CIPP A North American Perspective: Assessing the Performance of 40 Years of CIPP Lining Rehabilitation in Winnipeg, MB Canada

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Condition Assessment and Rehabilitation

AECOM

Water New Zealand Conference & Expo 2018 Hamilton, NZ

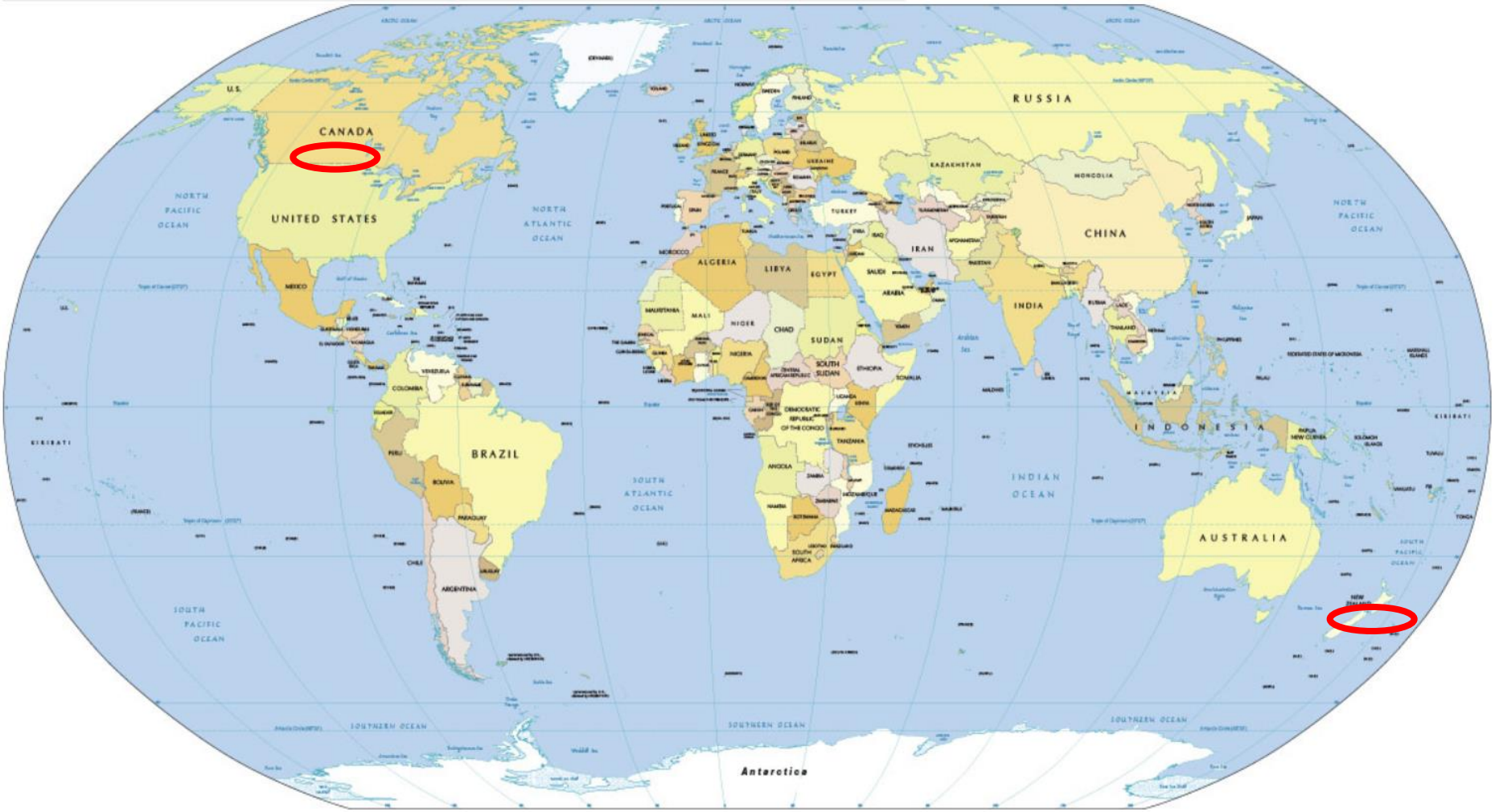
water NEW ZEALAND CONFERENCE & EXPO 19–21 September 2018, Hamilton

Overviews of Winnipeg's CIPP Program have been going on for a few years

- ***2013***
  - Reviewed performance and physical testing of CIPP installations from Winnipeg, MB, Canada from 1978
  - 34 year old liners (now 40 years old) were still in service, looked excellent and had excellent physicals
- ***2014***
  - Took a little closer look at the loading on the 1978 liners, and a very close look at a 1984 installation
- ***This presentation covers the whole program:***
  - 1978 to present day
  - 40 years of learning from scratch, making a few mistakes, always learning and always focused on documentation and quality assurance
  - Reporting on 2159 installs

Just where are we again…

- In the longitudinal centre of Canada
- 1 degree of latitude North of the US/Canada Border
- 17 time zones away



A brief history of CIPP Lining

Globally to the North American Market

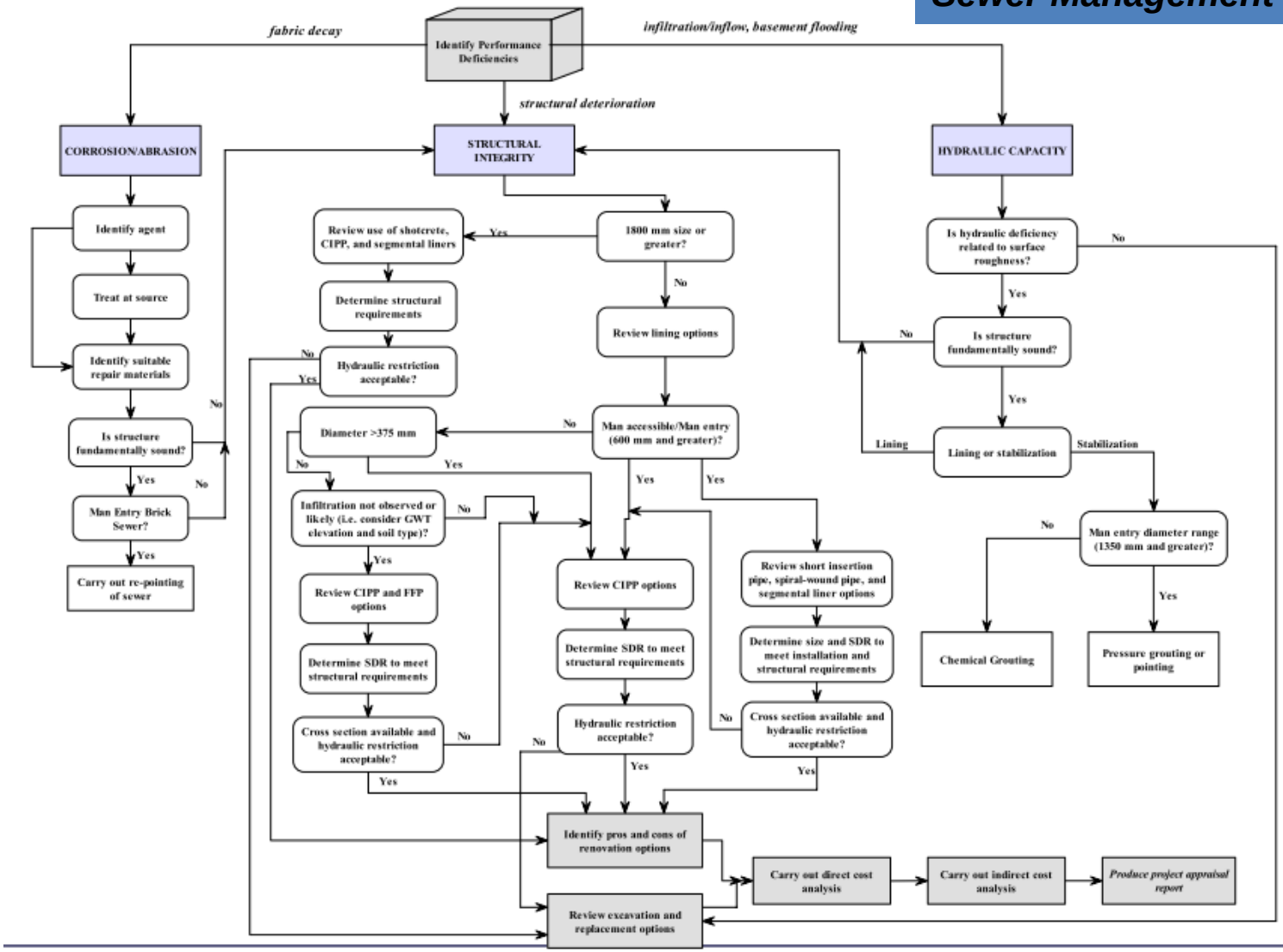
- First UK Patent – August 21, 1970
  - First commercial install in 1971 (Riverside Close - 1170mm by 600mm egg-shaped, brick host pipe)
  - Development of inversion process in 1973
  - The first Insituform® licenses were granted to British Contractors to rehabilitate sewers
- In 1976, licenses were granted to European and Australian Contractors
- In 1976 Insituform® came to North America
  - 1st NA install in Fresno, CA in 1976
  - 1st US patent in 1977
- 1989 –ASTM Standard F1216 governing design and installation

My home town

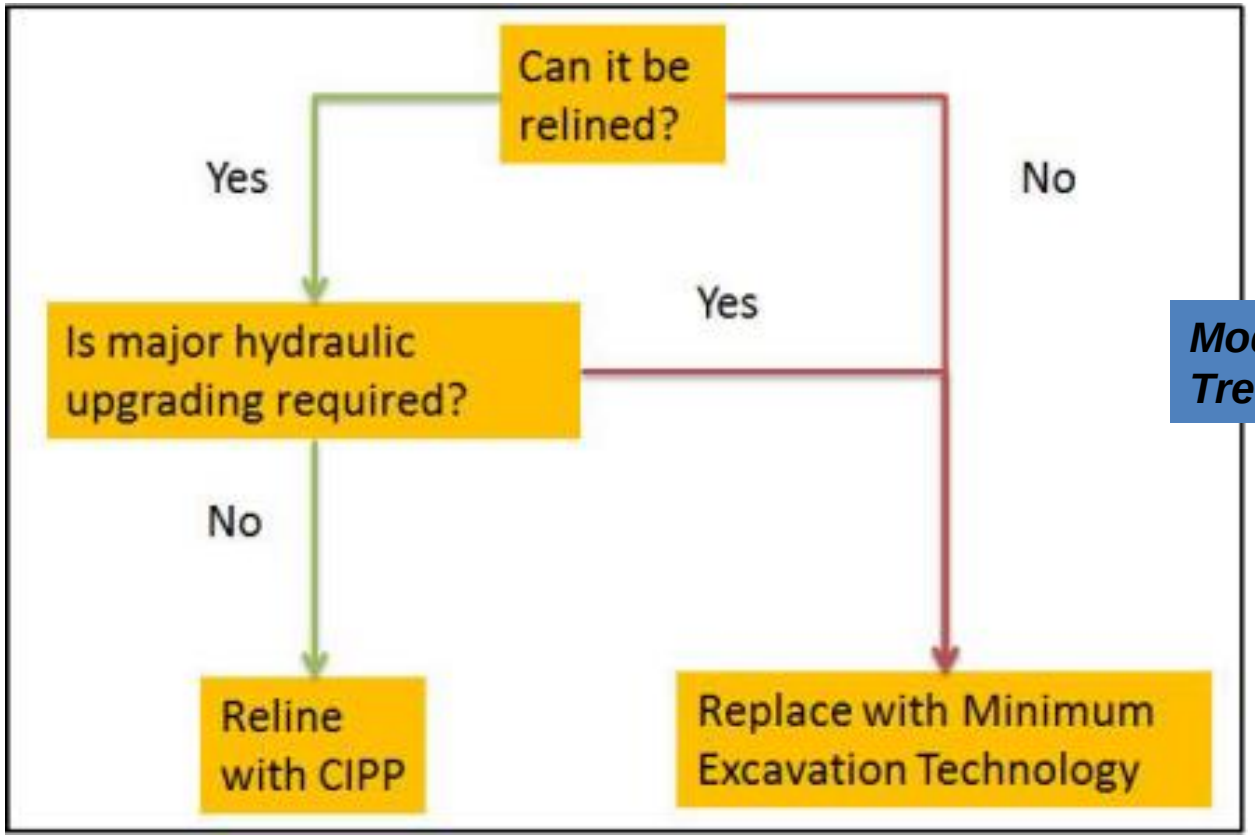
- 1978 – 1st installations on Richard and Kingsway
- 1984 – 2nd installations on Mission/Archibald
- 1987 to 1996 – cautiously more trials
- 1997 – Advent of modern program and technology selection criteria
  - CIPP takes over >85% of the rehab market
- 2008 – Gradual transition from Inversion and Hot Water Cure (IHW) to Air Inversion Steam Cure (AISC)
  - Increased use of reinforced composites in large, non-circular pipes

Initially the rehab selection process was robust but complex…

Generalized Design Process
Sewer Management Study - 1997

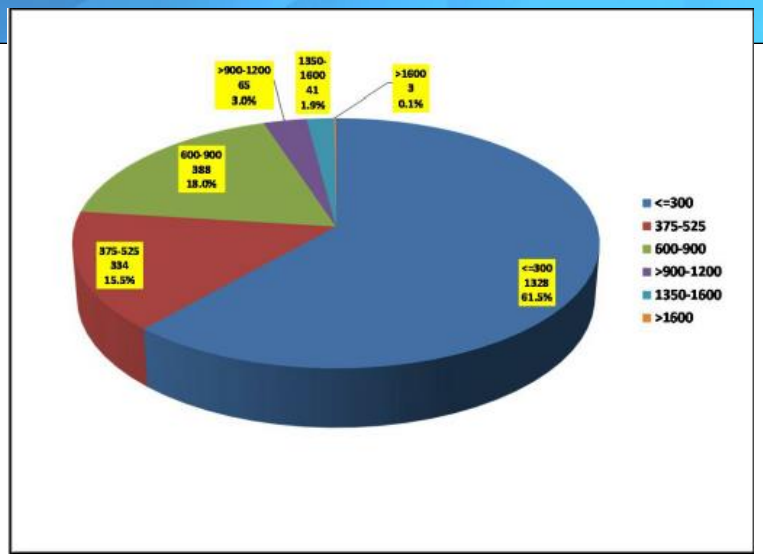


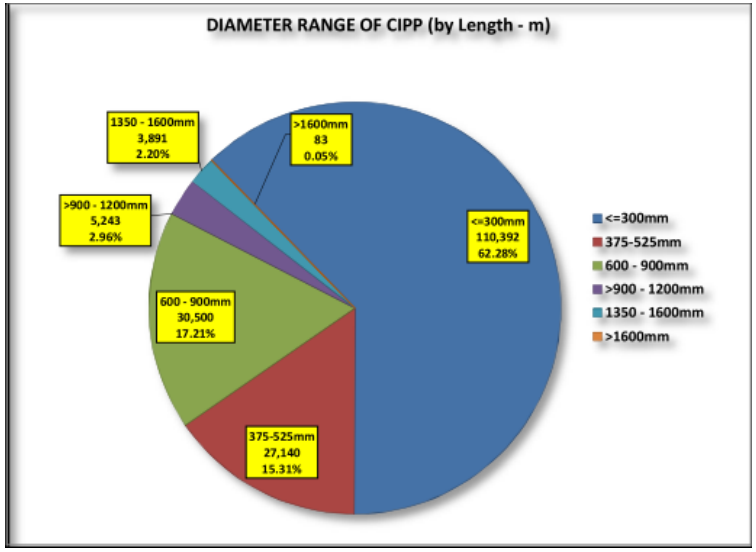
Economics of CIPP, soon made the selection process much simpler



Modern CIPP Decision Tree

How much CIPP was assessed?

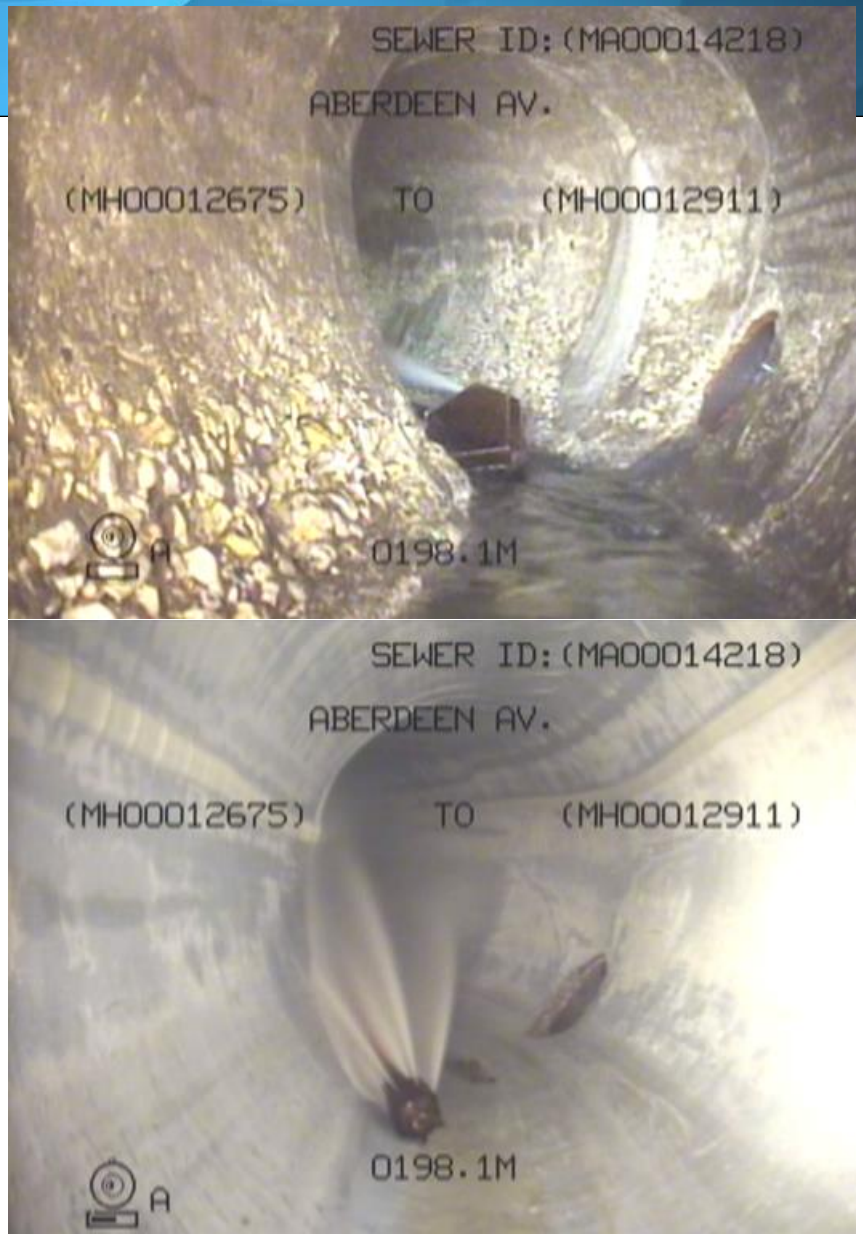




Diameter Range (mm)	*Number of Sections*	*Length (m/feet)*		*% of Total Length*
<=300 (12")	1328	110,392	362,178	62.28%
375-525 (15"-21")	334	27,140	89,041	15.31%
600-900 (24"-36)	388	30,500	100,066	17.21%
>900-1200 (36"-48")	65	5,243	17,200	2.96%
1350-1600 (54"-64")	41	3,891	12,765	2.20%
>1600 (64")	3	83	273	0.05%
Total	2159	177,248	581,523	100.00%

What's been relined?

- Over 2700 installs
  - 140 year old pipes
  - Sewers >1600 (64") high
    Up to 2990 Egg
  - >100 non-circular sewers
  - >80 brick sewers
  - Segmental clay tile sewers
  - Corrugated steel pipes
  - Concrete pipes
  - Many other pipes…



1978 to 1996
Everything didn't always go as planned… but it all worked out in the end

Year of CIPP Lining	Street	From	To	Diameter (mm and inches)		Current Liner Age	Length (m and feet)		Resin	Current Liner Visual Condition	Notable Comments from Installation
1978	Kingsway	Ruskin Row	Wellington Crescent	750	18	37	78.6	258	Polyester	As installed	1
1978	Richard	Strathcona	Clifton	750	30	37	128.3	421	Polyester	As installed	1
1984	Archibald	CN Pumping Station	Montcalm PS	750	30	31	201.0	659	Polyester	As installed	2
1987	Henderson Hwy	Talbot	Riverton	600	24	28	63.0	207	Epoxy	As installed	3
1987	Henderson Hwy	Chalmers	Harbison	600	24	28	234.0	768	Epoxy	As installed	4
1987	Henderson Hwy	Johnson	Chalmers	750	30	28	87.0	285	Epoxy	As installed	4
1989	Notre Dame Avenue	1st MH E of Wall Street	Downing Street	600	24	26	40.7	134	Vinyl Ester	As installed	5
1994	Portage Avenue	Erin Street	2nd MH E of Erin Street	600	24	21	36.9	121	Polyester	As installed	2
1994	William Avenue	Tecumseh	2nd MH E of Tecumseh	600	24	21	86.7	284	Polyester	As installed	2
1994	Isabel Street	Notre Dame Avenue	McDermot Avenue	600	24	21	57.4	188	Polyester	As installed	2
1994	Smith Street	York Avenue	to 1st MH S	750	30	21	51.1	168	Polyester	As installed	2
1994	Smith Street	1st MH S of York	2nd MH S of York	750	30	21	59.1	194	Polyester	As installed	2
1994	Smith Street	2nd MH S of York	Broadway Avenue	750	30	21	59.1	194	Polyester	As installed	2
1996	Princess Street	Bannatyne	1st MH N	450	18	19	13.0	43	Polyester	As installed	2
1996	Princess Street	1st MH N of Bannatyne	William Street	600	24	19	45.3	149	Polyester	As installed	2
1996	Princess Street	Alexander Avenue	1st MH N	600	24	19	47.2	155	Polyester	As installed	2
1996	Princess Street	1st MH N of Alexander	Logan Avenue	600	24	19	18.0	59	Polyester	As installed	2
						Total length (m/ft)	*1306.3*	*4,286*			

[1] *Initial CIPP install; lengths noted were successfully installed; 109 m installed and removed; didn't attempt last 200 m/656' of contract*

[2] *CIPP installed without technical difficulty*

[3] *CIPP liner installed 4.6 m/15' short - had to do 2nd inversion to complete*

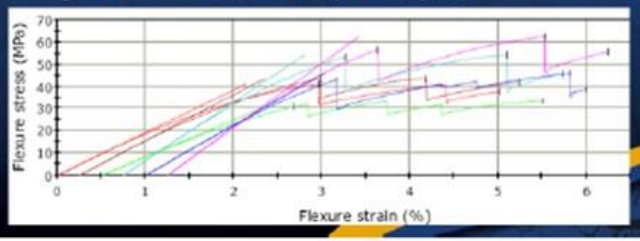
[4] *CIPP liners had random disbondment of polyurethane membrane during cure; relined with additional liner in 1988*

[5] *Multi-layered liner did not vary in circumference between layers, induced circumferential cracking at service reinstatements*
Relined with additional liner in 1990

Mechanical Properties of the oldest liners are impressive

Kingsway Results

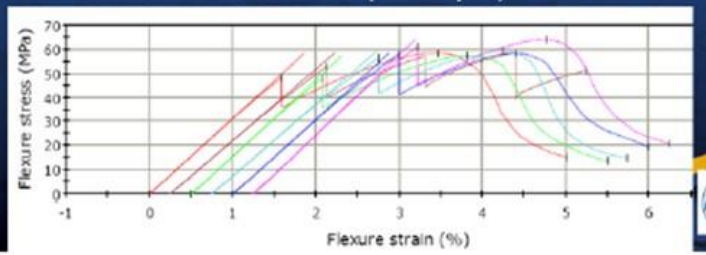
- Flexural Modulus
  - High end ~ 1881 MPa (272,816 psi) — Lined up stream
  - Low end ~ 2586 MPa (375,068 psi)
- Flexural Strength
  - Low end ~ 38 MPa (5511 psi)
  - High end ~ 51 MPa (7297 psi)



Richard Results

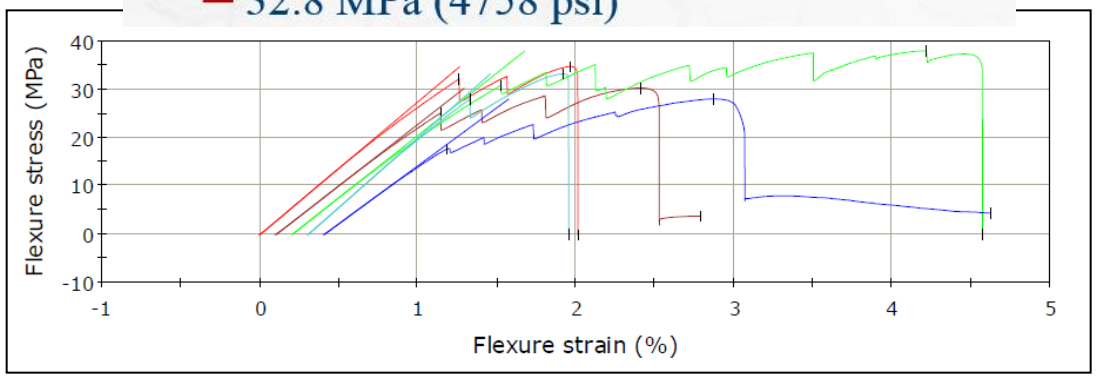
1978

- Flexural Modulus
  - High end ~ 3092 MPa (448,457 psi)
  - Low end ~ 3144 MPa (455,999 psi)
- Flexural Strength
  - High end ~ 50 MPa (7252 psi)
  - Low end ~ 58 MPa (8412 psi)



1984

- **Average flexural modulus**
  - 2621 MPa (380,186 psi)
- **Average flexural strength (ultimate)**
  - 32.8 MPa (4758 psi)



The Better Method of Pipeline Rehabilitation

Insituform of North America, Inc.
3315 Democrat Road
P. O. Box 181071
Memphis, Tennessee 38118

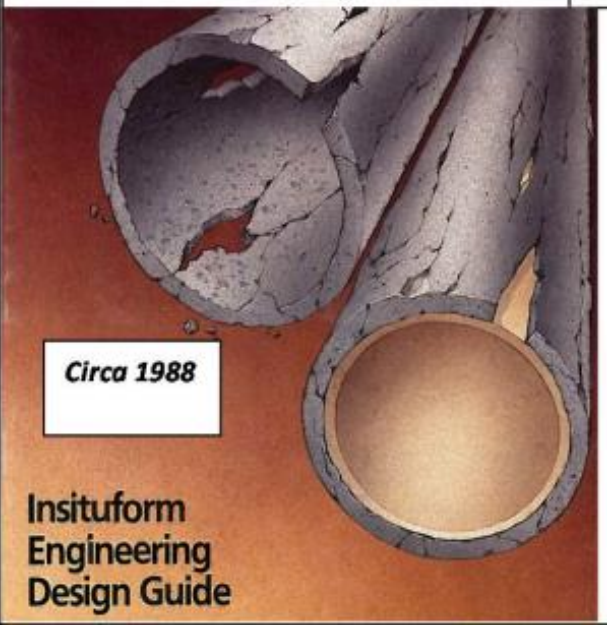
1983 Manual

Copyright 1983

INSITUFORM

Circa 1986

AN ENGINEERING MANUAL FOR THE DESIGN AND SPECIFICATION OF INSITUFORM LININGS



Designation: F 1216–89

AMERICAN SOCIETY FOR TESTING AND MATERIALS
1916 Race St., Philadelphia, Pa. 19103
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If not listed in the current combined index, will appear in the next edition.

Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube[1,2,3]

This standard is issued under the fixed designation F 1216; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice describes the procedures for the reconstruction of pipelines and conduits (4 to 96 in. diameter) by the installation of a resin-impregnated, flexible tube which is inverted into the existing conduit by use of a hydrostatic head. The resin is cured by circulating hot water within the tube. When cured, the finished pipe will be continuous and tight-fitting. This reconstruction process can be used in a variety of gravity and pressure applications such as sanitary s ·s, storm sewers, process piping, electrical conduits, and ventilation systems.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for informational purposes only.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*
D 543 Test Method for Resistance of Plastics to Chemical Reagents[4]
D 638 Test Method for Tensile Properties of Plastics[4]
D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials[4]
D 883 Definitions of Terms Relating to Plastics[5]
D 1600 Abbreviations of Terms Relating to Plastics[5]
D 3839 Practice for Underground Installation of Flexible Reinforced Thermosetting Resin Pipe and Reinforced Plastic Mortar Pipe[5]
F 412 Definitions of Terms Relating to Plastic Piping Systems[5]
2.2 *AWWA Standard:*
Manual on Cleaning and Lining Water Mains, M28[6]
2.3 *NASSCO Standard:*
Recommended Specifications for Sewer Collection System Rehabilitation[7]

NOTE 1—An ASTM Specification for Cured-In-Place Pipe materials appropriate for use in this standard is under preparation and will be referenced in this practice when published.

3. Terminology

3.1 *General*—Definitions are in accordance with Definitions D 883 and F 412. Abbreviations are in accordance with Abbreviations D 1600, unless otherwise indicated.

3.2 *Descriptions of Terms Specific to This Standard:*

3.2.1 *cured-in-place pipe (CIPP)*—a hollow cylinder containing a non-woven material surrounded by a cured thermosetting resin. Plastic coatings may be included. This pipe is formed within an existing pipe. Therefore, it takes the shape of and fits tightly to the existing pipe.

3.2.2 *inversion*—the process of turning the resin-impregnated tube inside out by the use of water pressure.

3.2.3 *lift*—a portion of the CIPP that has cured in a position such that it has pulled away from the existing pipe wall.

4. Significance and Use

4.1 This practice is for use by designers and specifiers, regulatory agencies, owners, and inspection organizations who are involved in the rehabilitation of conduits through the use of a resin-impregnated tube inverted through the existing conduit. As for any standard practice, modifications may be required for specific job conditions.

5. Recommended Materials

5.1 *Tube*—The tube should consist of one or more layers of flexible needled felt or an equivalent nonwoven material capable of: carrying resin, withstanding installation pressures and curing temperatures, and should be compatible with the resin system used. The material should be able to stretch to

[1] This practice is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.62 on Sewer.
Current edition approved March 31, 1989. Published June 1989.

[2] The rehabilitation of existing pipelines and conduits by the inversion and curing of a resin-impregnated tube is covered by a patent. (Insituform Pipes and Structures Ltd., Horsley Road, Kingsthorpe Northampton, England.) Interested parties are invited to submit information regarding the identification of acceptable alternatives to this patented item to the Committee on Standards, ASTM Headquarters, 1916 Race Street, Philadelphia, PA 19103. Your comments will receive careful consideration at a meeting of the responsible technical committee which you may attend.

[3] The following report has been published on this process: Driver, F. T., and Olson, M. R., "Demonstration of Sewer Relining by the Insituform Process, Northbrook, Illinois," EPA-600/2-83-064, Environmental Protection Agency, 1983. Interested parties can obtain copies from the Environmental Protection Agency or from a local technical library.

[4] *Annual Book of ASTM Standards*, Vol 08.01.

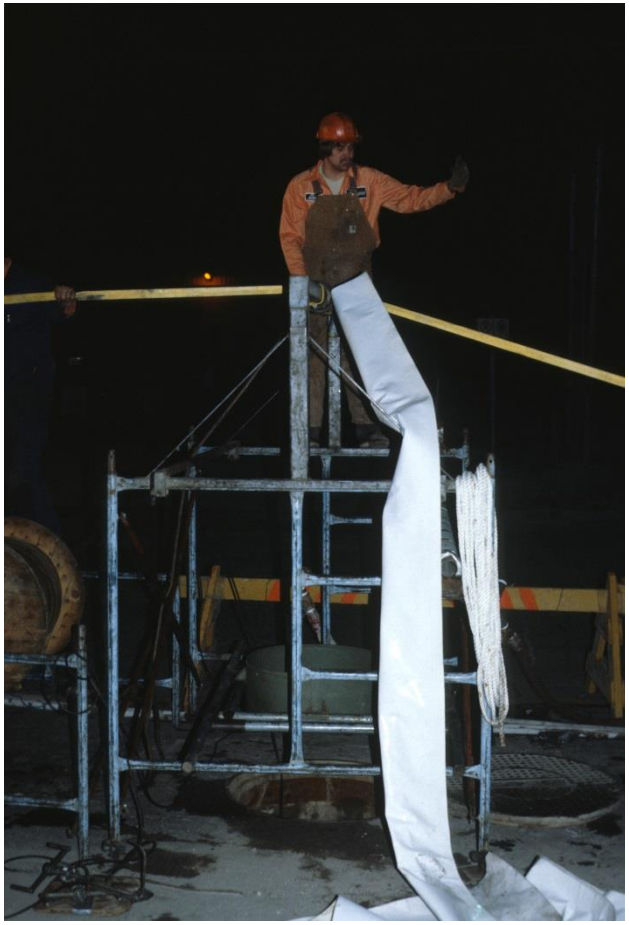
[5] *Annual Book of ASTM Standards*, Vol 08.04.

[6] Available from the American Water Works Association, 6666 W. Quincey Ave, Denver, CO 80235.

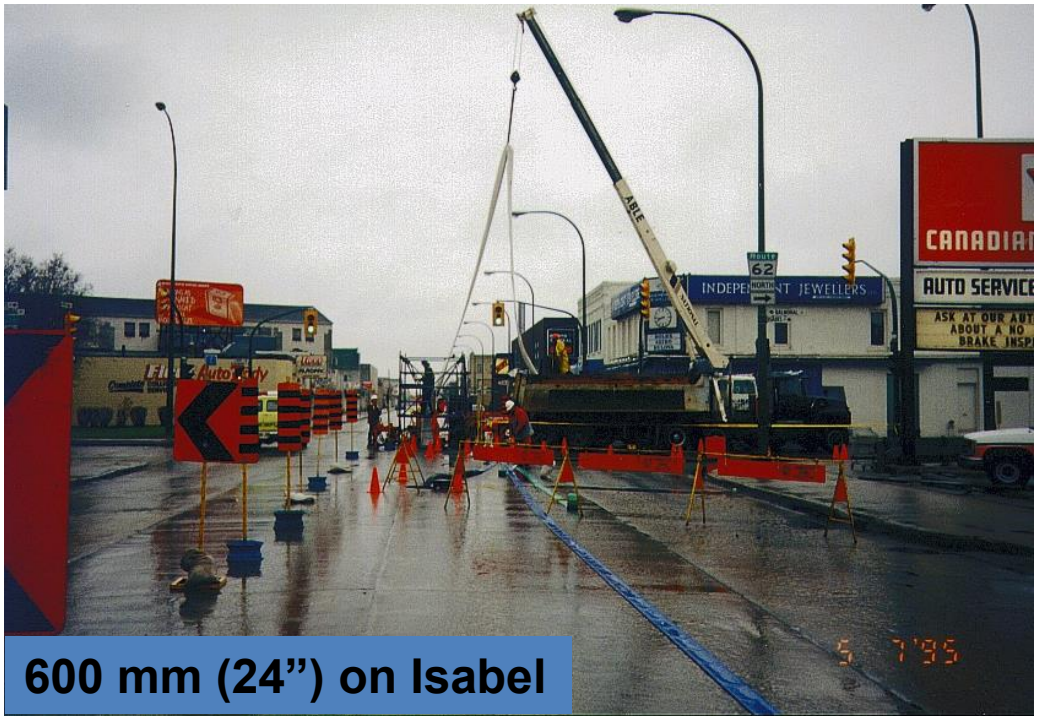
[7] Available from the National Association of Sewer Service Companies, 101 Wymore Rd., Suite 501, Altamonte, FL 32714.

Life before and after ASTM F1216

1984 Installation on Archibald

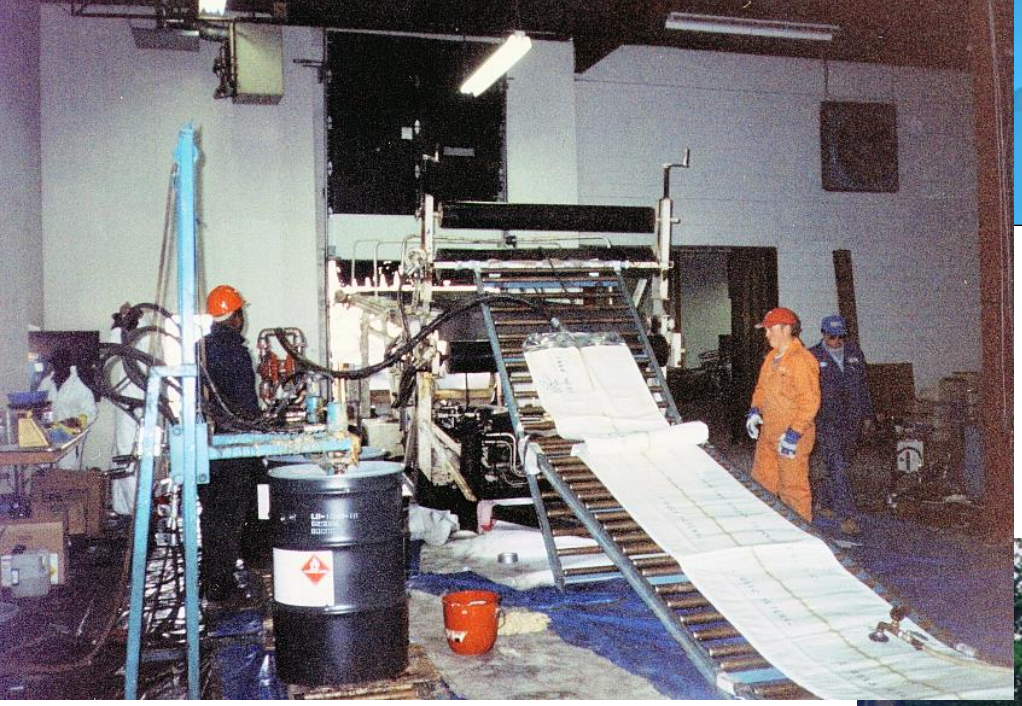


1994 Liner Insertions



600 mm (24”) on Isabel

750 mm (30”) on Carlton at Broadway



Wetout and Inversion of 750 mm (30”) on Carlton - 1994

Carlton – 1994 By-pass set up for 750 mm (30”) Liner

Smith – 1994 By-pass set up for 750 mm (30”) Liner

General Site Setup and Inversions of 600 mm (24”) Installation on Princess - 1994

Brief history of CIPP Design, Product and Curing Methods in local market

Year of Install	*Installation Standard*	*Design Basis*		*Tube Types*	*Curing methods used*
		PD	*FD*		
1978	None	None[1]	None[1]	Standard non-reinforced	Hot water
1984	Insituform Design Guide[2]	Modified Timoshenko Buckling Model	Spangler Deflection Model	Standard non-reinforced	Hot water
1987	Insituform Design Guide[3]	Modified Timoshenko Buckling Model	Spangler Deflection Model	Standard non-reinforced	Hot water
1989	Insituform Design Guide[4]	Modified Timoshenko Buckling Model	Modified AWWA Buckling and Spangler Deflection Model	Standard non-reinforced	Hot water
1994-1996	ASTM F1216-93	Modified Timoshenko Buckling Model	Modified AWWA Buckling	Standard non-reinforced	Hot water
1998-2007	ASTM F1216-93	Modified Timoshenko Buckling Model	Modified AWWA Buckling	Standard non-reinforced	Hot water
2008	ASTM F1216-07b	Modified Timoshenko Buckling Model	Modified AWWA Buckling (07 b version)	Standard non-reinforced	Hot water and steam cures
2014 to date	ASTM F1216-09	Modified Timoshenko Buckling Model	Modified AWWA Buckling (07 b version)	Standard, GF reinforced, CF reinforced	Hot water and steam cures

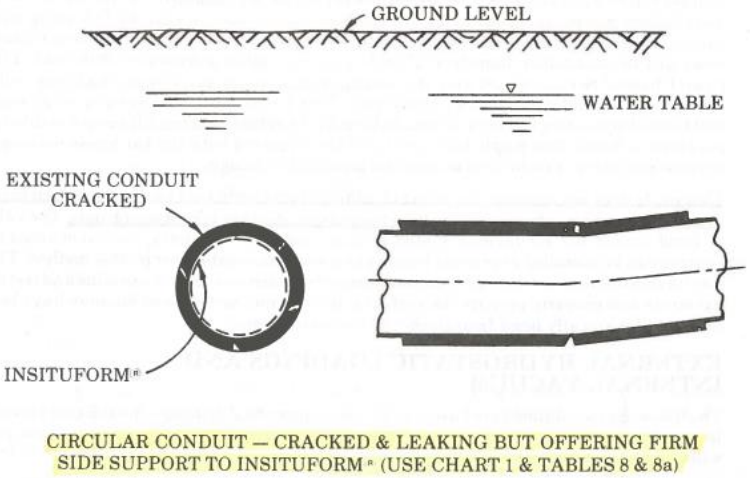
1 ***All tubes designed as 6 mm thick liners***

2 ***Insituform 1983 Design Guide***

3 ***Insituform circa 1986 Design Guide***

4 ***Insituform circa 1988 Design Guide***

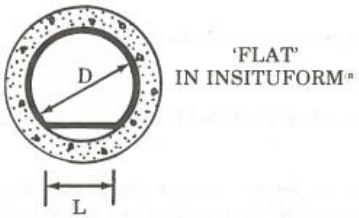
Pre-ASTM F1216 there were other design checks as well – PD design



CIRCULAR CONDUIT — CRACKED & LEAKING BUT OFFERING FIRM SIDE SUPPORT TO INSITUFORM® (USE CHART 1 & TABLES 8 & 8a)

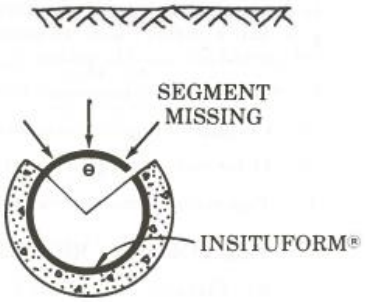
1983 Timoshenko Buckling modified by the work of Aggarwal and Cooper

PIPE DEFORMED CIRCULAR SECTION BUT FLAT PORTION

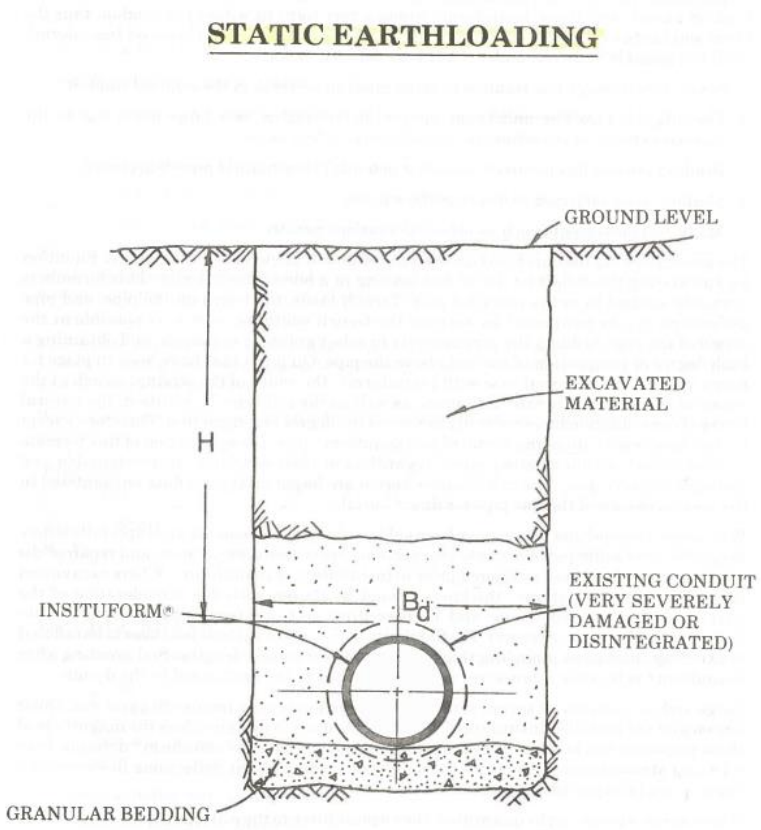


1983 Design Check for Flats and Missing Segments

PIPE SEVERELY DAMAGED — SEGMENT MISSING



Fully Deteriorated Design pre-ASTM F1216



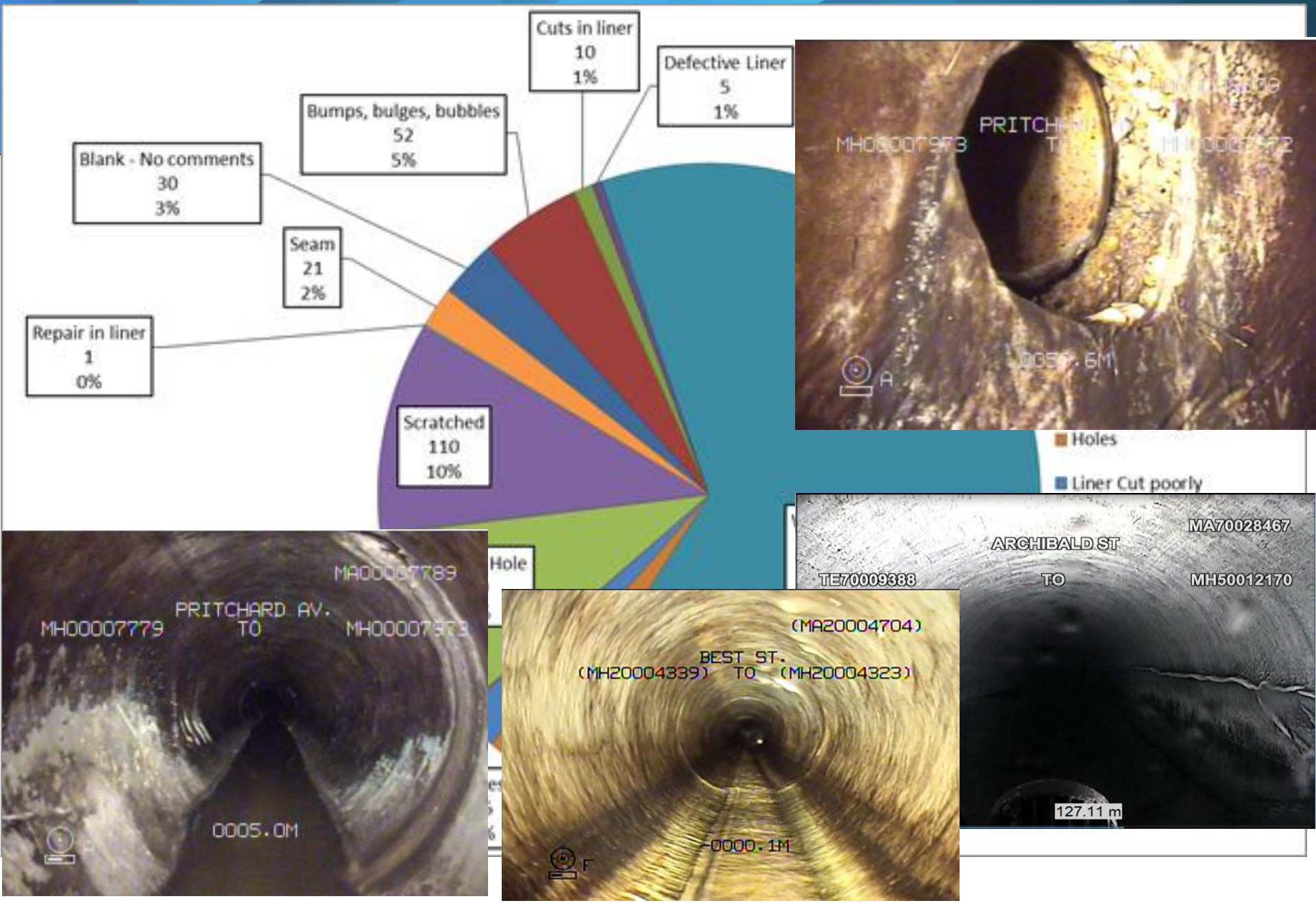
Spangler Design Checks to a deflection limit as opposed to modified AWWA Buckling

Street	Host Pipe Size (mm)	Liner Thickness (mm)	DR	Depth to Invert (m)
Archibald	762	21	36	8.17

Current Design Standard Thickness (mm)		Actual Nominal Thickness
Partially Deteriorated	Fully Deteriorated	
18.2	21.9	21.0

How have liners been assessed over time? And how many have we looked at?

- Modern Condition Assessment program
  - 1997 to date have inspected 100% of Combined and 95% of Sanitary Sewer inventory
- All 17 installations from 1978 through 1996 have been re-inspected
  - Mechanical properties re-assessed for 1978 and 1984 installations
- 1989 through 2012 had 1 year Warranty Inspections
  - 1,616 installations
  - A number also re-inspected again through modern condition assessment program


Cuts in liner
10
1%
Defective Liner
5
1%
Bumps, bulges, bubbles
52
5%
Blank - No comments
30
3%
Seam
21
2%
Repair in liner
1
0%
Scratched
110
10%
Hole
Holes
Liner Cut poorly
PRITCHARD AV.
MH00007779
TO
0005.0M
(MA20004704)
BEST ST.
(MH20004339) TO (MH20004323)
-0000.1M
ARCHIBALD ST
TE70009388
TO
MH50012170
MA70028467
127.11 m

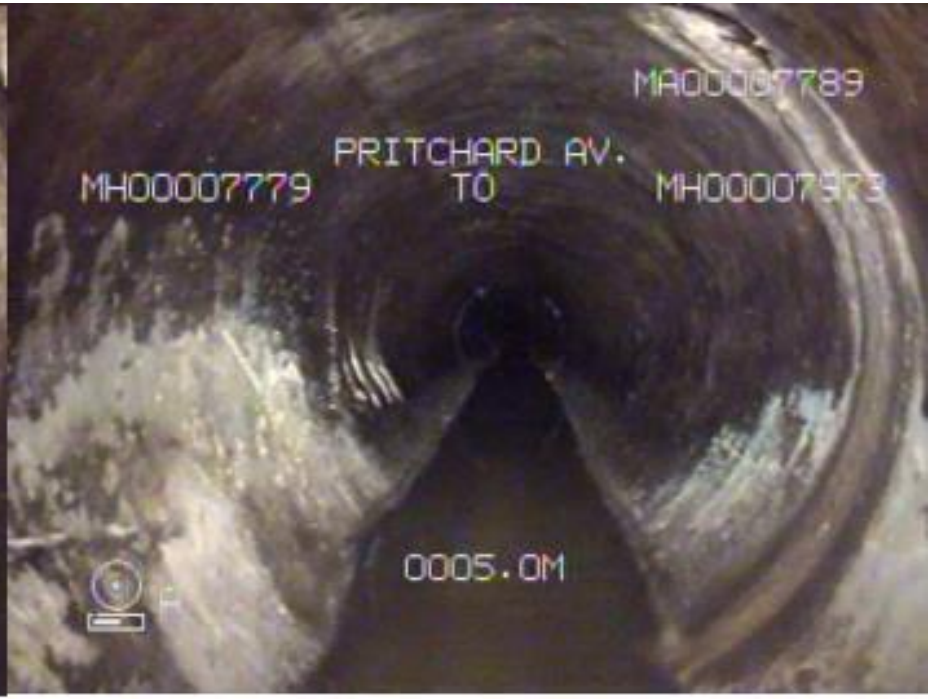
What questions should we be asking?

Criteria	*Frequency of Occurrence*
Does the liner have any visual evidence of material degradation?	***None found to date***
Is there any evidence of abrasion or wear?	***None found to date***
At manhole or defective service connections, is there any evidence of disbondment of the CIPP from the host pipe?	***None found to date***
In instances where a close-fit can be confirmed visually (e.g. typically in liners 450 mm (18 inches) and smaller), is there still evidence of a close-fit?	***Of 1058 lining observations picked up in all re-inspections, 1 service connection noted some disbondment and 22 manhole terminations were classified as defective These still need to be vetted against original coding or re-inspected to confirm whether the defects were brought into inventory directly as a result of the acceptance process or are progressive in nature.***
In installations with pronounced ovality, does the liner installation show evidence of overall structural stability (i.e. ellipsoid as opposed to irregular deflected shape, no progressive loss of cross section, no visual cracks or stress concentrations associated with exceeding the strain limits of the lining material, etc.)?	***None found to date***

5 years old

10 years old


MA00008009
PRITCHARD AV.
MH00007973
TO
0020.4M
A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PRITCHARD AV.
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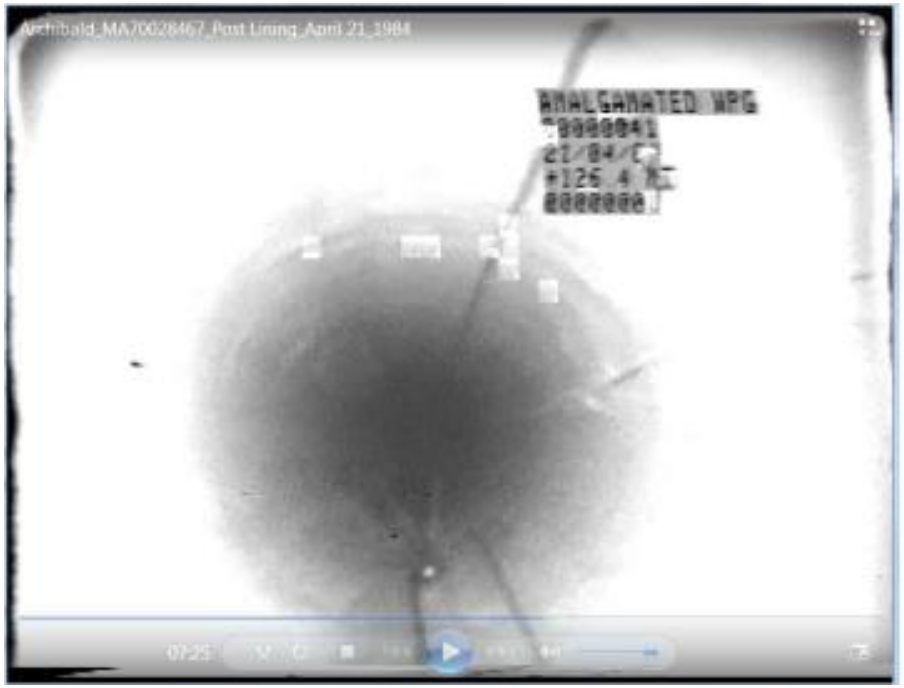
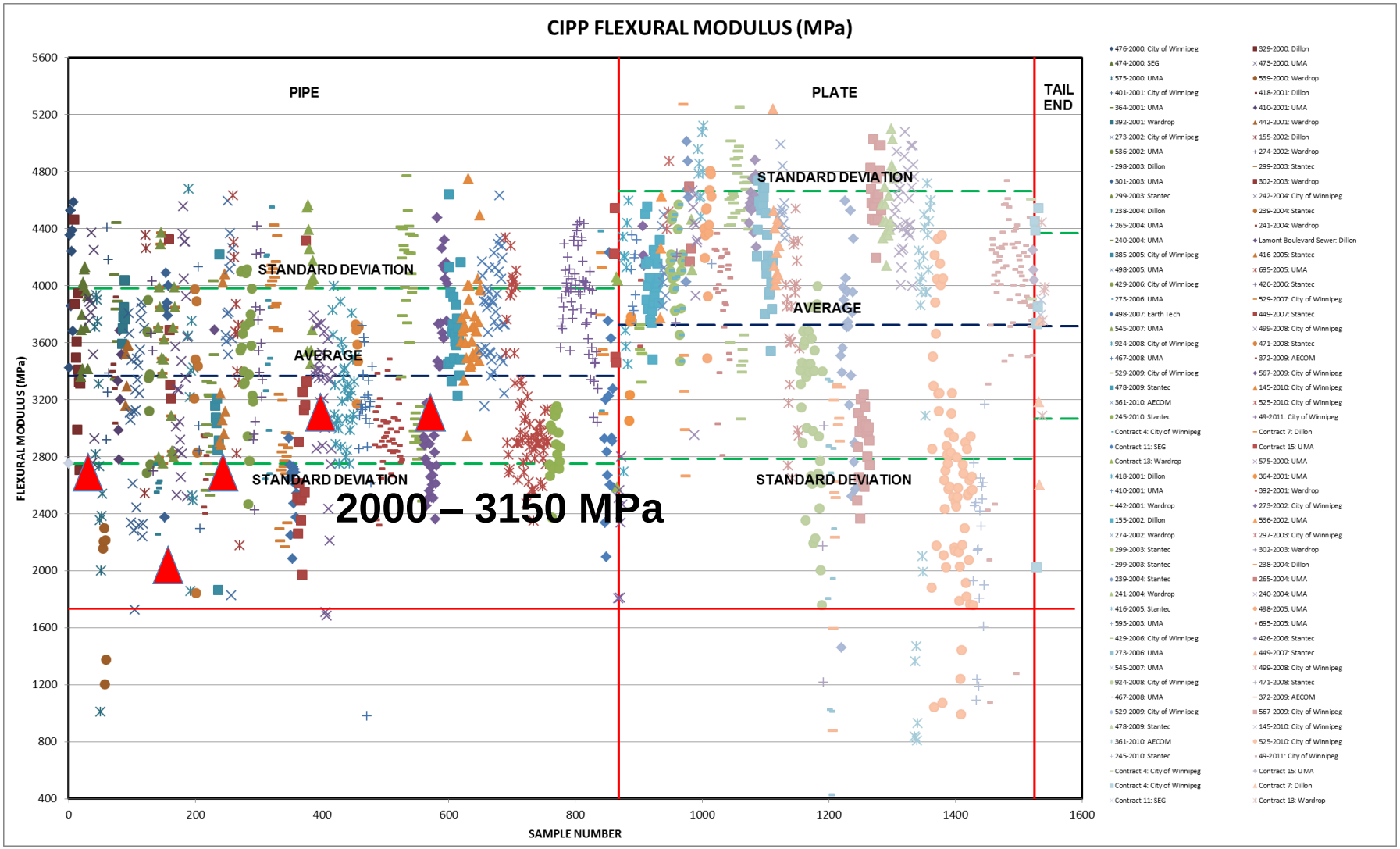
34 Years Ago and Now



40 years old and counting

Mechanical properties of the oldest liners look just like the newer liners – typical of a new unfilled polyester resin



Closure

- City of Winnipeg has had a 40 year history of CIPP Installations (>200 km/125 miles)
- A number of the early installations had their “challenges”
  - All that made it in though, are still in excellent condition
- In-service CIPP liners need to be assessed very judiciously to isolate inherent host pipe defects from liner defects
- Based on the review the liners will have a very, very long life (>>> original design life objectives ~ now projected to >100 years)
- Standard construction acceptance protocol over the life of the program has been adequate to achieve this
  - ASTM F1216 and D5813 sampling and visual acceptance criteria
  - CIPP Good Practice Guidelines

Thank you…

CIPP Program Practitioners:

- AECOM – *Chris Mitchell, Adam Braun, Darren Yarechewski, Marshall Gibbons, Marv McDonald*
- City of Winnipeg – *Ron Sorokowski, Kas Zurek, Armand Delaurier, Stacy Cournoyer*

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Winnipeg

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