

- Maximum allowable pulling force
- Site specific cure time
- Minimum pressure to hold liner tight against the host pipe
- Maximum pressure to ensure liner does not sustain damage
- Maximum and minimum cure temperatures
- Ambient temperature range allowable during installation
- Post cure temperature
- Temperature cure profile.
- Sample of temperature and pressure log to be used for monitoring the curing process
- Certification on manufacturer's letterhead indicating that the contractor is approved by the fabric tube and resin manufacturer to perform CIPP installation work.
- Manufacturer moisture limitations (e.g. installation in the dry, humidity restrictions, etc.).
- Material safety data sheets for all hazardous chemicals that will be used on the job site including resin, catalyst, cleaners, and repair agents. Identify the proposed use for each hazardous chemical and where it will be used in the work.
- Must provide and comply with specification for installation, and provide NCDOT Type 1 or Type 4 Certificates of compliance with material specifications as applicable to the below, or equivalent as approved by the Engineer:
 - ASTM D5813
 - ASTM F1216 for inverted CIPP
 - ASTM F1743 for pulled-in-place CIPP
 - ASTM F2019 for pulled-in-place GRP CIPP
 - ASTM F2599 for sectional inverted CIPP (applies to pipe sections, not full length)
- Long Term Modulus of Elasticity for calculations = 150,000 psi. NCDOT Type 2 or Type 5 certifications may be submitted by vendors or contractors for proof of alternate Long Term Modulus of Elasticity extrapolated from ASTM D2990, 10000-hour test. Design value of Long Term Modulus of Elasticity may be no greater than 50% of Initial Modulus of Elasticity. Tested value must be greater than or equal to value used in design equations.
- Initial Modulus of Elasticity for calculations = 300,000 psi. NCDOT Type 2 or Type 5 certifications may be submitted by vendors or contractors for proof of alternate Initial Modulus of Elasticity based on ASTM D790. Tested value must be greater than or equal to value used in design equations.
- Long Term Flexural Strength = 2250 psi. NCDOT Type 2 or Type 5 certifications may be submitted by vendors or contractors for proof of alternate Long Term Flexural Strength extrapolated from ASTM D2990, 10000-hour test. Tested value must be greater than or equal to value used in design equations.

When **Category B Fold and Form flexible liners** are specified, the liner system supplied by the Contractor shall conform to the following requirements as supported by contract submittals:

- Must list host pipe diameter ranges for which the product is applicable.
- Must indicate corrosion potential/acid reaction potential.
- Must list type of reforming method (steam, hot water, etc.).
- Certification on manufacturer's letterhead indicating that the contractor is approved by the manufacturer to perform installation work.
- Material safety data sheets for all hazardous chemicals that will be used on the job site. Identify the proposed use for each hazardous chemical and where it will be used in the work.

- Calculated minimum thickness of liner.
- Maximum allowable pulling force
- Site specific reforming & cooling time
- Minimum pressure to hold liner tight against the host pipe
- Maximum pressure to ensure liner does not sustain damage
- Maximum and minimum forming temperatures
- Ambient temperature range for installation.
- Sample of temperature and pressure log to be used for monitoring the curing process.
- Must provide and comply with specification for installation, and provide NCDOT Type 1 or Type 4 Certificates of compliance with material specifications as applicable to the below, or equivalent as approved by the Engineer:
 - ASTM D1784 defines PVC cell class referenced below
 - ASTM F1504 for PVC cell classification 12334 or 13223
 - ASTM F1533 for polyethylene
 - ASTM F714 for polyethylene min. cell classification 335420 and 2-4% carbon black
 - ASTM F1606 for deformed polyethylene
 - ASTM F1947 for folded PVC
- Methods & pipe classification not permitted for use due to low pipe strength:
 - ASTM F1867 for folded / formed PVC Type A
 - ASTM F1871 for PVC Type A cell classification 12111
- NCDOT Type 2 or Type 5 certifications must be submitted by vendors or contractors for proof of Long Term Modulus of Elasticity, 50-year sustained loading value, if the following values are not used in design calculations: 22,000 psi shall be used for HDPE, PE, PP; and 140,000 psi shall be used for PVC; per AASHTO LRFD Bridge Design Specifications 8th ed., Table 12.12.3.3-1.

When **Category C HDPE, PE, PVC, PP, solid wall slip liners** are specified, the liner system supplied by the Contractor shall conform to the following requirements as supported by contract submittals:

- Must list host pipe diameter ranges for which the product is applicable.
- Must indicate corrosion potential/acid reaction potential.
- Must be closed profile; i.e. no definable bell and spigot that protrudes from the outer wall of the pipe.
- Certification on manufacturer's letterhead indicating that the contractor is approved by the manufacturer to perform installation work.
- Material safety data sheets for all hazardous chemicals that will be used on the job site. Identify the proposed use for each hazardous chemical and where it will be used in the work.
- Calculated minimum thickness of liner.
- Maximum allowable pulling and/or pushing force
- Grouting mix design and manufacturer recommendations
- Installation procedures and recommendations.
- Must provide inside diameter and outside diameter of pipe.
- Must provide and comply with specification for installation, and provide NCDOT Type 1 or Type 4 Certificates of compliance with material specifications as applicable to the below, or equivalent as approved by the Engineer:
 - ASTM D1784 defines PVC cell class referenced below
 - ASTM D3350 defines PE cell class referenced below
 - ASTM F714 for solid wall polyethylene min cell classification 345464 and 2–4% carbon black

- AASHTO M326 for solid wall polyethylene
 - ASTM D3034 for solid wall PVC, min. cell classification 12454
 - ASTM F679 for solid wall PVC, large diameter, min. cell classification 12454
 - ASTM D2241 for solid wall PVC, min. cell classification 12454
 - ASTM F585 for polyethylene slip-line
 - ASTM F2620 for polyethylene heat fusion joining
- NCDOT Type 2 or Type 5 certifications must be submitted by vendors or contractors for proof of Long Term Modulus of Elasticity, 50-year sustained loading value, if the following values are not used in design calculations: 22,000 psi shall be used for HDPE, PE, PP; and 140,000 psi shall be used for PVC; per AASHTO LRFD Bridge Design Specifications 8th ed., Table 12.12.3.3-1.

When **Category D HDPE, PVC, PP corrugated, profile wall, steel reinforced, or spiral wound slip liners** are specified, the liner system supplied by the Contractor shall conform to the following requirements as supported by contract submittals:

- Must list host pipe diameter ranges for which the product is applicable.
 - Must indicate corrosion potential/acid reaction potential.
 - Certification on manufacturer's letterhead indicating that the contractor is approved by the manufacturer to perform installation work.
 - Material safety data sheets for all hazardous chemicals that will be used on the job site. Identify the proposed use for each hazardous chemical and where it will be used in the work.
 - Calculated minimum thickness of liner.
 - Maximum allowable pulling and/or pushing force
 - Grouting mix design and manufacturer recommendations
 - Installation procedures and recommendations.
- Must provide and comply with specification for installation, and provide NCDOT Type 1 or Type 4 Certificates of compliance with material specifications as applicable to the below, or equivalent as determined by the Engineer:
 - ASTM D1784 defines PVC cell class referenced below
 - AASHTO M294 for polyethylene profile wall (See NCDOT Standard Specifications 1032-7)
 - ASTM F894 for profile polyethylene
 - ASTM F2562 or F2435 for steel reinforced polyethylene min. cell classification 334452 and 2-4% carbon black
 - AASHTO M304 for profile PVC (see NCDOT Standard Specifications 1032-8)
 - ASTM F1803 for closed profile PVC
 - ASTM F949 and F794 for corrugated PVC min cell classification 12454
 - AASHTO M330 for corrugated polypropylene
 - AASHTO MP20-13 for steel reinforced polyethylene ribbed
 - ASTM F1735 PVC for profile strip / spiral wound, min. cell classification 12454
 - Steel Reinforced – Resin conforms to ASTM D3350, min. cell classification 335420 and 2-4% carbon black. Steel fully encapsulated.
 - ASTM F1697 PVC for profile strip / machine spiral wound, min. cell classification 12454
 - Steel Reinforced – Resin conforms to ASTM D3350, min. cell classification 335420 and 2-4% carbon black. Steel fully encapsulated.
 - ASTM F585 for polyethylene slip-line
 - ASTM F1698 for PVC spiral wound
 - ASTM F1741 for PVC machine spiral wound

- NCDOT Type 2 or Type 5 certifications must be submitted by vendors or contractors for proof of Long Term Modulus of Elasticity, 50-year sustained loading value, if the following values are not used in design calculations: 22,000 psi shall be used for HDPE, PE, PP; and 140,000 psi shall be used for PVC; per AASHTO LRFD Bridge Design Specifications 8th ed., Table 12.12.3.3-1.

Category E - Spray-on liners consist of conduit lining with spray applied, factory blended cementitious, geopolymer, or other material. The liner system supplied by the Contractor shall conform to the following requirements as supported by contract submittals:

- Must list host pipe diameter ranges for which the product is applicable.
- Must indicate corrosion potential/acid reaction potential.
- Must list liner material type.
- Must list typical, minimum, maximum application thicknesses.
- Must include documentation of specification or standard practice for installation.
- Minimum thickness of liner from design calculations.
- Manufacturer moisture limitations (e.g. installation in the dry, humidity restrictions, etc.).
- Certification on manufacturer's letterhead indicating that the contractor is approved by manufacturer to perform installation work.
- Material safety data sheets for all hazardous chemicals that will be used on the job site. Identify the proposed use for each hazardous chemical and where it will be used in the work.
- Site specific cure time
- Must provide volume (cubic yards or cubic feet) of liner material planned for use in each host pipe. For example, cubic yards of dry, unmixed cementitious liner material. This must match the value provided by design calculations.
- Ambient temperature range during installation.
- Other submittals as appropriate for the type of spray-on liner, as determined by the Engineer.
- Minimum thickness for cementitious or geopolymer liner material is 1 inch (clear of corrugations and / or bolt heads).
- For cementitious or geopolymer liners, submit to the Engineer NCDOT Type 2 or Type 5 certifications for the categories below, and a letter of certification from the manufacturer that states the material to be used conforms to manufacturer specifications. Actual properties must meet or exceed the values used in structural calculations when field tested.

Property	Test Method	Duration	Provide Value
Compressive Strength	AASHTO T106	3 Day	psi
		28 Days	psi
Flexural Strength	ASTM C 293	7 Days	psi
		28 Days	psi
Modulus of Elasticity	ASTM C 469	28 Days	psi
Tensile Strength	ASTM C 496	---	psi
Bond Strength	ASTM C 882	28 Days	psi

- For onsite or offsite Ready Mix or Project Produced cementitious or geopolymer liners (i.e. not “bag mixes” produced by a manufacturer), submit a mix design to the Engineer for approval.

- One of the following two submittal sets shall be required depending on whether the liner exhibits Rigid Pipe or Flexible Pipe behavior:
 - Liners which exhibit Rigid Pipe behavior, such as Cementitious or geopolymer liners, shall be treated as non-reinforced concrete pipe. Rigid Pipe behavior is characterized by cracking when subjected to 2% or greater deflection.
 - Provide NCDOT Type 2 or Type 5 certifications of allowable D-Load of proposed liner assuming fully deteriorated host pipe condition in accordance with ASTM C497 three edge bearing test for non-reinforced pipe.
 - The D-Load documentation submitted must be for test specimens that are less than or equal to the proposed liner thickness, equal to host pipe inside diameter and shape, and greater than or equal to host pipe ovality in the case of a deformed host pipe.
 - If manufacturer's ASTM C497 test is conducted on a smooth wall host form (such as a cardboard or plastic sonotube), and the proposed liner is to be installed in a host pipe with internal corrugations or bolt heads, only the liner thickness clear of the corrugations or bolt heads may be considered as structural.
 - Liners which exhibit Flexible Pipe behavior (can withstand greater than 2% deflection without structural damage) shall be treated as Thermoplastic Pipe. Cementitious and geopolymer liners are not eligible for this method:
 - Long Term Modulus of Elasticity, 50-year sustained loading value shall be used. Vendor or contractor must provide value used in calculations. It shall be estimated by using 50% of the Initial Modulus of Elasticity value provided by ASTM D790. Provide NCDOT Type 2 or Type 5 certifications for value used in calculations.
 - Tensile Strength 50-year sustained loading value (Fu) shall be used. Vendor or contractor must provide value used in calculations. It shall be estimated by using 50% of the Initial Tensile Strength value provided by ASTM D638. Provide NCDOT Type 2 or Type 5 certifications for value used in calculations.

Category F - Smooth-wall steel pipe liner rehabilitation materials shall conform to 1032-5 of the Standard Specifications, except as altered herein.

Grade B pipe shall be used with minimum wall thicknesses as listed in the *NCDOT Manual for Pipe Rehabilitation*.

The Contractor shall submit the following items to the Engineer:

- Material safety data sheets for all hazardous chemicals that will be used on the job site. Identify the proposed use for each hazardous chemical and where it will be used in the work.
- Grouting mix design and manufacturer recommendations.

III. CONSTRUCTION

Pre-Installation Inspection – The Contractor shall perform a pre-installation video inspection of pipe using NASSCO certified personnel. The camera shall be situated at the centerline of the pipe, and shall be mounted on a rubber tired or tracked pipe rover that allows for a 360-degree inspection. Inspection equipment shall be capable of measuring protrusions and obstructions of ½ inch or greater. Provide a pipe profile, on which deflections that may affect the installation of the liner are located and noted. The inspection shall be performed in the presence of the Engineer, unless waived by the Engineer. Dewater the host pipe to the satisfaction of the Engineer, and in accordance with NCDOT Best Management Practices for Construction and Maintenance Activities. A thorough culvert inspection is required to determine the number of existing “pipe to pipe” connections and the extent, if any, of obstruction removal and voids. The inspection shall be performed by experienced personnel trained in locating breaks, obstacles, voids and service connections. Video inspections shall be clearly labeled on the media with the time, date, and location of the pipe inspected. A copy of the video inspection shall be furnished to the Engineer at least 10 days prior to the start of rehabilitative construction. In the event the Contractor’s inspection shows the method of rehabilitation the Contractor has selected is no longer viable at that location as verified by the Engineer, the Contractor shall select another allowable method, if specified, from those designated in the Contract.

Pipe Clean-out - The Contractor shall clear the existing pipe(s) designated for rehabilitation of any debris, sediment, protrusions greater than ½ inch in height, and any other potential obstructions prior to the start of rehabilitation efforts. The Contractor shall then thoroughly clean and prepare the host pipe prior to the liner installation. Cleaning shall conform to the recommendations of the liner manufacturer, and any additional requirements of this special provision. In the absence of manufacturer recommendations, the Contractor shall submit his/her proposed method for cleaning and preparing the host pipe for the Engineer’s review and acceptance at least 10 working days prior to beginning the work at that location.

Grouting Host Pipe - The Contractor shall perform grouting work described in the contract, prior to pipe liner installation to correct existing deficiencies, such as voids.

Inlet & Outlet Sealing – All pipe liner installations shall be sealed to the host pipe at the terminal ends of the liner to prevent flow between the liner and host pipe.

De-Watering – All pipe liners and grout shall be installed in dry conditions. The Contractor shall de-water by diverting, pumping, or bypassing any water flow through an existing pipe or drainage system prior to and during the lining process. The method of de-watering is to be determined by the contractor but must be approved by the Engineer prior to implementing.

Disposal Plan – The Contractor shall submit a Disposal Plan to the Engineer a minimum of 10 days prior to installation. The Disposal Plan shall indicate how by-products and waste are to be contained, captured, transported offsite, and disposed of in accordance with project permits and local, state and federal regulations. It shall be the Contractor’s responsibility to report and take appropriate corrective actions to remediate any water quality alteration resulting from lining operations in accordance with project permits and applicable local, state or federal regulations. The cost for such remediation shall be at the Contractor’s expense.

Category A – Cured-In-Place Pipe liner method. The Cured-In-Place Pipe liner system shall be fabricated and installed in such a manner as to result in a maintained full contact tight fit to the internal

circumference of the host pipe for its entire length. The installation shall adhere to the cure times and temperatures stipulated in the manufacturer's recommended installation and cure specifications and the finished product shall be free of de-lamination, bubbling, rippling or other signs of installation failure.

Install per specification or standard practice for installation (ASTM F1216 inverted CIPP, or F1743 pulled-in-place CIPP, or F2019 pulled-in-place GRP CIPP, or F2599 sectional inverted CIPP for example).

Pulled-in-place liner installation must be accomplished without significant liner twisting, or stretching the liner greater than 1% of its original length during installation. At no time shall the pulling force, as measured by a contractor-provided dynamometer or load cell, exceed that established by the liner manufacturer. For liner lengths greater than 100 feet, protect the pipe liner end using a device that uniformly distributes the applied load around the perimeter of the liner.

Curing for styrene-based, epoxy-based, and vinyl ester-based CIPP may be accomplished by water, steam or ultraviolet light and shall be in accordance with the liner manufacturer's recommendations.

Installation and curing requirements of pipe sections shall be in accordance with the manufacturer's recommendations for the specific product, as applicable. The Contractor shall furnish installation and curing requirements for the various flexible liners including individual components of the system, tube type (reinforced or non-reinforced), manufacturer name and type of resin including catalyst, volume of resin required to achieve proper impregnation and curing. All components of the systems shall be as recommended by the manufacturer for the specific system used, and all components shall include lot numbers and expiration dates.

The Contractor shall place an impermeable barrier immediately upstream and downstream of the host pipe, prior to liner insertion, to capture any possible raw resin spillage during installation and shall dispose of any materials in accordance with the submitted disposal plan.

Where the pulled-in-place method of installation is used, the Contractor shall install a semi-rigid plastic slip sheet over any interior portions of the host pipe that could tear the outer film or over any significant voids in the host pipe.

Reconnect the existing storm drain lateral connections immediately after the liner has been cured in place. Use robotic cutting devices to re-establish tie-ins in non-man accessible pipes.

The Contractor shall monitor temperature via a minimum of three thermocouples on the outer surface (interface between the host pipe and liner) of the liner (one each at the upstream and downstream ends and one approximately mid-length of the host pipe). The Contractor shall monitor pressure during inversion and curing, and maintain pressure between minimum and maximum allowable pressures as provided by the manufacturer. The Contractor shall automatically log cure time-temperature and time-pressure data at 30 second intervals with a data logger and provide such information in a format acceptable to the Engineer.

Submit the tape and log of recorded temperatures and pressure to the Engineer within 48 hours after completing the resin-curing process.

The Contractor shall thoroughly rinse the cured lined pipe with clean water prior to re-introducing flow. The Contractor shall capture all cure water and/or steam condensate and rinse water and dispose of, in accordance with the submitted disposal plan.

Within 21 days of completing the resin curing at a given culvert location, submit the test results from a ISO 17025 lab suitable to the Engineer. The report must be signed by a representative of the independent testing lab. The report must include:

- Flexural strength and flexural modulus test results for field samples.
- Thickness measurements for the liner using prepared core samples.
- Description of the defects in the tested samples in terms of the effect on CIPP performance.

Make cured samples from the identical materials (tube, resin and catalyst) to be used for the CIPP. Identify each sample by date, contract number, drainage system number of the corresponding culvert, thickness, name of resin, and name of catalyst.

The samples must be 6 by 16 inches in size: Comply with the following sampling procedures unless UV cured:

- Place 3 aluminum-plate clamped molds, each containing a flat plate sample, inside the downtube when heated circulated water is used, and in the silencer when steam is used during the resin curing period
- Seal each flat plate sample in a heavy-duty plastic envelope inside the mold
- Remove the 3 cured flat plate samples after draining all of the moisture from the cured CIPP

If UV cured, comply with field sampling procedures under ASTM F2019, Section 7: Recommended Inspection Practices.

Test the samples for flexural properties under ASTM D790, ASTM D5813, ASTM F1216, ASTM F1743, or ASTM F2019. Verify that physical properties of the field samples comply with the minimum values under:

- ASTM F1216, Table 1 (modified values), for heat cured polyester, vinyl ester, and epoxy resins. The flexural strength must be at least 5,000 psi. The flexural modulus must be at least 300,000 psi.
- ASTM F2019, Table 1, for UV cured CIPP. The flexural strength must be at least 6,500 psi. The flexural modulus must be at least 725,000 psi. Comply with sampling and testing procedures under ASTM F2019, Section 7: Recommended Inspection Practices.

Take core samples in the presence of the Engineer. Comply with the following core sample requirements:

- Take 2 samples. Take the samples at least 1 foot from each end of the culvert at a location near the top of the culvert. Samples must be at least 2 inches in diameter.
- If culvert material is corrugated metal, obtain samples at the corrugation crests.

Prepare the core samples by separating the CIPP material from the culvert material. If heat cured, remove the film from the inner lining or preliner. If UV cured, remove the film from the inner and outer foil. Measure the thickness of the liner at 3 spots on each sample. If the culvert material is corrugated metal, measure the thickness at 3 spots that are along a line corresponding to the corrugation crests. Calculate the thickness as an average of at least 6 measurements.

If UV cured, comply with sampling and testing procedures under ASTM F2019, Section 7: Recommended Inspection Practices. If the culvert material is corrugated metal, measure the thickness at 3 spots that are along a line corresponding to the corrugation crests. Calculate the thickness as an average of at least 6 measurements.

All voids from core samples are to be filled with Type 1 epoxy resin as specified in NCDOT Standard Specifications for Roads and Structures, Section 1081.

CIPP may be rejected if any of:

- Actual temperature and curing time and schedule do not comply with those shown in the authorized work plan
- Pressure deviates more than 1 psi from the required pressure
- At any time during installation the manufacturer's required minimum cool-down time or maximum cool-down rate is violated
- There are defects including:
 - Concentrated ridges, including folds and wrinkles exceeding 8 percent of the CIPP diameter
 - Dry spots
 - Lifts
 - Holes
 - Tears
 - Soft spots
 - Blisters or bubbles
 - Delaminations
 - Gaps in the length of the CIPP
 - Gaps or a loose fit between the exterior of the CIPP and the culvert
- Test results indicate one of the following:
 - If heat cured, 2 of the 3 flat plate samples do not have any of the following:
 - the specified modulus of elasticity
 - the specified flexural strength
 - either the specified modulus of elasticity or the specified flexural strength
 - If UV cured, 2 of the 3 cured samples do not have any of the following:
 - the specified modulus of elasticity
 - the specified flexural strength
 - either the specified modulus of elasticity or the specified flexural strength
- The liner thickness is less than the greater of either one of the following:
 - Specified thickness
 - Calculated minimum thickness shown in your authorized work plan
- Materials and installation methods are not those shown in your authorized installation plan
- Defects are excessive or unrepairable
- CIPP is not continuous or does not fit tightly for the full length of the culvert

If UV cured, and post installation inspections reveal signs of incomplete curing (dripping resin, etc), contractor will trim liner obscuring uncured liner, re-wet, and re-cure with UV.

Category B - Fold and form flexible liners shall be installed per specification or standard practice for installation (ASTM F1606 deformed polyethylene, ASTM F1867 folded/formed PVC Type A, or ASTM F1947 folded PVC, for example).

The liner system shall be fabricated and installed in such a manner as to result in a maintained full contact tight fit to the internal circumference of the host pipe for its entire length. The installation shall adhere to the reforming pressures and temperatures stipulated in the manufacturer's recommended installation specifications and the finished product shall be free of bubbling, rippling or other signs of installation failure.

Installation and reforming requirements of pipe sections shall be in accordance with the manufacturer recommendations for the specific product as applicable. All components of the systems shall be as recommended by the manufacturer for the specific system used, and all components shall include lot numbers. The Contractor shall submit documentation from the manufacturer to verify compliance with the requirements of this paragraph as well as installation recommendations to the Engineer.

Reconnect the existing storm drain lateral connections immediately after the liner has been installed in place. Use robotic cutting devices to re-establish tie-ins in non-man accessible pipes.

The Contractor shall monitor temperature via a minimum of three thermocouples on the outer surface (interface between host pipe and liner) of the liner (one each at the upstream and downstream ends and one approximately mid-length of the host pipe). The Contractor shall automatically log cure time-temperature and time-pressure data at 30 second intervals with a data logger and provide such information in a format acceptable to the Engineer.

Submit the tape and log of recorded temperatures to the Engineer within 48 hours after completing the lining process. Submit the recorded pressure to the Engineer within 48 hours after completing the lining process.

Liner may be rejected if any of:

- Actual temperature and curing time and schedule do not comply with those shown in the authorized work plan
- Pressure deviates more than 1 psi from the required pressure
- There are defects including:
 - Concentrated ridges, including folds and wrinkles exceeding 8 percent of the liner diameter
 - Lifts
 - Holes
 - Tears
 - Soft spots
 - Blisters or bubbles
 - Gaps in the length of the liner
 - Gaps or a loose fit between the exterior of the liner and the culvert
- The liner thickness is less than the greater of either one of the following:
 - Specified thickness
 - Calculated minimum thickness shown in your authorized work plan
- Materials and installation methods are not those shown in installation plan
- Defects are excessive or unreparable
- Liner is not continuous or does not fit tightly for the full length of the culvert

Category C – HDPE, PE, PVC, or PP solid wall slip liner shall be installed per specification or standard practice for installation (ASTM F585 polyethylene slip-line, ASTM F2620 polyethylene heat fusion joining, for example).

Installation requirements of pipe sections shall be according the manufacturer recommendations for the specific product as applicable. All components of the systems shall be as recommended by the manufacturer for the specific system used, and all components shall include lot numbers.

Before lining, pull or push a mandrel through the existing pipe or perform laser survey to verify liner clearance. The liner must be positioned and secured to facilitate its complete encapsulation by grout. Follow the Manufacturer's recommendations for handling and assembling the pipe, and all provisions included in the design calculations. Reconnect the existing storm drain lateral connections immediately after the liner has been installed in place. Use robotic cutting devices to re-establish tie-ins in non-man accessible pipes. Prior to filling the annular space, connect and seal all laterals between the new liner pipe and the existing lateral.

Grout the entire annular space with non-shrink grout or an expansive admixture approved by the Manufacturer for use with the liner system. In the absence of Manufacturer recommendations for grout,

refer to Section 1003 of Standard Specifications. Provide a minimum annular space of 1 inch for grouting between the new and existing pipes. Provide details on how to hold the liner pipe to line and grade until the grout has set. Ensure the maximum pressure developed by the grout does not exceed the manufacturer's recommendation for the maximum allowable external pressure for the liner pipe. If the volume of the grout used is less than the anticipated (calculated) volume, or an inspection of the relined culvert indicates that there are voids in the annular space, the Contractor must provide the Engineer with a plan to rehabilitate all identified voids. Depending on the location and size of the voids, additional grouting may be required in these areas. This may be accomplished by re-grouting in those areas from within the culvert. The voids must be filled to the satisfaction of the Engineer at no additional cost. Grouting is included with the cost of pipe liner installation.

Lining with HDPE or PP: Field cuts will be permitted only at the terminal ends. No pipe sections less than 3 feet long will be allowed in any lining projects. Perform all butt fusion, welding and extrusion welding of pipe in accordance with the Manufacturer's recommendation. Based on existence of alignment breaks or pinch points in the host pipe, all joints shall be butt fusion welded, or extrusion welded unless alternate joining methods are approved by the Engineer, in which case limit joint separations to less than ½ inch between adjoining sections.

Lining with Polyvinyl Chloride Pipe: Reline with a PVC Pipe with integral bell and spigot joints. Field cuts will be permitted only at the terminal ends. No pipe sections less than 3 feet long will be allowed in any lining projects. The submittals must address the following PVC specific issues: Will the PVC liner will be pulled or pushed through the culvert, along with the type of pushing or pulling ring/plate to be used? Will a nose cone or different device be used in the process? How will the jacking, pulling or pushing loads on the liner be monitored in order to conform to Manufacturer's specifications and guidelines?

Category D - HDPE, PVC, or PP corrugated, profile, or spiral wound slip liner shall be installed per specification or standard practice for installation (ASTM F585 polyethylene slip-line, ASTM F1698 PVC spiral wound, ASTM F1741 PVC machine spiral wound, for example).

Installation requirements of pipe sections shall be according the manufacturer recommendations for the specific product as applicable. All components of the systems shall be as recommended by the manufacturer for the specific system used, and all components shall include lot numbers.

Before lining, pull or push a mandrel through the existing pipe to verify liner clearance. The liner must be positioned and secured to facilitate its complete encapsulation by grout. Follow the Manufacturer's recommendations for handling and assembling the pipe, and all provisions included in the design calculations. Immediately reconnect the existing storm drain lateral connections after the liner has been installed in place. Use robotic cutting devices to re-establish tie-ins in non-man accessible pipes. Prior to filling the annular space, connect and seal all laterals between the new liner pipe and the existing lateral.

Grout the entire annular space with non-shrink grout approved by the Manufacturer for use with the liner system. In the absence of Manufacturer recommendations for grout, refer to Section 1003 of Standard Specifications. Provide a minimum annular space of 1 inch around the circumference for grouting between the new and existing pipes. (Spiral Wound liner that is designed to fit tightly to the interior wall of the host pipe is not subject to the 1 inch annular space and grouting.) Provide details on how to hold the liner pipe to line and grade until the grout has set. Ensure the maximum pressure developed by the grout does not exceed the manufacturer's recommendation for the maximum allowable external pressure for the liner pipe. If the volume of the grout used is less than the anticipated (calculated) volume, or an inspection of the relined culvert indicates that there are voids in the annular space, the Contractor must

provide the Engineer with a plan to rehabilitate all identified voids. Depending on the location and size of the voids, additional grouting may be required in these areas. This may be accomplished by re-grouting in those areas from within the culvert. The voids must be filled to the satisfaction of the Engineer at no additional cost. Grouting is included with the cost of pipe liner installation.

Lining with HDPE or PP (does not apply to spiral-wound): Field cuts will be permitted only at the terminal ends. No pipe sections less than 3 feet long will be allowed in any lining projects. Perform all butt fusion, welding and extrusion welding of pipe in accordance with the Manufacturer's recommendation. Based on existence of alignment breaks or pinch points in the host pipe, all joints shall be butt fusion welded, or extrusion welded unless alternate joining methods are approved by the Engineer, in which case limit joint separations to less than ½ inch between adjoining sections.

Lining with Polyvinyl Chloride Pipe (does not apply to spiral-wound): Reline with a PVC Pipe with integral bell and spigot joints. Field cuts will be permitted only at the terminal ends. No pipe sections less than 3 feet long will be allowed in any lining projects. The submittals for this item provided for Department approval shall also address the following PVC specific issues prior to any work approval is granted: Will the PVC liner will be pulled or pushed through the culvert, along with the type of pushing or pulling ring/plate to be used? Will a nose cone or different device be used in the process? How will the jacking, pulling or pushing loads on the liner be monitored in order to conform to Manufacturer's specifications and guidelines?

Category E - Spray-On cementitious, geopolymer, or other materials shall be installed in accordance with the liner material manufacturer's recommendations. For spray-on cementitious, geopolymer, or other liner systems, the following requirements shall apply:

Control the temperature and humidity in the host pipe according to the manufacturer's recommendation, including stopping air drafts through the pipe. Measure and record the temperature and humidity. The Contractor shall automatically log cure time-humidity and time-temperature data at 30 minute intervals with a data logger and provide such information in a format acceptable to the Engineer.

Patch and fill voids, holes, and gaps in the host pipe with an approved hydraulic cement or the same cementitious or geopolymer based material to be used for the liner to provide a solid continuous surface on which to spray. Stop water infiltration into the host pipe by applying dry hydraulic cement, or other methods approved by the Engineer. Prepare lateral connections to the host pipe according to the manufacturer's recommendations. Record the batch or lot number from the containers used each day.

To achieve bonding to the host pipe: Before placing liner, remove all coatings, corrosion, and other surface material until only base steel (or other host pipe material) is exposed by sandblasting the portion of the culvert to be coated. Where human access is limited, you must substitute sandblasting with mechanical scraping tools, water-jetting and a swab. Ensure cleaning methods will not affect chemical properties of liner, or adhesion of liner.

Application of liner material must be uninterrupted and continuous. Use a machine approved by the manufacturer, and capable of projecting liner material against the culvert wall without rebound and at a velocity sufficient to cause liner material to pack densely and adhere in place. Obtain authorization from the Engineer for placing liner material by hand to fill gaps left by dewatering pipe during the time period after application before fully cured, while material may be added.

The machine operator must continuously monitor the application of cementitious material.

The travel of the projecting machine and the discharge rate of liner material must be entirely mechanically controlled and must produce a uniform thickness of liner material without segregation around the perimeter and along the culvert length. The pipeliner must be free of sand pockets or visible lack of homogeneity.

Contractor must submit an installation plan to the Engineer which details the number of passes, sled travel speed, and installation parameters relevant to the work.

Remove splatter and the accumulation of other undesirable substances along the culvert invert.

Obtain authorization from the Engineer for placing liner material by hand methods at sharp bends and special locations where machine placement is impracticable.

Provide a smooth finished surface texture.

After placement, the lining must be the greater of 1 inch thick (cementitious or geopolymer), or calculated thickness. For corrugated pipe, the thickness must be measured over the top of the corrugation crests. For host pipe with protruding bolt heads, the thickness must be measured over the top of the bolt heads. The tolerance for the pipe liner's thickness is plus 0.12 inch with no minus tolerance.

Depth gauges shall be installed in the soffit (12 o'clock position) of the host pipe every 10 feet along the length to allow determination of liner thickness. Depth gauges shall protrude from the host pipe wall a distance equivalent to the final surface of the liner, and shall remain in place permanently. Depth gauges shall be metal screws or rods with the shaft not greater than 3/16" diameter.

During the time period after application before fully cured, while material may be added, verify the applied thickness at least once every 10 feet to the satisfaction of the Engineer. Apply additional material to any areas found to be less than the design thickness.

Ensure the liner is continuous over the entire length of the host pipe and free from defects such as foreign inclusions, holes and cracks no larger than 0.01 inches wide. Ensure the renewed conduit is impervious to infiltration and exfiltration.

Protect walls, surfaces, streambed and plants at the entrance and exit of the host pipe from overspray. The Contractor shall install a temporary curtain at the outlet and inlet to prevent overspray during installation.

The Contractor shall thoroughly rinse the cured pipe with clean water and dispose of it in accordance with the disposal plan.

The Contractor shall reinstate water flow no sooner than recommended by manufacturer or 24 hours following installation, whichever is greater.

For cementitious or geopolymer spray-on liners, the Contractor shall prevent the escape of any rinse water from the lined pipe or otherwise capture it until he/she can either (1) dispose of it in accordance with the submitted disposal plan; or (2) continuously monitor the pH of the rinse water until the pH is less than 9 whereupon it may be released.

For other liner types, the Contractor shall capture and dispose of the rinse water in accordance with the submitted disposal plan, prior to reinstating flow.

Quality Control for Geopolymer or Cementitious Liner:

The Contractor shall submit NCDOT Type 1 or Type 4 certifications for each lined pipe in accordance with required cementitious liner properties table in the Materials section. Engineer, at his option, may collect concrete mix samples for testing. If the material does not achieve the specified properties listed in the Materials section, the pipe liner may be rejected. Submit a new work plan for the placement of material before replacing the rejected pipeliner.

The Contractor shall take core samples of the liner under direction and in the presence of the Engineer. Core sample diameter shall be at least twice the liner thickness. Repair cored area with liner material. The Department transports core samples to a Materials and Tests Regional Laboratory for testing.

- If there are visible defects in the pipeliner, submit a work plan for repairing the defects. Measure the length of the defect along the centerline of the culvert.
- If the length of the defect is 60 inches long or less, patch defects using the same cementitious material used in the work. Hand methods may be used.
- If the length of the defect is greater than 60 inches long, replace the defective length of the pipeliner for the full diameter of the pipeliner. Replace the defective length using machine methods.

Quality Control for other liner material will be determined per manufacturer recommendations and the Engineer.

Category F – Smooth wall steel pipe liner rehabilitation methods shall conform to Section 330 of the Standard Specifications, except as altered herein. The work shall be rehabilitation by the insertion of a smooth wall steel pipe into a host pipe. Where field welding is required, pipe shall be joined by butt welds in accordance with AWWA C-206. Field welded butt joints shall be complete joint penetration (CJP) and the adjoining members shall be assembled so that the seams in the adjacent pipe sections are offset from each other by at least five (5) times the thickness of the thinner member.

Welding procedures employed for welding shall be qualified by testing or prequalified in accordance with AWS D1.1

Personnel performing field welding operations shall have been tested and qualified by the Department.

The contractor shall provide a Certified Welding Inspector (CWI) on site during all welding and inspection operations to perform the necessary quality control examinations. Non-destructive testing/examination for testing to include visual outlined in the AWWA C-206 shall be provided at the contractor's expense.

Personnel performing these functions shall be qualified in accordance with AWS QC1 and/or the recommendations of the current edition of ASNT SNT-TC-1A. Radiographic and Hydrostatic testing is not required.

Before lining, pull or push a mandrel through the existing pipe to verify liner clearance. The liner must be positioned and secured to facilitate its complete encapsulation by grout. Follow the Manufacturer's recommendations for handling and assembling the pipe, and all provisions included in the design calculations. Reconnect the existing storm drain lateral connections after the liner has been installed in place. Use robotic cutting devices to re-establish tie-ins in non-man accessible pipes. Prior to filling the annular space, connect and seal all laterals between the new liner pipe and the existing lateral.

Grout the entire annular space with non-shrink grout approved by the Manufacturer for use with the liner system. In the absence of Manufacturer recommendations for grout, refer to Section 1003 of Standard Specifications. Provide a minimum annular space of 1 inch for grouting between the new and existing pipes. Provide details on how to hold the liner pipe to line and grade until the grout has set. Ensure the maximum pressure developed by the grout does not exceed the manufacturer's recommendation for the maximum allowable external pressure for the liner pipe. If the volume of the grout used is less than the anticipated (calculated) volume, or an inspection of the relined culvert indicates that there are voids in the annular space, the Contractor must provide the Engineer with a plan to rehabilitate all identified voids. Depending on the location and size of the voids, additional grouting may be required in these areas. This may be accomplished by re-grouting in those areas from within the culvert. The voids must be filled to the satisfaction of the Engineer at no additional cost. Grouting is included with the cost of pipe liner installation.

Post Installation Inspection – In addition to the inspection performed by the Department, the Contractor shall perform two post-installation video inspections using NASSCO certified personnel. The first inspection shall take place between 90 and 100 calendar days after completion of installation for each culvert or system to a single outfall. The second inspection shall take place 30 calendar days prior to the end of the liner warranty period (5 years, secured by construction bond). The camera shall be situated at the centerline of the pipe, and shall be mounted on a rubber tired or tracked pipe rover that allows for a 360-degree inspection. Inspection equipment shall be capable of measuring protrusions and obstructions of ½ inch or greater. The inspection shall be performed in the presence of the Engineer. Dewater the host pipe to the satisfaction of the Engineer. Video inspections shall be clearly labeled on the media with the time, date, and location of the pipe inspected. A copy of the video inspection shall be furnished to the Engineer prior to acceptance of the work.

The finished liner may be rejected if not continuous over its entire length and free from visual defects such as foreign inclusions, joint separation, cracks, insufficient liner thickness, material loss, roughness, deformation, dry spots, pinholes, insufficient bonding to host pipe, delamination, or other material or installation deficiencies as described herein.

Remedies for rejection of liner - In the event the first post inspection of the installation reveals defects in localized areas of the liner pipe (comprising less than 20 percent of the pipe length) the localized defects shall be repaired as specified by the manufacturer. Where defects occur on 20 percent or more of the pipe length the defects shall be repaired, however, the Contractor will not be allowed to continue with his methodology of installation and/or the liner system used until he/she can demonstrate to the Engineer that he/she has remedied his/her operations to a sufficient level of quality as determined by the engineer. All such remedial efforts shall be at the Contractor's expense. Further failure(s) to perform a proper installation may result in the disallowance of the use of that liner system and an adjustment in the cost or non-payment of the failed installations depending on the severity of the failure.

In the event the first post installation inspection is not conducted until all or most of the locations in the Contract permitting this methodology have been performed, and the inspection reveals defects on 20

percent or more of the host pipe's length, then an adjustment in the cost or non-payment of the failed installations may be made by the Engineer depending on the severity of the failure.

In the event the second post inspection of the installation reveals defects, the Department may execute the option to call the construction bond to reimburse the Department for repairs or corrections, or to act as an adjustment in the cost, or both.

IV. MEASUREMENT AND PAYMENT

Pre Installation Inspection will be measured and paid for as the actual number of linear feet of pipe inspected, including mobilization of equipment, and production of records. Linear footage is not increased for multiple passes of inspection equipment through a length of pipe.

Pipe Rehabilitation will be measured and paid for as the actual number of linear feet of pipe for the Size, and Method that has been incorporated into the completed and accepted work. Note: At locations shown in the Contract where multiple methods are permitted, the Contractor may select any of the methods specified, however, if only one method is specified, this will be the only method permitted at that location. This price shall include post installation inspection, cleaning and preparation of the host pipe, furnishing and installing the liner, lateral reconnection, coupling and expansion devices, annular cement grout, design (if necessary) and shop drawing preparation, furnishing and installing liner and all components of the liner system, capturing any discharges or releases during installation or curing operations, furnishing any documentation or fees required for effluent or condensate disposal, all testing and sampling including furnishing reports and pre and post installation video inspections, waste disposal costs, excavation, sheeting, shoring, disposing of surplus and unsuitable material; backfilling and backfill material; compaction, restoring existing surfaces, and clearing debris and obstructions.

De-Watering will be measured and paid as the actual number of water diversions or bypasses required to complete Pipe Rehabilitation work. Each instance of De-Watering paid includes De-Watering for pre-inspection, installation, post inspections, and remediation (if necessary). All materials, equipment, labor, or other resources required to de-watering a site shall be incidental to the unit cost for De-watering.

Payment will be made under:

Pay Item	Pay Unit
Pre Installation Inspection	Linear Foot
(Size) Pipe Rehabilitation CIPP Liner	Linear Foot
(Size) Pipe Rehabilitation Fold & Form Liner	Linear Foot
(Size) Pipe Rehabilitation Solid Wall Thermoplastic Slip Liner	Linear Foot
(Size) Pipe Rehabilitation Corrugated Thermoplastic Slip Liner	Linear Foot
(Size) Pipe Rehabilitation Spiral Wound Liner	Linear Foot
(Size) Pipe Rehabilitation Cementitious / Geopolymer Spray Liner	Linear Foot

(Size) Pipe Rehabilitation Spray Liner – Other

Linear Foot

(Size) Pipe Rehabilitation Smooth Wall Steel Slip Liner

Linear Foot

De-Watering

Each