Environmental Effects of Cured-in-Place Pipe Repairs

Requested by
Sean Penders, Design
David Melendrez, North Region Environmental Engineering

June 26, 2012

The Caltrans Division of Research and Innovation (DRI) receives and evaluates numerous research problem statements for funding every year. DRI conducts Preliminary Investigations on these problem statements to better scope and prioritize the proposed research in light of existing credible work on the topics nationally and internationally. Online and print sources for Preliminary Investigations include the National Cooperative Highway Research Program (NCHRP) and other Transportation Research Board (TRB) programs, the American Association of State Highway and Transportation Officials (AASHTO), the research and practices of other transportation agencies, and related academic and industry research. The views and conclusions in cited works, while generally peer reviewed or published by authoritative sources, may not be accepted without qualification by all experts in the field.

Executive Summary

Background

To rehabilitate culverts without disrupting highway corridors and causing long delays and significant added costs, Caltrans will need to use cured-in-place pipe (CIPP) repairs, a method of completely relining culverts using a thermosetting, resin-impregnated flexible tube that is inflated and cured with hot water or steam.

The North Coast Regional Water Quality Board (NCRWQB) is currently not permitting use of CIPP because of concerns that it negatively affects water quality. These concerns are based predominantly on a study by the Virginia Department of Transportation (DOT), which showed that CIPP sometimes caused residual styrene concentrations in the stormwater that were above the U.S. Environmental Protection Agency's maximum contaminant level for drinking water, and led to a moratorium on the use of CIPP in Virginia. However, subsequent Virginia DOT studies showed that the release of styrene was caused by poor CIPP installation practices, and implementing new specifications could eliminate these problems. With the new specifications in place, Virginia DOT has resumed its use of CIPP, and Caltrans has revised its CIPP specifications to take into account lessons learned by Virginia DOT. The NCRWQB uses Virginia DOT's earlier study to justify its restrictions on CIPP, not taking into account further developments in Virginia, and has made styrene effluent limits so low that using CIPP is impossible even with new installation practices. The NCRWQB is also requiring Caltrans to conduct a pilot study that would be cumbersome and impractical to perform.

Caltrans is interested in adopting a more scientific approach to the regulatory standards that will allow for continued use of CIPP. This Preliminary Investigation presents the results of a review of completed research and a survey of state practices addressing the use of CIPP in an environmentally safe manner. To gather information for this investigation, we:

- Conducted a literature search about the effects of CIPP on the environment, and responsible methods and practices for using CIPP with a focus on finding related studies by or on behalf of other state transportation agencies.

- Contacted Insituform Technologies, a CIPP manufacturer, regarding the environmental impacts of using CIPP.
- Performed a brief survey of members of the AASHTO Standing Committee on the Environment regarding DOT use of CIPP, asking whether they have faced water quality problems and how they have addressed them. After the survey, we conducted follow-up phone interviews with four of the participating DOTs: New York, Oregon, Virginia and Washington.

Summary of Findings

Our literature review found no additional published research about the environmental effects of CIPP installations beyond the reports referred to in Caltrans' request. We distributed the following survey to members of the AASHTO Standing Committee on the Environment:

1. Does your agency use cured-in-place pipe (CIPP) repairs as a method for rehabilitating culverts?

If yes to #1:

2. Please provide copies of or links to specifications and guidance related to your agency's use of CIPP.
3. Have you encountered any problems with your use of CIPP related to its effects on water quality? Has a water quality regulatory agency challenged the use of CIPP by your agency?
4. If yes to #3, how did you respond to these problems and concerns? Did you modify CIPP specifications, or have you conducted studies related to CIPP effects on water quality? (If so, please provide relevant reports.)
5. Who at your agency may we contact for further information about this issue (email and phone)?

Staff at 14 state DOTs and the Canadian province of Alberta responded to this survey. (See **Survey and Interview Results** beginning on page 7 of this report for the full text of these survey responses.) We also conducted follow-up interviews with four states (New York, Oregon, Virginia and Washington). Arkansas State Highway and Transportation Department did not respond to email or phone inquiries.

The survey and follow-up interviews confirm the lack of research into the environmental effects of CIPP installations, although two states—New York and Oregon—noted that they had done some water quality testing of CIPP installations. Further, Virginia DOT completed some recent testing of a CIPP repair (using new specifications) that showed the installation to have no water quality issues.

While 11 of 15 respondents said they use CIPP, only four states reported water quality issues:

- **New York:** Shortly after Virginia DOT's original study, a New York State DOT regional office expressed concerns about styrene from CIPP installations and conducted testing that found levels far in excess of allowable limits. As a consequence, New York State DOT revised its specifications and is currently confident that installations can be done without negative environmental impacts.
- **Oregon:** Oregon DOT took water quality samples from a "bungled" CIPP installation and found 174 parts per million of styrene. The contractor in this case used steam instead of hot water for curing and failed to divert incoming water. There was styrene discharge into the Willamette River, and styrene levels were so high that the responder had to wear a respirator to collect samples. Oregon DOT hopes that this scenario is a rare exception, and specifications call for all wastewater to be contained.
- **Virginia:** Virginia DOT recently conducted water quality testing on a CIPP repair that complied with its new specifications, and found the installation to be very clean. Samples were collected at the outlet a few days following installation and about 10 meters downstream, with results showing styrene levels of 0.294 mg/L at the outlet and 1.34 mg/L downstream. These levels are below the toxicity thresholds for rainbow trout (a common indicator species). In August 2012 the

agency will release reports on water quality testing results for both ultraviolet (UV)-based CIPP repairs and polyuria and cementitious spray-on liners.
- **Washington:** Washington State DOT has used CIPP repairs only on two design-build projects, but does not have specifications for CIPP repairs. Both projects had water quality issues, leading to a violation and $9,000 fine. As a consequence, the agency recommends that culverts be replaced rather than relined in most cases; when relining is used, water should be diverted around the pipe being relined.

Seven of the 11 respondents using CIPP provided specifications; Maryland and Washington noted that they do not have CIPP specifications.

Gaps in Findings

- There is no published research available on the environmental impacts of CIPP repairs beyond the original report by the Virginia Transportation Research Council (VTRC). (See Understanding the Environmental Implications of Cured-in-Place Pipe Rehabilitation Technology in **Related Research and Guidance**.) Further, only Virginia DOT has conducted water quality testing on a carefully controlled CIPP installation to evaluate the effectiveness of more stringent specifications.
- A number of states are planning to provide CIPP specifications but were unable to provide them within the deadline for this Preliminary Investigation.
- We talked briefly to Chris Hanson of Insituform Technologies, who was not aware of any research on the environmental effects of CIPP repairs, but he is making inquiries internally.
- We were unable to reach an appropriate contact at the Arkansas State Highway and Transportation Department, which Caltrans had singled out as being of interest.

Next Steps

Moving forward, we recommend that Caltrans:

- Contact Joe Sicluna of New York State DOT and Bridget Donaldson of Virginia DOT for water quality testing results of CIPP installations.
- Follow up with Bridget Donaldson of Virginia DOT for forthcoming reports on the water quality effects of repairs using UV-cured CIPP and spray-on liners.
- Follow up with Chris Hanson of Insituform Technologies on the results of internal inquires about the environmental effects of CIPP repairs.
- Contact Robert Trevis of Oregon DOT for further information about the use of CIPP in that state.

Contacts

During the course of this Preliminary Investigation, we spoke to or corresponded with the following individuals:

CIPP Vendor

Insituform Technologies
Chris Hanson
(916) 616-3920

State Agencies

New York
Michael Mathioudakis
New York State Department of Transportation
(518) 457-9800, mmathioudakis@dot.state.ny.us

Joe Sicluna
New York State Department of Transportation
(607) 721-8479, jsicluna@dot.state.ny.us

Oregon
Ken Cannon
Aquatic Biology Program Coordinator, Geo-Environmental Section
Oregon Department of Transportation
(503) 986-3518, ken.h.cannon@odot.state.or.us

William Fletcher
Water Resources Program Coordinator, Geo-Environmental Section
Oregon Department of Transportation
(503) 986-3509, william.b.fletcher@odot.state.or.us

Robert Trevis
Culvert Design Engineer
Oregon Department of Transportation
(503) 986-3860, robert.e.trevis@odot.state.or.us

Paul Wirfs
Oregon Department of Transportation
(503) 986-3526, paul.r.wirfs@odot.state.or.us

Virginia
Bridget Donaldson
Virginia Department of Transportation
(434) 293-1922, bridget.donaldson@vdot.virginia.gov

Washington
Christina Martinez
Washington State Department of Transportation
Compliance Branch Manager, Environmental Services
(360) 705-7448, martich@wsdot.wa.gov

Related Research and Guidance

"A Pilot Study for Retrospective Evaluation of Cured-in-Place Pipe (CIPP) Rehabilitation of Municipal Gravity Sewers," E. Allouche, S. Alam, J. Simicevic, R. Sterling, W. Condit, J. Matthews, A. Selvakumar, *Tunnelling and Underground Space Technology*, March 2012.
http://www.sciencedirect.com/science/article/pii/S088677981200034X
This paper presented results from a pilot project that tested CIPP liners for thickness, annular gap, ovality, density, specific gravity, porosity, flexural strength, flexural modulus, tensile strength, tensile modulus, surface hardness, glass transition temperature and Raman spectroscopy. Researchers also gathered environmental data, including external soil conditions and pH and internal waste stream pH. Samples retrieved from the four locations involved in the pilot study testing were in excellent condition after being in use for 25 years, 23 years, 21 years and 5 years, respectively. Overall, researchers concluded that there is no reason to anticipate that the liners evaluated in this pilot study will not last for their intended lifetime of 50 years and perhaps well beyond.

Review of Styrene Water Quality Goals and Recommended Next Steps for CIPP Projects, Brown and Caldwell, March 2012.
See Appendix A.
This technical memorandum briefly summarizes water quality issues related to styrene in CIPP rehabilitation projects and recommends potential next steps for Caltrans to consider in response to recent regulatory developments related to styrene, including modifying CIPP specifications to reflect lessons learned from Virginia DOT.

"State-of-the-Art Literature Review on In-Situ Pipe Repairs and Durability," Fazil Najafi, Brad Cooney, Adnan Javed, *TRB 90th Annual Meeting Compendium of Papers DVD*, Paper #11-1269, 2011.
Abstract available at http://trid.trb.org/view/2011/C/1091856
From the abstract: After an extensive literature review, it can be concluded that, when compared to the traditional open cut pipe replacement method, in-situ technologies cause less disruption to the surrounding environment, less inconvenience on the community, and in appropriate applications are more cost-effective.

A Technical Review of VTRC's Research Report: Understanding the Environmental Implications of Cured-in-Place Pipe Rehabilitation Technology, Ed Campbell, 2010.
See Appendix B
This report reviews the 2008 report by the VTRC, Understanding the Environmental Implications of Cured-in-Place Pipe Rehabilitation Technology, and concludes that it was executed poorly "without practical scientific reasoning." Criticisms cover the failure to evaluate curing methods other than steam (such as hot water and UV light), sampling methods and a lack of a cost-benefit analysis. The author concludes: "The VA DOT had a real opportunity to provide the industry with an independent review of its practices and refine them as needed to preserve their cost-effective (and environmentally-effective) usage. The report falls short on this and the conclusions reached were not based on sound engineering principles. The end result is a document that is misleading to the general public and of little use to the technical community without a lot of work to sort out the test results and what guidance they may provide."

"Creating Environmentally Sound Specifications for Culvert Rehabilitation: Virginia Applies Findings for Cured-in-Place Pipe Repair," Bridget Donaldson, Edward Wallingford, *TR News*, Issue 268, 2010: 47-49.
http://onlinepubs.trb.org/onlinepubs/trnews/trnews268RPO.pdf
This technical overview summarizes the VTRC's evaluation of the impacts of styrene-based CIPP repair on water quality. VTRC's findings led to the development of new construction specifications to minimize environmental risks and ensure maximum structural performance of the finished product. Specification

requirements are discussed as well as the benefits of more stringent controls of the installation process. Modified specifications require the following:

- Both an inner and an outer impervious film to envelop the resin-liner system and promote complete polymerization, prevent resin loss and prevent styrene contamination of the interior portion of the finished pipe.
- Use of a semirigid plastic slip sheet over significant voids and pipe intrusions that could damage the liner during insertion.
- Installation oversight by a trained inspector.
- Time-temperature monitoring, with data logging, at points throughout the length of the pipe for the curing of the lining material.
- Thorough rinsing of the finished product.
- Proper containment and disposal of effluent cure water and rinseate.
- Water and soil testing for styrene before and after installation.
- Corrective actions to remediate the accidental release of styrene.

"Environmental Implications of Cured-in-Place Pipe Rehabilitation Technology," *Transportation Research Record*, Vol. 2123, 2009: 172-179.
Citation at http://trid.trb.org/view/2009/C/880557; see Appendix C for full report.
From the abstract: In this study, seven styrene-based, steam-cured CIPP installations in surface water and storm water conveyances in Virginia were identified and observed over the course of 1 year. Although the sites were not directly linked to sources of drinking water, styrene levels at five sites were higher than the Environmental Protection Agency's maximum contaminant level for drinking water of 0.1 mg/L. These concentrations were detected at these sites for a minimum of 5 days to 71 days after installation. Certain measurements were also found to exceed the concentration required to kill 50% of several freshwater aquatic indicator species. The findings suggest that the elevated styrene levels could have resulted from one or a combination of the following: (a) installation practices that did not capture condensate containing styrene, (b) uncured resin that escaped from the liner during installation, (c) insufficient curing of the resin, and (d) some degree of permeability in the lining material. In response to the preliminary findings of this study, the Virginia Department of Transportation suspended the use of styrene CIPP for conveying surface or storm water while the department further evaluated CIPP repair and subsequently developed new requirements for these installations.

Guideline for the Use and Handling of Styrenated Resins in Cured-in-Place Pipe, NASSCO CIPP Committee, September 2008.
See Appendix D.
This document presents a state-of-the-art guideline for the use and handling of styrene-based resins in the CIPP pipeline rehabilitation industry. Members of the committee conclude that CIPP installation sites managed with good housekeeping will present little opportunity for human health risks and/or environmental risks; and that studies done to date have concluded that CIPP resin systems do not appear to be a significant source of styrene or any of the other volatile organic compounds that are typically of concern in occupational or air quality studies. They also note that relevant studies show styrene biodegrades quickly in most environments.

Understanding the Environmental Implications of Cured-in-Place Pipe Rehabilitation Technology, Bridget Donaldson, Andrew Baker, Virginia Transportation Research Council, May 2008.
http://www.virginiadot.org/vtrc/main/online_reports/pdf/08-r16.pdf; or see Appendix E.
From the abstract: To evaluate the potential for impacts on water quality from the steam-cured CIPP process, seven CIPP installations in surface water and stormwater conveyances were identified and observed over the course of a 1-year study in Virginia. Water samples were collected from each project site and analyzed for styrene. The results were then evaluated for compliance with established regulatory standards and published aquatic toxicity criteria. Water samples collected from pipe outlets at five of the seven CIPP installations showed detectable levels of styrene. Styrene concentrations were generally

highest in water samples collected during and shortly following installation. The maximum duration that styrene was detected at any site was 88 days following the CIPP installation. Although the sites in this study were not directly linked to sources of drinking water, styrene levels at five sites were higher than the U.S. Environmental Protection Agency's maximum contaminant level for drinking water of 0.1 mg/L. Styrene was detected at five sites for a minimum of 5 days to at least 71 days after installation and was detected at these sites up to 40 m downstream. Certain measurements were also found to exceed the values for EC50 (the concentration required to have a defined effect on 50 percent of a study population) or LC50 (the concentration required to kill 50 percent of a study population) for several freshwater aquatic indicator species. The findings suggest that the elevated styrene levels could have resulted from one or a combination of the following: (1) installation practices that did not capture condensate containing styrene, (2) uncured resin that escaped from the liner during installation, (3) insufficient curing of the resin, and (4) some degree of permeability in the lining material. A summary of the actions taken by the Virginia Department of Transportation (VDOT) in response to the preliminary findings of this study is also provided in this report. VDOT suspended the use of styrene-CIPP for pipes that convey surface or stormwater while further evaluating CIPP repair and subsequently developing new requirements for these installations. The new measures include substantial modifications to VDOT's CIPP specifications; an inspector training program; increased project oversight; and water and soil testing prior to and after CIPP installation. Reinstatement of statewide VDOT CIPP installations using the new procedures and specifications is planned for May 2008.

Survey and Interview Results

The full text of each survey response is provided below. Some responses have received minor edits for clarity. For reference, we have included an abbreviated version of each question before the response; for the full question text, please see the **Summary of Findings** on page 2 of this report.

Alberta

1. **Use of CIPP?** No.

2. **Specifications and guidance?** N/A.

3. **Water quality and regulatory problems?** N/A.

4. **Response to problems?** N/A.

5. **Staff contact information:** Des Williamson, Director, Bridge and Water Management Section, (780) 415-1015, des.williamson@gov.ab.ca.

Arizona

1. **Use of CIPP?** Yes. We have contracts through our procurement office and know of a few projects that opted to perform this type of work. AZDOT is still working on its survey response and will provide more information, including specifications, in the last week of June.

2. **Specifications and guidance?** N/A.

3. **Water quality and regulatory problems?** N/A.

4. **Response to problems?** N/A.

5. **Staff contact information:** Leigh Waite, Water Quality Analyst, Office of Environmental Services, (602) 712-6170, lwaite@azdot.gov.

Idaho

1. **Use of CIPP?** Yes.

2. **Specifications and guidance?** Not provided (awaiting response from Construction Engineer).

3. **Water quality and regulatory problems?** Not aware of any issues.

4. **Response to problems?** N/A.

5. **Staff contact information:** Sue Sullivan, Environmental Program Manager, (208) 334-8203, sue.sullivan@itd.idaho.gov.

Indiana

1. **Use of CIPP?** Yes.

2. **Specifications and guidance?** See the Technical Advisory for Pipe Lining, 1202-ta.pdf (Appendix F.1). The CIPP liners feature in the latter half of the Technical Advisory. See also a unique special provision (USP) that Indiana used as a specification in the past, CIPP USP.pdf (Appendix F.2).

3. **Water quality and regulatory problems?** I don't believe we've run into any problems with CIPP related to water quality. I've heard potential concerns about thermal pollution downstream of the structure from the steam used in the CIPP curing process, but none of the water quality regulatory agencies have challenged our use of CIPP.

4. **Response to problems?** N/A.

5. **Staff contact information:** Crystal Weaver, Hydraulics Manager, (317) 233-2096, cmweaver@indot.in.gov.

Maryland

1. **Use of CIPP?** The Maryland State Highway Administration (SHA) has had very limited experience with these types of repairs.

   From the Highway Hydraulics Division: We have used this in one or two instances under our time and materials contract several years ago. It was for a small diameter pipe for a storm drainage system—no stream, all dry system. No monitoring was done. Since this was time and materials contract, the work was prescribed in the field by SHA staff. We do not have specification.

   From the Structures Engineering Division: We do not use this product for several reasons, cost being one of them. Highway Hydraulics has used this system since they have smaller pipes and it is more cost effective to use for certain applications: small pipes under large fills. I am familiar with the product, one being called Insitu-Form East, which has been around for a long time. It is typically used in smaller diameter pipes such as 18" diameter or 2' diameter sewers, etc. We have never used it on any of our small structures or culverts.

2. **Specifications and guidance?** None. (See above.)

3. **Water quality and regulatory problems?** Not aware of any issues. (See above.)

4. **Response to problems?** N/A.

5. **Staff contact information:** Bruce Grey, (410) 545-8500, bgrey@sha.state.md.us.

.

New York

The following responses are based on phone conversations with Michael Mathioudakis and Joe Sicluna, interviewed at the suggestion of Bridget Donaldson of Virginia DOT.

1. **Use of CIPP?** Yes.

2. **Specifications and guidance?** See Appendix G.1 and Appendix G.2.

3. **Water quality and regulatory problems?**

   Michael Mathioudakis (Albany central office): New York has strict specifications for CIPP repairs, and since these specifications have been in place has not had any problems. It has done some informal, unscientific testing after implementation of these specifications and didn't find any problems. (See Appendix G.3 for testing results.) New York only allows use of water curing, and never steam curing or UV. NYSDOT uses CIPP widely and is happy with its current CIPP specifications. [Note that this answer conflicts with that given by Joe Sicluna below.]

   Joe Sicluna (Binghamton regional office): Our regional office expressed concerns about styrene from CIPP installations a few years ago. We tested styrene levels locally and found levels far in excess of allowable limits. (See Appendix G.3 for water sampling results.) The discharge of hot water was itself also a violation of water quality standards (both styrene and hot water can affect trout and other species). Contractors were supposed to prevent this sort of discharge from happening, but they tended to cut corners and at the time no one took it seriously. As a consequence, NYSDOT revised its specifications to the effect that contractors had to be in compliance with all applicable water quality regulations, and no more discharge of wastewater to surface waters is allowed; everything must be caught in a truck and taken for treatment (although I know of no place where this kind of waste can be treated). As a result, contractors are opting to use non-styrene products, and I know of no CIPP contract since the new specifications. [Note that this answer conflicts with that given by Michael Mathioudakis above.] CIPP probably can be used cleanly if materials are contained, but that depends on the contractor's due diligence. UV or steam would produce less wastewater, but the central office is against their use.

4. **Response to problems?** NYSDOT responded to concerns from a regional office by changing specifications.

5. **Staff contact information:** Michael Mathioudakis, (518) 457-9800, mmathioudakis@dot.state.ny.us;
   Joe Sicluna, (607) 721-8479, jsicluna@dot.state.ny.us.

Ohio

1. **Use of CIPP?** Yes—not used very often.

2. **Specifications and guidance?**
   http://www.dot.state.oh.us/Divisions/ConstructionMgt/Specification%20Files/834_04162010%20for%202010.pdf

   Submittals. Submit a written installation plan for the conduit renewal to the Engineer for acceptance at least ten days before beginning work. Include the following information:

1. Design calculations and shop drawings for the renewed conduit. Ensure the calculations and shop drawings address the polymer physical properties and the lining thickness as shown in the plans.

2. Methods of cleaning the host pipe.

3. Plan to bypass flow around the host pipe.

4. Video survey of the host pipe before installation.

5. Site specific health and safety plan.

Install resin based liner materials in a dry host pipe. Prevent the accumulation and flow of water through the host pipe and liner until after the work is complete.

3. **Water quality and regulatory problems?** Not aware of any issues.

4. **Response to problems?** N/A.

5. **Staff contact information:** Ron Trivisonno, Construction Hydraulics Engineer, Office of Construction Administration, (614) 644-6588, ron.trivisonno@dot.state.oh.us.

Oregon

The following responses are based on a phone call with Paul Wirfs and email correspondence with Ken Cannon and William Fletcher.

1. **Use of CIPP?** Yes.

2. **Specifications and guidance?** Our standard specifications and special provisions related to environmental protection are found here: http://www.oregon.gov/ODOT/HWY/SPECS/index.shtml; see Standard Specification, Section 00290 - Environmental Protection.

   For unique circumstances we use 00290 "Special Provisions." These are specs that can be modified to meet site specific concerns. "Specials" are found here: http://www.oregon.gov/ODOT/HWY/SPECS/Pages/2008_special_provisions.aspx#Part_00200

   Also for specs related to CIPP, see Section 00410 - Pipe Lining, found here: http://www.oregon.gov/ODOT/HWY/SPECS/Pages/2008_special_provisions.aspx#Part_00400; http://www.oregon.gov/ODOT/HWY/SPECS/Pages/standard_specifications.aspx

3. **Water quality and regulatory problems?**

   Paul Wirfs: To his knowledge there are no problems with water quality due to CIPP. (See William Fletcher's response below for a conflicting answer.) Specifications require that a containment system be put in place.

   Ken Cannon: Oregon fish passage laws limit our ability to use slip line technology on pipes in fish bearing streams. Slip line repair (in fish bearing streams) triggers a state law that requires us to meet fish passage standards at the site or mitigate off-site. Meeting the state fish passage standards usually means we have to replace the structure rather than repair it. My guess is that most (if not all) of our CIPP work is done on pipes that are not fish bearing, and therefore would not trigger fish passage laws. From the aquatic biology perspective, using the CIPP technology comes with concerns even in

non-fish bearing pipes. Chemical and heat contamination could be conveyed to areas where fish do reside. This kind of contamination could violate water quality standards and cause "take" of fish protected by the Endangered Species Act. For projects with these concerns, ODOT will direct contractors to protect natural resources through our Standard Specifications and Special Provisions.

William Fletcher: With regards to regulatory agency concerns, so far CIPP seems to have flown under the radar. According to one of our biologists who previously was the NMFS/ODOT liaison, the issue didn't come up, but he assumed this was more due to lack of awareness that the epoxy might be an issue than real comfort with its use. I suspect that if NMFS were aware of the Virginia Transportation Research Center study on styrene releases from CIPP they might be less sanguine. As it is, CIPP is not mentioned one way or the other in the programmatic [Biological Opinion] NMFS is developing for use on highway projects in Oregon. Our HazMat Program Coordinator, Jennie Armstrong, has provided me with the sampling results from a bungled installation of a CIPP repair. See attached sampling results (Appendix H.1 and Appendix H.2), which detected 174 parts per million of styrene. Jennie's description of the event is: "It wasn't really a spill in the traditional sense. The sub-sub-contractor was supposed to cure the pipe lining with hot water. Instead they used steam. This overheated the pipe lining such that it released more styrene (solvent) than it normally would and such that it melted the old asphalt lining in the original pipe. They also failed to divert all the incoming water so that water was able to flow between the old pipe and the new lining during installation. We also suspect they under-sized the lining, which further aided water in getting between the old pipe and the new lining. As a result the styrene laden water was able to dissolve the melted asphalt and wash it out into the Willamette River. The styrene levels were so high that our responder had to wear a respirator to collect samples." As far as we are aware, this is the only characterization ODOT has done on water flowing through a CIPP pipe, and it was (we hope) a deplorable exception to what should normally happen. Jennie has advocated ODOT treating all cure water and steam from CIPP like any other waste stream, i.e., it must be contained and treated properly. Our specs in 00290 call for wastes to be contained, characterized and disposed of properly.

Robert Trevis has more information on CIPP use in Oregon, but will be unable to respond until after June 22.

4. **Response to problems?** N/A.

5. **Staff contact information:** Paul Wirfs, (503) 986-3526, paul.r.wirfs@odot.state.or.us; Ken Cannon, Aquatic Biology Program Coordinator, Geo-Environmental Section, (503) 986-3518, ken.h.cannon@odot.state.or.us; William Fletcher, Water Resources Program Coordinator, Geo-Environmental Section, (503) 986-3509, william.b.fletcher@odot.state.or.us; Robert Trevis, Culvert Design Engineer, (503) 986-3860, robert.e.trevis@odot.state.or.us.

Pennsylvania

1. **Use of CIPP?** Yes. We have tried CIPP in a few projects, but it is currently not on our approved products list. The District has requested individual project approvals to use this product. We have received a New Product application for this product. We are currently evaluating the product, but a decision has not been made.

2. **Specifications and guidance?** See Appendix I.

3. **Water quality and regulatory problems?** None.

4. **Response to problems?** N/A.

5. **Staff contact information:** Sheri Little, Research Project Manager, (717) 787-3584, slittle@pa.gov.

Tennessee

1. **Use of CIPP?** No.

2. **Specifications and guidance?** N/A.

3. **Water quality and regulatory problems?** N/A.

4. **Response to problems?** N/A.

5. **Staff contact information:** Suzanne Herron, (615)741-2612, suzanne.herron@tn.gov.

Utah

1. **Use of CIPP?** Yes.

2. **Specifications and guidance?** See Appendix J.

3. **Water quality and regulatory problems?** None.

4. **Response to problems?** N/A.

5. **Staff contact information:** Denis Stuhff, Hydraulics Engineer, dstuhff@utah.gov.

Virginia

1. **Use of CIPP?** Yes.

2. **Specifications and guidance?** http://www.virginiadot.org/business/resources/const/cdmemo-0811.pdf. See page 5, Method D.

3. **Water quality and regulatory problems?** Styrene-based CIPP was evaluated in 2007, prior to the pipe repair memorandum provided in the above link. The following report describes the monitoring results and the resulting actions taken by VDOT: http://www.virginiadot.org/vtrc/main/online_reports/pdf/08-r16.pdf.

4. **Response to problems?** Report and resulting specifications are provided above. We are also currently completing water quality studies on unconventional CIPP (including UV-CIPP and styrene-free CIPP) and spray-on liners.

5. **Staff contact information:** Bridget Donaldson, (434) 293-1922, bridget.donaldson@vdot.virginia.gov.

Follow-up phone call with Bridget Donaldson: The new specifications for styrene-based CIPP are stringent enough to keep installations clean. Virginia conducted water quality on one installation and found it to be very clean. Samples were collected at the outlet a few days following installation, and about 10 meters downstream, with the following results for styrene levels:

- Outlet: 0.294 mg/L.
- Downstream: 1.34 mg/L.

These levels are below the toxicity thresholds for rainbow trout (a common indicator species).

Despite the fact that Virginia's specifications are working, it can be difficult to ensure a complete cure on all projects, which means that there is always the danger of uncured pockets of resin that leach into the water after installation.

Specifications have increased the costs and workload for contractors because they can't just release cure water downstream, but have to collect it and properly dispose of it at a wastewater facility; and they must hire an independent laboratory to do testing after installation. Consequently, the use of styrene-based CIPP in Virginia has become less common; epoxy-based and UV-based CIPP repairs are more common. Epoxy-based CIPP has its own water quality issues, and Virginia will also be tightening up its specifications for this method. UV-based CIPP seems to be cleaner than epoxy-based CIPP. In August 2012, VDOT will release reports on water quality testing results for both UV-based CIPP repairs and polyuria and cementitious spray-on liners (under the title "Water Quality Implications of Culvert Repair Options Available for Use by VDOT"; Caltrans recently accepted a spray-on liner into its list of approved products). The most popular method for repairing culverts other than CIPP involves steel liners (manufactured by DLB, Inc.). Before the use of CIPP and steel liners, Virginia used pneumatically applied concrete to patch holes, but such repairs did not last long, and there were concerns about raising the culvert's elevation and disrupting stream dynamics and aquatic passage.

Ms. Donaldson recommended talking to Joe Sicluna and Michael Mathioudakis of the New York State DOT, which conducted its own testing after Virginia's study. The agency found high styrene content after a few installations and developed specifications that are even more stringent than Virginia's. New York is the only other state that Ms. Donaldson knew of that was publically addressing CIPP installation water quality issues. She noted that many DOTs are probably reluctant to face the possibility that they might be engaged in environmentally damaging practices. However, she has also heard anecdotal evidence of other locales with CIPP-related water quality problems. Ontario has banned the use of CIPP repairs and the issue is now in litigation; there should be a ruling in January or February. Further, a California wastewater agency (Central Contra Costa Sanitary District, Martinez, CA) found that styrene from CIPP repairs damaged its systems.

Washington

1. **Use of CIPP?** Yes—on two projects.

2. **Specifications and guidance?** WSDOT has only used CIPP repairs on two design-build projects (on Interstate 405). The contracts did not specify how to replace the culverts, only that they needed to be replaced. WSDOT does not have any contract specifications for CIPP repairs, nor have we developed any project specific/special provisions for CIPP repairs. WSDOT is not planning on developing specifications for CIPP repairs due to the lack of success we've had with that type of work. WSDOT does have specifications for other types of trenchless techniques. Contact Jay Christianson at (360) 750-7269 for more information.

3. **Water quality and regulatory problems?** Yes. WSDOT had problems on both I-405 projects (in 2009-2010 timeframe) during Cured in Place Pipe rehab. The first was on the Kirkland Nickel Stage 1 Project (in the old culvert that used to carry Forbes Creek under I-405). The second was on the South Bellevue Nickel Project (Trail Creek). In both cases, the water that came into contact with the curing chemicals was accidentally released downstream resulting in water quality issues. On the I-405 Bellevue Project, the Washington State Department of Ecology issued a $9000 penalty to the contractor for the release of styrene into Trail Creek and failure to report. See our documented lessons learned and news items (Appendix K).

4. **Response to problems?** The following is in our lessons learned database:

   RECOMMENDATION: Describe how the knowledge gained can be used.

The team recommends all stream bearing culverts to be replaced instead of relined in most cases. However, if relining is still considered for use we recommend all water be diverted around the pipe being relined. The diversions should be placed well above the work. In addition, the pipe should be fully blocked downstream of the work to prevent any accidental spills from reaching waters of the state. The pipe should be cleaned of all liquid compounds and inspected either manually or with a camera before water is allowed to flow through it. Lastly, contingency and communication procedures should be in place and strictly followed before and during work and should include all entities which may be impacted including downstream jurisdictions. Changes to the work plan in the field during work should only be considered upon consultation with the Project Engineer and Environmental staff. Environmental staff should be on-site or on-call during these operations.

5. **Staff contact information:** Christina Martinez, Compliance Branch Manager, Environmental Services,
(360) 705-7448, martich@wsdot.wa.gov.

Follow-up phone call with Christina Martinez: Christina confirmed that Washington State DOT has used CIPP on only two projects, and that these involved a discharge of styrene into a creek. The smell of the styrene was noticed by nearby residents, and there was significant political fallout, a written violation and a fine. The two instances of use of CIPP were for design-build jobs, for which Washington State DOT doesn't direct the contractor on methods and technologies. Washington State DOT is doing a lot of culvert repairs because it has many older culverts that are undersized for fish passage; these typically require new and larger culverts, and so Washington State DOT is not typically relining a lot of culverts. It does some relining for stormwater infrastructure.

Wisconsin

1. **Use of CIPP?** No.

2. **Specifications and guidance?** N/A.

3. **Water quality and regulatory problems?** N/A.

4. **Response to problems?** N/A.

5. **Staff contact information:** Fred Wisner, Environmental Engineer, Environmental Services Section, (715) 499-5204, frederick.wisner@dot.wi.gov.

Wyoming

1. **Use of CIPP?** No.

2. **Specifications and guidance?** N/A.

3. **Water quality and regulatory problems?** N/A.

4. **Response to problems?** N/A.

5. **Staff contact information:** Bill Wilson, Standard Plans Group, (307) 777-4216, bill.wilson@wyo.gov.

APPENDIX A

Brown AND Caldwell

201 North Civic Drive
Walnut Creek, California, 94596
Tel: 925-937-9010
Fax: 925-937-9026

Technical Memorandum

FINAL

Prepared for: California Department of Transportation (Caltrans)
Project Title: Design Support

Technical Memorandum

Subject: Review of Styrene Water Quality Goals and Recommended Next Steps for CIPP Projects
Date: March 2, 2012
To: Hardeep S. Takhar, P.E., Chief, Office of Water Quality, Caltrans
From: Dr. Khalil Abusaba, Supervising Scientist
Copy to: Michael Flake, Analette Ochoa (WRECO)

Prepared by: Khalil Abusaba, Ph.D.

Reviewed by: Michael Flake, P.E.

1. Introduction

The purpose of this technical memorandum is to briefly summarize water quality issues related to styrene in cured-in-place pipeline (CIPP) rehabilitation projects, and recommend potential next steps for the California Department of Transportation (the Department) to consider in response to recent regulatory developments related to styrene. This memorandum presents a brief overview of those recent regulatory developments, summarizes water quality goals for styrene, presents a review of technical studies on styrene toxicity, and concludes with options for the Department to consider.

The basis for looking into styrene and CIPP was a June 2010, 401-Certification letter from the San Francisco Bay Regional Water Quality Control Board (SFRWQCB) to The California Department of Transportation, District 4 of the Department (SFRWQCB, 2010) regarding a Highway 17 culvert repair project. That letter cited a study by the Virginia Transportation Research Council (VTRC) on styrene residues from CIPP installations (Donaldson and Baker, 2008). The study showed detectable levels of styrene in water samples collected from pipe outlets at five of seven CIPP installations monitored. Styrene levels detected in the study exceeded the USEPA maximum contaminant level (MCL) of 0.1 mg/L (100 µg/L). The study authors suggested four possible causes of elevated styrene concentrations:

1. Installation practices that did not capture condensate;
2. Uncured resin that escaped from the liner during installation;
3. Insufficient curing of the resin; and
4. Some degree of permeability in the lining material.

Photographs from the VTRC document uncured resin waste adjacent to pipe outlets after CIPP installation. The study was commissioned by the Virginia Department of Transportation (VDOT), which had temporarily suspended the use of CIPP beginning in August 2007 because of concerns over styrene (Griffin, 2008). VDOT resumed use of CIPP in June 2008 after instituting the following measures to manage projects using CIPP linings:

1. Substantial modifications to VDOT's CIPP specifications, including requirements for the Contractor to:
   a. Implement control measures to capture raw styrene resin spills
   b. Obtain all necessary discharge-related permits
   c. Capture and properly dispose of all condensate and cure water
   d. Thoroughly rinse cured pipe with water and capture and properly dispose of rinse water prior to re-introducing flow
   e. Employ the services of an independent, environmental services, laboratory or consultant to collect and analyze soil and water samples upstream and downstream of the rehabilitation project before the project is initiated and one week after the pipe liner has cured.
2. An inspector training program;
3. Increased project oversight; and
4. Water and soil testing prior to and after CIPP installation.

The June 2010 letter by the SFRWQCB required certain conditions for the use of CIPP as part of the water quality certification. The letter required that CIPP specifications be submitted and accepted by the SFRWQCB's Executive Officer prior to proceeding with CIPP installations. According to the SFRWQCB, the accepted CIPP specs were to include:

1. Identification of the resin system and actual chemical name of the monomer that will be used during CIPP installation (including Material Safety Data Sheets);
2. Detailed specifications describing the containment method for all process water;
3. Specifications to repeatedly flush and capture water through the culvert after the liner has cured and installation is complete;
4. Specifications to test final flush water, including appropriate target constituents and testing methods. Flushing and testing shall be conducted until test results show acceptable levels of any target constituents, including styrene monomer or any other appropriate monomer and any toxic additives;
5. Specifications to appropriately dispose of all process and rinse water with receipt of disposal; and
6. Specifications to prohibit resumption of natural flow through the culvert until residual styrene concentrations are not greater than 1 part per billion (µg/L) 60 days after installation, or until other monomer-specific appropriate concentrations are not exceeded 60 days after installation.

The SFRWQCB cited the state-adopted MCL of 100 µg/L for protection of drinking water supplies, but did not explain the basis for the 1 µg/L restriction.

The water quality issues raised in the June 2010, 401-Certification letter could potentially constrain future use of CIPP by the Department and other parties seeking to rehabilitate storm drains. To address this, water quality goals for styrene and available information on styrene toxicity to aquatic life are summarized below, followed by some preliminary recommendations for reviewing and updating CIPP specifications.

2. Findings

This section summarizes the review of water quality goals and ecological effects of styrene.

2.1 Water Quality Goals

As noted above, the only enforceable numeric objective for styrene in California is the 100 µg/L water MCL for drinking water. That MCL would apply to receiving waters that are designated for municipal water supply (MUN). The Office of Environmental Health Hazard Assessment (OEHHA) has established a Public Health Goal (PHG) of 0.5 µg/L (OEHHA, 2010). OEHHHA established the PHG after conducting a risk assessment based on available scientific research on the toxicology and epidemiology of styrene. OEHHA recommended that for the purposes of the public health evaluation, styrene be considered a carcinogen. The drinking water PHG established by OEHHA is "that there is sufficient evidence that styrene causes cancer in animals and limited evidence in humans."

PHGs established by OEHHA are not enforceable as numeric limits in receiving water or discharges. Human health information, including PHGs, are considered, along with economic and technical feasibility criteria, by the California Department of Public Health (DPH) when adopting MCLs that are enforceable water quality objectives. DPH has not yet completed adoption of an MCL based on the new PHG for styrene. As DPH goes through the adoption process, it may choose to adopt an MCL higher than the PHG should DPH find sufficient evidence for the technical or economic infeasibility of attaining the PHG.

The State Water Resources Control Board (SWRCB) has a compilation of water quality goals (SWRCB, 2010) that cites a USEPA secondary MCL of 10 µg/L for styrene, in addition to the 100 µg/L primary MCL. However, the USEPA information on drinking water MCLs only lists the 100 µg/L primary MCL; no mention of a 10 µg/L

secondary MCL was found in readily available USEPA documentation (USEPA, 2010). Other goals listed by the SWRCB compilation include a reference dose of 140 µg/L established in USEPA's IRIS database, and a 931 µg/L health advisory level established by the national academy of sciences.

In summary, 100 µg/L is the lowest enforceable water quality objective goal for styrene that has been identified to date.

2.2 Ecological Effects of Styrene

A review of available scientific literature on styrene was conducted using Google Scholar (http:scholar.google.com), using the search words "styrene" "toxic" and confining the search to life, environmental, and biological sciences publications. Table 1 below summarizes effects thresholds for styrene that were identified in the literature. The effect thresholds summarized in Table 1 below are all higher than the 1 ppb limit specified by the SFRWQCB in their June 22, 2010 letter.

Table 1. Summary of Ecological Effects Thresholds for Styrene Identified in Published Scientific Articles

Effects Threshold (µg/L)	Basis (organism and effect)	Reference
121,040	Zebra fish (*Brachydanio rerio)* 96 hr LC_{50}	Shen and Yuan (2006)
72,770	Mitten crab (*E. sinensis*) 96 hr LC_{50}	Wang et al.(2007)
18,550	Eastern whipbird (*P. olivaceus*) 96 hr LC_{50}	Wang et al.(2007)
11,350	Water flea (*Daphnia magna*) 96 hr LC_{50}	Shen and Yuan (2006)
10,000	Fathead minnow (*Pimphales promelus*) 96 hr LC_{50}	Cushman et al (1997)
9,500	Amphipod (*Hyalella atzteca*) 96 hr LC_{50}	Cushman et al (1997)
8,960	Diatom (*N. closterium*) 96 hr EC_{50}	Wang et al.(2007)
7,960	Paper wasps (*P. chinensis*) 96 hr LC_{50}	Wang et al.(2007)
5,940	Marine green algae (*Platymonas sp.*) 96 hr EC_{50}	Wang et al.(2007)
4,700	Water flea (*Daphnia magna*) 48 hr EC_{50}	Cushman et al (1997)
4,100	Amphipod (*Hyalella atzteca*) NOEC	Cushman et al (1997)
4,000	Fathead minnow (*Pimphales promelus*) NOEC	Cushman et al (1997)
1,900	Water flea (*Daphnia magna*) 48 hr NOEC	Cushman et al (1997)
720	Freshwater green algae (*Selenastrum capricornutum*) 96 hr EC_{50}	Cushman et al (1997)
63	Freshwater green algae (*Selenastrum capricornutum*) NOEC	Cushman et al (1997)

LC50 = concentration at which mortality is observed in 50% of the test organisms
EC50 = concentration at which growth inhibition (algae and diatoms) or reproductive inhibition (water fleas) is observed in 50% of the test organisms
NOEC = No observable effect concentration

Low-level (NOEC = 63 µg/L) growth inhibition of freshwater green algae (*Selenastrum capricornutum*) was observed in one study. This apparent sensitivity stands in stark contrast to the threshold for growth inhibition of marine green algae (*Platymonas* species), which is a thousand fold higher. Many of the toxicology studies cited in Table 1 conclude that "styrene's potential impact on aquatic and soil environments is significantly mitigated by its volatility and biodegradability." A study by Alexander (1997) confirms that styrene concentrations rapidly decline in aerobic surface waters, as a result of volatilization, degradation, and sorption to soils.

2.3 Styrene Fate and Transport

The principal removal mechanism for styrene in natural waters is volatilization, although bio-degradation may also play a role. In practical terms, the most efficient way to remove styrene from CIPP installations is to ensure adequate curing time and heat. In the VTRC study by Donaldson and Baker (2008), styrene concentrations in water draining through CIPP installations exceeded the MCL (100 µg/L) at five of seven study sites for at least five days after CIPP installation was completed; in three of those sites, styrene concentrations above the MCL were detected 44 to 71 days after installation. The study authors cite the following as possible reasons for detection of residual styrene after CIPP projects were completed:

- Inadequate condensate capture
- Uncured resin escaping from the liner during installation
- Insufficient curing of the resin
- Some degree of permeability of the lining material.

Those observations informed the updates to the VDOT specifications for CIPP installations.

3. Recommendations

The establishment of 1 µg/L as a post- construction performance standard does not appear to have a regulatory or scientific basis for protection from ecological effects. Human health effects are currently regulated by the MCL for styrene, 100 µg/L. That human health MCL is lower than all but one of the ecological effects thresholds listed in Table 1 above.

The lowest identified ecological effects threshold (63 µg/L) is for growth inhibition of freshwater green algae. It would be reasonable and defensible for the Department to propose 63 µg/L as a receiving water goal for styrene in waters downstream of CIPP installations. This would attain the lowest known ecological effects threshold, and provide a margin of safety below the current human health based MCL. It would not be appropriate for the Department to implement the PHG of 0.5 µg/L, until DPH has completed its assessment of technical and economic feasibility and adopted a new MCL for styrene.

Implementation of Best Management Practices (BMPS) for styrene in CIPP would help the Department build a record to inform the technical and economic feasibility of attaining styrene concentrations lower than 63 µg/L in surface waters following CIPP installations. BMPs could be included as modifications to the existing standard specification for CIPP installations (California Department Transportation, 2009).

Many aspects of the VDOT contract specifications could be incorporated into the Department's updated CIPP specification; however, the VDOT specification to rinse with water should be revisited by the Department before stipulating such a measure. Because styrene is volatile, it may make more sense to force heated air or steam through a CIPP liner, or allow air curing for a prolonged period of time. Flushing with rinse water could generate large volumes of water requiring treatment prior to discharge, and is less efficient than using the inherent volatility of styrene to remove it from the CIPP installation.

The required curing time will vary depending on the ambient temperature of the installation and the complexity of the project. In general, greater pipe lengths and greater numbers of turns and bends in the pipe would lead to longer curing times; higher ambient temperatures could reduce curing times, while colder ambient temperatures could lengthen the time required to attain 63 µg/L in water draining through a CIPP project.

The revised CIPP specification would include the following requirements of the Contractor:

a. Divert water away from the pipeline prior to installation
b. Implement control measures to capture raw styrene resin spills

c. Obtain all necessary discharge-related permits
d. Capture and properly dispose of all condensate and cure water
e. Employ the services of an independent environmental services laboratory or consultant to collect and analyze soil and water samples upstream and downstream of the rehabilitation project before the project is initiated and one week after the pipe liner has cured.
f. Require soil and water samples to be analyzed using EPA Method 8260B to attain sufficiently low detection limits.
g. Allow sufficient time for air-curing, or force heated air or steam to increase the curing rate, so that water flowing through the CIPP installation does not cause receiving waters to exceed 63 µg/L.
h. If the contractor does not wish to assess dilution and mixing in receiving waters, they can choose to show that 63 µg/L is attained at the end-of-pipe after curing is complete
i. Do not remove the diversion until attainment of 63 µg/L in receiving waters or end-of-pipe can be demonstrated through monitoring.

As these specifications are implemented on a number of projects throughout the state, the Department can compile the information to provide to DPH to inform their analysis of the technical and economic feasibility of implementing an MCL lower than the current MCL of 100 µg/L for styrene.

References

Alexander, M., 1997, "Environmental Fate and Effects of Styrene," *Critical Reviews in Environmental Science and Toxicology*, 27(4), 383-410.

Baer, K.N., R.L. Boeri, T. Ward, and D. Dixon, 2002, "Aquatic Toxicity Evaluation of Para-methylstyrene," *Ecotoxicology and Environmental Safety*, 53(3), 432-438.

California Department of Transportation, 2009, *Cured-In-Place Pipeliner (CIPP)*, Caltrans Construction Contract Standards – Standard Special Provisions, 15-531_E_A07-31-09.

California Regional Water Quality Control Board – San Francisco Bay Region (SFRWQCB), 2010. *Water Quality Certification for the State route 17 Wet Pavement Correction and Culvert Repair Project, Unincorporated Santa Clara County*, June 22, 2010 Letter to Dina El-Tawansy.

California State Water Resources Control Board, 2010, "A Compilation of Water Quality Goals," http://www.waterboards.ca.gov/water_issues/programs/water_quality_goals/, last accessed August 27, 2010.

Cushman, J.R., , G.A. Rausina, G. Cruzan, and others, 1997, "Ecotoxicity Hazard Assessment of Styrene," *Ecotoxicology and Environmental Safety*, 37(2), 173-180.

Donaldson, B.M., and Baker, P.E., 2008, *Understanding the Environmental Implications of Cured-in Place Pipe Rehabilitation Technology*, Virginia Transportation Research Council, Final Report VTRC 08-R16.

Fu, M.H., and M. Alexander, 1992, "Biodegradation of Styrene in Samples of Natural Environments," *Environmental Science and Technology*, 26(8), 1540-1544.

Griffin, J., 2008, "Virginia DOT Lifts CIPP Ban," *Underground Construction*, June 2008, p. 44.

Kampbell, E., A Technical Review of VTRC's Research Report: Understanding the Environmental Implications of Cured-in-Place Pipe Rehabilitation Technology. Date and place of publication unknown (PDF provided by Caltrans).

Office of Environmental Health Hazard Assessment (OEHHA), 2010, *Public Health Goal for Styrene in Drinking Water*, California Environmental Protection Agency, Oakland California. http://oehha.ca.gov/water/phg/122810styrene.html

Qureshi, A.A., K.W. Flood, S.R. Thompson, and others, 1982, "Comparison of a Luminescent Bacterial Test with Other Bioassays for Determining Toxicity of Pure Compounds and Complex Effluents," *Aquatic Toxicology and Hazard Assessment: Fifth Conference, ASTM STP 766*. In: J.G. Pearson, R.B. Foster, and W.E. Bishop, Eds. *American Society for Testing Materials*, 179-185.

Shen, X. and Y. Qi, 2006, "Study on Acute Toxicity Effect on Aquatic Organism," *Marine Environmental Science*, 25(4), 33-35.

United States Environmental Protection Agency, 2010 "Basic Information About Styrene in Drinking Water," http://water.epa.gov/drink/contaminants/basicinformation/styrene.cfm, last accessed August 31, 2010.

Virginia Department of Transportation, 2008, *Guidelines for Pipe Culvert Replacement of Rehabilitation – Selection Criteria, Specifications, and Inspection*, CD-2008-11.

Wang, W., S.H. Wang, X. Bing and others, 2007, "Toxic Effects of Styrene on Some Aquatic Organisms," *Journal of Safety and Environment*, 7(5) 1-3.

APPENDIX B

A Technical Review of VTRC's Research Report: Understanding the Environmental Implications of Cured-in-Place Pipe Rehabilitation Technology

Ed Kampbell, P.E.

President, Rehabilitation Resource Solutions, LLC, 4862 Sarasota Court, Hilliard, OH 43026;
Ph 614-529-8204; Fax 614-573-7617; ekampbell@sbcglobal.net

In May of 2008 the VA DOT issued the results of a study (VTRC 08-R16) of which the purpose and scope was stated as "to evaluate the potential for impacts on water quality from use of the steam-cured CIPP process." What lead them to embark on this ambitious one year study of seven VA DOT construction sites is somewhat of a mystery; but, given the potential value of an independent investigative look at the potential environmental impacts of using styrenated resin systems in storm water system rehabilitation, the gains from such a study had the opportunity to be a great addition to the body of information available to the consulting engineering community as they continued to increase their usage of CIPP in this application. Sadly, the study, in this author's opinion, was executed poorly and the subsequent report was written without practical scientific reasoning. This paper will explore the path of the research, the findings of the researchers and the value of their technical conclusions.

All engineering works projects must contain an environmental assessment of the disruption that potentially might occur as a result of the contemplated work; and trenchless pipeline rehabilitation work using CIPP is no exception. CIPP projects, however, because of their short duration and limited area of impact typically should fall under the EPA's construction general permit (CGP); if at all. Projects fitting under the requirements of the CGA are those having an impact area of between one and five acres. This permitting program was established by the EPA in an effort to forego the massive amount of paperwork that would be required to address each individual small construction project such as those typical of CIPP projects. In this author's experience the impact areas of essentially all CIPP projects are less than one acre in size. Given such an extremely small footprint it is my interpretation of the regulations that CIPP project sites would be governed under the broader self oversight requirements for a hazardous material. Self oversight, however, can be a bit of a challenge as the EPA has no stated or pre-determined limits for discharges of water containing styrene from construction sites. Because of this the CIPP installer must consider the assimilative capacity of the downstream receiving ditch or waterway to accept the estimated VOC and/or thermal loading that will result from the installer's chosen process methodology as it pertains to the known downstream aquatic organisms. Compounding this analysis, the rapid volatilization of styrene in the environment has to be taken into account. Acute toxicity studies, by their nature, hold the concentrations of the "toxins" under scrutiny at a constant level for the reported study period; inconsistent with styrene's high volatilization rate in the real world. Further supporting this self diminishing impact is the fact that styrene has been confirmed to be *not bioaccumulative*.

In VTRC 08-R16 the researchers state that a literature review revealed that spills of uncured resin from CIPP installations can cause large fish kills. As an example of this fact they cited a Lockheed Martin Energy Systems internal report dated August 17, 1995, that recounted the installation of 280 linear feet of 36-inch diameter CIPP into a stormwater pipe. The CIPP was cured using hot water and during processing it was estimated that "approximately three to four gallons of uncured resin extruded into the manhole at the lower end of the liner …" Because the stormwater system under rehabilitation discharged into the East Fork Poplar Creek, the project's engineer directed the installer to hold the process water in the cured liner until it reached a temperature of 72 F before discharging it into the downstream piping and subsequent holding lake. Normally, the installer's processing steps called for cutting a 2-inch diameter hole to allow the 90-100 F water to drain slowly from the cured lined which had been demonstrated to cure "the extruded uncured resin causing it to precipitate out as an insoluble solid". The post installation discovery of a fish kill in the East Fork Poplar Creek having a measured dead count of 5500 fish was quickly attributed to a styrene release when a quantity of uncured resin was found in the downstream manhole of the lining work. The concentration level of the water in the manhole was around 100ppm. Curiously, the styrene concentration in the holding lake at this same point in time was found to be 0.066ppm; and the outfall point to the creek was not sampled. No information was given in the posted report to ascertain the validity of the assumption that styrene was indeed the culprit. Certainly a discharge containing 0.066ppm would not have triggered such an occurrence. On a positive note the report's author stated that, "After dead fish were observed, actions were implemented to remove the uncured resins from the creek and the storm drainage system. The creek, lake, and aquatic life returned to normal conditions after the cleanup efforts were completed." VTRC 08-R16's authors went on to state in their opinion that "Except in the immediate vicinity of a spill, exposures to styrene are not deemed to cause deleterious effects on natural communities of organisms. Styrene volatilizes rapidly and has not been shown to bioaccumulate in organisms to any measurable extent." Further, they related other bodies of work that had shown that styrene "introduced in river water in concentrations up to 37mg/L was reduced [naturally] by 99 percent after 20 days." And that "Fu and Alexander found that 50 percent of 2 to 10mg/L was lost by volatilization in 1 to 3 hours in lake water samples." Common sense tells one that while styrene can indeed kill fish and other aquatic organisms, the risks are essentially nil when proper housekeeping practices are in use to contain, pick up and dispose of any uncured resin that occurs during the installation of the CIPP. While this one incident was cited in the report, it's hard to find any other writings of styrene related fish kills caused by CIPP installations. There are numerous examples of this happening at resin manufacturing and processing facilities; but none that I could find for CIPP.

There were seven CIPP installation sites monitored for VTRC 08– R16 representing the installation practices of three CIPP installers. None of the installations chosen represented curing the CIPP by hot water or UV light; only sites utilizing the steam curing method were evaluated. Further, no review was made of the various installers curing expertise or confirmation of the resultant CIPP's percent of cure. Being culvert installations, the sites were classified as having low intermittent flow, low to medium continual flow, low to heavy continual flow, and medium to heavy continual flow. The

timing of the samples taken to measure the styrene content in the downstream waterway was varied; and in some cases no measurements were made until 15 days after the installation. At site number 4, the stormwater pipe only carried flow during rainfall events so the researchers chose to *pour one gallon of distilled water into the inlet of the pipe and capture it on the outlet end*; that's one gallon of water running through 121 linear feet of 24-inch diameter pipe. While the researchers stated that upstream samples were taken at sites 2, 5, and 7 at the commencement of testing, upstream samples were not taken at sites 1, 3, 4, and 6 at the commencement of their monitoring; nor were any upstream samples taken throughout the course of the study which could have provided the user of the report with confidence that the styrene concentrations were the resultant of the newly installed CIPP. This fact was particularly disturbing to the NASSCO styrene task group as the flows carried by these stormwater installations carry flow from the roadway; and automobile emissions are a known source of styrene in the environment. A condensed presentation of the styrene concentrations found by the researchers is shown in the table below.

Site #	Upstream	At Outlet	Post Curing, Conc. in ppm/Days after installation			
		(Condensate)				
1	N.R.	29	4.9/1	3.1/8	.009/32	
2	N.R.	31	1.2/1	44/6	22/24	1.4/50
3	N.R.	77	2.2/5	<0.005/23		
4	N.R.	N.R.	0.006/37	0.71/71	<0.005/88	
5	N.R.	N.R.	<0.005/15	<0.005/30		
6	N.R.	N.R.	43/15	0.14/44	<0.005/56	
7	N.R.	N.R.	<0.0058/16	<0.005/31		

What is the assimilative capacity of the seven project sites investigated? No analyses were made by the researchers.

Were there any observed fish kills or other environmental impact to these project sites? None were reported by the researchers.

As these are stormwater pipes, the contaminate loading rates should have been assessed based upon the assimilative capacity of the receiving waterway and the aquatic species therein. Instead, the concentrations measured by singly taken grab samples were compared against the maximum contaminant level for styrene in treated drinking water; o.1ppm. Additionally, we were provided with reference levels of styrene concentration for the water flea (48-hour E_{50}) and rainbow trout (96-hour LC_{50}). From the lack of documented environmental impacts at these sites one can logically conclude that the assimilative capacities of the receiving waterways were in fact not exceeded by the direct discharge of the measured styrene concentrations from these CIPP processing operations, or by the subsequent styrene concentrations measured in the stormwater flushing of the newly installed CIPP.

VTRC 08-R16's preliminary findings issued in mid, 2007 were that the VA DOT should suspend the use of styrene-based CIPP and undertake additional study to understand

CIPP, that the DOT should evaluate their contract documents to ensure that CIPP contractors are specifically required to prevent the escape or leaching of process residuals (capturing and properly disposing of cure water, cure steam condensate, and escaped resin), and if styrene-based CIPP is re-instated that the DOT should ensure that it has proper oversight on hand during the CIPP's installation. As a result of these findings and the researchers' recommendations, the following notable changes were issued by the VA DOT in April of 2008:

1. A project inspector, properly trained in CIPP, must be present for the duration of each installation.

2. The contractor must obtain and comply with all discharge related permits, including air, water, and wastewater treatment

3. Styrene resin based CIPP systems must have an impermeable inner and outer plastic film or plastic pre-liner to promote complete polymerization, prevent resin migration and loss, and prevent styrene contamination of the interior of the finished product.

4. For styrene resin based systems, the contractor shall place an impermeable sheet immediately upstream and downstream of the host pipe to capture any raw resin spillage during installation and shall remove and properly dispose of any waste materials

5. The contractor must submit preconstruction installation and cure specifications. Included therein shall be the requirement for monitoring temperature via a minimum of three thermocouples on the outer surface of the liner (one at the upstream end, one at the downstream end, and one at the approximate midpoint of the lining). The thermocouples shall be connected to a data logger capable of producing a print-out which shall be given to the project inspector.

6. Additional lining materials and measures to ensure the containment of resin and styrene

7. Procedures for monitoring the curing of the CIPP lining material

8. Thorough rinsing of the finished CIPP

9. The contractor shall capture and properly dispose of cure water, cure condensate, and rinse water by transporting it to an off-site disposal location

10. Water and soil testing to be done prior to and after installation. Samples shall be taken within three feet of both ends of the pipeline being rehabilitated. The post installation sampling must be accomplished within one week of the installation.

The results of the impact of the above made changes to the VA DOT's specifications have essentially been mixed. Some installers already had a policy in place to transport and dispose of the process water from hot water curing at a nearby wastewater

treatment facility because of the lack of definitive information on the process water's potential environmental impact and the general public's fear of chemicals that smell. Steam condensate is not typically transported away. Appropriate permits were obtained in the past by most installers; the question going forward is, "Have they been missing any required permitting?" In the short-term the requirements have resulted in some of the installers not bidding the DOT's projects while they sort out these new requirements. Those that are continuing to bid the work say the pricing of the work has approximately doubled since their implementation. The environmental costs to transport the water used in the CIPP processing (increased engine emissions, diesel usage, etc) have not been quantified. It is logical to conclude, however, that there has been a negative environmental and economical cost to the new requirements as the DOT has chosen to implement them. Is this added cost technically justified?

In the newly issued NASSCO *Guideline for the Use and Handling of Styrenated Resins in Cured-In-Place-Pipe* the guideline's authors concluded that "All CIPP resin systems require that good housekeeping be practiced by the installation team on the project site." Further, provisions must be made by the contractor in advance for containing any accidental spillage of the resin on the work area. By law, spills less than the hazardous materials "reportable quantity" of 1000 pounds of styrene (2500 pounds of resin) are to be handled in a responsible manner by the contractor. Absorption with an inert material and placing in an appropriate waste disposal container is the industry standard for handling small spills like this on the ground. Oil dry, kitty litter and sand work well for this action. If the spill occurs on a hard surface, the area should be scrubbed with soap and water after the bulk of the spill has been cleaned up by the absorbent material. If the spill gets into a waterway, the spill should be contained using a temporary dike. The resin can then be picked up by vacuuming the resin into a vacuum truck and subsequently placed in an appropriate waste disposal container.

It is imperative that the processing of the liner, whichever method of curing is used, is properly completed. Properly cured liners release little or no styrene to the environment. Thermocouples placed strategically in the liner-host pipe interface are a must. A written curing schedule developed for a CIPP system acknowledging the conditions that can be present in the curing environment and the resin system proposed will lead to a proper cure and a long CIPP life; and, in this author's opinion, no measurable environmental impact.

In the NASSCO guideline proper curing and handling of CIPP systems is recommended to be done using the following steps:

Water Curing

Sanitary Sewers

1. Cure resin system per written curing schedule
2. Release process water to the sewer after per industry standards during/after cool-down.

Storm Sewers and Culverts

1. Cure resin systems per written curing schedule
2. Based upon receiving waterway's assimilate capabilities
    a. Discharge water once at ambient air temperature

b. Discharge water once styrene concentration is confirmed to be at or below 25ppm; or
c. Transport process water to nearest wastewater treatment facility

Steam Curing

Sanitary Sewers

1. Cure resin system per written curing schedule
2. Release condensate water directly to receiving sewer while processing

Storm Sewers and Culverts

1. Cure resin system per written curing schedule
2. Based upon receiving waterway's assimilative capabilities
    a. Detain condensate in a lined holding pond until it cools to ambient
    b. Discharge water once styrene concentration is confirmed to be less than 25ppm; or
    c. Retrieve condensate by pumping it into the steam generation truck's reservoir; or
    d. Transport condensate to nearest wastewater treatment facility.

Using the above recommendations, any residual styrene concentrations from a properly cured resin system that are taken into the runoff water from storm events will typically be short-lived, in the range of less than 1.0ppm and therefore pose no significant environmental threat.

The VA DOT had a real opportunity to provide the industry with an independent review of its practices and refine them as needed to preserve their cost-effective (and environmentally-effective) usage. The report falls short on this and the conclusions reached were not based on sound engineering principles. The end result is a document that is misleading to the general public and of little use to the technical community without a lot of work to sort out the test results and what guidance they may provide.

APPENDIX C

Environmental Implications of Cured-in-Place Pipe Rehabilitation Technology

Bridget M. Donaldson

Cured-in-place pipe (CIPP) technology is commonly used for pipe rehabilitation, and transportation agencies are increasingly using it to repair damaged pipe culverts. In typical CIPP applications, a lining tube saturated with a styrene-based thermosetting resin is installed into the damaged pipe. Subsequent curing with a heat source results in a pipe within a pipe. In this study, seven styrene-based, steam-cured CIPP installations in surface water and storm water conveyances in Virginia were identified and observed over the course of 1 year. Although the sites were not directly linked to sources of drinking water, styrene levels at five sites were higher than the Environmental Protection Agency's maximum contaminant level for drinking water of 0.1 mg/L. These concentrations were detected at these sites for a minimum of 5 days to 71 days after installation. Certain measurements were also found to exceed the concentration required to kill 50% of several freshwater aquatic indicator species. The findings suggest that the elevated styrene levels could have resulted from one or a combination of the following: (*a*) installation practices that did not capture condensate containing styrene, (*b*) uncured resin that escaped from the liner during installation, (*c*) insufficient curing of the resin, and (*d*) some degree of permeability in the lining material. In response to the preliminary findings of this study, the Virginia Department of Transportation suspended the use of styrene CIPP for conveying surface or storm water while the department further evaluated CIPP repair and subsequently developed new requirements for these installations.

Because many pipes and culverts were placed more than 20 years ago, repair or replacement of damaged or worn pipes is becoming a large maintenance concern in the United States. Cured-in-place pipe (CIPP) rehabilitation is one of several "trenchless" pipe repair technologies that allow users to repair existing underground pipes in place rather than their using the conventional method of unearthing and replacing sections of damaged pipe. Trenchless technologies were first developed about 25 years ago and were used primarily in Western Europe until about 15 years ago, when departments of transportation and construction outfits in North America began to use them (*1*). In the mid-1990s, when the City of Houston, Texas, undertook a major overhaul of its sewer system, contractors used trenchless methods for 87% of the repairs, involving millions of feet of pipeline. Of the many trenchless methods available, contractors used CIPP technology significantly more than any other in situ pipe rehabilitation method (*2*). CIPP repair dominates the underground pipe rehabilitation industry (*3*), and both above- and underground CIPP rehabilitation is common worldwide. The CIPP business was pioneered by Insituform Technologies, Inc., which now performs projects for industries and municipalities in 40 countries and for transportation agencies in 36 U.S. states (*4*).

Despite its widespread and frequent use, little has been investigated about the environmental impact of CIPP technology on surface water or aquatic habitat. Although literature on the mechanisms involved in CIPP rehabilitation is readily available, studies have not been published that relate to the potential environmental impacts of effluent leaked or discharged downstream or chemicals leached from the cured pipe after the installation is completed. Of particular concern are the potential effects of styrene, which is commonly used as a main component of the resin that saturates the lining tube. Styrene is classified by the U.S. Environmental Protection Agency (EPA) as a mutagen and is thus potentially carcinogenic (*5*). In certain concentrations, styrene is toxic to aquatic species (*6–9*).

The Virginia Department of Transportation (VDOT) uses CIPP repair technology for many of its pipes that convey streams or storm water beneath or along roads. VDOT uses CIPP rehabilitation more than any other pipe repair method and issues contracts to several companies to perform this work (S. L. Hite, unpublished data).

BACKGROUND

Procedures and Materials for CIPP Installations

Typical CIPP operations begin with the project setup, which includes measures to prevent water flow through the damaged host pipe. ASTM standards for CIPP procedures specify that bypassing or diverting the flow should be done by pumping the flow to a downstream point (*10, 11*). Rocks and debris are then removed from the pipe. The next phase of the operation is liner insertion. The resin-saturated liner, which has been transported from the factory via a refrigerated truck, is inserted into the host pipe. Depending on the company, the liner is either pulled or inverted through the host pipe. Inversion is accomplished by forcing air into one end of the liner, causing the liner to turn inside-out as it travels the length of the host pipe. The liner is expanded to conform to the inner dimensions of the host pipe and is subsequently cured to form a pipe within a pipe. Typical curing is achieved by circulating heated water or steam through the pipe to polymerize the resin material. The curing process takes up to several hours, depending on the size of the pipe. It and the subsequent cool-down period generate spent process water or steam condensate. ASTM standards (*10, 11*) specify that, during the cool-down period, hot water or steam effluent should be drained through a small hole in the downstream end of the pipe and cool water should be introduced as a replacement. Following the cool-down period, the closed ends of the cured liner are cut open, and generally a video camera is inserted into

Virginia Transportation Research Council, 530 Edgemont Road, Charlottesville, VA 22903. Bridget.Donaldson@VDOT.Virginia.gov.

Transportation Research Record: Journal of the Transportation Research Board, No. 2123, Transportation Research Board of the National Academies, Washington, D.C., 2009, pp. 172–179.
DOI: 10.3141/2123-19

the pipe for a final inspection. A more detailed explanation of CIPP procedures is provided in ASTM F1743-96 (*10*), ASTM F1216-07b (*11*), and ASTM D5813-04 (*12*). These three standards contain a caveat that "it is the responsibility of the user to establish appropriate safety and health practices and determine applicability of regulatory limitations prior to use" (*10–12*).

The pipe lining material used in CIPP operations is composed of absorbent nonwoven felt fabric that is presaturated (at the manufacturing facility) with a thermosetting resin. Typically, the liner tube has a membrane coating to protect and contain the resin; the membrane is generally a flexible thermoplastic, such as polyethylene or polyurethane (*3*). This coating is normally only on the inner surface of the finished product. This arrangement allows the resin to migrate into any voids, such as joints or cracks, in the host pipe before curing. Three types of resins are typically used in CIPP applications: unsaturated polyester resins, vinyl ester resins, and epoxies (*3*). Unsaturated polyester resin and vinyl ester resins are the most common and contain styrene; epoxies do not.

The styrene content of polyester and vinyl ester resins is generally on the order of 30% to 50% (by weight). A material safety data sheet obtained from one vendor shows the styrene content of the resin to be 44% (by weight), with the remaining components made of unspecified polymers (50% to 54%) and colloidal silica (1% to 5%) (*13*).

Standards and Toxicity Studies on Styrene Concentrations in Water

The EPA drinking water standard lists the maximum contaminant level (MCL) for styrene as 0.1 mg/L (0.1 ppm) (*5*). The EPA does not have established regulatory standards for ecological toxicity specifically for styrene concentrations in water. In Canada, however, a section of the British Columbia Environmental Management Act sets limits for toxins in discharged effluent (*14*). Under the act's municipal sewage regulation (which includes regulations for surface water), effluent must not be discharged unless any toxins in the effluent are below the lethal limit for rainbow trout (*Oncorhynchus mykiss*) as determined by Environment Canada's 96-h lethal concentration (LC_{50}) bioassay test method (i.e., the concentration required to kill 50% of the test population after 96 h of exposure to that concentration) for this species (*15*).

Numerous acute toxicity studies have documented the impacts of styrene on aquatic organisms (*6–9*). Table 1 provides a summary of published values for acute styrene toxicity studies for several aquatic indicator species that are found in freshwater habitats throughout the United States. Indicator species are sensitive to pollutants, and their disappearance from a body of water can be indicative of contamination.

The literature reveals that spills of uncured resin from CIPP installations can cause large fish kills. About 3 to 4 gal of uncured resin were released during a CIPP installation (the location of which was not disclosed in the report) on a storm water drain (*16*). The residual uncured resins were carried to a creek, resulting in the death of more than 5,500 fish of various species. Water samples indicated a 100 ppm (100 mg/L) concentration of styrene in the downstream manhole at the project site (*16*). Except in the immediate vicinity of a spill, typical environmental exposures of styrene are not deemed to cause deleterious effects on natural communities of organisms (*17*). Styrene volatilizes rapidly and has not been shown to bioaccumulate in organisms to any measurable extent (*17*). Rates of volatilization are dependent on many factors, including styrene concentration, water temperature, and oxygen availability. Styrene compounds degrade more rapidly once microorganisms adapt to their presence (*17, 18*). Bogacka et al. found that the styrene (and other aromatic hydrocarbons) introduced to river water in concentrations up to 37 mg/L was reduced by 99% after 20 days (*18*). Fu and Alexander found that 50% of 2 to 10 mg/L was lost by volatilization in 1 to 3 h in lake water samples (*19*).

Styrene has a high degree of adsorption onto soils, and although styrene will mineralize to carbon dioxide under aerobic conditions (*19*), some is readily desorbed from soil and can enter groundwater. It is not expected to be transported considerable distances through soil, however, because of its high biodegradability (*19*).

PURPOSE AND SCOPE

The purpose of this study was to evaluate the potential for impacts on water quality from use of the steam-cured CIPP process. Of the thermosetting resins used in CIPP applications, styrene-based resins are the most common. Thus, this research focused on styrene-based CIPP products.

To gather information on the methods used in VDOT's CIPP installations and to analyze the impacts that the process might have on water quality, seven steam-cured CIPP installations in Virginia were identified and observed over the course of a 1-year study. Water

TABLE 1 Styrene Toxicities for Various Freshwater Indicator Species

Aquatic Species	LC_{50} or EC_{50}[a] (mg/L)	NOEC[b] (mg/L)	Reference
Water flea (*Daphnia magna*)	48-h EC_{50}: 4.7	1.9	(*6*)
	48-h EC_{50}: 1.3	0.81	(*7*)
Amphipod (*Hyalella azteca*)	96-h LC_{50}: 9.5	4.1	(*6*)
Fathead minnow (*Pimephales promelas*)	96-h LC_{50}: 5.2	2.6	(*7*)
	96-h LC_{50}: 10	4	(*8*)
Rainbow trout (*Oncorhynchus mykiss*)	96-h LC_{50}: 2.5	N/A	(*9*)
Freshwater green algae (*Selenastrum capricornutum*)	96-h EC_{50}: 0.72	0.063	(*6*)
	72-h EC_{50}: 2.3	0.53	(*7*)

[a]Lethal concentration (LC_{50}) and effective concentration (EC_{50}), or the concentration required to kill (LC_{50}) or have a defined effect (EC_{50}) on 50% of the test population after a given number of hours of exposure in that concentration.
[b]No observable effect concentration, or the highest limit at which no mortalities or abnormalities were observed.

samples were collected from each project site and analyzed for styrene. The results were then evaluated for compliance with established regulatory standards and published aquatic toxicity criteria.

METHODS

Seven CIPP installations were identified within the Piedmont and Blue Ridge physiographic provinces of Virginia, and water samples were collected over the course of this 1-year study (Table 2). The installations were conducted by three primary companies that perform CIPP rehabilitation in Virginia. All project sites were surface water conveyances in which the pipe inlet and outlet were exposed, with the exception of Site 4, which was an entirely subsurface storm water conveyance. None of these sites directly links to a source of drinking water.

Field Observations

Project sites were observed during CIPP installations and at various periods after the installations were complete. Because the CIPP installations observed continued up to 30 consecutive hours and because of the distance between the project sites, the author could not be present to collect samples at consistent intervals during and after all installations. Observations of incidents that could potentially result in adverse impacts to water quality were documented.

Water Samples

A control sample was collected from the water within 1 m of the pipe outlet at Sites 1, 3, and 4 immediately before CIPP installations. At sites that were not monitored until the installation was under way (Site 2) or until 15 to 16 days after installation (Sites 5 to 7), a control sample was collected after installation at least 10 m upstream from the pipe inlet. Water samples were collected at various intervals during installation at Sites 1, 2, and 3 and at various intervals after installation at all seven sites. During each sampling period, a sample was taken from the water within 1 m of the pipe outlet. During some sampling periods at five of the six surface water sites (Sites 1, 2, 3, 5, and 7), samples were also taken from the water 5 to 40 m downstream. At Sites 2 and 3, a sample was taken from the stream water within 1 m of the outlet during steam condensate release. Water samples were collected, depending on the site, for 30 to 116 days after CIPP installation, until the styrene concentration at the site was below the reporting limit (0.005 mg/L) of the primary laboratory (Microbac) used in this study.

The subsurface storm water pipe at Site 4 conveyed water only during rain events. Because it was difficult to time-sample collections with rain events, a rain event was simulated for each sampling period by pouring 1 gal of distilled water into the inlet of the repaired section of pipe and capturing the water as it flowed out of the outlet of the pipe section.

All samples were collected into 40-ml volatile organic analysis vials with HCl preservative. The samples were packed on ice and sent to the laboratory via an overnight courier service. All samples were analyzed by Microbac Laboratories in Baltimore, Maryland, for styrene in accordance with the EPA's SW-846 Method 8260B (*20*). Samples collected at the last one to two sampling periods from Sites 1, 4, 5, 6, and 7 were also sent to Air, Water, and Soil Laboratories, Inc., in Richmond, Virginia. These samples were also packed on ice and sent to the laboratory via an overnight courier service. Sample analyses were blind in that locations and project descriptions were not disclosed to either laboratory.

RESULTS

Field Observations

Table 3 lists observations during and following CIPP operations at Sites 1 through 4, including descriptions of post-project conditions shown in Figure 1.

The author observed effluent from the steam condensate being discharged downstream by workers at Sites 2 and 3. At Sites 1, 3, and 4, the author observed uncured resin residue waste immediately outside the pipe outlet or inlet. A sample of the uncured resin left in the streambed at Site 1 (collected 1 day after installation) had a styrene concentration of 580 mg/L.

TABLE 2 Project Descriptions for Seven CIPP Installations in Virginia

Site	County	Route No.	Pipe Size		Project
			Diameter (in.)	Length (ft)	
1	Spotsylvania	1316	36	71	Conveys an unnamed tributary drainage to Massaponax Creek. Drains into concrete-lined ditch. Continual flow.
2	Prince Edward	15	18	60	Conveys an unnamed tributary drainage to Briery Creek. Drains into earthen ditch. Intermittent flow.
3	Prince Edward	628	30	100	Conveys an unnamed tributary drainage to Dickenson branch of Briery Creek. Drains into stream bed. Continual flow.
4	Albemarle	1722	24	121	Conveys stormwater entirely below ground. Drains into stormwater pond. Intermittent flow.
5	Nottoway	460	15	112	Conveys an unnamed tributary drainage to Lazaretto Creek. Drains into stream bed. Continual flow.
6	Nottoway	460 (business)	18	64	Conveys an unnamed tributary drainage to Jacks Branch. Drains into stream bed. Intermittent flow.
7	Nottoway	613	30	60	Conveys an unnamed tributary drainage to Deep Creek. Drains into stream bed. Continual flow.

TABLE 3 Environmental Observations for Four CIPP Installations for Surface Water Conveyances

Site	Stream Flow Management	Curing Method	Effluent (Steam Condensate) Disposal Method	Postproject Conditions
1	Temporary dam	Steam	Not observed (authors not present at this stage of installation)	Extruded resin in stream (Figure 1*a*); algal blooms present at pipe outlet (0 to 10 m downstream, Figure 1*a*); residue present at pipe outlet (present at each sampling period up to study's end).
2	None necessary (dry pipe at time of installation)	Steam	Discharged by workers in stream (see associated water sample results in Figure 2)	Algal blooms present at pipe outlet (0 to 5 m downstream); residue present at pipe outlet (present at each sampling period up to study's end).
3	Temporary dam	Steam	Discharged by workers in stream (see associated water sample results in Figure 2)	Extruded resin in stream (Figure 1*b*); algal blooms present at pipe outlet (0 to 50 m downstream); residue present at pipe outlet (present at each sampling period up to study's end).
4	None necessary (dry pipe at time of installation)	Steam	Not observed (authors not present at this stage of installation)	Extruded resin just outside of pipe inlet (present at each sampling period up to study's end).

At Sites 1, 2, and 3, algal blooms were apparent within 6 to 8 days after installation (A. L. Mills, unpublished data); algae were not visible at any of these sites when visited before the CIPP installation and were not present upstream of the installation. (The other three surface water sites in this study were not monitored until 15 and 16 days after installation; algal blooms were not visible at these sites.) Algae appeared most dense at the pipe outlet (occurring up to 8 in. below the water surface), and the density decreased further downstream; the algae were present in clusters up to 50 m downstream from the repaired pipe section. Although the density of algal blooms appeared to decrease over time, blooms were observed 50 to 55 days after installation. Blooms were no longer visible 78 to 88 days after installation.

Water Samples

Styrene concentrations in all control samples were below the reporting limit (0.005 mg/L) of the primary laboratory used in this study. Samples were collected until styrene concentrations were below the reporting limit at all sites. Samples collected at the pipe outlet often contained residue that was visible on the water surface after installation.

Figure 2 provides styrene concentrations at all sites compared with the MCL of drinking water (0.1 mg/L) and with the median effective concentration (EC_{50}) required to induce a 50% effect) or LC_{50} values for two aquatic species (as detailed in Table 1), and the laboratory reporting limit (0.005 mg/L), with the horizontal lines indicating the MCL of drinking water (0.1 mg/L). For styrene concentrations

(a) (b)

FIGURE 1 Uncured resin waste (*a*) at Site 1 (gray substance adjacent to outlet and along rocks on right side of image), 1 week after installation, with algal blooms (brown cloudy substance in water) also visible, and (*b*) extruded during installation (white substance adjacent to pipeliner and in water) just before pipe end was cut.

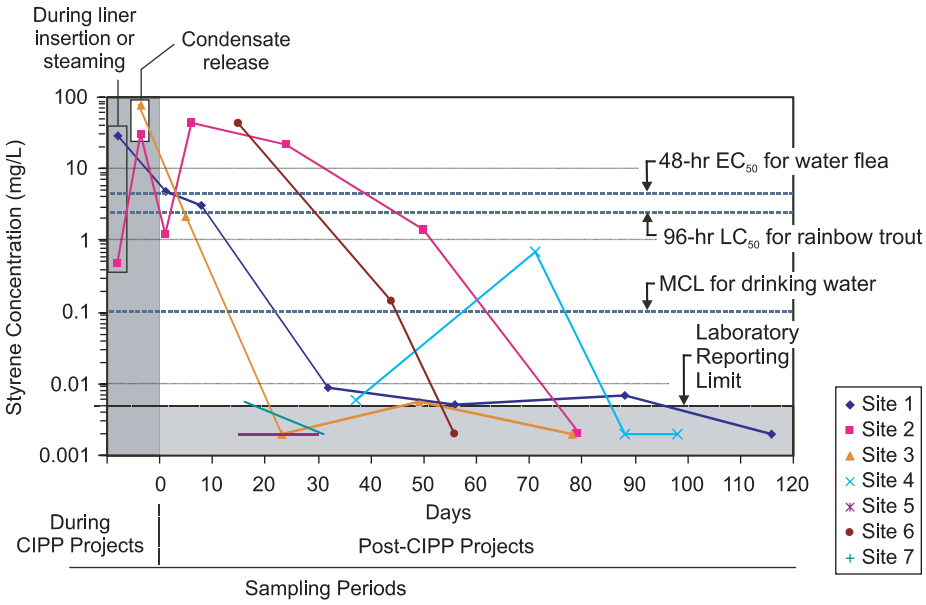


FIGURE 2 Styrene concentrations in water samples collected at pipe outlet during installation and at sampling periods up to 116 days after installation.

below the laboratory reporting limit, the data points shown merely indicate that sampling occurred and that the results were below the limit of 0.005 mg/L; they do not indicate the true concentration value. Samples for three sites were taken during installation, and samples for all sites were taken at various intervals after installation. No compounds other than styrene were detected in the laboratory analyses.

The results indicate that styrene concentrations were generally highest in water samples collected during installation, although comparable levels were detected at some sites several days after installation. The highest concentration (77 mg/L) was recorded at Site 3 at the outlet while steam condensate was discharged during the installation process.

Styrene concentrations and the duration of styrene's detectable presence were highly variable among sites. Samples from some sites did not show a consistent decrease in concentration, particularly at sites with low or intermittent water flow. Although none of the sites was directly linked to a source of drinking water, styrene concentrations exceeding the MCL for drinking water were measured at five of the seven study sites. The concentrations at Sites 1, 2, 3, and 6 exceeded the MCL for drinking water (0.1 mg/L) at sampling periods of 5 to 50 days after installation, and at Site 4, the concentration exceeded the MCL 71 days after installation during a period of very low flow. The maximum styrene concentrations at four sites (Sites 1, 2, 3, and 6) exceeded published EC_{50} or LC_{50} values (Table 1) for various aquatic species. At Site 2, the concentration exceeded these values for the water flea and the rainbow trout for the sampling period of 24 days.

DISCUSSION OF RESULTS

Specific Observations

At certain times after CIPP installation, styrene concentrations exceeded the MCL for drinking water at five of the seven study sites and exceeded the EC_{50} or LC_{50} values of the water flea (*6*) and the rainbow trout (*9*) (common indicator species) at four of the monitored project sites. Compared with samples collected from sites with continual water flow, samples from sites with intermittent flow contained relatively higher styrene concentrations for a greater length of time after CIPP installation. This observation suggests that flow volume and regularity are important factors in diluting styrene concentrations.

At the two sites where styrene was not detected, the initial sample was not collected until 15 and 16 days, respectively, after installation; therefore, it cannot be known whether these installations had any effect on water quality or whether styrene, if indeed present, had decreased to concentrations below detection. At sites where styrene was detected, styrene was above the laboratory reporting limit (0.005 mg/L) at sampling periods 44 to 88 days after installation.

Styrene concentrations reached as high as two orders of magnitude greater than the MCL for drinking water. Concentrations exceeded the MCL for drinking water for at least 5 days after installation at five sites and for at least 44 to 71 days at three of these sites. Concentrations above the MCL were detected up to 40 m downstream. Although the sites in this study do not directly link to a drinking water supply, roadway conveyances often carry water upon which a variety of aquatic species depend. The sample results from five of seven sites exceeded one or more aquatic toxicity criterion (EC_{50} or LC_{50} values, Table 2) for styrene, and concentrations exceeding these values were detected as far as 10 m downstream. Styrene concentrations at one site exceeded the EC_{50} value for the water flea and the LC_{50} value for the rainbow trout for the sampling period of 24 days following installation.

One apparent ecological change during this study was the emergence of algal blooms, which appeared at three surface water sites within 6 to 8 days after CIPP installation and remained at these sites for at least 50 to 55 days postinstallation. Algal blooms are often indicative of poor water quality (commonly from nitrogen or phosphorus pollution) and can have adverse ecological impacts (*21*). The fact that algal blooms were not seen at project sites before CIPP installation could suggest that some aspect of the CIPP process could be a contributing factor for the blooms, but the specific cause

(whether hot–effluent discharge, styrene leaching, factors unrelated to the installations, etc.) is unknown.

As typical CIPP resins contain between 30% and 50% styrene, even a relatively small amount of uncured resin could potentially result in water samples with detectable styrene concentrations at the project site or downstream. Any resin that might be unintentionally released during installation would not have been subject to the same curing conditions as the resin contained within the liner. A sample of the uncured resin waste in the streambed at Site 1 collected 1 day after installation had a styrene concentration of 580 mg/L. Styrene was detected at sites even where resin waste was either not released or had washed downstream; styrene was also detected at sites long after observed discharges of steam condensate had been flushed downstream. These observations, coupled with the length of time styrene was detected after installation, suggest that these installation practices (i.e., uncured extruded resin and discharge of the steam condensate effluent) were not solely accountable for the styrene concentrations in water. These findings suggest that the resin-saturated liner was not completely cured during the installation process and continued to leach styrene, perhaps through or around the inner-membrane liner.

Although the scope of this study did not lend itself to definitive determination of the specific contribution of styrene from each aspect of the CIPP process, the styrene concentrations identified in the laboratory tests of water samples may have resulted from one or a combination of the following: (*a*) installation practices that did not capture condensate containing styrene, (*b*) uncured resin that escaped from the liner during installation, (*c*) insufficient curing of the resin, and (*d*) some degree of permeability of the lining material.

Standards and Regulations

Although CIPP technology dominates the underground pipe rehabilitation industry and is a common method for above-ground pipe rehabilitation, only 3 of 85 trenchless pipe rehabilitation standards relate directly to CIPP methods and materials (*3*). ASTM standards for CIPP rehabilitation (*10–12*) do not separate surface water conveyance guidelines from those for sewer lines. They also do not address measures to ensure containment of the resin that saturates the lining material. Although ASTM standards (*10, 11*) contain a caveat that it is the user's responsibility to determine the applicability of regulatory limitations before use of the resin, the standards direct users to dispose of the curing water or condensed steam (effluent) by allowing it to drain from a hole made in the downstream end of the pipe. Again, ASTM standards for CIPP procedures specify that the flow be bypassed or diverted before CIPP installation (*10, 11*).

A culvert pipe liner guide (*22*) published by the FHWA lists existing specifications for pipe repair technologies and provides a decision analysis tool designed to help users choose an appropriate pipe repair method on the basis of various factors. The guide lists some specific environmental limitations of CIPP rehabilitation, including (*a*) possible thermal pollution from the discharge of the curing water, (*b*) potential toxicity of styrene-based resins before completion of the curing process, and (*c*) possible hazards to an environmentally sensitive area. The decision analysis tool addresses such concerns for CIPP technology by assigning it the highest ranking for environmental risk (on a scale of 1 to 5). Neither the guide nor the decision analysis tool, however, provides guidelines or additional specifications (beyond the referenced ASTM standards) to mitigate environmental risks.

The EPA does not have published standards for allowable levels of styrene for receiving streams; however, the discharge of pollutants (which includes chemical wastes) to waters of the United States is regulated (*23*). The discharge of steam condensate or spent cure water into waters of the United States would require a permit under the National Pollution Discharge Elimination System (NPDES) or state equivalent (*23, 24*). The permit conditions may require pretreatment and monitoring before any discharge. State environmental regulatory agencies also typically have additional statutory or regulatory authority or both to prevent or regulate the discharge of pollutants to state receiving waters, including groundwater (*25*). Although state or federal agencies could use published water quality standards, such as the relevant MCL, or published aquatic toxicity criteria to determine acceptable styrene levels, it is unclear what, if any, environmental regulation would govern the leaching of styrene from a finished CIPP product.

ACTIONS BY VDOT IN RESPONSE TO PRELIMINARY RESEARCH FINDINGS

VDOT took several actions upon receiving the preliminary research findings of this study:

1. VDOT's chief engineer immediately placed a stop work order on all styrene-based CIPP repair projects contracted by VDOT (*26*). VDOT subsequently elected to allow CIPP installations on sanitary sewer projects (under certain conditions) while continuing to review the use of styrene-based CIPP repair (*27*).
2. A VDOT task group led by VDOT's Environmental Division was formed to evaluate further the use of steam- and water-CIPP repair projects containing styrene. Task group participants included members of VDOT's Scheduling and Contract, Administrative Services, Materials, and Asset Management Divisions, as well as scientists from the Virginia Transportation Research Council (VTRC). Information gained from this evaluation was to be used to provide VDOT with recommendations for further action related to the use of styrene-based CIPP technology.
3. The task group conducted the evaluation, which included (*a*) acquiring the services of an independent environmental consultant to provide third-party verification of the preliminary study findings and to test additional CIPP sites, (*b*) meeting with the Virginia Department of Environmental Quality for support and guidance, and (*c*) holding two series of interviews with CIPP industry representatives.
4. The task group issued its evaluation report to the Office of the Commonwealth Transportation Commissioner in November 2007. The report provided recommendations about the modification of VDOT's CIPP contracting specifications, project management considerations, and conditions for reinstatement of styrene-based rehabilitation (*28*). The recommendations were primarily designed to prevent the unintentional release of styrene-based resin during installation and the leaching of styrene from the finished product.
5. The Office of the Commonwealth Transportation Commissioner charged VDOT's Scheduling and Contract Division with developing an action plan to implement the recommendations outlined in the task group report. In April 2008, these recommendations were implemented and are incorporated in a VDOT memorandum that includes revised CIPP specifications (*29*). These specifications include the following measures:

   – A requirement that a VDOT project inspector (who has undergone a CIPP training program) provide oversight of CIPP installations for the duration of each installation;

   – The acquisition of discharge-related permits, including air, water, and wastewater treatment;

– Requirements for compliance with ASTM and other applicable standards;

– A requirement that all CIPP installations be performed "in the dry" (i.e., no water contained or conveyed in the pipe during installation);

– A requirement that the contractor submit preconstruction installation and cure specifications;

– Additional lining materials and measures to ensure the containment of resin and styrene;

– Procedures for monitoring the curing of the CIPP lining material;

– Thorough rinsing of the finished product;

– Proper disposal of cure water, cure condensate, and rinsate; and

– Requirements for water and soil testing before and after installation.

Statewide VDOT CIPP installations using the new procedures and specifications (*29*) were reinstated in June 2008. These actions are part of VDOT's ongoing effort to prevent the risks associated with styrene-based CIPP technology and, in doing so, to ensure due diligence by VDOT for the protection of the public health and safety as well as the environment.

CONCLUSIONS

- The use of styrene-based CIPP technologies may result in detectable levels of styrene at and near the work site of the CIPP installation. In this study, styrene was detected in water samples collected from the pipe outlet during or after installation at five of the seven CIPP installations monitored in this study. Styrene concentrations in water samples ranged from <0.005 mg/L to 77 mg/L and were generally highest in samples collected during and shortly after installation. The maximum time styrene was detected at any site was 88 days following CIPP installation.
- Although further research is needed to discern the contribution from each potential source of styrene, the findings suggest that the elevated styrene levels could have resulted from one or a combination of the following: (*a*) installation practices that did not capture condensate containing styrene, (*b*) uncured resin that escaped from the liner during installation, (*c*) insufficient curing of the resin, and (*d*) some degree of permeability in the lining material. These factors appear to pose a risk of negative impacts from the use of styrene-based CIPP technologies.
- Under the observed conditions, styrene concentrations could result in violations of state or federal environmental standards or both. Although the EPA does not have published standards for allowable levels of styrene for receiving streams, the discharge of pollutants to waters of the United States is regulated under the NPDES permit program.
- Research on the ecological and species effects of chronic styrene exposure in natural conditions would be useful so as to foster an understanding of the potential impacts. These studies should also look at the factors that would create conditions leading to algal blooms.

ACKNOWLEDGMENTS

The author is grateful for the help from many VDOT employees. Ed Wallingford and Stanley Hite were valuable sources of information for this project. Appreciation is also extended to Shamsi Taghavi and David Bova for their assistance with sampling and to Ken Winter and Bryan Campbell of VDOT's Research Library for directing the author to numerous useful sources. Robert Harmon, Joseph Miller, Chris Jackson, William Bailey, Marek Pawlowski, and Michael Gosselin were helpful in providing information on the CIPP process and projects. Thanks also go to Aaron Mills of the University of Virginia for his assistance with algae identification and to Linda Evans, Ed Wallingford, Gary Allen, Michael Perfater, Bruce Carlson, G. Michael Fitch, and Amy O'Leary for providing helpful comments on an earlier version of the report. The author appreciates the opportunity provided by VDOT and VTRC to conduct this study.

REFERENCES

1. Lueke, J. S., and S. T. Ariaratnam. Rehabilitation of Underground Infrastructure Utilizing Trenchless Pipe Replacement. *Practice Periodical on Structural Design and Construction,* Vol. 6, No. 1, 2001, pp. 25–34.
2. Wright, A. G. Houston Hustles for Drier Ground. *Engineering News–Record,* Vol. 235, No. 16, 1995, pp. 25–32.
3. Hoffstadt, F. A. Cured-in-Place Pipe Structure in Infrastructure Rehabilitation. *Proc., 45th International SAMPE Symposium.* SAMPE Publishing, Covina, Calif., 2000.
4. Company Information. *Insituform Technologies.* Insituform.com/content/137/company_information.aspx. Accessed June 12, 2007.
5. *Technical Factsheet on Styrene.* U.S. Environmental Protection Agency. www.epa.gov/safewater/dwh/t-voc/styrene.html/. Accessed June 17, 2007.
6. Cushman, J. R., G. A. Rausina, G. Cruzan, J. Gilbert, E. Williams, M. C. Harrass, J. V. Sousa, A. E. Putt, N. A. Garvey, J. P. S. Laurent, J. R. Hoberg, and M. W. Machado. Ecotoxicity Hazard Assessment of Styrene. *Ecotoxicology and Environmental Safety,* Vol. 37, No. 2, 1997, pp. 173–180.
7. Baer, K. N., R. L. Boeri, T. J. Ward, and D. W. Dixon. Aquatic Toxicity Evaluation of Para-Methylstyrene. *Ecotoxicology and Environmental Safety,* Vol. 53, No. 3, 2002, pp. 432–438.
8. Machado, M. W. *Styrene-Acute Toxicity to Fathead Minnow (Pimephales promelas) Under Flow-Through Conditions.* Springborn Laboratories, Wareham, Mass., 1995.
9. Qureshi, A. A., K. W. Flood, S. R. Thompson, S. M. Janhurst, C. S. Inniss, and D. A. Rokosh. Comparison of a Luminescent Bacterial Test with Other Bioassays for Determining Toxicity of Pure Compounds and Complex Effluents. *Proc., Fifth Annual Symposium on Aquatic Toxicology and Hazard Assessment* (J. G. Pearson, R. B. Foster, and W. E. Bishop, eds.), American Society for Testing and Materials, Philadelphia, Pa., 1982.
10. ASTM F1743-96: Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation of Cured-in-Place Thermosetting Resin Pipe (CIPP). *ASTM Book of Standards,* Vol. 08.04. ASTM International, West Conshohocken, Pa., 2003.
11. ASTM F1216-07b: Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube. *ASTM Book of Standards,* Vol. 08.04. ASTM International, West Conshohocken, Pa., 2007.
12. ASTM D5813-04: Standard Specification for Cured-in-Place Thermosetting Resin Sewer Piping Systems. *ASTM Book of Standards,* Vol. 08.04. ASTM International, West Conshohocken, Pa., 2004.
13. *Hetron Q 6405 Resin.* MSDS 304.0329320-002.005. Ashland Distribution Co. and Ashland Specialty Chemical Co., Columbus, Ohio, 2005.
14. *Environmental Management Act, Municipal Sewage Regulation.* B.C. Reg. 129/99. Ministry of Environment, Province of British Columbia, Victoria, Canada, 1999. www.qp.gov.bc.ca/statreg/reg/E/EnvMgmt/129_99.htm#part2. Accessed Aug. 8, 2007.
15. *Biological Test Method: Acute Lethality Test Using Rainbow Trout.* Report EPS 1/RM/9 (with 1996 and 2007 amendments). Environment Canada, Ottawa, Ontario, 1990.
16. Fish Kill Resulting from Styrene Resin Spill. In *Lessons Learned Database,* Lockheed Martin Energy Systems. www.hss.energy.gov/csa/analysis/ll/. Accessed June 12, 2007.
17. Alexander, M. Environmental Fate and Effects of Styrene. *Critical Reviews in Environmental Science and Technology,* Vol. 27, No. 4, 1997, pp. 383–410.

18. Bogacka, T., Z. Makowski, and R. Ceglarski. The Breakdown of Aromatic Hydrocarbons in the Aqueous Environment. *Roczniki Panstwowego Zakladu Higieny,* Vol. 48, No. 2, 1997, pp. 149–161.
19. Fu, M. H., and M. Alexander. Biodegration of Styrene in Samples of Natural Environments. *Environmental Science and Technology,* Vol. 26, 1992, pp. 1540–1544.
20. *Method 8260B: Volatile Organic Compounds by Gas Chromatography/ Mass Spectrometry (GC/MS).* U.S. Environmental Protection Agency, 1996. www.epa.gov/epaoswer/hazwaste/test/pdfs/8260b.pdf. Accessed June 12, 2007.
21. *Water Quality Criteria for Nitrogen and Phosphorus Pollution.* U.S. Environmental Protection Agency. www.epa.gov/waterscience/criteria/nutrient/. Accessed June 28, 2007.
22. *Culvert Pipeliner Guide and Specifications.* FHWA-CFL/TD-05-003. Central Federal Lands Highway Division, FHWA, Lakewood, Colo., 2005. www.cflhd.gov/techDevelopment/completed_projects/hydraulics/culvert-pipe-liner/_documents/culvert-pipe-liner-guide-july2005.pdf. Accessed April 15, 2008.
23. *National Pollutant Discharge Elimination System (NPDES).* U.S. Environmental Protection Agency. cfpub.epa.gov/npdes/. Accessed June 12, 2007.
24. *Virginia Pollutant Discharge Elimination System Permit Program.* Virginia Department of Environmental Quality. www.deq.state.va.us/vpdes/homepage.html. Accessed June 12, 2007.
25. *Permits, Fees, and Regulations.* Virginia Department of Environmental Quality. www.deq.state.va.us/vpdes/permitfees.html. Accessed June 12, 2007.
26. Winstead, C. L. *Approved List Number 38, Pipe Rehabilitation Systems: Removal of Styrene-Based Liner from Approved List.* Memorandum MD 296-07. Materials Division, Virginia Department of Transportation, 2007. www.virginiadot.org/business/resources/bu-mat-MD296-07.pdf. Accessed April 15, 2008.
27. Winstead, C. L. *Approved List Number 38, Pipe Rehabilitation Systems: Applications for Styrene-Based Liners.* Memorandum MD 298-07. Materials Division, Virginia Department of Transportation, 2007. www.virginiadot.org/business/resources/bu-mat-MD298-07.pdf. Accessed April 15, 2008.
28. *Evaluation of the Use of Styrene-Based CIPP.* Task Group, Environmental Division, Virginia Department of Transportation, Richmond, 2007.
29. Coburn, W. B., Jr. *Pipe Replacement or Rehabilitation Contracts: Guidelines for Pipe Culvert Replacement or Rehabilitation—Selection Criteria, Specifications, and Inspection.* Memorandum CD 2008-11. Scheduling and Contract Division, Virginia Department of Transportation, 2008. www.virginiadot.org/business/resources/const/cdmemo-0811.pdf. Accessed April 16, 2008.

The Waste Management and Resource Efficiency in Transportation Committee sponsored publication of this paper.

APPENDIX D

GUIDELINE FOR THE USE AND HANDLING OF STYRENATED RESINS IN CURED-IN-PLACE-PIPE

Prepared by the NASSCO CIPP Committee:

Committee Member:	Title:	Company Affiliation:
▪ Norman E. “Ed” Kampbell	Principal Author	National Liner
▪ Lynn Osborn	Committee Chairman	Insituform Technologies, Inc.
▪ Marc Anctil	President, NASSCO	Logiball, Inc.
▪ Irvin Gemora	Exec.Director, NASSCO	NASSCO, Inc.
▪ Steve Gearhart	Committee Member	CIPP Corporation
▪ Geoff Yothers	Committee Member	Inliner Technologies, Inc.
▪ Greg Laszczynski	Committee Member	Mississippi Textiles Corporation
▪ Gerry Muenchmeyer	Committee Member	Muenchmeyer & Associates Inc.
▪ Kaleel Rahaim	Committee Member	Interplastic Corporation, Inc.
▪ Jim Harris	Committee Member	City of Murfreesboro, TN
▪ Larry Kiest	Committee Member	LMK Enterprises, Inc.

Disclaimer

This document presents a state-of-the-art guideline for the use and handling of styrene based resins in the CIPP pipeline rehabilitation industry. Following these guidelines does not guarantee that environmental damage, property damage, personal injury, or other damage or injury will not occur at, on**,** or near a CIPP installation site. CIPP projects and the associated risks vary tremendously and must be evaluated on a case-by-case basis. Some project circumstances may pose environmental risks completely unassociated with styrene. In addition, downstream sewers and receiving waters are variable, not only from place to place but also from time to time, and the discharge of cure water and condensates must be thoroughly evaluated for each installation. This document is not intended as a substitute for professional advice pertaining to the use and handling of styrene based resins, and it is recommended that a professional be consulted for such purposes. NASSCO makes no warranty of any kind whatsoever, whether express or implied, with respect to the guidelines set forth in this document. NASSCO disclaims any and all liability, including but not limited to property damage, personal injury, or any other manner of damage or injury arising out of the use of this document or the use and handling of styrene based resins in the CIPP pipeline rehabilitation industry.

EXECUTIVE SUMMARY

Styrenated resin systems as they are currently used today in cured in place pipe (CIPP) rehabilitation systems produce a safe and environmentally sound solution to the challenges of the need for restoring the nation's failing infrastructure. While current thought by U.S. academics assessing the overall use of styrene is leaning toward the conclusion that one might "reasonably anticipate styrene to be carcinogenic", a similar study carried out by the ECETOC (European Centre for Econtoxicology and Toxicology of Chemicals) concluded that "the carcinogenic potential of styrene, if one exists at all, is rated so low that occupational or environmental exposure to styrene is unlikely to present any carcinogenic hazard to man." Further, the current U.S. study background information states that there is no clear connection for styrene as a carcinogen until you add in the exposure to butadiene and/or benzene; both of which don't exist in the resin systems used by CIPP installers. The risk associated with styrene's use in CIPP is minimal and well within the Clean Water Acts' original intent of keeping the environment as free as is practical of chemical pollutants. CIPP installation sites managed with good housekeeping will present little opportunity for human health risks and/or environmental risks.

Although styrene occurs naturally in many foods such as cinnamon, coffee, and strawberries, styrene derived from petroleum and natural gas by-products have raised many questions about whether its usage in polyester and vinyl ester resin systems commonly used in CIPP to rehabilitate piping systems has the potential to adversely affect human health and/or the environment. While the CIPP process is a potential source of styrene, studies done to date have concluded that these type resin systems do not appear to be a significant source of styrene or any of the other volatile organic compounds (VOCs) that are typically of concern in occupational or air quality studies.

In a study undertaken by the Toronto Works and Emergency Services in 2001, AirZOne, Inc. conducted an investigation of the airborne concentrations of styrene and 24 other VOCs in eight randomly selected residences during the rehabilitation of sewers with CIPP installation. The study also measured ambient air quality, emissions from manholes and occupational exposure from these compounds. Air sampling was executed in three phases, before, during, and after the CIPP's installation. Styrene levels were elevated significantly during the CIPP installation in just two homes where the homes' traps were engineered to be dry in order to simulate a worst case scenario; the levels, although elevated, proved not to be a health concern. Levels measured in these eight homes were 0.1 to 0.2ppm. Styrene emissions from manholes during the CIPP process ranged from 0.16ppm to 3.2ppm. Personal exposure of the installation personnel in the breathing zone ranged from 0.08 to 0.5ppm. Styrene in the breathing zone was well below the industry's voluntary occupational limit of 50ppm for the installation personnel.

Independent, peer reviewed scientific journals have published numerous studies on the fate of styrene and its natural occurrence in the environment. "Biodegradation of Styrene in Samples of Natural Environments" by Min Hong Fu and Martin Alexander of Cornell University, concluded that styrene will be rapidly destroyed by biodegradation in most environments having oxygen; although the rates may be slow at low concentrations in lake waters and in environments at low pH. "Desorption and Biodegradation of Sorbed Styrene in Soil and Aquifer Solids" by Min Hong Fu, Hilary Mayton, and Martin Alexander of Cornell University, concluded that being broken down by microbes is a major fate mechanism by which styrene is destroyed in soils. The "Ecotoxicity Hazard Assessment of Styrene" by J.R. Cushman concluded that styrene was shown to be moderately toxic to fathead minnows, daphnids, and amphipods. It was further shown to be highly toxic to green algae, and slightly toxic to earthworms. There was no indication of a concern for chronic toxicity based on these studies. Styrene's potential impact on aquatic and soil environments, it was concluded, is significantly mitigated by the rapid rate at which it evaporates and biodegrades in the environment. And finally, Martin Alexander, in his "The Environmental Fate of Styrene", concluded that transport of styrene in nature is "very limited" because of its volatility from soils and surface waters, its rapid destruction in air, and its biodegradation in soils and surface and ground waters.

Because the styrene odor can be detected at such low concentrations (0.4 to 0.75ppm, depending on one's ability to detect odors), styrene's odor can be considered a nuisance to those not used to working around it. Some people are offended by this odor and are fearful of it; even though the concentrations they smell present no harm to them. To minimize odor problems during the installation of CIPP, residents should be advised to ensure that their sewer traps are in a proper state of repair. In cases of damaged, dry, or non-existent traps, the areas or rooms where floor drains or access to traps are located should be ventilated, if possible, by leaving doors or windows open to the outside during the CIPP installation process.

The CIPP installation contractor should practice good housekeeping and protect the project site such that any accidental resin spillage can be cleaned up and properly disposed of by the contractor. Given the nature of these resin systems to resist movement once placed in the tube's fiber matrix only very small quantities should be anticipated; excepting in the case of over-the-hole saturation installations.

The impact of styrene concentrations in the process water when discharged directly into a sewer collection system is insignificant. An eight inch pipeline 650 linear feet in length will discharge approximately 1700 gallons of water to the receiving sewer. At a typical concentration of 20ppm, the resultant discharge would be less than 0.3 pounds of styrene. A 48-inch pipeline 650 linear feet in length will discharge approximately 61,300 gallons of water to the collection system; which, again, amounts to approximately 10.2 pounds of styrene at a concentration level of 20ppm. With the assimilative capabilities of the downstream flows, no harm is thus anticipated to the wastewater treatment works and/or the POTW's discharge requirements.

Based upon the above given discharge quantities of typical CIPP installations, a CIPP installation contractor discharging these same quantities of process water to a ditch or other waterway is expected to meet the requirements of the EPA's small quantity generator exemption. In fact, due to the nomadic nature of the installer's discharges, a case could be made that the discharges fall under the category of non-point source contributions. However, the installation contractor is still advised to consider the negative impacts of the temperature of the water at discharge if the receiving drainage conveyance contains aquatic organisms that can be harmed by the possible sudden drop in available oxygen due to the large temperature difference between the process water and the receiving water body's temperature.

Any time an environmental release of a hazardous substance exceeds its reportable quantity as defined in 40 CFR Part 302, the contractor shall report this release immediately to the National Response Center (NRC). The reportable quantity for styrene per 40 CFR § 302.4 is 1000 pounds (or 2500 pounds of resin). Quantities below this amount are to be handled by the contractor in an expeditious manner; but do not require reporting.

INTRODUCTION

Styrene is the ideal monomer used for cross-linking polyester and vinyl ester resins. Although alternative monomers have been extensively investigated, none of those monomers have matched the overall performance of styrene. Over the last 30 years the increasing awareness of the need to limit the effects of styrene exposure have lead the polyester resin processing industry to pursue strategies to reduce exposure in the manufacturing and processing plant environment. Most, if not close to all, of the studies undertaken to date have centered on these producers and users environments which are dramatically different than the work environment of the CIPP installation contractor. Given the desire to address the rehabilitation industry's need for standards in the proper safe use and handling of styrenated resins for CIPP, NASSCO created a styrene task force to review the technical information available from these studies and current CIPP installation practices to produce this CIPP specific guideline. In addition to this guideline, NASSCO has prepared an Inspector Training Course to properly equip the owner and the project engineer with the necessary knowledge to ensure that a proper installation is achieved which will minimize the potential for release of styrene to the environment.

Polyester and vinyl ester resin systems have been used for more than 35 years in CIPP. During this timeframe there have been no noted serious consequences to their usage in CIPP. However, as no definitive document for these resin systems as used in this specific application existed, the unknown has given rise to speculation as to their safety with respect to the work force involved, the general public when the odors enter the structures connected to the piping under rehabilitation, and to the greater downstream environment from where the work is taking place.

Styrene is a common chemical compound found where we live and work. Indoor sources of styrene emissions include off-gassing of building materials and consumer products and tobacco smoke. Styrene is emitted from glued carpet, floor waxes and polishes, paints, adhesives, putty, etc.; and infiltration of gasoline-related VOCs from attached garages is well documented.

Styrene, with its low vapor pressure, is expected to exist solely as a vapor in the ambient atmosphere (Hazardous Substances Data Bank 2008). In its vapor phase it is expected to react rapidly with hydroxyl radicals and with ozone. Half-lives based on these reactions have been estimated to range from 0.5 to 17.0 hours (Luderer et al. 2005). Atmospheric washout (the removal from the atmosphere of gases and sometimes particles by their solution in or attachment to raindrops as they fall) is not expected to be an important process because of these rapid reaction rates and styrene's relatively high Henry's law constant (the extent to which a gas dissolves into a liquid is proportional to its vapor pressure). Outdoor air monitoring by the EPA for 259 monitoring sites involving some 8,072 observations in 2007 showed that the mean concentrations for these sites ranged from 0.028 to 5.74 ppb. The primary sources of styrene in outdoor air include emissions from industrial processes involving styrene and its polymers and copolymers, vehicle emissions, and other combustion processes.

Volatilization and biodegradation are expected to be the major fate and transformation processes in water. Again, based on its Henry's law constant, styrene is expected to volatilize rapidly from environmental waters; the extent of volatilization depends on the water depth and turbulence with low volatilization occurring in stagnant, deep water. The estimated volatilization half-life of styrene in a river three feet deep with a current of three feet per second and wind velocity of 9.5 feet per second is roughly three hours. Half-lives have been estimated from one hour for a shallow body of water to 13 days in a lake. Some biological oxygen demand studies have shown styrene to be biodegradable. Cohen et al. 2002 found that styrene generally does not persist in water because of it biodegradability and volatility.

MATERIAL FACTS

Styrene Monomer

Property	Value
Auto-ignition Temperature (in air)	914 F
Boiling Point:	
14.7 psi	293 F
1.9 psi	180 F
0.6 psi	130 F
Color	Colorless
Corrosivity	Non-corrosive to metals except copper and alloys of copper
Density (in air):	
32 F	7.71 lbs/US Gallon
68 F	7.55 lbs/US Gallon
122 F	7.33 lbs/US Gallon
Solubility: Styrene in Water	
32 F	0.018 gms/100 gmsH_20
104 F	0.040 gms/100 gmsH_20
176 F	0.062 gms/100 gmsH_20
Solubility: Water in Styrene	
32 F	0.020 gms/100 gms styrene
104 F	0.100 gms/100 gms styrene
176 F	0.180 gms/100 gms styrene
Vol. Shrinkage upon Polymerization, typ.	17%

RECEIVING AND STORING CIPP RESINS AND INITIATION CHEMICALS

Resins should be received and stored in controlled conditions. Today's state of the art facilities for tube saturation (wet out) consist of temperature controlled storage tanks mounted outside in a spill prevention area with interconnecting piping to the static mixing (and resin system disbursement) unit inside the saturation shop. This minimizes the typical styrene concentration in the work area to less than 0.5ppm, well below the industry's voluntary standard of 50ppm (for an 8-hour work period). The remainder of the facilities in use varies from working with resin stored in totes to resin stored in drums; and catalyzed by combining the initiators, typically Perkadox and Trigonox, with the resin directly in the drums or in a vat (batch mixing) using a mixing blade. These latter methodologies can, without proper ventilation create styrene concentrations around 2-3ppm in the work area. A well ventilated work area is recommended if mixing is to be done in this fashion.

Based on studies to date, worker exposure to concentrations between 20 and 50ppm have been shown to produce no negative health effects. At concentrations above 50ppm, reversible effects on the central nervous system have been observed. With increasing exposure levels, e.g. levels of 200ppm, a distinct irritation of mucous membranes can result. Such effects are reversible and similar in character to exposure to solvents without adequate ventilation

or after excessive intake of alcohol. According to a study carried out by the ECETOC (European Centre for Econtoxicology and Toxicology of Chemicals), the carcinogenic potential of styrene, if one exists at all, is rated so low that occupational or environmental exposure to styrene is unlikely to present any carcinogenic hazard to man.

Drums and Totes

Drums and totes of resin should not be allowed to stand in the sun for more than a few hours. As soon as possible after being received, drums and totes should be moved to a cool, shaded area. In hot weather they can be cooled with a water spray. It is advisable that inventories utilizing these two storage methods be kept to a minimum during summer months and that the resin be stored no longer than is necessary. Having the resin manufacturer acknowledge your usage rates and tailoring any additional inhibitor needs to compensate for the storage environment is strongly recommended.

Inhibitors are customarily added to resin systems to prevent polymer formation and oxidative degradation during shipment and storage. Inhibitors prevent polymerization in two ways; (1) they can react with and deactivate the free radicals in a growing polymer chain and (2) they can act as an antioxidant and prevent polymerization by reacting with oxidation products in the styrene monomer. Sufficient oxygen must be present for this inhibition to be realized. In the absence of oxygen, polymerization will take place as if no inhibitor were present. The rate of the inhibitor's depletion is dependent on the set of environmental conditions seen in the storage environment. Heat, water, and air can greatly accelerate the depletion of the inhibitor; with heat being the most influential. The table below illustrates the effects of temperature and oxygen levels on the storage time of styrenated resin systems.

Temperature	12ppm Inhibitor		50ppm Inhibitor Saturated w/ Air
	Saturated w/ Air	Less than 3ppm O_2	
60 F	6 months	10 to 15 days	1 year
85 F	3 months	4 to 5 days	6 months
110 F	8 to 12 days	Less than 24 hours	Less than 30 days

The safe storage and use of resins in non-bulk packaging is described in the National Fire Protection Association's (NFPA) code 30, chapter 4. Although each state can enforce other fire codes, such as the UFC and BOCA, the NFPA codes serve as a good initial planning document. It is strongly recommended that contractors engaged in their own saturating their tubes consult this book if they intend to store resins in non-bulk packaging.

Bulk Storage Tanks

In designing bulk storage facilities, certain basic factors must be considered. Resins containing the styrene monomer can be stored for relatively long periods of time if simple, but carefully prescribed conditions are met. In addition to the usual precautions taken with flammable liquids against fire and explosion hazards, precautions must also be taken against conditions that would promote the formation of polymer and oxidation products. To accomplish this, the design and construction of a satisfactory bulk storage system for styrenated resin systems requires careful consideration to eliminate excessive temperatures and to prevent contamination of the resin from infrequently used lines and other equipment.

Vertical storage tanks are commonly used for large volume storage. Horizontal storage tanks are equally satisfactory for resin storage; but are used for smaller volumes such as are typical of CIPP saturation facilities. The inlet and outlet piping is normally located near the bottom. To facilitate mixing where external refrigeration or heating are employed, it is recommended that either the inlet or outlet line operate through a floating swing-pipe adjusted so that the resin is always either withdrawn or discharged a few inches below the surface. Warm resin is with-

drawn from the top, circulated through the chiller, and discharged to the bottom of the tank; cooling the tank from the bottom up.

A self-supporting-type dome roof is recommended for vertical storage tanks. This type of construction simplifies the installation of tank linings and permits the rapid drainage of uninhibited condensed vapors back into the liquid resin, thus reducing the polymer and stalactite problem. Roof and sidewall openings above the normal liquid levels in the tank should be of large diameter and the number kept to as few as practical. Large diameter openings are easily lined and can also be used for dual service features.

Insulation and temperature control equipment are key elements of a well done bulk storage system. The resin should be kept around 65 F (between 60 F and 75 F is acceptable) to facilitate the saturation process and allow for proper maintenance of the calibration of the resin mixing system.

The working capacity of the storage tanks should be, within reason, based upon the installer's resin usage. A general rule of thumb is that a bulk tank system should be of a size to allow for the turning of the resin inventory every 45 days. Given that a full truckload shipment is approximately 4,500 gallons, a typical system would have a minimum storage volume of 5,500 to 6,000 gallons to ensure that the system does not completely empty prior to receiving another resin shipment.

Requirements of diking, tank spacing, and other features of safety are detailed in guidelines set by the National Fire protection Association (see NFPA 30, Chapter 2). These, as well as local building codes and governmental regulations, should be consulted since some requirements vary with the size and configuration of the installation.

Organic Peroxides

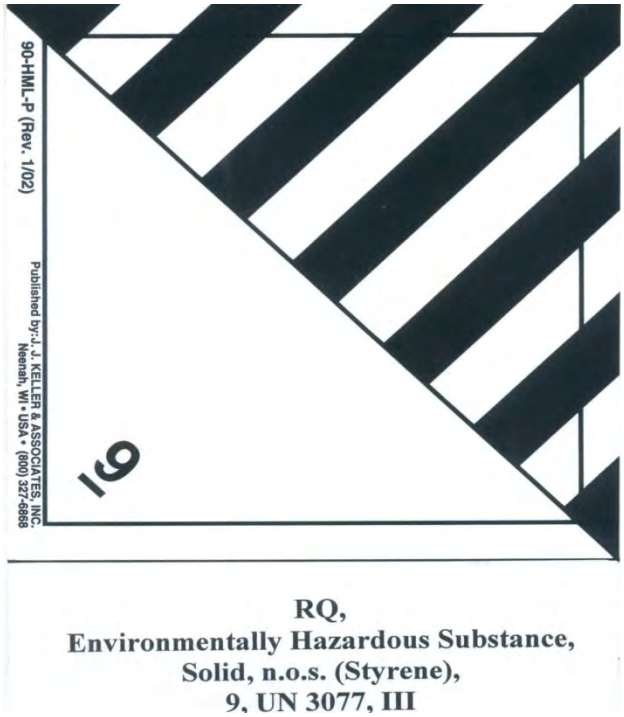
All peroxides are heat sensitive to some degree and require a controlled temperature for storage. Storage temperatures should be kept at, or below, 59 F for longer shelf life and stability. Prolonged storage at temperatures greater than 68 F is not recommended. Perkadox 16 will degrade if stored at elevated temperatures leading to gassing and potential container rupture which can result in a fire and/or explosion. Prolonged storage of Trigonox above 80 F is not recommended. All storage should be done in the peroxides' original containers away from flammables and all sources of heat, sparks, or flames; out of direct sunlight; and away from cobalt naphthenate, other promoters, accelerators, oxidizing or reducing agents, and strong acids or bases.

HANDLING CIPP RESINS AND INITIATION CHEMICALS

Styrene based polyester resins are sensitive to contact with both heavy metals and red metals. Interaction with these metals is not predictable as in some cases they will inhibit the cure; and in others they will accelerate it. Common metals to avoid are; copper, brass, beryllium, chromium, lead and galvanized metal. The recommended metals or plastics to be used for storage and piping are carbon steel, stainless steel, aluminum, polyethylene, polypropylene, and Teflon. Resin transfer hoses must be chemically resistant and approved for use with styrene.

TRANSPORTATION OF RESIN-SATURATED TUBES

Per previous correspondence with the Federal Highway Transportation Agency, the resin-saturated tube is considered an acceptable "container" for shipment to the project site from the saturation shop. Currently, each tube is to be identified on its end with a class 9 placard and a description of its contents as shown in the figure to the right. If any one tube being transported in the truck exceeds 1000 pounds of styrene (approximately 2500 pounds of resin), then the truck itself must be placarded with the class 9 placard bearing the UN 3077 designation.



The transporting truck should be equipped with provisions to keep the saturated tubes out of direct sunlight and at or below 40 F. The floor should be insulated well enough to keep any heat from the roadway generating heat in the stored liners.

Depending upon the number of tubes being shipped and/or the residence time in the truck, styrene concentration levels in the air space of the storage box can reach approximately 90ppm. While this level can be irritating to the eyes, it will not produce any harm to the workers (NIOSH allowable concentration for work areas is 215ppm STEL, or short term exposure limit) and dissipates quite rapidly once the doors are opened.

CIPP INSTALLATION PRACTICES

All CIPP resin systems require that good housekeeping be practiced by the installation team on the project site. Provisions must be made by the contractor in advance for containing any accidental spillage of the resin on the work area. Further, if more than 2500 pounds of resin (1000 pounds of styrene) is spilled, the spill must be reported to the appropriate local pollution control authorities. Spills less than this "reportable quantity" are to be handled in a responsible manner by the contractor. Absorption with an inert material and placing in an appropriate waste disposal container is the industry standard for handling small spills on the ground. Some absorbing agents, such as untreated clays and micas, will cause an exothermic reaction which might ignite the styrene monomer. For this reason, absorbing agents should always be tested for their effect on the polymerization of the monomer before they are used on larger spills. Claymax®, a loose "vermiculite-like" material has been found to be an effective absorbent. Oil dry, kitty litter and sand will also work well. If the spill occurs on a hard surface, the area should be scrubbed with soap and water after the bulk of the spill has been cleaned up by the absorbent material. If the spill gets into a waterway, the spill must be contained using a floating dike similar to those used for oil spills. The resin can then be picked up by vacuuming the resin into a vacuum truck and subsequently placed in an appropriate waste disposal container.

Water inversions require that consideration be given to the temperature of the process water and any styrene content it may have after the CIPP installation has been completed. Depending on the volume of water used in the processing and the receiving environment (sanitary sewer, drainage ditch, waterway, etc), the water may require transportation and/or treatment prior to its final disposition. As stated in the introduction of this guideline, styrene readily dissipates through volatilization and degradation. In order to ensure that the cured liner remains tight fitting and dimensionally stable with the release of the cure water, the standard in the industry is to require that the cool down be continued until the temperature of the liner (and the surrounding ground) is no more than 100 F. During the cool down process a small hole is made in the downstream end to release hot water as cold water is introduced at the boiler truck to facilitate this effort. Process water once the liner temperature reads 100 F will probably have a temperature around 90 F or less which has been observed to have a styrene concentration in the

range of 20 to 25ppm. The releasing of the process water directly to the sewer is not a problem due to the benefits of dilution in the downstream wastewater.

Process water released directly to a surface water course such as a drainage ditch or waterway must consider the allowable styrene concentration with respect to the receiving environment and the possible oxygen depleting capabilities of the process water's elevated temperature. Based upon the exhaustive literature review of the quick volatilization of the styrene and its potential to result in any long-term harm to plant and animal life, discharges of process water having the normal concentration levels of styrene and temperature at cool-down directly to a dry waterway should pose no harm. Further, while the common practice of many CIPP installers is to transport the process water to the nearest wastewater treatment facility, releases of process waters to ditches and/or waterways containing water and/or aquatic life containing no more than a concentration of 25ppm styrene and a temperature approximately equal to that of the receiving waterway should not create any environmental harm (see note below). For projects requiring large quantities of process water to be directly discharged to the environment, it is recommended that an engineering analysis be undertaken to determine the assimilative capacity of the receiving stream with respect to the temperatures and styrene concentrations anticipated.

Note: A typical 24-inch diameter culvert 100 linear feet in length will require around 2400 gallons of water to process. If released at 25ppm, the amount of styrene anticipated in its release is approximately 0.45 pounds.

Air inversion of the resin-saturated tube and curing the liner by the introduction of steam into the pressurized air flow greatly reduces the amount of styrene that will potentially be released into the environment. This is because the very quick cross-linking of the resin effectively binds up the styrene to a much higher degree using this method for curing. Most of the styrene released in this method of curing will be in the vapor form and requires little or no action on the contractor's part so long as the discharge point is maintained 6-inches above ground. The condensate generated in the pipeline being processed should be minimized by maximizing the flow of air for the site-specific conditions. The small volume of condensate produced during processing should be detained in a temporary impoundment if the quantity is expected to be discharged to a ditch or waterway containing water and/or aquatic life. Measurements made to date have shown that the condensate will probably have a concentration of around 30ppm. Depending upon the assimilative capacity of the receiving waterway, the condensate may be released once it has cooled to near ambient temperature (which will also result in a drop in the styrene concentration due to volatilization); or it can be retrieved into the steam generation system's water storage tank for later use in the production of steam during curing of the next CIPP.

It is imperative that the processing of the liner, whichever method of curing is used, is properly completed. Properly cured liners release little or no styrene to the environment. Thermocouples placed strategically in the liner-host pipe interface are a must. A written curing schedule developed for a CIPP system acknowledging the conditions present in the curing environment and the resin system proposed will lead to a proper cure and a long CIPP life; and no environmental impact.

SUMMARY

Proper curing and handling of CIPP systems should be done using the following guidelines:

Water Curing

Sanitary Sewers

1. Cure resin system per written curing schedule
2. Release process water to the sewer after per industry standards during/after cool-down.

Storm Sewers and Culverts

1. Cure resin systems per written curing schedule
2. Based upon receiving waterway's assimilate capabilities

a. Discharge water once at ambient air temperature
b. Discharge water once styrene concentration is confirmed to be at or below 25ppm; or
c. Transport process water to nearest wastewater treatment facility

Steam Curing

Sanitary Sewers

1. Cure resin system per written curing schedule
2. Release condensate water directly to receiving sewer while processing

Storm Sewers and Culverts

1. Cure resin system per written curing schedule
2. Based upon receiving waterway's assimilative capabilities
    a. Detain condensate in a lined holding pond until it cools to ambient
    b. Discharge water once styrene concentration is confirmed to be less than 25ppm; or
    c. Retrieve condensate by pumping it into the steam generation truck's reservoir; or
    d. Transport condensate to nearest wastewater treatment facility.

Any residual styrene concentrations from a properly cured resin system that are taken into the runoff water from storm events will typically be short-lived, in the range of less than 1.0ppm and therefore pose no significant environmental threat.

APPENDIX

Gunzel, W., 2002. Sewer reconstruction by means of pipe relining with special consideration of operationally contingent styrene materials. Engineering Office for Sewer Maintenance and Repair and Quality Management.

Lee, Robert K., 2008. Risks associated with CIPP lining of storm water pipes and the release of styrene. *Conference Proceedings of the North American Society for Trenchless Technology**. Paper E-1-05.

AirZOne, Inc. for Toronto Works and Emergency Services, March, 2001. A report on the monitoring of styrene in Toronto homes during the Cured in Place Pipe (CIPP) process for sewer pipe rehabilitation by Insituform.

Fu, Min Hong, and Anderson, Martin A., 1992. Biodegradation of styrene in samples of natural environments. *Environmental Science and Technology**, Vol. 26, No. 8, pp. 1540-1544.

Fu, Min Hong, Mayton, Hilary, and Alexander, Martin A., 1994. Desorption and biodegradation of sorbed styrene in soil and aquifer solids. *Environmental Toxicology and Chemistry**, Vol. 13, No. 5, pp. 749-753.

Cushman, J.R., et al, 1997. Ecotoxicity hazard assessment of styrene. *Ecotoxicology and Environmental Safety**, Vol. 37, pp. 173-180.

Alexander, Martin A., 1997. The environmental fate of styrene. *Critical Reviews in Environmental Science and Technology**, Vol. 27, pp. 383-410.

Dalton, Pamela, et al., 2003. Olfactory function in workers exposed to styrene in the reinforced-plastics industry. *American Journal of Medicine**, 44, pp. 1-11.

Lees, Peter S. J., et al., 2003. Exposure assessment for study of olfactory function in workers exposed to styrene in the reinforced-plastics industry. *American Journal of Industrial Medicine**, 44, pp. 12-23.

Sumner, Susan Jenkins, and Fennell, Timothy R., 1994. Review of the metabolic fate of styrene. *Critical Reviews in Toxicology**, 24(S1), S11-S33.

Green, Trevor, 2001. The toxicity of styrene to the nasal epithelium of mice and rats: studies on the mode of action and relevance to humans. *Chemico-Biological Interactions**, Vol. 137, pp. 185-202

Sarangapani, Ramesh, et al., 2002. Physiologically based pharmacokinetic modeling of styrene and styrene oxide respiratory-tract dosimetry in rodents and humans. *Inhalation Toxicology**, Vol. 14, pp. 789-834.

Brown, Nigel A., et al., 2000. A review of the developmental and reproductive toxicity of styrene. *Regulatory Toxicology and Pharmacology**, Vol. 32, pp. 228-247.

Cohen, Joshua T., et al, 2002. A comprehensive evaluation of the potential health risks associated with occupational and environmental exposure to styrene. *Journal of Toxicology and Environmental Health**, vol. 5, no. 1-2.

* indicates the paper was peer reviewed prior to publication.

APPENDIX E

Final Report VTRC 08-R16

Virginia Transportation Research Council

research report

Understanding the Environmental Implications of Cured-in-Place Pipe Rehabilitation Technology

http://www.virginiadot.org/vtrc/main/online_reports/pdf/08-r16.pdf

BRIDGET M. DONALDSON
Research Scientist
Virginia Transportation Research Council

ANDREW J. BAKER, P.E.
Graduate Research Engineer
Department of Civil and Environmental Engineering
University of Virginia

Virginia Transportation Research Council, 530 Edgemont Road,
Charlottesville, VA 22903-2454, www.vtrc.net, (434) 293-1900

Standard Title Page - Report on Federally Funded Project

1. Report No. FHWA/VTRC 08-R16	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Understanding the Environmental Implications of Cured-in-Place Pipe Rehabilitation Technology		5. Report Date May 2008 6. Performing Organization Code
7. Author(s) Bridget M. Donaldson and Andrew J. Baker		8. Performing Organization Report No. VTRC 08-R16
9. Performing Organization and Address Virginia Transportation Research Council 530 Edgemont Road Charlottesville, VA 22903		10. Work Unit No. (TRAIS) 11. Contract or Grant No. 80774
12. Sponsoring Agencies' Name and Address Virginia Department of Transportation 1401 E. Broad Street Richmond, VA 23219 FHWA 400 North 8th Street, Room 750 Richmond, VA 23219-4825		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

Cured-in-place (CIPP) rehabilitation is a commonly used technology for pipe repair, and transportation agencies are using CIPP technology to repair damaged pipe culverts. In typical CIPP applications, a lining tube saturated with a thermosetting resin is installed into the damaged pipe and cured with a heat source to form a pipe-within-a-pipe. This study focused on CIPP installations that use forced steam through the lining tube both to press the liner to the inside dimensions of the host pipe and to harden the resin-impregnated liner material. Of the thermosetting resins used in CIPP applications, styrene-based resins are the most common. This research focused on styrene-based CIPP products.

To evaluate the potential for impacts on water quality from the steam-cured CIPP process, seven CIPP installations in surface water and stormwater conveyances were identified and observed over the course of a 1-year study in Virginia. Water samples were collected from each project site and analyzed for styrene. The results were then evaluated for compliance with established regulatory standards and published aquatic toxicity criteria.

Water samples collected from pipe outlets at five of the seven CIPP installations showed detectable levels of styrene. Styrene concentrations were generally highest in water samples collected during and shortly following installation. The maximum duration that styrene was detected at any site was 88 days following the CIPP installation. Although the sites in this study were not directly linked to sources of drinking water, styrene levels at five sites were higher than the U.S. Environmental Protection Agency's maximum contaminant level for drinking water of 0.1 mg/L. Styrene was detected at five sites for a minimum of 5 days to at least 71 days after installation and was detected at these sites up to 40 m downstream. Certain measurements were also found to exceed the values for EC_{50} (the concentration required to have a defined effect on 50 percent of a study population) or LC_{50} (i.e., the concentration required to kill 50 percent of a study population) for several freshwater aquatic indicator species.

The findings suggest that the elevated styrene levels could have resulted from one or a combination of the following: (1) installation practices that did not capture condensate containing styrene, (2) uncured resin that escaped from the liner during installation, (3) insufficient curing of the resin, and (4) some degree of permeability in the lining material. A summary of the actions taken by the Virginia Department of Transportation (VDOT) in response to the preliminary findings of this study is also provided in this report. VDOT suspended the use of styrene-CIPP for pipes that convey surface or stormwater while further evaluating CIPP repair and subsequently developing new requirements for these installations. The new measures include substantial modifications to VDOT's CIPP specifications; an inspector training program; increased project oversight; and water and soil testing prior to and after CIPP installation. Reinstatement of statewide VDOT CIPP installations using the new procedures and specifications is planned for May 2008.

17 Key Words Cured-in-place, pipe repair, pipe rehabilitation, surface water conveyance, stormwater pipe, styrene, water quality, toxicity	18. Distribution Statement No restrictions. This document is available to the public through NTIS, Springfield, VA 22161.

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 23	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

FINAL REPORT

UNDERSTANDING THE ENVIRONMENTAL IMPLICATIONS OF CURED-IN-PLACE PIPE REHABILITATION TECHNOLOGY

Bridget M. Donaldson
Research Scientist
Virginia Transportation Research Council

Andrew J. Baker, P.E.
Graduate Research Engineer
Department of Civil and Environmental Engineering
University of Virginia

Virginia Transportation Research Council
(A partnership of the Virginia Department of Transportation
and the University of Virginia since 1948)

In Cooperation with the U.S. Department of Transportation
Federal Highway Administration

Charlottesville, Virginia

May 2008
VTRC 08-R16

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Virginia Department of Transportation, the Commonwealth Transportation Board, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

ABSTRACT

Cured-in-place (CIPP) rehabilitation is a commonly used technology for pipe repair, and transportation agencies are using CIPP technology to repair damaged pipe culverts. In typical CIPP applications, a lining tube saturated with a thermosetting resin is installed into the damaged pipe and cured with a heat source to form a pipe-within-a-pipe. This study focused on CIPP installations that use forced steam through the lining tube both to press the liner to the inside dimensions of the host pipe and to harden the resin-impregnated liner material. Of the thermosetting resins used in CIPP applications, styrene-based resins are the most common. This research focused on styrene-based CIPP products.

To evaluate the potential for impacts on water quality from the steam-cured CIPP process, seven CIPP installations in surface water and stormwater conveyances were identified and observed over the course of a 1-year study in Virginia. Water samples were collected from each project site and analyzed for styrene. The results were then evaluated for compliance with established regulatory standards and published aquatic toxicity criteria.

Water samples collected from pipe outlets at five of the seven CIPP installations showed detectable levels of styrene. Styrene concentrations were generally highest in water samples collected during and shortly following installation. The maximum duration that styrene was detected at any site was 88 days following the CIPP installation. Although the sites in this study were not directly linked to sources of drinking water, styrene levels at five sites were higher than the U.S. Environmental Protection Agency's maximum contaminant level for drinking water of 0.1 mg/L. Styrene was detected at five sites for a minimum of 5 days to at least 71 days after installation and was detected at these sites up to 40 m downstream. Certain measurements were also found to exceed the values for EC_{50} (the concentration required to have a defined effect on 50 percent of a study population) or LC_{50} (i.e., the concentration required to kill 50 percent of a study population) for several freshwater aquatic indicator species.

The findings suggest that the elevated styrene levels could have resulted from one or a combination of the following: (1) installation practices that did not capture condensate containing styrene, (2) uncured resin that escaped from the liner during installation, (3) insufficient curing of the resin, and (4) some degree of permeability in the lining material.

A summary of the actions taken by the Virginia Department of Transportation (VDOT) in response to the preliminary findings of this study is also provided in this report. VDOT suspended the use of styrene-CIPP for pipes that convey surface or stormwater while further evaluating CIPP repair and subsequently developing new requirements for these installations. The new measures include substantial modifications to VDOT's CIPP specifications; an inspector training program; increased project oversight; and water and soil testing prior to and after CIPP installation. Reinstatement of statewide VDOT CIPP installations using the new procedures and specifications is planned for May 2008.

FINAL REPORT

UNDERSTANDING THE ENVIRONMENTAL IMPLICATIONS OF CURED-IN-PLACE PIPE REHABILITATION TECHNOLOGY

Bridget M. Donaldson
Research Scientist
Virginia Transportation Research Council

Andrew J. Baker, P.E.
Graduate Research Engineer
Department of Civil and Environmental Engineering
University of Virginia

INTRODUCTION

Because many pipes and culverts were placed more than 20 years ago, repair or replacement of damaged or worn pipes is becoming a large maintenance concern in the United States. Cured-in-place pipe (CIPP) rehabilitation is one of several "trenchless" pipe repair technologies that allow users to repair existing underground pipes in place rather than using the conventional method of unearthing and replacing sections of damaged pipe. Trenchless technologies were first developed about 25 years ago and were used primarily in western Europe until about 15 years ago, when departments of transportation and construction outfits in North America began to use them.[1] In the mid-1990s when the city of Houston, Texas, undertook a major overhaul of its sewer system, contractors used trenchless methods for 87 percent of the repairs, involving millions of feet of pipe line. Of the many trenchless methods available, contractors used CIPP technology significantly more than any other in situ pipe rehabilitation method.[2] CIPP repair dominates the underground pipe rehabilitation industry,[3] and both under- and above-ground CIPP rehabilitation is common worldwide. The CIPP business was pioneered by Insituform Technologies, Inc., which now performs projects for industries and municipalities in 40 countries and for transportation agencies in 36 U.S. states.[4]

In typical CIPP applications, a lining tube is saturated with a thermosetting resin, installed into the existing pipeline, and cured into a pipe-within-a-pipe. Generally, curing is conducted by forcing heated water or steam through the pipe, which presses and hardens the resin-impregnated lining tube against the inside of the host pipe. The CIPP liners are fabricated from materials that, when cured, are able to withstand internal exposure to and the corrosive effects of normal wastewater or stormwater; gases containing hydrogen sulfide, carbon monoxide, carbon dioxide, methane, and dilute sulfuric acid; and soil bacteria.

Despite its widespread and frequent use, little has been investigated regarding the environmental impact of CIPP technology on surface water or aquatic habitat. Although literature on the mechanisms involved in CIPP rehabilitation is readily available, studies have not been published regarding the potential environmental impacts if effluent is leaked or discharged

downstream or if chemicals leach from the cured pipe after the installation is completed. Of particular concern are the potential effects of styrene, which is commonly used as a main component of the resin that saturates the lining tube. Styrene is classified by the U.S. Environmental Protection Agency (EPA) as a mutagen and is thus potentially carcinogenic.[5] In certain concentrations, styrene is toxic to aquatic species.[6-9]

The Virginia Department of Transportation (VDOT) uses CIPP repair technology for many of its pipes that convey streams or stormwater beneath or along roads. VDOT uses CIPP rehabilitation more than any other pipe repair method and issues contracts to several companies to perform this work (S.L. Hite, personal communication).

PURPOSE AND SCOPE

The purpose of this study was to evaluate the potential for impacts on water quality from use of the steam-cured CIPP process. Of the thermosetting resins used in CIPP applications, styrene-based resins are the most common. Thus, this research focused on styrene-based CIPP products.

To gather information on the methods used in VDOT's CIPP installations and to analyze the impacts that the process might have on water quality, seven steam-cured CIPP installations in Virginia were identified and observed over the course of a 1-year study. Water samples were collected from each project site and analyzed for styrene. The results were then evaluated for compliance with established regulatory standards and published aquatic toxicity criteria.

METHODS

To achieve the purpose of this study, two tasks were carried out:

1. literature review and information gathering

2. field monitoring of seven steam-cured CIPP installations in Virginia.

Literature Review and Information Gathering

The literature was reviewed for (1) the methods and materials used in CIPP rehabilitation and (2) the impacts of styrene on aquatic organisms. Online databases searched included Aqualine, Biological Sciences, Environmental Sciences and Pollution Management, Toxline, Agricola, Science Direct, and WorldCat, among others. Information was also gathered from the American Society of Testing and Materials' (ASTM) standards for CIPP rehabilitation, regulatory programs administered by the Virginia Department of Environmental Quality, and

other applicable organizations involved with water quality standards. Information on the hazards and regulations for styrene was obtained from the EPA's website.[5,10]

Field Monitoring

Seven CIPP installations were identified within the Piedmont and Blue Ridge Physiographic Provinces of Virginia, and water samples were collected over the course of this 1-year study (see Table 1). The installations were conducted by three primary companies that perform CIPP rehabilitation in Virginia. All project sites were surface water conveyances where the pipe inlet and outlet were exposed with the exception of Site 4, which was an entirely subsurface stormwater conveyance. None of these sites directly links to a source of drinking water.

Table 1. Project Descriptions for Seven CIPP Installations in Virginia

Site	County	Route No.	Pipe Size		Conveyance Description
			Diameter (in)	Length (ft)	
1	Spotsylvania	1316	36	71	Conveys an unnamed tributary drainage to Massaponax Creek. Drains into concrete-lined ditch. Continual flow.
2	Prince Edward	15	18	60	Conveys an unnamed tributary drainage to Briery Creek. Drains into earthen ditch. Intermittent flow.
3	Prince Edward	628	30	100	Conveys an unnamed tributary drainage to Dickenson branch of Briery Creek. Drains into stream bed. Continual flow.
4	Albemarle	1722	24	121	Conveys stormwater entirely below ground. Drains into stormwater pond. Intermittent flow.
5	Nottoway	460	15	112	Conveys an unnamed tributary drainage to Lazaretto Creek. Drains into stream bed. Continual flow.
6	Nottoway	460 (Business)	18	64	Conveys an unnamed tributary drainage to Jacks Branch. Drains into stream bed. Intermittent flow.
7	Nottoway	613	30	60	Conveys an unnamed tributary drainage to Deep Creek. Drains into stream bed. Continual flow.

Field Observations

Project sites were observed during CIPP installations and at various periods after the installations were complete. Because the CIPP installations observed continued up to 30 consecutive hours and because of the distance between the project sites, the authors could not be present to collect samples at consistent intervals during and after all installations. Observations of incidents that could potentially result in adverse impacts to water quality were documented.

Water Samples

A control sample was collected from the water within 1 m of the pipe outlet at Sites 1, 3, and 4 immediately prior to CIPP installations. At sites that were not monitored until the installation was underway (Site 2) or until 15 to 16 days after installation (Sites 5-7), a control sample was collected after installation at least 10 m upstream from the pipe inlet. Water samples were collected at various intervals during installation at Sites 1, 2, and 3 and at various intervals after installation at all seven sites. During each sampling period, a sample was taken from the water within 1 m of the pipe outlet. During some sampling periods at five of the six surface water sites (Sites 1, 2, 3, 5, and 7), samples were also taken from the water 5 to 40 m downstream. At Sites 2 and 3, a sample was taken from the stream water within 1 m of the outlet during steam condensate release. Water samples were collected at all sites for a maximum of 30 to 116 days, depending on the site, after CIPP installation until the styrene concentration at the site was below the reporting limit (0.005 mg/L) of the primary laboratory (Microbac) used in this study.

The subsurface stormwater pipe at Site 4 conveyed water only during rain events. Because it was difficult to time sample collections with rain events, a rain event was simulated for each sampling period by pouring 1 gal of distilled water into the inlet of the repaired section of pipe and capturing the water as it flowed out of the outlet of the pipe section.

All samples were collected into 40-ml volatile organic analysis (VOA) vials with HCl preservative. The samples were packed on ice and sent to the laboratory via an overnight courier service. All samples were analyzed for styrene in accordance with the EPA's SW-846 Method 8260B[11] by Microbac Laboratories in Baltimore, Maryland. Samples collected at the last one to two sampling periods from Sites 1, 4, 5, 6, and 7 were also sent to Air, Water, and Soil Laboratories, Inc., in Richmond, Virginia. These samples were also packed on ice and sent to the laboratory via an overnight courier service. Sample analyses were "blind" in that locations and project descriptions were not disclosed to either laboratory.

RESULTS

Literature Review and Information Gathering

Procedures and Materials for CIPP Installations

Typical CIPP operations begin with the project setup, which includes measures to prevent water flow through the damaged host pipe. ASTM standards for CIPP procedures specify that bypassing or diverting the flow should be done by pumping the flow to a downstream point.[12,13] Rocks and debris are then removed from the pipe. The next phase of the operation is liner insertion. The resin-saturated liner, which has been transported from the factory via a refrigerated truck, is inserted into the host pipe. Depending on the company, the liner is either pulled or inverted through the host pipe. Inversion is accomplished by forcing air into one end of the liner, causing the liner to turn inside-out as it travels the length of the host pipe. The liner is

expanded to conform to the inner dimensions of the host pipe and is subsequently cured to form a pipe-within-a-pipe. Typical curing is achieved by circulating heated water or steam through the pipe to polymerize the resin material. The curing process takes up to several hours, depending on the size of the pipe. The curing process and subsequent cool-down period generate spent process water or steam condensate. ASTM standards[12,13] specify that during the cool-down period, hot water or steam effluent should be drained through a small hole in the downstream end of the pipe and replaced with the introduction of cool water. Following the cool-down period, the closed ends of the cured liner are cut open, and generally a video camera is inserted into the pipe for a final inspection. A more detailed explanation of CIPP procedures is provided in ASTM F1743-96(2003),[12] ASTM F1216-07b,[13] and ASTM D5813-04.[14] These standards contain a caveat that "it is the responsibility of the user to establish appropriate safety and health practices and determine applicability of regulatory limitations prior to use."[12-14]

The pipe lining material used in CIPP operations is composed of absorbent non-woven felt fabric that is pre-saturated (at the manufacturing facility) with a thermosetting resin. Typically, the liner tube has a membrane coating to protect and contain the resin; the membrane is generally a flexible thermoplastic, such as polyethylene or polyurethane.[3] This coating is normally only on the inner surface of the finished product. This allows the resin to migrate into any voids in the host pipe such as joints or cracks prior to curing. Three types of resins are typically used in CIPP applications: unsaturated polyester resins, vinyl ester resins, and epoxies.[3] Unsaturated polyester resin and vinyl ester resins are the most common and contain styrene; epoxies do not.

The styrene content of polyester and vinyl ester resins is generally on the order of 30 to 50 percent (by weight). A Material Safety Data Sheet (MSDS) obtained from one vendor shows the styrene content of the resin to be 44 percent (by weight), with the remaining components composed of unspecified polymers (50% to 54%) and colloidal silica (1% to 5%).[15]

A CIPP installation process relatively new in the United States uses ultraviolet light to cure the resin in seconds rather than curing with steam or hot water. In this process, the resin is encapsulated within an impermeable fiberglass liner, presumably precluding resin extrusions or leaching of styrene after project completion.[16] This product and installation method have not been used for VDOT conveyances and were, therefore, not the product and method analyzed and described in this research.

Standards and Toxicity Studies on Styrene Concentrations in Water

The EPA drinking water standard lists the maximum contaminant level (MCL) for styrene as 0.1 mg/L (0.1 parts per million [ppm]).[5] The EPA does not have established regulatory standards for ecological toxicity specifically for styrene concentrations in water. In Canada, however, a section of the British Columbia Environmental Management Act sets limits for toxins in discharged effluent.[17] Under the act's Municipal Sewerage Regulation (which includes regulations for surface water), effluent must not be discharged unless any toxins in the effluent are below the lethal limit for rainbow trout (*Oncorhynchus mykiss*) as determined by Environment Canada's 96-hr LC_{50} bioassay test method (i.e., the concentration required to kill 50% of the test population after 96 hours of exposure to that concentration) for this species.[18]

Numerous acute toxicity studies have documented the impacts of styrene on aquatic organisms.[6-9] Table 2 provides a summary of published values for acute styrene toxicity studies for several aquatic indicator species that are found in freshwater habitats throughout the United States. Indicator species are sensitive to pollutants, and their disappearance from a body of water can be indicative of contamination.

The literature reveals that spills of uncured resin from CIPP installations can cause large fish kills. Three to four gallons of uncured resin were released during a CIPP installation (the location of which was not disclosed in the report) on a stormwater drain.[19] The residual uncured resins were carried to a creek, resulting in the death of more than 5,500 fish of various species. Water samples indicated a 100 ppm (100 mg/L) concentration of styrene in the downstream manhole at the project site.[19] Except in the immediate vicinity of a spill, typical environmental exposures of styrene are not deemed to cause deleterious effects on natural communities of organisms.[20] Styrene volatilizes rapidly and has not been shown to bioaccumulate in organisms to any measurable extent.[20] Rates of volatilization are dependent on many factors, including styrene concentration, water temperature, and oxygen availability. Styrene compounds degrade more rapidly once microorganisms adapt to their presence.[20,21] Bogacka et al. found that the styrene (and other aromatic hydrocarbons) introduced to river water in concentrations up to 37 mg/L was reduced by 99 percent after 20 days.[21] Fu and Alexander found that 50 percent of 2 to 10 mg/L was lost by volatilization in 1 to 3 hours in lake water samples.[22]

Styrene has a high degree of adsorption onto soils, and although styrene will mineralize to carbon dioxide under aerobic conditions,[22] some is readily desorbed from soil and can enter groundwaters. It is not expected to be transported considerable distances through soil, however, because of its high biodegradability.[22]

Table 2. Styrene Toxicities for Various Freshwater Indicator Species

Aquatic Species	LC_{50} or EC_{50}[a] (mg/L)	NOEC[b] (mg/L)	Reference
Water flea (*Daphnia magna*)	48-hr EC_{50}: 4.7 48-hr EC_{50}: 1.3	1.9 0.81	6 7
Amphipod (*Hyalella azteca*)	96-hr LC_{50}: 9.5	4.1	6
Fathead minnow (*Pimephales promelas*)	96-hr LC_{50}: 5.2 96-hr LC_{50}: 10	2.6 4	7 8
Rainbow trout (*Oncorhynchus mykiss*)	96-hr LC_{50}: 2.5	NA	9
Freshwater green algae (*Selenastrum capricornutum*)	96-hr EC_{50}: 0.72 72-hr EC_{50}: 2.3	0.063 0.53	6 7

[a]Lethal concentration (LC_{50}) and effective concentration (EC_{50}), or the concentration required to kill (LC_{50}) or have a defined effect on (EC_{50}) 50% of the test population after a given number of hours of exposure in that concentration.

[b]No Observable Effect Concentration or the highest limit at which no mortalities or abnormalities were observed.

Field Monitoring

Field Observations and Water Sampling Results

Field Observations

Table 3 lists observations during and following CIPP operations at Sites 1 through 4.

The authors observed effluent from the steam condensate being discharged downstream by workers at Sites 2 and 3. At Sites 1, 3, and 4, the authors observed uncured resin residue waste immediately outside the pipe outlet or inlet. A sample of the uncured resin left in the stream bed at Site 1 (collected 1 day after installation) had a styrene concentration of 580 mg/L.

At Sites 1, 2, and 3, algal blooms were apparent within 6 to 8 days after installation (Figure 3; A. Mills, personal communication); algae were not visible at any of these sites when visited before the CIPP installation and were not present upstream of the installation. (The other three surface water sites in this study were not monitored until 15 and 16 days after installation; algal blooms were not visible at these sites.) Algae appeared most dense at the pipe outlet (occurring up to 8 in below the water surface), and the density decreased further downstream; the algae were present in clusters up to 50 m downstream from the repaired pipe section. Although the density of algal blooms appeared to decrease over time, blooms were observed 50 to 55 days after installation. Blooms were no longer visible 78 to 88 days after installation.

Table 3. Environmental Observations for Four CIPP Installations for Surface Water Conveyances

Site	Stream Flow Management	Curing Method	Effluent (Steam Condensate) Disposal Method	Post-project Conditions
1	Temporary dam	Steam	Not observed (authors not present at this stage of installation)	Extruded resin in stream (Figure 1A); algal blooms present at pipe outlet (0 to 10 m downstream, Figure 1A); residue present at pipe outlet (present at each sampling period up to study's end)
2	None necessary (dry pipe at time of installation)	Steam	Discharged by workers in stream (see associated water sample results in Table 5 and Figure 4)	Algal blooms present at pipe outlet (0 to 5 m downstream); residue present at pipe outlet (present at each sampling period up to study's end, Figure 2)
3	Temporary dam	Steam	Discharged by workers in stream (see associated water sample results in Table 6 and Figure 4)	Extruded resin in stream (Figure 1B); algal blooms present at pipe outlet (0 to 50 m downstream, Figure 3); residue present at pipe outlet (present at each sampling period up to study's end)
4	None necessary (dry pipe at time of installation)	Steam	Not observed (authors not present at this stage of installation)	Extruded resin just outside of pipe inlet (present at each sampling period up to study's end)

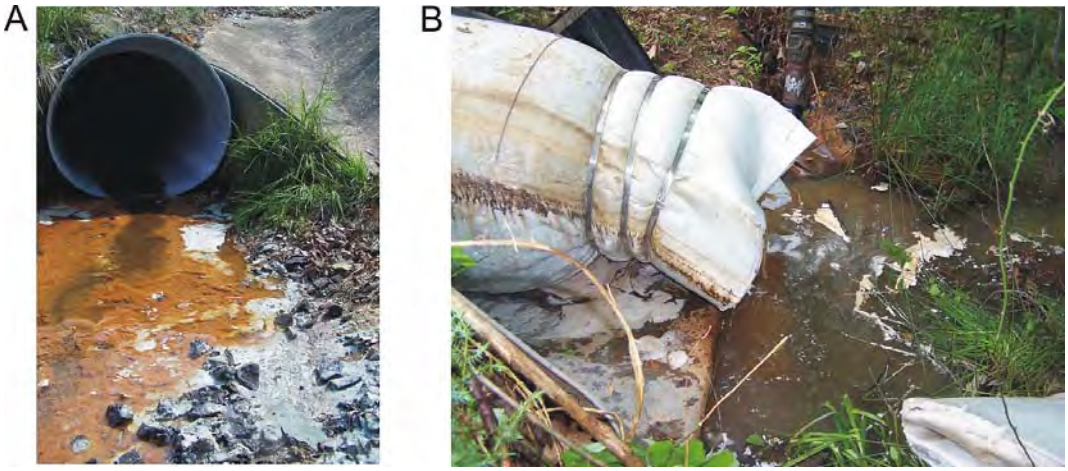


Figure 1. ***A:*** **Uncured resin waste (gray substance adjacent to outlet and along rocks on right side of image) at Site 1, 1 week after installation; algal blooms (brown cloudy substance in water) also visible.** ***B:*** **Uncured resin waste (white substance adjacent to pipe liner and in water) extruded during installation, just before pipe end was cut.**

Figure 2. Residue on water surface in pipe at Site 2 between stormwater events, 24 days after installation.

Figure 3. Algal blooms at Site 3, photographed 24 days after installation. Algal blooms appeared within 6 to 8 days after installation at Sites 1, 2, and 3 and were present up to 8 in below water surface near pipe outlet and up to 50 m downstream.

Water Sampling Results

Styrene concentrations in all control samples were below the reporting limit (0.005 mg/L) of the primary laboratory used in this study. Samples were collected until styrene concentrations were below the reporting limit at all sites. Samples collected at the pipe outlet often contained residue that was visible on the water surface after installation (Figure 2).

Sampling results from each of the seven sites after CIPP project initiation are provided in Tables 4 through 10 (all samples were analyzed by Microbac Laboratories unless otherwise noted). Although none of the monitored conveyances links directly to a drinking water supply, samples with styrene concentrations above the MCL for drinking water are noted in Tables 4 through 10 for comparative purposes; samples with concentrations above the EC_{50} or LC_{50} values for two common aquatic species listed in Table 2 are also noted.

Figure 4 provides styrene concentrations at all sites as compared with EC_{50} or LC_{50} values for two species (as detailed in Table 2). Samples for three sites were taken during installation, and samples for all sites were taken at various intervals after installation. No compounds other than styrene were detected in the laboratory analyses.

The results indicate that styrene concentrations were generally highest in water samples collected during installation, although comparable levels were detected at some sites several days after installation. The highest concentration (77 mg/L) was recorded at Site 3 at the outlet while steam condensate was discharged during the installation process.

Table 4. Site 1: Styrene Concentrations in Water Samples Collected During and After Installation (36-inch-diameter surface water conveyance, low to medium continual flow, Spotsylvania County)

Time		Styrene Concentration (mg/L)[a]			
		<1 m Downstream	**5 m Downstream**	**10 m Downstream**	**20 m Downstream**
During Project	30 min into liner insertion	24[b,c,d]			
	1 hr into liner insertion	29[b,c,d]			
After Project	1 day	4.9[b,c,d]		4.3[b,c]	
	8 days	3.1[b,c]		2.0[b]	0.18[b]
	32 days	0.009	0.0058		0.0085
	56 days	0.0052			<0.005
	88 days	0.0068			<0.005
	116 days	<0.005 <0.005[e]			

[a]Empty cells represent locations at which no samples were taken for that sampling period.
[b]Above maximum contaminant level for drinking water (0.1 mg/L).
[c]Above 96-hr LC_{50} for rainbow trout (2.5).
[d]Above 48-hr EC_{50} for water flea (4.7).
[e]Analyzed by Air, Water, and Soil Laboratories, Inc.

Table 5. Site 2: Styrene Concentrations in Water Samples Collected During and After Installation (18-inch-diameter surface water conveyance, low intermittent flow, Prince Edward County)

Time		Styrene Concentration (mg/L)[a]			
		Outlet	**5 m Downstream**	**10 m Downstream**	**20 m Downstream**
During Project	90 min into steaming	0.46[b,c]	0.0072		
	Condensate release	31[b,c,d]	20[b,c,d]		
After Project	1 day	1.2[b]			
	6 days	44[b,c,d]			
	24 days	22[b,c,d]	0.80[b]	0.14[b]	0.037
	50 days	1.4[b]			
	79 days	<0.005			

[a]Empty cells represent locations at which no samples were taken for that sampling period.
[b]Above maximum contaminant level for drinking water (0.1 mg/L).
[c]Above 96-hr LC_{50} for rainbow trout (2.5).
[d]Above 48-hr EC_{50} for water flea (4.7).

Table 6. Site 3: Styrene Concentrations in Water Samples Collected During and After Installation (30-inch-diameter surface water conveyance, medium to heavy continual flow, Prince Edward County)

Time		Styrene Concentration (mg/L)[a]				
		Outlet	5 m Downstream	10 m Downstream	20 m Downstream	40 m Downstream
During Project	Condensate release	77[b,c,d]	54[b,c,d]	5.7[b,c,d]		
After Project	5 days	2.2[b]		0.27[b]	0.52[b]	0.20[b]
	23 days	<0.005			<0.0050	
	49 days	0.0058	<0.005			
	78 days	<0.005				

[a]Empty cells represent locations at which no samples were taken for that sampling period.
[b]Above maximum contaminant level for drinking water (0.1 mg/L).
[c]Above 96-hr LC_{50} for rainbow trout (2.5).
[d]Above 48-hr EC_{50} for water flea (4.7).

Table 7. Site 4: Styrene Concentrations in Water Samples Collected After Installation (24-inch-diameter subsurface stormwater conveyance, low intermittent flow, Albemarle County)

Time		Styrene Concentration (mg/L)
		<1 m Downstream
After Project	37 days	0.0059
	71 days	0.71[a]
	88 days	<0.005 <0.005[b]

[a]Above maximum contaminant level for drinking water (0.1 mg/L).
[b]Analyzed by Air, Water, and Soil Laboratories, Inc.

Table 8. Site 5: Styrene Concentrations in Water Samples Collected After Installation (15-inch-diameter surface water conveyance, low to heavy continual flow, Nottoway County)

Time		Styrene Concentration (mg/L)	
		Outlet	10 m Downstream
After Project	15 days	< 0.005	
	30 days	< 0.005 < 0.005[a]	<0.005[a]

[a]Analyzed by Air, Water, and Soil Laboratories, Inc.

Table 9. Site 6: Styrene Concentrations in Water Samples Collected After Installation (18-inch-diameter surface water conveyance, low intermittent flow, Nottoway County)

Time		Styrene Concentration (mg/L)
		<1 m Downstream
After Project	15 days	43[a,b,c]
	44 days	0.140[a] 0.132[a,d]
	56 days	< 0.005 < 0.005[d]

[a]Above maximum contaminant level for drinking water (0.1 mg/L).
[b]Above 96-hr LC_{50} for rainbow trout (2.5).
[c]Above 48-hr EC_{50} for water flea (4.7).
[d]Analyzed by Air, Water, and Soil Laboratories, Inc.

Table 10. Site 7: Styrene Concentrations in Water Samples Collected After Installation (30-inch-diameter surface water conveyance, medium to heavy continual flow, Nottoway County)

Time		Styrene Concentration (mg/L)	
		Outlet	10 m Downstream
After Project	16 days	< 0.0058	
	31 days	< 0.005 < 0.005[a]	< 0.005[a]

[a]Analyzed by Air, Water, and Soil Laboratories, Inc.

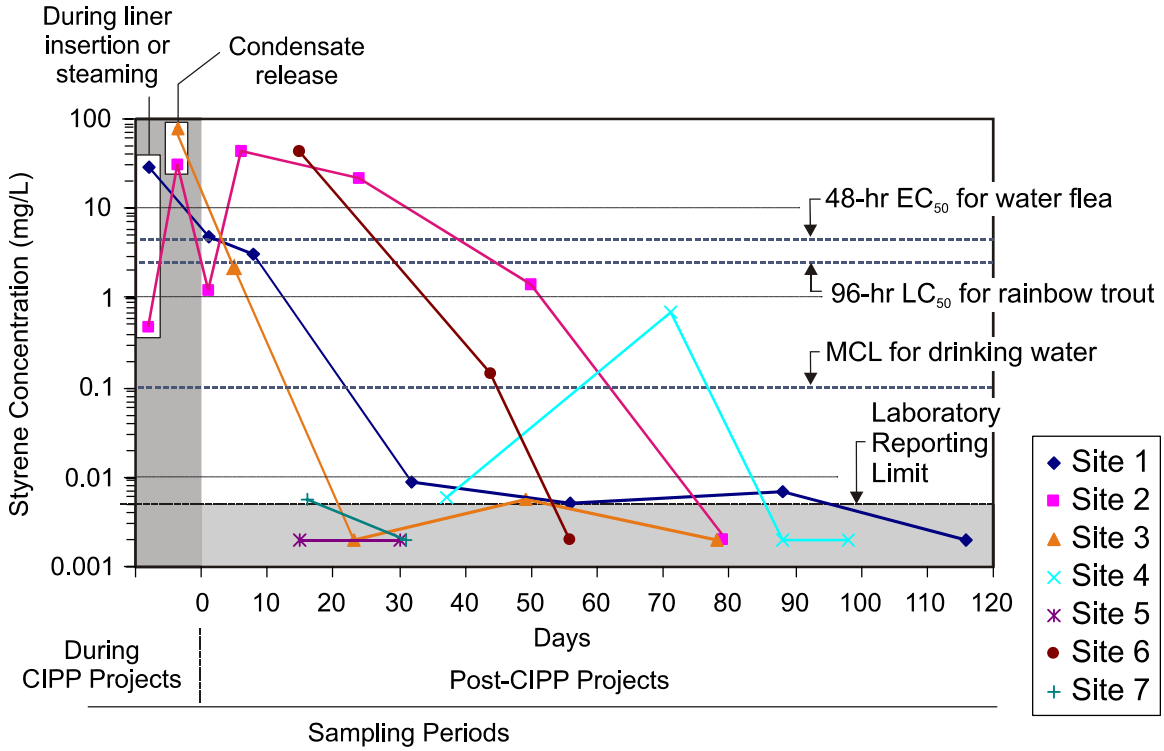


Figure 4. Styrene concentrations in water samples collected at pipe outlet during installation and at sampling periods up to 116 days after installation. Horizontal lines indicate the maximum contaminant level (MCL) of drinking water (0.1 mg/L), the EC_{50} or LC_{50} styrene concentrations for two aquatic species (as detailed in Table 2), and the laboratory reporting limit (0.005 mg/L). For styrene concentrations below the laboratory reporting limit, the data points shown merely indicate that sampling occurred and that the results were below the limit of 0.005 mg/L; they do not indicate the true concentration value.

Styrene concentrations and the duration of its detectable presence were highly variable among sites. Samples from some sites did not show a consistent decrease in concentration, particularly at sites with low or intermittent water flow. Although none of the sites was directly linked to a source of drinking water, styrene concentrations exceeding the MCL for drinking water were measured at five of the seven study sites. The concentrations at Sites 1, 2, 3, and 6 exceeded the MCL for drinking water (0.1 mg/L) at sampling periods of 5 to 50 days after installation, and at Site 4, the concentration exceeded the MCL 71 days after installation during a period of very low flow. The maximum styrene concentrations at four sites (Sites 1, 2, 3, and 6) exceeded published EC_{50} or LC_{50} values (Table 2) for various aquatic species. At Site 2, the concentration exceeded these values for the water flea and the rainbow trout at the sampling period of 24 days.

DISCUSSION

At certain times after CIPP installation, styrene concentrations exceeded the MCL for drinking water at five of the seven study sites and exceeded the EC_{50} or LC_{50} values of the water flea[6] and the rainbow trout[9] (common indicator species) at four of the monitored project sites. As compared with samples collected from sites with continual water flow, samples from sites with intermittent flow contained relatively higher styrene concentrations for a greater length of time after CIPP installation. This suggests that flow volume and regularity are important factors in diluting styrene concentrations.

At the two sites where styrene was not detected, the initial sample was not collected until 15 and 16 days, respectively, after installation; therefore, it cannot be known whether these installations had any effect on water quality or whether styrene, if indeed present, had decreased to concentrations below detection. At sites where styrene was detected, styrene was above the laboratory reporting limit (0.005 mg/L) at sampling periods 44 to 88 days after installation.

Styrene concentrations reached as high as two orders of magnitude greater than the MCL for drinking water. Concentrations exceeded the MCL for drinking water for at least 5 days after installation at five sites and for at least 44 to 71 days at three of these sites. Concentrations above the MCL were detected up to 40 m downstream. Although the sites in this study do not directly link to a drinking water supply, roadway conveyances often convey water upon which a variety of aquatic species depend. The sample results from five of seven sites exceeded one or more aquatic toxicity criterion (EC_{50} or LC_{50} values, Table 2) for styrene, and concentrations exceeding these values were detected as far as 10 m downstream. Styrene concentrations at one site exceeded the EC_{50} value for the water flea and the LC_{50} value for the rainbow trout at the sampling period of 24 days following installation.

One apparent ecological change during this study was the emergence of algal blooms, which appeared at three surface water sites within 6 to 8 days after CIPP installation and remained at these sites for at least 50 to 55 days post-installation. Algal blooms are often indicative of poor water quality (commonly from nitrogen or phosphorus pollution) and can have adverse ecological impacts.[23] The fact that algae blooms were not seen at project sites before CIPP installation could be seen to suggest that some aspect of the CIPP process could be a contributing factor for the blooms, but the specific cause (whether hot effluent discharge, styrene leaching, factors unrelated to the installations, etc.) is unknown.

As typical CIPP resins contain between 30 and 50 percent styrene, even a relatively small amount of uncured resin could potentially result in water samples with detectable styrene concentrations at the project site or downstream. Any resin that might be unintentionally released during installation would not have been subject to the same curing conditions as the resin contained within the liner. A sample of the uncured resin waste in the stream bed at Site 1 collected 1 day after installation had a styrene concentration of 580 mg/L. Styrene was detected at sites even where resin waste was either not released or had washed downstream; styrene was also detected at sites long after observed discharges of steam condensate had been flushed downstream. These observations, coupled with the length of time styrene was detected after installation, suggest that these installation practices (i.e., uncured extruded resin and discharge of

the steam condensate effluent) were not solely accountable for the styrene concentrations in water. These findings suggest that the resin-saturated liner was not completely cured during the installation process and continued to leach styrene, perhaps through or around the inner membrane liner.

Although the scope of this study did not lend itself to definitive determination of the specific contribution of styrene from each aspect of the CIPP process, the styrene concentrations identified in the laboratory tests of water samples may have resulted from one or a combination of the following: (1) installation practices that did not capture condensate containing styrene, (2) uncured resin that escaped from the liner during installation, (3) insufficient curing of the resin, and (4) some degree of permeability of the lining material.

Standards and Regulations

Although CIPP technology dominates the underground pipe rehabilitation industry and is a common method for above-ground pipe rehabilitation, only 3 of 85 trenchless pipe rehabilitation standards pertain directly to CIPP methods and materials.[3] ASTM standards for CIPP rehabilitation[12,-14] do not separate surface water conveyance guidelines from those for sewer lines. They also do not address measures to ensure containment of the resin that saturates the lining material. Although ASTM standards[12,13] contain a caveat that it is the user's responsibility to determine the applicability of regulatory limitations prior to use, the standards direct users to dispose of the curing water or condensed steam (effluent) by allowing it to drain from a hole made in the downstream end of the pipe. It is also important to note again that ASTM standards for CIPP procedures specify that the flow be bypassed or diverted before CIPP installation[12,13]

The FHWA culvert pipe liner guide[24] lists existing specifications for pipe repair technologies and provides a decision analysis tool designed to help users choose an appropriate pipe repair method based on various factors. The guide lists some specific environmental limitations of CIPP rehabilitation, including (1) possible thermal pollution from the discharge of the curing water, (2) potential toxicity of styrene-based resins prior to completion of the curing process, and (3) possible hazards to an environmentally sensitive area. The decision analysis tool addresses such concerns for CIPP technology by assigning it the highest ranking for environmental risk (on a scale of *1* to *5*). Neither the guide nor the decision analysis tool, however, provides guidelines or additional specifications (beyond the referenced ASTM standards) to mitigate environmental risks.

The EPA does not have published standards for allowable levels of styrene for receiving streams; however, the discharge of pollutants (which includes chemical wastes) to waters of the United States is regulated.[25] The discharge of steam condensate or spent cure water into waters of the United States would require a permit under the National Pollution Discharge Elimination System (NPDES) or state equivalent.[25,26] The permit conditions may require pre-treatment and monitoring prior to any discharge. State environmental regulatory agencies also typically have additional statutory and/or regulatory authority to prevent or regulate the discharge of pollutants to state receiving waters, including groundwater.[27] Although the state and/or federal agencies could use published water quality standards such as the relevant MCL or published aquatic

toxicity criteria to determine acceptable styrene levels, it is unclear what, if any, environmental regulation would govern the leaching of styrene from a finished CIPP product.

ACTIONS TAKEN BY THE VIRGINIA DEPARTMENT OF TRANSPORTATION IN RESPONSE TO PRELIMINARY RESEARCH FINDINGS

The authors provided VDOT with the preliminary research findings of this study along with three recommendations:

1. *VDOT should suspend styrene-based CIPP and undertake additional study of its installation and use to gain a better understanding of the technology and its potential impacts.*

2. *VDOT should evaluate their contract specifications to ensure that CIPP contractors are specifically required to prevent the escape or leaching of process residuals and to capture and properly dispose of residuals including cure water, cure steam condensate, and escaped resin.*

3. *If styrene-based CIPP is reinstated, VDOT should also ensure that proper oversight is provided to ensure compliance with any revisions to the specifications.*

VDOT took several actions upon receiving the preliminary findings:

1. *VDOT's Chief Engineer immediately placed a stop work order on all styrene-based CIPP repair projects contracted by VDOT.*[28] VDOT subsequently elected to allow CIPP installations on sanitary sewer projects (under certain conditions) while continuing to review the use of styrene-based CIPP repair.[29]

2. *A VDOT task group led by VDOT's Environmental Division was formed to evaluate further the use of steam- and water-CIPP repair projects containing styrene.* Task group participants included members of VDOT's Scheduling & Contract, Administrative Services, Materials, and Asset Management Divisions, as well as scientists from the Virginia Transportation Research Council (VTRC). Information gained from this evaluation was to be used to provide VDOT with recommendations for further action regarding the use of styrene-based CIPP technology.

3. *The task group conducted the evaluation,* which included acquiring the services of an independent environmental consultant to provide third party verification of the preliminary study findings and to test additional CIPP sites, meeting with the Virginia Department of Environmental Quality for support and guidance, and holding two series of interviews with CIPP industry representatives.

4. *The task group issued their evaluation report to the Office of the Commonwealth Transportation Commissioner in November 2007.* The report[30] provided recommendations regarding the modification of VDOT's CIPP contracting specifications, project management

considerations, and conditions for reinstatement of styrene-based rehabilitation. The recommendations were primarily designed to prevent the unintentional release of styrene-based resin during installation and the leaching of styrene from the finished product.

5. *The Office of the Commonwealth Transportation Commissioner charged VDOT's Scheduling & Contract Division with developing an action plan to implement the recommendations outlined in the task group report.* In April 2008, these recommendations were implemented and are incorporated in a VDOT memorandum that includes revised CIPP specifications.[31] These specifications include the following measures:

- a requirement that a VDOT project inspector (who has undergone a CIPP training program) provide oversight of CIPP installations for the duration of each installation.
- the acquisition of discharge-related permits, including air, water, and wastewater treatment
- ASTM and other applicable standard compliance requirements
- a requirement that all CIPP installations be performed in the dry (i.e. no water is contained or conveyed in the pipe during installation)
- a requirement that the contractor submit preconstruction installation and cure specifications
- additional lining materials and measures to ensure the containment of resin and styrene
- procedures for monitoring the curing of the CIPP lining material
- thorough rinsing of the finished product
- proper disposal of cure water, cure condensate, and rinseate
- requirements for water and soil testing prior to and after installation.

Reinstatement of statewide VDOT CIPP installations using the new procedures and specifications[31] is planned for May 2008. These actions are part of VDOT's ongoing effort to prevent the risks associated with styrene-based CIPP technology and, in doing so, to ensure due diligence by VDOT for the protection of the public health and safety as well as the environment.

CONCLUSIONS

- *The use of styrene-based CIPP technologies may result in detectable levels of styrene at and near the work site of the CIPP installation.* In this study, styrene was detected in water

samples collected from the pipe outlet during or after installation at five of the seven CIPP installations monitored in this study. Styrene concentrations in water samples ranged from <0.005 mg/L to 77 mg/L and were generally highest in samples collected during and shortly after installation. The maximum time styrene was detected at any site was 88 days following CIPP installation.

- *Although further research is needed to discern the contribution from each potential source of styrene, the findings suggest that the elevated styrene levels could have resulted from one or a combination of the following: (1) installation practices that did not capture condensate containing styrene, (2) uncured resin that escaped from the liner during installation, (3) insufficient curing of the resin, and (4) some degree of permeability in the lining material.* These factors appear to pose a risk of negative impacts from the use of styrene-based CIPP technologies.

- *Under the observed conditions, styrene concentrations could result in violations of state and/or federal environmental standards.* Although the EPA does not have published standards for allowable levels of styrene for receiving streams, the discharge of pollutants to waters of the United States is regulated under the NPDES permit program.

- *Research on the ecological and species effects of chronic styrene exposure in natural conditions would be useful in order to foster an understanding the potential impacts.* These studies should also look at the factors that would create conditions leading to algal blooms.

RECOMMENDATIONS

Given the planned reinstatement of CIPP installations by VDOT in May 2008 under the new specifications, the following recommendations are offered:

1. *Once CIPP installations are reinstated, VTRC should evaluate them to determine whether styrene leaches from the "cured" pipe under conditions that ensure strict control of process residuals.*

2. *VTRC should assess the environmental effects, if any, of other trenchless pipe repair technologies frequently used by VDOT.*

ACKNOWLEDGMENTS

The authors are grateful for the help they received from many VDOT employees. Ed Wallingford and Stanley Hite were valuable sources of information for this project. Appreciation is also extended to Shamsi Taghavi and David Bova for their assistance with sampling and to Ken Winter and Bryan Campbell at VDOT's Research Library for directing them to numerous useful sources. Robert Harmon, Joseph Miller, Chris Jackson, William

Bailey, Marek Pawlowski, and Michael Gosselin were helpful in providing information regarding the CIPP process and projects. Thanks also go to Aaron Mills of the University of Virginia for his assistance with algae identification and to Linda Evans, Ed Wallingford, Gary Allen, Michael Perfater, Bruce Carlson, G. Michael Fitch, and Amy O'Leary for providing helpful comments on an earlier version of the report. The authors appreciate the opportunity provided by VDOT and VTRC to conduct this study.

REFERENCES

1. Lueke, J.S., and Ariaratnam, S.T. Rehabilitation of Underground Infrastructure Utilizing Trenchless Pipe Replacement. *Practice Periodical on Structural Design and Construction,* Vol. 6, No. 1, 2001, pp. 25-34.

2. Wright, A.G. Houston Hustles for Drier Ground. *Engineering News-Record,* Vol. 235, No. 16, 1995, pp. 25-32.

3. Hoffstadt, F.A. Cured-in-Place Pipe Structures in Infrastructure Rehabilitation. In *Proceedings of the 45th International SAMPE Symposium.* SAMPE Publishing, Covina, Calif., 2000.

4. Insituform. Company Information. http://insituform.com/content/137/company_information.aspx. Accessed June 12, 2007.

5. U.S. Environmental Protection Agency. Technical Factsheet on: STYRENE. http://www.epa.gov/safewater/dwh/t-voc/styrene.html/. Accessed June 17, 2007.

6. Cushman, J.R., Rausina, G.A., Cruzan, G., Gilbert, J., Williams, E., Harrass, M.C., Sousa, J.V., Putt, A.E., Garvey, N.A., Laurent, J.P.S., Hoberg, J.R., and Machado, M.W. Ecotoxicity Hazard Assessment of Styrene. *Ecotoxicology and Environmental Safety,* Vol. 37, No. 2, 1997, pp. 173-180.

7. Baer, K.N., Boeri, R.L., Ward, T.J., and Dixon, D.W. Aquatic Toxicity Evaluation of Para-Methylstyrene. *Ecotoxicology and Environmental Safety,* Vol. 53, No. 3, 2002, pp. 432-438.

8. Machado, M.W. *Styrene-acute Toxicity to Fathead Minnow (Pimephales promelas) Under Flow-through Conditions.* Springborn Laboratories, Wareham, Mass., 1995.

9. Qureshi, A.A., Flood, K.W., Thompson, S.R., Janhurst, S.M., Inniss, C.S., and Rokosh, D.A. Comparison of a Luminescent Bacterial Test with Other Bioassays for Determining Toxicity of Pure Compounds and Complex Effluents. In J.G. Pearson, R.B. Foster, and W.E. Bishop (eds.), *Proceedings of the Fifth Annual Symposium on Aquatic Toxicology and Hazard Assessment.* American Society for Testing and Materials, Philadelphia, 1982.

10. U.S. Environmental Protection Agency. *Styrene Fact Sheet.* http://www.epa.gov/chemfact/styre-fs.txt/. Accessed June 17, 2007

11. U.S. Environmental Protection Agency. *Method 8260B, Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (gc/ms).* 1996. http://www.epa.gov/epaoswer/hazwaste/test/pdfs/8260b.pdf. Accessed June 12, 2007.

12. ASTM International. ASTM F1743-96(2003): Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation of Cured-in-Place Thermosetting Resin Pipe (CIPP). In *ASTM Book of Standards,* Vol. 08.04. West Conshohocken, Pa., 2003.

13. ASTM International. ASTM F1216-07b: Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube. In *ASTM Book of Standards,* Vol. 08.04. West Conshohocken, Pa., 2007.

14. ASTM International. ASTM D5813-04: Standard Specification for Cured-in-Place Thermosetting Resin Sewer Piping Systems. In *ASTM Book of Standards,* Vol. 08.04. West Conshohocken, Pa., 2004.

15. Ashland Distribution Co. and Ashland Specialty Chemical Co. Hetron Q 6405 Resin. MSDS No. 304.0329320-002.005. Columbus, Ohio, 2005.

16. Reline America, Inc. UV Cured-in-place lining. http://www.relineamerica.com/. Accessed July 21, 2007.

17. *Environmental Management Act, Municipal Sewage Regulation*. B.C. Reg. 129/99. British Columbia, Canada, 1999. http://www.qp.gov.bc.ca/statreg/reg/E/EnvMgmt/129_99.htm#part2. Accessed August 8, 2007.

18. Environment Canada. *Biological Test Method: Acute Lethality Test Using Rainbow Trout. Report EPS 1/RM/9 (with 1996 and 2007 amendments)*. Ottowa, Ontario, Canada, 1990.

19. Lockheed Martin Energy Systems. *Fish Kill Resulting from Styrene Resin Spill*. Lessons Learned Database. http://www.hss.energy.gov/csa/analysis/ll/. Accessed June 12, 2007.

20. Alexander, M. Environmental Fate and Effects of Styrene. *Critical Reviews in Environmental Science and Technology,* Vol. 27, No. 4, 1997, pp. 383-410.

21. Bogacka, T., Makowski, Z. and Ceglarski, R. The Breakdown of Aromatic Hydrocarbons in the Aqueous Environment. *Roczniki Panstwowego Zakladu Higieny,* Vol. 48, No. 2, 1997, pp. 149-161.

22. Fu, M.H., and Alexander, M. Biodegration of Styrene in Samples of Natural Environments. *Environmental Science and Technology,* Vol. 26, 1992, pp. 1540-1544.

23. U.S. Environmental Protection Agency. *Water Quality Criteria for Nitrogen and Phosphorus Pollution.* http://www.epa.gov/waterscience/criteria/nutrient/. Accessed June 28, 2007.

24. Thornton, C.I., Robeson, M.D., Girard, L.G., and Smith, B.A. *Culvert Pipe Liner Guide and Specifications.* Publication No. FHWA-CFL/TD-05-003. Federal Highway Administration, Central Federal Lands Highway Division, Lakewood, Col., 2005. http://www.cflhd.gov/techDevelopment/completed_projects/hydraulics/culvert-pipe-liner/_documents/culvert-pipe-liner-guide-july2005.pdf. Accessed April 15, 2008.

25. U.S. Environmental Protection Agency. *National Pollutant Discharge Elimination System (NPDES).* http://cfpub.epa.gov/npdes/. Accessed June 12, 2007.

26. Virginia Department of Environmental Quality. *Virginia Pollutant Discharge Elimination System Permit Program.* http://www.deq.state.va.us/vpdes/homepage.html. Accessed June 12, 2007.

27. Virginia Department of Environmental Quality. *Permits, Fees, and Regulations*. http://www.deq.state.va.us/vpdes/permitfees.html. Accessed June 12, 2007.

28. Winstead, C.L. Approved List Number 38, Pipe Rehabilitation Systems: Removal of Styrene-Based Liner from Approved List. VDOT Materials Division Memorandum No. MD 296-07. Virginia Department of Transportation, Materials Division, Richmond, 2007 http://www.virginiadot.org/business/resources/bu-mat-MD296-07.pdf. Accessed April 15, 2008.

29. Winstead, C.L. Approved List Number 38, Pipe Rehabilitation Systems: Applications for Styrene-Based Liners. VDOT Materials Division Memorandum No. MD 298-07. Virginia Department of Transportation, Materials Division, Richmond, 2007. http://www.virginiadot.org/business/resources/bu-mat-MD298-07.pdf. Accessed April 15, 2008.

30. [Virginia Department of Transportation Task Group]. *Evaluation of the Use of Styrene-based CIPP.* Virginia Department of Transportation, Environmental Division, Richmond, 2007.

31. Coburn, W.B., Jr. Pipe Replacement or Rehabilitation Contracts: Guidelines for Pipe Culvert Replacement or Rehabilitation—Selection Criteria, Specifications, and Inspection. Commonwealth of Virginia Department of Transportation Construction Directive Memorandum. CD 2008-11. Virginia Department of Transportation, Scheduling & Contract Division, Richmond, 2008. http://www.virginiadot.org/business/resources/const/cdmemo-0811.pdf. Accessed April 16, 2008

INDIANA DEPARTMENT OF TRANSPORTATION

Driving Indiana's Economic Growth

Design Memorandum No. 12-02
Technical Advisory

February 16, 2012

TO: **All Design, Operations, and District Personnel, and Consultants**

FROM: ***/s/ Crystal M. Weaver***
Crystal M. Weaver
Manager, Office of Hydraulics
Bridge Design, Inspection, Hydraulics, and Technical Support Division

SUBJECT: **Pipe Lining**

ADDS: ***Indiana Design Manual*** **Section 31-4.05(06)**

EFFECTIVE: **Immediately**

A. Introduction

Pipe lining is a technique for rehabilitating a culvert in poor condition where replacement is difficult. Pipe lining can be used for a circular or deformed culvert. The common types of pipe lining used for a circular culvert are solid-wall high-density polyethylene (HDPE) pipe, profile-wall HDPE pipe, profile-wall polyvinyl-chloride (PVC) or a cured-in-place (CIPP) system. The types used for a deformed culvert are oval-shaped solid-wall HDPE pipe or CIPP. See INDOT *Standard Specifications* Section 725 for more information. Pipe-lining considerations include the following.

1. The structure barrel should be relatively straight, not significantly damaged, and basically intact.

2. The backfill around the structure should be free from large voids.

3. There should be sufficient room to work from at least one end of the existing structure.

4. The structure is in a location where a road closure is impractical.

B. Design Criteria

1. A structure may not increase backwater over existing conditions, unless the increase is contained within the right of way and the outlet velocity is less than 13 ft/s.

2. Riprap scour protection should be used as described in *Indiana Design Manual* Section 31-3.04(03).

3. An HY-8 hydraulic analysis of each proposed pipe liner should be completed.

4. The smooth-interior hydraulic design will be based on a minimum Manning's *n* value of 0.012.

5. The largest possible liner should be used though a smaller liner can be hydraulically adequate.

6. Because of cost, a CIPP liner should be considered only if other liner choices cannot be applied. A CIPP liner should be used only in an existing structure with an equivalent diameter of 96 in. or less.

7. A CIPP liner will reduce the existing structure size as follows.

    a. For an equivalent diameter of 24 in., the diameter is reduced by 1 in.
    b. For an equivalent diameter of 27 in. through 48 in., the diameter is reduced by 2 in.
    c. For an equivalent diameter of 54 in. through 72 in., the diameter is reduced by 3 in.
    d. For an equivalent diameter of 78 in. through 96 in., the diameter is reduced by 4 in.

8. Deviation from the design criteria described above will require a design exception subject to Office of Hydraulics approval.

CMW:alu

6. All stream restoration measures shall be installed and all banks graded in accordance with the plans. All grading shall be stabilized at the end of each day using mulched seeding or seeding with erosion control mat.

7. After an area is completed and stabilized, the clean water dike shall be removed. After the first sediment flush, a new clean water dike shall be established upstream from the old sediment dike. Finally, upon establishment of a new sediment dike below the old one, the old sediment dike shall be removed.

8. A pump-around shall be installed on any tributary or storm drain outfall which contributes base flow to the work area. This shall be accomplished by locating a sandbag dike at the downstream end of the tributary or storm drain outfall and pumping the stream flow around the work area. This water shall discharge onto the same velocity dissipater used for the main stem pump-around.

9. If a tributary is to be restored, construction shall take place on the tributary before work on the main stem reaches the tributary confluence. Construction in the tributary, including pump-around measures, shall follow the same sequence as for the main stem. When construction on the tributary is completed, work on the main stem shall resume. Water from the tributary shall continue to be pumped around the work area in the main stem.

The cost of dewatering the stream channel, pumps, perpetuating existing median drainage, velocity dissipators, and other incidentals will not be paid for separately, but the cost thereof shall be included in the cost of the pipe liner.

SEEDING OF DISTURBED AREAS

An undistributed quantity of 2000 sys., Mulched Seeding, R is provided for seeding that may be required at disturbed areas within the right-of-way during the Slip Lining Process. At all other locations outside the right-of-way, Mulched Seeding, R shall be placed to reseed areas disturbed by the Slip Lining Process at no additional cost.

For additional information see Section 725.

CURED-IN-PLACE PIPE LINERS

Description

This work shall consist of the fabrication, installation, and curing of a cured-in-place pipe, CIPP, liner into existing circular or deformed pipe structures in accordance with 105.03.

Materials

The CIPP liner shall be in accordance with ASTM D 5813, Type III and shall be UV and abrasion resistant. The liners shall be designed in accordance with ASTM D 1216 for a fully deteriorated condition.

Construction Requirements

RIGHT-OF-ENTRY AREAS. If the right-of-way does not provide sufficient room for—performance of the work, rights-of-entry from all appropriate adjacent property owners shall be obtained prior to beginning work in accordance with 107.14. A temporary fence shall be installed as required to prevent encroachment of the public or livestock into the work area. Upon completion of the work, disturbed areas on private property shall be restored in accordance with 107.14.

TRAFFIC MAINTENANCE. Maintenance of traffic shall be in accordance with 104.04 and 801.

MAINTENANCE OF DRAINAGE. Drainage shall be maintained during the installation and curing operations in a manner that does not damage adjacent property.

PRE-INSTALLATION REQUIREMENTS. Before beginning the liner installation operation, three copies of design calculations shall be submitted to the Engineer. The design calculations shall be sealed by a professional engineer and shall certify:

(a) the proposed liner thickness was determined in accordance with ASTM F 1216,
(b) the required curing pressure, and
(c) the proposed waterway opening is in accordance with the plans.

Prior to installing the CIPP liner, a video inspection of the structure shall be performed. This inspection is to identify cavities in the structure that need to be repaired, identify connecting structures that shall be perpetuated, etc. The video shall become the property of the Department. Cavities adjacent to the existing structure and existing jagged edges or other deformities that impact the liner operation or function shall be repaired in accordance with the manufacturer's recommended procedures. All foreign material shall be removed from the existing structure in accordance with the ASTM specifications for the installation method and disposed of in accordance with 203.10.

INSTALLATION REQUIREMENTS. The CIPP liner shall be installed by the inversion method or the pulled-in-place method. Inversion installation of the CIPP liner shall be in accordance with ASTM F 1216. Pulled-in-place installation of the CIPP liner shall be in accordance with ASTM F 1743. The cured CIPP liner shall be inspected and video taped for workmanship. Defects in workmanship as defined in ASTM D 5813 section 6.2 shall be repaired or the CIPP liner shall be replaced so it meets the requirements of these specifications. The repaired or replaced CIPP liner shall be re-video taped. The video tape shall become the property of the Department. The installed CIPP liner shall be tested for delamination in accordance with the appropriate ASTM specification. The cured CIPP liner shall be cut within 2 in. of the ends of the existing structure. Where beveled inlets are required, the details shown in the plans shall be followed. Existing connections, including underdrains or another pipe structure, to the structure to be lined shall be perpetuated through the liner.

The liner shall be permanently marked with a stainless steel label with a minimum thickness of 0.080 in. located above the structure low water elevation and within 6 in. of the structure end. The information shown on the label shall be at least 1/2 in. tall and include the month and year of installation, the liner source, and the ASTM material specifications.

QC/QA PROCEDURE:

(a) For each existing structure lined, a type A certification in accordance with 916 and a test report in accordance with ASTM D 5813, section 7.3 shall be submitted.

(b) An independent laboratory shall test field-cured samples from each CIPP liner installation. Appropriate documentation for the independent laboratory shall be provided prior to installation of the CIPP liner. Testing results shall be provided to the Engineer within 7 days of receipt.

(c) At each structure to be lined, two flat plate samples shall be field cured and submitted for testing. The samples shall be taken directly from the wet out tube, clamped between flat plates and cured in the downstream end of the tube. As an alternative, two restrained end samples may be used for liners installed in pipes between 8 and 18 in. in diameter, or equivalent. The field-cured samples shall be submitted to the laboratory within 3 days of the completion of the installation.

(d) The field-cured samples shall be conditioned, prepared, and tested in accordance with ASTM D 5813. The wall thickness and flexural tests need only be performed on the structural portion of the CIPP liner only.

WARRANTY. The Contractor shall warrant, for a period of five years, all defects which will adversely affect the integrity or strength of the liner. The Contractor shall repair or replace, at Contractor's expense, such defects in a manner mutually agreed upon by the Department and the Contractor.

Method of Measurement

CIPP liners will be measured by the linear foot, complete in place. An allowance of 5 ft per existing structure or pipe will be made for the perpetuation of an existing structure or pipe through the liner.

Basis of Payment

The accepted quantities of pipe liner, cured-in-place, will be paid for at the contract unit price per linear foot for the pay item area of the existing structure in which the liner is installed, complete in place. The installed liner shall provide an opening area equal or greater than the proposed opening area shown in the plans.

Perpetuating the direct connection of an existing structure or pipe through the liner will be paid for by means of an allowance of 5 ft of pipe liner, cured-in-place for each such connection.

Payment will be made under.

Pay Item	**Pay Unit Symbol**
Pipe Liner, Cured-In-Place, _____ dia	in..... LFT
Pipe Liner, Cured-In-Place, _____ area	sft..... LFT

The cost of repairing jagged edge or deformities to existing pipe, filling cavities around the existing pipe with flowable backfill or grout, acquisition and restoration of required right-of-entry areas, erection, maintenance, and removal of temporary fence, removal and reattachment of end sections for access, removing foreign material from the existing pipe, maintaining existing water flow, maintaining traffic, perpetuation of connections to the structure to be lined, warranties and all other incidentals shall be included in the cost of the pay items in this section.

There will be no payment for the installation or removal of any liner that cannot be successfully installed due to the condition of the existing pipe.

If the existing pipe or other objects not designated for removal are damaged while performing this work, it shall be considered unauthorized work and repaired or replaced in accordance with 105.11.

~~DOCUMENTATION OF DRAINAGE STRUCTURES~~

~~The Contractor shall verify existing pipe dimensions before ordering material.~~

~~The Contractor shall provide digital photographic documentation of each opening of the drainage structures showing before and after conditions of the slip lining procedure. Cost shall be included in the "Pipe Liner,….." pay items.~~

~~LINER PLACEMENT~~

~~Liners shall be placed so that the flow line is maintained as close as possible to original elevation. The liner will be blocked down (forced to stay on the bottom of the existing pipe) in order to minimize any increase in the flow line. To keep the grade of the liner and help push the liner in the existing pipe, a rail system can be used in the installation. A rail system will help minimize the point loading on the liner if the bottom of the existing culvert is deteriorated.~~

To:		New York State Department of Transportation ENGINEERING INSTRUCTION	EI 10-yyy
Title: **REVISION TO DESIGN GUIDELINES FOR REHABILITATION OF CULVERT AND STORM DRAIN PIPE**			
Distribution: Manufacturers (18) Local Govt. (31) Agencies (32) Surveyors (33) Consultants (34) Contractors (39) _____ ( )		Approved: _____ __ _____ __ __ Date	

ADMINISTRATIVE INFORMATION:

- Effective Date: This Engineering Instruction (EI) is effective for projects submitted for Letting on or after September 2nd, 2010 and will be incorporated into future versions of Chapter 8 Highway Drainage, Section 8.6.7., Rehabilitation of Culverts and Storm Drains, of the Highway Design Manual. This EI is being issued concurrently with EI 10-xxx Revisions to Standard Specifications 602 – REHABILATION OF CULVERT AND STORM DRAIN PIPE.
- Superseded Issuances: EI 01-029 Design Guidelines for Rehabilitation of Culvert and Storm Drain Pipe.
- Disposition of Issued Materials: HDM Section 8.6.7., Rehabilitation of Culverts and Storm Drains

PURPOSE: This EI issues revisions to the design guidance on the selection and use of the various rehabilitation items.

TECHNICAL INFORMATION:

- Updated Design Guidelines & Guidance for highway engineers.
- Office of Design will implement this revision into the next edition of HDM Section 8.6.7.
- Cost Impact: No figurative cost impact is currently available but substantial savings will be realized in the capital program if the most cost effective culvert rehabilitation method is selected. Depending on site conditions and material selection, rehabilitation may be more cost effective than replacement. The key is always to use the least costly rehabilitation method unless unique conditions dictate otherwise.
- Changes being affected by this Issuance: Provides structured and concise guidance on how to select the most appropriate rehabilitation scheme for a particular culvert based on site conditions. Provides guidance on how to properly specify the two new HDPE relining items (smooth and profile wall). Provides guidance on when to specify and how to

properly execute Cured in Place Pipe (CIPP) applications.

IMPLEMENTATION: (Supersedes EI 01-029)

- Manner / method/ time frame in which to implement the above-stated information/ policy / guidance: Regional Design, Construction and Materials Engineers, MO Offices of Design, Construction and Technical Services should review and become familiar with the content of this EI so that it is implemented in their daily duties if necessary.
- Disapproved Special Specifications - N/A/,
- Disapproved Standard Specifications - N/A. (EI 10-xxx revises Standard Spec 602)
- New Specifications-N/A

TRANSMITTED MATERIALS: This EI transmits the revision of HDM Section 8.6.7, Rehabilitation of Culvert and Storm Drain Pipe, for both Metric and U.S. Customary applications.

BACKGROUND: Section 602 of the Standard Specifications was created in 2001.Since then, advances in materials and technologies utilized in culvert rehabilitation, have resulted in methodologies with a high quality end product. These methodologies can be delivered in a speedy and non-interfering way and can be implemented in environmentally sensitive areas. The current issuance aims to provide designers with the most current information and clear guidance on materials and methodologies in culvert and storm drain pipe rehabilitation. It also aims at delivering the safest and highest quality rehabilitated culvert and storm drain pipes with the lowest cost/benefit ratio possible, thereby resulting in substantial life cycle cost savings. The intent of the specification language and history behind the specifications development is provided in the concurrently issued EI 10-xxx Revisions to Standard Specifications 602 Rehabilitation of Culverts and Storm Drains.

DISTRIBUTION: MO, all 11 regional offices, FHWA, Thruway Authority, AGC.

REFERENCES: N/A.

CONTACT: Direct question on this EI to Ed Lucas or Michael Mathioudakis of the Materials Bureau via e-mail at elucas@dot.state.ny.us or mmathioudakis@dot.state.ny.us.

DESIGN GUIDELINES FOR REHABILITATION OF CULVERTS AND STORM DRAINS

I. General

Replacement of a buried pipe system will seldom be a viable alternative in locations where long detours or extensive disruption to traffic will occur. When replacement is neither viable nor economically desirable, existing pipes may be rehabilitated by one of the following options:

• Structural paving of the invert with PCC is an excellent rehabilitation methodology when the culvert has maintained its original shape, even if it exhibits considerable invert deterioration. Structural invert paving should be the predominant choice for rehabilitating large diameter arches and culverts, where using a new pipe lining method is very much cost prohibitive. Invert and barrel deterioration are the prime considerations when deciding on the extent and boundaries of the structural invert paving operation. These boundaries should be clearly shown on the contract documents. For personnel / labor access safety reasons, structural paving of the invert should not be specified in culverts with diameters smaller than **48", except when no other option is feasible.**

Design details on structural invert paving along with an extended guidance can be found in Section 6 of this document. This item may also be used in conjunction with shotcreting of the entire remaining culvert barrel (i.e. beyond the structural paving limits) further improving the structural capacity of the rehabilitated culvert. This hybrid rehabilitation scheme is recommended when the circumferential integrity of the culvert is questionable.

• Lining with Shotcrete. This is a cost effective solution for large size culverts and arches that are experiencing distress in sidewalls, roof, and invert. The culvert should not display any significant structural deficiencies, buckling or other forms of deformation. It can also be used in combination with paving inverts. The plans need to indicate the reinforcement and the limit along the periphery. Utilizing welding or stainless steel mechanical anchors in reinforcement anchoring are the only options allowed. Lining with shotcrete could encompass the entire barrel of the pipe. A minimum cover of 2 inches over the corrugation crests is recommended. If for other reasons a designer would like to specify a thicker cover this must be clearly indicated on the plans. To accommodate the proper installation and application equipment, the item can only be used in culverts with a minimum diameter of 48 inches.

Liming – General For the remaining three items, (lining with CIPP, lining concrete pipe with CIPP and lining with a new pipe) the designer must provide on the plans all necessary information so that the Approved List installers are able to calculate the design (dead and live) loads on each culvert based on the same critical design input parameters. The provided information must **at minimum** include, but it is not limited to, the culvert maximum depth of cover, estimated soil modulus and estimated water table elevation above culvert invert for the site. This information should be clearly noted on the plans, as: "The maximum depth of cover is estimated from the top of the pipe to…", or "The estimated water table elevation is measured from the culvert invert". By providing this information on the plans, we improve the uniformity of bidding, since all submitted bids will be relying on the same design input parameters. Subcontractors mobilization cost should also be considered when selecting relining methodologies. For example, if CIPP lining has been selected for twelve culverts with bends while HDPE lining has been proposed for three straight run culverts, unless the three straight run culverts were of very large diameter (approaching 42" in

diameter), it may be cost prohibitive to mobilize another subcontractor (HDPE lining) when the CIPP one will already be on site.

• Lining with New Pipe. This rehabilitation technique can restore both structural and hydraulic capacity of a pipe. It is appropriate for culverts ranging in diameters from 12 through 120 inches. The existing (host) pipe should be relatively free of large bulges which may prevent the new pipe from freely sliding through it. If bulges or other obstructions exist, they should be (if possible) eliminated in order to accommodate the unobstructed insertion of the new liner pipe. Lining pipe generally comes in 20 foot lengths and requires adequate end access space to accommodate insertion. When end access is limited, shorter pipe lengths may be utilized but they have to be special ordered. Designers should contact lining pipe manufacturers or suppliers in advance to determine availability of short lengths. All available pipe rehabilitation materials are presented in Section 6 of this Design Guidance.

When end access of an existing large pipe (72 inches or larger) is limited, Galvanized Steel Plate, Steel Structural Plate and Galvanized Steel Tunnel Liner Plate may be a cost effective pipe lining options. This is true, only if structural paving is not an option. These methodologies will also restore a culvert's structural integrity.

Designers should never specify the grout mix design used to fill the annular space between the existing pipe and the lining pipe. It is the manufacturer's representative responsibility to recommend a suitable grout compatible with the lining material used. The grout material recommendation must be included in the submitted written proposal to the EIC, in accordance to the specifications. The compressive strength of the grout is completely ignored (it is assumed that it carries no load and it does not contribute to the structural capacity of the composite "old pipe-grout-liner pipe" structure) in the liner thickness design calculations. Completely deteriorated conditions (i.e. it possesses zero remaining structural capacity) are assumed for the existing pipe during these calculations. Consequently, the proposed liner is required to possess adequate structural capacity to carry the entire calculated dead and live load.

The reader is strongly encouraged to review Section 6 of this Design Guidance for a detailed presentation of the above mentioned rehabilitation techniques. Additional guidance regarding the rehabilitation of culverts is provided in AASHTO's Highway Drainage Guidelines, Volume XIV.

2. Evaluating the existing culvert and site conditions

During hydraulic calculations to determine the minimum required diameter which satisfies the facility's hydraulic demand, the proposed lining pipe's wall thickness and/or the corrugation pattern may dictate the choice of lining materials.

It is imperative that the existing (host) culvert is thoroughly inspected in order determine the most appropriate type of rehabilitation. The inspection should determine culvert's dimensions, material type, overall condition and structural integrity as well as site and/ or existing pipe end accessibility for inserting lining pipe. Inspectors should clearly map the location and extent of distressed areas as well as all existing obstructions / buckles which may impact the size and insertion of the proposed lining pipe. Buckled pipes can be jacked near to their original shape provided that working room and proper access are available. However, excessive buckling of the existing pipe may severely obstruct and consequently preclude the use of any lining pipe. If visual inspection of the existing pipe for whatever reason is not feasible, a robotic or other remote means inspection

method is warranted.

Special order lining pipe lengths may be available for some types of lining pipes. If needed and as it was recommended in the "Lining with a new pipe" section, Designers should contact the pipe manufacturer or supplier to determine availability of shorter lining pipe lengths and approximate material costs.

If significant pipe perforations and/or backfill subsidence has been observed, consult with the Regional Geotechnical Engineer to determine the extent of any voids that may exist in the backfill material in the area above and immediately adjacent to the culvert.

3. Hydraulics & Service Life

All material used in culvert and storm drain rehabilitation should meet structural, hydraulic and service life requirements as identified in Chapter 8 of the Highway Design Manual. For design calculation purposes, the existing culvert and any annular fill material (e.g. grout) used in the lining application are assumed to provide no additional service life nor contribute to the structural capacity of the lining pipe.

4. Geotechnical Issues

Consult with the Regional Geotechnical Engineer to determine and map the extent of any voids that may exist in the backfill material adjacent to the culvert. Voids not immediately adjacent to the culvert, which may have developed via infiltration of backfill fines into the culvert, are typically filled from above using a series of drill holes. For the sake of uniform bidding purposes, when voids are present, the Plans should include the following details: general site conditions, access, proposed end treatments, profiles and grade staging, voids mapping, any special situations, relevant restrictions, etc. The Regional Geotechnical Engineer should be contacted for selecting the voids filling material in the backfill.

Very rarely culvert bearing embankments require grouting immediately prior to culvert rehabilitation. Extensive embankment grouting (filling of voids beyond culvert vicinity) is pursued only when the Designer and/or a Geotechnical Engineer decide(s) that the observed settlement poses a serious and immediate threat to the embankment integrity. Established practice for most cases dictates completing the lining work prior to addressing any settlement related issues

5. Cost

Each rehabilitation methodology has its own pay item which includes all labor and materials cost necessary to complete the installation. The depth of cover (or fill height above the culvert) and ground water table elevation impact the bidding price of a liner. The fill material in the backfill area above the pipe is paid for under a separate item provided by the Geotechnical Engineer.

6. Available lining methodologies and recommended conditions for use:

6.1 If the culvert possesses reduced but adequate structural capacity and the culvert has maintained its original shape some structural capacity can be restored by rehabilitating the barrel. Under these conditions, the culvert could be effectively rehabilitated by selecting one of the

following two methodologies:

6.1-1 Structural Paving of Inverts with Portland Cement Concrete (PCC)

Structural Paving of Inverts with Portland Cement Concrete (PCC). This is a relatively low cost solution for rehabilitating culverts and arches experiencing invert distress, primarily caused by abrasion or a combination of abrasion and corrosion. Generally, if the pipe or arch has maintained its original shape and does not experience other major structural deficiencies except the invert loss, the culvert can be rehabilitated by structurally paving the invert, regardless if the invert shows considerable deterioration. Due to the higher cost of lining pipes using other approved rehabilitation methodologies, the effectiveness of invert paving for invert distressed drainage facilities should be explored first. Structural invert paving is appropriate when there are no other major structural deficiencies in the culvert besides the invert deterioration, and the pipe is also of sufficient size (a minimum culvert diameter of 48" is recommended) to accommodate safe execution of this work. The designer should clearly indicate in the plans the concrete cover over the corrugation crests, the type and layout of the concrete reinforcement, and the paving area limits along the periphery of the culvert. Note that the periphery paving limits should always extend beyond the area of significant corrosion loss, allowing reinforcement to be attached onto sound metal locations on both sides of the invert. The 602 standard specification requires that all reinforcement details shall be shown on the plans.

Design Standard details of structural invert paving of culverts spanning up to 10 feet and bearing up to 20 feet of fill over the crown have been developed by the Office of Structures (DCES) and are included in this Design Guidance for designers' reference. Electronic copies of theses details can be provided upon request. Repairs for culverts falling outside these parameters need to be designed on an individual basis and the Office of Structures can be consulted for assistance. Welded wire fabric reinforcement embedded in a 4" deep/thick concrete slab over the corrugation crest is recommended for structural invert paving of round pipes and arches spanning up to 6 feet. The welded wire fabric reinforcement can be attached directly onto the corrugations by welding or utilizing stainless steel mechanical anchors. These are the only two anchoring options allowed for welded wire fabric reinforcement embedded in 4" thick concrete slab for culverts spanning less than 6 feet.

Reinforcement bars are recommended for all arches (regardless of span) and also for all round pipes spanning between 6 and 10 feet. The reinforcement is embedded in a 6" or 8" thick concrete slab, depending on the culvert's span, with a minimum of 2" reinforcement cover. Shear transfer is achieved by anchoring shear studs to the corrugation crests (see relevant drawing detail Figure 2). Reinforcement bars shall only be attached to shear studs (never directly to the culvert walls) by wire tying (see relevant drawing detail Figure 1), Reinforcement bar sizes will be selected based on the recommendations established by the Office of Structures (DCES) (see Figure 3). All reinforcement and shear studs should be covered with concrete and the concrete should be sloped in such a way as to prevent water ponding on the side walls. Small areas of suspected metal loss around culverts circumference do not necessarily preclude the use of this item as an effective rehabilitation technique, since the remaining circumference above the structurally paved invert area could also be lined with shotcrete. Since these treatments modify culverts hydraulics characteristics, designers may want to consult with the Hydraulics Design section on this topic. Designers are also reminded that a culvert with a previously paved invert could also be revisited and re-rehabilitated with concrete lining.

6.1-2 Lining with Shotcrete

If the entire culvert circumference or an area beyond the extent of structural paving exhibits signs of minor corrosion, generally less than 20% of the total perforated area, lining with shotcrete is a viable option. Designers may utilize the Design Standard details for structural paving developed by the Office of Structures and included in this document, after simply substituting the concrete with the appropriate shotcrete items. As mentioned in the previous section, shotcrete can be used in conjunction with structural invert paving to address corrosion beyond the extent of paving. Shotcrete can also be used for localized rehabilitation of a distressed culvert section. If properly specified, this method can also restore culvert structural capacity. Designers are directed to use a Manning's "n" value of 0.013 for hydraulic calculations in the shotcreted area of the culvert. For personnel / labor access safety reasons, this lining methodology should not be utilized in culverts with diameters smaller than 48".

6.2 If the structural integrity of the culvert is questionable, the following six lining options may be considered:

6.2-1 Lining with High Density Polyethylene Pipe (HDPE)

High Density Polyethylene Pipe meeting *ASTM F 894 (Profile Wall)* or *ASTM F 714 (Smooth Wall)* may be used in association with the height of cover table provided below. There are two types of HDPE liners: a profile wall often without exterior corrugations, and a smooth solid wall pipe. The exterior and interior diameters of these liners vary among manufacturers. Considerable confusion has been generated when specifying the required size of these two lining pipes. Profile wall pipe is specified by the inside diameter, and as the required load increases, the wall profile thickens. Smooth wall pipe is specified by the outside diameter and the actual inside diameter diminishes with greater loads, as the wall thickens. Smooth wall HDPE lining pipe has a much higher material cost because of the larger resin volume required for its fabrication compared to the profile wall. For good grouting practice purposes Standard Specification 602 requires a minimum annular space of 1 inch between the host pipe and the liner. Therefore the outside diameter of the liner pipe must be a minimum of 2 inches smaller than the diameter of the existing (host) pipe. This is an important size constraint when calculating the hydraulic capacity of the relined installation. As a result of these dimensional constraints, designers are at times forced to specify the more expensive smooth wall liner pipe vs. the cheaper profile wall. When this is the case, because for the same load carrying capacity, the smooth wall liner pipe possesses a thinner wall section, allowing for more interstitial space between the proposed liner and the host pipe. To prevent problems during construction between the two wall types, both types have there own specification and the Designers' wall selection should be clearly indicated in the plans. The original specification has been retained as an optional item. It can be used when abundant interstitial / annular space exists and the consequences of a potentially arbitrary swap in the field are not a major concern. Currently available diameters for these pipes range from 18 to 60 inches for solid wall pipe, and 18 to 96 inches for profile wall pipe.

A very frequent question when lining with HDPE pipe is what joint type will result in the best future performance of the installation. The primary purpose of the joints is to hold the pipe segments firmly together and in line through the insertion process and until the grout sets in place. The issue of joint type selection for HDPE liners is addressed in the revised 602 specification as: "*Perform all butt fusion and extrusion welding of HDPE pipe in accordance with the Manufacturer's recommendation*" and "*Alternate joining methods will be subject to approval by*

the Director, Materials Bureau". Two mechanical joints are currently approved, a threaded joint and a smooth exterior bell and spigot joint. A mechanical joint wrap process has been evaluated and approved with some dimensional restrictions associated with its use at this time. However, butt fusion and extrusion welding are still the most durable joining methods, effectively creating a continuous liner pipe but they are also more labor intensive and hence more expensive than other joining methods. When alignment breaks or pinch points are encountered in a project, designers should only consider butt fusion and extrusion welding as the joining methods of choice, as they provide the most reliable joints for these challenging site conditions. Designer choices as such, should be clearly stated in the notes and placed in a very prominent spot in the contract documents. The notes should also explicitly state that these joint selection restrictions solely apply to the host pipes possessing these challenging morphological conditions.

Diameter (Inches)	Maximum Allowable Height of Cover ([1]Feet)
18	30
21	30
24	33
27	26
30	26
33	26
36	26
42	23
48	23
54	26
60	26
65	26
72	26
84	33
96	36

[1] *Maximum vertical distance between the top of the pipe and the top of pavement.*

6.2-2 Lining with Cured in Place Pipe (CIPP)

Lining with Cured in Place Pipe (CIPP) is an option for round pipes when end access is limited, pipe alignment includes bends, or when other lining methods would seriously reduce culvert hydraulic capacity. CIPP can restore both the structural and the hydraulic capacity of a pipe. Although this item is relatively expensive compared to other relining items, it could be the best rehabilitation alternative if all or some of the above site conditions exist. Designers bear the sole responsibility in making this selection decision based on site conditions and associated regional installation cost. This item should never be considered as a viable rehabilitation method for arches or rectangular culverts. CIPP is best suited for circular drainage facilities with limited access to and ranging in diameter from 12 to 42 inches. CIPP technology can be applied to lining larger diameter culverts, but in these cases, the installation cost is usually prohibitive and CIPP lining should only be considered for very short lengths. The ability to prepare ("wet") the liner off site as opposed to "wet" it on site (near the culvert's access point) greatly impacts operational cost. High depths of cover and elevated water tables demand thicker CIPP liners. These adverse site conditions coupled with large diameter and/or long host culverts, result in very heavy liners, which forces to perform the "wetting" operation over the culvert's access point. This additional cost may render the overall cost of this operation prohibitive. Consult with the Materials Bureau when dealing with large diameter and/or excessively long liners.

Lining Concrete Pipe with Cured in Place Pipe (CIPP) is an option created to utilize a partially deteriorated design methodology and can ONLY be used for lining concrete pipes. This item should ONLY be used when the concrete pipe still possesses some measurable structural capacity but inspections have raised some concerns, which can be alleviated by lining. These concerns may include, but are not limited to, damaged or separated joints, infiltration of ground water from faulty joints or incipient cracks (cracks not threatening the structural capacity of the concrete pipe) or as a precautionary measure for abrasion protection. The designer may follow the same guidance as with CIPP (see above), but the alternate pay item should be selected. It is anticipated that invoking the partially deteriorated design methodology, ONLY where warranted, will result in substantial material cost savings and reduced overall bid prices.

A Manning's coefficient "n" value of 0.013 should be used for hydraulic calculations in all CIPP sections. The CIPP relining item is often selected by designers as a result of two very important features. The usually improved Manning's coefficient of the rehabilitated culvert coupled with the smallest cross section reduction possible as a result of selecting CIPP vs. any other relining methodology. Once again, only round culverts should be lined with this method. The anticipated service life of this treatment is 70 years.

It is imperative that all obstructions in the culvert are removed prior to initiating the CIPP lining procedure. The bid price for the CIPP item includes the cost of removing any obstructions, along with re-establishing culvert to secondary pipe connections and the removal of any protruding pipes as required. It should be noted that Department policy for storm drainage allows addition of pipe connections onto a pipe only within a structure (e.g. manhole, drop chamber, etc.) and never in between such structures, so finding all pipe to pipe connections should be a fairly straight forward process. A thorough culvert inspection is required to determine the number of existing "pipe to pipe" connections and the extent, if any, of obstructions removal. If the culvert opening

(36" in diameter or less) prohibits a human-led visual inspection, a closed circuit television inspection should be performed by experienced personnel trained in locating breaks, obstacles and service connections during the design phase of the project. This information should be made available to all bidders so that it assists them in preparing an accurate bid.

Designers should be aware that in the field, the liner is then inverted and filled with water, which pushes the liner through the culvert. The water also holds the resin-impregnated liner in position and in contact with the host pipe. The water is circulated through a mobile boiler which raises its temperature in excess of 160°F. The heat of the circulating water cures the resin and transforms the formerly flexible liner into a solid continuous conduit. The liner curing process typically lasts several hours. Once the liner is completely cured, the curing water is removed, then all (if any) service connections are restored, the completed liner should be inspected, often using a closed circuit television and robotic cutting devices, especially for culverts less than 36" in diameter.

Environmental impact concerns and information gathered from the extensive use of CIPP, have led to a series of new product developments as well as amendments to installation procedures. Curing water from CIPP installations utilizing a styrene-based resin contains some styrene residual. NYS Surface Water and Groundwater Quality Standards and Groundwater Effluent Limitations (6NYCRR Part 703) set quantitative and qualitative standards for effluents to NYS water bodies. These standards may vary for different classes of receiving waters or for discharging it to groundwater. NYS Water Quality Standards include specific guidelines for discharging certain pollutants (including styrene) to Class A waters and/or groundwater, namely 0.05 ppm for class A waters and 0.005 ppm for groundwater respectively. The general conditions listed in 6NYCRR Part 701 apply to all water classifications. They dictate that discharges shall not cause impairment of the best usages of the receiving water (as specified by the water classifications) both at the location of discharge or at any other location which may be affected by such discharge. Note that thermal loading considerations are directly related to the release temperature and discharge rate of the curing water. Provisions for handling and/or disposal alternatives as well as other control procedures are included in the specifications to address the presence of styrene in the curing water and other potential releases to water and air from the by-products of the CIPP installation. These provisions include:

- Some procedural changes to enhance control of the CIPP process and leakage of resin, including utilizing a preliner bag and excavating a temporary resin control pit at the outlet.
- Allowing the use of non-styrene based resins containing less than five percent volatile organic compounds (VOCs) with less than 0.1 percent hazardous air pollutants (HAPs). These resins are now included in the 602 Standard Specifications and can be used by the Contractor in any CIPP site. The **cured liner** should also contain *less than 0.1 percent of water quality pollutants (as listed in 6 NYCRR Parts 700-705)".* NYSDOT may determine and dictate that at certain areas of greater environmental concern (i.e. in the vicinity of class A water sources or at other locations presenting other needs) non-styrene based resins MUST be used. If the Department requires the use of only a designated resin type, the resin type requirements shall be clearly noted in the contract documents; otherwise, the Contractor may select the resin type from the resin approved list included in the CIPP Approved Installer's Materials Procedure document.

- In all CIPP installations utilizing a styrene based resin, it is required to collect the curing water for:
  - Reuse in another curing operation

- Treatment or disposal at an off-site facility; or
- Release on site after treatment to standards dictated by NYSDEC and with approvals from NYSDEC.

- Summarizing, the resin type alternatives for CIPP work are to either use a non-styrene based resin or follow additional controls when using a styrene-based resin.

Areas of environmental concern may include, but are not limited to, fishing streams and ponds, upstream of public water sources, densely populated urban areas where residents are concerned about the short lasting odor of the styrene during curing, etc. Waters classified as Class A are: a source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing (i.e. waters suitable for fish, shellfish, and wildlife propagation and survival). Although numerical standards are not listed for other classes of streams in 6NYCRR Part 703, the general requirements of Part 701 apply (i.e. discharge must not cause impairment of the best usages of the receiving water).

The designer shall determine the location of each installation in respect to environmental resources including the classes of streams/watercourses in the vicinity of the project. The regional environmental unit and/or "Environmental Viewer" (A GIS application currently available at the Office of the Environment Intradot site and under the manual / applications tab, subsection GIS Application) shall be consulted for stream classification and other relevant environmental information. For installations close to and presenting the potential for curing water releases to class A streams or releases of other concern, the requirement for using a non-styrene based resin should be considered.

If designers determine that a non-styrene based resin shall be used in a specific CIPP installation, then the relining project's contract documents have to clearly and unambiguously specify that "a *resin containing less than five percent volatile organic compounds (VOCs) with* less than 0.1 *percent hazardous air pollutants (HAPs) must be used*". It should also clearly state that "the **cured liner** should contain *less than 0.1 percent of water quality pollutants (as listed in 6 NYCRR Parts 700-705)".* Use of these resins will result in a significant increase to the rehabilitation cost, approximately double to the materials cost of using regular styrene based resins in 2009 market prices. Therefore the decision to specify non-styrene based resins should not be made lightly and never prior to evaluating whether the use of styrene based resins combined with other alternative provisions to control the release of the curing water provide both enough site environmental protection and project cost savings. These provisions (listed now in the 602 Standard Specification) include but they should not be limited to: Removal (pumping out) of the curing water at the end of the CIPP installation and transporting it to an appropriate disposal facility instead of free draining it at the outlet, providing for a resin catchment pit excavated right at the culvert's outlet to create ideal conditions for the collection of the trace amounts of styrene, temperature control of the released curing water, as well as combinations of the above. Again, designer's stipulations on environmental protection provisions should be clearly indicated on the plans as they may substantially impact the operational cost. These stipulations should be limited to the class of the neighboring stream or water course class which may be impacted by the release of the curing water, the need for utilizing a styrene or a non-styrene based resin, the maximum allowed release temperature of the curing water and the size of the resin catchment pit.

The majority of the environmental controls in any CIPP project are dictated by the written agreement (Materials Procedure) between the Approved List installer and the Materials Bureau. If

designers have any concerns about using the CIPPL relining item at a specific location, especially when styrene based resins are employed, they should first consult with the Materials Bureau.

Current designs address fill heights up to a maximum of 50 feet. If the fill height over the CIPP installation exceeds 50 feet at any point along the culvert alignment, contact the Materials Bureau to coordinate an evaluation of the proposed CIPP liner design.

6.2-3 Lining with Polyvinyl Chloride Pipe

The 602 relining specification also allows the contractor to use PVC pipe meeting ASTM F 1803, ASTM F 949, and two new standards, ASTM F 679 or ASTM F 3034 (small diameters 12" or 15") as a relining item. PVC pipe is currently available in diameters ranging from 12 inches through 36 inches on the current Approved List. Please always consult the Approved List for the addition of new manufacturers and/or products as well as for the currently approved sizes for each PVC item. PVC lining pipes are corrosion and abrasive resistant. A Manning's coefficient value of 0.013 should be used for all hydraulic capacity calculations related to PVC pipes.

Some PVC pipes are more brittle than other flexible relining items. Therefore, designers should determine prior to specifying it, that the condition and shape of the host culvert will allow for an unobstructed insertion of the PVC lining pipe.

Since the 602 relining specification requires a minimum annular space of 1" for effective grouting, the outside diameter of the liner pipe needs to be a minimum of 2" smaller than the inside diameter of the existing (host) pipe when calculating the hydraulic capacity of the new installation. Profile wall pipe (ASTM F 949) is specified by the pipe's inside diameter while the respective outside diameters can be found in ASTM F 949. ASTM F 1803 lists only the inside diameter of these respective items, therefore designers must consult with the pipe manufacturer to obtain the outside diameter information. Both ASTM F 949 and ASTM F 1803 pipes possess joints that are flush with the outside diameter. However, ASTM F 679 and ASTM F 3034 pipes do not have a joint flush with the outside diameter of the pipe but rather a bell and spigot joint protruding from the outer pipe shell. Therefore, FOR ASTM F 679 & ASTM F 3034 pipes, it is **the outside diameter of the joint and not the outside diameter of the pipe** which dictates the maximum allowable liner diameter for a particular application. Because of this confusion, the lack of readily available info for some PVC pipes and in order to properly evaluate selected PVC pipe size compliance with the minimum required annular space for effective grouting, **designers are strongly encouraged to always consult with the Approved List manufacturer's representative about the maximum outside dimension of any PVC pipe.**

The table below provides the allowable fill heights for each size of PVC liner pipe. If the fill height exceeds 50 feet at any point along the pipe alignment, contact the Materials Bureau for approval of the proposed liner design. The anticipated service life of a PVC liner is 70 years.

Diameter (Inches)	Maximum Allowable Height of Cover ([1]Feet)
12	50

15	46
18	33
21	50
24	50
30	50
36	26

[1] *Maximum vertical distance between the top of the pipe and the top of pavement.*

6.2-4 Lining with Tunnel Liner Plate

In some closed drainage systems, space constraints may limit lining options which involve installing full lengths of pipe sections. In these cases, galvanized tunnel liner plate may be a viable option. Tunnel liner plate can be inserted and assembled within the host culvert as the laying length of individual sections is 18 inches. Galvanized Tunnel Liner Plate may require a PCC invert to provide the required service life and hydraulic performance as stated in the Highway Design Manual, Chapter 8.

Structural paving of the invert improves the hydraulic efficiency of the culvert and protects the tunnel liner bolt flanges from abrasion caused by bedload. When site conditions dictate that only tunnel liner plates can accommodate the structural demand of the culvert, but hydraulics analysis dictates that a low Manning material must be used, shotcreting the invert or HDPE lining is a valid solution. Consult the Materials Bureau for further guidance when such cases arise.

6.2-5 Lining with Polymer Coated Corrugated Steel Pipe (CSP) or Concrete Lined Corrugated Steel Pipe (CSP)

When a CSP has reached the end of its anticipated service life, the culvert can be relined with either, Polymer Coated CSP or Concrete Lined CSP.

The anticipated service life of these materials should be determined based on the discussion presented in Chapter 8 of the Highway Design Manual (Section 8.6.2.2). For Concrete Lined Corrugated Steel Pipe its anticipated service life should be determined consistent with Section 8.6.2.2, Table 8.8 as the service life of a Metallic Coated (Galvanized) Steel Pipe with the concrete lining providing an additional 30 years of anticipated service life.

If the rehabilitated pipe is anticipated to be subjected to potentially abrasive bed loads or to be exposed to high concentrations of industrial waste,, both of these CSP relining items are suitable for these conditions. The suggested Manning's coefficient "n" value will range from 0.013 to 0.026, depending on the corrugation pattern selected. Except for Concrete Lined Corrugated Steel Pipe (CSP), the recommended Manning coefficient "n" values for all drainage materials are

provided in the Highway Design Manual, Chapter 8, Section 8.6.3.1. An "n" value of 0.013 should be used for Concrete Lined CSP. Since relining any culvert results in a reduced hydraulic diameter of the host pipe, a smooth interior liner should be considered as a replacement.

The height of fill tables provided in Chapter 8 of the Highway Design Manual shall be used to select the thinnest gauge steel pipe which meets the site's height of fill requirements. Designers should be reminded that the structural criteria for corrugated steel pipe, as listed in Chapter 8 of the HDM, must be used when lining with concrete lined CSP. The concrete lining does not contribute anything additional to the structural capacity of the corrugated steel pipe.

The relining materials discussed in this section are available in various diameters, appropriate gauges, and corrugation configurations. The desirable pipe type should be specified using the pay items.

6.2-6 Lining with Steel Structural Plate Pipe or Pipe Arches

Steel structural plate can be partially or fully assembled and pushed or pulled into place within the pipe. This lining option should be considered for large diameters where other items are unavailable. If the plate sections are too large to be inserted into the host culvert through the exposed ends, then an excavation and a field cut through the culvert roof would be required. Every effort should be made to ensure that the excavation and field cut are located where it will be the least disruptive to traffic.

Designers must clearly indicate on the plans to structurally pave the invert of the plate pipe or arch when it is anticipated that the culvert will be exposed to an abrasive flow environment. Such aggressive flow environments substantially shorten the life expectancy of the rehabilitated facility. The structural paving of the invert is a second protection and, as such, it be paid as a separate item from the steel structural plate. The extent of the invert structural paving (primarily its width) must be clearly indicated on the plans and must also encompass (with some margin of safety) the entire area most likely to be exposed to the abrasive environment.

To:		*New York State Department of Transportation* **ENGINEERING INSTRUCTION**	**EI 10-xxx**

Title: Revisions to Standard Specifications 602 – REHABILATION OF CULVERT AND STORM DRAIN PIPE

Distribution:
- ☐ Manufacturers (18)
- ☐ Local Govt. (31)
- ☐ Agencies (32)
- ☐ Surveyors (33)
- ☐ Consultants (34)
- ☐ Contractors (39)
- ☐ _____( )

Approved: _____ Date _____

ADMINISTRATIVE INFORMATION:

- Effective Date: This Engineering Instruction (EI) is effective beginning with projects submitted for the letting of September 2th, 2010" (See EI 02-010.)
- Superseded Issuances: Section 602 - REHABILITATION OF CULVERT AND STORM DRAIN PIPE.
- Disposition of Issued Materials: Replace Section 602 of the Standard Specifications.

PURPOSE: This EI revises §602 - REHABILITATION OF CULVERT AND STORM DRAIN PIPE of the Standard Specifications.

TECHNICAL INFORMATION:

- Updated Design Guidelines for these items are being issued with EI 10-yyy
- New Construction Inspection Manual (CIM) Guidance for these items will be issued with a future EI after the completion of this review.
- Actions : None
- Cost Impact: Savings will be realized if guidance for selecting the most appropriate rehabilitation methodology is followed and contractor executes the work following the best recommended practice. Additionally, the clarity incorporated into the new specification, should reduce costly misinterpretation issues during construction.
- Changes Being Affected By This Issuance: This issuance introduces new structural paving items, improvements to shotcrete lining methodology and new lining with HDPE items. The revised CIPP lining specification section addresses significant changes in the CIPP lining practice as well as environmental concerns by introducing non-VOC, non-styrene resins in this process. This issuance also adds new lining with galvanized steel items while it removes aluminum lining items from the standard specification a result of past improper use. These aluminum relining items can still be used via special specifications after approval by the Director, Materials Bureau.
- Removed/replaced Specifications: Remove existing 706-06 "Polyester Formed In Place Pipe Liner" and we replace it with a new specification 706-09 "Cured In Place Pipe (CIPP) Liner".
- Revised Specifications: 706-10 Polyvinyl Chloride Pipe (relining). Two additional ASTM PVC items were added to the Material Requirements section of this specification.

IMPLEMENTATION: (See EI 02-010.)

- Manner/method/time frame in which to implement the above-stated information/policy/guidance.
- Disapproved Special Specifications - 01602.90nnnn M- Lining Existing Culvert with Corrugated Structural Plate Arch, 01602.9001 02- Lining Existing Culvert with Corrugated Metal Box Culvert Superstructure, 602.9002nn02- Lining with Corrugated Metal Arch (metric), 603.01 39 M- Rehabilitation of Existing Storm Drain Pipelines by Cured in Place Inversion Lining,

- Disapproved Standard Specifications - 602.200, Paving Inverts with Portland Cement Concrete, 602.35xx, Lining with Polyester Formed in Place Pipe Liner, 602.40xx, Lining with Corrugated Aluminum Pipe Type IR, 602.45xx, Lining with Aluminum Coated (Type 2) CSP Type IR, 12 gauge, 602.47xxxx, Lining with Aluminum Coated (Type2) CSP Type IIR, 10 gauge, 602.50xxxx, Lining with Aluminum Structural Plate Pipe (230x65), 602.52xxxx, Lining with Aluminum Structural Plate Pipe Arch (230x65), 602.600101, Lining with Aluminum Tunnel Liner Plate 3.18 mm thick, 602.600102, Lining with Aluminum Tunnel Liner Plate 3.81 mm thick, 602.600201, Lining with Aluminum Tunnel Liner Plate 4.45 mm thick, 602.600202, Lining with Aluminum Tunnel Liner Plate 5.08 mm thick, 602.600301, Lining with Aluminum Tunnel Liner Plate 5.72 mm thick, 706-06 Polyester Formed in Place Pipe Liner.
- New Specifications- 602.2002, Structural Paving of Inverts with Portland Cement Concrete, 602.26xx, Lining with Smooth Wall High Density Polyethylene Pipe, 602.27xx, Lining with Profile Wall High Density Polyethylene Pipe, 602.36xx, Lining with Cured in Place Pipe (CIPP), 602.37xx, Lining Concrete pipe with Cured in Place Pipe (CIPP), 602.51xxxx, Lining with Steel Structural Plate Pipe, 602.53xxxx, Lining with Steel Structural Plate Pipe Arch, 706-09 Cured in Place Pipe (CIPP) Liner
- Standard Pay Items associated with Section 602 are provided on pages x to y of this EI. Existing and new pay items have both been included for clarity.

TRANSMITTED MATERIALS: This EI issues the revisions of both the Metric and English version of §602 - REHABILITATION OF CULVERT AND STORM DRAIN PIPE of the Standard Specifications It also deletes both Metric and English versions of §706-06 Polyester Formed in Place Pipe Liner in its entirety from the standard specifications and replaces them with §706-09 Cured in Place Pipe (CIPP) Liner.

BACKGROUND: Since the creation of Section 602 in 2001, these specifications have proven an effective tool for addressing the condition of New York State's culverts, a critical group of assets. Many changes in the way these specifications are used, and administered, have occurred since then, and the reissuance of this section reflects current best practices.

The following describes the problems with the current specification and how they are addressed in this new issuance:

PAVING OF INVERTS: In the currently approved specification, this term refers to an inadequate process, which does not restore any structural capacity to the culvert. Since the introduction of Section 602 in 2001, designers have provided notes on the plans to address this shortcoming.

STRUCTURAL PAVING OF INVERTS: In this issuance, this is a culvert specific design aiming at restoring the structural integrity of the invert of the rehabilitated culvert.

LINING WITH SHOTCRETE: In this issuance this item includes several alternate reinforcement and height of cover options, which provides designers additional flexibility to incorporate these items to a variety of site conditions.

LINING WITH HDPE: Two new items for HDPE pipe lining have been created in this issuance so that the designer can specify either the solid or the profile wall type as per project's needs. This addition will minimize confusion and arbitrary item changes during construction due to the different dimensional criteria (primarily inside vs. outside diameter) each wall type uses.

LINING WITH PVC PIPE: Two new items of PVC pipe lining have been added in this issuance to increase equivalent products availability.

CIPP LINING: The existing section on Lining with Polyester Formed in Place Pipe Liner is being deleted and is replaced in the new issuance with a section entitled Lining with Cured in Place Pipe. This change

was dictated by the need to accommodate new environmentally friendly resins introduced in the markets over the past few years for CIPPL work conducted in environmentally sensitive areas. Detailed guidance on the use of the CIPP item is also included in this issuance. A partially deteriorated design methodology for CIPP work in concrete culverts ONLY, is also introduced.

Galvanized steel structural plate pipes and arches lining items have been added in this issuance, to address abrasion resistance and invert durability concerns for larger culverts. These items complement the only other uncoated steel relining item, namely the steel tunnel liner plate family.

All aluminum lining pay items have been deleted from the standard specification as stream carried bedload has diminished the expected service life in several rehabilitated installations. These aluminum items will still be available for use wherever their use is warranted thru the use of special specifications.

The new design guidance being issued with the companion EI will assist designers in making better material and pay item choices for relining projects.

REFERENCES: N/A.

CONTACT: For any questions on this EI please contact Ed Lucas (elucas@dot.state.ny.us) or 518 457 4590) OR Michael Mathioudakis (mmathioudakis@dot.state.ny.us or 518 457 9800) of the Materials Bureau.

Table 1 Approved 602.25xx pay items.

Item No. 602.25xx Lining with High Density Polyethylene Pipe	
Diameter inches (mm)	Item No.
18 (450)	.2518
21 (525)	.2521
24 (600)	.2524
27 (675)	.2527
30 (750)	.2530
33 (825)	.2533
36 (900)	.2536
42 (1050)	.2542
48 (1200)	.2548
54 (1350)	.2554
60 (1500)	.2560
66 (1650)	.2566
72 (1800)	.2572
84 (2100)	.2584
96 (2400)	.2596

Table 2 Approved 602.26xx pay items.

Item No. 602.26xx Lining with Smooth Wall High Density Polyethylene Pipe	
Diameter inches (mm)	Item No.
18 (450)	.2618
21 (525)	.2621
24 (600)	.2624
27 (675)	.2627
30 (750)	.2630
33 (825)	.2633
36 (900)	.2636
42 (1050)	.2642
48 (1200)	.2648
54 (1350)	.2654
60 (1500)	.2660
66 (1650)	.2666
72 (1800)	.2672
84 (2100)	.2684
96 (2400)	.2696

Table 3 Approved 602.27xx pay items.

Item No. 602.27xx Lining with Profile Wall High Density Polyethylene Pipe	
Diameter inches (mm)	Item No.
18 (450)	.2718
21 (525)	.2721
24 (600)	.2724
27 (675)	.2727
30 (750)	.2730
33 (825)	.2733
36 (900)	.2736
42 (1050)	.2742
48 (1200)	.2748
54 (1350)	.2754
60 (1500)	.2760
66 (1650)	.2766
72 (1800)	.2772
84 (2100)	.2784
96 (2400)	.2796

Table 4 Approved 602.30xx pay items.

Item No. 602.30xx Lining With Polyvinyl Chloride Pipe	
Diameter inches (mm)	Item No.
12 (300)	.3012
15 (375)	.3015
18 (450)	.3018
21 (525)	.3021
24 (600)	.3024
30 (750)	.3030
36 (900)	.3036

Table 5 Approved 602.36xx pay items.

Item No. 602.36xx Lining With Cured in Place Pipe (CIPP)	
Diameter inches (mm)	Item No.
12 (300)	.3612
15 (375)	.3615
18 (450)	.3618
21 (525)	.3621
24 (600)	.3624
30 (750)	.3630
36 (900)	.3636
42 (1050)	.3642
48 (1200)	.3648

Table 6 Approved 602.37xx pay items.

Item No. 602.37xx Lining Concrete Pipe With Cured in Place Pipe (CIPP)	
Diameter inches (mm)	Item No.
12 (300)	.3712
15 (375)	.3715
18 (450)	.3718
21 (525)	.3721
24 (600)	.3724
30 (750)	.3730
36 (900)	.3736
42 (1050)	.3742

Table 7 Approved 602.51xx pay items.

Item No. 602.51xx Lining with Steel Structural Plate Pipe 6" x 2"(150x50)							
Diameter inches (mm)	Gauge						
	12	10	8	7	5	3	1
60 (1525)	.510101	.510102	.510103	.510104	.510105	.510106	.510107
66 (1675)	.510201	.510202	.510203	.510204	.510205	.510206	.510207
72 (1830)	.510301	.510302	.510303	.510304	.510305	.510306	.510307
78 (1980)	.510401	.510402	.510403	.510404	.510405	.510406	.510407
84 (2135)	.510501	.510502	.510503	.510504	.510505	.510506	.510507
90 (2285)	.510601	.510602	.510603	.510604	.510605	.510606	.510607
96 (2440)	.510701	.510702	.510703	.510704	.510705	.510706	.510707
102 (2590)	.510801	.510802	.510803	.510804	.510805	.510806	.510807
108 (2745)	.510901	.510902	.510903	.510904	.510905	.510906	.510907
114 (2895)	.511001	.511002	.511003	.511004	.511005	.511006	.511007
120 (3050)	.511101	.511102	.511103	.511104	.511105	.511106	.511107
126 (3200)	.511201	.511202	.511203	.511204	.511205	.511206	.511207
132 (3355)	.511301	.511302	.511303	.511304	.511305	.511306	.511307
138 (3505)	.511401	.511402	.511403	.511404	.511405	.511406	.511407
144 (3660)	.511501	.511502	.511503	.511504	.511505	.511506	.511507
150 (3810)	.511601	.511602	.511603	.511604	.511605	.511606	.511607
156 (3960	.511701	.511702	.511703	.511704	.511705	.511706	.511707
162 (4115)	.511801	.511802	.511803	.511804	.511805	.511806	.511807
168 (4265)	.511901	.511902	.511903	.511904	.511905	.511906	.511907
174 (4420)	.512001	.512002	.512003	.512004	.512005	.512006	.512007
180 (4570)	.512101	.512102	.512103	.512104	.512105	.512106	.512107

Table 8 Approved 602.52xx pay items.

Item No. 602.52xx Lining with Steel Structural Plate Pipe Arch 230x65

Due to the number of size combinations for this item, pay item numbers will be generated by DQAB as needed. Consult with the Materials Bureau for standard industry sizes available.

Table 9 Approved 602.65xx pay items.

Item No. 602.65xx Lining With Concrete Lined CSP 2- 2/3"x 1/2" (68 x 13), 12 gauge			
Diameter inches (mm)	Gauge		
	14	12	10
48 (1200)	.654814	.654812	.654810
54 (1350)	.655414	.655412	.655410

Table 10 Approved 602.70xx pay items.

Item No. 602.70xx Lining With Concrete Lined CSP 5" x 1" (125 x 25), 12 gauge			
Diameter Inches (mm)	Gauge		
	14	12	10
60 (1500)	.706014	.706012	.706010
66 (1650)	.706614	.706612	.706610
72 (1800)	.707214	.707212	.707210
78 (1950)	.707814	.707812	.707810
84 (2100)		.708412	.708410
90 (2250		.709012	.709010
96 (2400)		.709612	.709610
100 (2550)		.702102	.700102
106 (2700)			.700108

Table 11 Approved 602.75xx pay items.

Item No. 602.75xx Lining With Polymer Coated CSP 2- 2/3"x 1/2" (68 x 13), 12 gauge	
Diameter Inches (mm)	Item No.
18 (450)	.751812
21 (525)	.752112
24 (600)	.752412
30 (750)	.753012
36 (900)	.753612
42 (1050)	.754212
48 (1200)	.754812
54 (1350)	.755412

Table 12 Approved 602.80xx pay items

Item No. 602.80xx Lining With Polymer Coated CSP 3" x 1" (75x25) or 5" x 1" (125x25), 12 gauge	
Diameter Inches (mm)	Item No.
60 (1500)	.806012
66 (1650)	.806612
72 (1800)	.807212
78 (1950)	.807812
84 (2100)	.808412
90 (2250)	.809012
96 (2400)	.809612
100 (2550)	.801112
106 (2700)	.801312
112 (2850)	.801512
118 (3000)	.801712

Section 600
INCIDENTAL CONSTRUCTION

SECTION 601 (VACANT)

SECTION 602 - REHABILITATION OF CULVERT AND STORM DRAIN PIPE

602-1 DESCRIPTION. Rehabilitate culvert and storm drain pipe in accordance with these specifications, the contract documents, and as directed by the Engineer.

602-2 MATERIAL REQUIREMENTS.

602-2.01 General. Materials requirements are specified in the following subsections:

Portland Cement Concrete	501
Shotcrete	583
Concrete Repair Material	701-04
Vertical Overhead Patching Material	701-08
Grout Sand	703-04
Cured in Place Pipe (CIPP) Liner	706-09
PVC Pipe (relining)	706-10
(Profile Wall)	
(Corrugated)	
High Density Polyethylene Pipe (relining)	706-11
(Profile Wall)	
(Smooth Wall)	
Corrugated Steel Pipe	707-02
(Concrete Lined)	
(Polymer Coated)	
Tunnel Liner Plate (relining)	707-05
(Steel)	
Corrugated Structural Steel Plate for Pipe and Pipe Arches	707-09
Anchor Bolts for Corrugated Culverts	707-20
Zinc Chromate Primer	708-04
Membrane Curing Compound	711-05

602-2.02 Grout for Annular Space. Design the grout for the annular space between the existing pipe and new liner pipe in accordance with the pipe Manufacturer's recommendations. Calculate the required volume of grout based on the existing culvert/storm drain internal diameter (minus deformations) and the external diameter of liner pipe. All grout components must appear on the Approved List unless approved by the Director, Materials Bureau.

602-3 CONSTRUCTION DETAILS. Provide the Engineer, a minimum of 10 days prior to starting the work, a written proposal of how the work will progress. The proposal shall include dewatering of the pipe; procedures for maintaining line and grade of the lining pipe; pipe manufacturer's recommendations for the assembly of preapproved joints or joint fusion methods; bracing methods; grout mix design and

void filing techniques. Such proposals are also required, regardless of the rehabilitation method, for shotcreting, concrete, and void filling methods.

602-3.01 Existing Pipe Preparation. Dewater, clean and inspect the existing pipe. Determine the location of and remove obstructions that may prevent proper installation of the paving or lining material. Inspect small inaccessible pipes, generally less than 1200 mm in diameter, using a closed circuit television and camera to provide a visual inspection. Provide strutting and bracing as required to ensure stability of the pipe.

602-3.02 Handling & Installing Lining Materials

- ***General.*** Install each run of lining pipe with the same material for the entire run unless otherwise identified in the contract documents or approved by the Engineer. Do not allow water to flow along the invert during concrete or fill material placement.

- ***Structural Paving of Inverts with Concrete.*** Apply §603-3.07 Concrete Paving for Corrugated Structural Plate Pipe with the exception of the following:
- The limits of the paved area along the invert's periphery, concrete cover thickness over the crests of the corrugations and concrete reinforcement details will be indicated on the plans. If welding has been used to anchor the reinforcement on a galvanized section of the pipe and upon completion of the anchoring, restore the coating in accordance with §702-02 Corrugated Steel Pipe, E. Coating Repair. Coating restoration is not required where mechanical anchoring of the reinforcement has been utilized.
- Use Class D, Class H or Class J concrete for paving of the invert.

C. Lining with Shotcrete. Apply all requirements of Section 583, Shotcrete with the exception of the following:
- Shotcrete may be used to line concrete pipes, stone arches and corrugated metal pipes.
- All reinforcement design and details (e.g. spacing, anchoring, etc.) will be indicated on the plans. If welding has been used to anchor the reinforcement on a galvanized section of the pipe and upon completion of the anchoring, restore the coating in accordance with §702-02 Corrugated Steel Pipe, E. Coating restoration is not required where mechanical anchoring of the reinforcement has been utilized.
- Apply a minimum 50 mm thick shotcrete layer over the crests of the corrugations. The shotcrete layer limits along the periphery will be indicated on the plans.

D. Lining with* Cured in Place Pipe (CIPP) *Liner. The CIPP contractor and its representatives shall appear on the Department's Approved List of Materials and Equipment, Rehabilitation of Culverts and Storm Drains section.

The CIPP contractor shall provide the Engineer a report with design details and calculations for determining the minimum required thickness of the cured-in-place-pipe (CIPP) liner, the minimum internal pressure required to hold the wetted liner tight against the host pipe, and the maximum allowable internal pressure so as not to damage the wetted liner. All design calculations shall assume a fully deteriorated host pipe, unless Item 602.36xx M, Lining Concrete pipe with Cured in Place Pipe (CIPP), is specified. All liner installations require the excavation of a resin containment pit to facilitate the installer's collection and subsequent disposal of any waste (styrene or non-styrene) and / or curing water from the jobsite. When the liner curing is completed, the installer will remove all

waste prior to the lined pipe being put back in service. The plans will indicate the size of the excavation for the resin containment pit. The excavation, temporary storage of the fill and restoration of the downstream channel will be paid for under *206-04 Trench and Culvert Excavation –O.G.*

Use a resin / liner system meeting the following criteria:

- System consists of one or more layers of flexible needled felt or an equivalent material as approved by the Materials Bureau.
- Liner is flexible enough to fit irregular pipe sections and able to negotiate pipe bends.

Liner's surface must be coated with a plastic material compatible with the proposed resin. All liners containing styrene based resins require the use of a pre liner, to be inserted into the existing pipe before insertion of the CIPP liner. In addition to the pre liner, single or double sided liners may be specified in the contract plans, due to the environmental setting of a particular application.

A thermoset resin and catalyst or an epoxy resin and hardener system, compatible with the proposed inversion system shall be used. If indicated in the contract documents, a resin containing less than five percent volatile organic compounds (VOCs) with less than 0.1 percent hazardous air pollutants (HAPs) and less than 0.1 percent of water quality pollutants as listed in 6 NYCRR Parts 700-705 shall be supplied. If the resin type (styrene or non-styrene) is not specified on the plans, the installer has the option to select the resin type. Resin volumetric shrinkage is limited to less than one percent. Proposed resin shall be compatible with the proposed inversion process.

- Vacuum impregnate the liner with resin. Use a volume of resin capable of filling all voids in the liner material at nominal thickness and diameter. Adjust this resin volume by adding a minimum of 5% excess resin to allow for changes in resin volume due to polymerization and for any resin migration into the cracks and joints of the original pipe.

1. Installation. A cured-in-place-pipe (CIPP) liner may be installed into the host pipe by hydrostatic head, air pressure inversion, or a combination of the two. Do not exceed the manufacturer recommended maximum pressure to the liner felt fiber during the inversion process. Pulled in place installations may be allowed if it is indicated on the contract documents or if the installer is given prior approval by the Director, Materials Bureau.

a. **Hydrostatic Head.** The standpipe height must be sufficient to maintain at least the minimum required pressure between the CIPP liner and the existing (host) pipe. The lower end of the liner must extend beyond the outlet end whenever possible. Where changes in elevation may create excessive stresses on the liner felt, the use of bulkheads may be necessary. Alternative installation methods using a hydrostatic head will be subject to approval by the Director, Materials Bureau.

b. **Air Pressure.** The liner may be inverted using air pressure to extend it to the termination point. The air pressure needs to be adjusted and sustained to a level capable of holding the liner against the host pipe regardless of the curing method proposed to be used.

2. Curing. Cure the liner by circulating heated water throughout the section. Uniformly raise the temperature of the water above the level required to cure the resin. Monitor and record both the temperature of the curing water exiting the heating source and the temperature of the curing water returning to the heating source. Monitor and record the observed temperatures by the remote sensors on the liner-host pipe interfaces, located in the upstream and downstream area of the pipe. The remote temperature sensors readings will be used for monitoring the progress of curing and its duration. The minimum curing time is the sum of the minimum recommended initial and post-curing times as per the liner resin supplier's

recommendations. The onset of the initial curing approximately occurs when all remote temperature sensors register a temperature consistent with the "exotherm", which shall be included in the Manufacturer's recommendations. Post-cure the liner at least for the minimum post-curing time *and at the minimum post-curing* temperature level, as per the liner Manufacturer's recommendations. Add post-curing time for any deviations from the recommended post-curing temperature levels. All resin Manufacturers' curing proposals require approval by the Director of Materials Bureau prior to its initial use by the Department. Also, a new curing proposal submission for approval is required if an already approved liner Manufacturer introduces a new resin formulation and/or a new liner curing method to a Department contract.

3. ***Water and Material Management.*** After post-curing is completed, manage the curing water so that it does not cause or contribute to a violation of water quality standards to receiving waters or groundwater 6 NYCRR Part 700-704. In particular, the CIPP Contractor shall note the surface water quality and groundwater standards at 6 NYCRR Part 703 for pollutants such as styrene and thermal discharges. The CIPP Contractor shall enquire as to the classification of potential receiving surface waters in the project location if this information is not provided in the contract documents.

A. Handling of curing water used in a styrene based thermoses resin liner installation:
   1. Collect and transport curing water from the site for reuse within another CIPP location; and/or
   2. Collect the water and dispose or treat at off site facilities. Transport wastewaters within vehicles that have a waste transporter permit 6NYCRR 364. Off-site disposal shall be at a publicly owned treatment works or at a disposal facility permitted to accept the wastewater. Treatment by the Contractor off site shall be conducted to reduce concentrations of styrene to acceptable levels to meet water quality standards prior to discharge to the receiving waters; and/or
   3. Treat wastewater on-site to acceptable styrene and thermal loading and discharge to receiving waters in accordance with agreements received from the Regional NYSDEC Office.

B. For curing water from non-styrene based processes, collect water for disposal off-site as described in A1 and A2 above or discharge on site if it does not contain pollutants that could cause or contribute to a violation of water quality standards. Reduce temperature to prevent a violation of the thermal standards to the receiving waters.

C. Collect any excess resin and any curing materials at the upstream and downstream ends of the installation for disposal.

D. Record and document quantities of curing water removed from the site. Provide record/documentation of the reuse and/or disposal facility and quantity disposed of curing water leaving the site.

After post-curing is completed, cool the liner to a temperature of 38° C prior to relieving the static head in the inversion standpipe. Cool-down may be accomplished by adding cool water into the inversion standpipe to replace warm curing water being removed from the liner. Contract documents may contain restrictions on the temperature of the released curing water or whether the curing water needs to be removed and treated. Any other proposed liner curing

methods will be subject to the approval of the Director, Materials Bureau.

4. Workmanship / Damage / Defects. The finished pipe liner shall be continuous over the entire length of an inversion run and be free of dry spots, lifts and delaminations. If any dry spots, lifts and delaminations exist, remove the liner in those areas. Mark a line 1 m from both ends of the distressed area, cut the distressed area out, and replace it. If the Cured-In Place-Pipe (CIPP) liner does not fit against its termination point, seal the space between the pipe and liner with a resin mixture compatible with the CIPP. The liner may be sampled and tested for tensile and flexural properties in accordance with ASTM F 1216 at the discretion of the Department. Failure to meet the designed properties will be a cause for liner rejection.

5. Storm Drain Lateral Connections. Reconnect the existing storm drain lateral connections after the liner has been cured in place. Use robotic cutting devices to reestablish tie-ins in non-man accessible pipes.

E. Lining with a new Liner Pipe-General. Before lining, pull or push a single piece of liner pipe 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 approved written proposal.

When required, reconnect existing storm drain lateral connections by utilizing an open cut excavation, internal connection or remote installation using robotics. 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. Provide a minimum annular space of 25 mm 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.

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 EIC 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 to the state. Grout that fills invert and connected voids is covered in the cost for these items.

1. Lining with Polyethylene Pipe. Prior to lining, follow in its entirety all provisions of §602-3.02 E. Lining with a new Liner Pipe–General.

Reline with Smooth Wall Polyethylene Pipe or Profile Wall Polyethylene Pipe, as indicated in the contract documents.

Install all pipe, fittings, adapters and appurtenances according to the Manufacturer's recommendations. Limit joint separations to less than 12 mm between adjoining sections. Field cuts will be permitted only at the terminal ends. No HDPE pipe sections less than 1 m long will be allowed in any lining project.

Perform all butt fusion, welding and extrusion welding of HDPE pipe in accordance with the Manufacturer's recommendation. A Manufacturer's representative – or an individual trained by the manufacturer – must be present at all times during any fusion or welding operations. Alternate joining methods will be subject to approval by the Director, Materials Bureau.

2. Lining with Polyvinyl Chloride Pipe. Prior to lining, follow in its entirety all provisions

of §602-3.02 E. Lining with a new Liner Pipe-General.

Reline with a Profile Wall PVC Pipe or Corrugated Wall PVC Pipe with integral bell and spigot joints.

The installation proposal for this item to be submitted by the contractor for Departmental approval should in addition address the following PVC specific issues prior to any work approval is granted; Whether the PVC liner will be pulled or pushed through the culvert and the type of pushing or pulling ring/plate to be used. Whether a nose cone or a different device will be used in this process and how the jacking, pulling or pushing loads on the liner will be monitored in order to conform to the PVC liner's Manufacturer's specifications and guidelines. Include PVC liner's Manufacturer's specifications and guidelines in the submitted for approval proposal. Follow all Manufacturer's recommendations during joint assembly operations.

2. Lining with Corrugated Metal Pipe. Reline with Polymer Coated Corrugated Steel Pipe, or Concrete Lined Corrugated Steel Pipe.

Prior to lining, follow in its entirety all provisions of §602-3.02 E. Lining with a new Liner Pipe-General.

Insert and brace the liner pipe to the specified line and grade, and align adjacent pipe sections such that port holes, if used, are placed as detailed in the contract plans (Alignment bolts are not adequate bracing by themselves). Sever all alignment bolts not fully turned out and grind them flush to the new pipe interior. If port holes are used, provide fittings and plugs compatible with the delivery equipment. Insert the plugs into the fittings as the operation is completed. Limit joint separations to 12 mm between adjoining sections. To ensure that grout remains in the annular space, place internal expanding joint bands with annular corrugations and foam gaskets at each joint. Before grouting the annular space, brace and strut the bands. Do not obstruct with any bracing material the flow of grout into the annular space. Remove the bracing, struts and bands upon completion of this work.

4. Lining with Corrugated Steel Structural Plate Pipe. Prior to lining, follow in its entirety all provisions of §602-3.02 E. Lining with a new Liner Pipe- General.

Align adjacent pipe sections such that port holes, if used, are placed as detailed in the contract plans. If port holes are used, provide port hole fittings and plugs compatible with the delivery equipment. Insert the plugs into the fittings as the grouting operation is completed. Alignment bolts are not adequate bracing by themselves. Sever all alignment bolts not fully turned out and grind them flush to the new pipe interior. Do not obstruct with any bracing material the flow of grout into the annular space.

5. Lining with Steel Tunnel Liner Plate. Prior to lining, follow in its entirety all provisions of §602-3.02 E. Lining with a new Liner Pipe-General.

Line with tunnel liner plates (two flange). Use a lap type longitudinal seam. Fabricate the lap to allow a continuous cross section of the plates through the seam. Use an offset depth equal to the metal thickness for the full width of plate, including flanges. Drilling, punching or drifting to correct defects in manufacturing will not be permitted. Plates with improperly punched holes will be rejected.

Use 5 bolts per 450 mm width of plate in each lapped longitudinal joint and stagger the bolts in the ridges and valleys. Follow the Manufacturer's recommendation for circumferential and longitudinal bolt spacing.

602-3.03 Damaged Pipe and Repair. Repair all damage to the existing host pipe that is strictly obstructing the progress of the relining operation. Repair any damage to the newly installed liner caused

during construction, consistent with the recommendations of Section 603-3.04 Damaged Pipe and Repair.

602-4 METHOD OF MEASUREMENT

602-4.01 Lining with new pipe. This work will be measured as the number of meters along the bottom centerline, measured to the nearest meter.

602-4.02 Paving inverts. This work shall be measured as the number of paved square meters, measured to the nearest square meter. It shall be determined by calculating the paved arc surface, as the product of the paved arc width measured along the pipe circumference and the paved arc length measured along the centerline of the pipe,.

602-4.03 Shotcreting. This work shall be measured as the number of shotcreted square meters, measured to the nearest square meter. It shall be determined by calculating the shotcreted arc surface, as the product of the shotcreted arc width measured along the pipe circumference and the shotcreted arc length measured along the centerline of the pipe,.

602-5 BASIS OF PAYMENT. Include the cost of furnishing all labor, materials, and equipment necessary to complete the work in the unit price bid. Include the cost of all fill material needed to fill the annular space between the existing pipe and the liner pipe, and the removal of any obstructions, intrusions or damaged pipe prior to lining.

For Paving Inverts and Shotcreting, include the cost of furnishing all labor, materials and equipment necessary to complete the work for the unit price bid and include all necessary preparations to the existing pipe.

Payment will be made under:

Item No.	Item	Pay Unit
602.2002	Structural Paving of Inverts with Portland Cement Concrete	Square Meter
602.2101	Lining Culvert with Shotcrete	Square Meter
602.25xx	Lining with High Density Polyethylene Pipe	Meter
602.26xx	Lining with Smooth Wall High Density Polyethylene Pipe	Meter
602.27xx	Lining with Profile Wall High Density Polyethylene Pipe	Meter
602.30xx	Lining with Polyvinyl Chloride Pipe	Meter
602.36xx	Lining with Cured in Place Pipe (CIPP)	Meter
602.37xx	Lining Concrete pipe with Cured in Place Pipe (CIPP)	Meter
602.51xxxx	Lining with Steel Structural Plate Pipe	Meter
602.53xxxx	Lining with Steel Structural Plate Pipe Arch	Meter
602.550101	Lining with Steel Tunnel Liner Plate 3.43 mm thick	Square Meter
602.550102	Lining with Steel Tunnel Liner Plate 4.17 mm thick	Square Meter
602.550103	Lining with Steel Tunnel Liner Plate 4.55 mm thick	Square Meter
602.550104	Lining with Steel Tunnel Liner Plate 5.31 mm thick	Square Meter
602.550105	Lining with Steel Tunnel Liner Plate 6.07 mm thick	Square Meter
602.65xx	Lining with Concrete-Lined CSP (68x13)	Meter
602.70xx	Lining with Concrete-Lined CSP (125x25)	Meter
602.75xx	Lining with Polymer Coated CSP 12ga, (68x13)	Meter
602.80xx	Lining with Polymer Coated CSP 12ga, (75x25) or (125x25)	Meter

Refer to Contract Proposal for full Item Number and full description.

Delete 706-06 Polyester Formed in Place Pipe Liner in its entirety from the standard specifications and replace with the following:

706-09 Cured in Place Pipe (CIPP) Liner

SCOPE. This specification covers the material requirements for cured in place pipe liners, or a resin and hardener system, used in rehabilitation of culverts and storm drains.

GENERAL. The flexible liner will be fabricated from one or more layers of polyester felt, or from an alternate material approved by the Director of the Materials Bureau. An impermeable polyurethane or polyvinyl chloride material will be bonded to one or both sides of the felt liner. A styrene or a non styrene based thermoset resin and catalyst or an epoxy resin and hardener system, compatible with the proposed inversion system must be used. If indicated in the contract documents, a resin containing less than five percent volatile organic compounds (VOCs) with zero percent hazardous air pollutants (HAPs) must be supplied. Resin volumetric shrinkage is limited to less than one percent. Proposed resin must be compatible with the proposed inversion process.

MATERIAL REQUIREMENTS. Supply a resin and hardener system material conforming to the following minimum values:

Property	Standard	Required*
Tensile Stress, MPa	ASTM D638	20
Flexural Stress, MPa	ASTM D790	30
Flexural Modulus, MPa	ASTM D790	1700

* If the submitted design calculations indicate higher values, these values will become the minimum values for these liners properties.

BASIS OF ACCEPTANCE. Acceptance of this material will be based on the manufacturer's / installer's name appearing on the Approved List for Rehabilitation of Culverts and Storm Drains. Application for approval and entering into the aforementioned list shall be in accordance with *Materials Procedure 04-001, Approval Process for POLYESTER FORMED IN PLACE PIPE LINER 706-06*

In Item "**706-10 POLYVINYL CHLORIDE PIPE (relining)**" of the Standard Specifications, delete the **MATERIALS REQUIREMENTS** section and replace it with the following:

"***MATERIALS REQUIREMENTS.*** *The Polyvinyl Chloride pipe materials must conform to ASTM F 1803 (Profile Wall), ASTM F 949 (Corrugated), ASTM F 679, or ASTM F 3034. All materials supplied will be clearly marked with the appropriate ASTM as certified*".

Section 600
INCIDENTAL CONSTRUCTION

SECTION 601 (VACANT)

SECTION 602 - REHABILITATION OF CULVERT AND STORM DRAIN PIPE

602-1 DESCRIPTION. Rehabilitate culvert and storm drain pipe in accordance with these specifications, the contract documents, and as directed by the Engineer.

602-2 MATERIAL REQUIREMENTS.

602-2.01 General. Materials requirements are specified in the following subsections:

Portland Cement Concrete	501
Shotcrete	583
Concrete Repair Material	701-04
Vertical Overhead Patching Material	701-08
Grout Sand	703-04
Cured in Place Pipe (CIPP) Liner	706-09
PVC Pipe (relining)	706-10
(Profile Wall)	
(Corrugated)	
High Density Polyethylene Pipe (relining)	706-11
(Profile Wall)	
(Smooth Wall)	
Corrugated Steel Pipe	707-02
(Concrete Lined)	
(Polymer Coated)	
Tunnel Liner Plate (relining)	707-05
(Steel)	
Corrugated Structural Steel Plate for Pipe and Pipe Arches	707-09
Anchor Bolts for Corrugated Culverts	707-20
Zinc Chromate Primer	708-04
Membrane Curing Compound	711-05

602-2.02 Grout for Annular Space. Design the grout for the annular space between the existing pipe and new liner pipe in accordance with the pipe Manufacturer's recommendations. Calculate the required volume of grout based on the existing culvert/storm drain internal diameter (minus deformations) and the external diameter of liner pipe. All grout components must appear on the Approved List unless approved by the Director, Materials Bureau.

602-3 CONSTRUCTION DETAILS. Provide the Engineer, a minimum of 10 days prior to starting of the work, a written proposal of how the work will progress. The proposal shall include dewatering of the pipe; procedures for maintaining line and grade of the lining pipe, pipe manufacturer's recommendations for the assembly of preapproved joints, or joint fusion methods; bracing methods; grout mix design; and void filing techniques. Such proposals are also required, regardless of the rehabilitation method, for shotcreting, concrete, and void filling methods.

602-3.01 Existing Pipe Preparation. Dewater, clean and inspect the existing pipe. Determine the location of and remove obstructions that may prevent proper installation of the paving or lining material. Inspect small inaccessible pipes, generally less than 48 inches in diameter, using a closed circuit television and camera to provide a visual inspection. Provide strutting and bracing as required to ensure stability of the pipe.

602-3.02 Handling & Installing Lining Materials

A. General. Install each run of lining pipe with the same material for the entire run unless otherwise identified in the contract documents or approved by the Engineer. Do not allow water to flow along the invert during concrete or fill material placement.

B. Structural Paving of Inverts with Concrete. Apply §603-3.07 Concrete Paving for Corrugated Structural Plate Pipe with the exception of the following:

- The limits of the paved area along the invert's periphery, concrete cover thickness over the crests of the corrugations and concrete reinforcement details will be indicated on the plans. If welding has been used to anchor the reinforcement on a galvanized section of the pipe and upon completion of the anchoring, restore the coating in accordance with §702-02 Corrugated Steel Pipe, E. Coating Repair. Coating restoration is not required where mechanical anchoring of the reinforcement has been utilized.
- Class D, Class H or Class J concrete will be used for paving of the invert.

C. Lining with Shotcrete. Apply all requirements of Section 583, Shotcrete with the exception of the following:

- Shotcrete may be used to line concrete pipe, stone arches, and corrugated metal pipes.
- All reinforcement design and details (e.g. spacing, anchoring, etc.) must be indicated on the plans. If welding has been used to anchor the reinforcement on a galvanized section of the pipe and upon completion of the anchoring, restore the coating in accordance with §702-02 Corrugated Steel Pipe, E. Coating restoration is not required where mechanical anchoring of the reinforcement has been utilized.
- Apply a minimum 2 inch thick shotcrete layer over the crests of the corrugations. The shotcrete layer limits along the periphery will be indicated on the plans.

D. Lining with* Cured in Place Pipe (CIPP) *Liner. The CIPP contractor and its representatives shall appear on the Department's Approved List of Materials and Equipment, Rehabilitation of Culverts and Storm Drains section.

The CIPP contractor shall provide the Engineer a report with design details and calculations for determining the minimum required thickness of the cured-in-place-pipe (CIPP) liner, the minimum internal pressure required to hold the wetted liner tight against the host pipe, and the maximum allowable internal pressure so as not to damage the wetted liner. All design calculations shall assume a fully deteriorated host pipe, unless Item 602.36xx M, Lining Concrete pipe with Cured in Place Pipe (CIPP), is specified. All liner installations require the excavation of a resin containment pit to facilitate the installer's collection and subsequent disposal of any waste (styrene or non-styrene) and / or curing water from the jobsite. When the liner curing is completed, the installer will remove all waste prior to the lined pipe being put back in service. The plans will indicate the size of the excavation for the resin containment pit. The excavation, temporary storage of the fill and restoration

of the downstream channel will be paid for under *206-04 Trench and Culvert Excavation –O.G.*

Use a resin / liner system meeting the following criteria:

- System consists of one or more layers of flexible needled felt or an equivalent material as approved by the Materials Bureau.
- Liner is flexible enough to fit irregular pipe sections and able to negotiate pipe bends.

Liner's surface must be coated with a plastic material compatible with the proposed resin. All liners containing styrene based resins require the use of a pre liner, to be inserted into the existing pipe before insertion of the CIPP liner. In addition to the pre liner, single or double sided liners may be specified in the contract plans, due to the environmental setting of a particular application.

A thermoset resin and catalyst or an epoxy resin and hardener system, compatible with the proposed inversion system shall be used. If indicated in the contract documents, a resin containing less than five percent volatile organic compounds (VOCs) with less than 0.1 percent hazardous air pollutants (HAPs) and less than 0.1 percent of water quality pollutants as listed in 6 NYCRR Parts 700-705 shall be supplied. If the resin type (styrene or non-styrene) is not specified on the plans, the installer has the option to select the resin type. Resin volumetric shrinkage is limited to less than one percent. Proposed resin shall be compatible with the proposed inversion process.

- Vacuum impregnate the liner with resin. Use a volume of resin capable of filling all voids in the liner material at nominal thickness and diameter. Adjust this resin volume by adding a minimum of 5% excess resin to allow for changes in resin volume due to polymerization and for any resin migration into the cracks and joints of the original pipe.

1. Installation. A cured-in-place-pipe (CIPP) liner may be installed into the host pipe by hydrostatic head, air pressure inversion, or a combination of the two. Do not exceed the manufacturer recommended maximum pressure to the liner felt fiber during the inversion process. Pulled in place installations may be allowed if it is indicated on the contract documents or if the installer is given prior approval by the Director, Materials Bureau.

c. **Hydrostatic Head.** The standpipe height must be sufficient to maintain at least the minimum required pressure between the CIPP liner and the existing (host) pipe. The lower end of the liner must extend beyond the outlet end whenever possible. Where changes in elevation may create excessive stresses on the liner felt, the use of bulkheads may be necessary. Alternative installation methods using a hydrostatic head will be subject to approval by the Director, Materials Bureau.

d. **Air Pressure.** The liner may be inverted using air pressure to extend it to the termination point. The air pressure needs to be adjusted and sustained to a level capable of holding the liner against the host pipe regardless of the curing method proposed to be used.

2. Curing. Cure the liner by circulating heated water throughout the section. Uniformly raise the temperature of the water above the level required to cure the resin. Monitor and record both the temperature of the curing water exiting the heating source and the temperature of the curing water returning to the heating source. Monitor and record the observed temperatures by the remote sensors on the liner-host pipe interfaces, located in the upstream and downstream area of the pipe. The remote temperature sensors readings will be used for monitoring the progress of curing and its duration. The minimum curing time is the sum of the minimum recommended initial and post-curing times as per the liner resin supplier's recommendations. The onset of the initial curing approximately occurs when all remote temperature sensors register a temperature consistent with the "exotherm", which shall be

included in the Manufacturer's recommendations. Post-cure the liner at least for the minimum post-curing time *and at the minimum post-curing* temperature level, as per the liner Manufacturer's recommendations. Add post-curing time for any deviations from the recommended post-curing temperature levels. All resin Manufacturers' curing proposals require approval by the Director of Materials Bureau prior to its initial use by the Department. Also, a new curing proposal submission for approval is required if an already approved liner Manufacturer introduces a new resin formulation and/or a new liner curing method to a Department contract.

4. ***Water and Material Management***. After post-curing is completed, manage the curing water so that it does not cause or contribute to a violation of water quality standards to receiving waters or groundwater 6 NYCRR Part 700-704. In particular, the CIPP Contractor shall note the surface water quality and groundwater standards at 6 NYCRR Part 703 for pollutants such as styrene and thermal discharges. The CIPP Contractor shall enquire as to the classification of potential receiving surface waters in the project location if this information is not provided in the contract documents.

A. Handling of curing water used in a styrene based thermoses resin liner installation:

1. Collect and transport curing water from the site for reuse within another CIPP location; and/or
2. Collect the water and dispose or treat at off site facilities. Transport wastewaters within vehicles that have a waste transporter permit 6NYCRR 364. Off-site disposal shall be at a publicly owned treatment works or at a disposal facility permitted to accept the wastewater. Treatment by the Contractor off site shall be conducted to reduce concentrations of styrene to acceptable levels to meet water quality standards prior to discharge to the receiving waters; and/or
3. Treat wastewater on-site to acceptable styrene and thermal loading and discharge to receiving waters in accordance with agreements received from the Regional NYSDEC Office.

B. For curing water from non-styrene based processes, collect water for disposal off-site as described in A1 and A2 above or discharge on site if it does not contain pollutants that could cause or contribute to a violation of water quality standards. Reduce temperature to prevent a violation of the thermal standards to the receiving waters.

C. Collect any excess resin and any curing materials at the upstream and downstream ends of the installation for disposal.

D. Record and document quantities of curing water removed from the site. Provide record/documentation of the reuse and/or disposal facility and quantity disposed of curing water leaving the site.

After post-curing is completed, cool the liner to a temperature of 100^{0} F prior to relieving the static head in the inversion standpipe. Cool-down may be accomplished by adding cool water into the inversion standpipe to replace warm curing water being removed from the liner. Contract documents may contain restrictions on the temperature of the released curing water or whether the curing water needs to be removed and treated. Any other proposed liner curing methods will be subject to the approval of the Director, Materials Bureau.

4. Workmanship / Damage / Defects. The finished pipe liner shall be continuous over the entire length of an inversion run and be free of dry spots, lifts and delaminations. If any dry spots, lifts and delaminations exist, remove the liner in those areas. Mark a line 3 feet from both ends of the distressed area, cut the distressed area out, and replace it. If the Cured-In Place-Pipe (CIPP) liner does not fit against its termination point, seal the space between the pipe and liner with a resin mixture compatible with the CIPP. The liner may be sampled and tested for tensile and flexural properties in accordance with ASTM F 1216 at the discretion of the Department. Failure to meet the designed properties will be a cause for liner rejection.

5. Storm Drain Lateral Connections. Reconnect the existing storm drain lateral connections after the liner has been cured in place. Use robotic cutting devices to reestablish tie-ins in non-man accessible pipes.

E. Lining with a new Liner Pipe-General. Before lining, pull or push a single piece of liner pipe 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 articles included in the approved written proposal.

When required, reconnect existing storm drain lateral connections by utilizing an open cut excavation, internal connection or remote installation using robotics. 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. 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.

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 EIC 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 to the state. Grout that fills invert and connected voids is covered in the cost for these items.

1. Lining with Polyethylene Pipe. Prior to lining, follow in its entirety all provisions of §602-3.02 E. Lining with a new Liner Pipe - General

Reline with Smooth Wall Polyethylene Pipe or Profile Wall Polyethylene Pipe, as indicated in the contract documents.

Install all pipe, fittings, adapters and appurtenances according to the Manufacturer's recommendations. Limit joint separations to less than ½ inch between adjoining sections. Field cuts will be permitted only at the terminal ends. No HDPE pipe sections less than 3 feet long will be allowed in any lining projects.

Perform all butt fusion, welding and extrusion welding of HDPE pipe in accordance with the Manufacturer's recommendation. A Manufacturer's representative – or an individual trained by the manufacturer – must be present at all times during any fusion or welding operations. Alternate joining methods will be subject to approval by the Director, Materials Bureau.

2. Lining with Polyvinyl Chloride Pipe. Prior to lining, follow in its entirety all provisions of §602-3.02 E. Lining with a new Liner Pipe – General.

Reline with a Profile Wall PVC Pipe or Corrugated Wall PVC Pipe with integral bell and spigot joints.

The installation proposal for this item to be submitted by the contractor for Departmental approval should in addition address the following PVC specific issues prior to any work approval is granted; Whether the PVC liner will be pulled or pushed through the culvert and the type of pushing or pulling ring/plate to he used. Whether a nose cone or a different device will be used in this process and how the jacking, pulling or pushing loads on the liner will be monitored in order to conform to the PVC liner's Manufacturer's specifications and guidelines. Include PVC liner's Manufacturer's specifications and guidelines in the submitted for approval proposal. Follow all Manufacturer's recommendations during joint assembly operations.

3. Lining with Corrugated Metal Pipe. Reline with Polymer Coated Corrugated Steel Pipe or Concrete Lined Corrugated Steel Pipe.

Prior to lining, follow in its entirety all provisions of §602-3.02 E. Lining with a new Liner Pipe.

Insert and brace the liner pipe to the specified line and grade, and align adjacent pipe sections such that port holes, if used, are placed as detailed in the contract plans (Alignment bolts are not adequate bracing by themselves). Sever all alignment bolts not fully turned out and grind them flush to the new pipe interior. If port holes are used, provide fittings and plugs compatible with the delivery equipment. Insert the plugs into the fittings as the operation is completed. Limit joint separations to ½ inch between adjoining sections. To ensure that grout remains in the annular space, place internal expanding joint bands with annular corrugations and foam gaskets at each joint. Before grouting the annular space, brace and strut the bands. Do not obstruct with any bracing material the flow of grout into the annular space. Remove the bracing, struts and bands upon completion of this work.

4. Lining with Corrugated Steel Structural Plate Pipe. Prior to lining, follow in its entirety all provisions of §602-3.02 E. Lining with a new Liner Pipe.

Align adjacent pipe sections such that port holes, if used, are placed as detailed in the contract plans. If port holes are used, provide port hole fittings and plugs compatible with the delivery equipment. Insert the plugs into the fittings as the grouting operation is completed. Alignment bolts are not adequate bracing by themselves. Sever all alignment bolts not fully turned out and grind them flush to the new pipe interior. Do not obstruct with any bracing material the flow of grout into the annular space.

5. Lining with Steel Tunnel Liner Plate. Prior to lining, follow in its entirety all provisions of §602-3.02 E. Lining with a new Liner Pipe.

Line with tunnel plate (two flange). Use a lap type longitudinal seam. Fabricate the lap to allow a continuous cross section of the plates through the seam. Use an offset depth equal to the metal thickness for the full width of plate, including flanges. Drilling, punching or drifting to correct defects in manufacturing will not be permitted. Plates with improperly punched holes will be rejected.

Use 5 bolts per 18 inch width of plate in each lapped longitudinal joint and stagger the bolts in the ridges and valleys. Follow the Manufacturer's recommendation for circumferential and longitudinal bolt spacing.

602-3.03 Damaged Pipe and Repair. Repair all damage to the existing host pipe caused that is strictly obstructing the progress of the relining operation. Repair any damage to the newly installed liner

caused during construction, consistent with recommendations of Section 603- 3.04 Damaged Pipe and Repair.

602-4 METHOD OF MEASUREMENT

602-4.01 Lining with new pipe. This work will be measured as the number of feet along the bottom centerline, measured to the nearest foot.

602-4.02 Paving inverts. This work shall be measured as the number of paved square feet, measured to the nearest square feet. It shall be determined by calculating the paved arc surface, as the product of the paved arc width measured along the pipe circumference and the paved arc length measured along the centerline of the pipe.

602-4.03 Shotcreting. This work shall be measured as the number of shotcreted square feet, measured to the nearest square feet. It shall be determined by calculating the shotcreted arc surface, as the product of the shotcreted arc width measured along the pipe circumference and the shotcreted arc length measured along the centerline of the pipe.

602-5 BASIS OF PAYMENT. Include the cost of furnishing all labor, materials, and equipment necessary to complete the work in the unit price bid. Include the cost of all fill material needed to fill the annular space between the existing pipe and the liner pipe, and the removal of any obstructions, intrusions or damaged pipe prior to lining.

For Paving Inverts and Shotcreting, include the cost of furnishing all labor, materials and equipment necessary to complete the work for the unit price bid and include all necessary preparations to the existing pipe.

Payment will be made under:

Item No.	Item	Pay Unit
602.2002	Structural Paving of Inverts with Portland Cement Concrete	Square Feet
602.2101	Lining Culvert with Shotcrete	Square Feet
602.25xx	Lining with High Density Polyethylene Pipe	Feet
602.26xx	Lining with Smooth Wall High Density Polyethylene Pipe	Feet
602.27xx	Lining with Profile Wall High Density Polyethylene Pipe	Feet
602.30xx	Lining with Polyvinyl Chloride Pipe	Feet
602.36xx	Lining with Cured in Place Pipe (CIPP)	Feet
602.37xx	Lining Concrete pipe with Cured in Place Pipe (CIPP)	Feet
602.51xxxx	Lining with Steel Structural Plate Pipe	Feet
602.53xxxx	Lining with Steel Structural Plate Pipe Arch	Feet
602.550101	Lining with Steel Tunnel Liner Plate 10ga	Square Feet
602.550102	Lining with Steel Tunnel Liner Plate 8ga	Square Feet
602.550103	Lining with Steel Tunnel Liner Plate 7ga	Square Feet
602.550104	Lining with Steel Tunnel Liner Plate 5ga	Square Feet
602.550105	Lining with Steel Tunnel Liner Plate 3ga	Square Feet
602.65xx	Lining with Concrete-Lined CSP (2- 2/3"x1/2")	Feet
602.70xx	Lining with Concrete-Lined CSP (5"x1")	Feet
602.75xx	Lining with Polymer Coated CSP 12ga, (2- 2/3"x1/2")	Feet
602.80xx	Lining with Polymer Coated CSP 12ga, (3"x1") or (5"x1")	Feet

Refer to Contract Proposal for full Item Number and full description.

Delete 706-06 Polyester Formed in Place Pipe Liner in its entirety from the standard specifications and replace with the following:

706-09 Cured in Place Pipe (CIPP) Liner

SCOPE. This specification covers the material requirements for cured in place pipe liners, or a resin and hardener system, used in rehabilitation of culverts and storm drains.

GENERAL. The flexible liner will be fabricated from one or more layers of polyester felt, or from an alternate material approved by the Director of the Materials Bureau. An impermeable polyurethane or polyvinyl chloride material will be bonded to one or both sides of the felt liner. A styrene or a non styrene based thermoset resin and catalyst or an epoxy resin and hardener system, compatible with the proposed inversion system must be used. If indicated in the contract documents, a resin containing less than five percent volatile organic compounds (VOCs) with zero percent hazardous air pollutants (HAPs) must be supplied. Resin volumetric shrinkage is limited to less than one percent. Proposed resin must be compatible with the proposed inversion process.

MATERIAL REQUIREMENTS. Supply a resin and hardener system material conforming to the following minimum values:

Property	Standard	Required*
Tensile Stress, psi	ASTM D638	3000
Flexural Stress, psi	ASTM D790	4500
Flexural Modulus, psi	ASTM D790	250000

* If the submitted design calculations indicate higher values, these values will become the minimum values for these liners properties.

BASIS OF ACCEPTANCE. Acceptance of this material will be based on the manufacturer's / installer's name appearing on the Approved List for Rehabilitation of Culverts and Storm Drains. Application for approval and entering into the aforementioned list shall be in accordance with *Materials Procedure 04-001, Approval Process for POLYESTER FORMED IN PLACE PIPE LINER 706-06.*

In Item "**706-10 POLYVINYL CHLORIDE PIPE (relining)**" of the Standard Specifications, delete the **MATERIALS REQUIREMENTS** section and replace it with the following:

"***MATERIALS REQUIREMENTS.*** *The Polyvinyl Chloride pipe materials must conform to ASTM F 1803 (Profile Wall), ASTM F 949 (Corrugated), ASTM F 679, or ASTM F 3034. All materials supplied will be clearly marked with the appropriate ASTM as certified*".

Summary of Water Sampling
CIPP for 4 Culverts

Background and Introduction

Cured-in-place-pipe (CIPP) replacements have been used by NYSDOT for several years. The technology provides a convenient way to replace failing culvert pipes particularly those that are deeply buried and difficult to access. Four different contractors have been approved to install CIPP throughout New York State. The culverts described in this report were worked on by PipeVision.

The CIPP process involves impregnating felt with styrene monomer and peroxide compounds to enhance curing. The liner is placed in the failing culvert and filled with water that is then heated to 200 degrees F for a specified length of time. Diesel powered furnaces are used to heat the water which is circulated through the culvert, typically for two hours. Once the curing is deemed complete the water is left to cool before it is released.

The purpose of this study is to determine the styrene monomer levels before, during, and immediately after the CIPP is installed. If styrene levels are detected appropriate control measures will be developed.

Materials and Methods

After consultation with the Main Office Materials Section and the Environmental Science Bureau the following sampling protocol was agreed upon. For each culvert evaluated samples would be taken from:

1. Upstream or updtich before work begins
2. Downstream or downditch before work begins
3. Water source before it is put in truck
4. Water truck on site
5. During curing
6. Downstream or downditch at release
7. Downstream or downditch after release

If the stream or ditch is dry soil samples will be taken for analysis.

Samples were placed in laboratory prepared vials that were kept on ice until they were delivered to the laboratory. The samples were analyzed for styrene using gas chromatography and mass spectroscopy according the EPA method 8260. The laboratory is certified by the New York State Department of Health (#10795) and the U.S. EPA (#NY00935).

Results

Four installations were monitored. All culverts were located under I-88 in Broome or Chenango Counties. The ultimate receiving water for these streams or ditches is the Susquehanna River.

1. Culvert A – under westbound I-88, just over one mile east of Bainbridge (wb station 1 + 980; C4), 42 inch pipe, 30.79 meters long.
2. Culvert B – under westbound I-88 (wb station 3 + 160), 48 inch pipe, 30.79 meters long
3. Culvert C – under east bound I-88, between exits 5 and 6 (eb station 15 + 370), 36 inch pipe; 36 inch diameter, 140 feet long
4. Culvert D – under exit 6 westbound on ramp ; 24 inch diameter, 159 feet long.

Because of the wet summer in 2009, water samples upstream and downstream in each of these location could be taken. Field notes are included at the end of this report.

Culvert A

The results from sampling culvert A, under westbound I-88, are summarized in Table 1.

Table 1. Results from water sampling culvert A

Date	Sample Number	Sample Location	Styrene Concentration mg/L (ppm)
7/29	A-1	Upstream	1.1
	A-2	From bag after curing temperature reached	37
7/30	A-3	Immediately downstream from culvert	73
7/31	A-4	From inside bag after hole was made	110
	A-5	5 feet downstream from culvert	75
8/03	A-6	Downstream from culvert outlet	1.0

The liner was already placed in the culvert before any samples were taken for culvert A.

Figure 1 The photo on the left shows the scaffold holding the liner in the inlet to culvert A. The diesel powered furnaces to heat the curing water are on the trucks. The photo on the right shows the hoses that re-circulate the water.

Figure 2 the photo on the left shows the outlet of the pipe that was replaced in the summer of 2008 using the CIPP technique. This is the location where sample A-1 was taken. The trickle of water that left the culvert under the eastbound lanes of I-88 traveled along the rocky ditch shown in the photo on the right. The location of the inlet to culvert A is marked by the orange scaffolding and the white trucks.

Figure 3 The lining in the outlet from culvert A after curing complete and holes were made in the bag to collect water (A-4). The photo on right shows water leaking from the holes before the end was cut.

Figure 4 The outlet from culvert A flows downhill to the Susquehanna River. The photo on the left shows pieces of felt that had not been impregnated with styrene. This felt was placed in the stream in an attempt to collect uncured styrene. The photo on the right shows a little further downstream where samples A-5 and A-6 were taken.

The smell of styrene was apparent when in the vicinity of the culvert during most of the curing-in-place process. When curing temperatures were reached steam often escaped from both ends of the culvert. Plumes of diesel exhaust were also apparent when the diesel furnaces were working to heat the water.

It is important to note that the upstream sample in this case was downstream from where CIPP was installed during the summer of 2008. Interstate 88 is a two lane divided highway with a median in the middle. The culvert under the eastbound lanes was repaired last summer; the culvert under the westbound lanes is part of this study.

Culvert B

The results from sampling culvert B, under westbound I-88, are summarized in Table 2.

Table 2. Results from water sampling culvert B

Date	Sample number	Sample Location	Styrene Concentration mg/L (ppm)
7/30	B-1	Upstream from culvert before work	ND
	B-2	Downstream from culvert before work	ND
	B-3	From Clifford Hay's water truck	0.016
	B-4	Water source (hydrant)	ND
7/31	B-5	From inside bag after hole was made (temp ~ 110 – 120 F)	130
8/03	B-6	Downstream from culvert after work	3.6

Culvert B was easily reached on the upstream (south) side, but the downstream (north) side of the culvert was at the bottom of a 50 foot drop and was difficult to reach.

Samples from the stream carried by culvert B were taken before work started. The entire installation process was observed. The felt sock that has been impregnated with styrene, trigonox 311 and perkadox 16 was kept on ice until it was unloaded at culvert B. Scaffolding is placed above the inlet to the culvert. Workers on the scaffolding wrestle the impregnated lining to the scaffold and attach the ends to a fixture on the scaffold. Then workers jump on the lining to begin turning it inside out. Other workers help by pull the lining from outside and below. The process is labor intensive and takes a few hours. Once the lining is actually placed inside the culvert water pressure is used.

The smell of styrene is strong by the truck and where the workers are turning the sock inside out.

Figure 5 TCI taking water sample from upstream of culvert B. Scaffolding is already in place. Photo on the right show the outlet from culvert B.

Figure 6 Liner is unrolled from truck and fed through the specialized equipment on top of the platform.

Figure 7 Small jets of water and steam can be observed once the liner is in place and the water heated to 200 degrees F.

Culvert C

The results from sampling culvert C, under eastbound I-88, are summarized in Table 3.

Table 3. Results from water sampling culvert C

Date	Sample Number	Sample Location	Styrene Concentration mg/L (ppm)
8/04	C-1	Upstream from pipe	ND
8/04	C-2	From bag before curing temperature reached	250
8/04	C-3	Bette and Cringe water truck	ND
8/04	C-4	Water source (Belden Brook)	ND
8/04	C-5	DI at outlet of culvert	48
8/04	C-6	From bag after curing temperature reached	54
8/05	C-7	Water from cured pipe at release	41

Figure 8 Culvert C is under the eastbound lanes of I-88. The photo on the left show the lining as it enters the culvert. Sample C-1 was taken upstream as indicated. The photo on the right shows the median where the outlet from culvert C is located.

Figure 9 The outlet from culvert C is located in a DI.

Once the lining for culvert C was in place and heated to 200 degrees F, sample C-6 was taken directly from the water seeping out of the liner. The following day, the end of the lining was cut with a saws-all. The person using the saws-all positioned himself in the DI while he was cutting the lining. Once the lining was cut water spued out. The cut in the end of the lining was about a square foot. Once the cut was made the person came out of the DI. It took about 45 minutes for the entire culvert to drain. Interestingly there were pockets of very hot water that were evidenced by the steam coming off the effluent at discreet intervals. Sample C-7 was taken at the beginning of the release.

Culvert D

The results from sampling culvert D, under the westbound on-ramp to I-88 at exit 6, are summarized in Table 4.

Table 4. Results from water sampling culvert D

Date	Sample Number	Sample Location	Styrene Concentration mg/L (ppm)
8/12	D-1	From bag after curing temperature reached	63
8/12	D-2	15 feet downstream after curing	39
8/12	D-3	Ditch upstream from DI	ND
8/12	D-4	Source water from Belden Brook	ND
8/13	D-5	Water released from cured pipe	120
8/13	D-6	Water from water truck	0.007
8/13	D-7	15 feet downstream after lining cut	33

Figure 10 The photo on the left shows the lining as it enter culvert D. The photo on the right indicates where the updtich water sample was taken (D-3).

Figure 11 Photo on the left shows the lining in culvert D before it has been cut. Photo on the right shows the cut lining. The blue plastic tubing used to convey the heated water to the end of the lining *in situ* can be seen in this photo.

Discussion

The concentration of styrene at the time the water was released from the lining after curing was complete are summarized in Table 5. Another important variable is the total amount of styrene that is released to the environment, or the mass loading. The mass loading value for styrene during release can be calculated by multiplying the concentration of styrene in the curing water in mg/L by the total volume of the culvert in liters, and converting from kilograms to pounds (Table 5).

Table 5. Mass loading values for each culvert

Culvert	Culvert Diameter (inches)	Culvert Length (feet/meters)	Concentration during release (mg/L)	Mass loading (pounds)
A	42	30.79 meters	110	7.1
B	48	30.79 meters	130	10.2
C	36	140 feet	41	2.5
D	24	159 feet	120	3.9

The concentration and mass loading values obtained during this study of four culverts are similar to the values reported by the Virginia Department of Transportation and the trade association (VDOT) that represents the CIPP industry. There are, however, important differences among these reports. In addition, the mass loading values calculated in this report may underestimate the actual styrene released because they do not include styrene that escaped during the placement and curing process prior to releasing the water.

The VDOT appears to use steam curing. In 2007 VDOT suspended its CIPP installations in order to evaluate environmental effects. The CIPP installations were resumed in 2008 with several additional safeguards, including acquisition of discharge-related permits, proper disposal of

cure water, cure condensate and rinse, water and soil testing before and after installation, and ongoing additional research.

The trade group publication prepared by the NASSCO CIPP Committee (2008) indicates that release water from cured linings should not exceed 25 ppm of styrene in order to prevent environmental harm. There is no documentation of the rationale for this number given in the publication.. The trade publication also states that "properly cured liners release little or not styrene to the environment ." No data, however, is presented to support this claim. The results obtained at the four installations reported in this document suggest that styrene is present when installation is done properly.

All the installations observed in this report were cured by using water heated to 200 degrees F for a minimum of 2 hours. The quality control aspects of these culvert replacements were conducted by other NYS DOT personnel. Temperature measurements were done during the curing process. Although temperature readings were not conducted prior to, or at, release of water from the completed pipe lining, the water in the lining was allowed to cool at least overnight. Nonetheless, temperatures of release water appeared to be about 100 degrees F by feel. During release of the curing water from culvert C it was noted that there was a pocket of relatively hotter water that was released about 15 minutes after the release began. Typically it takes about 45 minutes for the curing water to drain from a culvert.

The upstream sample for culvert A was taken at the outfall of a culvert lined in 2008. This was done because the CIPP operation was already in progress when sampling commenced and because the channel connecting the culvert lined last year and the one lined this year was very rocky and that was the only place a sample could be withdrawn. There are approximately 25 meters between the outfall of the culvert under the eastbound lanes (lined in 2008) and the inlet of the culvert under the westbound lanes (culvert A). In a similar situation where the culvert under the westbound lanes (culvert B) is approximately 30 meters from the culvert under the eastbound lanes, the sample was taken just upstream from the inlet. In this sample no styrene was detected even though it was receiving water that had flowed through the culvert lined with the CIPP process the previous year (2008).

Human Health Risks

Although some organizations claim that styrene is not a carcinogen others, including the American Conference of Governmental Industrial Hygienists (ACGIH) classifies styrene as an A4 substance which means that human carcinogenicity cannot be conclusively determined because of lack of data and the International Agency for Research in Cancer (IARC) classifies styrene as a 2B substance which means it is possibly a human carcinogen. The types of cancer possibly associated with styrene exposure are leukemiea and hematopoietic neoplasms. Systemic effects of styrene include central nervous system impairment and irritation. Long term adverse effects have also been reported for the liver and kidneys. There is evidence that styrene is mutagenic.

Styrene odor can be detected in the air at levels well below allowable exposure limits. The odor threshold for styrene has been reported to be between 0.06 and 4.6 ppb by a chemical company fact sheet; and 8 ppb (0.036mg/cubic meter) by the U.S. EPA.

Ecological Health Risks

An important consideration for adverse ecological effects is the half-life of styrene. Apparently styrene breaks down fairly quickly in the atmosphere through reactions primarily with hydroxyl radicals and ozone (Spectrum Laboratories). Degradation of styrene in soil and water occurs primarily by two processes, volatization and microbial breakdown. The rate of volatization in water is heavily dependent on temperature and depth of water. Half-life ranges from 3 to 13 days (Guo and Mulligan, 2006). The half-life in soil and groundwater is longer and ranges between 6 weeks and 7.5 months (ATSDR, 1992).

The Canadian interim guideline for the protection of freshwater life is 72 ug/L, 72 ppb. This guideline is based on acute toxicity to vertebrates and invertebrates, and chronic toxicity to plants.

Another important environmental parameter is the temperature of the released water, not only for trout streams but also for benthic organisms. There have been reports of algal blooms after CIPP repairs. These observations may be associated with water temperature.

Regulatory Issues and Exposure Limits

Although the trade group publication prepared by NASSCO CIPP committee (2008) suggests that the release does not qualify as a point source discharge, the Clean Water Act requires that all discharges of pollutants to surface water be authorized by a permit issued by the U. S. EPA or its designee. The U. S. EPA drinking water limit for styrene is 0.1 ppm (100 ppb), or 0.1 mg/L. In New York the Department of Environmental Conservation issues discharge permits. According to the DEC regulations (702.16(c)(1)) a discharge from a point source or outlet must contain 5ug/L of styrene or less unless a permit is obtained. The DEC presumes that discharge to the ground or unsaturated zone is a discharge to groundwater.

Despite attempts to lower the allowable exposure limit for an 8-hour time-weighted exposure, the current limit promulgated by OSHA is 100 ppm. The basis of the permissible exposure limit is to prevent narcosis in the workplace The ACGIH, however, recommends an 8-hour, time-weighted threshold limit value of 20 ppm, with a short term exposure limits of 40 ppm. PESH (Public Employees Safety and Health) also promulgates values lower than the OSHA occupational exposure limit.

References

EPA technical fact sheet on: styrene

Styrene Monomer (http://www.ejnet.org/plastics/polystyrene/styrene.html), accessed September 2009.

Chemical Fact Sheet, styrene (http://www.speclab.com/compound/c100425.htm), accessed September 2009.

Canadian Council of Ministers of the Environment. 1999. Canadian water quality guidelines for the protection of aquatic life: Styrene. In: Canadian environmental quality guidelines, 1999, Canadian Council of Minister of the Environment, Winnipeg.

International Agency for Research on Cancer (IARC) – Summaries and Evaluation (http://www.inchem.org/documents/iarc/vol82/82-07.html), accessed September 2009.

U. S. EPA, Technology Transfer Network, Air Toxics Web Site, Styrene, (http://www.epa.gov/ttn/uatw/hlthef/styrene.html), accessed August 2009

Jon Luoma, 2002, Under the Influence in "NRCD OnEarth Magazine," (http://www.nrdc.org/OnEarth/02fall/iarc.asp) accessed August 2009

ATSDR (Agency for Toxic Substances and Disease Registry, September 2007 (http://www.atsdr.cdc.gov/tfacts53.html) accessed August 2009.

Hemminki, K and P Vodicka. 1995. Styrene: from characterization of DNA adducts to application in styrene-exposed lamination workers. Toxicology Letters 77:153-161.

U. S. EPA, Basic Information about Styrene in Drinking Water (http://www.epa.gov/safewater/contaminants/basicinformation/styrene.html) accessed August 2009)

Guo, Y and C N Mulligan. 2006. "Combined treatment of styrene," in Hazardous Materials in the Soil and Atmosphere, ed. Robert Hudson. Novia Scotia Publishers, Inc. pp. 1 – 38.

Guidelines for the Use and Handling of the Styrenated Resons in Cured-In-Place-Pipe, National Association of Sewer Service Companies (NASSCO) (www.nassco.org/publications/misc/guide_hand_styren_resins.pdf) accessed September 2009.

Griffin, J. 2008. Virginia DOT Lifts CIPP Ban, Underground Construction, June 2008 (uconline.com).

Donaldson, B M and A J Baker. 2008. Understanding the environmental Implications of cured-In-Place_Pipe Rehabilitation Technology. *Final Report VTRC 08-R16.* Virginia Transportation Research Council, 530 Edgemont Road, Charlottesville, VA 22903-24554, www.vtrc.net, 434-293-1900. (http:// vtrc.virginiadot.org/PubDetails.aspx?PubNo=08-R16)

APPENDIX H.1

Jim,
Attached are the sample results for a water sample collected by ODOT on July 13, 2005 from water from the pipe lining and existing pipe at 3:30 pm. The analysis detected 174 parts per million Styrene.
Please share the report with the responsible party.

I have reviewed the analytical results form samples collected by NRC and they detected 9.05 parts per million Styrene from a liquid sample that was collected from the pipe discharge to the river. In addition gasoline, diesel, and heavy oil hydrocarbons were detected in the water sample and diesel/heavy oil was detected in the solid sample.

I do not have the details of where these samples were collected from.

I have contacted DEQ and informed them of the sample results for NRC and ODOT. They will contact NRC to discuss the results.

I recommend the following:

ODOT receive a complete final copy of the spill report submitted to DEQ detailing the site cleanup response,
ODOT receive a copy of all communication between the responsible party and DEQ,
ODOT receive a plan for additional work required by DEQ to determine full site clean up,
ODOT receive a final determination from DEQ that all cleanup work has been performed to their satisfaction.

I believe that additional sampling should be performed to determine if Styrene and hydrocarbons are still discharging to the river and if soils have been impacted by the spill.

Thanks Jim Orr

www.ncalabs.com

Seattle 11720 North Creek Pkwy N, Suite 400, Bothell, WA 98011-8244
425.420.9200 fax 425.420.9210
Spokane East 11115 Montgomery, Suite B, Spokane, WA 99206-4776
509.924.9200 fax 509.924.9290
Portland 9405 SW Nimbus Avenue, Beaverton, OR 97008-7132
503.906.9200 fax 503.906.9210
Bend 20332 Empire Avenue, Suite F-1, Bend, OR 97701-5711
541.383.9310 fax 541.382.7588
Anchorage 2000 W International Airport Road, Suite A-10, Anchorage, AK 99502-1119
907.563.9200 fax 907.563.9210

July 19, 2005

Jim Orr
ODOT - Region 1 HazMat
123 NW Flanders
Portland, OR 97209

RE: St. Johns

Enclosed are the results of analyses for samples received by the laboratory on 07/14/05 17:35.
The following list is a summary of the NCA Work Orders contained in this report.
If you have any questions concerning this report, please feel free to contact me.

Work	Project	ProjectNumber
P5G0569	St. Johns	N/A

Thank You,

Sarah Rockwell

Sarah Rockwell For Lisa Domenighini, Project Manager

www.ncalabs.com

Seattle 11720 North Creek Pkwy N, Suite 400, Bothell, WA 98011-8244
phone: (425) 420.9200 fax: (425) 420.9210
Spokane East 11115 Montgomery, Suite B, Spokane, WA 99206-4776
phone: (509) 924.9200 fax: (509) 924.9290
Portland 9405 SW Nimbus Avenue, Beaverton, OR 97008-7132
phone: (503) 906.9200 fax: (503) 906.9210
Bend 20332 Empire Avenue, Suite F-1, Bend, OR 97701-5711
phone: (541) 383.9310 fax: 541.382.7588
Anchorage 2000 W International Airport Road, Suite A-10, Anchorage, AK 99502-1119
phone: (907) 563.9200 fax: (907) 563.9210

ODOT - Region 1 HazMat
123 NW Flanders
Portland, OR 97209

Project Name: **St. Johns**
Project Number: N/A
Project Manager: Jim Orr

Report Created:
07/19/05 16:33

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
Pipe 1	P5G0569-01	Water	07/13/05 15:30	07/14/05 17:35

Sarah Rockwell For Lisa Domenighini, Project Manager

www.ncalabs.com

Seattle 11720 North Creek Pkwy N, Suite 400, Bothell, WA 98011-8244
phone: (425) 420.9200 fax: (425) 420.9210
Spokane East 11115 Montgomery, Suite B, Spokane, WA 99206-4776
phone: (509) 924.9200 fax: (509) 924.9290
Portland 9405 SW Nimbus Avenue, Beaverton, OR 97008-7132
phone: (503) 906.9200 fax: (503) 906.9210
Bend 20332 Empire Avenue, Suite F-1, Bend, OR 97701-5711
phone: (541) 383.9310 fax: 541.382.7588
Anchorage 2000 W International Airport Road, Suite A-10, Anchorage, AK 99502-1119
phone: (907) 563.9200 fax: (907) 563.9210

ODOT - Region 1 HazMat
123 NW Flanders
Portland, OR 97209

Project Name: **St. Johns**
Project Number: N/A
Project Manager: Jim Orr

Report Created:
07/19/05 16:33

Volatile Organic Compounds per EPA Method 8260B

North Creek Analytical - Portland

Analyte	Method	Result	MDL*	MRL	Units	Dil	Batch	Prepared	Analyzed	Notes
P5G0569-01RE2 Water Pipe 1 Sampled: 07/13/05 15:30										
Acetone	EPA 8260B	ND	-----	50000	ug/l	2000x	5070730	07/19/05	07/19/05 14:22	
Benzene	"	ND	-----	2000	"	"	"	"	"	
Bromobenzene	"	ND	-----	2000	"	"	"	"	"	
Bromochloromethane	"	ND	-----	2000	"	"	"	"	"	
Bromodichloromethane	"	ND	-----	2000	"	"	"	"	"	
Bromoform	"	ND	-----	2000	"	"	"	"	"	
Bromomethane	"	ND	-----	10000	"	"	"	"	"	
2-Butanone	"	ND	-----	20000	"	"	"	"	"	
n-Butylbenzene	"	ND	-----	10000	"	"	"	"	"	
sec-Butylbenzene	"	ND	-----	2000	"	"	"	"	"	
tert-Butylbenzene	"	ND	-----	2000	"	"	"	"	"	
Carbon disulfide	"	ND	-----	20000	"	"	"	"	"	
Carbon tetrachloride	"	ND	-----	2000	"	"	"	"	"	
Chlorobenzene	"	ND	-----	2000	"	"	"	"	"	
Chloroethane	"	ND	-----	2000	"	"	"	"	"	
Chloroform	"	ND	-----	2000	"	"	"	"	"	
Chloromethane	"	ND	-----	10000	"	"	"	"	"	
2-Chlorotoluene	"	ND	-----	2000	"	"	"	"	"	
4-Chlorotoluene	"	ND	-----	2000	"	"	"	"	"	
1,2-Dibromo-3-chloropropane	"	ND	-----	10000	"	"	"	"	"	
Dibromochloromethane	"	ND	-----	2000	"	"	"	"	"	
1,2-Dibromoethane	"	ND	-----	2000	"	"	"	"	"	
Dibromomethane	"	ND	-----	2000	"	"	"	"	"	
1,2-Dichlorobenzene	"	ND	-----	2000	"	"	"	"	"	
1,3-Dichlorobenzene	"	ND	-----	2000	"	"	"	"	"	
1,4-Dichlorobenzene	"	ND	-----	2000	"	"	"	"	"	
Dichlorodifluoromethane	"	ND	-----	10000	"	"	"	"	"	
1,1-Dichloroethane	"	ND	-----	2000	"	"	"	"	"	
1,2-Dichloroethane	"	ND	-----	2000	"	"	"	"	"	
1,1-Dichloroethene	"	ND	-----	2000	"	"	"	"	"	
cis-1,2-Dichloroethene	"	ND	-----	2000	"	"	"	"	"	
trans-1,2-Dichloroethene	"	ND	-----	2000	"	"	"	"	"	
1,2-Dichloropropane	"	ND	-----	2000	"	"	"	"	"	
1,3-Dichloropropane	"	ND	-----	2000	"	"	"	"	"	
2,2-Dichloropropane	"	ND	-----	2000	"	"	"	"	"	
1,1-Dichloropropene	"	ND	-----	2000	"	"	"	"	"	
cis-1,3-Dichloropropene	"	ND	-----	2000	"	"	"	"	"	
trans-1,3-Dichloropropene	"	ND	-----	2000	"	"	"	"	"	
Ethylbenzene	"	ND	-----	2000	"	"	"	"	"	
Hexachlorobutadiene	"	ND	-----	8000	"	"	"	"	"	
2-Hexanone	"	ND	-----	20000	"	"	"	"	"	
Isopropylbenzene	"	ND	-----	4000	"	"	"	"	"	

Sarah Rockwell

Sarah Rockwell For Lisa Domenighini, Project Manager

www.ncalabs.com

Seattle 11720 North Creek Pkwy N, Suite 400, Bothell, WA 98011-8244
phone: (425) 420.9200 fax: (425) 420.9210
Spokane East 11115 Montgomery, Suite B, Spokane, WA 99206-4776
phone: (509) 924.9200 fax: (509) 924.9290
Portland 9405 SW Nimbus Avenue, Beaverton, OR 97008-7132
phone: (503) 906.9200 fax: (503) 906.9210
Bend 20332 Empire Avenue, Suite F-1, Bend, OR 97701-5711
phone: (541) 383.9310 fax: 541.382.7588
Anchorage 2000 W International Airport Road, Suite A-10, Anchorage, AK 99502-1119
phone: (907) 563.9200 fax: (907) 563.9210

ODOT - Region 1 HazMat	Project Name:	**St. Johns**	
123 NW Flanders	Project Number:	N/A	Report Created:
Portland, OR 97209	Project Manager:	Jim Orr	07/19/05 16:33

Volatile Organic Compounds per EPA Method 8260B

North Creek Analytical - Portland

Analyte	Method	Result	MDL*	MRL	Units	Dil	Batch	Prepared	Analyzed	Notes
P5G0569-01RE2 Water Pipe 1 Sampled: 07/13/05 15:30										
p-Isopropyltoluene	EPA 8260B	ND	-----	4000	ug/l	2000x	5070730	07/19/05	07/19/05 14:22	
4-Methyl-2-pentanone	"	ND	-----	10000	"	"	"	"	"	
Methyl tert-butyl ether	"	ND	-----	2000	"	"	"	"	"	
Methylene chloride	"	ND	-----	10000	"	"	"	"	"	
Naphthalene	"	ND	-----	4000	"	"	"	"	"	
n-Propylbenzene	"	ND	-----	2000	"	"	"	"	"	
Styrene	"	**174000**	-----	2000	"	"	"	"	"	
1,1,1,2-Tetrachloroethane	"	ND	-----	2000	"	"	"	"	"	
1,1,2,2-Tetrachloroethane	"	ND	-----	2000	"	"	"	"	"	
Tetrachloroethene	"	ND	-----	2000	"	"	"	"	"	
Toluene	"	ND	-----	2000	"	"	"	"	"	
1,2,3-Trichlorobenzene	"	ND	-----	2000	"	"	"	"	"	
1,2,4-Trichlorobenzene	"	ND	-----	2000	"	"	"	"	"	
1,1,1-Trichloroethane	"	ND	-----	2000	"	"	"	"	"	
1,1,2-Trichloroethane	"	ND	-----	2000	"	"	"	"	"	
Trichloroethene	"	ND	-----	2000	"	"	"	"	"	
Trichlorofluoromethane	"	ND	-----	2000	"	"	"	"	"	
1,2,3-Trichloropropane	"	ND	-----	2000	"	"	"	"	"	
1,2,4-Trimethylbenzene	"	ND	-----	2000	"	"	"	"	"	
1,3,5-Trimethylbenzene	"	ND	-----	2000	"	"	"	"	"	
Vinyl chloride	"	ND	-----	2000	"	"	"	"	"	
o-Xylene	"	ND	-----	2000	"	"	"	"	"	
m,p-Xylene	"	ND	-----	4000	"	"	"	"	"	

Surrogate(s):	*4-BFB*	*Recovery: 103%*	*Limits: 75 - 120 %*	*1x*	"
	1,2-DCA-d4	*89.0%*	*77 - 129 %*	"	"
	Dibromofluoromethane	*91.0%*	*80 - 121 %*	"	"
	Toluene-d8	*92.0%*	*80 - 120 %*	"	"

Sarah Rockwell

Sarah Rockwell For Lisa Domenighini, Project Manager

www.ncalabs.com

Seattle 11720 North Creek Pkwy N, Suite 400, Bothell, WA 98011-8244
phone: (425) 420.9200 fax: (425) 420.9210
Spokane East 11115 Montgomery, Suite B, Spokane, WA 99206-4776
phone: (509) 924.9200 fax: (509) 924.9290
Portland 9405 SW Nimbus Avenue, Beaverton, OR 97008-7132
phone: (503) 906.9200 fax: (503) 906.9210
Bend 20332 Empire Avenue, Suite F-1, Bend, OR 97701-5711
phone: (541) 383.9310 fax: 541.382.7588
Anchorage 2000 W International Airport Road, Suite A-10, Anchorage, AK 99502-1119
phone: (907) 563.9200 fax: (907) 563.9210

ODOT - Region 1 HazMat
123 NW Flanders
Portland, OR 97209

Project Name: **St. Johns**
Project Number: N/A
Project Manager: Jim Orr

Report Created:
07/19/05 16:33

Volatile Organic Compounds per EPA Method 8260B - Laboratory Quality Control Results

North Creek Analytical - Portland

QC Batch: 5070730 **Water Preparation Method: EPA 5030B**

Analyte	Method	Result	MDL*	MRL	Units	Dil	Source Result	Spike Amt	% REC	(Limits)	% RPD	(Limits)	Analyzed	Notes
Blank (5070730-BLK1)									Extracted: 07/19/05 07:59					
Acetone	EPA 8260B	ND	---	25.0	ug/l	1x	--	--	--	--	--	--	07/19/05 10:48	
Benzene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Bromobenzene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Bromochloromethane	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Bromodichloromethane	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Bromoform	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Bromomethane	"	ND	---	5.00	"	"	--	--	--	--	--	--	"	
2-Butanone	"	ND	---	10.0	"	"	--	--	--	--	--	--	"	
n-Butylbenzene	"	ND	---	5.00	"	"	--	--	--	--	--	--	"	
sec-Butylbenzene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
tert-Butylbenzene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Carbon disulfide	"	ND	---	10.0	"	"	--	--	--	--	--	--	"	
Carbon tetrachloride	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Chlorobenzene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Chloroethane	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Chloroform	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Chloromethane	"	ND	---	5.00	"	"	--	--	--	--	--	--	"	
2-Chlorotoluene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
4-Chlorotoluene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
1,2-Dibromo-3-chloropropane	"	ND	---	5.00	"	"	--	--	--	--	--	--	"	
Dibromochloromethane	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
1,2-Dibromoethane	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Dibromomethane	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
1,2-Dichlorobenzene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
1,3-Dichlorobenzene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
1,4-Dichlorobenzene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Dichlorodifluoromethane	"	ND	---	5.00	"	"	--	--	--	--	--	--	"	
1,1-Dichloroethane	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
1,2-Dichloroethane	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
1,1-Dichloroethene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
cis-1,2-Dichloroethene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
trans-1,2-Dichloroethene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
1,2-Dichloropropane	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
1,3-Dichloropropane	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
2,2-Dichloropropane	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
1,1-Dichloropropene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
cis-1,3-Dichloropropene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
trans-1,3-Dichloropropene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Ethylbenzene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Hexachlorobutadiene	"	ND	---	4.00	"	"	--	--	--	--	--	--	"	
2-Hexanone	"	ND	---	10.0	"	"	--	--	--	--	--	--	"	

Sarah Rockwell

Sarah Rockwell For Lisa Domenighini, Project Manager

www.ncalabs.com

Seattle 11720 North Creek Pkwy N, Suite 400, Bothell, WA 98011-8244
phone: (425) 420.9200 fax: (425) 420.9210
Spokane East 11115 Montgomery, Suite B, Spokane, WA 99206-4776
phone: (509) 924.9200 fax: (509) 924.9290
Portland 9405 SW Nimbus Avenue, Beaverton, OR 97008-7132
phone: (503) 906.9200 fax: (503) 906.9210
Bend 20332 Empire Avenue, Suite F-1, Bend, OR 97701-5711
phone: (541) 383.9310 fax: 541.382.7588
Anchorage 2000 W International Airport Road, Suite A-10, Anchorage, AK 99502-1119
phone: (907) 563.9200 fax: (907) 563.9210

ODOT - Region 1 HazMat
123 NW Flanders
Portland, OR 97209

Project Name: **St. Johns**
Project Number: N/A
Project Manager: Jim Orr

Report Created:
07/19/05 16:33

Volatile Organic Compounds per EPA Method 8260B - Laboratory Quality Control Results

North Creek Analytical - Portland

QC Batch: 5070730 **Water Preparation Method: EPA 5030B**

Analyte	Method	Result	MDL*	MRL	Units	Dil	Source Result	Spike Amt	% REC	(Limits)	% RPD	(Limits)	Analyzed	Notes
Blank (5070730-BLK1)									Extracted: 07/19/05 07:59					
Isopropylbenzene	EPA 8260B	ND	---	2.00	ug/l	1x	--	--	--	--	--	--	07/19/05 10:48	
p-Isopropyltoluene	"	ND	---	2.00	"	"	--	--	--	--	--	--	"	
4-Methyl-2-pentanone	"	ND	---	5.00	"	"	--	--	--	--	--	--	"	
Methyl tert-butyl ether	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Methylene chloride	"	ND	---	5.00	"	"	--	--	--	--	--	--	"	
Naphthalene	"	ND	---	2.00	"	"	--	--	--	--	--	--	"	
n-Propylbenzene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Styrene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
1,1,1,2-Tetrachloroethane	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
1,1,2,2-Tetrachloroethane	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Tetrachloroethene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Toluene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
1,2,3-Trichlorobenzene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
1,2,4-Trichlorobenzene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
1,1,1-Trichloroethane	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
1,1,2-Trichloroethane	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Trichloroethene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Trichlorofluoromethane	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
1,2,3-Trichloropropane	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
1,2,4-Trimethylbenzene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
1,3,5-Trimethylbenzene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
Vinyl chloride	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
o-Xylene	"	ND	---	1.00	"	"	--	--	--	--	--	--	"	
m,p-Xylene	"	ND	---	2.00	"	"	--	--	--	--	--	--	"	
Surrogate(s): 4-BFB		*Recovery: 100%*			*Limits: 75-120%*	"							*07/19/05 10:48*	
1,2-DCA-d4		*90.0%*			*77-129%*	"							*"*	
Dibromofluoromethane		*93.5%*			*80-121%*	"							*"*	
Toluene-d8		*95.0%*			*80-120%*	"							*"*	

Sarah Rockwell

Sarah Rockwell For Lisa Domenighini, Project Manager

www.ncalabs.com

Seattle 11720 North Creek Pkwy N, Suite 400, Bothell, WA 98011-8244
phone: (425) 420.9200 fax: (425) 420.9210
Spokane East 11115 Montgomery, Suite B, Spokane, WA 99206-4776
phone: (509) 924.9200 fax: (509) 924.9290
Portland 9405 SW Nimbus Avenue, Beaverton, OR 97008-7132
phone: (503) 906.9200 fax: (503) 906.9210
Bend 20332 Empire Avenue, Suite F-1, Bend, OR 97701-5711
phone: (541) 383.9310 fax: 541.382.7588
Anchorage 2000 W International Airport Road, Suite A-10, Anchorage, AK 99502-1119
phone: (907) 563.9200 fax: (907) 563.9210

ODOT - Region 1 HazMat
123 NW Flanders
Portland, OR 97209

Project Name: **St. Johns**
Project Number: N/A
Project Manager: Jim Orr

Report Created:
07/19/05 16:33

Volatile Organic Compounds per EPA Method 8260B - Laboratory Quality Control Results

North Creek Analytical - Portland

QC Batch: 5070730 **Water Preparation Method: EPA 5030B**

Analyte	Method	Result	MDL*	MRL	Units	Dil	Source Result	Spike Amt	% REC	(Limits)	% RPD	(Limits)	Analyzed	Notes
LCS (5070730-BS1)														
							Extracted: 07/19/05 07:59							
Benzene	EPA 8260B	20.8	---	1.00	ug/l	1x	--	20.0	104%	(80-120)	--	--	07/19/05 08:35	
Chlorobenzene	"	20.8	---	1.00	"	"	--	"	104%	(80-124)	--	--	"	
1,1-Dichloroethene	"	20.4	---	1.00	"	"	--	"	102%	(78-120)	--	--	"	
Toluene	"	20.6	---	1.00	"	"	--	"	103%	(80-124)	--	--	"	
Trichloroethene	"	19.9	---	1.00	"	"	--	"	99.5%	(80-132)	--	--	"	
Surrogate(s):	*4-BFB*	*Recovery:*	*102%*		*Limits:*	*75-120%*	"						*07/19/05 08:35*	
	1,2-DCA-d4		*90.5%*			*77-129%*	"						"	
	Dibromofluoromethane		*93.5%*			*80-121%*	"						"	
	Toluene-d8		*94.0%*			*80-120%*	"						"	
Matrix Spike (5070730-MS1)							**QC Source: P5G0419-01**							
							Extracted: 07/19/05 07:59							
Benzene	EPA 8260B	20.4	---	1.00	ug/l	1x	ND	20.0	102%	(80-124)	--	--	07/19/05 09:02	
Chlorobenzene	"	19.8	---	1.00	"	"	ND	"	99.0%	(72.9-134)	--	--	"	
1,1-Dichloroethene	"	19.6	---	1.00	"	"	ND	"	98.0%	(79.3-127)	--	--	"	
Toluene	"	20.0	---	1.00	"	"	ND	"	100%	(79.7-131)	--	--	"	
Trichloroethene	"	34.0	---	1.00	"	"	15.2	"	94.0%	(68.4-130)	--	--	"	
Surrogate(s):	*4-BFB*	*Recovery:*	*106%*		*Limits:*	*75-120%*	"						*07/19/05 09:02*	
	1,2-DCA-d4		*92.0%*			*77-129%*	"						"	
	Dibromofluoromethane		*96.0%*			*80-121%*	"						"	
	Toluene-d8		*98.0%*			*80-120%*	"						"	
Matrix Spike Dup (5070730-MSD1)							**QC Source: P5G0419-01**							
							Extracted: 07/19/05 07:59							
Benzene	EPA 8260B	20.6	---	1.00	ug/l	1x	ND	20.0	103%	(80-124)	0.976%	(25)	07/19/05 09:29	
Chlorobenzene	"	19.9	---	1.00	"	"	ND	"	99.5%	(72.9-134)	0.504%	"	"	
1,1-Dichloroethene	"	19.8	---	1.00	"	"	ND	"	99.0%	(79.3-127)	1.02%	"	"	
Toluene	"	20.4	---	1.00	"	"	ND	"	102%	(79.7-131)	1.98%	"	"	
Trichloroethene	"	34.0	---	1.00	"	"	15.2	"	94.0%	(68.4-130)	0.00%	"	"	
Surrogate(s):	*4-BFB*	*Recovery:*	*106%*		*Limits:*	*75-120%*	"						*07/19/05 09:29*	
	1,2-DCA-d4		*91.5%*			*77-129%*	"						"	
	Dibromofluoromethane		*94.0%*			*80-121%*	"						"	
	Toluene-d8		*97.0%*			*80-120%*	"						"	

Sarah Rockwell

Sarah Rockwell For Lisa Domenighini, Project Manager

www.ncalabs.com

Seattle 11720 North Creek Pkwy N, Suite 400, Bothell, WA 98011-8244
phone: (425) 420.9200 fax: (425) 420.9210
Spokane East 11115 Montgomery, Suite B, Spokane, WA 99206-4776
phone: (509) 924.9200 fax: (509) 924.9290
Portland 9405 SW Nimbus Avenue, Beaverton, OR 97008-7132
phone: (503) 906.9200 fax: (503) 906.9210
Bend 20332 Empire Avenue, Suite F-1, Bend, OR 97701-5711
phone: (541) 383.9310 fax: 541.382.7588
Anchorage 2000 W International Airport Road, Suite A-10, Anchorage, AK 99502-1119
phone: (907) 563.9200 fax: (907) 563.9210

ODOT - Region 1 HazMat	Project Name:	**St. Johns**	
123 NW Flanders	Project Number:	N/A	Report Created:
Portland, OR 97209	Project Manager:	Jim Orr	07/19/05 16:33

Notes and Definitions

Report Specific Notes:

None

Laboratory Reporting Conventions:

DET - Analyte DETECTED at or above the Reporting Limit. Qualitative Analyses only.

ND - Analyte NOT DETECTED at or above the reporting limit (MDL or MRL, as appropriate).

NR / NA - Not Reported / Not Available

dry - Sample results reported on a dry weight basis. Reporting Limits are corrected for %Solids when %Solids are <50%.

wet - Sample results and reporting limits reported on a wet weight basis (as received).

RPD - Relative Percent Difference. (RPDs calculated using Results, not Percent Recoveries).

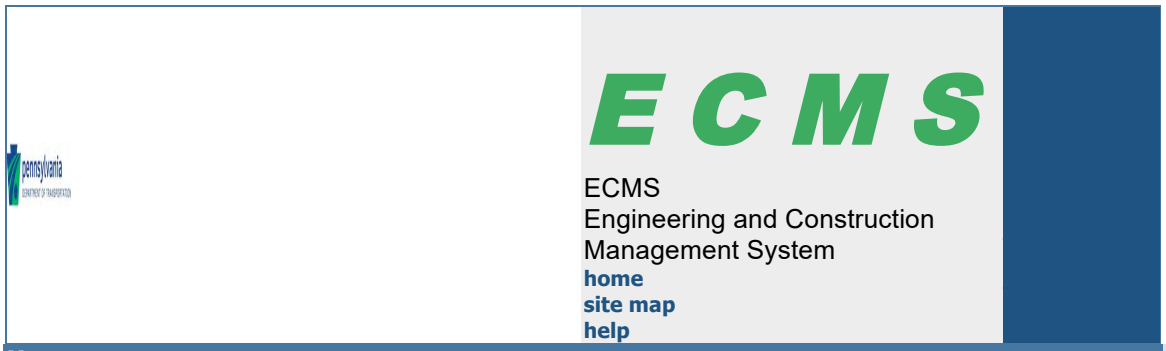
MRL - METHOD REPORTING LIMIT. Reporting Level at, or above, the lowest level standard of the Calibration Table.

MDL* - METHOD DETECTION LIMIT. Reporting Level at, or above, the statistically derived limit based on 40CFR, Part 136, Appendix B. *MDLs are listed on the report only if the data has been evaluated below the MRL. Results between the MDL and MRL are reported as Estimated results.

Dil - Dilutions are calculated based on deviations from the standard dilution performed for an analysis, and may not represent the dilution found on the analytical raw data.

Reporting limits - Reporting limits (MDLs and MRLs) are adjusted based on variations in sample preparation amounts, analytical dilutions and percent solids, where applicable.

APPENDIX I



Home
Search

Bonding Agencies
Bonds

Bonds
Sureties

Business Partner
Bonding Agencies
Consultants
Contractors
Sureties

Planned Projects
Advertisements
Selection Results

Bid Packages
Bid Results

Consultants
Contractors
Forum

Agreements
Invoices
CAS Summary

Asphalt Diesel Prices
Item Price History
Master Items
Special Provisions
Steel Prices
Work Class Codes

Projects
Estimates
Work Orders
Resources

AASHTO
Highway Engineering Exchange Program (HEEP)
Other DOTs
PA Unified Certification Program (UCP)

Project Special Provisions

Project Information - 85753

Projects Portal

Screen Help

Application Permissions

Back

Copy

Help

(hidden) (hidden) (hidden) (hidden) (hidden) (hidden) (hidden) (hidden)

SPECIAL PROVISION

(hidden) (hidden) (hidden)

Project: 85753 Standard (hidden) / Federal Oversight (hidden)

Short Description:	Crawford I-79 PM			Org Code:	0110
County:	Crawford	**SR:**	79	**Section:**	A14
District:	01	**Group ID:**	ERP	**Municipality:**	GREENWOOD

General

Type: Project Specific **Addendum:** 0 (hidden)

Detail

Index or Category: **District:**

Sequence ID: 0 (hidden)

Version: 0

Provision Name: c96018 - ITEM 9601-5000 - 30" CURED -IN-PLACE PIPE (hidden)

Completed: Yes (hidden)

Associated Items

Item Number	Item Description
9601-5000	30" CURED-IN-PLACE PIPE

Header

ITEM 9601-5000 - 30" CURED-IN-PLACE PIPE

(hidden)

Provision Body

DESCRIPTION - This work is the reconstruction of existing pipes using cured in place resin-impregnated flexible tubes.

MATERIAL -

- Tube - ASTM F1216. Tube to be fabricated to size that will form to the internal circumference and length of pipe culvert. Make allowance for circumferential stretching during inversion.

  If glass fiber reinforcement is used in the tube, provide layers of unreinforced, resin absorbent material on the inside and outside of the tube to protect the fibers from being exposed to the pipe flow or external water.
  Plastic coat the outside layer of the tube before inversion with a translucent flexible material that is compatible with the resin system used. Fully bond any plastic coatings on the tube that will become the inside surface of the finished cured-in-place pipe to the absorbent tube material.
  No intermediate or encapsulated elastomeric layers are permitted. No materials that are subject to delamination in the cured-in-place pipe are permitted.

- Resin - ASTM F1216, Section 5.2.

  Dark or non-reflective nature wall colors of interior pipe surfaces of the cured-in-place pipe that could inhibit proper closed circuit television inspection are not permitted.

CONSTRUCTION -
Structural Requirements.
Design cured-in-place pipe in accordance with ASTM F1216 and as follows:
No bonding of cured-in-place pipe to the original pipe wall.
External Hydrostatic Design. Submit acceptable third party testing and verification of the enhancement factor K for the manufacturer of the cured-in-place pipe product.
Provide a strong and uniform bond between all cured-in-place pipe layers. All layers, after cure, to form one homogeneous structural pipe wall with no part of the tube left unsaturated with resin.

Testing Requirements.
Chemical Resistance. Cured-in-place pipe must meet the chemical resistance guidelines of ASTM F1216. Submit samples of tube and resin system for testing similar to that proposed for actual construction. Samples with and without plastic coating must meet chemical testing requirements.
Long-term Reduction in Physical Properties. Submit long-term creep data in accordance with ASTM D2990 for the manufacturer of the cured-in-place pipe product. Duration of creep testing to be a minimum of 10,000 hours.
Hydraulic Capacity. Submit calculations that support the cured-in-place pipe has at least 100% of the full flow capacity of the original pipe before rehabilitation. Calculated capacities may be derived using a commonly accepted roughness coefficient for the original pipe material. A typical roughness coefficient of the cured-in-place pipe to be verified by third party test data.
Cured-in-place Pipe Field Samples. To verify past performance, submit a minimum of 15 test results from previous field installations of the same resin system and tube materials as proposed for the actual installation. These test results must verify that the cured-in-place pipe physical properties have been achieved in previous field applications.
If glass fiber reinforcement is used, submit strain-corrosion testing in accordance with ASTM D3681.
Installation.
Install cured-in-place pipes in accordance with the guidelines of ASTM F1216, and as follows:
Clean pipe of all debris prior to installation of cured-in-place process. Satisfactorily dispose of removed material.
Resin Impregnation. Use a sufficient quantity of resin for tube impregnation to fill the volume of air voids in the tube with additional allowances for polymerization shrinkage and the loss of resin through cracks and irregularities in the original pipe wall. Use vacuum impregnation process. Use a roller system to uniformly distribute the resin throughout the tube.
Do not insert absorbent layers of tube into the existing pipe without the layers being fully vacuum impregnated with resin.
Limit tube installation forces or pressures so as not to stretch the tube longitudinally by more than 5% of the original length.
Completely remove any bladders or tubes used to inflate the tube material against the original pipe that were not fully bonded to the tube material prior to insertion into the original conduit after cured-in-place pipe installation.
Dewater the existing pipe for any cured-in-place installation that does not use an inversion method to expand the tube against the pipe wall. This involves the elimination of any incoming water (infiltration of inflow) and the removal of standing water. Use flow diversion as necessary for installation. Prepare and submit a flow diversion plan to the Engineer and Crawford County Conservation District for approval. Do not begin lining operations without written approval of flow diversion plan.
Inspection.
Provide one cured-in-place pipe sample for each pipe size installed from a section of the cured-in-place pipe at the termination point that has been inverted through a like diameter pipe which has been held in place by a suitable heat sink, such as sandbags.
Test cured-in-place pipe samples in accordance with ASTM F1216.
Test for leakage during cure while under a positive head. Visually inspect cured-in-place pipe in accordance with ASTM F1216.
MEASUREMENT AND PAYMENT - Linear Foot

Audit Information

Created By	Created On	Modified By	Modified On
Bob W Loy/PennDOT	05/21/2009 08:07:10 AM	Bob W Loy/PennDOT	05/28/2009 01:31:20 PM

June 25, 2009

SPECIAL PROVISION

PROJECT #
PIN #

SECTION 02617S

CURED-IN-PLACE PIPE (CIPP) LINER

Add Section 02617:

PART 1 GENERAL

1.1 SECTION INCLUDES

A. Install CIPP liner into existing host pipes at the locations shown on the plans in conformance with the details shown on the plans, and as specified in this Special Provision.

B. Prepare to install the liner by cleaning and inspecting existing host pipe.

1.2 RELATED SECTIONS

A. Section 00820: Legal Relations and Responsibility to Public

B. Section 01554: Traffic Control

1.3 REFERENCES

A. AASHTO LRFD Bridge Design Specifications, Customary U.S. Units, 5th Edition, with 2010 Interim Revisions

B. ASTM F 1216: Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube

C. ASTM F 1743: Rehabilitation of Existing Pipelines and Conduits by Pulled-in- Place Installation of Cured-in-Place Thermosetting Resin Sewer Pipe

1.4 DEFINITIONS **Not Used**

1.5 SUBMITTALS

A. Submit two copies of each submittal for review. Each copy will contain all applicable drawings, calculations, and a written work plan.
   1. Identify in the work plan details of the proposed method of construction, sequence of operations to be performed during construction, a detailed schedule of construction, and a traffic control plan.
   2. Sufficiently detail the drawings, calculations, and descriptions in order to demonstrate to the Engineer whether the proposed materials and procedures will meet the requirements of this Section.
   3. Sign and seal the structural designs and other engineered components by a registered Professional Engineer.

B. Use a three-ring binder, divided into the sections listed below with the identified information for the submittal format.
   1. Structural Data – Use the naming convention used on the plan sheets for each host culvert being lined including:
      a. The specific pipe liner (by trade name).
      b. The nominal and true inside and outside pipe liner diameters.
      c. The net wall area of the pipe liner in square inches of material per lineal foot of pipe liner.
      d. The Manufacturer's recommended maximum and minimum fill height limits for the identified liner.
         1) Meet or exceed AASHTO HL-93 or interstate alternate loading in accordance with current AASHTO LRFD Bridge Design Specifications and interim specifications for liner load capability.
      e. Host pipe is considered to be fully deteriorated and unable to carry loads.
      f. Liner structure must be capable of supporting the maximum fill height at the subject location.
      g. Maximum allowable ovaling is five percent.
   2. Traffic Control Plan – Comply with Section 01554. Include the following plan for each host culvert being lined:
      a. Locations and dimensions of any temporary access roads
      b. Locations and dimensions of liner assembly and insertion area "footprints"
      c. Distance of insertion footprint from the traveled way
      d. Proposed traffic control
      e. Amount of time the footprint will be exposed
      f. Shoring method if a pit or excavation is proposed

3. Installation Plan – Address the following:
    a. Method of liner installation (pulled-in-place or inversion method).
    b. Clearly identify the method being used to guide and ease the pipe liner into place if pulling will be done.
    c. Identify the Manufacturer's recommended maximum pulling force if pulling will be done.
    d. Specific resin to be used.
    e. Curing method such as water, hot air, steam, etc.
    f. Proposed length, access, and termination points for each run.
4. Installation Limitations – Identify the following installation limits for each host culvert being lined:
    a. Manufacturer's recommended maximum, minimum, and ideal installation temperatures
    b. Manufacturer's recommended curing times including heat sink effects and variations in post liner length
    c. Manufacturer's safety data sheets for all materials used including but not limited to sheets for the resin, catalyst, cleaners, and repair agents
5. Manufacturer Certifications – Include the following:
    a. Pipe liner manufacturer's certification that the liner materials furnished will be compatible for the intended installation method, service conditions, and host pipe material
    b. Copy of Manufacturer's installation procedure guidelines
    c. Manufacturer's recommended liner joint assembly recommendations

C. Do not begin work until the submittals have been reviewed and accepted by the Engineer.
    1. The Engineer will have five working days for review and approval.
    2. Provide new submittals upon receiving notification that the submittals are insufficient.
        a. Allow an additional five working days for the Engineer's review and approval.

PART 2 PRODUCTS

2.1 TUBE LINER LAYERS

A. Use only CIPP liner products approved by the Engineer.
    1. Fabricate the liner layers to fit the host pipe tightly.

B. The liner may consist of one or more layers of woven or non-woven material capable of carrying resin and withstanding installation forces, pressures, and curing temperatures.

C. The liner must be compatible with the resin system used and able to fit irregularities in the host pipe.
   1. Stagger longitudinal and circumferential joints between layers so they do not overlap.

D. Provide a standard metal end section or other end treatment as directed by the Engineer at all culvert inlets.

E. Provide a 45 degree beveled inlet condition in all headwalls.
   1. Bevel will be 1 inch per diameter foot of culvert up to a maximum of 8 inches.

2.2 RESINS

A. Resin actuated liners may be either a chemically resistant isophthalic based polyester resin, a vinyl ester thermosetting resin and catalyst system, or an epoxy resin and hardener.

B. Compatible with the installation process.

C. Able to cure in the presence or absence of water.

D. May contain fillers for viscosity control, fire retardance, air release, or extension of pot life.
   1. Thixotropic agents that do not interfere with visual inspection may be added for viscosity control.

E. Can contain pigments, dyes, or colors that do not interfere with visual inspection of the resin-impregnated pipe liner.

PART 3 EXECUTION

3.1 ORDERING LINER

A. Prior to ordering pipe liner:
   1. Clean and then inspect the existing host pipe designated for lining using a colored TV inspection system when indicated in the plans.
      a) Record single frames of video images and live video as well as inspection data onto a CD/DVD.
         1) The CD/DVD becomes the property of the Department.

b) Draw attention to all recognizable defects and imperfections.
c) Accurately note all pertinent details regarding access locations along the length of the pipe.
d) Record on video image the distance inside the existing host pipe and the time and date of the inspection
e) Store and link captured videos to the inspection data.
f) Provide the ability for any captured video to be played back from a CD/DVD by any user with a PC utilizing standard viewers.
g) Provide the ability for inspection files to be exported onto other database file formats to interface with UDOT programs.

2. Verify the specified pipe liner, in ambiguous cases, will fit by passing a test mandrel with an external diameter the same or larger than the proposed liner through the full length of the existing host pipe.
3. Inform the Engineer of any existing pipe culvert sections that have collapsed or are otherwise impassable.
4. The Department reserves the right to eliminate pipe lining from the contract if the Engineer determines that an existing pipe culvert cannot be lined.
5. Include documentation showing that the liner system meets AASHTO LRFD structural requirements for the specified fill height and a fully deteriorated host pipe condition.

3.2 INSTALLATION SPECIFICATIONS

A. Install pipe liner according to manufacturer's installation recommendations and installation plan submittal unless specified in this Section.

B. Meet minimum requirements for installation of the pipe liner using any inversion process in compliance with ASTM F 1216 or a pulled-in-place installation in compliance with ASTM F 1743.

3.3 INSERTION

A. Minimize to the extent practical the disturbance of vegetation and to the extent of any temporary excavations when lining host pipe.

B. Sidecast excavated material onto upland areas, not in wetlands if excavation of wetland areas is necessary.

C. Perform all work within the limits of the Department right-of-way unless otherwise approved by the Engineer.

D. Complete insertion of pipe liner, backfill, and compact any disturbed channel areas before moving to next pipe liner location.
   1. Minimize the amount of time insertion excavation area is open and exposed.

E. Take all precautions necessary to prevent cave-ins.
   1. Comply with the sanitary, health, and safety requirements in Section 00820.

F. Sections of the inlet and outlet, ends of existing host pipe culvert, fence, and other items not otherwise specified for removal in the plans may be removed to provide room for construction of an insertion area.
   1. Replace and install new items of the same size, shape, and materials as those that have been removed.
   2. Include payment for removal and replacement of items in the pipe liner item, not as a separate pay item.

3.4 HOST PIPE CULVERTS

A. Clean existing host pipe of all sediment and debris just prior to pipe liner insertion.
   1. Remove all debris or other materials from the original pipe so that the inserted liner will not be resting on or against nor be irregularly supported by such materials.

B. Use a cleaning method and tools that will not cause damage to the host pipe.
   1. Repair damaged host pipe to accept the liner at no additional expense to the Department.

C. Control all sediment from cleaning to prevent it from being transported into streams and wetlands.
   1. The Engineer may require pulling a test head through the pipe to determine the sufficiency of the cleaning effort.

D. Provide adequate flow control when necessary to complete the installation process.
   1. Possible methods include but are not limited to dewatering and temporary detours.

E. The existing host pipe may have holes where undermining of the backfill material has occurred due to piping, water exfiltration or infiltration.
   1. Fill any void space in the soil envelope around the existing host pipe with polyurethane foam or low-density cementitious grout.

3.5 PIPE LINER

A. Unload and store liner components in a secure location.
   1. Maintain a 30 ft minimum distance from the traveled way.

B. Lap or connect joints according to the manufacturer's recommendations.

C. Insert the pipe liner according to submitted insertion plan and manufacturer’s installation recommendations.

D. Handle and insert the pipe liner in a manner that will not cause damage to the pipe liner.
   1. Replace damaged or liner materials at no additional expense to the Department.

E. Allow the pipe liner to cool in the host pipe long enough to adjust to its natural geometry.
   1. Strictly follow the manufacturer’s recommended relaxation period required to hold the CIPP liner against the host pipe.

F. Repair the failure of the liner system due to inadequately cleaned host pipes at no cost to the Department.

G. Cut pipe liner neatly and smoothly at each end of the host pipe to prevent snagging and collection of debris.

H. The finished pipe liner is to be continuous over the entire length of an insertion run between two manholes or structures and be as free as commercially practical from visual defects such as foreign inclusions, dry spots, air bubbles, pinholes, dimples and delamination.
   1. The pipe liner is to be impervious and free of any leakage from the pipe to the surrounding ground or from the ground to the inside of the lined pipe.

3.6 RESIN IMPREGNATION

A. Notify the Engineer at least two working days before starting impregnation.

B. Strictly follow the manufacturer’s recommendations.

C. Store impregnated liner in an area where the temperature is controlled within range recommended by the manufacturer.

3.7 RESTORE EXCAVATED AREA

A. Restore excavated or disturbed area due to insertion pit excavation or other disturbance to immediate area.

B. Backfill and compact excavation material to match the shape of the surrounding surface.

C. Topsoil and seed disturbed area: Use original soils and plants in wetland areas.

3.8 FINAL ACCEPTANCE

A. Reinspect the rehabilitated pipe using a colored TV inspection system when indicated in the plans.
   1. The CD/DVD becomes the property of the Department.

B. Verify that all lateral and inlet connections have been restored.

END OF SECTION

APPENDIX K

Company fined for Bellevue chemical spill
By JOHN STANG
SEATTLEPI.COM STAFF
The state has fined a Bellevue project $9,000 for chemical spills in the summer of 2009 and has issued a citation for failure to report the first.

Washington's Department of Ecology fined Michel's Pipe Services of Salem, Ore., for spills in July 2009, during work under Interstate 405 near Southeast Eighth Street in Bellevue, the agency announced Monday.

It also issued a warning letter to the Washington State Department of Transportation for not properly supervising the situation.

On two July 2009 nights, the subcontractor used air pressure and steam to install a plastic lining in a 24-inch culvert that carries Trail Creek beneath I-405, an Ecology Department news release said.

The creek's water flow was diverted during the operation. On July 15, an unexpected flow of groundwater interfered with the process, and Michel's used an inflatable plug to block that flow, the state release said.

The plug failed. Some resin entered the creek and was not reported.

Odors from the creek led to a state investigation the next day. The Ecology Department found in the water mineral oil and styrene, which is poisonous to crayfish and other crustaceans. Dead crayfish were found.

A similar plugging failure occurred the next night when the contractors tried to repeat the operation. This time, it was reported to the state.

The Bellevue Parks Department closed trails around the spill to prevent people being exposed to toxic compounds. Styrene odor remained in the area until at least July 24.

“The damage to the creek could have been minimized if workers had taken precautions to intercept any releases that might occur. Given the toxicity of substances involved, this should have been standard practice," said David Byers, who supervises the Ecology Department's spill-response team.

“We have completed projects of this type for over 20 years in Washington and across North America, and have never had a similar release. Some unusual circumstances appear to have come together to cause this incident. Regardless, we have put in place new procedures to ensure that this type of incident will be prevented," said Michel's vice president David Stegman.

Michel's has 30 days to appeal to the Ecology Department or to the Washington State Pollution Control Hearings Board. It plans to do so, the state news release said.

John Stang can be reached at 206-448-8030 or johnstang@seattlepi.com.

FOR IMMEDIATE RELEASE
July 17, 2009

Contacts: Seema Javeri, WSDOT Project Engineer, 206.794.6220
Steve Peer, I-405 Communications, 425.301.2023

WSDOT and I-405 contractors report spill on South Bellevue project

BELLEVUE – The Washington State Department of Transportation is investigating an apparent discharge into Trail Creek near Bellefields Nature Park in Bellevue earlier today. A subcontractor working for Atkinson Construction working to widen I-405 in South Bellevue inadvertently allowed a small amount of water carrying lubricant and curing compound to flow into the creek when equipment failed. The lubricant is mineral oil.

The Washington Department of Ecology was notified just after 8 a.m. Friday, July 17. WSDOT briefed investigators with the Department of Ecology regarding WSDOT and the Atkinson Construction's plan to manage the discharge.

"It is standard WSDOT practice to report potential environmental violations to the Department of Ecology," said Seema Javeri, WSDOT Project Engineer. "We will work closely with DOE to review our practices on this project."

Just after 7 a.m., contractor crews were installing a liner in a 24-inch corrugated metal pipe that runs east to west under I-405 just north of I-90. The liner extends the life of the old pipe and allows water to pass more efficiently under I-405. The liner, tied on one end, became stuck and crews used water to get the liner moving. The knotted end punctured and 100-200 gallons of water carrying two quarts of lubricant and curing compound surged out of the pipe and over carefully placed sandbags.

A small amount of these fluids flowed into Trail Creek. Crews immediately dammed the creek. The creek will remain dammed for several hours while the water is cleaned.

"We take these environmental violations very seriously," said Denise Cieri, I-405 Deputy Project Director. "This is not how we do business."

These compounds are not harmful however, styrene, a quick-curing substance, smells like model airplane glue. Because of the smell, WSDOT is closing the lake-to-lake trail in the area until midnight. The trail should open, as usual, on Saturday, July 18.

For more information on this project:
www.wsdot.wa.gov/Projects/i405/112thAvetoSE8th/.

###