

IMPACT OF WEATHER STRESSORS TO IDENTIFY VULNERABLE BRIDGE ELEMENTS  
IN GEORGIA TOWARDS DATA DRIVEN ASSEST MANAGEMENT

by SPENCER KOPF

(Under the Direction of Mi Geum Chorzepa)

ABSTRACT

This thesis aims to identify vulnerable bridge elements in Georgia susceptible to weather stressors snow, precipitation, hot and cold temperatures, and proximity to the coast. To achieve this, the National Bridge Inventory (NBI), National Bridge Element (NBIE), and National Oceanic and Atmospheric Administration (NOAA) data were analyzed alongside Georgia Department of Transportation (GDOT) bridge inspection reports from 2015 to 2022. The analysis resulted in a flagging mechanism that identified vulnerable elements, while inspection reports provided qualitative details about each bridge. The study aims to help counties understand how bridge elements perform over time and anticipate maintenance, rehabilitation, and replacement decisions. The findings show precipitation is the most significant stressor correlating with vulnerable elements' deterioration when left unaddressed. The deliverable is a resource guide for counties identifying vulnerable locations and bridge elements highlighting needs for preemptive maintenance related to weather stressors. The guide illustrates incurred cost of inactivity in maintenance.

INDEX WORDS: Bridge, Maintenance, Management, National Bridge Inventory (NBI),  
Weather

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by

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## TABLE OF CONTENTS

<b>BACKGROUND.....</b>	<b>1</b>
<b>PROBLEM STATEMENT .....</b>	<b>3</b>
<b>RESEARCH OBJECTIVES.....</b>	<b>3</b>
<b>CHAPTER 1. LITERATURE REVIEW .....</b>	<b>5</b>
<b>CURRENT BRIDGE CONDITIONS IN USA .....</b>	<b>5</b>
<b>IMPACT OF WEATHER ON BRIDGE INFRASTRUCTURE.....</b>	<b>20</b>
<b>CHAPTER 2. RESEARCH METHODOLOGY AND RESULTS .....</b>	<b>26</b>
<b>ANALYSIS METHODOLOGY .....</b>	<b>26</b>
<b>METHODOLOGY FOR DEVELOPING A WEATHER-RELATED RISK GUIDE FOR     COUNTIES .....</b>	<b>65</b>
<b>RESULTS FROM ANALYZING BRIDGE INSPECTION REPORTS.....</b>	<b>66</b>
<b>CHAPTER 3. A RESOURCE GUIDE FOR COUNTIES.....</b>	<b>338</b>
<b>SCOPE.....</b>	<b>338</b>
<b>THREE MAIN ELEMENTS OF THE RESOURCE GUIDE.....</b>	<b>338</b>
<b>CHAPTER 4. CONCLUSIONS AND RECOMMENDATIONS .....</b>	<b>348</b>
<b>CONCLUSIONS.....</b>	<b>348</b>
<b>RECOMMENDATIONS .....</b>	<b>355</b>
<b>ACKNOWLEDGMENTS .....</b>	<b>356</b>
<b>REFERENCES.....</b>	<b>357</b>
<b>APPEDIX A. A WEATHER STRESSOR RESOURCE GUIDE FOR COUNTY-OWNED BRIDGES .....</b>	<b>362</b>

## LIST OF FIGURES

<b>Figure 1 - National Highway System in Georgia *NTS (GDOT, 2019).</b> .....	<b>14</b>
<b>Figure 2 - Funds Available for SRS Maintenance and Reconstruction (GDOT, 2019)</b> .....	<b>17</b>
<b>Figure 3 – Current Georgia State-Owned Bridge Condition (Good, Fair, Poor)</b> .....	<b>19</b>
<b>Figure 4 – Current County-Owned Bridges Condition (Good, Fair, Poor)</b> .....	<b>19</b>
<b>Figure 5 – Scour and Undermining (FHWA, 2012)</b> .....	<b>22</b>
<b>Figure 6 – NOAA Weather Download Interface Step 1</b> .....	<b>29</b>
<b>Figure 7 – NOAA Weather Download Interface Step 2, Appling County</b> .....	<b>30</b>
<b>Figure 8 - Spatial Distribution of NOAA Weather Stations in Georgia with 2021 data</b> .....	<b>31</b>
<b>Figure 9 - Station USC00093621 (Blue) Paired to Nearest Bridge Assets (Red)</b> .....	<b>33</b>
<b>Figure 10 – Days Under 32° F vs NBI Substructure Condition</b> .....	<b>34</b>
<b>Figure 11 – State Owned DT32 Bridge Heat Map (color = days)</b> .....	<b>36</b>
<b>Figure 12 – County Owned DP10 Bridge Heat Map (color = days)</b> .....	<b>37</b>
<b>Figure 13 – State Owned DX90 Bridge Heat Map (color = days)</b> .....	<b>38</b>
<b>Figure 14 – County Owned SNOW Bridge Heat Map (color = inches per year)</b> .....	<b>39</b>
<b>Figure 15: Average DT32 per bridge by County, 2021</b> .....	<b>42</b>
<b>Figure 16 - Counties of Interest DT32</b> .....	<b>43</b>
<b>Figure 17 - Counties of Interest DX90</b> .....	<b>44</b>
<b>Figure 18: Average DX90 per bridge by County, 2021</b> .....	<b>45</b>
<b>Figure 19 – Average DP10 per bridge by County, 2021</b> .....	<b>47</b>
<b>Figure 20 - Counties of Interest DP10</b> .....	<b>47</b>
<b>Figure 21 - Counties of Interest SNOW</b> .....	<b>49</b>
<b>Figure 22 – Bridges Containing EN107 Steel Girder, 2021</b> .....	<b>50</b>
<b>Figure 23 – Bridges Containing EN225 Steel Pile, 2021</b> .....	<b>50</b>
<b>Figure 24 – Counties of Coastal Interest</b> .....	<b>52</b>
<b>Figure 25 – EN16 State Owned Bridges Percentage in Condition State One</b> .....	<b>56</b>
<b>Figure 26 – EN16 State Owned Bridges Percentage in Condition State Two</b> .....	<b>57</b>
<b>Figure 27 – EN16 State Owned Bridges Percentage in Condition State Three</b> .....	<b>58</b>
<b>Figure 28 – EN16 State Owned Bridges Percentage in Condition State Four</b> .....	<b>59</b>
<b>Figure 29 – EN16 County Owned Bridges Percentage in Condition State One</b> .....	<b>60</b>
<b>Figure 30 – EN16 County Owned Bridges Percentage in Condition State Two</b> .....	<b>61</b>

<b>Figure 31 – EN16 County Owned Bridges Percentage in Condition State Three .....</b>	<b>62</b>
<b>Figure 32 – EN16 County Owned Bridges Percentage in Condition State Four .....</b>	<b>63</b>
<b>Figure 33: Percent of EN215 in CS3 by location, 2021. County-Owned (Left) vs State-Owned (Right).....</b>	<b>67</b>
<b>Figure 34 - Location of Selected DT32 Bridges for EN215 .....</b>	<b>69</b>
<b>Figure 35 – Average EN215 by County (Left) vs DT32 Counties (Right) .....</b>	<b>69</b>
<b>Figure 36 – EN215 EHI Distribution DT32 (Bottom) vs Other Counties (Top).....</b>	<b>70</b>
<b>Figure 37 - EN215 in 2014 (Left) and 2020 (Right).....</b>	<b>71</b>
<b>Figure 38 – Bridge 213-5009-0 Reinforced Concrete Abutment EHI by Year .....</b>	<b>72</b>
<b>Figure 39: Bridge 291-5028-0 Side View (GDOT, 2021) .....</b>	<b>72</b>
<b>Figure 40: , Bridge 291-5028-0 Reinforced Concrete Abutment EHI by Year .....</b>	<b>73</b>
<b>Figure 41: Concrete Spalling in Abutment 1 in 2014 (Left) and 2021 (Right).....</b>	<b>74</b>
<b>Figure 42: Reinforced Concrete Abutment Area Loss (GDOT, 2021) .....</b>	<b>74</b>
<b>Figure 43: Bridge 055-5009-0 Side View (GDOT, 2022) .....</b>	<b>75</b>
<b>Figure 44: Bridge 055-5009-0 Top View (GDOT, 2022).....</b>	<b>76</b>
<b>Figure 45: Bridge 055-5009-0 Void Repair Side View(Left) and Top View (Right).....</b>	<b>76</b>
<b>Figure 46: Spalling in Abutment 2 (GDOT, 2022).....</b>	<b>77</b>
<b>Figure 47: Undermining in Abutment 1 (GDOT, 2020).....</b>	<b>77</b>
<b>Figure 48: Left Side View of Bridge 213-0045-0 (GDOT, 2022).....</b>	<b>78</b>
<b>Figure 49: Top Waterway View of Bridge 213-0045-0 (GDOT, 2022).....</b>	<b>79</b>
<b>Figure 50: Bridge 213-0045-0-0 EHI by Year .....</b>	<b>80</b>
<b>Figure 51: Bridge 055-5045-0 Right Side View (GDOT, 2020).....</b>	<b>80</b>
<b>Figure 52: Bridge 055-5045-0 Top View Sketch (GDOT, 2018).....</b>	<b>81</b>
<b>Figure 53: Bridge 055-5045-0 Abutment 1 2014 (Left) vs 2020 .....</b>	<b>82</b>
<b>Figure 54: Bridge 055-5045-0 Abutment 1 Settlement Crack (GDOT, 2020).....</b>	<b>82</b>
<b>Figure 55: Arch Span with Exposed Rebar Covered with Epoxy vs Rebar with No Epoxy (GDOT, 2020).....</b>	<b>84</b>
<b>Figure 56: Bridge 213-0033-0 Left Side View (GDOT, 2020) .....</b>	<b>84</b>
<b>Figure 57: Bridge 213-0033-0 Left Shoulder 2016(Right) vs 2020(Left) .....</b>	<b>84</b>
<b>Figure 58: Progression of Pier Degradation 2014(Left) to 2020(Right).....</b>	<b>85</b>
<b>Figure 59 - Bridge 213-5004-0 Side View (GDOT, 2021) .....</b>	<b>86</b>
<b>Figure 60 – Bridge 213-5004-0 Reinforced Concrete Abutment EHI by Year .....</b>	<b>86</b>
<b>Figure 61 - Concrete Loss on Abutment 3 (GDOT, 2019).....</b>	<b>87</b>

<b>Figure 62 - Large Crack on Abutment 1 Discovered (GDOT, 2019)</b> .....	<b>87</b>
<b>Figure 63 - Bridge 213-5004-0 Top View (GDOT, 2019)</b> .....	<b>88</b>
<b>Figure 64 - 100% Section Loss in Lateral Bracing (GDOT, 2020)</b> .....	<b>88</b>
<b>Figure 65: Bridge 055-5026-0 Side View (GDOT, 2020)</b> .....	<b>89</b>
<b>Figure 66: Reinforced Concrete Abutment on Bridge 055-5026-0 (GDOT, 2020)</b> .....	<b>89</b>
<b>Figure 67: Bridge 055-5041-0 Deck Bottom (Right) and Top (Right) Deterioration (GDOT, 2020)</b> .....	<b>90</b>
<b>Figure 68: Scour at Abutment 1 (GDOT, 2014)</b> .....	<b>91</b>
<b>Figure 69: Void at Abutment 1 (GDOT, 2020)</b> .....	<b>91</b>
<b>Figure 70: Side View of Bridge 241-5024-0 (GDOT, 2020)</b> .....	<b>92</b>
<b>Figure 71: Bridge 241-5024-0 Reinforced Concrete Abutment EHI by Year</b> .....	<b>93</b>
<b>Figure 72: Concrete Spalling and Exposed Rebar in Abutment 1 of Bridge 241-5024-0, 2017</b> .....	<b>94</b>
<b>Figure 73: Concrete Degradation and Exposed Rebar at Waterline in Abutment 1 of Bridge 241-5024-0 (GDOT, 2018)</b> .....	<b>95</b>
<b>Figure 74: Concrete Cracking and Honeycombing in Abutment 1 of Bridge 241-5024-0 (GDOT, 2022)</b> .....	<b>96</b>
<b>Figure 75: Honeycombing Patch in Abutment 1 of Bridge 241-5024-0 (GDOT, 2022)</b> .....	<b>96</b>
<b>Figure 76: Concrete Spalling in Abutment 1 of Bridge 241-5024-0 (GDOT, 2022)</b> .....	<b>97</b>
<b>Figure 77: Reinforced Concrete Deck Patching on Bridge 241-5024-0 (GDOT, 2022)</b> .....	<b>98</b>
<b>Figure 78 - Bridge 055-5030-0 Side View (GDOT, 2022)</b> .....	<b>99</b>
<b>Figure 79 – Bridge 055-5030-0 Deck Spalling (GDOT, 2022)</b> .....	<b>100</b>
<b>Figure 80 – Bridge 055-5030-0 Wide Flange 100% Section Loss (GDOT, 2022)</b> .....	<b>101</b>
<b>Figure 81 – Reinforced Concrete Pile Cap Wear on Bridge 055-5030-0 (GDOT, 2017)</b> ....	<b>102</b>
<b>Figure 82 – Spalling in Reinforced Concrete Abutment on Bridge 055-5030-0 (GDOT, 2020)</b> .....	<b>102</b>
<b>Figure 83 – Scour at Reinforced Concrete Pier Wall on Bridge 055-5030-0 (GDOT, 2020)</b> .....	<b>103</b>
<b>Figure 84 – Bridge 313-5028-0 Reinforced Concrete Girder Spalling 2014 (Top) vs 2020 (Bottom)</b> .....	<b>105</b>
<b>Figure 85: Percent of EN110 in Condition State One by Location, 2021. County-Owned (Top) vs State-Owned (Bottom)</b> .....	<b>108</b>
<b>Figure 86 – EHI of EN110 DT32 Counties (Left) vs NonDT32 Counties (Right)</b> .....	<b>109</b>
<b>Figure 87 – Average EHI of EN110 by County (Left) vs DT32 Counties (Right)</b> .....	<b>109</b>
<b>Figure 88 – RC Girder Number of Assets Built by Year (InspectX)</b> .....	<b>110</b>

<b>Figure 89 – PSC Girder Number of Assets Built by Year (InspectX).....</b>	<b>110</b>
<b>Figure 90 - Location of Selected DT32 Bridges for EN110 .....</b>	<b>111</b>
<b>Figure 91 – Bridge 295-0015-0 Side View (GDOT, 2021).....</b>	<b>113</b>
<b>Figure 92 – Bridge 295-0015-0 Typical Girder Spalling (GOT, 2021).....</b>	<b>114</b>
<b>Figure 93 – Bridge 295-0015-0 EHI by Year .....</b>	<b>115</b>
<b>Figure 94 – Bridge 295-0039-0 Side View (GDOT, 2021).....</b>	<b>116</b>
<b>Figure 95 – Bridge 295-0039-0 Concrete Spalling (GDOT, 2021) .....</b>	<b>116</b>
<b>Figure 96 – Bridge 295-0039-0 Concrete Cracking (GDOT, 2019).....</b>	<b>117</b>
<b>Figure 97 – Bridge 295-0039-0 Reinforced Concrete Abutment 2015 (Top) vs 2021 (Bottom).....</b>	<b>118</b>
<b>Figure 98 – Bridge 295-0041-0 Side View (GDOT, 2021).....</b>	<b>119</b>
<b>Figure 99 – Bridge 295-0041-0 Reinforced Concrete Girder Spalling (GDOT, 2021) .....</b>	<b>120</b>
<b>Figure 100 – Bridge 295-0041-0 Reinforced Concrete Pier Cap (GDOT, 2021).....</b>	<b>121</b>
<b>Figure 101 – Bridge 055-5037-0 Side View (GDOT, 2022).....</b>	<b>122</b>
<b>Figure 102 – Bridge 055-5037-0 Reinforced Concrete Girder Spalling (GDOT, 2020) .....</b>	<b>123</b>
<b>Figure 103 – Bridge 055-5037-0 Reinforced Concrete Girder Spalling (GDOT, 2020) .....</b>	<b>123</b>
<b>Figure 104 – Bridge 083-0026-0 Reinforced Concrete Girder Typical Cracking (GDOT, 2019).....</b>	<b>124</b>
<b>Figure 105 – Bridge 295-5011-0 Side View (GDOT, 2022).....</b>	<b>125</b>
<b>Figure 106 – Bridge 295-5011-0 Reinforced Concrete Girder Typical Spalling (GDOT, 2022).....</b>	<b>126</b>
<b>Figure 107 – Bridge 083-0027-0 Side View (GDOT, 2022).....</b>	<b>127</b>
<b>Figure 108 – Bridge 083-0027-0 Reinforced Concrete Girder Spalling (GDOT, 2019) .....</b>	<b>128</b>
<b>Figure 109 – Bridge 083-0027-0 Reinforced Concrete Girder Cracking (GDOT, 2019) ...</b>	<b>128</b>
<b>Figure 110 – Bridge 083-0027-0 Reinforced Concrete Girder Spalling (GDOT, 2019) .....</b>	<b>129</b>
<b>Figure 111 – Bridge 295-0004-0 Side View (GDOT, 2015).....</b>	<b>130</b>
<b>Figure 112 – Bridge 295-0004-0 Reinforced Concrete Girder Cracking with Efflorescence (GDOT, 2020).....</b>	<b>131</b>
<b>Figure 113 – Bridge 295-0040-0 Side View (GDOT, 2021).....</b>	<b>132</b>
<b>Figure 114 – Bridge 295-0040 Reinforced Concrete Girder Spalling (GDOT, 2023).....</b>	<b>133</b>
<b>Figure 115: Percent of EN234 in Condition State One by Location, 2021. County- Owned (Top) vs State-Owned (Bottom) .....</b>	<b>135</b>
<b>Figure 116 – EHI of EN234 DT32 Counties (Top) vs NonDT32 Counties (Bottom) .....</b>	<b>136</b>
<b>Figure 117 – Average EHI of EN234 by County (Left) vs DT32 Counties (Right).....</b>	<b>136</b>

<b>Figure 118 - Location of Selected DT32 Bridges for EN234 .....</b>	<b>137</b>
<b>Figure 119 – Bridge 295-5012-0 Reinforced Concrete Pier Cap EHI by Year .....</b>	<b>138</b>
<b>Figure 120 – Bridge 295-5012-0 Reinforced Concrete Pier Cap Spalling (GDOT, 2017)..</b>	<b>139</b>
<b>Figure 121 – Bridge 295-5012-0 Reinforced Concrete Pier Cap Spalling (GDOT, 2021)..</b>	<b>140</b>
<b>Figure 122 – Bridge 295-5012-0 Reinforced Concrete Pier Cap Efflorescence (GDOT, 2017).....</b>	<b>140</b>
<b>Figure 123 – Bridge 083-0012-0 Side View (GDOT, 2021).....</b>	<b>141</b>
<b>Figure 124 – Bridge 083-0012-0 Reinforced Concrete Pier Cap Spalling with Exposed Rebar (GDOT, 2019).....</b>	<b>142</b>
<b>Figure 125 – Bridge 083-0012-0 Reinforced Concrete Pier Cap Failed Spall Repair (GDOT, 2019).....</b>	<b>142</b>
<b>Figure 126 – Bridge 083-0012-0 Element EHI by Year.....</b>	<b>143</b>
<b>Figure 127 – Bridge 083-0012-0 Joint Failure (GDOT, 2017) .....</b>	<b>143</b>
<b>Figure 128 – Bridge 295-5013-0 Bridge Side View (GDOT, 2021).....</b>	<b>145</b>
<b>Figure 129 – Bridge 295-5013-0 EHI by Year .....</b>	<b>145</b>
<b>Figure 130 – Bridge 295-5013-0 Reinforced Concrete Pier Cap Cracking (GDOT, 2021)</b>	<b>146</b>
<b>Figure 131 – Bridge 291-0017-0 Reinforced Concrete Pier Cap (GDOT, 2021).....</b>	<b>147</b>
<b>Figure 132 – Bridge 311-5001-0 Side View (GDOT, 2021).....</b>	<b>148</b>
<b>Figure 133 – Bridge 311-5001-0 Pier Cap Cracking (GDOT, 2018) .....</b>	<b>149</b>
<b>Figure 134 – Bridge 311-5001-0 Element EHI by Year.....</b>	<b>149</b>
<b>Figure 135 – Bridge 213-0001-0 Reinforced Concrete Pier Cap Spalling with Rebar Section Loss (GDOT, 2020) .....</b>	<b>150</b>
<b>Figure 136 – Bridge 213-0001-0 Reinforced Concrete Pier Cap Cracking in Wrap Repair (GDOT, 2020).....</b>	<b>151</b>
<b>Figure 137 – Bridge 213-0001-0 EHI by Year .....</b>	<b>152</b>
<b>Figure 138 – Bridge 313-0004-0 Reinforced Concrete Pier Cap Spalling, 2022 .....</b>	<b>153</b>
<b>Figure 139 – Bridge 291-0018-0 Element EHI by Year.....</b>	<b>154</b>
<b>Figure 140 – Bridge 291-0018-0 Reinforced Concrete Pier Cap Cracking (GDOT, 2018)</b>	<b>155</b>
<b>Figure 141 – Bridge 213-0008-0 Pier Cap Concrete Cracking (GDOT, 2022).....</b>	<b>156</b>
<b>Figure 142 – Bridge 313-5028-0 Bridge Side View (GDOT, 2022).....</b>	<b>157</b>
<b>Figure 143 – Bridge 313-5028-0 Pier Cap Cracking (GDOT, 2022) .....</b>	<b>157</b>
<b>Figure 144 – Bridge 313-5028-0 Abutment 3 Undermining (GDOT, 2022) .....</b>	<b>158</b>
<b>Figure 145 – Bridge 313-5028-0 Abutment 3 Pile 1 Section Loss (GDOT, 2022).....</b>	<b>158</b>
<b>Figure 146 – Bridge 313-5028-0 Span 2 Cracking (GDOT, 2022).....</b>	<b>159</b>

<b>Figure 147 – Bridge 313-5028-0 Span 1 Spalling (GDOT, 2020).....</b>	<b>159</b>
<b>Figure 148: EN215 Percent in CS3 by location, 2021 County-Owned (Left) vs State-Owned (Right).....</b>	<b>161</b>
<b>Figure 149 - Location of Selected DP10 Bridges for EN225 .....</b>	<b>162</b>
<b>Figure 150 – Bridge 241-0016-0 Side View (GDOT, 2022).....</b>	<b>163</b>
<b>Figure 151 – Bridge 241-0016-0 Steel Pile Section Loss at Ground Level (GDOT, 2022) .</b>	<b>165</b>
<b>Figure 152 – Erosion at Abutment 5 on Bridge 241-0016-0 (GDOT, 2020) .....</b>	<b>166</b>
<b>Figure 153 – Bridge 241-0016-0 EHI by Year, 2015-2021.....</b>	<b>167</b>
<b>Figure 154 – Bridge 241-0016-0 Failing Joint (GDOT, 2020).....</b>	<b>168</b>
<b>Figure 155 – Bridge 241-0016-0 Efflorescence at Reinforced Concrete Top Flange (GDOT, 2020).....</b>	<b>168</b>
<b>Figure 156 – Bridge 241-0016-0 Steel Pile Section Loss at Deck (GDOT, 2020).....</b>	<b>169</b>
<b>Figure 157 – Bridge 187-0006-0 EN225 EHI (Top) and Operating Rating (Right) by Year.....</b>	<b>171</b>
<b>Figure 158 – Bridge 187-0006-0 Pile Condition, 2019 .....</b>	<b>172</b>
<b>Figure 159 – Logjam at Bridge 187-0006-0 (GDOT, 2020).....</b>	<b>172</b>
<b>Figure 160 – Minor Bending in Steel Pile in Bridge 187-0006-0 (GDOT, 2020) .....</b>	<b>173</b>
<b>Figure 161 – Bridge 0047-5012-0 Typical Steel Pile Section Loss (GDOT, 2019).....</b>	<b>174</b>
<b>Figure 162 – Bridge 055-5001-0 Typical Steel Pile Section Loss (GDOT, 2020).....</b>	<b>175</b>
<b>Figure 163 – Bridge 055-5001-0 Steel Pile Connection 2016 (Top) vs 2022 (Bottom) .....</b>	<b>176</b>
<b>Figure 164 – Bridge 055-5001-0 Steel Pile Connection 2016 (Top &amp; Middle) vs 2022 (Bottom).....</b>	<b>177</b>
<b>Figure 165 – Bridge 055-5030-0 Steel Girder Condition (GDOT, 2020) .....</b>	<b>178</b>
<b>Figure 166 – Bridge 055-5030-0 Deck Topside Condition (GDOT, 2022) .....</b>	<b>179</b>
<b>Figure 167 – Bridge 055-5030-0 Deck Condition (GDOT, 2022).....</b>	<b>181</b>
<b>Figure 168 – Bridge 055-5030 Drift at Bent 3 2012 (Top) vs 2020 (Middle &amp;Bottom).....</b>	<b>184</b>
<b>Figure 169 – Bridge 055-5030-0 Bent 2 Scour (GDOT, 2020).....</b>	<b>185</b>
<b>Figure 170 – Bridge 291-5026-0 Steel Pile Condition (GDOT, 2019).....</b>	<b>186</b>
<b>Figure 171 – Bridge 291-5026-0 Scour (GDOT, 2019).....</b>	<b>187</b>
<b>Figure 172 – Bridge 291-5035-0 Side View (GDOT, 2019).....</b>	<b>188</b>
<b>Figure 173 – Bridge 291-5035-0 Steel Pile Corrosion (GDOT, 2020).....</b>	<b>189</b>
<b>Figure 174 – Bridge 291-5035-0 Erosion, 2015 (Top) and Erosion Repair, 2016 (Bottom).....</b>	<b>190</b>
<b>Figure 175 – Bridge 129-5003-0 Side View, 2022 .....</b>	<b>191</b>

<b>Figure 176 – Bridge 111-5002-0 Steel Pile Condition at Bent 2 (GDOT, 2016) .....</b>	<b>192</b>
<b>Figure 177 – Bridge 111-5002-0 Typical Steel Pile Condition (GDOT, 2019).....</b>	<b>192</b>
<b>Figure 178 – Bridge 111-5002-0 Steel Pile Conditions (GDOT, 2021) .....</b>	<b>194</b>
<b>Figure 179 – Bridge 111-5002-0 Steel Pile Repair (GDOT, 2022) .....</b>	<b>195</b>
<b>Figure 180 – Bridge 111-5002-0 Abutment Repair 2019 (Top) vs 2022 (Bottom) .....</b>	<b>196</b>
<b>Figure 181: EN210 Percent in CS3 by location, 2021. County-Owned (Left) vs State-Owned (Right).....</b>	<b>198</b>
<b>Figure 182 – EHI of EN210 DP10 Counties (Bottom) vs NonDP10 Counties (Top) .....</b>	<b>199</b>
<b>Figure 183 - Location of Selected DP10 Bridges for EN210 .....</b>	<b>200</b>
<b>Figure 184 – Bridge 213-0044-0 Sideview (GDOT, 2022) .....</b>	<b>201</b>
<b>Figure 185 – Bridge 213-0044-0 Typical Pier Wall Abrasion (GDOT, 2020).....</b>	<b>202</b>
<b>Figure 186 – Bridge 233-055-0 Column 3-2 2016 (Top) vs 2022 (Bottom) .....</b>	<b>203</b>
<b>Figure 187 – Bridge 233-5036-0 Pier Wall Scour (GDOT, 2021) .....</b>	<b>204</b>
<b>Figure 188 – Bridge 233-5026-0 Side View (GDOT, 2022).....</b>	<b>206</b>
<b>Figure 189 – Bridge 313-5008-0 Pier Wall Spall (Top) vs Repaired (Bottom).....</b>	<b>207</b>
<b>Figure 190 – Bridge 313-5008-0 Abutment pile 100% Section Loss (GDOT, 2020).....</b>	<b>208</b>
<b>Figure 191 – Bridge 313-5002-0 Side View (GDOT, 2022).....</b>	<b>209</b>
<b>Figure 192 – Bridge 313-5002-0 Reinforced Concrete Pier Wall Condition (GDOT, 2020).....</b>	<b>209</b>
<b>Figure 193 – Bridge 213-0048-0 Side View (GDOT, 2022).....</b>	<b>210</b>
<b>Figure 194 – Bridge 213-0048-0 Steel Girder Corrosion (GDOT, 2020) .....</b>	<b>211</b>
<b>Figure 195 – 213-0017-0 Side View (GDOT, 2022) .....</b>	<b>212</b>
<b>Figure 196 – Bridge 213-0017-0 Scouring at Bent 4, 2022 .....</b>	<b>213</b>
<b>Figure 197 – Bridge 213-0017-0 Pier Wall 2 Abrasion Area (GDOT, 2020).....</b>	<b>214</b>
<b>Figure 198 – Bridge 213-0017-0 Bent Cap 4 Spall 2016 (Top) vs 2020 (Bottom).....</b>	<b>215</b>
<b>Figure 199 – Bridge 083-0046-0 Side View (GDOT, 2022).....</b>	<b>216</b>
<b>Figure 200 - Location of Selected DP10 Bridges for Scour .....</b>	<b>218</b>
<b>Figure 201 – Bridge 123-5060 Side View (GDOT, 2021).....</b>	<b>219</b>
<b>Figure 202 – Bridge 213-0044-0 Volumetric Flowrate No Precipitation (Top) vs With Precipitation (Bottom) .....</b>	<b>221</b>
<b>Figure 203 – Bridge 313-5083-0 Bent 2 Scour (GDOT, 2020).....</b>	<b>222</b>
<b>Figure 204 – Bridge 313-5083-0 Abutment Undermining (GDOT, 2020) .....</b>	<b>223</b>
<b>Figure 205 – Bridge 311-0040-0 Abutment Repair (GDOT, 2020) .....</b>	<b>224</b>

<b>Figure 206 – Bridge 311-0040-0 Erosion (GDOT, 2020) .....</b>	<b>225</b>
<b>Figure 207 – Bridge 213-5044-0 Bridge Side View (GDOT, 2022).....</b>	<b>226</b>
<b>Figure 208 – Bridge 213-5044-0 Abutment One Scour (GDOT, 2016) .....</b>	<b>227</b>
<b>Figure 209 – Bridge 213-5044-0 Abutment One Scour (GDOT, 2018) .....</b>	<b>228</b>
<b>Figure 210 – Bridge 213-5044-0 Abutment One Scour (GDOT, 2020) .....</b>	<b>229</b>
<b>Figure 211 – Bridge 187-0016-0 Bent Cap 5 Spalling (GDOT, 2020) .....</b>	<b>231</b>
<b>Figure 212 – Bridge 187-0016-0 Bent Cap 9 Spalling 2020 (Top) vs 2022 (Bottom) .....</b>	<b>232</b>
<b>Figure 213 – Bridge 129-0009-0 Scour at Bent 15 2015 (Top) vs 2019 (Bottom) .....</b>	<b>234</b>
<b>Figure 214 – Bridge 123-5024-0 Abutment 2 Undermining (GDOT, 2021) .....</b>	<b>236</b>
<b>Figure 215 – Bridge 123-0036-0 Settlement Cracking (GDOT, 2022) .....</b>	<b>237</b>
<b>Figure 216 – Bridge 123-0036-0 Abutment Void (GDOT, 2020).....</b>	<b>238</b>
<b>Figure 217 – Bridge 147-5080-0 Typical Abutment Condition (GDOT, 2021) .....</b>	<b>239</b>
<b>Figure 218 – Bridge 213-5045-0 Failed Compression Joint (GDOT, 2022).....</b>	<b>241</b>
<b>Figure 219 – Bridge 213-5045-0 Bridge Deck Cracking at Abutment (GDOT, 2022).....</b>	<b>242</b>
<b>Figure 220 – Bridge 157-5084-0 Failed Compression Joint (GDOT, 2022).....</b>	<b>243</b>
<b>Figure 221 – Bridge 213-0008-0 Compression Joint 2015 (Top) vs 2018 (Middle) vs 2022 (Bottom).....</b>	<b>246</b>
<b>Figure 222 – Bridge 097-5059-0 Failing Joint (GDOT, 2019).....</b>	<b>247</b>
<b>Figure 223 – Bridge 045-5018-0 Joint Condition 2016 (Top) vs 2021 (Bottom).....</b>	<b>248</b>
<b>Figure 224 – Bridge 089-0131-0 Strip Seal Expansion Joint Typical Condition (GDOT, 2016).....</b>	<b>249</b>
<b>Figure 225 – Bridge 089-0131-0 Debris Build Up on Bent Cap 3 (GDOT, 2019) .....</b>	<b>250</b>
<b>Figure 226 – Bridge 257-0001-0 Typical Joint Condition (GDOT, 2021).....</b>	<b>251</b>
<b>Figure 227 – Bridge 241-5051-0 Joint Condition (GDOT, 2020).....</b>	<b>252</b>
<b>Figure 228 – Bridge 045-0079-0 Steel Pier Cap 2014 (Top) vs 2022 (Bottom) .....</b>	<b>254</b>
<b>Figure 229 – Bridge 045-5027 Steel Pier Cap Condition (GDOT, 2022) .....</b>	<b>255</b>
<b>Figure 230 – Bridge 231-5002-0 Steel Pier Cap Condition 2016 (Top) vs 2022 (Bottom)..</b>	<b>257</b>
<b>Figure 231 – Bridge 283-5026-0 Typical Pile Condition (GDOT, 2019).....</b>	<b>258</b>
<b>Figure 232 – Bridge 175-5086-0 Scour (GDOT, 2021).....</b>	<b>259</b>
<b>Figure 233 – Bridge 231-5024-0 Side View (GDOT, 2021).....</b>	<b>259</b>
<b>Figure 234 – Bridge 231-5024-0 Typical Reinforced Concrete Pile Condition (GDOT, 2021).....</b>	<b>260</b>
<b>Figure 235 – Bridge 297-5062-0 Steel Abutment Condition 2013 (Top) vs 2021 (Bottom)</b>	<b>261</b>

<b>Figure 236 – Bridge 045-5126-0 Steel Abutment Condition (GDOT, 2021).....</b>	<b>262</b>
<b>Figure 237: Percent of EN16 in Condition State One by Location, 2021. County-Owned (Top) vs State-Owned (Bottom) .....</b>	<b>263</b>
<b>Figure 238 – EHI of EN16 Snow Counties (Top) vs Non Snow Counties (Bottom) .....</b>	<b>265</b>
<b>Figure 239 – EHI of EN16 by County (Left) vs Snow Counties (Right).....</b>	<b>265</b>
<b>Figure 240 - Location of Selected Snow Bridges for EN16 .....</b>	<b>267</b>
<b>Figure 241 – Bridge 291-0018-0 Side View (GDOT, 2021).....</b>	<b>268</b>
<b>Figure 242 – Deck Spall 2014 (Top) vs 2017 (Middle) vs 2019 (Bottom).....</b>	<b>270</b>
<b>Figure 243 – Deck Spalling 2014 (Top) vs 2019 (Bottom).....</b>	<b>272</b>
<b>Figure 244 – Bridge 291-0018-0 Bridge Erosion (GDOT, 2014).....</b>	<b>273</b>
<b>Figure 245 – Bridge 241-5036-0 EHI by Year .....</b>	<b>274</b>
<b>Figure 246 – Bridge 241-5036-0 Span 3 Beam 3 Concrete Spall 2014 (Top) vs 2020 (Bottom).....</b>	<b>277</b>
<b>Figure 247 – Bridge 241-5036-0 Span 3 Beam 1 Concrete Cracking 2014 (Top) vs 2022 (Bottom).....</b>	<b>279</b>
<b>Figure 248 – Bridge 241-5036-0 Span 1 Beam 1 Concrete Spalling 2014 (Top) vs 2020 (Bottom).....</b>	<b>281</b>
<b>Figure 249 – Bridge 187-0007-0 EHI by Year .....</b>	<b>283</b>
<b>Figure 250 – Bridge 187-0007-0 Concrete Spalling 2013 (Top) vs 2019 (Bottom).....</b>	<b>284</b>
<b>Figure 251 – Bridge 291-0002-0 Bridge Deck Concrete Spall in Span 1 2014 (Top) vs 2019 (Bottom).....</b>	<b>286</b>
<b>Figure 252 – Bridge 241-0018-0 Deck Condition 2014 (Top) vs 2022 (Bottom).....</b>	<b>287</b>
<b>Figure 253 – Bridge 241-0018-0 Bridge Deck Condition 2014 (Top) vs 2022 (Bottom) .....</b>	<b>289</b>
<b>Figure 254 – Bridge 257-0008-0 Bridge Spalling Under Span 3 2015 (Top) vs 2021 (Bottom).....</b>	<b>290</b>
<b>Figure 255 – Bridge 257-0012-0 Plan View (GDOT, 2021) .....</b>	<b>291</b>
<b>Figure 256 – Bridge 257-0012-0 Side View (GDOT, 2021).....</b>	<b>292</b>
<b>Figure 257 – Bridge 257-0012-0 Concrete Spalling (GDOT, 2021).....</b>	<b>293</b>
<b>Figure 258 – Bridge 257-0012-0 Concrete Spalling with Epoxy Painting (GDOT, 2021) ..</b>	<b>294</b>
<b>Figure 259 – Bridge 241-0016-0 EHI by Year .....</b>	<b>295</b>
<b>Figure 260 – Bridge 241-0016-0 Typical Deck Cracking (GDOT, 2022).....</b>	<b>296</b>
<b>Figure 261 – Bridge 241-0016-0 Deck Cracking Underside (GDOT, 2020) .....</b>	<b>296</b>
<b>Figure 262 – Bridge 241-0016-0 Beam 9 Concrete Spalling 2016 (Top) vs 2020 (Bottom) ..</b>	<b>298</b>
<b>Figure 263 – Bridge 157-5046-0 Reinforced Concrete Top Flange Concrete Spall 2014 (Top) vs 2022 (Bottom).....</b>	<b>299</b>

<b>Figure 264 – Bridge 157-5046-0 Reinforced Concrete Top Flange Concrete Spall with Loose Aggregates (GDOT, 2022) .....</b>	<b>300</b>
<b>Figure 265: Percent of EN510 in Condition State One by Location, 2021. County-Owned (Top) vs State-Owned (Bottom) .....</b>	<b>302</b>
<b>Figure 266 – EHI of EN510 Snow Counties (Top) vs Non Snow Counties (Bottom) .....</b>	<b>303</b>
<b>Figure 267 – EHI of EN510 by County (Left) vs Snow Counties (Right) .....</b>	<b>303</b>
<b>Figure 268 - Location of Selected Snow Bridges for EN510 .....</b>	<b>304</b>
<b>Figure 269 – Bridge 311-5047-0 Transverse Cracking (GDOT, 2020) .....</b>	<b>306</b>
<b>Figure 270 – Bridge 311-5012-0 Deck Condition 2014 (Top) vs 2022 (Bottom).....</b>	<b>307</b>
<b>Figure 271 – Bridge 137-0029-0 EN510 EHI by Year .....</b>	<b>307</b>
<b>Figure 272 – Bridge 137-0029-0 Protective Wearing Surface at Bent 2 Condition 2014 (Top) vs 2022 (Bottom).....</b>	<b>309</b>
<b>Figure 273 – Bridge 213-0044-0 Deck Condition 2014 (Top) vs 2016 (Middle) vs 2020 (Bottom).....</b>	<b>310</b>
<b>Figure 274 – Bridge 291-5044-0 Steel Beam Corrosion (GDOT, 2021) .....</b>	<b>311</b>
<b>Figure 275- Bridge 291-5044-0 Deck Condition (GDOT, 2014) .....</b>	<b>312</b>
<b>Figure 276 – Bridge 291-5048-0 Asphalt Cracking (GDOT, 2019) .....</b>	<b>313</b>
<b>Figure 277 – Bridge 137-0028-0 Deck Condition 2016 (Top) vs 2018 (Middle) vs 2022 (Bottom).....</b>	<b>314</b>
<b>Figure 278 – Bridge 137-5064-0 Deck Condition 2020 (Top)) vs 2022 (Bottom) .....</b>	<b>315</b>
<b>Figure 279 – Bridge 187-0011-0 Deck Condition 2016 (Top) vs 2022 (Bottom).....</b>	<b>317</b>
<b>Figure 280 – Bridge 187-0007-0 Deck Condition 2015 (Top) vs 2021 (Bottom).....</b>	<b>318</b>
<b>Figure 281: Percent of EN226 in Condition State One by Location, 2021. County-Owned (Top) vs State-Owned (Bottom) .....</b>	<b>319</b>
<b>Figure 282 – EN226 EHI Distribution Across Coastal Counties.....</b>	<b>320</b>
<b>Figure 283 – EN226 EHI Distribution Across Non Coastal Counties.....</b>	<b>320</b>
<b>Figure 284 - Location of Selected Coastal Bridges for EN226.....</b>	<b>321</b>
<b>Figure 285 – Bridge 039-0001-0 Prestressed Concrete Piles Typical Condition (GDOT, 2021).....</b>	<b>322</b>
<b>Figure 286 – Bridge 039-0009-0 Prestressed Concrete Pile Typical Cracking and Abrasion (GDOT, 2021).....</b>	<b>324</b>
<b>Figure 287 – Bridge 039-0049-0 EHI by Year .....</b>	<b>325</b>
<b>Figure 288 – Bridge 039-0049-0 Prestressed Concrete Piles Typical Condition (GDOT, 2021).....</b>	<b>326</b>
<b>Figure 289 – Bridge 039-0049-0 Reinforced Concrete Girder Condition 2017 (Top) vs 2021 (Bottom).....</b>	<b>327</b>

<b>Figure 290 – Bridge 127-0029-0 EHI by Year .....</b>	<b>328</b>
<b>Figure 291 – Bridge 127-0029-0 Typical Pile Cracking (GDOT, 2022) .....</b>	<b>329</b>
<b>Figure 292 – Bridge 051-0142-0 Pile Cracking 2014 (Top) vs 2022 (Bottom) .....</b>	<b>330</b>
<b>Figure 293 – Bridge 039-0051-0 Abutment Undermining (GDOT, 2019) .....</b>	<b>331</b>
<b>Figure 294 – Bridge 039-0051-0 Typical Prestressed Concrete Pile Cracking (GDOT, 2021).....</b>	<b>332</b>
<b>Figure 295- Bridge 039-5029-0 Abutment Undermining (GDOT, 2019).....</b>	<b>333</b>
<b>Figure 296- Bridge 039-5029-0 Abutment Undermining (GDOT, 2019).....</b>	<b>333</b>
<b>Figure 297- Bridge 039-5029-0 Pile Cracking (GDOT, 2019).....</b>	<b>334</b>
<b>Figure 298- Bridge 127-0034-0 Plan View (GDOT, 2022).....</b>	<b>335</b>
<b>Figure 299- Bridge 127-0034-0 Bent 3 Pile 2 Cracking 2014 (Top) vs 2022 (Bottom).....</b>	<b>336</b>
<b>Figure 300 – Bridge 170-0006-0 Typical Cracking in PSC Piles (GDOT, 2022).....</b>	<b>337</b>

## LIST OF TABLES

<b>Table 1 - Coding and Descriptions for Component Condition Ratings (FHWA, 2005).....</b>	<b>6</b>
<b>Table 2 - Coding and Descriptions for Scour Condition Ratings (FHWA, 2005).....</b>	<b>7</b>
<b>Table 3 – Reinforced Concrete Element Defects (AASHTO., 2019).....</b>	<b>8</b>
<b>Table 4 – Steel Element Defects (AASHTO., 2019).....</b>	<b>10</b>
<b>Table 5 - Nonlinear Health Index Coefficients (Jiang &amp; Rens, 2010).....</b>	<b>11</b>
<b>Table 6 - Condition Index Zones (Jiang &amp; Rens, 2010).....</b>	<b>11</b>
<b>Table 7 - Condition Index Scales (Jiang &amp; Rens, 2010).....</b>	<b>11</b>
<b>Table 8 - Summary of GDOT Treatments by Work Type (GDOT, 2019).....</b>	<b>15</b>
<b>Table 9 – GDOT Maintenance Priority Summary.....</b>	<b>18</b>
<b>Table 10 - Asset Data Useful for Vulnerability Assessment (FHWA, 2017).....</b>	<b>23</b>
<b>Table 11 – Analysis Methodology.....</b>	<b>26</b>
<b>Table 12 – Weather Variables Available in the NOAA Dataset.....</b>	<b>27</b>
<b>Table 13 - 15 Counties with the Highest DT32, 2021.....</b>	<b>43</b>
<b>Table 14 - 15 Counties with the Highest DX90, 2021.....</b>	<b>45</b>
<b>Table 15 - 15 Counties with the Highest DP10, 2021.....</b>	<b>48</b>
<b>Table 16 – Counties of SNOW Intrest.....</b>	<b>49</b>
<b>Table 17 – Georgia Counties with Coastline.....</b>	<b>51</b>
<b>Table 18 – Summary of DT32, DP10, and Snow Counties of Intrest.....</b>	<b>53</b>
<b>Table 19 – GA NBI Element Data Example.....</b>	<b>54</b>
<b>Table 20 - Lowest 10 DT32 Bridges by EHI of EN215.....</b>	<b>68</b>
<b>Table 21 – Bridge 055-5030-0 Maintenance Items, 2022.....</b>	<b>104</b>
<b>Table 22 - Lowest 10 DT32 Bridges by EHI of EN110.....</b>	<b>111</b>
<b>Table 23 – Bridge 295-0039-0 Maintenance Items (GDOT, 2021).....</b>	<b>119</b>
<b>Table 24 – Bridge 295-0041-0 Maintenance Items (GDOT, 2021).....</b>	<b>122</b>
<b>Table 25 - Lowest 25 DT32 Bridges by EHI of EN234.....</b>	<b>137</b>
<b>Table 26 – Bridge 0083-0012-0 Maintenance Priority (GDOT, 2021).....</b>	<b>144</b>
<b>Table 27 - Lowest 10 DP10 Bridges by EHI of EN225.....</b>	<b>162</b>
<b>Table 28 – Bridge 241-0016-0 Steel Pile Measurements by Year.....</b>	<b>164</b>
<b>Table 29 - Lowest 10 DP10 Bridges by EHI of EN110.....</b>	<b>200</b>
<b>Table 30 – Bridge Identified for Scour Study.....</b>	<b>217</b>

<b>Table 31 – Bridge 123-5024-0 Abutment 1 Scour Measurements .....</b>	<b>235</b>
<b>Table 32 – Bridge 123-5024-0 Abutment 2 Scour Measurements .....</b>	<b>235</b>
<b>Table 33 – 2021 Worst Elements by EHI in Georgia.....</b>	<b>240</b>
<b>Table 34 - Lowest 10 Snow Bridges by EHI of EN16 .....</b>	<b>266</b>
<b>Table 35 – Bridge 241-5036 Maintenance Items, 2022 .....</b>	<b>282</b>
<b>Table 36 - Lowest 10 Snow Bridges by EHI of EN510 .....</b>	<b>304</b>
<b>Table 37 - Lowest 10 Coatsal Bridges by EHI of EN226.....</b>	<b>321</b>
<b>Table 38: Results Matrix .....</b>	<b>350</b>

## **BACKGROUND**

The state of Georgia has over 14,000 bridges in the state that are essential for the infrastructure of the state. This makes bridges one of the most valuable assets to the state, and their maintenance and upkeep should be a focus of the state of Georgia. The average GDOT owned bridge was designed for 50 years, and the average age of National Highway System bridges in Georgia is 46 years (GDOT, 2019). Ensuring the bridges are in stable condition is critical for the state's economy, the safety of travelers, and asset management.

Bridge degradation and asset management plans are not unique to Georgia as they are that all state and local governments must consider. The American Road and Transportation Builders Association (ARTBA) Bridge report 2021 In the United States, 224,000 bridges require repair, and 78,777 require maintenance. Such high number of bridges needing maintenance means over 1/3 of US bridges must be either repaired or replaced. The estimated cost to replace all the bridges based on average price data from GDOT would be over 58 million dollars. In addition to the challenges related to managing assets required to repair bridges, there is also the safety issue. There are over 43,500 bridges rated as "structurally deficient," and motorists cross these bridges 167.5 million times a day. At the current rate, it would take close to 30 years to repair all the bridges deemed "structurally deficient" in the United States.

Georgia is no different from the rest of the country regarding bridge conditions. According to the ARBTA 2021 report the state of Georgia alone, 319 bridges are deemed to have elements in the "poor" or worse category. In addition, the state has also identified 13,720 bridges that need to be repaired at an estimated cost of 12 billion dollars. It is critical for the state of Georgia to properly allocate funds and resources to properly repair bridges and determine the

bridges and components to prioritize. Such action will save state resources and help ensure the safety of people who use the roadways of Georgia.

To help manage its assets, the state of Georgia attempts to utilize a data-driven approach. The national bridge inventory (NBI) is a public database comprising mandated inspection ratings completed for the bridges in the United States bi-annually. Starting in 2015, inspectors began gathering element data, which places each element of the bridge into a condition state. The availability of this new data is valuable as it can help DOTs better understand the components of bridges that need to be addressed.

Studies have been conducted using this data to try and determine the most influential factors on bridge conditions. For example, (Huang, 2010) developed an artificial neural network that predicted deck depreciation, considering attributes found in NBI data like the number of spans, deck area, design load, and average daily traffic (ADT). This study found that age and maintenance history are the two most relevant model inputs. Deterioration modeling that takes climate into account has also been considered. For example, (Qiao et al., 2016) developed a model for bridges in Indiana that considered age, condition, traffic volume, waterways, location, and environmental factors. This model used the NOAA weather variables of annual precipitation, number of hot days, number of cold days, and average annual temperature. The model found that age and current rating are the most likely factors to influence transition are age and current condition. However, the number of cold days also affected the deck deterioration model. In 2019 (Liu & El-Gohary, 2019). considered NOAA weather data from nine states across the United States, pairing the weather stations with bridges. The machine learning model showed that the weather data only marginally impacted the model's performance.

Despite varying results from bridge deterioration models that consider climatic factors, it is evident that weather plays a factor in bridge asset management and maintenance decision-making. (Markolf et al., 2019) show that weather and climate stressors and hazards should be recognized and prioritized in transportation asset management. Knowing that weather plays a vital role in bridge asset management, and due to limitations in current depreciation models that only partially capture the true impact of weather on bridges, this paper proposes a new approach. Using NBI and NBI element data, bridges will be selected and using inspection reports, the visual impacts of weather that cannot be found in data will be analyzed.

## **PROBLEM STATEMENT**

The primary goal of this research study is to help the state of Georgia and local municipalities better understand how the weather in different regions of Georgia affects the various components of bridges. Risk is a requirement for BAMPs, and weather and climate are classified as risks; therefore, the state needs to understand how weather can impact bridge conditions. By better understanding what weather patterns impact specific elements of bridges, GDOT can work with local governments to help work on better maintaining elements affected by weather, so that bridge assets have a longer lifespan.

## **RESEARCH OBJECTIVES**

The goal of this research is to look at the impact of weather stressors on bridge elements in Georgia. After assessing the impacts, bring out an understanding of what these impacts, mean for future bridge maintenance. Use visual components of the NBI data to show the impacts. Include a description of elements that the state can do a better job maintaining in the future, and recommend changes moving forward to help better mitigate risk and extend bridge service life.

Rank bridge components to improve to increase bridge service life. Additionally, this study intends to bridge the gap between data and inspection reports. The following research questions will be addressed.

1. Are elements in poor condition states attributable to weather stressors?
2. Do weather stressors impact certain bridge elements more than others?
3. Is quantitative NBIE consistent with qualitative information? Is additional knowledge gained from qualitative information?
4. What bridge elements are most vulnerable to weather stressors and how do they respond over time?

## **CHAPTER 1. LITERATURE REVIEW**

### **CURRENT BRIDGE CONDITIONS IN USA**

According to the ARTBA Bridge report 2021, 224,000 bridges are in need of repair, and 78,777 bridges need to be replaced in the United States. This means that over 1/3 of bridges in the U. S. need to be either repaired or replaced.

In addition to the challenges related to the management of assets required to repair bridges, there is also the issue of safety. There are over 43,500 bridges that are rated as “structurally deficient”, and motorists cross these bridges 167.5 million times a day. At the current rate, it would take close to 30 years to repair all the bridges that are deemed “structurally deficient.”.

### **National Bridge Inventory**

After a 1967 bridge collapse over the Ohio River that resulted in the loss of 46 lives, Congress and Lyndon B. Johnson came together to add the first federal bridge inspection program to the Federal-Aid Highway bill. This addition to the legislation added stricter standards for safety inspections of bridges in the United States. This law also required the US Secretary of Transportation to maintain a database of these bridge inspections. This requirement resulted in the creation of the NBI database that presents a picture of the location, construction materials/method, size, description, and general condition of each bridge on public or publicly accessible land. Currently, the NBI gives a rating of 0-9 to each bridge's substructure, superstructure, and deck. The FHWA determines the deck rating from the condition of all the deck surfaces: top, underside, and sides. This rating does not consider the condition of wearing surfaces, bridge rails, joint assemblies, or scuppers. The FHWA considers the superstructure to be all members above the bearings and includes girders/beams, slabs of concrete rigid frame

bridges, and legs/knees/girders for concrete/ steel rigid K-Frame or Delta-Frame bridges. This rating does not consider the condition of the bearing, protective coating systems, or the presence of drift/debris. The FHWA considers substructures to be backwalls, members below girders/beams, and include thrust blocks, abutments, footings, and foundation piles exposed by scouring/erosion. **Table 1** shows the coding system used for these ratings. Each state is required to inspect every bridge on publicly accessible land biannually.

**Table 1 - Coding and Descriptions for Component Condition Ratings (FHWA, 2005)**

Code	Condition	Description
N	NOT APPLICABLE	Component does not exist.
9	EXCELLENT	Isolated inherent defects.
8	VERY GOOD	Some inherent defects.
7	GOOD	Some minor defects.
6	SATISFACTORY	Widespread minor or isolated moderate defects.
5	FAIR	Some moderate defects; strength and performance of the component are not affected.
4	POOR	Widespread moderate or isolated major defects; strength and/or performance of the component is affected.
3	SERIOUS	Major defects; strength and/or performance of the component is seriously affected. Condition typically necessitates more frequent monitoring, load restrictions, and/or corrective actions.
2	CRITICAL	Major defects; component is severely compromised. Condition typically necessitates frequent monitoring, significant load restrictions, and/or corrective actions in order to keep the bridge open.
1	IMMINENT FAILURE	Bridge is closed to traffic due to component condition. Repair or rehabilitation may return the bridge to service.
0	FAILED	Bridge is closed due to component condition, and is beyond corrective action. Replacement is required to restore service.

The FHWA also requires a scour condition rating that follows a similar coding format as the deck, substructure, and superstructure rating. **Table 2** shows the description of the scour ratings and coding.

**Table 2 - Coding and Descriptions for Scour Condition Ratings (FHWA, 2005)**

<b>Code</b>	<b>Condition Description</b>
<b>N</b>	<b>Bridge does not cross over water.</b>
<b>9</b>	<b>No scour.</b>
<b>8</b>	<b>Insignificant scour.</b>
<b>7</b>	<b>Some minor scour.</b>
<b>6</b>	<b>Widespread minor or isolated moderate scour.</b>
<b>5</b>	<b>Moderate scour; strength and stability of the bridge are not affected.</b>
<b>4</b>	<b>Widespread moderate or isolated major scour; strength and/or stability of the bridge is affected.</b>
<b>3</b>	<b>Major scour; strength and/or stability of the bridge is seriously affected. Condition typically necessitates more frequent monitoring, load restrictions, and/or corrective actions.</b>
<b>2</b>	<b>Major scour; strength and/or stability of the bridge is severely compromised. Condition typically necessitates frequent monitoring, significant load restrictions, and/or corrective actions to keep the bridge open.</b>
<b>1</b>	<b>Bridge is closed to traffic due to scour condition. Channel rehabilitation may return the bridge to service.</b>
<b>0</b>	<b>Bridge is closed due to scour condition, and is beyond corrective action. Bridge replacement is needed to restore service.</b>

### **Element Based Inspection Data**

In 2011 (updated in 2013), the American Association of State Highway and Transportation Officials (AASHTO) published the first edition of the *Manual for Bridge Element Inspection* (MBEI) (Highway & Officials, 2010). Before its publication, the *AASHTO Guide for Commonly Recognized (CoRe) Structural Elements (Bridges, 1997)*, published in 1997, was the standard for collecting bridge element information. On July 6th, 2012, President Barack Obama signed the Moving Ahead for Progress in the 21st Century Act (MAP-21) into law. MAP-21 focuses on performance-based bridge asset management and requires responsible transportation

agencies to report bridge element data and submit them for the NBI database. Since 2014 all states have transitioned to using element data. The bridge elements in the MBEI are classified into three different categories; Agency-Defined Elements (ADEs), Bridge Management Elements (BMEs), and National Bridge Elements (NBEs). The new MBEI also sets the number of Condition States (CS) at four, where CS1 represents “Good” condition, CS2 represents the “Fair” condition, CS3 represents “Poor” condition, and CS4 represents “Severe” condition. This new manual also separates structural elements and protective elements. For example, a steel girder and steel protective paint are now inspected as separate items. There are varying levels of how state DOTs are incorporating this data in their bridge asset management.

#### **AASHTO Bridge Element Inspection Standards (AASHTO., 2019)**

In 2019, a updated version of the bridge element inspection standards was published. The new guide showed the defects that inspectors are to look for by bridge construction material. Based on the severity of the defect the inspectors were to classify the element in on of the four condition states. The defects for reinforced concrete and steel are shown in **Table 3** and **Table 4**.

**Table 3 – Reinforced Concrete Element Defects (AASHTO., 2019)**

**Defects for Reinforced Concrete**

Defects	CS 1	CS 2	CS 3	CS 4
	GOOD	FAIR	POOR	SEVERE
Delamination/Spall/ Patched Area (1080)	None.	Delaminated. Spall 1 in. or less deep or 6 in. or less in diameter. Patched area that is sound.	Spall greater than 1 in. deep or greater than 6 in. diameter. Patched area that is unsound or showing distress. Does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or bridge; OR a structural review has been completed and the defects impact strength or serviceability of the element or bridge.
Exposed Rebar (1090)	None.	Present without measurable section loss.	Present with measurable section loss but does not warrant structural review.	
Efflorescence/Rust Staining (1120)	None.	Surface white without build-up or leaching without rust staining.	Heavy build-up with rust staining.	
Cracking (RC) (1130)	Insignificant cracks or moderate-width cracks that have been sealed.	Unsealed moderate-width cracks, or unsealed moderate pattern (map) cracking.	Wide cracks or heavy pattern (map) cracking.	
Abrasion/Wear (PSC/RC) (1190)	No abrasion or wearing.	Abrasion or wearing has exposed coarse aggregate but the aggregate remains secure in the concrete.	Coarse aggregate is loose or has popped out of the concrete matrix due to abrasion or wear.	
Settlement (4000)	None.	Exists within tolerable limits or arrested with no observed structural distress.	Exceeds tolerable limits but does not warrant structural review.	
Scour (6000)	None.	Exists within tolerable limits or has been arrested with effective countermeasures.	Exceeds tolerable limits but is less than the critical limits determined by scour evaluation and does not warrant structural review.	
Damage (7000)	Not applicable.	The element has impact damage. The specific damage caused by the impact has been captured in CS 2 under the appropriate material defect entry.	The element has impact damage. The specific damage caused by the impact has been captured in CS 3 under the appropriate material defect entry.	The element has impact damage. The specific damage caused by the impact has been captured in CS 4 under the appropriate material defect entry.

**Table 4 – Steel Element Defects (AASHTO., 2019)**

**Defects for Steel Elements**

Defects	CS 1	CS 2	CS 3	CS 4
	GOOD	FAIR	POOR	SEVERE
Corrosion (1000)	None.	Freckled rust. Corrosion of the steel has initiated.	Section loss is evident or pack rust is present but does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or bridge; OR a structural review has been completed and the defects impact strength or serviceability of the element or bridge.
Cracking (1010)	None.	Crack that has self-arrested or has been arrested with effective arrest holes, doubling plates, or similar.	Identified crack that is not arrested but does not warrant structural review.	
Connection (1020)	Connection is in place and functioning as intended.	Loose fasteners or pack rust without distortion is present but the connection is in place and functioning as intended.	Missing bolts, rivets, or fasteners; broken welds; or pack rust with distortion but does not warrant a structural review.	
Distortion (1900)	None.	Distortion not requiring mitigation or mitigated distortion.	Distortion that requires mitigation that has not been addressed but does not warrant structural review.	
Settlement (4000)	None.	Exists within tolerable limits or arrested with no observed structural distress.	Exceeds tolerable limits but does not warrant structural review.	
Scour (6000)	None.	Exists within tolerable limits or has been arrested with effective countermeasures.	Exceeds tolerable limits but is less than the critical limits determined by scour evaluation and does not warrant structural review.	
Damage (7000)	Not applicable.	The element has impact damage. The specific damage caused by the impact has been captured in CS 2 under the appropriate material defect entry.	The element has impact damage. The specific damage caused by the impact has been captured in CS 3 under the appropriate material defect entry.	

These tables were also updated to include photos for inspectors to use to gauge severity.

This guide also provides definitions for each of the elements that inspectors classify on bridges.

**Element Health Index**

“According to Pontis theory (AASHTO, 2003) , the element health index is the ratio of the sum of the current quantities in each condition state multiplied by corresponding coefficients, over the initial total quantity of the element” (Jiang & Rens, 2010). Using the four condition state

percentages provided by the NBI element inspection data, the overall health of the element can be calculated in a condition index (CI) range. This CI rating is a numerical value ranging from 0% to 100% that rates the current state of the element. Using the CI states can help with bridge management practices because the EHI can also better quantify the health of individual bridge components.

**Table 5 - Nonlinear Health Index Coefficients (Jiang & Rens, 2010)**

Number of condition states	State 1	State 2	State 3	State 4	State 5
3	1.00	0.20	0.00		
4	1.00	0.40	0.10	0.00	
5	1.00	0.60	0.30	0.10	0.00

**Table 6 - Condition Index Zones (Jiang & Rens, 2010)**

Zone	CI range (%)	Action
1	71–100	Immediate action not required
2	41–70	Economic analysis of repair alternatives recommended to determine appropriate maintenance action
3	0–40	Detailed evaluation required to determine the need for repair, rehabilitation or reconstruction, safety evaluation recommended

**Table 7 - Condition Index Scales (Jiang & Rens, 2010)**

Value	Condition description
85–100	Excellent—no noticeable defects, some aging or wear visible
70–84	Very good—only minor deterioration or defects evident
55–69	Good—some deterioration or defects evident, function not impaired
40–54	Fair—moderate deterioration, function not seriously impaired.
25–39	Poor—serious deterioration in at least some portion of structure, function seriously impaired
10–24	Very poor—extensive deterioration, barely functional
0–9	Failed—general failure or failure of a major component no longer functional

## **Risk as a Requirement in BAMPs (FHWA, 2017)**

“The Moving Ahead for Progress in the 21st Century Act (MAP-21) amended 23 U.S.C. 119 to require State Departments of Transportation (DOTs) to develop risk-based Transportation Asset Management Plans (TAMPs). On October 24, 2016, the Federal Highway Administration (FHWA) adopted a final TAMP rule that elaborates on the MAP-21 requirements.” (FHWA, 2017). In 2017 the FHWA released a document that offers guidance on how risk can be applied to help meet these risk-based requirements on TAMPs.

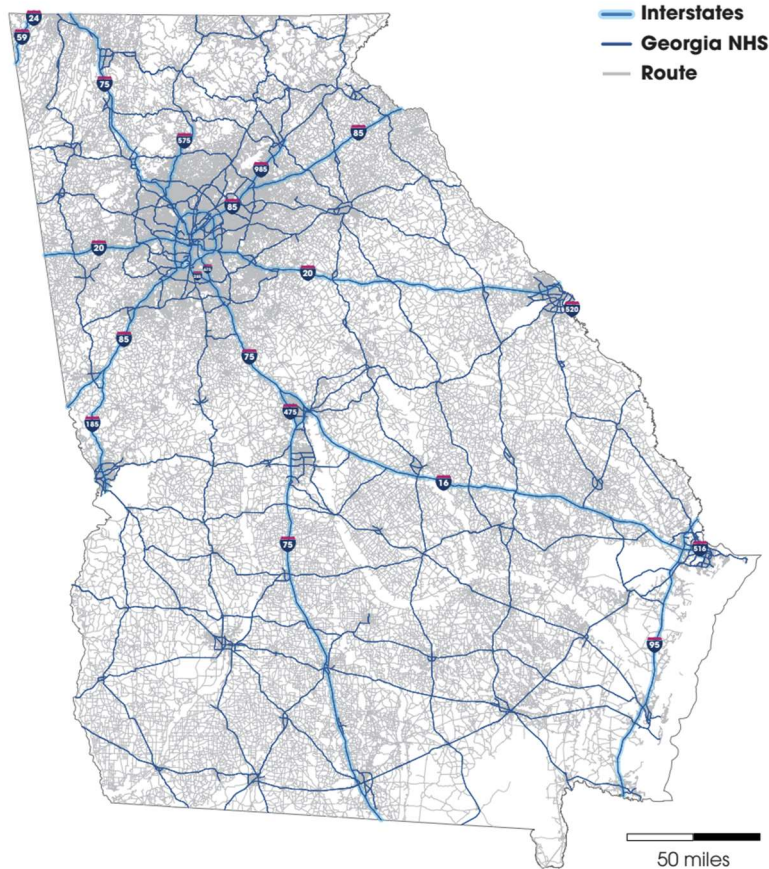
The FHWA defines a risk-based management plan as one “that identifies, assesses, and prioritizes the uncertainties, variability, and threats that could impede its objectives” (FHWA, 2017). The FHWA proposes a multi-step process in incorporating risk into TAMPs. The second step is risk identification, which entails identifies threats, opportunities, uncertainty, and variability that can impact transportation assets. Later in the document, the FHWA states that current and future environmental conditions are one of the most likely current and future risks to be identified by agencies. The FHWA then states that for climatic and geological risks, the agencies may want to create a summary of how they impact resources, performance, and influence tradeoffs, now and in the future.

Additionally, Bipartisan Infrastructure Law (BIL) went into effect on October 1, 2021. This BIL takes the requirement of risk further and makes including extreme weather and resilience a requirement of their risk management plans. Many state departments of transportation are due to report a new TAMP in 2022 (including GA) and must include this in the new TAMP to be considered for approval. The FHWA expects these new TAMPs will “clearly explain the processes used to develop extreme weather and resilience portions of the risk

management and life cycle planning portions of the TAMP” and “include discussions of extreme weather and resilience in the risk management and life-cycle planning sections of the TAMP.”

### **Current GDOT Bridge Asset Management Practices (GDOT, 2019)**

The Georgia Department of Transportation currently has its Transportation Asset Management Plan (TAMP) for fiscal years 2019-2028 publicly and accessible online. Georgia's TAMP meets the requirements of a TAMP described in Title 23 Code of Federal Regulations. This TAMP focuses on bridges on the health of bridges and pavements on the National Highway System (NHS). **Figure 1** displays the 7,100 miles of centerline and the 4,050 bridge structures that are a part of the NHS system in Georgia as of 2019. The 4,050 bridges have a total deck area of 65,732,990 square feet. Even though the scope of the TAMP focuses on these assets, GDOT states that the TAMP also considers other transportation systems.



**Figure 1 - National Highway System in Georgia \*NTS (GDOT, 2019).**

Engineers have designed most of the bridges in the Georgia NHS with a 50-year lifespan and recently constructed bridges with a 75-year lifespan. GDOT believes these bridges can outlive these lifespans with appropriate preservation steps. However, GDOT recognizes that "the planning of preservation work is partly a scientific activity that depends on research about deterioration, risks and costs." (GDOT, 2019) Different aspects of bridges deteriorate at different rates, so careful planning is required to manage assets properly. GDOT gives an example: expansion joints wear out quickly, decks degrade at a moderate rate, and piers generally last a long time.

GDOT uses AASHTOWare Bridge Management software (BrM) to track inventory, condition states and plan maintenance. The BrM considers the NBI data and the AASHTO-regulated element data. GDOT has input bridge treatments and typical costs they utilize to maintain and improve performance in BrM software.

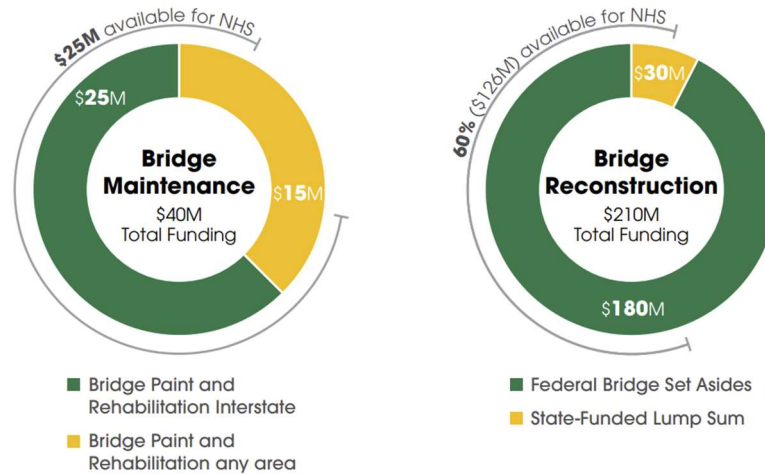
**Table 8 - Summary of GDOT Treatments by Work Type (GDOT, 2019)**

<b>Work Type</b>	<b>Treatment Description</b>	<b>Typical Treatments</b>	<b>Approximate Unit-Cost</b>
<b>Maintenance</b>	Condition-based or interval-based activities that do not require engineering or multi-year programming, usually determined by local crews.	<ul style="list-style-type: none"> <li>• Drift removal</li> <li>• Deck sweeping and/or bridge washing</li> <li>• Minor deck spall repairs or deck crack sealing</li> <li>• Cleaning of scuppers and expansion joints</li> <li>• Cleaning and lubrication of bearings</li> <li>• Spot painting of girder ends or bearings</li> </ul>	\$4 to \$25 per square foot
<b>Preservation</b>	Actions or strategies that prevent, delay or reduce deterioration of bridges or bridge elements.	<ul style="list-style-type: none"> <li>• Seal bridge decks (polymer overlay)</li> <li>• Paint steel super and substructure components</li> <li>• Joint replacements or resealing of joints</li> <li>• Minor spall repairs to the super and substructure components</li> <li>• Edge beam reconstruction</li> <li>• Major deck spall repairs</li> <li>• Slope paving repair</li> <li>• Installation of sway bracing</li> <li>• Epoxy injection of cracks</li> <li>• Header repair</li> </ul>	\$7 to \$42 per square foot
<b>Rehabilitation</b>	Major work required to restore or increase the structural integrity of a bridge, as well as improvements to function, capacity, resilience or safety.	<ul style="list-style-type: none"> <li>• Deck Rehab</li> <li>• Latex overlay</li> <li>• Polyester Polymer Concrete Overlay</li> <li>• Hydro-blasting of the bridge deck overlay</li> <li>• Replacement of the deck</li> <li>• Pile encasements/jacketing</li> <li>• Bridge jacking to reset bearings or increase vertical clearance</li> <li>• Steel or concrete beam repair or replacement</li> <li>• Major spall repairs to the super and substructures components</li> <li>• Scour counter measures</li> <li>• Carbon-reinforced polymer repairs and strengthening</li> <li>• Wingwall repair on culverts</li> <li>• Heat straightening of damage steel beams</li> <li>• Widening of the bridge</li> </ul>	\$43 to \$82 per square foot
<b>Reconstruction</b>	Bridge Replacement – Removal of an existing bridge and construction of a replacement bridge to serve the same alignment as the removed bridge.		\$250 per square foot

GDOT utilizes actions in the "Maintenance" section in **Table 8** to slow the rate of deterioration. These action items are generally low-cost and minimally disruptive.

In regard to risk, GDOT has included this per MAP-21. GDOT defines extreme weather events and natural disasters as risk items. A GDOT funding reserve exists for transportation asset repair in the case of a natural disaster. Additionally, Georgia has identified areas of Georgia that are at increased risk of natural disasters and extreme weather events. GDOT mentions flooding, storms, and fires as potential extreme weather or natural disaster risks. Georgia's TAMP does not mention extreme climatic factors that certain regions of Georgia experience as a risk factor. For example, Northern counties experience higher rainfall and freeze-thaw cycles, while coastal counties can experience exposure to salt-related environmental experiences.

In the TAMP GDOT also provides a framework for the funds available for bridge investment. **Figure 2** summarizes the bridge maintenance and reconstruction funding available for SRS and NHS bridges. For maintenance there was \$40 million projected to be available in 2020, with \$25 million going towards interstate rehabilitation and the remaining \$15 million able to be used in any area. \$25 million (62.5%) is available for NHS bridges. For bridge reconstruction there was \$210 million projected for 2021, with \$180 million being set aside for federal bridges. Up to \$126 million was available to use for NHS bridges.



**Figure 2 - Funds Available for SRS Maintenance and Reconstruction (GDOT, 2019)**

It is important to note that Georgia's TAMP guide lacks any discussion on helping support local municipalities that must maintain and reconstruct bridges. Although these county and city-owned bridges fall outside the scope of GDOT's TAMP, they are used by state citizens and are vital for local economies, which are vital for the state's overall health.

### ***Current GDOT Maintenance Priority System***

Mr. Byron Patterson, the bridge asset manager at GDOT, was contacted to ask about GDOT's priority definitions and maintenance practices. These are for internal communication only and are not under any federal policies. Grading a maintenance need is subjective, and allotment varies in different inspection teams.

**Table 9** presents each priority level and a brief description. Mr. Patterson also noted that GDOT plans on implementing a "B+" maintenance priority, but this priority level is not currently in use.

**Table 9 – GDOT Maintenance Priority Summary**

<b>Priority</b>	<b>Priority Descriptions</b>
<b>A</b>	Immediate maintenance required; current condition poses a hazard to public safety
<b>B</b>	Schedule maintenance
<b>C</b>	Preventative maintenance

In addition to these definitions, each maintenance activity has a corresponding code and description of each priority class for the specific activity.

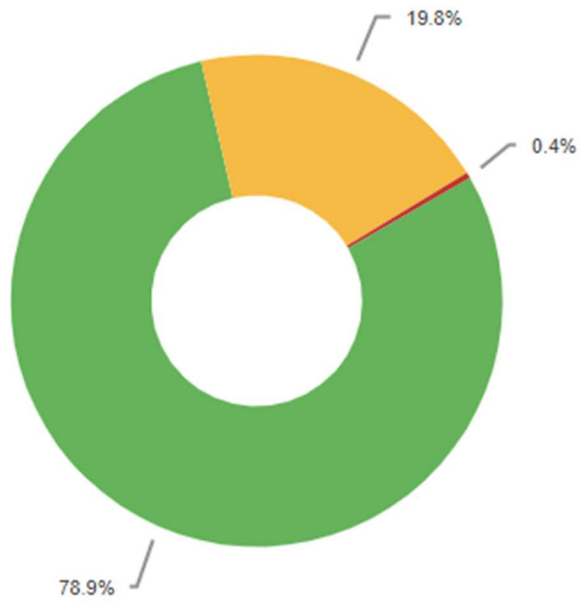
**Current Bridge Conditions in Georgia**

Georgia’s bridges are primarily owned and maintained by two ownership groups, state and county agencies. Looking at these ownership groups, one can see that bridges owned and maintained by state agencies are in significantly better condition than county-owned bridges.

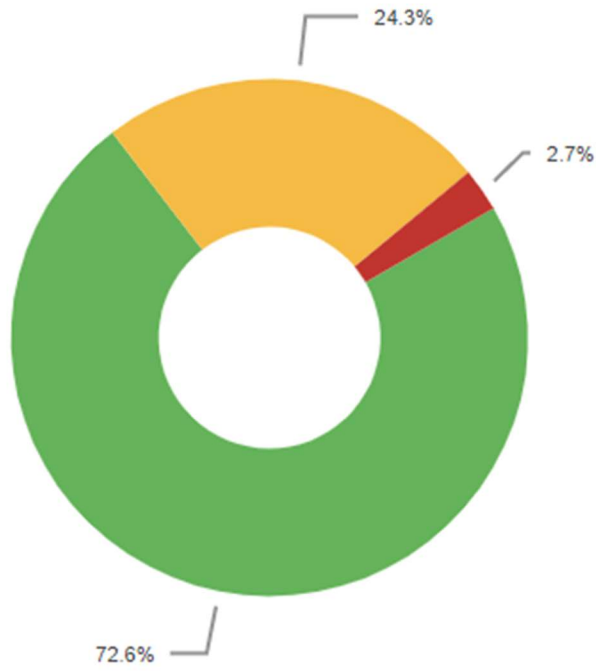
In Georgia, as of November 2022, 6,894 bridges are owned and maintained by the state. These bridges have an average deck and substructure condition rating of 6.9 and an average superstructure rating of 7.2. Of these bridges, only 25 or 0.4% are in “poor” condition, and only 36 have a reduced load posting.

On the other hand, as of November 2022, 7,187 bridges in Georgia are owned and operated by county agencies. The average deck rating of these bridges is 6.8, the superstructure rating is 6.9, and the average substructure rating is 6.7. However, 191 county-owned bridges, or 2.7%, are in poor condition. Additionally, 1,242 bridges have a posting for a reduced load rating.

These statistics show that the county-owned bridges lag in conditions in Georgia. This report will attempt to determine if climatic impacts disproportionately impact county-owned bridges.



**Figure 3 – Current Georgia State-Owned Bridge Condition (Good, Fair, Poor)**



**Figure 4 – Current County-Owned Bridges Condition (Good, Fair, Poor)**

## **IMPACT OF WEATHER ON BRIDGE INFRASTRUCTURE**

Climate and weather patterns affect all forms of transportation infrastructure, and bridge assets are not exempt. There have been many studies done examining the impacts of weather and climate on bridge infrastructure. For example (Berg et al., 2006) concluded that one of the most important factors impacting deck life was reinforcing steel corrosion. Cracks in concrete allow aggressive agents to attack reinforcing steel (Kan et al., 2010).

### **Terminology Commonly Used in Bridge Asset Management**

It is important to understand terms commonly used by inspectors and engineers in bridge asset management reports. The following terms are commonly used by engineers and/or inspectors to describe deterioration of various bridge components.

#### *Spalling*

A *concrete spall* is a depression resulting from the separation or removal of concrete from the surface of the concrete. Generally, a concrete fracture is parallel to the structure. This fracture is caused by overstressing of the concrete. Once the fracture initiates a crack, it grows wider from debris, freeze/thaw cycles, and additional overstress. During this cycle, the fracture will increase in size until a crack grows until it forms a spall is formed. (FHWA, 2012) The FHWA defines a *large spall* as any spall greater than 6” in diameter or 1” deep. Spalling can weaken the structure and make the structure susceptible to more damage.

#### *Freeze-Thaw Cycles*

Freeze-thaw cycles are the result of water freezing in the capillaries and pores of concrete mixtures. The result of this freezing is the overstressing of the concrete, which leads to cracking,

crumbling, and scaling. The pressure caused by freeze-thaw cycles causes deterioration of concrete. (FHWA, 2012)

### *Efflorescence*

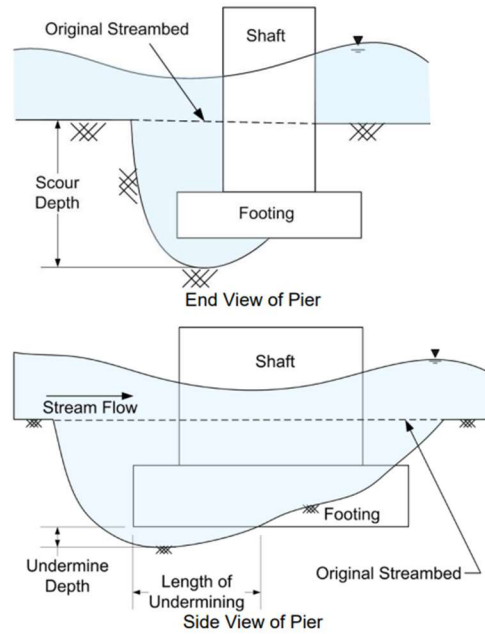
When moisture seeps into cracks on a concrete surface and there is an increased flow of moisture within the concrete. The increased flow of moisture can create a whitish surface deposit that appears on the face on the concrete. This phenomenon is called efflorescence. Efflorescence is the result of calcium carbonate leached from concrete and other carbonate and chloride compounds. Generally bridges that have efflorescence staining are located in humid environments.

### *Scour*

The FHWA defines scour as “the engineering term for erosion caused by water of the soil surrounding a bridge foundation. (Arneson et al., 2012) Currently the FHWA has three manuals issued to provide guidance on bridge scour. These manuals are *HEC-18: Evaluating Scour at Bridges*, *Hec-20 Stream Stability of Highway Bridges*, and *HEC-23 Bridge Scour and Stream Instability Countermeasures*. In *HEC-18* the FHWA presents several variables that can cause scour, including rainfall, river geometry and bridge geometry.

### *Undermining*

Undermining occurs when supporting material is scoured away from under the substructure. Undermining requires immediate correction as it can affect the stability of a structure. **Figure 5** shows an image of scour caused undermining.



**Figure 5 – Scour and Undermining (FHWA, 2012)**

### *Drift*

Drift occurs when floating debris in a body of water accumulates at the foundation of a bridge. Often, it is wood from trees that have fallen into the water. Drift accumulation can increase during a flood event and seriously damage a structure or lead to a failure. The main issues that can occur from drift are damage to structural elements, risk of flooding upstream, increased sediment buildup, and contributions to scour (Schmocker & Hager, 2010)

### *Honeycombing*

*Honeycombing* is a concrete defect in which the concrete was not properly consolidated. Reasons for poor consolidation could include poor consolidation methods or poor framework design. Voids then occur due to coarse and fine aggregates and cement segregation (Dawari & Vesmawala, 2013).

### Other Factors Impacting Bridge Condition (FHWA, 2017)

Weather is not the only factor impacting bridge condition ratings. Thus, it is important to recognize other factors that can impact bridge conditions. The FHWA recommends including other types of data in any vulnerability study relating to weather. Some of the factors outside of weather that have an impact on bridge conditions are presented in **Table 10**.

**Table 10 - Asset Data Useful for Vulnerability Assessment (FHWA, 2017)**

<b>Factors Impacting Asset Condition</b>
Age of Asset
Design Life and Stage of Life
Geographic Location
Elevation Information
Current and Historical Condition
Level of Use (Past/Present/Future)
Replacement Cost
Maintenance Schedule and Cost
Structural Design
Materials Used in Construction and Repair
Degree of Redundancy

Many of these factors will be considered in this study due to their availability in the NBI database, NBI element database, and the GDOT application, InspectX. The age of the asset, location, elevation, and condition are accessible in the NBI database. The Average Daily Traffic (ADT) is also available, but there are questions to the accuracy of this data (Trammell). These

data points will be used to help determine how the climatic factors are impacting bridges in Georgia. The structural design, maintenance information, and historical condition can be closely analyzed by using the GDOT tool InspectX. By considering multiple factors impacting bridge conditions and using historical inspection reports and photos, GDOT can better understand how the weather impacts bridge conditions.

### **Vulnerability and Adaption Framework (FHWA, 2017)**

The definition that the FHWA gives for a vulnerability assessment is an “assessment that examines how climate stressors (e.g., increased annual precipitation) may directly or indirectly affect important transportation assets (e.g., bridges).” This guide produced by the FHWA gives a guide on completing a vulnerability impact assessment. The first step is to define the study scope and articulate objectives. Articulating objectives early in the project helps to define the level of detail, data types, tools, and skills required to carry out the assessment. The FHWA recognizes that there can be a wide range of planned studies, from comprehensive network studies to detail-specific analyses. The next step in the process is to define a study scope. The FHWA recommends when creating a scope to select the transportation asset of study and identify key climate variables that may impact those assets. Researchers can consider various factors when selecting assets to include in a study, including jurisdictional, geographic, stage of life, most critical, representative, and planned assets. Data availability can play a significant role in selecting what assets researchers include in the study. Next, the selection of climate variables to include in the study comes into play. The FHWA defines *climate variable* as “the condition (e.g., precipitation) that affects the transportation system and will be analyzed in a vulnerability assessment” and defines *climate stressor* (e.g. hazard/threat) as “the magnitude(s) of the climate variable (e.g., more frequent precipitation events) that may harm the system.” The FHWA gives

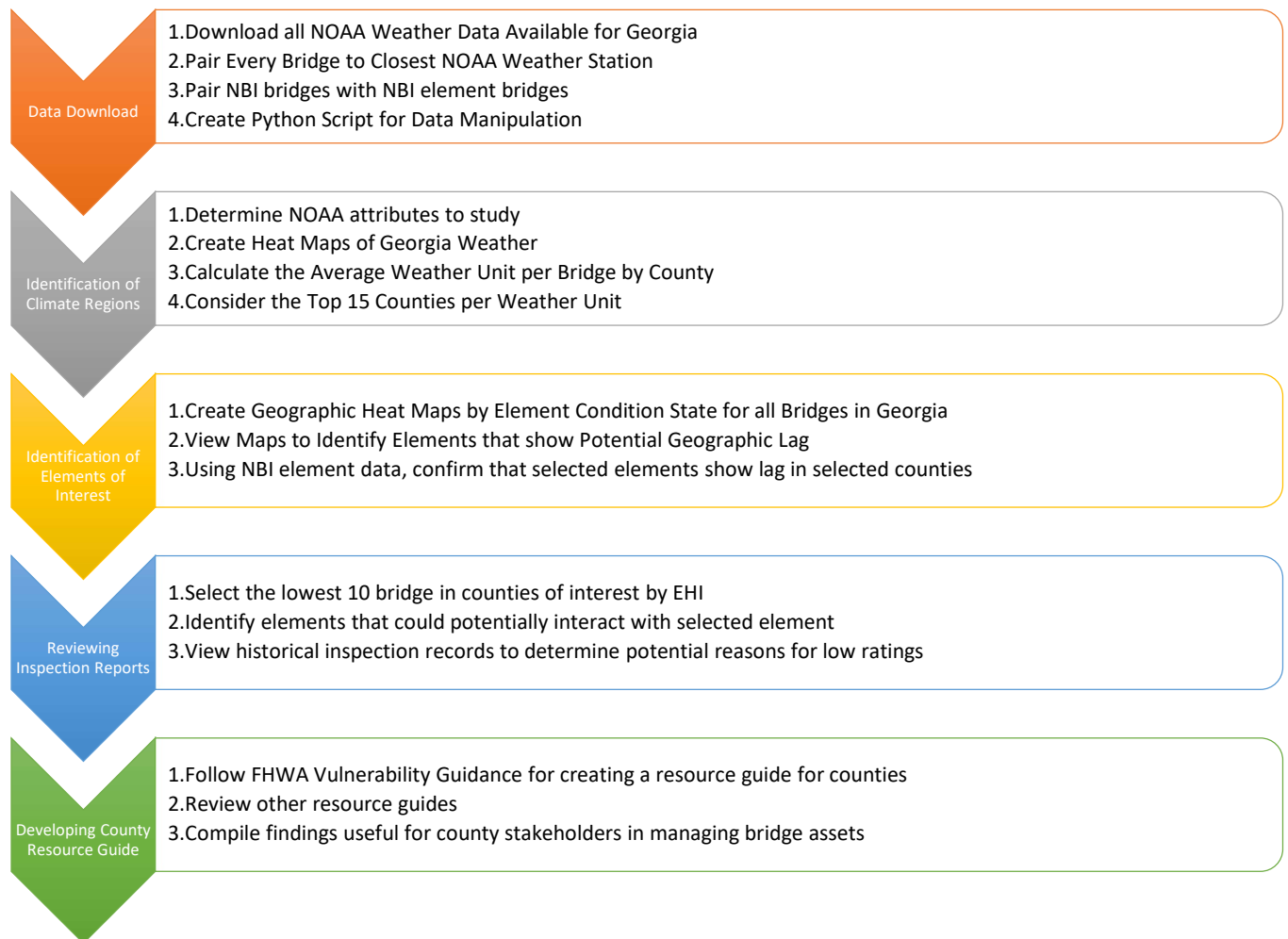
some examples of climate variables that could impact transportation systems; they include temperature, precipitation, sea level, storm surges and waves, permafrost thaw, streamflow, and drought. The vulnerability assessment should focus on the climatic factors that will significantly impact the regional transportation network. After determination of the scope of the study, FHWA recommends a download of data and gives best practices for downloading data. After compiling data, the study team can create an assessment of vulnerability and identification of adaptation options.

## CHAPTER 2. RESEARCH METHODOLOGY AND RESULTS

### ANALYSIS METHODOLOGY

The methodology to account for weather factors and their potential impact on bridge assets in Georgia is described in this chapter. Additionally, based on preliminary research during literature review it is evident that county owned bridges are lacking in condition ratings compared to state owned bridges. While looking at elements impacted by weather, state vs county owned bridges will also be looked at.

**Table 11 – Analysis Methodology**



## Download NOAA Data

The first step in the analysis process was downloading weather data to analyze climatic elements. NOAA weather data was selected for download based on the FHWA's *Vulnerability Assessment and Adaption Framework*. This guide for state transportation agencies gives recommendations for climate data resources for a vulnerability study. One of the sources this guide recommends is federal science and engineering agencies and lists the National Oceanic Atmospheric Agency (NOAA) as an agency that has relevant historical weather data. After accessing the site, the dataset chosen was the Global Summary of the Year (GSOY) Version 1 from the National Oceanic and Atmospheric Administration. This dataset provided weather data gathered from over 200 weather stations throughout Georgia and contained several significant parameters related to precipitation and temperature, which are displayed in **Table 12**. Unfortunately, not all weather stations could be used for this research because many contained null values for many parameters. Once the null values had been removed, approximately 50 weather stations for the state were available per year. This dataset is gathered from the Global Historical Climatology Network (GHCN), a historical weather dataset managed by the National Climatic Data Center (NDCC). This dataset consists of weather stations fixed to the Earth's surface that report daily precipitation and temperature data. The annual averages in this dataset are computed from the monthly data, and annual values are set to null if one or more months of data is excluded.

**Table 12 – Weather Variables Available in the NOAA Dataset**

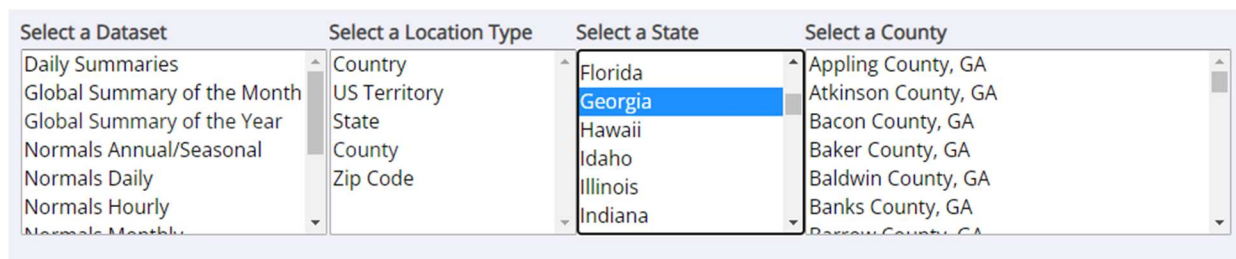
<b>Variable Name</b>	<b>Number of Characters (If Applicable)</b>	<b>Variable Description</b>
STATION	11	Station Identification Code
LATITUDE	8	Latitude in decimated degrees
LONGITUDE	9	Longitude in decimated degrees

ELEVATION	13	Elevation above MSL in meters
DATE	4	Year of record
AWND	-	Average Annual Windspeed, miles per hour
CDS D	-	Number of days with a mean temperature of greater than 65° Fahrenheit
DP01	-	Number of days with greater than or equal to 0.01" of precipitation for the given year.
DP10	-	Number of days with greater than or equal to 0.1" of precipitation for the given year.
DP1X	-	Number of days with greater than or equal to 1.0" of precipitation for the given year.
DSND	-	Number of days with greater than or equal to 1.0" of snowfall for the given year.
DT00	-	Number of days with a maximum temperature of less than or equal to 0 degrees Fahrenheit.
DT32	-	Number of days with a maximum temperature of less than or equal to 32 degrees Fahrenheit.
DX70	-	Number of days with a maximum temperature less than or equal to 70
DX90	-	Number of days with a maximum temperature greater than or equal to 90
EMNT	-	Lowest daily minimum temperature for the year, given in Fahrenheit
EMSD	--	Highest daily snow depth for the year, given in inches
EMSN	-	Highest daily snowfall in the year, given in inches
EMXP	-	Highest daily total of precipitation, given in inches
EMXT	-	Highest daily maximum temperature for the year, given in Fahrenheit
HDSD	-	Number of days with a mean temperature of less than 65° Fahrenheit
PRCP	-	Total annual precipitation, given in inches
SNOW	-	Total annual snowfall, given in inches

TAVG	-	Average Annual Temperature, given in Fahrenheit
TMAX	-	Average of mean monthly maximum temperatures, given in Fahrenheit
TMIN	-	Average of mean monthly minimum temperatures, given in Fahrenheit







Note: '-' indicates Not Applicable

To download the data, a summary of each county was downloaded. **Figure 6** shows the interface used on the NOAA website. First, the "Global Summary of Year" was selected, then "County" was the location type selected. Next, "Georgia" was selected as the state, and each county was selected once.



**Figure 6 – NOAA Weather Download Interface Step 1**

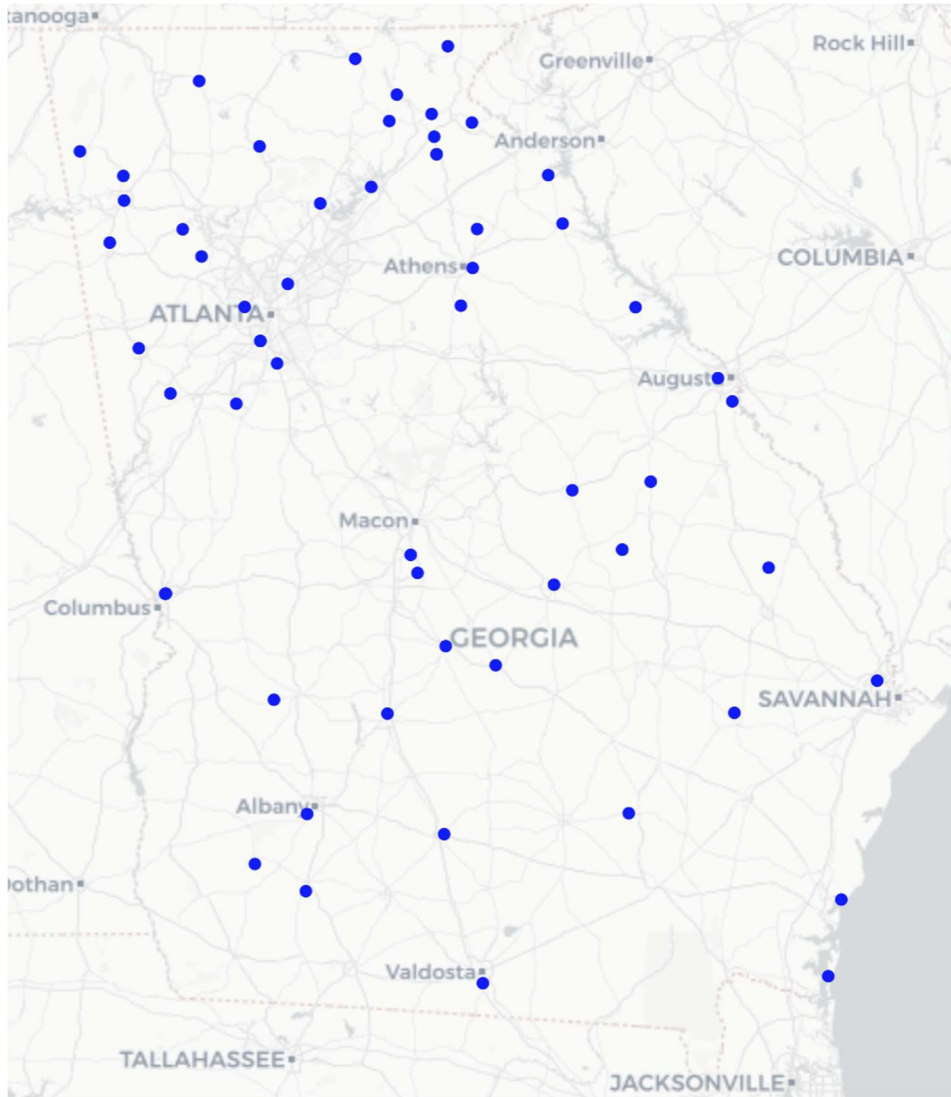
After selecting the county, the user adds the location to the cart. The location includes all current and historical NOAA weather stations in the county. For example, **Figure 7** shows the six weather stations that are or were historically located in Appling County.

STATION DETAILS	
<p><b>BAXLEY 0.7 NNE, GA US</b>  <a href="#">View Full Details</a>             Station ID: GHCND:US1GAAP0005            Period of Record: 2020-01-01 to 2021-01-01</p>	<a href="#">ADD TO CART</a>
<p><b>BAXLEY 3.0 NW, GA US</b>  <a href="#">View Full Details</a>             Station ID: GHCND:US1GAAP0006            Period of Record: 2019-01-01 to 2020-01-01</p>	<a href="#">ADD TO CART</a>
<p><b>BAXLEY 5 NNW, GA US</b>  <a href="#">View Full Details</a>             Station ID: GHCND:USC00090670            Period of Record: 2005-01-01 to 2015-01-01</p>	<a href="#">ADD TO CART</a>
<p><b>BAXLEY GEORGIA, GA US</b>  <a href="#">View Full Details</a>             Station ID: GHCND:USR0000GBAX            Period of Record: 2004-01-01 to 2021-01-01</p>	<a href="#">ADD TO CART</a>
<p><b>PINEY BLUFF, GA US</b>  <a href="#">View Full Details</a>             Station ID: GHCND:USC00097055            Period of Record: 1943-01-01 to 1948-01-01</p>	<a href="#">ADD TO CART</a>
<p><b>SURRENCY, GA US</b>  <a href="#">View Full Details</a>             Station ID: GHCND:USC00098476            Period of Record: 1956-01-01 to 2003-01-01</p>	<a href="#">ADD TO CART</a>

**Figure 7 – NOAA Weather Download Interface Step 2, Applying County**

Once the county's station is in the cart, the user can select the output format between "pdf" and "CSV." For this use, the "CSV" output was selected. Next, the date range was selected, and all available data were selected for this use. The years of available data for each county were variable and were dependent on the weather station's years of availability. After selecting the years of data, the data types were selected. For the initial download, all the data available at each station was selected. However, not all stations recorded the same data. For example, some stations did not have the capability to measure snow accumulation. The data downloaded is summarized in **Table 12**. The CSV file was renamed as the data was downloaded to match the corresponding county. Following this process, a dataset of all NOAA weather stations in Georgia was assembled in CSV format. This process also ensured that no stations were skipped or repeated. These individual county CSV files were combined using a python command to create a

single Georgia dataset that could be used in further analysis. After assessing the dataset, it was determined that there was an adequate resolution, specifically in North Georgia, where the daily climatic factors are extreme.



**Figure 8 - Spatial Distribution of NOAA Weather Stations in Georgia with 2021 data**

Once the weather data was downloaded the climatic attributes of interest were selected. This study intends to identify the “extreme” climatic factors that impact the structure daily. For example, an extreme event like a hurricane or tornado may have a large impact on structures. However, this study looks to study the effects of more extreme daily climatic impacts. For

example, regions of Georgia that experience colder/hotter temperatures, more rain, or salt. These events are not out of the ordinary for these specific regions, but Georgia is a diverse state and the different climatic conditions bridge assets must be resilient against varies regionally.

After defining this project scope, the weather variables of study were chosen to study. The first weather variable that was chosen to study was days where the highest recorded temperature remained below 32 degrees Fahrenheit, this will be referred to as DT32 for the remainder of the paper. This variable was selected to help study the bridges in Georgia that experience the coldest weather.

The next NOAA variable selected for study was days with greater than or equal to 0.10” of precipitation, which will be referred to as DP10 throughout this report. This factor was selected to consider not just areas that receive precipitation, but to study areas that receive heavy sustained rainfall. It is expected that these rainfall events will have a larger impact on bridge assets than smaller precipitation events.

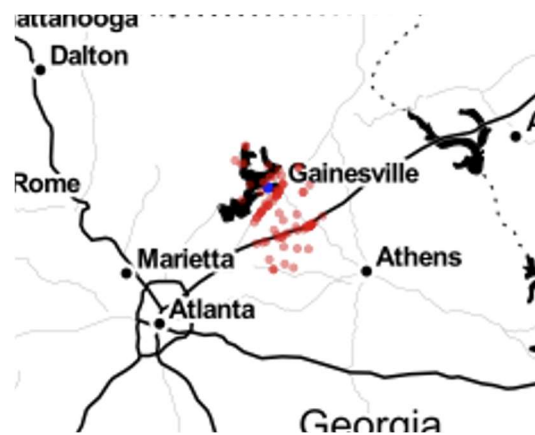
Additionally, days with a temperature of over 90 degrees Fahrenheit will be studied to try and find elements that are prone to degradation when exposed to high heat. This climatic factor will be referred to as DX90 for the remainder of the paper.

Snow and coastal counties are also to be studied. These climatic factors are not extreme, but the present unique challenges in asset management that other counties/regions of Georgia do not experience.

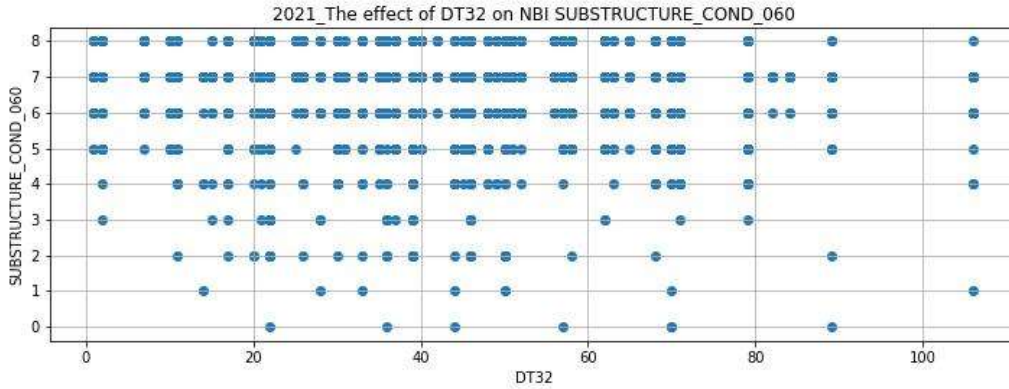
### **Pairing Bridge Assets to Weather Stations**

After downloading the weather data in Georgia, it became essential to match each weather station with a bridge asset. This matching process was completed using the haversine formula to match every bridge asset to the nearest weather station. By doing this, every bridge in the state is

assigned a value for each of the parameters offered by the NOAA weather dataset. Figures were then generated to show each weather station and the paired bridges assets. **Figure 9** shows an example of a weather station pairing with state-owned bridge assets. This process is accomplished by sorting the weather data by year. This process was done by isolating weather data annually using tools in python. Weather stations in Georgia and the bridges assets in Georgia change year to year. For example, new bridges and weather stations are built and decommissioned annually. Once this process was complete, a dataset with each bridge ID and corresponding weather data was assembled in order to combine the NBI and weather data. By combining the weather and bridge dataset the approximate weather the bridge experiences on an annual basis was known. Initially a data analysis was conducted using xy plots to try and determine correlation between climatic factors on NBI data. However, after producing the plots no clear correlations were observed. An example of one of the plots is shown in **Figure 10**.



**Figure 9 - Station USC00093621 (Blue) Paired to Nearest Bridge Assets (Red)**



**Figure 10 – Days Under 32° F vs NBI Substructure Condition**

### *Haversine Formula*

The Haversine formula was implemented using a Python script to determine the distance between the bridges and the weather stations based on the locations provided by the NOAA data and the NBI data. The Haversine formula is a method that determines the distance between two points on a circle and is shown in **Eq 1**, where  $\zeta_1$  and  $\zeta_2$  are the latitude of point the bridge and the weather station in radians.  $\lambda_1$  and  $\lambda_2$  are the longitude of the bridge and weather station in radians.

$$\mathbf{hav}(\theta) = \mathbf{hav}(\zeta_2 - \zeta_1) + \mathbf{cos}(\zeta_1) \mathbf{cos}(\zeta_2) \mathbf{hav}(\lambda_2 - \lambda_1) \quad \mathbf{Eq (1)}$$

Next, the haversine function is applied to the central angle equation and gives the following equation:

$$\mathbf{hav}(\theta) = \mathbf{sin}^2\left(\frac{\theta}{2}\right) = \mathbf{(1 - cos}(\theta)\mathbf{)/2} \quad \mathbf{Eq (2)}$$

The next step to solving the distance formula is to use the arcsin function. This step will give the following equation:

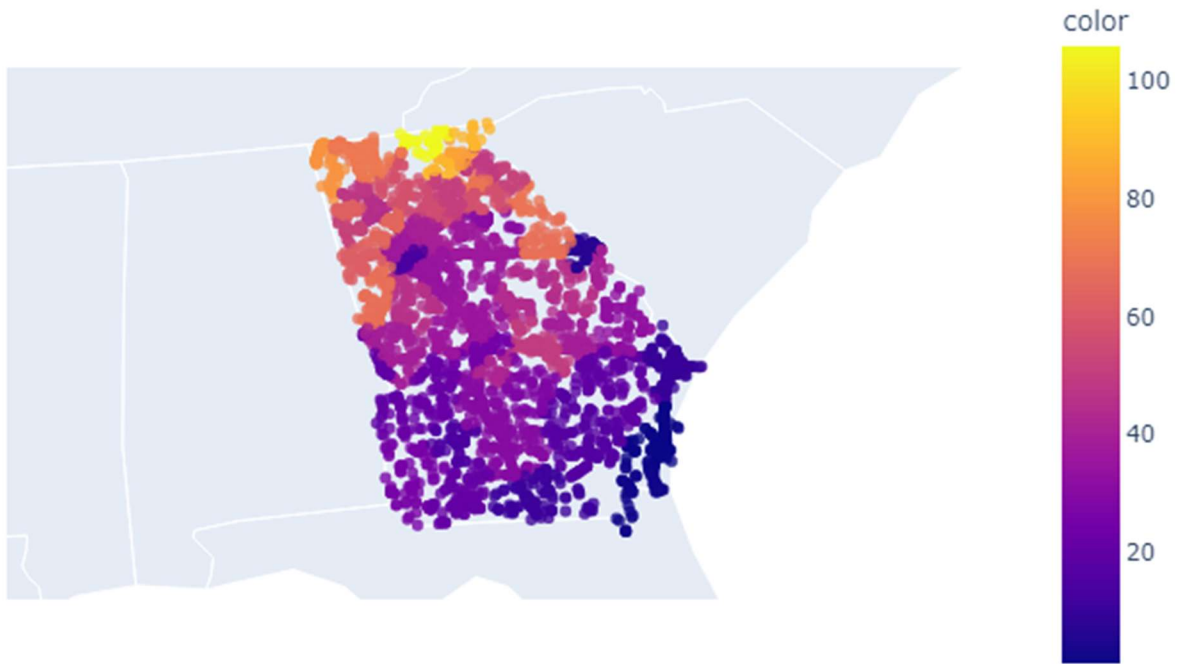
$$d = 2r \arcsin (\sqrt{\sin^2((\zeta_2 - \zeta_1)/2) + \cos(\zeta_1)\cos(\zeta_2)\sin^2((\lambda_2 - \lambda_1)/2)} \quad \text{Eq (3)}$$

The Python script replicates this formula and matches each bridge with the closest weather station.

### *Generation of NOAA Weather Heat Maps*

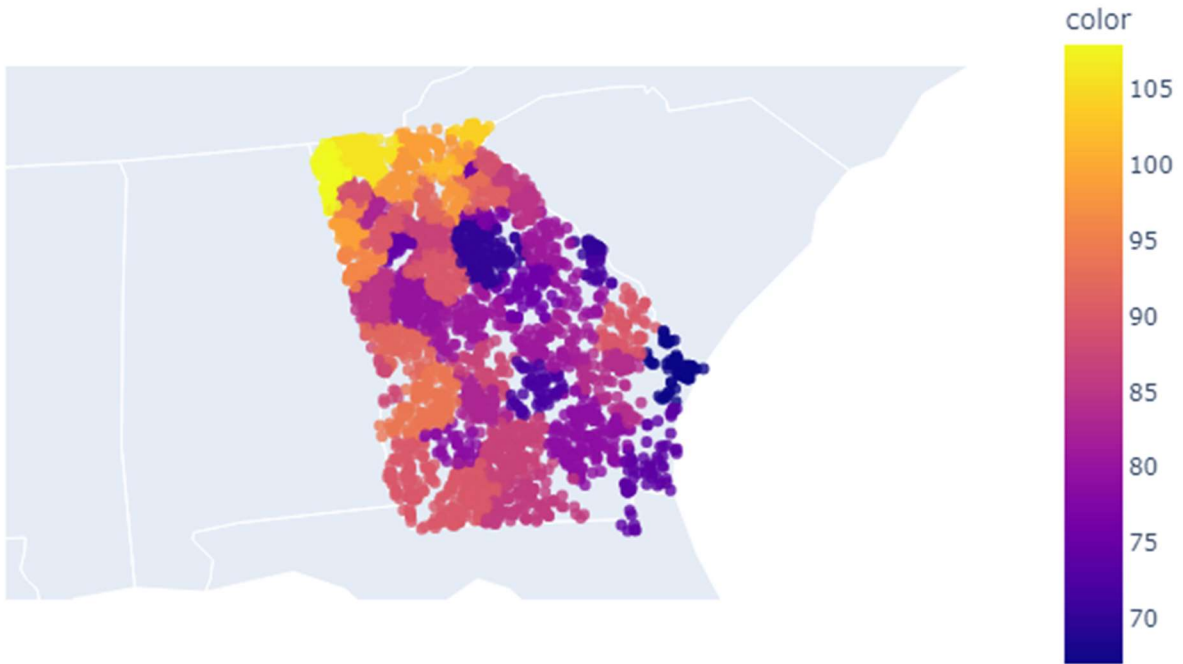
Once each bridge was paired with a corresponding weather station, all bridges had weather variables associated with them. To better understand the climate regions in Georgia, a geographic heat map was generated with each of the climatic variables considered in the Georgia dataset to help better visualize the weather regions that impact bridges in Georgia. The latitude and longitude that were provided in the NBI database were used to geographically plot each asset. In addition, the bridges were broken down into state owned and county owned assets to help better visualize the distribution of these bridges throughout Georgia. This is particularly of interest because county owned bridges are more likely to have a lower condition rating. **Figure 11–Figure 14** display the heat maps for each NOAA climatic factor considered in the study.

2021 GA NOAA Weather Stations DT32



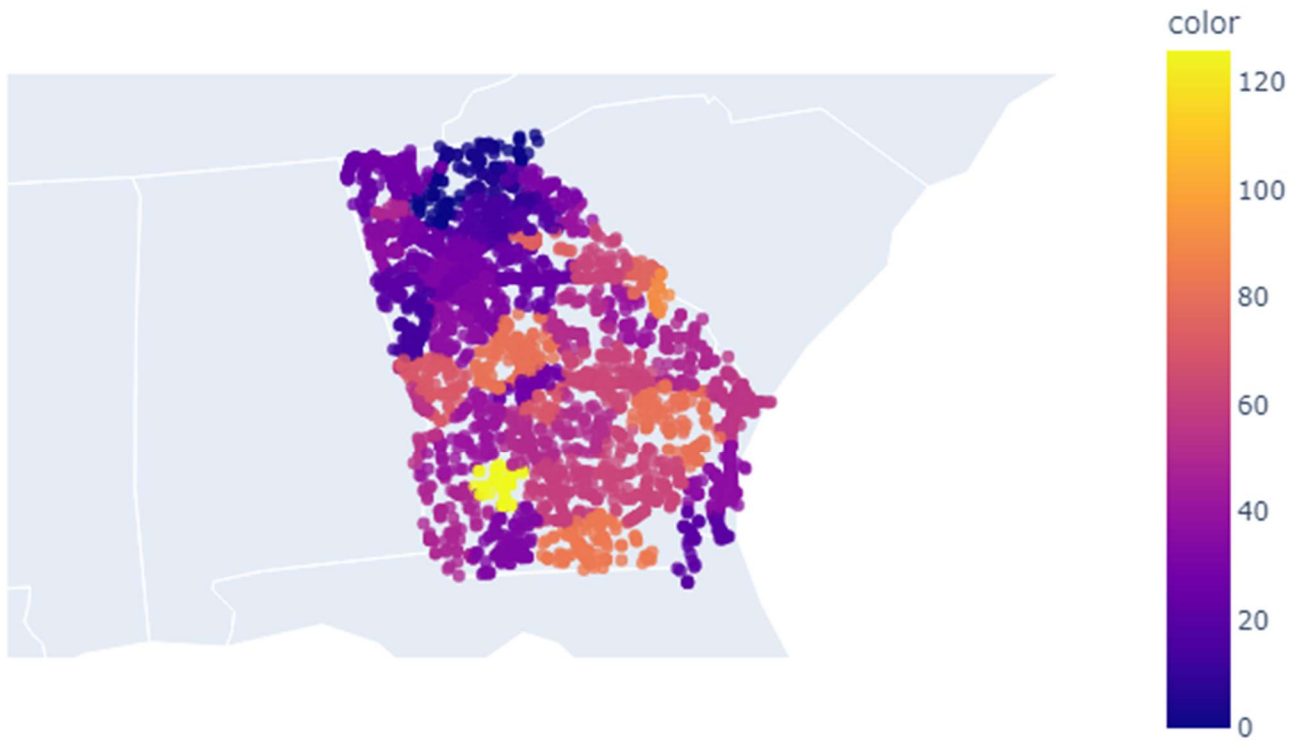
**Figure 11 – State Owned DT32 Bridge Heat Map (color = days)**

2021 GA NOAA Weather Stations DP10



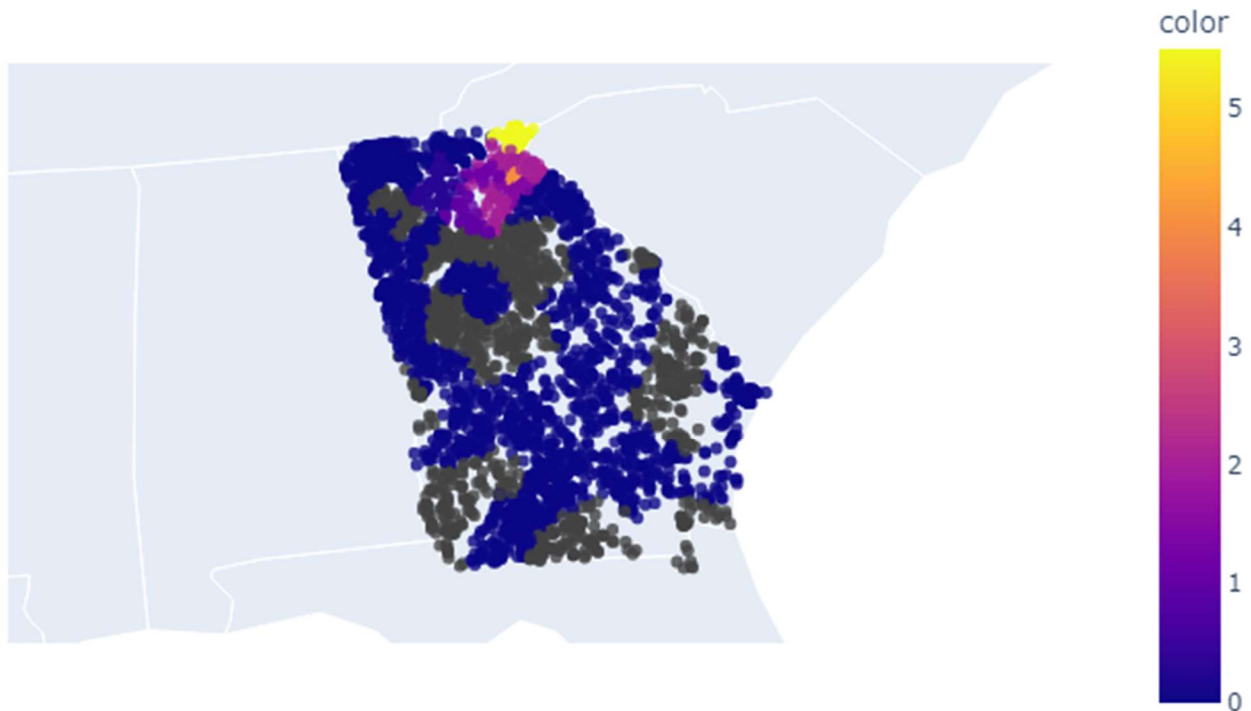
**Figure 12 – County Owned DP10 Bridge Heat Map (color = days)**

## 2021 GA NOAA Weather Stations DX90



**Figure 13 – State Owned DX90 Bridge Heat Map (color = days)**

## 2021 GA NOAA Weather Stations SNOW



**Figure 14 – County Owned SNOW Bridge Heat Map (color = inches per year).**

Viewing these maps from the years 2000-2021 regions of interest are identified to study. The counties located in Northern Georgia were identified as counties that should be further studied to investigate whether bridge components that are potentially negatively affected by precipitation and colder weather have been affected. Additionally, counties located in Southern regions of Georgia experience higher temperatures.

## **Selecting Counties of Interest**

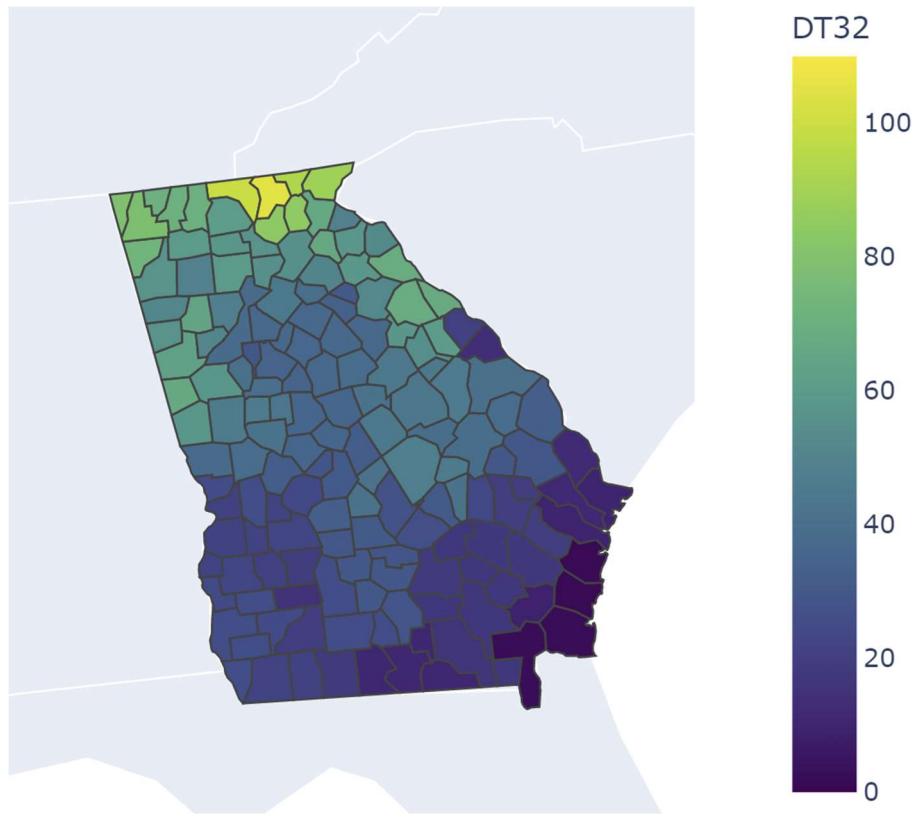
After viewing the weather heat maps, it was determined that selecting counties of interest based on the NOAA weather variables selected is the best way to proceed. This decision was made for several regions. First, it was apparent from the weather heat maps that the climatic regions in Georgia are different than the GDOT inspection areas. Additionally creating counties of interest will better help isolate bridges in the NBI database and make future decisions. To select the counties of interest, the bridges with their corresponding NOAA weather variables were grouped by county using the county code provided by the NBI database. From there, the annual mean weather variable for all bridges in counties were taken, and the highest 15 counties were selected for study. Using DT32 for example, the mean DT32 per bridge was taken by county. This process was used as each county has a different number of weather stations and corresponding bridges. Additionally, the closest weather station to a bridge could be located in a different county. For these reasons, this method was chosen to capture the counties and their bridges that are most impacted by the climatic factors chosen from the NOAA dataset. The results and counties of interest are summarized below. For each weather element and the corresponding counties there is an expected result on the bridges in Georgia. Using data and the inspection reports provided by GDOT these hypotheses will be tested.

### ***Number of Days Under 32 Fahrenheit (DT32)***

The first weather element studied from the NOAA dataset was the number of days with a maximum temperature of under 32 degrees (DT32). This data will show the regions of Georgia that are more susceptible to the impacts on bridges caused by exposure to cold temperatures. Cold temperatures mean that there will be an increase in freeze-thaw cycles. Engineers widely

accept that freeze-thaw cycles in bridges impact the durability of structural components, mainly concrete elements (West et al., 1999) and joints (Li et al., 2012). Once joints experience distress, water can infiltrate through the joint to the superstructure and substructure elements. Another attribute of cold weather that harms bridge conditions is the use of deicing salt. The necessary use of deicing salt is one of the most significant challenges (Wang et al., 2006) of bridge maintenance. Current deicing methods can cause significant corrosion to bridge elements, particularly exposed steel. The deicing salt can lead to rapid bridge degradation when combined with the effects of freeze-thaw cycles. The 15 counties with the highest number of days with a maximum temperature of under 32 degrees are referred to as DT32 counties hereafter.

DT32 counties are much more likely to experience freeze-thaw cycles throughout the year as the geographic location of Georgia means that, unlike Northern states, it will not remain under freezing for long periods. One of the most significant impacts a freeze-thaw cycle can have on a bridge is the deck and the expansion joints (Palu & Mahmoud, 2019). Water can seep into pavements on the deck, and over time cracking on all bridge elements can expand until it reaches the road surface (Barde et al., 2009). A similar cracking effect can occur on bridge substructure elements, particularly in humid environments. Locations with moderate winter climates, such as Georgia, can experience more significant damage to bridge substructures than areas with severe winter climates such as Alaska because of the freezing and unfreezing of water (West et al., 1999)

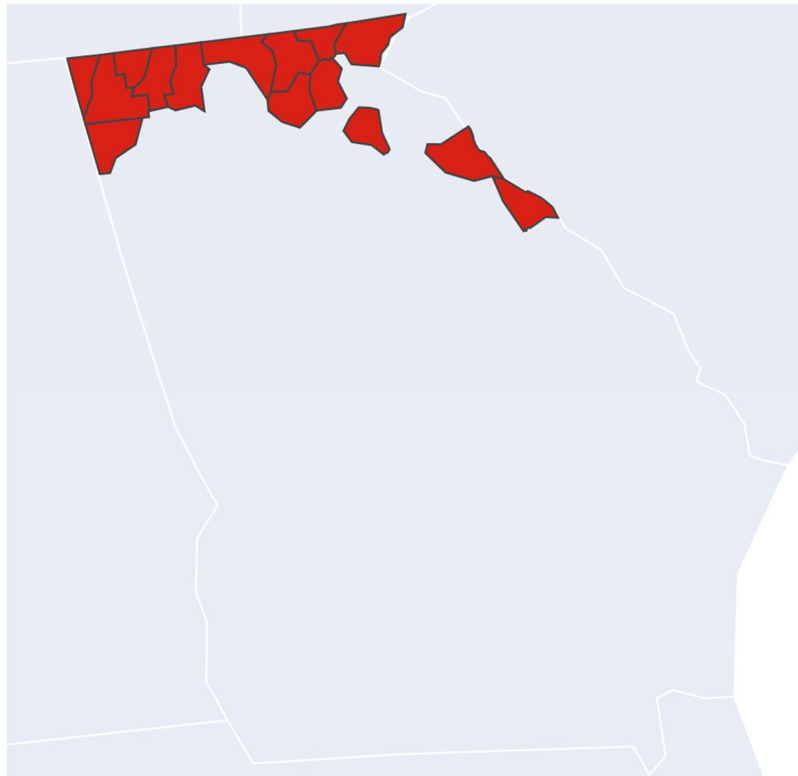


**Figure 15: Average DT32 per bridge by County, 2021**

Using the NOAA data, paired with the bridges by county names, the average DT32 per bridge in each county was calculated and the 15 counties with the highest DT32 per bridge were selected to study. **Table 13** shows the 15 highest counties and their corresponding inspection district. As expected, most of the counties that experience cold weather are located in the north of the state. GDOT District 6 and District 1 were the districts identified to be most impacted by cold weather as shown in **Figure 16**.

**Table 13 - 15 Counties with the Highest DT32, 2021**

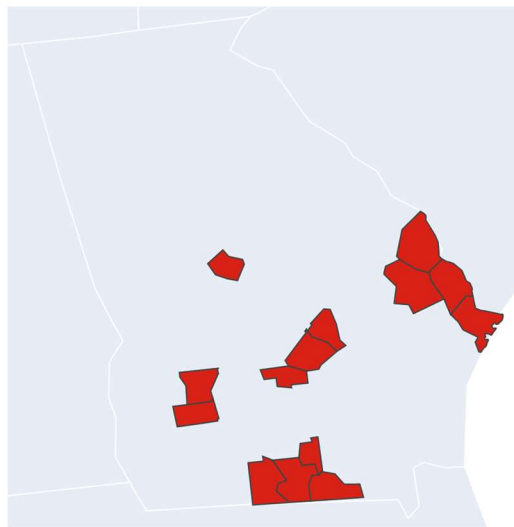
FIPS	County	GDOT District
11	Banks	1
47	Catoosa	6
55	Chattooga	6
83	Dade	6
111	Fannin	6
105	Elbert	1
181	Lincoln	2
187	Lumpkin	1
213	Murray	6
241	Rabun	1
281	Towns	1
291	Union	1
295	Walker	6
311	White	1
313	Whitfield	6



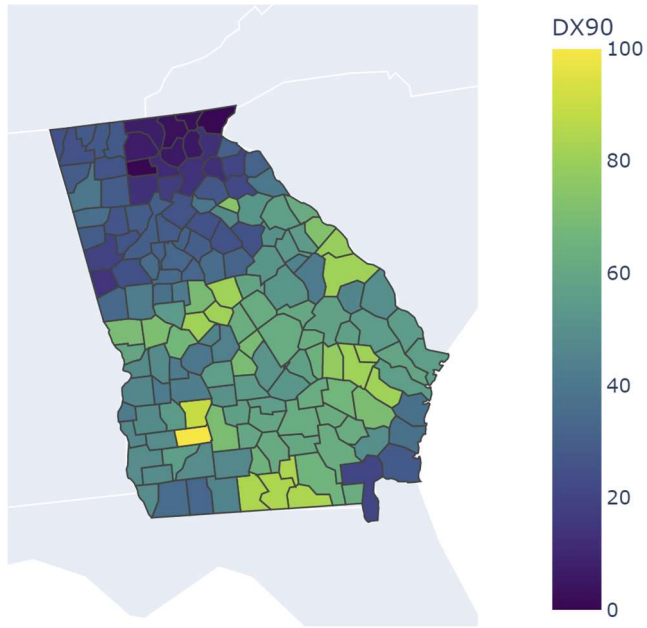
**Figure 16 - Counties of Interest DT32**

### ***Days over 90 Fahrenheit (DX90)***

There are several parts of Georgia that experience days over 90 degrees Fahrenheit and based off many studies it is expected that the number of days with a temperature over 90 degrees will continue increasing (Alexander et al., 2006). These heat days can have an impact on bridge assets. For example, in July 2018 a heatwave in Chicago prevented the opening of movable deck in Chicago due to a heat induced closure of the joint. In addition to the impact heat can have on joints, the expansion of materials can also cause stress cracking.



**Figure 17 - Counties of Interest DX90**



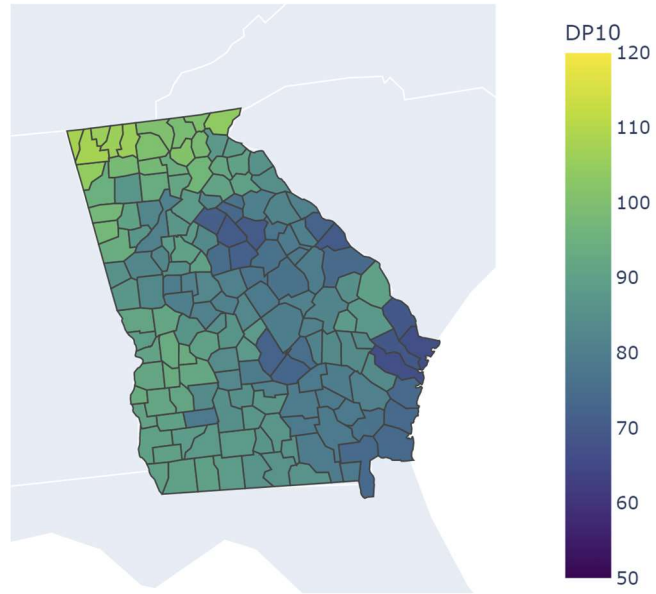
**Figure 18: Average DX90 per bridge by County, 2021**

**Table 14 - 15 Counties with the Highest DX90, 2021**

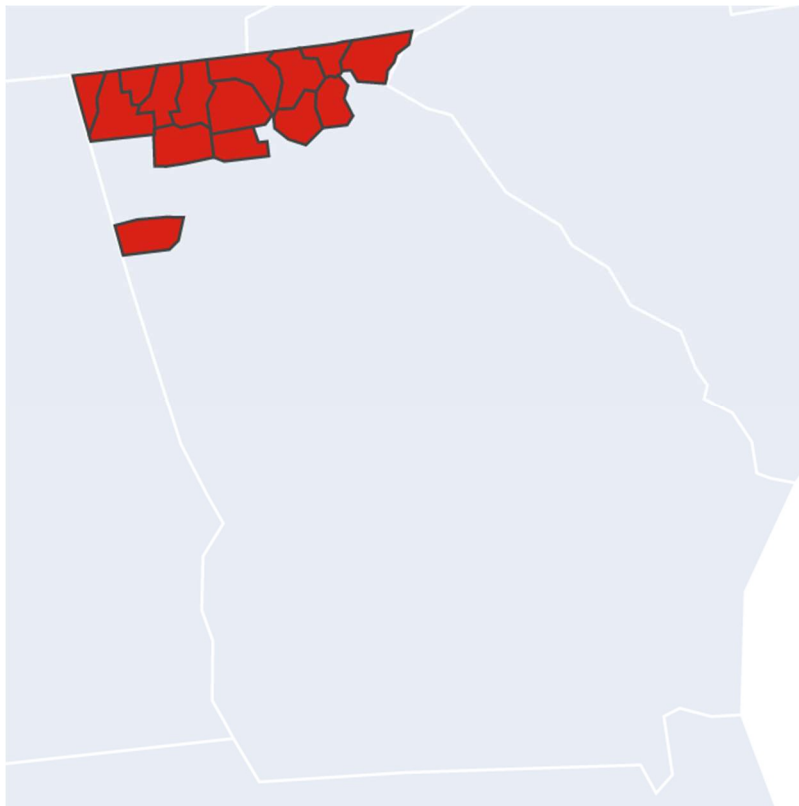
FIPS	County	GDOT District
21	Bibb	3
27	Brooks	4
33	Burke	2
79	Crawford	3
95	Dougherty	4
101	Echols	4
109	Evans	5
169	Jones	3
173	Lanier	4
177	Lee	4
183	Long	5
185	Lowndes	4
245	Richmond	2
267	Tattnall	5
279	Toombs	5

### ***Days with Over 0.10” of Precipitation (DP10)***

Precipitation is an event that engineers must design all infrastructure to withstand, from roads to buildings. Like most infrastructure assets, bridges experience the impacts of heavy precipitation events. Heavy rainfall, either in short periods or over long periods, can cause flooding, negatively impacting bridges' condition ratings. When assessing bridges in DP10 counties, there are several expected impacts. The first is scour risk. A majority of bridge failures in the United States are as a result of scour (Specifications, 2004). Although scour can be caused by several factors, precipitation does play a significant role. Heavier storm events, as well as high annual precipitation, can lead to scour forming on bridges. Another impact to look for in examining inspection reports is the presence of rust and corrosion on steel members of bridges. Areas that have many precipitations are likely to have a more humid environment which can cause the buildup of corrosion and rust, mainly when steel elements are left without protective paint. The last impact from precipitation that will be looked for in the inspection reports is drift. When rains wash items into rivers and creeks, they can float downstream and get caught in the elements of bridges. When not removed, they can cause a hazard to motorists or damage to the bridge.



**Figure 19 – Average DP10 per bridge by County, 2021**



**Figure 20 - Counties of Interest DP10**

Counties of interest were selected based on the days with over 0.10” of precipitation experienced in year. **Figure 20** and **Table 15** show the counties that are selected for study. The counties in Georgia that experience the most rainfall are located in the northern part of the state, so as the impacts of precipitation are studied, the impacts of other climatic factors that impact these regions will also be considered. It is expected that in these regions’ issues relating to scour, erosion, corrosion of metal, and cracking will be the primary deficiencies found in these regions.

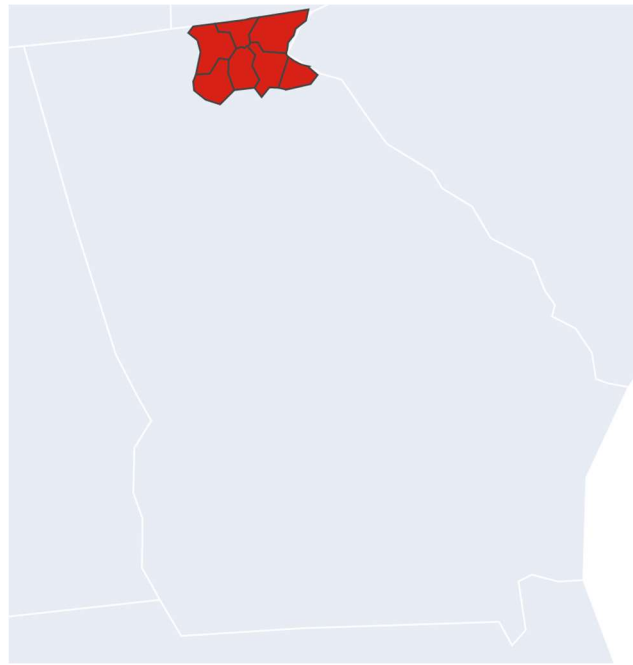
**Table 15 - 15 Counties with the Highest DP10, 2021**

FIPS	County	GDOT District
47	Catoosa	6
83	Dade	6
111	Fannin	6
123	Gilmer	6
129	Gordon	6
187	Lumpkin	1
213	Murray	6
227	Pickens	6
241	Rabun	1
233	Polk	6
281	Towns	1
291	Union	1
295	Walker	6
311	White	1
313	Whitfield	6

***Snow***

Snowfall is not as common as other weather stressors in Georgia, however it still can impact bridge assets. The combination of cold temperatures and moisture can cause the propagation of cracking and spalling through freeze-thaw cycles. Additionally, deicing chemicals are known to cause deterioration of bridge elements. Because snowfall in Georgia is variable year to year, the

average snowfall over the past three years was considered, and the selected snow counties of interest are shown in **Figure 21** and **Table 16**.



**Figure 21 - Counties of Interest SNOW**

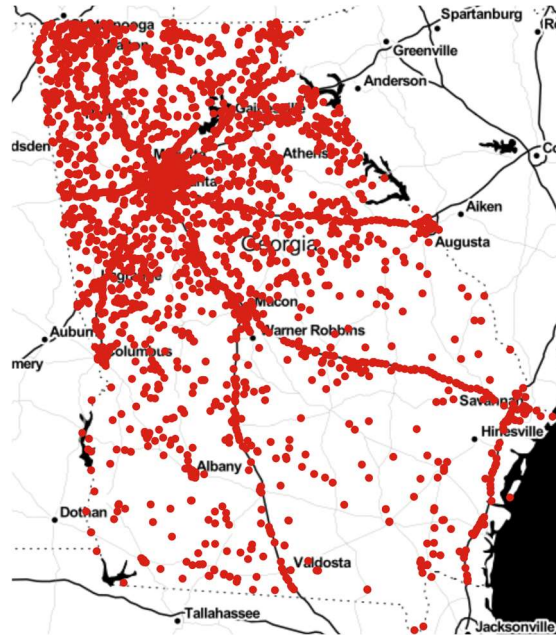
**Table 16 – Counties of SNOW Intrest**

FIPS	County	GDOT District
137	Habersham	1
187	Lumpkin	1
241	Rabun	1
257	Stephens	1
281	Towns	1
291	Union	1
311	White	1

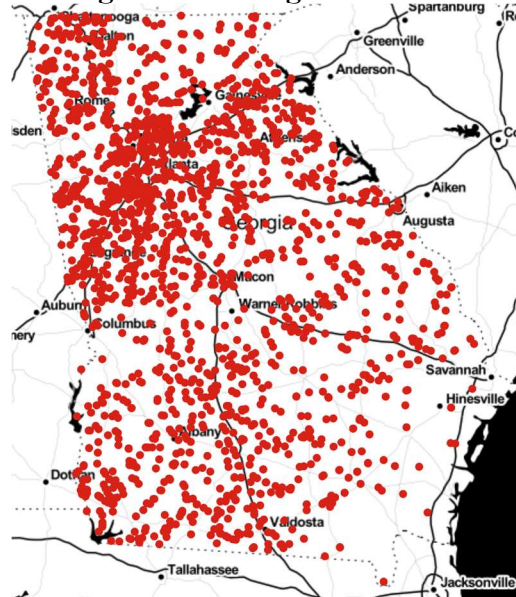
***Coastal***

Like bridges that are exposed to deicing salts, bridges in close proximity to the coast are also more susceptible to corrosion. This is because they are exposed to an “aggressive environment,

where the concrete is exposed to chloride ions that initiates the chloride corrosion. This is one of the most severe durability threats to steel bridges (Biondini & Frangopol, 2016), but as shown in **Figure 22** and **Figure 23** GDOT has strategically avoided placing bridges with steel members near the coast.



**Figure 22 – Bridges Containing EN107 Steel Girder, 2021**



**Figure 23 – Bridges Containing EN225 Steel Pile, 2021**

However, corrosion is still a risk factor in these coastal counties in reinforced concrete bridges as they contain steel reinforcement. Steel corrosion is the main cause of deterioration if reinforced concrete structures (Rodrigues et al., 2021). Additionally, the increase of chloride in marine environments is a major cause of steel pitting. The counties in Georgia located near these marine environments have different challenges in bridge asset management, that will be explored through InspectX.

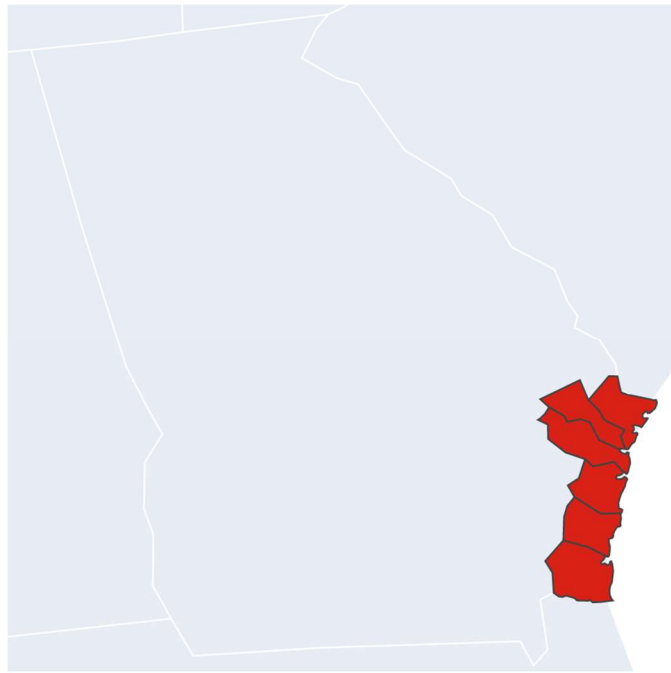
Even if steel reinforcement is not entirely exposed, salt environments can still impact the strength of the member. (Kim et al., 2014) found that half cell potential, a non-destructive technique to evaluate corrosion of steel in concrete, measurements increase linearly with crack size in salt sprayed environments. They also found that corrosion length of steel nonlinearly increases with increasing crack width on concrete structures exposed to salt sprayed environments.

Additionally, it is widely recognized that chloride penetration and the corrosion of the rebar that follows has a negative impact service life of bridges (Kirkpatrick et al., 2002), and this has even been modeled (Guzmán et al., 2011).

It is expected that the bridges exposed to marine salt environments are going to experience much more concrete cracking than other areas of the state.

**Table 17 – Georgia Counties with Coastline**

FIPS	County	GDOT District
39	Camden	5
127	Glynn	5
191	McIntosh	5
179	Liberty	5
51	Chatham	5



**Figure 24 – Counties of Coastal Interest**

***Counties with Overlap***

It is important to note the interaction between the selected climatic variables. After the counties of interest were selected there were some overlapping counties, particularly in North Georgia. This part of the state experiences cold weather, days of rain, and snowfall. This was to be expected after looking at the heat maps shown in **Figure 11 - Figure 14**. A summary of the overlapping counties of interest can be seen in **Table 18**. Understanding counties that experience several weather variables will be important when reviewing inspection reports. It will be important to note potential interactions and the impacts they can have on bridge elements.

**Table 18 – Summary of DT32, DP10, and Snow Counties of Interest**

County	DT32	DP10	SNOW
Banks	Green	Red	Green
Barrow	Red	Red	Green
Catoosa	Green	Green	Red
Chattooga	Green	Red	Red
Columbia	Red	Red	Green
Dade	Green	Green	Red
Dawson	Red	Red	Green
Elbert	Green	Red	Red
Fannin	Green	Green	Red
Forsyth	Red	Red	Green
Franklin	Red	Red	Green
Gilmer	Red	Green	Red
Gordon	Red	Green	Red
Gwinnett	Red	Red	Green
Habersham	Red	Red	Green
Hall	Red	Red	Green
Jackson	Red	Red	Green
Lincoln	Green	Red	Red
Lumpkin	Green	Green	Green
Murray	Green	Green	Red
Pickens	Red	Green	Red
Polk	Red	Green	Red
Rabun	Green	Green	Green
Stephens	Red	Red	Green
Towns	Green	Green	Green
Union	Green	Green	Red
Walker	Green	Green	Red
White	Green	Green	Green
Whitfield	Green	Green	Red

**Identifying Vulnerable Elements**

After selecting the counties of interest, a process for selecting bridge elements from the NBI element needed to be determined. Generating a visual aid to understand better the bridge

elements and the geographic distribution of conditions across Georgia. Unfortunately, the NBI element database only includes a bridge structure number, element number (EN), state ID, total quantity, and the quantity in each condition state. A representative sampling is presented in **Table 19**. A python script was created to better process data to align relevant information from the NBI database to the elements in the NBI element database. This process was done on a year-to-year basis.

**Table 19 – GA NBI Element Data Example**

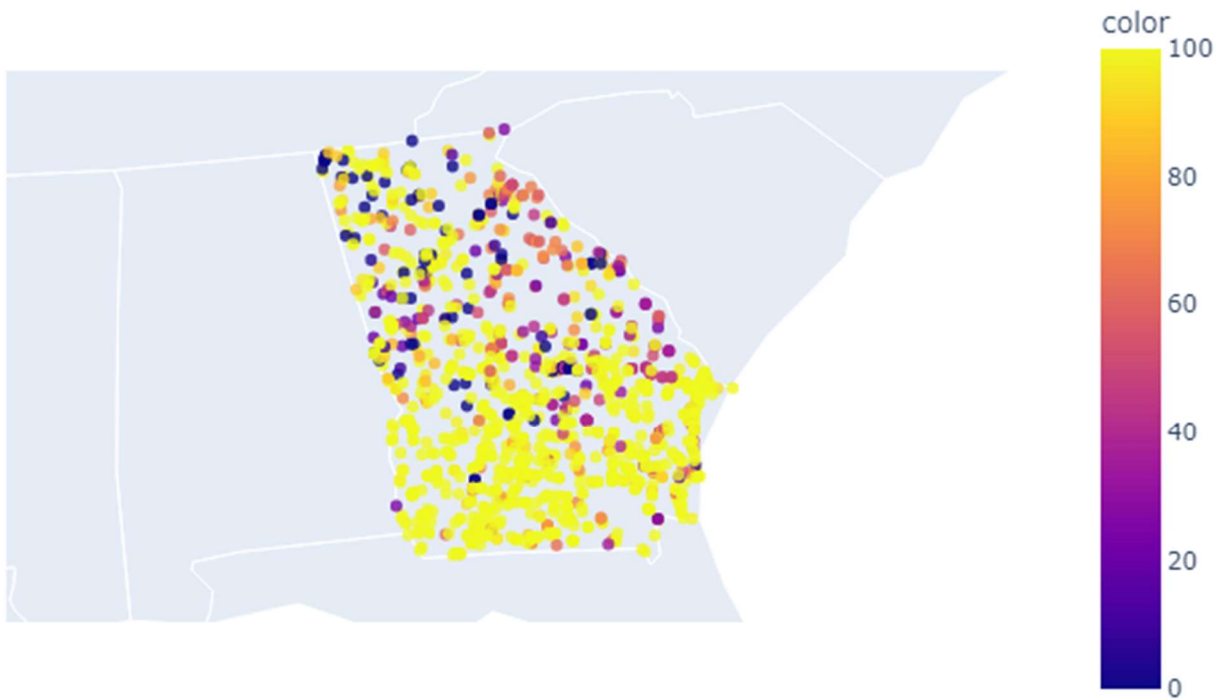
STATE	STRUCNUM	EN	TOTALQTY	CS1	CS2	CS3	CS4
13	100140	515	4528	4528	0	0	0
13	100140	515	10200	10200	0	0	0
13	100140	515	28	11	0	17	0
13	100140	515	16	4	2	10	0
13	100230	16	10164	10164	0	0	0
13	100230	105	2520	2520	0	0	0
13	100230	215	72	72	0	0	0
13	100230	226	65	65	0	0	0
13	100230	234	468	468	0	0	0
13	100230	301	525	525	0	0	0
13	100230	330	1570	1570	0	0	0
13	100230	510	10164	10164	0	0	0

In addition to creating a python script that paired NBI element data and NBI data, a python script was also created to manipulate the geographic information found in the NBI database into latitude and longitude measurements to plot. This script was also created in python. The NBI database presents the latitude and longitude as items five and six. The FHWA reports these as a nine-digit number in `XXYYZZZZ` format. The FHWA format translates to the format of `XX°YY'ZZ.ZZ"`. This degree minute second format had to be converted to degree decimal form for plotting. Once both the NBI and NBI element data had been manipulated, the plotting process could begin.

The bridges were separated by state-owned bridges and county-owned bridges before plotting. This decision was made for two reasons. First, because oftentimes state-owned and county-owned bridges contain different elements. By plotting these separately, the difference in elements used can be visualized. Secondly, state and county municipalities have different maintenance methods and timelines. Viewing the state and county-owned maps simultaneously, elements that appear to lag in condition state can also be identified.

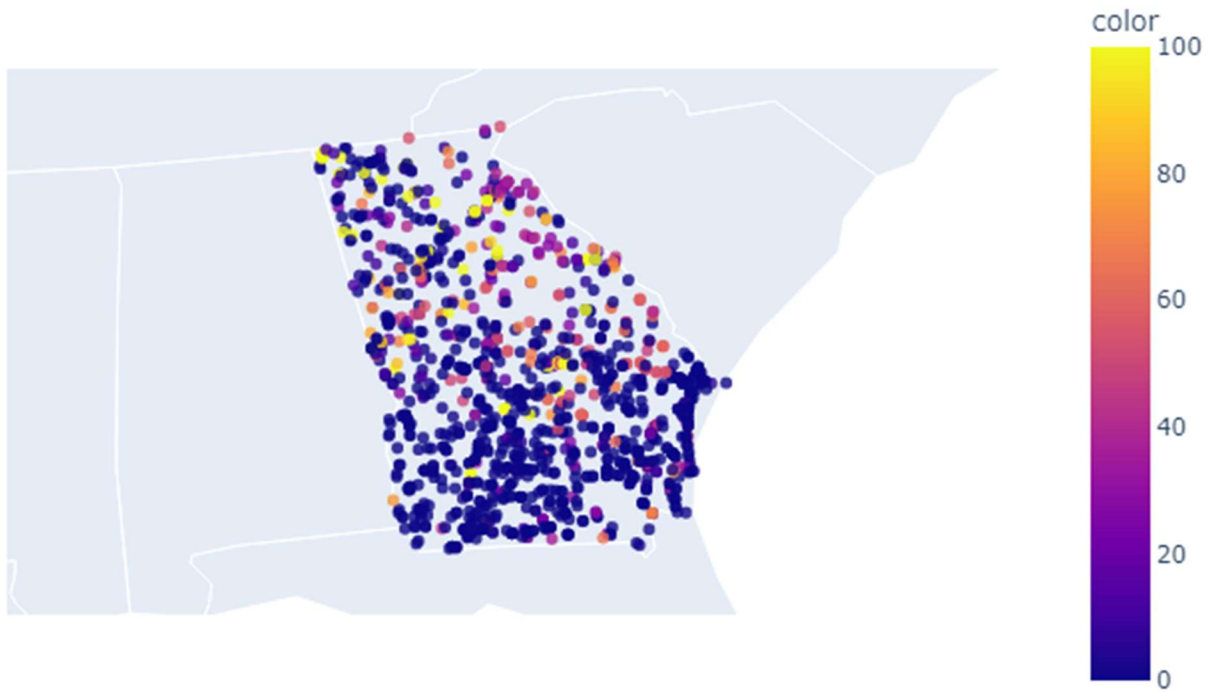
The element data presents elements with different quantities, so to better understand element health, a python script was developed to calculate a percentage for each condition state per element. This calculation was done by dividing the total quantity in each condition state by the total quantity so that each element on each bridge had calculated a percentage in condition states one, two, three, and four. These values were then plotted on a geographic heat map. **Figure 25–**  
**Figure 32** show what these maps look like for element 16, the reinforced concrete top flange.

2021 Element Number 16 - % in CS1



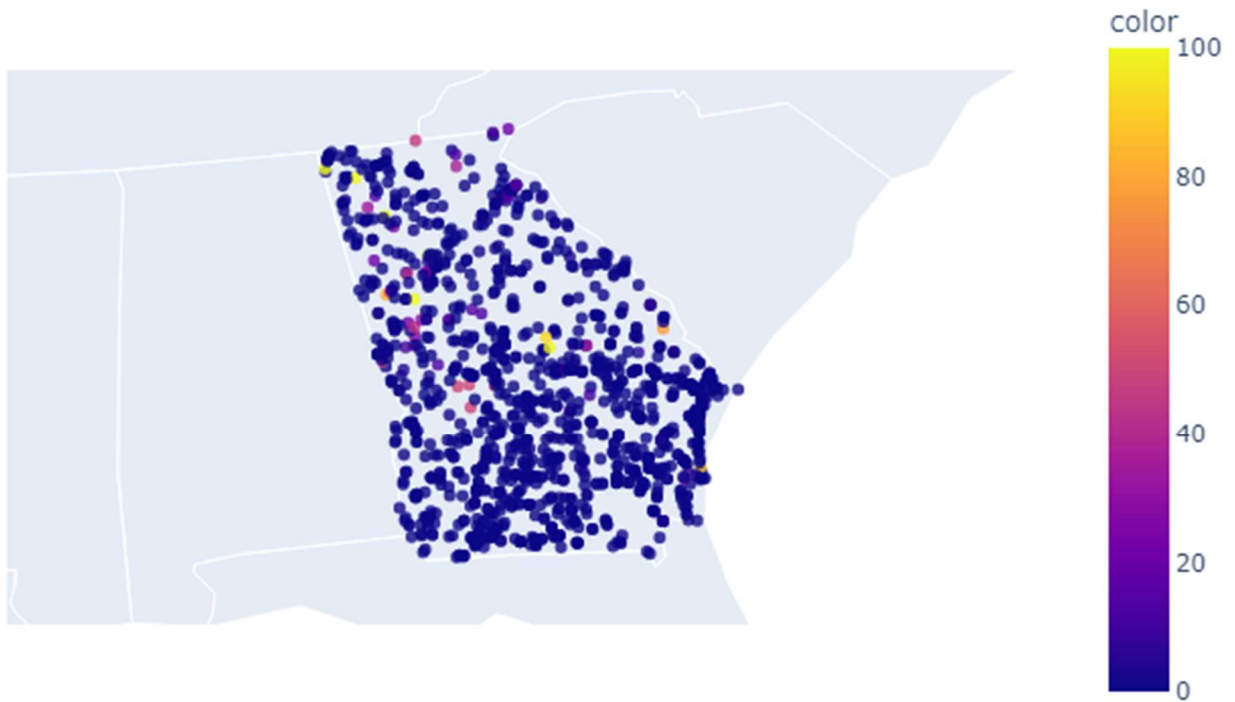
**Figure 25 – EN16 State Owned Bridges Percentage in Condition State One**

2021 Element Number 16 - % in CS2



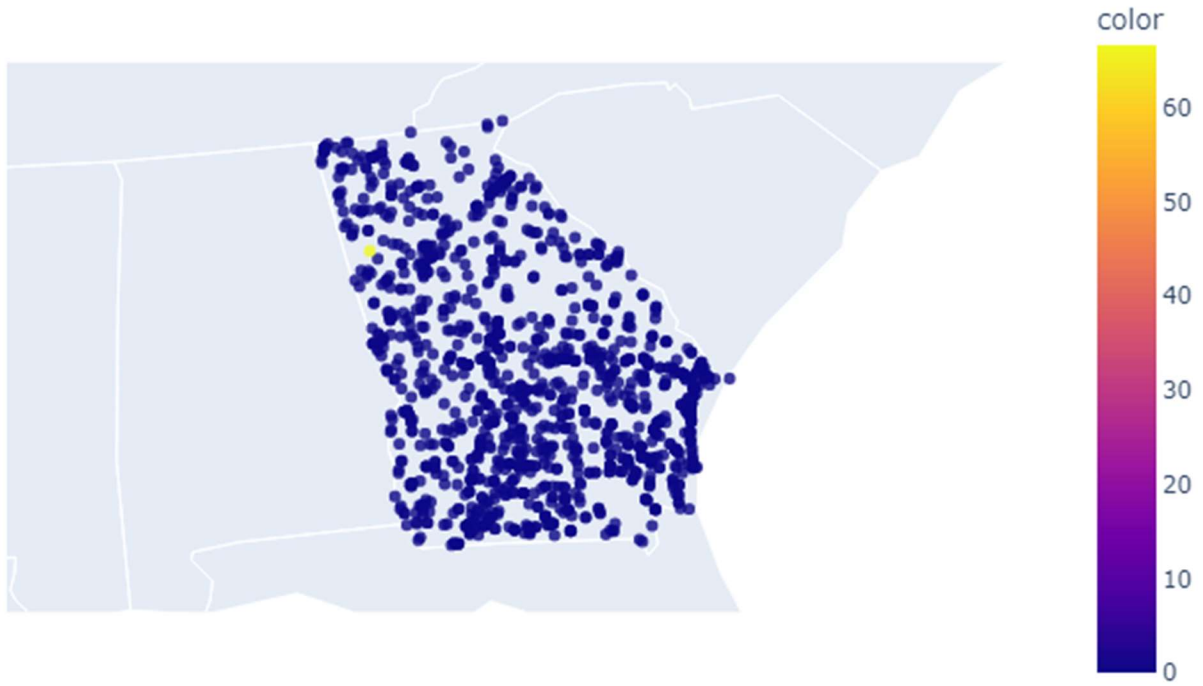
**Figure 26 – EN16 State Owned Bridges Percentage in Condition State Two**

2021 Element Number 16 - % in CS3



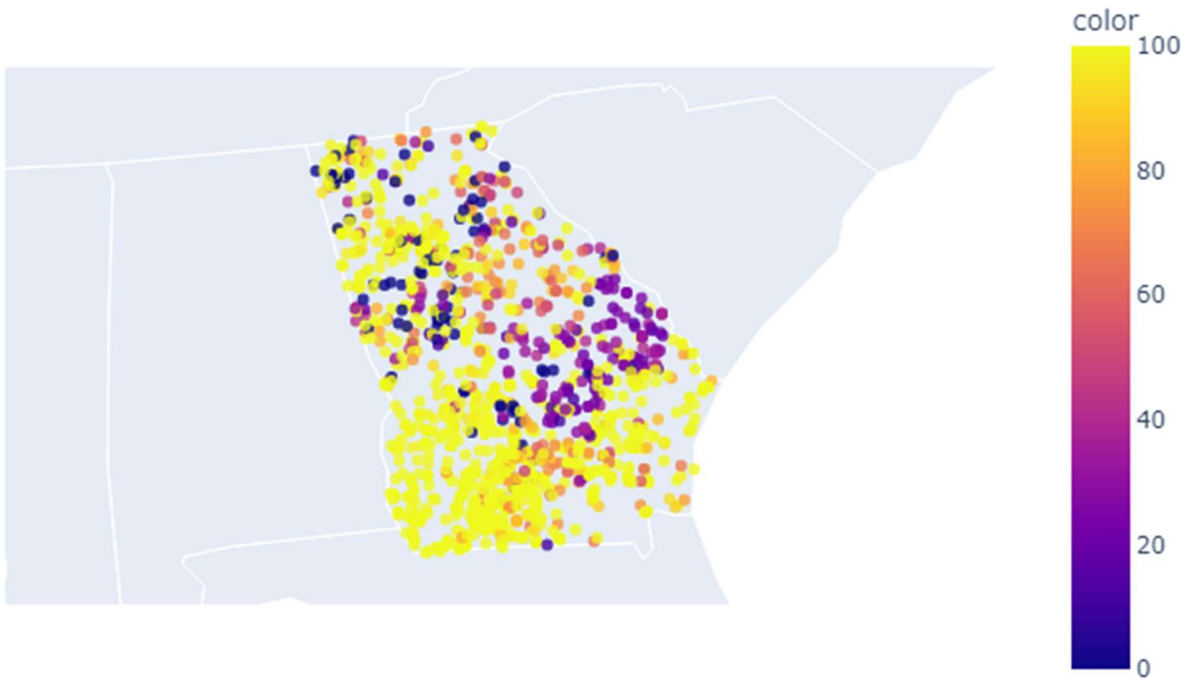
**Figure 27 – EN16 State Owned Bridges Percentage in Condition State Three**

2021 Element Number 16 - % in CS4



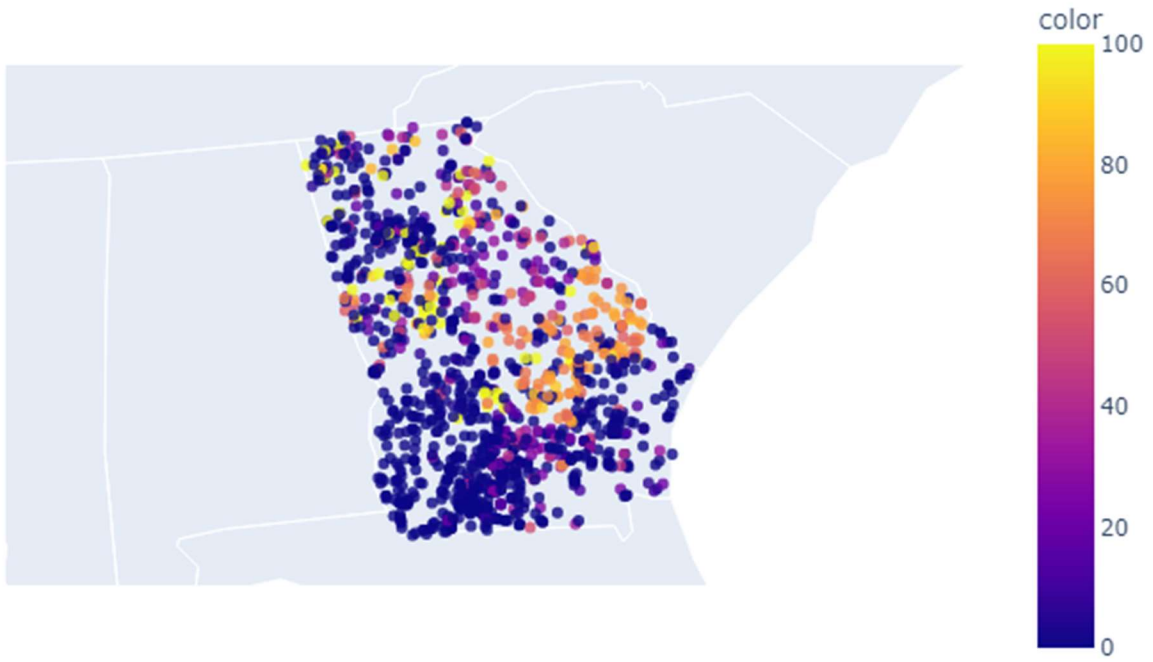
**Figure 28 – EN16 State Owned Bridges Percentage in Condition State Four**

2021 Element Number 16 - % in CS1



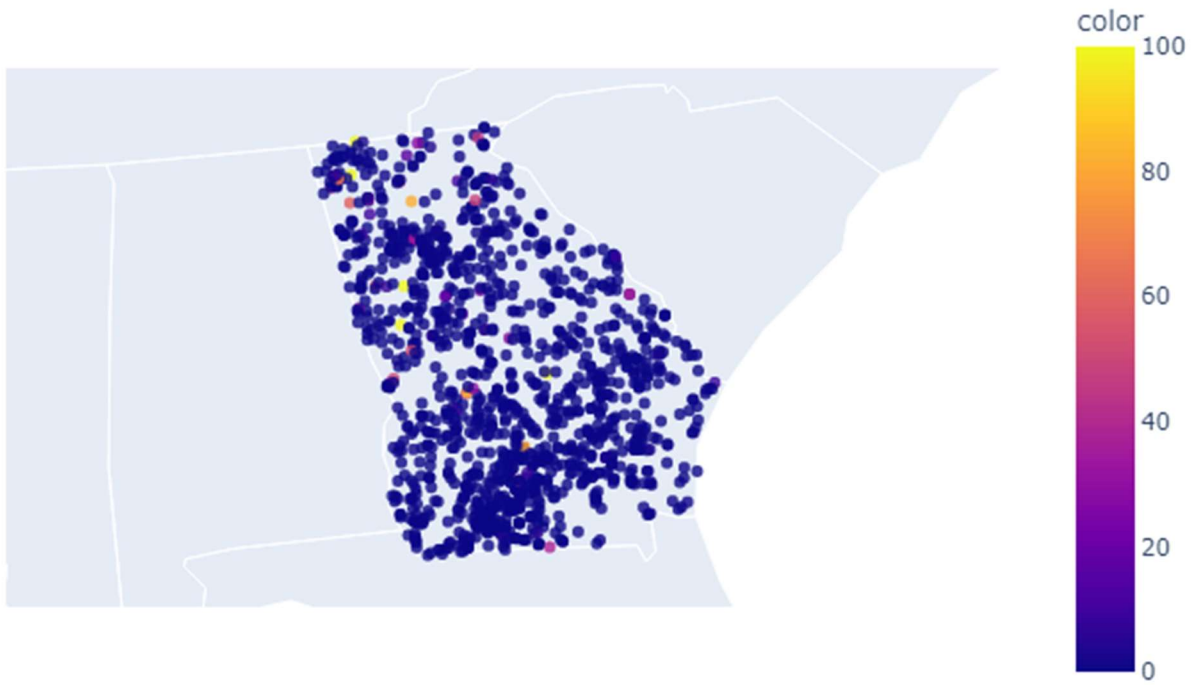
**Figure 29 – EN16 County Owned Bridges Percentage in Condition State One**

2021 Element Number 16 - % in CS2



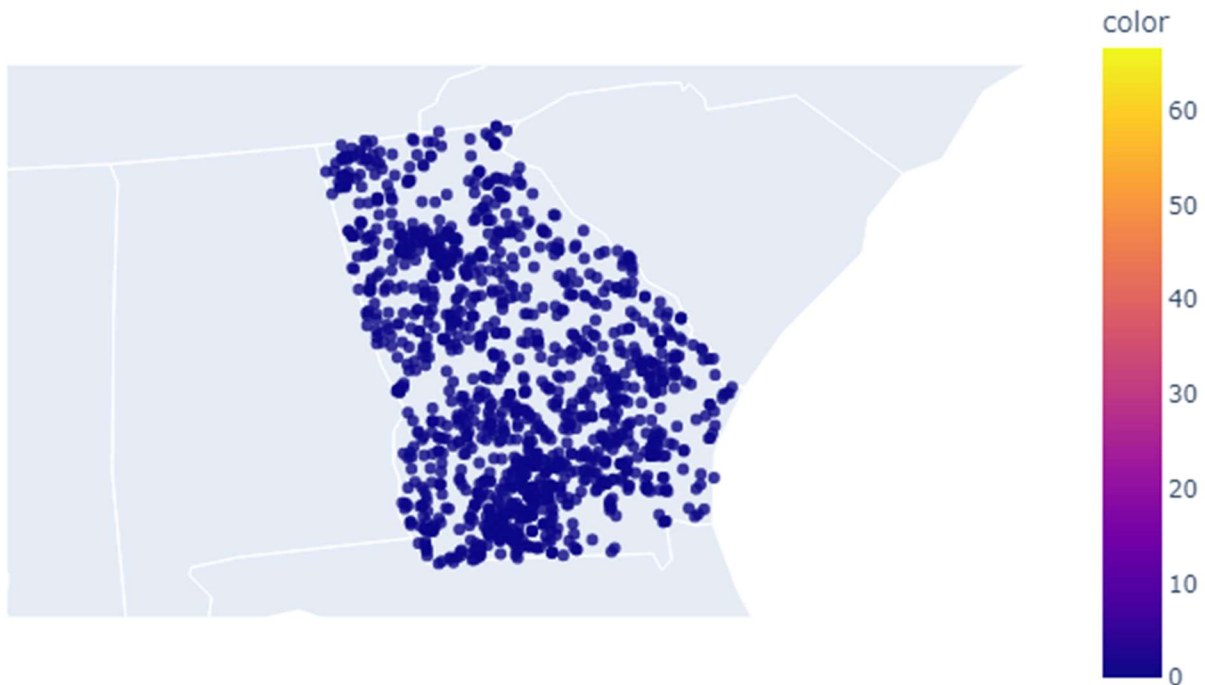
**Figure 30 – EN16 County Owned Bridges Percentage in Condition State Two**

2021 Element Number 16 - % in CS3



**Figure 31 – EN16 County Owned Bridges Percentage in Condition State Three**

## 2021 Element Number 16 - % in CS4



**Figure 32 – EN16 County Owned Bridges Percentage in Condition State Four**

By viewing these maps for each element in Georgia, an understanding of the geographical element trends in the state and elements of interest could be selected. Once elements of interest were selected, data analysis was done using the EHI to compare the element with other bridges in the state. Once this analysis was completed and elements were confirmed to be lacking in counties of interest, an analysis was completed using historical GDOT inspection reports. This was done to confirm the visual conclusions that the elements were lagging in these counties.

## **SELECTING BRIDGES TO STUDY**

Once elements of interest were selected for study and research was completed about the overall health of the element statewide. In the counties of interest, the process of studying bridges began. For the study, the lowest 10 bridges by EHI were isolated in python and selected for further study. Initially, trends of these 10 bridges are analyzed to see if any factors contribute to this element having a low EHI. Once the process of analyzing the NBI data is complete, then a more thorough analysis of the bridges will be completed.

Before looking at inspection reports, a box chart for the EHI of the elements of the 10 bridges is produced. By producing this chart, elements with low EHI can be identified and studied while looking at inspection reports. Additionally, engineering conclusions can be drawn about bridge elements that impact each other. A python script that plots the EHI of all elements in the bridge by year was generated to further aid in drawing these conclusions. Viewing this chart helps see if a bridge's elements are connected.

Another python tool used while studying the bridges plots the operating rating by year. The operating rating is valuable when studying bridges, as it only changes based on a professional engineer's decision. It shows that an element or elements on a bridge have degraded (or been maintained) to the point where they influence the bridge's safety. This information is also valuable because it is based on an engineer's opinion and not just an inspector's opinion.

Although these tools are valuable when studying bridges, the primary information utilized in the research is the GDOT inspection reports. Reports and photos from the bridges will be studied to determine the reason for the poor condition state ratings. Although data tells part of the story, it only offers part of the picture. To fully understand why these elements in the counties are lagging, the inspection reports and photos can be analyzed to draw engineering conclusions.

Another goal in viewing the inspection reports is to find ways that GDOT can better improve their inspection and reporting processes.

## **METHODOLOGY FOR DEVELOPING A WEATHER-RELATED RISK GUIDE FOR COUNTIES**

Once the analysis of identifying vulnerable elements and areas is complete a resource guide will be completed to help counties better understand how weather stressors impact their bridge assets. After going through inspection reports there will be a number of lessons learned in regard to how elements deteriorate and warning signs that counties should be alert for. By alerting vulnerable counties of the elements and deterioration they should be paying special attention to maintenance, restoration, and replacement (MRR) activities can be better planned. Additionally showing visuals for the consequences of not completing recommended maintenance can be a powerful tool.

### **Identification of Main Elements of a Resource Guide**

This section provides planned sections for a weather-related resource guide for counties. The inspiration for the guide comes from the FHWA's Vulnerability Assessment Guidelines , and other DOT resources for counties.

#### ***Weather Stressor Overview***

This section will describe each weather stressor and the potential elements and impacts it can have on bridge infrastructure. Additionally, this part of the guide will include photos from inspection reports showing the damage that each weather stressors can have on the element. This section will include a color-coded map so counties can easily tell what weather stressors their

counties are more likely to experience, it will also have a geographic map that shows counties where and what elements are more at risk.

### ***Bridge Case Studies***

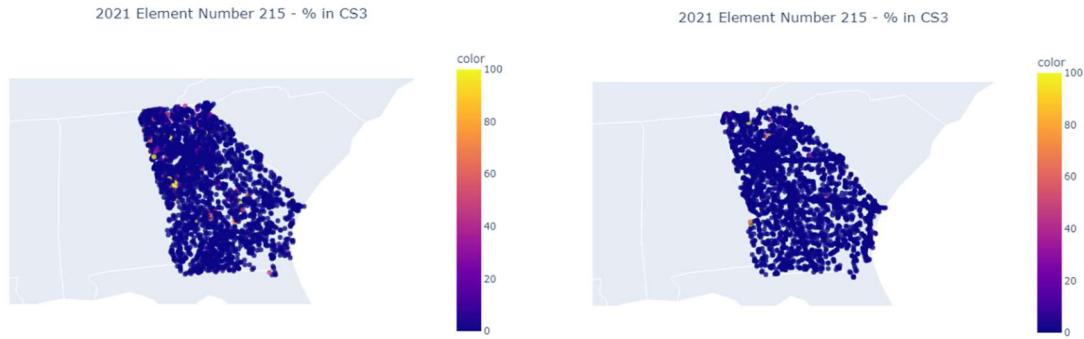
Bridges will be selected for case studies to show counties what can happen when certain maintenance items are ignored. The goal is to show how rapidly certain elements can deteriorate when exposed to one or multiple weather stressors. The cost of postponing maintenance on these bridges will be provided to give counties a resource to use when requesting funding. A cost estimation tool from a Minnesota DOT resource will be used to show the additional estimated costs incurred from missing maintenance.

## **RESULTS FROM ANALYZING BRIDGE INSPECTION REPORTS**

### **Days with a Maximum Temperature Under 32 Degrees**

#### ***Element 215 Reinforced Concrete Abutment***

One element identified through the generated heatmaps as potentially affected by days under 32 degrees was the reinforced concrete abutment. This element (EN215) was isolated by looking at the geographic heat maps (see below) and noticing a trend of more abutments condition states 3 and 4 around the 15 counties of DT32 interest.



**Figure 33: Percent of EN215 in CS3 by location, 2021. County-Owned (Left) vs State-Owned (Right)**

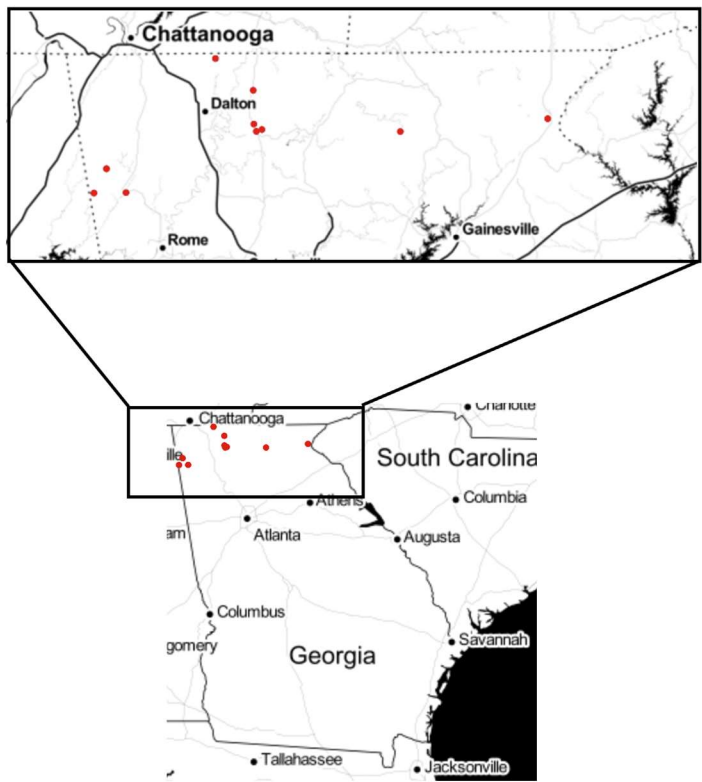
A reinforced concrete abutment is a common structural element on a bridge that transfers loads from the superstructure to the ground. Several reinforced concrete abutments can be found on a bridge based on need and design choices/criteria. The AASHTO Bridge Element inspection manual provides standards for the inspection of EN215. AASHTO defines this element as a reinforced concrete abutment, “this includes the sheet material retaining the embankment and wing walls, abutment extensions, and any other monolithically placed concrete elements. This is for all abutments regardless of protective systems.” The quantity calculation of this element is performed by summing the width of the reinforced concrete abutment, including the wingwall and abutment extensions.

Georgia has 8,811 bridges with at least one reinforced concrete abutment, and there is at least one bridge in each county built with a reinforced concrete abutment. In the 15 counties of interest, 675 bridges contain a reinforced concrete abutment. The bridges that pass over waterways are exposed to high moisture and cold temperatures. This shows a strong correlation between poor reinforced concrete abutment condition, waterway overpasses, and cold weather. The average EHI in non DT32 counties is 95.4, while the average EHI in DT32 counties is 88.3.

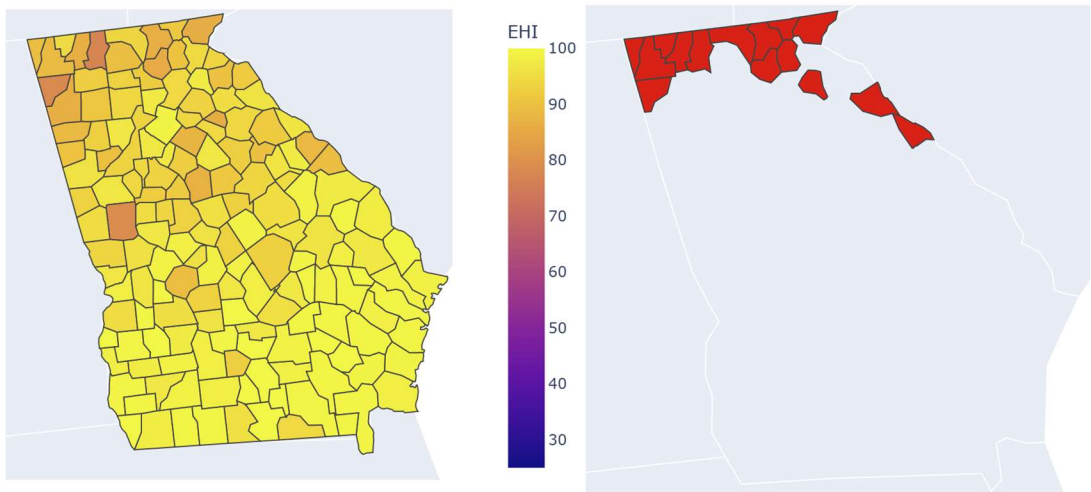
Subsequently, the ten bridges with the lowest element health index were selected to confirm the hypothesis that days under 32 and vicinity to water negatively impact reinforced concrete abutment health. 10 bridges were selected to conduct a case study on and review the details of condition states. **Table 20** gives a summary of the bridges selected, and **Figure 34** shows the geographic location of the bridges studied.

**Table 20 - Lowest 10 DT32 Bridges by EHI of EN215**

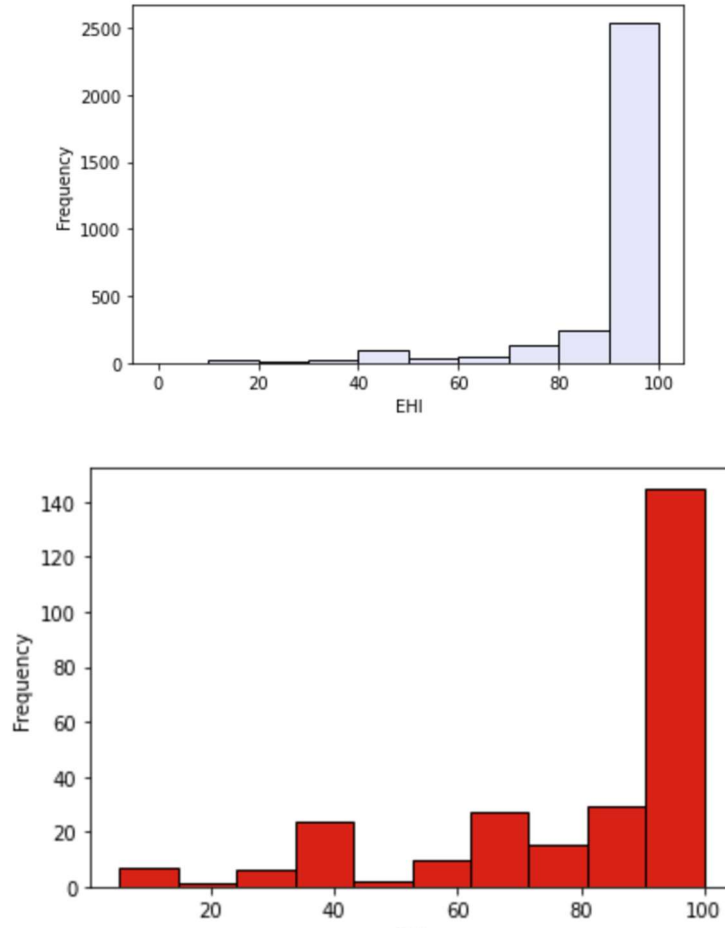
Bridge ID	County	Owner	Year Built	Service Under	Substructure NBI Rating	EHI
213-5009-0	Murray	County	1922	Waterway	4	7.222
055-5026-0	Chattooga	County	1981	Waterway	5	10
055-5045-0	Chattooga	County	1954	Waterway	4	10
213-0033-0	Murray	State	1910	Waterway	5	10
213-0045-0	Murray	County	1911	Waterway	5	10
241-5024-0	Rabun	City	1932	Waterway	6	10.79
291-5028-0	Union	County	1962	Waterway	6	19.31
055-5009-0	Chattooga	County	1958	Waterway	5	25
213-5004-0	Murray	County	1933	Waterway	4	25
313-5028-0	Whitfield	County	1969	Waterway	5	25



**Figure 34 - Location of Selected DT32 Bridges for EN215**



**Figure 35 – Average EN215 by County (Left) vs DT32 Counties (Right)**



**Figure 36 – EN215 EHI Distribution DT32 (Bottom) vs Other Counties (Top)**

*Bridge 213-5009-0*

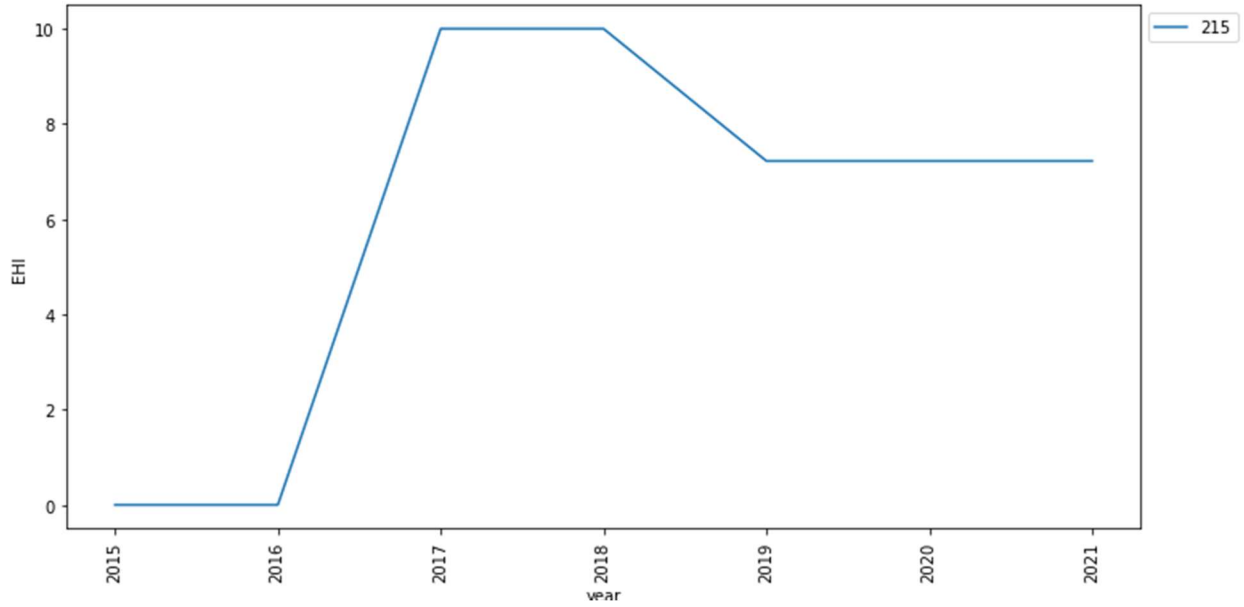
Bridge 213-5009 bridge was constructed in 1922 and is owned and maintained by Murray County. This bridge was identified for study as it is in a DT32 county of interest and had a low reinforced concrete abutment EHI score. A study was completed on the reinforced concrete abutment by reviewing inspection reports available in InspectX, starting in the first year of available NBI element data, 2015 (reported in 2016). Using photos from InspectX, it was determined that the reinforced concrete abutment underwent weather-related deterioration. Bridge 213-5009-0 shows a significant increase in concrete cracking and spalling under beams one and two in abutment one between 2014-2020. These changes are shown in

**Figure 37.** The cracking and spalling are likely attributable to the freeze-thaw cycles typical when the weather falls under 32 degrees when around moisture. This issue was likely exacerbated by the age of the bridge. From the location of the spalls it is also possible that the failure is bearing related. In addition, there has also been structural degradation throughout the rest of the abutment. Due to its age, proximity to water, and location in cold weather, this bridge was vulnerable to accelerated reinforced concrete abutment decay. **Figure 38** shows the changes in EHI over time. The condition jumped between the first and second inspection, despite no maintenance being performed on the structure.

The undermining in abutment one was 1.0' x 2.0' x 4.0' in 2022. It was reported that the area of undermining was 1.0' x 2.0'-5.0' in 2016, so this has only grown a small amount.



**Figure 37 - EN215 in 2014 (Left) and 2020 (Right)**



**Figure 38 – Bridge 213-5009-0 Reinforced Concrete Abutment EHI by Year**

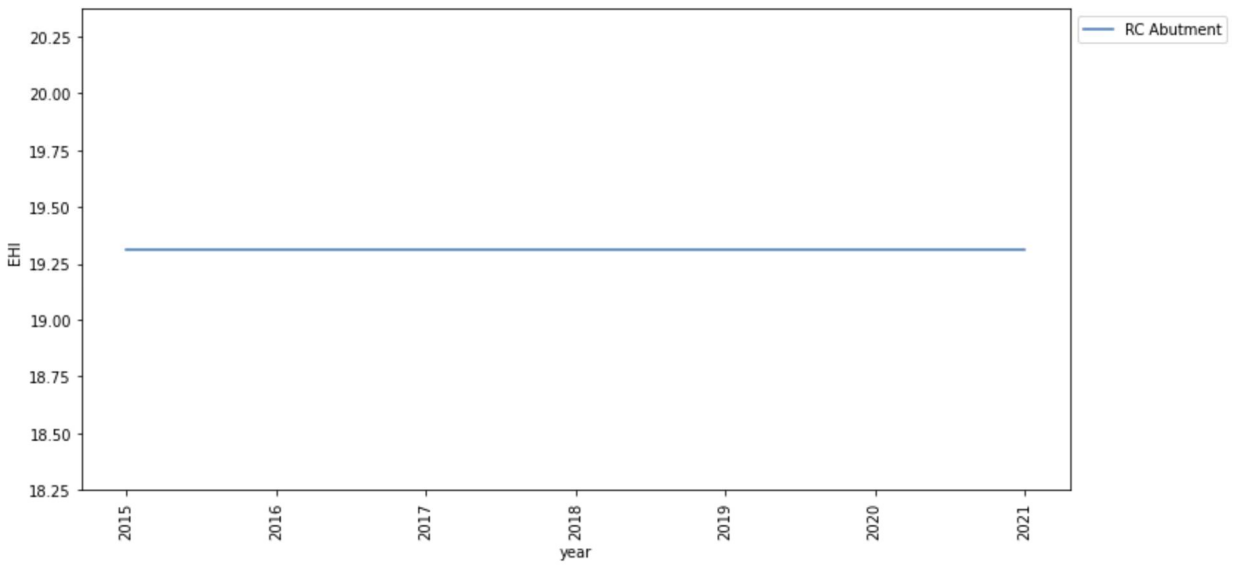
*Bridge 291-5028-0*

Bridge 291-5028-0 (**Figure 39**) is a single span steel bridge constructed in 1962 that passes over the Toccoa River in Union county. Union county is responsible for the maintenance and upkeep of this bridge.



**Figure 39: Bridge 291-5028-0 Side View (GDOT, 2021)**

As shown in **Figure 40** the reinforced concrete abutments have remained in same the condition state since its first element inspection was reported in 2015.



**Figure 40: , Bridge 291-5028-0 Reinforced Concrete Abutment EHI by Year**





**Figure 41: Concrete Spalling in Abutment 1 in 2014 (Left) and 2021 (Right)**

After examining the photos from inspection reports, it became clear that the concrete abutments are in poor health. The 2021 inspection report noted heavy concrete deterioration, spalling, exposed sole plates, and scour. The same issues were noted on inspection reports from 2014, and listed as maintenance items. Since then, these conditions worsened, with no maintenance being performed. **Figure 41** shows that in 2014 this bridge had concrete spalling on abutment one. By 2021 this abutment had more concrete deterioration, with larger and deeper areas of spalling.



**Figure 42: Reinforced Concrete Abutment Area Loss (GDOT, 2021)**

**Figure 42** shows reinforced concrete abutment loss that was unreported before 2021. This is additional concrete spalling that did not change the EHI of the bridge. This spall is of note as it

impacts the bearing area of the superstructure. A spall at a bearing area should be prioritized maintenance.

*Bridge 055-5009-0*

Bridge 055-5009-0 (**Figure 43**) is a single-span steel bridge owned and maintained by Chattooga county. This bridge was built in 1958 and rehabilitated in 1978. It passes over Lowe Branch Creek on Marble Springs Road. This bridge's substructure consists of two vertical wall reinforced concrete abutments that show signs of weather-related degradation.



**Figure 43: Bridge 055-5009-0 Side View (GDOT, 2022)**



**Figure 44: Bridge 055-5009-0 Top View (GDOT, 2022)**

In 2010 this reinforced concrete abutment had voids behind abutment one that was as large as 7.0' x 6.0. In 2010 these voids underwent maintenance by the county and were repaired, as seen in **Figure 45**. This bridge was noted to be on school bus route, which could be why the county chose to take action and repair the bridge.



**Figure 45: Bridge 055-5009-0 Void Repair Side View(Left) and Top View (Right)**

However, after repairs to the substructure, in 2014, minor spalls were reported in abutment two and undermining of 3.0 along the back wall of abutment one. At the time of the most recent inspection report, there was clear evidence of continued weather-related decoration. The area of undermining at abutment one had grown to 3.5' and inspectors recorded concrete spalling in

abutment one as being up to 5.0' long. Despite the increased degradation of spalling and undermining, the element condition state remained unchanged from the first inspection. Abutment maintenance requests have remained in inspection reports since 2014 but have yet to be addressed. As a result, deterioration due to freeze-thaw cycles and erosion have worsened the conditions of the abutments making repairs more challenging and expensive. Additionally, unreported concrete cracking and abrasion were observed, shown in **Figure 47**.



**Figure 46: Spalling in Abutment 2 (GDOT, 2022)**



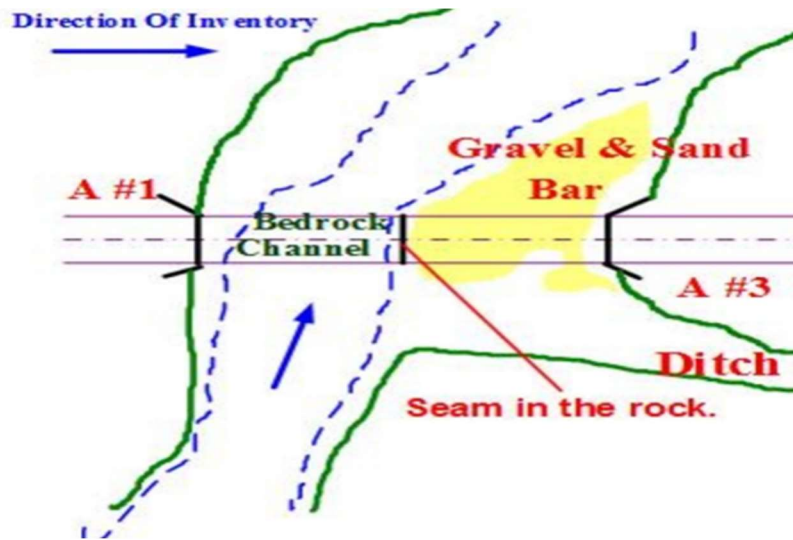
**Figure 47: Undermining in Abutment 1 (GDOT, 2020)**

*Bridge 213-0045-0*

Bridge 213-0045-0 is owned and maintained by Murray County on Old Highway 411, passing over a creek. **Figure 48** shows a profile photo of this bridge from 2022. The bridge is in good condition despite being built in 1911 (reconstructed in 1935); the inspection report in 2014 gave the deck, superstructure, and substructure an NBI rating of “6.” In 2016 this abutment had an EHI of 10.0, because of abrasion and wear. There are no photos of the abutments from any inspection reports, but **Figure 49** shows that abutment one is adjacent to the creek. This additional abrasion/wear is likely a result of proximity to water and the age of the structure.



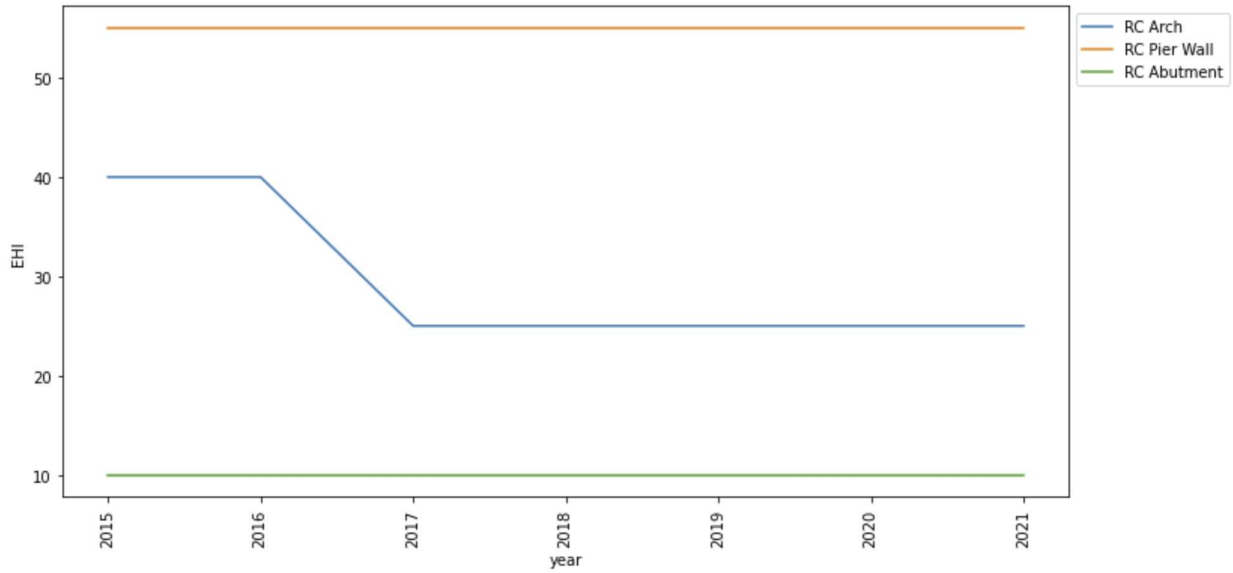
**Figure 48: Left Side View of Bridge 213-0045-0 (GDOT, 2022)**



**Figure 49: Top Waterway View of Bridge 213-0045-0 (GDOT, 2022)**

This bridge also shows degradation of the other concrete components. In 2016 50% of the reinforced concrete pier wall had fallen into condition state three, and the concrete arch had spalled, falling into condition state two. By 2016 it also had 50% of its length in condition state three.

**Figure 50** helps visualize the progression of these elements. A potential reason the reinforced concrete abutments have fallen and remained in condition state three is a lack of maintenance priority. Areas of the concrete arch superstructures and the asphalt deck have been patched in recent years, while there has yet to be a maintenance request reported for the reinforced concrete abutment. The spalling observed is consistent with spalls caused from freeze-thaw cycles, common in cold areas.



**Figure 50: Bridge 213-0045-0-0 EHI by Year**

*Bridge 055-5045-0*

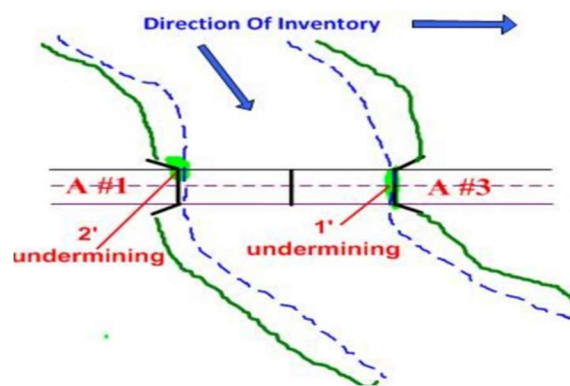
Bridge 055-5045-0 (**Figure 51**) was constructed in 1954 and reconstructed in 1987. It is owned and maintained by Chattooga County and passes over Telgoa Creek on Neal Gap Road. The bridge has a reduced capacity due to the lack of load-carrying capacity at the bent.



**Figure 51: Bridge 055-5045-0 Right Side View (GDOT, 2020)**

The deficiencies in this bridge are found in the substructure, mainly the reinforced concrete abutment. The issues appear to be the result of rainfall, freezing temperatures, the age of the bridge, and the lack of maintenance. The reinforced concrete abutment has remained in condition state three since the first element inspection.

Before reconstruction in 1987, this bridge experienced undermining at each abutment. **Figure 52** shows the top view presented in the reports. In 2014, there was undermining, and scour reported at abutment one and undermining along the entire face of abutment 3. In 2014, the county was advised to repair the scour present at the abutments. No maintenance was performed, and in 2020 a sizeable vertical crack, shown in **Figure 54**, appeared on abutment three due to settlement (GDOT, 2020). Inspectors reported the cracks to be 1.25” wide. Additionally, a 0.5” wide crack was noted in the right abutment three wing wall. Both cracks are vulnerable to increase in size due to this bridge’s proximity to water and the freezing temperatures that Chattooga County experiences. The cracking caused by abutment settlement is from weather impacts, either in the form of rainfall or freezing temperatures. Repairing settlement remains the maintenance priority for this bridge, followed by repairs to the railing and superstructure.



**Figure 52: Bridge 055-5045-0 Top View Sketch (GDOT, 2018)**



**Figure 53: Bridge 055-5045-0 Abutment 1 2014 (Left) vs 2020  
(Right)**



**Figure 54: Bridge 055-5045-0 Abutment 1 Settlement Crack (GDOT, 2020)**

### *Bridge 213-0033-0*

Bridge 213-0033-0 is a state-owned and maintained bridge in Murray County that passes over Rock Creek on US 76/ SR 282. This bridge was originally constructed in 1910 and widened in 1935. This bridge is in below-average condition, with a deck rating of "7", a superstructure rating of "4", and a substructure rating of "5."

The reinforced concrete abutment has remained in condition state three since its first inspection by GDOT. Unfortunately, GDOT inspectors did not capture any relevant photos of the reinforced concrete abutments, so it is hard to track this element's health to see its progression. Since 2014,

inspectors have noted weather-related degradation in other substructure elements. Inspectors noted that the abutments, piers, and footers have moderate to severe abrasion. The most recent report notes spalling and cracking in the piers and the abutments. Photos of the piers show weather-related degradation from 2014-2020, specifically in the reinforced concrete piers. In 2020, there is notably more spalling at the base of the pier and above the larger area of spalling. This increased spalling is likely attributable to the proximity to moisture and the freeze-thaw cycles in Murray County. Efflorescence also appeared in 2020. The superstructure of this bridge is also made of concrete and experienced similar degradation issues addressed by GDOT. The superstructure experienced spalling that exposed rebar, which a maintenance team covered with epoxy. Covering the exposed rebar with epoxy could have prevented the rebar from experiencing section loss and prevented further concrete deterioration.

In addition to being a DT32 county, Murray County also is a DP10 county. High levels of rainfall can cause erosion. **Figure 57** shows the measures taken to prevent the erosion caused by Rock Creek from reaching the roadway. In 2014 riprap was added behind the wing wall at abutment four to contain washout occurring at the abutment. However, by 2018 the scour reached within 3.0' of the roadways, and additional maintenance was required to prevent the scour from reaching the road.



**Figure 55: Arch Span with Exposed Rebar Covered with Epoxy vs Rebar with No Epoxy**  
(GDOT, 2020)



**Figure 56: Bridge 213-0033-0 Left Side View (GDOT, 2020)**



**Figure 57: Bridge 213-0033-0 Left Shoulder 2016(Right) vs 2020(Left)**



**Figure 58: Progression of Pier Degradation 2014(Left) to 2020(Right)**

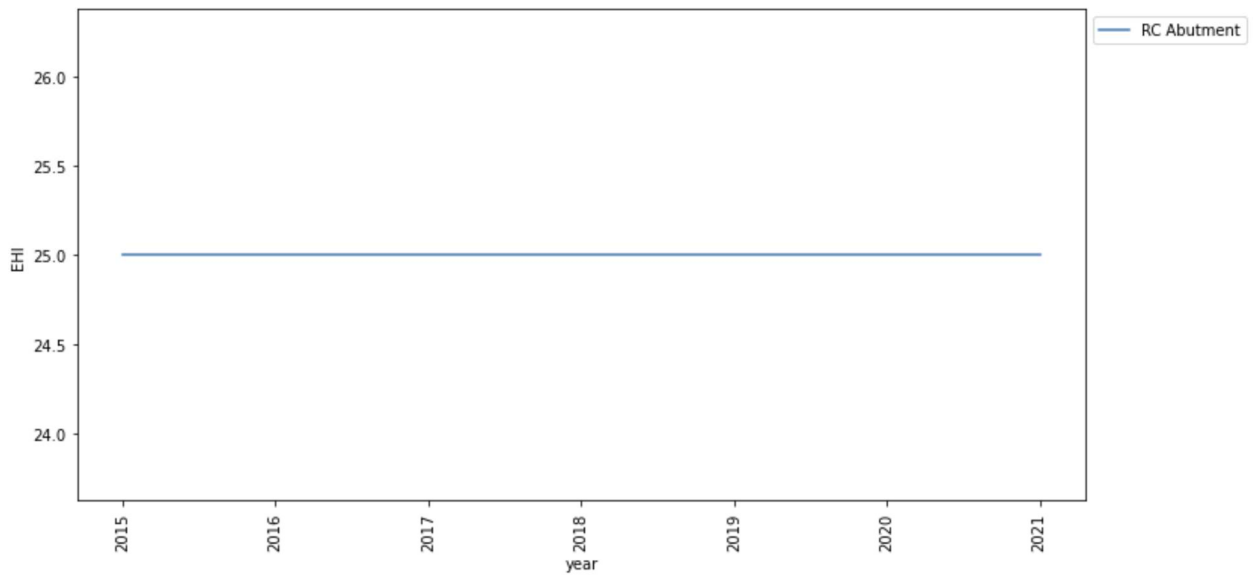
*Bridge 213-5004-0*

Bridge 213-5004-0 (**Figure 59**) is a two span steel bridge owned and maintained by Murray county constructed in 1933. This bridge has undergone weather related degradation since its construction. In 2018 this bridge was closed for a structural inspection due to severe corrosion and section loss of the steel beams. It was reopened in 2018 with a reduced load capacity of 5 tons, and is currently on a six month inspection cycle due to the advanced section loss in the superstructure. The superstructure fell into poor condition from the combination of lack of maintenance and proximity to moisture. Painting and cleaning this steel could have prevented the defects shown in **Figure 64**. Although the main concern on this bridge is the superstructure elements there are other trends to notice. The bridge is in extremely poor condition with an NBI deck rating of “3”, substructure rating of “4” and superstructure rating of “3.” In 2018 this bridge had maintenance performed on the deck, as construction teams overlaid 2.0” of asphalt while the bridge was closed. The deck remains in poor condition due to the concrete spalling and corrugated steel rust on the deck, but the wearing surface is in good condition. This showed maintenance priority when all components of the bridge are in need of retrofitting. A new concrete crack appeared in the abutment in 2019, shown in **Figure 62**. This crack from

settlement, which is the result of either rainfall washing out soil, or the soil freezing and thawing leading to the abutment shifting. The EHI of the bridge abutment did not change when this crack appeared.



**Figure 59 - Bridge 213-5004-0 Side View (GDOT, 2021)**



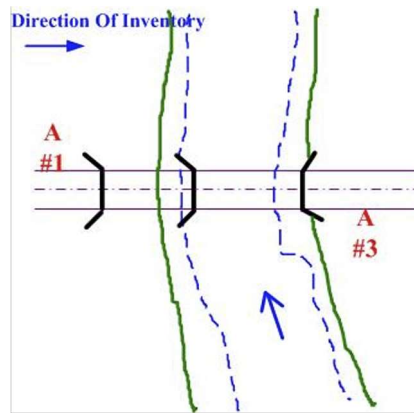
**Figure 60 – Bridge 213-5004-0 Reinforced Concrete Abutment EHI by Year**



Figure 61 - Concrete Loss on Abutment 3 (GDOT, 2019)



Figure 62 - Large Crack on Abutment 1 Discovered (GDOT, 2019)



**Figure 63 - Bridge 213-5004-0 Top View (GDOT, 2019)**



**Figure 64 - 100% Section Loss in Lateral Bracing (GDOT, 2020)**

*Bridge 055-5026-0*

Bridge 055-5026 (**Figure 65**) is a single-span steel bridge that passes over Alpine Creek on Buck Gardner Road. This bridge was built in 1981 and has been under the ownership of Chattooga County. This bridge is under 50 years old, showing that reinforced concrete abutments can fall into poor condition less than 50 years after construction. The overall bridge health is satisfactory as its most recent inspection gave NBI ratings of “5” deck rating, a “6” superstructure rating, and a “5” substructure rating.



**Figure 65: Bridge 055-5026-0 Side View (GDOT, 2020)**

The reinforced concrete abutment on this bridge has remained entirely in condition state three due to severe abrasion and concrete scaling ever since GDOT began collecting element inspection data. It was challenging to track the health of this element outside of inspectors' notes and element condition ratings, because the oldest photo of the reinforced concrete abutment was from 2020. The lack of photos is because the abutment is challenging to access. A dive team is required to inspect the abutment. In 2018 the reinforced concrete abutments were noted to have severe cracking and abrasion but not undermining. However, by 2020 one of the abutments was noted to have undermining 0.5' back x 0.5' high x 6.0' long. The undermining is likely due to the precipitation and the adjacent waterway. The crack shown in **Figure 66** appears to be the result of abutment settlement.



**Figure 66: Reinforced Concrete Abutment on Bridge 055-5026-0 (GDOT, 2020)**

Despite an additional defect, undermining, appearing in the 2020 inspection, the EHI of the abutment did not change.

*Bridge 055-5041-0*

Bridge 055-5041-0 was built in 1923 and is on CR178 before it dead ends. This bridge passes over Chappel Creek, and Chattooga County is responsible for the maintenance. The bridge is

inspected more than biannually because of poor deck and superstructure conditions. The deck has advanced deterioration, deep spalling and an NBI rating of “3.” The superstructure reflects the deck score, as the deck is the load-carrying element of this bridge. Overall, it is experiencing heavy corrosion (**Figure 67**). Both the deck and superstructure ratings can be attributed to the climatic impacts in this area. Freeze-thaw cycles and humidity typical in Chattooga County, as well as the age of the structure and the location crossing the waterway, likely led to the degradation of the superstructure and deck components.



**Figure 67: Bridge 055-5041-0 Deck Bottom (Right) and Top (Right) Deterioration (GDOT, 2020).**

This bridge is also experiencing degradation of the substructure. Both reinforced concrete abutments have remained fully in condition state three since their first NBI element inspection. They are both noted as having abrasion and wear. Inspectors also noted that the bedrock was exposed to erosion at the base of the abutment. However, the biggest issue with the substructure of this bridge is the impact of the creek and scour. As early as 2014, scour was reported and shown in **Figure 68**, and inspectors recommended Chattooga County install riprap to mitigate the effects of the scour. However, as recently as November 2022, these maintenance items have not been addressed. In 2014 there was undermining of up to 2.0’ recorded behind the same abutment, which inspectors documented by photo in 2020 (**Figure 69**).



**Figure 68: Scour at Abutment 1 (GDOT, 2014)**



**Figure 69: Void at Abutment 1 (GDOT, 2020)**

*Bridge 241-5024-0*

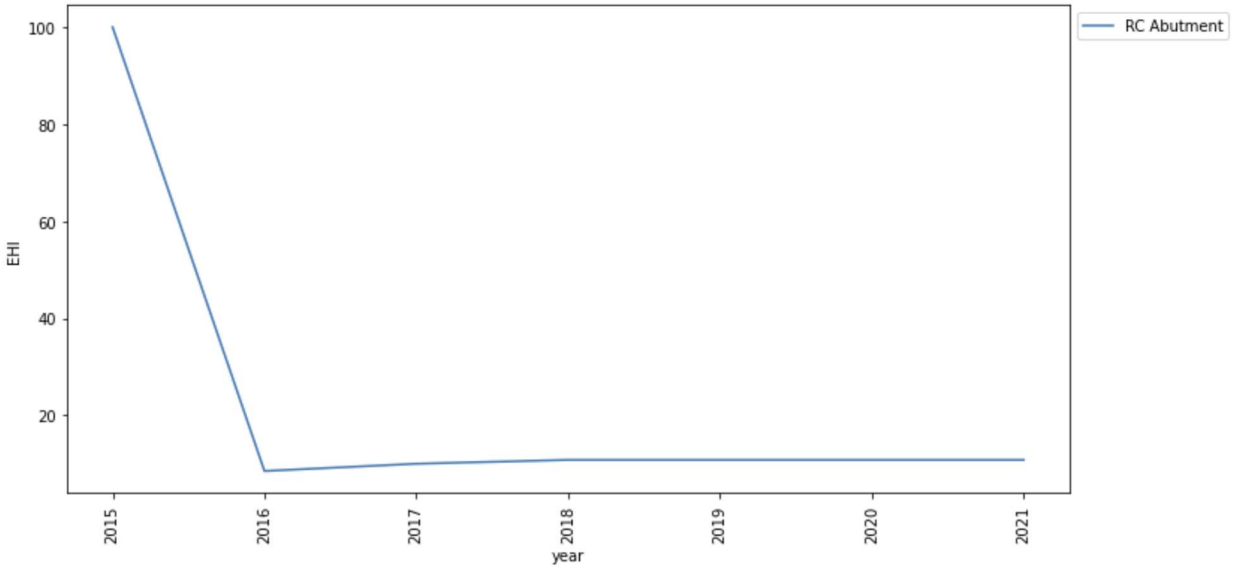
Bridge 241-5024-0 (**Figure 70**) is a concrete spandrel arch bridge constructed in 1932. The bridge is located on Old US 441 and passes over the Tallulah River. It is owned and maintained by the city. The bridge requires a specialized underwater inspection at least every five years. It

has two wall-style abutments on either end that support concrete arches, and has moderate to heavy concrete deterioration due to aging, salting, and winter freeze-thaw cycles.



**Figure 70: Side View of Bridge 241-5024-0 (GDOT, 2020)**

**Figure 71** gives a visualization of how to reinforced concrete abutment EHI changed by year. It was rated as 100 in 2015, because the first year this bridge was inspected using the new element inspection standards was in 2016.



**Figure 71: Bridge 241-5024-0 Reinforced Concrete Abutment EHI by Year**

In 2016, a dive inspection team rated 85% of this abutment in condition state three because of heavy abrasion one foot below the arch rib and an area of concrete honeycombing 6.0' long by 1.0'-2.0' wide. There was also vertical shrinkage cracking beginning to occur at both abutments and spalling that exposed rebar reported in abutment one near the water line. Additionally, the inspection team reported concrete efflorescence and degradation in abutment one. The report included a maintenance note to seal the spalling at abutment one. An inspection in 2017 reported the abutments to be 100% in condition state three. A jump from condition state four to condition state three is noteworthy, as no recorded maintenance had been completed on the bridge since the last rating. Additionally, the inspection in 2017 reported further degradation. During this inspection, the report listed a large area of honeycombing (6.0' x 1.0') with up to 6.0" penetration into the concrete. This spalling also exposed three pieces of rebar with 100% section loss. In addition, significant spalling is reported with exposed rebar on the right side of abutment one at the deck, as seen in **Figure 72**. The spalling shown is located near a joint and could be

from liquid leaking down and undergoing freeze-thaw cycles. The inspection team also did not report efflorescence or rust, but the concrete appears to have efflorescence and rust.



**Figure 72: Concrete Spalling and Exposed Rebar in Abutment 1 of Bridge 241-5024-0, 2017**

Photos from an underwater inspection in 2018 revealed the extent of the concrete damage at the water line of the abutment as shown in **Figure 73**.



**Figure 73: Concrete Degradation and Exposed Rebar at Waterline in Abutment 1 of Bridge 241-5024-0 (GDOT, 2018)**

In 2018, a specialized inspection was conducted on the abutments, and the team found cracks measuring 1/64" in both abutments and measured the spalling in **Figure 72** to be 22" x 28" x 2". Additionally, the inspection team reported the concrete deterioration and efflorescence shown in **Figure 76**. At the end of the inspection, the report recommended repair to the spalling and exposed rebar in the abutment.

The most recent inspection in 2022 recorded the same issues that previous years' inspections noted with some additions. The cracking in abutment one reached 0.0625", as shown in **Figure 76**. This would be at risk of Additionally, the extent of the concrete honeycombing was captured and is shown in **Figure 75**. Despite it being difficult to see, inspectors noted that this is the honeycombing.



**Figure 74: Concrete Cracking and Honeycombing in Abutment 1 of Bridge 241-5024-0 (GDOT, 2022)**



**Figure 75: Honeycombing Patch in Abutment 1 of Bridge 241-5024-0 (GDOT, 2022)**

**Figure 76** shows that there was also concrete spalling recorded at the intersection of the abutment and deck that was not reported in previous years.



**Figure 76: Concrete Spalling in Abutment 1 of Bridge 241-5024-0 (GDOT, 2022)**

Maintenance requests for the concrete spalling and cracking were requested as early as 2015 and have not been filled yet. There is a trend of bridge degradation over this time that could have been prevented by filling maintenance requests before spalling and cracking increased.

Another element of interest on this bridge is the reinforced concrete deck. In 2014 the inspection report noted that the deck had recently had maintenance construction on the deck, as seen in

**Figure 77.**



**Figure 77: Reinforced Concrete Deck Patching on Bridge 241-5024-0 (GDOT, 2022)**

This repair was made to repair deterioration from deicing salts and freezing temperatures. While this repair was made, repairs on the substructure and superstructure were neglected.

*Bridge 055-5030-0*

Bridge 055-5030, seen in **Figure 78** is owned by Chattooga county and has a wide variety of deteriorations that appear to be due to the weather conditions experienced in Chattooga County. This bridge is a two-span steel bridge initially constructed in 1958 that passes over the Chattooga river on Center Post Road.



**Figure 78 - Bridge 055-5030-0 Side View (GDOT, 2022)**

At the last inspection, inspectors assessed the deck, substructure, and superstructure, giving each an NBI score of “4.” Many of the deficiencies in this structure could be attributable to climatic-related impacts.

The deck has cracked along the top, and the bottom and bottom of the deck are experiencing efflorescence. Additionally, the bottom of the deck has spalling that is deep enough to expose the rebar. The deck overhangs and asphalt overlay are also experiencing large areas of spalling. It is of note that even with extensive evidence of deterioration in the deck, the pourable joint deal remains in condition state one. The deterioration in the deck appears to be from poor concrete strength, likely as a result of freezing temperatures and proximity to moisture.



**Figure 79 – Bridge 055-5030-0 Deck Spalling (GDOT, 2022)**

The bridge superstructure consists of three spans that use wide flange members. In 2002, Chattooga County replaced, cleaned, and painted the beams in span one, while the beams in spans 2 and 3 were last painted in 1958. The beams in spans two and three are experiencing heavy corrosion, and each has multiple areas of total section loss. The difference in corrosion impact shows the importance of preservation steps relevant stakeholders should take to preserve steel superstructures, particularly in areas that experience high humidity levels, like Chattooga County.



**Figure 80 – Bridge 055-5030-0 Wide Flange 100% Section Loss (GDOT, 2022)**

While the deck of this bridge experienced deterioration likely due to freeze-thaw cycles and the superstructure experienced deterioration likely due to proximity to humidity and water, the substructure experienced degradation from these climatic factors working together. The substructure consists of two reinforced concrete abutments, two reinforced concrete pier walls, and a reinforced concrete pier cap. Each of these structural components has experienced similar degradation.

Freeze-thaw cycles have likely impacted EN235, the reinforced concrete pile caps. It has corroded the area where the steel girders rest, as seen in **Figure 81**.



**Figure 81 – Reinforced Concrete Pile Cap Wear on Bridge 055-5030-0 (GDOT, 2017)**

In addition to the pile caps degrading, the abutments and pier walls are also experiencing concrete spalling at the superstructure that should be patched and repaired to prevent continued weathering from the climatic elements in this area.



**Figure 82 – Spalling in Reinforced Concrete Abutment on Bridge 055-5030-0 (GDOT, 2020)**

At the base of the substructure, both the pier walls and abutments have experienced scour and drift accumulation due to the bridge's proximity to the Chattooga River. These issues led bridge inspectors to assess a Scour Critical Rating of "5."



**Figure 83 – Scour at Reinforced Concrete Pier Wall on Bridge 055-5030-0 (GDOT, 2020)**

This bridge has a long list of maintenance items to complete to maintain the safety of this asset as seen in **Table 21**.

**Table 21 – Bridge 055-5030-0 Maintenance Items, 2022**

Activity	Priority	Location	Comments
815-Bridge Curb/Rail Repair	B	Rear left guardrail	Repair damage.
810-Deck Repair	B	Spans 2 and 3	Repair spalls in the bottom of deck and overhangs.
830-Repair Main Structural Members	B	Superstructure	Repair superstructure steel section loss and corrosion.
830-Repair Main Structural Members	B	Bent 2 cap	Repair moderate spalls.
845-Other Bridge Maintenance	B	Bent 3	Remove massive drift pile.
845-Other Bridge Maintenance	B	Bent 2	Repair scour.
845-Other Bridge Maintenance	B	Bent 3 column 2 spread footer	Repair void in the footer.
000-Bridge Painting	C	Superstructure	Clean and paint steel super and substructure members.
000-Bridge Painting	C	Helper bent at abutment 4	Clean and paint pile.
815-Bridge Curb/Rail Repair	B	span 1 right bridge rail and span 3 left bridge rail and post	Repair collision damage.
810-Deck Repair	B	Span 2 and 3 deck curb	Repair curb as needed.
845-Other Bridge Maintenance	C	Gutter line	Remove debris and grass.
845-Other Bridge Maintenance	C	Bent 3 cap	Remove drift from on top of cap.

*Bridge 313-5028-0*

Bridge 313-5028-0 is a county owned and maintained bridge located in Whitfield County. The bridge was originally constructed in 1969 and passes over Mills Creek. The bridge was identified because of a low reinforced concrete abutment EHI. The reason why this abutment scored low was scouring. Both abutments have undermining that expose piles. Abutment one had a measured area of 3.2'x3.2' in 2022, and abutment three had an area of 3.6' x 2.4'. Unfortunately, the areas of scour was not measured by inspectors in previous years. The county had made previous repairs, but they were not sufficient as the piles were still exposed piles and the scour at the abutments. In addition to the scour, the bridge showed other impacts of weather stressors.

Element 110, the reinforced concrete girder/beam has shown the impacts of being in a freezing environment.



**Figure 84 – Bridge 313-5028-0 Reinforced Concrete Girder Spalling 2014 (Top) vs 2020 (Bottom)**

There have been unfilled maintenance requests to repair these spalls, and the scour. Since the requests were not filled the spalls grew larger and the abutment piles experienced section loss. The steel piles also need to be painted, or they are at risk of further corrosion and section loss.

#### *Summary of Reinforced Concrete Abutment*

There were several lessons learned when viewing inspection reports of poorly rated reinforced concrete abutments in freezing counties. All of the bridges identified were bridges that passed

over water, showing that the impacts of water can cause an abutment to deteriorate. These impacts were observed in two forms; the impacts of erosion and the impacts of freeze-thaw exacerbated because of the proximity to a humid environment. Additionally, the reinforced concrete abutments studied were also older bridges, meaning that for these elements to reach this condition weather had to impact the element for years. Abutment deterioration is generally not fast occurring.

There were three primary defects that the reinforced concrete abutments showed in the cases studied were concrete spalling, settlement cracking, and undermining/scour. Several of these defects could be attributed to weather stressors experienced in the Northern regions of Georgia. Despite the defects it did not appear that poor reinforced concrete abutment condition generally had a large impact on the load rating of the bridges, due to the massive sizes of the structures.

The concrete spalling observed on the abutments could not be 100% attributed to weather stressors. Most of the spalls observed were located underneath bearing areas, meaning that they could have come from live loads. Although it is possible that freeze-thaw cycles contributed to the spalling as well, either growing the size of the spalls or making the concrete weaker and more susceptible to spalling. Counties appeared to not prioritize maintenance suggestions by GDOT inspectors that recommended patching these spalls. This is likely because these spalls did not impact load capacity.

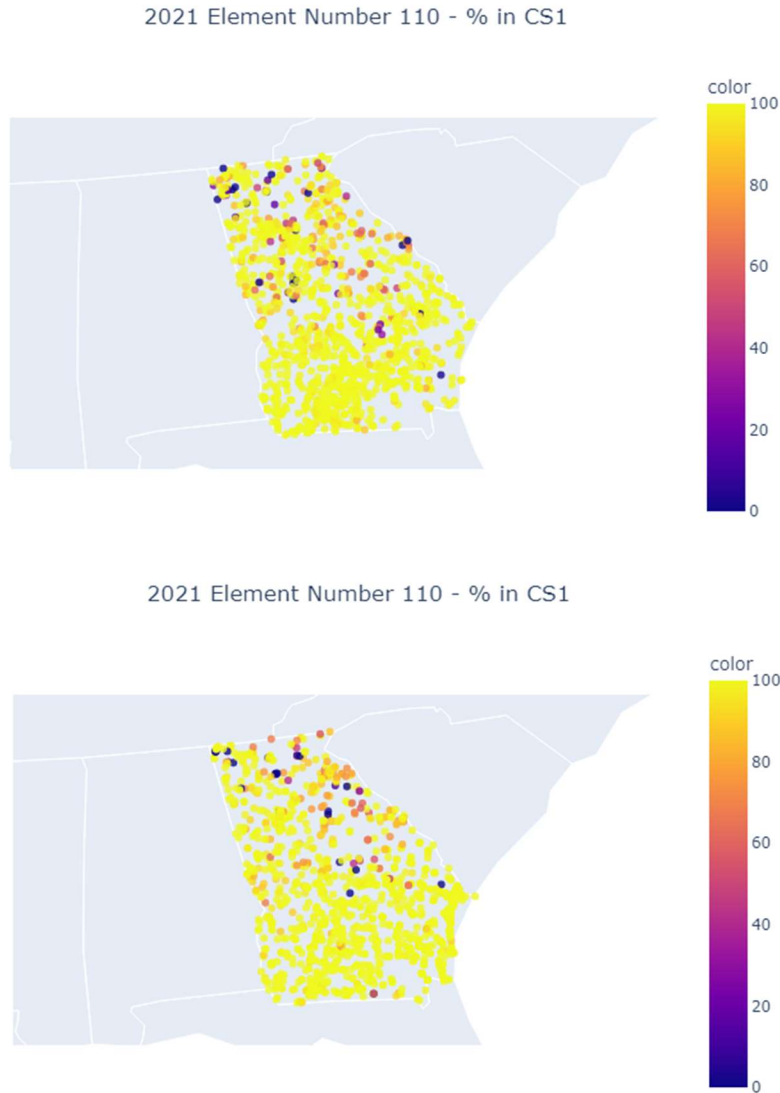
The next defect that appeared on two of ten bridges was a settlement crack. Both cracks were large in size, as settlement does not normally produce minor cracks or spalls. Both of these cracks were over 1.0” in width. The settlement was likely caused by weather stressors, either precipitation or from freezing and thawing of the ground soil. Unfortunately, there is little

counties can do to prevent these deteriorations, and they are expensive to fully repair. Sealing the cracks is an option, but they may reopen with further settling.

The last impact that was observed from the inspection reports was undermining and scour. Of the ten bridges studied, seven had problems with undermining of the abutment or scour. These defects can be directly linked to weather impacts as the flow of water around the substructure removed. It appeared that most of the erosion that occurred around the substructures could have been prevented with rip-rap or minor preventative measures. This was the only maintenance issue that was addressed by counties on the ten bridges studied.

### ***Element 110 Reinforced Concrete Girder/Beam***

Element 110, the reinforced concrete girder/beam was selected to study in the DT32 counties from the element heat maps shown in **Figure 85**. This element is relatively common in Georgia, as in 2021, 2,708 unique bridges contained at least one reinforced concrete girder. Additionally, at least one bridge contains a reinforced concrete girder in all 159 counties in the state. A reinforced concrete girder is a superstructure element used to support bridge decks. Element 110 is used to describe all reinforced concrete girders regardless of protective systems in place. AASHTO provides condition state definitions, feasible actions, and element definitions for the reinforced concrete girders in their guide for element inspection.

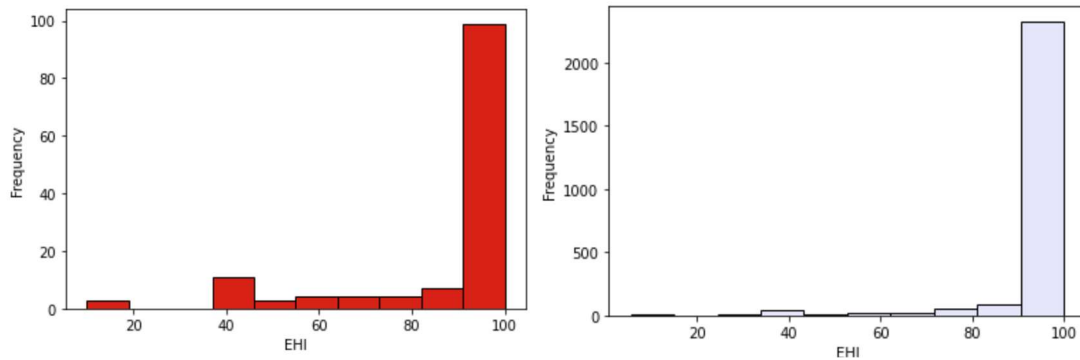


**Figure 85: Percent of EN110 in Condition State One by Location, 2021. County-Owned (Top) vs State-Owned (Bottom)**

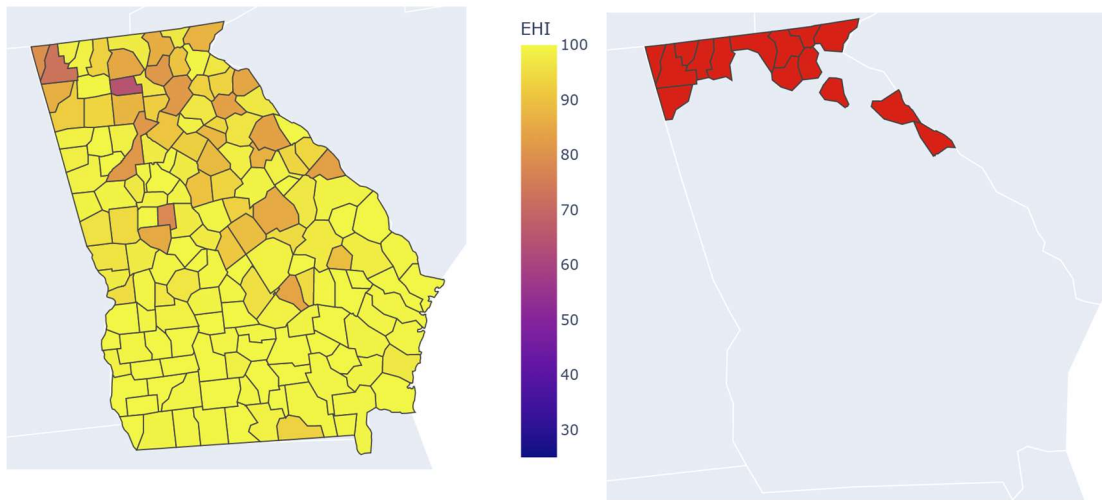
From these maps, there appeared to be more poor condition elements in areas of Georgia experiencing the coldest weather. After further studying this element, this element is in worse condition in DT32 counties than in other counties. In counties that are not DT32 counties, the average EHI for this element was 96.6, while in DT32 counties of interest, the EHI was 87.7. The disparity in average EHI shows that bridges in these counties lag in EHI compared to the overall health of bridges in the state. There is a higher frequency of reinforced concrete girders in

the 40-80 health rating that occur in DT32 counties than in other Georgia counties, shown in **Figure 86**.

Additionally, **Figure 87** shows that this element appears to be in worse condition in several of the selected DT32 counties.

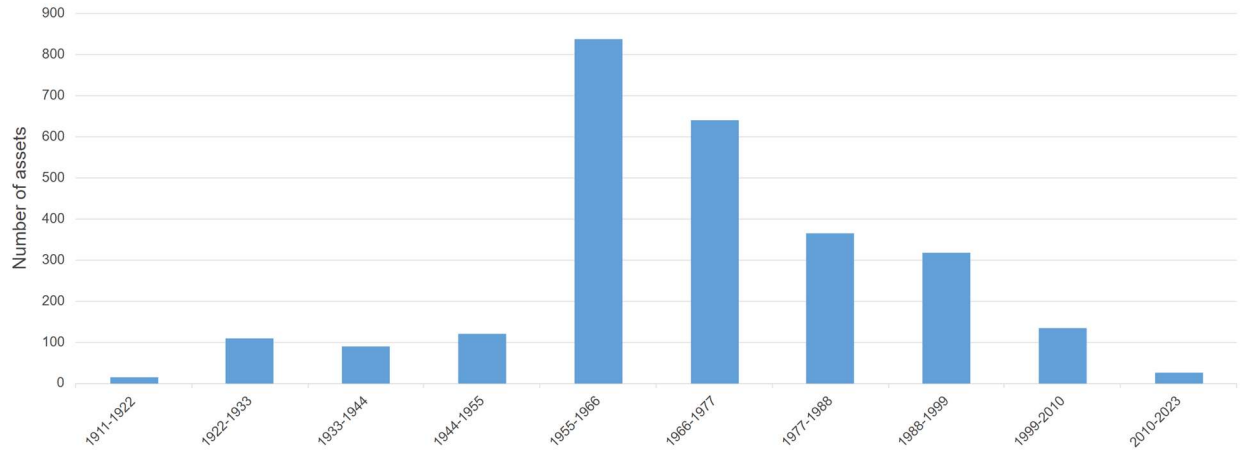


**Figure 86 – EHI of EN110 DT32 Counties (Left) vs NonDT32 Counties (Right)**

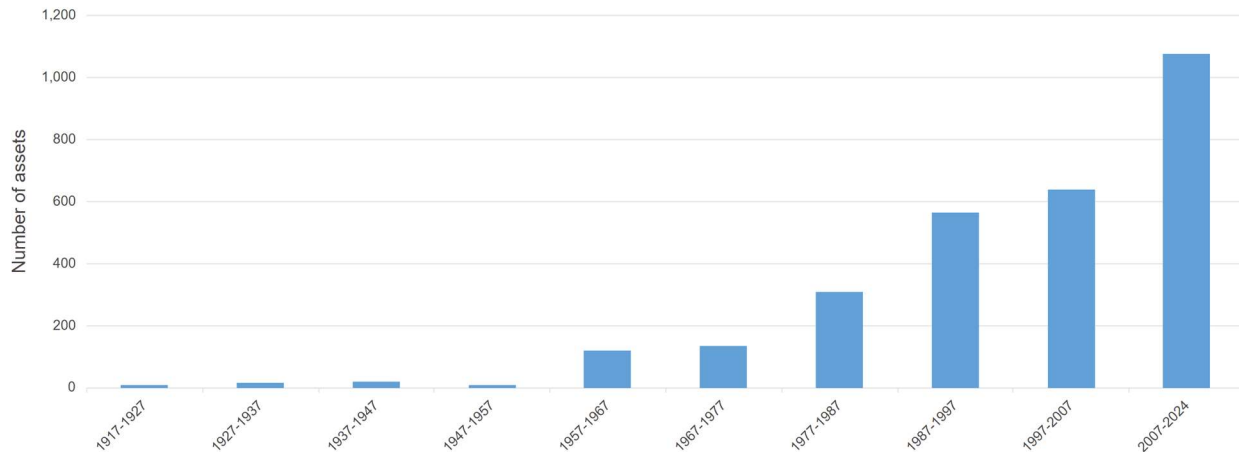


**Figure 87 – Average EHI of EN110 by County (Left) vs DT32 Counties (Right)**

It is important to note that the reinforced concrete girder is a bridge element that is being constructed less as new methods, primarily the prestressed concrete girder. Using the GDOT tool, InspectX, **Figure 88** and **Figure 89** were generated for both the reinforced concrete girder, and the prestressed concrete girder to show construction trends and likely future maintenance needs.



**Figure 88 – RC Girder Number of Assets Built by Year (InspectX)**



**Figure 89 – PSC Girder Number of Assets Built by Year (InspectX)**

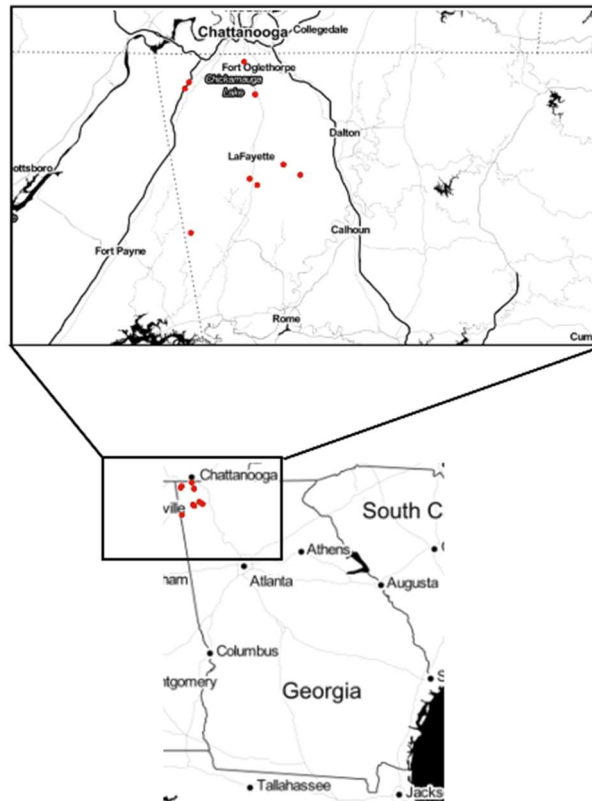
A majority of the reinforced concrete girders in Georgia were built between 40-70 years ago. Maintenance will not be necessary in the long term, but in the coming years preservation and rehabilitation strategies will be important with the bridges containing these elements.

Once element 110 was identified to be potentially impacted by days under 32 degrees, it was important to investigate bridge maintenance reports to determine if the lower element health index ratings in these 15 counties are because of climatic factors. The lowest 10 bridges by

reinforced concrete girder EHI were selected to further study. **Table 22** shows the lowest ten, and **Figure 90** shows the location of the ten bridges of study.

**Table 22 - Lowest 10 DT32 Bridges by EHI of EN110**

Bridge ID	County	Owner	Year Built	Service Under	Superstructure NBI Rating	EHI
295-0015-0	Walker	State	1932	Waterway	6	10
295-0039-0	Walker	County	1973	Waterway	5	10
295-0041-0	Walker	County	1936	Waterway	5	39.625
055-5037-0	Chattooga	County	1918	Waterway	5	40
083-0026-0	Dade	State	1967	Roadway	6	40
083-0027-0	Dade	State	1967	Roadway	6	40
083-0028-0	Dade	State	1967	Roadway	6	40
295-0004-0	Walker	State	1930	Waterway	6	40
295-0040-0	Walker	County	1930	Waterway	6	40
295-5011-0	Walker	County	1918	Waterway	6	40



**Figure 90 - Location of Selected DT32 Bridges for EN110**

When looking at the worst 10 bridges by EHI in the DT32 counties there are trends that stand out. First is that most of these bridges pass over a waterway. This is expected, as this additional exposure to moisture is expected to increase the severity and number of freeze-thaw cycles. Additionally, most of these bridges are more than 50 years old. This means that the weather factors they are exposed to daily have impacted them for upwards of five decades and the reinforced concrete has likely experienced deterioration. Another note is that of these 10 selected bridges, it was evenly split between county ownership and state ownership showing that unlike other elements the poorest elements were not primarily county owned.

#### *Bridge 295-0015-0*

Bridge 295-0015-0 (**Figure 91**) is a three-span concrete bridge owned and maintained by Walker County. This bridge passes over West Armuchee Creek on SR136. Originally constructed in 1932, this bridge has experienced severe concrete-related degradation. Of the concrete elements in this bridge that have experienced deterioration, the concrete girder is in the worse condition. Of the 270' of reinforced concrete girder in this bridge, 270' are in condition state three. The reason for the concrete girder's rating stated in the element defect data is cracking, efflorescence, and concrete spalling that has exposed rebar to weather elements.



**Figure 91 – Bridge 295-0015-0 Side View (GDOT, 2021)**

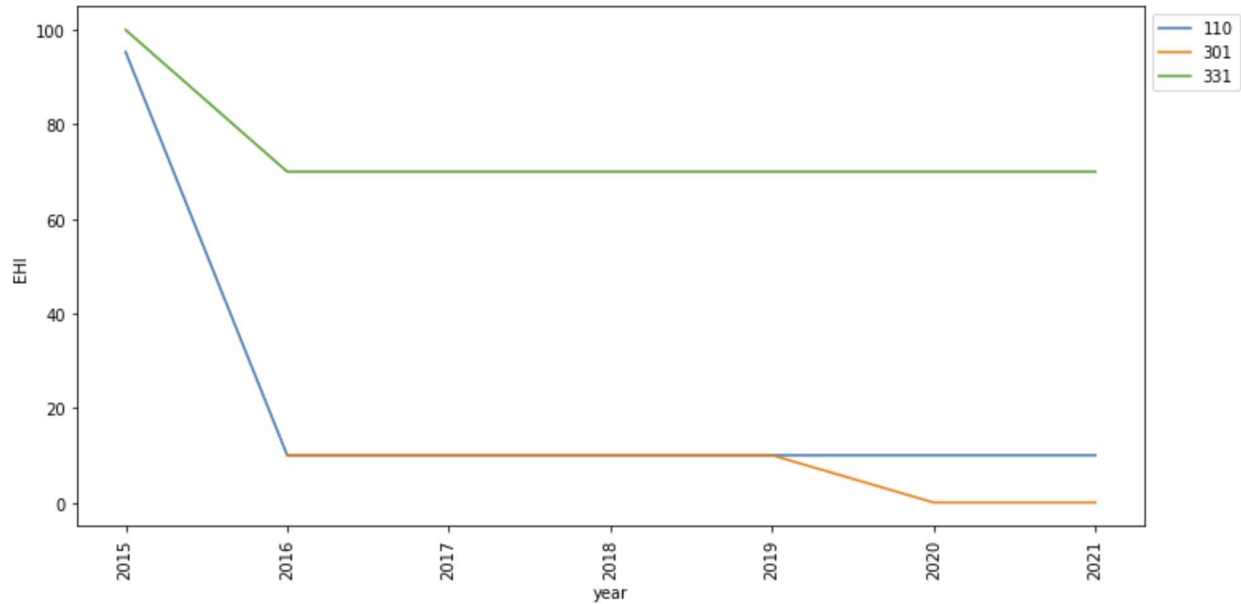
However, historical NBI data showed that the reinforced concrete girder was not always in poor condition. The first NBI element inspection gave the reinforced concrete girder an EHI of 95.33. However, by the next inspection, the element health index dropped to its current score of 10. In 2015 inspectors reported minor cracking and efflorescence. Inspectors also noted shallow steel spalls. Unfortunately, no photos of the girder degradation were taken during this inspection.

At the next inspection, inspectors reported cracking, spalling, and efflorescence. Inspectors noted that the girder's spalls exposed rebar and included a maintenance request to patch the areas of spalling that exposed rebar.



**Figure 92 – Bridge 295-0015-0 Typical Girder Spalling (GOT, 2021)**

An interesting note about this bridge is the interaction between different elements. Inspectors note that efflorescence is building up, especially around the joints. The location of the efflorescence build-up is interesting to note because the same year the reinforced concrete girder dropped in condition state, the joint did too. The increased flow of water through the joints increased moisture in the element, and in combination with the high number of freeze-thaw cycles experienced in Walker County, could have led to the large concrete spalls that this bridge experienced. **Figure 93** shows the interaction between the joints EN301&331 and the girder EN110. Unfortunately, there are no photos of the damaged joints on the bridge.



**Figure 93 – Bridge 295-0015-0 EHI by Year**

*Bridge 295-0039-0*

Bridge 295-0039-0 (**Figure 94**) is a Walker County-owned and maintained bridge initially constructed in 1973. This structure currently requires a reduced load posting due to the extensive concrete deterioration throughout the bridge. The superstructure is currently in condition state three and has been since the first element inspection in 2015. The superstructure consists of three spans with six county “T” beams per span. The beams currently have areas of honeycombing and moderate cracking throughout the span. There are also several large spalls on the beams, with the largest recorded being 0.7’x0.7’x0.3’. This spall is located at the midspan of the beam.



**Figure 94 – Bridge 295-0039-0 Side View (GDOT, 2021)**



**Figure 95 – Bridge 295-0039-0 Concrete Spalling (GDOT, 2021)**



**Figure 96 – Bridge 295-0039-0 Concrete Cracking (GDOT, 2019)**

Although the reinforced concrete girders are in poor condition on this bridge, other components of this bridge are in poor condition. However, the reinforced concrete girders of the bridge were overlooked while crews performed other maintenance on this bridge.

In 2021, Bridge 295-0039-0 underwent maintenance on the deck and the substructure. The deck received a new asphalt coat to help prevent the leaking that has been causing large amounts of efflorescence to build up on the underside of the deck.

This bridge also underwent maintenance to repair severe scour-related impacts. **Figure 97** shows the substructure before and after the maintenance occurred in 2021. The reinforced concrete abutment had undermining that had entirely exposed the steel piles.



**Figure 97 – Bridge 295-0039-0 Reinforced Concrete Abutment 2015 (Top) vs 2021 (Bottom)**

One could make the case that while maintenance crews were performing maintenance on other elements on the bridge, spall repair and crack sealing could have been performed to prevent further weather-related degradation on the superstructure and the raising of the condition state. The maintenance item list (**Table 23**) had all these repairs noted, and only two were completed.

**Table 23 – Bridge 295-0039-0 Maintenance Items (GDOT, 2021)**

Activity	Priority	Location	Comments
845-Other Bridge Maintenance	B	Bent 2, bent 3 and abutment 4.	repair scour and undermining.
810-Deck Repair	B	deck	remove asphalt overlay and repair deck cracking and concrete deterioration
845-Other Bridge Maintenance	B		Repair right side bridge rail spalling.
830-Repair Main Structural Members	B	Superstructure	Repair spalls and seal cracks in superstructure.

*Bridge 295-0041-0*

Bridge 295-0041-0, initially constructed in 1936 with five spans of reinforced concrete “T” beams, is a Walker County-owned and maintained bridge that passes over Dry Creek on Old Trion Highway. Each span contains four reinforced concrete beams. In 1977 the bridge was expanded using a wide flange steel beam, shown in **Figure 98**.



**Figure 98 – Bridge 295-0041-0 Side View (GDOT, 2021)**

This bridge maintained the same EHI from the first element inspection report in 2015. In 2015 it received an EHI of 40.0 and dropped to 39.635 in 2019. The beams have moderate cracking

throughout and a spalling area of 0.6'x0.2'x0.2' on the beams in two locations. These spalls have exposed rebar. **Figure 99** shows one of the spalls noted in the inspection report.



**Figure 99 – Bridge 295-0041-0 Reinforced Concrete Girder Spalling (GDOT, 2021)**

Both spalls in the reinforced concrete girders are located directly underneath one of the seal joints. These joints have been in condition state four since the first inspection report, and inspectors noted leakage. The concrete bents located at the joints have also experienced similar concrete spalling, shown in **Figure 100**.



**Figure 100 – Bridge 295-0041-0 Reinforced Concrete Pier Cap (GDOT, 2021)**

It appears that water is leaking through the joints, and concrete spalling occurs when the water is exposed to freeze-thaw cycles typical in this area. It is also likely that this spalling could have occurred from live loads on the bridge deck,

Since 2015, maintenance work has been completed on this bridge. In 2019 maintenance crews removed drift and repaired a reinforced concrete pier cap to fix the settlement. However, maintenance crews did not address the concrete spalling and joint damage. **Table 24** shows the list of current maintenance items, and repairing the joints is only a “C” priority. However, after studying this bridge, one could argue that the joint leakage is the cause of some of the deterioration of the superstructure and substructure elements.

**Table 24 – Bridge 295-0041-0 Maintenance Items (GDOT, 2021)**

Activity	Priority	Location	Comments
845-Other Bridge Maintenance	B	Abutment 1 and bents 2 and 3.	Repair scour and undermining.
800-Bridge Joint Sealing	C	Deck joints.	Clean and seal.
810-Deck Repair	B	deck surface	Seal cracking and patch spalls.
	A	Bent 2 column 1	Repair settled and sshifted stand along column
830-Repair Main Structural Members	B	Caps	Repair spalls.
	B	around structure	remove drift and vegetation
	B	Bent 2	Remove drift
000-Bridge Painting	C	superstructure	clean and paint steel beams

*Bridge 055-5037-0*

Bridge 055-5037-0 (**Figure 101**) is a single-span concrete bridge owned and maintained by Chattooga County. The structure was initially built in 1918, making it over 100 years old. This bridge passes over Shinbone Creek on Massey Road.



**Figure 101 – Bridge 055-5037-0 Side View (GDOT, 2022)**

The reinforced concrete girders currently have an EHI of 40.00. The concrete girders are primarily in condition state two because of spalling with exposed rebar and cracking. The

concrete spalling is located near the midspan and at the abutment. Since the structure's construction, the spalling present is the possible result of freeze-thaw cycles. **Figure 102** and **Figure 103** show the concrete spalling and exposed rebar.



**Figure 102 – Bridge 055-5037-0 Reinforced Concrete Girder Spalling (GDOT, 2020)**



**Figure 103 – Bridge 055-5037-0 Reinforced Concrete Girder Spalling (GDOT, 2020)**

*Bridge 083-0026-0*

Bridge 083-0026 differs from previously studied bridges. Built in 1967, this is a state-owned and maintained bridge that does not pass over a waterway. However, the reinforced concrete girders in this bridge have remained in condition state two since the first element inspection in 2015. The beams are in condition state two because of concrete cracking throughout the bridge superstructure.



**Figure 104 – Bridge 083-0026-0 Reinforced Concrete Girder Typical Cracking (GDOT, 2019)**

**Figure 104** shows the cracking in the reinforced concrete girder, which appears minor compared to other cracking/spalling observed in reinforced concrete girders with similar EHIs.

*Bridge 295-5011-0*

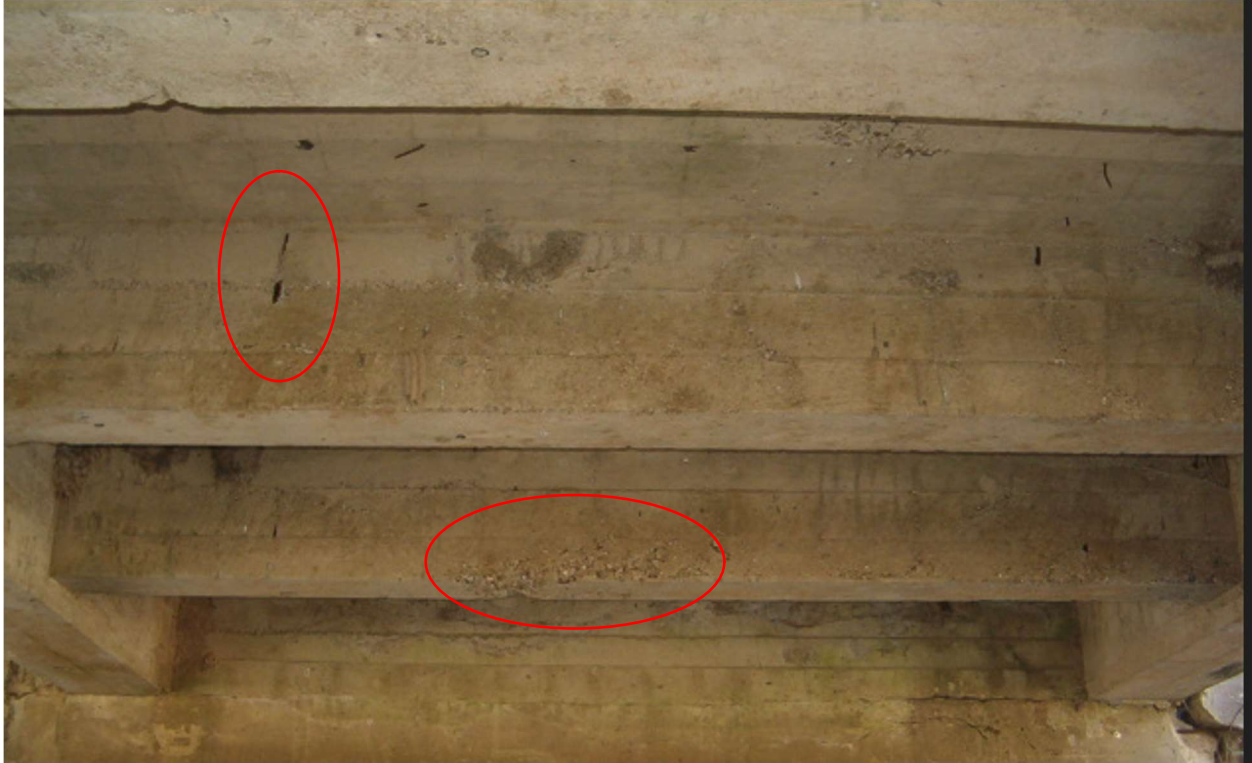
Bridge 295-5011-0 (**Figure 107**), initially constructed in 1918 and widened in 1980, is owned and maintained by Walker County and passes over Cane Creek on Lee School Road. This bridge

contains two spans, each with two longitudinal and six transverse beams. The section was widened in 1980 with steel wide flange members, and the reinforced concrete girders were constructed in 1918.



**Figure 105 – Bridge 295-5011-0 Side View (GDOT, 2022)**

The first element inspection report placed the reinforced concrete girder in condition one before it fell into condition two in 2017. It has remained in condition state two since 2017, with the primary reason behind this classification being cracking and spalling, with some of the spalls exposing the steel reinforcement. The cracking and spalling are considered minor, which is why this bridge is classified in condition state two. **Figure 106** shows typical cracking and spalling in the reinforced concrete girder of this bridge, with circles to highlight areas of spalling.



**Figure 106 – Bridge 295-5011-0 Reinforced Concrete Girder Typical Spalling (GDOT, 2022)**

Even though the concrete spalling in this bridge is not severe, when comparing this county-owned bridge to state-owned bridges of the same condition state, the reinforced concrete girder is in worse condition than the reinforced concrete girders in similar condition states.

*Bridge 083-0027-0*

Bridge 083-0027-0 (**Figure 111**) is a state owned and maintained bridge located in Dade County. This bridge was originally constructed in 1967 and passes over Hicks Hollow Road on I-59 Northbound.

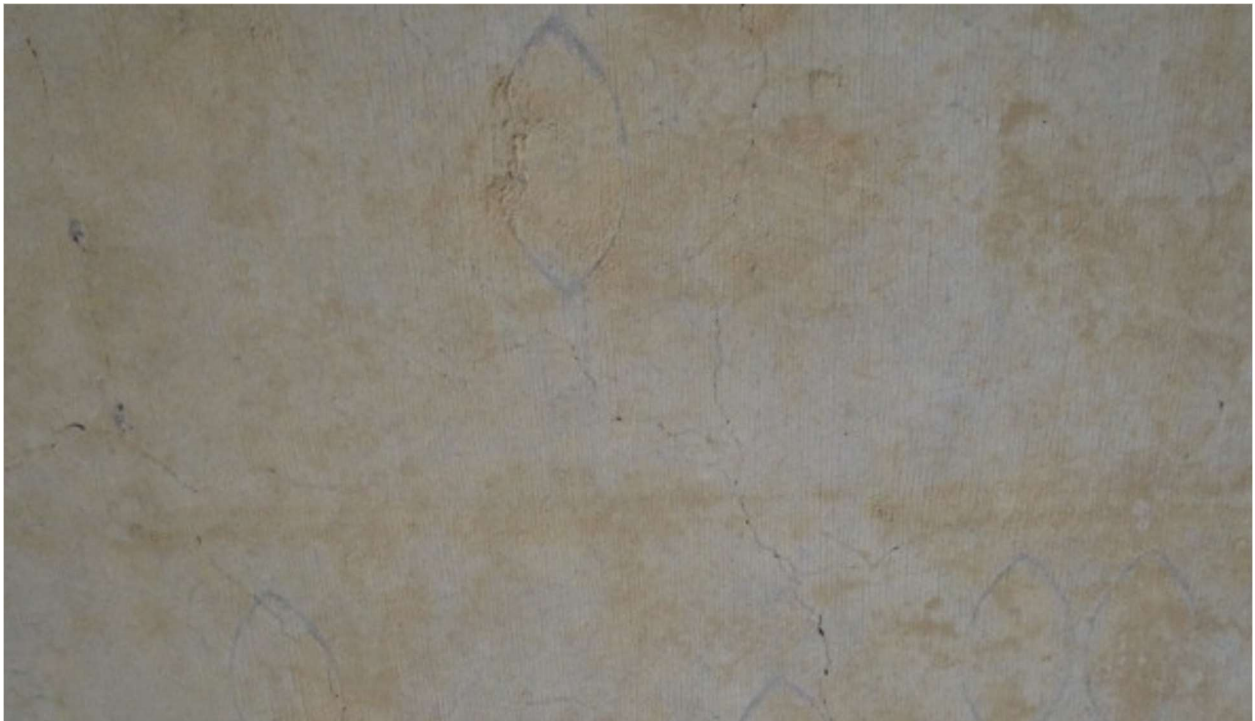


**Figure 107 – Bridge 083-0027-0 Side View (GDOT, 2022)**

The reinforced concrete girder consists of 3 spans each with six arched bottom concrete “T” beams. It has maintained an EHI of 40.0 since the first element inspection in 2015. The beams have moderate deflection cracks as well as some minor spalling in the beams at the abutments. The cracking and spalling are relatively minor and are pictured in **Figure 108**, **Figure 109**, and **Figure 110**.



**Figure 108 – Bridge 083-0027-0 Reinforced Concrete Girder Spalling (GDOT, 2019)**



**Figure 109 – Bridge 083-0027-0 Reinforced Concrete Girder Cracking (GDOT, 2019)**



**Figure 110 – Bridge 083-0027-0 Reinforced Concrete Girder Spalling (GDOT, 2019)**

After examining the inspection reports it is likely that the spalling and cracking found on this bridge structure are likely attributable to the live loads that this bridge is exposed to, not the weather.

#### *Bridge 083-0028-0*

Bridge 083-0028-0 is a state owned and maintained bridge asset located in Dade County that was constructed in 1967. This bridge has a reinforced concrete girder EHI score of 40.0, meaning that inspectors placed the entire element in condition state two. Inspectors placed it in this condition state due to minor cracking and a single minor spall. There is no evidence that these defects are the result of weather stressors and inspectors have not recommended maintenance currently.

*Bridge 295-0004-0*

Bridge 295-0004-0 (**Figure 113**) is a state owned and maintained bridge in Walker County. This bridge was originally built in 1930 and was widened in 1964 and widened again in 1987. The bridge originally consisted on wide flange beams, but the approach spans of the bridge consist of concrete “T” beams. This section of the bridge was widened with a reinforced concrete channel beam and a prestressed concrete beam.



**Figure 111 – Bridge 295-0004-0 Side View (GDOT, 2015)**

The reinforced concrete beams have maintained a condition state two rating since the first element inspection in 2015. The primary reason for the condition state two classification is the presence of cracking and efflorescence on the beams.



**Figure 112 – Bridge 295-0004-0 Reinforced Concrete Girder Cracking with Efflorescence  
(GDOT, 2020)**

The cracking on this bridge could have been attributable to weather stressors deteriorating the concrete strength. Additionally, the joints in this bridge were noted to have leakage. This bridge's proximity to a water source is probably the reason why this bridge has efflorescence staining in cracks.

*Bridge 295-0040-0*

Bridge 295-0040-0 (**Figure 113**) is a Walker County and maintained bridge that passes over Dry Creek at Salem Road. It was originally built in 1930 with 2 longitudinal reinforced concrete girders and five reinforced concrete beams. It was widened in with steel members in 1952.



**Figure 113 – Bridge 295-0040-0 Side View (GDOT, 2021)**

The reinforced concrete girders on this bridge have remained in condition state two since the first element inspection in 2015. The reason for the condition state two classification is minor cracking throughout the beam as well as some small spalls that have exposed rebar. These impacts shown in **Figure 114** appear much worse visually than defects observed with similar element classifications.



**Figure 114 – Bridge 295-0040 Reinforced Concrete Girder Spalling (GDOT, 2023)**

*Summary of Reinforced Concrete Beam*

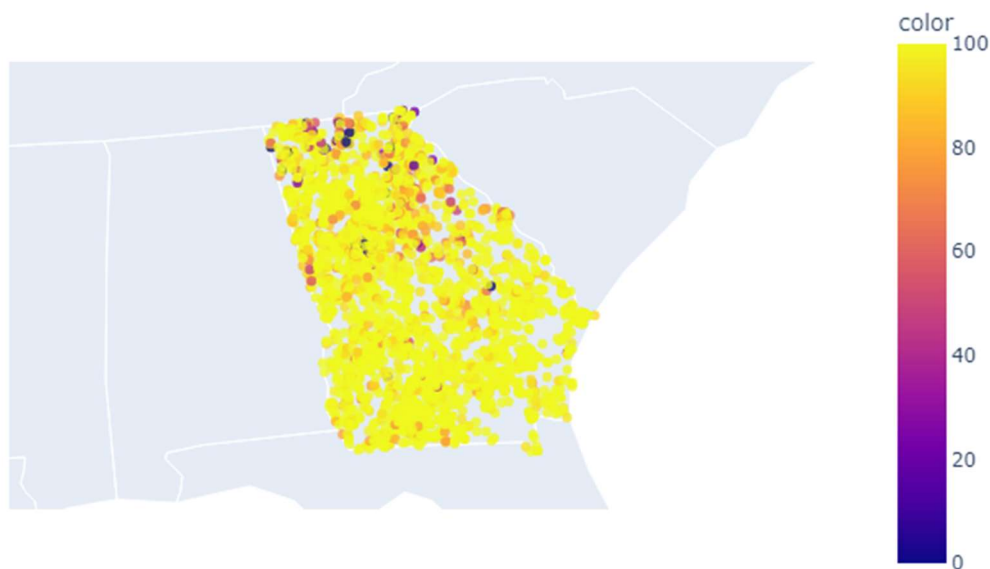
The reinforced concrete beam was studied because of a correlation between poor element health and freezing temperatures. The findings from this section were inconclusive. The primary defects were spalling and cracking. It is possible that these defects were the result of freeze-thaw cycles, but they could also have been the cause of aging and concrete failure. It is possible that the freeze-thaw cycles that north Georgia experiences contributed to the degradation of the concrete girders. There were several bridges studied that showed concrete spalls and cracks growing larger over time. The bridges that appeared in the worse visual condition were county owned bridges that had experienced concrete spalling that led to rebar being exposed and suffering from section loss. Compared with the state-owned bridges studied, these defects appeared much worse. This provided an example that the NBI data provided by inspectors does not always tell the full picture. Elements with the exact same rating can have different defects and one can appear in much worse condition visually.

### ***Element 234 Reinforced Concrete Pier Cap***

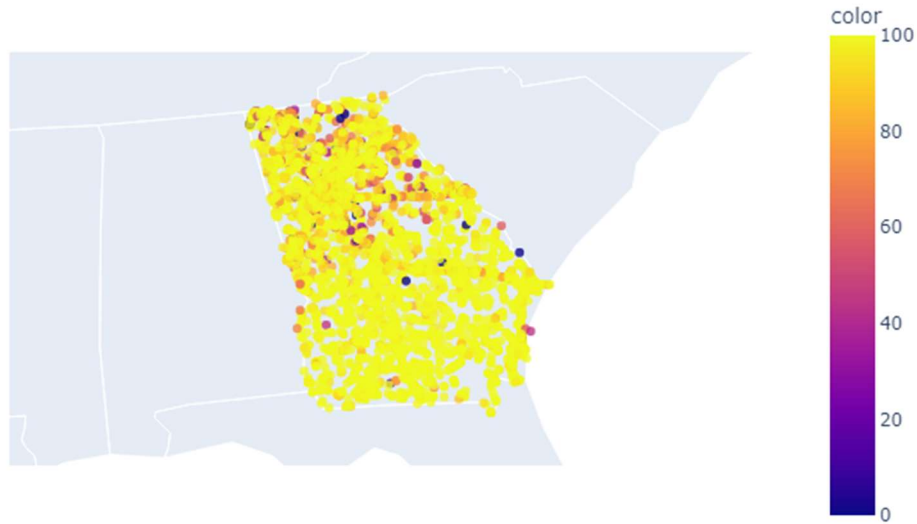
A reinforced concrete pier cap is an element that supports and transfers loads from bridge girders to bridge pilings. The AASHTO Bridge Element Inspection Guide Manual gives inspectors guidance when classifying reinforced concrete pier caps into the four condition states. This element is critical for overall bridge health, safety, and functionality.

The reinforced concrete pier cap was selected to study based on the hypothesis that cold weather in Georgia disproportionately affects certain concrete elements and based on the geographic condition state maps shown in **Figure 115**.

2021 Element Number 234 - % in CS1



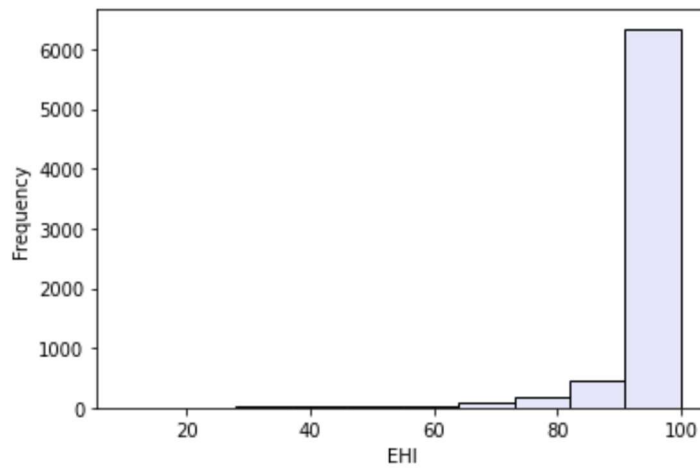
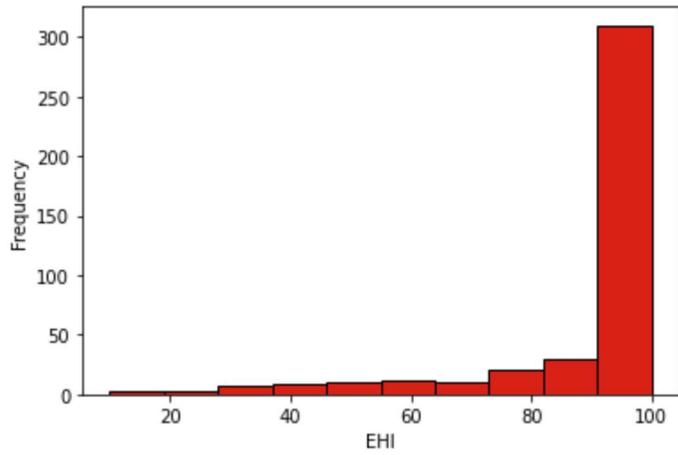
2021 Element Number 234 - % in CS1



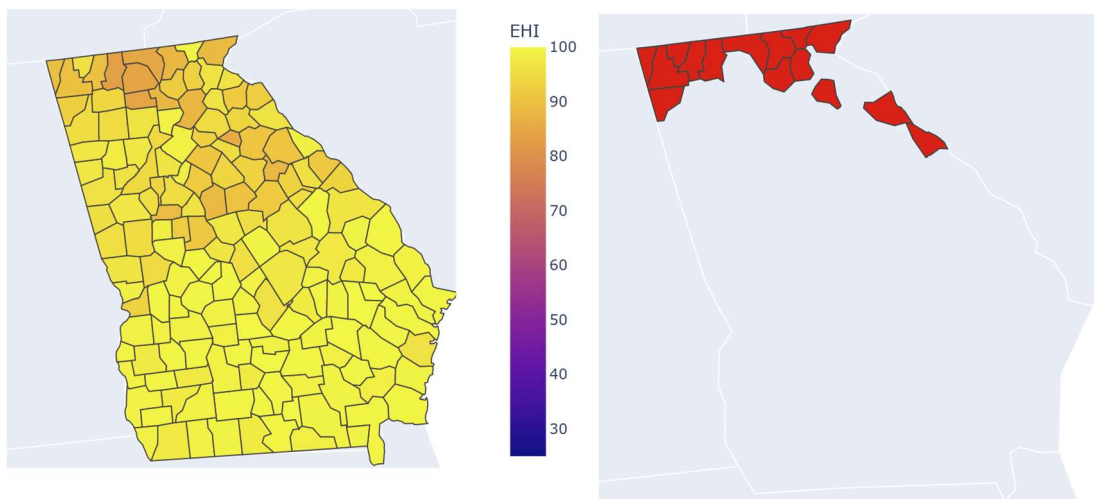
**Figure 115: Percent of EN234 in Condition State One by Location, 2021. County-Owned (Top) vs State-Owned (Bottom)**

Based on the heat maps, a further assessment was completed to determine if this element was truly lagging in condition state in the DT32 counties. 7,592 bridges in Georgia contain a reinforced concrete pier cap. In DT32 counties, 410 bridges contain a reinforced concrete pier cap, making it a commonly used bridge element in Georgia and the DT32 counties of interest.

The average EHI in DT32 counties was calculated to be 90.6, compared to the average EHI in all other counties of 96.6. **Figure 116** also shows that in DT32 counties, the distribution skews towards lower EHI when compared to counties that do not experience as many freezing days as these counties. **Figure 117** shows



**Figure 116 – EHI of EN234 DT32 Counties (Top) vs NonDT32 Counties (Bottom)**

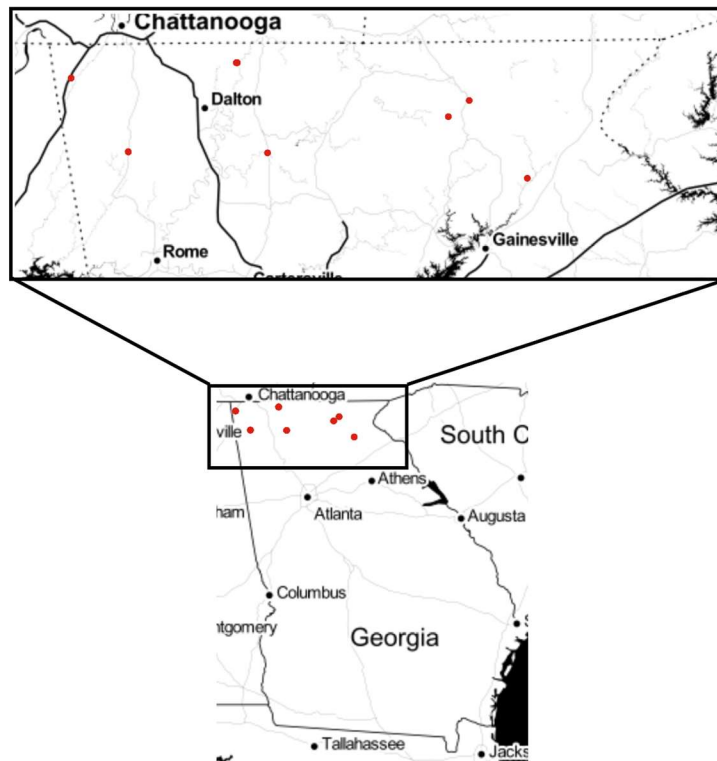


**Figure 117 – Average EHI of EN234 by County (Left) vs DT32 Counties (Right)**

Once this element was selected, the lowest 10 bridges by EHI of element 234 were identified for further study.

**Table 25 - Lowest 25 DT32 Bridges by EHI of EN234**

Bridge ID	County	Owner	Year Built	Service Under	Superstructure NBI Rating	EHI
295-5012-0	Walker	County	1922	Relief for Waterway	5	10
083-0012-0	Dade	State	1967	Highway	7	21.757
295-5013-0	Walker	County	1922	Waterway	5	23.929
291-0017-0	Union	State	1931	Waterway	6	28.947
311-5001-0	White	County	1967	Waterway	7	30
213-0001-0	Murray	State	1957	Relief for Waterway	8	30.521
291-0018-0	Union	State	1962	Waterway	6	33.077
213-0008-0	Murray	State	1974	Waterway	7	36.25
313-0004-0	Whitfield	State	1957	Waterway	6	83.654
313-5028-0	Whitfield	County	1969	Waterway	6	35.38

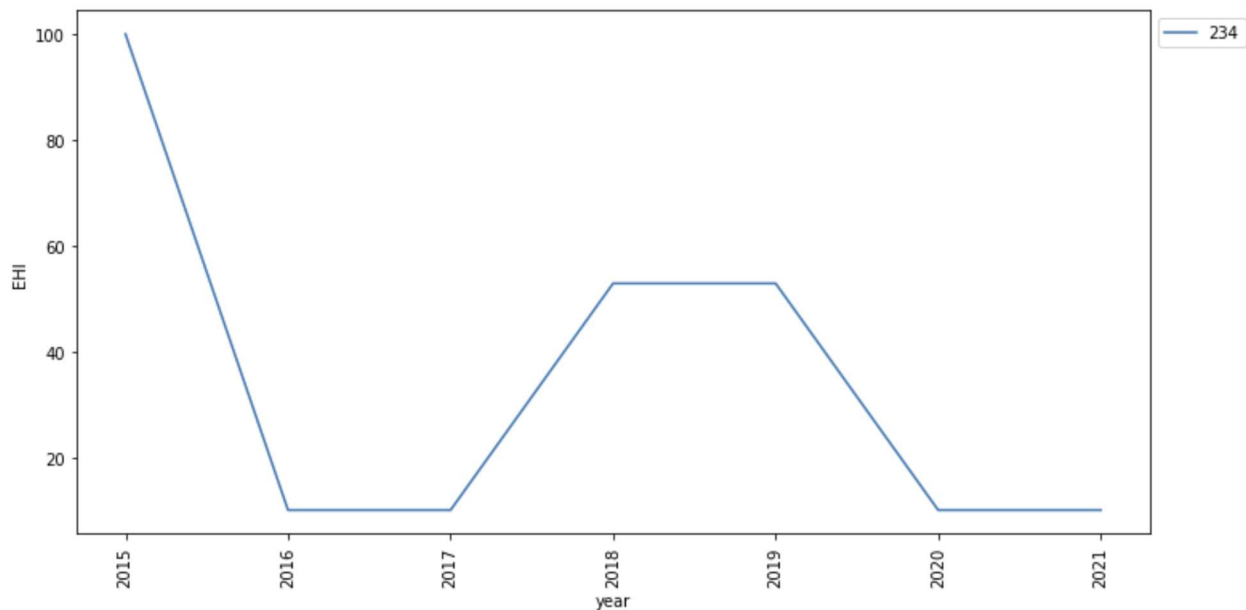


**Figure 118 - Location of Selected DT32 Bridges for EN234**

When looking at the 10 lowest bridges, some trends stand out. First, passing over a waterway appears to influence the EHI. Like many other elements, age and owner play a significant role in EHI.

*Bridge 295-5012-0*

Bridge 295-5012-0 is a multi-span steel bridge initially constructed in 1922, passing over Cane Creek on Trion Road is owned and maintained by Walker County. This bridge's reinforced concrete pier caps are in extremely poor condition due to concrete efflorescence staining, cracking, and large spalling. When assessing this bridge, the NBI element data tells a poor story of the condition of the reinforced pier cap. The EHI derived from the element data does a poor job of showing the actual condition of this bridge year by year. A plot showing the changes annually in EHI is shown in **Figure 119**.

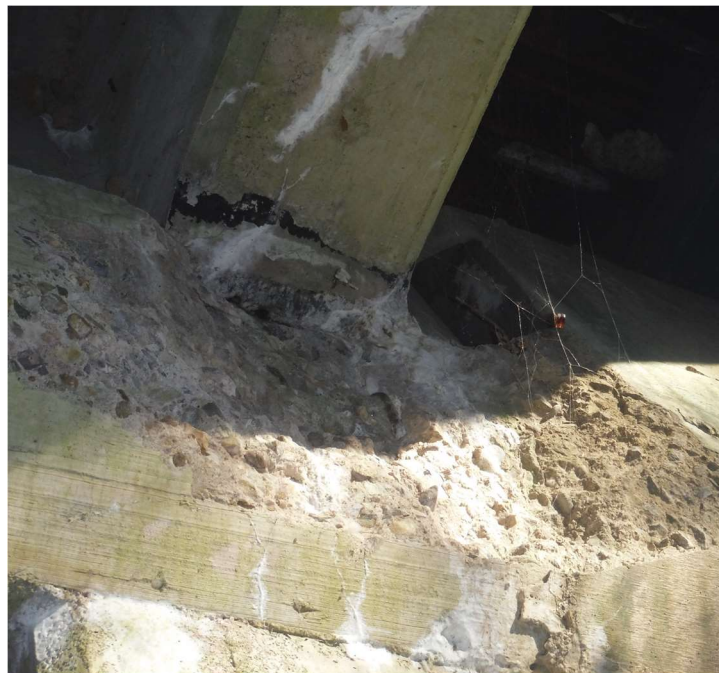


**Figure 119 – Bridge 295-5012-0 Reinforced Concrete Pier Cap EHI by Year**

This reinforced concrete girder is in very poor condition, despite what the inspection data said in 2018. The efflorescence, spalling, and cracking were present in 2018 when the condition rose

and dropped again. **Figure 120 - Figure 122** shows the concrete spalling and efflorescence present throughout the life of this bridge. With no maintenance work completed, the element score raised and lowered, showing that NBI element data only sometimes tells the complete picture.

Additionally, based on the measurement of the spall, an argument could be made that the reinforced concrete girder should have been classified in condition state four. AASHTO rates spalling with a diameter of 6' or a depth of 1" to be medium-severe. In 2021 the spalling of this pier cap was recorded to be 1.5' x 2.5' x 0.3'. The degradation of this reinforced concrete pier cap appears to be much more severe than the NBI element data shows.



**Figure 120 – Bridge 295-5012-0 Reinforced Concrete Pier Cap Spalling (GDOT, 2017)**



**Figure 121 – Bridge 295-5012-0 Reinforced Concrete Pier Cap Spalling (GDOT, 2021)**



**Figure 122 – Bridge 295-5012-0 Reinforced Concrete Pier Cap Efflorescence (GDOT, 2017)**

Despite maintenance being recommended by inspectors it has yet to be performed. This spalling is important to fix as they are located at bearing areas and pose a risk to motorist safety.

Inspectors also noted that the joints are leaking. The leaking joints allow liquids to flow, which deteriorates the concrete located underneath them. **Figure 122** shows how efflorescence is located under these leaking joints, showing that there is increased moisture in the concrete in these areas.

*Bridge 083-0012-0*

Bridge 083-0012-0 (**Figure 123**) is a state owned and maintained bridge located in Dade County. This bridge was originally constructed in 1967 and was widened in 2001.



**Figure 123 – Bridge 083-0012-0 Side View (GDOT, 2021)**

The reinforced concrete pier caps currently have an EHI of 21.76 due to extensive cracking spalling. The spalling is deep enough to have exposed rebar in several areas, and some areas of rebar have experienced section loss. This score is improved from its original NBI element score; in 2019, it jumped from 10.0 to 21.76. The jump in EHI is likely due to the maintenance performed on the bridge. Despite attempts to seal the spalling and cracking with epoxy, inspectors noted that the caps continue to spall. **Figure 124** and **Figure 125** show the reinforced concrete pier cap spalling with and without epoxy coating.

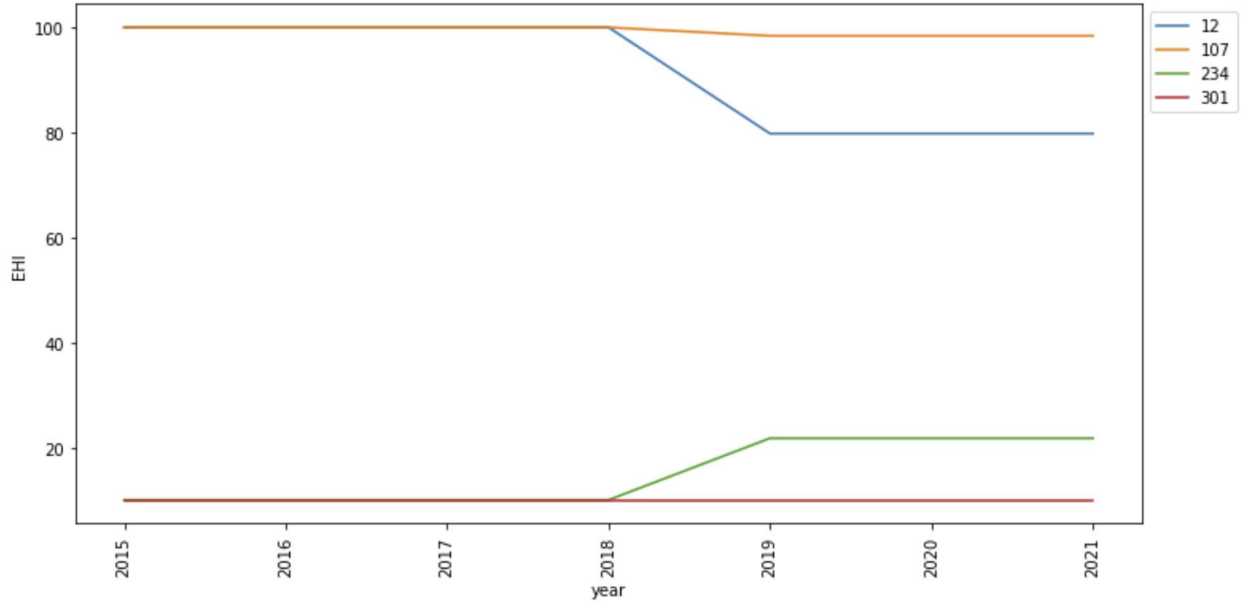


**Figure 124 – Bridge 083-0012-0 Reinforced Concrete Pier Cap Spalling with Exposed Rebar (GDOT, 2019)**



**Figure 125 – Bridge 083-0012-0 Reinforced Concrete Pier Cap Failed Spall Repair (GDOT, 2019)**

This bridge is fairly new and does not pass over a water source like many other bridges with poor reinforced concrete pier cap conditions. **Figure 126** shows the EHI of other major bridge elements over the years and could explain why the pier cap is in such poor condition.



**Figure 126 – Bridge 083-0012-0 Element EHI by Year**

When looking at the NBI element data, there is only one other element that stands out, EN301, the pourable seal joint. This element has remained in condition state three since the first element inspection in 2015. **Figure 127** shows the poor condition of the seal joint.



**Figure 127 – Bridge 083-0012-0 Joint Failure (GDOT, 2017)**

Inspectors have made notes about how the joints are missing material and leaking. Based on the condition of the joints and the pier cap, one could hypothesize that the poor reinforced concrete pier cap condition could be attributable to the poor joint conditions. However, **Table 26** shows that fixing the joints is given the lowest maintenance priority.

**Table 26 – Bridge 0083-0012-0 Maintenance Priority (GDOT, 2021)**

Activity	Priority	Location	Comments
800-Bridge Joint Sealing	C	Deck joints	Clean and seal joints.
810-Deck Repair	B	Deck	Repair spalls and seal cracks.
830-Repair Main Structural Members	B	substructure	Repair spalls in the caps.
000-Bridge Painting	C	Superstructure	Clean and paint.
815-Bridge Curb/Rail Repair	B	Bridge rail.	Repair spalls in bridge rail as needed.
845-Other Bridge Maintenance	B	Rear and forward approach slabs	Seal cracks and patch spall in forward approach slab.
805-Header Joint Reconstruction/Repair	B	Span 4 eastbound turn lane at bent 5 joint header	Patch spall.

The spalling in the pier cap appears to be from corrosion of the rebar. Chemicals, liquids, and debris leaking through open cracks to the pier cap could cause corrosion of the steel, which leads to extensive corrosion and spalling this bridge shows.

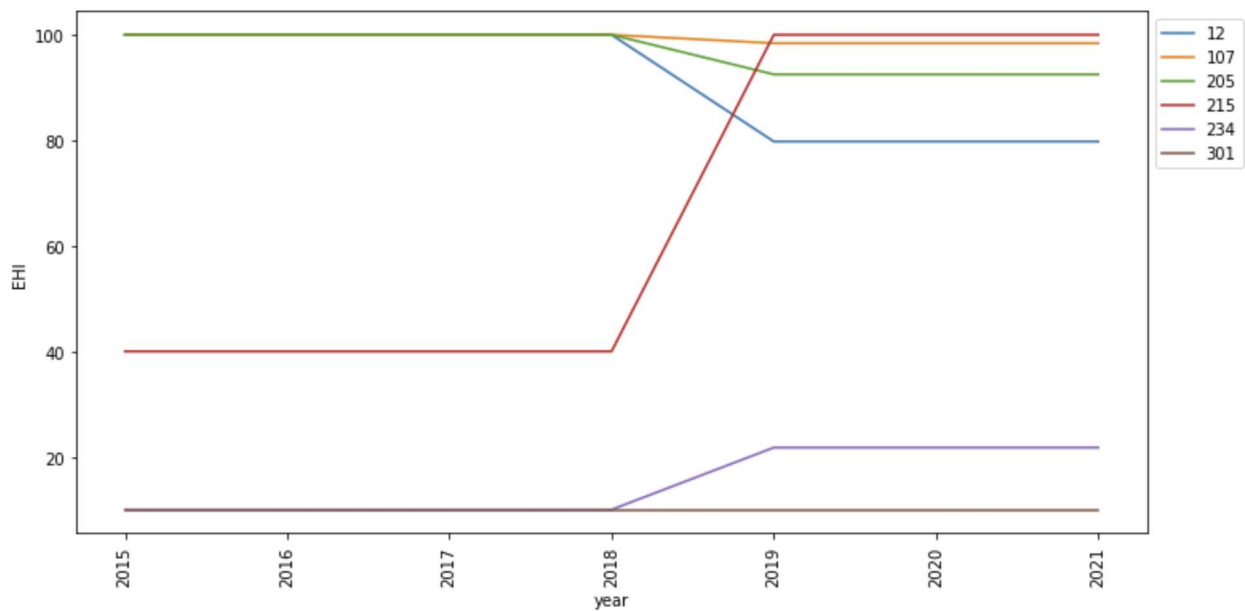
*Bridge 295-5013-0*

Bridge 295-5013-0 (**Figure 128**) is a Walker County-owned and maintained bridge that passes over Cane Creek on Trion Road. This bridge was originally constructed in 1922, and Walker County widened the bridge in 1980.



**Figure 128 – Bridge 295-5013-0 Bridge Side View (GDOT, 2021)**

Overall, the bridge is in “Fair” condition as the substructure, deck, and superstructure all have received an NBI element score of 5. Two elements stand out when looking further at the structure using the NBI elemental ratings.



**Figure 129 – Bridge 295-5013-0 EHI by Year**

The two lower-rated elements on this bridge are EN234, the reinforced concrete pier cap, and EN301, the pourable seal joint. Inspectors have noted that the deck joints are leaking.

Additionally, inspectors noted that the caps have cracking and efflorescence. However, the bridge's condition was not photographed thoroughly, and **Figure 130** is the only image of the joints or the cracking on the caps.



**Figure 130 – Bridge 295-5013-0 Reinforced Concrete Pier Cap Cracking (GDOT, 2021)**

One could hypothesize that the poor joint condition had an impact on the pier cap condition. Chemicals and liquids leaking through the open joints into the pier caps, weaken the concrete, and could be the cause of the cracking shown in **Figure 130**. This cracking is also at risk of worsening in condition if left unaddressed. Other bridges show spalling in similar areas (*Bridge 295-5013-0*).

#### *Bridge 291-0017-0*

Bridge 291-0017-0 is a state owned and maintained bridge located in Union County. The bridge passes closely over Slaughter Creek, and shows cracking throughout the reinforced concrete pier

cap. **Figure 131** show that repairs have been completed on these pier caps before. It is likely that this element would be in worse condition without these maintenance tasks.



**Figure 131 – Bridge 291-0017-0 Reinforced Concrete Pier Cap (GDOT, 2021)**

The cracking and spalling is likely from proximity to water and the freezing temperatures. Additionally, the efflorescence present has rust staining, meaning that the reinforcing steel in the pier cap is corroded. This will continue to cause cracking and spalling in the pier cap.

#### *Bridge 311-5001-0*

Bridge 311-5001-0 (**Figure 132**) is a county owned and maintained bridge located in White County. This bridge was built in 1967 and passes over a lake that stays full year-round.

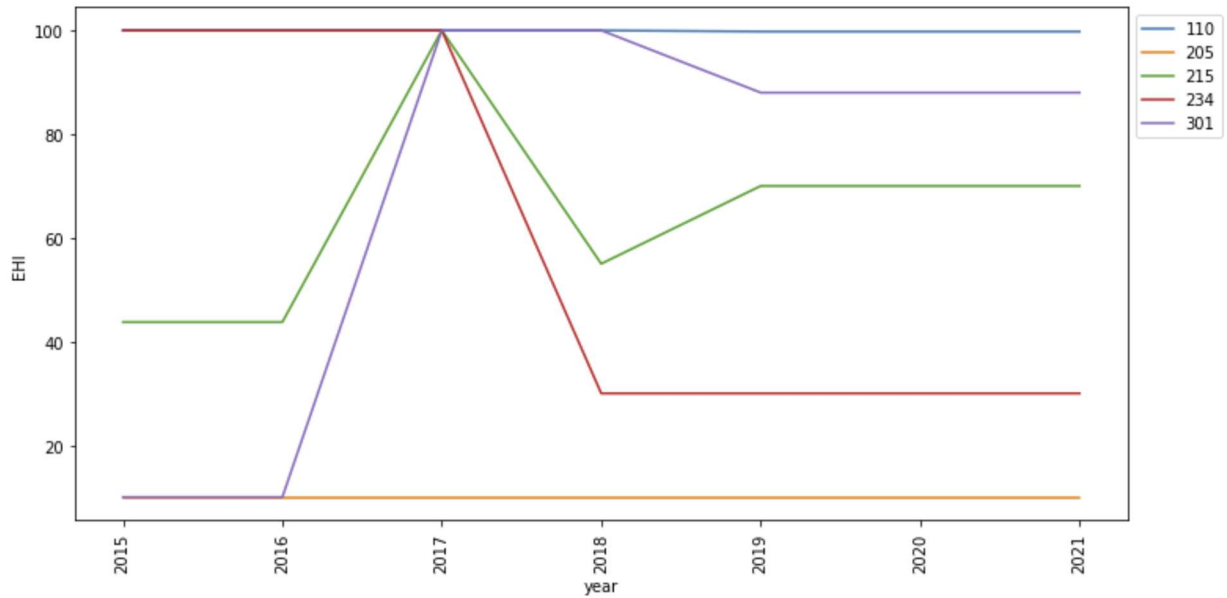


**Figure 132 – Bridge 311-5001-0 Side View (GDOT, 2021)**

The proximity to water and geographic location means the concrete elements of this bridge are exposed to water and the freeze-thaw cycles in White County. Divers inspecting the cap reported both vertical and horizontal cracks that are up to 1/16” throughout the caps, shown in **Figure 133**. These cracks appeared in the 2018 inspection, resulting in a drop in pier cap EHI as well as an NBI substructure score, shown in **Figure 134**. However, these cracks have not worsened as of 2022. The joints are also leaking in this bridge, and the condition of the joint dropped the same year as the cracking in the pier cap appeared.



**Figure 133 – Bridge 311-5001-0 Pier Cap Cracking (GDOT, 2018)**



**Figure 134 – Bridge 311-5001-0 Element EHI by Year**

*Bridge 213-0001-0*

Bridge 213-0001-0 is a Murray County-owned and maintained bridge that passes over the Conasauga River overflow on SR2. This bridge was originally constructed in 1957 and consists of 10 spans of wide flange steel members supported by reinforced concrete pier caps. Overall, the bridge is in “Fair to Good” condition. The deck and substructure have an NBI score of “6,” and a superstructure score of “7.” The only aspect of this bridge that is not in good to satisfactory condition are the reinforced concrete pier caps which have experienced corrosion, cracking, and spalling. These have been repaired, and the bridge is currently on a 12-month inspection cycle to monitor the repair.

However, even with the repair which happened before 2015, the reinforced concrete pier caps have still experienced cracking and spalling, with some even impacting the repairs. **Figure 135** and **Figure 136** shows the spalling and cracking inspectors found throughout the bridge.

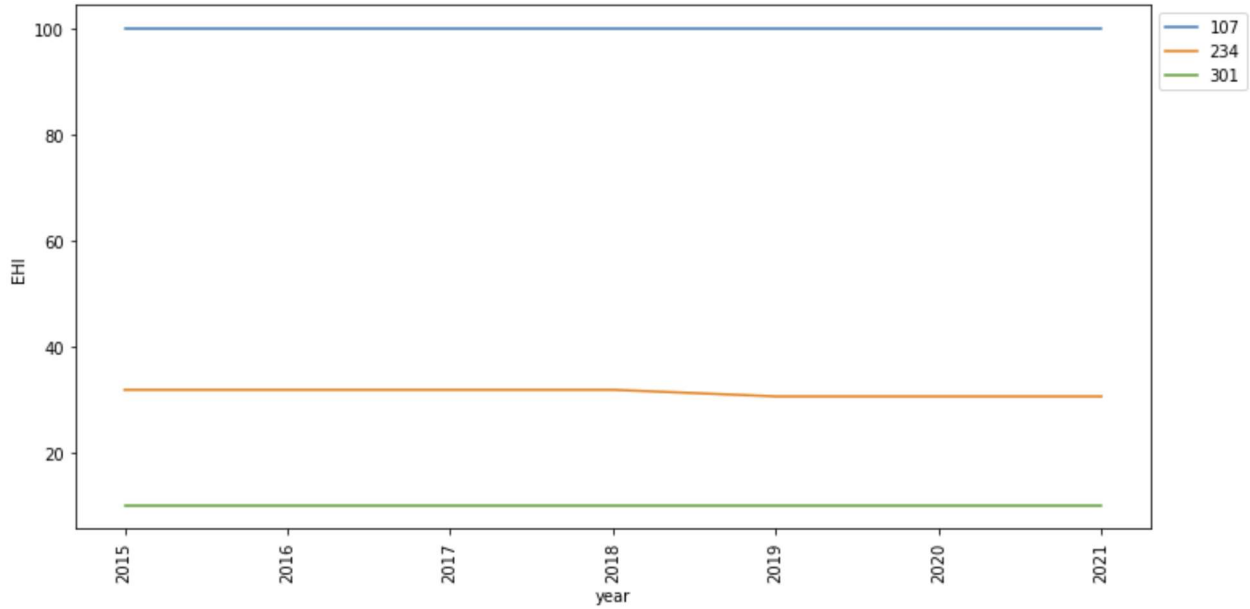


**Figure 135 – Bridge 213-0001-0 Reinforced Concrete Pier Cap Spalling with Rebar Section Loss (GDOT, 2020)**



**Figure 136 – Bridge 213-0001-0 Reinforced Concrete Pier Cap Cracking in Wrap Repair  
(GDOT, 2020)**

When looking at the other elements in this bridge, the only element that stands out is the seal joints. Inspectors have noted from the first element inspection that the joints are leaking. **Figure 137** shows the EHI of EN301 (pourable seal joint), EN234 (reinforced concrete pier cap), and EN107 (steel girder). The leaking joints combined with the cold weather experienced in Murray County are likely contributing to the continued reinforced concrete pier cap degradation.



**Figure 137 – Bridge 213-0001-0 EHI by Year**

*Bridge 313-0004-0*

Bridge 313-004-0 is a state owned and maintained bridge located in Whitfield County. The bridge was originally constructed in 1957 to pass over the Conasauga River. This bridge has had problems with its reinforced concrete pier cap and the state has The spalls are located at the connection to the steel piles. **Figure 138** shows the spalling in bent 5.



**Figure 138 – Bridge 313-0004-0 Reinforced Concrete Pier Cap Spalling, 2022**

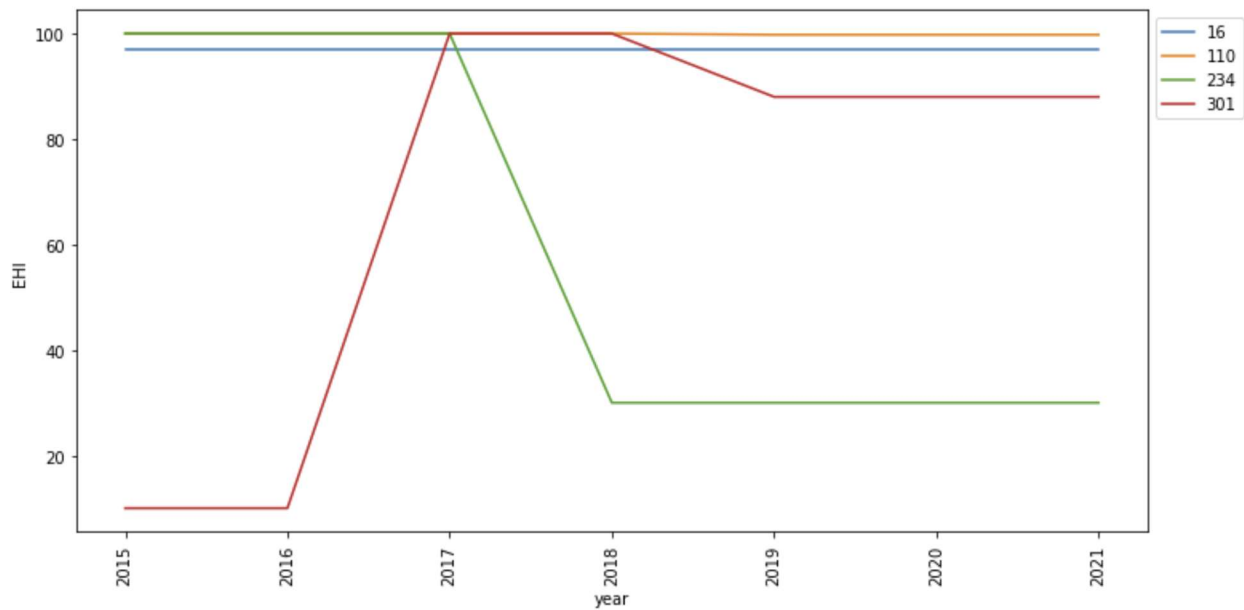
These spalls were first reported in 2020, and although inspectors did not document their findings photographically, they noted concrete cracking on bent 5 in the 2016 and 2018 inspections. It is possible that these cracks turned into spalls. Sealing cracks could have prevented these large spalls from occurring.

Additionally, the joints on the bridge were reported by inspectors to be leaking. This could have contributed to the poor pier cap health.

#### *Bridge 291-0018-0*

Bridge 291-0018-0 is a state-owned and maintained bridge located in Union County. The bridge is a five-span concrete bridge supported by reinforced concrete pier caps. It was initially

constructed in 1962 and passes over the Nottely River on Town Creek Road. The bridge is in satisfactory condition as the substructure, deck, and superstructure all have an NBI score of “6.” However, one element that is lagging behind the rest is EN234, the reinforced concrete pier caps. The lag is visible by tracking the EHI by year in **Figure 139**.



**Figure 139 – Bridge 291-0018-0 Element EHI by Year**

Inspectors have rated the reinforced concrete pier caps low due to cracking, spalling, exposed rebar, and rebar section loss. These defects are the result of the weather-related attributes found in Union County. The cracks on the reinforced concrete pier cap could turn into spalls when exposed to the freeze-thaw cycles experienced in Union County. **Figure 140** shows reinforced concrete pier cap cracking on the bridge.



**Figure 140 – Bridge 291-0018-0 Reinforced Concrete Pier Cap Cracking (GDOT, 2018)**

*Bridge 213-0008-0*

Bridge 213-0008-0 is a state owned and maintained bridge asset located in Murray County. It was originally constructed in 1974. Since 2015 this bridge has had a maintenance request to seal the bridge joints. The bridge has concrete cracking in the pier caps, however as of 2022 the cracking was minor and not fast progressing. It appeared to be a result of live loads on the bridge, because of the location of the cracks shown in **Figure 141**. However, it is possible that leaking through the joints could have weakened the concrete to make the bridge more susceptible to concrete cracking.



**Figure 141 – Bridge 213-0008-0 Pier Cap Concrete Cracking (GDOT, 2022)**

*Bridge 313-5028-0*

Bridge 313-5028-0 (**Figure 142**) is a county owned and maintained bridge located in Whitfield County. It was constructed in 1969 to pass over Mills Creek.



**Figure 142 – Bridge 313-5028-0 Bridge Side View (GDOT, 2022)**

This bridge was identified because of the reinforced concrete pier cap, EHI in the 2021 NBIE data of 35.8. This EHI was taken from an inspection on the bridge in 2020. After reviewing historical inspection reports, it appears that there are discrepancies in this element's scoring. The reinforced concrete pier caps have experienced small cracking, measured to range from 0.016" - 0.030" in width, shown in. Inspectors noted that these are "load-related cracks."



**Figure 143 – Bridge 313-5028-0 Pier Cap Cracking (GDOT, 2022)**

Despite there being no maintenance performed on the reinforced pier cap and the cracks remaining, the EHI of the bridge pier cap has gradually risen over the years. It jumped from 10 to 35.8 at the 2018 inspection, and from 35.8 to 91.7 during the 2022 inspection.

In addition to the moderate cracking reported at the pier cap, there is other deterioration reported in this bridge. Both abutments have experienced severe undermining. Abutment one has undermining 3.2' x 3.2' x length of structure, exposing three piles (which are corroded).

Abutment three has an area of 2.6' x 2.4' x the length of the structure, exposing three piles, one of which has section loss.



**Figure 144 – Bridge 313-5028-0 Abutment 3 Undermining (GDOT, 2022)**



**Figure 145 – Bridge 313-5028-0 Abutment 3 Pile 1 Section Loss (GDOT, 2022)**

In addition to this undermining from Mills Creek, the superstructure has also deteriorated. There is longitudinal cracking and spalling reported on the reinforced concrete girders. The cracking is

something the county should seek to address ASAP, as the longitudinal cracking is likely to progress into spalling, as it already has in some portions, see **Figure 146** and **Figure 147**. It is likely the cracks in span 2 could progress in a similar manner to the spalls in span 1.



**Figure 146 – Bridge 313-5028-0 Span 2 Cracking (GDOT, 2022)**



**Figure 147 – Bridge 313-5028-0 Span 1 Spalling (GDOT, 2020)**

### *Summary of Reinforced Concrete Pier Cap*

The reinforced concrete pier cap saw similar weather related impacts as the reinforced concrete girder, four with spalling and all the caps with cracking. The severe spalling left rebar exposed. In three of the four bridges with spalling, the spalls were located under a bearing area. This finding leads to the conclusion that live loads are likely to have caused these failures. It is possible that the concrete was weakened by continuous freeze-thaw cycles in this area. It is important that counties understand and assess this risk as a loss of bearing area the pier cap can lead to a loss in bearing area and ultimately a mandated load posting. Poor joint condition was also observed in nine of the ten bridges studied. It is likely that liquids, salts, and debris are leaking through joints and exacerbating damage to pier caps.

An additional concern with reinforced concrete pier cap spalling is injury to motorists. On bridges that pass over roadways, spalled falling concrete can strike motorists' vehicles.

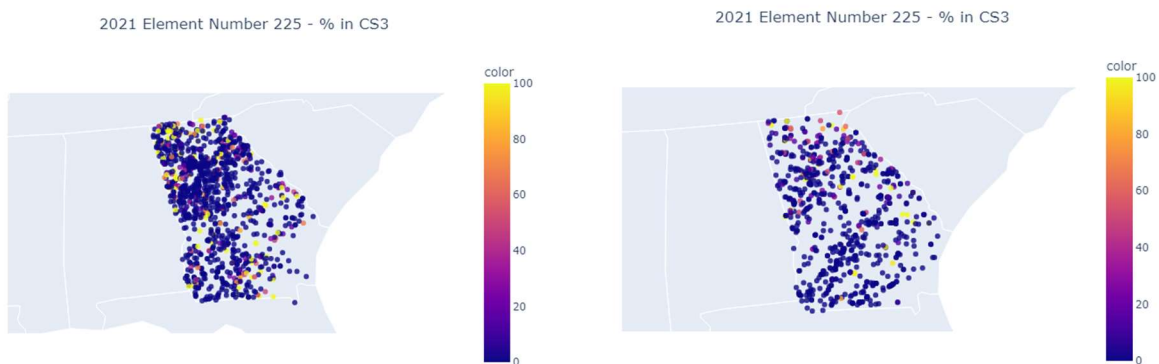
### *Summary of Findings*

After analyzing the three elements identified as at risk in DT32 there were several findings. First, concrete elements are most vulnerable in these areas. This is likely due to the increased number of freeze-thaw cycles that the identified areas experience annually. It was found that if one of these concrete elements have deterioration in the form of spalling or cracking it is likely that other reinforced concrete elements are suffering from similar deterioration. Another finding is that waterways make it more likely that concrete elements have cracking and spalling. However, substructure concrete elements suffer from freeze-thaw cycles when passing over waterways than superstructure elements.

## Days with Precipitation Greater than or Equal to 0.10”

### *Element 225 Steel Pile*

The steel pile was first identified using **Figure 148**. The steel pile is a common element in Georgia, found in 156 of 159 counties and on 2,058 unique bridges. In the DP10 counties there are 175 bridges that contain a steel pile cap. The average EHI in Non DT32 counties is 73.0, while the average EHI in DT32 counties is 47.0. The element health index shows that the counties that are experiencing larger amounts of precipitation also have bridges with lower steel pier cap ratings.



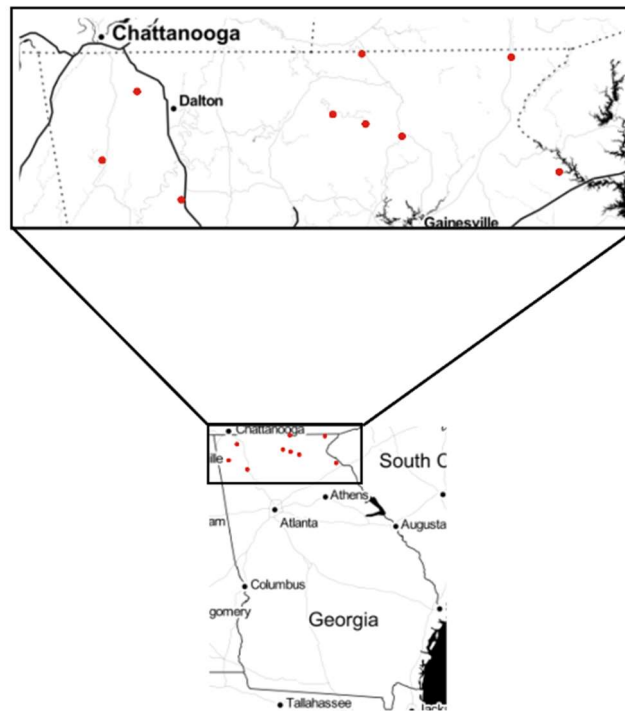
**Figure 148: EN215 Percent in CS3 by location, 2021 County-Owned (Left) vs State-Owned (Right)**

The AASHTO Bridge inspection guide gives guidelines for inspectors to classify the steel piles into condition states by year. The guide defines this element only as steel piles that are continuously submerged in water, and the unit presented in the element inspection data is a single pile.

The bridges of interest in this county were selected to study by isolating the ten lowest rated steel pier by EHI. **Table 27** shows the bridges, and **Figure 149** shows the geographic locations.

**Table 27 - Lowest 10 DP10 Bridges by EHI of EN225**

Bridge ID	County	Owner	Year Built	Service Under	Substructure NBI Rating	EHI
241-0016-0	Rabun	State	1926	Waterway	5	5.556
187-0006-0	Lumpkin	State	1929	Waterway	4	7.778
047-5012-0	Catoosa	County	1974	Waterway	6	10
055-5001-0	Chattooga	County	1957	Waterway	5	10
111-5002-0	Fannin	County	1969	Waterway	1	10
129-5003-0	Gordon	County	1982	Waterway	6	10
291-5026-0	Union	County	1984	Waterway	6	10
291-5035-0	Union	County	1985	Waterway	6	10
257-0012-0	Stephens	County	1963	Waterway	4	33.125



**Figure 149 - Location of Selected DP10 Bridges for EN225**

Several conclusions can be drawn from the NBI data associated with these 10 bridges. The first is that year built plays a significant role in the condition of the steel pier. Of the 10 bridges, 15

are over 50 years old, and 20 are 40+ years old. Another note is that even though the reinforced steel pier is a part of the substructure, it does not play a prominent role in the NBI substructure score. In these bridges, the NBI substructure ranges from 1 to 7.

#### *Bridge 241-0016-0*

Bridge 241-0016-0 is a state-owned and maintained bridge that passes over Betty Creek on US15 in Rabun County. This bridge is a three-span concrete bridge that the state last widened in 1981. The bridge is in poor condition, with many defects attributed to Rabun County's weather. The deck has an NBI score of “6,” the superstructure a “6”, and the substructure a “4.”



**Figure 150 – Bridge 241-0016-0 Side View (GDOT, 2022)**

This bridge has experienced problems from the top down and the bottom up. This bridge's most apparent cause of weather-related degradation is the proximity to Betty Creek and the increased

flow rate during a precipitation event. The humid climate present at the bridge has also impacted the overall condition at the base of the structure. The most evident impact these climatic factors have left is scouring and corrosion at the base of the bridge. There are nine steel piles in the bridge; four are in condition state three, and five are in condition state 4. The steel piles have experienced section loss in the webs to where there is only around 3/8" of steel left. The piles have shown measurable section loss, summarized in **Table 28** Most of the piles have experienced steel loss of up to 1/8". **Figure 151** shows a typical section of steel piling at ground level.

**Table 28 – Bridge 241-0016-0 Steel Pile Measurements by Year**

Location	Section Loss 2014	Section Loss 2018	Section Loss 2022
Bent 2 Pile 1	1/8" Flange 1/16" Web	1/8" Flange 1/8" Web	¼" Web 1/8" Flange
Bent 2 Pile 2	N/A	1/16" flange 1/16" web	¼" remaining in web 1/8" flange
Bent 3 Piles 1&2	1/16" web and flange	1/16" web and 1/8" in web	1/16" web (ground) Average of 1/8" in web 1/8-1/16" remaining in flange
Bent 4 Pile 1	1/8" web 1/16" flange	1/8" web 1/16" flange	NA

Bent 4 Pile 2	1/16" web 1/16" f;ange	1/8" web 1/8" flange	1/16" in web @cap 3/8" remaining @ground 8/8"-7/16" remaining at ground
Bent 4 Pile 4	1/8" flange @ cap 3/16" at flange/web @ ground	1/8" flange @ cap 3/16" at flange/web @ ground	4" x 1" perforation hole 1/16" flange remaining



**Figure 151 – Bridge 241-0016-0 Steel Pile Section Loss at Ground Level (GDOT, 2022)**

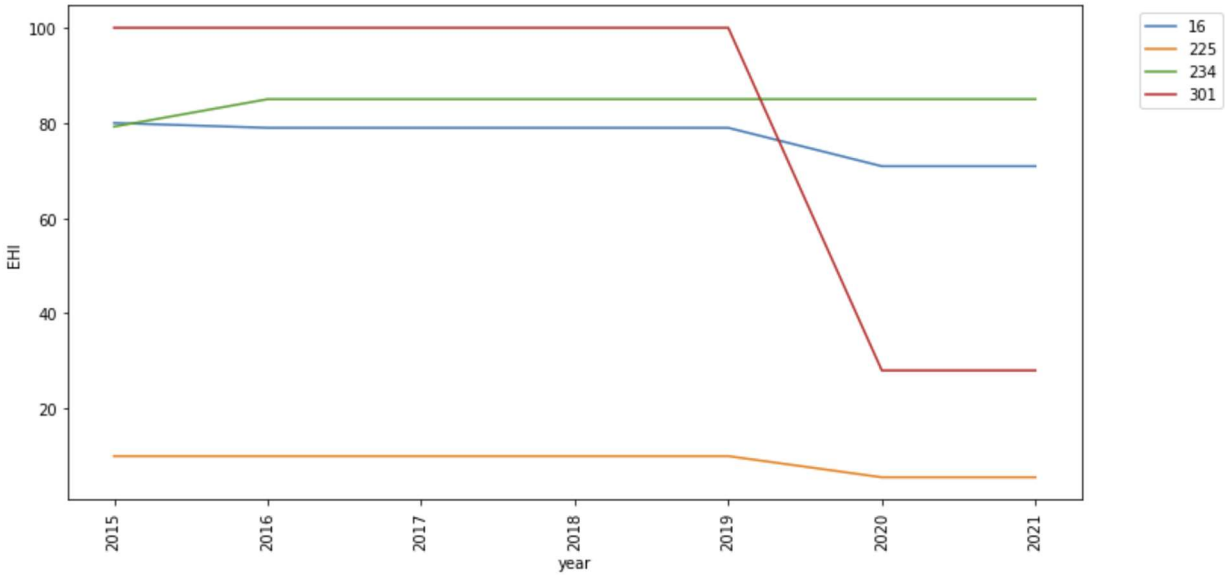
The 2020 inspection report noted that there is severe erosion at the abutments. The inspectors noted lateral bank erosion and highwater scour at both banks. Inspectors measured the largest area of erosion as 12'x40'x4'. This large area of scour and erosion has left the piles under the

abutment visible. This erosion is likely the result of the proximity to water and the number of rain days Rabun County experiences annually.



**Figure 152 – Erosion at Abutment 5 on Bridge 241-0016-0 (GDOT, 2020)**

Climatic impacts also affect bridge 241-0016-0, which started at the top and trickled down. In addition to being a DP10 county, Rabun County is also a DT32 county and a SNOW county. Rabun county experiences many severe climatic impacts means that this bridge has been subjected to snowfall, icing, and deicing methods like salting. These impacts impact the deck but can have a trickle-down effect on other elements of the bridge structure. The impacts of deicing methods on this bridge were evident in the 2020 inspection report. Between the 2018 and 2020 inspections, there was a drop in three elements relating to the deck. Elements 16, 301, and 225; the reinforced concrete top flange, pourable seal joint, and steel piles all dropped in the element health index, shown in **Figure 153**.



**Figure 153 – Bridge 241-0016-0 EHI by Year, 2015-2021**

In 2020, the deck joint was reportedly pulling loose and missing. This joint missing means that elements under the deck, usually protected from weather impacts like precipitation, were subjected to them. Inspectors reported the reinforced concrete top flange (EN16) to have significant cracking and efflorescence. The report stated that most efflorescence and cracking were located at the edges, where they meet the beams. It is likely that the water trickled through the exposed joints and remained on the top flange during precipitation events, causing efflorescence to form.

Additionally, the steel piles all reported section loss and perforation at the cap line. A build-up of water could have allowed this continued corrosion. The impacts are shown in **Figure 154 – Figure 156**.



**Figure 154 – Bridge 241-0016-0 Failing Joint (GDOT, 2020)**



**Figure 155 – Bridge 241-0016-0 Efflorescence at Reinforced Concrete Top Flange (GDOT, 2020)**



**Figure 156 – Bridge 241-0016-0 Steel Pile Section Loss at Deck (GDOT, 2020)**

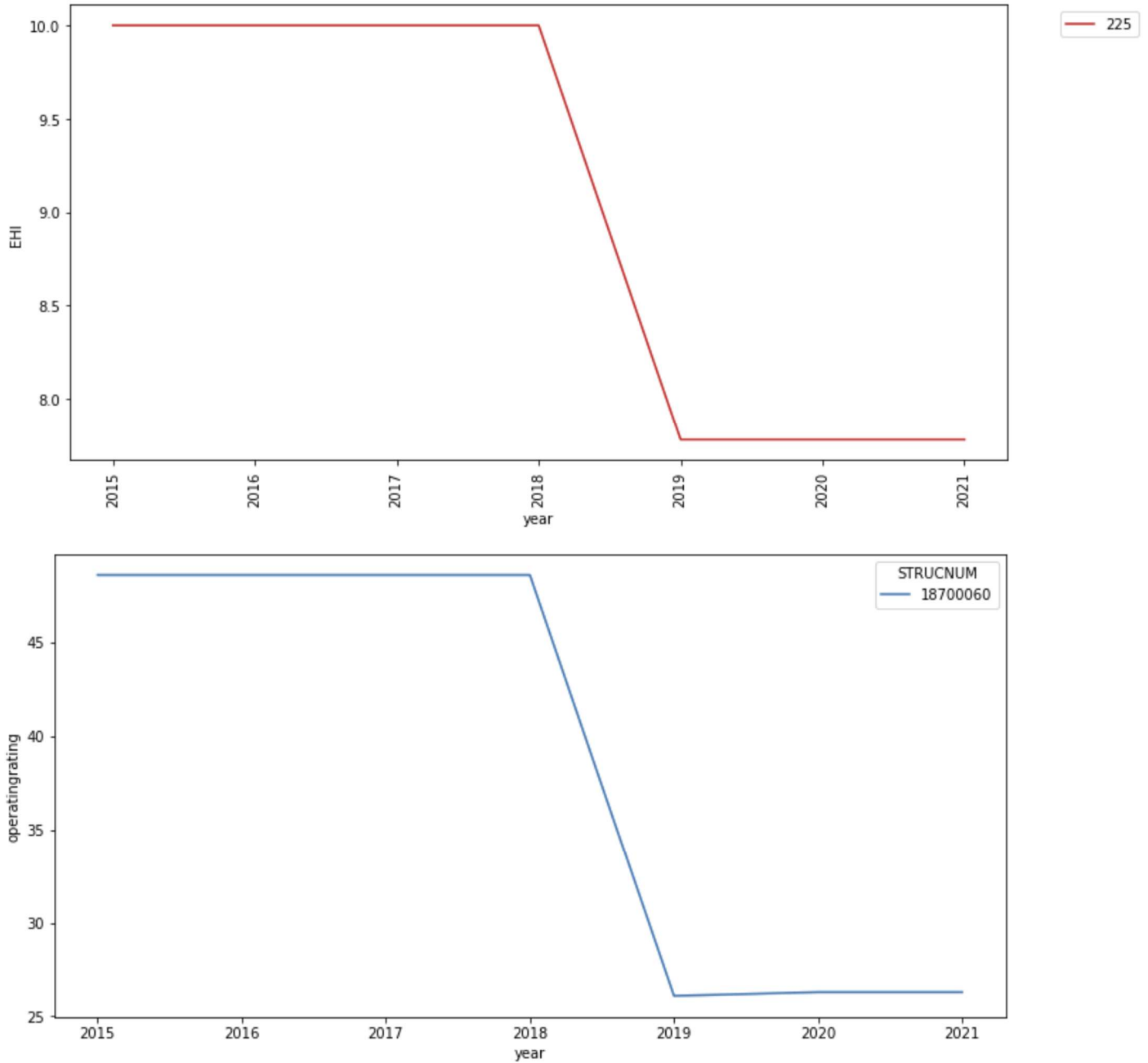
After looking at this bridge more maintenance was necessary to prevent the continued degradation of concrete and steel elements. For example, repairing the steel section loss and then repainting could have prevented the drop of the steel piers from condition three to four. Additionally, preventing further scour should be a priority at this bridge. The erosion is already significant, and the bridge is at risk of becoming unstable with a larger than expected storm event.

#### *Bridge 187-0006-0*

Bridge 187-0006-0 is a state-owned four-span bridge that passes over the Chestatee River in Lumpkin County on US19. The bridge deck is supported by 360' of prestressed concrete girders, which are supported by nine steel piles, and two concrete abutments. Even though this bridge was originally constructed in 1929, the state widened the bridge in 1987 using steel piles. This means that the steel piles in this bridge are only 35 years old. The deck and superstructure in this

bridge both have minor problems and were scored a “7” in the most recent inspection. However, the substructure received a score of “4” primarily due to the advanced deterioration of the steel piles. Several factors are impacting the steel piles. Since mandated element inspection scoring and reporting, scour, corrosion, and drift have all impacted the steel piles over the years.

The first impact noted was in 2019. In 2019 the condition state of several of the steel piles dropped from condition state three to condition state four. The drop was due to heavy rust, pitting, and section loss in the steel piles. Most of the section loss is at the ground and the cap line, likely attributable to the humid environment in which this bridge is. The protective steel coating in this bridge substructure also failed and could have prevented the section loss in the steel piles if maintained. The steel piles had not been painted since they were originally constructed. The drop in the steel pile coincided with a drop in the operating rating of the bridge, shown in **Figure 157**. The drop indicates that weathering of the steel piles played a significant role in this bridge’s safety and overall health. Repairing the section loss in the piles is the top maintenance priority on the bridge.



**Figure 157 – Bridge 187-0006-0 EN225 EHI (Top) and Operating Rating (Right) by Year**



**Figure 158 – Bridge 187-0006-0 Pile Condition, 2019**

This bridge was also impacted by an extreme weather event in 2020. In 2020, Hurricane Zia made landfall in the Southeast United States, dumping large amounts of precipitation on many parts of Georgia. In the aftermath of this large rainfall event, a 14.0' tall log drift was discovered at this bridge, which caused the closure of the bridge structure.



**Figure 159 – Logjam at Bridge 187-0006-0 (GDOT, 2020)**

After removing this logjam, inspectors noted one of the piles had local scour, which had exposed the pile under the encasement. Additionally, inspectors reported bending in the same pile as the debris pile. If the continued corrosion and section loss of the steel piles are not addressed, a similar weather event could cause the total failure of a steel pile.



**Figure 160 – Minor Bending in Steel Pile in Bridge 187-0006-0 (GDOT, 2020)**

*Bridge 047-5012-0*

Bridge 047-5012-0 is a local county design originally constructed in 1974. This bridge is a three-span steel bridge supported by ten steel piles. Catoosa County owns and maintains this bridge, and it passes over Little Chickamauga Creek on Yates Springs Road. Overall, this bridge is in good to fair condition with an NBI deck and superstructure score of 7 and a substructure score of 6. The substructure shows degradation that requires maintenance attention, primarily due to the impacts of heavy precipitation. Two of the reinforced concrete abutments have scour and undermining. Additionally, inspectors have rated the steel piles as condition state three since the first element data inspection. These steel piles were last painted in 1996. This means it took these

piles exposed to a waterway less than 20 years to go from freshly painted to an EHI of 10.0. This is consistent with GDOT recommendations for painting (GDOT, 2013).



**Figure 161 – Bridge 0047-5012-0 Typical Steel Pile Section Loss (GDOT, 2019)**

**Figure 161** shows the corrosion that is impacting the steel piles. Inspectors measured the section loss to only be 0.06” in depth. The steel pitting is not critical, but with the protective paint no longer being present, and the steel piles’ proximity to water, this corrosion could increase and require a load reduction. There has already been an increase in the size of the section loss. In 2014, the steel section loss was recorded to only be 0.003”, meaning it has grown almost 25x since 2014. In 2014, inspectors noted that cleaning, repainting, and encasing the piles in concrete

#### *Bridge 055-5001-0*

Bridge 055-5001-0 is owned and maintained by Chattooga County, which passes over Cane Creek on Ridgeway Road. The 5-span concrete bridge was originally built in 1957 and is supported by two reinforced concrete abutments and sixteen steel piles. Since the first element inspection report, this bridge has had all 16 steel piles assessed to be in condition three. The low inspection grades are due to corrosion caused by the humid environment is in and the failure of

the protective steel paint. Maintenance was requested in 2014 to encase the piers with concrete and to clean and repaint the piles but work still needs to be done. The corrosion on these steel piles were located at the top 2” and the bottom 14” of the piles. The corrosion resulted in section loss of the piles. Most piles had measured section loss around 1/16” in 2016. In the 2020 inspection reports this section loss size had grown to 1/8” to .188”. This is 2x more than the section loss was 6 years earlier.



**Figure 162 – Bridge 055-5001-0 Typical Steel Pile Section Loss (GDOT, 2020)**

The corrosion of this element also appeared to impact the pier cap. At piles four and five, there was spalling. It is likely the steel pile corrosion weakened the concrete, causing the pier cap to spall, shown in **Figure 163**



**Figure 163 – Bridge 055-5001-0 Steel Pile Connection 2016 (Top) vs 2022 (Bottom)**



**Figure 164 – Bridge 055-5001-0 Steel Pile Connection 2016 (Top & Middle) vs 2022  
(Bottom)**

This shows how elements in poor condition can impact other elements. Element interaction is important to consider when making maintenance decisions.

#### *Bridge 055-5030-0*

Bridge 055-5030 is bridge and maintained by Chattooga County. This bridge was originally constructed in 1958. There is severe corrosion of the steel girders in this bridge that caused it to be load reduced. This bridge has a wide range of defects that could be attributed to weather stressors. The defect that stands out the most is the corrosion of the steel girder, shown in **Figure 165**.



**Figure 165 – Bridge 055-5030-0 Steel Girder Condition (GDOT, 2020)**

The corrosion and section loss could be attributable to the bridge's proximity to the water in addition to the humid environment caused by the many days of precipitation. However, preventative maintenance could have prevented the girder condition from deteriorating, leading to a load posting.

In addition to the superstructure, this bridge also has two types of deck deterioration. The surface of the deck has cracking and spalling that could be attributed to deicing salts and freeze-thaw cycles and are shown in **Figure 166**. This cracking was first reported in 2020.



**Figure 166 – Bridge 055-5030-0 Deck Topside Condition (GDOT, 2022)**

The cracking on the topside of the deck is minor when compared to the cracking that is visible on the underside and sides of the deck. Both have major spalls that have been identified in inspection reports as 2012. However, inspectors have done a poor job of tracking the progression of these spalls. The photos recorded are shown in **Figure 167**. These photos show the severity of the spalls.





**Figure 167 – Bridge 055-5030-0 Deck Condition (GDOT, 2022)**

Additionally, there are concerns at the substructure. The first is a large drift accumulation. This can contribute to scouring. **Figure 168** shows the difference in drift accumulation at bent 3 over the years.







**Figure 168 – Bridge 055-5030 Drift at Bent 3 2012 (Top) vs 2020 (Middle & Bottom)**

The inspection team recommended the removal of this drift in 2012 but with inactivity the county was left with a more expensive maintenance activity. This accumulation of drift can lead to increased scour at substructure elements. Inspectors first recorded scour at Bent 2 in 2020, shown in **Figure 169**. It cannot be confirmed but it is possible that the drift accumulation caused this scour.



**Figure 169 – Bridge 055-5030-0 Bent 2 Scour (GDOT, 2020)**

*Bridge 227-0009-0*

Bridge 227-0009-0 is a five-span concrete bridge on SR53 over Long Swamp Creek. This Pickens County-owned bridge was initially constructed in 1929 and widened in 1980. The structure has experienced corrosion of the steel piles because of humidity in the surrounding environment and the lack of protective paint. All twelve piles are noted to be in similar condition, with corrosion and steel pitting. Additionally, some steel piles have section loss.

One thing of note on this bridge is concrete spalling at the bottom of the deck and the joints. The spalling location is of note because inspectors placed this joint in condition state three since the first element inspections. One could imagine precipitation leaking through the joint and impacting other parts of the structure.

*Bridge 291-5026-0*

Bridge 291-5016 is a five-span prestressed concrete bridge that passes over the Toccoa River on Gaddistown Road in Union County. This bridge substructure has experienced degradation primarily due to the impacts of high precipitation totals. The steel piles in this bridge have suffered from drift, scour, and steel section loss/corrosion, shown in **Figure 170** and **Figure 171**. The rest of the structure is in excellent condition. The poor pile condition is likely from a combination of weather and lack of maintenance by the county. Cleaning and painting the piles could have prevented the degradation.



**Figure 170 – Bridge 291-5026-0 Steel Pile Condition (GDOT, 2019)**



**Figure 171 – Bridge 291-5026-0 Scour (GDOT, 2019)**

*Bridge 291-5035-0*

Bridge 291-5035-0, seen in **Figure 172**, is 4 span concrete bridge that passes over the Nottely River on John Smith Road. The bridge is owned and maintained by Union County and was originally constructed in 1985. The bridge is in good to satisfactory condition, as inspectors gave the deck and superstructure an NBI score of “7” and the substructure a score of “6.”



**Figure 172 – Bridge 291-5035-0 Side View (GDOT, 2019)**

The primary reasons for the reduced substructure scores have to do with impacts likely caused by climatic impacts experienced in union County. The steel piles are experiencing corrosion of up to 1/8”, shown in **Figure 173**. Additionally, this bridge is experiencing scour and erosion at the base of the steel piles and at the abutment. Unfortunately, no photos were taken of the scour and erosion. Inspectors did note that there was erosion control completed by the county in 2016, but that even after the repair there was still scour and erosion present. It would be valuable to have photos of the noted scour and erosion to see the impacts of the repair the county completed in 2016. Additionally, **Figure 173** shows cracks at the pier cap, where the steel pile is. It is likely that the corrosion of the steel pile could have contributed to this cracking.



**Figure 173 – Bridge 291-5035-0 Steel Pile Corrosion (GDOT, 2020)**





**Figure 174 – Bridge 291-5035-0 Erosion, 2015 (Top) and Erosion Repair, 2016 (Bottom)**

*Bridge 129-5003-0*

Bridge 129-5003-0 is a county owned and maintained bridge located in Gordon County. The bridge passes over Oothkalooga Creek and was originally constructed in 1982. The bridge is supported by four steel piers. However, in 2017 inspectors deemed that these piles were in condition state three because of corrosion. In 2015, inspectors noted the corrosion, and recommended cleaning, painting, and encasing the steel piles to prevent further corrosion. They noted that at this time there was no section loss. By 2019 there was section loss of up to 0.06” reported on the flanges of the steel piles. The steel piles sit in a pool that fills up with precipitation, shown in **Figure 175**. This proximity and exposure to water contributed to the steel pile deterioration.



**Figure 175 – Bridge 129-5003-0 Side View, 2022**

This bridge also gives a case study as to how fast this element can fall into condition state three without cleaning and painting. Just 40 years after construction this element has fallen into poor condition. The piles have corrosion and section loss consistent with other bridges studied.

#### *Bridge 111-5002-0*

Bridge 111-5002-0 is a county owned and maintained bridge located in Fannin County. The bridge was originally constructed in 1969 and passes over Noontootla Creek. This bridge was identified for further study because of the condition of the steel piles. However, after studying the inspection reports this bridge had multiple defects that could be related to weather stressors. The first is the steel piles. In 2004 the county encased the piles that were located in the channel. At the time of this the county also painted all steel piles but did not clean the piles. However, by 2012 the piles were reported as having section loss of 1/32” to 1/16”. In 2016 the deck joints were reported to be leaking. In 2016 inspectors also noted that the piles had “moderate section

loss” and noted the need for repair of the joints and the piles. **Figure 176** shows the pile condition at bent 2 in 2016.



**Figure 176 – Bridge 111-5002-0 Steel Pile Condition at Bent 2 (GDOT, 2016)**

By 2019, section loss of up to ¼” was reported in the pile flanges and section loss of 1/16” was reported in the webs. Unfortunately, the photos from the 2019 inspection report are not labeled, but none of the photos or inspectors notes mention 100% section loss.



**Figure 177 – Bridge 111-5002-0 Typical Steel Pile Condition (GDOT, 2019)**

By 2021, the bridge was closed by inspectors because of the advanced section loss on the steel piles. The piles had 100% section loss in some areas, and heavy corrosion in other areas. Most flanges had just ¼” of flange remaining.





**Figure 178 – Bridge 111-5002-0 Steel Pile Conditions (GDOT, 2021)**

In 2021, steel piles were encased so the bridge could be reopened, the repair is seen in **Figure 179**.



**Figure 179 – Bridge 111-5002-0 Steel Pile Repair (GDOT, 2022)**

However, this repair is not the only repair that was completed on the bridge in 2022. The abutment and joint also underwent maintenance. The reinforced concrete abutment underwent rapid deterioration due to erosion related issues. In 2016 inspectors noted “minor settlement at abutment four” that did not require maintenance. By 2019 this minor area had grown to an area of 0.6’ x 3.0’ x 10.0’. This was also repaired in 2021, when the steel piles were encased.



**Figure 180 – Bridge 111-5002-0 Abutment Repair 2019 (Top) vs 2022 (Bottom)**

These repairs allowed for the substructure NBI rating to rise to a 7. Up from a 5 in 2019 and a 1 in 2021.

### *Bridge 257-0012-0*

Bridge 257-0012-0 is a county owned and maintained bridge located in Stephens County. These steel piles have an EHI of 52.5. Eight of the sixteen piles are in condition state one, four in condition state three, and four in condition state four. The piles that are in poor condition have advanced section loss and hour glassing underwater. There is also scour that is causing unsupported pile lengths. The piles were painted recently, 2008, so the corrosion in the piles is not severe above water, because of the recent painting and the encasement. However, a dive team has noted that the portion of the piles below the waterline are in poor condition.

### *Summary of Steel Pile*

The steel pile was identified as a poor element because of the poor condition in North Georgia. This area of the state experiences more annual days of rainfall annually, making it a more humid environment. A more humid environment has the chance to cause steel to corrode at a faster rate. After reviewing ten bridges with poor steel pile condition, there are two main concerns that county officials should be aware of when it comes to steel piles. First is an issue that can occur on almost any substructure element that passes over water, scour. Of the ten bridges studied, two had scour severe enough to report at the steel piles. As with any substructure element, county officials should monitor and create maintenance plans for bridges and elements at risk for scour. All ten of the bridges studied had varying levels of steel corrosion. There are several lessons to be learned from the steel corrosion. First, cleaning painting steel piles in the first few years they fall into condition state three could save counties from having to pay more to replace them later. When steel piles fall into condition state four, they require a posting on the bridge. From the maintenance reports that included measurements it was shown that once a steel pile reaches condition state three, they can lose up to 1/8" of section per year. Once they reach their late life

they can deteriorate quickly, and if the corrosion is severe enough can cause the closure of a bridge.

### ***Element 210 Reinforced Concrete Pier Wall***

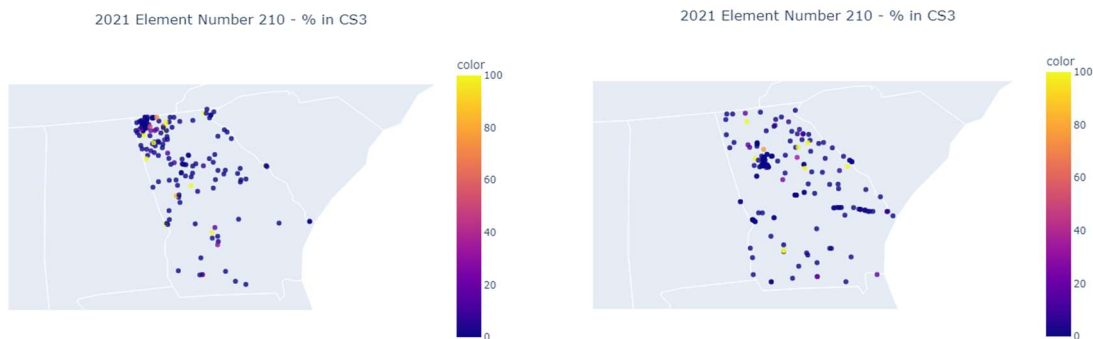
A reinforced concrete pier wall is a substructure element found on bridges throughout Georgia.

A concrete pier wall is used to support a bridge.

These elements are almost exclusively used in bridges that pass over water, so they are particularly at risk for environmental impact. Especially in DP10 counties where larger number of days with heavy precipitation can cause deterioration. The AASHTO Bridge Element Guide gives the condition state definitions, feasible actions, as well as major and minor defect definitions.

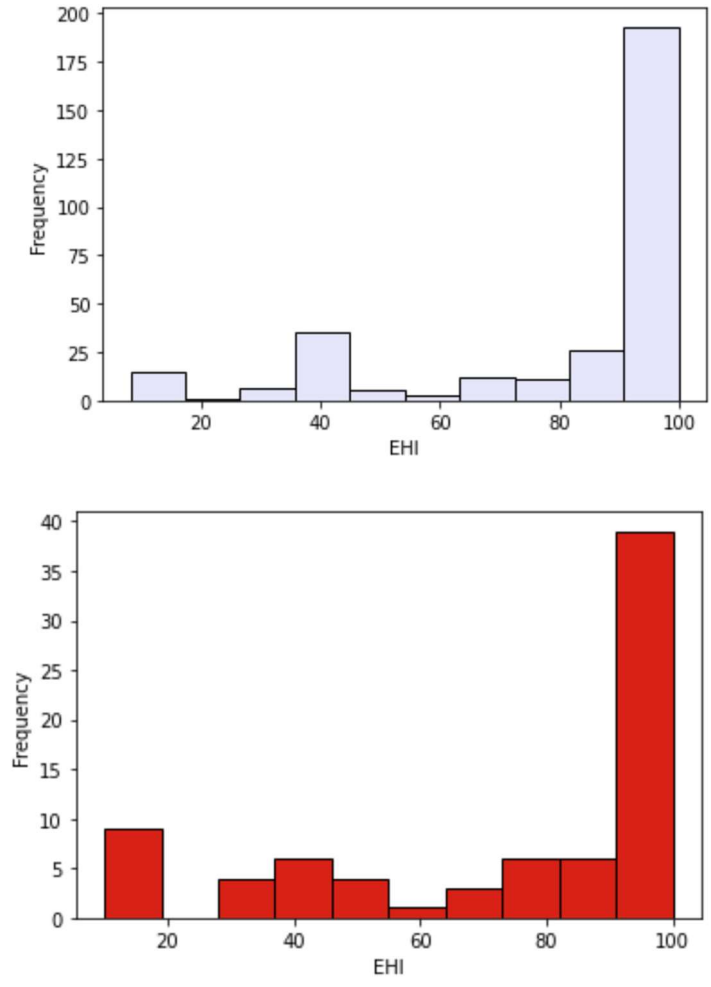
The primary defects noted by AASHTO associated with rainfall are cracking and spalling. Additionally scour, settlement, and efflorescence are attributable to wet environments.

The reinforced concrete pier wall was first identified visually using the images found in **Figure 181**.



**Figure 181: EN210 Percent in CS3 by location, 2021. County-Owned (Left) vs State-Owned (Right)**

After visually identifying this element the NBI element data was analyzed to determine if there is lag in DP10 counties. The EHI of EN110 in DP10 counties is 73.9 compared to an EHI of 82.5 found in non DP10 counties. **Figure 182** shows the distribution of the EHI scores of reinforced concrete pier walls in DP10 and nonDP10 counties. This figure shows that there is a higher concentration of reinforced concrete pier walls with lower scores in DP10 counties.



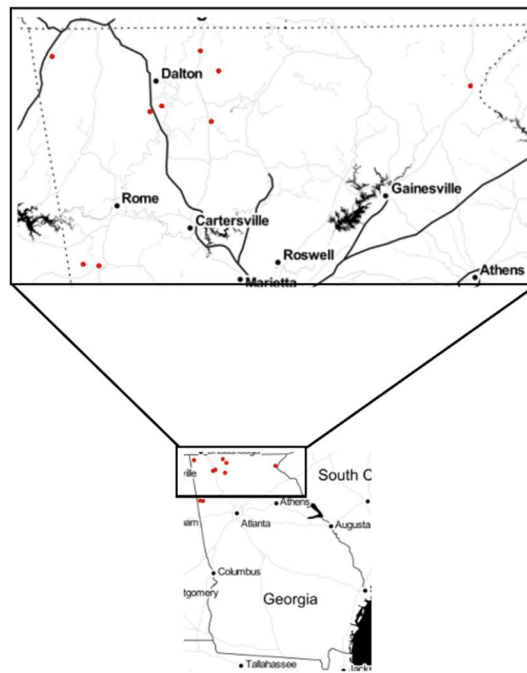
**Figure 182 – EHI of EN210 DP10 Counties (Bottom) vs NonDP10 Counties (Top)**

After identifying a skew to the selected DP10 counties, bridges from DP10 counties were selected to study. The lowest 10 bridges by EHI were selected for further study seen in **Table 29** and **Figure 183**.

**Table 29 - Lowest 10 DP10 Bridges by EHI of EN210**

Bridge ID	County	Owner	Year Built	Service Under	Substructure NBI Rating	EHI
213-0043-0	Murray	County	1928	Waterway	5	10
213-0048-0	Murray	County	1934	Waterway	5	10
233-0055-0	Polk	City	1918	Railroad	3	10
233-5036-0	Polk	County	1938	Waterway	6	10
241-5025-0	Rabun	City	1932	Waterway	6	10
313-5008-0	Whitfield	County	1986	Waterway	4	28.71
213-0017-0	Murray	State	1925	Waterway	5	29.412
313-5002-0	Whitfield	County	1924	Waterway	4	36.154
083-0046-0	Dade	County	1981	Waterway	7	40

There are several trends that one can gather from the NBI data. The first is that a majority of these bridges are county owned assets. This makes these bridges more likely to lag behind in condition ratings. Secondly, most of the bridges with lower EHI ratings were built before 1950, meaning that the climatic impacts found in these Northern counties have been impacting the bridges for over 70 years.



**Figure 183 - Location of Selected DP10 Bridges for EN210**

*Bridge 213-0043-0*

Bridge 213-0043-0 (**Figure 184**) is a county owned and maintained bridge located in Murray County. The bridge passes over the Coosawattee River. The bridge was constructed in 1928 and consists of six concrete spans. The reinforced concrete pier wall had an EHI of 100.0 at the first element inspection in 2016, but at the next inspection in 2018, the EHI had fallen to a 10.0. Inspectors noted abrasion and wear at the base of the pier wall, shown in **Figure 185**. However, by 2022 inspectors noted additional defects at the reinforced concrete pier walls. In 2022, inspectors noted spalling with rebar exposed that had section loss and drift accumulation at the pier wall. Despite additional defects being reported the EHI of the pier wall was unchanged. The additional defects appear to be the result of rainfall (drift and abrasion) and freezing temperatures (spalling).



**Figure 184 – Bridge 213-0044-0 Sideview (GDOT, 2022)**



**Figure 185 – Bridge 213-0044-0 Typical Pier Wall Abrasion (GDOT, 2020)**

*Bridge 233-0055-0*

Bridge 233-055-0 is a city owned and maintained bridge located in Polk County. It was originally constructed in 1918, making this bridge over 100 years old. The bridge was identified because of the poor condition of the reinforced concrete pier wall, but the other concrete elements on this bridge are in poor condition as well. The bridge is load posted for 5 tons, and the deck, substructure, and superstructure all have an NBI score of 3. This bridge does not pass over water, and there is no evidence that the defects are specifically weather related, but it is likely that over the life of the bridge that weather contributed to its deterioration. Even within the past 10 years the bridge has deteriorated rapidly, with spalls and cracking growing larger. **Figure 186** shows an example on one of the reinforced concrete columns from 2016-2022.



**Figure 186 – Bridge 233-055-0 Column 3-2 2016 (Top) vs 2022 (Bottom)**

It is likely that freeze-thaw cycles could have contributed to this deterioration, but concrete age is likely the most significant cause of the rapid concrete deterioration of this column.

*Bridge 233-5036-0*

Bridge 233-5036-0 is a county owned and maintained bridge located in Polk County. This bridge was built in 1938, and widened in 1952. The three steel spans cross Dry Creek and are supported

by a reinforced concrete pier wall in the center. In addition to deck cracking and steel corrosion, this bridge also has experienced the impact of precipitation in the form of scour. This bridge has undergone special inspections to measure the size of the scour at the reinforced concrete pier wall. In 2013, the divers noted a void sized at 2.0' x 5.5', and noted that it needed to be repaired. At the next dive inspection in 2015, the void had grown to 3.5' x 5.5'. By the next dive inspection in 2017, divers measured the same size void, but by 2019 it had been filled in with silt and was just 1.5' x 5.5'. By 2021, the void had grown again to 3.0' x 5.5', and throughout this process no piles were exposed. Additionally, the 2021 inspection report revealed a spall in the pier wall.



**Figure 187 – Bridge 233-5036-0 Pier Wall Scour (GDOT, 2021)**

### *Bridge 241-5025-0*

Bridge 241-5025-0 is a city owned and maintained bridge located in Rabun County. It was originally constructed in 1932 and passes over the Tallulah River. Inspectors have noted that the interior piers have “exhibit heavy concrete deterioration with efflorescence and crumbling due to salts.” This bridge is almost 100 years old, so concrete deterioration from weather stressors is expected. Because of the size of the structure there has not been a load reduction, and the bridge has not shown rapid deterioration from 2014-2022. The pier wall also has an area of scour reported, but it has not grown since 2014.

### *Bridge 233-5026-0*

This is a single span concrete bridge owned and operated by Polk County. The bridge is constructed like a culvert. This bridge is extremely old, built in 1920 and has severe cracking of concrete components as well as scour noted at the substructure. Both of the bents have scour reported. There are inspectors notes to repair the scour and cracking present. However, it is likely that this bridge is planned for replacement soon, which is why no maintenance has been performed. The cracking does not visually appear to have progressed, and the scour and undermining was reported to be unchanged in size from 2014-2022. **Figure 188** shows the advanced cracking in this structure.



**Figure 188 – Bridge 233-5026-0 Side View (GDOT, 2022)**

*Bridge 313-5008-0*

Bridge 313-5008-0 is a Whitfield County owned and maintained bridge. It was originally constructed by the county in 1986 to cross Swamp Creek. Before the county performed maintenance in 2022, this bridge has severe defects with the reinforced concrete pier wall that caused the bridge to have a posting, because of the reduced bearing area on steel beams. As early as 2004, inspectors noted spalls under the beams that impacted bearing area, and noted for the county to make repairs. However, until recently the county did not make repairs. Inspectors noted that these spalls happened because the bridge was unable to expand and contract. **Figure 189** shows that pier wall under beam 6 before and after repair.



**Figure 189 – Bridge 313-5008-0 Pier Wall Spall (Top) vs Repaired (Bottom)**

In addition to the spalling at the pier wall, the county also repaired undermining the was occurring at both abutments. The undermining was so severe that it caused one of the piles at the abutment to have 100% section loss, shown in **Figure 190**. This shows the necessity for counties

to repair abutment undermining in a timely manner, as once piles have section loss, there is little counties can do to return that assets to previous condition.



**Figure 190 – Bridge 313-5008-0 Abutment pile 100% Section Loss (GDOT, 2020)**

*Bridge 313-5002-0*

Bridge 313-5002-0 is a county owned and maintained bridge that was originally constructed in 1924. The bridge has experienced concrete deterioration that is to be expected with the age of the structure. There are spalls and heavy abrasion on the pier walls. It appears that the abrasion could have been caused from drift hitting the pier wall during a rain event. Over the years, the bridge has continued to deteriorate slowly.



**Figure 191 – Bridge 313-5002-0 Side View (GDOT, 2022)**



**Figure 192 – Bridge 313-5002-0 Reinforced Concrete Pier Wall Condition (GDOT, 2020)**

The main issues on this bridge are abrasion and wear, shown in **Figure 192**. The deterioration appears to be a combination of freezing temperatures and rainfall acting together.

*Bridge 213-0048-0*

Bridge 213-0048-0 is a county owned and maintained bridge located in Murray County. It was originally built in 1934 by the US Forest Service to pass over Emery Creek.



**Figure 193 – Bridge 213-0048-0 Side View (GDOT, 2022)**

The reinforced concrete pier wall has remained in condition state 3 (EHI of 10.0) since the first element inspection. The reasons that inspectors noted was abrasion and wear. However, it did not impact the load capacity of the bridge. In addition to this abrasion, inspectors also noted 2.0' of scour at the pier wall, and a logjam that was removed in 2020. Unfortunately, inspectors have not captured images of this element.

The main defect of this bridge is the steel girders. They have not been painted since the original construction and are in poor condition. There are several areas that have 100% section loss in the web and flange, shown in **Figure 194**.



**Figure 194 – Bridge 213-0048-0 Steel Girder Corrosion (GDOT, 2020)**

*Bridge 213-0017-0*

Bridge 213-0017-0 is a county owned and maintained bridge located in Murray County. It was originally constructed in 1925 to pass Sumac Creek.



**Figure 195 – 213-0017-0 Side View (GDOT, 2022)**

The reinforced concrete pier walls were rated in poor condition due to delamination, spalling, cracking, and exposed rebar. This is likely from the poor concrete condition that is likely a result of weathering over the almost 100 years this bridge has been in service. There are also signs of erosion and scour at bridges, however they are not located at the pier walls.



**Figure 196 – Bridge 213-0017-0 Scouring at Bent 4, 2022**

The abrasion at this pier wall is more severe than other bridges studied, with a large area of abrasion being noted at pier wall two. There is even a section of ice in the image captured, showing that it is likely that freeze-thaw cycles impacted this defect. Both areas have exposed rebar.



**Figure 197 – Bridge 213-0017-0 Pier Wall 2 Abrasion Area (GDOT, 2020)**

There are additional spalls and cracks in the arch portion of the bridge, and one of the pier caps has shown rapid deterioration since 2016, with an area of spall under a beam growing larger,

shown in **Figure 198**. In 2020 the spall area was recorded as 3.2' x 0.8' x 0.3', that resulted in a loss of bearing area of 2.5''



**Figure 198 – Bridge 213-0017-0 Bent Cap 4 Spall 2016 (Top) vs 2020 (Bottom)**

*Bridge 083-0046-0*

Bridge 083-0046-0 is a county owned and maintained bridge located in Dade County. It was built in 1981 with salvaged GDOT beams.



**Figure 199 – Bridge 083-0046-0 Side View (GDOT, 2022)**

The reinforced concrete pier wall has maintained an EHI of 40.0 since the first element inspection due to abrasion. However, it is not noted as serious. GDOT inspectors have not recommended maintenance currently. There is a small area of scour located at one of the wing walls. This erosion is attributable fully to rain as the channel this bridge passes over remains dry except during rainstorms. The abrasion in the reinforced pier wall is also attributable to these rain events. Unfortunately, inspectors have not captured images of the abrasion.

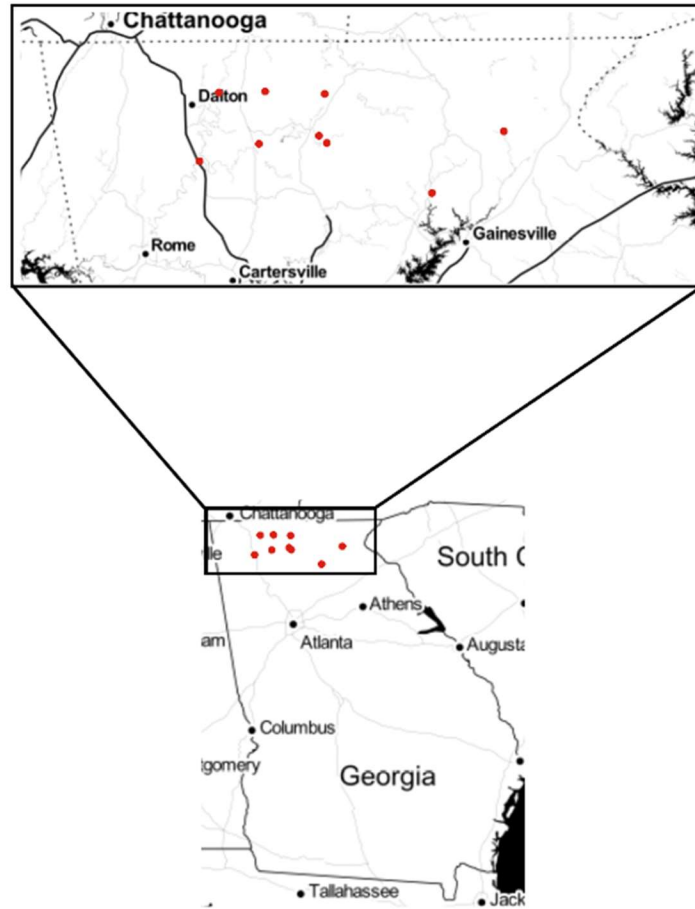
### ***Scour Critical***

When studying bridge elements in Georgia it was clear the scour had a big impact on bridge condition in the state. However, unlike previous elements studied scour is not a bridge element, so a different process was used to identify bridge elements. Three different methods were used to select bridge impacted by scour. Three bridges were selected using the “Scour Critical” NBI

score. This rating is limited by the fact that there are 4,421 bridges in Georgia that pass over a waterway the have a “U” score for this NBI item. Three bridges were selected using the “Channel Protection” NBI score. In 2022, a “Scour” score was added to the NBI database for all bridges that pass over a waterway. This score was used to select four bridges. **Figure 200** shows the geographic location of the selected bridges, and **Table 30** summarizes the bridges.

**Table 30 – Bridge Identified for Scour Study**

Bridge ID	County	Owner	Year Built	Service Under	Substructure NBI Rating	Scour Critical
123-0036-0	Gilmer	County	1958	Waterway	3	U
123-5024-0	Gilmer	County	1959	Waterway	2	U
123-5060-0	Gilmer	County	2001	Waterway	6	U
129-0009-0	Gordon	State	1930	Waterway	6	5
187-0016-0	Lumpkin	State	1976	Waterway	6	5
213-0044-0	Murray	County	1921	Waterway	5	U
213-5044-0	Murray	County	2011	Waterway	5	5
311-0040-0	White	State	1990	Waterway	7	5
313-5083-0	Whitfield	County	2001	Waterway	7	5



**Figure 200 - Location of Selected DP10 Bridges for Scour**

*Bridge 123-5060-0*

Bridge 123-5060-0 is a county owned and maintained bridge located in Gilmer County. This is a new bridge, as it was constructed in 2001. It is a single span bridge that passes over the Cartecay River Tributary and is seen in **Figure 201**.



**Figure 201 – Bridge 123-5060 Side View (GDOT, 2021)**

Since the first element inspection in 2015, areas of undermining at the abutment had been reported. In 2015 an area with a height of 1.0' was measured at abutment two, and inspectors had recommended that riprap be installed to correct and prevent further undermining from occurring. Since this inspection the undermining has continued to grow, in 2019 it was reported by inspectors to be 1.0' x 1.2', and in 2021 it was reported to be 1.0' x 1.5'. As of 2021, a maintenance item to repair the undermining in abutment two remains.

#### *Bridge 213-0044-0*

Bridge 213-0044-0 is a county owned and maintained bridge located in Murray County. The single span bridge was originally built in 1921 and widened in 1968 and passes over Willbanks Branch. It has dealt with rapid undermining of both abutments. The first mention of the undermining by inspectors was in 2018, when they noted an area of 1.4' on the left side of abutment one. Additionally, inspectors noted the presence of a drift pile. By 2020, undermining

was reported in both abutments, with the area in abutment one being reported as 0.6'x1.4'x5.0', and the area in abutment three reported as 4.0 x 6.5'. The inspectors recorded the same measurements in 2022. However, this bridge shows how rapidly areas of undermining can grow. One interesting thing observed in the inspection photos was the difference in the creek flowrate when captured at different times.





**Figure 202 – Bridge 213-0044-0 Volumetric Flowrate No Precipitation (Top) vs With Precipitation (Bottom)**

*Bridge 313-5083-0*

Bridge 313-5083-0 is a county owned and maintained bridge located in Whitfield County, passing over the Conasauga River. This 14-span prestressed concrete bridge was originally constructed in 2001 to replace an old bridge structure. Overall, this bridge is in good condition, as the superstructure, substructure, and deck all received an NBI score of “7” from 2014-2022. However, this bridge was selected due to the scour critical score. It received a score of “5” from every year since 2014 due to scour at one of the bents. Additionally in 2018 inspectors recorded undermining for the first time.

The 2014 inspection report noted the necessity of installing rip-rap to prevent the bridge from experiencing further scour. As of 2022 these maintenance requests have not been filled. Unfortunately, the first photos recorded from this bridge are from 2020, so it is impossible to track the condition of the scour year by year to see its progression since the maintenance request was placed, but **Figure 203** shows the severity of the scour, and **Figure 204** shows the area of undermining at the abutment.



**Figure 203 – Bridge 313-5083-0 Bent 2 Scour (GDOT, 2020)**



**Figure 204 – Bridge 313-5083-0 Abutment Undermining (GDOT, 2020)**

*Bridge 311-0040-0*

Bridge 311-0040-0 is a county owned and maintained bridge located in White County. This bridge was constructed in 1990 and passes over Sautee Creek. It was selected for study, because despite high NBI scores on the deck, substructure, and superstructure, the scour critical score was a “5.”

Although this bridge was deemed scour critical there was no scour noted by inspectors since 2014.

Despite there being no scour present, the impacts of precipitation are still evident on this bridge. Erosion is noted at both abutments, and this bridge previously had erosion rehabilitation actions completed, shown in **Figure 205**.



**Figure 205 – Bridge 311-0040-0 Abutment Repair (GDOT, 2020)**

The 2014 inspection report noted that the repair shown in **Figure 205** had been completed recently, but also noted that abutment one had similar erosion problems and placed a maintenance note to repair this erosion. There were no additional photos of erosion captured on

this bridge until 2020, shown in **Figure 206**, but if erosion repair was needed it could have been a better allocation of the counties resources to repair both abutments at the same time.



**Figure 206 – Bridge 311-0040-0 Erosion (GDOT, 2020)**

*Bridge 213-5044-0*

Bridge 213-5044-0 is Murray County owned and maintained bridge originally constructed in 2011. The single span steel bridge passes over Dill Creek, and is shown in **Figure 207**.



**Figure 207 – Bridge 213-5044-0 Bridge Side View (GDOT, 2022)**

Since this is a new bridge, overall, it is in good condition. However, since its commissioning, it has continued to scour. The first scour was observed in 2014, where inspectors noted an area of washout sized as 5.0' x 3.5' x 1.0'. By 2016 this area had grown to 15.0' x 5.0' x 2.5' and had exposed a pile. The photo from the 2016 inspection report is shown in **Figure 208**. 2016 is also the first year that inspectors noted the need for maintenance on the structure. Inspectors dropped the NBI substructure rating to a 5, noting that it could be raised once the scour washout had been addressed.



**Figure 208 – Bridge 213-5044-0 Abutment One Scour (GDOT, 2016)**

In 2018, inspectors once again measured the size of the washout under the abutment, and it had increased in size again. The new dimensions were measured as 15.0' x 5.0' x 3.0'. **Figure 209** shows the photo the inspection team documented from this year.



**Figure 209 – Bridge 213-5044-0 Abutment One Scour (GDOT, 2018)**

In 2020, the size of the abutment undermining measured by the inspection team had grown again. This year it was measured to be 6.0' x 4.5' x 24.0', and instead of having just one pile exposed there were now 4 piles exposed. **Figure 210** shows the condition recorded at the inspection report in 2020.



**Figure 210 – Bridge 213-5044-0 Abutment One Scour (GDOT, 2020)**

Unfortunately, no new photos were captured in 2022, however no maintenance had been completed on this abutment. This bridge shows that unlike many of the other deficiencies that bridges in Georgia experience, age of the structure does not matter. This bridge is less than 15 years old and has advanced scour. It also shows how fast scour can grow when left unaddressed.

*Bridge 187-0016-0*

Bridge 187-0016-0 is a state owned and maintained bridge located in Lumpkin County. This three-span concrete bridge was constructed in 1976 and passes over the Chestatee River. This bridge was identified by its scour critical scour of “5,” however after studying past inspection reports there was not major erosion or scour issues with this bridge. In 2022, inspectors noted “minor lateral bank erosion,” but this is the only mention of any erosion related issues. Additionally, there are no photos that show the extent of the damage done by the erosion. However, when studying this bridge there was damage to the bridge that could have been caused by environmental factors.

In 2016, inspectors noted a minor spall on bent cap 5 with no rebar exposed sized at 5” x 6” x ½”. By 2020 this same spall had increased to 22” x 14” x 2.5” and had exposed rebar. Unfortunately, no photo was captured during the 2016 inspection, but the photo from the 2020 inspection is seen in **Figure 211**.



**Figure 211 – Bridge 187-0016-0 Bent Cap 5 Spalling (GDOT, 2020)**

There is also spalling on bent cap 9. In 2016 inspectors made a note to seal the cracking on bent cap 9, and in the 2020 inspection report a photo of the cracking was recorded. By 2022 the cracking had turned into a spall measuring 1.0' x 2.0' with exposed rebar.



**Figure 212 – Bridge 187-0016-0 Bent Cap 9 Spalling 2020 (Top) vs 2022 (Bottom)**

Both show how fast minor cracks and spalls can turn into larger cracks and spalls, particularly in humid environments that experience freeze-thaw cycles.

### *Bridge 129-0009-0*

Bridge 129-0009-0 is a state-owned bridge that is in Gordon County. This 17-span bridge was originally constructed in 1930, but a majority of the bridge was constructed in 1980 as a part of a widening project. Overall, the bridge is in good condition with areas of concrete spalling and cracking in members of the superstructure and substructure. There is also some minor corrosion on the steel piles. However, the main weather-related issue with this bridge is scour. In 2015, inspectors noted “slight scour around columns.” Despite this note there was no maintenance items recommended by inspectors. By the 2019 inspection, scour had removed around 7.0’ of soil from around the base of the steel piles. **Figure 213** shows bent 15 in 2015 and 2019.





**Figure 213 – Bridge 129-0009-0 Scour at Bent 15 2015 (Top) vs 2019 (Bottom)**

This bridge shows how rapidly scour can happen, as it was not even noted in the inspection notes leading up to 2019.

*Bridge 123-5024-0*

Bridge 123-5024-0 is a county owned and maintained bridge located in Gilmer County. It was built in 1980 to provide service over Rolston Creek. However, this bridge has dealt with growing scour issues since 2016.



Inspectors updated scour measurements seen in **Table 31** and **Table 32**.

**Table 31 – Bridge 123-5024-0 Abutment 1 Scour Measurements**

2015	minor
2017	No change
2019	6' long x 6" high x 6" back
2021	6' long x 6" high x 6" back

**Table 32 – Bridge 123-5024-0 Abutment 2 Scour Measurements**

2015	12" or less
2017	6" deep with 1.0' of penetration along whole face
2019	8" deep with 2.0' of penetration along whole

	face
	1' deep and 2.0' back along full face

In 2021 a crack also appeared in abutment two that could be the result of the undermining.



**Figure 214 – Bridge 123-5024-0 Abutment 2 Undermining (GDOT, 2021)**

Despite this increase in size, the EHI of the reinforced concrete abutments actually increased over this time from 40.0 to a 55.0.

GDOT inspectors did not recommend repair in 2015, but by 2017 maintenance on the abutments was recommended.

*Bridge 123-0036-0*

Bridge 123-0036-0 is a county owned and maintained bridge located in Gilmer County. It was constructed in 1958 and passes over Boardtown Creek. This bridge has experienced major scour issues in both abutment one and bent two. Inspectors have documented the progression of the erosion in abutment one. In 2023, inspectors noted an area of erosion of 1' x2' x 4' on the upstream side of abutment one. In 2017 the area was noted to be moderate, sized between 2'-4'.

However, in 2017 the scour was severe enough to where inspectors noted that the abutment had leaned forward. By 2023, undermining on the downstream side of 5.5' x 0.9' was also reported. This was larger than the 1.0' x 0.9' area reported in 2021. Additionally, bent two has reported erosion of 3.0' x 1.0' x 1.0', that was unchanged in 2023. Significant measures will need to be taken to repair this bridge.



**Figure 215 – Bridge 123-0036-0 Settlement Cracking (GDOT, 2022)**



**Figure 216 – Bridge 123-0036-0 Abutment Void (GDOT, 2020)**

*Bridge 147-5080-0*

Bridge 147-5080-0 is a county owned and maintained bridge located in Hart County. This bridge has experienced severe scouring of the abutments which has dropped the NBI substructure score to a “4.” The scouring and erosion has been severe enough to expose the piles and cause corrosion of them. **Figure 217** shows the typical pile conditions. Despite maintenance being recommended to repair the scouring, there has been none performed allowing the scour to worsen from the weather stressors experienced in the area.



**Figure 217 – Bridge 147-5080-0 Typical Abutment Condition (GDOT, 2021)**

*Summary of Scour Critical Bridges*

Scour was identified as a vulnerability associated with days of precipitation. However, this impacts multiple substructure elements, and the “Scour Critical” NBI rating was determined to not be a good way to identify bridges that were experiencing scour. Many bridges were identified that received a “U” rating in this category. Scour also impacts multiple substructure elements. Counties should monitor the condition of bridges that pass over waterways as scour can progress quickly, especially in fast moving waterways. After reviewing the inspection reports there were several conclusions to be drawn. First, counties should look to protect substructure elements from scour or repair them. In five of the ten bridges studied the size of the scour or undermining grew from the time inspection crews recommended maintenance. Since this repair is a cost per area, counties could protect these assets. Unlike the other elements studied, scour impacted bridges at differing rates. Some bridges that had scour experienced either no scour progression or small progression between inspections, while others rapidly progressed. Most other bridge defects caused by weather stressors appeared on bridges aged over 50 years. Scour impacted old

and new bridges. Counties should carefully monitor bridges that pass over waterways, particularly in areas that experience more rainfall.

## **DX90**

Georgia has a hot climate, with most areas impacted by heat. After following a similar process to the previous counties, no elements were identified through a visual inspection or data in the highest 15 counties or through the element data health indexes. As heat impacts most regions of Georgia a new methodology was proposed to identify the bridge elements most impacted. The average EHI for each bridge element in Georgia was calculated and of the bridges calculated, the worse scores of commonly found elements in Georgia were selected for study. Of these elements, three locally owned bridges were selected to study to determine the reasons why these elements had fallen into poor condition. **Table 33** shows the elements selected for this study.

**Table 33 – 2021 Worst Elements by EHI in Georgia**

<b>Element Number</b>	<b>Element Name</b>	<b>GA EHI</b>
<b>EN302</b>	Compression Joint	66.5467
<b>EN300</b>	Strip Seal Joint	64.4884
<b>EN301</b>	Pourable Joint	64.0088
<b>EN303</b>	Assembly with Seal Joint	60.1769
<b>EN231</b>	Steel Pier Cap	56.699
<b>EN227</b>	Reinforced Concrete Pile	56.0676
<b>EN219</b>	Steel Abutment	51.8478

## ***EN302 Compression Joint***

### *Bridge 213-5045-0*

Bridge 213-5045-0 is a county owned and maintained bridge located in Murray County. This bridge does not pass over a waterway, and is a new structure, constructed in 2012. The bridge was selected to study because just 10 years after construction, the compression joint was given an EHI score of 0, because of leakage at the abutments. The joint condition is shown below in **Figure 218** as well as a crack skew at the failed joint. There is nothing in the inspection reports that indicates that this failure was related to weather stressors. It is much more likely that this failure was the result of traffic or poor construction. However, it is known that failing joints cause the leakage of debris, salts, and water to the substructure elements.



**Figure 218 – Bridge 213-5045-0 Failed Compression Joint (GDOT, 2022)**



**Figure 219 – Bridge 213-5045-0 Bridge Deck Cracking at Abutment (GDOT, 2022)**

*Bridge 157-5084-0*

Bridge 157-5084-0 is a multi-span prestressed concrete bridge located in Jackson County. Built in 2002, this county owned and maintained bridge has failed compression joints at the abutments. These were first noted by inspectors in 2010. Despite the failed compressive joints, the rest of the bridge appears to be in good condition, with the deck, superstructure, and substructure all receiving an NBI score above a 7. The joints allowing a free flow of water for over 10 years does not appear to have impacted other elements. Unfortunately, there were no photos of the joint before failure, and the current condition is shown in **Figure 220**. Despite the joint being comprised since 2010, there has yet to be maintenance performed on the joint.



**Figure 220 – Bridge 157-5084-0 Failed Compression Joint (GDOT, 2022)**

*Bridge 213-0008-0*

Bridge 213-0008-0 is a state owned and maintained bridge located in Murray County. The bridge was opened in 1974, and allows US411 to pass over the Coosawatte River. There is one compression joint at abutment one in this bridge. In 2015 inspectors noted that the joint was beginning to fail, as some of the rubber was loose, but the NBIE data still reflected an EHI of 100. Inspectors requested maintenance for the joint. In 2018 the joint condition visually had worsened, but the NBIE data was unchanged. By 2022 the compression joint at abutment one had entirely come out, and had an EHI of 0.0. **Figure 221** shows the progression of the joint deterioration.







**Figure 221 – Bridge 213-0008-0 Compression Joint 2015 (Top) vs 2018 (Middle) vs 2022 (Bottom)**

***EN300 Strip Seal Expansion Joint***

***Bridge 097-5059-0***

Bridge 097-5059-0 is a county owned and maintained bridge located in Douglas County. The bridge was constructed in 2001 with prestressed concrete girders to pass over State Route 8. Overall, the bridge is in great condition, with an NBI deck score of “7”, with inspectors noting shrinkage cracking and failing/leaking joints. This bridge has one strip seal expansion joint and four pourable seal joints. The pourable seal joints are in condition state three and the strip seal expansion joint is in condition state one and four. Inspectors first noted that the joints failed in 2009, just eight years after bridge construction. The joint at bent three was the first that

inspectors noted to fail. As of 2021 the bent three pier cap is the only one to note efflorescence and cracking. Inspectors note that the cracking is from shear, but the efflorescence at this pier cap could be the result of water being able to penetrate through the failed joint. Unfortunately, inspectors did not photograph this pier cap, but one of the failing joints is shown in **Figure 222**.



**Figure 222 – Bridge 097-5059-0 Failing Joint (GDOT, 2019)**

*Bridge 045-5018-0*

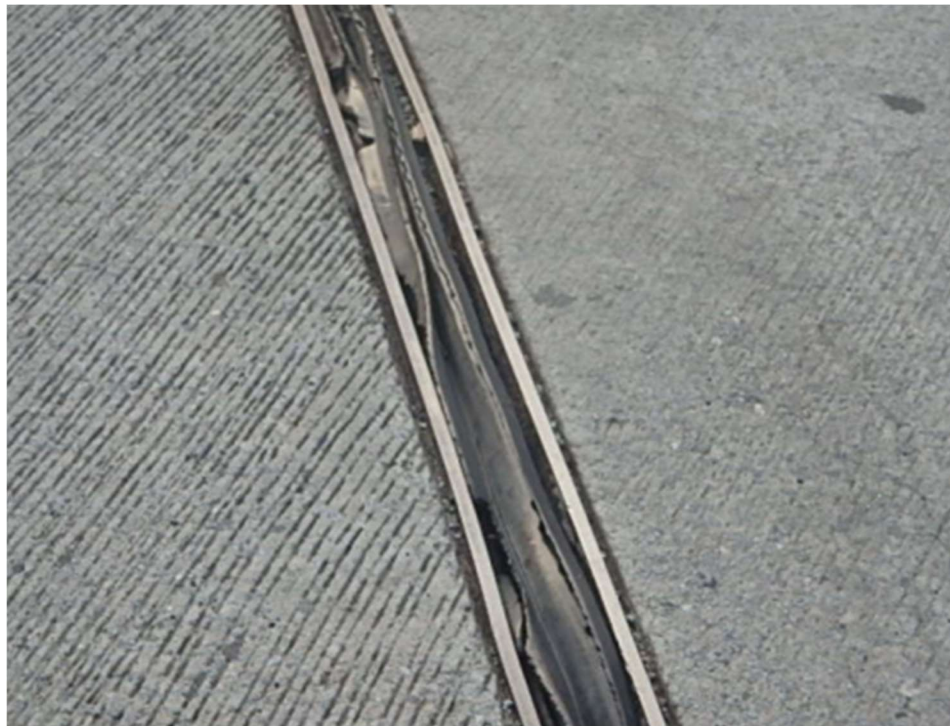
Bridge 045-5018-0 is a county owned and maintained bridge located in Carroll County. The bridge was originally constructed in 1960 and passes over Garrett Creek. The bridge has two strip seal expansion joints, however in the most recent inspection, they were reclassified to pourable expansion joints. The joints have been leaking since 2012, which could be causing a faster progression of the corrosion of the steel pier cap. Since they were first noted leaking in 2012, vegetation has started growing through them, shown in **Figure 223**. Despite inspectors recommending maintenance, no maintenance has been performed.



**Figure 223 – Bridge 045-5018-0 Joint Condition 2016 (Top) vs 2021 (Bottom)**

*Bridge 089-0131-0*

Bridge 089-0131-0 is a county owned and maintained bridge located in Dekalb County. This bridge passes over a railroad and was built in 1977. This bridge was selected, because the strip seal joint was deemed to be in condition state four. Inspectors determined that both the strip seal expansion joints at bent two and four were leaking and allowing the free flow of water. However, this is not a new or rapidly developed issue. The joints were reported to have failed since the first available report in 2004. Inspectors placed a maintenance request that has yet to be filled, meaning that these joints have been allowing the flow of water and other debris for nearly 20 years. There was cracking a debris build up reported on the bents in inspection reports and shown in **Figure 225** that is likely linked to the poor joint conditions. Additionally, all the joints on this bridge have failed, not just the expansion joints.



**Figure 224 – Bridge 089-0131-0 Strip Seal Expansion Joint Typical Condition (GDOT, 2016)**



**Figure 225 – Bridge 089-0131-0 Debris Build Up on Bent Cap 3 (GDOT, 2019)**

### ***EN303 Assembly Joint with Seal***

#### *Bridge 115-5005-0*

Bridge 115-5005-0 is a county owned and maintained bridge located in Floyd County. This steel bridge was constructed in 1969. In 2007 this bridge had a spring tensioned armored joint tightened. When this repair was made, the joint was not sealed. The pourable seal joints were also reported to be leaking on inspection reports since this repair. Unfortunately, inspectors did not capture images of these bridge defects. However, maintenance could have been performed on other bridge joints in 2007, but was not.

#### *Bridge 257-0001-0*

Bridge 257-0001-0 is a county owned and maintained bridge located in Stephens County. It was originally constructed in 1949 and passes over a railroad. The assembly joint with seal was

deemed to fall into condition state four. The joints have been covered with asphalt as early as 2002, and maintenance has been requested since this time, because the joints were noted to be leaking. However, the EHI of this element consistently dropped since the first inspection report, despite no changes in condition being noted in inspector's notes.



**Figure 226 – Bridge 257-0001-0 Typical Joint Condition (GDOT, 2021)**

*Bridge 241-5051-0*

Bridge 241-5015-0 is a county owned and maintained bridge in Rabun County. This bridge was built in 1985 and passes over the Tallulah River. The assembly joint maintained an EHI of 100 until 2022, when it fell to 0 because of leakage. Despite previous photos showing leakage in the joints, this is the first year inspectors adjusted the element score. The joints had likely been leaking for several years as there is vegetation growing from the joints, shown in **Figure 227**.



**Figure 227 – Bridge 241-5051-0 Joint Condition (GDOT, 2020)**

***EN231 Steel Pier Cap***

***Bridge 045-0079-0***

Bridge 045-009-0 was built in 1971, and is owned and maintained by Carroll County. The bridge was identified because of the poor condition of the steel pier caps. The steel pier caps were classified to be in condition state three because of the corrosion and the loss of the protective painting. **Figure 228** shows the change from 2014, when inspectors first recommended that this element be painted, to 2022.





**Figure 228 – Bridge 045-0079-0 Steel Pier Cap 2014 (Top) vs 2022 (Bottom)**

Over these years there was no section loss reported by inspectors, but there was corrosion. The county should consider cleaning and painting the steel elements to prevent section loss and reduced load capacity. It appears this bridge element is in poor condition because of the age of the structure, the proximity to humidity, and the lack of preventative maintenance.

*Bridge 045-5027-0*

Bridge 045-5027-0 is a county owned and maintained bridge located in Carroll County. This bridge has a posting of 5 tons due to the poor condition of the timber piles and deck. It had previously been posted at three tons but was raised after the piles were sounded in 2022. It was

identified for study because of the poor steel pier cap condition. Similarly to the previous bridge studied, there was no noted changes between the steel pier cap conditions in the 8 year span between 2104-2022.



**Figure 229 – Bridge 045-5027 Steel Pier Cap Condition (GDOT, 2022)**

*Bridge 231-5002-0*

Bridge 531-5002-0 is a county owned and maintained bridge located in Pike County. It was originally built in 1970 and passes over Turnpike Creek. This bridge was identified to study the steel pier cap condition. Since the first inspection report the steel pier cap EHI has fallen from 40 to 10. The corrosion has worsened over the years, although it is difficult to observe visually through photos. **Figure 230** shows the progression of the steel corrosion from 2016-2022.





**Figure 230 – Bridge 231-5002-0 Steel Pier Cap Condition 2016 (Top) vs 2022 (Bottom)**

There visually appears to be more steel pitting in 2022. However, with cleaning and painting these members could be classified as a higher condition state, and there would be less risk of load posting from steel member corrosion and section loss.

### ***EN227 Reinforced Concrete Pile***

#### ***Bridge 283-5026-0***

Bridge 283-5026-0 was built in 1959. Overall, the bridge in good health, with a deck and superstructure NBI score of 7 and a substructure score of 6. This bridge was identified because of the reinforced concrete pile. They appear to have deteriorated from weather impacts, but not

rapidly. The typical abrasion on the pile is shown in **Figure 231**. Inspectors placed the reinforced concrete bents in condition state three due to this abrasion.



**Figure 231 – Bridge 283-5026-0 Typical Pile Condition (GDOT, 2019)**

*Bridge 175-5086-0*

Bridge 175-5086-0 was built in 1940. This bridge is in poor condition with concrete cracking and spalling throughout the reinforced concrete elements. Inspectors placed this bridge's reinforced concrete piers in condition state three due to minor scour issues. Inspectors first measured the scour undermining as 12" +/- in 2017, after reporting it in 2015. It remained the same in the 2019 and 2021 inspections. **Figure 232** shows the photo inspectors captured of the typical scour in the 2021 inspection report.



**Figure 232 – Bridge 175-5086-0 Scour (GDOT, 2021)**

*Bridge 231-5024-0*

Bridge 231-5024-0 was originally constructed in 1954 and passes over Elkins Creek. Inspectors placed the reinforced concrete piers in condition state two due to abrasion. This is likely a cause of weathering over the 70 years the bridge has been in service.



**Figure 233 – Bridge 231-5024-0 Side View (GDOT, 2021)**



**Figure 234 – Bridge 231-5024-0 Typical Reinforced Concrete Pile Condition (GDOT, 2021)**

***EN219 Steel Abutment***

***Bridge 297-5062-0***

Bridge 297-5062-0 is a county owned and maintained bridge located in Walton County. It was identified because of the poor steel abutment condition, with an EHI of 10.0. The steel abutment has maintained this EHI since the initial inspection. It appears that the corrosion is the result of proximity to humidity and lack of maintenance painting. **Figure 235** shows the abutment condition from 2013 to 2021.





**Figure 235 – Bridge 297-5062-0 Steel Abutment Condition 2013 (Top) vs 2021 (Bottom)**

*Bridge 045-5126-0*

Bridge 045-5126-0 is a county owned and maintained bridge located in Carroll County. It passes over Little Tallapoosa River. It was identified for study because of the poor steel abutment condition rating. After examining inspection reports the steel abutment was in poor condition because of steel rusting. The other steel members of the bridge were also in poor condition. The bridge has a load posting, and inspectors have recommended steel cleaning and painting. Preventative maintenance at this stage would prevent steel section loss and irreversible consequences of corrosion.



**Figure 236 – Bridge 045-5126-0 Steel Abutment Condition (GDOT, 2021)**

*Bridge 045-0079-0*

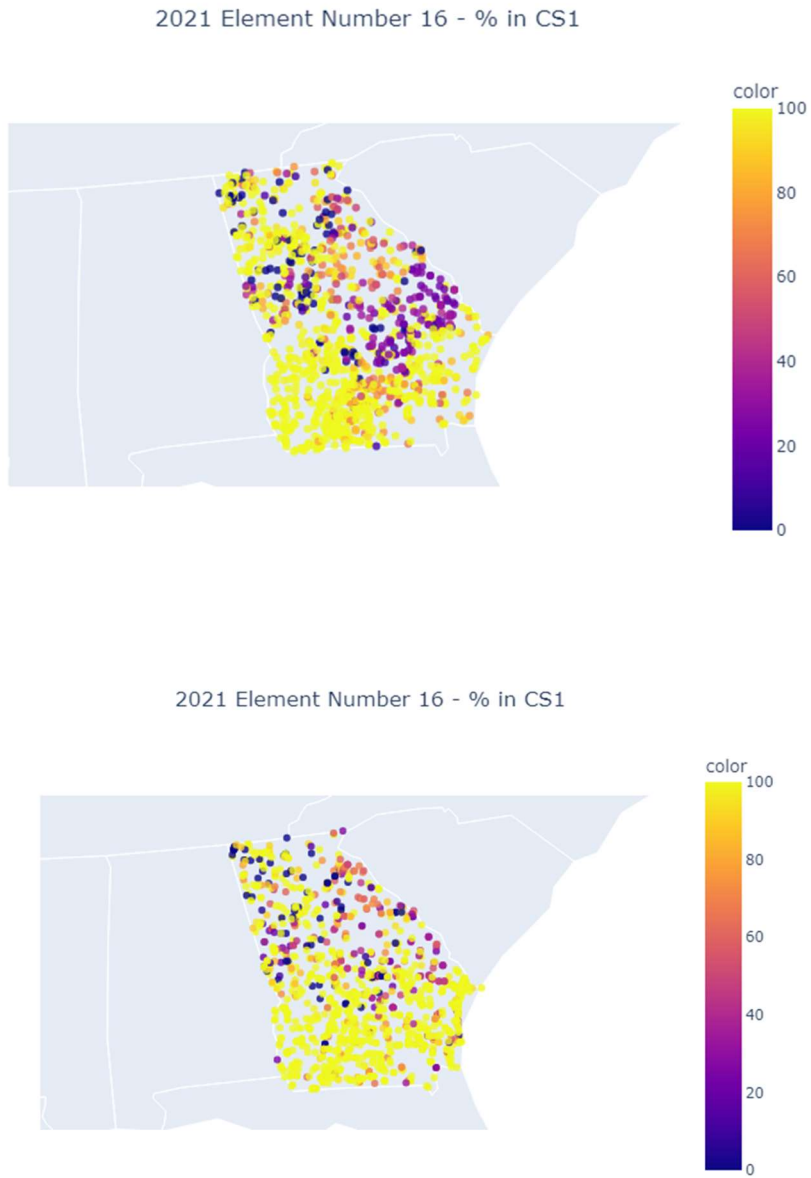
This bridge was previously studied in the steel pier cap section. However, the steel abutments display similar corrosion issues to the bridges previously studied in this section.

**SNOW**

***EN16 Reinforced Concrete Top Flange***

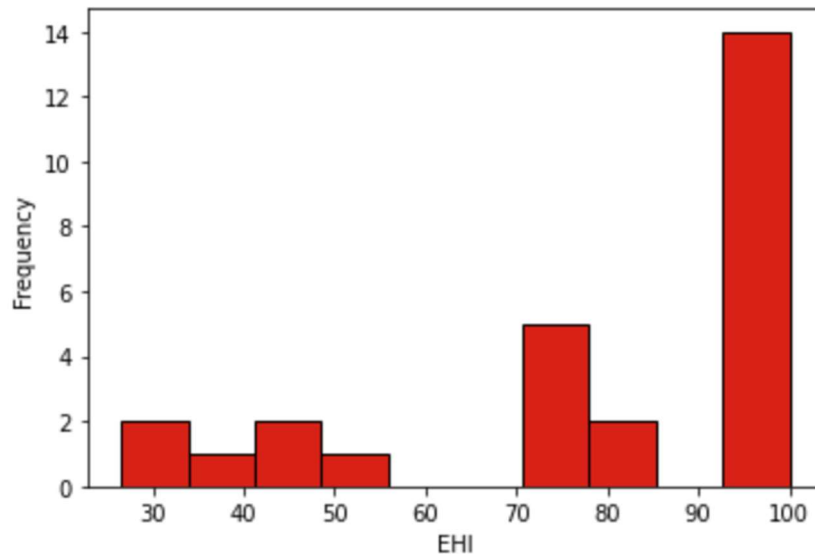
Element 16, the reinforced concrete top flange was first selected to study in the Snow counties from the element heat maps shown in **Figure 237**. A reinforced concrete girder is a superstructure element used to support bridge decks. Element 110 is used to describe all

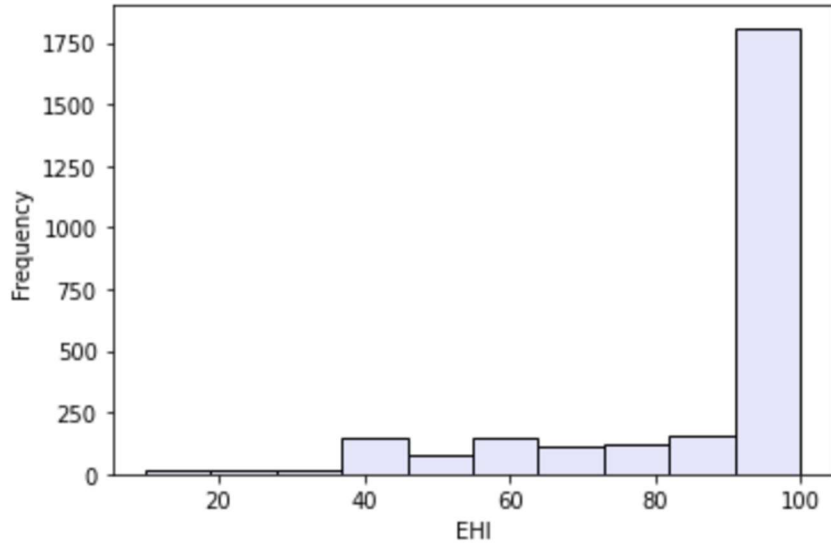
reinforced concrete girders regardless of protective systems in place. AASHTO provides condition state definitions, feasible actions, and element definitions for the reinforced concrete girders.



**Figure 237: Percent of EN16 in Condition State One by Location, 2021. County-Owned (Top) vs State-Owned (Bottom)**

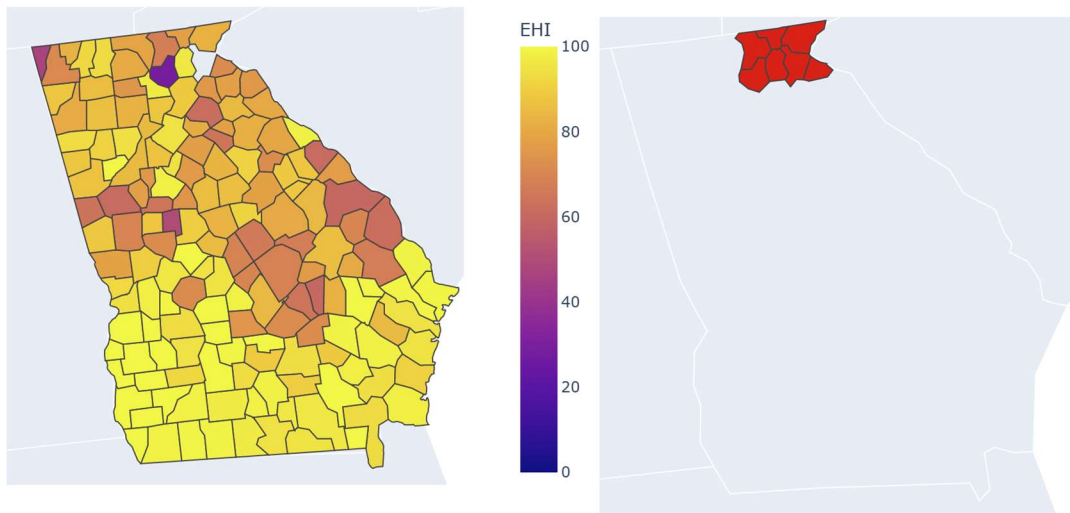
From these maps, there appeared a skew to the areas of Georgia that experience the coldest weather and the most snowfall. Based on the findings from the literature review, it was expected that deck elements would show impacts of snowfall, freezing temperatures, and deicing chemicals. After further studying this element, this element is in worse condition in snow counties than in other counties. This element is relatively common in Georgia, as in 2021, 2,818 unique bridges contained at least one reinforced concrete top flange. Additionally, at least one bridge contains a reinforced top flange in all 159 counties in the state. In counties that were not identified as snow counties, the average EHI for this element was 87.83, while in snowfall counties of interest, the EHI was 80.11. The disparity in average EHI shows that bridges in these counties lag in EHI compared to the overall health of bridges in the state. There is a higher frequency of reinforced concrete top flanges in the 40-80 health rating that occur in DT32 counties than in other Georgia counties, shown in the distribution graphs in **Figure 238**.





**Figure 238 – EHI of EN16 Snow Counties (Top) vs Non Snow Counties (Bottom)**

Lastly a heat map was generated that calculates the average EHI of EN16 by county and compared side by side to determine if there appeared to be in worse condition in the anticipated areas, shown in **Figure 239**



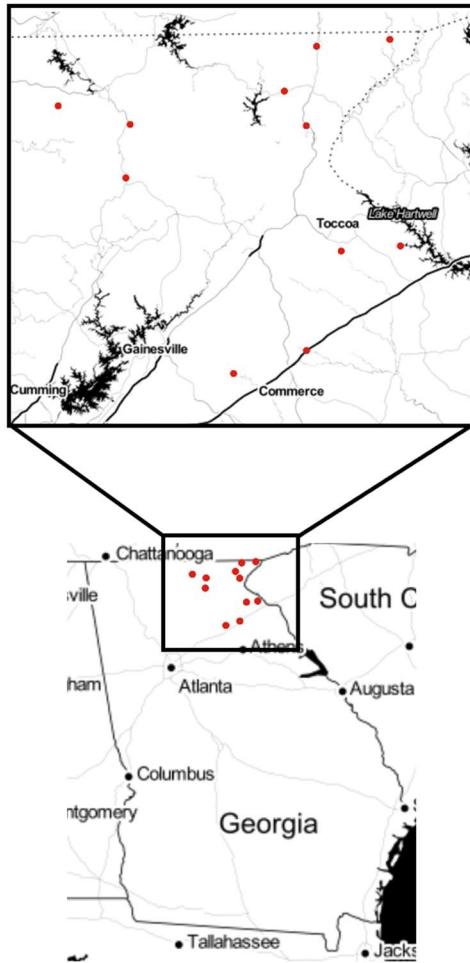
**Figure 239 – EHI of EN16 by County (Left) vs Snow Counties (Right)**

Once the element was selected for study the 10 worst by EHI in the selected snow counties. The bridges are summarized in **Table 34** and mapped in **Figure 240**.

**Table 34 - Lowest 10 Snow Bridges by EHI of EN16**

Bridge ID	County	Owner	Year Built	Service Under	Deck NBI Rating	EHI
011-0033-0	Banks	State	1963	Waterway	6	32.768
157-5046-0	Jackson	County	1959	Waterway	5	25.42
187-0007-0	Lumpkin	State	1929	Waterway	5	28.75
241-0016-0	Rabun	State	1926	Waterway	6	70.917
241-0018-0	Rabun	State	1938	Waterway	6	49.706
241-0033-0	Rabun	County	1920	Waterway	7	73.707
241-5036-0	Rabun	County	1928	Waterway	5	26.501
257-0008-0	Stephens	State	1960	Waterway	7	76.066
257-0012-0	Stephens	County	1963	Waterway	7	40.148
291-0002-0	Union	County	1973	Waterway	7	45.311
291-0018-0	Union	State	1962	Waterway	6	44.94

From an initial look at the inspection data two trends initially stand out. The first is that all 10 bridges pass over a waterway. This means that proximity to moisture or a waterway could have a significant influence on the EHI of this bridge. The second trend is that all the bridges are at least 60 years old.



**Figure 240 - Location of Selected Snow Bridges for EN16**

*Bridge 291-0018-0*

Bridge 291-0018-0, **Figure 241**, is a state-owned bridge located in Stephens County. The bridge was originally constructed in 1960 and consists of 3 reinforced concrete T-beams.



**Figure 241 – Bridge 291-0018-0 Side View (GDOT, 2021)**

This bridge has several defects that could be attributed to weather stressors. The first is concrete spalling on the deck. There are several reasons why a concrete spall can occur on a deck, so it cannot be directly attributed to weather stressors, however knowing that Union County is located in an area of Georgia that experiences high snowfall totals, it is likely that weather had an influence on the spalling. **Figure 242** and **Figure 243** show the progression of one of the concrete deck spalls from 2014-2019.





**Figure 242 – Deck Spall 2014 (Top) vs 2017 (Middle) vs 2019 (Bottom)**





**Figure 243 – Deck Spalling 2014 (Top) vs 2019 (Bottom)**

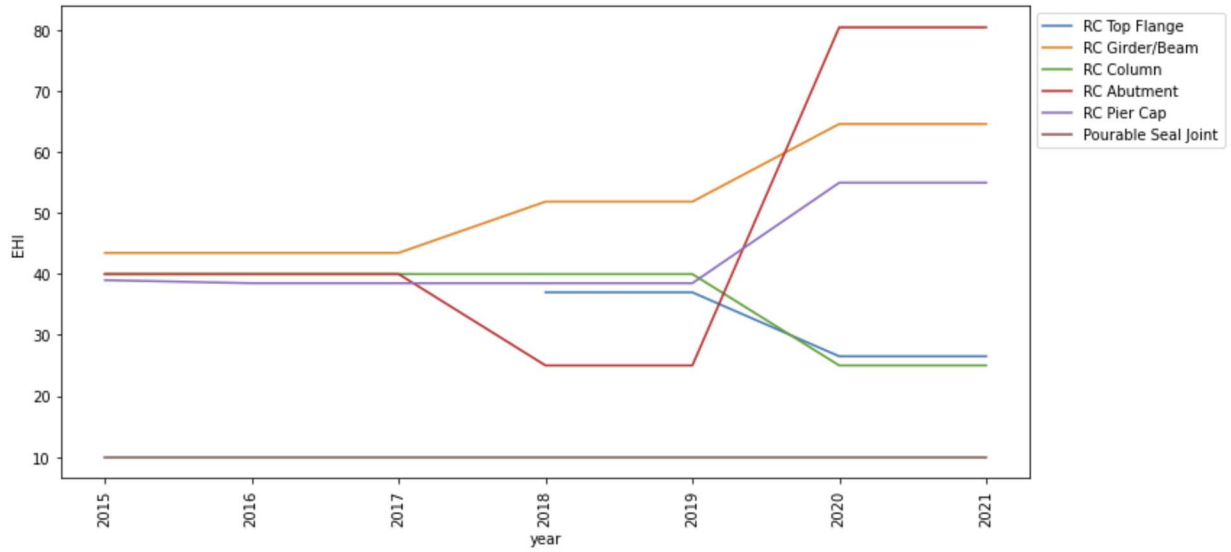
In addition to the deck spalling there is also cracking reported throughout the substructure and superstructure of this element, with the number of cracks and spalls increasing each inspection since 2014. Additionally, there was erosion reported in 2014, shown in **Figure 244**. However, these defects have not appeared to have grown based on inspectors notes to date.



**Figure 244 – Bridge 291-0018-0 Bridge Erosion (GDOT, 2014)**

*Bridge 241-5036-0*

Bridge 241-5036-0 is a county owned and maintained bridge located in Rabun County. This three-span concrete bridge was originally constructed in 1928 and passes over Timpson Creek. This bridge was originally selected because of the EHI rating of EN16, the reinforced concrete top flange. However, after reviewing the inspection reports there are deficiencies in other bridge elements that were impacted by the weather stressors in Rabun County. The bridge shows weather related impacts in deck, superstructure, and substructure elements. **Figure 245** shows the bridge element's EHI by year.



**Figure 245 – Bridge 241-5036-0 EHI by Year**

The superstructure of this bridge has experienced heavy cracking and spalling. The 2014 inspection report noted several cracks and spalls. At this time inspectors also noted the need to seal these cracks and spalls. As of 2022, these have not been fixed, and as a result the condition of these superstructure elements has worsened. **Figure 246 – Figure 248** show the progression of the degradation.







**Figure 246 – Bridge 241-5036-0 Span 3 Beam 3 Concrete Spall 2014 (Top) vs 2020 (Bottom)**





**Figure 247 – Bridge 241-5036-0 Span 3 Beam 1 Concrete Cracking 2014 (Top) vs 2022  
(Bottom)**





**Figure 248 – Bridge 241-5036-0 Span 1 Beam 1 Concrete Spalling 2014 (Top) vs 2020  
(Bottom)**

These photos provide a visual to how rapidly concrete bridge elements can deteriorate in areas that experience freeze-thaw cycles and are exposed to moisture.

In addition to the concrete superstructure elements that experienced deterioration, the reinforced concrete abutment has also experienced deterioration from weather stressors. The reinforced concrete abutment has experienced abrasion, cracking, erosion, and spalling. In the 2014 inspection report, inspectors noted areas of undermining and scour. In 2014 inspectors noted that this needed to be repaired. However, as of 2022 this maintenance request has yet to be

completed. There are also cracks that have turned into spalls on the reinforced concrete abutment, similar to the superstructure.

The deck has also experienced deterioration. Inspectors reported scaling and cracking, as well as deck joints that are completely washed out. **Table 35** shows unresolved maintenance items that have remained in the queue for years.

**Table 35 – Bridge 241-5036 Maintenance Items, 2022**

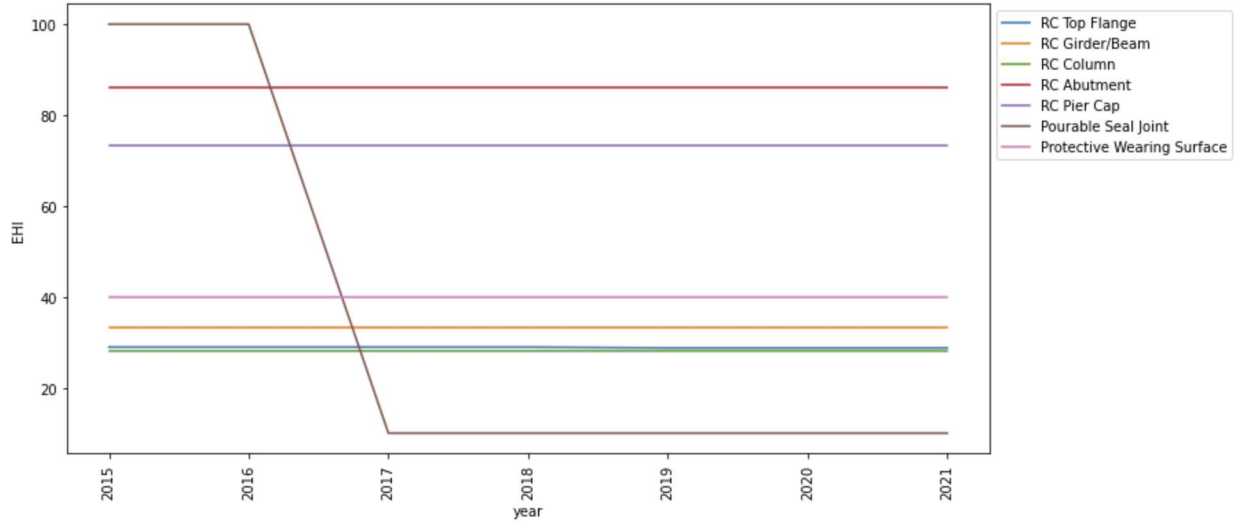
Activity	Priority	Location	Comments
520-Brush and Tree Cutting	B	Structure	Cut vegetation.
800-Bridge Joint Sealing	C	Deck joints	Clean and seal deck joints
830-Repair Main Structural Members	B	Superstructure and substructure	Repair concrete cracking, deterioration, and spalling in the superstructure and substructure.
845-Other Bridge Maintenance	B	Abutment 4	Repair and recover scour and undermining.
810-Deck Repair	B	Deck	Repair cracking, spalling, and deterioration of concrete, on the deck top, bottom, and overhangs.

*Bridge 241-0033-0*

This bridge is a county owned bridge that is in good condition. Despite being built in 1920 and in an area that deals with weather stressors the bridge is in good condition. The only maintenance items are to repair minor spall in the deck and to repair erosion and a log jam. There is minor cracking on the deck, with some efflorescence. However, it does not appear to be a severe issue.

*Bridge 187-0007-0*

Bridge 187-0007-0 is a state owned and maintained bridge located in Lumpkin County. This bridge was originally constructed in 1929 and passes over Boggs Creek. There has been severe reinforced concrete deterioration throughout the deck and superstructure components of this bridge.



**Figure 249 – Bridge 187-0007-0 EHI by Year**

Since 2014 there have been many maintenance requests overlooked to patch spalling and cracking on the concrete elements of the bridge. A replacement bridge is projected to have completed construction in 2023, which explains why the state strategically chose not to invest in maintenance on this bridge.





**Figure 250 – Bridge 187-0007-0 Concrete Spalling 2013 (Top) vs 2019 (Bottom)**

**Figure 250** provides another example of how fast a reinforced concrete element of a bridge can deteriorate when exposed to weather stressors like snow, humidity, and freeze-thaw cycles. It is clear that humidity was impacting the elements, from the efflorescence leaking from the cracks.

#### *Bridge 291-0002-0*

Bridge 291-0002-0 is a county owned and maintained bridge located in Union County. This four span concrete bridge passes over Youngcane Creek, and was constructed in 1973. Overall, the bridge is in good condition. When inspectors completed the evaluation in 2014, they noted some spalling and cracking on the deck that exposed steel reinforcement. They also made a note that it needed to be sealed. When the bridge was inspected in 2019, the same spalls were once again

reported, but they had grown in size. Inspectors also noted that the steel had heavy rust. These spalls, and the increase in spall size cannot be directly linked to weather stressors, but it is a possibility that the weather stressors and the lack of preventative maintenance caused the spalling to increase in size.



**Figure 251 – Bridge 291-0002-0 Bridge Deck Concrete Spall in Span 1 2014 (Top) vs 2019  
(Bottom)**

*Bridge 241-0018-0*

This is a state owned and maintained bridge located in Rabun County. It is a concrete bridge originally constructed in 1939, that passes over Big Creek. Inspector have noted that this bridge has experienced “moderate to heavy scaling and surface deterioration dur to age, salts, and freeze thaw cycles.” However, 20-30% of these deck areas have been repaired, mitigating some of the deck deterioration.





**Figure 252 – Bridge 241-0018-0 Deck Condition 2014 (Top) vs 2022 (Bottom)**

This bridge shows how snow, deicing salts, and freeze-thaw cycles can work to deteriorate a bridge deck in a vulnerable area.





**Figure 253 – Bridge 241-0018-0 Bridge Deck Condition 2014 (Top) vs 2022 (Bottom)**

Despite the visual of the deck appearing worse in 2014, the NBI deck score increased from a “5” to a “6” during these years.

#### *Bridge 257-0008-0*

Bridge 257-0008-0 is a state owned and maintained bridge located in Stephens County. It was originally constructed in 1960 and passes over North Fork Broad River. The bridge has several concrete deck spalling issues throughout, recorded in 2015 by inspectors. There were concrete spalls in span 2, span 3, and the deck overhang. Inspectors left a note to seal these spalls. **Figure 254** shows the progression of one of the spalls that was left unaddressed. As seen, it went from a spall with no rebar showing, to a spall with rebar.

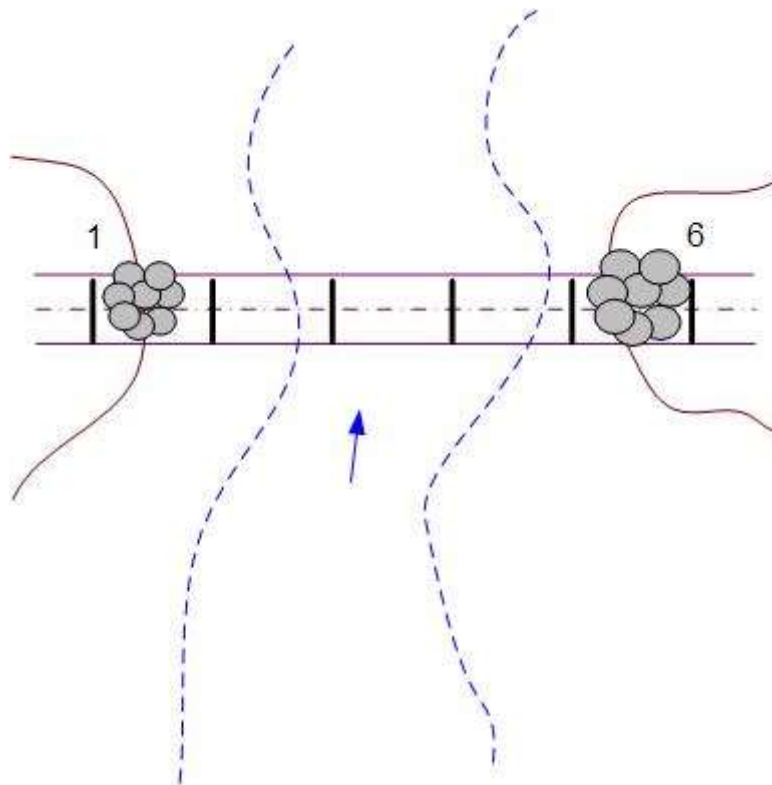


**Figure 254 – Bridge 257-0008-0 Bridge Spalling Under Span 3 2015 (Top) vs 2021 (Bottom)**

Freeze-thaw cycles and road salting cannot be confirmed as the reason why this bridge degraded rapidly, but it can be considered as a factor.

*Bridge 257-0012-0*

Bridge 127-0012-0 is a county owned and maintained bridge located in Stephens County. The concrete bridge is supported by steel piles, and was originally constructed in 1963. The bridge has experienced problems with scour, and so the substructure is rated only a “4,” and has undergone preventive maintenance. However, there are maintenance requests in the deck that have been overlooked. Inspectors have reported cracking and spalling in the deck since 2013, and recommended patching the spall and sealing the cracks to prevent further deterioration. Unfortunately, no measurements or photos were captured, making it impossible to track the changes of this bridge over time. However, the spalls are big enough to be considered “severe” and have exposed rebar. The cracking also looks to be at risk of turning into a spall without maintenance. **Figure 257** and **Figure 258** show the cracking and spalling inspectors have noted.



**Figure 255 – Bridge 257-0012-0 Plan View (GDOT, 2021)**



**Figure 256 – Bridge 257-0012-0 Side View (GDOT, 2021)**



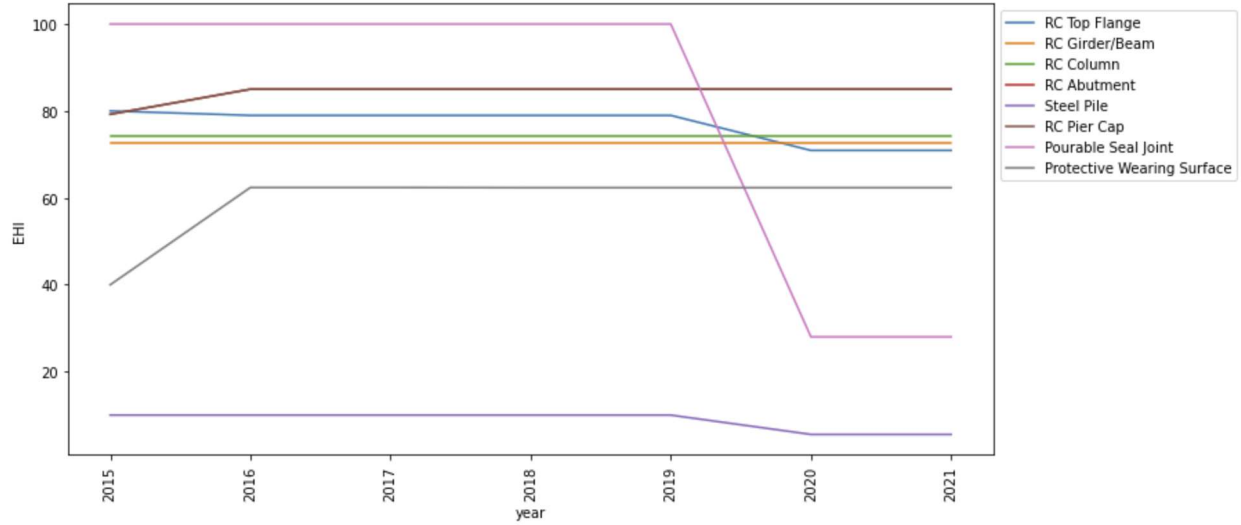
**Figure 257 – Bridge 257-0012-0 Concrete Spalling (GDOT, 2021)**



**Figure 258 – Bridge 257-0012-0 Concrete Spalling with Epoxy Painting (GDOT, 2021)**

*Bridge 241-0016-0*

Bridge 241-0016-0 was previously discussed in the DP10 section due to the advanced deterioration of the steel piles. However, there has also been deterioration of deck and superstructure elements of this bridge. **Figure 259** shows the changes in EHI of the various elements in this bridge.



**Figure 259 – Bridge 241-0016-0 EHI by Year**

As shown in the Figure, the reinforced concrete top flange had a EHI drop, attributable to spalls appearing. An example of one is shown in **Figure 262**. Inspectors noted degradation of the deck between 2016-2021, although the data does not show this. Inspectors noted an increase in crack size on the asphalt overlay from 1/8” to 3/8”. Typical deck cracking is shown in **Figure 260**. The reinforced concrete girder also had a drop in condition visually that was not reflected in the NBIE data as a previously recorded crack turned into a large spall, Shown in **Figure 262**.



**Figure 260 – Bridge 241-0016-0 Typical Deck Cracking (GDOT, 2022)**



**Figure 261 – Bridge 241-0016-0 Deck Cracking Underside (GDOT, 2020)**





**Figure 262 – Bridge 241-0016-0 Beam 9 Concrete Spalling 2016 (Top) vs 2020 (Bottom)**

*Bridge 157-5046-0*

Bridge 157-5046-0 is a county owned and maintained bridge located in Jackson County. This bridge was originally constructed in 1959, and passes over the North Oconee River. Currently the bridge is posted because of the degraded condition of the concrete superstructure. There are election cracks throughout. Additionally there are random cracks and spalls throughout the bottom of the deck, and the progression of one of the spalls can be seen in Figure XX.



**Figure 263 – Bridge 157-5046-0 Reinforced Concrete Top Flange Concrete Spall 2014 (Top) vs 2022 (Bottom)**

On the top of the deck, inspectors note shrinkage cracking, as well as loose and missing aggregate, with scaling. This deterioration is typical with scaling found in areas impacted by freezing temperatures, and snowfall, as well as deicing chemicals used.



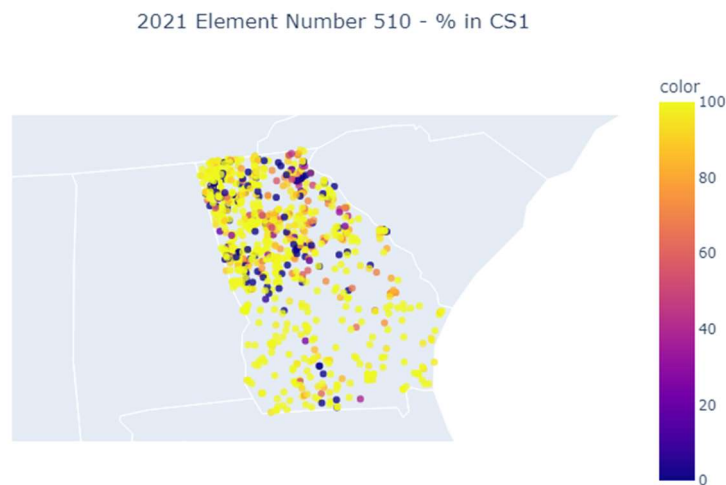
**Figure 264 – Bridge 157-5046-0 Reinforced Concrete Top Flange Concrete Spall with Loose Aggregates (GDOT, 2022)**

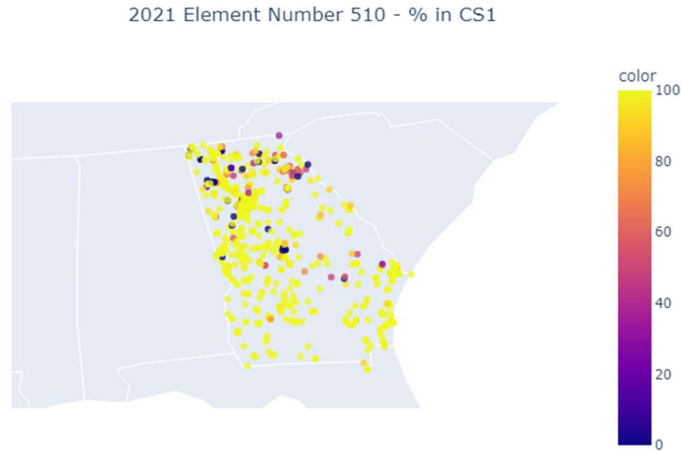
*Summary of Reinforced Concrete Top Flange*

When this element was chosen, the expectation was to see the damages caused by deicing salts on the surface of the deck. However, after reviewing inspection reports the damages were primarily on the bottom of the deck. The spalling and cracking were consistent with the cracking and spalling seen in the DT32 section. When the spalls that were measured grew, they grew an average of XX square feet every 4 years. Some of the protective wearing surfaces in this region showed damages that could be related to weather stressors.

*EN510 Protective Wearing Surface*

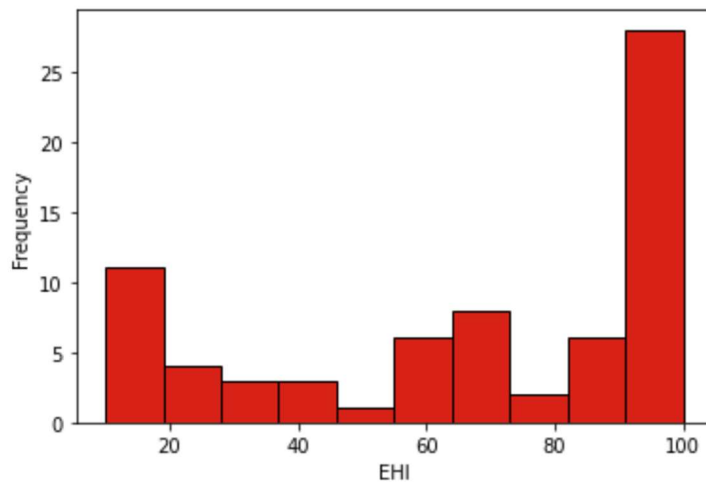
The protective wearing surface is a bridge element that is used to protect a bridge deck from further deterioration from weather elements or from traffic. Currently in Georgia there are 4,277 bridges that have protective wearing surfaces of some kind. There are many types of protective wearing surfaces that bridges managers and engineers can choose to install on a bridge including but not limited to; concrete, asphalt, epoxy coating, and polymer concrete. The NBIE data does not code the different overlays differently, so all types of overlays fall under EN510. Each of these elements also has an element parent number (EPN) associated with them. The EPN is the element that the overlay was installed to protect. For the scope of this study all overlay materials and EPNs were studied. This element was first identified to possibly be impacted through the condition state maps shown in **Figure 265**.

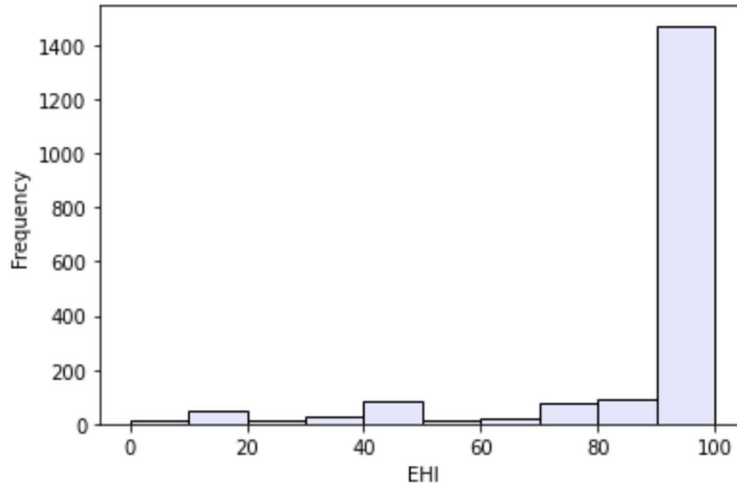




**Figure 265: Percent of EN510 in Condition State One by Location, 2021. County-Owned (Top) vs State-Owned (Bottom)**

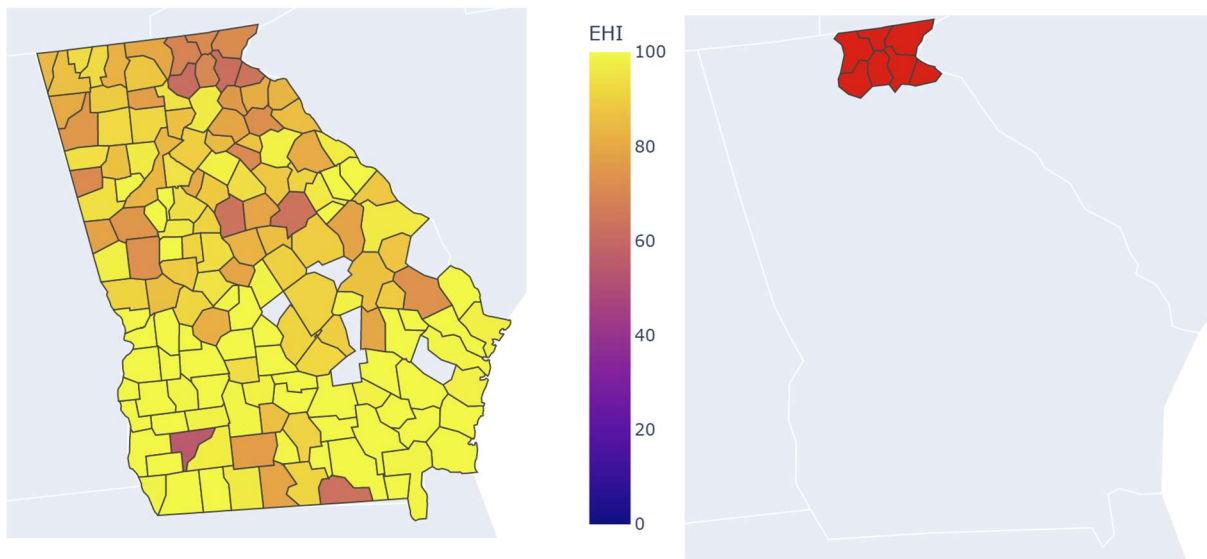
Once this element was identified, a further analysis into the condition of these elements in snow counties versus other Georgia counties was completed. The average EHI of this element in counties other than the snow counties was calculated to be 89.79 and the average EHI in snow counties was calculated to be 67.01. Next, distribution plots were generated showing that in snow counties there was a higher distribution of low EHIs than in non-snow counties. These can be seen in **Figure 266**.





**Figure 266 – EHI of EN510 Snow Counties (Top) vs Non Snow Counties (Bottom)**

Lastly, a county heat map for Georgia was generated showing the average EHI by county for this element. This revealed that some of the counties with poor EN510 conditions were also the counties identified as snow counties of interest.

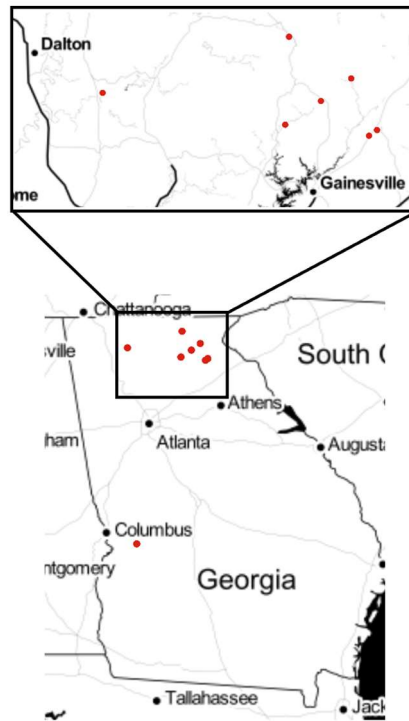


**Figure 267 – EHI of EN510 by County (Left) vs Snow Counties (Right)**

Once this element was confirmed for study, the lowest ten bridges by EHI were selected. This are found in **Table 36**, and their geographic location are shown in **Figure 268**.

**Table 36 - Lowest 10 Snow Bridges by EHI of EN510**

Bridge ID	County	Owner	Year Built	Service Under	Deck NBI Rating	EHI
137-0028-0	Habersham	State	1979	Highway	7	10
137-0029-0	Habersham	State	1979	Highway	6	10
137-5064-0	Habersham	County	2005	Waterway	7	10
187-0011-0	Lumpkin	State	1937	Waterway	6	10
311-5047-0	White	County	1996	Waterway	7	10
311-5012-0	White	County	1980	Waterway	7	19.375
213-0044-0	Murray	County	1921	Waterway	5	19.418
291-5048-0	Union	County	1995	Waterway	7	27.133



**Figure 268 - Location of Selected Snow Bridges for EN510**

*Bridge 311-5047-0*

Bridge 311-5047-0 is a county owned bridge located in White County. This single span timber bridge was constructed in 1996 and passes over Tesnatee Creek. This bridge presents an

interesting case study as the structure has been closed since 2002, however in 2015 White County requested that the bridge be added back to the inventory as it is still passable (it is only blocked with a dirt pile) although the road is rarely used. The bridge's asphalt wearing surface has remained in condition state three since the original inspection, with inspectors noting transverse cracking throughout. Unfortunately, due to the bridge being covered with leaves it is impossible to track the changes in cracking annually, but one could conclude that weather and the freezing temperatures experienced in White County caused the transverse cracking to form. Although there are many factors that influence cracking, it is likely that weather played a large role in the cracks forming on this bridge, especially knowing that it had no car traffic over these years.



**Figure 269 – Bridge 311-5047-0 Transverse Cracking (GDOT, 2020)**

*Bridge 311-5012-0*

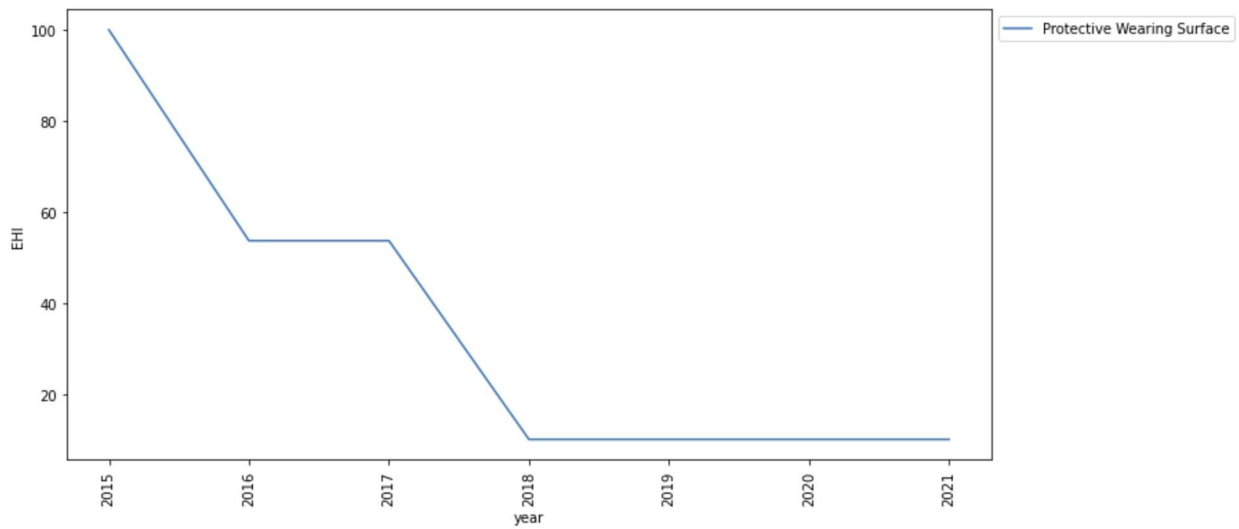
Bridge 311-5012-0 is a county owned and maintained bridge located in White County. This eight-span bridge was originally constructed in 1980 and passes over Sautee Creek. The bridge is in good condition overall, as inspectors have deemed the deck, substructure, and superstructure to have an NBI rating of “7.” In 2014 bridge inspectors noted asphalt cracking at the deck and panel joints as well as minor deck spalling. In 2014 inspectors recommend three maintenance items; sealing deck joints and joint spalling, sealing longitudinal panel joints, and sealing the deck spalling. However, as of 2022 these maintenance items had not been addressed, and as a result the condition of the deck had worsened. Although the condition state remained unchanged throughout the previous eight years of inspection, photos from the bridge can show the changes. Unfortunately, the photos captured in previous years inspection reports were not of great quality.



**Figure 270 – Bridge 311-5012-0 Deck Condition 2014 (Top) vs 2022 (Bottom)**

*Bridge 137-0029-0*

Bridge 137-0029-0 is a state owned and maintained bridge located in Habersham County. It was constructed in 1979 and passes over a roadway. This bridge was selected for study because of the condition of the protective wearing surface on the bridge. **Figure 271** shows the EHI of the protective wearing surface by year since the first element inspection report.



**Figure 271 – Bridge 137-0029-0 EN510 EHI by Year**





**Figure 272 – Bridge 137-0029-0 Protective Wearing Surface at Bent 2 Condition 2014 (Top)  
vs 2022 (Bottom)**

The rest of the deck has fallen into poor condition as well, but it cannot be attributed fully to the weather stressors impacting this region of Georgia. Other factors like ADT could have contributed to the protective wearing surface degradation. However, it is possible that the roadway was impacted by the presence of deicing salts and freeze thaw cycles.

*Bridge 213-0044-0*

Bridge 213-0044-0 was previously studied in the scour section. In addition to the scouring and lack of channel protection at the abutment, the deck also showed rapid weather-related

deterioration. Inspectors did not measure the size of the cracks, but the photos they captured show the progression of the deterioration.



**Figure 273 – Bridge 213-0044-0 Deck Condition 2014 (Top) vs 2016 (Middle) vs 2020 (Bottom)**

*Bridge 291-5044-0*

Bridge 291-5044-0 is a Union County owned and maintained bridge. It was originally constructed in 1980 as an overpass to the Nottely River. Despite the bridge being under 50 years old, it has fallen into poor condition, and one of the factors is the weather impacting the bridge.

The first problem in this bridge is in the superstructure. The steel girders have heavy corrosion and section loss at the webs. This bridge is located in a high humidity region, with close proximity to water. Preventative maintenance, such as painting could have prevented the bridge steel girders from experiencing section loss, and being load posted. Unfortunately, this bridge will likely have a shorter service life because of the lack of maintenance.



**Figure 274 – Bridge 291-5044-0 Steel Beam Corrosion (GDOT, 2021)**

In 2014, this bridge’s reinforced concrete deck was failing, likely to the combination of freeze-thaw cycles and deicing salts, shown in **Figure 275**.



**Figure 275- Bridge 291-5044-0 Deck Condition (GDOT, 2014)**

The county decided to use an asphalt overlay to protect the reinforced concrete deck, which inspectors first noted in 2017. However, by 2021 this wearing surface had already fallen into “poor” condition by EHI, with a score of 25. Unfortunately, there are not any photos from the inspection report to show the degradations. However, the condition falling this quickly shows how rapidly weather can cause deck condition to fall.

#### *Bridge 291-5048-0*

This bridge is a Union County owned and maintained bridge that passes over the Nottely River. It was built in 1995, and the bridge elements are in good health. The only element that has fallen behind in condition is wearing surface placed on the bridge to protect the timber deck. Inspectors reduced this element’s condition state due to cracking reported throughout. **Figure 276** shows

the cracking that was reported in 2019 as up to 3/16” in width. By the 2021 report inspectors noted that the size of these cracks had grown to ¼”. Unfortunately, inspectors did not capture these images.



**Figure 276 – Bridge 291-5048-0 Asphalt Cracking (GDOT, 2019)**

*Bridge 137-0028-0*

Bridge 137-0028-0 is a state owned and maintained bridge located in Habersham County. It was originally opened in 1979 and services US 23 over CR 542 J Warren Road. There is extensive asphalt overlay cracking and spalling throughout the bridge. As a result this bridge has had a drop in EHI to a 10. The EHI of this element has not impacted the deck rating, which remains a 7. Although the EHI has remained the same since 2016, visually the condition appears much worse. It is possible that snow or freeze-thaw cycles contributed to this deterioration.



**Figure 277 – Bridge 137-0028-0 Deck Condition 2016 (Top) vs 2018 (Middle) vs 2022  
(Bottom)**

It appears attempts were made to patch the surface, but total replacement could have been a better option. Despite the deterioration shown in **Figure 277** the condition state of this element remained the same.

*Bridge 137-5064-0*

Bridge 137-5064-0 is a county owned and maintained bridge located in Habersham County. The wearing surface was replaced in 2022 to fix cracking that was up to 1/8". This repair did not impact the NBI deck score as it remained a 7. However, by repairing these cracks the county will prevent the asphalt crack size from growing or spalling.



**Figure 278 – Bridge 137-5064-0 Deck Condition 2020 (Top)) vs 2022 (Bottom)**

*Bridge 187-0011-0*

Bridge 187-0011-0 is a state owned and maintained bridge located in Lumpkin County. The bridge was originally constructed in 1937, but was widened in 1985. The bridge was identified because of the low EHI of the protective asphalt surface over the reinforced concrete deck. Throughout the bridge there is spalling, transverse and longitudinal cracking in the asphalt overlay. There are patchwork repairs to patch the spalling of the asphalt around the joints. Inspectors also note that the original side of the concrete deck has heavy deterioration from age and salts, making it likely that snow and freezing temperatures played a role in the deterioration of this bridge deck.





**Figure 279 – Bridge 187-0011-0 Deck Condition 2016 (Top) vs 2022 (Bottom)**

In addition to the poor asphalt condition, this bridge also has spalling with exposed rebar on beams and pier caps, erosion and scour issues at pier caps and a drift build up.

*Bridge 187-0007-0*

Bridge 187-0007-0 is a state owned and maintained bridge located in Lumpkin County. This bridge was previously studied in the reinforced concrete top girder section. In addition to the deterioration discussed in that section, the asphalt wearing surface also experienced deterioration from snow and freeze-thaw. This asphalt wearing surface maintained an NBI score of 40.0 throughout the photos shown below.

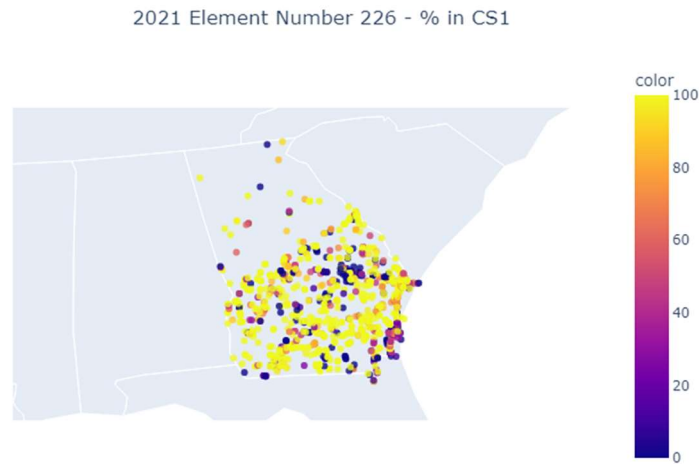
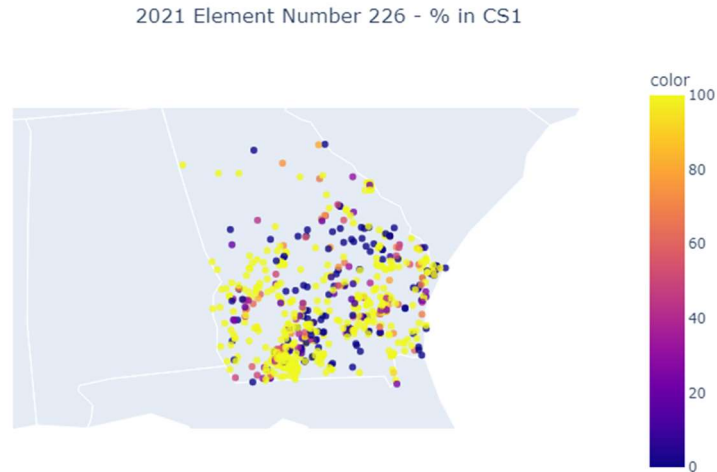


**Figure 280 – Bridge 187-0007-0 Deck Condition 2015 (Top) vs 2021 (Bottom)**

## **Coastal Counties**

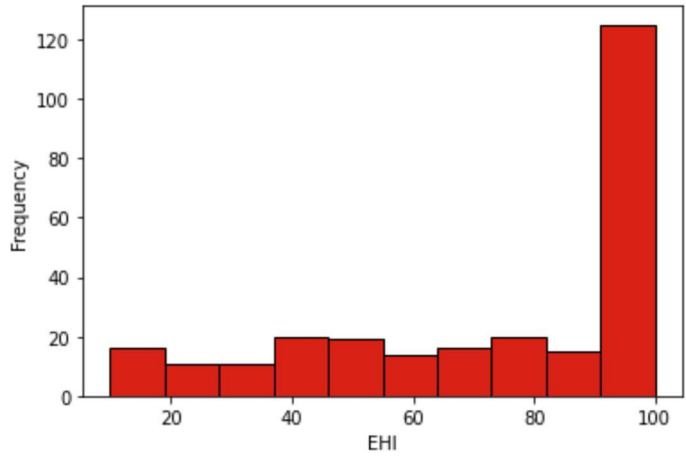
### ***EN226 Prestressed Concrete Pile***

Element number 226, the prestressed concrete pile was originally identified using the condition state geographic plots shown in **Figure 281**.

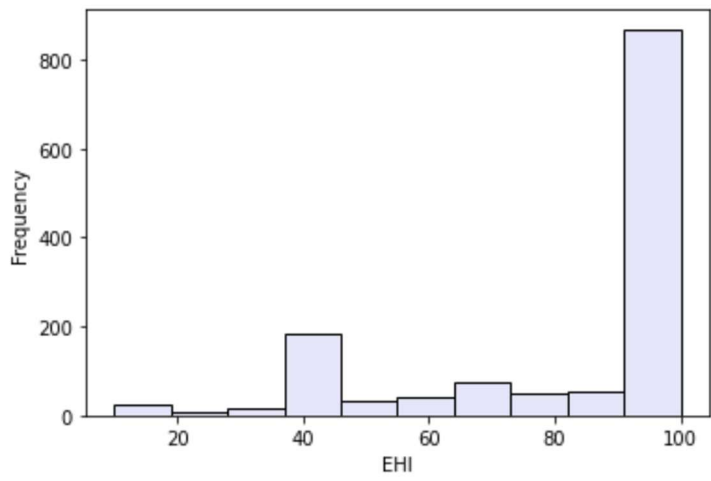


**Figure 281: Percent of EN226 in Condition State One by Location, 2021. County-Owned (Top) vs State-Owned (Bottom)**

These plots showed a lag in condition state in the coastal counties, which was confirmed through the data. The average EHI of EN226 in non-coastal counties was 83.11 compared to an average EHI of 73.98 in coastal counties. Additionally, the distribution plots in **Figure 282** show that in coastal counties there is a higher distribution of lower rated prestressed concrete piles in coastal counties.



**Figure 282 – EN226 EHI Distribution Across Coastal Counties**

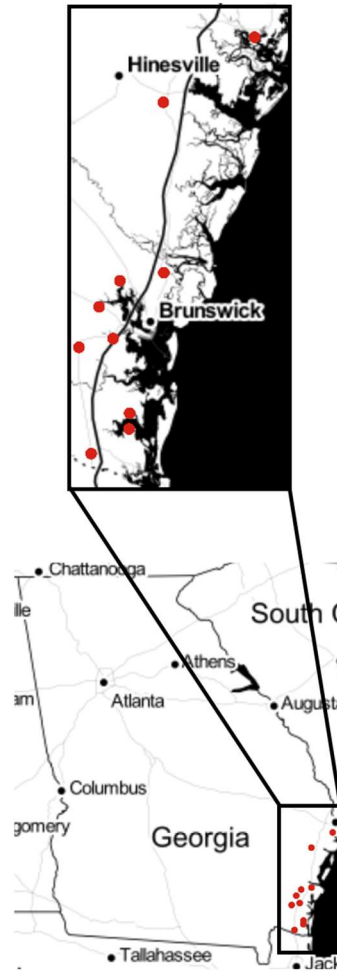


**Figure 283 – EN226 EHI Distribution Across Non Coastal Counties**

Next, the 10 lowest bridge by prestressed concrete pile element health index were selected and are summarized in **Table 37** and shown geographically in **Figure 284**

**Table 37 - Lowest 10 Coastal Bridges by EHI of EN226**

Bridge ID	County	Owner	Year Built	Service Under	Substructure NBI Rating	EHI
039-0001-0	Camden	State	1949	Waterway	5	10
039-0009-0	Camden	State	1955	Waterway	5	10
039-0049-0	Camden	County	1964	Waterway	5	10
039-0051-0	Camden	County	1978	Waterway	6	10
039-5029-0	Camden	County	1982	Waterway	5	10
051-0142-0	Chatnam	County	1975	Waterway	5	25
127-0010-0	Glynn	State	1955	Waterway	7	10
127-0029-0	Glynn	State	1960	Waterway	6	10
127-0034-0	Glynn	State	1964	Waterway	5	10
179-0006-0	Liberty	State	1955	Waterway	5	10



**Figure 284 - Location of Selected Coastal Bridges for EN226**

As expected, all ten of the bridges provided service over a waterway. Most of the bridges were also aged at over 50 years, meaning that the impacts of a coastal environment impacted the

*Bridge 039-0001-0*

Bridge 039-0001-0 is a state owned and maintained bridge located in Camden County. The five span bridge was originally constructed in 1949 and passes over a tidal zone. The bridge consists of 20 prestressed concrete piles, which inspectors have deemed to fall in condition state three since the first element inspection on this bridge. There has been crack maintenance and repair done to this bridge's prestressed concrete piles over the course of its life, which could be the reason why none of the cracks are severe or why there is no exposed rebar. **Figure 285** shows typical pile cracking on this bridge.



**Figure 285 – Bridge 039-0001-0 Prestressed Concrete Piles Typical Condition (GDOT, 2021)**

The only current maintenance request is to patch the cracking on the prestressed concrete piles. This is important to complete, especially in a salt environment where corrosion can occur quickly. However, there is no evidence in inspection reports that the cracking was caused by the proximity to a salt environment.

*Bridge 039-0009-0*

Bridge 039-0009-0 is a state owned and maintained bridge located in Camden County. It was originally constructed in 1955 and passes over a tidal zone.

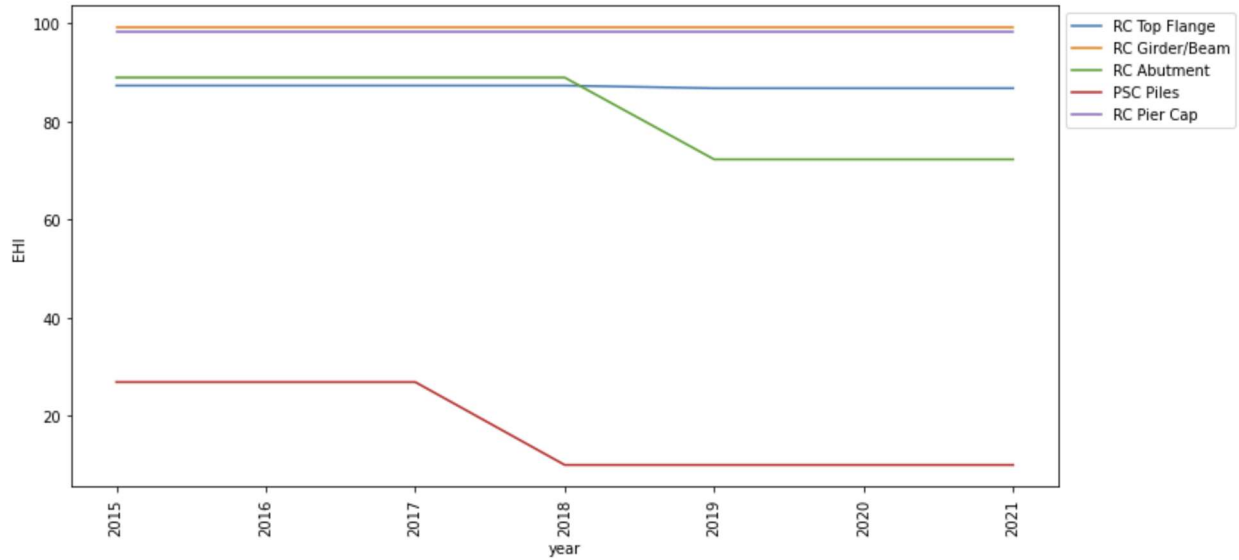
The prestressed concrete piles have remained in condition state three since the first element inspection in 2016, due to cracking. **Figure 286** shows the typical cracking this bridge has experienced.



**Figure 286 – Bridge 039-0009-0 Prestressed Concrete Pile Typical Cracking and Abrasion (GDOT, 2021)**

*Bridge 039-0049-0*

This is a Camden County owned and maintained bridge that was constructed in 1964. It consists of five spans and passes over Deep Creek. Overall the bridge is fairly healthy, the lowest NBI score was given to the substructure with a rating of “5. ” **Figure 287** shows the EHI’s of each bridge element by year.



**Figure 287 – Bridge 039-0049-0 EHI by Year**

The lowest scores were given to the substructure elements, the prestressed concrete piles and the reinforced concrete abutment.

The prestressed concrete piles reported cracking throughout the piles, which was the justification for the low element condition rating. However, the cracking in the prestressed concrete piles has yet to expose any rebar. shows the typical cracking on the prestressed concrete piles.



**Figure 288 – Bridge 039-0049-0 Prestressed Concrete Piles Typical Condition (GDOT, 2021)**

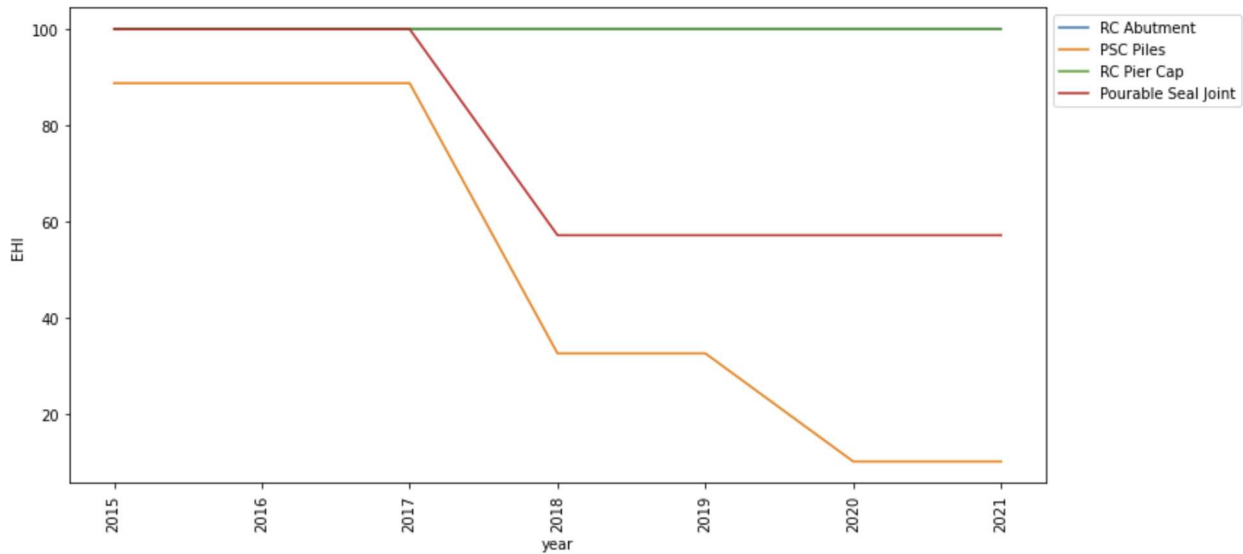
The superstructure of this bridge is a lesson into how fast the salt environment can attack a bridge. In 2017 and 2019 inspectors noted longitudinal cracking in span two of the concrete girder. By 2021, this had progressed to a spall with significant corrosion of the rebar.



**Figure 289 – Bridge 039-0049-0 Reinforced Concrete Girder Condition 2017 (Top) vs 2021 (Bottom)**

*Bridge 127-0029-0*

Bridge 127-0029-0 is a state-owned and maintained bridge located in Glynn county. This three span concrete bridge is located over a tidal zone and was originally constructed in 1960. It has maintained a good condition rating, in 2022 the NBI deck and superstructure rating were deemed a “7” and the substructure rating a “6.” However, the element rating of the prestressed concrete piles that support this bridge have fallen into poor condition. **Figure 290** shows the trend of the EHI of the prestressed concrete piles annually.



**Figure 290 – Bridge 127-0029-0 EHI by Year**

The condition of the prestressed piles has fallen, with drops in the 2020 inspection and the 2018 inspection. The reason for each drop was additional cracking that appeared in the prestressed concrete piles. During the first element inspection in 2016 inspectors noted that repairs were needed to seal the cracks on the prestressed piles. **Figure 291** shows the typical cracking that inspectors noted. Additionally, this image shows an exposed section of rebar that has been noted in inspections since 2016. After looking at the inspections, the cracking in the prestressed

concrete piles is likely not from exposure to a salt environment, if not repaired the cracking could lead to an increased deterioration of the rebar in the concrete.



**Figure 291 – Bridge 127-0029-0 Typical Pile Cracking (GDOT, 2022)**

*Bridge 051-0142-0*

Bridge 051-0142-0 is a Chatham County owned and operated bridge that passes over the Vernon Creek River Tributary. This prestressed concrete bridge consists of two spans and was constructed in 1975. The bridge has remained in good condition throughout its service life, with the exception of the prestressed concrete piles. Since the first NBIE inspection report in 2014, these piles have remained in condition state two and three, with the reasoning behind the reduced

grade noted as cracking. In 2014, the inspectors noted the need to repair the cracks they recorded. As of 2022 this maintenance item has not been completed, and although it is not reflected in the NBIE data, the condition of the prestressed concrete piles has worsened. **Figure 292** shows the progression of the cracking in pile four at bent two from 2014-2022.



**Figure 292 – Bridge 051-0142-0 Pile Cracking 2014 (Top) vs 2022 (Bottom)**

This increase in crack size is particularly concerning in this salt environment as the larger the crack size is the more corrosion will occur on the reinforcement in the prestressed concrete piles.

*Bridge 039-0051-0*

Bridge 039-0051-0 is a county owned and maintained bridge located in Camden County. This bridge was originally constructed in 1978, and despite its age is in good condition. The bridge passes over a tidal zone, and the deck and superstructure are supported by two reinforced concrete abutments and ten prestressed concrete piles. The substructure elements have degradation that is typical in tidal areas, cracking and undermining of the abutment. The cracking in the piles has been noted by inspectors as early as 2015, with maintenance suggested. However, to this date the cracking has not appeared to progress. There has yet to be any rebar exposed. Despite photos of the undermining being captured, inspectors do not note it in the inspection report. This is of note, as from the photo it appears to be a large area of undermining that has an exposed a pile, shown in **Figure 293**.



**Figure 293 – Bridge 039-0051-0 Abutment Undermining (GDOT, 2019)**

**Figure 294** shows typical pile cracking in this bridge structure. One thing of note is that during high tide the cracks are fully submerged, meaning that these piles are exposed to higher concentrations of salt water.



**Figure 294 – Bridge 039-0051-0 Typical Prestressed Concrete Pile Cracking (GDOT, 2021)**

*Bridge 039-5029-0*

Bridge 039-5029-0 is a county owned and maintained bridge originally constructed in 1982. Overall the bridge is in good condition, with a deck and a superstructure score of “7.” The substructure received a core of “5.” However, the only problems observed in this bridge were minor, and by completing maintenance Camden County could raise the overall condition of this bridge. The only problems noted in the substructure were cracking in the piles and erosion at the abutments. Unfortunately photos of these were only captured in 2019, and the inspectors did not record measurements so it is impossible to track the deterioration. However, by completing

recommended maintenance activities on the elements shown in **Figure 295-297**, the bridge substructure NBI score could be raised for this bridge.



**Figure 295- Bridge 039-5029-0 Abutment Undermining (GDOT, 2019)**



**Figure 296- Bridge 039-5029-0 Abutment Undermining (GDOT, 2019)**



**Figure 297- Bridge 039-5029-0 Pile Cracking (GDOT, 2019)**

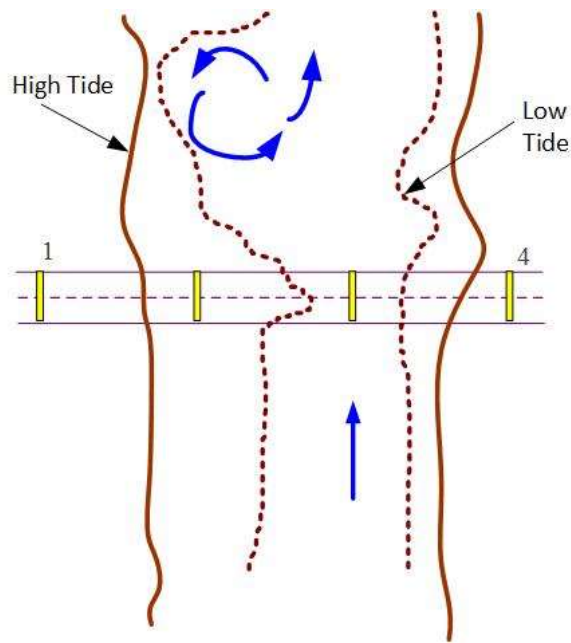
*Bridge 127-0010-0*

Bridge 127-0010-0 is a state owned and maintained bridge originally constructed in 1955. The bridge was identified because of the prestressed concrete piles having an EHI of 10. However, after reviewing inspection reports it was found that the reason inspectors placed each of the prestressed concrete pile into condition state three was heavy abrasion. Although this element had a low NBIE score, it did not seem to impact the overall substructure NBI score which remained a 7. Unfortunately, inspectors did not capture photos of the abrasion.

*Bridge 127-0034-0*

Bridge 127-0034-0 is a state owned and maintained bridge located in Glynn County. This bridge passes over College Creek and was originally constructed in 1964. This bridge is supported by eight prestressed concrete piles that were all deemed to be in condition state three by inspectors in 2022 due to cracking.

In 2014, 2018, and 2022 GDOT conducted a detailed inspection of the piles, measuring the location and size of the cracking. In each inspection report cracking was noted at pile one of bent 2 and piles 1-4 of bent three. The cracking in bent two pile one had no reported growth. However, in bent 3 there was reported increases in cracking between these three underwater inspections. In Bent 3 Pile 3, cracks grew from 1/8" to 3/16" and 1/16" to 1/8" between 2014-2018. Additionally Bent 3 Pile 2 had cracking that grew from 1/16" to 1/8". **Figure 299** shows the cracking.



**Figure 298- Bridge 127-0034-0 Plan View (GDOT, 2022)**



**Figure 299- Bridge 127-0034-0 Bent 3 Pile 2 Cracking 2014 (Top) vs 2022 (Bottom)**

*Bridge 179-0006-0*

Bridge 179-0006-0 is a state owned and maintained bridge located in Liberty County. The bridge was originally built in 1955 to pass over a tidal zone. All ten of the prestressed concrete piles were deemed to be in condition state three, corresponding to an EHI of 10.0. This is the same

score the prestressed piles had in the first element inspection. **Figure 300** shows the typical cracking that caused the piles to fall in condition state three. There has been an open maintenance request to seal these cracks since 2016.



**Figure 300 – Bridge 170-0006-0 Typical Cracking in PSC Piles (GDOT, 2022)**

## **CHAPTER 3. A RESOURCE GUIDE FOR COUNTIES**

Using the results and findings of this study, a guide was created to help local governments better understand how weather can impact their bridges, and to provide maintenance recommendations, based on GDOT publications, other DOT guides, and bridge maintenance and preservation studies. (Bowman & Moran, 2015) and (Weykamp et al., 2009) were used as resources to help better understand how state departments of transportation manage bridge preservation and maintenance.

### **SCOPE**

The scope of this guide details weather stressors that occur now or have occurred in previous years. Although there are many projections that weather stressors and extremes are expected to worsen in the coming years, that goes beyond the scope of this guide.

### **THREE MAIN ELEMENTS OF THE RESOURCE GUIDE**

The guide will contain three main components. An introduction and background, an overview of the five weather stressors commonly experienced in Georgia, and an overview of the elements that are most vulnerable to these weather stressors. The goal of this guide is to provide a highly visual easily digestible guide that asset managers will be able to use for several reasons.

- Understand the impacts of weather on bridges.
- Understand elements that are more vulnerable.
- View the impacts weather can have with neglected maintenance.
- Provide maintenance tips.
- Show costs associated with lack of maintenance.

### ***Introduction and Overview***

This section will provide a brief introduction and define the scope of the guide. It will provide definitions that will be used throughout the guide, It will also provide terms commonly used in bridge maintenance and provide a description of NBIE data and EHI.

### ***Overview of Weather Stressors***

This part of the guide will discuss the five weather stressors identified to impact Georgia. Heat maps were created in ArcGIS that show the distribution of the weather throughout the state to avoid singling out counties impacted. Additionally, the ways these weather stressors are known and were observed to impact bridges were provided.

### ***Overview of Vulnerable Elements***

This section works through each of the elements studied in the thesis. Each element consists of two pages. The first describes what the element is and the factors that impact its condition. A map showing the EHI of all the bridges in Georgia was created through ArcGIS to provide counties with a visualization of where these elements are in worst condition are located. The second part of this section is a bridge case study. One of the studied bridges that was representative was selected to feature in this part of the guide. Photos were provided to show how deterioration visually appears on the bridge element. Additionally, cost estimations were provided to show how oftentimes delaying maintenance can lead to higher costs. Lastly, short nontechnical maintenance tips were provided to help bridge asset managers better prioritize maintenance were provided for each element. These tips were broken down by

- Duration: When should maintenance occur?
- Focus: Areas to focus on when performing maintenance

- Associated Elements: Elements to maintain that will help the condition of the highlighted element.

A literature review of common bridge maintenance activities by DOTs was conducted to supplement the guide. The recommendations presented in this guide are presented in the following statements. These are recommended maintenance practices that can mitigate the impact of weather stressors:

- Identify bridges that are vulnerable to weather stressors and can experience faster deterioration. In particular, bridges crossing over waterways.
- Clean and reseal joints when over 50% fall in condition state two or below. (GDOT, 2013)
- Plan on painting structural steel once every 20-25 years (GDOT, 2013)
- Consider spot painting in areas that deteriorate the fastest. (MDOT, 2011)
- Replace joints on a 10–15-year cycle, depending on % of truck ADT (GDOT, 2013)
- Clean decks and joints after season if de-icing salts are used (GDOT, 2013)
- Clean deck drains once a year. (MDOT, 2011)
- Install a deck overlay if >50% of deck falls into condition state two or below (GDOT, 2013)
- If any bridge element is identified as showing scour or erosion, evaluate for a scour countermeasure. The most common countermeasures used are riprap placement (FHWA) and spur dikes (HEC-20). Riprap placement is the most commonly used scour countermeasures among state DOTs (Barkdoll et al., 2007)
- Seal and patch cracks and spalls on concrete elements to prevent further crack and spall propagation. (GDOT, 2013) (MDOT, 2011)

- Consult an engineer or GDOT to check feasibility of maintenance rehabilitation, or replacement (MRR) plans.

The following sections will highlight and describe the lessons learned from the bridge studies that were used to create the guide.

### *Reinforced Concrete Top Flange*

This element was identified to be impacted by snowfall using the NBI element data in the counties most impacted by snow. From the ten bridge inspection reports studied it was clear that snowfall and freezing temperatures impacted the bridge element's condition. This was clear through photographic evidence of deck abrasion and scaling and concrete spalling on the deck and underside. Additionally, all ten bridges passed over a waterway, showing that even though this bridge is a deck item, it is at increased risk of deterioration from weather, as proximity to moisture will increase the severity of freeze-thaw cycles. Seven of these ten bridges showed a drop in EHI since element inspections began and all ten bridges had maintenance requests that had gone unfulfilled for an average length of 9.54 years. Additionally, seven bridges had leaking joints. For these reasons recommendations were made using the GDOT 2013 Bridge Structures Maintenance Plan. The following recommendations were made.

- Counties should patch spalls and seal cracks when the deck when 20% of the deck area is in condition state two.
- The deck should be protected with an overlay when the deck reaches 50% into condition state two or worse.
- Seal joints in a timely manner to protect main structural elements and the underside of the top flange.

A bridge case study featuring a bridge that showed a bridge that dropped in EHI to show why prompt maintenance is important was presented. This bridge highlighted the need for timely maintenance for reinforced concrete top flanges, and showed the costs associated when these elements are not properly protected.

### *Reinforced Concrete Girder/Beam*

This element was hypothesized to be impacted by freezing temperatures using the NBI and NOAA data available. The findings of the study confirm this hypothesis after an evaluation of the primary concerns and maintenance requests. Six of ten girders studied had spalling, three with exposed rebar. Exposed rebar indicates severe degradation. Two out of ten had leaking joints, which leads to water infiltration and corrosion of the reinforcing steel. Six of the ten girders had open maintenance requests, and the average time the maintenance requests were open was 2.6 years. This delay can lead to further degradation. Spalls were commonly found at beam ends, likely from the increased stress found at the ends. This finding shows that special attention should be given to these areas during maintenance and inspection. From the study, a county owned bridge that showed visual deterioration was selected to present to counties to show the costs incurred from ignoring maintenance items. Additionally, the following maintenance tips were recommended.

- Seek to seal cracks and repair spalls within three years.
- Seal small cracks and repair visible cracks to prevent propagation, spalling, and delamination.
- Prioritize crack repair in bridges that pass over a waterway.

Maintaining and extending the life of this element will be essential for counties in the coming years, as most of the bridges with a reinforced concrete girder were built between 1950-1970 and are approaching having been in service for 50+ years.

### *Steel Girder*

This element was not studied to be impacted by weather stressors, however after reviewing over 100 bridges in Georgia it was clear that maintenance was essential for this element. A case study was selected that compared two bridges built within one year of each other. Both passed over a waterway and were in North Georgia counties. One superstructure had received regular cleaning and painting, while the other had not been cleaned or painted a single time. The bridge that had received no maintenance had to have a span replaced after 44 years and was load posted for just 8 tons. The bridge that had undergone maintenance and cleaning had an NBI superstructure rating of “6” after 68 years of service. This case study was presented to encourage counties to perform cyclical maintenance on steel structural elements. The following tips for maintenance were presented.

- Schedule bridge girder cleaning and painting every 20-25 years as recommended by GDOT.
- Spot paint vulnerable areas like beam ends and connections
- Seal deck joints to prevent free flow of water the steel girders

### *Reinforced Concrete Pier Cap*

The reinforced pier caps were hypothesized to be impacted by freezing temperatures, and a study of ten bridges with poor reinforced concrete pier cap conditions was conducted to evaluate the primary concerns and maintenance issues. The primary concerns were cracking and spalling, six

of the ten reinforced concrete pier caps had concrete spalling, five with exposed reinforcing steel. Additionally, nine of ten had leaking joints, which could lead to water and chemical; infiltration and corrosion of steel reinforcement.

All ten pier caps had open maintenance items, indicating that maintenance requests were made, but unaddressed. These maintenance requests had been open for an average of 4.7 years showing that encouraging reinforced pier cap maintenance was important.

The most common areas of deterioration were under bearing areas and at substructure connections. These are areas exposed to increased stress, therefore special attention should be given during maintenance. A bridge was selected for case study that showed how cracks can turn into spalls in a short amount of time, and how spalls can grow rapidly when maintenance is unaddressed. The following tips were given to counties to help them better maintain reinforced concrete pier caps.

- Attempt to seal cracks and repair spalls in three years or less
- Prioritize sealing cracks and spalls located under bearing areas and at substructure connection.
- Seal open joints to prevent debris, chemicals, and water to compromise concrete strength.

### *Steel Pile*

A study of ten bridges with poor steel pile condition was conducted to determine if weather impacted the condition of the piles. The study found that that all ten piles had corrosion and section loss. Two of the ten piles had 100% section loss, indicating severe degradation and compromised structural integrity of the bridge. Seven out of ten piles had leaking joints, which could lead to water infiltration, causing corrosion of the steel. Three out of ten piles had scour issues. The piles studied were last painted an average of 34.1 years ago, and nine had open

maintenance requests. The maintenance items had been opened an average of 6.55 years. This is an issue since six of the piles had section loss worsen since 2016. Delayed maintenance leads to further degradation, bridge closure, and increased repair costs. A bridge case study that highlighted a bridge closure was presented. Additionally, the following maintenance tips were provided for counties.

- Plan and schedule painting and cleaning once every 20-25 years. Spot paint as needed
- Once signs of deterioration appear, plan to paint within the year. The pile ends are where the most severe corrosion occurs.
- Pier caps often have cracking and spalling when corrosion is present on steel pile near connection.

#### *Prestressed Concrete Pile*

All ten prestressed concrete piles showed signs of impact from a marine environment in the form of cracking and biofouling. Cracks can lead to further salt penetration and rebar corrosion. To encourage counties to perform maintenance, a bridge that shows how cracking can worsen when left unaddressed was highlighted and the following maintenance tips were provided.

- Seek to repair cracks within 4 years' time.
- Seal small cracks to prevent the loss of concrete cover and confinement.
- Prioritize crack repair in bridge elements exposed to a salt environment.

#### *Reinforced Concrete Pier Wall*

Ten reinforced concrete pier walls in poor condition were studied to determine if rain impacted the condition. After study it was concluded that rain and freezing temperatures impacted the condition of these elements. The study found evidence of cold temperature impacts with five pier

walls having large spalls. Signs of rainfall impact were shown through two with scour damage and two with massive drift piles. A case study of a bridge that showed drift pile accumulation was selected to encourage counties to remove drift in a timely manner, as drift is proven to cause scour and erosion. The following maintenance tips were provided.

- Seek to remove large debris as soon as it is reported
- Larger substructure elements are more likely to accumulate drift
- Other substructure elements are at higher risk for erosion and scour damage when debris accumulation is left unaddressed

### *Reinforced Concrete Abutment*

The study conducted on ten reinforced concrete abutments determined that they are impacted by freezing temperatures and moisture. All ten were located adjacent to a waterway. Bridges that pass over a waterway are at increased risk for weather-related deterioration due to increased exposure to moisture and erosion. Eight of the ten bridges had problems with erosion and undermining, while five had spalling issues. This section highlighted maintenance activities to perform when spalling and cracking is present as the next section focuses on erosion control measures to perform. The following maintenance tips were recommended in the guide.

- Patch spalls and seal cracks when they appear.

### *Scour Critical Bridges*

Scour was important to feature in the resource guide as it was the weather impact that was observed the most throughout the study. Scour and erosion are the result of precipitation and an increased flowrate. There were several findings from the study that were highlighted in the resource guide. First, unlike other elements studied scour impacted old and new bridges.

Counties should be aware of bridges passing over water and be prepared to repair erosion. Five of the bridges showed a rapid increase in erosion area, showing that maintenance is important. Neglected maintenance can lead to higher costs and risk of structure instability. From the findings the following recommendations were made.

- Once scour appears it can worsen within two years, seek to repair as soon as it is discovered.
- Monitor bridges that pass over waterways for scour. Particularly bridges with fast moving flows, or after rain events.
- Superstructure and deck elements can be impacted if the structure settles.

## CHAPTER 4. CONCLUSIONS AND RECOMMENDATIONS

### CONCLUSIONS

This study identified five types of weather stressors in Georgia that bridge asset managers and decision makers should be aware of.

- Days Below 32° F
- Days Above 90° F
- Exposure to a Marine Environment
- Snowfall
- Day with above 0.10” of Precipitation

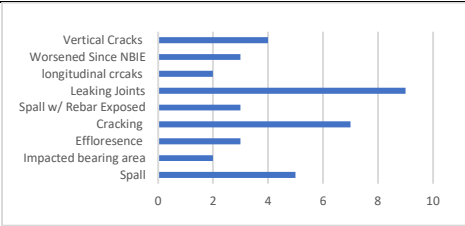
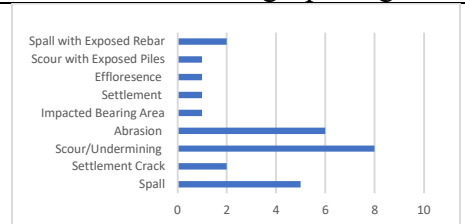
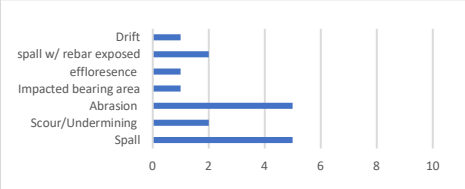
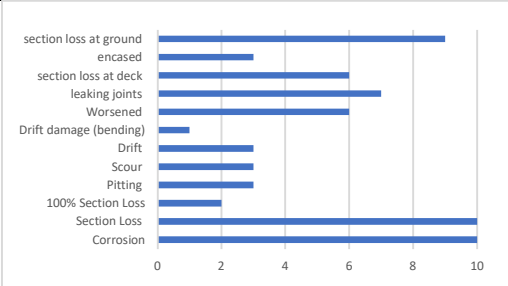
From these five weather stressors, 1-3 vulnerable bridge elements for each stressor were selected for further study. For each element selected, ten bridges with poor element condition in the most impacted counties of the state were reviewed using historical inspection notes, photos, and defect information in conjunction with NBI and NBIE data. Using this data, analysis on bridges was performed on the bridges to determine the following. Additionally, the six lowest bridge elements by EHI in Georgia were identified, and three bridges were identified for further study. As the analysis process was created, research questions that hoped to be created throughout the study were created.

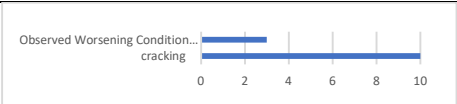
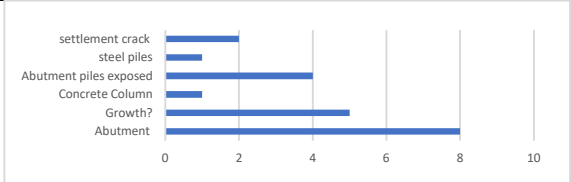
- Were weather stressors responsible for the poor element conditions?
- What bridge elements are more vulnerable to each weather stressor?
- How can local bridge asset manager better service MRR activities in light of weather impacts?
- How rapidly do bridge elements deteriorate from each bridge element.

**Table 38** provides a matrix that summarizes the defects and basic findings of the bridge case studies.

**Table 38: Results Matrix**

Weather Stressors					Vulnerable Elements	Defects in element on 10 bridge	Summary of Findings
Snowfall	DX90	DT32	DP10	Marine			
					Protective Wearing Surfaces (EN510)	<p>Cracking on protective surfaces Cracking/spalling dominate</p>	9 bridges showed impacts of snow and DT32
					RC Top Flange EN16	<p>Deck - Spalling/Joints/Efflorescence</p>	4 showed impact of DT32 2 showed impact of snow
					RC Girder EN110	<p>Superstructure – Spalling/cracking/some joints</p>	5 showed evidence of DT32 impact.

				<p>RC Pier Cap <i>EN234</i></p>	 <p>RC Connecting Component - Joints/Cracking/Spalling</p>	<p>2 bridges showed impact of DT32.</p> <p>Impacts of unsealed joints were observed on 8 bridges.</p>
				<p>RC Abutment <i>EN215</i></p>	 <p>RC Substructure – Scour/Abrasion by Rainfall/Spalling</p>	<p>In addition to the 10 bridges studied, 16 additional bridges were observed with deteriorated abutments.</p> <p>22/26 bridges were impacted by rainfall.</p>
				<p>RC Pier Wall <i>EN210</i></p>	 <p>RC Substructure - Abrasion by?/Spalling</p>	<p>2 bridges showed impact of DT32</p> <p>6 bridges showed impact of DP10</p>
				<p>Steel Pile <i>EN225</i></p>	 <p>Steel Substructure - Section Loss and Corrosion</p>	<p>9 bridges showed impact of a DP10 environment</p>

					<p><b>Prestressed Concrete Piles EN226</b></p>  <p><b>Prestressed Substructure - Cracking</b></p>	<p>All 10 bridges showed impact of marine environment</p>
					 <p><b>Abutment/Scour/Erosion</b></p>	<p>All 10 bridges showed signs of weather impact.</p> <p>Half of the bridges showed rapid scouring/erosion</p>

Each element studied had different findings that are concluded in each section. However, the overall findings of the study are as follows.

- Weather stressors appeared to have an impact on bridge element condition in Georgia. Precipitation and freezing temperatures appeared to be the most impactful weather stressors based on cracking, spalling, corrosion, and erosion and scour events
- Concrete and substructure elements were the most vulnerable to deterioration from weather impacts. Specifically, the reinforced concrete abutment showed the most impact from weather rainfall and freezing temperatures, in the form of scour, spalling, and cracking.
- Bridges that pass over waterways are more likely to be impacted by rainfall and freezing temperatures due to proximity to moisture and increased flow during precipitation events.
- PSC substructure elements are more susceptible to cracking when exposed to marine environments, relative to PSC elements in other environments, and PSC deck and superstructure elements in similar environments.
- RC pier caps are at increased risk for weather related deterioration particularly when joints are leaking. 9/10 bridges studied in RC pier cap section had leaking joints.
- Precipitation impact in the form of scour, undermining, and erosion was the fastest to appear. It was found to impact bridges aged under 15 years. Other weather stressors were found to impact bridge elements with ages > 30 years. Scour areas also showed rapid growth in several cases.
- Snowfall, freezing temperatures, marine environment and precipitation had the biggest impact on bridges with a service life of over 30 years. However, the USA has many

bridges that are approaching or over 50 years in service. Maintaining and extending the lives of these bridges is critical, particularly for smaller governments with limited resources.

- As anticipated, steel piles were observed deteriorating rapidly when exposed to moisture. At least two bridges with steel piles showed 100% section loss on piles after maintenance was left unaddressed for six years. If cyclical maintenance items were addressed, this weather stressor likely would have had less of an impact.

Additionally, inspection photos documented in the past 10 years were reviewed to visually represent deteriorations.

In addition to learning about how weather stressors impact bridges in Georgia, conclusions about NBI and NBIE data were drawn using EHI. The following were the main findings.

- NBIE is a valuable tool, it provides a better overall picture of bridge health than NBI data. However, NBIE has only been collected since 2015 (reported in 2016), and so there are limitations to the dataset. Currently in Georgia, there is a small sample of bridge elements in condition state four.
- Condition states (CSs) and EHI, which is a weighted-average score of CSs, are not comparable across elements. An element with a score of 10.0 can be in much worse condition than another element that has a score of 10.0. Understand the defects commonly associated with an element and consult inspection reports and photos when using NBIE data. Understand what the element data shows. This understanding will provide a deeper understanding of the results of any study involving NBIE data.
- Use inspection reports, which include reasons for reduced condition ratings in conjunction with NBIE data. Inspection reports provide the inspector's reasoning for the

reduced condition state and provide photos. This added element of detail provides a clearer picture of bridge deterioration mechanisms and the extent of bridge and element damages.

- 14 bridge elements were studied that had inconsistencies between inspection report/photo data and NBIE data. These include defects in condition ratings with no maintenance performed, worsening visual/measured condition with no change in NBIE data, and elements with defects that were classified in condition state one.

## **RECOMMENDATIONS**

After completing the study, a visually focused guide was created for local asset managers to show how weather impacts the condition of certain bridge elements. Using existing DOT resources and the findings from the study, a visual guide presenting weather stressors, bridge maintenance terminology, examples of weather impact on bridges, cost estimations, and maintenance tips was created.

Considering new technology and future research trends, this study also recommends computer vision-based deep learning algorithms or text recognition of inspection reports to understand trends will enable capturing trends in bridge element health and more. This study concluded that inspection reports contain valuable information that can be consistently harvested using computer science methods.

Additionally, this study shows that photos can provide information about bridge condition that gives a deeper knowledge than data alone. With this knowledge, inspectors should prioritize tracking element condition visually and synthesize the overall condition using 3D photogrammetry. This can be done through photos, or in the future using drones to resolve

inconsistencies found in the reports. With visual data, AI research could be conducted using visual data, to gain a better understanding of bridge conditions, and to be able to rate bridges without human bias or error.

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**APPEDIX A. A WEATHER STRESSOR RESOURCE GUIDE FOR COUNTY-OWNED BRIDGES**

# IMPACT OF WEATHER STRESSORS ON BRIDGE ASSETS



A Guide for Local Georgia Governments  
-prepared by the University of Georgia

May 2023

# CONTENT

01 INTRODUCTION

02 WEATHER STRESSORS

03 VULNERABLE BRIDGE  
ELEMENTS

04 CONCLUSION

# INTRODUCTION 1.0



## PURPOSE OF GUIDE



This document aims to inform local Georgia governments of the potential impacts of weather stressors on their bridge assets by highlighting the following:

1. The most common weather stressors in Georgia and the potential impacts they have on bridge assets.
2. Bridge elements that are most affected by weather.

Additionally, this guide seeks to show the safety and financial impacts that local governments can experience when bridge maintenance requests go unfulfilled.

This guide intends to help counties prioritize maintenance and rehabilitation actions to better manage bridge assets.

# INTRODUCTION

## 1.1

### Commonly used Terms in Bridge Asset Management

Concrete Cracking – Concrete cracking is the formation of cracks on the surface or inside the concrete. Cracking can occur from various factors, including improper construction methods, overstress, overloading, thermal expansion, and concrete shrinkage.



Concrete Spalling – Concrete Spalling is the flaking/chipping of the surface of a concrete surface. This leads to loss of material, and the potential for reinforcing steel to be exposed

Corrosion – the process of decaying in metal bridge elements that leads to issues with the integrity of the bridge



Freeze-Thaw Cycle – A freeze-thaw cycle is water's repeated freezing and thawing. When water freezes, it expands which can lead to cracking, spalling, and degradation of concrete bridge elements and can lead to the settlement of bridge abutments.

# INTRODUCTION

## 1.1

### Commonly used Terms in Bridge Asset Management

Efflorescence - Efflorescence is a white powdery deposit that appears on the surface of concrete, caused by the migration of salts to the surface. It is most often an indicator that moisture has infiltrated the structure and can be an indication of damage to the structure. It impacts aesthetics and should be cleaned as it can worsen over time.



Scour - the erosion of soil around the foundation of a bridge caused by water.

Undermining - the erosion of soil under the foundation of the bridge caused by water.



Section Loss - the loss of a cross-sectional area due to corrosion (or concrete spalling). This leads to a loss of strength for the impacted member, and oftentimes to the structure as a whole.

# INTRODUCTION

# 1.2

## National Bridge Inventory Element Data

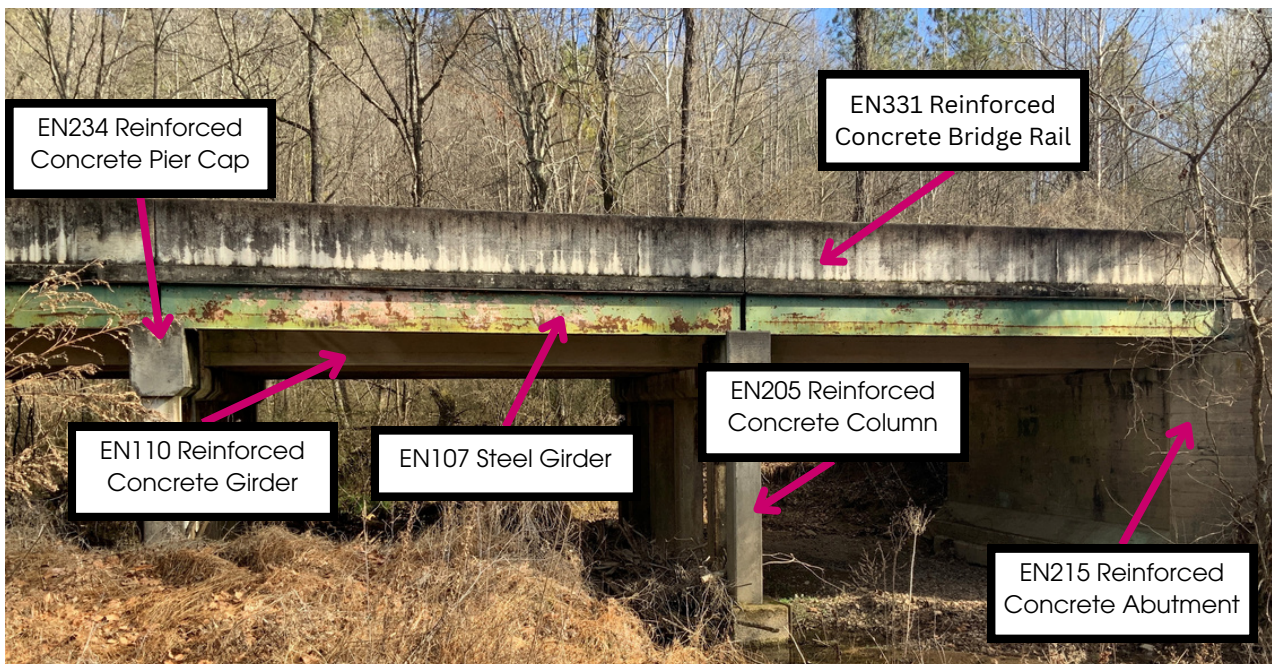
In 2015 GDOT inspectors began gathering condition-based data about each individual component of a bridge by material. This new data allows for better health monitoring and maintenance. The data can be accessed from FHWA or a bridge's inspection report.

Each inspection report will list each element of the bridge and its condition state. If the bridge drops in condition, the associated defect will be listed.

Each element is classified into the four condition states shown below:

CS 1	CS 2	CS 3	CS 4
GOOD	FAIR	POOR	SEVERE

An example of a bridge broken down element by element is shown below:



*Bridge by Element*

# INTRODUCTION

# 1.3

Georgia is a diverse state regarding weather, with different regions experiencing different weather stressors annually. Understanding the challenges that your county experiences are essential. In general, the Northern highlands of Georgia experience colder, rainier days, with more snowfall, while southern areas of the state experience hot days. Georgia is uniquely exposed to the coastal line.

## WHAT IS A BRIDGE ELEMENT HEALTH INDEX (EHI)?



GDOT inspectors have started classifying each bridge component, based on material and function, in 4 condition states, based on the element's condition.

Element Health Index (EHI) is a score calculated on a 100-scale to represent the condition states of the bridge elements.

- EHI 0-40: Poor Condition
- EHI 41-70: Fair Condition
- EHI 71-100: Good Condition

## WHAT IS A WEATHER STRESSOR?



The National Oceanic and Atmospheric Administration (NOAA) defines weather as the conditions over a short period of time: one hour, a month, or even a year. Weather is different from climate as it refers to the “average” weather over a long period of time, around 30 years.

This guide defines a weather stressor as an amount of weather that can be harmful to a transportation system. This is consistent with the Federal Highway Administration (FHWA) definition of a stressor as the threshold where a variable may become harmful to a transportation asset.

# WEATHER STRESSORS

# 2.0

Georgia is a diverse state by weather. Different regions of the state experience different weather impacts. Weather impacts bridges every day, and asset managers should be aware of the impacts weather can cause and methods to mitigate the impact.



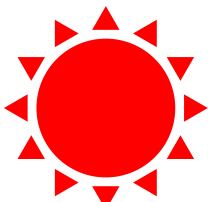
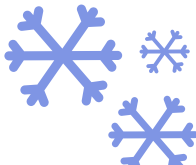

## WEATHER STRESSORS IN GEORGIA



Weather stressors include:

1. Days over 0.10" of precipitation. The weather variable is days of precipitation, and the associated threshold of harm is 0.10".
2. Days under 32 F. The weather variable of days is cold days, and the threshold of harm is below 32 degrees Fahrenheit.
3. Days over 90 F. The weather variable is hot days, and the threshold of harm is over 90 degrees Fahrenheit.
4. Snowfall. The weather variable is precipitation, and the threshold of harm is precipitation in the form of snowfall.
5. Marine environment. The weather variable is exposure to moisture, and the threshold of harm is a marine environment.

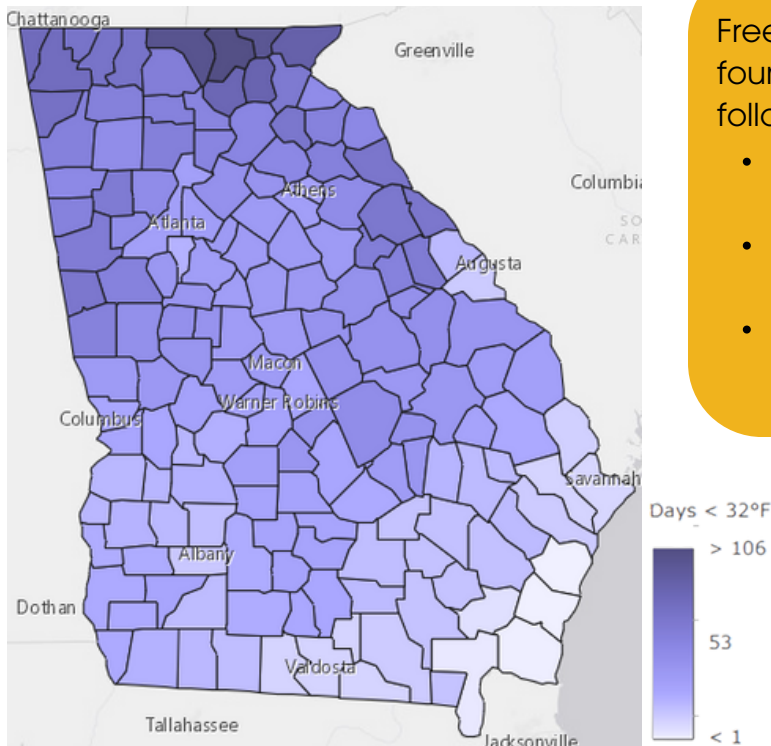
The table below will give indicators to the bridge elements vulnerable to the corresponding weather stressor.

Days over 0.10" Precipitation	Days under 32F	Days Over 90 F	Snowfall	Marine environment
				

# WEATHER STRESSORS

## 2.1

Days < 32° F



Freezing temperatures are found to impact the following bridge elements:

- Reinforced Concrete Superstructure Elements
- Reinforced Concrete Abutments
- Concrete Deck Elements



Freezing temperatures generally impact bridges through the following mechanisms:

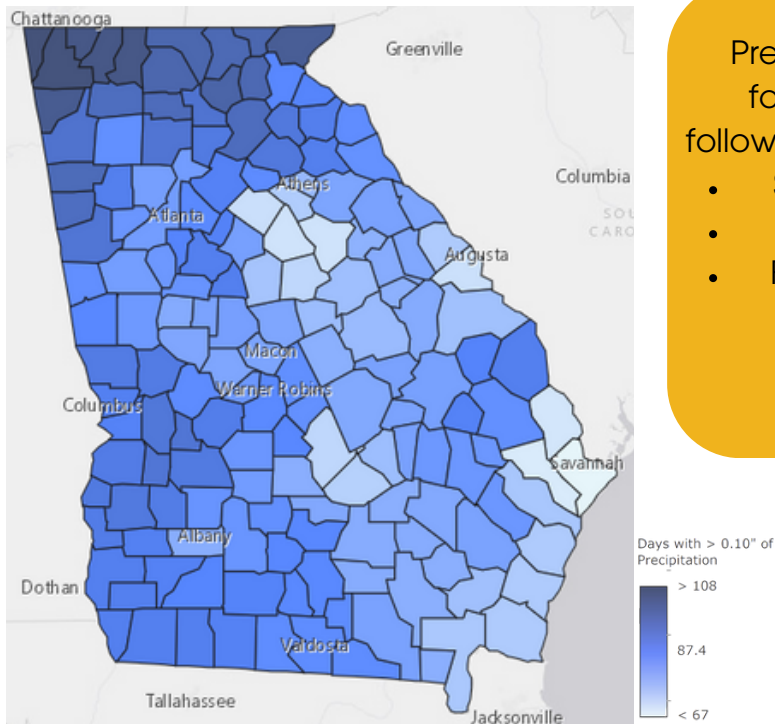
- Deterioration through expansion and thawing in concrete due to freeze-thaw cycles. Oftentimes, exposure to freeze-thaw cycles will exacerbate already existing problems. For example, a concrete spall grows larger each year as it is exposed to freeze-thaw cycles.
- Settlement of substructure elements as the soil beneath freezes and thaws due to exposure to freeze-thaw cycles.
- Faster deterioration of concrete and steel elements as a result of de-icing methods employed.

Freezing temperatures have proven to have a significant impact on several bridge elements, including those listed above. In particular those near moisture or passing over water.

# WEATHER STRESSORS

## 2.2

### Days > 0.10" Precipitation



Precipitation has been found to impact the following bridge elements.

- Steel Bridge Girders
- Steel Piles
- Foundation Elements (Scour Risk)



The impacts of precipitation are:

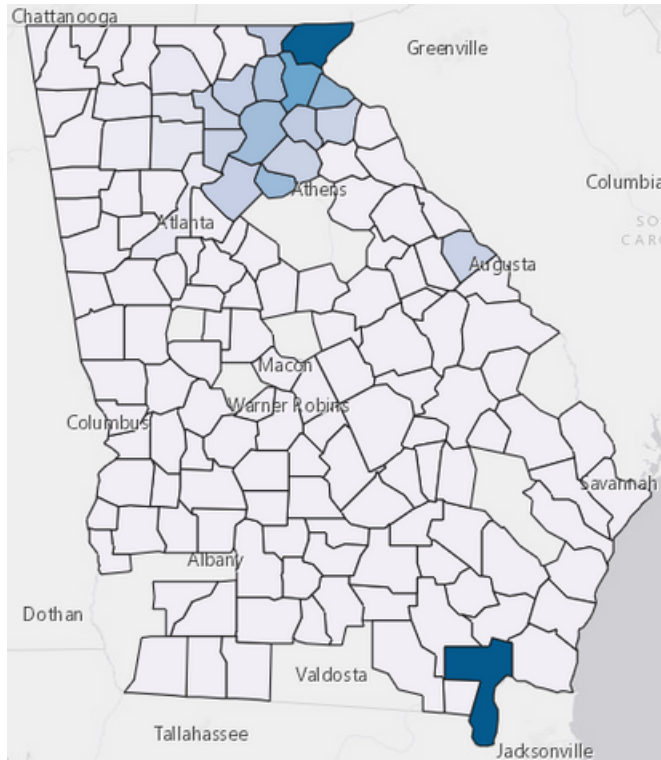
- Corrosion: Moisture can cause corrosion of steel members and reinforcing steel in concrete
- Freeze-Thaw Cycles: In cold areas precipitation can freeze causing damage to bridge elements.
- Scour/Undermining: Rainfall can cause flooding which can lead to scour and undermining of bridge foundations.

Bridge asset managers should be aware of the damage that rain events can do. Water is an extremely powerful force of nature that must be taken into consideration when making decisions about bridges. Precipitation has the power to deteriorate a structure over years, or potentially cause damage in a single large rain event. Many parts of the state receive large precipitation totals or accumulations.

# WEATHER STRESSORS

## 2.3

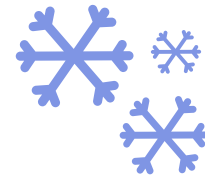
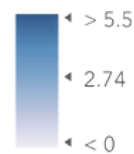
### Snowfall



Several bridge elements have been identified as being particularly vulnerable to snowfall.

- Concrete Deck Components
- Concrete Superstructure Components

Annual Snowfall (inches)



Snowfall impacts bridges two-fold.

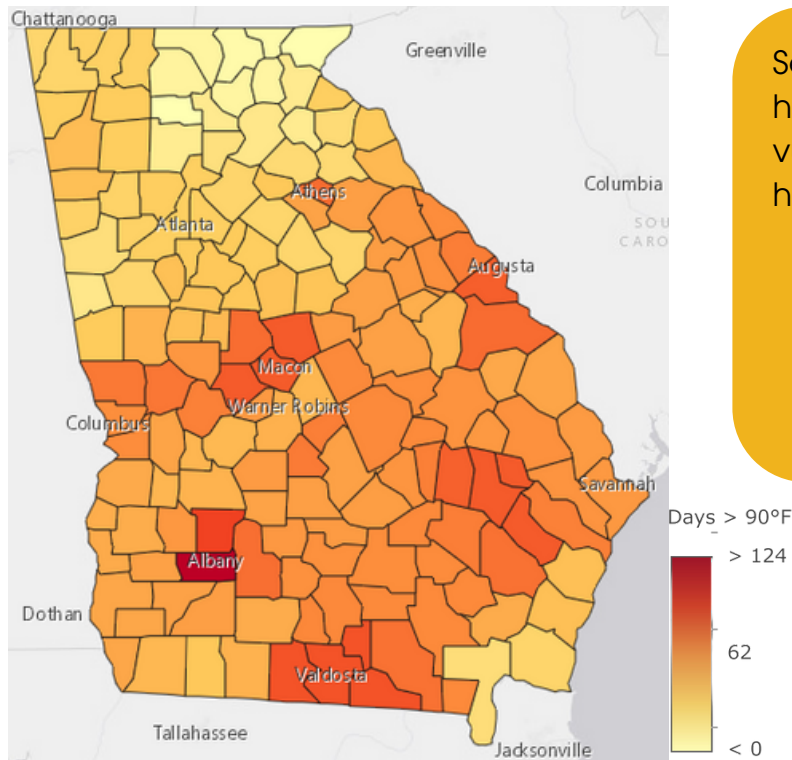
- Melting and freezing can cause the expansion of bridge elements, oftentimes resulting in cracking and fatigue.
- Deicing salts can cause or accelerate cracking, fatigue, and corrosion in concrete and steel bridge elements.

Bridge asset managers should seek to mitigate the impacts of snow with proper cyclical maintenance activities. These include but are not limited to, deck cleaning, crack repair, installing protective overlays, and joint sealing. In addition to the impact snow can have on the safety of motorists, snow can also significantly impact bridge elements. Relative to the rest of the country, Georgia does not experience high quantities of snowfall. However, historically several parts of the state experience snowfall annually. Often, the snowfall is highly localized, and the map above shows an example.

# WEATHER STRESSORS

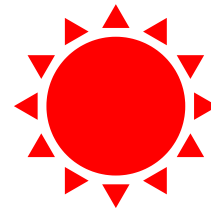
## 2.4

Days > 90° F



Several bridge elements have been identified as vulnerable to days of heat.

- Joints
- Overlays (and associated materials)
- Bearings



Heat can have an impact on bridge assets in several ways:

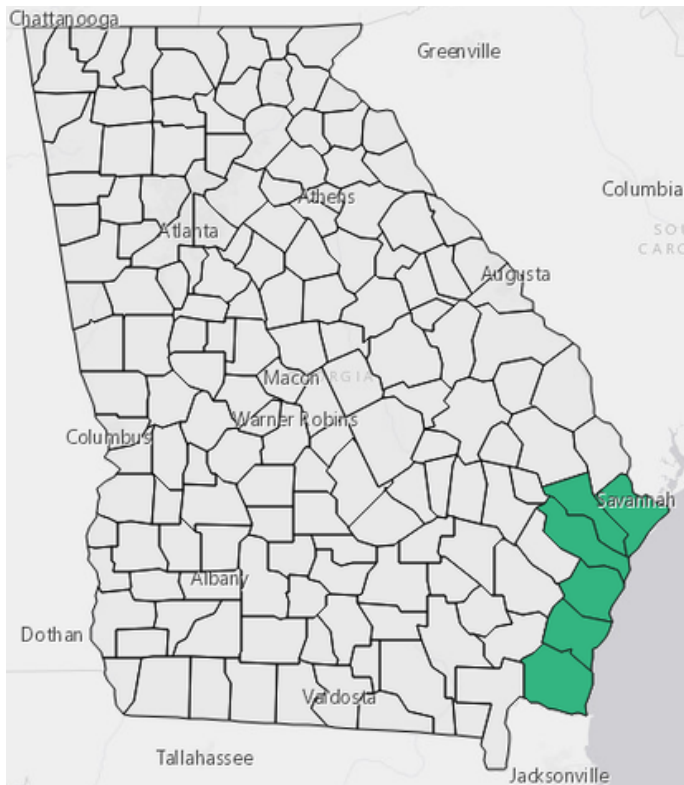
- Heat can cause the expansion of materials, which leads to increased stress and potential structural damage as well as joint failures.
- Heat can cause protective paint on steel bridge components to peel over time.
- Constant exposure to heat can cause fatigue of materials.

Bridge asset managers should evaluate vulnerable elements from heat, although oftentimes not as evident as freezing temperatures. Historically, Georgia has experienced very hot weather. Climatologists project that the number of hot days will increase in the future.

# WEATHER STRESSORS

## 2.5

### Exposure to a Marine Environment



The following elements are relatively more vulnerable to the marine environment.

- Prestressed Concrete Piles
- Connections such as dowel bars used in older bridges.



Exposure to a marine environment impact bridges in the following way:

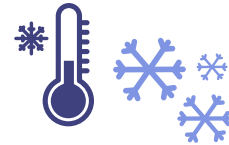
- Corrosion: Salt can cause rapid corrosion of metal components
- Concrete Deterioration: When salt penetrates concrete it can cause cracking and corrosion of the reinforcing steel.
- Scour: Currents can cause scouring of bridge substructure components
- Biofouling: Barnacles and other marine organisms can attach to a bridge substructure and cause aesthetic issues.

Proximity to a marine environment is known to have a negative impact on infrastructure as listed above, and bridge assets are not exempt. Cyclical bridge maintenance activities like cleaning and crack sealing can help bridge condition in these areas.

# VULNERABLE ELEMENTS

## 3.1

### Reinforced Concrete Top Flange

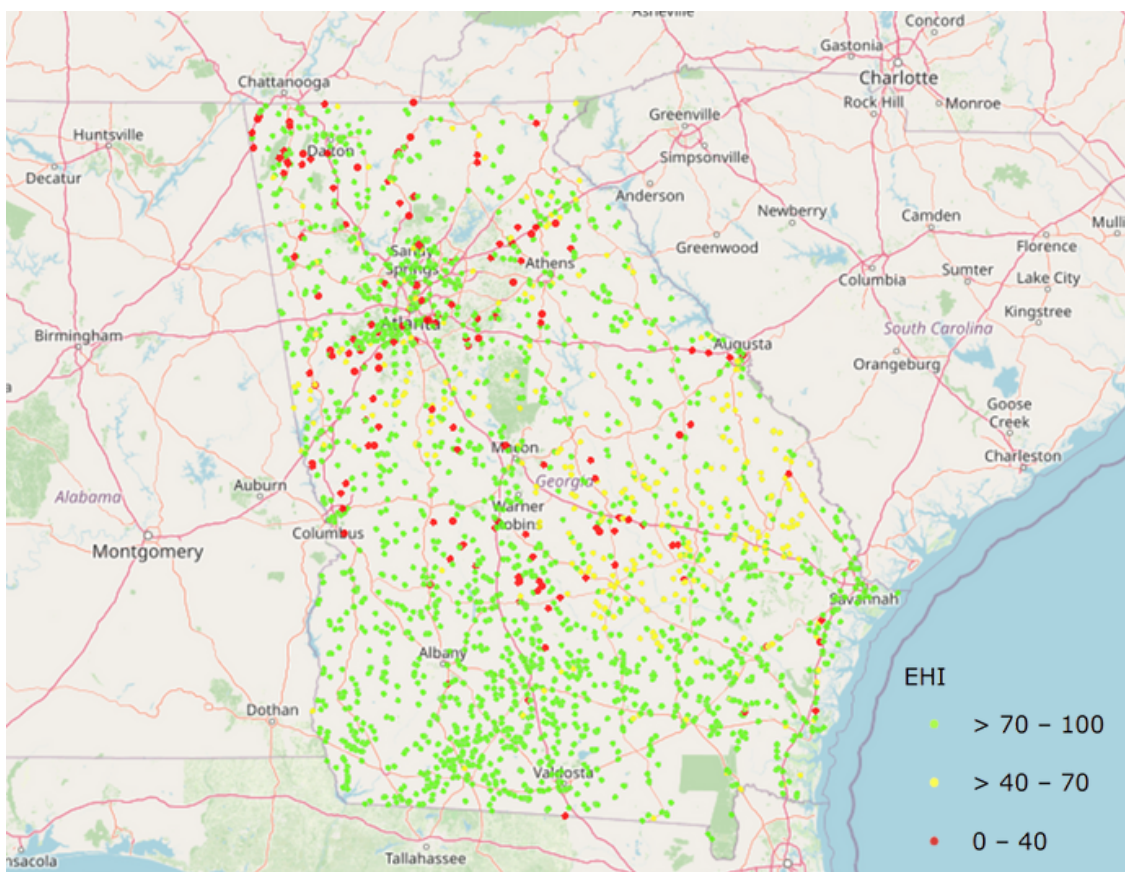


The common signs of distress in a reinforced concrete top flange are:

- Cracking: Considered “poor” when crack width is  $> 1.25"$  or spacing of cracks is  $< 1.0'$
- Spalls: Considered “poor” when a spall is  $> 1.0"$  deep or  $6.0"$  in diameter
- Efflorescence: Considered “poor” when there is heavy build-up with rust staining

The reinforced concrete top flange is a bridge girder top flange exposed to traffic. This element includes tee beams, bulb-tees, and girders that require traffic to ride on the top flange.

The reinforced concrete top flange is a deck component of the bridge. This means it is more likely to be exposed to rain, snow, and deicing salts than other bridge elements. In counties that experience these conditions, monitoring this element closely and performing maintenance and rehabilitation activities when necessary is essential.

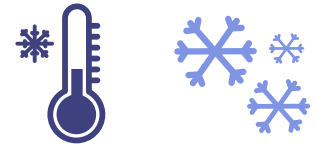


*Reinforced Concrete Top Flange EHI by Location*

# BRIDGE CASE STUDY

# 3.1

## Reinforced Concrete Top Flange



### Tips for Maintenance

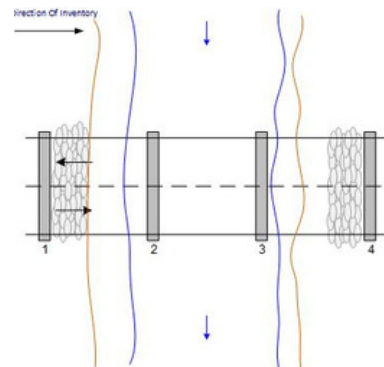
Duration: Seek to patch spalls when a deck is less than than 20% in condition state 2

Focus: Protect with overlay when deck falls over 50% into condition state 2 or lower

Associated Elements: Protecting deck elements with overlays/ joint sealing helps to protect main structural members

This is a bridge that has had poor deck condition. During the first NBIE inspection report in 2014, the deck had reported 100% of the deck area in condition state 2 or below from snow and freezing-related impacts. This corresponded to an EHI of 38.3. By 2022 due to continued impacts of weather, the deck had fallen into worse condition, with a corresponding EHI of 26.0

In this time, the county tried to mitigate the impacts by patching spalls. However, a better course of action for this bridge would have been a protective overlay to protect the whole deck. The patching did not improve the deck condition or help stop the weather impact. Although more expensive up front, an overlay would have improved the condition of this bridge.



2014

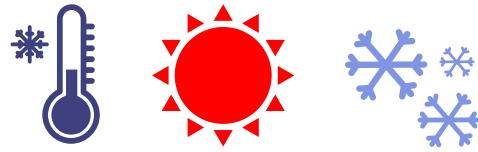


2022

# VULNERABLE ELEMENTS

## 3.2

### Pourable Joint Seal

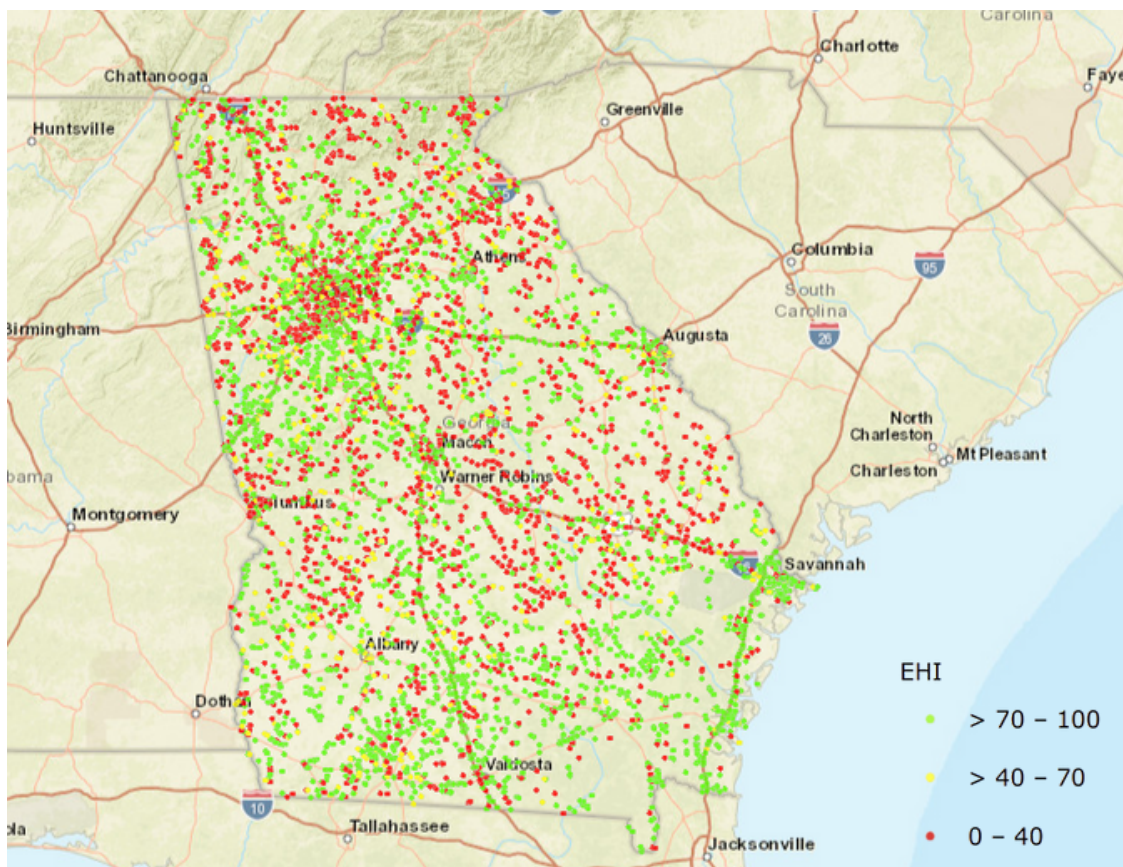


Common signs of distresses in a protective seal joint are:

- Leakage: Considered "severe" when there is a free flow of water
- Loss of Adhesion: Considered "severe" when there is a complete loss of adhesion
- Seal Damage: Considered "severe" when punctured completely or missing completely
- Cracking: Considered "severe" when a crack fully penetrates the seal.

The weather can impact these elements in several ways. Hot days can cause the seals to lose adhesion to the bridge deck and fail. Freezing days can also cause the joint to lose adhesion. Factors outside of weather, such as Average Daily Traffic (ADT), influence bridge seal joint conditions.

These elements are quickly deteriorating, and bridge asset managers should plan to allocate maintenance funds to bridges with this element.



*Pourable Joint Seal by EHI*

# BRIDGE CASE STUDY

## 3.2

### Pourable Seal Joint

#### Tips for Maintenance

1. Duration: Attempt to seal joints when they fall below 50% in condition state 2. Plan on sealing every 10 years
2. Associated element(s): Seal deck joints as open joints allow debris and water to leak and compromise the concrete strength of substructure elements and corrode

The case below shows the difference between a freshly sealed joint and a joint that is leaking. This bridge also dealt with poor steel pile conditions that caused the bridge to close. It is possible that poor joint condition and liquids and chemicals from the deck leaking caused the piles to fail.

Sealing piles is a small cost that can protect the condition of bridge elements



*Before  
Repair*



*After  
Repair*

# VULNERABLE ELEMENTS

## 3.3

### Reinforced Concrete Girder

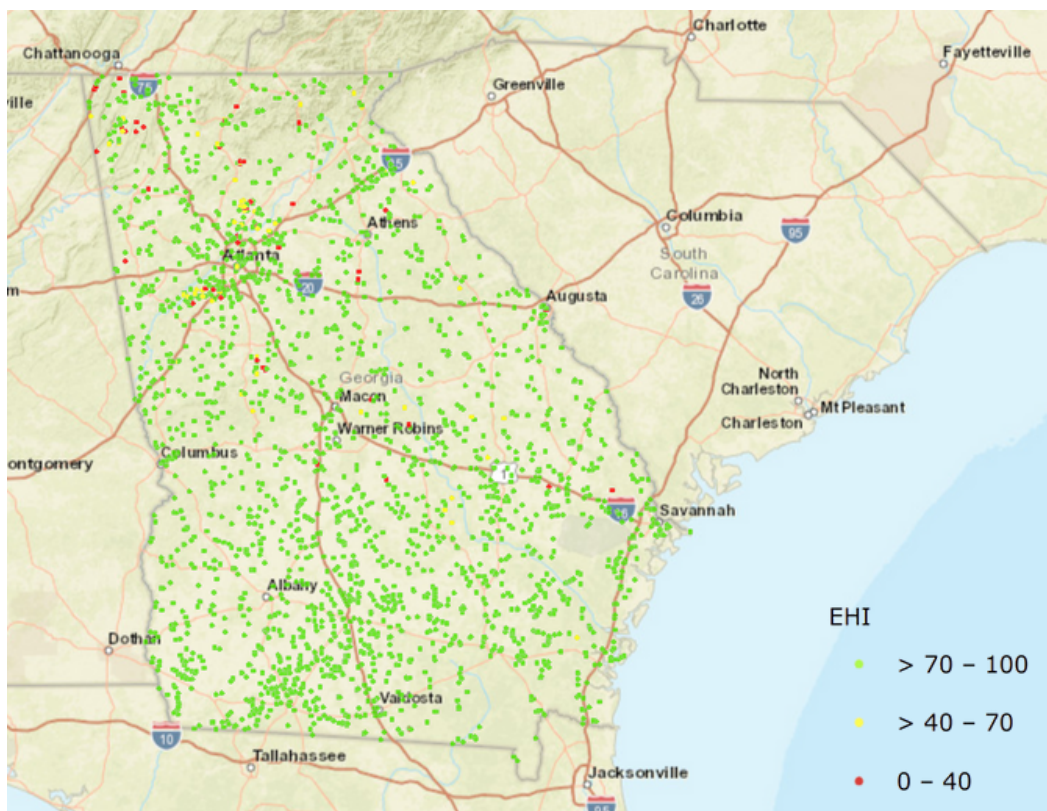


Common signs of distress in a reinforced concrete girder are

- Cracking: Considered “poor” when crack width is  $> 1.25''$  or spacing of cracks is  $< 1.0'$
- Spalls: Considered “poor” when a spall is  $> 1.0''$  deep or  $6.0''$  in diameter
- Efflorescence: Considered “poor” when there is heavy build-up with rust staining

The reinforced concrete girder is a horizontal structural element that spans between supports to support the deck of a bridge. The girder transfers the loads from the deck to the substructure. Reinforcing steel added to the concrete helps increase strength.

Many factors can cause reinforced concrete girders to deteriorate, and maintenance should be performed to prevent further degradation. Since this element is load-bearing, bridges may be load posted if defects become too severe.



*Reinforced Concrete Girder EHI by Location*

# BRIDGE CASE STUDY

# 3.3

## Reinforced Concrete Girder

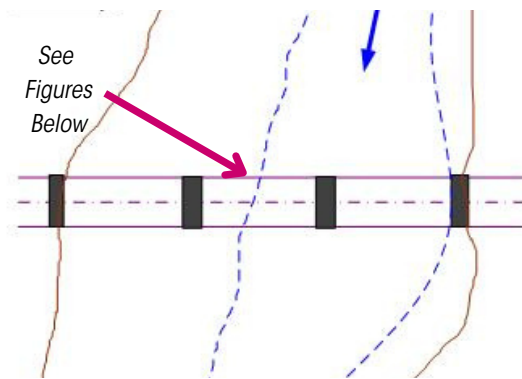
### Tips for Maintenance

1. Duration: Seek to seal cracks when first noted by the inspector and repair spalls within 3 years, particularly on structural elements
2. Focus: Seal small cracks, repair visible cracks to prevent crack propagation at the bottom face (see B below), spalling, and/or cover delamination (see C).
3. Prioritize crack repair in substructure elements providing service over waterways.

The bridge shown below demonstrates how fast reinforced concrete components such as girders can deteriorate, specifically in areas impacted by freeze-thaw cycles.

This is an older bridge that has dealt with rapid deterioration in concrete. The girders have suffered from rapid decline, with small cracks turning into large spalls and longitudinal cracks into cover delamination.

The estimated cost of repairing these overhead cracks in 2014 might have been around \$2,000. Because of the age of the structure and this deteriorating condition, this bridge will have to be replaced in the near future.



2014



2020

# VULNERABLE ELEMENTS

## 3.4

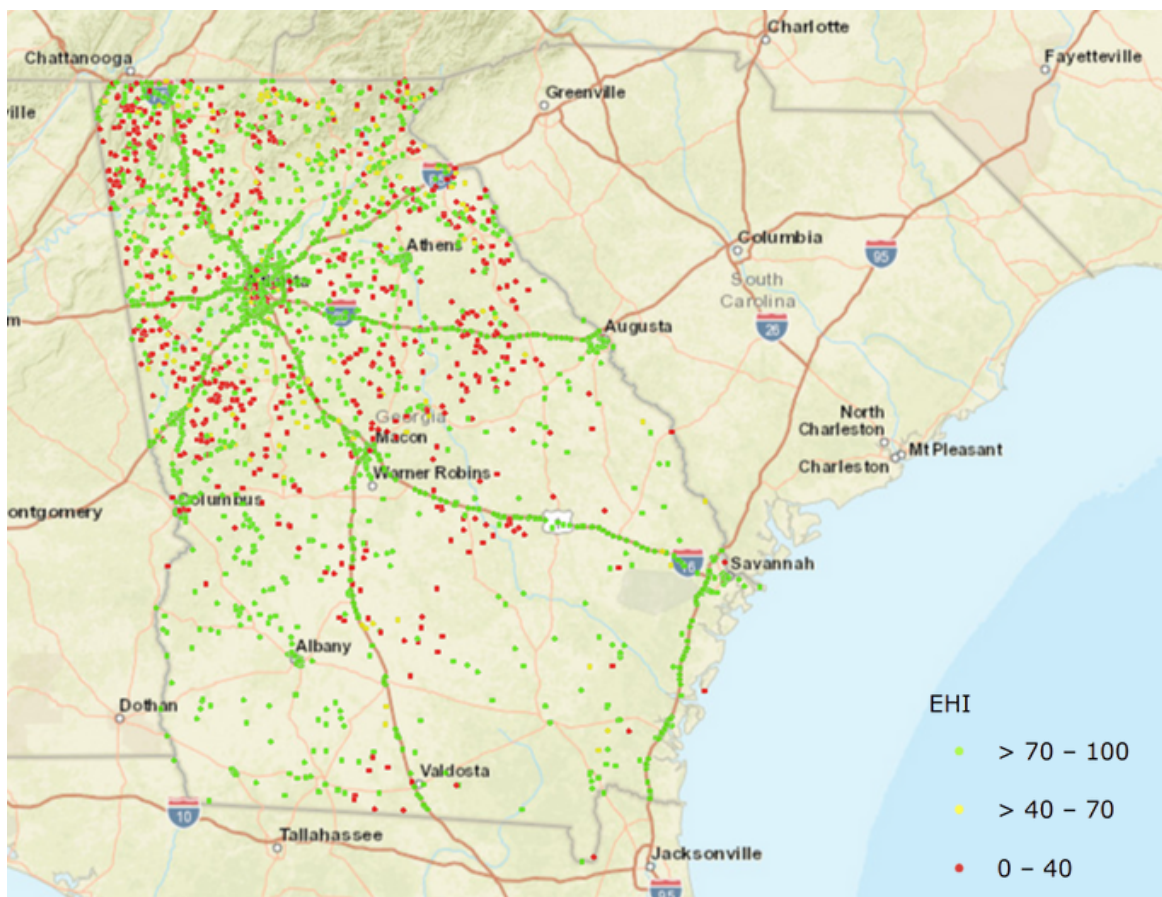
### Steel Girder



Steel girders are the horizontal support beams in a bridge structure. These are often used because they can span long distances without intermediate supports. They transfer the load on the deck to the substructure elements. These steel beams can be fabricated in a few cross sections, but wide flange members are most commonly found. When a steel beam/girder enters condition state four, it requires a load reduction. AASHTO lists the following defects for inspectors to note in an inspection.

- Corrosion: Steel Pitting and section loss not impacting load is considered moderate.
- Connections: Missing bolts, broken welds, severed connections.
- Cracking: Cracks that are not addressed

The main environmental impact on steel girders in Georgia is corrosion. When exposed to humidity, this bridge element can corrode. Preventative maintenance is critical with this element, particularly when in higher-risk areas.



*Steel Girder EHI by Location*

# BRIDGE CASE STUDY

## Steel Girder

# 3.4

### Tips for Maintenance

**Duration:** Schedule bridge steel girder painting regularly. GDOT recommends painting steel girders once every 20-25 years.

**Focus:** Spot paint vulnerable parts of beams like beam ends and connections

**Associated Elements:** Seal deck joints when they fall at or below 5% in condition state 2

This is a case study of two bridges built within one year of each other. They both pass over waterways. However, the bridge on the right has undergone regular steel girder cleaning and painting.

The bridge on the left was last painted when the bridge was constructed, and as a result, it has fallen into poor condition. Due to this, one span had to be replaced 44 years after the construction. After 65 years of service, the bridge's load rating was reduced to 8 tons and will need to be replaced to allow school buses or emergency vehicles to cross.

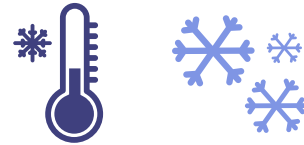
The bridge on the right that received regular painting and cleaning is not load posted and remains in "Fair" condition.



# VULNERABLE ELEMENTS

# 3.5

## Reinforced Concrete Pier Cap



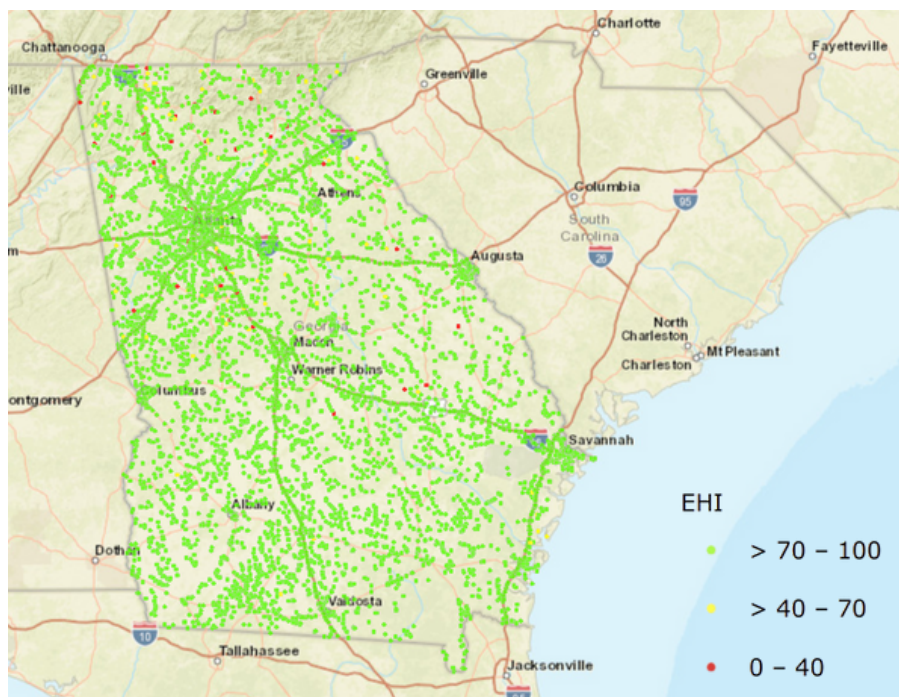
Common signs of distresses in a reinforced concrete abutment are:

- Cracking: considered "poor" when  $> 0.125"$  in width or when cracks are spaced  $< 1.0'$
- Spalling: considered "poor" when  $> 1.0"$  deep,  $6.0"$  in diameter, or if there is exposed rebar
- Efflorescence: considered "poor" if there is heavy surface build-up with rust staining

A reinforced concrete pier cap is a structural element of a bridge used to transfer a load from the deck to the bridge column or piers. This element is also referred to as the pier cap beam.

These elements are more vulnerable when the associated bridge is in an area that experiences cold weather or snowfall. Reinforcing steel can corrode and cause cracking and spalling. Additionally, freeze-thaw cycles can cause concrete cracking and spalling.

This is an important element to perform maintenance on, as cracks and spalls can impact the superstructure bearing area and lead to reduced bridge service loads.



*Reinforced Concrete Pier Cap EHI by Location*

# BRIDGE CASE STUDY

# 3.5

## Reinforced Concrete Pier Cap

### Tips for Maintenance

1. Duration: Attempt to seal cracks and repair spalls on pier caps within 3 years as they tend to worsen beyond this timeframe.
2. Location of Focus: Prioritize sealing cracks and repairing spalls at pier cap beams, focusing on areas under bearing and where beams join to the substructure (see A below).
3. Associated element(s): Seal deck joints as open joints allow debris and water to leak and compromise concrete strength.

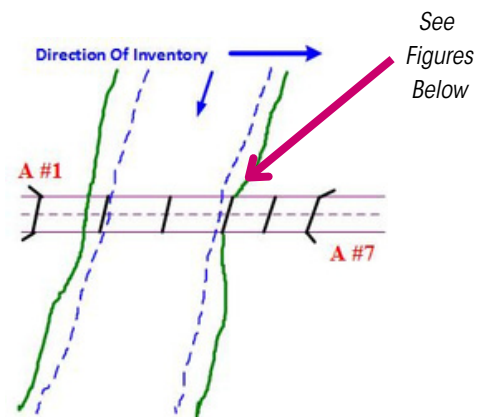
The bridge shown below maintained an NBI substructure score of 5, despite worsening visual conditions. It is noted as the minimum tolerable condition to not warrant a posting. In 2014, inspectors noted cracking in bent 5 and recommended sealing.

The estimated cost of repairing these cracks with an epoxy injection might have been around \$210 for the 3' of cracks reported. It would have been an additional \$3,900 to reseal the joints in 2014.

To repair the new spalling 6 years later in the pier cap alone will cost ~\$2,000, and the joints will still need to be sealed (>\$3,900). If these spalls are left unaddressed, it will likely result in a load posting on this bridge.



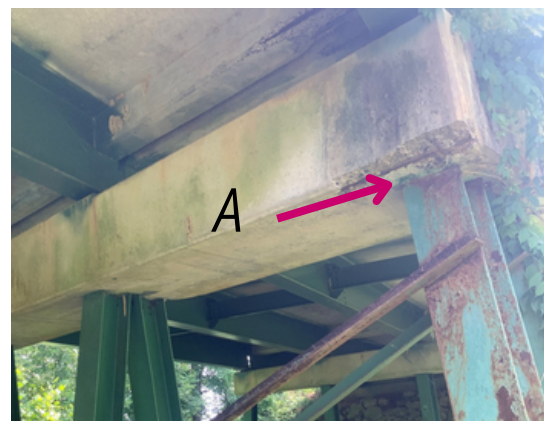
See Figures Below



See Figures Below



2014



2020

# VULNERABLE ELEMENTS

## 3.6

### Steel Pile



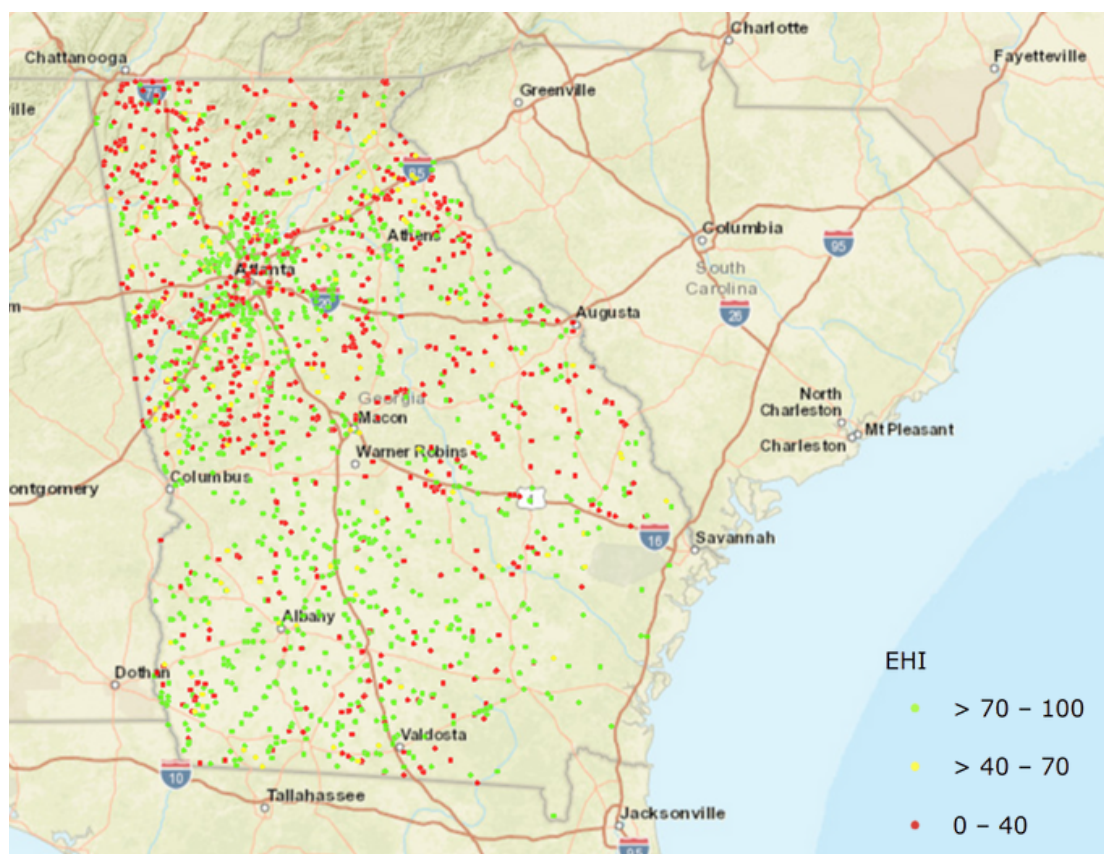
The common signs of distress in a steel pile are

- Corrosion: Considered "poor" when section loss or pack rust is present
- Cracking: Considered "poor" when a crack is present but does not require structural review
- Scour: Considered severe when scour may impact structure stability

A steel pile is a steel member used to support bridges. They provide a strong, stable foundation for the bridge structure. Steel piles are often found under abutments to keep them steady. However, this element refers to steel piles that are above ground.

These elements are highly vulnerable to corrosion when left without protective paint. Maintenance should be prioritized for bridges that cross water and are in high-humidity areas to prevent corrosion.

This element is of note to maintain as a drop into condition state four means the structure will have a reduced load posting.



*Steel Pile EHI by Location*

# BRIDGE CASE STUDY

# 3.6

## Steel Pile

### Tips for Maintenance

Duration: Paint every 20-25 years. Spot paint as needed

Focus: Once signs of deterioration in paint is noted, seek to clean and paint within the year. Take note of pile condition at ends, this is where the most severe corrosion occurs.

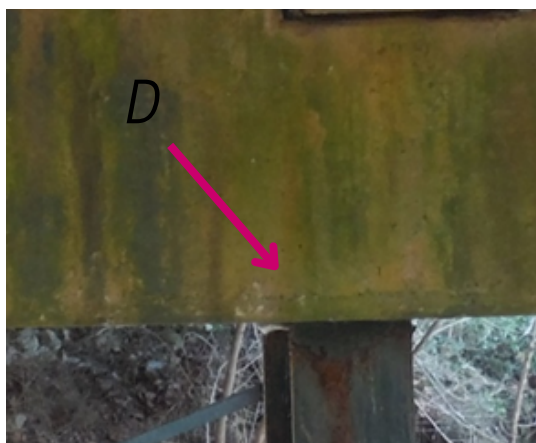
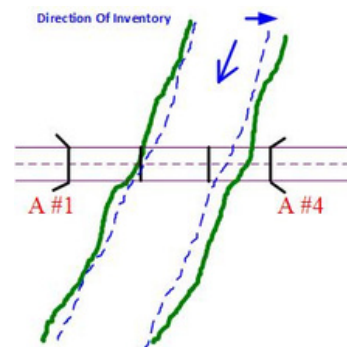
Associated Elements: Pier Caps often show signs of cracking when steel piles have corrosion

This bridge, including the steel piles shown below, were last painted in 2004. Eight steel piles support the bridge structure and are encased in concrete at the base. In 2014, the bridge was posted due to a deteriorating condition.

The corrosion in the piles was located where it meets the deck (see D below). In 2016, section loss (3/16" reduction in thickness), which reduced by the condition rating. By 2019, section loss of 1/4" was recorded.

By 2021, several piles had 100% section loss (see E). The bridge was closed until repairs could be made. This shows how rapidly piles can deteriorate in humid environments.

The bridge closure could have been avoided if the piles had been cleaned and painted. This would have only cost ~\$6,000.



2016

2021

# VULNERABLE ELEMENTS

## 3.7

### Prestressed Concrete Pile



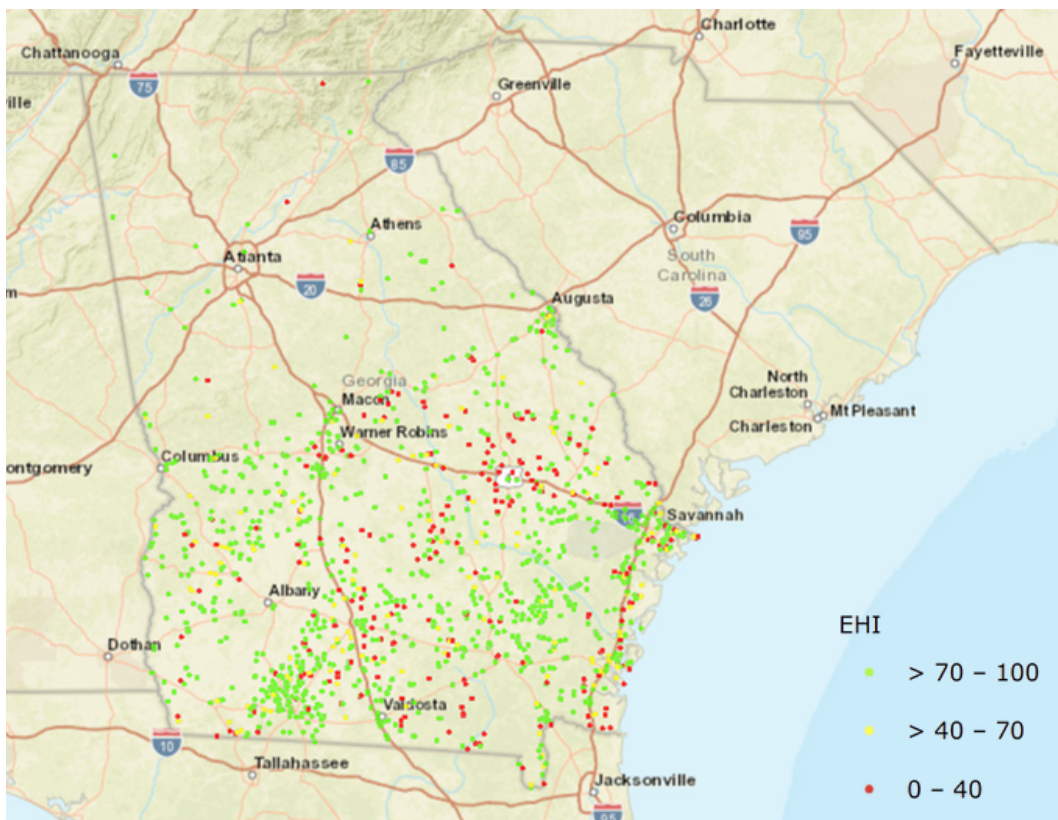
Common signs of distress in a prestressed concrete pile are:

- Spalls: Considered severe when greater than 1.0" deep or greater than 6.0" in diameter
- Exposed Rebar: Considered "poor" when rebar has section loss
- Cracking: Considered "poor" when wide or heavy cracking patterns appear
- Abrasion: Considered "poor" when aggregate is loose or has popped out
- Scour: Considered "severe" when the structure has stability risk

A prestressed concrete pile is a substructure bridge element that transfers loads from the deck and superstructure to the ground. Prestressing the piles before service makes them highly resistant to buckling and bending.

These piles are commonly found in coastal regions as designers avoid using more corrodible materials like steel in marine environments.

The most common defect on these elements was cracking that started as minor. When exposed to salt; cracks can increase in width anywhere from 1/16" -1/8" annually. As crack size increases, more salt can penetrate the structure, causing rapid deterioration of the structure. Filling cracks when they are hairline can prevent further cracking and increase maintenance costs.



*Prestressed Concrete Pile EHI by Location*

# BRIDGE CASE STUDY

# 3.7

## Prestressed Concrete Pile

### Tips for Maintenance

Duration: Cracks in this element tend to grow up to 1/8" wider in 4 years time. Look to repair cracks within 4 years to prevent cracking progression.

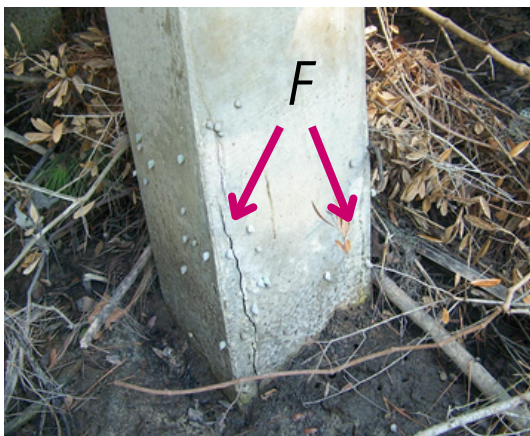
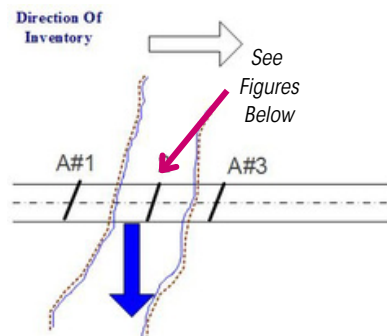
Focus: Sealing small cracks and/or repairing large cracks to prevent the loss of concrete cover and confinement.

Associated elements: Prioritize crack repair in bridge elements exposed to a salt environment.

The prestressed concrete pile below supports a bridge that passes over a tidal zone and is exposed to a marine environment. The exposure to salt caused cracking in the prestressed pile.

The cracks (see F) allowed an increased flow of salt, allowing cracking to progress and resulting in a loss of column confinement.

Repairing cracks by means of a crack injection and/or sealing in 2014 would have been ~\$200. However, the pile will likely need repair and a jacket wrap to support the superstructure. Leading to an increased cost in repair costs.



2014



2022

# VULNERABLE ELEMENTS

# 3.8

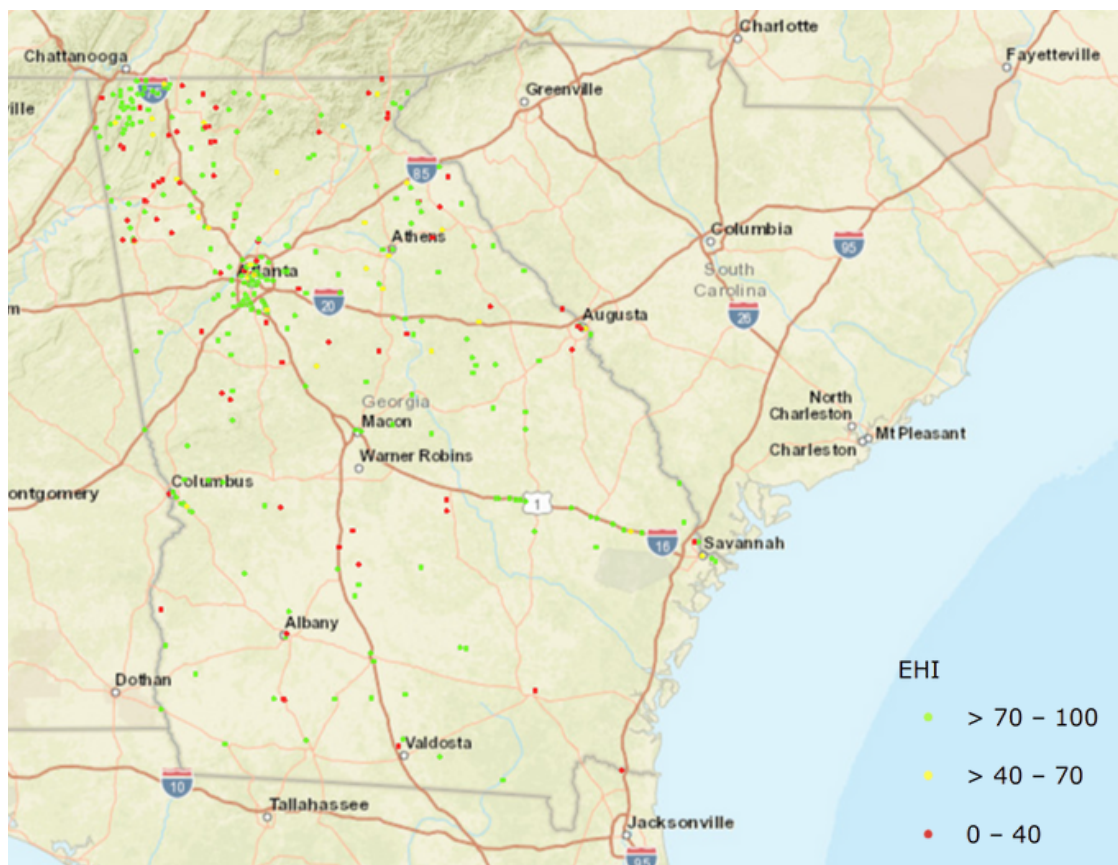
## Reinforced Concrete Pier Wall



The common signs of distress in a reinforced concrete pier wall are:

- Cracking: Considered “poor” when crack width is  $> 1.25''$  or spacing of shots is  $< 1.0'$
- Spalls: Considered “poor” when a spall is  $> 1.0''$  deep or  $6.0''$  in diameter
- Efflorescence: Considered “poor” when there is heavy build-up with rust staining
- Scour: Minor when it does not impact stability
- Settlement: Minor when settlement does not affect load capacity.
- Abrasion: Considered severe when aggregate is loose or has popped out

Another issue that is common with reinforced concrete pier walls is drift accumulation. Drift accumulation can contribute to scour and erosion as it changes the water flow. It can also cause structural damage due to the massive size of these structures. However, spalls and cracks that impact the bearing area should be addressed.



*Reinforced Concrete Pier Wall EHI by Location*

# BRIDGE CASE STUDY

# 3.8

## Reinforced Concrete Pier Wall

### Tips for Maintenance

Duration: Seek to remove large debris as soon as it is reported.

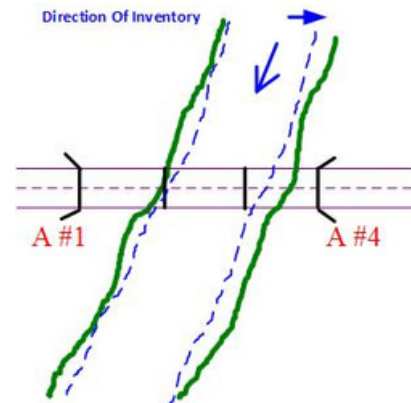
Focus: Larger substructure elements like pier walls are more likely to gather debris.

Associated Elements: Other substructure elements are at higher risk for scour damage when debris is left unaddressed.

This bridge noted a large drift build-up in 2012, and inspectors noted that it should be removed. However, the large drift was left unaddressed and worsened. In 2020, scour was found at the substructure.

The altered channel flow from the massive debris pile likely caused this scouring. The more drift that is allowed to accumulate, the more expensive the removal cost will become.

Drift can cause scouring or potentially damage other substructure elements.



2012



2020

# VULNERABLE ELEMENTS

# 3.9

## Reinforced Concrete Abutment

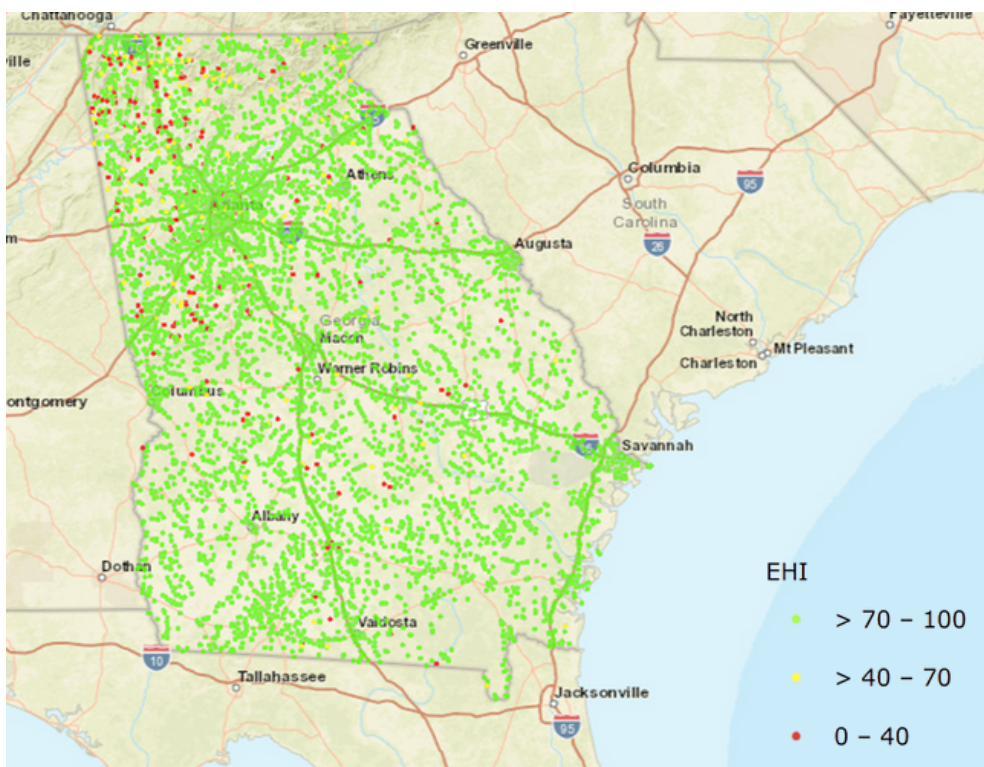


Common signs of distresses in a reinforced concrete abutment are:

- Cracking: considered severe when  $> 0.125''$  in width or when cracks are spaced  $< 1.0'$
- Spalling: considered severe when  $> 1.0''$  deep,  $6.0''$  in diameter, or if there is exposed rebar
- Efflorescence: considered severe if there is heavy surface build-up with rust staining
- Scour: Considered major when the structure has stability risk
- Settlement: Considered severe when the structure is at risk of reduced load capacity

A reinforced concrete abutment is a substructure element of a bridge used to transfer loads from a bridge deck to the foundation. The abutment consists of concrete and reinforcing steel. When inspected, the reinforced concrete abutment and extensions or wing walls are considered.

These elements are more vulnerable when the associated bridge is used to pass over water. Proximity to water increases the scour risk, and exposure to water increases the risk of freeze-thaw cycles.



*Reinforced Concrete Abutment EHI by Location*

# BRIDGE CASE STUDY

# 3.9

## Reinforced Concrete Abutment

### Tips for Maintenance

Duration: Patch Spalls and cracks as soon as they appear. Cover exposed rebar to prevent section loss.

Focus: Areas near bearing areas and along water lines are more likely to be impacted.

Associated Elements: If spalls grow too large bearing areas of superstructure elements can be impacted.

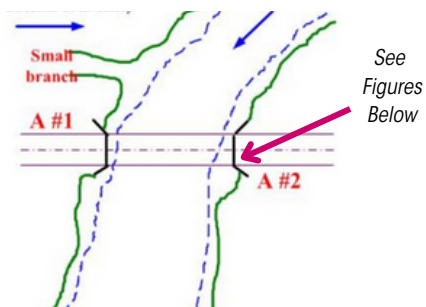
This bridge shows an example of how reinforced concrete abutment spalling can progress when left unaddressed. In 2016, inspectors noted small areas of cracking and spalling on the reinforced concrete abutment below the superstructure element.

In six years' time, the spalling progressed significantly, with the area of spalling increasing. Spall repairs are area repairs, so the larger they grow, the more expensive the repair will be.

Due to the location of the spall (see G), under a bearing area, the bridge's load capacity was also impacted by the deterioration.



See Figures Below



2016



2022

# VULNERABLE ELEMENTS

# 3.10

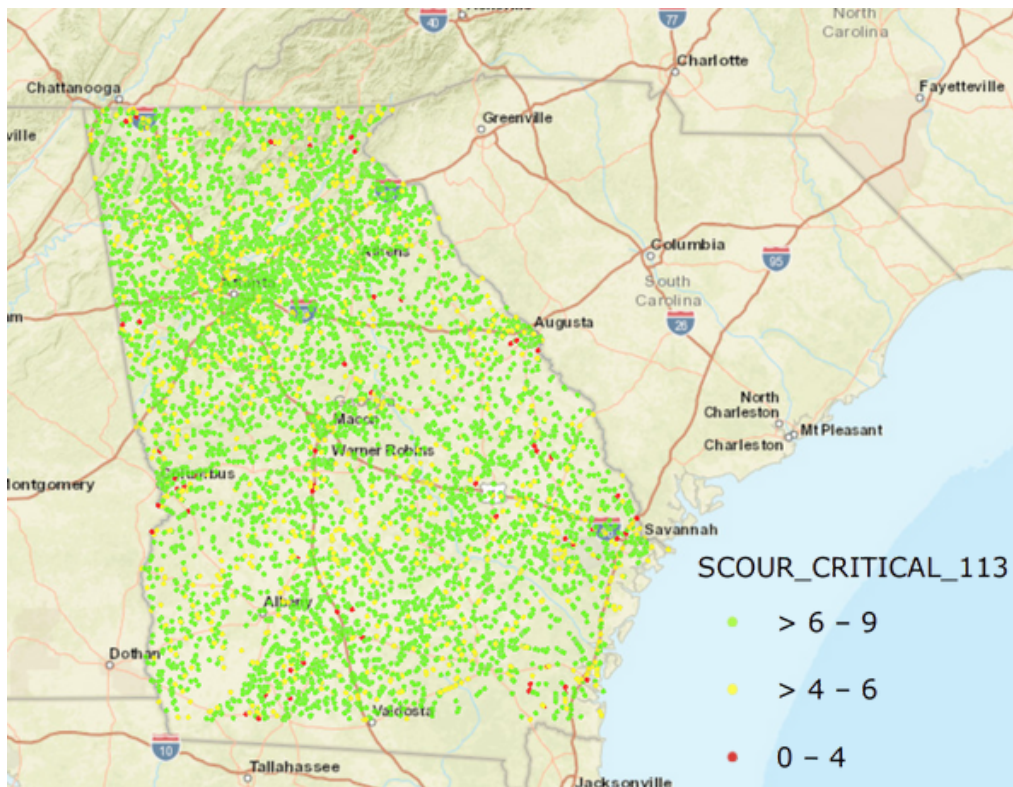
## Scour Vulnerable Elements



Scour is the erosion of soil/sediment from around a bridge foundation caused by water. Scour can impact any bridge structure that crosses bodies of water. As water flows around the bridge foundation, it can cause the removal of soil, causing a hole to form. The spot that is created can weaken the foundation, leading to a potential collapse. Scour can occur gradually over time or rapidly during high-flow events after a day of high precipitation levels. Several factors can cause scour.

- Water flow rate: The faster the water flows, the more likely the water is to take the soil.
- Bed Material: The bed that the body of water is on impacts scour as coarser, heavier materials like gravel are less likely to flow away.
- Bridge Geometry: The size and shape of superstructure materials can impact flow and the amount of scour.
- Severe weather: Severe weather events can cause an increase in flow, leading to an increase in scour.

Using mitigation efforts like rip-rap and spur dikes can mitigate the impacts of scour.



*Scour Critical Assets by Location*

# BRIDGE CASE STUDY

# 3.10

## Scour Vulnerable Elements

### Tips for Maintenance

Duration: Once scour appears, it often significantly worsens within 2 years, seek to repair as soon as it is discovered.

Focus: Pay close attention to bridges that pass over waterways, particularly fast-moving flows.

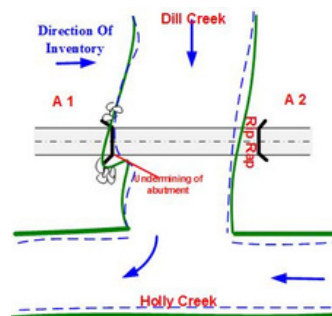
Associate element(s): Superstructure and deck elements can be impacted by settlement due to scour

The bridge shown below opened in 2012. It has experienced severe scour. Unlike other bridge defects, scour can appear rapidly.

From 2016-2020, this bridge saw an increase in erosion of 423 sf. In addition to the increase in erosion area, the scour exposed the piles under the bridge.

This bridge now likely needs extensive repairs, which will cost the county more, than if repairs had been made when the scour first appeared.

This scour also dropped the NBI substructure rating of the bridge from a 9 to a 5. This is a perfect example of how an earlier repair would save money.



2016



2018



2020

# CONCLUSION

# 4.0

## TIPS FOR BETTER ASSET MANAGEMENT



Identify bridges with increased vulnerability. These include but are not limited to

- Bridges over 30 years old
- Bridges that pass over a waterway
- Bridges that are de-iced using chemicals during winter months
- Understand the bridge elements under your county's jurisdiction. Note the cyclical, preventative, and condition-based maintenance activities associated.

This can be as simple as taking an inventory of all bridges and noting bridges at higher risk of weather-related impacts.

Plan for Cyclical Maintenance Activities Recommended by GDOT when a bridge is constructed. (not clear what this means) Identify bridges that will need to have cyclical maintenance performed. These include but are not limited to

- Cleaning Decks and Joints: Wash after every cold season if de-icing agents were used.
- Deck Drains: Clean once per year
- Concrete Members (non-deck): Evaluate and clean on a 10-year cycle.
- Structural Steel: Paint every 20-25 years
- Expansion Joints: Evaluate every 10-15 years

Use NBI element data to perform conditional maintenance activities (InspectX has a filtering option).

- Clean and Reseal Joints: When any amount falls into condition state 3
- Patch concrete members: When an element falls > 20% in condition state 2 or lower.

Weather plays just a part in bridge conditions, and the elements not presented in this guide can show deterioration from weather. Local governments should recognize that inspectors are not engineers and can send any plans to GDOT for prioritization and feasibility.