

### 4.3 Analytical Methods and Results

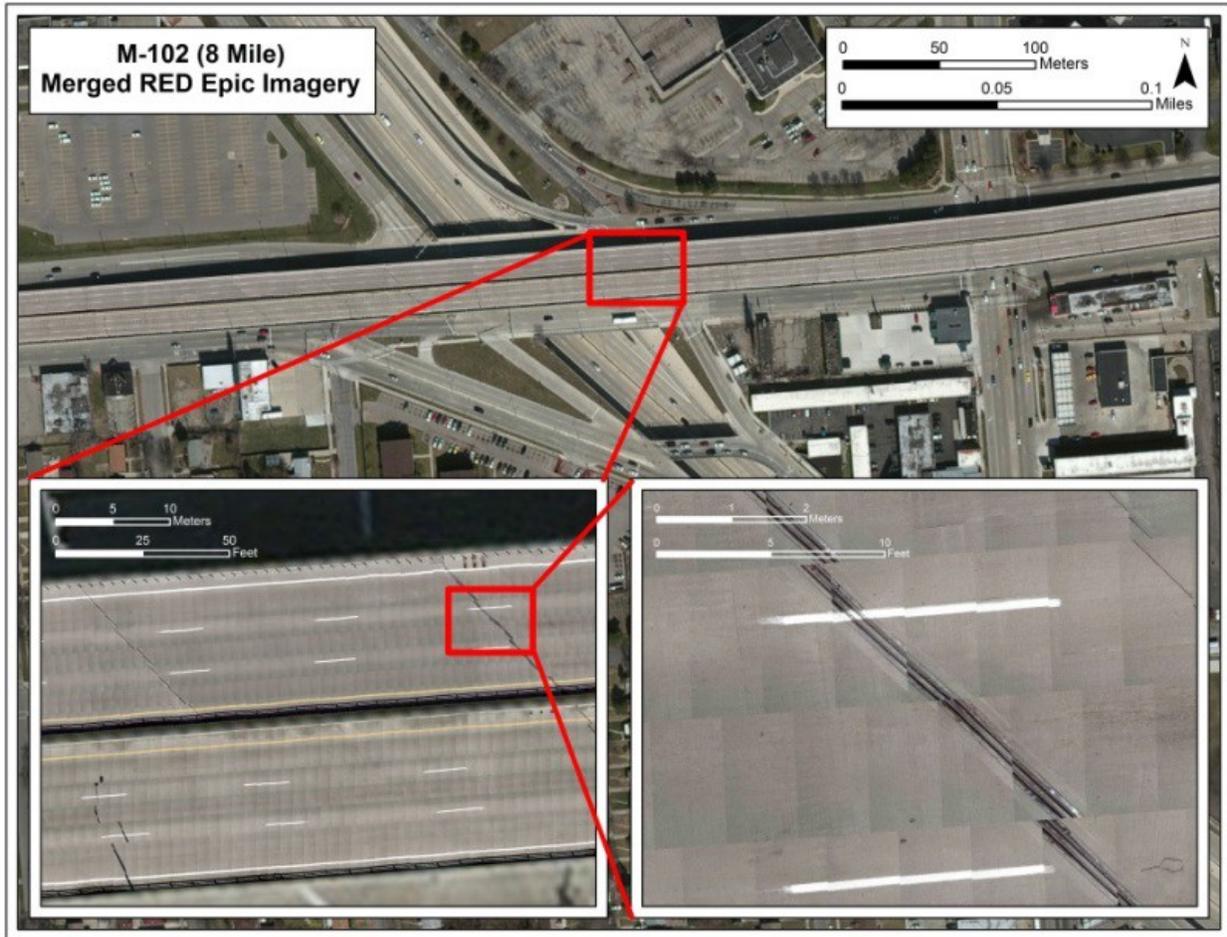
Before data collection began at each bridge location, both the RED Epic optical and FLIR thermal cameras were attached side-by-side to front of the data collection vehicle (Figure 22). Additionally, the BVRCS GoPro Hero 3 cameras were attached to the front of the vehicle. Data collection consisted of driving the vehicle across each bridge multiple times to ensure imagery corresponding to each lane was collected, requiring the vehicle pass over the right and left sides of each lane. During the collections, highway traffic was not restricted and public access to each bridge was allowed. The data collection vehicle remained at highway speeds (approximately 70 mph) leading up to the bridge sites, but slowed down to near-highway speeds (approximately 45mph) when data collection was occurring, and sped back up to the original speed after data collection for each pass was complete. MDOT assisted by providing shadow vehicles for the I- 75 NB, I-75 SB and I-696 bridges due to higher traffic volumes at those locations.



**Figure 22: The data collection vehicle (left) and both the RED Epic and FLIR thermal infrared cameras attached to the vehicle.**

#### 4.3.1 8 Mile

After processing, merging, and georeferencing both optical and thermal imagery data sets, the outputs were placed within GIS software to provide visualization of distress features. Through using an automated script created to correct the overlap in individual frames extracted from RED Epic video imagery, individual frames were cropped and placed end-to-end, resulting in a single image for subsets of the bridge deck. The subsets were then merged together and georeferenced to ESRI base maps to create a single image per pass over the bridge. For the optical imagery, this serves as the visual basis of the bridge deck. As seen in Figure 23, the separate passes over the bridge deck do not necessarily line up with one another, resulting in slight distortion of pavement markings and bridge joints. However, the merged optical imagery proved useful as it provided an overview of how the bridge deck appeared during data collection. This bridge deck contained no spalls outside of the bridge joint area.



**Figure 23: RED Epic imagery merged together to form spall locations on the bridge deck of M-102 (8 Mile) eastbound and westbound.**

Similarly, the thermal imagery was also merged together through the same automated script. Individual frames were cropped and placed end-to-end, resulting in a single image for subsets of the bridge deck. The subsets were then merged together and georeferenced to ESRI base maps to create a single image per pass over the bridge (Figure 24). GS Infrastructure, Inc. inspected the thermal imagery and indicated any location that appeared to have a potential delamination. The merged optical and thermal images can then be placed on top of another and by using transparent layers in the GIS software; a better overview of where potential delaminations exist on the bridge deck can be seen (Figure 25). In total, 398 potential delaminations were identified by GS Infrastructure, Inc., totaling an area of 2,942 ft<sup>2</sup>, or approximately 1.73% of the entire bridge deck.

In the visualization of distress features, each feature is color coded by condition state as defined by Element #12 – Reinforced Concrete Deck in the AASHTO Bridge Element Inspection Manual (AASHTO, 2015) and Condition State Table 1 – Reinforced Concrete in the MDOT Bridge Inspection Manual (MDOT, 2015). Condition state levels for defined for Good (CS 1), Fair (CS 2), Poor (CS 3), and Severe (CS 4). For spalling or delaminations of reinforced concrete bridge decks, a condition state of 1 indicates no distress; CS2 is assigned when a spall is 1 in. or less deep, or less than 6 in. diameter, and patching is sound; CS3 is assigned for spalls greater than 1 in. deep

or 6 in. diameter. CS4 warrants further structural review to determine the effect on strength or serviceability of the element or the review has been conducted and the distress has been found to impact the strength or serviceability of the bridge deck element. All delaminations are automatically placed into CS2, independent of size. For the overall summary of each span's condition, please reference Figure 40 and Table 8 in Section 4.3.6.

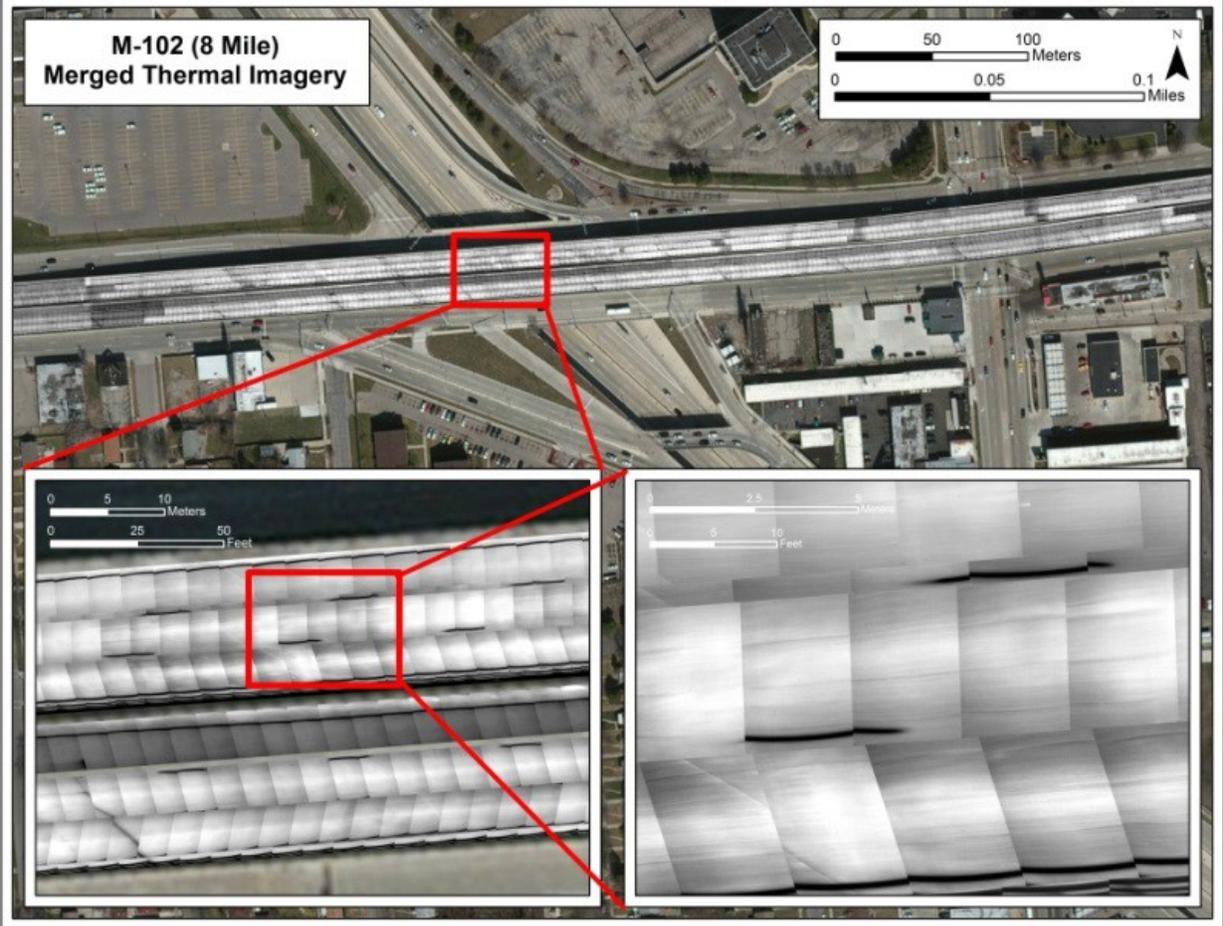
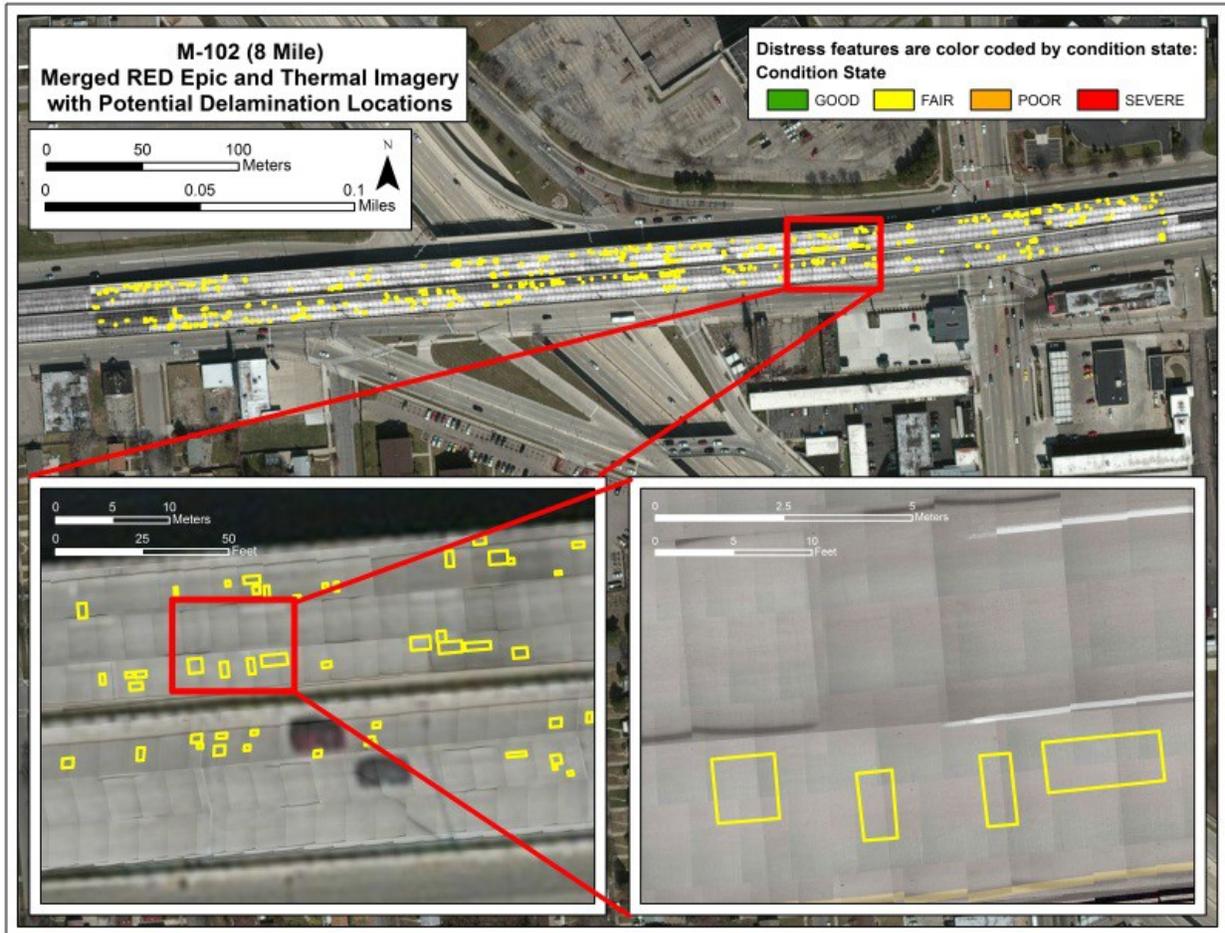


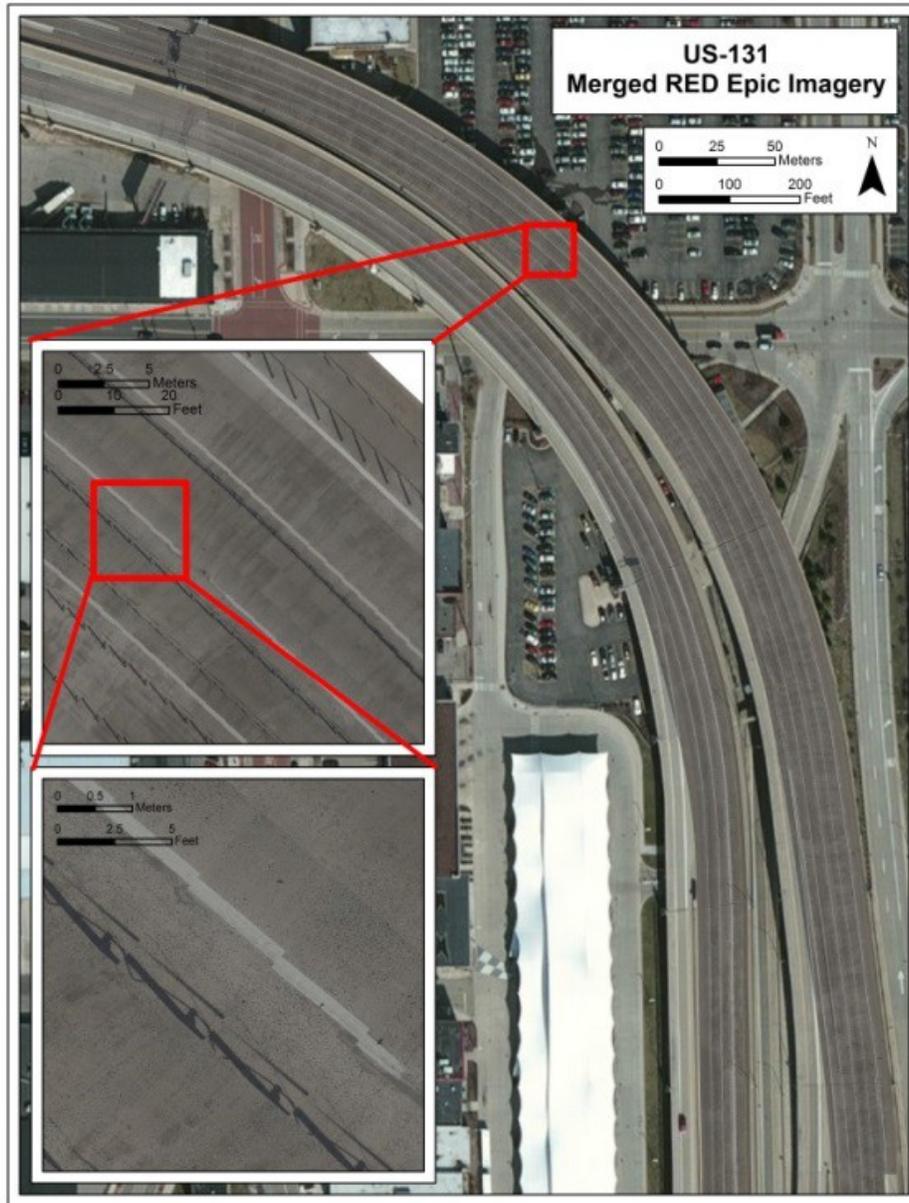
Figure 24: Merged thermal imagery merged of M-102 (8 Mile) eastbound and westbound bridge decks.



**Figure 25: Locations of potential delaminations for M-102 (8 Mile) eastbound and westbound bridge decks.**

### **4.3.2 US-131 NB/SB**

By using the same script that automated the merging of each individual frames extracted from the RED Epic video imagery for the M-102 (8 Mile) bridge deck, a single merged image of US-131 north and southbound bridge decks were created (Figure 26). Similar to the M-102 (8 Mile) bridge deck, the optical image was created though the merging of imagery from the different vehicle passes over each lane. The separate passes over the bridge deck did not line up perfectly with one another, resulting in slight distortion of pavement markings and bridge joints. However, the merged optical imagery proved useful as it provided an overview of how the bridge deck appeared during data collection.



**Figure 26: RED Epic imagery merged together to form the US-131 northbound and southbound bridge decks.**

After merging the thermal imagery from US-131 through the use of the automated merging script, the merged output was georeferenced to ESRI base maps (Figure 27). GS Infrastructure, Inc. inspected the thermal imagery and indicated any location that appeared to have a potential delamination. The merged optical and thermal images were then placed on top of one another and through the use of transparent layers in the GIS software, an overview of potential delaminations and spalls appear on the bridge deck (Figure 28). In total, 133 potential delaminations (34 northbound and 90 southbound) were identified by GS Infrastructure, Inc. totaling an area of 532 ft<sup>2</sup>, or approximately 0.25% of both bridge decks combined. For the overall summary of each span's condition, please reference figures 41 and 42 and tables 9 and 10 in Section 4.3.6.

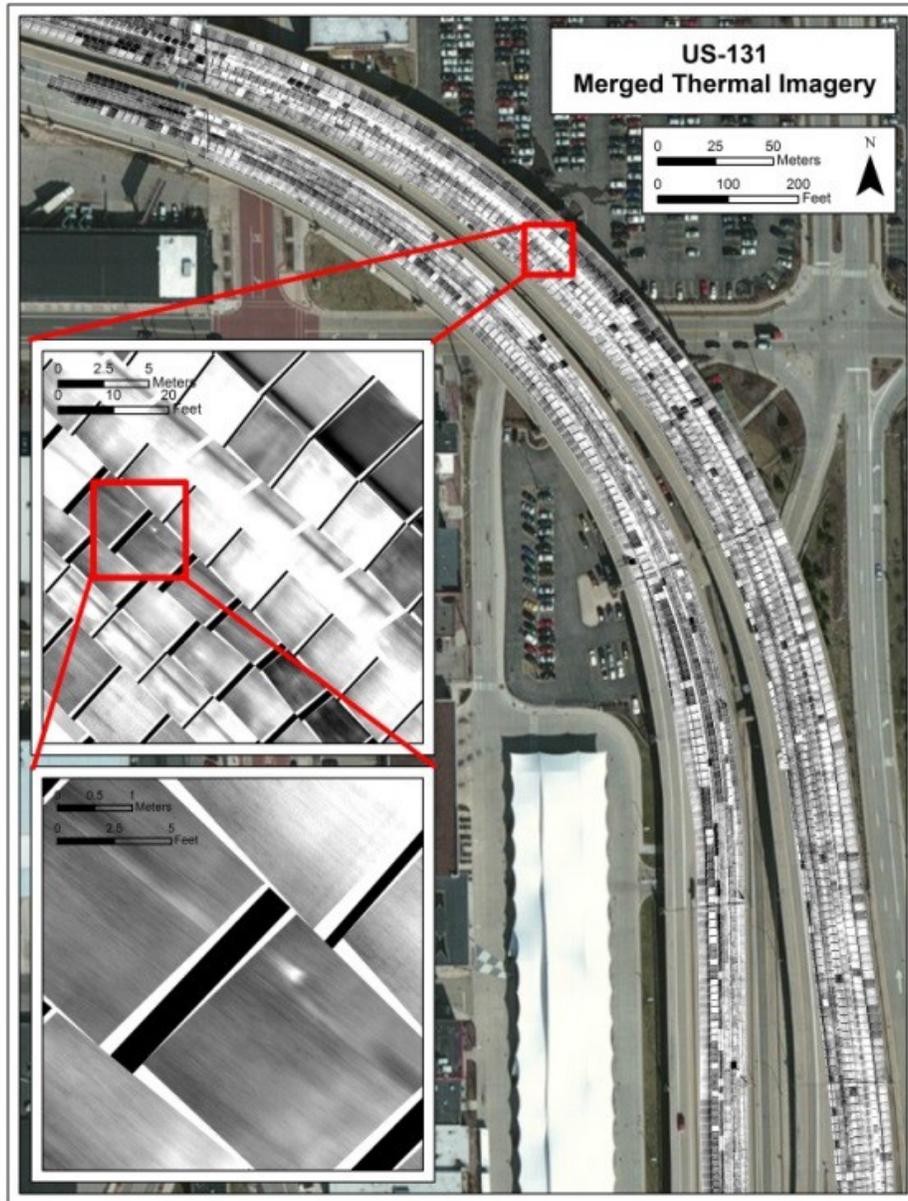
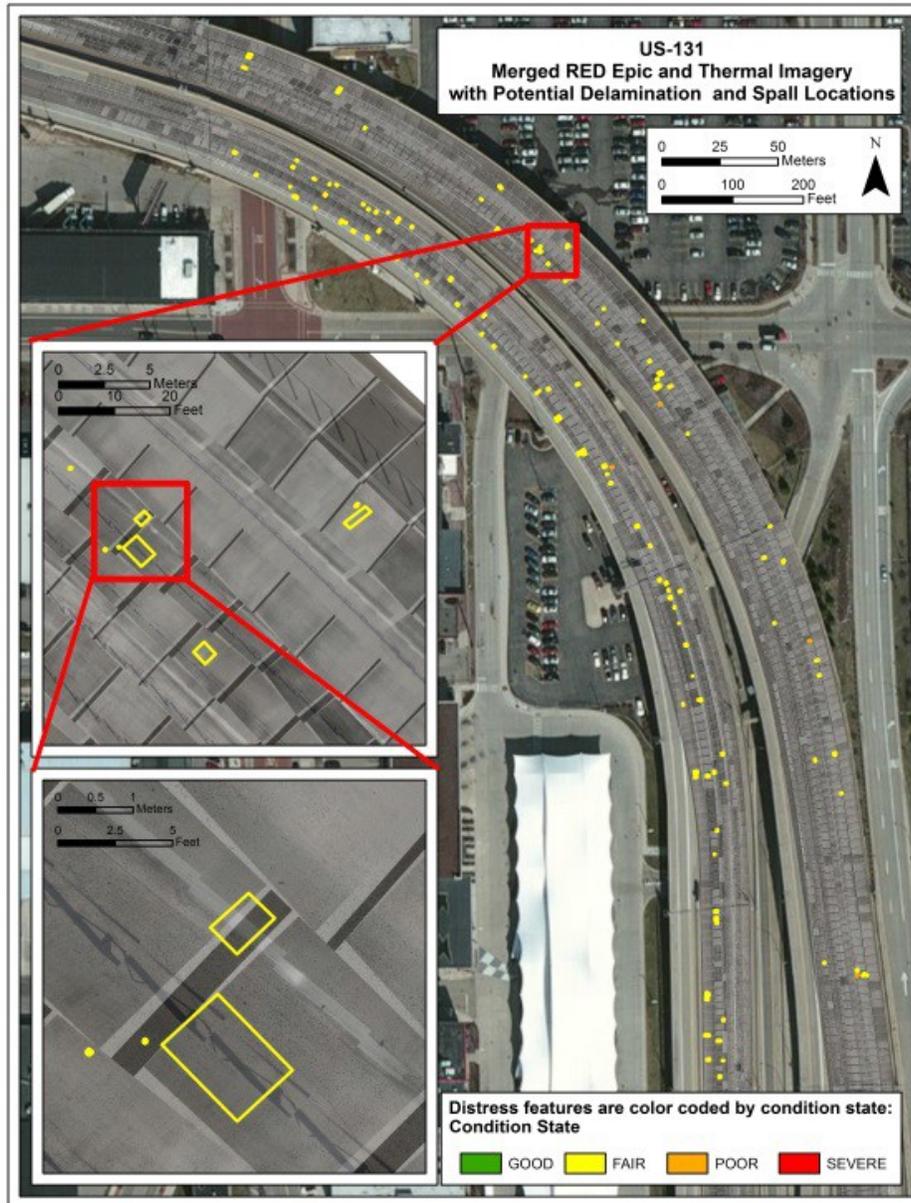


Figure 27: Merged thermal imagery of US-131 northbound and southbound bridge decks.



**Figure 28: Location of potential delaminations and spalls on US-131 northbound and southbound bridge decks.**

### 4.3.3 I-75 NB/SB

Upon merging the individual frames from the RED Epic for each separate pass over the bridge decks, a single merged image of the I-75 north and southbound bridge decks was created (Figure 29). Imagery from separate passes over the bridge deck did not line up perfectly with one another, resulting in slight distortion of pavement markings and bridge joints. However, the merged optical imagery proved useful as it provided an overview of how the bridge deck appeared during data collection.

After merging the thermal imagery from I-75 north and southbound decks, respectively,

through the use of the automated merging script, the merged output was georeferenced to ESRI base maps (Figure 30). GS Infrastructure, Inc. inspected the thermal imagery and indicated any location that appeared to have a potential delamination. The merged optical and thermal images were then placed on top of one another and through the use of transparent layers in the GIS software, an overview of potential delamination locations and spalling appear on the bridge (Figure 31). In total, 1,877 potential delaminations (515 northbound and 1,362 southbound) were identified by GS Infrastructure, Inc. totaling an area of 16,328 ft<sup>2</sup>, or approximately 8.50% of both bridge decks combined. As previously noted, spalls and delaminations are color-coded by condition state as noted in AASHTO BEIM (2015). For the overall summary of each span's condition, please reference figures 43 and 44 and tables 11 and 12 in Section 4.3.6.

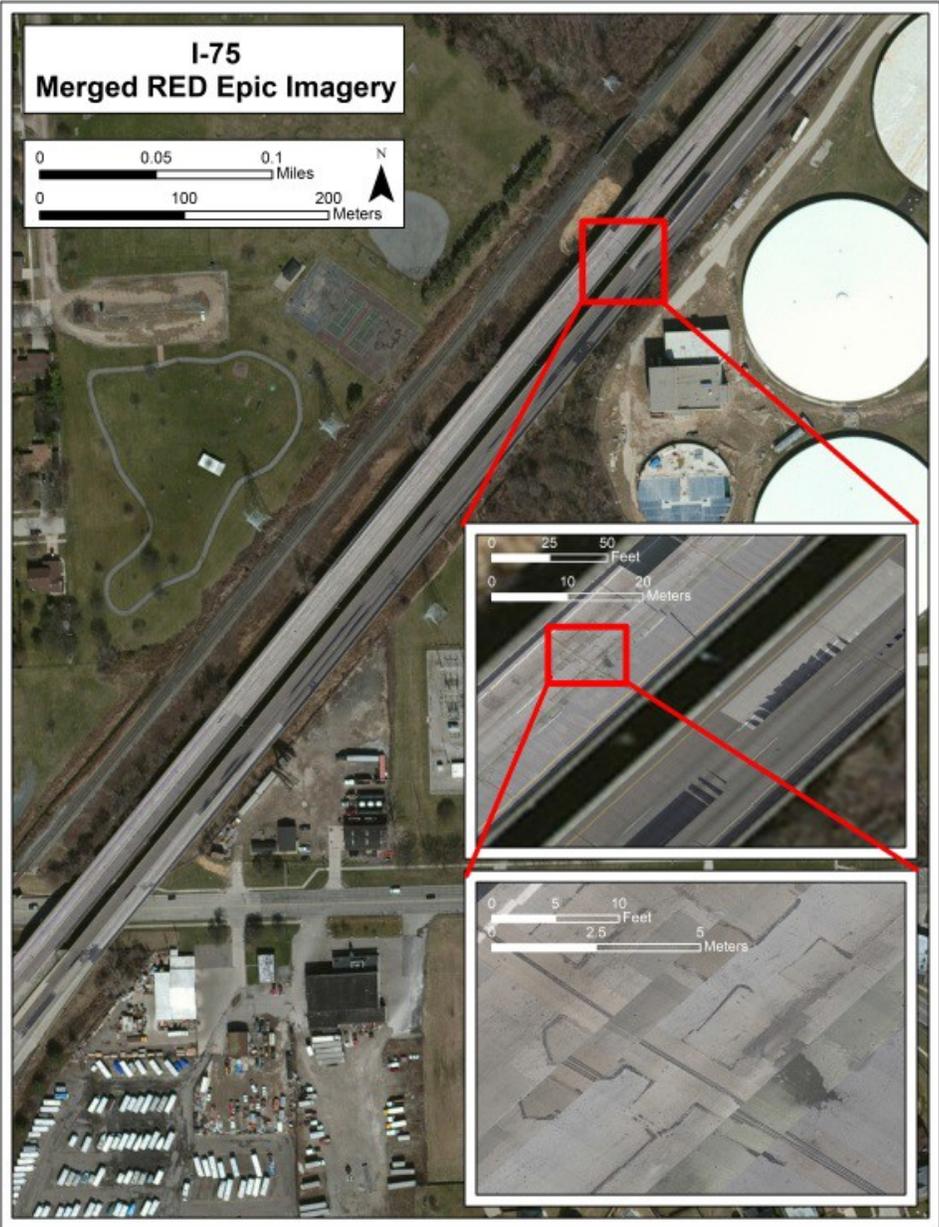


Figure 29: RED Epic imagery merged together to form I-75 northbound and southbound bridge decks.

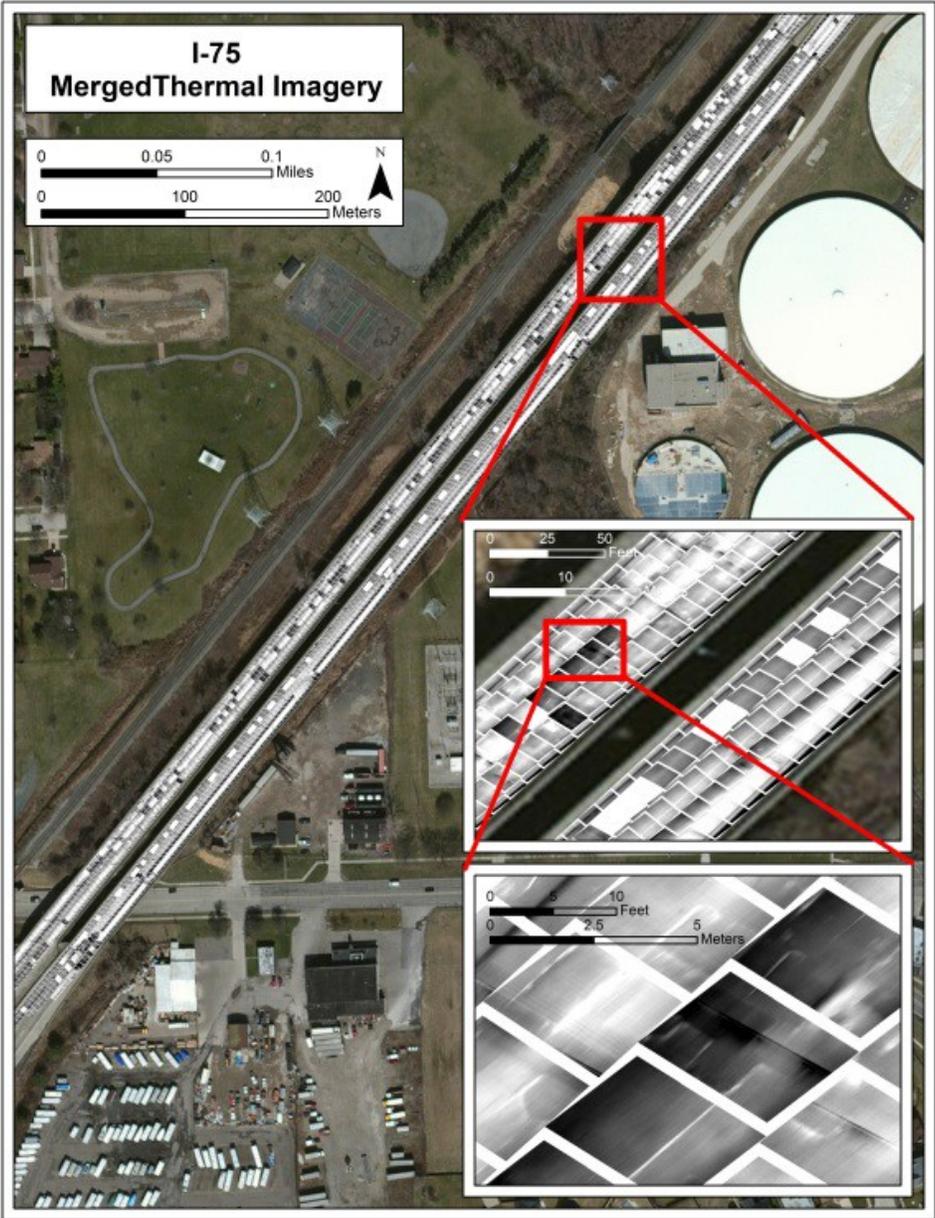
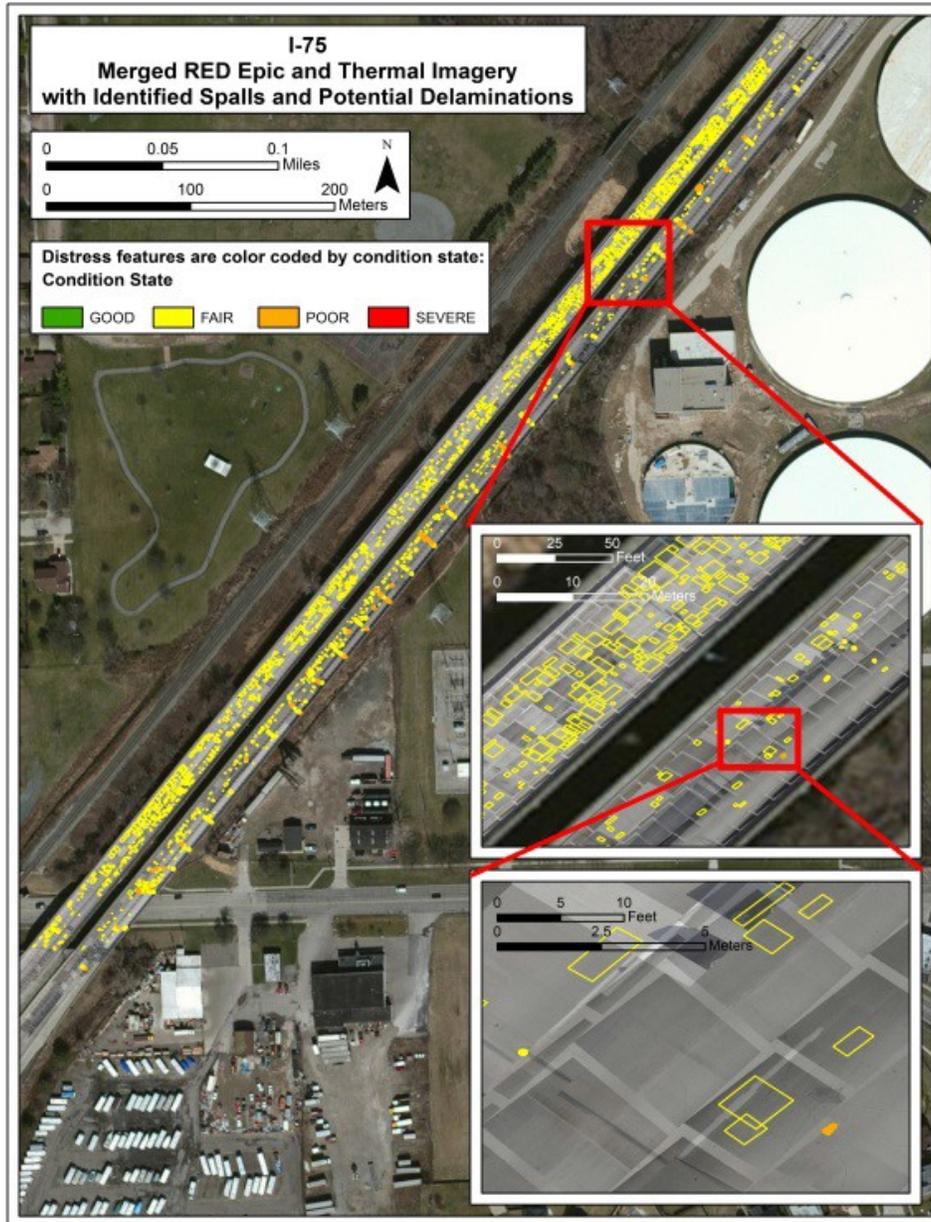


Figure 30: Merged thermal imagery of I-75 northbound and southbound bridge decks.



**Figure 31: Location of potential delaminations and spalls for I-75 northbound and southbound decks.**

#### **4.3.4 I-696**

Upon merging the individual frames from the RED Epic for each separate pass over the bridge decks, a single merged image of the I-696 west and eastbound bridge decks were created (Figure 32). The imagery from the separate passes over the bridge deck did not line up perfectly with one another, resulting in slight distortion of pavement markings and bridge joints. However, the merged optical imagery proved useful as it provided an overview of how the bridge deck appeared during data collection.

After merging the thermal imagery from I-696 through the use of the automated merging script, the merged output was georeferenced to ESRI base maps (Figure 33). GS Infrastructure inspected the thermal imagery and indicated any location that appeared to have a potential

delamination. The merged optical and thermal images were then placed on top of one another and through the use of transparent layers in the GIS software, a better overview of where potential delaminations exist and how it appears on the bridge deck can be seen (Figure 34). In total, 203 potential delaminations were identified by GS Infrastructure, Inc., totaling an area of 1,125 ft<sup>2</sup>, or approximately 1.10%. For the overall summary of each span's condition, please reference Figure 45 and Table 13 in Section 4.3.6.

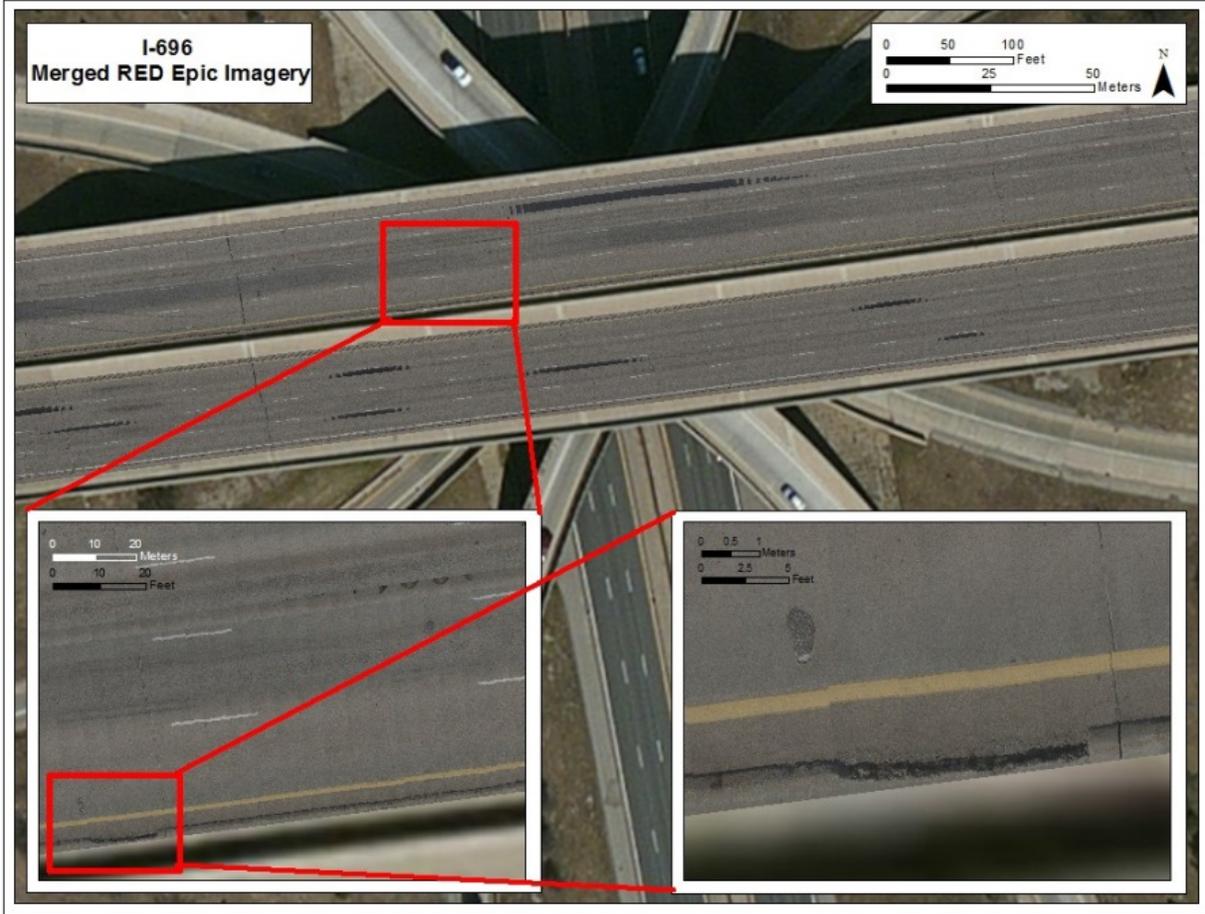


Figure 32: RED Epic imagery merged together to form I-696 eastbound and westbound bridge decks.

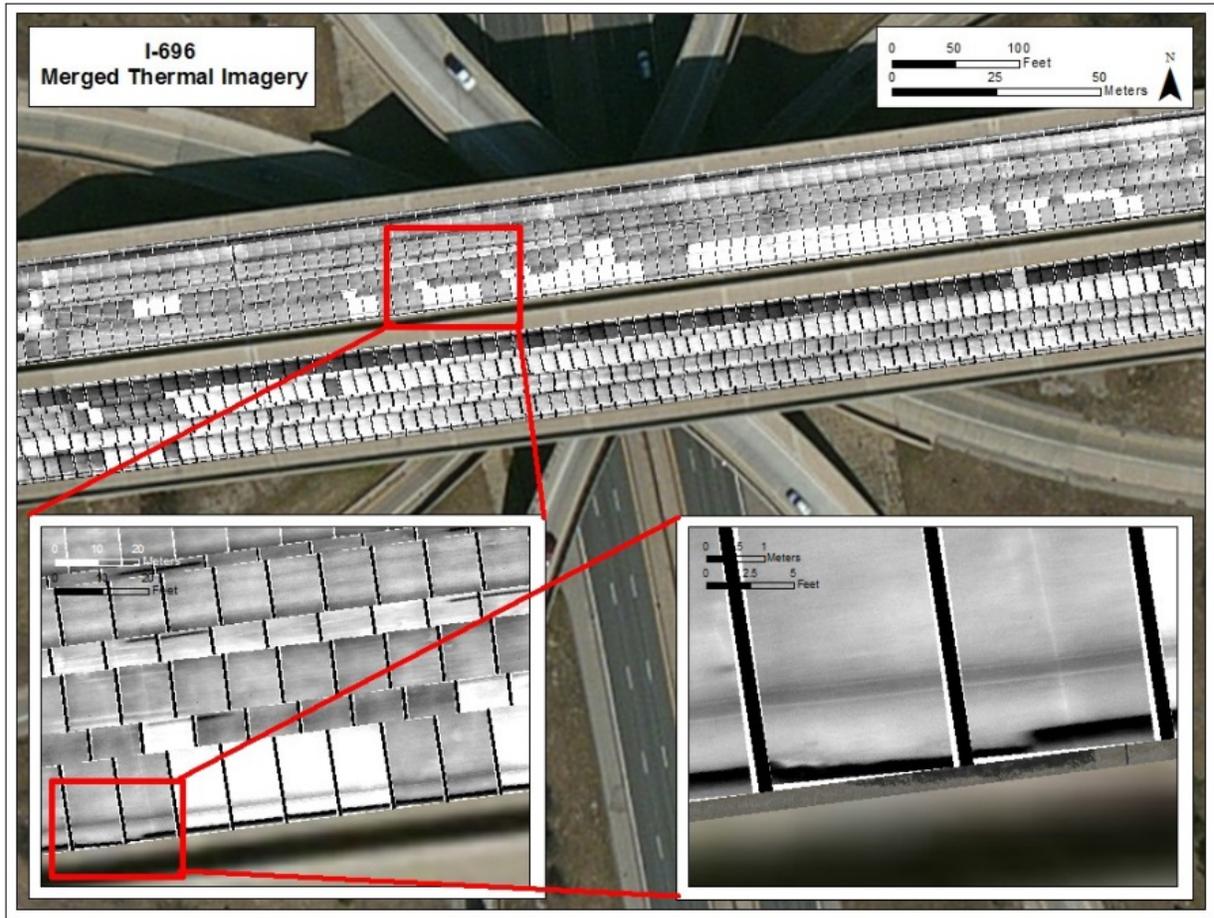


Figure 33: Merged thermal imagery of the I-696 bridge deck.

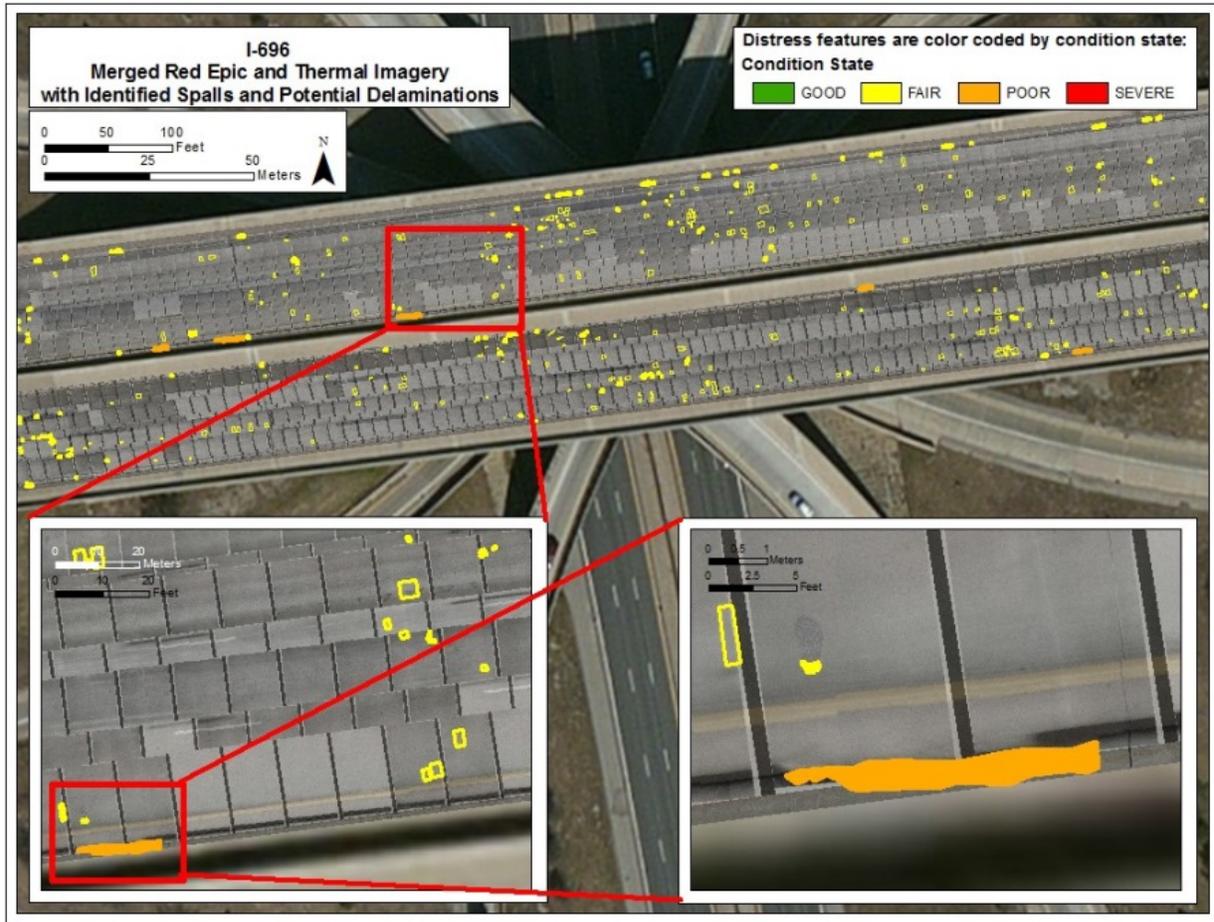
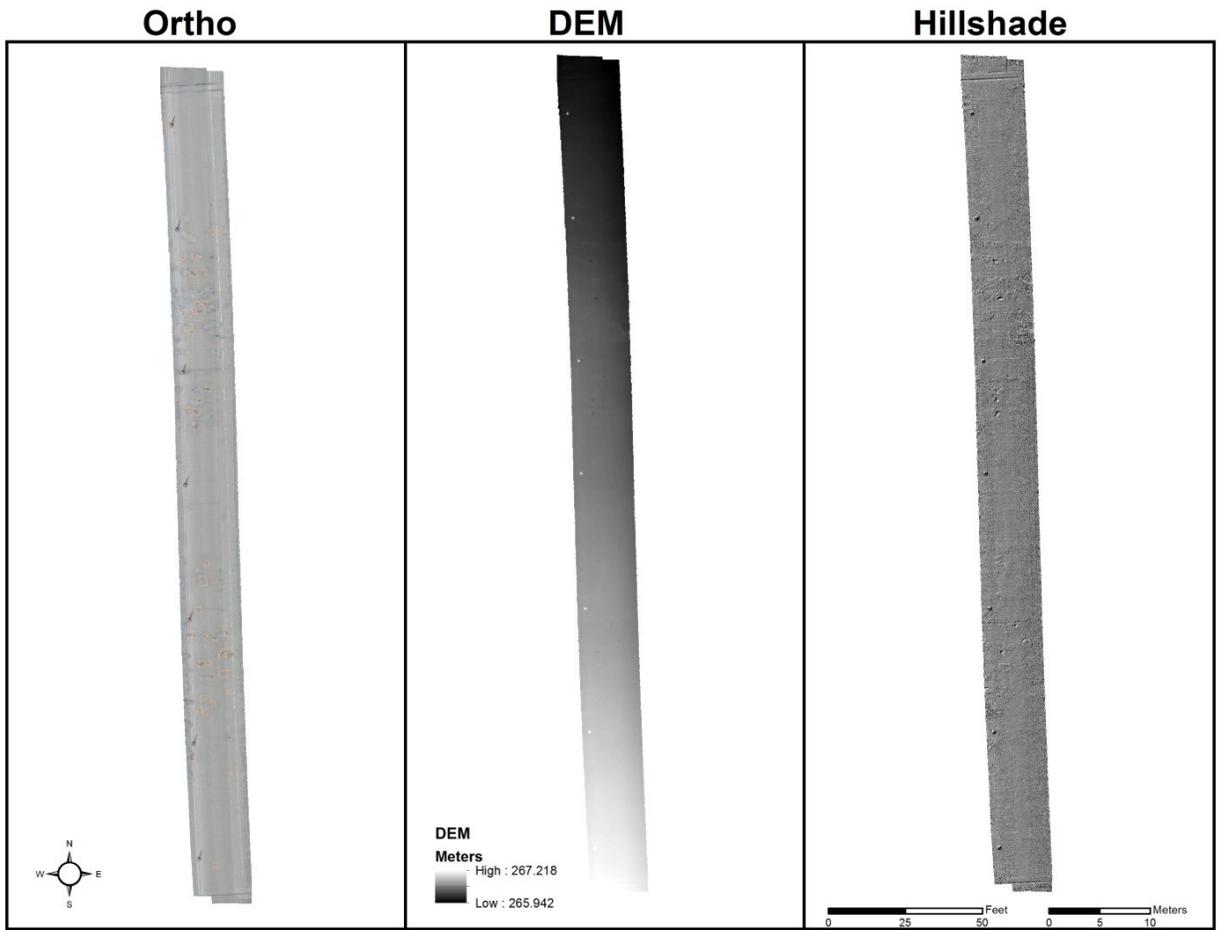


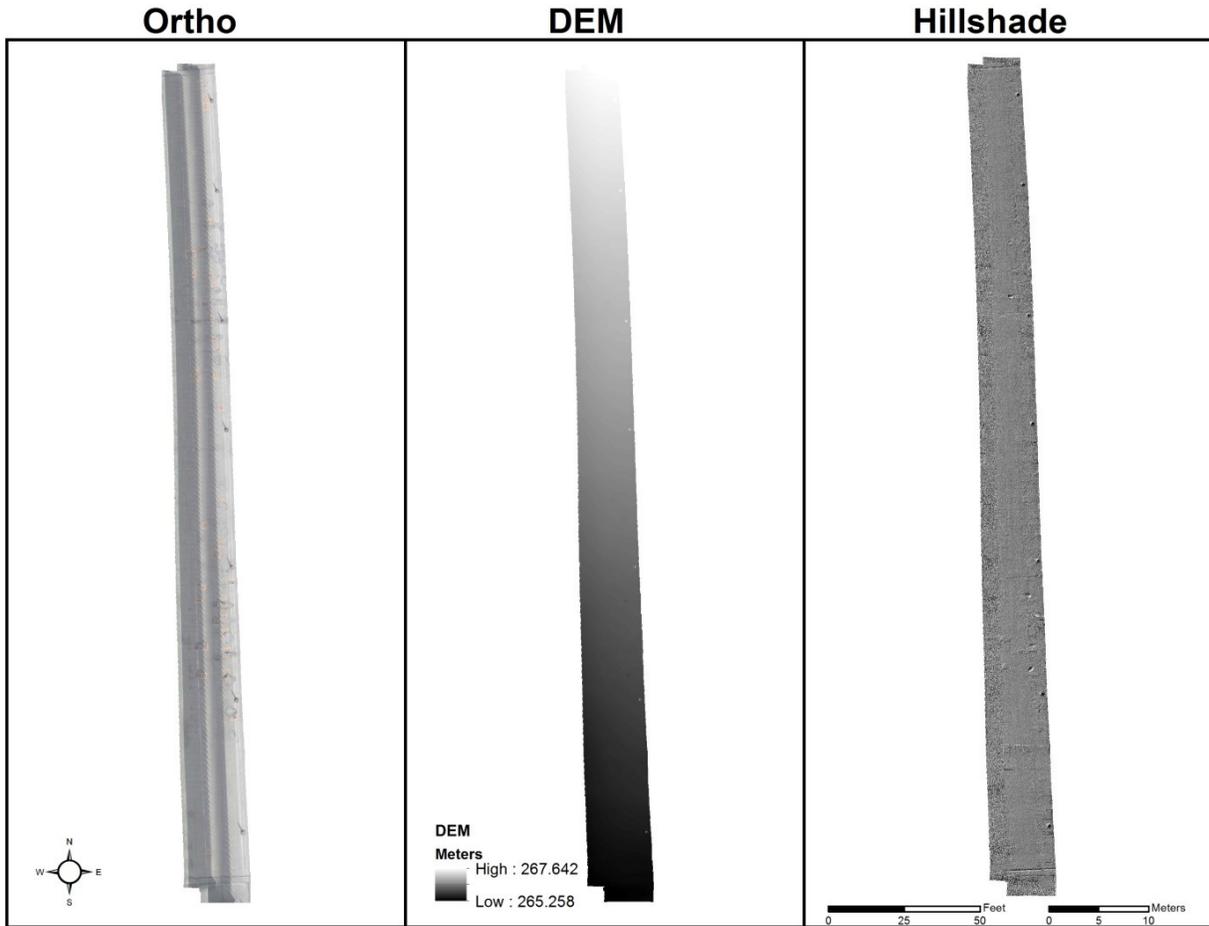
Figure 34: Location of potential delaminations and spalls on the I-696 bridge deck.

#### 4.3.5 3DOBS Accuracy Assessment

With the ability to process the RED Epic imagery through Agisoft PhotoScan, full models were created of each lane of the Lake Nepessing Rd. bridge deck (StrID: 5330) in Lapeer. Unlike the large deck bridges, the vehicle speed was limited to no more than 10 mph due to the space constraints of the required bridge lane closures. Both the north (Figure 35) and southbound (Figure 36) lanes were processed using the geotagged imagery. Each orthoimage has a resolution of 0.8 mm (~ 1/32 in.) and the DEM has a resolution of 3.2 mm (~1/8 in.). The orthoimage was used to calculate the length and width of each spall and patch while the DEM is used to calculate the depth of the spalls. Also shown in Figures 37 and 38 are hillshade views generated to produce a shadowed 3D image of the DEM through ArcGIS.



**Figure 35: Final products (Orthoimage, DEM and Hillshade) of the northbound lane of Lake Nepessing Rd. bridge deck.**

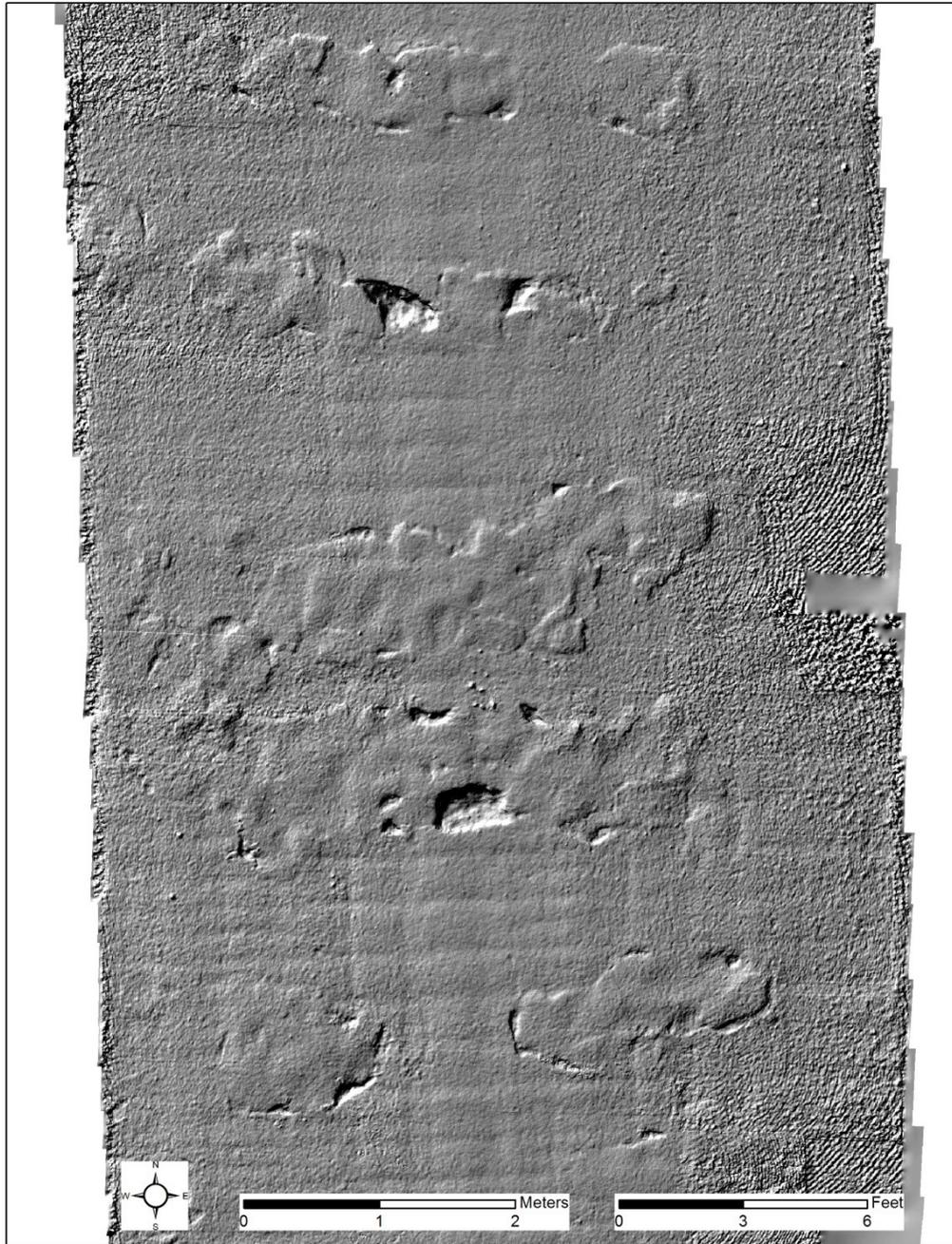


**Figure 36: Final products (Orthoimage, DEM and Hillshade) of the southbound lane of Lake Nepessing Rd. bridge deck.**

Figure 37 shows a zoomed in section of the northbound lane of Lake Nepessing Rd. bridge deck. With a high-resolution orthoimage model, spalls and patches can be located and measured to compare to the in situ measurements. The hillshade of the DEM was reconstructed to show the detail of the patches and spalls (Figure 38). The increased noise on the right and left sides of the hillshade is a result of those areas being mostly flat and with less imagery overlap. There is less overlap on the sides than the center of the model. The edges were reconstructed from a single pass resulting in a point on the ground being represented in five frames. The center of the model was reconstructed from the overlap of both passes of the data collection resulting in a point on the ground being represented in at least 10 frames. The noise in the z-axis, or the amount of random error in the model reconstruction, in the center of the model is 0.16 in. (4.2mm) while on the sides of the model is up to 1.79 in. (4.5cm). Features such as spalls cannot be distinguished if they are less than this error.



**Figure 37: Zoomed in portion of the Orthoimage of northbound Lake Nepessing Rd. bridge deck.**



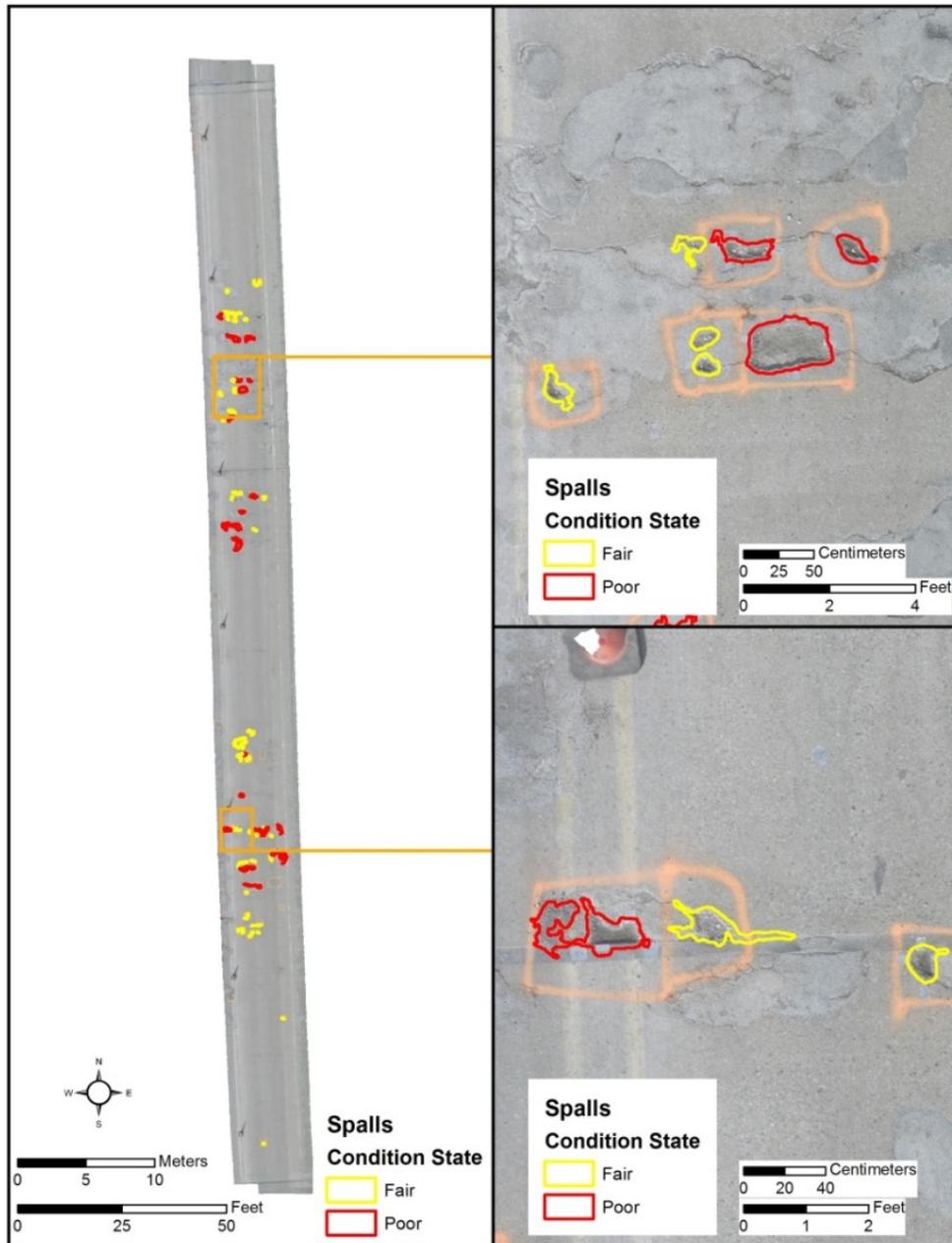
**Figure 38: Zoomed in portion of the Hillshade view of northbound Lake Nepessing Rd. bridge deck.**

Both northbound and southbound lanes were processed through Agisoft PhotoScan using only the geotagged RED Epic imagery. The northbound lane was also processed using ground control markers with the raw un-geotagged RED Epic frames. This was done using eight of the ground control marks placed on the deck prior to the data collection to compare the difference in reconstruction accuracies between using only geotagged imagery and ground control markers. Camera orientation information is not needed for the processing of imagery when using ground control markers as the software determines the model orientation based on the GPS locations of the

markers on the model.

This type of DEM output provides MDOT with the ability to gather other types of useful information about a bridge deck as shown in the original USDOT Bridge Condition Remote Sensing project (Ahlborn et al, 2013). International Roughness Index (IRI) data can be extracted from these high resolution DEMs, which in turn can inform MDOT of the overall ride quality of a vehicle as it travels across a bridge. This could be accomplished by extracting elevation values from the DEM along simulated tire tracks digitized within ArcGIS, and evaluating the difference in elevation along the tire track within ProVAL, a software application used for analyzing pavement profiles.

A spall detection algorithm developed under the USDOT/RITA Bridge Condition Assessment Using Remote Sensors project (Ahlborn et al., 2013) was used on the resulting DEMs to create a spalls shapefile for the Lake Nepessing Rd. bridge deck. Figure 39 is an example of the northbound lane of Lake Nepessing Rd with the detected spalls layer. The spalls layer also contains area and volume of the detected spalls. Lake Nepessing Rd bridge deck is estimated to be 80.4 ft<sup>2</sup> or about 1% of the bridge deck is spalled based on the detected spalls layer. Of the spalls detected 68% were in Condition State 2 and 32% were in Condition State 3.



**Figure 39: Northbound Lake Nepessing Rd bridge deck orthoimage with the detected spalls layer showing the location of spalls.**

There were three models made for Lake Nepessing Rd. The first two models, South Geotag and North Geotag, were reconstructed using the geotagged RED imagery. The third model, North Markers, was reconstructed using non-geotagged RED imagery and ground control markers to set the coordinate system and scale the model. Table 6 is a comparison of field measurements to model measurements for the North Markers model. In the “Diff” column a positive number indicates the model estimated the feature to be larger than in situ measurements and a negative number indicates the model estimated the feature to be smaller than in situ measurements.

**Table 6: Comparison of the measurements taken of distress features on from the field and from the Agisoft 3D model using ground control markers.**

FeatureID	Feature Type	Field Length (in)	Model Length (in)	Diff (in)	Field Width (in)	Model Width (in)	Diff (in)	Field Depth (in)	Model Depth (in)	Depth Diff (in)
JS11	Spall	9.50	9.47	0.03	6.00	5.96	0.04	0.75	0.52	0.23
JS13	Spall	9.25	9.29	0.04	8.25	8.21	0.04	1.00	0.36	0.64
JS21	Spall	6.50	6.48	0.02	2.50	2.46	0.04	0.50	0.20	0.30
JS22	Spall	3.50	2.78	0.72	2.00	2.15	0.15	0.50	0.26	0.24
JS23	Patch	23.50	23.33	0.17	13.00	13.02	0.02	N/A	N/A	N/A
JS24	Spall	14.00	13.76	0.24	6.00	5.95	0.05	1.25	1.03	0.22
JS25	Spall	18.50	18.31	0.19	10.25	10.37	0.12	1.50	1.11	0.39
JS26	Spall	13.25	13.25	0.00	4.00	4.00	0.00	1.00	0.79	0.21
JS27	Spall	16.00	15.85	0.15	5.50	5.35	0.15	2.25	1.73	0.52
JS28	Spall	11.75	11.65	0.10	5.25	5.27	0.02	1.25	0.84	0.41
JS29	Spall	13.50	13.51	0.01	7.50	7.46	0.04	1.75	0.88	0.87
JS30	Spall	16.50	16.44	0.06	10.50	10.59	0.09	1.50	0.21	1.29
JS31	Spall	6.25	6.24	0.01	4.50	4.48	0.02	1.50	0.59	0.91
JS32	Spall	12.25	12.16	0.09	4.50	4.59	0.09	1.00	0.94	0.06
JS33	Spall	17.00	16.90	0.10	6.00	6.01	0.01	1.50	1.59	0.09
JS34	Spall	13.75	13.71	0.04	4.00	3.99	0.01	2.00	1.01	0.99
JS35	Spall	5.00	5.00	0.00	2.50	2.77	0.27	0.50	0.54	0.04
JS36	Spall	8.50	8.30	0.20	2.25	2.27	0.02	1.00	0.64	0.36
JS37	Spall	8.25	8.23	0.02	3.75	3.54	0.21	1.00	0.71	0.29
JS38	Spall	5.50	5.50	0.00	3.25	3.29	0.04	1.25	0.79	0.46
JS39	Spall	20.00	19.83	0.17	12.50	12.44	0.06	1.75	1.66	0.09
JS40	Spall	13.00	12.84	0.16	4.50	4.50	0.00	1.00	0.81	0.19
JS41	Spall	10.75	10.16	0.59	4.50	4.45	0.05	1.25	0.83	0.42
LN12	Spall	9.53	9.59	0.06	4.84	4.85	0.01	1.02	0.56	0.46
LN23	Spall	4.80	4.75	0.05	3.82	3.80	0.02	0.55	0.29	0.26
LN24	Spall	15.00	16.93	1.93	2.72	2.68	0.04	0.98	0.78	0.20
LN25	Spall	10.87	10.75	0.12	2.83	2.79	0.04	0.98	0.61	0.37
LN26	Spall	6.81	6.88	0.07	2.48	2.36	0.12	0.71	0.45	0.26
LN28	Spall	19.13	19.19	0.06	7.87	7.88	0.01	0.75	0.69	0.06
LN29	Spall	4.02	4.10	0.08	2.56	2.59	0.03	0.43	0.19	0.24
LN30	Spall	3.98	3.90	0.08	3.74	3.70	0.04	0.79	0.48	0.31
LN31	Spall	7.01	7.01	0.00	3.74	3.83	0.09	0.75	0.44	0.31
LN32	Spall	7.56	7.54	0.02	2.24	2.19	0.05	0.51	0.43	0.08
LN33	Spall	5.98	5.91	0.07	4.41	4.43	0.02	0.63	0.47	0.16
LN34	Spall	28.58	28.41	0.17	12.01	11.79	0.22	1.77	1.70	0.07
LN35	Spall	20.91	20.50	0.41	11.06	10.90	0.16	1.89	1.80	0.09
LN36	Spall	7.76	7.49	0.27	3.35	3.36	0.01	0.87	0.50	0.37
LN37	Spall	7.72	7.77	0.05	4.53	4.52	0.01	1.06	0.77	0.29
LN38	Spall	9.76	9.80	0.04	3.70	3.65	0.05	0.79	0.51	0.28
LN39	Spall	6.69	6.69	0.00	4.09	4.09	0.00	0.71	0.66	0.05
LN40	Spall	8.35	8.39	0.04	3.54	3.59	0.05	1.06	0.57	0.49
LN41	Spall	26.38	26.06	0.32	12.91	12.86	0.05	1.85	1.75	0.10
LN42	Spall	12.68	12.43	0.25	8.50	8.47	0.03	1.10	1.02	0.08

Table 7 shows summary statistics for each of the three models generated for Lake Nepessing Rd. There were 31 spalls and 7 patches measured on the southbound lanes and 42 spalls and 1 patch measured on the northbound lanes. The values used for these statistics are the absolute values

of the difference values shown in Table 6. This is to show the absolute difference between the field measurements and the model reconstruction and to calculate the coefficient of variation which requires only positive values.

**Table 7: Comparison of spall measurements taken from the field and from the 3D model generated from the RED Epic imagery.**

<b>Markers North</b>			
<b>XY Error</b>		<b>Z Error</b>	
Average (in)	0.11	Average (in)	0.33
Min (in)	0.00	Min (in)	0.04
Max (in)	1.93	Max (in)	1.29
St Dev (in)	0.23	St Dev (in)	0.27
Coeff of Variation	2.04	Coeff of Variation	0.84
<b>GPS North</b>			
<b>XY Error</b>		<b>Z Error</b>	
Average (in)	0.16	Average (in)	0.32
Min (in)	0.00	Min (in)	0.01
Max (in)	1.47	Max (in)	1.12
St Dev (in)	0.22	St Dev (in)	0.25
Coeff of Variation	1.36	Coeff of Variation	0.76
<b>GPS South</b>			
<b>XY Error</b>		<b>Z Error</b>	
Average (in)	0.33	Average (in)	0.29
Min (in)	0.00	Min (in)	0.00
Max (in)	2.34	Max (in)	0.74
St Dev (in)	0.42	St Dev (in)	0.19
Coeff of Variation	1.29	Coeff of Variation	0.67

**4.3.6 Span Condition Ratings**

As part of determining the overall condition of a bridge deck through the use of remote sensing techniques, MDOT requested that in addition to the mapping of potential spalls and delaminations, quantitative values of each bridge condition distress be broken down by bridge span, condition state, and entire bridge deck. The different condition states for each type of bridge distress are based on MDOT’s Michigan Bridge Element Inspection Manual (MDOT, 2015) and are as follows:

- Condition State 1 – Good: the span cannot contain any spall or delamination distress feature.
- Condition State 2 – Fair: the span would contain the presence of a delamination or a spall that is one inch or less in depth or less than six inches in diameter.
- Condition State 3 – Poor: the bridge span must contain a spall that is greater than one inch deep or greater than six inches in diameter and the span cannot warrant structural review.
- Condition State 4 – Severe: the span condition must warrant structural review to determine strength or serviceability capacity.

Using MDOT’s Bridge Safety Inspection Reports retrieved from the MiBridge website, the number of approach and main spans were determined. Based on these numbers and imagery of each bridge, the location of each bridge span was determined. The 8 Mile Bridge did not contain any

spalls, and therefore the condition state of each span was based on the presence or absence of a delamination. All 15 spans (3 main spans and 12 approach spans) of the bridge contained the presence of at least one delamination. Through GIS analysis, the total bridge deck area was calculated to be 167,660 ft<sup>2</sup>. The total delaminated area as reported through digitization and georeferencing of thermal infrared digital imagery was calculated to be 3,092 ft<sup>2</sup>, or 1.84% of the total bridge deck. This also indicates that 3,092 ft<sup>2</sup> (1.84%) of the total bridge deck falls under Condition State 2 – Fair. As there were no reported spalls on the bridge deck, the remaining 164,568 ft<sup>2</sup> (98.16%) of bridge deck is classified as Condition State 1 – Good (Table 8 and Figure 40). The spans with the greatest and least area of delaminations are span 8 and span 12, respectively. For the location of individual distress features, please reference Figure 25 in Section 4.3.1.

**Table 8: Area of Condition States per span for the M-102 (8 Mile) bridge deck.**

Location: M- 102 (8 Mile)	Area of Span (ft <sup>2</sup> )	Area Cond. State 1 (ft <sup>2</sup> ) <b>GOOD</b>	Area Cond. State 2 (ft <sup>2</sup> ) <b>FAIR</b>	Area Cond. State 3 (ft <sup>2</sup> ) <b>POOR</b>	Area Cond. State 4 (ft <sup>2</sup> ) <b>SEVERE</b>
Span 1	8,221	8,093	128	0	0
Span 2	8,217	7,997	220	0	0
Span 3	8,646	8,481	165	0	0
Span 4	11,552	11,434	118	0	0
Span 5	11,521	11,340	181	0	0
Span 6	11,502	11,280	222	0	0
Span 7	19,525	19,114	411	0	0
Span 8	11,540	11,117	423	0	0
Span 9	8,593	8,441	152	0	0
Span 10	11,855	11,663	192	0	0
Span 11	11,798	11,511	287	0	0
Span 12	11,887	11,824	63	0	0
Span 13	12,861	12,598	263	0	0
Span 14	9,996	9,860	136	0	0
Span 15	9,945	9,814	131	0	0
<b>Total</b>	<b>167,660</b>	<b>164,568</b>	<b>3,092</b>	<b>0.00</b>	<b>0.00</b>
		<b>(98.16%)</b>	<b>(1.84%)</b>	<b>(0%)</b>	<b>(0%)</b>

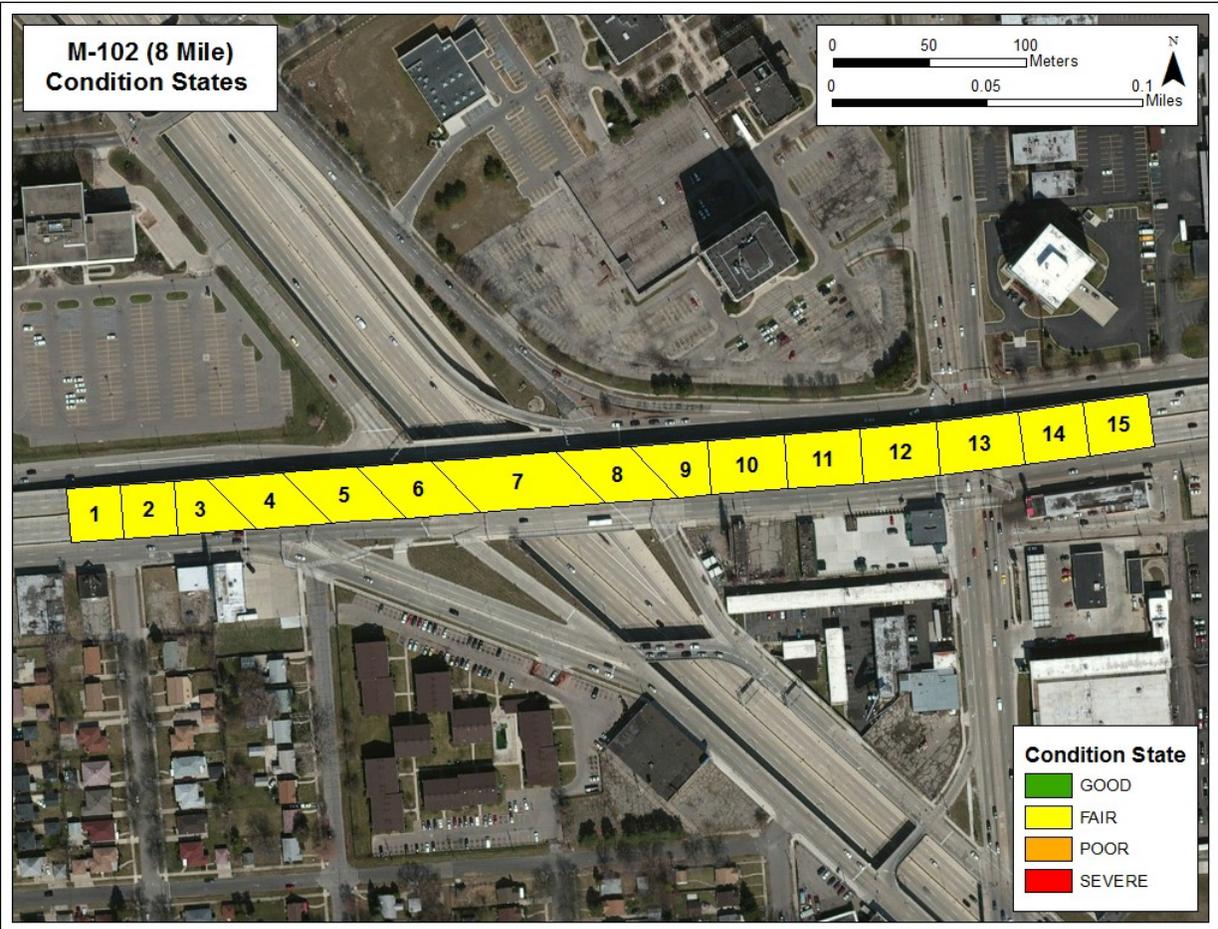
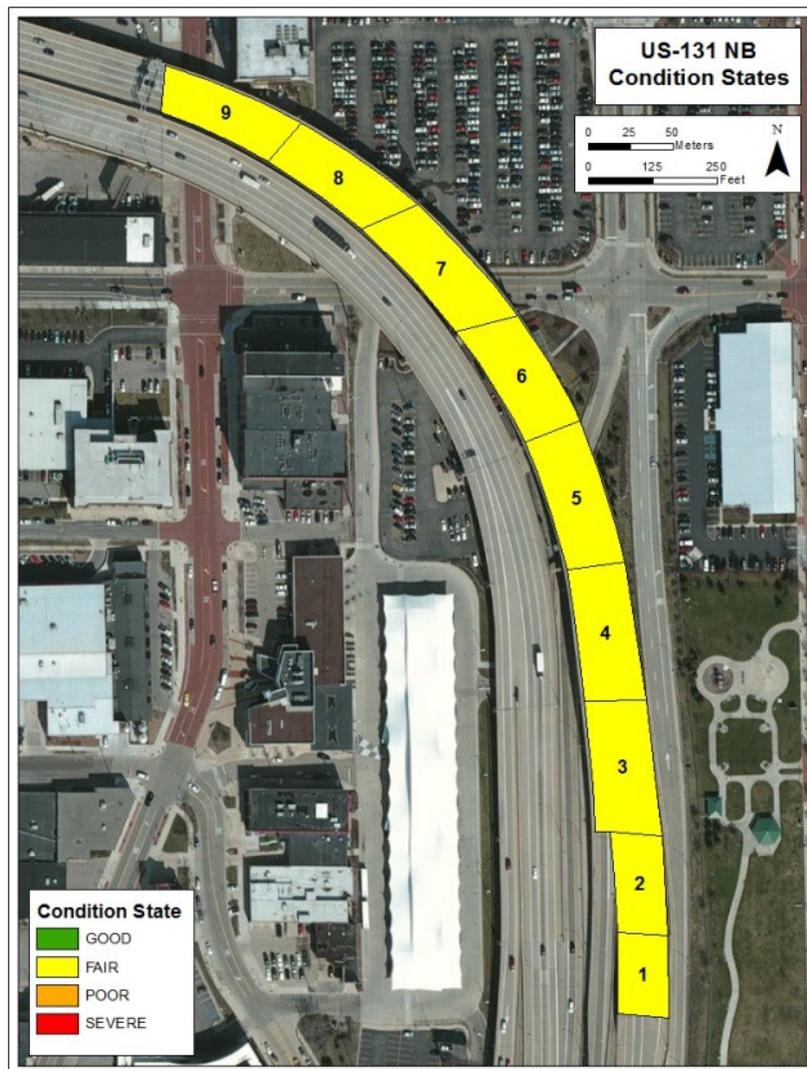


Figure 40: Summary of Condition state per span at M-102 (8 Mile).

The US-131 northbound bridge contained 24 spalls and 37 delaminations within the defined 9 spans of the bridge deck (9 main spans and 0 approach spans). Through GIS analysis, the total bridge deck area was calculated to be 115,926 ft<sup>2</sup>. The total area of Condition State 2 – Fair distress features was determined to be 168 ft<sup>2</sup>, or approximately 0.15% of the total bridge deck (168 ft<sup>2</sup> classified as delaminations and 0.35 ft<sup>2</sup> classified as spalls that are 6 inches or less in diameter). Likewise, the total area of Condition State 3 – Poor distress features was determined to be 0.23 ft<sup>2</sup>, or approximately 0% of the total bridge deck (consisting of only spalls that are greater than 6 inches in diameter because delaminations are always classified as Condition State 2). The remainder of the bridge deck not containing spalls or delaminations was classified as Condition State 1 – Good and equates to 115,757 ft<sup>2</sup>, or approximately 99.85% (Table 9 and Figure 41). For the location of individual distress features, please reference Figure 28 in Section 4.3.2.

**Table 9: Area of condition state per span for the US-131 northbound bridge deck.**

Location: US131	Area of Span (ft <sup>2</sup> )	Area Cond. State 1 (ft <sup>2</sup> ) GOOD	Area Cond. State 2 (ft <sup>2</sup> ) FAIR	Area Cond. State 3 (ft <sup>2</sup> ) POOR	Area Cond. State 4 (ft <sup>2</sup> ) SEVERE
Span 1	7,642	7,629	13	0	0
Span 2	9,318	9,299	19	0	0
Span 3	15,456	15,451	5	0	0
Span 4	14,872	14,865	7	0	0
Span 5	15,120	15,105	15	0	0
Span 6	13,711	13,675	36	0	0
Span 7	15,524	15,489	35	0	0
Span 8	12,647	12,643	4	0	0
Span 9	11,635	11,601	34	0	0
<b>Total</b>	<b>115,926</b>	<b>115,757</b>	<b>168</b>	<b>0</b>	<b>0</b>
		<b>(99.85%)</b>	<b>(0.15%)</b>	<b>(0%)</b>	<b>(0%)</b>

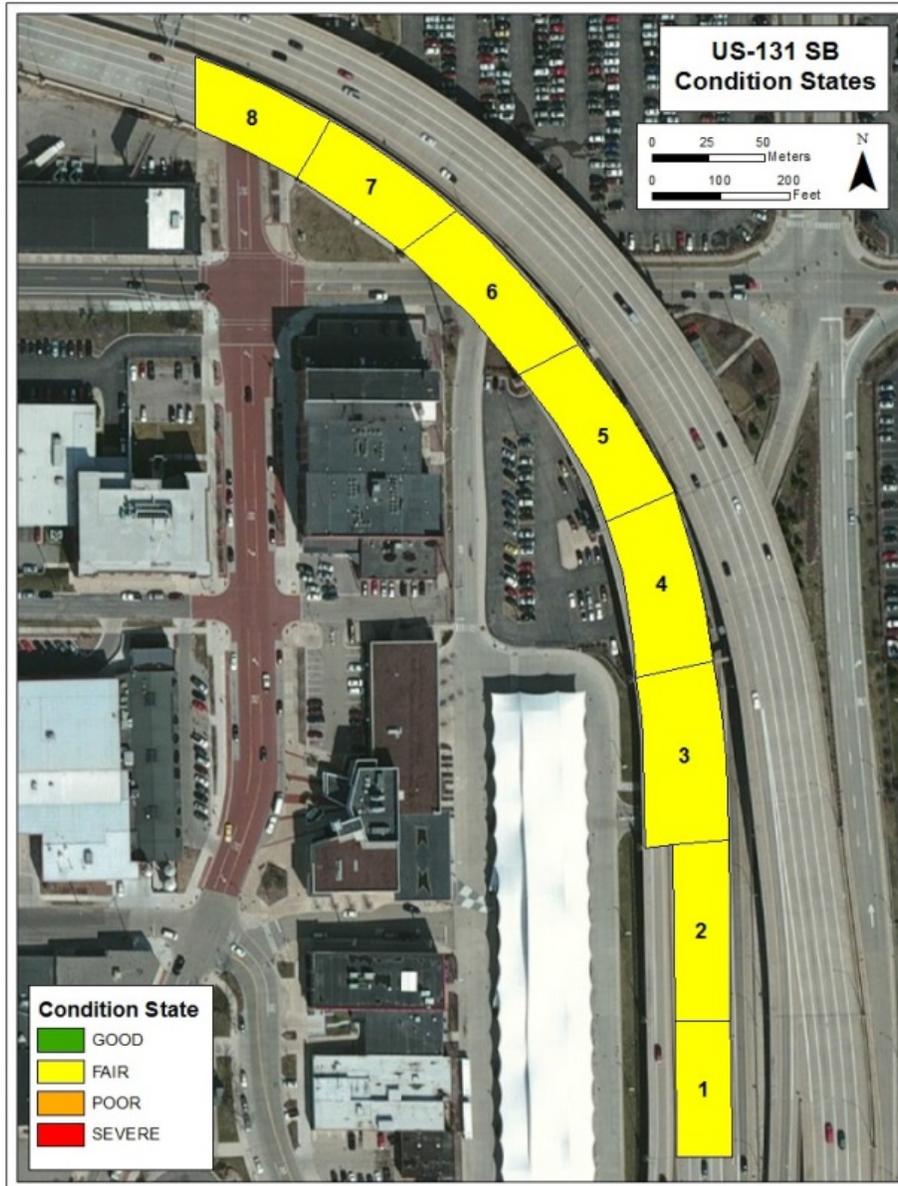


**Figure 41: Summary of condition state per span at US-131 northbound.**

The US-131 southbound bridge contained 1 spall and 96 delaminations within the defined 8 spans of the bridge deck (8 main spans and 0 approach spans). Through GIS analysis, the total bridge deck area was calculated to be 98,090 ft<sup>2</sup>. The total area of Condition State 2 – Fair distress features was determined to be 364 ft<sup>2</sup>, or approximately 0.37% of the total bridge deck (364 ft<sup>2</sup> classified as delaminations and 0.07 ft<sup>2</sup> as spalling). The remainder of the bridge deck not containing spalls or delaminations was classified as Condition State 1 – Good and equates to 97,726 ft<sup>2</sup>, or approximately 99.63% (Table 10 and Figure 42). For the location of individual distress features, please reference Figure 28 in Section 4.3.2.

**Table 10: Area of condition state per span for the US-131 southbound bridge deck.**

Location: US131	Area of Span (ft <sup>2</sup> )	Area Cond. State 1 (ft <sup>2</sup> ) GOOD	Area Cond. State 2 (ft <sup>2</sup> ) FAIR	Area Cond. State 3 (ft <sup>2</sup> ) POOR	Area Cond. State 4 (ft <sup>2</sup> ) SEVERE
Span 1	8,609	8,599	10	0	0
Span 2	11,378	11,317	61	0	0
Span 3	16,329	16,294	35	0	0
Span 4	14,180	14,129	51	0	0
Span 5	13,327	13,253	74	0	0
Span 6	13,355	13,314	41	0	0
Span 7	10,027	9,999	28	0	0
Span 8	10,887	10,823	64	0	0
<b>Total</b>	<b>98,090</b>	<b>97,726</b>	<b>364</b>	<b>0.00</b>	<b>0.00</b>
		<b>(99.63%)</b>	<b>(0.37%)</b>	<b>(0%)</b>	<b>(0%)</b>



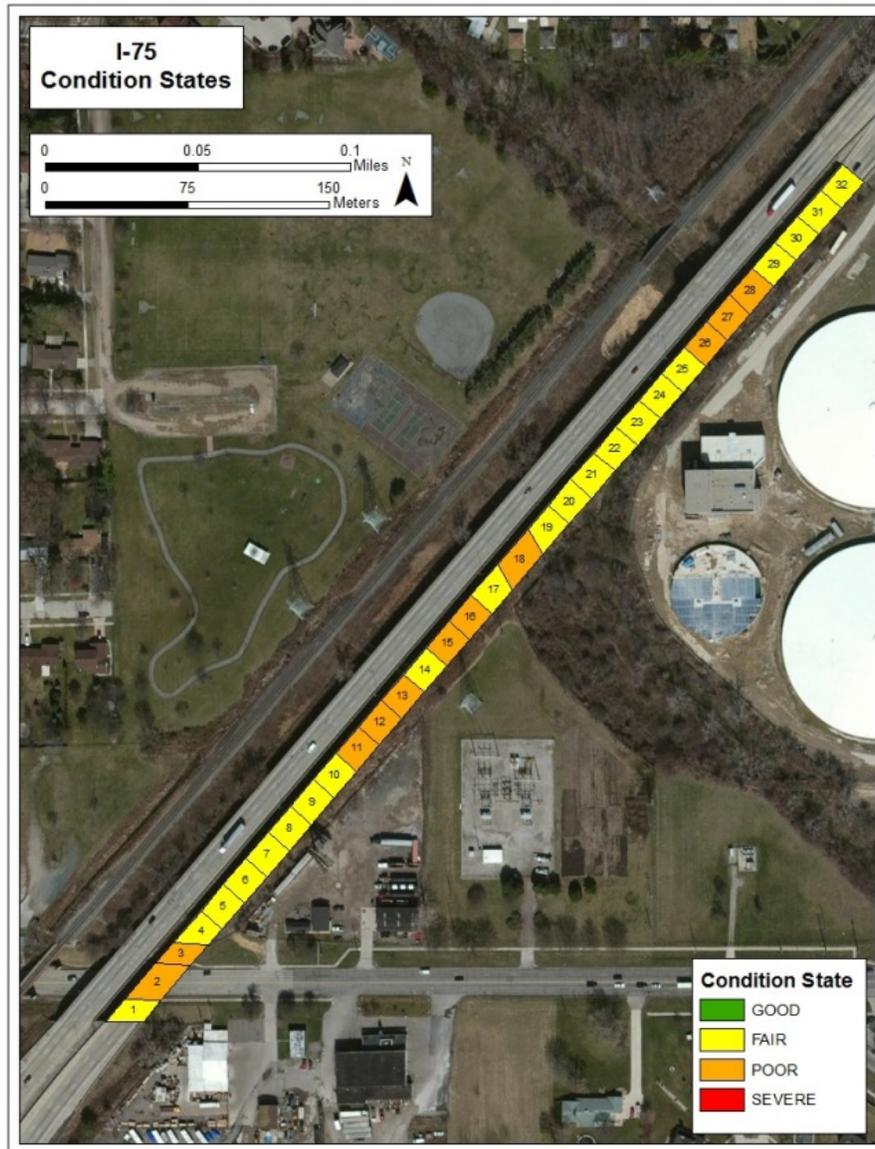
**Figure 42: Summary of condition state per span at US-131 southbound.**

The I-75 northbound bridge contained 227 spalls and 529 delaminations within the defined 32 spans of the bridge deck (27 main spans and 5 approach spans). Through GIS analysis, the total bridge deck area was calculated to be 95,014 ft<sup>2</sup>. The total area of Condition State 2 – Fair distress features was determined to be 2,211 ft<sup>2</sup>, or approximately 2.33% of the total bridge deck (2,204 ft<sup>2</sup> classified as delaminations and 7 ft<sup>2</sup> classified as spalls that are 6 inches or less in diameter). Likewise, the total area of Condition State 3 – Poor distress features was determined to be 28 ft<sup>2</sup>, or approximately 0.03% of the total bridge deck (consisting of only spalls that are greater than 6 inches in diameter because delaminations are always classified as Condition State 2). The remainder of the bridge deck not containing spalls or delaminations was classified as Condition

State 1 – Good and equates to 92,776 ft<sup>2</sup>, or approximately 97.64% (Table 11 and Figure 43). For the location of individual distress features, please reference Figure 31 in Section 4.3.3.

**Table 11: Area of condition states per span for the I-75 northbound bridge deck.**

Location: I75 NB	Area of Span (ft <sup>2</sup> )	Area Cond. State 1 (ft <sup>2</sup> ) GOOD	Area Cond. State 2 (ft <sup>2</sup> ) FAIR	Area Cond. State 3 (ft <sup>2</sup> ) POOR	Area Cond. State 4 (ft <sup>2</sup> ) SEVERE
Span 1	2,477	2,437	40	0	0
Span 2	3,949	3,872	76	1	0
Span 3	2,287	2,023	264	1	0
Span 4	2,657	2,598	58	0	0
Span 5	2,948	2,857	92	0	0
Span 6	2,905	2,857	48	0	0
Span 7	2,975	2,899	75	0	0
Span 8	2,926	2,843	84	0	0
Span 9	2,963	2,900	63	0	0
Span 10	2,945	2,855	89	0	0
Span 11	2,906	2,777	127	2	0
Span 12	2,913	2,824	89	1	0
Span 13	2,884	2,785	97	2	0
Span 14	2,929	2,869	60	0	0
Span 15	2,959	2,878	77	4	0
Span 16	2,925	2,835	87	3	0
Span 17	3,070	2,979	92	0	0
Span 18	3,945	3,799	144	2	0
Span 19	2,986	2,953	33	0	0
Span 20	2,925	2,887	38	0	0
Span 21	2,981	2,958	23	0	0
Span 22	2,891	2,869	22	0	0
Span 23	3,006	2,972	34	0	0
Span 24	2,977	2,933	43	0	0
Span 25	2,920	2,838	82	0	0
Span 26	2,955	2,917	37	1	0
Span 27	3,038	2,987	48	4	0
Span 28	2,989	2,923	60	5	0
Span 29	2,936	2,895	41	0	0
Span 30	2,992	2,963	29	0	0
Span 31	2,941	2,910	31	0	0
Span 32	2,914	2,885	29	0	0
<b>Total</b>	<b>95,014</b>	<b>92,776</b>	<b>2,211</b>	<b>28</b>	<b>0</b>
		<b>(97.64%)</b>	<b>(2.33%)</b>	<b>(0.03%)</b>	<b>(0%)</b>

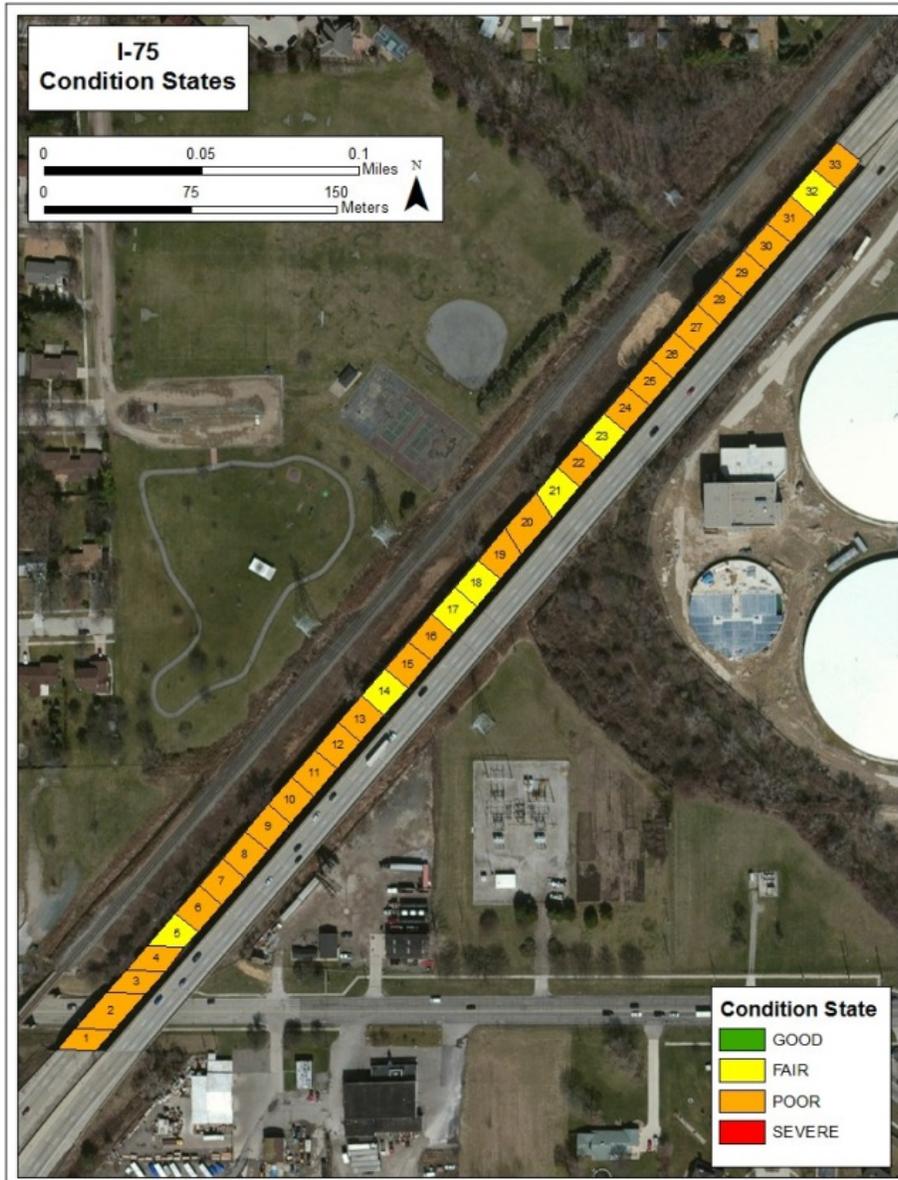


**Figure 43: Summary of condition state per deck span at I-75 northbound.**

The I-75 southbound bridge contained 905 spalls and 1,410 delaminations within the defined 33 spans of the bridge deck (6 main spans and 27 approach spans). Through GIS analysis, the total bridge deck area was calculated to be 97,401 ft<sup>2</sup>. The total area of Condition State 2 – Fair distress features was determined to be 14,139 ft<sup>2</sup>, or approximately 14.52% of the total bridge deck (14,119 ft<sup>2</sup> classified as delaminations and 20 ft<sup>2</sup> classified as spalls that are 6 inches or less in diameter). Likewise, the total area of Condition State 3 – Poor distress features was determined to be 44 ft<sup>2</sup>, or approximately 0.04% of the total bridge deck (consisting of only spalls that are greater than 6 inches in diameter because delaminations are always classified as Condition State 2). The remainder of the bridge deck that did not contain any spalls or delaminations was classified as Condition State 1 – Good and equated to 83,219 ft<sup>2</sup>, or approximately 85.44% (Table 12 and Figure 44). For the location of individual distress features, please reference Figure 31 in Section 4.3.3.

**Table 12: Area of condition state per span for the I-75 southbound bridge deck.**

Location: I-75 SB	Area of Span (ft <sup>2</sup> )	Area Cond. State 1 (ft <sup>2</sup> ) GOOD	Area Cond. State 2 (ft <sup>2</sup> ) FAIR	Area Cond. State 3 (ft <sup>2</sup> ) POOR	Area Cond. State 4 (ft <sup>2</sup> ) SEVERE
Span 1	2,321	2,268	52	1	0
Span 2	3,965	3,114	849	3	0
Span 3	2,430	1,928	500	3	0
Span 4	2,610	1,661	948	1	0
Span 5	2,601	2,127	473	0	0
Span 6	2,918	2,147	771	1	0
Span 7	2,940	2,181	759	1	0
Span 8	2,917	2,265	651	1	0
Span 9	2,884	2,378	504	1	0
Span 10	2,918	2,235	682	1	0
Span 11	2,871	2,353	517	1	0
Span 12	2,969	2,711	257	1	0
Span 13	2,935	2,797	137	1	0
Span 14	2,936	2,580	357	0	0
Span 15	2,938	2,694	243	1	0
Span 16	2,917	2,667	249	1	0
Span 17	2,946	2,807	139	0	0
Span 18	2,972	2,857	114	0	0
Span 19	3,021	2,775	238	8	0
Span 20	3,810	3,262	545	3	0
Span 21	2,975	2,563	412	0	0
Span 22	2,902	2,585	316	1	0
Span 23	2,900	2,418	482	0	0
Span 24	2,927	2,607	319	1	0
Span 25	2,925	2,730	194	1	0
Span 26	2,910	2,558	350	2	0
Span 27	2,949	2,298	648	2	0
Span 28	2,984	2,228	755	1	0
Span 29	3,020	2,399	620	2	0
Span 30	3,041	2,700	340	1	0
Span 31	3,035	2,745	289	1	0
Span 32	3,018	2,876	142	0	0
Span 33	2,993	2,706	287	1	0
<b>Total</b>	<b>97,401</b>	<b>83,219</b>	<b>14,139</b>	<b>44</b>	<b>0</b>
		<b>(85.44%)</b>	<b>(14.52%)</b>	<b>(0.04%)</b>	<b>(0%)</b>

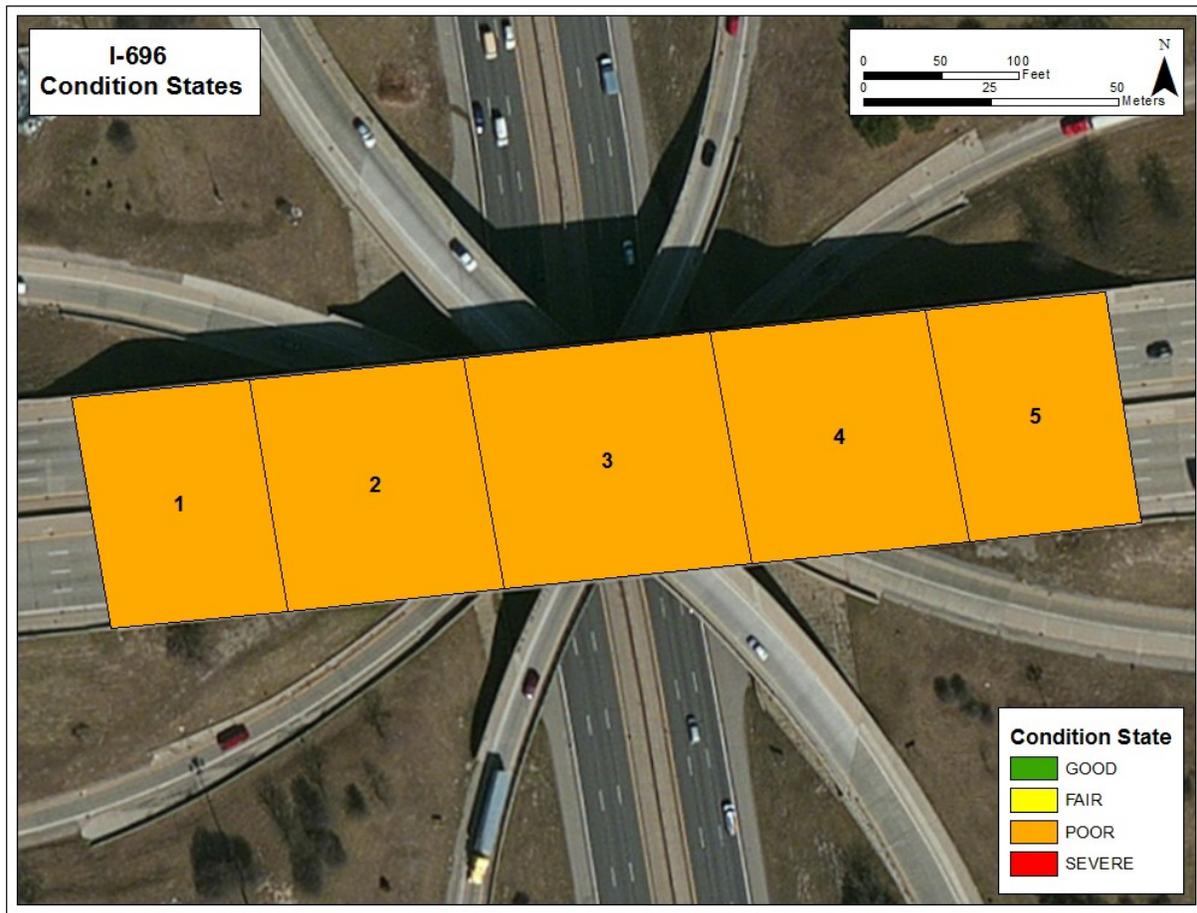


**Figure 44: Summary of condition state per deck span at I-75 southbound.**

The I-696 bridge contained 118 spalls and 261 delaminations within the defined 5 spans of the bridge deck (3 main spans and 2 approach spans). The total area of Condition State 2 – Fair distress features was determined to be 808 ft<sup>2</sup>, or approximately 0.79% of the total bridge deck (806 ft<sup>2</sup> classified as delaminations and 2 ft<sup>2</sup> classified as spalls that are 6 inches or less in diameter). Likewise, the total area of Condition State 3 – Poor distress features was determined to be 91 ft<sup>2</sup>, or approximately 0.08% of the total bridge deck (consisting of only spalls since delaminations are always classified as Condition State 2). The remainder of the bridge deck that did not contain spalls or delaminations was classified as Condition State 1 – Good and equated to 101,309 ft<sup>2</sup>, or approximately 99.12% (Table 13 and Figure 45). For the location of individual distress features, please reference Figure 34 in Section 4.3.4.

**Table 13: Area of condition state per deck span for the I-696 bridge.**

Location: I696 / I75	Area of Span (ft <sup>2</sup> )	Area Cond. State 1 (ft <sup>2</sup> ) GOOD	Area Cond. State 2 (ft <sup>2</sup> ) FAIR	Area Cond. State 3 (ft <sup>2</sup> ) POOR	Area Cond. State 4 (ft <sup>2</sup> ) SEVERE
Span 1	17,541	17,428	84	29	0
Span 2	21,329	21,214	99	16	0
Span 3	24,463	24,154	285	24	0
Span 4	21,511	21,277	225	9	0
Span 5	17,363	17,237	114	13	0
<b>Total</b>	<b>102,207</b>	<b>101,309</b>	<b>808</b>	<b>91</b>	<b>0</b>
		<b>(99.12%)</b>	<b>(0.79%)</b>	<b>(0.09%)</b>	<b>(0%)</b>



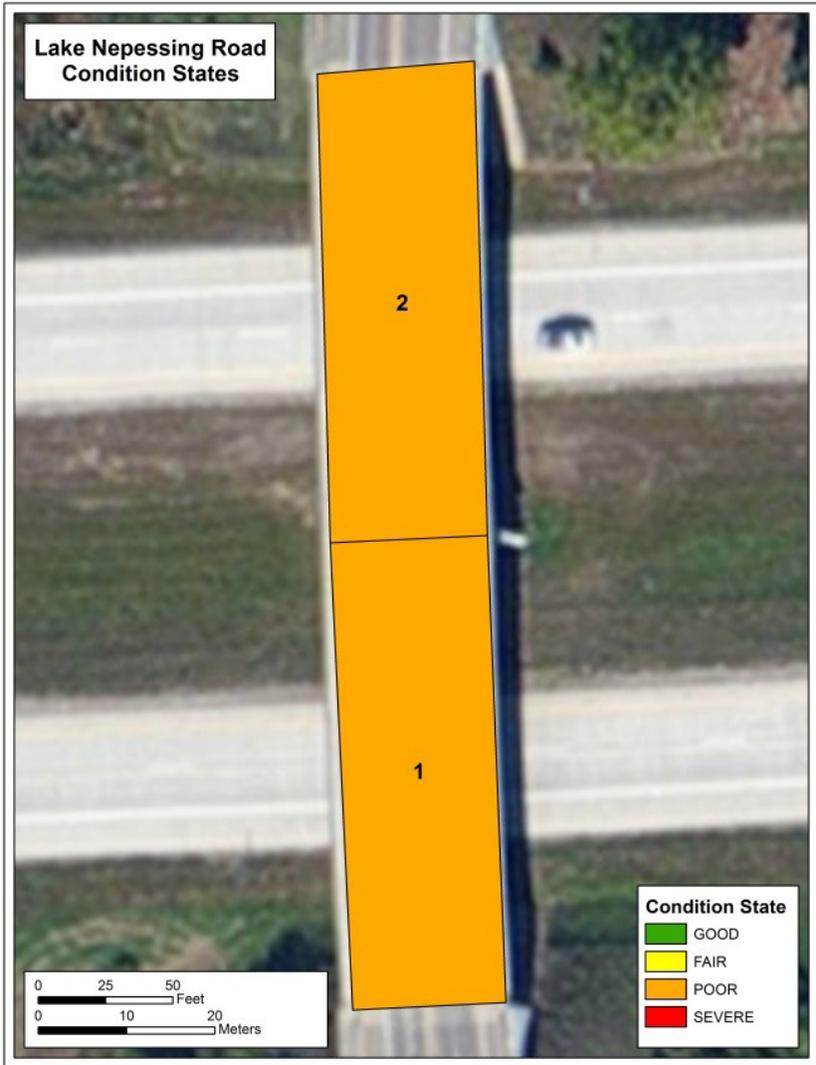
**Figure 45: Summary of condition state per deck span at I-696.**

In the 3DOBS accuracy assessment, the Lake Nepessing Rd. bridge deck contained 75 spalls manually measured within the defined two spans of the bridge deck (2 main spans and 0 approach spans). The detection of delaminations through the use of thermal imagery was not conducted on this bridge and therefore the condition state values do not contain any delamination measurements. Based on MDOT bridge inspection reports, the total bridge deck area is 11,721 ft<sup>2</sup>. The total area of Condition State 2 – Fair distress features was determined to be 1 ft<sup>2</sup>, or approximately 0.01% of the total bridge deck. Likewise, the total area of Condition State 3 – Poor distress features was

determined to be 36ft<sup>2</sup>, or approximately 0.31% of the total bridge deck (consisting of only spalls that are greater than 6 inches in diameter). The remainder of the bridge deck that did not contain any spalls was classified as Condition State 1 – Good and equated to 11,684 ft<sup>2</sup>, or approximately 99.68% (Table 14 and Figure 46).

**Table 14: Condition states of each deck span for the Lake Nepessing Rd. bridge.**

Location: Lake Nepessing	Area of Span (ft <sup>2</sup> )	Area Cond. State 1 (ft <sup>2</sup> ) GOOD	Area Cond. State 2 (ft <sup>2</sup> ) FAIR	Area Cond. State (ft <sup>2</sup> ) POOR	Area Cond. State 4 (ft <sup>2</sup> ) SEVERE
Span 1	5924	5905	1	18	0
Span 2	5797	5779	0	18	0
<b>Total</b>	<b>11,721</b>	<b>11,684</b>	<b>1</b>	<b>36</b>	<b>0</b>
		(99.68%)	(0.01%)	(0.31%)	(0%)



**Figure 46: Summary of condition state per deck span at Lake Nepessing Rd.**