Aluminum Box Culverts with Bottoms Review

North Carolina Department of Environment and Natural Resources

Division of Water Quality

Transportation Permitting Unit

February 2012

The NDCDWQ gratefully acknowledges the NCDOT staff that participated in the site visits and provided additional information, especially Mr. Jerry Lindsey and Mr. Roger Bryan.

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Introduction

The North Carolina Division of Water Quality (NCDWQ), Transportation Permitting Unit staff, has seen requests from the North Carolina Department of Transportation (NCDOT) to install aluminum box culverts. Traditionally, these requests have been associated with efforts to replace old timber-pile bridges that have reached or exceeded their useful life or to replace failed culvert pipes (often multiple pipes) which are usually much smaller than aluminum box culverts which replace them.

In an effort to maintain stream crossings such that they are safe to the traveling public, existing culverts and small bridges are replaced as they reach the end of their design or useful life, if not before. Most bridges and culverts being replaced have been in service for many decades. Older bridges may be constructed of concrete on wooden or steel piles. The vast majority of box culverts in the state are constructed of concrete. However, since the early 1980's, NCDOT has used box culverts constructed of aluminum to replace some of these older structures (personal communication, Jerry Lindsey, NCDOT).

Aluminum box culverts are available in two different styles. One style is bottomless and is built on concrete footers which in turn typically sit upon a solid bedrock foundation. The foundation and footers support the weight of the culvert as well as the weight of the fill, roadbed, and traffic. The second style has a bottom, and is usually a compressed oval shape, much like a "D", with the bottom area being nearly flat. This type is often used when a suitable bedrock foundation is not available. The NCDWQ requires these culverts to be buried, unless a factor is present that would prevent sufficient burial. If the structure is not backfilled during construction then it is expected that when these culverts are buried sediment will settle in the bottom of the culvert through natural events. When this occurs it presents a more natural setting, more closely mimicking the pre-installation condition of the stream. This in turn allows for acceptable flow and aquatic life passage during low and extreme low flow conditions.

Currently, there are at least seventy-five aluminum box culverts installed throughout the state (personal communication, Jerry Lindsey, NCDOT). At present, it is unclear how many of those installed are bottomless and how many are bottomed. When aluminum box culverts are used, the NCDWQ generally prefers the bottomless type, as it allows for the natural stream bed, location, and function to remain in a more natural state. The installation process for bottomed culverts is more intrusive to the stream than that of bottomless culverts. While both types may require dewatering, the whole stream bed must be excavated down in order to properly set a bottomed culvert. Excavation several feet below the natural stream bed is often required as a bed of gravel, stone, or other supporting material must be laid to support the weight of the culvert and provide a level substrate for the bottom to rest on. Generally, the installation of a bottomless culvert involves excavation for the footers to be installed, leaving much of the natural stream bed undisturbed.

While there may or may not be financial savings for the use of aluminum box culverts over other traditional methods or structures, the NCDOT reports that there are other benefits which are considered when deciding on replacement construction. For example, aluminum box culverts parts can be, depending on the overall size, delivered to the site and assembled on nearby land. Once the culvert is assembled, it can be lowered into place very quickly once the site has been prepped for installation. This

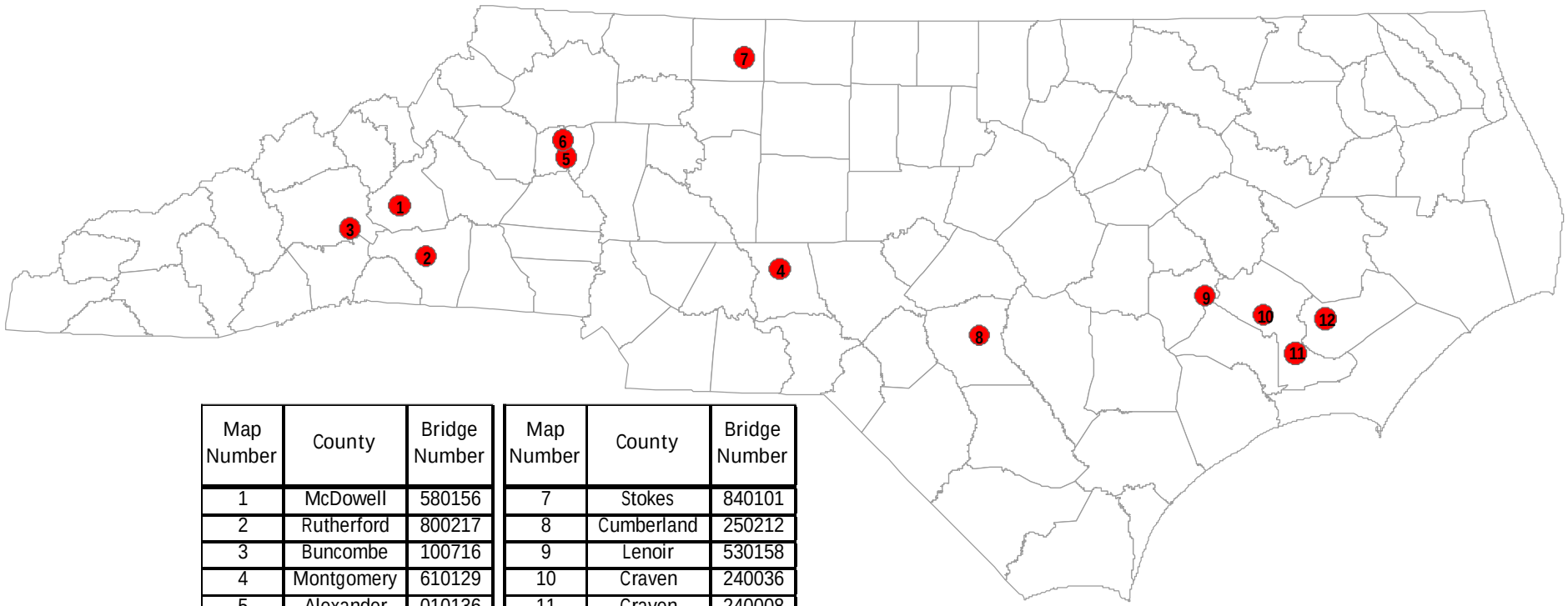
shortens the overall construction time and allows the road to be closed for a shorter length of time. In extreme cases however, the structure must be assembled in place, although thus far these appear to be rather rare cases. The width of aluminum box culvert openings can be much wider than that of a poured concrete box culvert, which can reduce maintenance by allowing larger debris to pass through the opening rather than getting trapped in smaller openings and requiring time and effort to remove (Roger Bryan, personal communication, NCDOT).

While the NCDOT has always strived to reduce the costs of construction and maintenance where possible, the recent downturn in the economy has led to tighter restrictions of the budget, and the NCDOT has had to look even harder for ways to reduce costs associated with construction and maintenance. Nonetheless, in 2011, the North Carolina Legislature designated $440 million dollars to the NCDOT to accelerate the replacement of bridges which have become obsolete and have reached the end of their expected life. The money was allocated to be spent in 2012 and 2013. For reasons discussed above, the NCDWQ may see an increase in NCDOT requests for the use of aluminum box culverts to replace small bridges in situations where site-specific conditions may allow.

NCDWQ staff has reported that some of the aluminum box culverts may not be functioning as expected with respect to stream function and stability. Primary concerns with any type of culvert installation include aquatic life passage issues, maintaining flow under low flow and extreme low flow conditions, over-widening or excavation of the stream, and bank instability. The NCDWQ 401 Water Quality Certification addresses these concerns by requiring culverts to be buried twenty percent of the opening diameter for culverts with openings less than four feet and be buried at least one-foot for openings greater than four-feet. Additionally, excavation of the stream shall be kept to a minimum and the stream shall not be over-widened. Again, because more of the stream channel typically has to be disturbed during construction and installation these concerns are more likely to become issues in installations where bottomed aluminum box culverts are used.

In November and December 2011, NCDWQ staff, in coordination with NCDOT staff, visited twelve stream crossings where bottomed aluminum culverts were installed (Figure 1). Three were located in the western area of the state, five in the central portion, and four in the eastern part of the state. While not intended to be an exhaustive study of the culverts, staff documented such things as culvert installation, aquatic passage ability, stream stability, culvert slope, sediment deposition within the culvert, and depth of installation. Several pictures were taken at each of the sites as well. This information was then analyzed to determine if any specific issues could be documented, and if so, what circumstances may be contributing factors. It was also used to determine potential future installation guidelines.

Figure 1: Location of Aluminum Box Culverts Reviewed



Map Number	County	Bridge Number
1	McDowell	580156
2	Rutherford	800217
3	Buncombe	100716
4	Montgomery	610129
5	Alexander	010136
6	Alexander	010058

Map Number	County	Bridge Number
7	Stokes	840101
8	Cumberland	250212
9	Lenoir	530158
10	Craven	240036
11	Craven	240008
12	Pamlico	630039

Site Reviews

The following section contains a summary of information and observations from each of the twelve sites visited. Again, this study was not intended to be comprehensive and provide a complete assessment of aluminum box culverts installation and function, but rather to see if the culverts were meeting the NCDWQ's aquatic life passage requirements, verify that the culvert did not appear to be causing any stream instability, and identify any other issues that the NCDWQ may consider significant. In the process, it was desired that any issues found could be discussed with NCDOT staff and perhaps some general criteria could be set to possibly avoid issues in the future.

As part of each site evaluation, some basic information was recorded about the site and photos were taken to document the site. Much of this information is included below in the review of the sites. It should be remembered that these sites were only visited once, so information presented only represents a "snapshot" of the site. Additionally, with respect to aquatic life passage, the sites were visited in the fall when low flow conditions would not be expected. Therefore, some assumptions and speculation were made regarding what conditions might actually be present during low flow and extreme low flow conditions.

For the purposes of this review, the state was divided into three general areas, the western area of the state, the central area, and the coastal area. Geographically speaking, these areas would generally be associated with the mountains, the piedmont, and the coast, respectively. It is recognized that conditions vary greatly across the state. Steep slopes, bedrock and cobble are predominant in the western part of the state while lower gradient systems with lower velocities and finer sediment are found in the coastal areas of the state. Because of these differences, the information presented below is arranged by the region of the state in which they are located. Sites were primarily selected based on location and recommendations by NCDOT staff.

The information presented below was gathered from a variety of sources. Structure centerline length, opening width, year of installation, and opening size were provided by NCDOT (Jerry Lindsey, personal communication, NCDOT). The area draining to the culvert was determined using the 1/9" arc resolution National Elevation Dataset (NED) available from the USGS (http://gisdata.usgs.gov/website/seamless/viewer.htm) which was then analyzed using ArcMap 9.2 and Spatial Analyst to determine watershed area and stream locations for mapping purposes. Land cover data from 2006 (the most recent available) was also downloaded from the USGS website (http://gisdata.usgs.gov/website/seamless/viewer.htm) and analyzed to obtain the primary uses within a given watershed. Land cover is reported in twenty-four categories, and was analyzed to provide general information about the watershed. The three most dominant land covers are included in the summaries. All sites are located in mostly rural areas, as reflected in the land cover analyses.

Sediment depth estimates were made using a surveyor's rod in deeper waters and/or visually observed in shallower areas which were easily accessible. Sediment composition was also based mostly on visual observation. Other information, such as structure slope and previous structures were primarily provided from past bridge inspection reports and engineering reports. Additionally, NCDOT staff from various sections participated in the reviews with NCDWQ staff. Some of the information discussed below arose from discussions during the onsite reviews.

Sites in Western North Carolina

NCDOT Bridge No. 580156, S.R. 1771 (Dairy Road), McDowell County

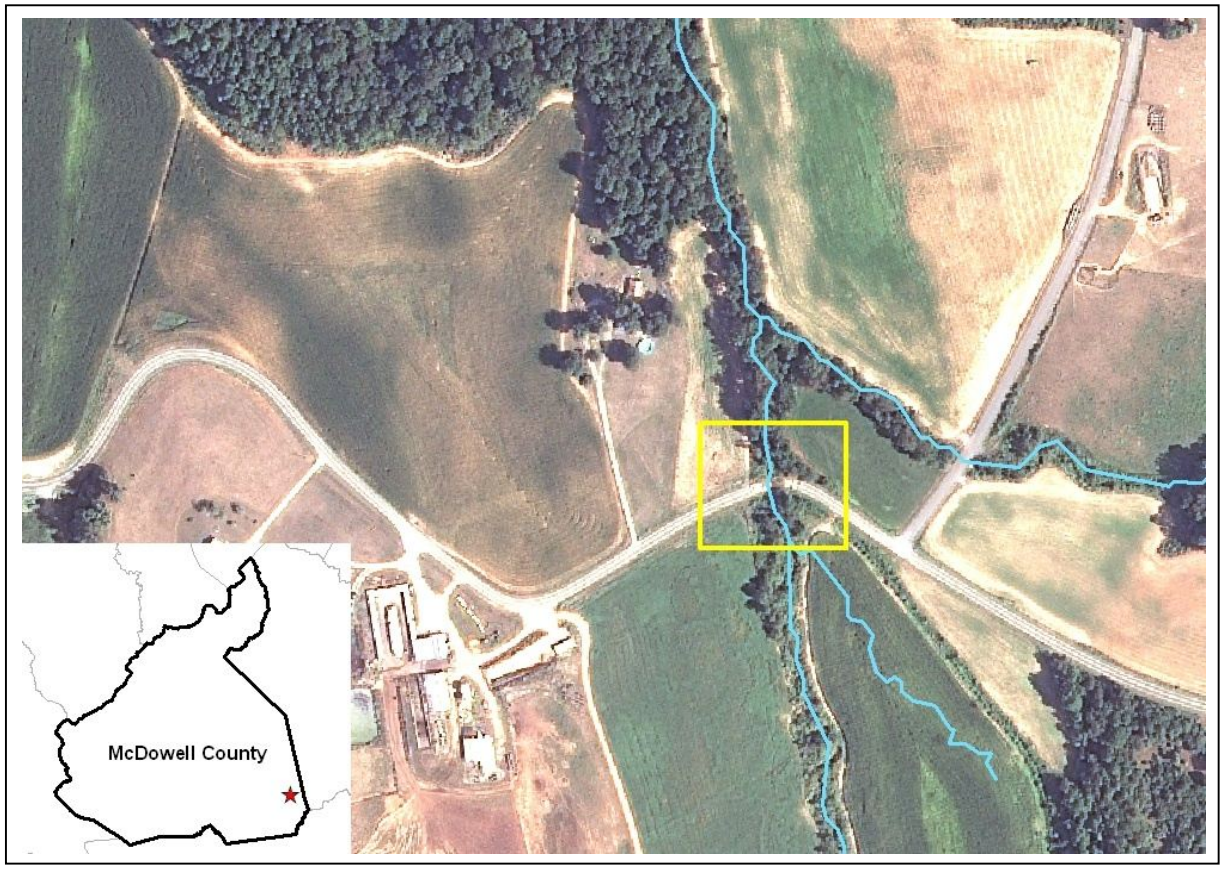
Table 1: Summary Information for Bridge No. 580156, McDowell County

Date Visited:	11/21/2011
Year Installed:	2011
Ecoregion:	Piedmont
Stream Name:	Magazine Branch
River Basin:	Catawba
Culvert Buried:	Yes
Latitude:	35.601
Longitude:	-81.854
Drainage Area:	2.19 mi²
Centerline Length:	40'
Opening Width:	30' 6"
Opening Height:	7' 7"
Approx. Width of Natural Stream:	5 ft
Approx. Structure Slope:	<1%
Primary Streambed Sediment:	Silt

This site is located in the very southeastern part of McDowell County, several miles southeast of the City of Marion, on S.R. 1771, which is also known as Dairy Road. It is situated on Magazine Branch (DWQ Index No. 11-32-2-9-2; class C) in the Catawba River basin and generally flows to the north.

The structure was installed in June 2011; four-to-five months prior to the review and was chosen to replace an existing twenty- foot-four-inch long bridge.

Figure 2: Location of Bridge No. 580158, McDowell County



During the review, it was observed that water in the culvert was about twelve-inches deep and was flowing several feet per second. In the thirty days prior to the site visit the site had received 2.70 inches of rain, including 1.34 inches in the five days prior to the review (MPE estimates). Even though installation was only several months prior to the review, at least two bankfull events are believed to have occurred prior to the review.

It was determined that the structure is currently buried about eighteen-inches at the center point of the opening. During construction, the area under the culvert was excavated an additional three feet below the planned bed elevation of the structure. This additional excavated area was filled with stone on which the structure was set.

The natural channel width is approximately five feet. During construction, riprap was placed at the inlet and outlet of the structure such that the natural width of five feet would be maintained. The riprap was added in the areas that were excavated out in order to install the culvert on both the inlet and outlet of the structure. This allowed the natural flow of water to enter and exit the structure in the middle of the opening, rather being guided or forced to one side or against the walls of the structure. There was no fabric placed under the riprap. The intent was to allow vegetation to establish within the riprap field. It is the intent of the NCDOT to plant live-stake trees during the next planting season. This should help to further establish a stable floodplain bench and banks.

Figure 3: General Sediment Profile for Bridge No. 580156, McDowell County

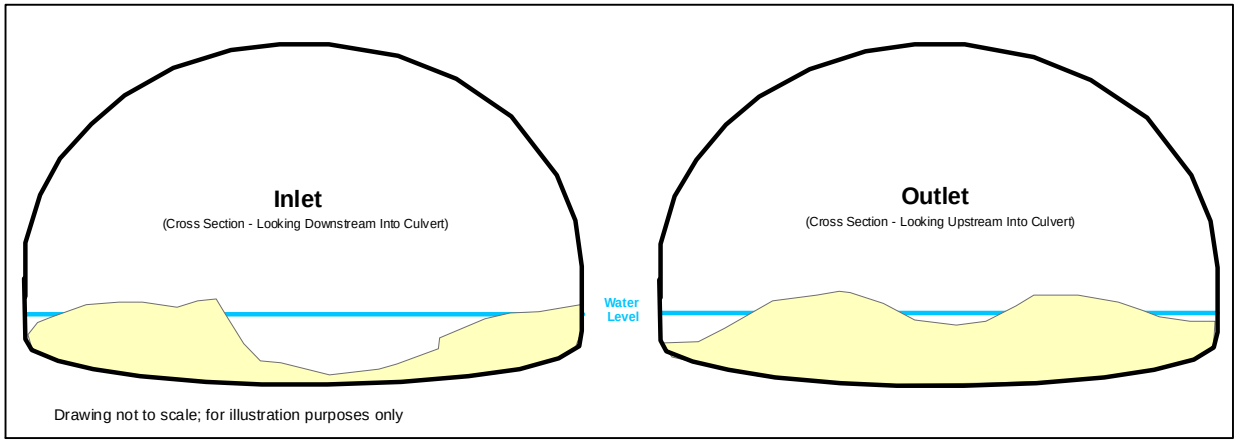
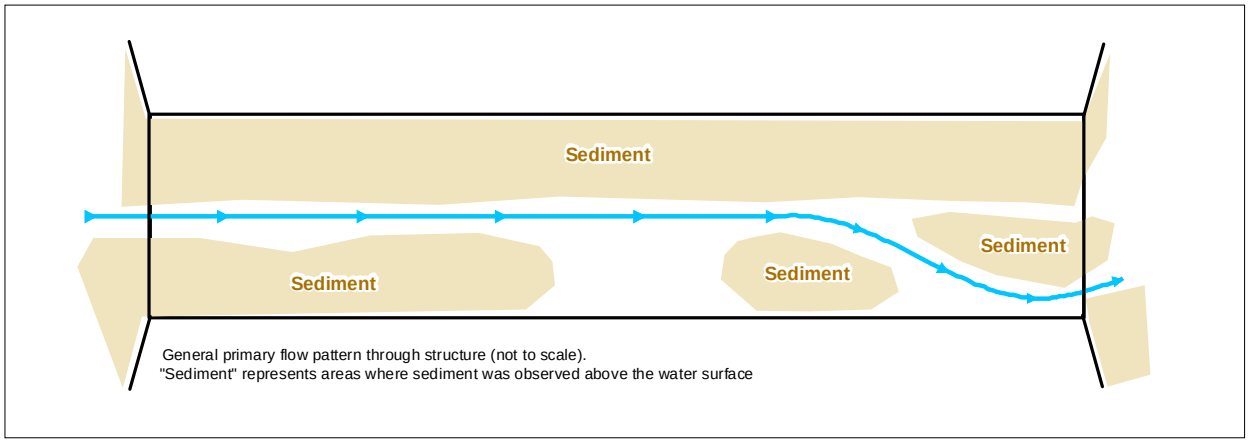


Figure 4: General Flow Profile for Bridge No. 580156, McDowell County



There was no material placed within the structure during installation, and a portion of the structure bottom could be seen at the inlet side. However, sediment had begun to settle out in the structure and the water was starting to form its own channel within the deposited sediment. Native sediment is very fine and appears to settle out fairly quickly. This is evident by the amount of sediment that has settled out in the few months the structure had been in place. On the upstream side of the structure inlet, there was approximately thirteen to fourteen-inches of sediment that had been deposited. The channel at the inlet was in the middle of the structure, no doubt guided by the riprap fields discussed earlier. At the outlet there was approximately sixteen to seventeen-inches of sediment that had been deposited. The main channel on the outlet side was on the right side of the structure (looking downstream). It is expected that sediment will continue to be deposited in the structure as weather events allow.

No scour was observed around the structure, most likely because the rip rap was providing protection. The stream has become incised, and as such, no floodplain was available. Prior to the structure being installed, the banks surrounding the previous bridge were unstable. There was still evidence of unstable banks some distance downstream of the structure. To help stabilize the banks in the general area of the structure, the banks had been cut back, and a field of riprap was installed in all four quadrants. One of the upstream quadrants had fill placed over the riprap overlain by coir fiber matting. The area was then seeded for stabilization. Because of these actions, the banks surrounding the structure were stable.

The area draining to the culvert is approximately 2.19 square miles. The primary land cover is deciduous forest (48.8 percent), followed by pasture/hay (26.0 percent) and evergreen forest (8.6 percent).

Figure 5: Drainage Area for Bridge No. 580156, McDowell County

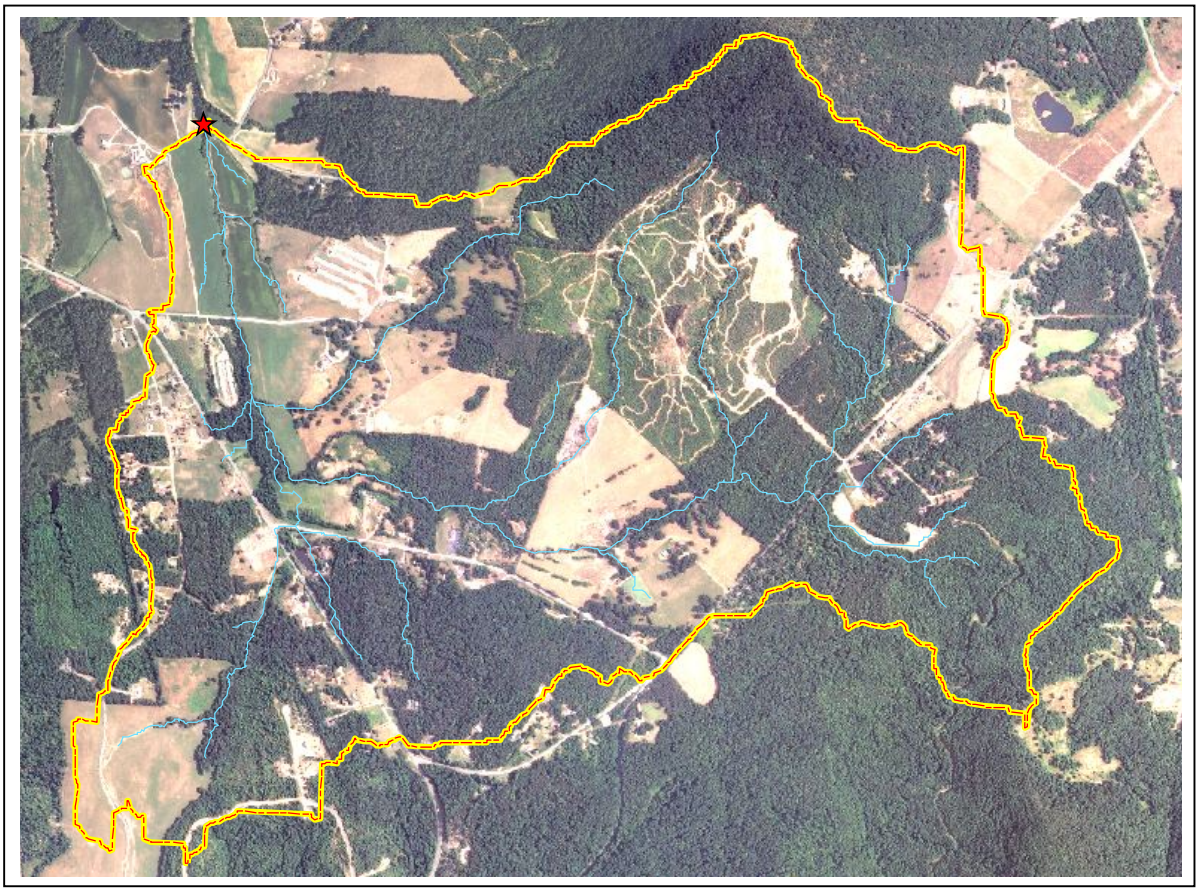


Figure 6: Photographs of Bridge No. 580156, McDowell County

Downstream side of structure

Downstream through structure

Downstream through structure

Upstream through structure

Stream upstream of structure

Stream downstream of structure

NCDOT Bridge No. 800217 S.R. 1520 (Rock Road), Rutherford County

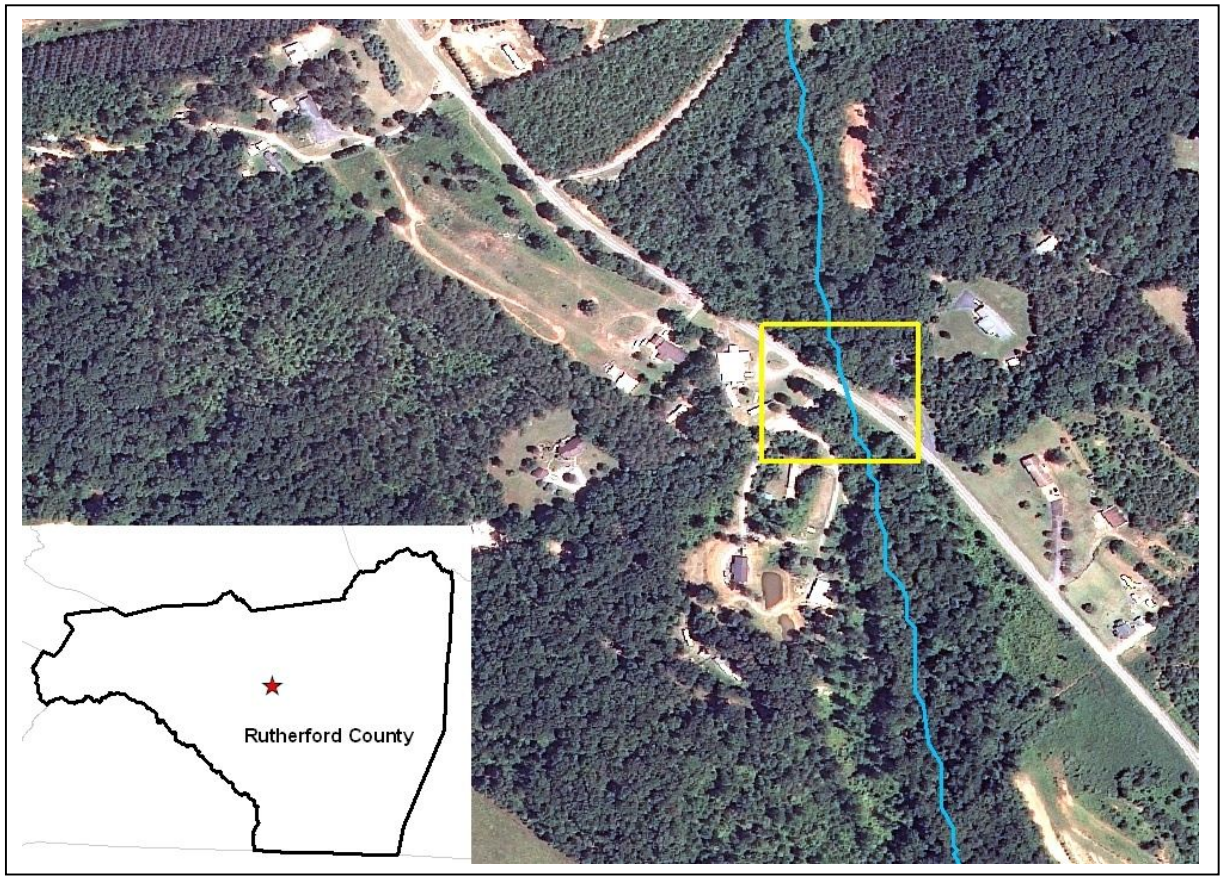
Table 2: Summary Information for Bridge No. 800127, Rutherford County

Date Visited:	11/21/2011
Year Installed:	2011
Ecoregion:	Piedmont
Stream Name:	UT to Catheys Creek
River Basin:	Broad
Culvert Buried:	Yes
Latitude:	35.42
Longitude:	-81.942
Drainage Area:	0.96 mi^2
Centerline Length:	99'
Opening Width:	32' 7"
Opening Height:	7' 9"
Approx. Width of Natural Stream:	6 feet
Approx. Structure Slope:	0.40%
Primary Streambed Sediment:	Cobble/Gravel/Sand

This site is located in central Rutherford County, north of the Towns of Rutherfordton, Ruth, and Spindale. The culvert is located on an unnamed tributary to Catheys Creek (DWQ Index No. for Catheys Creek is 9-41-13-(0.5); Class WS-V), which generally flows in a southerly direction in the Broad River basin. The upstream area draining to the culvert is approximately 0.96 square miles, the smallest in the study.

This ninety-nine-foot structure was installed in 2011 and was chosen to replace a twenty-foot long bridge.

Figure 7: Location of Bridge No. 800217, Rutherford County



Installation of the structure was completed in early October 2011. Therefore, the structure had been installed just over one month at the time of the review. It should be noted that, at 99 feet in length, this structure is one of, if not the, longest aluminum box culverts in the State. The structure had to be assembled in place rather than being assembled nearby and set into place.

During the review there was water flowing at the site which was about four-inches deep. In the thirty days prior to the review, there was 2.42 inches of rain, 1.30 inches of which fell within the five days prior to visiting the site (MPE estimate).

The structure currently appears to be buried just under three feet at the center of the opening. Native sediment was placed in the culvert during construction using a small excavator. A channel was created in the middle of the structure with benches on each side. The sediment was covered with coir fiber matting. Areas outside of the structure were seeded and are planned to be over-seeded during the next growing season.

Figure 8: General Sediment Profile for Bridge No. 800217, Rutherford County

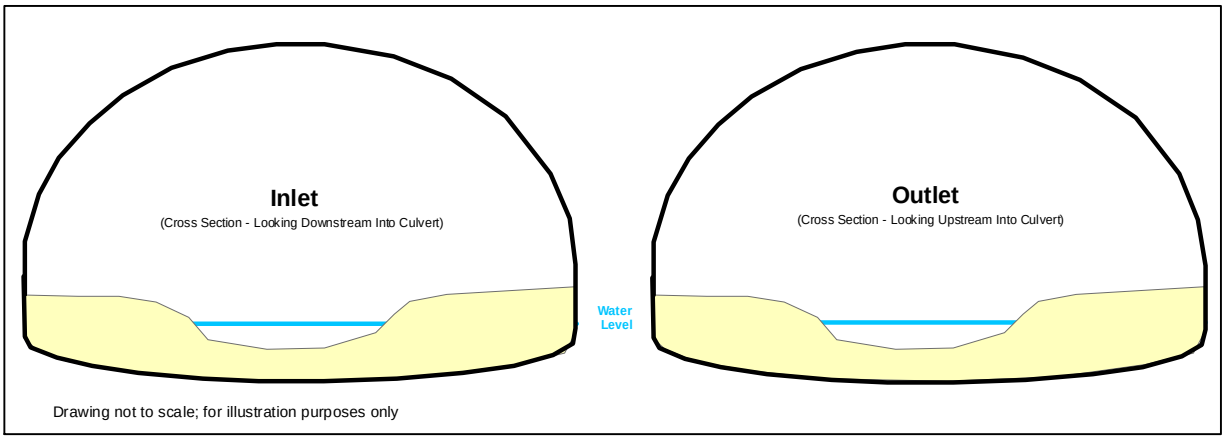
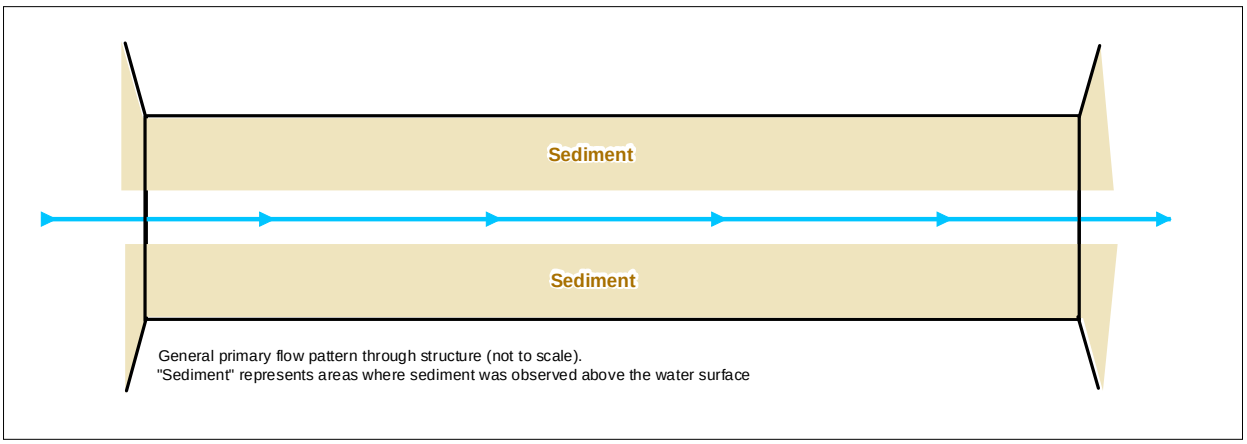


Figure 9: General Flow Profile for Bridge No. 800217, Rutherford County



The natural stream width is about six feet. The system is rather low gradient for the western piedmont, and the drainage area is small. Native sediment was used to create benches and a defined channel in the disturbed and excavated areas as well as inside the structure which were then covered with coir fiber

matting for stabilization purposes. The benches within the structure were approximately ten to twelve-inches high above the thalweg. The bottom of the culvert was not visible at any point. Aquatic passage was sufficient and would appear to be able to carry low flows effectively.

All four stream banks in the excavated or disturbed area had been stabilized with rip rap. Because of this the banks in the area of the structure were stable. There are stormwater discharge points on either side of the structure on the upstream side. The natural channel has been incised several feet both upstream and downstream of the structure. Due to the incision of the stream and the fill from the road, there was not much floodplain to access when needed.

The area draining to the culvert is approximately 0.96 square miles. The largest category of land cover in the drainage area is pasture/hay (36.1 percent), followed by deciduous forest (25.5 percent) and grassland/herbaceous (11.6 percent).

Figure 10: Drainage Area for Bridge No. 800217, Rutherford County

Figure 11: Photographs of Bridge No. 800217, Rutherford County

Downstream at structure

Upstream through structure

Downstream through structure

Downstream through structure

Upstream of structure

Downstream of structure

NCDOT Bridge No. 100716, S.R. 2832 (Kirstein Road), Buncombe County

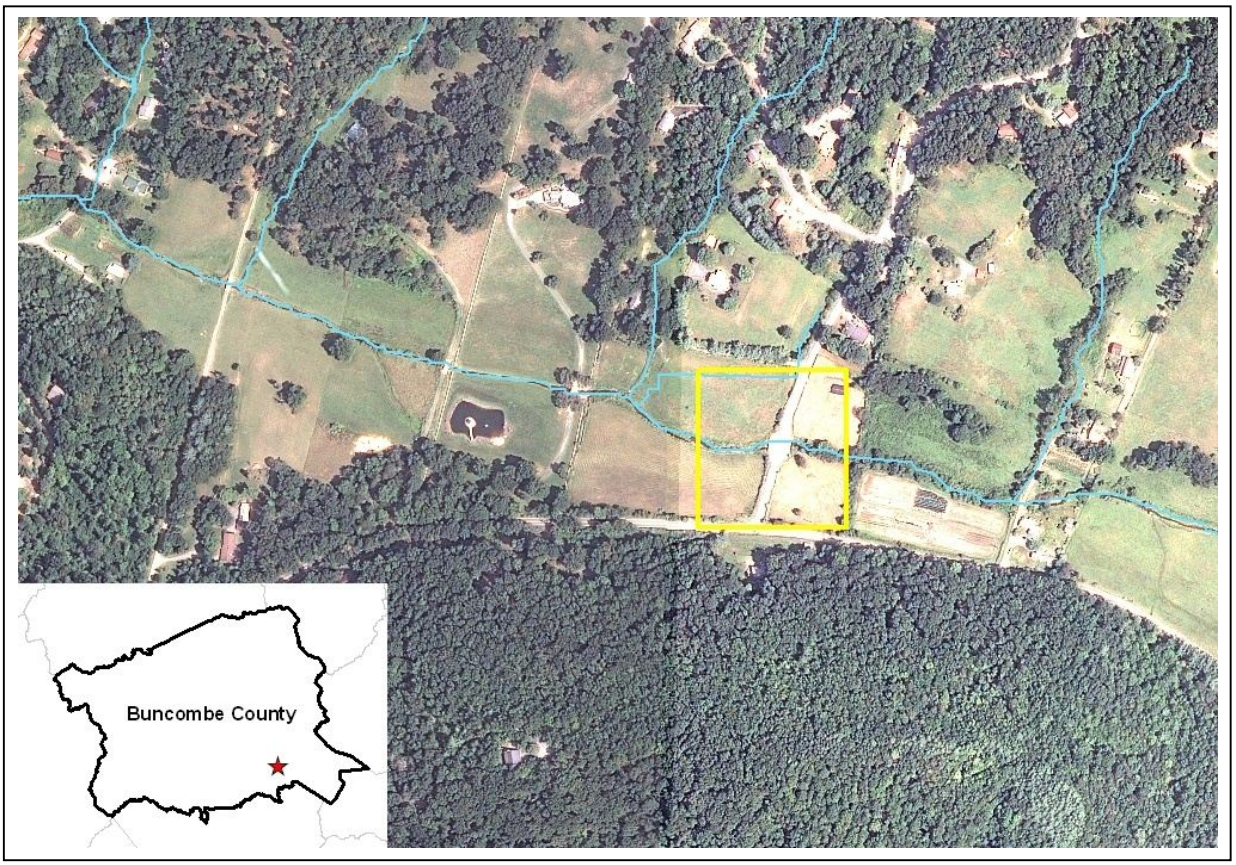
Table 3: Summary Information for Bridge No. 100716, Buncombe County

Date Visited:	11/21/2011
Year Installed:	2004
Ecoregion:	Mountains
Stream Name:	Garren Creek
River Basin:	French Broad
Culvert Buried:	Yes
Latitude:	35.527
Longitude:	-82.372
Drainage Area:	3.16 mi²
Centerline Length:	60'
Opening Width:	24' 3"
Opening Height:	7' 4"
Approx. Width of Natural Stream:	4 feet
Approx. Structure Slope:	0.60%
Primary Streambed Sediment:	Silt/Sand

This site is located in southeastern Buncombe County, west of southern Asheville and southwest of the Town of Black Mountain. The culvert is located on Garren Creek (DWQ Index No. 6-57-6, Class C;Tr) and flows in a general northwest direction in the French Broad River basin. The upstream area draining to the culvert is approximately 3.16 square miles.

This sixty-foot long structure was installed in 2004 and was chosen to replace a twenty-six-foot long bridge.

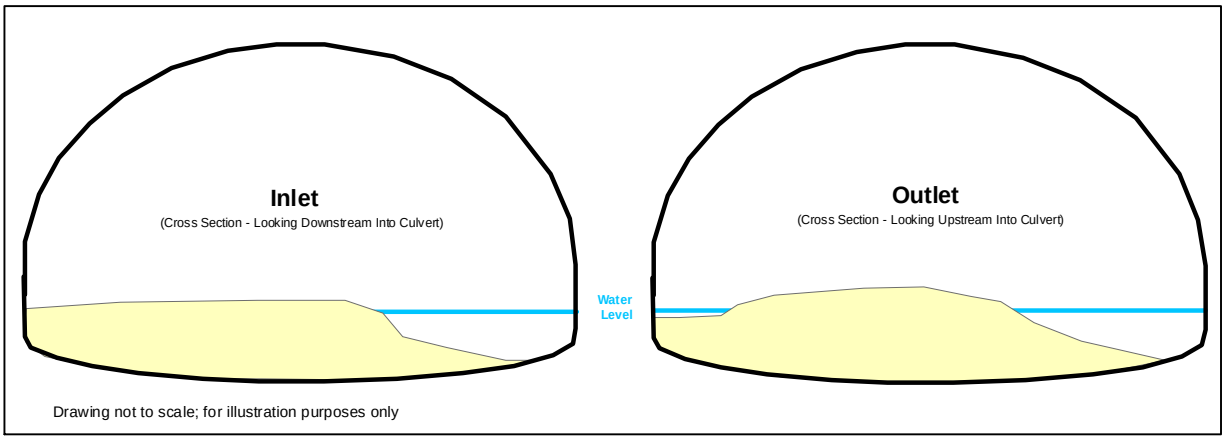
Figure 12: Location of Bridge No. 100716, Buncombe County



Water was present and flowing at a moderate pace. In the thirty days prior to the site review 2.56 inches of rain fell, including 0.85 inches in the five days prior to the visit.

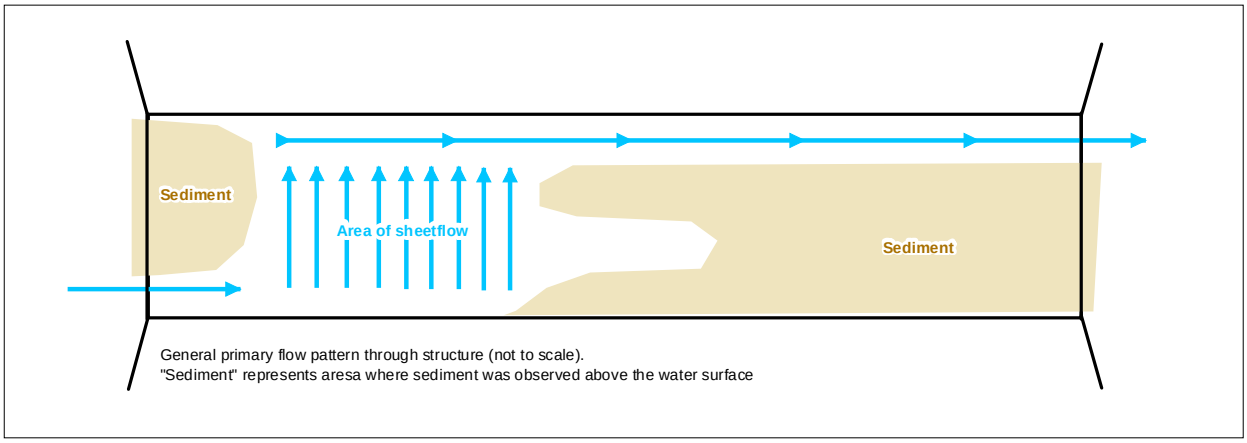
Currently, the culvert is not buried very well. The bottom of the structure could easily be seen at the inlet and outlet side. No sediment was placed in the structure during construction. There was a good amount of sediment that had been deposited in the structure through natural processes. The dominant sediment in the stream is silty sand with gravel. The majority of sediment deposited is on the right side of the structure (looking downstream), locating the stream channel on the left side of the structure against the wall. It is thought that the structure was buried about twelve-inches at installation, although it is not apparent at this time. As evident by the watermarks on the interior structure walls, flows often reach twelve-inches higher than that observed during the visit.

Figure 13: General Sediment Profile for Bridge No. 100716, Buncombe County



The natural channel width is approximately four feet. The stream widens out to approximately 14 feet in the area excavated at the inlet. The flow enters the culvert on the right side against the wall. Within the first few feet of the inlet of the culvert, the water becomes very shallow (approximately two-inches) and sheet flows down a shallow slope to the left side of the culvert against the wall where it reconcentrates and continues to flow against the wall until exiting the structure.

Figure 14: General Flow Profile for Bridge No. 100716, Buncombe County



Aquatic passage during low flow conditions could be an issue. The water depth in the sheetflow area was only a few inches, and may present a passage issue for larger organisms now, but if the water level drops much it could be an issue for nearly all organisms.

There was a small amount of riprap placed on the banks for stabilization and the banks appeared to be well vegetated and stable. There is an active horse pasture on the northeast and southeast side of the crossing. As observed during the visit, the horses access the pastures on both sides of the stream by crossing through the stream. While the horse crossing was muddy, it did not appear to be affecting stream or bank stability. There are no signs of scour at either the inlet or outlet headwalls of the structure. Some floodplain does exist, but would most likely only be accessible during higher flow events.

The area draining to the culvert is approximately 3.16 square miles. The dominant land cover in the drainage area by far is deciduous forest (85.3 percent), followed by pasture/hay (6.6 percent) and maintained grass (3.3 percent).

Figure 15: Drainage Area for Bridge No. 100716, Buncombe County

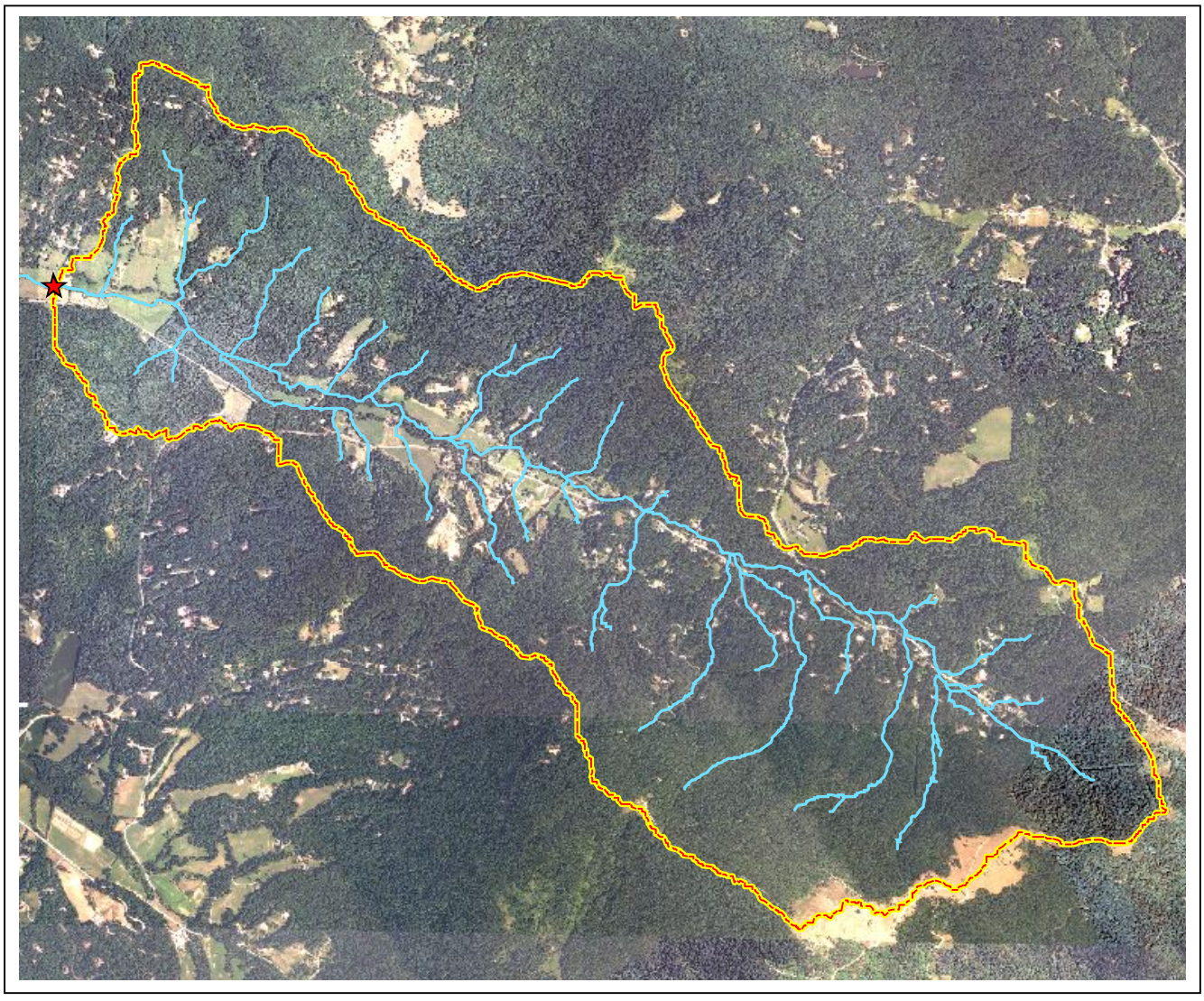


Figure 16: Photographs of Bridge No. 100716, Buncombe County

Upstream through structure

Main flow at outlet of structure

Downstream of structure

Upstream of structure (horse crossing on left side middle)

Immediately downstream of structure

Downstream right bank

Sites in Central North Carolina

NCDOT Bridge No. 610129, S.R. 1318 (Shiloh Church Road), Montgomery County

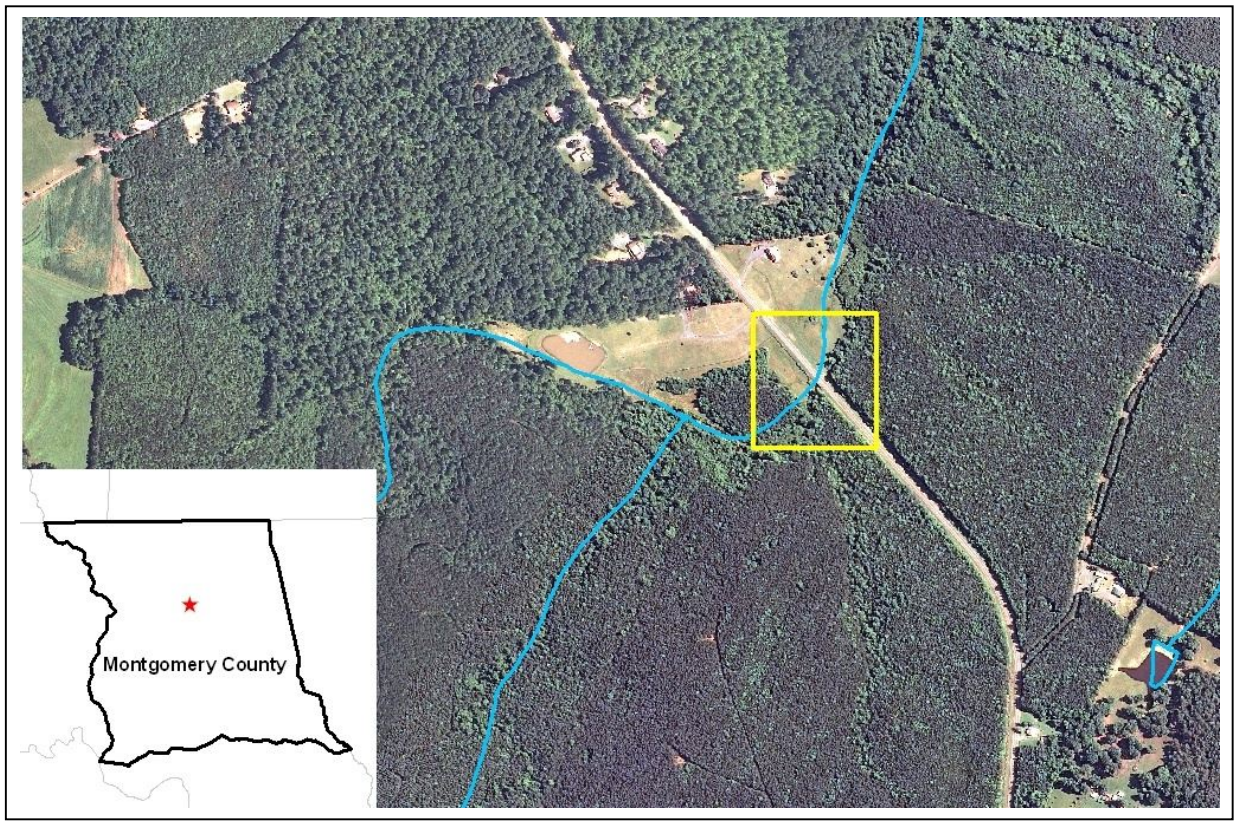
Table 4: Summary Information for Bridge No. 610129, Montgomery County

Date Visited:	11/28/2011
Year Installed:	2001
Ecoregion:	Piedmont
Stream Name:	Bishop Creek
River Basin:	Lumber
Culvert Buried:	Yes
Latitude:	35.383
Longitude:	-79.91
Drainage Area:	3.97 mi^2
Centerline Length:	45' 7"
Opening Width:	25'
Opening Height:	9' 5"
Approx. Width of Natural Stream:	6 feet
Approx. Structure Slope:	0.30%
Primary Streambed Sediment:	Sand/Gravel

This site is located in central Montgomery County, north of the Town of Troy, on S.R. 1318, also known as Shiloh Church Road. It is located on Bishop Creek (DWQ Index No. 13-25-20-8-1; class C; HQW). Bishop Creek generally flows to the northeast in the Lumber River basin. The area draining to the culvert is approximately 3.97 square miles.

The structure was installed in 2001, about ten years prior to the visit. The structure, forty-five-feet-seven-inches long, was chosen to replace a forty-foot bridge.

Figure 17: Location of Bridge No. 610129, Montgomery County



Water was present and flowing during the visit. Water depth in the thalweg was approximately twelve-inches with a moderate flow. In the thirty days prior to the visit, the area received 2.78 inches of precipitation, 0.56 inches of which fell within the five days preceding the visit (MPE estimate).

Although the structure was buried one-foot during construction, the structure is not buried very well at this time. The bottom of the structure can be seen throughout in the main channel of flow. No back-filling of the structure occurred when it was installed; therefore all sediment deposits are from natural events. The structure has a bench on the right side in the structure, consisting primarily of sand and gravel. Due to the benches, the main flow channel was on the left side of the structure wall. Water in the thalweg was approximately twelve-inches deep. Waterlines on the interior walls indicate that flows at least three feet higher than observed during the visit have occurred. Due to the dark color and staining on the walls it appears that flows two feet higher than observed occur regularly.

It should be noted that a headcut was seen approximately twenty feet upstream of the culvert inlet. It is unclear if this is directly related to the structure. The drop associated with the headcut is approximately eight-inches.

Figure 18: General Sediment Profile for Bridge No. 610129, Montgomery County

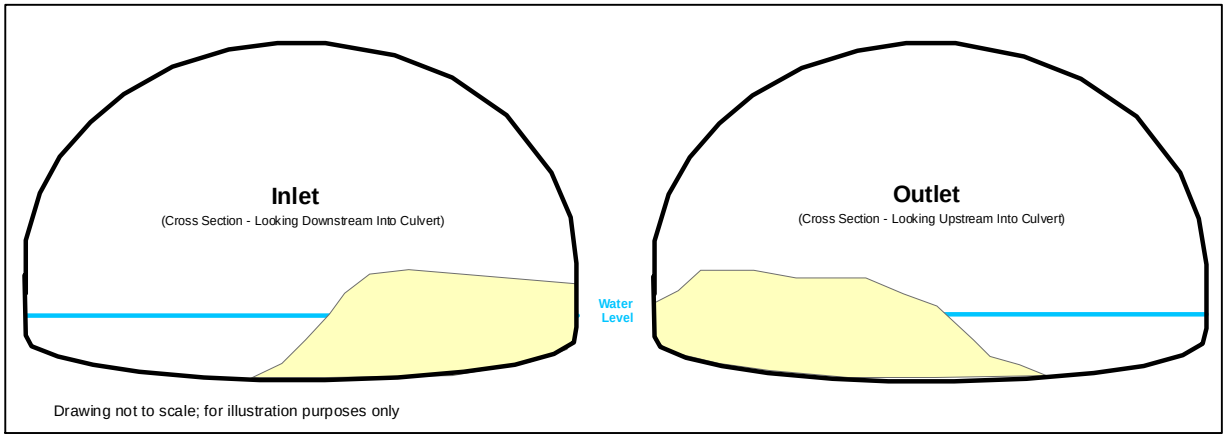
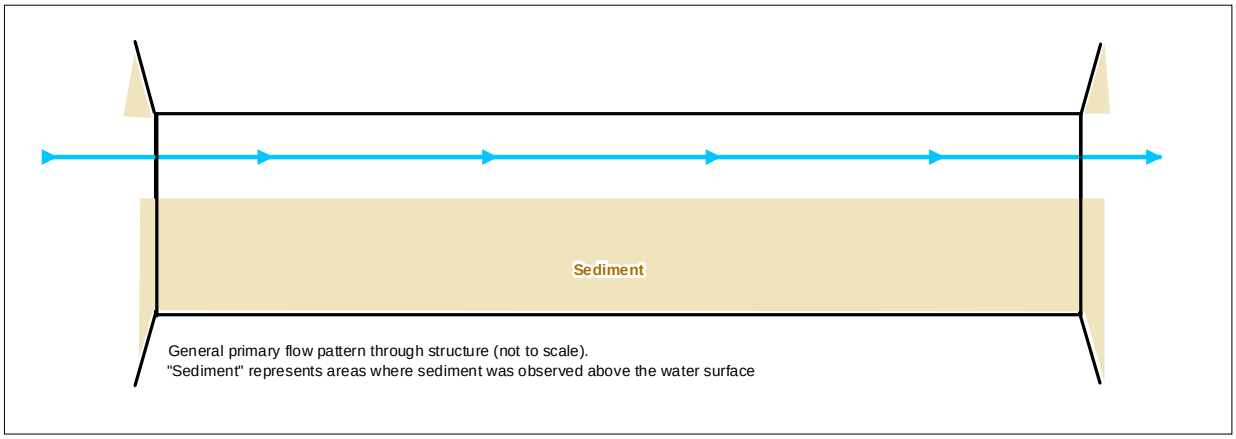


Figure 19: General Flow Profile for Bridge No. 610129, Montgomery County



The width of the natural channel is approximately five feet. The stream widens to about twelve feet in the culvert. When looking downstream, the water enters and exits the culvert on the left side, with the main channel of flow remaining against the left wall, utilizing approximately half of the width if the structure.

The banks on both the inlet and outlet of the structure are well vegetated and show no signs of being unstable. There was no noticeable use of rip rap to stabilize the banks. There are no signs of scour on the inlet or outlet headwalls of the structure. There was some flood plain that could be accessed if necessary. Based on what was observed, it appears that aquatic passage could be maintained during low flow conditions.

The area draining to the structure is approximately 3.97 square miles. The dominant land cover in the water shed is deciduous forest (29.6 percent), followed by evergreen forest (27.01 percent) and grassland/herbaceous (11.08 percent).

Figure 20: Drainage Area for Bridge No. 610129, Montgomery County

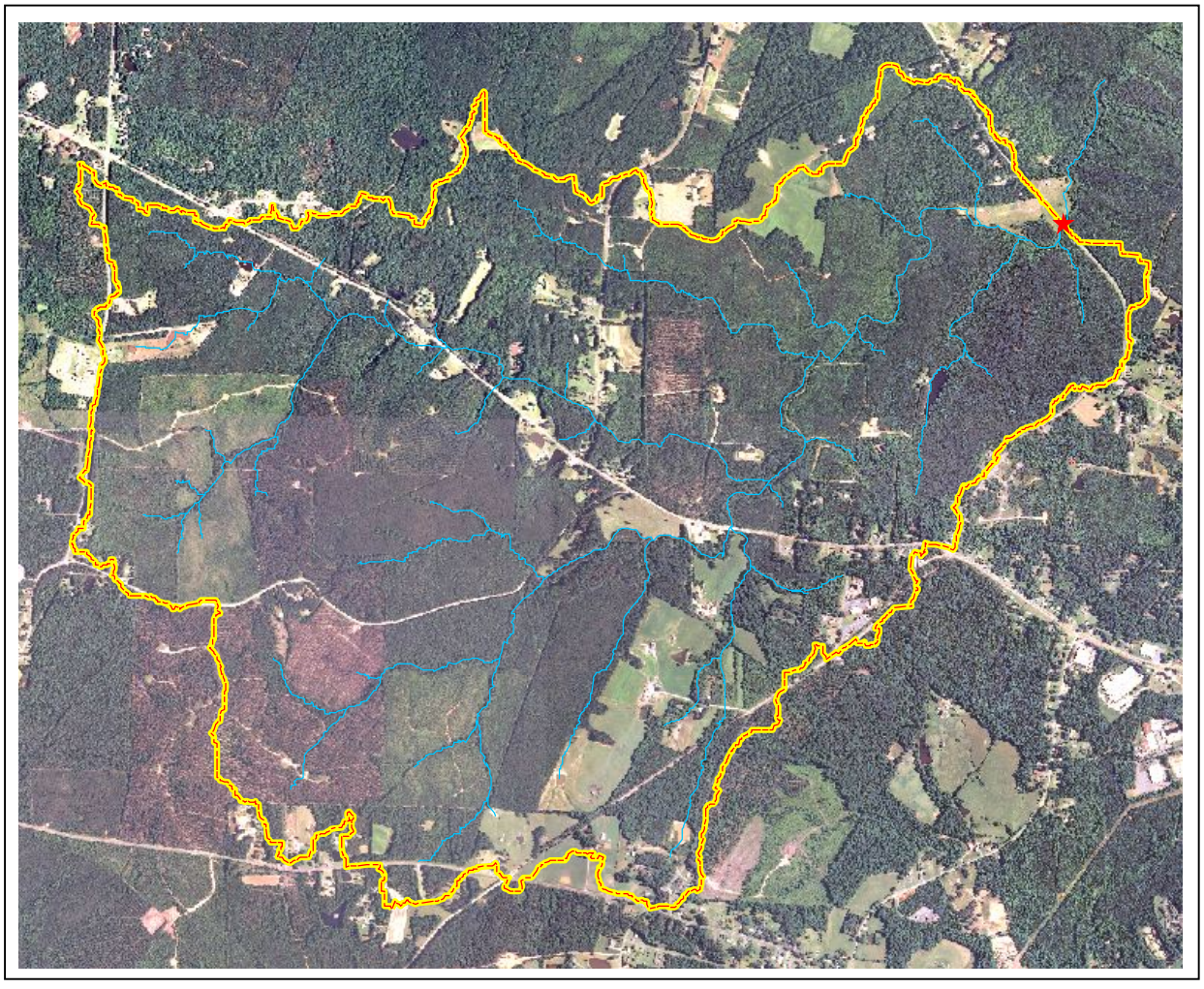


Figure 21: Photographs of Bridge No. 610129, Montgomery County

Downstream through structure

Downstream side of structure

Upstream through structure

Downstream of structure

Upstream of structure

Upstream of structure (headcut located above white foam)

NCDOT Bridge No. 010136, S.R. 1607 (Macedonia Church Road), Alexander County

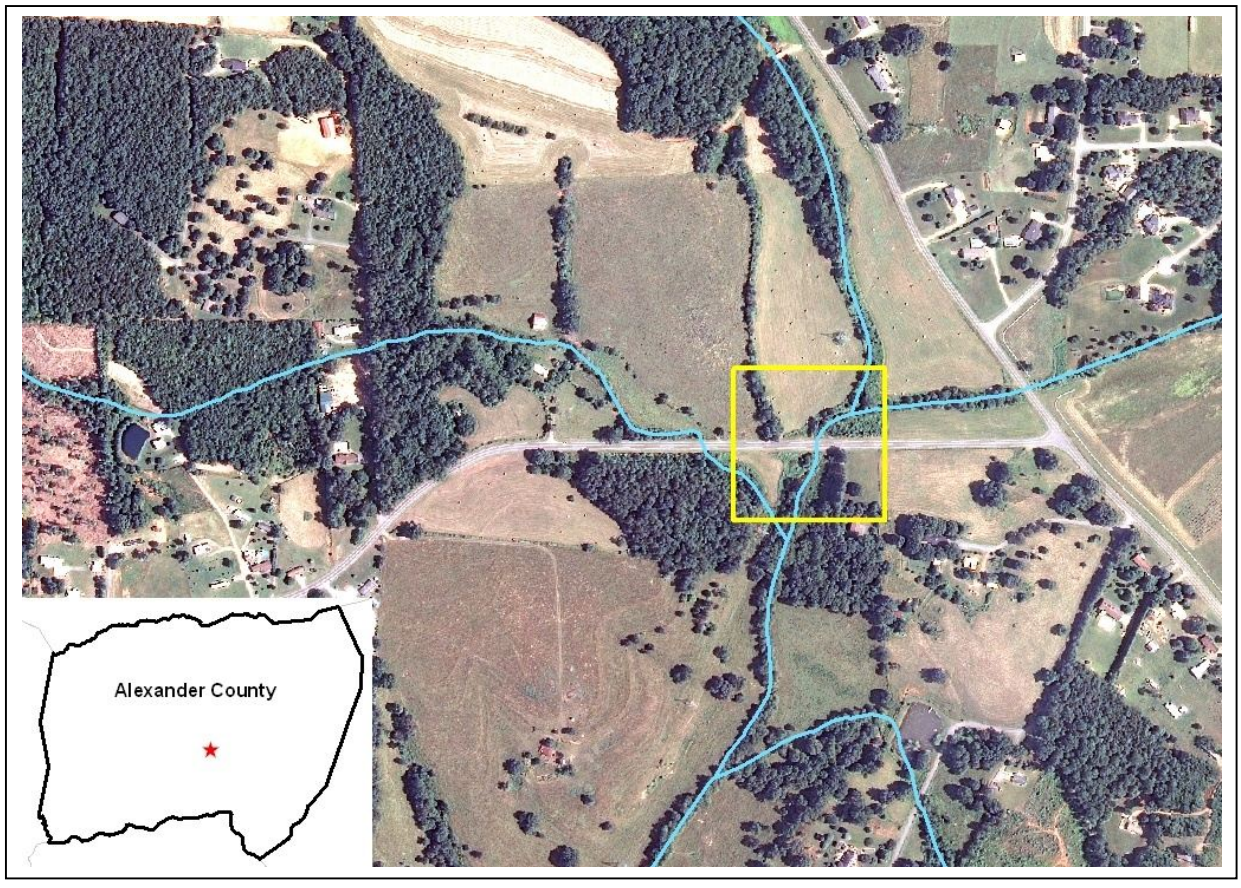
Table 5: Summary Information for Bridge No. 010136, Alexander County

Date Visited:	11/28/2011
Year Installed:	1998
Ecoregion:	Piedmont
Stream Name:	Glade Creek
River Basin:	Broad
Culvert Buried:	Yes
Latitude:	35.895
Longitude:	-81.162
Drainage Area:	5.42 mi^2
Centerline Length:	54'
Opening Width:	24' 3"
Opening Height:	15' 7"
Approx. Width of Natural Stream:	15 feet
Approx. Structure Slope:	0.40%
Primary Streambed Sediment:	Sand/gravel/pebbles

This site is located in central Alexander County, south of the Town of Taylorsville, on S.R. 1607, also known as Macedonia Church Road. It is located on Glade Creek (DWQ Index No. 11-69-07-(0.7); class WS-IV). Glade Creek generally flows to the southwest in the Broad River basin. The area draining to the culvert is approximately 5.42 square miles.

The structure is one of two that have been in place since 1998, about 13 years, and have been in place the longest of the structures included in this review. This fifty-four-foot structure was chosen to replace a ninety-eight-foot bridge.

Figure 22: Location of Bridge No. 010136, Alexander County



During the visit water was present and flowing. Water depth was approximately four-inches with a strong flow. In the thirty days preceding the visit, 3.54 inches of rain fell, 0.51 inches fell in the five days prior to the visit.

The structure was buried one-foot during construction. It was noted that in excavating for the placement of the culvert bedrock was encountered and needed to be removed. It was also noted that because of the bedrock, the structure may not have been buried as deep as it might would have been had the bedrock not been an issue, even though it was buried one-foot.

The bottom of the structure could be seen throughout the structure in the main channel of flow. It is unclear if the structure was backfilled during construction; but it is unlikely. If it was backfilled, it is obvious that any backfill washed out of the structure. It appears that the sediment within the structure was deposited through weathering events. On the outlet side, a rather large mound of sediment, primarily sand and gravel, has been deposited which is supporting some vegetation.

Figure 23: General Sediment Profile for Bridge No. 010136, Alexander County

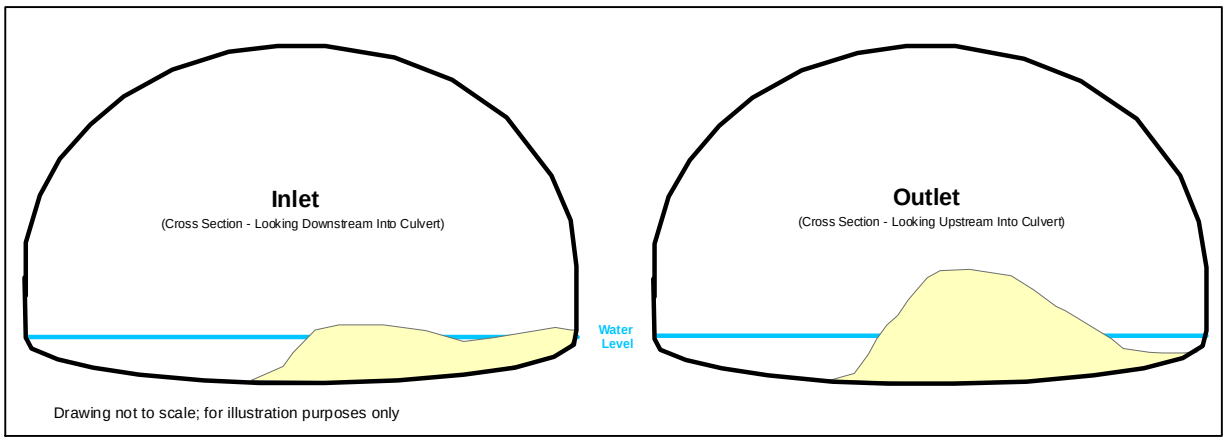
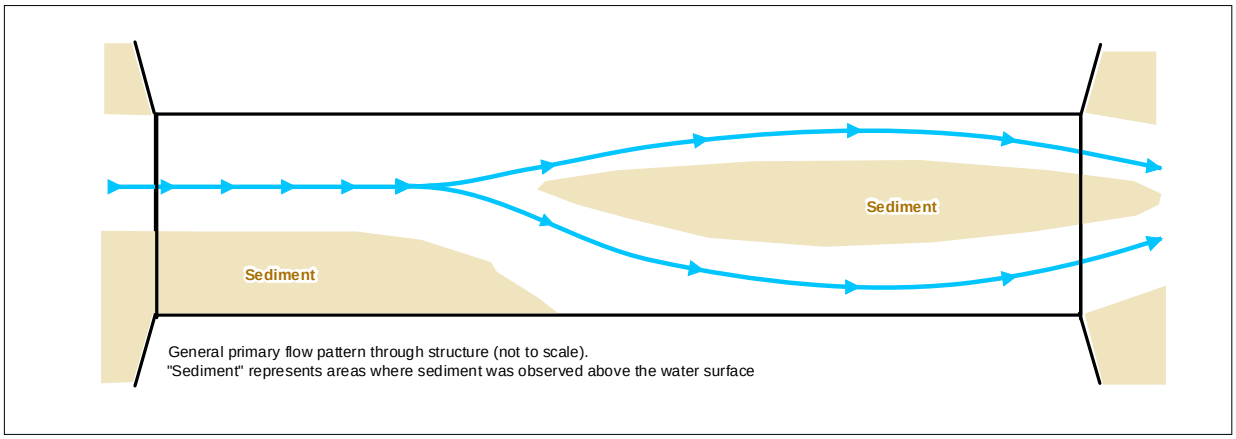


Figure 24: General Flow Profile for Bridge No. 010136, Alexander County



The width of the natural stream is approximately fifteen feet. The primary flow into the structure is on the left side. The flow is then split by a large mound of deposited sediment before combining again after

exiting the structure. The majority of the flow is on the right side of the structure, flowing against the wall for most of its length. The rest of the flow is on the left side, which also flows against the wall.

There was no apparent rip rap used to stabilize the banks. There was some erosion evident on the banks, especially the right bank on the downstream side. Despite evidence of past erosion, the banks did seem to be stable for the most part and well vegetated. There was no evidence of scour at the structure headwalls. Aquatic passage was found to be sufficient during the review, and would most likely be adequate during low flow conditions. The stream has down cut, and the banks are steep. As a result, any floodplain would be difficult to access, even under higher flows.

The area draining to the structure is approximately 5.42 square miles. The dominant land cover in this area is pasture/hay (38.83 percent), followed by low density residential (19.08 percent) and deciduous forest (16.30 percent)

Figure 25: Drainage Area for Bridge No. 010136, Alexander County

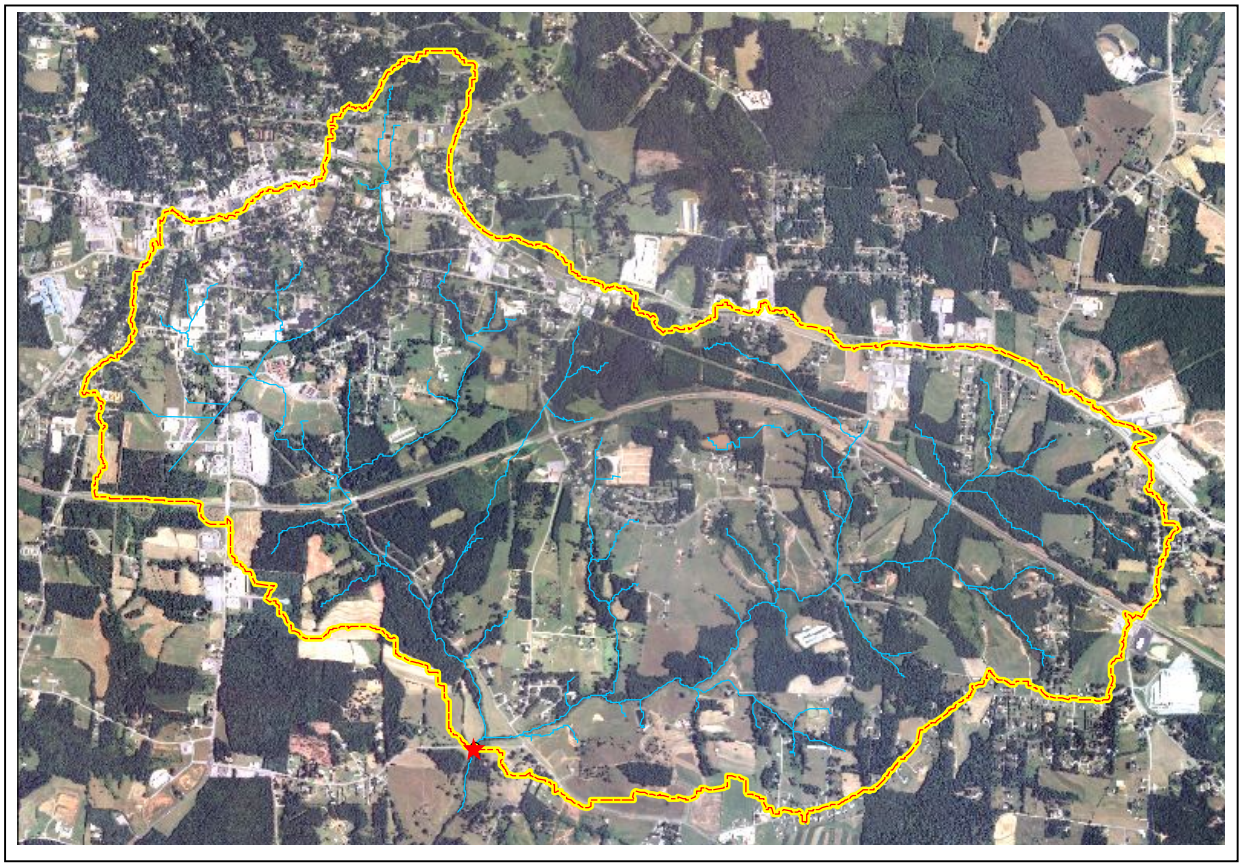


Figure 26: Photographs of Bridge No. 010136, Alexander County

Outlet of structure

Inlet of structure

Upstream of structure

Upstream of structure

Downstream of structure

Downstream of structure

NCDOT Bridge No. 010058, S.R. 1405 (Jolly Cemetery Road), Alexander County

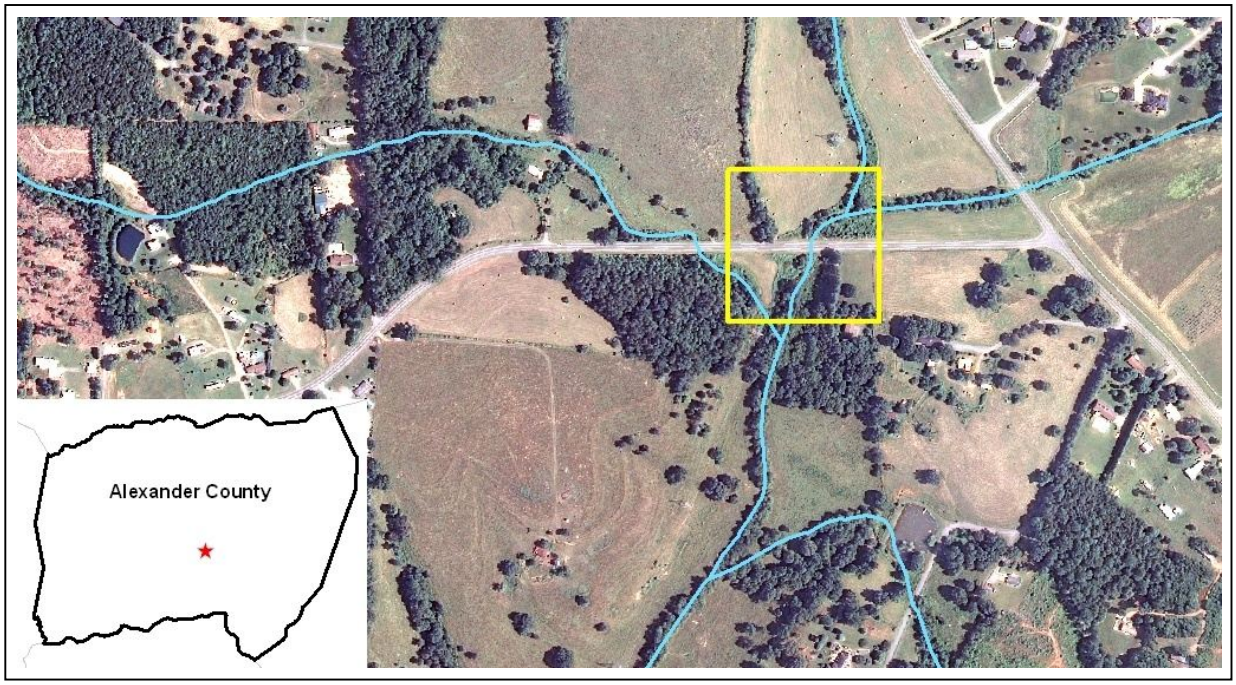
Table 6: Summary Information for Bridge No. 010058, Alexander County

Date Visited:	11/28/2011
Year Installed:	2011
Ecoregion:	Piedmont
Stream Name:	Muddy Fork
River Basin:	Broad
Culvert Buried:	Yes
Latitude:	35.964
Longitude:	-81.182
Drainage Area:	2.30 mi^2
Centerline Length:	50 feet
Opening Width:	29' 8"
Opening Height:	9' 4"
Approx. Width of Natural Stream:	8 feet
Approx. Structure Slope:	0.50%
Primary Streambed Sediment:	Sand/pebbles

This site is located in central Alexander County, north of the Town of Taylorsville on S.R. 1405, also known as Jolly Cemetery Road. It is located on Muddy Fork (DWQ Index No. 11-69-4; Class C) in the Broad River basin. It generally flows to the south. The area draining to the structure is approximately 2.30 square miles.

The structure was installed in the spring of 2011, several months prior to the visit. The fifty-foot long structure was chosen to replace a thirty-foot-seven-inch long bridge.

Figure 27: Location of Bridge No. 010058, Alexander County



During the visit water was present and flowing slowly. Water depth was approximately three-inches. In the thirty days prior to the visit, the area received 3.73 inches of precipitation, of which 0.60 inches fell within the five days preceding the visit.

During construction, the structure was buried and backfilled with approximately fifteen-inches of native material backfill, which is sand with pebbles. The bottom of the culvert was not visible at any point. Unique to this structure is a knee wall. This wall is a three-sided piece attached to the wall and floor of the structure and occupies about half the floor of the structure and is about three feet tall. It is meant to act as a constructed bench. The area inside the knee wall is open, with the intent that it would fill with sediment as higher flows allow. Inside the wall there was a thin layer of sediment and several inches of water. The knee wall can be seen in the photographs included below (Figure 31).

On the right sides of the banks on both the inlet and outlet side of the structure, at the ends of the knee wall, were placed large flat boulders. The boulders were covered with soil and coir fiber matting then vegetated with grass. This was meant to act as a bench, being even with the knee wall, and help create a more defined channel leading into the structure.

Staining on the structure walls indicate that flows several inches higher than that observed have occurred. Backfill on the stream channel side of the structure appeared flat, with no apparent thalweg or channel defined for lower flows. In its current state, it is unknown if water depth would be sufficient for aquatic life passage during low flow conditions. If a more defined channel were to form under lower flow conditions, it may be sufficient to allow proper aquatic life passage.

Figure 28: General Sediment Profile for Bridge No. 010058, Alexander County

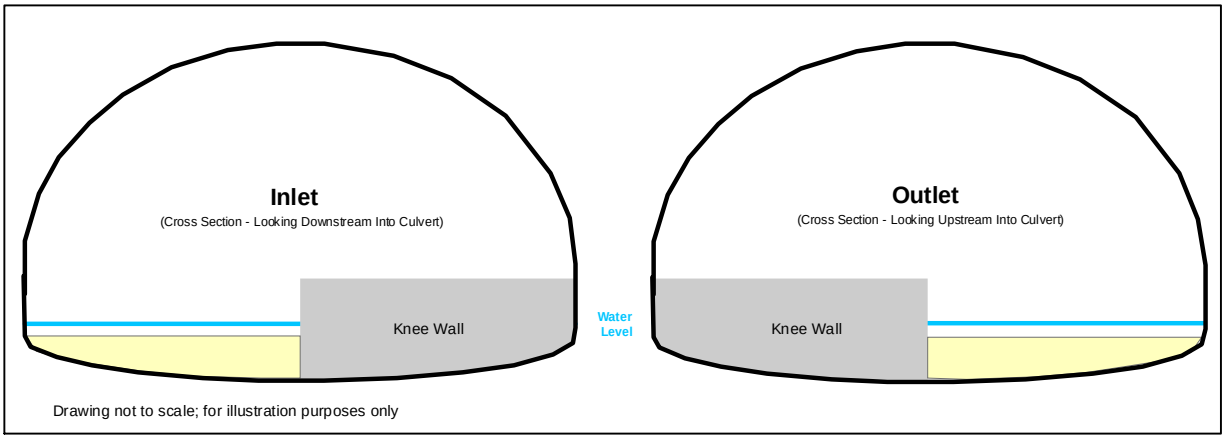
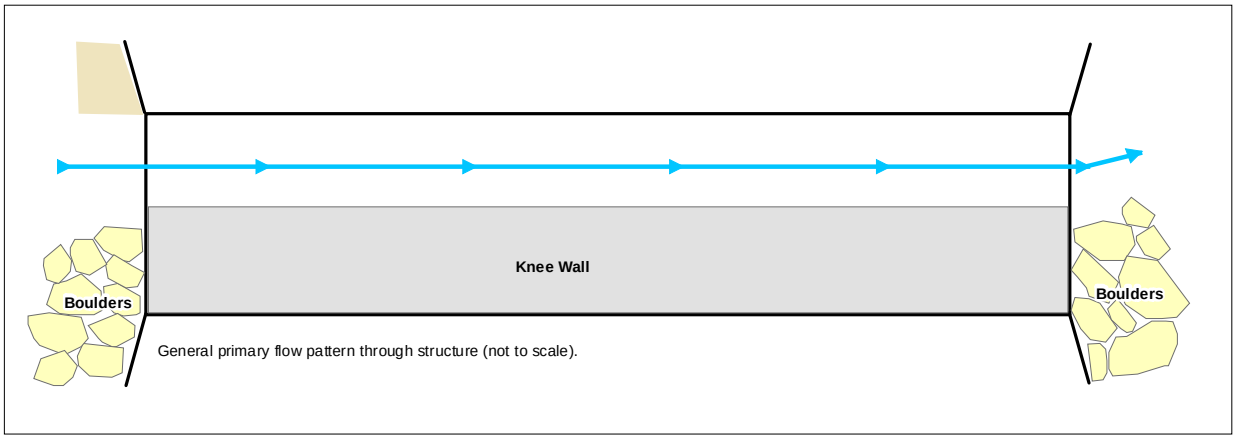


Figure 29: General Flow Profile for Bridge No. 010058, Alexander County



All four quadrants of the structure were actively being used as cattle pasture. The areas are not fenced off from the stream, so cattle have and do access the stream regularly. As a result, many areas of the banks are unstable and being used as access areas. There is an area on the downstream left bank that shows signs of erosion. No scour was noted at the headwalls of the structure. There was a floodplain, but it would only accessible at higher flows.

The upstream area draining to the culvert is approximately 2.30 square miles. The dominant land cover in the drainage area is deciduous forest (41.35 percent), followed by pasture/hay (30.86 percent) and evergreen forest (10.82 percent).

Figure 30: Drainage Area for Bridge No. 010058, Alexander County

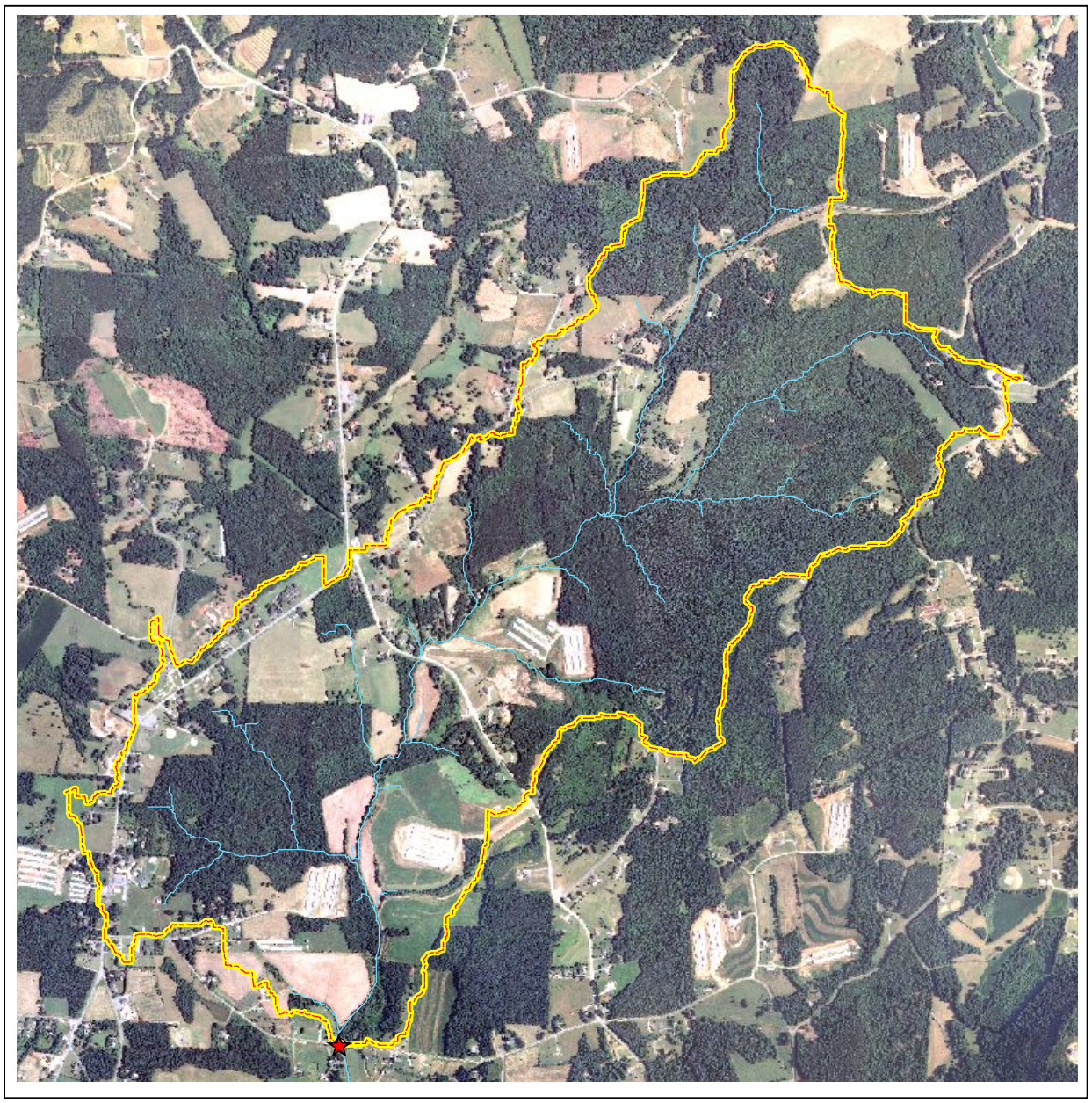


Figure 31: Photographs of Bridge No. 010058, Alexander County

Inlet of structure (under construction)

Downstream through structure (knee wall on right)

Downstream through structure

Upstream of structure

Upstream of structure

Downstream of structure

NCDOT Bridge No. 840101, S.R. 1405 (Power Dam Road), Stokes County

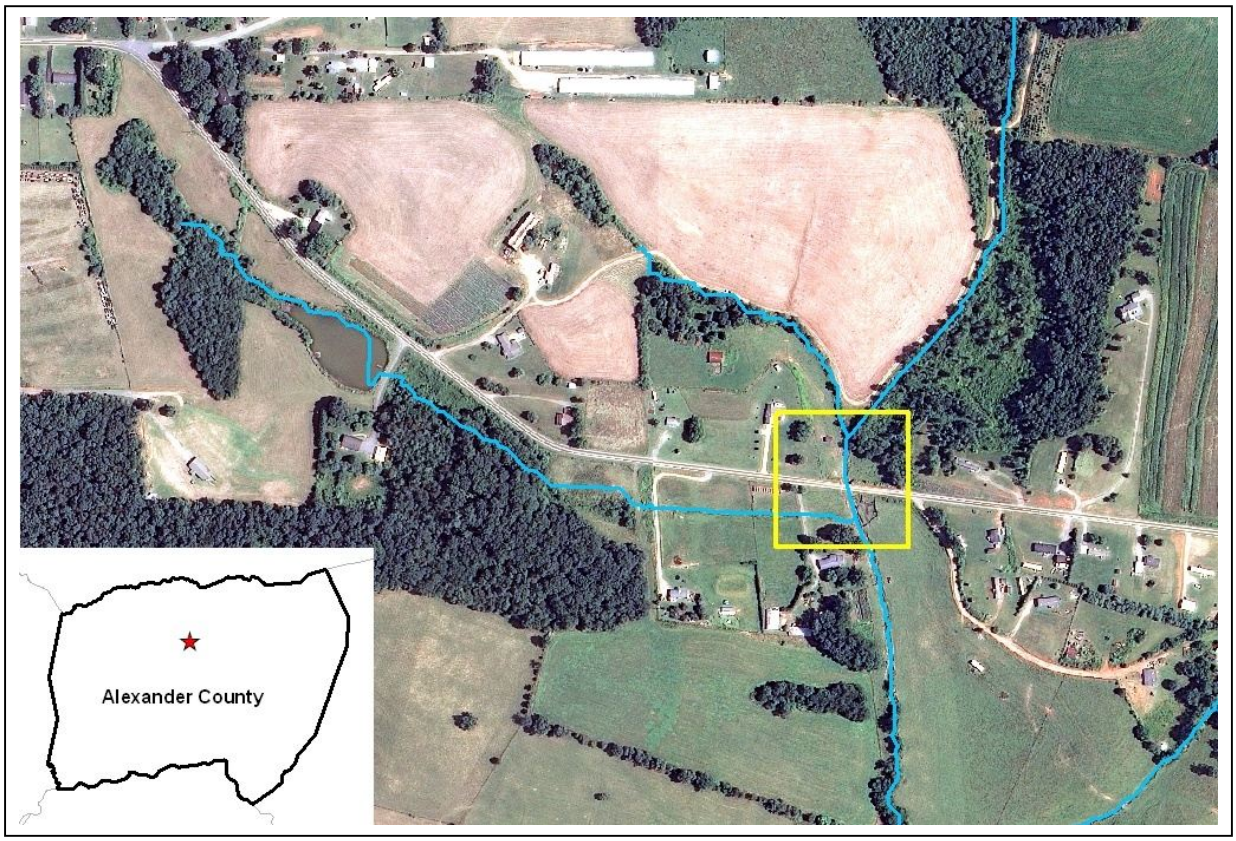
Table 7: Summary Information for Bridge No. 840101, Stokes County

Date Visited:	11/28/2011
Year Installed:	2005
Ecoregion:	Piedmont
Stream Name:	Zilpher Creek
River Basin:	Roanoke
Culvert Buried:	No
Latitude:	36.372
Longitude:	-80.133
Drainage Area:	3.69 mi²
Centerline Length:	72 feet
Opening Width:	24' 3"
Opening Height:	15' 7"
Approx. Width of Natural Stream:	18
Approx. Structure Slope:	4.00%
Primary Streambed Sediment:	Sand/gravel

This site is located in east central Stokes County, north of the Town of Walnut Cove, on S.R. 1405, also known as Power Dam Road. It is located on Zilpher Creek (DWQ Index No. 22-23; Class C) in the Roanoke River basin. It generally flows to the east. The upstream area draining to the culvert is approximately 3.69 square miles.

The structure was installed in 2005, approximately six years prior to the visit. The seventy-two-foot long structure was chosen to replace two very perched culverts one-hundred-eight-inches in diameter.

Figure 32: Location of Bridge No. 840101, Stokes County



This is the only structure included in the review that has a series of baffles built into the structure. The baffles were required because of the slope of the structure (about four percent) and may have been requested by the U.S. Fish and Wildlife Service. As can be seen in the photographs below (Figure 36), the spillway portion of the baffles is twelve-inches high; the rest of the baffles are twenty-eight-inches high. The spillway portion of the baffles is approximately one-third the width of the structure. Water was observed spilling over the baffles. The structure is located on Zilpher Creek, approximately 0.16 miles upstream of the confluence with the Dan River. As a result, the creek occasionally receives flooding from the river. Waterlines and staining on the walls indicate that water depths have reached six feet numerous times, and have reached as high as ten feet.

During the visit, water was present and flowing, with a depth in the structure of approximately twelve-inches behind the baffles, spilling over them. In the thirty days preceding the visit, the area received 4.56 inches of precipitation, 0.29 inches of which fell within the preceding five days.

Due to the size of the structure and other constraints, the structure was assembled in place. It was not buried when installed and no backfill material was placed in it. There was some sediment, which is primarily sand and gravel, building behind the baffles; but for the most part sediment is absent in the structure. The floor was clearly visible throughout the majority of the structure.

Figure 33: General Sediment Profile for Bridge No. 840101, Stokes County

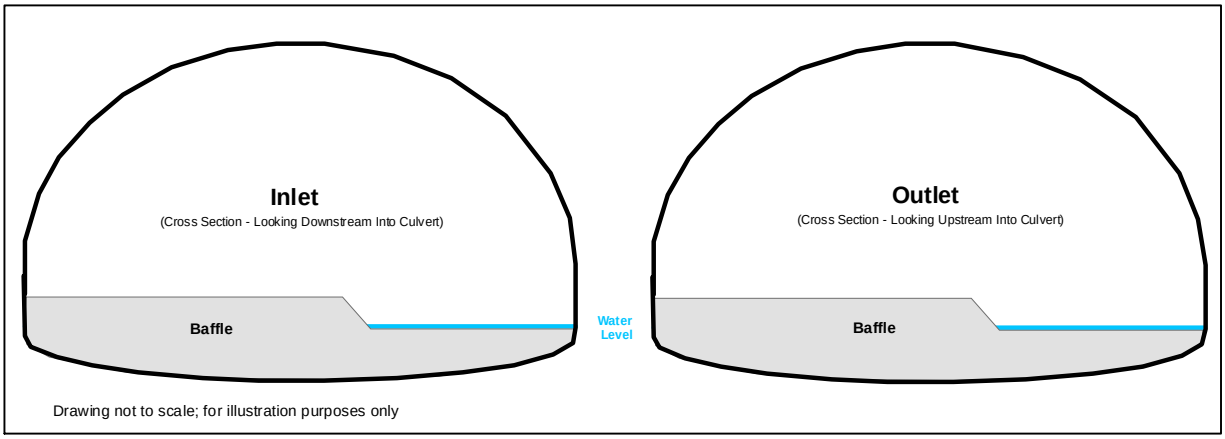
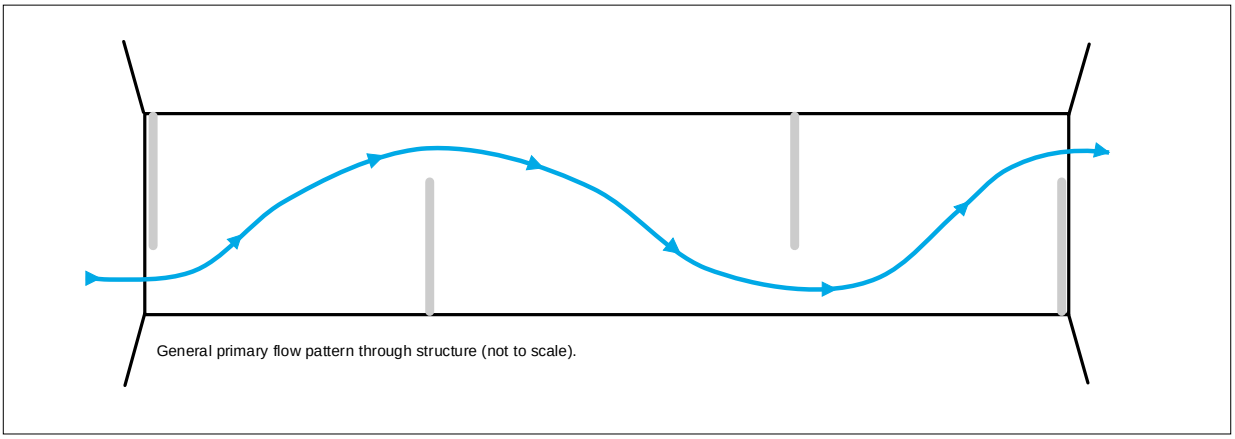


Figure 34: General Flow Profile for Bridge No. 840101, Stokes County



Material had been deposited through natural occurrences on the downstream right side such that a broad bench had formed. This area was most likely excavated during construction. Rip rap was used to stabilize the banks, which are steep, but are well vegetated and appear to be stable. As the banks are very steep and the stream sits rather far down in its valley, it would be difficult to access any floodplain. Although no scour was observed at the headwalls, water was noticed to be seeping out around the headwall on the downstream side, which did not appear to be a significant issue.

The natural width of the stream is approximately eighteen feet. During the visit, the water level in the structure was low enough that it was being controlled by the baffles. Water depth over the baffles was about one-half-inch. It is not believed that flow through the structure would be maintained during low flow conditions, ultimately impeding aquatic life passage.

The area draining to the structure is approximately 3.69 square miles. The dominant land cover in the drainage area is deciduous forest (64.21 percent), followed by evergreen forest (12.73 percent) and pasture/hay (10.31 percent).

Figure 35: Drainage Area for Bridge No. 840101, Stokes County

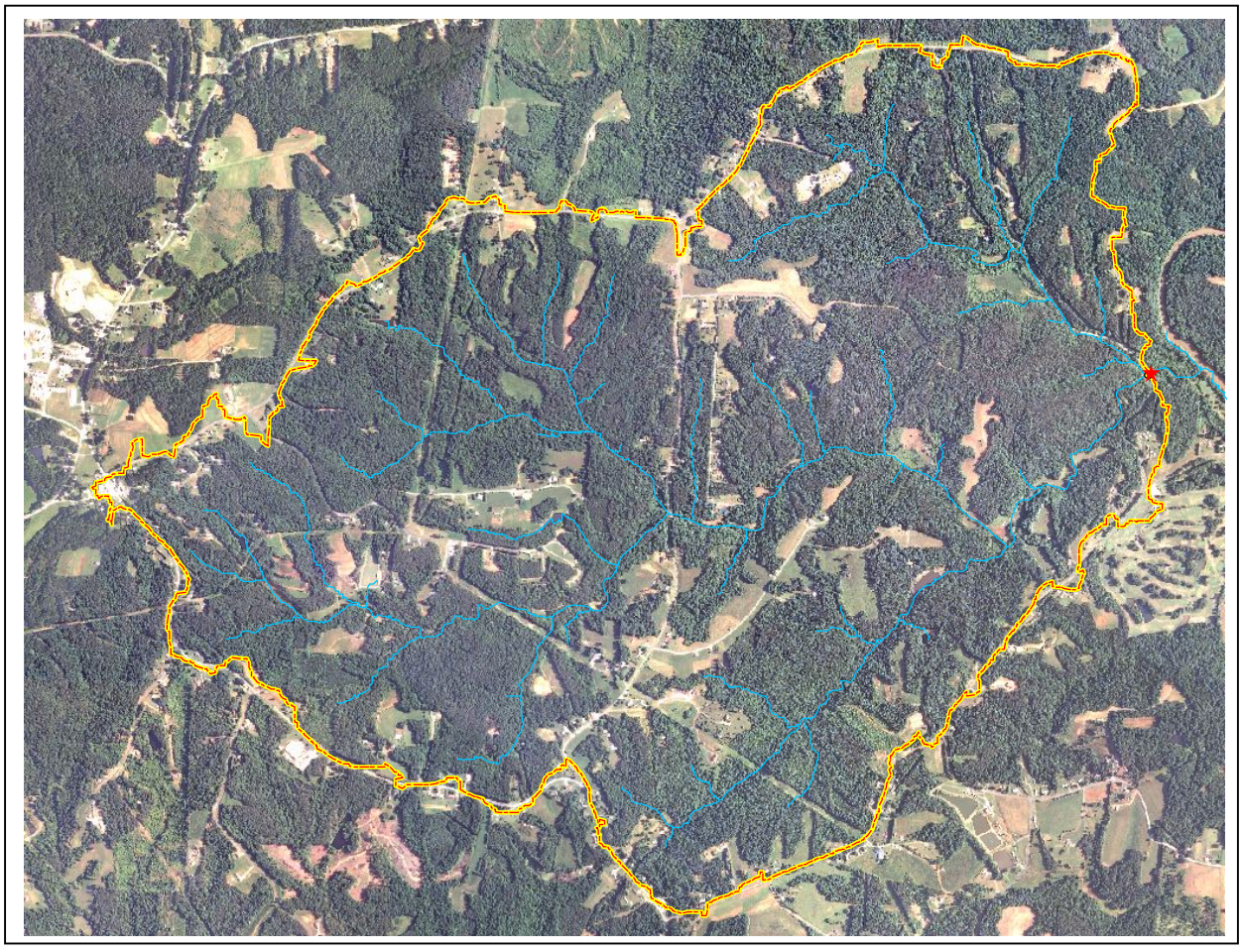


Figure 36: Photographs of Bridge No. 840101, Stokes County

Upstream through structure

Intlet of structure

Downstream of structure

Downstream of structure

Upstream of structure

Upstream of structure

NCDOT Bridge No. 250212, S.R. 1838 (Dunn Road), Cumberland County

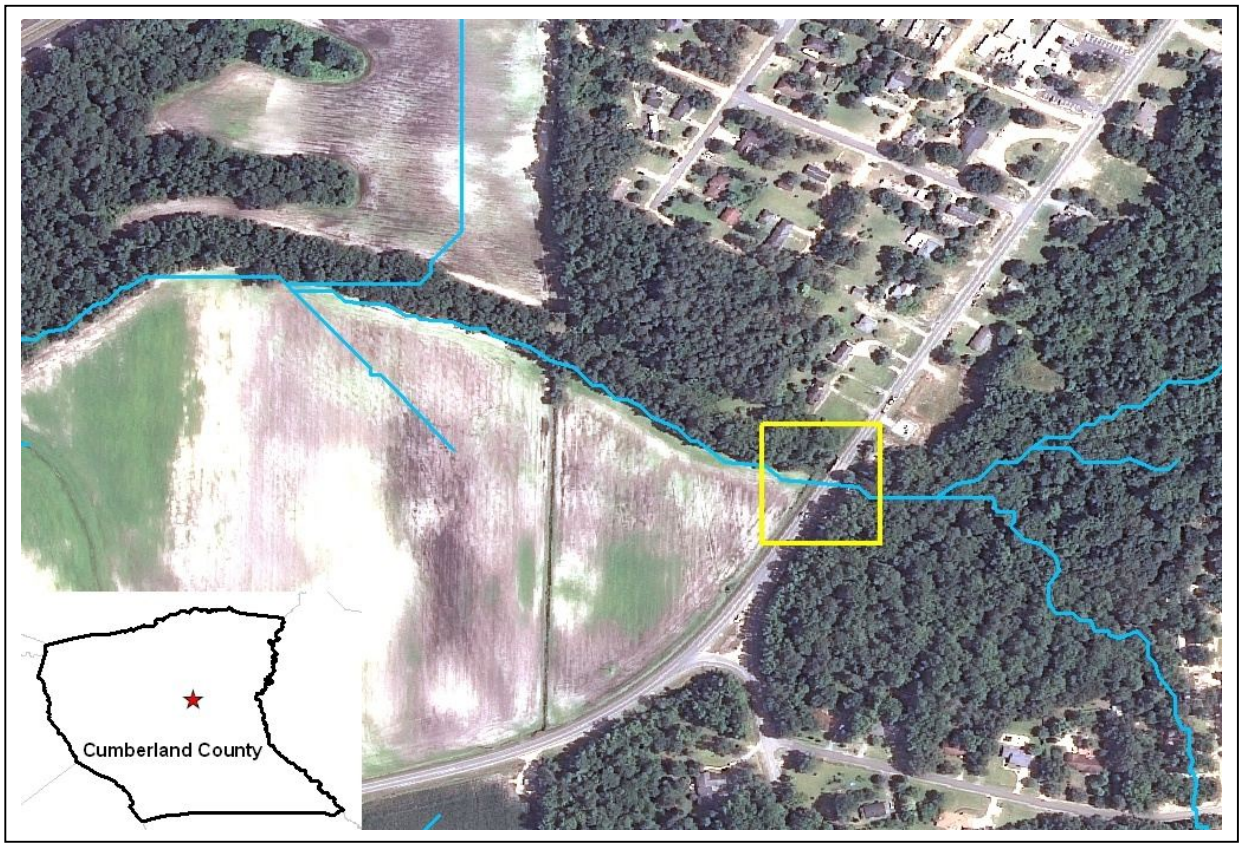
Table 8: Summary Information for Bridge No. 250212, Cumberland County

Date Visited:	11/1/2011
Year Installed:	2010
Ecoregion:	Piedmont
Stream Name:	Reese Creek
River Basin:	Cape Fear
Culvert Buried:	No
Latitude:	35.081
Longitude:	-78.796
Drainage Area:	7.82 mi²
Centerline Length:	67' 5"
Opening Width:	34' 4"
Opening Height:	13' 1"
Approx. Width of Natural Stream:	6'
Approx. Structure Slope:	0.70%
Primary Streambed Sediment:	Sand

This site is located in central Cumberland County, west of the City of Fayetteville, just off Interstate 95 on S.R. 1838, also known as Dunn Road. It is located on Reese Creek (DWQ Index no. 18-28-2; class C), which flows generally to the west in the Cape Fear River Basin. The upstream drainage area of the structure is approximately 7.82 square miles, the largest included in the review.

The structure was installed in 2010, approximately one year prior to the visit. This sixty-seven-foot-five-inch structure was chosen to replace a forty-eight foot bridge.

Figure 37: Location of Bridge No. 250212, Cumberland County



There was a good amount of water flowing in the stream, and water was generally two-feet deep. Although not measured, the water was flowing at several feet-per-second. In the thirty days prior to the visit, the site received 2.67 inches of rain, including 0.23 inches the day prior to the visit.

It appears as though the culvert may have been buried several inches. There did not appear to be any attempt to place sediment within the culvert to cover the bottom. An approximately ten-foot wide area of the culvert floor was visible on the inlet side near the middle of the structure. The bottom of the culvert was not visible on the outlet side. Sediment appeared to be settling out within the culvert at both ends, except for where the bottom could be seen at the inlet. There was considerably more sediment deposition at the outlet than at the inlet. Sediment deposition in the middle of the culvert was not assessed as the water was too deep. At the water level observed during the visit, the stream was using the full width of the culvert. Since the natural stream is only about six-feet wide above and below the culvert, it is expected that, due to the decrease in flow, sediment will continue to be deposited within the culvert.

Figure 38: General Sediment Profile for Bridge No. 250212, Cumberland County

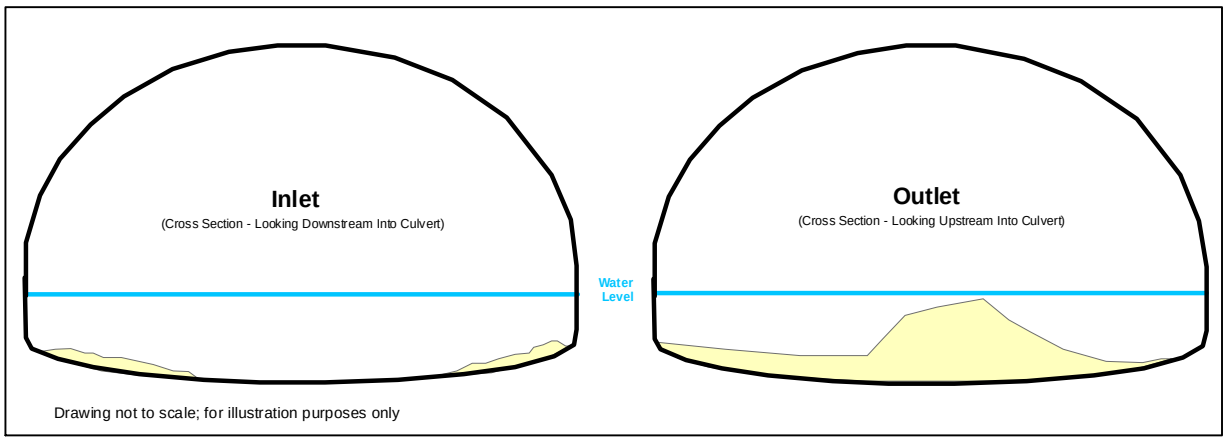
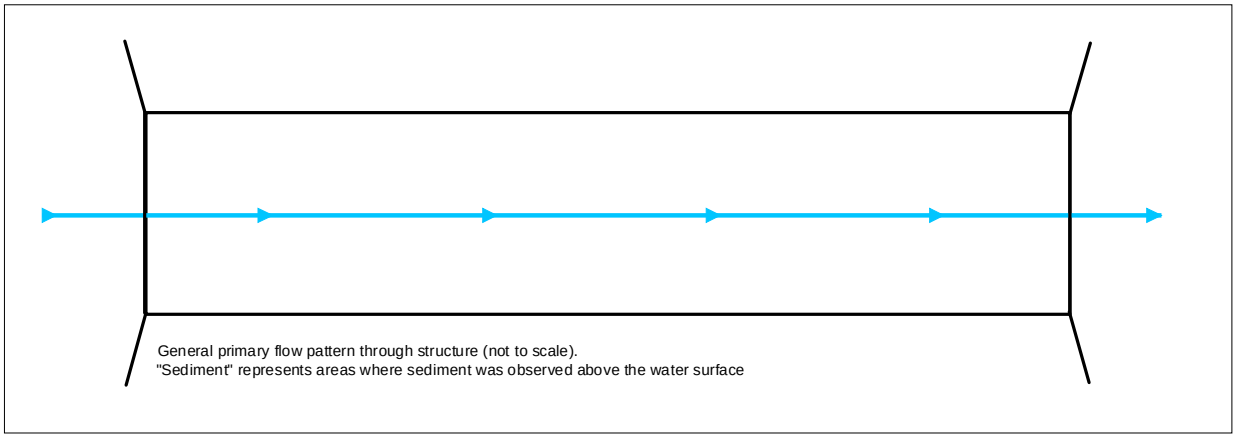


Figure 39: General Flow Profile for Bridge No. 250212, Cumberland County



It was evident that higher flow events have occurred since the culvert was installed as a waterline was observed in the culvert approximately two feet higher than the water level and rack-lines were observed on the banks.

All four banks bordering the culvert were armored with rip-rap. All banks appeared stable and showed no signs of instability and no signs of scour at the headwalls were apparent. An eighteen-inch drain culvert is located in the bank on the southwest bank. An ephemeral stream is located on the southeast side approximately forty feet upstream of the culvert inlet. It was approximately two feet wide, and contained no water. Due to the height of the banks, there is no floodplain that would be accessible.

Because there is little sediment or defined channel within the structure and the water was deep, the stream was utilizing the whole width of the structure to convey flow. At the time of the visit there was sufficient water, approximately two feet deep, to allow for proper aquatic passage. There was sediment being deposited in the culvert, especially at the outlet end. In its current condition, it is not believed that the structure would allow for proper aquatic life passage during low flow conditions. However, over the next few years it is quite possible that enough sediment would be deposited such that a defined channel could be established, allowing for better aquatic life passage at extreme low flow conditions.

The area draining to the culvert is approximately 7.82 square miles, which is the largest of those included in the review. The dominant land cover in the watershed is woody wetlands (26.77 percent), followed by evergreen forest (20.92 percent) and cultivated crops (16.24 percent).

Figure 40: Drainage Area for Bridge No. 250212, Cumberland County

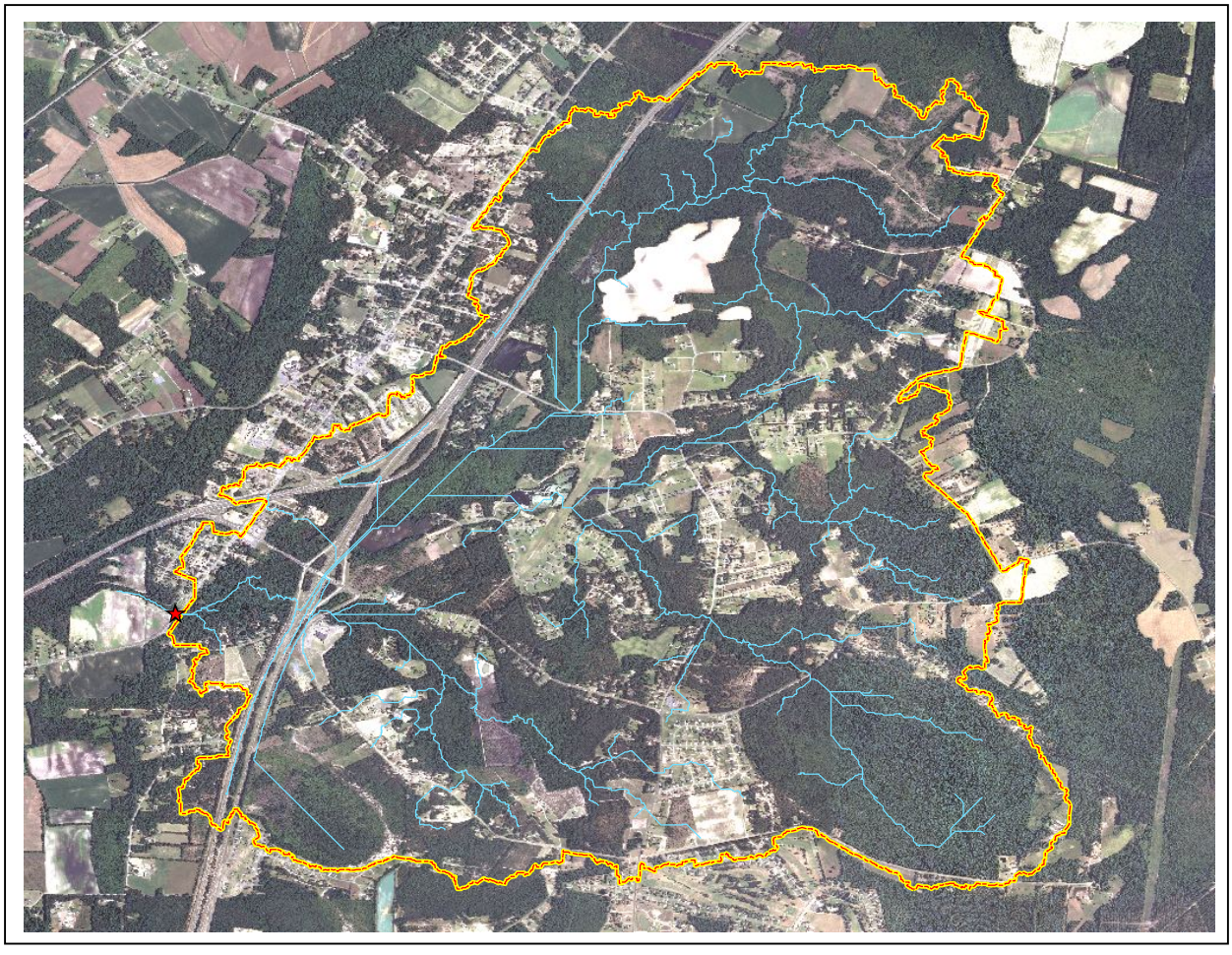


Figure 41: Photographs of Bridge No. 250212, Cumberland County

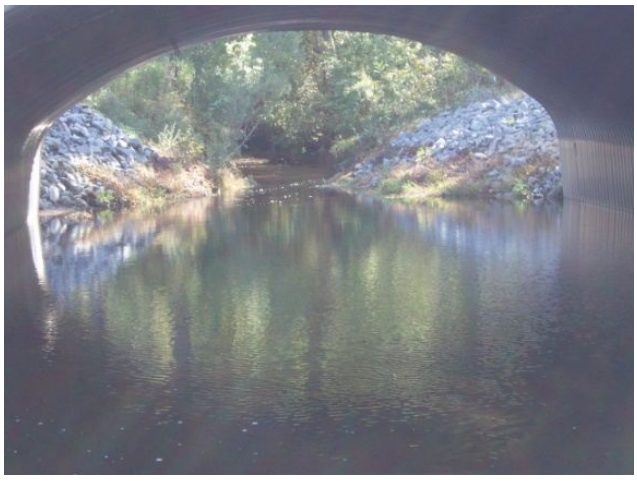
Outlet of structure

Inlet of structure

Downstream of structure

Downstream of structure

Downstream of structure



Upstream through structure

Sites in Eastern North Carolina

NCDOT Bridge No. 240036, S.R. 1244 (Hymans Road), Craven County

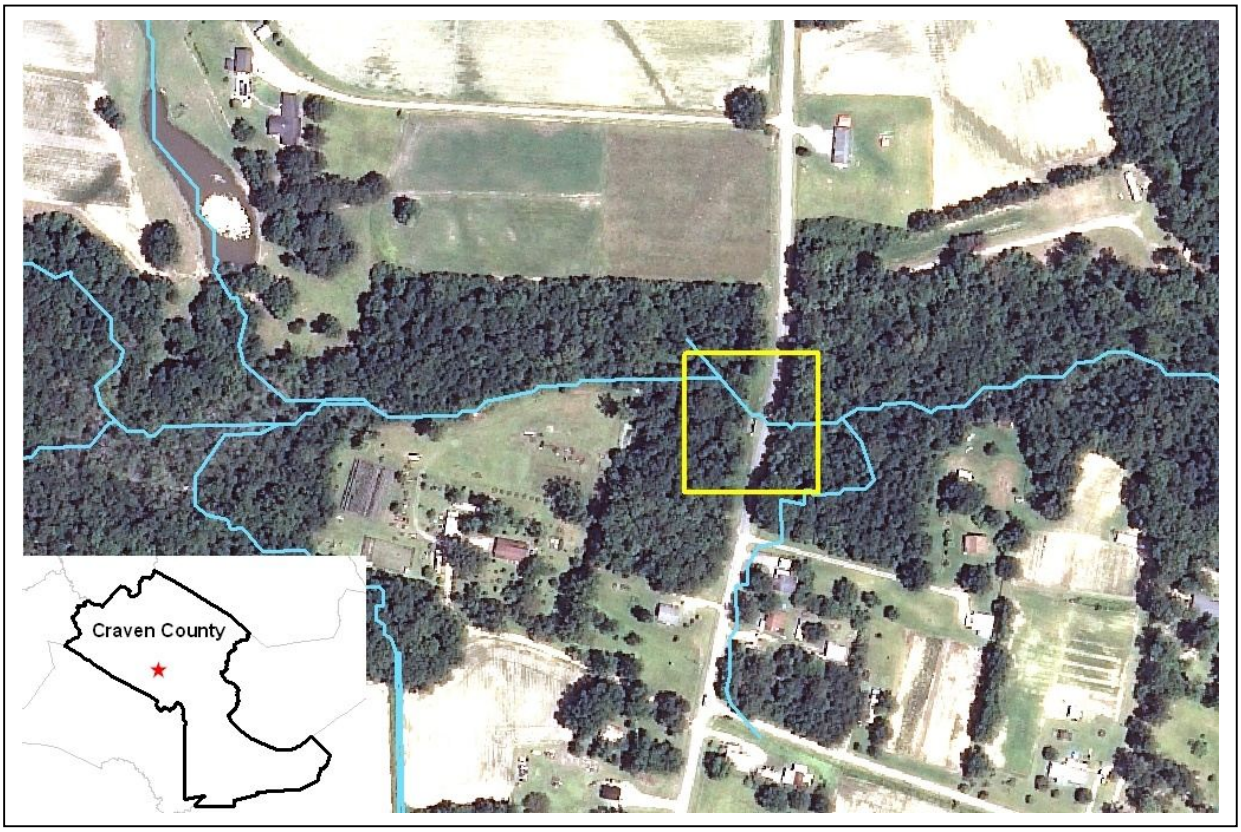
Table 9: Summary Information for Bridge No. 240036, Craven County

Date Visited:	12/13/2011
Year Installed:	2001
Ecoregion:	Outer Coastal Plain
Stream Name:	Fork of Bachelor Creek
River Basin:	Neuse
Culvert Buried:	Yes
Latitude:	35.165
Longitude:	-77.178
Drainage Area:	3.74 mi²
Centerline Length:	49'
Opening Width:	25' 4"
Opening Height:	10' 2"
Approx. Width of Natural Stream:	20
Approx. Structure Slope:	0.68%
Primary Streambed Sediment:	Silt

This site is located in west central Craven County, northwest of the City of New Bern on S.R. 1244, also known as Hymans Road. It is located on a Fork of Bachelor Creek (DWQ Index No. 27-98-2.2; Class C;Sw;NSW), which flows generally to the east in the Neuse River Basin. The area upstream draining to the structure is approximately 3.74 square miles.

This forty-nine-foot structure was installed in 2001, replacing a thirty-five-foot-three-inch bridge.

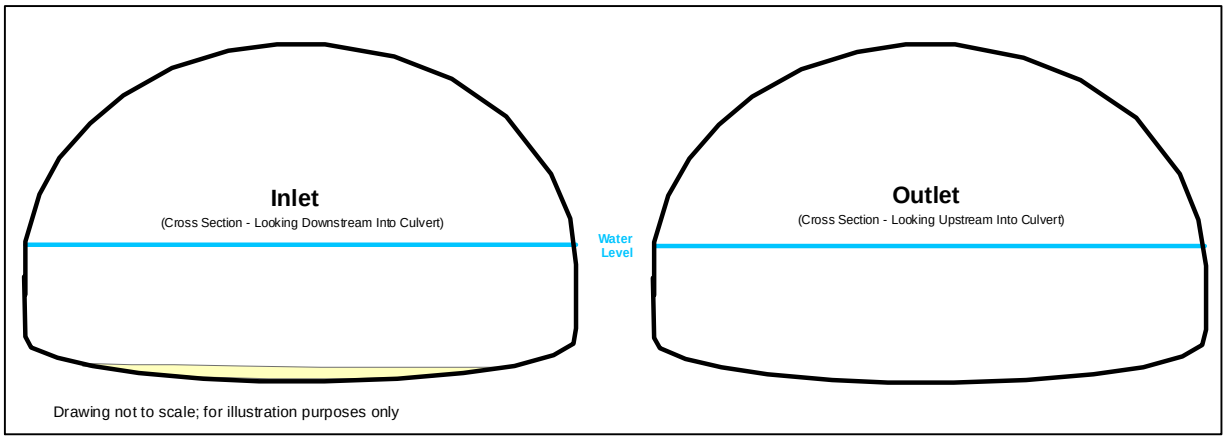
Figure 42: Location of Bridge No. 240036, Craven County



There was water standing in the channel, with little flow detected. The area had received 1.24 inches of precipitation in the thirty days prior to the visit, of which none fell within the five days prior to the visit.

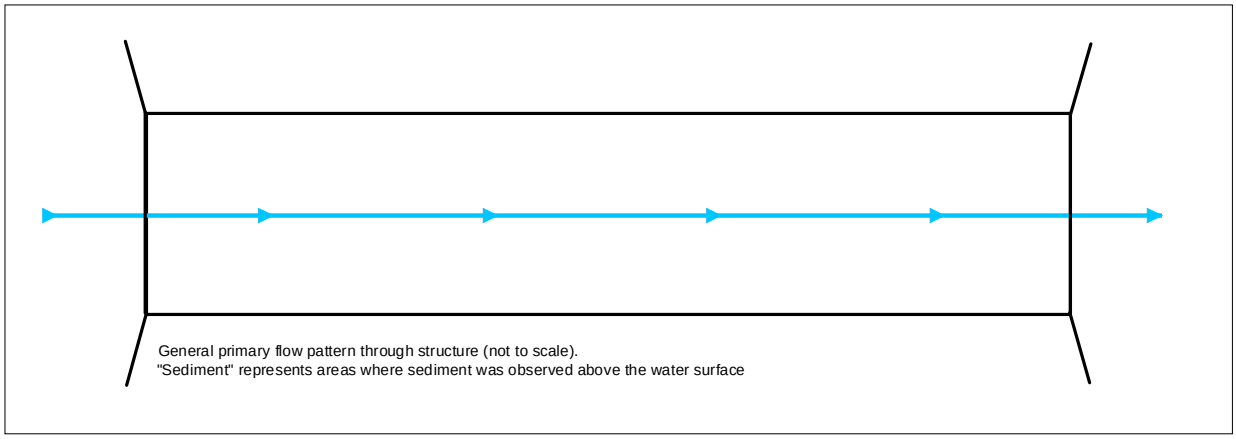
Although it could not be confirmed, it is believed that the structure was buried one-foot when installed. The structure was not backfilled. The water was several feet deep and discolored, making it difficult to visually assess the bottom of the culvert, and consequently whether any sediment had deposited in the bottom. A survey rod was used to probe the bottom at the inlet and outlet. Based on the probing, it is believed that a few inches of sediment has settled out at the inlet, but it is not believed that any sediment has settled on the outlet side. Additionally, since the bottom of the channel could not be inspected, stream bottom composition could not be analyzed. However, based on bank sediment observations, it is believed that it may be comprised primarily of silt.

Figure 43: General Sediment Profile for Bridge No. 240036, Craven County



Water was present at the site, and was deep; approximately five-foot-three-inches. The width of the natural stream is approximately twenty-feet. There was no discernable flow in the area of the structure. Water lines and staining on the interior structure walls indicate that flows have been approximately eighteen-inches higher than what was observed. It is believed that water stands in the stream most of, if not all of, the year. Due to the depth of the water, the stream was utilizing the full width of the structure to convey water. Water was very sufficient to allow for aquatic life passage during the visit, and if water does stand in the structure throughout the year, aquatic passage would be sufficient.

Figure 44: General Flow Profile for Bridge No. 240036, Craven County



Small amounts of rip-rap were used to help stabilize the banks on all four corners. There was some undercutting of the banks observed, but this did not appear to be very recent based on the vegetation. The banks were well vegetated with grasses and some shrubs and appeared to be mostly stable. A floodplain was present and should be easily accessible during higher flows. Scour was not observed at the headwall. As can be seen in the photographs of the downstream views of the structure presented below, no fill was placed at the headwall to bring the banks even to the natural banks or to the structure opening. It was discussed that this void may have been a result of scour associated with the bridge that was replaced rather than excavation due to structure installation.

The area upstream draining to the culvert is approximately 3.74 square miles. The dominant land cover in the watershed is evergreen forest (27.23 percent), followed by grassland/herbaceous (21.30 percent) and shrub/scrub (19.94 percent).

Figure 45: Drainage Area for Bridge No. 240036, Craven County

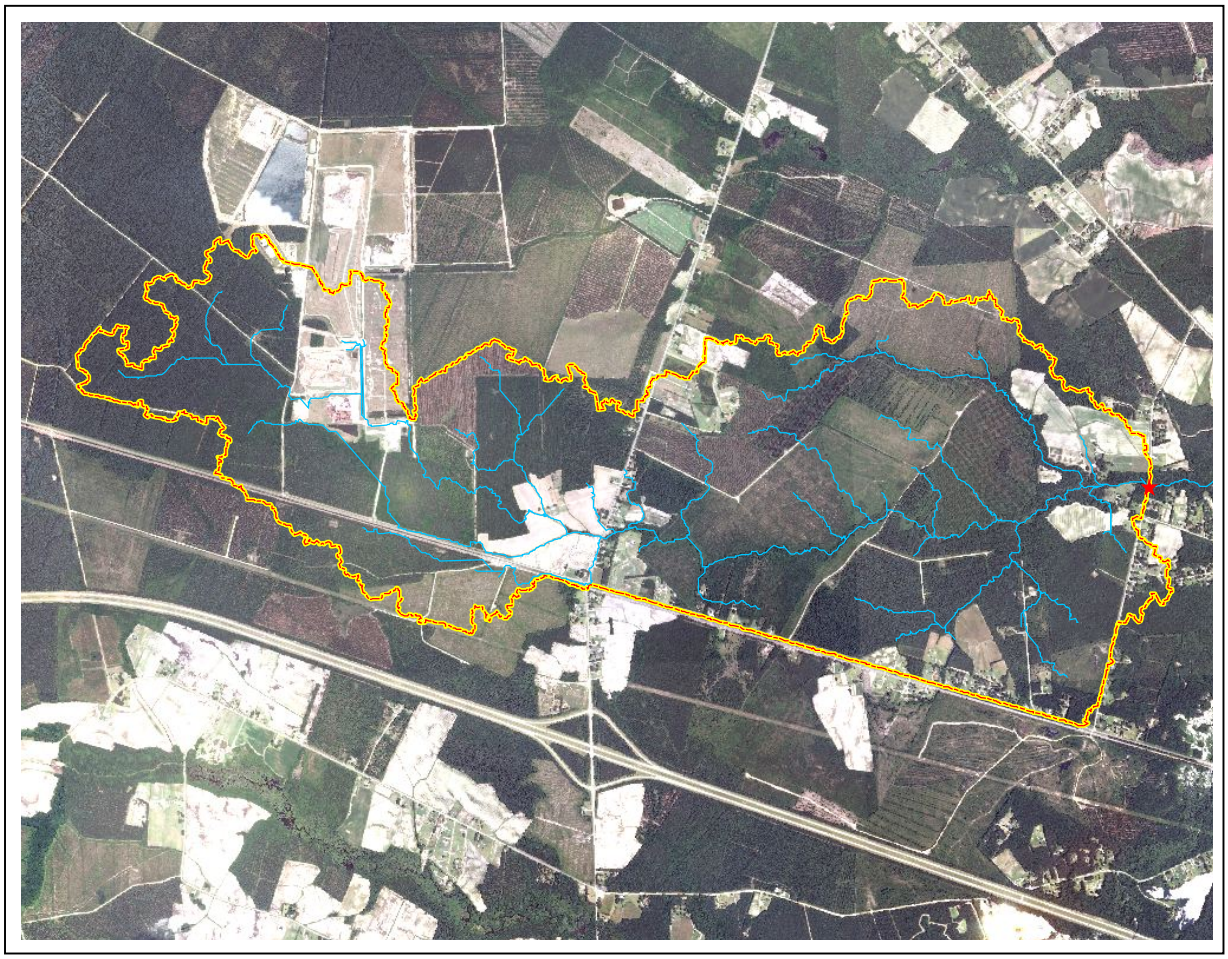


Figure 46: Photographs of Bridge No. 240036, Craven County

Outlet of structure

Inlet of structure

Inlet of structure – no fill against headwall

Downstream of structure

Upstream of structure

Upstream of structure

NCDOT Bridge No. 240008, S.R. 1102 (Tebo Road), Craven County

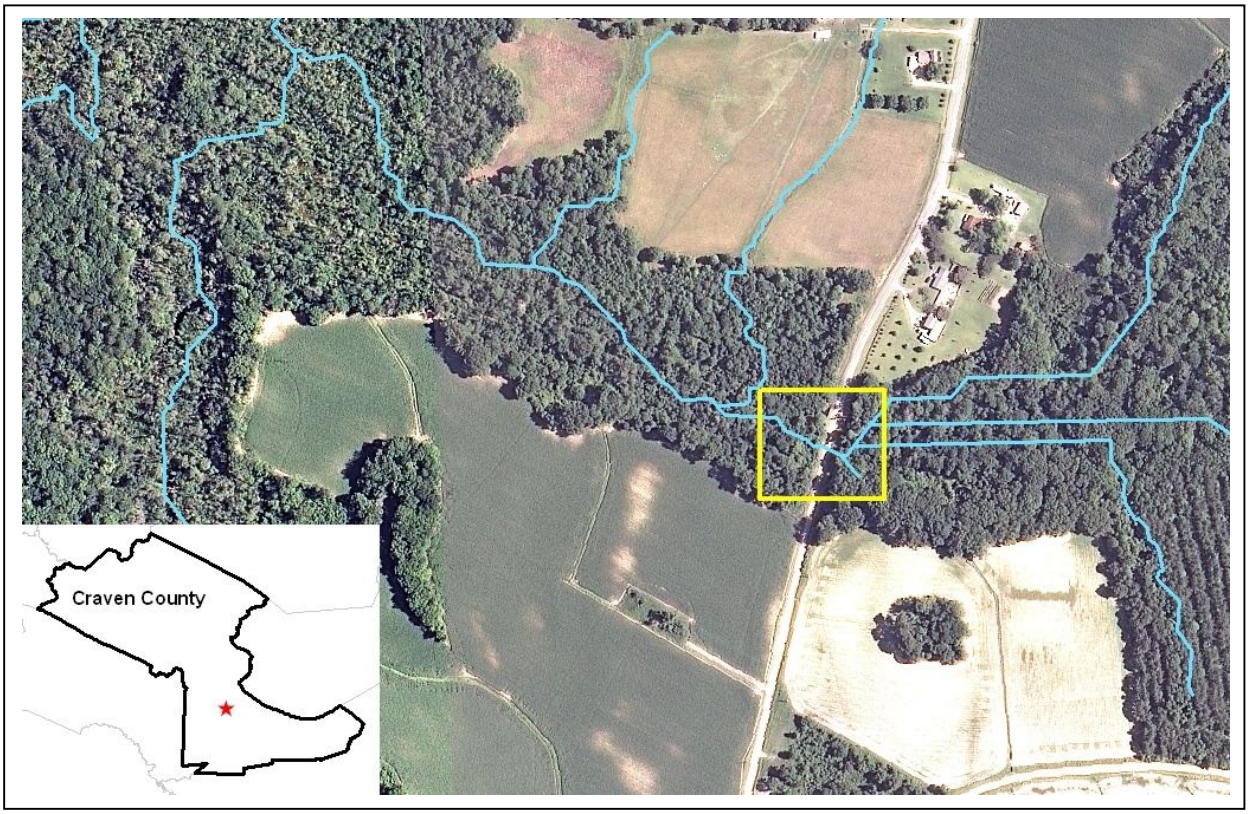
Table 10: Summary Information for Bridge No. 240008, Craven County

Date Visited:	12/13/2011
Year Installed:	1998
Ecoregion:	Outer Coastal Plain
Stream Name:	Branch of Brice's Creek
River Basin:	Neuse
Culvert Buried:	No
Latitude:	34.798
Longitude:	-76.995
Drainage Area:	3.21 mi²
Centerline Length:	49' 11"
Opening Width:	22' 8"
Opening Height:	5' 3"
Approx. Width of Natural Stream:	20'
Approx. Structure Slope:	0.00%
Primary Streambed Sediment:	Silt

This site is located in central Craven County, south of the City of New Bern and northwest of the City of Havelock, on S.R. 1102, also known as Tebo Road. It is located on a Branch of Brice's Creek (DWQ Index No. 27-101-40-3; Class C;Sw;NSW) and generally flows to the northwest in the Neuse River Basin. The area draining to the structure is approximately 3.21 square miles.

This forty-nine-foot-eleven-inch structure has been in place since 1998 and was chosen to replace a thirty-one-foot bridge.

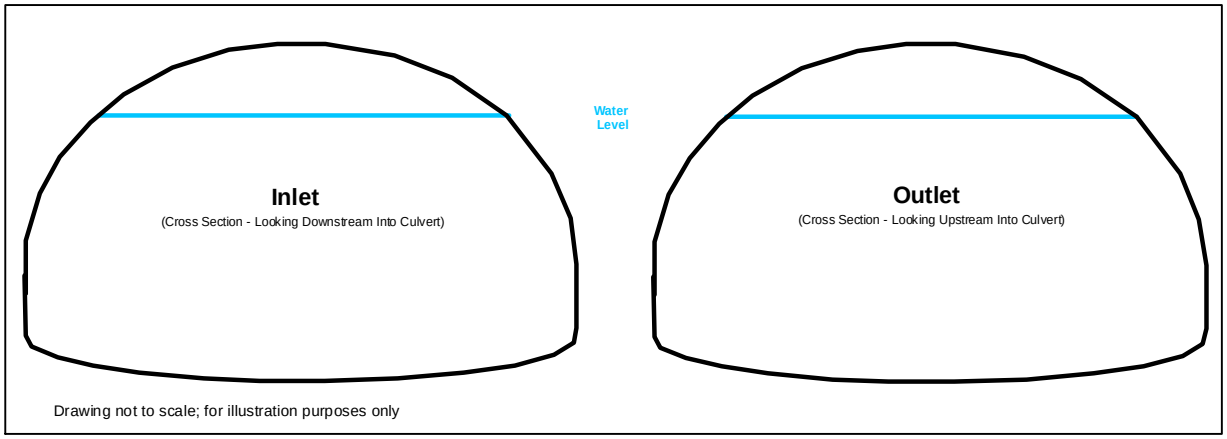
Figure 47: Location of Bridge No. 240008, Craven County



Water was present and standing in the stream and was several feet deep. No evidence of flow was detected. In the thirty days prior to the site visit, the area received 1.09 inches of rain, none of which fell within the preceding five days of the visit.

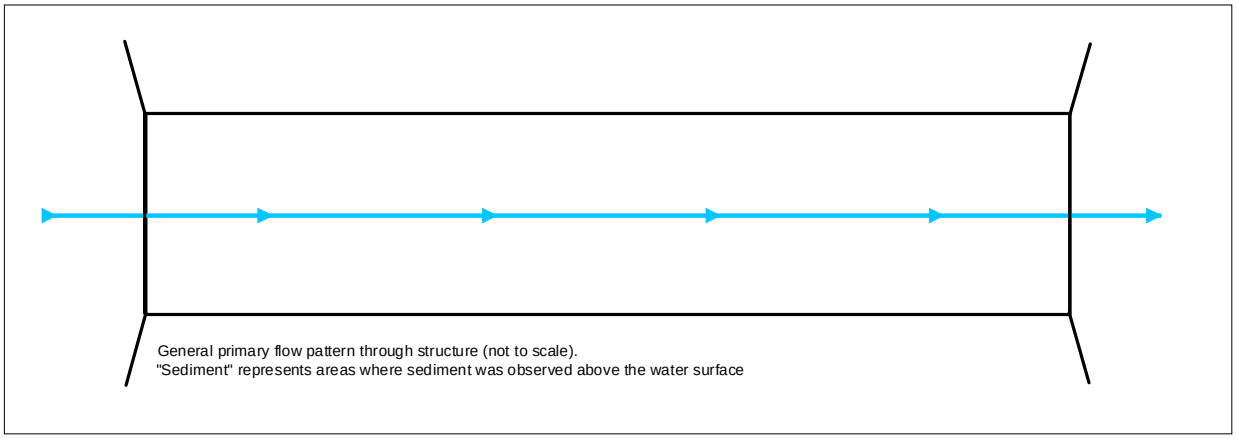
It was not able to be determined if this structure had been buried when constructed. It is also doubtful that any backfill or sediment would have been placed in the structure during construction. The water was several feet deep and discolored, making very difficult to survey the culvert for sediment and burial. The bottom of the structure was probed using a surveyor's rod. It did not appear as though any sediment had built up on the bottom of the bottom. For reasons stated above, stream bottom material could not be determined; however, it is suspected to be primarily silt.

Figure 48: General Sediment Profile for Bridge No. 240008, Craven County



Water was present at the site, and was rather deep; approximately three-feet-nine-inches. The water was nearing the top of the opening. At five-foot-three-inches high, the water level was within eighteen-inches of the top of the opening. It was noted that this structure and road are over-topped regularly in large weather events. This could be supported by the waterlines and staining on the headwalls, which were even with the top of the opening. The width of the natural stream system is approximately twenty-feet, and is split into two channels on the upstream side before converging and entering the structure. Aquatic life passage would not have been an issue during the visit, nor is it believed to be an issue under normal low flow conditions as it is likely that water stands in the structure all the time.

Figure 49: General Flow Profile for Bridge No. 240008, Craven County



No rip-rap was noticed on the upstream side; however, a small amount of marl was placed on the outlet side of the structure for bank stabilization. The banks appeared stable and well vegetated. The area is very low with a nice floodplain that could easily be accessed when necessary. Scour was not observed at the headwalls. However, as can be seen in the photographs of the structure presented below, no fill was placed at the headwall to bring the banks even to the existing bank or the structure opening.

The area draining to the structure is approximately 3.21 square miles. The dominant land cover is woody wetlands (54.37 percent), followed by evergreen forest (12.36 percent) and shrub/scrub (11.25 percent).

Figure 50: Drainage Area for Bridge No. 240008, Craven County

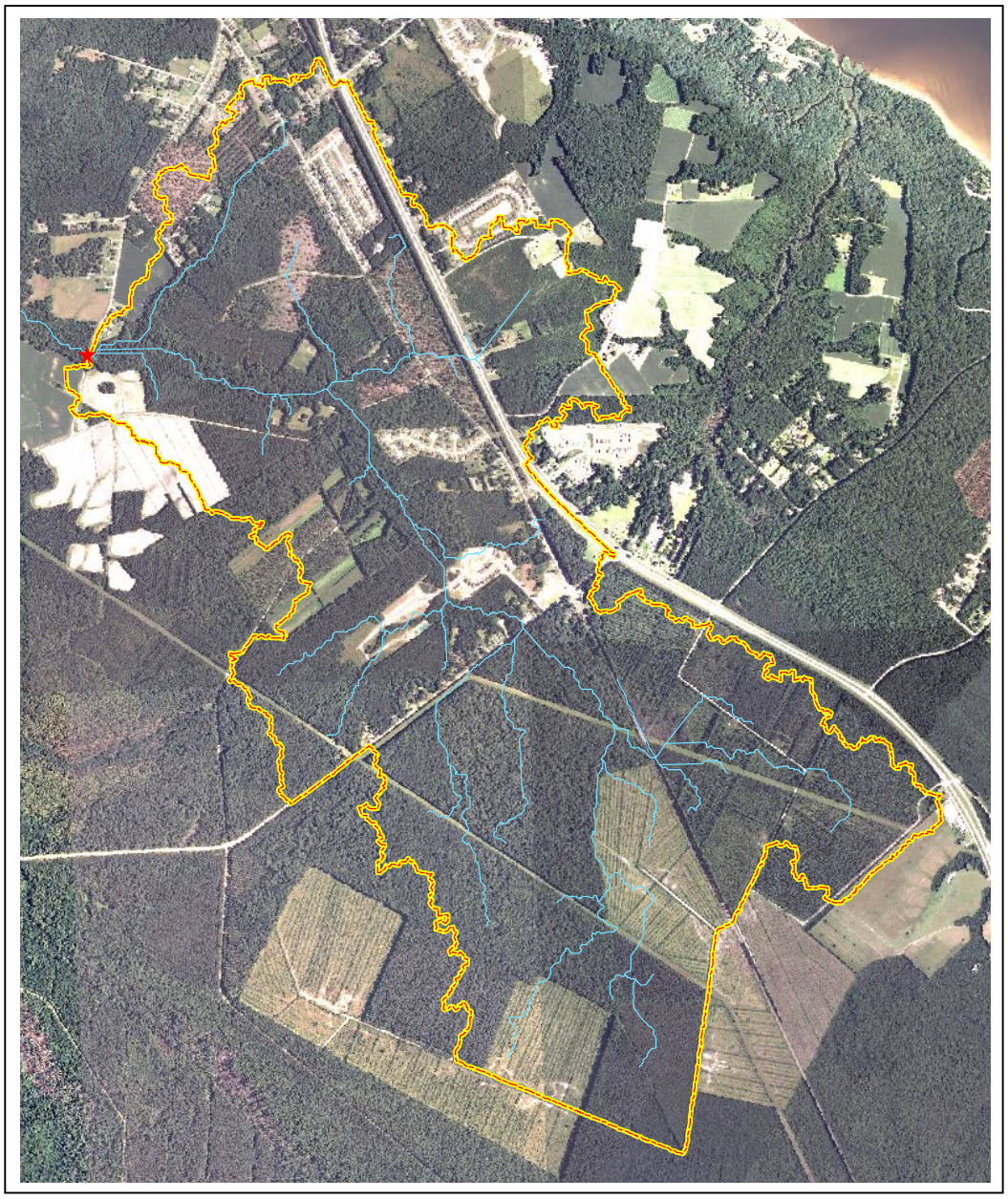


Figure 51: Photographs of Bridge No. 240008, Craven County

Inlet of structure

Inlet of structure

Outlet of structure

Downstream of structure

Upstream of structure

Upstream of structure

NCDOT Bridge No. 530158, S.R. 1804 (Neuse Road), Lenoir County

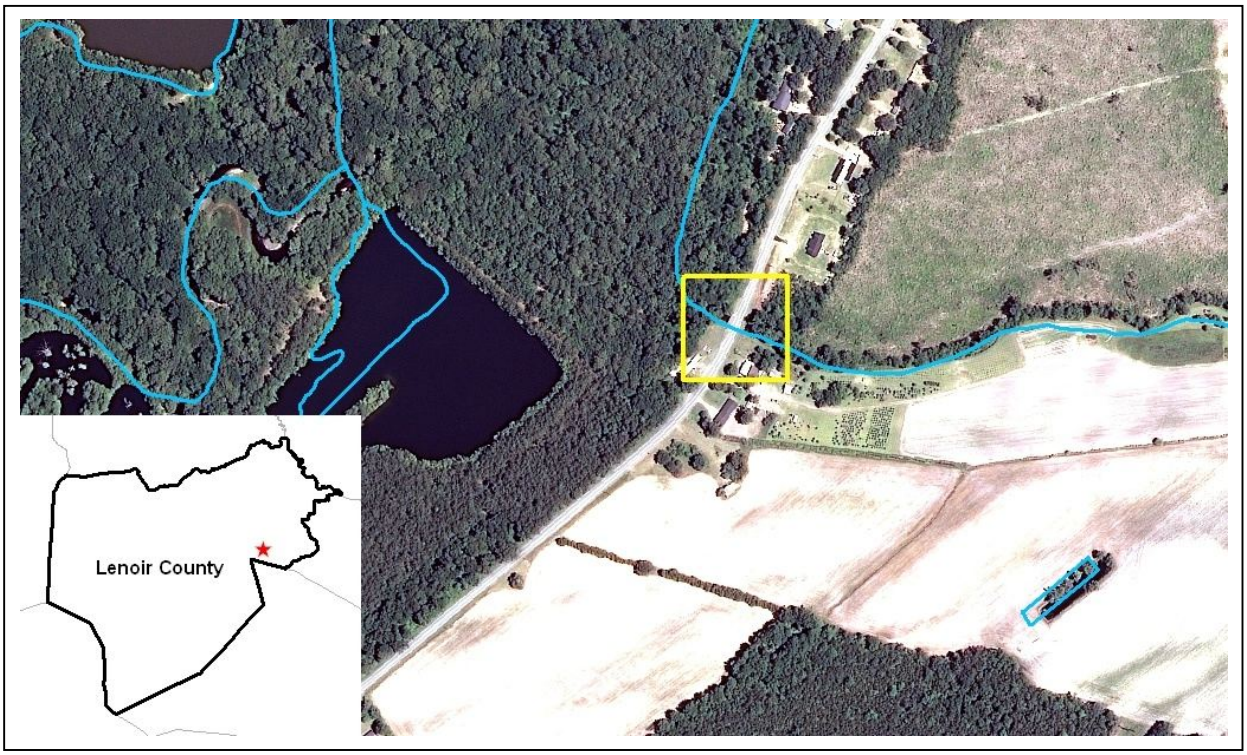
Table 11: Summary Information for Bridge No. 530158, Lenoir County

Date Visited:	12/13/2011
Year Installed:	2002
Ecoregion:	Inner Coastal Plain
Stream Name:	Fork of Southwest Creek
River Basin:	Neuse
Culvert Buried:	Yes
Latitude:	35.258
Longitude:	-77.507
Drainage Area:	3.81 mi²
Centerline Length:	49' 7"
Opening Width:	23' 7"
Opening Height:	9' 3"
Approx. Width of Natural Stream:	15 feet
Approx. Structure Slope:	0.50%
Primary Streambed Sediment:	Silt

This site is located in eastern Lenoir County, east of the City of Kinston, on S.R. 1804, also known as Neuse Road. It is located on a Fork of Southwest Creek (DWQ Index No. 27-80-9; Class C;Sw;NSW), which generally flows to the northwest within the Neuse River Basin. The area draining to the structure is approximately 3.81 square miles.

The forty-nine-foot-seven-inch structure was installed in 2002 and was chosen to replace a thirty-six-foot long bridge.

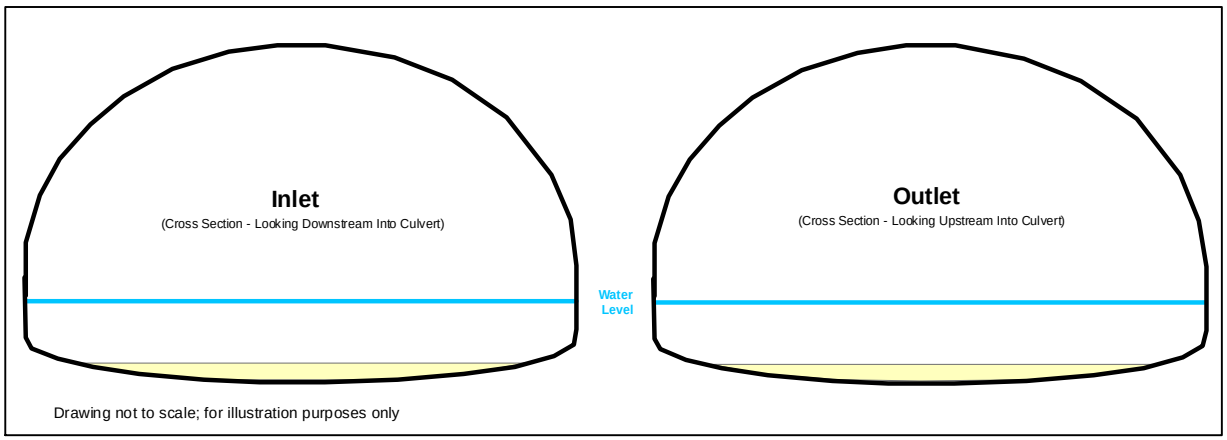
Figure 52: Location of Bridge No. 530158, Lenoir County



Water was present and was several feet deep. It was moving very slowly; the only detectable movement was observed upstream of the structure. The area received 1.13 inches of precipitation in the thirty days prior to the visit, none of which fell within the five preceding days.

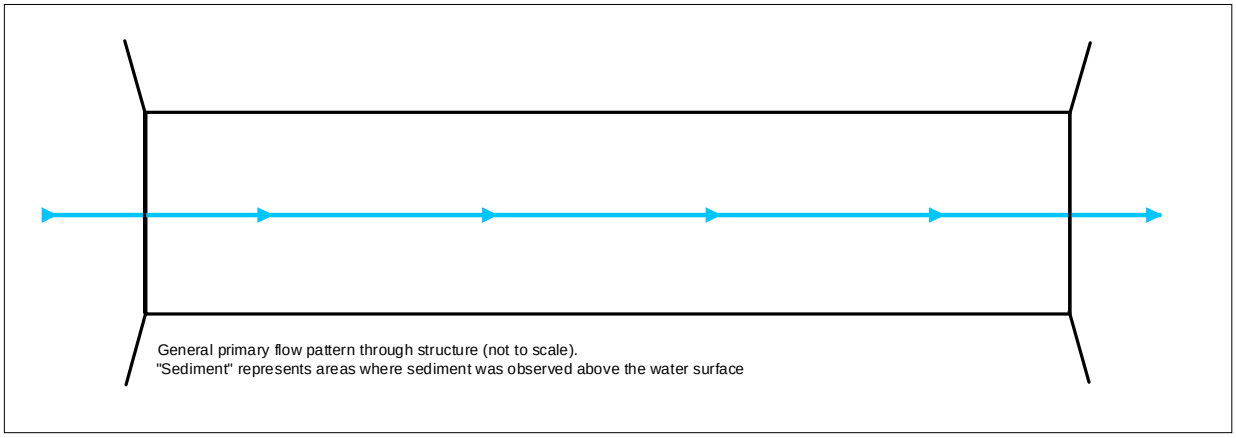
The structure was buried one-foot when installed, although no backfill was placed in the structure at the time. Although the water was somewhat deep, it was clear enough that the bottom of the channel could be seen. As such, it was able to be determined that sediment had been deposited in the structure. It was determined that approximately three inches of sediment had been deposited inside at both the inlet and outlet of the structure. The channel bottom appeared to be primarily silt. The floor of the structure was not visible.

Figure 53: General Sediment Profile for Bridge No. 5300158, Lenoir County



Water was present during the visit and was approximately two feet deep. The width of the natural stream is approximately fifteen feet. The only evidence of flowing water could be found some distance upstream as the water worked its way around some woody debris in the stream channel. Water lines in the structure and on the headwalls indicate that water levels at about two feet higher than what was observed occur at least somewhat regularly. It is believed that water stands in the channel and structure for most of the year, if not all year. Due to the depth of the water, the stream was utilizing the full width of the structure. The structure is located approximately three-quarters of a mile from the Neuse River, so it is possible that the stream holds backwater from the river, especially at high flows. Water depth during the review was plenty sufficient to allow for aquatic life passage. Most likely, sufficient water would be present throughout the year to allow sufficient passage.

Figure 54: General Flow Pattern for Bridge No. 530158, Lenoir County



Small amounts of rip-rap were used to stabilize the banks. However, it has been vegetated over and is difficult to see in some areas. The banks appeared to be stable and well vegetated with no signs of any undercutting or erosion. A floodplain does exist, and would be easily accessible on the downstream side if needed, which is a more natural and undisturbed area than the upstream side. On the upstream side, the water would need to come up a little higher to access any floodplain. This is most likely because fill was brought in when the adjacent lots were developed.

The banks on the right side of the stream at the headwall on both the upstream and downstream side did not have fill placed up to the opening. Since this situation is common to both sides, it is doubtful that it is due to scour and most likely a relict condition from the previous structure. The left banks do not show any signs of scour and do have fill to the opening.

The area upstream area draining to the structure is approximately 3.81 square miles. The primary land cover in the drainage area is cultivated crops (49.15 percent), followed by evergreen forest (21.95 percent) and woody wetlands (9.79 percent).

Figure 55: Drainage Area for Bridge No. 530158, Lenoir County

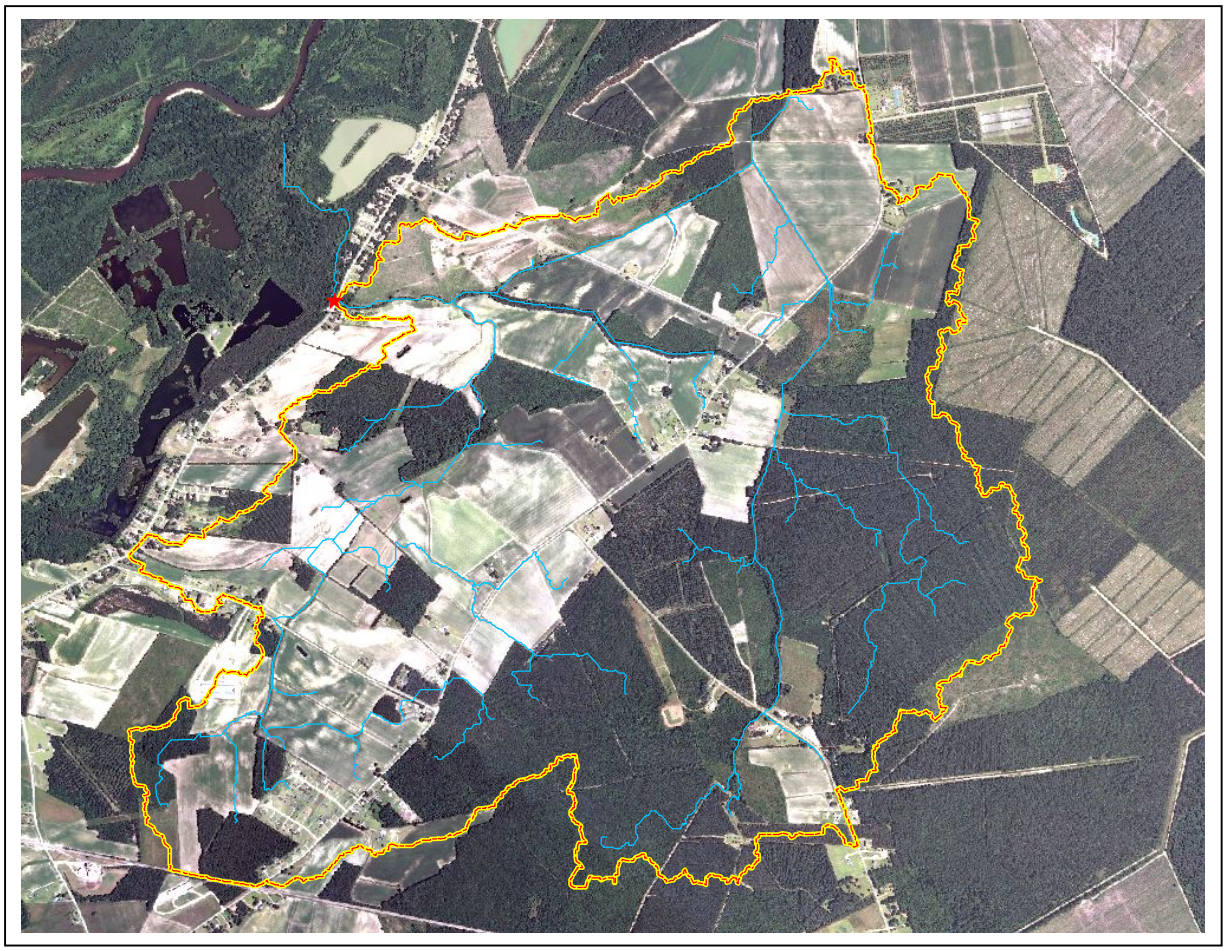


Figure 56: Photographs of Bridge No. 530158, Lenoir County

Inlet of structure

Outlet of structure

Downstream of structure

Upstream of structure

Downstream of structure

Upstream of structure

NCDOT Bridge No. 680039, S.R. 1205 (Courtland Drive), Pamlico County

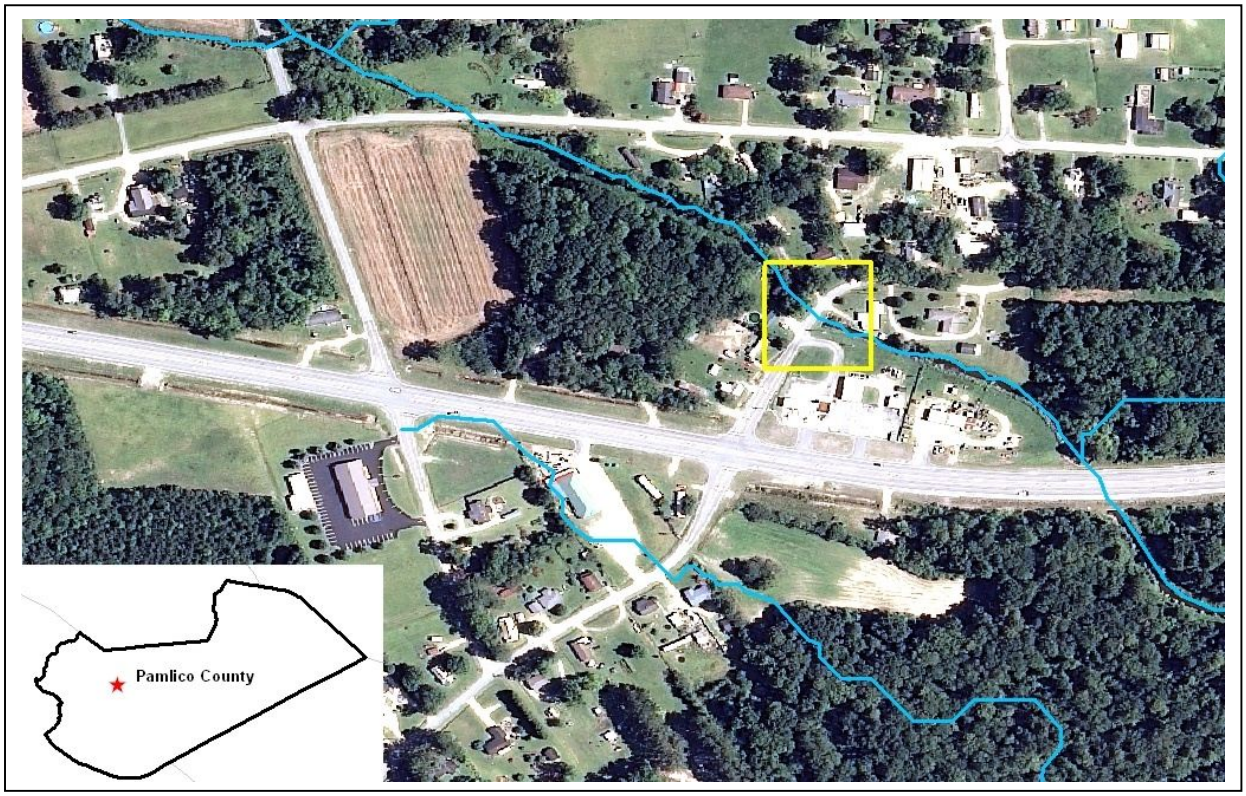
Table 12: Summary Information for Bridge No. 680039, Pamlico County

Date Visited:	12/13/2011
Year Installed:	2002
Ecoregion:	Outer Coastal Plain
Stream Name:	South Prong of Bay River
River Basin:	Neuse
Culvert Buried:	Yes
Latitude:	35.144
Longitude:	-76.816
Drainage Area:	2.35 mi^2
Centerline Length:	50'
Opening Width:	24' 3"
Opening Height:	7' 3"
Approx. Width of Natural Stream:	25'
Approx. Structure Slope:	Unknown
Primary Streambed Sediment:	Silt/sand

This site is located in west central Pamlico County, in the Town of Alliance, on S.R. 1205, also known as Courtland Drive. It is located on the South Prong of Bay River (DWQ Index No. 25-150-3; Class SC;Sw;NSW), and generally flows to the southeast in the Neuse River Basin. The upstream area draining to the structure is approximately 2.35 square miles.

This fifty-foot structure has been in place since 2002 and was chosen to replace a thirty-three-foot bridge.

Figure 57: Location of Bridge No. 680039, Pamlico County

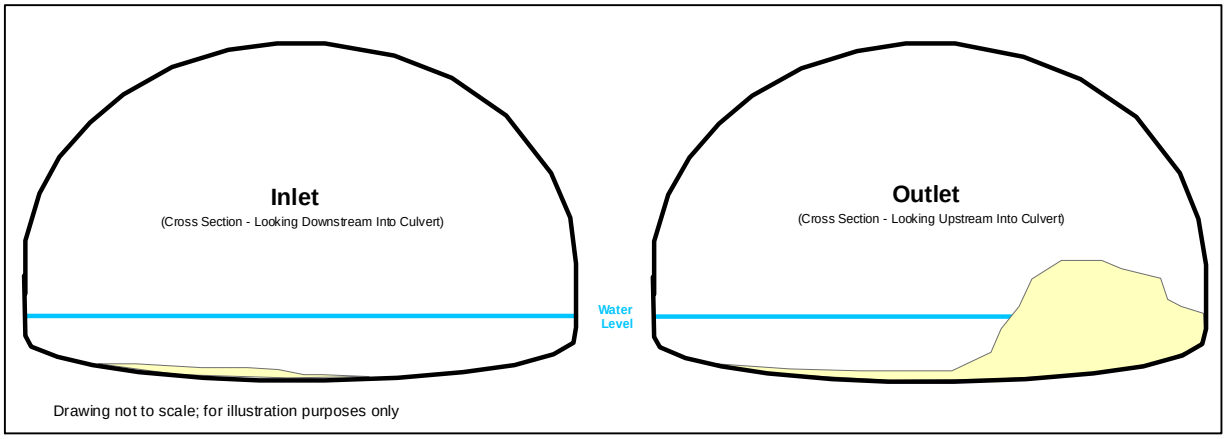


Water was present and flowing at a moderate pace. In the thirty days prior to the visit, the area received 1.47 inches of rain; 0.02 inches of which fell within the preceding five days of the visit.

This structure was replaced as a "prompt action" call to the NCDOT. In this case, it is believed that something catastrophic happened to the previous bridge, which resulted in this structure being installed. Due to the nature of the action, no survey report was available for this structure. Therefore, it is not known if this structure was buried or what grade the structure was placed on.

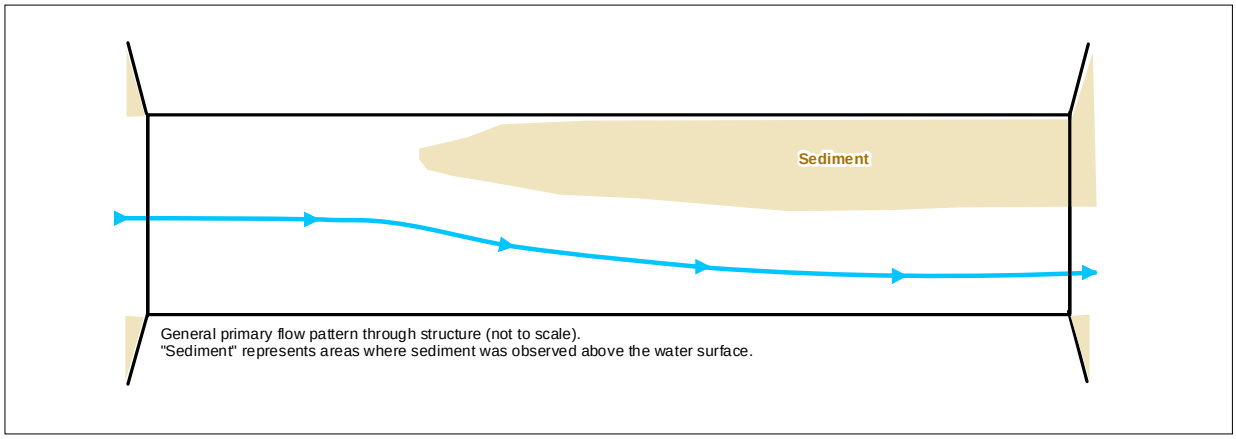
If any backfill was placed in the structure during construction, much of it has washed out. The bottom of the structure could be seen on the inlet side, especially on the right side. Sediment, which is sandy silt, had built up on the downstream left side of the structure, forming a rather high bench of approximately three-feet at the highest point. Aside from the bench, the outlet contained approximately one-inch of sediment; the floor of the structure could not be seen.

Figure 58: General Sediment Profile for Bridge No. 680039, Pamlico County



Water depth was about eighteen-inches. The width of the natural stream is approximately twenty-feet. Water was flowing at a slow pace through the structure. Waterlines and staining on the inside walls indicate that water frequently reaches two-feet above what was observed. The water was deep enough in the channel that the width of the structure was being used to convey the stream. The water depth during the visit would have easily been enough to allow for aquatic life passage. It is uncertain if sufficient water would be present during extreme low flow conditions to allow for adequate passage.

Figure 59: General Flow Pattern for Bridge No. 680039, Pamlico County



Small amounts of rip-rap were used on all four corners of the structure to help stabilize the banks. There was more rip-rap used on the upstream side than on the downstream side. Much of it has vegetation growing over it. All banks appeared stable, but steep on the downstream side. The downstream channel had been channelized, modified, and most likely fill had been brought in for development of the adjacent properties. The downstream channel appeared more natural. No scour was noticed at either headwall.

The area draining to the structure is approximately 2.35 square miles. The primary land cover is cultivated crops (50.40 percent), followed by woody wetlands (19.71 percent) and evergreen forest (10.08 percent).

Figure 60: Drainage Area for Bridge No. 680039, Pamlico County

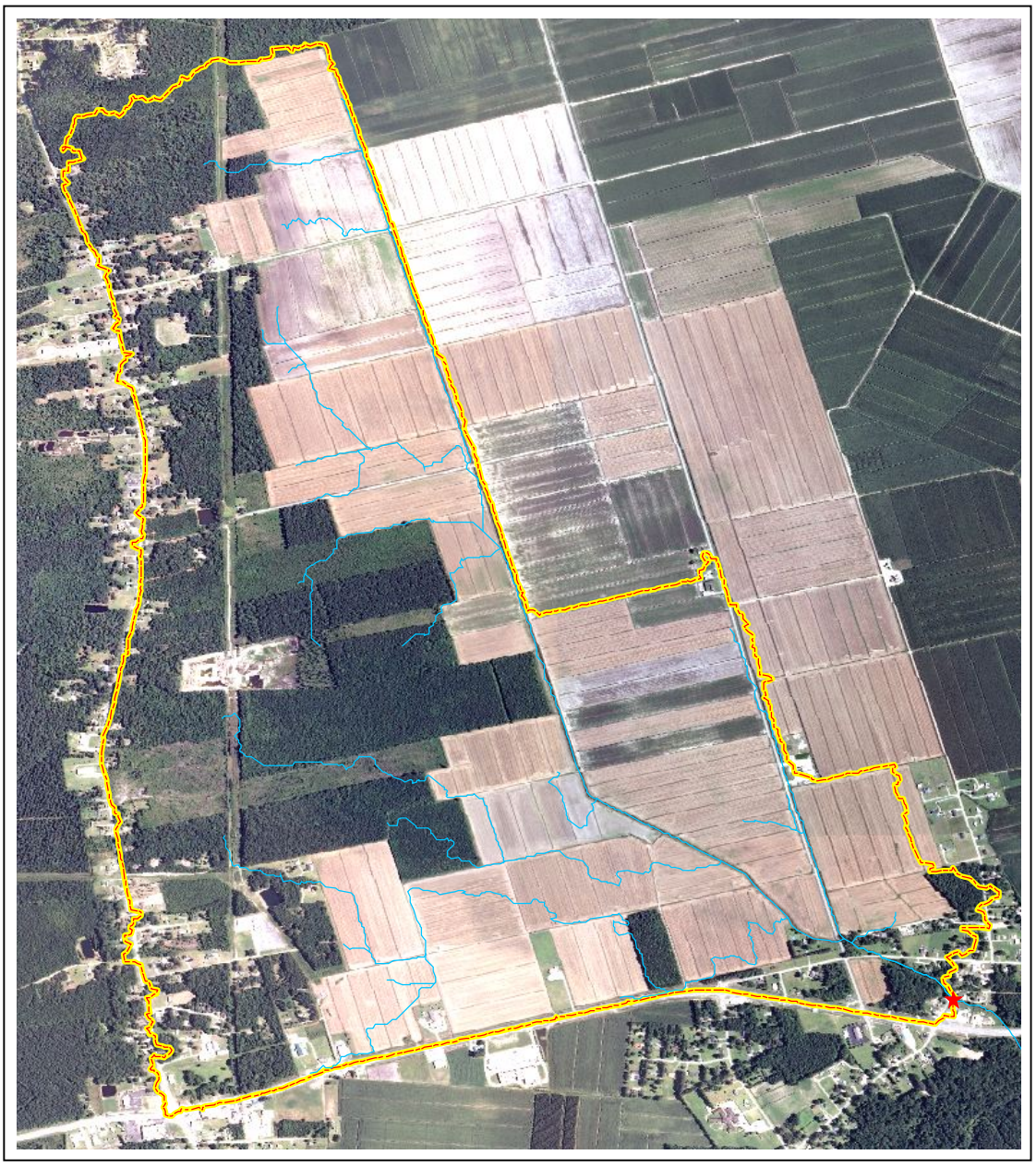


Figure 61: Photographs of Bridge No. 680039, Pamlico County

Outlet of structure

Outlet of structure

Downstream through structure

Upstream of structure

Downstream of structure

Downstream of structure

Discussion

Information provided by the NCDOT indicates that there are at least seventy-five aluminum box culverts installed across the state. Additional information provided by NCDOT shows that an aluminum box culvert was installed as early as 1983 in Stanly County. However, it does not appear that they were installed with any frequency until the mid to late 1990's. The majority of the structures installed are located in the central piedmont and the northern outer coastal area, as shown in Figure 62. The structures included in this study were installed between 1998 and the summer of 2011. This allowed for a good cross section with respect to age, as the structures had been in place between several months and thirteen years. Figure 63 below includes the structures reviewed by installation year.

Figure 62: Location of NCDOT Aluminum Box Culverts

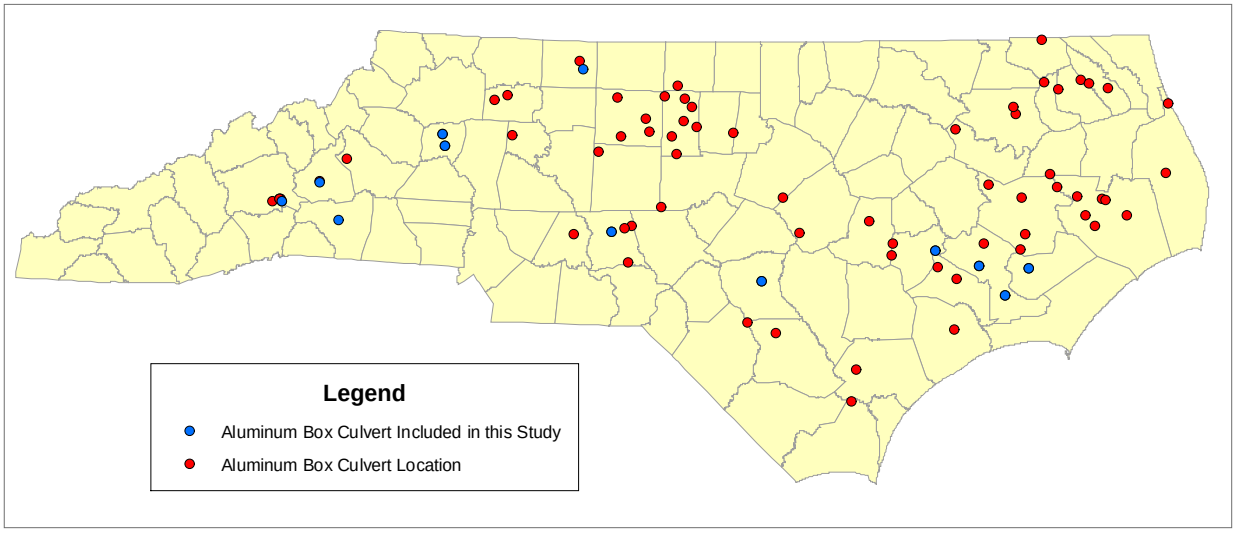
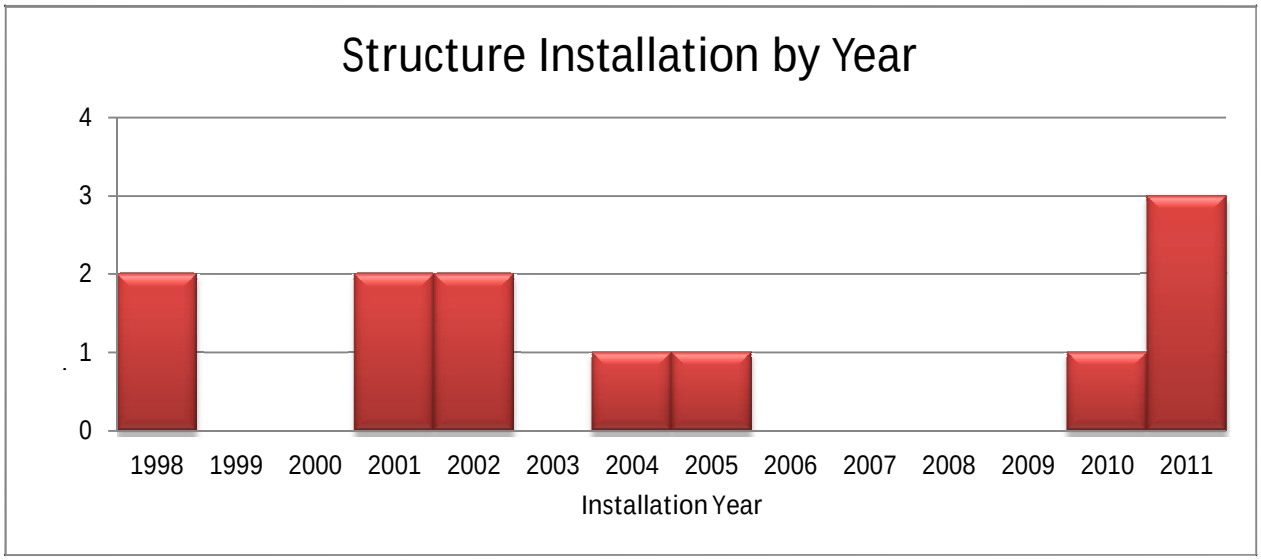


Figure 63: Structure Installation by Year



One goal of the study was to select a good cross section of structures. This was accomplished in many respects, including structure age, Ecoregion, size (length and opening), structure slope, and stream size. The table below presents basic data collected for each structure.

Table 13: Summary Information of Structures Reviewed

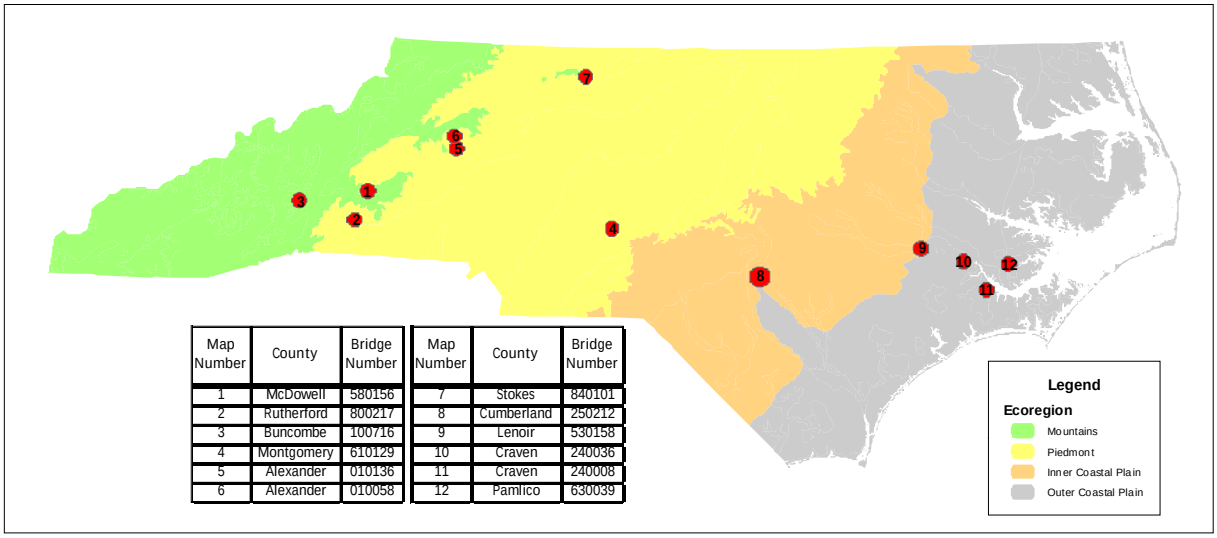
Bridge No.	County	Ecoregion	Length	Opening Width	Opening Height	Installed	Structure Slope (percent)	Buried	Drainage Area (mi^2)	Bottom Visible
100716	Buncombe	Mountains	60'	24' 3"	7' 4"	2004	0.6	No	3.16	No
580156	McDowell	Piedmont	40'	30' 6"	7' 7"	2011	1.0	Yes	2.19	No
800217	Rutherford	Piedmont	99'	32' 7"	7' 9"	2011	0.4	Yes	0.96	No
610129	Montgomery	Piedmont	45' 7"	25'	9' 5"	2001	0.3	Yes	3.97	No
010136	Alexander	Piedmont	54'	24' 7"	9' 9"	1998	0.4	Yes	5.42	Yes
010058	Alexander	Piedmont	50'	29' 8"	9' 4"	2011	0.5	Yes	2.3	No
840101	Stokes	Piedmont	72'	24' 3"	15' 7"	2005	4.0	No	3.69	Yes
250212	Cumberland	Piedmont	67' 5"	34' 4"	13' 1"	2010	0.7	Yes	7.82	Yes
530158	Lenoir	Coastal Plain	49' 7"	23' 7"	9' 3"	2002	0.5	Yes	3.63	No
240036	Craven	Coastal Plain	49'	25' 4"	10' 2"	2001	0.7	Yes	3.74	Unknown
240008	Craven	Coastal Plain	49' 11"	22' 8"	5' 3"	1998	0.0	Unknown	3.21	Unknown
630039	Pamlico	Coastal Plain	50'	24' 3"	7' 3"	2002	Unknown	Yes	2.35	Yes

As can be seen in the table, nine of eleven culverts are known or believed to have been buried during installation; burial was unable to be determined at one site. One of the structures, Bridge Number 100716 in Buncombe County could not be buried due to bedrock, although there was insufficient bedrock to support a bottomless culvert. Most of the structures that are buried are thought or known to be buried one-foot, although a few appeared to be buried only a few inches.

Structures included in the review were also selected based on location within the State. Using the Level III Ecoregion divisions, the state is divided into four Ecoregions - mountains, piedmont, inner coastal plain and outer coastal plain (Figure 64). There is only one structure included in the review which is located in the mountains. The lack of mountain sites is primarily because bedrock is extremely prevalent in the mountains, which usually makes bottomless culverts the better choice. For the same reason, it was difficult finding bottomed structures in the western piedmont area. On the contrary, there are numerous structures in the outer coastal plain region. All of the aluminum box culverts in this Ecoregion have bottoms as bedrock is virtually non-existent at shallow depths. The lack of bedrock should make excavation and installation easier, especially for structures with bottoms. The predominance of structures on the coast can be seen in Figure 62.

In addition to bedrock, there are other significant differences among Ecoregions. With respect to this study, another difference is stream gradient or slope. While stream slopes were not considered in this review, the slope of the stream plays an important role in the slope of the structure, which was considered. There were not enough sites to draw any meaningful statistical conclusions; however, simple observations can be made.

Figure 64: Structure Location by Ecoregion



Map Number	County	Bridge Number
1	McDowell	580156
2	Rutherford	800217
3	Buncombe	100716
4	Montgomery	610129
5	Alexander	010136
6	Alexander	010058

Map Number	County	Bridge Number
7	Stokes	840101
8	Cumberland	250212
9	Lenoir	530158
10	Craven	240036
11	Craven	240008
12	Pamlico	630039

As shown in Table 14 below, the range of slopes for all structures except for the one in the mountains and one in the coast (no engineering report was available and the slope could not be determined) ranged from 0.0 percent to 4.0 percent. For the piedmont, slopes ranged from 0.3 percent to 4.0 percent while coastal slopes ranged from 0.0 percent to 0.7 percent. The 4.0 percent structure slope found at Bridge Number 840101 in Stokes County is considerably steeper than the rest of those found in the study; so much so that it could probably be considered an outlier. The rest of the slopes were equal to or less than 1.0 percent. As discussed in the review of Bridge Number 840101, the structure had baffles installed in it, in part to control the flow of the 4.0 percent slope. It was also noted that there was little sediment building behind the baffles, and the vast majority of the culvert floor was visible.

Table 14: Table of Structure Slopes

	Minimum	Average	Maximum	Range	N*
All Data	0.0%	0.9%	4.0%	4.0	10
Piedmont	0.3%	1.1%	4.0%	3.7	7
Inner and Outer Coast	0.0%	0.4%	0.7%	0.7	3

* There was only one site in the mountains which was not included; at one site the slope is unknown and could not be included.

Unless a bridge is constructed at a crossing, structure slope is something that is considered when deciding what type of structure to use, as this plays a role in stream stability. As mentioned above, nearly all structures are believed to be installed on slopes less than or equal to one percent. With exception of Bridge Number 610129 in Montgomery County, the streams showed no apparent signs of being unstable. In Montgomery County, a small headcut was observed upstream of the structure. As with any structure used to convey a stream, the natural slope of the stream should be matched as closely as possible. Based on observations, aluminum box culverts placed on slopes up to one percent seem to work well. Based on limited data from the study, it is unclear what would be an acceptable cutoff slope, which should be site specific. Structure slope is something that should be considered very carefully during design once the engineering report has been completed.

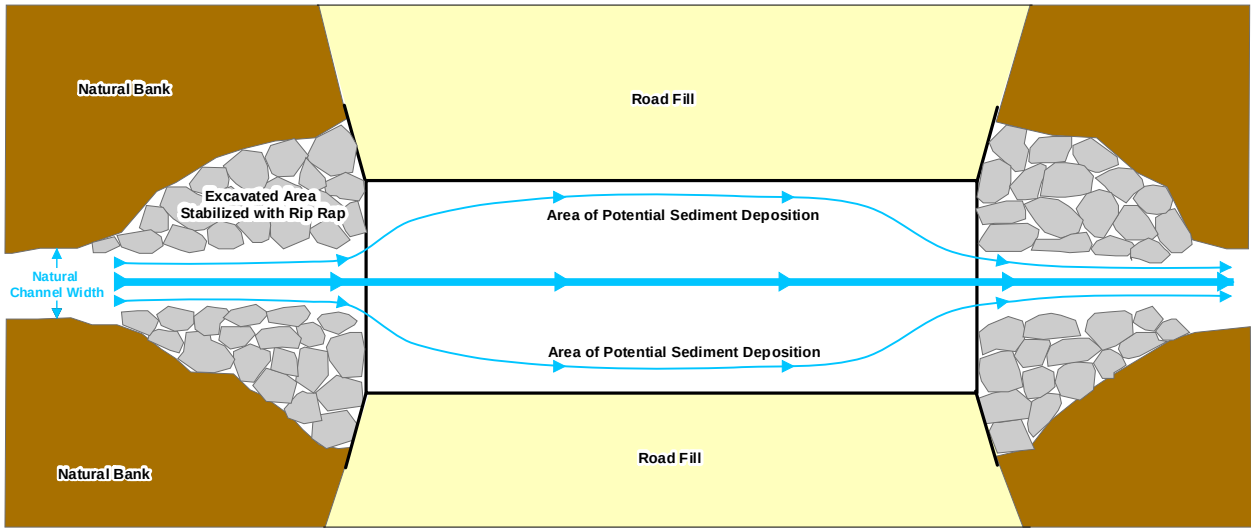
Another situation of concern for the NCDWQ was whether or not the bottom of the structure was visible or exposed. For aquatic life passage concerns, it is important to have sediment on the floor of the structure and it is equally important that the structure be able to properly convey the stream during low flow events. Backfill was not placed in the vast majority of structures during construction. However, in most cases at least some sediment had been deposited on the floor through natural events. Even so, in at least four of the twelve culverts the bottom was visible. It is evident that, with exception of Bridge Numbers 580156 in McDowell County, 800217 in Rutherford County, and 010058 in Alexander County, culverts were buried one-foot or less. Bridge Number 580156 in McDowell County was buried about fifteen-inches and backfilled; 800217 in Rutherford County was buried just under three-feet and backfilled; and 580156 in McDowell County was buried about eighteen-inches and was not backfilled. The structure floor was not visible in any of these structures. It should also be noted that all three of these were installed in 2011, and thereby have been in place less than one year. It is also believed that all three structures would have very little trouble, if any, conveying water under low flow conditions allowing sufficient aquatic life passage to be maintained.

Another consideration with respect to low flow conditions in the structures is the size of the opening and the nearly flat floor. These structures generally have wide openings. Structures in the review had openings between twenty-two and thirty-five feet. If an aluminum box culvert had not been used it is likely that a multiple barrel reinforced concrete box culvert (RCBC) would have been used. To match these opening widths, any RCBC used would have required a multiple barrel structure. When multiple barrels are used, they can be designed (and often are) such that one barrel conveys base and low flow water while other barrels may have sills installed which allow for conveyance during higher flows. When used in this manner, a much smaller width is allowed for base and low flow conveyance than had an aluminum box culvert with a single opening been used. This is to say, that unless an aluminum box culvert is backfilled and benches created, or a design is used that allows for sediment to naturally settle out in a reasonable amount of time, the opening width of the aluminum box culvert is such that base flow may, and low flows probably will, be spread out too much to allow for adequate aquatic life passage. In many cases the structure cannot be backfilled. In these cases there is a design solution that may help expedite sediment deposition within the structure.

When the aluminum box culvert in McDowell County was installed, it could not be backfilled due to the height of the opening, which is around seven-foot-six-inches. The width of the structure opening is over thirty-feet but the width of the natural stream is only about five-feet. As a solution, a rip-rap channel was constructed at the inlet and outlet of the structure to maintain the five-foot wide stream width, matching the natural width of the channel. The rip rap was placed such that it is even with the headwall on both the inlet and the outlet, but not in the structure itself, guiding the flow into and out of the culvert in the middle of the opening, yet still maintaining the approximate width of the natural stream. The rip rap was covered with soil and vegetated. As no backfill was placed in the culvert, sediment was allowed to deposit in the structure through natural processes. Because the stream was guided into and out of the middle of the structure it is expected that sediment would deposit along the walls rather than in the middle of the structure. Additionally, this kept the main portion of flow from entering the structure along a wall and potentially compromising the integrity of the structure. In the few months the structure has been in place, an impressive amount of sediment had already been deposited in the

culvert and a channel was beginning to form near the middle of the structure. The general concept is illustrated in Figure 65 below.

Figure 65: Basic Inlet and Outlet Design of Bridge No. 580156 in McDowell County



Based on observations, it may be necessary to bury these structures deeper than the typical one-foot. If this is to be done, it must be considered during the design phase. The culvert would need to be designed to have a taller opening, but since aluminum box culverts can be manufactured in just about any size, adding additional height of one-to-two-feet should be a possibility without compromising the necessary hydraulic conveyance capacity. NCDWQ proposes a burial depth of at least two-feet, although deeper may be preferred under certain circumstances. While this concept may not be practicable in all situations, it should be considered when practicable.

All of the structures reviewed on the coast had several feet of water standing in the channel and culvert. If the water was moving it tended to be very slow. In most of the piedmont sites water was much shallower, usually several inches and was moving at a much higher velocity. It is advisable to first consider the typical depth and velocity of the stream being conveyed. However, as best as practicable, such considerations should be made under typical low flow conditions when aquatic life passage would be more problematic. This information should be able to be obtained through the engineering report.

Based on observations made, there were no obvious signs of structures not performing as intended on the day of the review. Water was present at all sites and in sufficient quantity that the structures were conveying the stream. Aquatic life passage did not appear to be of concern during the review, but one can only speculate what would occur at these structures during low flow events. There were no signs of significant, active bank erosion or scour at the headwalls, although a small headcut was present just upstream of Bridge Number 610129 in Montgomery County.

Conclusions

As discussed previously, at the time of the review, the culverts were performing in a satisfactory manner. No significant issues were identified. However, there were some distinct differences in the way several of the culverts had been installed. This is most likely due to two reasons. First, there are geographic differences between the mountains, piedmont, and coastal areas of the state. Many of these differences, as they relate to this study, have been discussed in detail previously. Second, there has been a concerted effort in some of the more recent installations to improve the way structures convey water.

There are two primary concerns that the NCDWQ has with any structure placed in a jurisdictional stream to convey water. The first is stream stability and the second is aquatic life passage, especially under base and low flow conditions. Observations made during the review of these structures tried to address if either of these are of concern with current installation practices and use of aluminum box culverts. In light of these two primary concerns, and information gathered during the review, the NCDWQ suggest the following three guidelines be considered when an aluminum box culvert is to be installed:

1. When practicable, bury the structure deeper than is the typical, current practice. The NCDWQ believes that these structures, primarily because of their size and flat bottom, would better address concerns if buried deeper than the one-foot which has been typical in past installations of nearly all structures over forty-eight-inches. If practicable, these structures should probably be buried at least two-feet and perhaps even deeper in higher velocity streams. For this to be done, burial depth would need to be considered during the design phase of the project. Aluminum culverts would need to be constructed such that they are taller, but not wider (as to not unnecessarily over-widen the stream), to allow for the extra burial depth yet still allow for adequate hydraulic conveyance. The NCDWQ realizes that there will be instances where culverts cannot be buried more than one foot. Each project will need to be evaluated on its merit as well as the prevailing site conditions regarding burial depth.

   Nearly all culverts visited were buried at least one-foot. Three were buried between eighteen- and thirty-six-inches. All three of these were very recent installations, having been installed within the previous six months or so. Two of these were backfilled while the third was not, although plenty of sediment had been deposited in the third. Culverts which were buried one foot or less were more likely to have the floor at least partially, if not nearly completely, exposed. Burying these structures deeper allows a better opportunity for sediment to deposit in the culvert. This would help better define a channel and, in turn, should allow for better aquatic life passage under base and low-flow conditions.

2. Floodplain benches should be constructed at the inlet and outlet in a manner that helps preserve the natural stream width. During construction, an area wider than the structure width is excavated out to allow for placement of the structure. Often this area is backfilled after construction, but is only filled to the opening, potentially leaving this area wider than the natural stream width. Over-widening of the stream should be avoided as it can lead to instability and aquatic life passage issues. To help prevent over-widening in the excavated areas and help preserve stream stability, floodplain

benches should be constructed in these areas. A good example of this was seen at Bridge Number 580156 in McDowell County. The area around the headwalls which was excavated to install the structure was filled with rip-rap such that the natural width of the stream was maintained (approximately 5 feet). Material was only placed up to the headwall; no material was placed in the structure itself. This allowed the stream to be guided into and out of the middle of the structure while maintaining an acceptable stream width at the headwalls (see Figures 4, 6, and 65). The rip-rap was then covered with soil and vegetated for stability purposes. While this structure had only been installed for a few months, there was enough sediment settling out that benches were beginning to form along the walls and a channel was forming near the center of the culvert. The structure was buried approximately eighteen-inches and no part of the floor was visible.

While most structures were not backfilled during construction, at least two were backfilled with native material which was stockpiled during the excavation phase. The two that had been backfilled were buried deeper than those that were not to account for the additional material. Backfilling may be an acceptable practice, provided the material is suitable and it is stable enough that it will not lead to significant downstream transportation during large storm events. However, depending on the soil type, if a structure is buried deeper than one foot and is not backfilled, headcut formation may be of concern. If it is suspected that headcut formation may be an issue, then measures such as inlet protection should be implemented to lessen the likelihood of a headcut forming. Such situations should be discussed with NCDWQ staff prior to application submittal and will be considered on its own merit and situation.

3. Aluminum box culverts should be considered only in low slope situations. All but one structure reviewed was placed on a slope less than or equal to one percent. Bridge Number 840101 in Stokes County, placed on a four percent slope, was much steeper than the others. It was the only structure with baffles, which may have been required in part due to the steep slope. It was installed in 2005 and had been in place for approximately six years. Even so, very little sediment had been deposited, and the floor was visible throughout the structure. All other structures appeared to be functioning well and were at a low enough slope that in most cases at least some sediment settled in the structure. Any sediment in structures placed at steeper slopes may tend to destabilize at higher flows or velocities and become part of the bedload. Information gathered during the review indicates that structures placed on a one percent slope or less tend to work satisfactorily, but a four percent slope is too steep. While the NCDWQ may not feel comfortable in approving structures on slopes much greater than one percent, approval will depend upon specific site conditions.

While the NCDWQ in no way objects to the use of aluminum box culverts with bottoms, it is believed that after this review there are prudent design considerations which should be considered. It is understood that these suggested practices will need to be evaluated for each specific project and should be discussed with NCDWQ staff prior to implementation. These practices will need to be considered in the design stage, but should not generally present a hardship to the NCDOT if proper engineering is performed ahead of time so these design guidelines can be considered. Nearly all, if not all, of the necessary information needed to employ these designs should already be determined for compilation of the engineering reports used to design the structure.

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