study are 60” or larger in size, and will be subject to the requirement of a 1’ buried invert. Therefore, 56 of the 56 crossings identified and analyzed in this study will be 72 inches or larger and would qualify as major crossings.

During final design, the NCDOT Hydraulics Unit will require that the analysis of any crossing which has a total span of more than 20 feet be to the same level of detail as a bridge crossing (a BSR may be required, but at minimum, a HEC-RAS analysis will be performed in addition to the preparation of the CSR). These locations will also become part of the NCDOT Bridge Inventory and will be subject to regular inspection by bridge maintenance personnel. This will include many of the double- and triple-barrel culverts identified in our analysis.

It should be noted, as shown in **Table 4 – Recommended Preliminary Crossing Sizes**, that there was one location where the HDS-5 calculations indicated that a box culvert would meet the hydraulic requirements, but field investigation and/or research at NCDOT showed that there was a single or multi-span bridge either upstream or downstream of the crossing. In these cases, it was assumed that a bridge similar to or larger than the existing one would be required and the recommended structure was changed appropriately.

4 SUMMARY OF RESULTS

A total of 56 crossing locations were identified, analyzed, and assigned a preliminary crossing size and type. Of these crossing locations, 8 were identified as bridges, 39 were major culvert crossings (larger than 72 inches in diameter), and 9 were 60" or 66" pipe culverts. After accounting for the Corps requirement that all culverts larger than 48 inches be buried one (1) foot below grade, however, all of the crossings over 60" were increased in size and 29 additional crossings became major crossings. Thus, all of the 56 crossings studied qualify as major crossings.

Table 4 – Recommended Preliminary Crossing Sizes identifies many parameters which should be useful as alternatives are considered such as preliminary culvert size and length, approximate bridge length, fill height at the crossing location, and floodplain width (if the alignment crosses a detailed study area). Each crossing location was assigned a unique crossing ID and, in addition to this ID, the Segment ID and the Detailed Study Alternative ID are also included in the table.

Based on the profiles included for each location, the minimum required bridge length for the 8 assumed bridge locations was estimated by assuming a 10' setback from the top of the existing bank locations and 2:1 spill through slopes at each abutment (per NCDOT Hydraulics Unit direction). This estimated length is also provided for an additional 9 locations where a triple barrel culvert was recommended since this structure is large enough that a bridge was considered a possibility in final design and could be warranted due to other considerations (cost, excessive culvert length, fill, etc.). These estimates are also provided on **Table 4 – Recommended Preliminary Crossing Sizes**. The estimated bridge lengths do not attempt to span any existing floodplains or floodways at this time and were not modeled hydraulically, but are the minimum lengths necessary geometrically based on the proposed vertical alignment and the existing topography at the crossing location.

Please refer to **Table 4 – Recommended Preliminary Crossing Sizes** for a summary of the preliminary size assigned to each crossing location.

TABLE 4 - RECOMMENDED PRELIMINARY CROSSING SIZES

CULVERT ID	SEGMENT ID	DETAILED STUDY ALTERNATIVE ID	CATCHMENT AREA (ac)	DESIGN FLOW (Q_{50} cfs)	CULVERT SIZE	BRIDGE	72" & LARGER	60" & 66" CULVERTS	54" & SMALLER	EXISTING STRUCTURE AT, U/S, OR D/S?	EXISTING STRUCTURE TYPE & SIZE	FLOODPLAIN WIDTH (ft)	FLOODWAY WIDTH (ft)	BASE FLOOD ELEVATION (ft)	FILL HEIGHT ABOVE INVERT (ft)	RECOMMENDED PRELIMINARY STRUCTURE (INCL. 1' BURIED)	CULVERT/RCB LENGTH (ft)	WAS A BRIDGE OPTION EVALUATED AT THIS LOCATION?	ESTIMATED BRIDGE LENGTH (ft)
1	2	C,C1,C2,C3,D,D1,D2,D3	486.60	1394.61	3-(6'x10') RCB		1			At, D/S	At - 2-66" RCP, D/S - 3-142"x91" CMP Arch	-	-		13.3	3-(7'x10') RCB	322	Yes	75
3	18A	A,A1,A2,A3,B,B1,B2,B3	829.66	1562.50	3-(6'x10') RCB		1			U/S	36' Single 42'x5' PPC Crownspan	282	107	668.10	24.1	3-(7'x10') RCB	267	Yes	135
4	2	C,C1,C2,C3,D,D1,D2,D3	116.34	433.50	6'X10' RCB		1			--		-	-		20.8	7'x10' RCB	864	No	
5	18A	A,A1,A2,A3,B,B1,B2,B3	41.32	155.40	60" RCP			1		--		-	-		34.1	72" RCP	368	No	
5A	18A	A,A1,A2,A3,B,B1,B2,B3	1629.48	2628.89	3-(8'x12') RCB		1			At	3-142"x91" CM Pipe Arch	52	52	660.50	11.9	3-(9'x12') RCB	95	Yes	50 (FW)
6	18A	A,A1,A2,A3,B,B1,B2,B3	2385.75	3350.34	3-(10'x10') RCB		1			U/S	36' Single Steel Span on I-beams	458	160	643.40	17.2	3-(11'x10') RCB	252	Yes	135
7	18A	A,A1,A2,A3,B,B1,B2,B3	49.34	194.25	66" RCP			1		--		-	-		17.4	6'x6' RCB	232	No	
8	2	C,C1,C2,C3,D,D1,D2,D3	273.85	1073.27	2-(8'x8') RCB		1			--		316	-	639.00	20.2	2-(9'x8') RCB	358	No	
9	18A	A,A1,A2,A3,B,B1,B2,B3	316.63	999.64	2-(7'x8') RCB		1			--		196	-	638.00	23.8	2-(8'x8') RCB	339	No	
10	2, 18A	ALL	97.43	357.42	6'X7' RCB		1			--		-	-		32.3	7'x7' RCB	280	No	
11	2, 18A	ALL	34.66	137.27	60" RCP			1		--		-	-		16.5	72" RCP	231	No	
12	21	ALL	91.02	334.11	6'X7' RCB		1			--		-	-		31.6	7'x7' RCB	369	No	
13	21	ALL	77.26	282.31	6'X6' RCB		1			--		176	-	617.10	25.1	7'x6' RCB	264	No	
14	21	ALL	502.24	1102.39	2-(8'x8') RCB		1			--		400	-	613.90	31.5	2-(9'x8') RCB	283	No	
15	22A, 30	ALL	51.86	209.79	72" RCP		1			--		-	-		13.7	6'x6' RCB	342	No	
16	30	B,B1,B2,B3,D,D1,D2,D3	95.24	347.06	6'X7' RCB		1			--		-	-		14.4	7'x7' RCB	273	No	
17	22A	A,A1,A2,A3,C,C1,C2,C3	115.93	372.55	6'X8' RCB		1			--		-	-		14.8	7'x8' RCB	259	No	
19	30	B,B1,B2,B3,D,D1,D2,D3	7154.93	6233.42	BRIDGE	1				U/S	110' 3-Span RC Deck on PPC Girders	1300	441	607.50	21.7	150' BRIDGE	222	Yes	150
19A	30	B,B1,B2,B3,D,D1,D2,D3	163.42	513.35	6'X10' RCB		1			--		279	-	607.00	20.9	7'x10' RCB	261	No	
20	30	B,B1,B2,B3,D,D1,D2,D3	7404.50	6318.17	BRIDGE	1				At	3-11'x14' RC Box Culvert	775	73	605.00	15.1	75' BRIDGE	114	Yes	75 (FW)
21	22A	A,A1,A2,A3,C,C1,C2,C3	7410.86	6321.44	BRIDGE	1				U/S	3-11'x14' RC Box Culvert	607	182	603.70	12.4	110' BRIDGE	223	Yes	110
22	22A	A,A1,A2,A3,C,C1,C2,C3	118.78	305.37	6'X6' RCB		1			--		286	-	603.70	12.4	7'x6' RCB	404	No	
22A	22A	A,A1,A2,A3,C,C1,C2,C3	7700.64	6374.90	BRIDGE	1				U/S	3-11'x14' RC Box Culvert	1132	305	601.80	7.5	165' BRIDGE	120	Yes	75
22B	22A	A,A1,A2,A3,C,C1,C2,C3	111.60	331.93	6'X7' RCB		1			--		193	-	599.00	6.3	7'x7' RCB	113	No	
23	22A	A,A1,A2,A3,C,C1,C2,C3	56.19	207.20	72" RCP		1			--		-	-		40.2	6'x6' RCB	549	No	
24	22A, 30	ALL	188.57	490.96	6'X10' RCB		1			--		-	-		28.1	7'x10' RCB	366	No	
25	22A, 30	ALL	43.25	163.17	66" RCP			1		--		-	-		15	6'x6' RCB	235	No	
26	22A, 30	ALL	32.81	129.50	60" RCP			1		--		54	-	588.80	14.6	72" RCP	231	No	
27	31	ALL	2623.03	1576.57	3-(6'x12') RCB		1			D/S	2-128"x83" CM Pipe Arch	329	-	543.50	27.9	3-(7'x12') RCB	249	Yes	175
28	31	ALL	99.45	360.01	6'X7' RCB		1			--		-	-		16.1	7'x7' RCB	553	No	
29	31	ALL	72.43	259.00	6'X6' RCB		1			At		-	-		34.1	7'x6' RCB	471	No	
30	34, 36	ALL	10271.69	6359.83	BRIDGE	1				--		115	-	509.80	47.5	240' BRIDGE	422	Yes	240
31	34, 36	ALL	180.80	470.33	6'X10' RCB		1			--		-	-		20.9	7'x10' RCB	224	No	
32	34, 36	ALL	34.04	132.09	60" RCP			1		--		-	-		13.1	72" RCP	424	No	
33	36	A,A2,B,B2,C,C2,D,D2	70.21	256.41	6'X6' RCB		1			--		-	-		23.3	7'x6' RCB	809	No	
34	34	A1,A3,B1,B3,C1,C3,D1,D3	74.21	269.36	6'X6' RCB		1			--		-	-		11.4	7'x6' RCB	553	No	
35	36	A,A2,B,B2,C,C2,D,D2	82.69	297.85	6'X6' RCB		1			--		-	-		12.4	7'x6' RCB	216	No	
36	36	A,A2,B,B2,C,C2,D,D2	41.17	155.40	60" RCP			1		--		-	-		19.9	72" RCP	218	No	
37	36	A,A2,B,B2,C,C2,D,D2	46172.31	11661.67	BRIDGE	1				--		402	198	464.00	48.9	320' BRIDGE	421	Yes	320
38	36	A,A2,B,B2,C,C2,D,D2	9293.78	4755.65	BRIDGE	1				U/S	47' Single Steel Span on I-beams	472	-	461.00	39.8	280' BRIDGE	297	Yes	280
39	34	A1,A3,B1,B3,C1,C3,D1,D3	55671.84	14257.78	BRIDGE	1				--		1057	-	460.00	57.5	BRIDGE	383	Yes	375
40	36	A,A2,B,B2,C,C2,D,D2	89.16	315.98	6'X7' RCB		1			--		-	-		28.5	7'x7' RCB	744	No	
41	36	A,A2,B,B2,C,C2,D,D2	64.07	238.28	72" RCP		1			--		-	-		8.7	6'x6' RCB	452	No	
42	36	A,A2,B,B2,C,C2,D,D2	48.60	183.89	66" RCP			1		--		-	-		8	6'x6' RCB	104	No	
43	34	A1,A3,B1,B3,C1,C3,D1,D3	74.82	279.72	6'X6' RCB		1			--		77	-	524.20	39.3	7'x6' RCB	194	No	
44	36	A,A2,B,B2,C,C2,D,D2	238.69	660.53	7'x12' RCB		1			--		210	-	517.50	14.9	8'x12' RCB	363	No	
45	34	A1,A3,B1,B3,C1,C3,D1,D3	296.23	734.40	7'x12' RCB		1			--		138	-	508.60	32.8	8'x12' RCB	499	No	
46	34	A1,A3,B1,B3,C1,C3,D1,D3	2018.58	2668.59	3-(8'x12') RCB		1			U/S	2-12'x6' RC Box Culvert	309	66	506.80	25.9	3-(9'x12') RCB	365	Yes	150
47	36	A,A2,B,B2,C,C2,D,D2	1994.29	2649.21	3-(8'x12') RCB		1			D/S	2-12'x6' RC Box Culvert	447	209	509.60	33.4	3-(9'x12') RCB	312	Yes	215
48	36	A,A2,B,B2,C,C2,D,D2	103.83	375.76	6'X8' RCB		1			--		-	-		17.5	7'x8' RCB	222	No	
49	34	A1,A3,B1,B3,C1,C3,D1,D3	101.03	369.62	6'X8' RCB		1			--		-	-		8.8	7'x8' RCB	359	No	
50	40, 41	ALL EXCEPT C	52.96	196.84	66" RCP			1		--		-	-		39.8	6'x6' RCB	182	No	
51	40	A,A1,A3,B,B1,C1,D,D1	134.84	509.24	6'X10' RCB		1			--		-	-		50	7'x10' RCB	531	No	
52	41	A2,B2,B3,C2,C3,D2,D3	184.11	636.80	7'X10' RCB		1			--		-	-		38.1	8'x10' RCB	295	No	
53	40	A,A1,A3,B,B1,C1,D,D1	879.16	1632.12	3-(6'x12') RCB		1			At	2-8'x7' RC Box Culvert	328	38	518.00	20	3-(7'x12') RCB	312	Yes	70
54	41	A2,B2,B3,C2,C3,D2,D3	886.14	1639.91	3-(6'x12') RCB		1			At	2-8'x7' RC Box Culvert	328	38	518.00	15.3	3-(7'x12') RCB	221	Yes	70
						8	39	9	0										

2.4 Wetlands and/or Waters of the United States

There are a significant number of wetlands and/or streams identified within the study area and each of the DSA alignments has a varying degree of wetland impacts. The project team included field biologists who performed a qualitative analysis and delineation of the streams within the proposed project corridors and the extent of existing wetlands. The field biologists, in most cases, identified the stream classification (ephemeral, intermittent, or perennial), the presence of wetlands, classification of wetland significance, and the presence of ponds. The results of these analyses have been summarized by Environmental Services, Incorporated (ESI) in a draft report entitled "Natural Resources Technical Report for the Monroe Connector-Bypass –Mecklenburg and Union Counties, North Carolina." In addition to providing valuable data on the relative environmental impact potential of each DSA alignment, this data also assisted in the selection of the crossing locations to be visited in the field as part of this study.

2.5 Permit Requirements

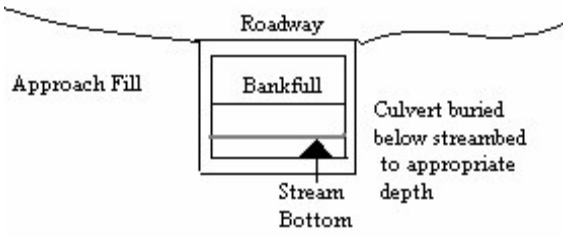
Although it is anticipated that an individual permit will be required for this project, according to the Draft SAW Regional Conditions (Corps Action ID: SAW-2006-41003-5NC) for Nationwide Permits (NWP) issued on October 10, 2006, there are numerous requirements for the drainage crossings in North Carolina that may, nevertheless, impact the final design. This document, in its entirety, is contained in **Appendix A – Permit Information**, and the relevant portions are excerpted below:

All Nationwide Permits

- *NWPs may not be used for activities that may result in the loss or degradation of greater than 300 total linear feet of perennial stream or intermittent stream that exhibits important aquatic function(s). Loss of stream includes the linear feet of stream bed that is filled, excavated, or flooded by the proposed activity. [Note: The Corps uses the Stream Quality Assessment Worksheet, located with Permit Information on the Regulatory Program Web Site to aid in the determination of the intermittent channel stream status.]*
- *Prior to use of any NWP (except 13, 27, 29 and 39), for any activity which impacts more than 150 total linear feet of perennial stream or intermittent stream , the applicant must comply with Nationwide Permit General Condition 27 (Construction Period).*
- *For all NWPs that involve the construction of culverts, measures will be included in the construction that will promote the safe passage of fish and other aquatic*

organisms. The dimension, pattern, and profile of the stream above and below a pipe or culvert should not be modified by widening the stream channel or by reducing the depth of the stream in connection with the construction activity

- *All culverts in the 20 CAMA coastal counties must be buried to a depth of one foot below, and at the same slope as, the bed of the stream or wetland.*
  For all other counties, culvert inverts will be buried at least one foot below the bed of the stream for culverts greater than 48 inches in diameter. For culverts 48 inches in diameter or less, culverts shall be placed directly on the stream bed or buried as practicable and appropriate to maintain aquatic passage, and every effort shall be made to maintain the existing channel slope.
  A waiver from the specifications in this Regional Condition may be requested in writing.

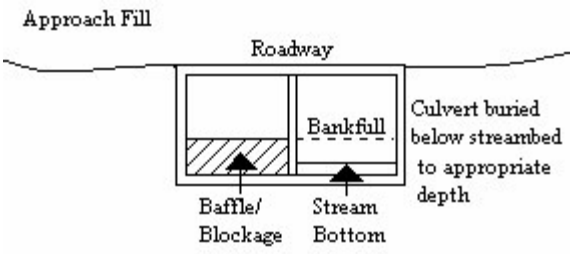


The waiver will only be issued if it can be demonstrated that the impacts of complying with this Regional condition would result in more adverse impacts to the aquatic environment.

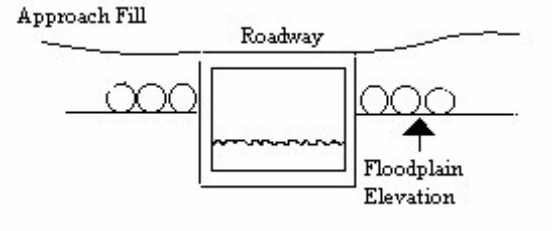
- *For any NWP that permanently impacts more than 150 linear feet of perennial and/or intermittent stream, the applicant shall provide a mitigation proposal to compensate for the loss of aquatic function associated with the proposed activity.*

NWP #14 - Linear Transportation Crossings

- *Applicants shall employ natural channel design to the maximum extent practicable for stream relocations. In the event it is not practicable to employ natural channel design, any stream relocation shall be considered a permanent impact and the applicant shall provide a mitigation plan to compensate for the loss of aquatic function associated with the proposed activity.*
- *Bank-full flows (or less) shall be accommodated through maintenance of the existing bank-full channel cross sectional area. Additional culverts at such crossings shall be allowed only to receive flows exceeding bank-full.*



- *Where adjacent floodplain is available, flows exceeding bank-full should be accommodated by installing culverts at the floodplain elevation.*

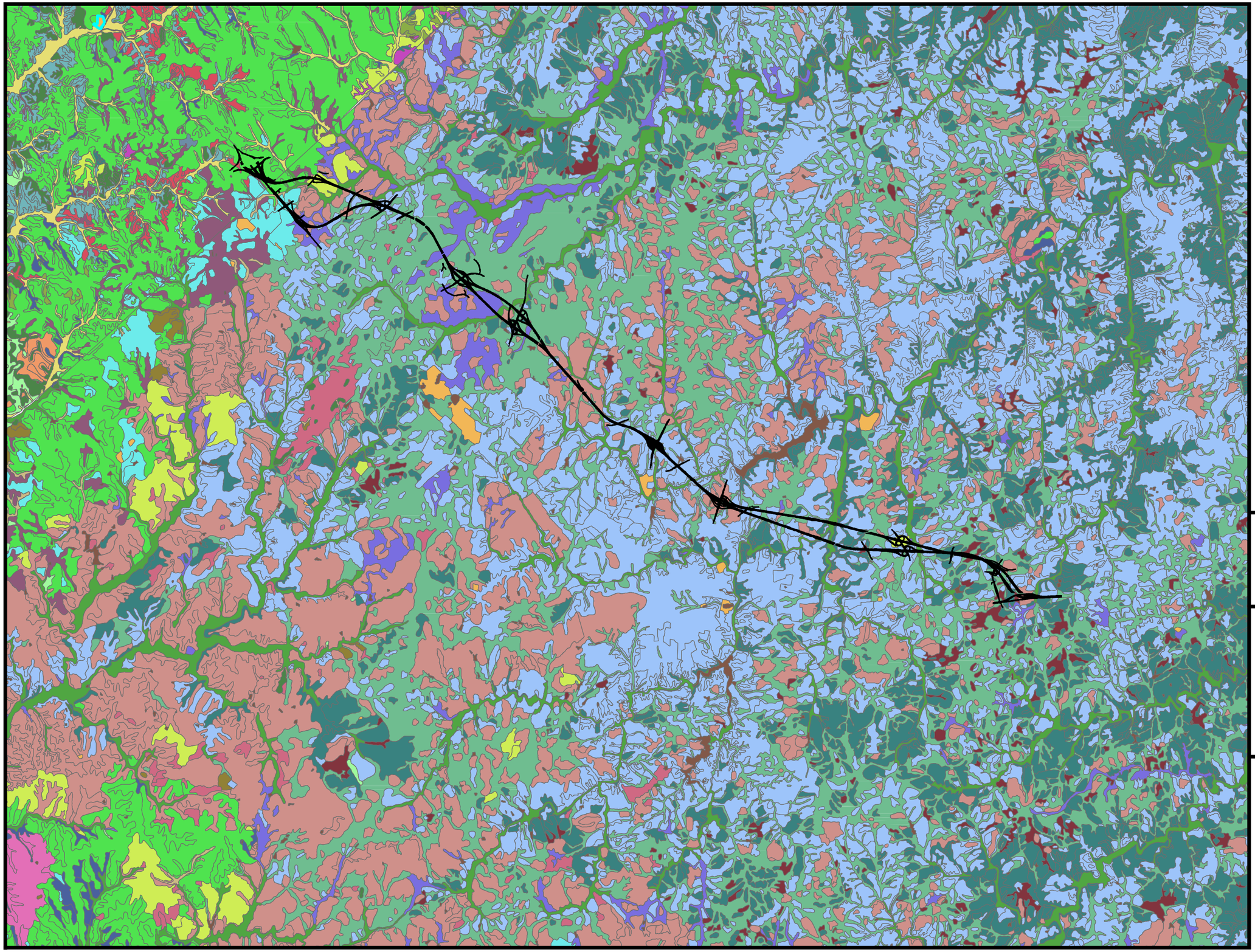


Given the above requirements, the number of crossing locations, and the level of impact at each crossing, it is clear that an individual permit will be required for this project and that an NWP will not be applicable. Also, in addition to the above requirements, a State Storm Water Permit will be required if the project crosses HQW (High Quality Waters) or ORW (Outstanding Resource Waters), however, neither of these waters are known to be within the study area.

No evidence of FEMA Buyout Property was found within the project area and no impacts to such property are expected.

2.6 Soils

Based upon GIS information obtained from the Natural Resources Conservation Service (formerly Soil Conservation Service), the soils within the study area are comprised of twenty-eight (28) major soils units (excluding dams, quarry pits and water). Since a detailed hydrologic analysis using HEC-1 or HEC-HMS was not performed as part of this study, these soil groups were not utilized in the hydrologic analysis; however, they have been identified and are included in this report as **Figure 4 – Soils Map**.

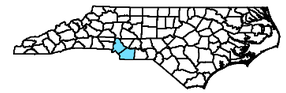


Legend

Proposed Alignments

Soil Series

- Ailey
- Appling
- Badin
- Cecil
- Chewacla
- Cid
- Colfax
- Creedmoor
- Dams
- Davidson
- Enon
- Gaston
- Georgeville
- Goldston
- Helena
- Iredell
- Lignum
- Mecklenburg
- Misenheimer
- Monocan
- Pacolet
- Quarry Pits
- Secrest
- Tatum
- Udorthents
- Urban land
- Vance
- Water
- White Store
- Wilkes
- Zion



Mecklenburg and Union Counties
North Carolina Counties

Source: Mecklenburg and Union Counties GIS.
Map Printed On 09-19-08.

W

0 5,000 10,000
Feet

NORTH CAROLINA Turnpike Authority

STIP PROJECT
NO. R-3329/R-2559

Mecklenburg County and
Union County

MONROE CONNECTOR/ BYPASS

SOILS MAP

Figure 4

Figure_4_SoilsMap.mxd 09-19-08

2.7 USGS Gage Locations

Although none are known to exist within the project watershed, numerous USGS gages are in close proximity. The gages nearest the project watershed are as follows:

1. Station No.: 0212467595
   Station Name: Goose Creek at SR 1525 near Indian Trail, NC
2. Station No.: 0214657975
   Station Name: Irvins Creek at SR 3168 near Charlotte, NC

2.8 FEMA Flood Zone Delineations

FEMA FIRM Panels were obtained for Union and Mecklenburg Counties and there are numerous locations where the alternative alignments cross an area that has a designated floodplain. The corresponding Flood Insurance Study (FIS) report was also obtained and the discharges used in the FEMA analyses were included in the decision table used to determine the design discharge. In order to establish the FEMA discharge at a particular crossing location, the location was identified on the included FEMA FIRM panels and, if the crossing fell within a detailed study area, the river reach was noted and the nearest applicable discharge was obtained from the FIS document. In addition to the data contained in the appendix, **Figure 3 – Aerials With FEMA Floodplains & Floodways** has also been developed which shows the floodplain locations within the study area and their relation to the DSA alignments. The FEMA FIRM panels are included in **Appendix A – Referenced Reports and Data**.

2.9 Hazardous Spill Basins

A portion of the proposed corridor near Twitty Lake passes through an area designated as a hazardous spill basin area (see Figure 6). All roadways within this area will incorporate hazardous spill basins designed according to the requirements stipulated in the NCDOT document entitled *Best Management Practices for Protection of Surface Waters*. Additional specific guidance in the location and design of these basins can be found in *Appendix O – Guidelines for the Location and Design of Hazardous Spill Basins* of the *Guidelines for Drainage Studies and Hydraulic Design*, available from the NCDOT Hydraulics Unit.

3 HYDROLOGIC/HYDRAULIC ANALYSIS

3.1 Drainage Basin Delineation

Initially, a target contributing area was selected that would likely produce sufficient runoff to merit the installation of a 60-inch or larger culvert. The 60-inch size was chosen since the NWP requirements state that any culvert over 48" in diameter must have the invert buried one (1) foot to meet environmental requirements for fish and wildlife passage. This would require increasing the installed size of all 60" diameter culverts to 72 inches.

To ensure that no potential locations were missed in the analysis, the minimum area warranting a 60-inch or greater culvert was set at approximately 30 acres, which an initial USGS urban regression equation calculation showed to produce a flow that would require a 60-inch RCP culvert at a 0.5% slope. Using these constraints, a total of 56 crossing locations were identified and analyzed. Maps of these crossing locations and associated drainage areas can be found in **Appendix C – Drainage Area Exhibits**.

3.2 Hydrologic Computations

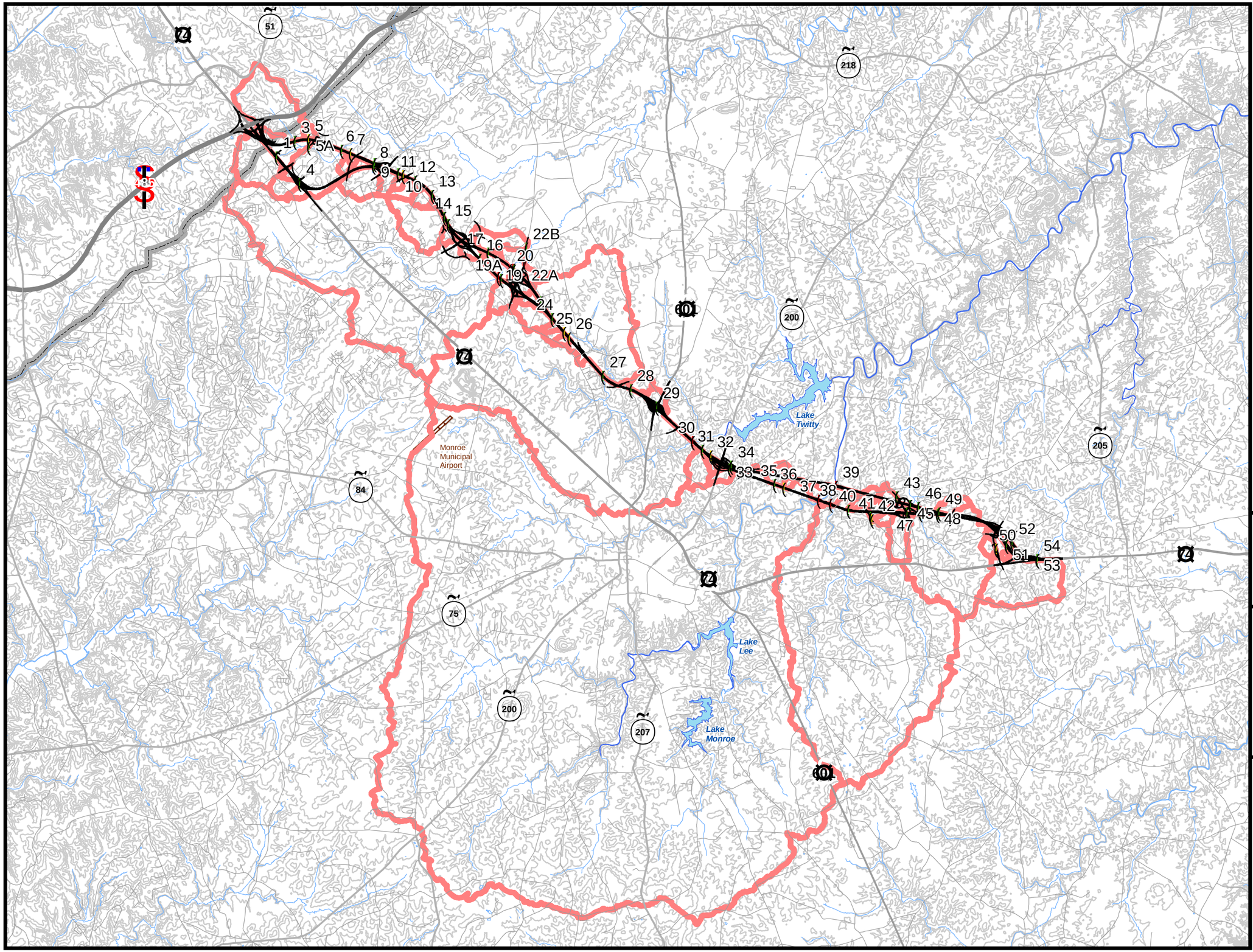
An analysis of the available methodologies showed the USGS Urban Equation, and the FEMA data to be in reasonably close agreement. Based on discussions with the NCDOT Hydraulics Unit for the Gaston Connector project (Meeting held 9/14/07), it was agreed that the USGS and NCDOT Urban results would be utilized for analysis and design given the expected future growth and development in this area (calculations using Rural methodology would not be used). For areas less than 100 acres, the NCDOT Urban Highway Charts produced discharges that were notably less than the USGS Urban Equation and NCDOT believed that these lower values were more reasonable for the smaller drainage areas. Therefore, the peak runoff for each location was computed using the NCDOT Highway charts for urban conditions (areas less than 100 acres), the USGS Urban Regression Equations (areas greater than 100 acres), and any FEMA FIS data that was available. The resulting calculated peak discharges at each location were compared to the FEMA data (if available) and the highest value was chosen for analysis (see **Table 2 – Hydrologic Calculation Summary** for the resulting flows).

The USGS Urban Equation requires an estimate of the percentage of impervious area. PBS&J compiled GIS zoning data from various regional and municipal entities to develop a customized future condition land use file that spans the entire area delineated for hydrologic and hydraulic analysis. Using GIS processes, contributing drainage areas for the various DSAs were intersected with the custom land use file to perform summary statistics. Total

amount of acres per TR-55 Cover Type (i.e. Commercial, Industrial, etc.) for each sub-basin were obtained and multiplied by the applicable average percent impervious area as reported in Table 2-2a, Chapter 2, Technical Release 55 (Urban Hydrology for Small Watersheds) written by the Natural Resources Conservation Service. These products were summed and divided by the respective contributing drainage area (in acres) to determine the percentage of impervious area. These percentages used for the USGS calculations are included in a table in **Appendix C – Hydrologic and Hydraulic Calculations**.

The NCDOT Urban Highway Chart requires the selection of a development type. Since all of the drainage areas under 100 acres in size are adjacent to the proposed corridors and could eventually be developed commercially, it was decided that all areas would be designated "Small Area Full Business" and assigned a correction factor of 1.4 (see NCDOT "*Guidelines for Drainage Studies and Hydraulic Design*").

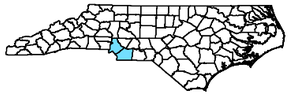
Once the LEDPA alternative is selected, it is assumed that the hydrologic calculations will be revisited in greater detail and individual values can be assigned for each drainage basin. Please refer to **Figure 5 - Off-Site Drainage Area Map** for an overall view of the project watershed. For maps of individual contributing drainage areas, refer to **Appendix C – Hydrologic and Hydraulic Calculations**.



Legend

Stream Crossings

- 60" - 66" diameter
- 72" diameter or larger
- Bridge
- Proposed Alignments
- Off-Site Drainage Area
- 20-ft Contours
- Interstate Highway
- US Highway
- NC State Highway
- State Road
- River / Stream
- Lake
- County Boundary



Mecklenburg and Union Counties
North Carolina Counties

Source: Mecklenburg County and Union County GIS.
Map Printed On 10-21-08.

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NORTH CAROLINA Turnpike Authority

STIP PROJECT NO. R-3329/R-2559

Mecklenburg County and Union County

MONROE CONNECTOR/ BYPASS

OFF-SITE DRAINAGE AREA MAP

Figure 5

Figure_5_OffsiteDrainageAreaMap.mxd 10-21-08

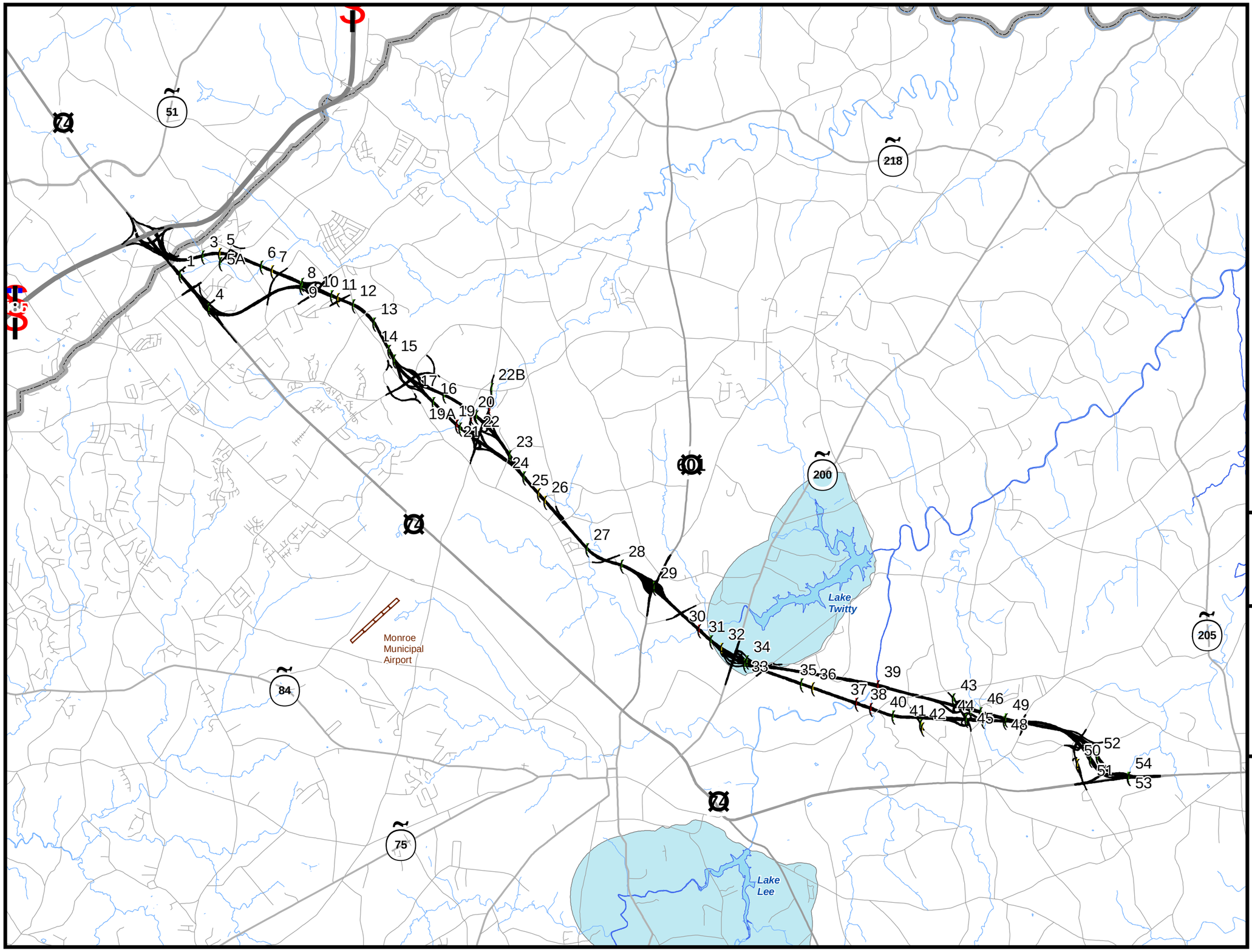
TABLE 2 - HYDROLOGIC CALCULATION SUMMARY

CULVERT ID	CATCHMENT AREA (ac)	CATCHMENT AREA (sq mi)	NCDOT RUNOFF Q_{50} (cfs)	NCDOT RUNOFF Q_{100} (cfs)	USGS URBAN Q_{50} ANALYSIS (cfs)	USGS URBAN Q_{100} ANALYSIS (cfs)	FEMA RUNOFF Q_{50} (cfs)	FEMA RUNOFF Q_{100} (cfs)		DESIGN FLOW Q_{50} (cfs)	DESIGN FLOW Q100 (cfs)
1	486.60	0.7603			1394.61	1498.42				1394.61	1498.42
3	829.66	1.2963			1562.50	1704.37	914.00	1050.00		1562.50	1704.37
4	116.34	0.1818			433.50	485.91				433.50	485.91
5	41.32	0.0646	155.40	180.60						155.40	180.60
5A	1629.48	2.5461			2628.89	2819.22	1325.00	1645.00		2628.89	2819.22
6	2385.75	3.7277			3350.34	3576.14	1663.00	1903.00		3350.34	3576.14
7	49.34	0.0771	194.25	225.75						194.25	225.75
8	273.85	0.4279			1073.27	1149.82		421.00		1073.27	1149.82
9	316.63	0.4947			999.64	1085.92		421.00		999.64	1085.92
10	97.43	0.1522	357.42	415.38						357.42	415.38
11	34.66	0.0542	137.27	159.53						137.27	159.53
12	91.02	0.1422	334.11	388.29						334.11	388.29
13	77.26	0.1207	282.31	328.09				193.00		282.31	328.09
14	502.24	0.7848			1102.39	1213.35		995.00		1102.39	1213.35
15	51.86	0.0810	209.79	243.81						209.79	243.81
16	95.24	0.1488	347.06	403.34						347.06	403.34
17	115.93	0.1811			372.55	423.63				372.55	423.63
19	7154.93	11.1796			6233.42	6613.62	2761.00	3335.60		6233.42	6613.62
19A	163.42	0.2553			513.35	575.62				513.35	575.62
20	7404.50	11.5695			6318.17	6706.06	2871.00	3467.00		6318.17	6706.06
21	7410.86	11.5795			6321.44	6709.48	2886.00	3485.00		6321.44	6709.48
22	118.78	0.1856			305.37	354.36				305.37	354.36
22A	7700.64	12.0322			6374.90	6773.42	2934.00	3547.00		6374.90	6773.42
22B	111.60	0.1744			331.93	380.94				331.93	380.94
23	56.19	0.0878	207.20	240.80						207.20	240.80
24	188.57	0.2946			490.96	556.75				490.96	556.75
25	43.25	0.0676	163.17	189.63						163.17	189.63
26	32.81	0.0513	129.50	150.50				131.00		129.50	150.50
27	2623.03	4.0985			1576.57	1817.45		1805.00		1576.57	1817.45
28	99.45	0.1554	360.01	418.39						360.01	418.39
29	72.43	0.1132	259.00	301.00						259.00	301.00
30	10271.69	16.0495			6359.83	6854.57	5860.00	6470.00		6359.83	6854.57
31	180.80	0.2825			470.33	534.46				470.33	534.46
32	34.04	0.0532	132.09	153.51						132.09	153.51
33	70.21	0.1097	256.41	297.99						256.41	297.99
34	74.21	0.1160	269.36	313.04						269.36	313.04
35	82.69	0.1292	297.85	346.15						297.85	346.15
36	41.17	0.0643	155.40	180.60						155.40	180.60
37	46172.31	72.1442			11661.67	12760.28		10000.00		11661.67	12760.28
38	9293.78	14.5215			4755.65	5244.92		3870.00		4755.65	5244.92
39	55671.84	86.9872			14257.78	15443.21		11094.00		14257.78	15443.21
40	89.16	0.1393	315.98	367.22						315.98	367.22
41	64.07	0.1001	238.28	276.92						238.28	276.92
42	48.60	0.0759	183.89	213.71						183.89	213.71
43	74.82	0.1169	279.72	325.08				244.00		279.72	325.08
44	238.69	0.3730			660.53	736.43		507.00		660.53	736.43
45	296.23	0.4629			734.40	819.09		513.85		734.40	819.09
46	2018.58	3.1540			2668.59	2887.68	1240.13	1517.17		2668.59	2887.68
47	1994.29	3.1161			2649.21	2867.02	1172.74	1435.65		2649.21	2867.02
48	103.83	0.1622			375.76	424.65				375.76	424.65
49	101.03	0.1579			369.62	417.81				369.62	417.81
50	52.96	0.0827	196.84	228.76						196.84	228.76
51	134.84	0.2107			509.24	566.12				509.24	566.12
52	184.11	0.2877			636.80	703.50				636.80	703.50
53	879.16	1.3737			1632.12	1777.90	765.00	943.00		1632.12	1777.90
54	886.14	1.3846			1639.91	1786.25	765.00	943.00		1639.91	1786.25

3.3 Field Investigations

During the scope development for this project, the project team identified 210 potential stream crossings (of all sizes) located within the proposed right-of-way alignments of the DSAs. These potential locations for field visits were selected based on the presence of a stream line designation on the USGS Quad Map, which is generally an indicator of a significant perennial stream. Given that this is a planning study and due to the sheer number of locations, it was initially estimated (prior to beginning the study) that 75 locations will require a 72-inch or larger diameter pipe and 15 locations will require a bridge structure. Based on prior negotiations, it had been decided that all bridge locations and 10% of culvert locations would be visited in the field. These estimates yielded a total of 24 field visit locations (15 bridges and 8 culverts). During the initial hydrologic analysis, however, 56 major crossing locations identified and 8 of them seemed to qualify as bridge location and the remaining 48 as culvert locations. The culvert and bridge locations evaluated in this analysis are shown on **Figure 6 – Bridge & Culvert Locations**.

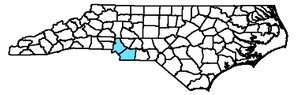
Identification of those crossings that were more critical, and thus more deserving of a field visit, involved not only the peak flow, but also a review of the data gathered by the field biologists in the vicinity of the crossings. The field biologists, in most cases, identified the stream classification (ephemeral, intermittent, or perennial), the presence of wetlands, classification of wetland significance, and the presence of ponds. PBS&J also looked at potential linear stream relocations and considered that in the selection of critical crossings. Based on this information, 24 crossing locations were selected for field investigation: eight (8) bridge locations and 16 culvert locations. These locations are shown on **Figure 7 – Field Visit Locations** and the data for these locations is summarized in **Table 3 – Preliminary Crossing Sizes and Field Visit Locations**. Field evaluation forms and photographs of the critical crossings can be found in **Appendix B – Field Investigations Data**.



Legend

Stream Crossings

- 60" - 66" diameter
- 72" diameter or larger
- Bridge
- Proposed Alignments
- Interstate Highway
- US Highway
- NC State Highway
- State Road
- River / Stream
- Lake
- Hazard Spill Basin Boundary
- County Boundary



Mecklenburg and Union Counties
North Carolina Counties

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Mecklenburg County and Union County

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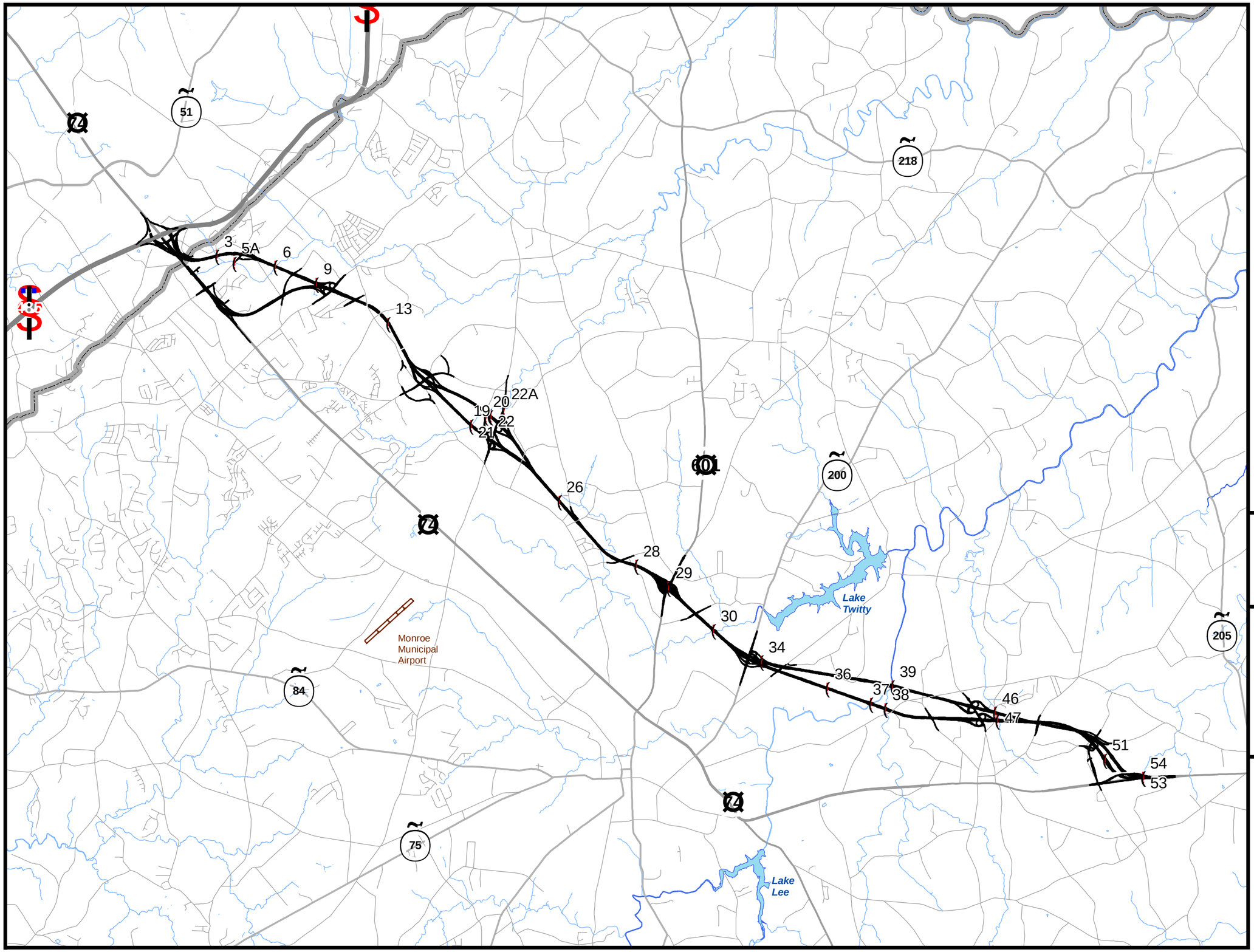
BRIDGE & CULVERT LOCATIONS & HAZARDOUS SPILL BASIN BOUNDARY

Figure 6

Figure_6_Bridge&CulvertLocations.mxd 12-08-08

TABLE 3 - PRELIMINARY CROSSING SIZES AND FIELD VISIT LOCATIONS

CULVERT ID	CATCHMENT AREA (ac)	DESIGN FLOW (Q_{50} cfs)	CULVERT SIZE	BRIDGE	72" & LARGER	60" & 66" CULVERTS	54" & SMALLER	STREAM, WETLAND, OR POND ID	STREAM NAME	STREAM CLASSIFICATION	WETLAND RATING	RECOMMEND SITE VISIT?	JUSTIFICATION FOR FIELD VISIT
1	486.60	1394.61	3-(6'x10') RCB		1			S014a,b,c,d,e, S015a	N. Fork Crooked Creek Trib. 5	32.5 (a-e), 23.75			
3	829.66	1562.50	3-(6'x10') RCB		1			S008a, W003, W004	N. Fork Crooked Creek Trib. 5	45.5	27, 61	Y	Large Culvert w/Wetland Impacts
4	116.34	433.50	6'X10' RCB		1			S017b,c	N. Fork Crooked Creek Trib. 4	39.25, 39.25			
5	41.32	155.40	60" RCP			1		S009c		34.5			
5A	1629.48	2628.89	3-(8'x12') RCB		1			S008b	N. Fork Crooked Creek	45.5		Y	
6	2385.75	3350.34	3-(10'x10') RCB		1			S008c, W005	N. Fork Crooked Creek	45.5	65	Y	Possible Bridge, High Wetland
7	49.34	194.25	66" RCP			1		S012a,b		19, 19			
8	273.85	1073.27	2-(8'x8') RCB		1			S031c, SO28c, W017, W019	N. Fork Crooked Creek Trib. 5	30.5, 32	41 (2)		
9	316.63	999.64	2-(7'x8') RCB		1			S028c, W018	N. Fork Crooked Creek Trib. 5	32	41	Y	
10	97.43	357.42	6'X7' RCB		1			S034		31.25			
11	34.66	137.27	60" RCP			1		S036		31.25			
12	91.02	334.11	6'X7' RCB		1			S037c,d, P09		37.5, 37.5			
13	77.26	282.31	6'X6' RCB		1			S038a,b, W022b, W024, W025	N. Fork Crooked Creek Trib. A	25.5, 25.5	48 (2), 38	Y	
14	502.24	1102.39	2-(8'x8') RCB		1			S039c	N. Fork Crooked Creek Trib. B	33			
15	51.86	209.79	72" RCP		1			S043		19.5			
16	95.24	347.06	6'X7' RCB		1			S052a,b		23.75, 23.75			
17	115.93	372.55	6'X8' RCB		1			S056a,b, P14, W033a,b		26.5, 26.5	52 (2)		
19	7154.93	6233.42	BRIDGE	1				S047	S. Fork Crooked Creek	55		Y	Bridge Location
19A	163.42	513.35	6'X10' RCB		1			S055		19.5			
20	7404.50	6318.17	BRIDGE	1				S047, W041	S. Fork Crooked Creek	55	43	Y	Bridge Location
21	7410.86	6321.44	BRIDGE	1				S047, S058d, S061, W040d	S. Fork Crooked Creek	55, 26.5, 26.5	47	Y	Bridge Location
22	118.78	305.37	6'X6' RCB		1			S047, S058d, S061, P26		55, 26.5, 26.5		Y	Possible Bridge Location
22A	7700.64	6374.90	BRIDGE	1				S047, W044	S. Fork Crooked Creek	22	45	Y	Bridge Location
22B	111.60	331.93	6'X7' RCB		1								
23	56.19	207.20	72" RCP		1			S064b,c		24.5, 24.5			
24	188.57	490.96	6'X10' RCB		1			S068a,b,c		21.5 (a-c)			
25	43.25	163.17	66" RCP			1		S070b		20.5			
26	32.81	129.50	60" RCP			1		S071, W073a,b	E. Fork Stewarts Creek Trib 1A	20.5	52	Y	
27	2623.03	1576.57	3-(6'x12') RCB		1			S076	E. Fork Stewarts Creek	53			
28	99.45	360.01	6'X7' RCB		1			S080a,b,c, W080		36.25 (a-c)	52	Y	
29	72.43	259.00	6'X6' RCB		1			S081a, W082		41.75	46	Y	
30	10271.69	6359.83	BRIDGE	1				S082	Stewarts Creek	32.5		Y	Bridge Location
31	180.80	470.33	6'X10' RCB		1			S086, S088a, W093		31.5, 19.5	49		
32	34.04	132.09	60" RCP			1		S089a, W099, P43		19	36		
33	70.21	256.41	6'X6' RCB		1			S094, S095a,b, S096, S097, W104.5, W104		24.5, 24.5, 24.5, 24.5, 22	57 (2)		
34	74.21	269.36	6'X6' RCB		1			S093a,b, S094, W104, P46		22, 30.5,24.5	57	Y	
35	82.69	297.85	6'X6' RCB		1			S103a,b, S106, W107		31.5, 31.5, 25	48		
36	41.17	155.40	60" RCP			1		S108a,b, W110, W111, W112		22, 34.5	65 (3)	Y	High Wetland Rating
37	46172.31	11661.67	BRIDGE	1				S111, W123	Richardson Creek	50.25	56	Y	Bridge Location
38	9293.78	4755.65	BRIDGE	1				S112	Ray's Fork	49.25		Y	Bridge Location
39	55671.84	14257.78	BRIDGE	1				S111, S115b	Richardson Creek	50.25, 36		Y	Bridge Location
40	89.16	315.98	6'X7' RCB		1			S140f, W139, W140		39	45 (2)		
41	64.07	238.28	72" RCP		1			S145		19.5			
42	48.60	183.89	66" RCP			1							
43	74.82	279.72	6'X6' RCB		1			S146c,d, W150	Meadow Branch Trib. 2	19.5, 32	44		
44	238.69	660.53	7'x12' RCB		1			S156a,b	Half Way Branch	39, 39			
45	296.23	734.40	7'x12' RCB		1			S156b, W156	Half Way Branch	39	47		
46	2018.58	2668.59	3-(8'x12') RCB		1			S152, S154c, W161, W163, W168, W169	Half Way Branch	43.5, 30	47, 49, 62, 48	Y	Possible Bridge Location
47	1994.29	2649.21	3-(8'x12') RCB		1			S152, W167, W169, W170	Half Way Branch	43.5	62, 48 (2)	Y	Possible Bridge Location
48	103.83	375.76	6'X8' RCB		1			S158		33.25			
49	101.03	369.62	6'X8' RCB		1			S158		33.25			
50	52.96	196.84	66" RCP			1							
51	134.84	509.24	6'X10' RCB		1			S161b,c, W176		27, 42.5	58	Y	
52	184.11	636.80	7'X10' RCB		1			S161c, W176		42.5	58		
53	879.16	1632.12	3-(6'x12') RCB		1			S169a,b, S172d, W201	Salem Creek	42.5, 42.5, 34	53	Y	Large Culvert w/Wetland Impacts
54	886.14	1639.91	3-(6'x12') RCB		1			S169a,b, S172d, W201	Salem Creek	42.5, 42.5, 34	53	Y	Large Culvert w/Wetland Impacts
				8	39	9	0						



Legend

- Field Visit Locations
- Proposed Alignments
- Interstate Highway
- US Highway
- NC State Highway
- State Road
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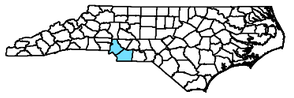
- Lake
- County Boundary



Mecklenburg and Union Counties
North Carolina Counties

Source: Mecklenburg County and Union County GIS.
Map Printed On 09-19-08.

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Mecklenburg County and
Union County

MONROE CONNECTOR/ BYPASS

FIELD VISIT LOCATIONS

Figure 7

Figure_7_FieldVisitLocations.mxd 09-19-08

3.4 Research at NCDOT Hydraulics Unit

To supplement the field reconnaissance, PBS&J conducted research at the NCDOT Hydraulics Unit in Raleigh, NC to evaluate the history and performance of existing drainage structures and, consequently, make appropriate recommendations. Although many of the drainage structures were identified on the NCDOT maps, only a limited number of Bridge Survey Reports (BSRs) and Culvert Survey Reports (CSRs) were obtained during a search through NCDOT hardcopy files. The preparation of BSRs and CSRs is a relatively new requirement, and a BSR and/or CSR would only have been prepared if the structure in question had either been constructed recently at a new location, or had been recently replaced at an existing location. NCDOT Hydraulics Unit does not have BSRs and CSRs on the majority of older existing structures in the state. Following identification of the drainage structure, the structure numbers and locations were provided to NCDOT Hydraulics staff, who researched their digital files to determine whether any additional information was available on these structures. Based on the computer search, a Bridge Inspection Report (BIR) was obtained for every crossing of interest. Since a BIR is based upon a field inspection of a structure, this document contains pertinent data on structure type and material, geometric data, age and service life, etc. All above reports provided by NCDOT are included in **Appendix A – Referenced Reports and Data**.

3.5 Hydraulic Computations

During the field investigations, there were several locations where an existing structure was present some distance upstream and/or downstream of the proposed crossing. In those cases, the approximate size and location of the structure was noted on the field visit forms and this information was then used as an aid in selecting the proposed size for the crossing.

According to the methodology spelled out in the NCDOT guidelines, the peak runoff was computed at each location using one or more methods. The results of the peak flow calculations were compared, and the highest value at each location was chosen as the design value for the proposed crossing. Using this design flow, the preliminary size of the crossing was chosen based on inlet control calculations using HDS-5 methodology. The sizing guideline in the scope-of-work is as follows:

> *Size preliminary box culverts for total head loss less than or equal to 1.0 foot for the 100-year flood. Inlet control HW/D = 1.2 or less for Design Year Flood. Size preliminary bridges to provide equal or greater conveyance.*

The first of these guidelines can only be strictly followed if a hydraulic analysis is performed (since you need to compare the proposed water surface with the normal water surface elevation to determine the increase in backwater). Preliminary culvert sizing is done using HDS-5 calculations, which do not compute backwater. Since any culvert designed with an HW/D of 1.2 for the design year event will, by definition, cause backwater in both the design event and the 100-year event, it should be noted that the culvert sizes determined in this analysis may not account for the impact of backwater or ponding on the upstream side of the culvert and a larger structure may be recommended during final design to address this concern. NCDOT Hydraulics Unit recommended that all culverts be sized for the 50-year event assuming an HW/D of 1.2.

It is important to note that the purpose of the Preliminary Hydraulic Tech Memo is to determine a preliminary drainage structure size which can then be used, in conjunction with many other factors, to evaluate the Detailed Study Alternatives. It is important, at this level, to determine whether the drainage structure will be a pipe culvert, a box culvert, or a bridge; to determine an approximate length; and to estimate the amount of fill which will be required. The purpose of this analysis is not to determine the final drainage structure size, since there is insufficient information to do so at this time. Once the LEDPA has been selected, a detailed hydrologic and hydraulic analysis will be performed for each crossing location to determine the actual size and configuration of the structure. Also, for all new locations on FEMA-regulated streams, a Conditional Letter of Map Revision (CLOMR) and Letter of Map Revision (LOMR) must be prepared and submitted. If the structure can be documented, through detailed analysis, to cause no increase in the base flood elevation (BFE) at any cross section, it may be possible for the site to be processed through the Memorandum of Agreement (MOA) that NCDOT has with the North Carolina Floodplain Mapping Program. Because Mecklenburg County is recognized as a Cooperative Technical Partner with FEMA, any impacts to regulated streams within Mecklenburg County would have to be reviewed by the County and the aforementioned MOA would not be applicable.

In order to facilitate the preliminary sizing, it was necessary to clarify the analysis criteria. Although the revised criteria are different from that contained in the scope-of-work, they have been altered in such a way that the guidelines are clearer, and the resulting structures will be sized in accordance with NCDOT guidelines.

Pipe Culverts: HW/D is less than or equal to 1.2 for the 50-year discharge. Drainage area is typically less than 100 acres. The maximum size will be 72” RCP; larger crossings will require a box culvert. The inverts of all pipe culverts over 48” will be buried one (1) foot below grade.

Box Culverts: HW/D is less than 1.2 for the 50-year flow. Drainage area is typically between 100 acres and 10 square miles. The inverts of all box culverts will be buried one (1) foot below grade. The minimum size will be a single-barrel 6x6 RCB and the maximum size will be a triple-barrel 12x12 RCB; larger crossings will require a bridge.

Bridges: The drainage area for bridge crossings is typically greater than 10 square miles. If the crossing is in a FEMA detailed study area, bridge should span the floodway/floodplain and no-rise criteria will apply. If the crossing is not in a detailed study area, one (1) foot of backwater is permitted and bridge length will be determined based on field investigation (upstream and downstream structures) and/or a profile along the proposed roadway alignment, and/or aerial photography. Since bridge hydraulics are not being performed for preliminary design, the length and number of spans will be estimated based on the above data.

In order to maintain consistency, a range of flows was established for which a given culvert size was appropriate and any crossing whose peak flow fell within that range utilized the same culvert size. A culvert selection matrix was created from this data and this matrix was used for preliminary sizing at the culvert crossings. This matrix and the supporting HDS-5 printouts are included in the appendix. The range of potential crossings included single-barrel circular culverts, single-, double-, and triple-barrel box culverts, and bridges. The largest box culvert size included in the matrix was a triple-barrel, 12-foot by 12-foot RCB (Reinforced Concrete Box) and any crossing that required more than that was assumed to be a single- or multi-span bridge. The culvert hydraulic calculations included in this report are for inlet control only and reflect the actual hydraulic opening required for the given flow (excluding any buried depth). The adjusted culvert size (taking into account upstream and downstream structures, buried invert requirements, and other non-hydraulic constraints) is presented in **Table 4 – Recommended Preliminary Crossing Sizes**, but hydraulic calculations were not performed using this larger size. The box culvert sizes included in the tables presented in this report are listed as height x width (H x W), thus a 7'x 10' RCP is 7 feet in height and 10 feet in width.

The Corps of Engineers NWP requirement that the invert of all box culverts and all pipe culverts exceeding 48 inches in diameter be buried one (1) foot below grade is in addition to the size shown in the accompanying tables. This means that the 60-inch and 66-inch culverts identified in this analysis would be subject to such a requirement and would, therefore, have to be increased to 72 inches or greater in size (60 inches will be increased to 72 inches, 72 inches will be increased to a 6x6 RBC). All of the structures identified in this