Memorandum

Date: May 9, 2012

Subject: ***Stormwater Runoff from Bridges: Final Report to Joint Transportation Oversight Committee Revision May 2012***

A report entitled *Stormwater Runoff from Bridges: Final Report to Joint Legislation Transportation Oversight Committee, in Fulfillment of Session Law 2008-107* (hereafter referred to as the *Final Report*) was prepared by URS Corporation for the North Carolina Department of Transportation (NCDOT) in July 2010. Errors were recently discovered in the calculation of unit event loads, annual loading rates, and runoff volumes that were provided in Section 4 and Appendix 3-G of the *Final Report*. The calculation errors have been corrected and the associated text and tables in the *Final Report* have been revised. Following is a summary of updated text and tables included in the revision:

- Pages 4-9 through 4-16 in Section 4 were updated, including all text and tables on these pages:
    - Table 4.2-2 on pages 4-10 through 4-13 was updated with corrected median unit event loads and average unit annual loading rates.
    - Table 4.2-3 on page 4-14 was updated with corrected annual loading rate values.
    - Table 4.2-4 on page 4-16 was updated with corrected annual loading rate values.
- All tables in Appendix 3-G (Tables 3-G.1 to 3-G.15) were updated with corrected runoff volume values.

The *Final Report* was prepared to fulfill requirements of Session Law 2008-107 and included information and analysis associated with water and sediment quality, stream and bridge deck hydrology, stream biological assessments, applicable stormwater control measures (SCMs) for bridges, and cost estimates for SCMs. For additional information and analysis associated with water/sediment quality and hydrologic data collected for the project, the reader is directed to a report prepared by the United States Geological Survey (USGS) entitled *Scientific Investigations Report 2011-5180: Characterization of Stormwater Runoff from Bridges in North Carolina and the Effects of Bridge Deck Runoff on Receiving Streams* published in 2011. This report is available online at http://pubs.usgs.gov/sir/2011/5180/.

The updated text and tables included in the revision are attached to this memorandum and can be used as replacement pages for the *Final Report*. For questions or more information, please contact Matt Lauffer at mslauffer@ncdot.gov or Alex Nice at alex.nice@urs.com.

Replacement pages 4-9 through 4-16 in Section 4

for

Stormwater Runoff from Bridges: Final Report to Joint Transportation Oversite Committee (July 2010)

Revision May 2012

T_p = average time of precipitation (wet) at the monitoring site (years)
T_d = average time of dry periods at the monitoring site (years)

The Wu and Allan method for calculating annual loading was selected for the project for several reasons:

- Data from the Wu and Allan (2001) report was used previously by NCDOT to establish nutrient area loading rates for nitrogen and phosphorus in runoff (NCDOT, 2009a). Using the same method allows for defensible comparisons of the BSP dataset against previously calculated values.
- The Wu and Allan method takes full advantage of the potential hydrologic data that could be available for each storm event. Wu and Allan compared results of their method to results from Scheuler's Simple Method, which relies on estimates of hydrologic data from precipitation and representative concentration values and concluded that estimates of total nitrogen export from runoff were overestimated by Scheuler's Simple Method (Wu and Allan, 2001). (Note: for the current study, Scheuler's Simple Method was used to calculate runoff volumes to facilitate application of the Wu and Allan method because discharge data were not available at the time of this analysis.)
- The Wu and Allan method incorporates a non-dimensional correction factor to account for the site-specific ratio of time of precipitation to time of dry weather (wet to dry ratio). This correction factor helps prevent overestimating or underestimating pollutant loads if the storm events collected do not necessarily represent the precipitation pattern implicitly assumed in a model.

Bridge vs. Roadway Annual Pollutant Loading Rates

Median unit event loads and average unit annual loading rates for the 15 BSP bridge deck runoff monitoring sites are summarized in table 4.2-2. Table 4.2-3 provides a visual representation of the average unit annual loading rate at each site compared to the median value for all 15 sites. Based on visual inspection, annual loading rates for metals appear to be relatively higher at sites located in the Blue Ridge and Piedmont ecoregions as compared to sites located in the Coastal ecoregion. There was no discernible trend in annual loading rates for nutrients and solids for the different ecoregions. In general, annual loading rates at the Swannanoa River, Mallard Creek, and Swift Creek sites were relatively higher than the other sites; annual loading rates at the Dillingham Creek, Mango Creek, and Smith Creek sites were relatively lower than the other sites. It should be noted that the unit annual loading rates reported for each site in table 4.2-2 are based on an average of rates calculated for each event (rather than a median). The average value was considered to be a more appropriate comparison to the literature values, as many of these studies employed similar methods. However, it should be noted that a single high or low EMC value can bias the average annual value. For example, the higher annual loading rates calculated for bis-phthalate at Smith Creek and for orthophosphate at Flat Creek were each weighted by one relatively higher EMC value. Future evaluation of these data may identify these higher EMC values as outliers, and exclude them from the calculation of annual loading rates, provided some basis for their removal is established. However, for the current study, these relatively higher values were not excluded because no such basis was established.

A comparison of annual loading rates calculated for the 15 BSP bridge deck runoff monitoring sites to highway and bridge loading values reported in literature studies is provided in table 4.2-4. The median and range of loading values reported for the 15 sites were calculated using the following steps:

1. A unit event loading rate (lb/ac-yr) was calculated for each parameter, storm event, and site.
2. An average unit annual loading rate (lb/ac-yr) was calculated for each site and parameter as the average of the values from each storm event computed in Step 1, adjusted using the site-specific wet to dry ratio. A summary of these average unit annual loading rates is presented in table 4.2-2.
3. The median and range of annual loading rates reported in table 4.2-4 was determined using the 15 average annual loading rates computed in Step 2 for each parameter.

Table 4.2-2: Median Unit Event Loads (lb/ac) and Average Unit Annual Loading Rates (lb/ac-yr) at the 15 BSP Monitoring Sites

Stream Name, Bridge Number		Flat Creek, 100250		Big Ivy Creek, 100734		Dillingham Creek, 100145		Swannanoa River, 100494	
North Carolina Ecoregion		Blue Ridge		Blue Ridge		Blue Ridge		Blue Ridge	
Parameter		lb/ac	lb/ac-yr	lb/ac	lb/ac-yr	lb/ac	lb/ac-yr	lb/ac	lb/ac-yr
Solids	Total Dissolved Solids	2.58E+00	5.13E+02	3.93E+00	3.84E+02	2.33E+00	1.93E+02	8.44E+00	8.55E+02
	Total Suspended Solids	1.63E+00	4.65E+02	1.26E+01	1.35E+03	2.86E+00	3.78E+02	1.32E+01	1.31E+03
Nutrients	Total Phosphorus	8.8E-03	3.9E+00	5.0E-02	1.2E+01	1.4E-02	1.3E+00	4.3E-02	4.8E+00
	Orthophosphate	4.3E-03	2.2E+00	2.5E-03	2.8E-01	1.5E-03	1.5E-01	3.4E-03	5.4E-01
	Total Nitrogen	4.3E-02	2.0E+01	1.1E-01	9.6E+00	6.4E-02	4.8E+00	1.5E-01	2.0E+01
	Ammonia	7.3E-03	6.2E+00	1.6E-03	2.9E-01	3.0E-03	2.3E-01	6.5E-03	1.4E+00
	Total Kjeldahl Nitrogen	3.7E-02	1.5E+01	8.8E-02	7.6E+00	4.0E-02	3.7E+00	1.1E-01	1.4E+01
	Nitrate + Nitrite	1.1E-02	3.6E+00	1.7E-02	2.0E+00	1.2E-02	1.1E+00	4.8E-02	6.1E+00
Trace Metals	Total Recoverable Arsenic	3.1E-05	8.7E-03	1.1E-04	1.1E-02	1.4E-04	1.3E-02	1.1E-04	1.2E-02
	Total Recoverable Cadmium	4.0E-06	9.1E-04	1.5E-05	1.4E-03	8.4E-06	5.0E-04	5.0E-05	6.0E-03
	Dissolved Cadmium	3.0E-06	6.5E-04	1.8E-06	1.9E-04	1.6E-06	1.7E-04	1.2E-05	1.8E-03
	Total Recoverable Chromium	1.3E-04	4.3E-02	1.5E-03	1.5E-01	4.5E-04	4.2E-02	1.8E-03	2.2E-01
	Total Recoverable Copper	2.60E-04	6.15E-02	1.76E-03	1.65E-01	5.15E-04	1.41E-01	4.18E-03	5.61E-01
	Dissolved Copper	1.3E-04	2.7E-02	2.2E-04	1.7E-02	1.4E-04	1.1E-02	1.2E-03	1.4E-01
	Total Recoverable Iron	4.96E-02	1.91E+01	7.46E-01	8.65E+01	1.95E-01	1.99E+01	4.99E-01	7.94E+01
	Total Recoverable Nickel	1.5E-04	4.4E-02	7.6E-04	8.1E-02	2.1E-04	2.1E-02	6.7E-04	8.8E-02
	Total Recoverable Lead	5.41E-05	1.69E-02	1.1E-03	1.27E-01	1.79E-04	1.90E-02	2.92E-03	3.24E-01
	Dissolved Lead	5.9E-06	2.0E-03	5.1E-06	4.6E-04	3.3E-06	3.0E-04	3.1E-05	3.8E-03
	Total Recoverable Manganese	1.64E-03	6.30E-01	1.24E-02	1.65E+00	3.80E-03	4.47E-01	9.88E-03	1.37E+00
	Total Recoverable Zinc	2.65E-03	7.78E-01	2.18E-02	2.32E+00	3.31E-03	3.82E-01	3.68E-02	4.59E+00
	Dissolved Zinc	1.93E-03	5.37E-01	1.47E-03	1.72E-01	5.61E-04	4.84E-02	4.04E-03	6.97E-01
	Total Recoverable Aluminum	2.78E-02	1.11E+01	4.35E-01	4.85E+01	1.16E-01	1.29E+01	2.69E-01	3.30E+01
	Total Recoverable Mercury	1.1E-06	1.1E-04	1.4E-06	1.6E-04	7.6E-07	7.4E-05	2.0E-06	2.0E-04
Semi-volatiles	Bis(2-ethylhexyl)phthalate	6.5E-05	1.7E-02	1.0E-04	1.2E-02	2.3E-05	2.8E-03	5.8E-04	5.3E-02
Hydro-Carbons	Oil and Grease	5.5E-01	2.1E+02	5.4E-01	7.5E+01	3.07E-01	2.3E+01	1.0E+00	1.6E+02

Table 4.2-2: Median Unit Event Loads (lb/ac) and Average Unit Annual Loading Rates (lb/ac-yr) at the 15 BSP Monitoring Sites (continued)

Stream Name, Bridge Number		Boylston Creek, 440008		Mallard Creek, 590296		Mountain Creek, 310005		Little River, 310064	
North Carolina Ecoregion		Blue Ridge		Piedmont		Piedmont		Piedmont	
Parameter		lb/ac	lb/ac-yr	lb/ac	lb/ac-yr	lb/ac	lb/ac-yr	lb/ac	lb/ac-yr
Solids	Total Dissolved Solids	2.15E+00	5.70E+02	8.64E+00	3.36E+02	2.87E+00	2.52E+02	2.13E+00	4.02E+02
	Total Suspended Solids	7.63E+00	9.40E+02	1.58E+01	1.44E+03	1.99E+00	4.36E+02	2.17E+00	1.64E+03
Nutrients	Total Phosphorus	7.5E-02	4.5E+00	6.2E-02	5.8E+00	1.2E-02	3.8E+00	5.9E-03	3.8E+00
	Orthophosphate	5.6E-03	5.1E-01	1.6E-03	1.5E-01	4.1E-03	5.7E-01	5.8E-04	7.6E-02
	Total Nitrogen	2.3E-01	2.1E+01	2.3E-01	1.6E+01	1.2E-01	1.8E+01	6.0E-02	2.5E+01
	Ammonia	2.2E-02	4.1E+00	1.0E-02	5.7E-01	2.2E-02	3.2E+00	1.9E-03	3.6E+00
	Total Kjeldahl Nitrogen	2.1E-01	1.6E+01	1.5E-01	1.2E+01	9.4E-02	1.4E+01	4.4E-02	1.8E+01
	Nitrate + Nitrite	2.7E-02	5.2E+00	7.4E-02	3.9E+00	2.6E-02	3.4E+00	1.5E-02	7.1E+00
Trace Metals	Total Recoverable Arsenic	2.8E-04	2.5E-02	3.0E-04	2.3E-02	4.9E-05	8.4E-03	5.6E-05	1.6E-02
	Total Recoverable Cadmium	2.3E-05	2.1E-03	7.0E-05	6.0E-03	4.7E-06	7.4E-04	5.7E-06	2.0E-03
	Dissolved Cadmium	4.8E-06	7.2E-04	6.0E-06	7.2E-04	2.5E-06	3.4E-04	1.2E-06	3.1E-04
	Total Recoverable Chromium	5.1E-04	5.2E-02	3.5E-03	3.2E-01	1.6E-04	2.3E-02	1.3E-04	8.8E-02
	Total Recoverable Copper	1.54E-03	1.01E-01	1.02E-02	6.26E-01	6.24E-04	1.02E-01	3.69E-04	1.49E-01
	Dissolved Copper	2.8E-04	2.7E-02	1.2E-03	6.5E-02	4.4E-04	5.9E-02	1.6E-04	3.1E-02
	Total Recoverable Iron	5.51E-01	4.95E+01	6.53E-01	7.29E+01	5.54E-02	1.37E+01	4.84E-02	3.31E+01
	Total Recoverable Nickel	4.5E-04	4.0E-02	1.5E-03	1.1E-01	2.0E-04	4.6E-02	9.8E-05	4.6E-02
	Total Recoverable Lead	1.05E-03	8.27E-02	3.44E-03	7.57E-01	4.26E-04	5.09E-02	2.50E-04	2.28E-01
	Dissolved Lead	1.7E-05	2.3E-03	3.3E-05	3.6E-03	1.9E-05	2.7E-03	5.3E-06	1.2E-03
	Total Recoverable Manganese	1.67E-02	1.49E+00	2.10E-02	2.50E+00	6.10E-03	9.26E-01	2.39E-03	2.25E+00
	Total Recoverable Zinc	1.43E-02	1.34E+00	7.29E-02	6.42E+00	4.2E-03	7.31E-01	3.40E-03	1.37E+00
	Dissolved Zinc	4.16E-03	4.50E-01	8.83E-03	5.91E-01	3.30E-03	4.23E-01	1.18E-03	2.59E-01
	Total Recoverable Aluminum	4.91E-01	3.72E+01	3.26E-01	3.10E+01	4.41E-02	1.06E+01	4.57E-02	2.63E+01
	Total Recoverable Mercury	2.0E-06	4.0E-04	2.5E-06	1.8E-04	5.5E-07	1.1E-04	5.1E-07	3.0E-04
Semi-volatiles	Bis(2-ethylhexyl)phthalate	1.64E-04	2.5E-02	8.0E-04	7.3E-02	8.4E-05	1.0E-02	1.0E-04	3.9E-02
Hydro-Carbons	Oil and Grease	1.31E+00	1.2E+02	1.2E+00	1.5E+02	3.6E-01	4.9E+01	2.7E-01	7.7E+01

Table 4.2-2: Median Unit Event Loads (lb/ac) and Average Unit Annual Loading Rates (lb/ac-yr) at the 15 BSP Monitoring Sites (continued)

Stream Name, Bridge Number		Perry Creek, 910124		Mango Creek, 911102		Swift Creek, 910255		Middle Creek, 910273	
North Carolina Ecoregion		Piedmont		Piedmont		Piedmont		Piedmont	
Parameter		lb/ac	lb/ac-yr	lb/ac	lb/ac-yr	lb/ac	lb/ac-yr	lb/ac	lb/ac-yr
Solids	Total Dissolved Solids	4.34E+00	3.48E+02	8.28E+00	1.35E+02	8.14E+00	8.01E+02	4.58E+00	2.34E+02
	Total Suspended Solids	4.78E+00	6.75E+02	6.07E+00	1.34E+02	1.50E+01	1.46E+03	3.99E+00	3.85E+02
Nutrients	Total Phosphorus	1.3E-02	2.5E+00	1.9E-02	2.8E-01	4.4E-02	5.2E+00	2.0E-02	2.0E+00
	Orthophosphate	9.2E-04	1.7E-01	4.1E-03	5.1E-02	5.0E-03	5.5E-01	3.7E-03	1.8E-01
	Total Nitrogen	9.8E-02	1.1E+01	1.5E-01	2.5E+00	2.6E-01	2.2E+01	1.8E-01	9.0E+00
	Ammonia	6.1E-03	1.4E+00	1.1E-02	1.6E-01	8.8E-03	2.0E+00	2.1E-02	1.2E+00
	Total Kjeldahl Nitrogen	7.2E-02	8.3E+00	8.6E-02	1.4E+00	2.7E-01	2.6E+01	1.4E-01	7.2E+00
	Nitrate + Nitrite	2.7E-02	2.9E+00	6.4E-02	1.0E+00	4.4E-02	3.8E+00	3.4E-02	1.8E+00
Trace Metals	Total Recoverable Arsenic	1.1E-04	1.1E-02	2.5E-04	3.6E-03	1.4E-04	1.7E-02	2.1E-04	1.3E-02
	Total Recoverable Cadmium	9.2E-06	1.6E-03	2.8E-05	3.3E-04	3.5E-05	3.1E-03	1.5E-05	8.9E-04
	Dissolved Cadmium	3.2E-06	3.5E-04	4.1E-06	1.3E-04	3.7E-06	3.0E-04	4.6E-06	2.4E-04
	Total Recoverable Chromium	5.7E-04	8.5E-02	8.4E-04	1.1E-02	2.6E-03	2.6E-01	1.0E-03	6.4E-02
	Total Recoverable Copper	2.19E-03	2.76E-01	4.05E-03	1.26E-01	4.74E-03	3.81E-01	1.99E-03	2.51E-01
	Dissolved Copper	4.8E-04	5.2E-02	5.8E-04	8.5E-03	8.6E-04	6.9E-02	8.0E-04	3.9E-02
	Total Recoverable Iron	1.44E-01	4.22E+01	3.41E-01	5.72E+00	6.11E-01	5.11E+01	1.87E-01	1.49E+01
	Total Recoverable Nickel	2.6E-04	4.7E-02	5.3E-04	6.7E-03	7.8E-04	8.0E-02	3.2E-04	2.0E-02
	Total Recoverable Lead	1.16E-03	1.55E-01	8.34E-04	1.68E-02	9.78E-03	8.63E-01	3.51E-03	2.34E-01
	Dissolved Lead	1.1E-05	1.0E-03	2.0E-05	2.3E-04	3.4E-05	4.2E-03	3.7E-05	2.2E-03
	Total Recoverable Manganese	4.41E-03	9.94E-01	9.01E-03	1.42E-01	2.64E-02	1.97E+00	6.61E-03	5.98E-01
	Total Recoverable Zinc	8.56E-03	9.91E-01	2.14E-02	2.52E-01	1.78E-02	2.31E+00	1.06E-02	6.18E-01
	Dissolved Zinc	1.61E-03	1.66E-01	1.70E-03	3.17E-02	3.74E-03	2.75E-01	2.83E-03	1.46E-01
	Total Recoverable Aluminum	9.60E-02	1.92E+01	2.83E-01	3.52E+00	3.28E-01	3.13E+01	1.02E-01	9.48E+00
	Total Recoverable Mercury	5.2E-07	8.5E-05	2.3E-06	3.7E-05	1.9E-06	2.5E-04	1.5E-06	1.0E-04
Semi-volatiles	Bis(2-ethylhexyl)phthalate	1.9E-04	2.8E-02	4.7E-04	1.8E-02	2.8E-04	5.2E-02	2.5E-04	2.3E-02
Hydro-Carbons	Oil and Grease	6.1E-01	5.9E+01	1.3E+00	1.9E+01	9.1E-01	1.2E+02	8.2E-01	5.2E+01

Table 4.2-2: Median Unit Event Loads (lb/ac) and Average Unit Annual Loading Rates (lb/ac-yr) at the 15 BSP Monitoring Sites (continued)

Stream Name, Bridge Number		Black River, 810014		Smith Creek, 640132		Town Creek, 090061	
North Carolina Ecoregion		Coastal		Coastal		Coastal	
Parameter		lb/ac	lb/ac-yr	lb/ac	lb/ac-yr	lb/ac	lb/ac-yr
Solids	Total Dissolved Solids	4.77E+00	2.69E+02	4.97E+00	1.99E+02	5.88E+00	7.01E+02
	Total Suspended Solids	6.21E+00	5.55E+02	3.93E+00	1.41E+02	7.20E-01	2.48E+02
Nutrients	Total Phosphorus	6.9E-02	4.1E+00	3.4E-02	2.5E+00	1.9E-02	2.5E+00
	Orthophosphate	1.9E-02	1.1E+00	2.2E-03	2.5E-01	3.4E-03	5.1E-01
	Total Nitrogen	2.8E-01	1.8E+01	6.7E-02	2.9E+00	1.1E-01	1.3E+01
	Ammonia	8.28E-02	4.0E+00	5.3E-03	2.0E-01	3.2E-03	4.2E-01
	Total Kjeldahl Nitrogen	2.7E-01	1.6E+01	4.7E-02	1.1E+00	8.7E-02	1.0E+01
	Nitrate + Nitrite	4.7E-02	2.2E+00	2.4E-02	1.1E+00	2.1E-02	2.3E+00
Trace Metals	Total Recoverable Arsenic	3.7E-04	2.5E-02	1.6E-04	7.8E-03	2.7E-04	3.2E-02
	Total Recoverable Cadmium	1.7E-05	1.5E-03	2.7E-05	8.6E-04	7.2E-06	9.0E-04
	Dissolved Cadmium	7.1E-06	5.4E-04	2.5E-06	1.4E-04	2.2E-06	2.7E-04
	Total Recoverable Chromium	4.1E-04	4.9E-02	9.6E-04	5.8E-02	2.0E-04	2.8E-02
	Total Recoverable Copper	1.11E-03	7.90E-02	1.62E-03	1.01E-01	8.18E-04	8.28E-02
	Dissolved Copper	5.5E-04	2.7E-02	2.3E-04	1.1E-02	3.0E-04	3.9E-02
	Total Recoverable Iron	8.73E-02	1.49E+01	2.21E-01	1.48E+01	5.37E-02	6.43E+00
	Total Recoverable Nickel	2.6E-04	2.8E-02	5.5E-04	2.9E-02	2.1E-04	2.4E-02
	Total Recoverable Lead	8.26E-04	7.63E-02	6.25E-04	2.59E-02	3.82E-04	5.47E-02
	Dissolved Lead	3.2E-05	2.3E-03	4.9E-06	2.7E-04	6.2E-06	1.0E-03
	Total Recoverable Manganese	7.08E-03	6.31E-01	6.82E-03	2.64E-01	2.03E-03	2.01E-01
	Total Recoverable Zinc	1.29E-02	1.01E+00	8.25E-03	3.79E-01	6.85E-03	6.25E-01
	Dissolved Zinc	6.07E-03	5.22E-01	9.81E-04	3.87E-02	2.07E-03	2.14E-01
	Total Recoverable Aluminum	9.76E-02	7.14E+00	1.10E-01	4.62E+00	3.78E-02	3.60E+00
	Total Recoverable Mercury	1.4E-06	8.4E-05	9.9E-07	6.1E-05	6.0E-07	1.0E-04
Semi-volatiles	Bis(2-ethylhexyl)phthalate	1.5E-04	1.4E-02	3.2E-04	1.2E-01	1.2E-04	1.7E-02
Hydro-Carbons	Oil and Grease	7.6E-01	5.4E+01	9.7E-01	4.7E+01	6.3E-01	7.4E+01

Table 4.2-3: Visual Comparison of Unit Annual Loading Rates for BSP Monitoring Sites

		North Carolina Ecoregion and BSP Monitoring Site														
		Blue Ridge					Piedmont							Coastal		
	Parameter	Flat Creek	Big Ivy Creek	Dillingham Creek	Swannanoa River	Boylston Creek	Mallard Creek	Mountain Creek	Little River	Perry Creek	Mango Creek	Swift Creek	Middle Creek	Black River	Smith Creek	Town Creek
Solids	Total Dissolved Solids															
	Total Suspended Solids															
Nutrients	Total Phosphorus															
	Orthophosphate															
	Total Nitrogen															
	Ammonia															
	Total Kjeldahl Nitrogen															
	Nitrate + Nitrite															
Trace Metals	Total Recoverable Arsenic															
	Total Recoverable Cadmium															
	Dissolved Cadmium															
	Total Recoverable Chromium															
	Total Recoverable Copper															
	Dissolved Copper															
	Total Recoverable Iron															
	Total Recoverable Nickel															
	Total Recoverable Lead															
	Dissolved Lead															
	Total Recoverable Manganese															
	Total Recoverable Zinc															
	Dissolved Zinc															
	Total Recoverable Aluminum															
	Total Recoverable Mercury															
Semi-Volatiles	Bis(2-ethylhexyl)phthalate															
Hydro-carbons	Oil and Grease															

Note: Shades of cells represent the tendency of the site-specific average annual loading rate towards the following ranges:

- Annual site loading rate is less than or equal to the median annual loading rate of all 15 BSP bridge sites.
- Annual site loading rate is greater than the median value and less than twice the median value of all sites.
- Annual site loading rate is two times greater than the median value and less than five times the median of all sites.
- Annual site loading rate is five times greater than the median annual loading rate of all 15 BSP bridge sites.

Literature values presented in table 4.2-4 are based on the work of several researchers who have reported on highway, secondary roadway, and bridge deck runoff characteristics throughout the United States. A compilation of median, minimum, and maximum values for these studies is provided in appendix 4-A.

Median annual loading rates for each parameter estimated as part of this study were compared to median values reported in three other bridge deck studies (table 4.2-4) to assess if the results of this study were generally inline with previous efforts. A summary of this comparison follows:

Rates below or equal to other bridge deck values:

- total dissolved solids
- total suspended solids
- dissolved orthophosphate
- ammonia
- total recoverable cadmium
- total recoverable chromium
- total recoverable copper
- dissolved copper
- total recoverable nickel
- total recoverable lead

Rates above other bridge deck values:

- total phosphorus
- total nitrogen
- total kjeldahl nitrogen
- dissolved zinc
- oil and grease

Likewise, following is a comparison of median annual loading rates calculated for the 15 BSP bridge deck runoff monitoring sites to median values reported in other highway studies for the applicable parameters:

Rates below or equal to other highway values:

- total dissolved solids
- dissolved orthophosphate
- nitrate + nitrite
- total recoverable cadmium
- total recoverable chromium
- total recoverable nickel
- total recoverable lead

Rates above other highway values:

- total suspended solids
- total phosphorus
- total nitrogen
- ammonia
- total kjeldahl nitrogen
- total recoverable copper
- total recoverable iron
- total recoverable zinc
- oil and grease

In general, BSP median loading rates for oil and grease and most nutrients appear to be higher than literature values, while rates for most metals and solids appear to be lower than literature values. While a comparison of the median rates is instructive, inspection of the range of loading rates provides additional insight into how the BSP unit annual loading rates compare to values from the other studies. As shown, ranges of BSP unit annual loading rates for most parameters are either within or below ranges reported in other highway studies; these parameters include total dissolved solids, total suspended solids, orthophosphate, ammonia, total kjeldahl nitrogen, total recoverable cadmium, total recoverable copper, total recoverable lead, total recoverable zinc, and oil and grease. For parameters where BSP maximum loading rates were higher than ranges reported in the other highway studies (including total phosphorus, total nitrogen, nitrate plus nitrite, total recoverable chromium, total recoverable iron, and total recoverable nickel), the BSP maximum values were generally comparable or within an order of magnitude of the maximum unit annual loading rate values reported by the other highways studies. It should also be noted that ranges for most literature values are very large (orders of magnitude for oil and grease and other parameters).

The comparison of unit annual loading rates provides no compelling evidence to suggest that bridge deck runoff loads in this study are consistently higher or lower than stormwater runoff loads from other studies.

Table 4.2-4: Comparison of BSP Bridge Deck Runoff Annual Loading Rates to Literature Values

Parameters		Units	Literature Annual Loading Rates				BSP Annual Loading Rates	
			Bridge Deck[a], n = 3		Highway[b], n > 29		Bridge Deck, n = 15	
			Range	Median	Range	Median	Range	Median
Solids	Total Dissolved Solids	lb/ac-yr	210 - 1,914	1,062	41 - 1,896	654	135 - 855	348
	Total Suspended Solids	lb/ac-yr	423 - 2,389	826	2 - 10,583	185	134 - 1643	555
Nutrients	Total Phosphorus	lb/ac-yr	0.8 - 0.83	0.82	0.01 - 8.9	0.91	0.28 - 12	3.8
	Orthophosphate	lb/ac-yr	0.31 - 1.1	0.71	0.01 - 3.7	0.55	0.051 - 2.0	0.28
	Total Nitrogen	lb/ac-yr	9.71	9.71	0.29 - 21.1	5.18	2.5 - 25	16
	Ammonia	lb/ac-yr	2.88 - 8.1	5.49	0.09 - 10.6	0.73	0.16 - 6.2	1.4
	Total Kjeldahl Nitrogen	lb/ac-yr	6.58 - 13.9	6.88	0.84 - 28.51	7.9	1.1 - 26	12
	Nitrate + Nitrite	lb/ac-yr	-----	-----	1.8 - 4.2	3.1	1.0 - 7.1	2.9
Trace Metals	Total Recoverable Arsenic	lb/ac-yr	-----	-----	-----	-----	0.0036 - 0.032	0.013
	Total Recoverable Cadmium	lb/ac-yr	0.03	0.03	0.006 - 0.05	0.03	0.00033 - 0.0060	0.0014
	Dissolved Cadmium	lb/ac-yr	-----	-----	-----	-----	0.0001 - 0.002	0.0003
	Total Recoverable Chromium	lb/ac-yr	0.08	0.08	0.01 - 0.09	0.06	0.011 - 0.32	0.058
	Total Recoverable Copper	lb/ac-yr	0.12 - 0.20	0.16	0.001 - 4.17	0.07	0.061 - 0.63	0.14
	Dissolved Copper	lb/ac-yr	0.03	0.03	-----	-----	0.0085 - 0.14	0.031
	Total Recoverable Iron	lb/ac-yr	-----	-----	0.047 - 25.70	2.23	5.72 - 86.5	19.9
	Total Recoverable Nickel	lb/ac-yr	0.08	0.08	0.02 - 0.06	0.04	0.0067 - 0.11	0.044
	Total Recoverable Lead	lb/ac-yr	0.07 - 0.18	0.125	0.001 - 18.9	0.40	0.0168 - 0.863	0.0827
	Dissolved Lead	lb/ac-yr	-----	-----	-----	-----	0.00023 - 0.0042	0.0020
	Total Recoverable Manganese	lb/ac-yr	-----	-----	-----	-----	0.142 - 2.50	0.926
	Total Recoverable Zinc	lb/ac-yr	1.23	1.23	0.002 - 9.28	0.28	0.252 - 6.42	0.991
	Dissolved Zinc	lb/ac-yr	0.21	0.21	-----	-----	0.0317 - 0.697	0.259
	Total Recoverable Aluminum	lb/ac-yr	-----	-----	-----	-----	3.52 - 48.5	12.9
	Total Recoverable Mercury	lb/ac-yr	-----	-----	-----	-----	0.000037 - 0.00040	0.00011
Semi-volatiles	Bis(2-ethylhexyl)phthalate	lb/ac-yr	-----	-----	-----	-----	0.003 - 0.1	0.02
Hydro-carbons	Oil and Grease	lb/ac-yr	19.5 - 58.3	31.16	0.05 - 684	14.1	19 - 211	74

Notes:

[a] Bridge deck literature values are from the following studies: Malina et al., 2005a; Wu and Allan, 2001; and Wu et al., 1998.

[b] Literature values for highway roads include freeways, highways, and secondary roads from the following studies: Wu and Allan, 2009; Skipper, 2008; Gilbert and Clausen, 2006; Burton and Pitt, 2002; Wu and Allan, 2001; Wu et al., 1998; Barrett et al., 1995a; Barrett et al., 1995b, and Horner, 1992.

Replacement pages 3-G-1 through 3-G-15 in Appendix 3-G

for

Stormwater Runoff from Bridges: Final Report to Joint Transportation Oversite Committee (July 2010)

Revision May 2012

Table 3-G.1: Hydrologic Data Summary for Bridge 100734 over Big Ivy Creek (USGS Station 354728082321901)

Contributing Drainage Area = 0.08 ac. Total Wet Time / Total Dry Time [a] = 0.014

Sample Start Date	Sample Start Time	Sample End Date	Sample End Time	Hydrologic Data for Wet Weather Period [b]				Sample Event Precipitation Intensity [e]	
				Antecedent Dry Period [c] (days)	Precipitation Total (in)	Total Bridge Deck Runoff Volume [d] (liters)	Total Bridge Deck Runoff Duration (hr) [h]	Average Intensity (in/hr)	Maximum Intensity (in/hr)
6/16/2009	21:14	6/17/2009	07:46	5.0	1.31 [f]	10195	1.5	0.10	0.70
7/8/2009	09:31	7/8/2009	10:15	2.5	0.14 [f]	1117	0.5	0.07	0.07
7/27/2009	21:57	7/27/2009	22:28	6.0	0.12	937	0.6	0.17	0.12
7/30/2009	19:36	7/30/2009	20:03	2.0	0.54	4219	0.7	0.77	0.54
8/10/2009	14:55	8/11/2009	14:18	5.0	0.57	4453	1.0	0.02	0.37
9/9/2009	12:00	9/9/2009	14:07	9.0	0.47 [f]	3687	0.7	0.14	0.32
9/16/2009	09:44	9/16/2009	11:25	6.5	0.76 [f]	5929	3.3	0.10	0.12
10/12/2009	11:27	10/14/2009	10:29	2.5	0.81 [f]	6297	2.9	0.01	0.08
10/31/2009	11:23	10/31/2009	22:18	4.0	0.70 [f]	5500	NA [g]	0.04	0.10
11/30/2009	07:11	11/30/2009	14:22	7.0	0.11	859	1.8	0.01	0.10
1/16/2010	23:32	1/17/2010	03:23	16.5	0.58	4531	5.0	0.10	0.16
2/5/2010	11:13	2/5/2010	18:42	2.5	0.78	6093	1.7	0.03	0.12

Notes:

a. Wet Time to Dry Time Ratio calculated using one-minute rain gauge data provided by the United States Geological Survey (USGS). Precipitation data was converted from one-minute to five-minute time intervals for the calculation. The beginning of a wet period (storm event) was defined as the first time step after a dry period when the total precipitation measured over the preceding 1-hour interval was greater than 0.01 inches. The end of a wet period was defined as the first time step after a wet period when the total precipitation measured over the following 1-hour interval was less than or equal to 0.01 inches. To be defined as a wet period, total precipitation was required to be greater than 0.1 inches. Dry periods less than 30 minutes in duration are combined with previous and following wet periods to form one wet period. It should be noted that the wet to dry time ratio was based on data from the entire period of record for the rain gauge and will not be comparable to the antecedent dry period and runoff duration shown in the table, which were based on data for the sample events only.

b. For the sample events, the wet weather period includes the sample period and the period before and after a sampling event with measured precipitation of at least 0.01 inches. The wet weather period end time occurs when the precipitation falls below 0.01 inches. The end time for the wet weather event varied and was determined on a case by case basis. Precipitation totals were calculated from USGS rain gauge data, where available. When USGS rain gauge data were not available, NCDOT Multi-Sensor Precipitation Estimates (MPE) were used, as noted.

c. For the sample events, antecedent dry period is the dry time between wet weather events in which less than 0.1 inches of precipitation was measured within a six hour period. Precipitation data evaluated on an hourly basis and obtained from the NCDOT MPE website (www.nc-climate.ncsu.edu/dot/).

d. Bridge deck runoff volume calculated using the Simple Method with a runoff coefficient of 0.95. [Runoff Volume (ac-ft) = Runoff Coefficient * Precipitation (ft) * Outlet Drainage Area (ac)]

e. Sample event is the period from the start of sampling to the end of sampling as provided by USGS. Average intensity calculated for precipitation occuring during the sample event time only. Maximum intensity taken as the intensity calculated over a 60 minute period. Precipitation values 30 minutes preceeding and following the sampling event start and stop time were used in calculations, but only values within the time frame of the sampling event were taken into consideration for the maximum intensity value.

f. Precipitation data obtained from NCDOT MPE website (www.nc-climate.ncsu.edu/dot/) for these sample events.

g. Data not reported due to potential malfunction in precipitation or discharge measuring devices.

h. Runoff duration based on provisional USGS hydrograph data.

Table 3-G.2: Hydrologic Data Summary for Bridge 810014 over Black River (USGS Station 344516078172101)

Contributing Drainage Area = 0.11 ac. Total Wet Time / Total Dry Time [a] = 0.014

Sample Start Date	Sample Start Time	Sample End Date	Sample End Time	Hydrologic Data for Wet Weather Period [b]				Sample Event Precipitation Intensity [e]	
				Antecedent Dry Period [c] (days)	Precipitation Total (in)	Total Bridge Deck Runoff Volume [d] (liters)	Total Bridge Deck Runoff Duration (hr) [h]	Average Intensity (in/hr)	Maximum Intensity (in/hr)
4/11/2009	12:31	4/11/2009	13:30	8.5	0.55	5,919	1.1	0.24	0.36
4/14/2009	10:01	4/14/2009	12:15	3.0	0.87	9,345	3.8	0.10	0.26
5/4/2009	14:46	5/7/2009	08:28	12.5	1.34	14,394	6.0	0.02	0.25
6/4/2009	20:05	6/5/2009	19:15	3.0	1.57	16,864	3.2	0.03	0.65
7/16/2009	17:07	7/18/2009	01:12	9.0	0.60	6,445	2.6	0.02	0.23
7/27/2009	19:08	7/29/2009	15:32	3.0	0.46	4,941	0.4	0.01	0.42
9/16/2009	23:37	9/17/2009	01:18	16.5	0.37	3,974	1.9	0.17	0.23
11/10/2009	13:59	11/11/2009	09:30	26.5	3.76	40,388	19.1	0.11	0.36
1/17/2010	01:09	1/17/2010	05:55	16.5	0.78	8,378	3.9	0.13	0.28
1/30/2010	04:43	1/30/2010	14:37	4.5	0.61 [f]	6,595	4.1	0.05	0.13
2/5/2010	09:30	2/5/2010	14:18	2.5	1.74	18,690	8.0	0.06	0.09

Notes:

a. Wet Time to Dry Time Ratio calculated using one-minute rain gauge data provided by the United States Geological Survey (USGS). Precipitation data was converted from one-minute to five-minute time intervals for the calculation. The beginning of a wet period (storm event) was defined as the first time step after a dry period when the total precipitation measured over the preceding 1-hour interval was greater than 0.01 inches. The end of a wet period was defined as the first time step after a wet period when the total precipitation measured over the following 1-hour interval was less than or equal to 0.01 inches. To be defined as a wet period, total precipitation was required to be greater than 0.1 inches. Dry periods less than 30 minutes in duration are combined with previous and following wet periods to form one wet period. It should be noted that the wet to dry time ratio was based on data from the entire period of record for the rain gauge and will not be comparable to the antecedent dry period and runoff duration shown in the table, which were based on data for the sample events only.

b. For the sample events, the wet weather period includes the sample period and the period before and after a sampling event with measured precipitation of at least 0.01 inches. The wet weather period end time occurs when the precipitation falls below 0.01 inches. The end time for the wet weather event varied and was determined on a case by case basis. Precipitation totals were calculated from USGS rain gauge data, where available. When USGS rain gauge data were not available, NCDOT Multi-Sensor Precipitation Estimates (MPE) were used, as noted.

c. For the sample events, antecedent dry period is the dry time between wet weather events in which less than 0.1 inches of precipitation was measured within a six hour period. Precipitation data evaluated on an hourly basis and obtained from the NCDOT MPE website (www.nc-climate.ncsu.edu/dot/).

d. Bridge deck runoff volume calculated using the Simple Method with a runoff coefficient of 0.95. [Runoff Volume (ac-ft) = Runoff Coefficient * Precipitation (ft) * Outlet Drainage Area (ac)]

e. Sample event is the period from the start of sampling to the end of sampling as provided by USGS. Average intensity calculated for precipitation occuring during the sample event time only. Maximum intensity taken as the intensity calculated over a 60 minute period. Precipitation values 30 minutes preceeding and following the sampling event start and stop time were used in calculations, but only values within the time frame of the sampling event were taken into consideration for the maximum intensity value.

f. Precipitation data obtained from NCDOT MPE website (www.nc-climate.ncsu.edu/dot/) for these sample events.

g. Data not reported due to potential malfunction in precipitation or discharge measuring devices.

h. Runoff duration based on provisional USGS hydrograph data.

Table 3-G.3: Hydrologic Data Summary for Bridge 440008 over Boylston Creek (USGS Station 352231082325601)

Contributing Drainage Area = 0.24 ac. Total Wet Time / Total Dry Time [a] = 0.025

Sample Start Date	Sample Start Time	Sample End Date	Sample End Time	Hydrologic Data for Wet Weather Period [b]				Sample Event Precipitation Intensity [e]	
				Antecedent Dry Period [c] (days)	Precipitation Total (in)	Total Bridge Deck Runoff Volume [d] (liters)	Total Bridge Deck Runoff Duration (hr) [h]	Average Intensity (in/hr)	Maximum Intensity (in/hr)
6/4/2009	01:21	6/5/2009	04:37	6.0	0.75	17,577	7.1	0.03	0.15
6/10/2009	16:34	6/10/2009	17:15	2.0	2.33	54,606	1.6	1.23	1.62
7/22/2009	06:29	7/22/2009	17:41	9.0	0.37	8,671	1.0	0.03	0.21
8/2/2009	01:43	8/2/2009	10:03	4.0	0.30	7,031	1.5	0.03	0.16
8/4/2009	17:01	8/5/2009	16:16	2.0	0.77	18,046	2.2	0.03	0.52
9/20/2009	04:45	9/20/2009	15:25	1.0	3.07	71,949	4.5	0.21	0.44
10/23/2009	13:53	10/23/2009	21:05	6.0	0.90 [f]	21,046	3.0	0.09	0.28
12/2/2009	03:11	12/2/2009	13:33	1.5	2.17	50,856	10.2	0.15	0.27
1/16/2010	22:56	1/17/2010	04:43	16.5	1.56	36,560	6.3	0.25	0.35

Notes:

a. Wet Time to Dry Time Ratio calculated using one-minute rain gauge data provided by the United States Geological Survey (USGS). Precipitation data was converted from one-minute to five-minute time intervals for the calculation. The beginning of a wet period (storm event) was defined as the first time step after a dry period when the total precipitation measured over the preceding 1-hour interval was greater than 0.01 inches. The end of a wet period was defined as the first time step after a wet period when the total precipitation measured over the following 1-hour interval was less than or equal to 0.01 inches. To be defined as a wet period, total precipitation was required to be greater than 0.1 inches. Dry periods less than 30 minutes in duration are combined with previous and following wet periods to form one wet period. It should be noted that the wet to dry time ratio was based on data from the entire period of record for the rain gauge and will not be comparable to the antecedent dry period and runoff duration shown in the table, which were based on data for the sample events only.

b. For the sample events, the wet weather period includes the sample period and the period before and after a sampling event with measured precipitation of at least 0.01 inches. The wet weather period end time occurs when the precipitation falls below 0.01 inches. The end time for the wet weather event varied and was determined on a case by case basis. Precipitation totals were calculated from USGS rain gauge data, where available. When USGS rain gauge data were not available, NCDOT Multi-Sensor Precipitation Estimates (MPE) were used, as noted.

c. For the sample events, antecedent dry period is the dry time between wet weather events in which less than 0.1 inches of precipitation was measured within a six hour period. Precipitation data evaluated on an hourly basis and obtained from the NCDOT MPE website (www.nc-climate.ncsu.edu/dot/).

d. Bridge deck runoff volume calculated using the Simple Method with a runoff coefficient of 0.95. [Runoff Volume (ac-ft) = Runoff Coefficient * Precipitation (ft) * Outlet Drainage Area (ac)]

e. Sample event is the period from the start of sampling to the end of sampling as provided by USGS. Average intensity calculated for precipitation occuring during the sample event time only. Maximum intensity taken as the intensity calculated over a 60 minute period. Precipitation values 30 minutes preceeding and following the sampling event start and stop time were used in calculations, but only values within the time frame of the sampling event were taken into consideration for the maximum intensity value.

f. Precipitation data obtained from NCDOT MPE website (www.nc-climate.ncsu.edu/dot/) for these sample events.

g. Data not reported due to potential malfunction in precipitation or discharge measuring devices.

h. Runoff duration based on provisional USGS hydrograph data.

Table 3-G.4: Hydrologic Data Summary for Bridge 100145 over Dillingham Creek (USGS Station 354607082260901)

Contributing Drainage Area = 0.32 ac. Total Wet Time / Total Dry Time [a] = 0.012

Sample Start Date	Sample Start Time	Sample End Date	Sample End Time	Hydrologic Data for Wet Weather Period [b]				Sample Event Precipitation Intensity [e]	
				Antecedent Dry Period [c] (days)	Precipitation Total (in)	Total Bridge Deck Runoff Volume [d] (liters)	Total Bridge Deck Runoff Duration (hr) [h]	Average Intensity (in/hr)	Maximum Intensity (in/hr)
5/24/2009	09:25	5/26/2009	02:47	6.5	0.39 [f]	12,249	33.4	0.01	0.10
6/16/2009	20:17	6/16/2009	20:47	5.0	0.70 [f]	21,842	0.6	0.69	0.69
7/8/2009	09:12	7/9/2009	19:48	2.0	0.47	14,687	2.0	0.005	0.20
7/20/2009	16:26	7/23/2009	11:00	4.5	0.12	3,750	0.6	0.002	0.07
7/27/2009	21:02	7/27/2009	21:31	5.0	0.10	3,125	0.5	0.16	0.10
7/30/2009	14:26	7/31/2009	11:23	1.0	0.36	11,249	1.9	0.01	0.18
8/10/2009	14:02	8/11/2009	13:38	4.5	0.34 [f]	10,624	1.2	0.003	0.06
9/16/2009	11:49	9/18/2009	06:53	7.0	0.39	12,187	1.2	0.005	0.11
10/9/2009	22:51	10/14/2009	13:30	5.0	0.93	29,061	1.7	0.008	0.12
11/10/2009	07:01	11/10/2009	14:40	9.0	1.91	59,684	10.0	0.07	0.16
1/16/2010	18:13	1/17/2010	04:41	22.5	0.87 [f]	27,311	31.4	0.06	0.21

Notes:

a. Wet Time to Dry Time Ratio calculated using one-minute rain gauge data provided by the United States Geological Survey (USGS). Precipitation data was converted from one-minute to five-minute time intervals for the calculation. The beginning of a wet period (storm event) was defined as the first time step after a dry period when the total precipitation measured over the preceding 1-hour interval was greater than 0.01 inches. The end of a wet period was defined as the first time step after a wet period when the total precipitation measured over the following 1-hour interval was less than or equal to 0.01 inches. To be defined as a wet period, total precipitation was required to be greater than 0.1 inches. Dry periods less than 30 minutes in duration are combined with previous and following wet periods to form one wet period. It should be noted that the wet to dry time ratio was based on data from the entire period of record for the rain gauge and will not be comparable to the antecedent dry period and runoff duration shown in the table, which were based on data for the sample events only.

b. For the sample events, the wet weather period includes the sample period and the period before and after a sampling event with measured precipitation of at least 0.01 inches. The wet weather period end time occurs when the precipitation falls below 0.01 inches. The end time for the wet weather event varied and was determined on a case by case basis. Precipitation totals were calculated from USGS rain gauge data, where available. When USGS rain gauge data were not available, NCDOT Multi-Sensor Precipitation Estimates (MPE) were used, as noted.

c. For the sample events, antecedent dry period is the dry time between wet weather events in which less than 0.1 inches of precipitation was measured within a six hour period. Precipitation data evaluated on an hourly basis and obtained from the NCDOT MPE website (www.nc-climate.ncsu.edu/dot/).

d. Bridge deck runoff volume calculated using the Simple Method with a runoff coefficient of 0.95. [Runoff Volume (ac-ft) = Runoff Coefficient * Precipitation (ft) * Outlet Drainage Area (ac)]

e. Sample event is the period from the start of sampling to the end of sampling as provided by USGS. Average intensity calculated for precipitation occuring during the sample event time only. Maximum intensity taken as the intensity calculated over a 60 minute period. Precipitation values 30 minutes preceeding and following the sampling event start and stop time were used in calculations, but only values within the time frame of the sampling event were taken into consideration for the maximum intensity value.

f. Precipitation data obtained from NCDOT MPE website (www.nc-climate.ncsu.edu/dot/) for these sample events.

g. Data not reported due to potential malfunction in precipitation or discharge measuring devices.

h. Runoff duration based on provisional USGS hydrograph data.

Table 3-G.5: Hydrologic Data Summary for Bridge 100250 over Flat Creek (USGS Station 354306082372601)

Contributing Drainage Area = 0.05 ac.

Total Wet Time / Total Dry Time [a] = 0.016

Sample Start Date	Sample Start Time	Sample End Date	Sample End Time	Hydrologic Data for Wet Weather Period [b]				Sample Event Precipitation Intensity [e]	
				Antecedent Dry Period [c] (days)	Precipitation Total (in)	Total Bridge Deck Runoff Volume [d] (liters)	Total Bridge Deck Runoff Duration (hr) [h]	Average Intensity (in/hr)	Maximum Intensity (in/hr)
7/27/2009	21:30	7/28/2009	03:23	7.0	0.25	1,221	0.7	0.04	0.20
7/30/2009	14:59	7/30/2009	20:07	0.5	0.61	2,978	0.5	0.10	0.30
8/11/2009	13:52	8/11/2009	15:29	5.5	0.47	2,295	0.9	0.21	0.35
9/9/2009	12:09	9/9/2009	14:17	9.0	1.27	6,201	0.5	0.59	1.06
9/16/2009	09:19	9/16/2009	17:31	7.0	0.74	3,613	0.6	0.06	0.37
10/31/2009	18:58	11/1/2009	00:47	4.0	0.51	2,490	1.1	0.08	0.15
11/10/2009	07:30	11/10/2009	11:26	9.0	0.53	2,588	2.6	0.10	0.17
11/10/2009	17:14	11/11/2009	04:47	0.0	1.58	7,714	1.3	0.11	0.21
2/5/2010	17:07	2/5/2010	18:50	0.1	0.12	586	1.1	0.05	0.10

Notes:

a. Wet Time to Dry Time Ratio calculated using one-minute rain gauge data provided by the United States Geological Survey (USGS). Precipitation data was converted from one-minute to five-minute time intervals for the calculation. The beginning of a wet period (storm event) was defined as the first time step after a dry period when the total precipitation measured over the preceding 1-hour interval was greater than 0.01 inches. The end of a wet period was defined as the first time step after a wet period when the total precipitation measured over the following 1-hour interval was less than or equal to 0.01 inches. To be defined as a wet period, total precipitation was required to be greater than 0.1 inches. Dry periods less than 30 minutes in duration are combined with previous and following wet periods to form one wet period. It should be noted that the wet to dry time ratio was based on data from the entire period of record for the rain gauge and will not be comparable to the antecedent dry period and runoff duration shown in the table, which were based on data for the sample events only.

b. For the sample events, the wet weather period includes the sample period and the period before and after a sampling event with measured precipitation of at least 0.01 inches. The wet weather period end time occurs when the precipitation falls below 0.01 inches. The end time for the wet weather event varied and was determined on a case by case basis. Precipitation totals were calculated from USGS rain gauge data, where available. When USGS rain gauge data were not available, NCDOT Multi-Sensor Precipitation Estimates (MPE) were used, as noted.

c. For the sample events, antecedent dry period is the dry time between wet weather events in which less than 0.1 inches of precipitation was measured within a six hour period. Precipitation data evaluated on an hourly basis and obtained from the NCDOT MPE website (www.nc-climate.ncsu.edu/dot/).

d. Bridge deck runoff volume calculated using the Simple Method with a runoff coefficient of 0.95. [Runoff Volume (ac-ft) = Runoff Coefficient * Precipitation (ft) * Outlet Drainage Area (ac)]

e. Sample event is the period from the start of sampling to the end of sampling as provided by USGS. Average intensity calculated for precipitation occuring during the sample event time only. Maximum intensity taken as the intensity calculated over a 60 minute period. Precipitation values 30 minutes preceeding and following the sampling event start and stop time were used in calculations, but only values within the time frame of the sampling event were taken into consideration for the maximum intensity value.

f. Precipitation data obtained from NCDOT MPE website (www.nc-climate.ncsu.edu/dot/) for these sample events.

g. Data not reported due to potential malfunction in precipitation or discharge measuring devices.

h. Runoff duration based on provisional USGS hydrograph data.

Table 3-G.6: Hydrologic Data Summary for Bridge 310064 over Little River (USGS Station 360829078550901)

Contributing Drainage Area = 0.13 ac. Total Wet Time / Total Dry Time [a] = 0.021

Sample Start Date	Sample Start Time	Sample End Date	Sample End Time	Hydrologic Data for Wet Weather Period [b]				Sample Event Precipitation Intensity [e]	
				Antecedent Dry Period [c] (days)	Precipitation Total (in)	Total Bridge Deck Runoff Volume [d] (liters)	Total Bridge Deck Runoff Duration (hr) [h]	Average Intensity (in/hr)	Maximum Intensity (in/hr)
6/15/2009	14:04	6/15/2009	15:21	3.5	1.25	15,868	0.4	0.80	0.93
7/5/2009	15:53	7/5/2009	20:41	17.5	0.28	3,554	0.6	0.05	0.23
7/17/2009	14:21	7/17/2009	15:05	11.5	0.44	5,586	0.7	0.53	0.43
7/30/2009	16:27	7/30/2009	18:28	7.0	0.18	2,285	0.4	0.08	0.17
8/5/2009	23:01	8/5/2009	23:37	3.0	0.11	1,396	0.6	0.13	0.11
9/17/2009	01:44	9/17/2009	03:34	9.0	0.39	4,951	5.0	0.07	0.13
10/12/2009	14:38	10/12/2009	15:39	14.0	0.27	3,428	2.6	0.08	0.09
10/24/2009	06:47	10/24/2009	07:50	11.5	0.53	6,728	1.8	0.15	0.16
11/10/2009	13:07	11/10/2009	19:56	9.0	5.20 [f]	66,012	34.4	0.06	0.17
1/17/2010	00:33	1/17/2010	05:34	9.0	1.42	18,026	6.8	0.12	0.33
2/2/2010	12:37	2/2/2010	18:05	2.5	0.30	3,808	5.6	0.01	0.03
2/5/2010	10:01	2/5/2010	14:13	3.0	1.66	21,073	12.5	0.10	0.20

Notes:

a. Wet Time to Dry Time Ratio calculated using one-minute rain gauge data provided by the United States Geological Survey (USGS). Precipitation data was converted from one-minute to five-minute time intervals for the calculation. The beginning of a wet period (storm event) was defined as the first time step after a dry period when the total precipitation measured over the preceding 1-hour interval was greater than 0.01 inches. The end of a wet period was defined as the first time step after a wet period when the total precipitation measured over the following 1-hour interval was less than or equal to 0.01 inches. To be defined as a wet period, total precipitation was required to be greater than 0.1 inches. Dry periods less than 30 minutes in duration are combined with previous and following wet periods to form one wet period. It should be noted that the wet to dry time ratio was based on data from the entire period of record for the rain gauge and will not be comparable to the antecedent dry period and runoff duration shown in the table, which were based on data for the sample events only.

b. For the sample events, the wet weather period includes the sample period and the period before and after a sampling event with measured precipitation of at least 0.01 inches. The wet weather period end time occurs when the precipitation falls below 0.01 inches. The end time for the wet weather event varied and was determined on a case by case basis. Precipitation totals were calculated from USGS rain gauge data, where available. When USGS rain gauge data were not available, NCDOT Multi-Sensor Precipitation Estimates (MPE) were used, as noted.

c. For the sample events, antecedent dry period is the dry time between wet weather events in which less than 0.1 inches of precipitation was measured within a six hour period. Precipitation data evaluated on an hourly basis and obtained from the NCDOT MPE website (www.nc-climate.ncsu.edu/dot/).

d. Bridge deck runoff volume calculated using the Simple Method with a runoff coefficient of 0.95. [Runoff Volume (ac-ft) = Runoff Coefficient * Precipitation (ft) * Outlet Drainage Area (ac)]

e. Sample event is the period from the start of sampling to the end of sampling as provided by USGS. Average intensity calculated for precipitation occuring during the sample event time only. Maximum intensity taken as the intensity calculated over a 60 minute period. Precipitation values 30 minutes preceeding and following the sampling event start and stop time were used in calculations, but only values within the time frame of the sampling event were taken into consideration for the maximum intensity value.

f. Precipitation data obtained from NCDOT MPE website (www.nc-climate.ncsu.edu/dot/) for these sample events.

g. Data not reported due to potential malfunction in precipitation or discharge measuring devices.

h. Runoff duration based on provisional USGS hydrograph data.

Table 3-G.7: Hydrologic Data Summary for Bridge 590296 over Mallard Creek (USGS Station 351911080450501)

Contributing Drainage Area = 0.39 ac. Total Wet Time / Total Dry Time [a] = 0.017

Sample Start Date	Sample Start Time	Sample End Date	Sample End Time	Hydrologic Data for Wet Weather Period [b]				Sample Event Precipitation Intensity [e]	
				Antecedent Dry Period [c] (days)	Precipitation Total (in)	Total Bridge Deck Runoff Volume [d] (liters)	Total Bridge Deck Runoff Duration (hr) [h]	Average Intensity (in/hr)	Maximum Intensity (in/hr)
6/4/2009	19:30	6/5/2009	10:05	6.0	2.70	102,826	0.9	0.18	0.88
6/16/2009	18:48	6/17/2009	09:46	4.0	0.70	26,659	2.9	0.04	0.60
7/6/2009	01:50	7/9/2009	03:33	17.0	0.55	20,946	3.8	0.01	0.36
7/21/2009	19:35	7/22/2009	23:33	8.5	1.20	45,701	3.3	0.04	0.68
8/5/2009	18:35	8/5/2009	23:45	5.0	0.93	35,418	2.5	0.14	0.61
9/16/2009	15:02	9/17/2009	05:03	6.0	0.83	31,610	2.0	0.05	0.61
10/27/2009	13:45	10/27/2009	21:16	3.0	1.40 [f]	53,470	8.3	0.14	0.56
12/8/2009	18:26	12/9/2009	05:49	5.5	1.28	48,747	10.8	0.07	0.39
1/16/2010	18:57	1/17/2010	01:44	16.5	1.24	47,224	11.1	0.09	0.21
2/13/2010	02:35	2/15/2010	11:34	2.5	0.34	12,948	9.0	0.01	0.17

Notes:

a. Wet Time to Dry Time Ratio calculated using one-minute rain gauge data provided by the United States Geological Survey (USGS). Precipitation data was converted from one-minute to five-minute time intervals for the calculation. The beginning of a wet period (storm event) was defined as the first time step after a dry period when the total precipitation measured over the preceding 1-hour interval was greater than 0.01 inches. The end of a wet period was defined as the first time step after a wet period when the total precipitation measured over the following 1-hour interval was less than or equal to 0.01 inches. To be defined as a wet period, total precipitation was required to be greater than 0.1 inches. Dry periods less than 30 minutes in duration are combined with previous and following wet periods to form one wet period. It should be noted that the wet to dry time ratio was based on data from the entire period of record for the rain gauge and will not be comparable to the antecedent dry period and runoff duration shown in the table, which were based on data for the sample events only.

b. For the sample events, the wet weather period includes the sample period and the period before and after a sampling event with measured precipitation of at least 0.01 inches. The wet weather period end time occurs when the precipitation falls below 0.01 inches. The end time for the wet weather event varied and was determined on a case by case basis. Precipitation totals were calculated from USGS rain gauge data, where available. When USGS rain gauge data were not available, NCDOT Multi-Sensor Precipitation Estimates (MPE) were used, as noted.

c. For the sample events, antecedent dry period is the dry time between wet weather events in which less than 0.1 inches of precipitation was measured within a six hour period. Precipitation data evaluated on an hourly basis and obtained from the NCDOT MPE website (www.nc-climate.ncsu.edu/dot/).

d. Bridge deck runoff volume calculated using the Simple Method with a runoff coefficient of 0.95. [Runoff Volume (ac-ft) = Runoff Coefficient * Precipitation (ft) * Outlet Drainage Area (ac)]

e. Sample event is the period from the start of sampling to the end of sampling as provided by USGS. Average intensity calculated for precipitation occuring during the sample event time only. Maximum intensity taken as the intensity calculated over a 60 minute period. Precipitation values 30 minutes preceeding and following the sampling event start and stop time were used in calculations, but only values within the time frame of the sampling event were taken into consideration for the maximum intensity value.

f. Precipitation data obtained from NCDOT MPE website (www.nc-climate.ncsu.edu/dot/) for these sample events.

g. Data not reported due to potential malfunction in precipitation or discharge measuring devices.

h. Runoff duration based on provisional USGS hydrograph data.

Table 3-G.8: Hydrologic Data Summary for Bridge 911102 over Mango Creek (USGS Station 354703078304801)

Contributing Drainage Area = 1.29 ac. Total Wet Time / Total Dry Time [a] = 0.014

Sample Start Date	Sample Start Time	Sample End Date	Sample End Time	Hydrologic Data for Wet Weather Period [b]				Sample Event Precipitation Intensity [e]	
				Antecedent Dry Period [c] (days)	Precipitation Total (in)	Total Bridge Deck Runoff Volume [d] (liters)	Total Bridge Deck Runoff Duration (hr) [h]	Average Intensity (in/hr)	Maximum Intensity (in/hr)
3/19/2009	20:17	3/19/2009	22:51	3.0	0.44 [f]	55,175	4.1	0.09	0.12
3/27/2009	15:58	3/28/2009	22:14	0.5	0.96 [f]	121,182	11.6	0.03	0.31
5/4/2009	21:44	5/8/2009	00:23	13.0	3.28	413,179	10.3	0.04	1.41
5/16/2009	11:58	5/17/2009	13:32	7.0	1.48	186,435	7.1	0.03	0.36
6/15/2009	16:42	6/16/2009	14:24	5.0	1.88	236,822	8.7	0.08	0.58
10/24/2009	05:06	10/27/2009	04:06	9.5	0.18	22,674	15.8	0.002	0.03
11/10/2009	19:22	11/11/2009	19:44	9.0	3.91	492,540	29.8	0.14	0.32
11/22/2009	22:56	11/23/2009	13:11	3.5	0.45	56,686	11.3	0.03	0.12
1/17/2010	01:47	1/17/2010	18:31	16.5	1.46	183,915	11.9	0.09	0.39
2/2/2010	14:17	2/3/2010	18:18	2.5	0.26	32,752	13.8	0.005	0.08
2/5/2010	08:41	2/5/2010	21:52	2.0	1.84	231,784	15.8	0.12	0.26

Notes:

a. Wet Time to Dry Time Ratio calculated using one-minute rain gauge data provided by the United States Geological Survey (USGS). Precipitation data was converted from one-minute to five-minute time intervals for the calculation. The beginning of a wet period (storm event) was defined as the first time step after a dry period when the total precipitation measured over the preceding 1-hour interval was greater than 0.01 inches. The end of a wet period was defined as the first time step after a wet period when the total precipitation measured over the following 1-hour interval was less than or equal to 0.01 inches. To be defined as a wet period, total precipitation was required to be greater than 0.1 inches. Dry periods less than 30 minutes in duration are combined with previous and following wet periods to form one wet period. It should be noted that the wet to dry time ratio was based on data from the entire period of record for the rain gauge and will not be comparable to the antecedent dry period and runoff duration shown in the table, which were based on data for the sample events only.

b. For the sample events, the wet weather period includes the sample period and the period before and after a sampling event with measured precipitation of at least 0.01 inches. The wet weather period end time occurs when the precipitation falls below 0.01 inches. The end time for the wet weather event varied and was determined on a case by case basis. Precipitation totals were calculated from USGS rain gauge data, where available. When USGS rain gauge data were not available, NCDOT Multi-Sensor Precipitation Estimates (MPE) were used, as noted.

c. For the sample events, antecedent dry period is the dry time between wet weather events in which less than 0.1 inches of precipitation was measured within a six hour period. Precipitation data evaluated on an hourly basis and obtained from the NCDOT MPE website (www.nc-climate.ncsu.edu/dot/).

d. Bridge deck runoff volume calculated using the Simple Method with a runoff coefficient of 0.95. [Runoff Volume (ac-ft) = Runoff Coefficient * Precipitation (ft) * Outlet Drainage Area (ac)]

e. Sample event is the period from the start of sampling to the end of sampling as provided by USGS. Average intensity calculated for precipitation occuring during the sample event time only. Maximum intensity taken as the intensity calculated over a 60 minute period. Precipitation values 30 minutes preceeding and following the sampling event start and stop time were used in calculations, but only values within the time frame of the sampling event were taken into consideration for the maximum intensity value.

f. Precipitation data obtained from NCDOT MPE website (www.nc-climate.ncsu.edu/dot/) for these sample events.

g. Data not reported due to potential malfunction in precipitation or discharge measuring devices.

h. Runoff duration based on provisional USGS hydrograph data.

Table 3-G.9: Hydrologic Data Summary for Bridge 910273 over Middle Creek (USGS Station 353633078411001)

Contributing Drainage Area = 0.15 ac. Total Wet Time / Total Dry Time [a] = 0.014

Sample Start Date	Sample Start Time	Sample End Date	Sample End Time	Hydrologic Data for Wet Weather Period [b]				Sample Event Precipitation Intensity [e]	
				Antecedent Dry Period [c] (days)	Precipitation Total (in)	Total Bridge Deck Runoff Volume [d] (liters)	Total Bridge Deck Runoff Duration (hr) [h]	Average Intensity (in/hr)	Maximum Intensity (in/hr)
5/17/2009	10:35	5/17/2009	11:24	6.0	0.76	11,132	1.3	0.38	0.46
6/4/2009	21:59	6/5/2009	02:51	6.5	1.33	19,481	1.3	0.26	0.63
6/16/2009	04:06	6/16/2009	10:15	6.0	0.93	13,622	1.8	0.14	0.39
7/13/2009	09:00	7/13/2009	12:27	4.0	0.71	10,400	2.2	0.19	0.53
8/22/2009	15:08	8/22/2009	18:43	5.0	0.58	8,496	3.2	0.09	0.22
9/22/2009	07:57	9/22/2009	18:24	5.0	0.53	7,763	3.8	0.02	0.15
10/12/2009	14:58	10/12/2009	20:04	19.5	0.13	1,904	1.7	0.02	0.04
11/10/2009	18:33	11/11/2009	00:25	9.0	3.17	46,433	16.8	0.15	0.22
12/25/2009	10:01	12/25/2009	18:08	6.0	0.67	9,814	4.0	0.08	0.18
1/17/2010	02:20	1/17/2010	05:46	16.5	1.04	15,234	4.0	0.16	0.32
2/5/2010	09:30	2/5/2010	14:18	2.0	1.68	24,608	9.4	0.08	0.11

Notes:

a. Wet Time to Dry Time Ratio calculated using one-minute rain gauge data provided by the United States Geological Survey (USGS). Precipitation data was converted from one-minute to five-minute time intervals for the calculation. The beginning of a wet period (storm event) was defined as the first time step after a dry period when the total precipitation measured over the preceding 1-hour interval was greater than 0.01 inches. The end of a wet period was defined as the first time step after a wet period when the total precipitation measured over the following 1-hour interval was less than or equal to 0.01 inches. To be defined as a wet period, total precipitation was required to be greater than 0.1 inches. Dry periods less than 30 minutes in duration are combined with previous and following wet periods to form one wet period. It should be noted that the wet to dry time ratio was based on data from the entire period of record for the rain gauge and will not be comparable to the antecedent dry period and runoff duration shown in the table, which were based on data for the sample events only.

b. For the sample events, the wet weather period includes the sample period and the period before and after a sampling event with measured precipitation of at least 0.01 inches. The wet weather period end time occurs when the precipitation falls below 0.01 inches. The end time for the wet weather event varied and was determined on a case by case basis. Precipitation totals were calculated from USGS rain gauge data, where available. When USGS rain gauge data were not available, NCDOT Multi-Sensor Precipitation Estimates (MPE) were used, as noted.

c. For the sample events, antecedent dry period is the dry time between wet weather events in which less than 0.1 inches of precipitation was measured within a six hour period. Precipitation data evaluated on an hourly basis and obtained from the NCDOT MPE website (www.nc-climate.ncsu.edu/dot/).

d. Bridge deck runoff volume calculated using the Simple Method with a runoff coefficient of 0.95. [Runoff Volume (ac-ft) = Runoff Coefficient * Precipitation (ft) * Outlet Drainage Area (ac)]

e. Sample event is the period from the start of sampling to the end of sampling as provided by USGS. Average intensity calculated for precipitation occuring during the sample event time only. Maximum intensity taken as the intensity calculated over a 60 minute period. Precipitation values 30 minutes preceeding and following the sampling event start and stop time were used in calculations, but only values within the time frame of the sampling event were taken into consideration for the maximum intensity value.

f. Precipitation data obtained from NCDOT MPE website (www.nc-climate.ncsu.edu/dot/) for these sample events.

g. Data not reported due to potential malfunction in precipitation or discharge measuring devices.

h. Runoff duration based on provisional USGS hydrograph data.

Table 3-G.10: Hydrologic Data Summary for Bridge 310005 over Mountain Creek (USGS Station 360908078540701)

Contributing Drainage Area = 0.21 ac. Total Wet Time / Total Dry Time [a] = 0.019

Sample Start Date	Sample Start Time	Sample End Date	Sample End Time	Hydrologic Data for Wet Weather Period [b]				Sample Event Precipitation Intensity [e]	
				Antecedent Dry Period [c] (days)	Precipitation Total (in)	Total Bridge Deck Runoff Volume [d] (liters)	Total Bridge Deck Runoff Duration (hr) [h]	Average Intensity (in/hr)	Maximum Intensity (in/hr)
5/4/2009	21:21	5/7/2009	01:09	14.5	0.61	12,509	2.7	0.01	0.28
5/26/2009	11:28	5/26/2009	16:07	0.5	0.22	4,511	0.9	0.03	0.06
6/4/2009	17:21	6/5/2009	00:41	6.0	1.75	35,887	7.2	0.05	0.17
7/5/2009	15:52	7/5/2009	20:53	17.5	0.23	4,717	0.8	0.04	0.18
7/17/2009	14:21	7/18/2009	00:11	11.5	1.20	24,608	1.8	0.06	0.66
7/29/2009	15:59	7/30/2009	18:14	6.0	0.26	5,332	1.3	0.01	0.14
9/17/2009	01:56	9/17/2009	06:01	9.0	0.35	7,177	8.2	0.04	0.09
10/12/2009	14:32	10/12/2009	16:36	14.0	0.25	5,127	2.1	0.06	0.09
10/24/2009	07:03	10/24/2009	07:57	11.5	0.43	8,818	2.1	0.12	0.13
1/17/2010	01:18	1/17/2010	05:07	9.0	1.14	23,378	6.0	0.12	0.26
2/2/2010	18:06	2/2/2010	22:15	2.5	0.23	4,717	2.3	0.05	0.12
2/5/2010	09:45	2/5/2010	15:29	2.0	1.60	32,811	9.7	0.11	0.19

Notes:

a. Wet Time to Dry Time Ratio calculated using one-minute rain gauge data provided by the United States Geological Survey (USGS). Precipitation data was converted from one-minute to five-minute time intervals for the calculation. The beginning of a wet period (storm event) was defined as the first time step after a dry period when the total precipitation measured over the preceding 1-hour interval was greater than 0.01 inches. The end of a wet period was defined as the first time step after a wet period when the total precipitation measured over the following 1-hour interval was less than or equal to 0.01 inches. To be defined as a wet period, total precipitation was required to be greater than 0.1 inches. Dry periods less than 30 minutes in duration are combined with previous and following wet periods to form one wet period. It should be noted that the wet to dry time ratio was based on data from the entire period of record for the rain gauge and will not be comparable to the antecedent dry period and runoff duration shown in the table, which were based on data for the sample events only.

b. For the sample events, the wet weather period includes the sample period and the period before and after a sampling event with measured precipitation of at least 0.01 inches. The wet weather period end time occurs when the precipitation falls below 0.01 inches. The end time for the wet weather event varied and was determined on a case by case basis. Precipitation totals were calculated from USGS rain gauge data, where available. When USGS rain gauge data were not available, NCDOT Multi-Sensor Precipitation Estimates (MPE) were used, as noted.

c. For the sample events, antecedent dry period is the dry time between wet weather events in which less than 0.1 inches of precipitation was measured within a six hour period. Precipitation data evaluated on an hourly basis and obtained from the NCDOT MPE website (www.nc-climate.ncsu.edu/dot/).

d. Bridge deck runoff volume calculated using the Simple Method with a runoff coefficient of 0.95. [Runoff Volume (ac-ft) = Runoff Coefficient * Precipitation (ft) * Outlet Drainage Area (ac)]

e. Sample event is the period from the start of sampling to the end of sampling as provided by USGS. Average intensity calculated for precipitation occuring during the sample event time only. Maximum intensity taken as the intensity calculated over a 60 minute period. Precipitation values 30 minutes preceeding and following the sampling event start and stop time were used in calculations, but only values within the time frame of the sampling event were taken into consideration for the maximum intensity value.

f. Precipitation data obtained from NCDOT MPE website (www.nc-climate.ncsu.edu/dot/) for these sample events.

g. Data not reported due to potential malfunction in precipitation or discharge measuring devices.

h. Runoff duration based on provisional USGS hydrograph data.

Table 3-G.11: Hydrologic Data Summary for Bridge 910124 over Perry Creek (USGS Station 355247078325001)

Contributing Drainage Area = 0.30 ac. Total Wet Time / Total Dry Time [a] = 0.015

Sample Start Date	Sample Start Time	Sample End Date	Sample End Time	Hydrologic Data for Wet Weather Period [b]				Sample Event Precipitation Intensity [e]	
				Antecedent Dry Period [c] (days)	Precipitation Total (in)	Total Bridge Deck Runoff Volume [d] (liters)	Total Bridge Deck Runoff Duration (hr) [h]	Average Intensity (in/hr)	Maximum Intensity (in/hr)
5/4/2009	20:51	5/5/2009	18:09	3.0	1.29	37,791	3.9	0.05	0.42
5/16/2009	13:48	5/17/2009	11:22	2.0	0.62	18,163	2.2	0.02	0.21
5/24/2009	20:57	5/26/2009	13:05	7.0	1.69	49,509	2.4	0.01	0.56
6/4/2009	16:45	6/5/2009	02:52	7.0	1.05	30,760	2.4	0.22	0.43
7/6/2009	06:30	7/6/2009	06:49	4.0	0.08	2,344	0.4	0.12	0.07
7/13/2009	10:02	7/13/2009	11:36	7.0	0.30	8,789	1.1	0.16	0.27
7/28/2009	20:03	7/29/2009	13:52	4.5	0.14	4,101	0.5	0.01	0.09
9/26/2009	17:29	9/27/2009	09:26	4.0	0.18	5,273	3.2	0.01	0.10
10/24/2009	10:50	10/24/2009	18:56	10.0	0.07	2,051	1.4	0.01	0.03
1/17/2010	00:03	1/17/2010	06:37	16.5	1.17	34,275	4.5	0.14	0.48
2/2/2010	10:03	2/2/2010	13:16	2.5	0.20	5,859	12.8	0.02	0.03
2/5/2010	07:39	2/5/2010	11:45	2.0	1.62	47,458	9.6	0.05	0.07

Notes:

a. Wet Time to Dry Time Ratio calculated using one-minute rain gauge data provided by the United States Geological Survey (USGS). Precipitation data was converted from one-minute to five-minute time intervals for the calculation. The beginning of a wet period (storm event) was defined as the first time step after a dry period when the total precipitation measured over the preceding 1-hour interval was greater than 0.01 inches. The end of a wet period was defined as the first time step after a wet period when the total precipitation measured over the following 1-hour interval was less than or equal to 0.01 inches. To be defined as a wet period, total precipitation was required to be greater than 0.1 inches. Dry periods less than 30 minutes in duration are combined with previous and following wet periods to form one wet period. It should be noted that the wet to dry time ratio was based on data from the entire period of record for the rain gauge and will not be comparable to the antecedent dry period and runoff duration shown in the table, which were based on data for the sample events only.

b. For the sample events, the wet weather period includes the sample period and the period before and after a sampling event with measured precipitation of at least 0.01 inches. The wet weather period end time occurs when the precipitation falls below 0.01 inches. The end time for the wet weather event varied and was determined on a case by case basis. Precipitation totals were calculated from USGS rain gauge data, where available. When USGS rain gauge data were not available, NCDOT Multi-Sensor Precipitation Estimates (MPE) were used, as noted.

c. For the sample events, antecedent dry period is the dry time between wet weather events in which less than 0.1 inches of precipitation was measured within a six hour period. Precipitation data evaluated on an hourly basis and obtained from the NCDOT MPE website (www.nc-climate.ncsu.edu/dot/).

d. Bridge deck runoff volume calculated using the Simple Method with a runoff coefficient of 0.95. [Runoff Volume (ac-ft) = Runoff Coefficient * Precipitation (ft) * Outlet Drainage Area (ac)]

e. Sample event is the period from the start of sampling to the end of sampling as provided by USGS. Average intensity calculated for precipitation occuring during the sample event time only. Maximum intensity taken as the intensity calculated over a 60 minute period. Precipitation values 30 minutes preceeding and following the sampling event start and stop time were used in calculations, but only values within the time frame of the sampling event were taken into consideration for the maximum intensity value.

f. Precipitation data obtained from NCDOT MPE website (www.nc-climate.ncsu.edu/dot/) for these sample events.

g. Data not reported due to potential malfunction in precipitation or discharge measuring devices.

h. Runoff duration based on provisional USGS hydrograph data.

Table 3-G.12: Hydrologic Data Summary for Bridge 640132 over Smith Creek (USGS Station 341528077550701)

Contributing Drainage Area = 0.49 ac. Total Wet Time / Total Dry Time [a] = 0.019

Sample Start Date	Sample Start Time	Sample End Date	Sample End Time	Hydrologic Data for Wet Weather Period [b]				Sample Event Precipitation Intensity [e]	
				Antecedent Dry Period [c] (days)	Precipitation Total (in)	Total Bridge Deck Runoff Volume [d] (liters)	Total Bridge Deck Runoff Duration (hr) [h]	Average Intensity (in/hr)	Maximum Intensity (in/hr)
5/26/2009	01:21	5/26/2009	13:38	7.5	1.65	78,951	2.7	0.12	0.53
6/15/2009	22:02	6/16/2009	09:51	1.0	0.60	28,709	5.1	0.05	0.36
7/6/2009	00:25	7/7/2009	01:46	0.5	5.28 [f]	252,785	9.5	0.20	1.99
7/16/2009	19:10	7/18/2009	01:48	2.5	0.27	12,919	3.3	0.01	0.12
8/2/2009	16:21	8/2/2009	22:45	9.0	0.16	7,656	2.6	0.02	0.10
9/22/2009	22:39	9/22/2009	23:04	0.5	1.47	70,338	4.7	0.56	0.56
10/5/2009	08:37	10/5/2099	10:21	8.0	0.42	20,097	6.8	0.15	0.21
11/10/2009	12:57	11/13/2009	01:24	15.0	4.00	191,395	36.4	0.06	0.70
1/16/2010	23:59	1/17/2010	07:42	16.5	1.14	54,548	8.0	0.13	0.41
1/30/2010	05:46	1/30/2010	17:10	5.0	0.42	20,097	9.3	0.04	0.11
2/5/2010	10:56	2/5/2010	22:09	2.5	1.62	77,515	10.9	0.08	0.53

Notes:

a. Wet Time to Dry Time Ratio calculated using fifteen-minute rain gauge data provided by the United States Geological Survey (USGS). The beginning of a wet period (storm event) was defined as the first time step after a dry period when the total precipitation measured over the preceding 1-hour interval was greater than 0.01 inches. The end of a wet period was defined as the first time step after a wet period when the total precipitation measured over the following 1-hour interval was less than or equal to 0.01 inches. To be defined as a wet period, total precipitation was required to be greater than 0.1 inches. Dry periods less than 30 minutes in duration are combined with previous and following wet periods to form one wet period. It should be noted that the wet to dry time ratio was based on data from the entire period of record for the rain gauge and will not be comparable to the antecedent dry period and runoff duration shown in the table, which were based on data for the sample events only.

b. For the sample events, the wet weather period includes the sample period and the period before and after a sampling event with measured precipitation of at least 0.01 inches. The wet weather period end time occurs when the precipitation falls below 0.01 inches. The end time for the wet weather event varied and was determined on a case by case basis. Precipitation totals were calculated from USGS rain gauge data, where available. When USGS rain gauge data were not available, NCDOT Multi-Sensor Precipitation Estimates (MPE) were used, as noted.

c. For the sample events, antecedent dry period is the dry time between wet weather events in which less than 0.1 inches of precipitation was measured within a six hour period. Precipitation data evaluated on an hourly basis and obtained from the NCDOT MPE website (www.nc-climate.ncsu.edu/dot/).

d. Bridge deck runoff volume calculated using the Simple Method with a runoff coefficient of 0.95. [Runoff Volume (ac-ft) = Runoff Coefficient * Precipitation (ft) * Outlet Drainage Area (ac)]

e. Sample event is the period from the start of sampling to the end of sampling as provided by USGS. Average intensity calculated for precipitation occuring during the sample event time only. Maximum intensity taken as the intensity calculated over a 60 minute period. Precipitation values 30 minutes preceeding and following the sampling event start and stop time were used in calculations, but only values within the time frame of the sampling event were taken into consideration for the maximum intensity value.

f. Precipitation data obtained from NCDOT MPE website (www.nc-climate.ncsu.edu/dot/) for these sample events.

g. Data not reported due to potential malfunction in precipitation or discharge measuring devices.

h. Runoff duration based on provisional USGS hydrograph data.

Table 3-G.13: Hydrologic Data Summary for Bridge 100494 over Swannanoa River (USGS Station 353708082182101)

Contributing Drainage Area = 1.41 ac. Total Wet Time / Total Dry Time [a] = 0.028

Sample Start Date	Sample Start Time	Sample End Date	Sample End Time	Hydrologic Data for Wet Weather Period [b]				Sample Event Precipitation Intensity [e]	
				Antecedent Dry Period [c] (days)	Precipitation Total (in)	Total Bridge Deck Runoff Volume [d] (liters)	Total Bridge Deck Runoff Duration (hr) [h]	Average Intensity (in/hr)	Maximum Intensity (in/hr)
3/25/2009	05:50	3/25/2009	19:51	8.5	1.12	154,210	12.8	0.07	0.18
3/27/2009	11:53	3/29/2009	02:57	1.0	1.60	220,300	18.4	0.04	0.24
3/31/2009	19:03	4/3/2009	03:27	2.5	0.64	88,120	15.2	0.01	0.12
4/10/2009	10:17	4/10/2009	12:12	7.0	0.45	61,959	2.1	0.21	0.12
5/1/2009	09:34	5/3/2009	22:19	11.0	0.80	110,150	3.9	0.01	0.27
6/10/2009	18:12	6/10/2009	19:58	1.0	0.47	64,713	1.6	0.23	0.45
6/16/2009	20:58	6/17/2009	08:37	5.0	0.84	115,657	1.3	0.07	0.48
7/28/2009	17:12	7/29/2009	15:33	15.5	0.60	82,612	1.1	0.02	0.35
8/10/2009	13:07	8/11/2009	14:56	5.0	0.97	133,557	1.5	0.03	0.81
9/9/2009	13:27	9/10/2009	07:43	1.5	0.43	59,206	0.8	0.02	0.26
10/12/2009	11:58	10/14/2009	13:21	7.0	1.09	150,079	NA [g]	0.02	0.24
10/23/2009	14:31	10/24/2009	03:32	6.5	0.96	132,180	4.6	0.07	0.23
11/10/2009	06:24	11/10/2009	19:51	9.0	3.97	546,619	19.3	0.13	0.28

Notes:

a. Wet Time to Dry Time Ratio calculated using one-minute rain gauge data provided by the United States Geological Survey (USGS). Precipitation data was converted from one-minute to five-minute time intervals for the calculation. The beginning of a wet period (storm event) was defined as the first time step after a dry period when the total precipitation measured over the preceding 1-hour interval was greater than 0.01 inches. The end of a wet period was defined as the first time step after a wet period when the total precipitation measured over the following 1-hour interval was less than or equal to 0.01 inches. To be defined as a wet period, total precipitation was required to be greater than 0.1 inches. Dry periods less than 30 minutes in duration are combined with previous and following wet periods to form one wet period. It should be noted that the wet to dry time ratio was based on data from the entire period of record for the rain gauge

b. For the sample events, the wet weather period includes the sample period and the period before and after a sampling event with measured precipitation of at least 0.01 inches. The wet weather period end time occurs when the precipitation falls below 0.01 inches. The end time for the wet weather event varied and was determined on a case by case basis. Precipitation totals were calculated from USGS rain gauge data, where available. When USGS rain gauge data were not available, NCDOT Multi-Sensor Precipitation Estimates (MPE) were used, as noted.

c. For the sample events, antecedent dry period is the dry time between wet weather events in which less than 0.1 inches of precipitation was measured within a six hour period. Precipitation data evaluated on an hourly basis and obtained from the NCDOT MPE website (www.nc-climate.ncsu.edu/dot/).

d. Bridge deck runoff volume calculated using the Simple Method with a runoff coefficient of 0.95. [Runoff Volume (ac-ft) = Runoff Coefficient * Precipitation (ft) * Outlet Drainage Area (ac)]

e. Sample event is the period from the start of sampling to the end of sampling as provided by USGS. Average intensity calculated for precipitation occuring during the sample event time only. Maximum intensity taken as the intensity calculated over a 60 minute period. Precipitation values 30 minutes preceeding and following the sampling event start and stop time were used in calculations, but only values within the time frame of the sampling event were taken into consideration for the maximum intensity value.

f. Precipitation data obtained from NCDOT MPE website (www.nc-climate.ncsu.edu/dot/) for these sample events.

g. Data not reported due to potential malfunction in precipitation or discharge measuring devices.

h. Runoff duration based on provisional USGS hydrograph data.

Table 3-G.14: Hydrologic Data Summary for Bridge 910255 over Swift Creek (USGS Station 354217078392201)

Contributing Drainage Area = 0.18 ac. Total Wet Time / Total Dry Time [a] = 0.018

Sample Start Date	Sample Start Time	Sample End Date	Sample End Time	Hydrologic Data for Wet Weather Period [b]				Sample Event Precipitation Intensity [e]	
				Antecedent Dry Period [c] (days)	Precipitation Total (in)	Total Bridge Deck Runoff Volume [d] (liters)	Total Bridge Deck Runoff Duration (hr) [h]	Average Intensity (in/hr)	Maximum Intensity (in/hr)
5/17/2009	10:50	5/17/2009	11:13	6.0	1.53	26,893	3.3	1.05	0.87
5/25/2009	18:05	5/26/2009	19:09	0.2	0.23	4,043	1.1	0.01	0.14
6/4/2009	22:15	6/5/2009	02:53	7.0	1.27	22,323	1.7	0.26	0.59
6/16/2009	04:54	6/16/2009	07:07	0.5	4.81	84,546	NA [g]	0.58	1.47
7/13/2009	09:21	7/13/2009	12:40	26.0	0.58	10,195	1.5	0.11	0.42
7/27/2009	16:22	7/27/2009	16:57	1.5	0.65	11,425	0.4	1.00	0.65
8/21/2009	13:40	8/22/2009	13:15	1.0	0.63	11,074	1.3	0.02	0.35
9/17/2009	01:55	9/17/2009	07:45	9.0	0.43	7,558	1.4	0.05	0.15
11/10/2009	19:05	11/11/2009	08:40	10.0	3.94	69,254	16.3	0.16	0.31
12/25/2009	10:01	12/25/2009	17:34	6.0	0.69	12,128	4.8	0.09	0.19
1/17/2010	01:43	1/17/2010	04:46	16.5	1.25	21,971	4.9	0.13	0.23
2/5/2010	08:02	2/5/2010	20:09	2.0	1.92	33,748	5.9	0.12	0.25

Notes:

a. Wet Time to Dry Time Ratio calculated using one-minute rain gauge data provided by the United States Geological Survey (USGS). Precipitation data was converted from one-minute to five-minute time intervals for the calculation. The beginning of a wet period (storm event) was defined as the first time step after a dry period when the total precipitation measured over the preceding 1-hour interval was greater than 0.01 inches. The end of a wet period was defined as the first time step after a wet period when the total precipitation measured over the following 1-hour interval was less than or equal to 0.01 inches. To be defined as a wet period, total precipitation was required to be greater than 0.1 inches. Dry periods less than 30 minutes in duration are combined with previous and following wet periods to form one wet period. It should be noted that the wet to dry time ratio was based on data from the entire period of record for the rain gauge and will not be comparable to the antecedent dry period and runoff duration shown in the table, which were based on data for the sample events only.

b. For the sample events, the wet weather period includes the sample period and the period before and after a sampling event with measured precipitation of at least 0.01 inches. The wet weather period end time occurs when the precipitation falls below 0.01 inches. The end time for the wet weather event varied and was determined on a case by case basis. Precipitation totals were calculated from USGS rain gauge data, where available. When USGS rain gauge data were not available, NCDOT Multi-Sensor Precipitation Estimates (MPE) were used, as noted.

c. For the sample events, antecedent dry period is the dry time between wet weather events in which less than 0.1 inches of precipitation was measured within a six hour period. Precipitation data evaluated on an hourly basis and obtained from the NCDOT MPE website (www.nc-climate.ncsu.edu/dot/).

d. Bridge deck runoff volume calculated using the Simple Method with a runoff coefficient of 0.95. [Runoff Volume (ac-ft) = Runoff Coefficient * Precipitation (ft) * Outlet Drainage Area (ac)]

e. Sample event is the period from the start of sampling to the end of sampling as provided by USGS. Average intensity calculated for precipitation occuring during the sample event time only. Maximum intensity taken as the intensity calculated over a 60 minute period. Precipitation values 30 minutes preceeding and following the sampling event start and stop time were used in calculations, but only values within the time frame of the sampling event were taken into consideration for the maximum intensity value.

f. Precipitation data obtained from NCDOT MPE website (www.nc-climate.ncsu.edu/dot/) for these sample events.

g. Data not reported due to potential malfunction in precipitation or discharge measuring devices.

h. Runoff duration based on provisional USGS hydrograph data.

Table 3-G.15: Hydrologic Data Summary for Bridge 090061 over Town Creek (USGS Station 340813077591601)

Contributing Drainage Area = 0.18 ac. Total Wet Time / Total Dry Time [a] = 0.018

Sample Start Date	Sample Start Time	Sample End Date	Sample End Time	Hydrologic Data for Wet Weather Period [b]				Sample Event Precipitation Intensity [e]	
				Antecedent Dry Period [c] (days)	Precipitation Total (in)	Total Bridge Deck Runoff Volume [d] (liters)	Total Bridge Deck Runoff Duration (hr) [h]	Average Intensity (in/hr)	Maximum Intensity (in/hr)
5/7/2009	09:46	5/7/2009	10:47	22.0	0.67	11,777	0.8	0.54	0.65
5/26/2009	00:53	5/26/2009	01:58	7.5	0.25	4,394	1.2	0.16	0.20
6/15/2009	22:33	6/16/2009	07:22	1.0	0.48	8,437	2.8	0.04	0.06
7/6/2009	07:13	7/6/2009	23:04	3.0	1.14	20,038	2.5	0.02	0.26
7/16/2009	19:34	7/18/2009	01:56	2.5	0.18	3,164	0.7	0.01	0.08
7/31/2009	21:15	8/2/2009	16:25	7.0	0.54	9,492	1.3	0.01	0.22
9/22/2009	03:47	9/22/2009	13:21	15.0	2.18	38,318	2.9	0.13	0.61
10/5/2009	08:12	10/5/2009	09:29	8.0	0.56	9,843	1.0	0.13	0.15
11/10/2009	14:59	11/13/2009	03:32	15.0	3.44	60,465	4.9	0.05	0.53
1/17/2010	01:10	1/17/2010	06:18	16.5	1.11	19,511	3.7	0.10	0.24
1/30/2010	06:19	1/30/2010	16:43	5.0	0.39	6,855	4.2	0.04	0.14

Notes:

a. Wet Time to Dry Time Ratio calculated using fifteen-minute rain gauge data provided by the United States Geological Survey (USGS). The beginning of a wet period (storm event) was defined as the first time step after a dry period when the total precipitation measured over the preceding 1-hour interval was greater than 0.01 inches. The end of a wet period was defined as the first time step after a wet period when the total precipitation measured over the following 1-hour interval was less than or equal to 0.01 inches. To be defined as a wet period, total precipitation was required to be greater than 0.1 inches. Dry periods less than 30 minutes in duration are combined with previous and following wet periods to form one wet period. It should be noted that the wet to dry time ratio was based on data from the entire period of record for the rain gauge and will not be comparable to the antecedent dry period and runoff duration shown in the table, which were based on data for the sample events only.

b. For the sample events, the wet weather period includes the sample period and the period before and after a sampling event with measured precipitation of at least 0.01 inches. The wet weather period end time occurs when the precipitation falls below 0.01 inches. The end time for the wet weather event varied and was determined on a case by case basis. Precipitation totals were calculated from USGS rain gauge data, where available. When USGS rain gauge data were not available, NCDOT Multi-Sensor Precipitation Estimates (MPE) were used, as noted.

c. For the sample events, antecedent dry period is the dry time between wet weather events in which less than 0.1 inches of precipitation was measured within a six hour period. Precipitation data evaluated on an hourly basis and obtained from the NCDOT MPE website (www.nc-climate.ncsu.edu/dot/).

d. Bridge deck runoff volume calculated using the Simple Method with a runoff coefficient of 0.95. [Runoff Volume (ac-ft) = Runoff Coefficient * Precipitation (ft) * Outlet Drainage Area (ac)]

e. Sample event is the period from the start of sampling to the end of sampling as provided by USGS. Average intensity calculated for precipitation occuring during the sample event time only. Maximum intensity taken as the intensity calculated over a 60 minute period. Precipitation values 30 minutes preceeding and following the sampling event start and stop time were used in calculations, but only values within the time frame of the sampling event were taken into consideration for the maximum intensity value.

f. Precipitation data obtained from NCDOT MPE website (www.nc-climate.ncsu.edu/dot/) for these sample events.

g. Data not reported due to potential malfunction in precipitation or discharge measuring devices.

h. Runoff duration based on provisional USGS hydrograph data.