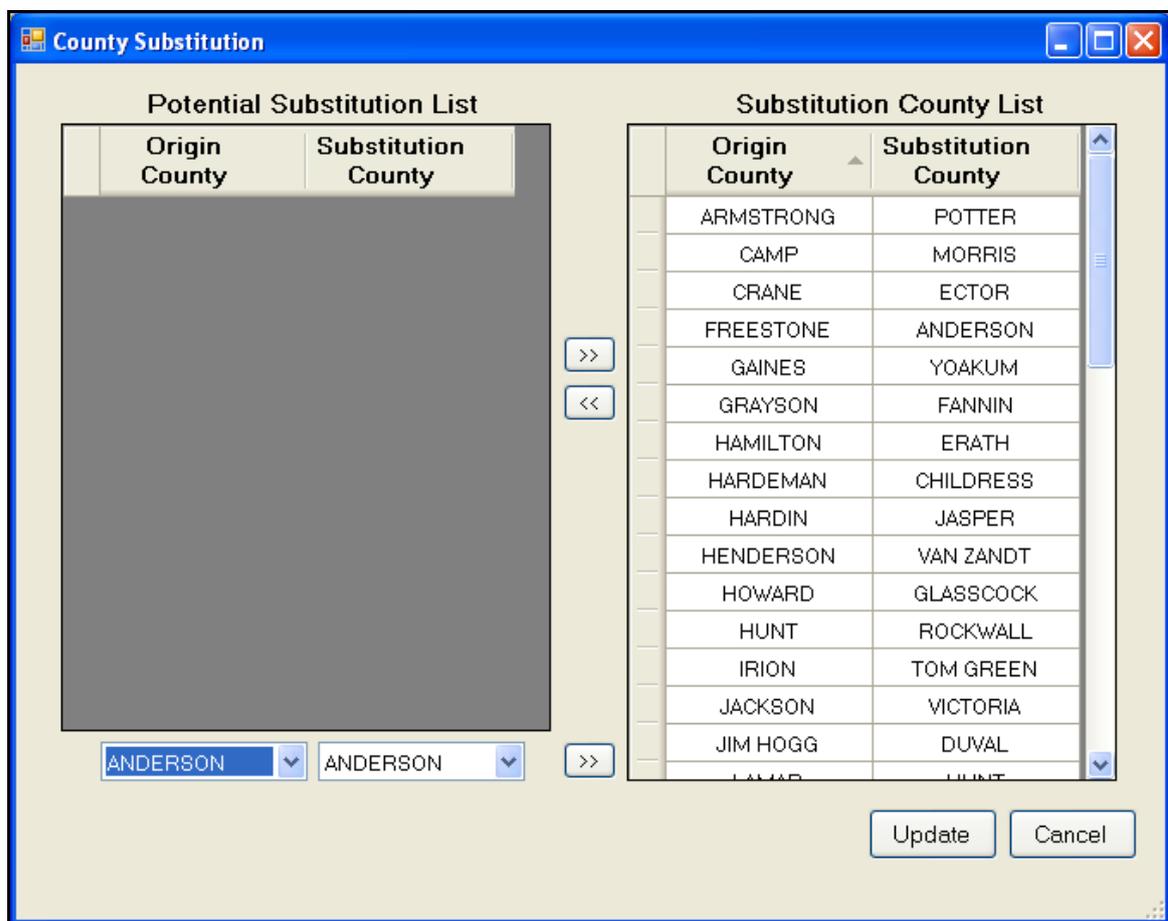
In addition to the precipitation data file, the program requires the file of weather stations from which rainfall data were downloaded. This file provides the locations of the weather stations, which the program uses to link the rainfall data to the different counties of the state. In the example given in Figure A1, the station file is named *Data\9433954244327\_2009\_stn.txt*. Download this file from the NCDC website.

The remaining four files in the *Input Section* of Figure A1 are written to the default data subdirectory during setup. These files are described as follows:

- *Data\County\_mean\_monthly.csv*: a comma-separated-value file of mean monthly precipitations for each Texas county. Researchers determined the mean monthly precipitations using rainfall data that covers the period from 1978 to the last year of record (typically 2009). The program uses this file to fill missing rainfall data.
- *Data\District\_Mean\_Precip\_Load.csv*: a comma-separated-value file of 30-year average rainfall value, existing regional factor, and allowable wheel load for each of the 25 districts comprising the state. The program uses this file to compute regional factors.
- *Data\District\_Annual\_Precip.csv*: a comma-separated-value file of average yearly rainfall values for each district. This file spans several years of data and gets updated each time the program is used to determine the average rainfall values for the given year. Initially, after program setup, *District\_Annual\_Precip.csv* has the average yearly rainfall values from 2005 to 2008. The program uses this file along with the calculated district average rainfall values for the current year to compute the 5-year (2005 to 2009) average rainfall per district, which is then divided by the corresponding 5-year statewide average to determine the rainfall factor for the given district and year.
- *Data\Substitute\_County\_List.csv*: a comma-separated-value file used to fill missing data. If data from a given county are missing, the program uses data from the substitute county identified in this file. The default list created during setup identifies missing/substitute county pairs established from this implementation project. Specifically, if a county has missing data for the given analysis year,

researchers identified another county to substitute for the missing information. In general, researchers made this assignment based on the closest county that belongs to the same climatic division as the county with missing data. The NCDC rainfall data file identifies the climatic division for each weather station in each Texas county.

The user can edit *Substitute\_County\_List.csv* by clicking the button labeled *Edit County Substitution List* at the bottom left-hand corner of the input screen shown in Figure A1. If the user clicks on this button, the program displays the *County Substitution* dialog box shown in Figure A2.

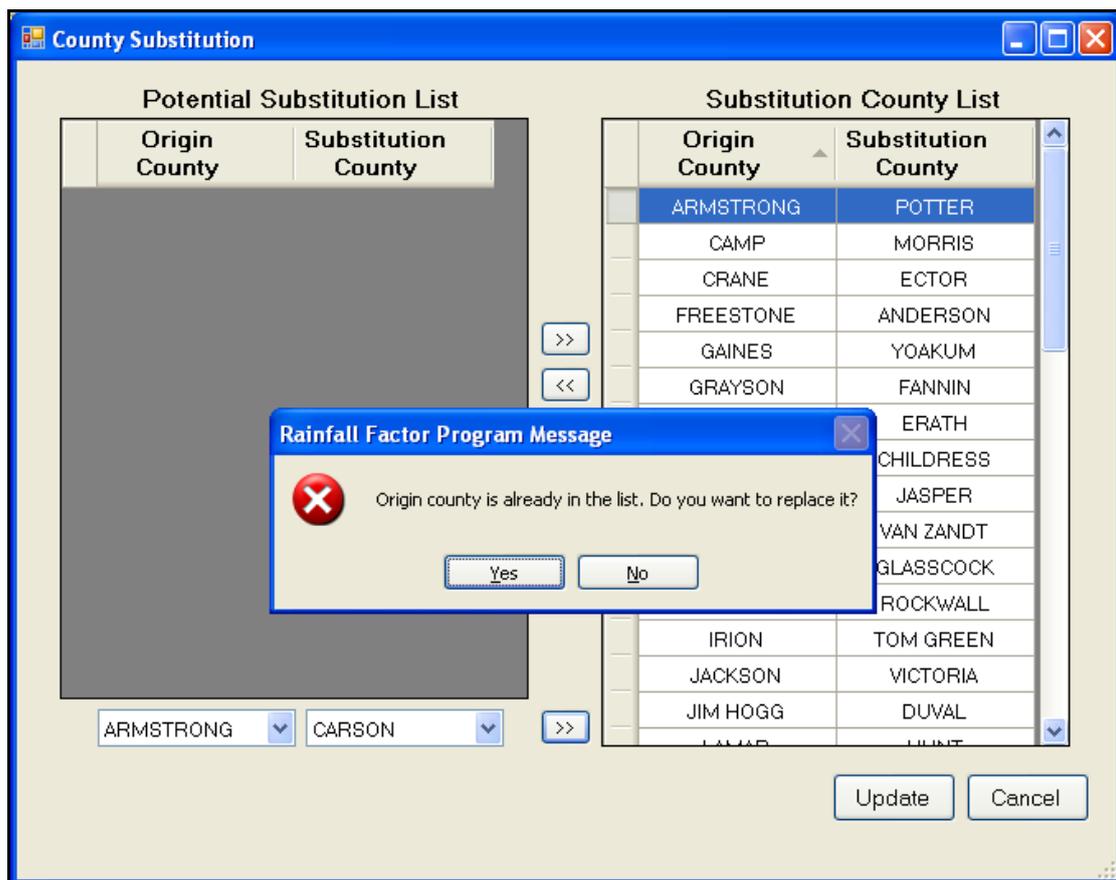


**Figure A2. Screen for Editing Substitute County List.**

The *Substitution County List* on the right-hand side of the dialog box shows the current content of the *Substitute\_County\_List.csv* file. The *Origin County* in this list identifies the Texas county with missing data for the given analysis year while the *Substitution County* identifies the county where the program obtains the data to fill in missing information on the *Origin County*. These cases arise when weather stations have missing rainfall data for certain months in the precipitation data file downloaded from the

NCDC. As noted previously, the substitution is made based on the closest county that belongs to the same climatic division as the county with missing data.

To edit the current list, the user can specify a different origin/substitution county pair through the pull-down menus on the bottom left-hand side of the screen shown in Figure A2 (below the box labeled *Potential Substitution List*). On each menu, click the down arrow to show a list of Texas counties. Use the left menu to identify the *Origin County* by scrolling down the list to search for that county. Then, select the county from the list by clicking on its name. Similarly, use the right pull-down menu to identify the *Substitution County*. After specifying the origin/substitution county pair, click the double right arrow beside the pull-down menus to add that pair to the current list. If the specified origin county is already on this list, the program will ask whether the user wants to replace the current pair on the list with the specified pair, as illustrated in Figure A3. This example shows Carson as the new *Substitution County* specified for Armstrong, which is already on the current list. The user simply clicks *Yes* or *No* to enter his/her response.



**Figure A3. Program Message to Confirm Replacement of Existing Origin/Substitution County Pair.**

To remove an origin/substitution county pair from the list, identify the pair to delete by clicking either the origin or substitution county name. Then, click the double left arrow on the middle of the screen to move the pair from the current list to the *Potential Substitution List* on the left-hand side of the screen shown in Figure A2. Any county pair on this list can be moved back to the *Substitution County List* by clicking the double right arrow on the middle of the screen. This option permits the user to undo any deletions made to the *Substitution County List*. Once all changes to this list have been made, click the *Update* button on the dialog box to save all changes and update the *Substitute\_County\_List.csv* file. Otherwise, click *Cancel* to ignore all edits and leave the current file unchanged.

Clicking the *Update* or *Cancel* button in Figure A2 brings the user back to the input screen shown in Figure A1. Click the check box beside *Alternative Regional Factors based on User-Specified Limits* to enter a different set of limits for calculating regional factors. If the user checks this option, the program displays the input boxes shown in Figure A4 where he/she can enter a different set of lower and upper limits for calculating regional factors.

The screenshot shows a software window titled "Maintenance Cost Allocation Factors" with three tabs: "Input", "Log", and "Factors". The "Input" tab is active. Under the heading "INPUT SECTION", there are several input fields, each with a browse button (three dots):

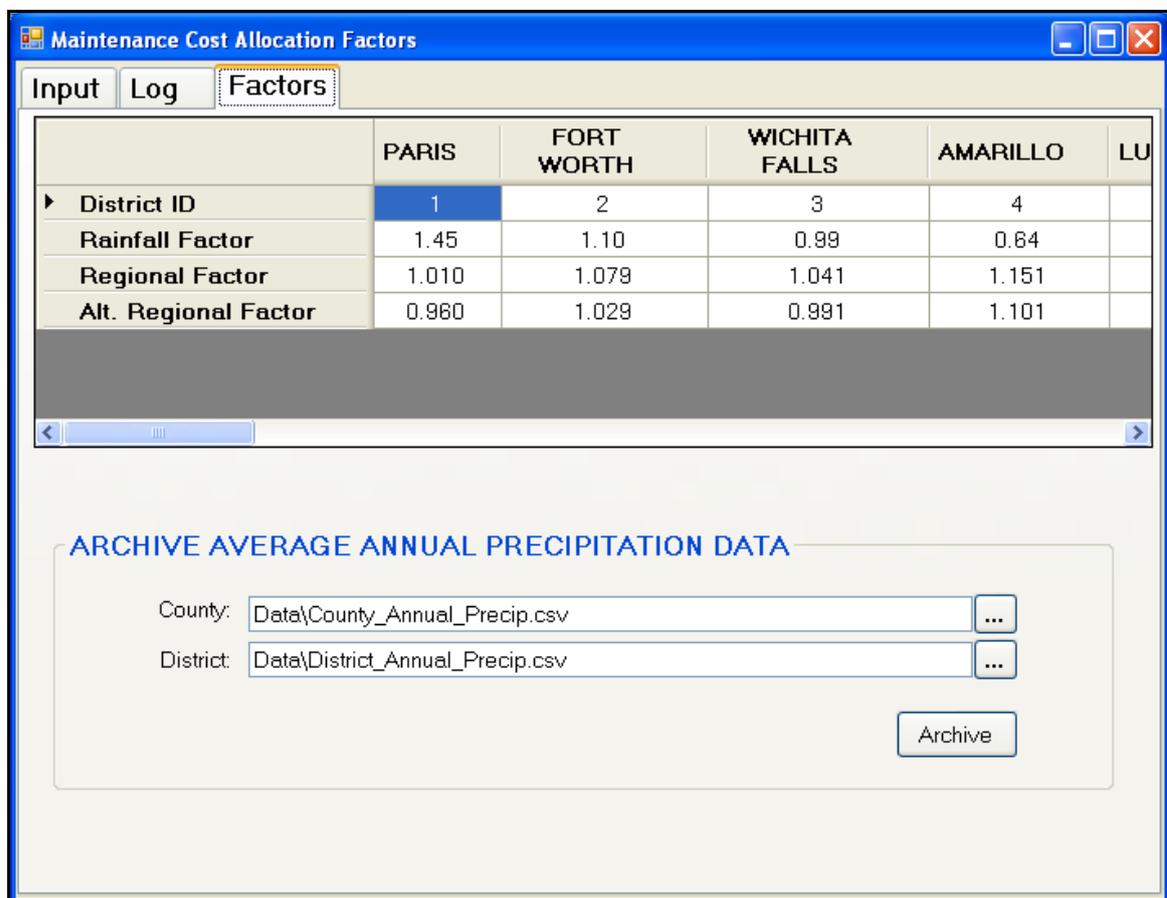
- Year: 2009 (dropdown menu)
- Data File: Data\9433954244327\_2009\_dat.txt
- Station File: Data\9433954244327\_2009\_stn.txt
- County List: Data\County\_mean\_monthly.csv
- District List: Data\District\_Mean\_Precip\_Load.csv
- District Avg. Data: Data\District\_Annual\_Precip.csv
- Substitute County List: Data\Substitute\_County\_List.csv

Below these fields is a section with a checked checkbox:  Alternative Regional Factors based on User-Specified Limits. Underneath this checkbox are two input boxes: Lower Limit: 1.0 and Upper Limit: 1.2. At the bottom of the dialog are three buttons: "Edit County Substitution List", "Run", and "Exit".

**Figure A4. User Input of Alternative Lower and Upper Limits for Calculating Regional Factors.**

By default, the lower and upper limits are set to 1.0 and 1.2, respectively, which are the current limits used by TxDOT. Enter a different set of limits (such as 0.95 to 1.15) in the corresponding input boxes to calculate regional factors based on alternative limits. Then, click *Run* on the input screen to calculate regional and rainfall factors based on the user-specified inputs.

To view the factors computed by the program, click on the *Factors* tab shown in Figure A1. The program then displays the results as illustrated in Figure A5. Drag the scroll bar at the bottom of the figure to view the cost allocation factors computed for the different districts. In the example shown, two sets of regional factors are included with the results, which correspond to the case where the user specified an alternative set of limits for calculating regional factors.



**Figure A5. Calculated Rainfall and Regional Factors from MCAF Utility.**

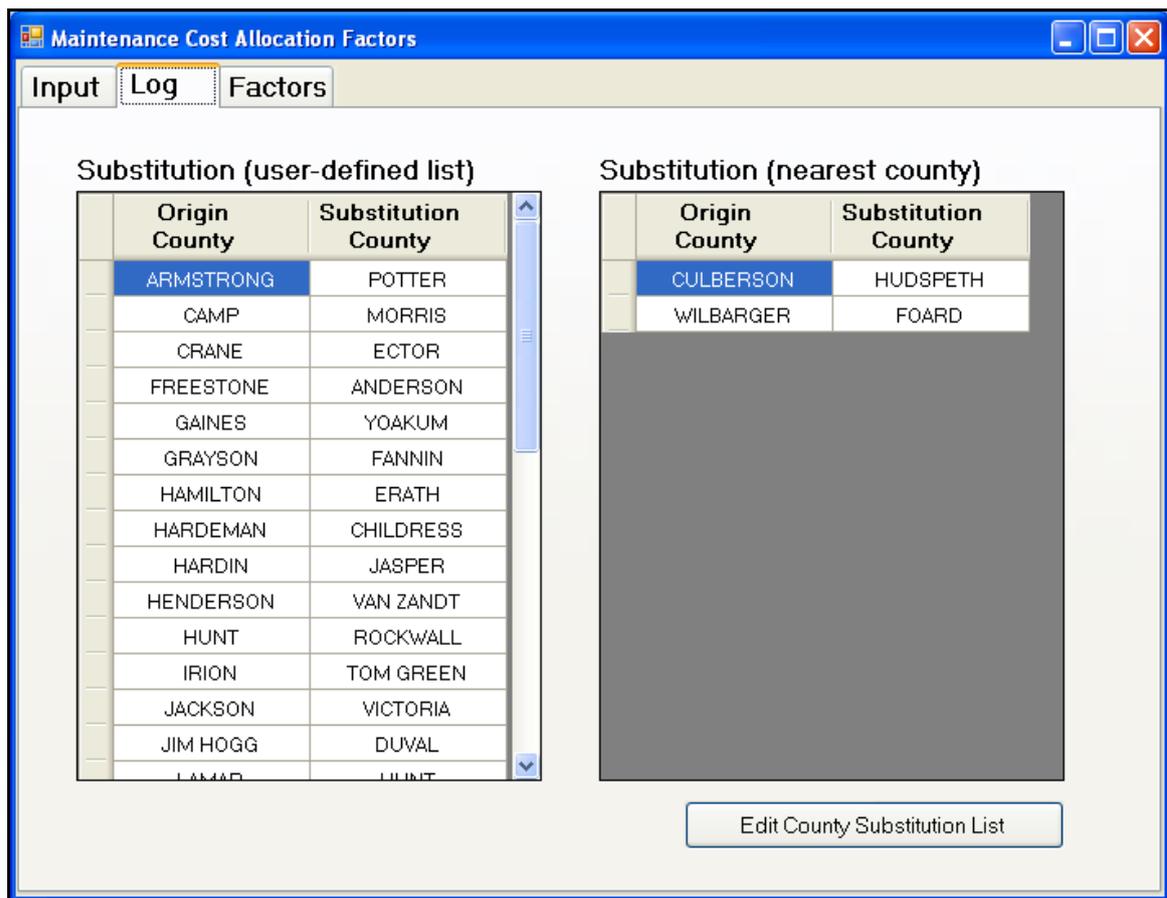
The first set of regional factors in the third row of the output screen is based on the default lower and upper limits of 1.0 and 1.2, respectively. The second set of regional factors shown in the last row is based on the alternative limits specified by the user. In the example shown, the alternative regional factors are based on lower and upper limits of 0.95 and 1.15, respectively.

The output format shown in Figure A5 permits the user to copy the rainfall or regional factors, and paste them directly into the appropriate cells of TxDOT's maintenance cost allocation spreadsheet. To copy a row of factors, first drag the computer's mouse over the 25 cells comprising that row. Then, press *Ctrl C* concurrently on the keyboard to copy the factors into the computer's memory. Position the cursor onto the first cell (corresponding to the Paris District) of the row for those factors in the cost allocation spreadsheet, and press *Ctrl V* concurrently on the keyboard to paste the factors into their corresponding cells.

The output screen shown in Figure A5 also permits the user to save the average county, and average district rainfall values into the corresponding archive files specified in the figure. The file *County\_Annual\_Precip.csv* contains the yearly average rainfall values for the different Texas counties. Initially, after program setup, this file has the average rainfall values from 2005 to 2008. If the user runs the program to compute average rainfall values for 2009, he/she can update this file to include the 2009 average rainfall values for the 254 counties comprising the state. The user also has the option to write the calculated district average rainfall values for the same year to the corresponding archive file specified in the output screen. In the example given in Figure A5, the average rainfall district values are saved to *District\_Annual\_Precip.csv*, which is the same file of district average yearly rainfall values specified in the input screen of Figure A1.

Click the *Archive* button of the output screen to save the average county and average district rainfall values determined for the specified year. This function updates the corresponding archive files to add the current year average rainfall values computed by the program. The user can then use these updated files to compute the rainfall factors for the succeeding year using the precipitation data for that new year.

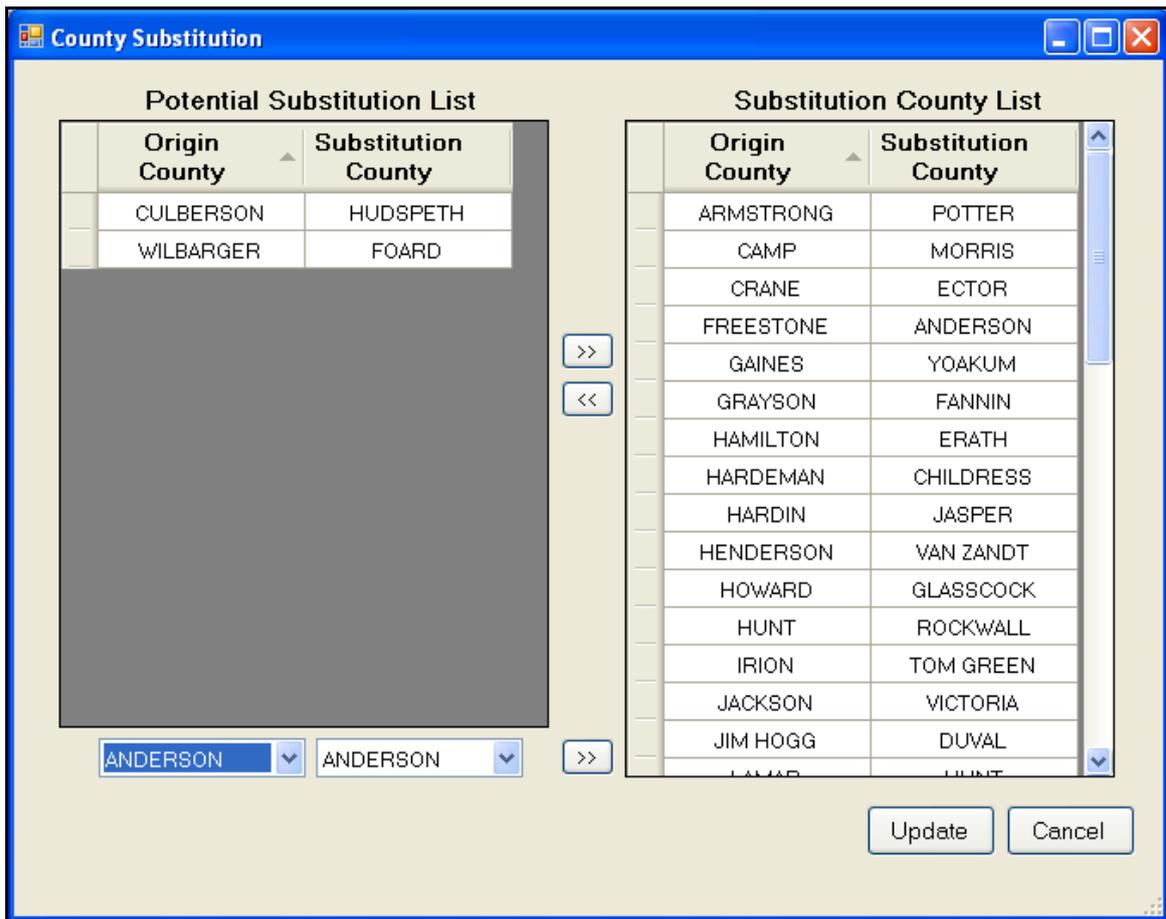
Clicking the *Log* tab accesses the remaining screen of the MCAF program. This screen provides a log of the substitutions made by the program to fill in missing rainfall data. Figure A6 illustrates these substitutions, which shows two types of substitution lists. The list on the left-hand side of the figure is based on the current *Substitute County List* file specified by the user in Figure A1. The list on the right-hand side identifies substitutions made by the program during runtime to fill in missing rainfall data for counties not included in the user-defined list. The example given in Figure A6 illustrates the case where the program found other counties (not included in the user-defined list) with missing rainfall data for certain months of the current year.



**Figure A6. Program Log Showing Substitutions to Fill Missing Rainfall Data.**

The list on the right-hand side of the figure shows substitutions based on finding the closest county belonging to the same climatic division as the county with missing rainfall data (the *Origin County* in Figure A6). To find substitute counties, the program first looks at the user-defined list. If the county with missing data is not on this list, the program then performs a search to find the closest county with available rainfall data that belongs to the same climatic division as the *Origin County*. If this search is not successful, the program then uses the appropriate 30-year average rainfall value(s) obtained from the file *County\_mean\_monthly.csv* to fill in missing rainfall data for the given county and missing month(s).

The user can edit the current *Substitute County List* by clicking the *Edit County Substitution List* button in Figure A6. The program then displays the *County Substitution* dialog box shown in Figure A7. This figure is similar to the dialog box given in Figure A2, except that the *Potential Substitution List* shows the substitutions determined during runtime based on finding the closest county belonging to the same climatic division as the *Origin County*.

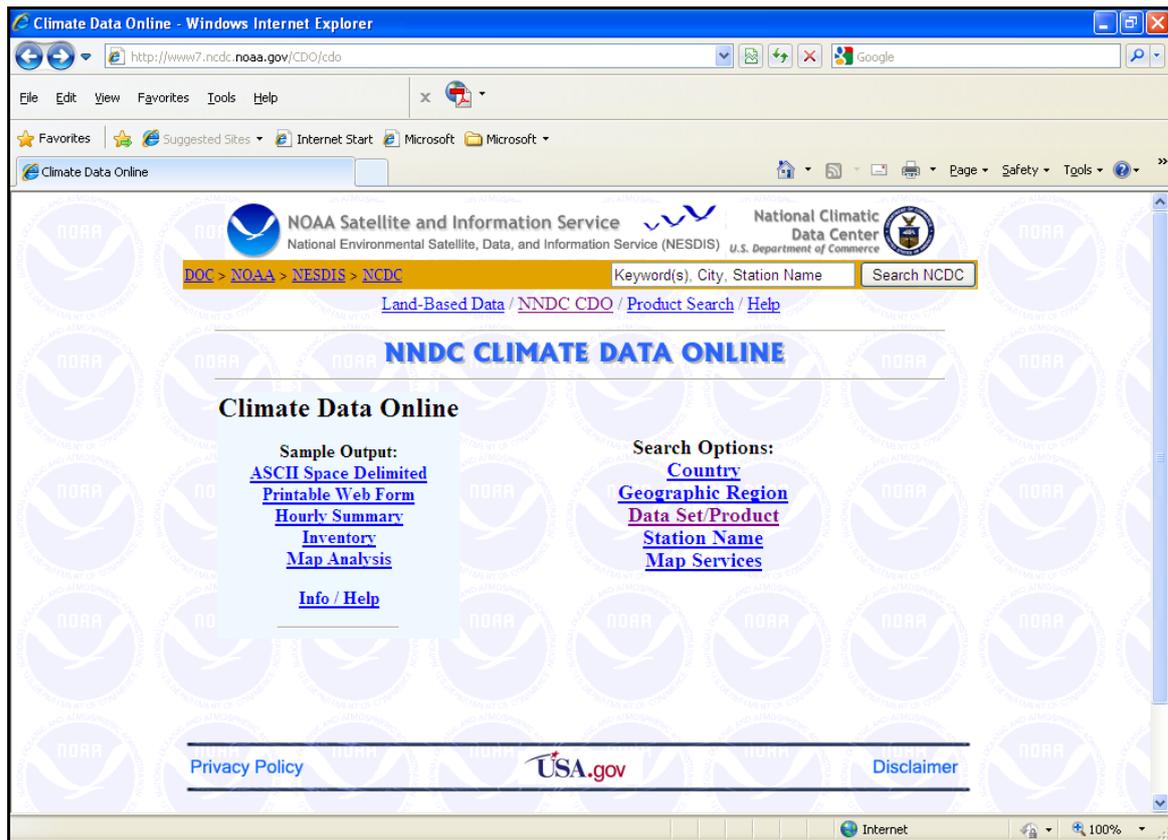


**Figure A7. Screen to Edit Substitute County List with Substitutions Determined during Runtime.**

To add pairs of counties identified in the *Potential Substitution List* to the current user-defined list, simply select the pairs to add and click the double right arrow on the middle of the figure. The user can select particular pairs by pressing the *Ctrl* key while clicking on each pair to add to the user-defined list. Select a range of counties by clicking on the first pair of the range. Then, scroll down the list and hold the *Shift* key while clicking on the last pair of the range. Click the double right arrow to add the selected range to the current user-defined list. Press the *Update* button to add the selected county pairs and update the current list. Otherwise, press the *Cancel* button to leave this list unchanged.

## **INSTRUCTIONS TO DOWNLOAD WEATHER DATA**

As discussed previously, the MCAF program requires rainfall data from Texas weather stations and the locations of these stations. The required input data may be downloaded from the NCDC website by typing and entering the following address on the web browser: <http://www7.ncdc.noaa.gov>. Figure A8 shows the NCDC web page that is displayed on the computer's monitor after entering this address.



**Figure A8. National Climatic Data Center Web Page.**

Click on *Data Set/Product*, under *Search Options* of the menu in Figure A8. The user then gets to the screen shown in Figure A9 where he/she can select from a list of data sets or products to download. Scroll down the list of *Data Set/Product Options* and select *Surface Data, Monthly (over 18,000 US, some non-US sites)* as illustrated in Figure A9. Then, click on the *Access Data/Products* button. The web browser then displays the *Monthly Surface Data* menu shown in Figure A10. Scroll down the list of states and territories and select Texas from the list. Then, click on *Entire State* to download data from all Texas weather stations, and click *Continue*.

The web browser then displays the screen shown in Figure A11. From this menu, the user specifies the type of data to download by scrolling down the list of meteorological elements. Since the MCAF utility uses rainfall data as input, select *TPCP Total monthly precip (in.)* from the list of meteorological elements as illustrated in Figure A11. The user will also need to specify the range of years that the download will cover. To download rainfall data for the 2009 calendar year, specify 2009 as the *From* and *To* year as illustrated in Figure A11. Then, under *Select Output Format* click on *Delimited – No Station Names* and select *Comma* as the format delimiter.

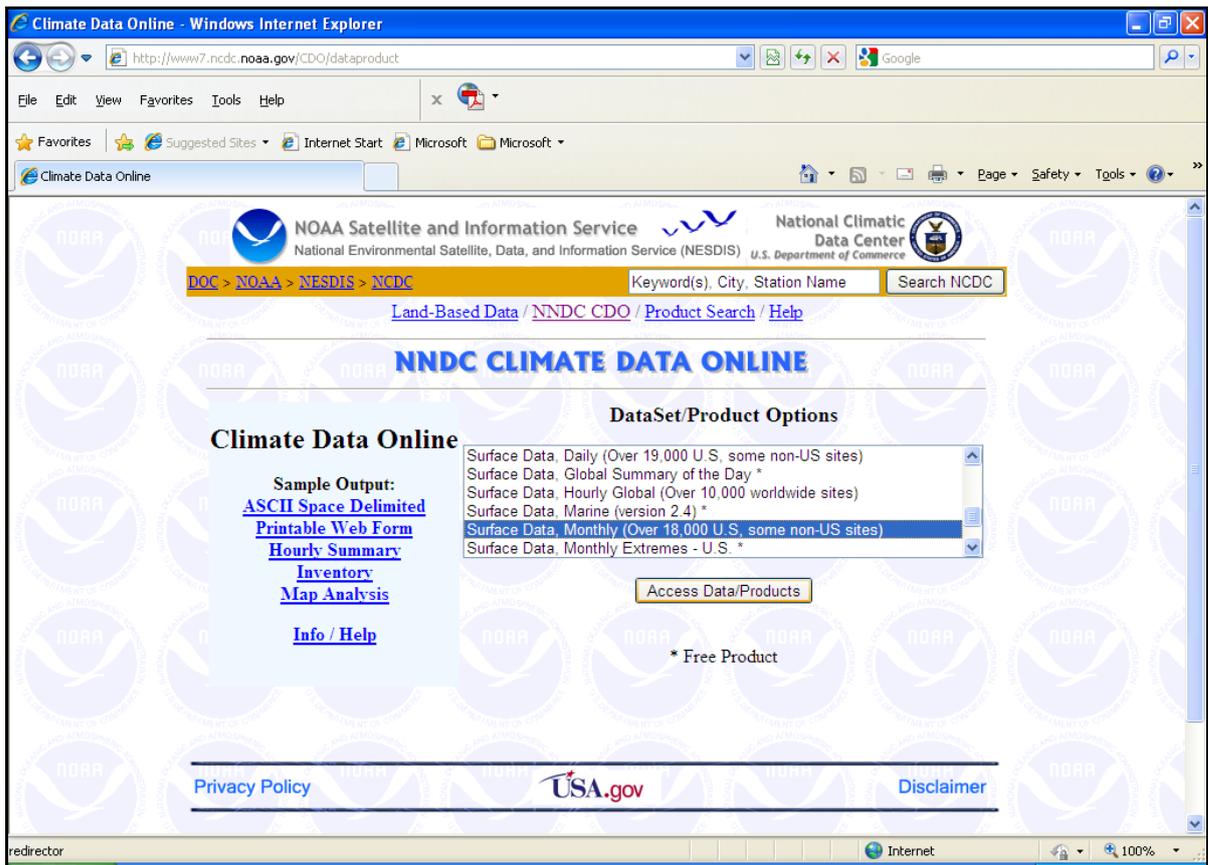


Figure A9. Web Page of Data Set/Product Options.

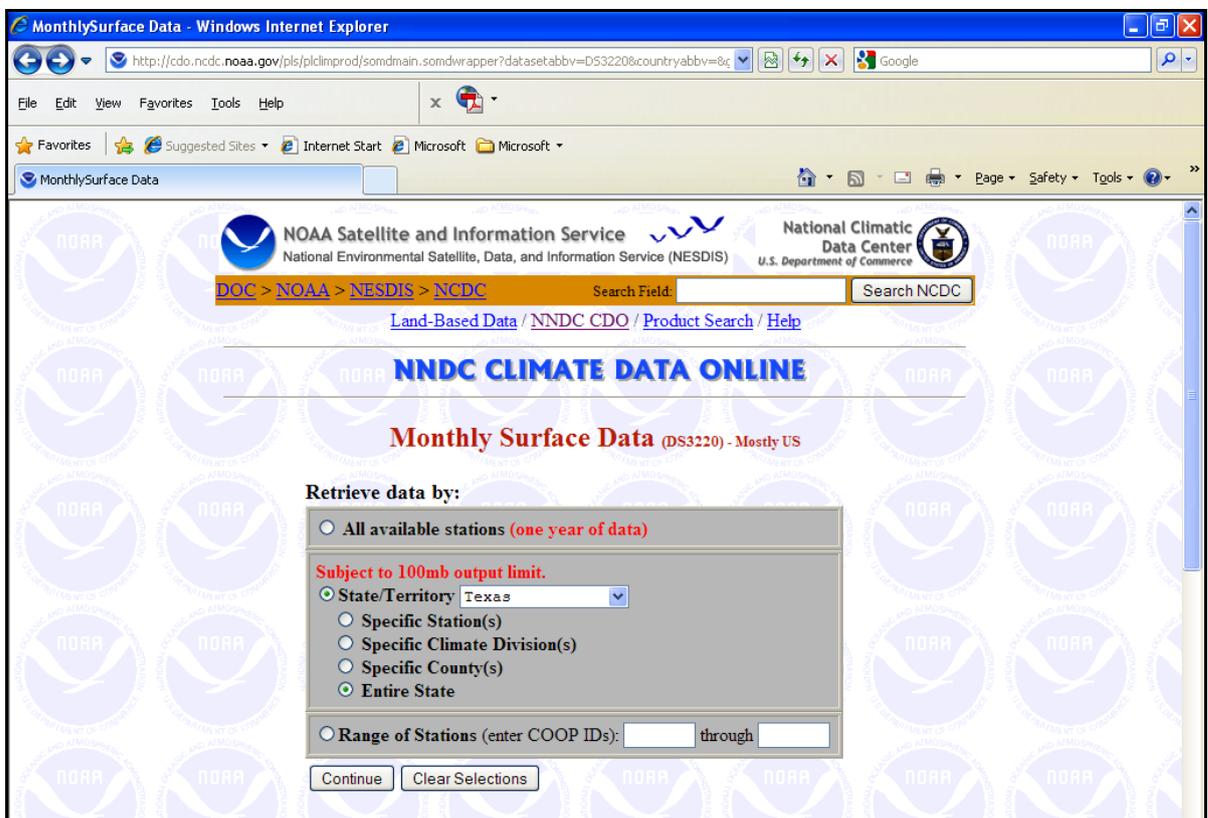
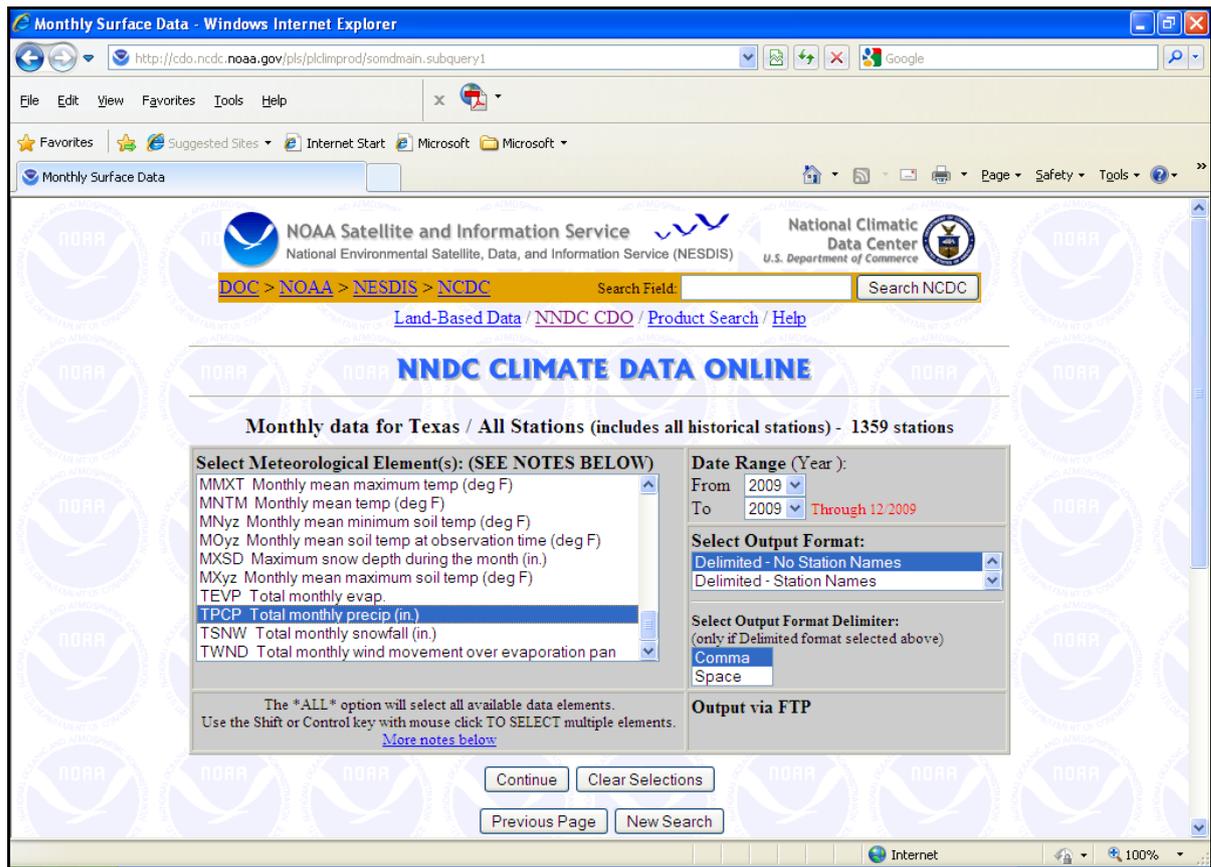


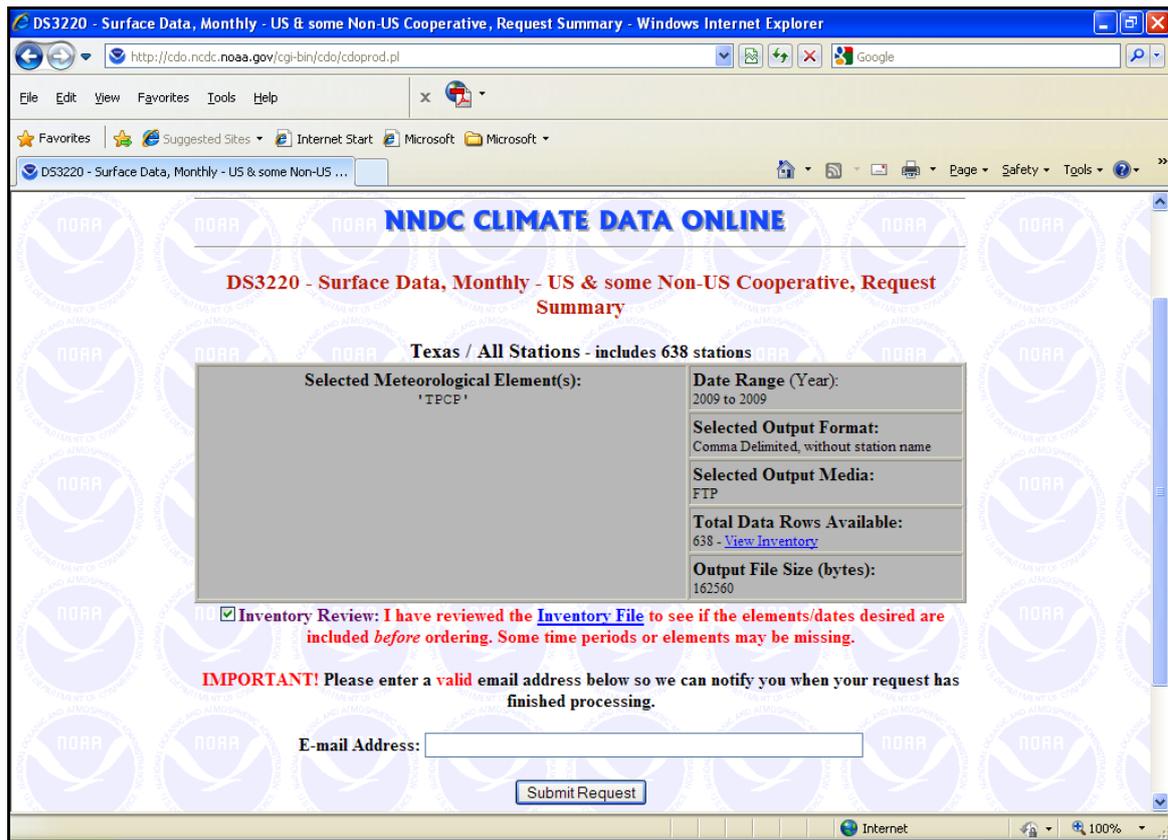
Figure A10. Menu to Select State for Data Download.



**Figure A11. Menu to Specify Data Element, Time Interval, and Data Format.**

In current TxDOT practice, maintenance allocations for the next fiscal year (beginning September 1) are usually established within the first half of the present calendar year. Thus, rainfall data for the preceding year will have to be downloaded and input to the MCAF program. For the example given in Figure A11, 2010 is assumed as the current calendar year. Thus, the program will need 2009 rainfall data to compute the applicable rainfall factors for establishing the FY11 maintenance budget. This calculation will use the 2009 data along with the archived rainfall data in *County\_Annual\_Precip.csv* to compute 5-year average rainfall values to determine the rainfall factors. The user then updates this data file to include the 2009 rainfall data for calculating rainfall factors in the next budget cycle. Thus, in practice, only the rainfall data for the preceding year will need to be downloaded.

After making the selections in Figure A11, click on the *Continue* button below the menu. Figure A12 shows the next screen to confirm the user selections. To make changes, click on the *Back* button of the web browser to return to the menu shown in Figure A11. Otherwise, check the box to the left of *Inventory Review* and type in your email address. Then, click on the *Submit Request* button.



**Figure A12. Menu to Confirm Selections for Data Download.**

The web browser then displays the page shown in Figure A13, which informs the user that his/her request has been submitted for processing. This page also shows the user's Request ID (CDO01835643 in the example shown) and a URL to access the requested files. Click on the URL to view and save the files to your computer.

Figure A14 shows the next screen, which presents a list of URLs to access the data files associated with your request. Click on the *Data File* and *Station List* URLs to view and save these files to your computer. The data file will have the rainfall records for the calendar year specified, while the station list identifies the weather stations and gives their locations. You will need these files to run the MCAF program.

To download the rainfall data file, click on its URL to view the data on the web browser as illustrated in Figure A15. To save the data to your computer, click on the *Page* button of the web browser, and select *Save As* from the list (Figure A16). You will then be shown a dialog box where you can specify a filename in which to save the data or accept the default filename provided with your request. You will need to use the default file type (Text) and file encoding (Unicode, UTF-8) to save your file. Repeat this same procedure to view and save the *Station List* file. After this step, you will have the rainfall and station data files to compute rainfall factors using the MCAF program.

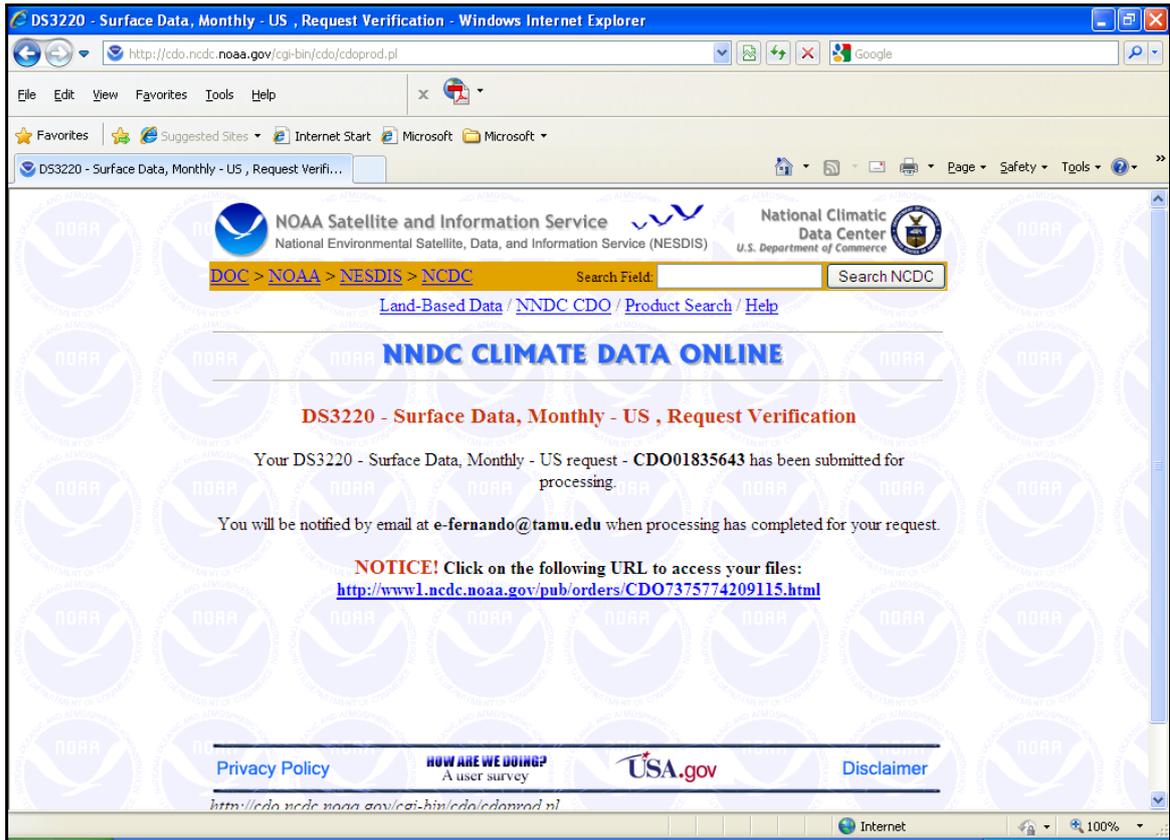


Figure A13. Screen with URL to Access Data Files Requested.

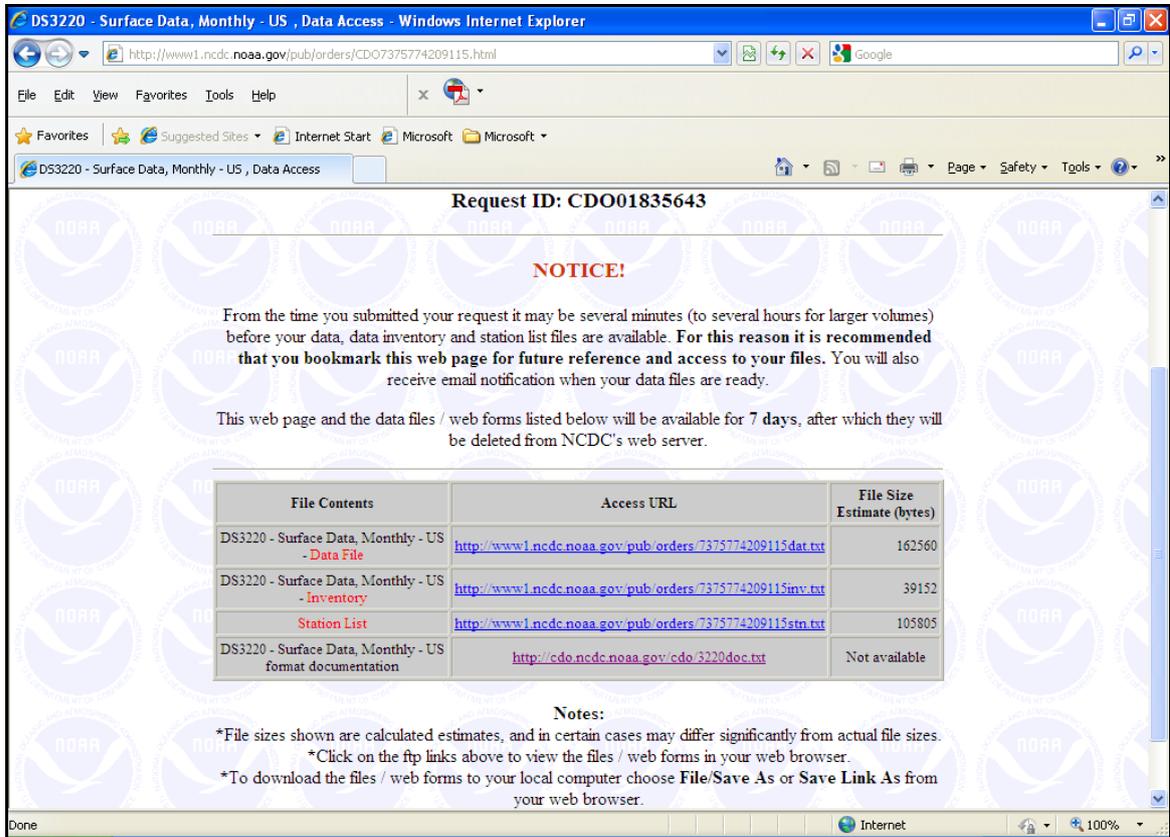


Figure A14. List of URLs to View and Save Rainfall and Station Data Files.

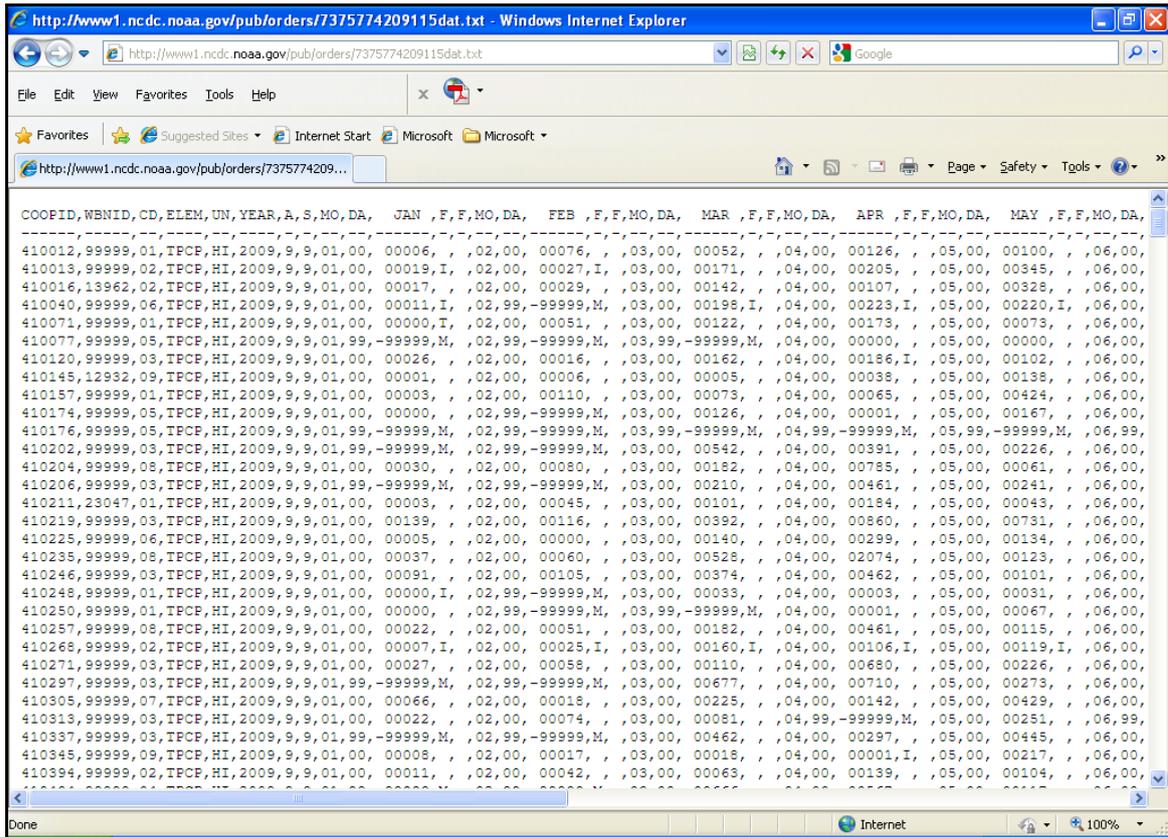


Figure A15. Viewing Rainfall Data File on Web Browser.

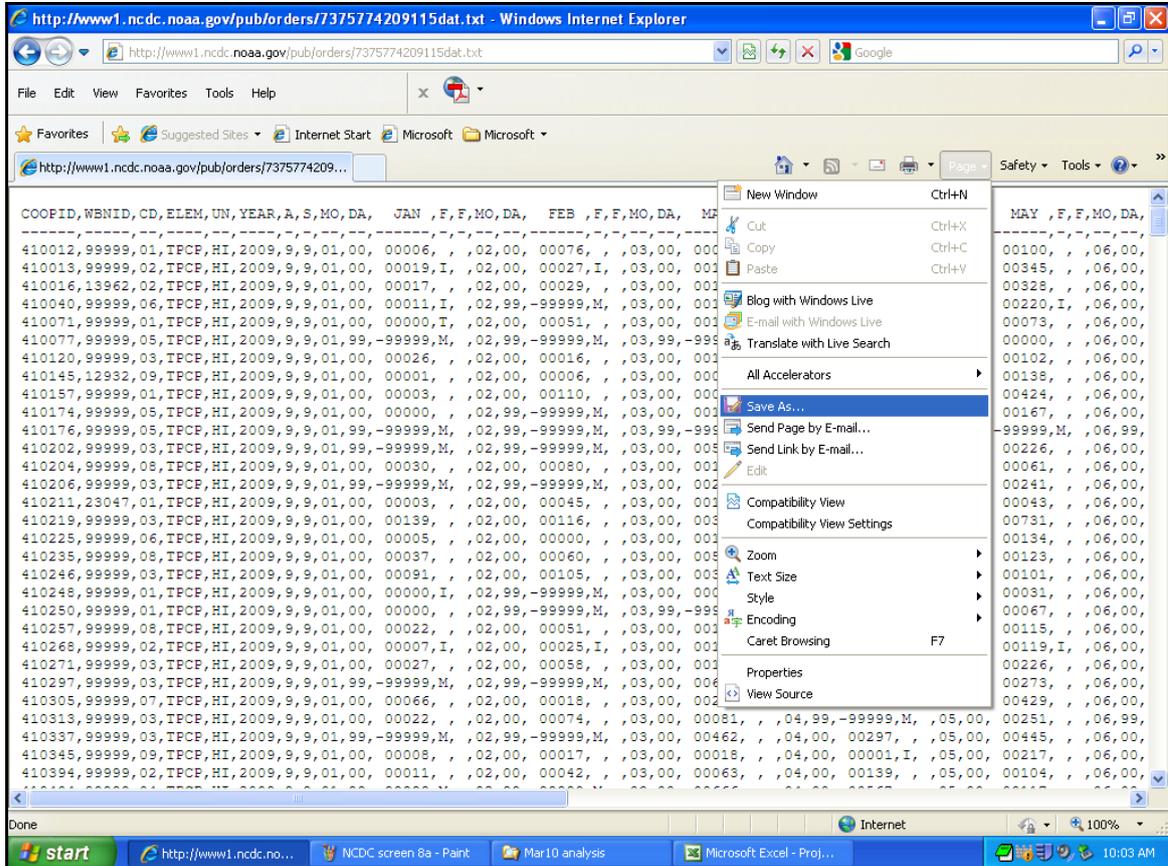


Figure A16. Saving Rainfall Data File.

