Material Specification for Large Diameter Watermains

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TS 7.80.01 SCOPE

This specification covers materials for large diameter watermain piping ranging in size from 750 to 2300 mm nominal diameter.

TS 7.80.01.01 Application

The permitted pipe materials and additional protection based on the risk area of the project have been determined and the risk areas are defined in subsection TS 7.80.01.02 below and may also be shown on the Contract Drawings. The Contractor is to select the pipe material(s) from the permitted pipe materials for each construction project.

The pipe materials listed below with the additional protection as specified herein are generally acceptable to the City are

- ductile iron (DI)
- high density polyethylene (HDPE)
- prestressed concrete cylinder pipe (PCCP)
- polyvinyl chloride (PVC)
- carbon steel and stainless steel.

Irrespective of the high, medium or low risk area designation, the Contractor has to provide stainless steel pipe within chambers. The stainless steel pipe shall be 304L or 316L and Schedule 40. A higher schedule pipe shall be provided due to design requirement and if a higher schedule pipe is required, the design engineer will specify that information on Contact Drawings. For typical line valve, air valve, drain valve and other chamber details, refer to the Contract Drawings.

TS 7.80.01.02 Risk Area Assessment

For the purposes of selecting the pipe material for the project, the design engineer or engineering consultant shall complete Table 1 below:

Table 1: Risk area assessment

From Street	To Street	Risk Area

TS 7.80.02 REFERENCES

This specification refers to the following standards, specifications or publications:

City of Toronto Standard Specifications

TS 7.10	Construction Specification for the Cleaning and Cement Mortar Lining of Cast and Ductile Iron Watermain
TS 7.22	Construction Specification for Cathodic Protection of New Watermains
TS 7.40	Construction Specification for Watermain and Water Service Tracer Wire
TS 415	Amendment to OPSS 415 (Nov 2013) – Construction Specification for Pipeline and Utility Installation by Tunnelling
TS 416	Amendment to OPSS 416 (Nov 2013) – Construction Specification for Pipeline and Utility Installation by Jacking and Boring
TS 441	Amendment to OPSS 441 (Nov 2014) – Construction Specification for Watermain Installation in Open Cut
TS 1802	Amendment to OPSS 1802 (Nov 2015) – Material Specification for Smooth Walled Steel Pipe

City of Toronto Standard Drawings

T-1110.01-1	Class A Trench Detail High Risk PCCP
T-1110.01-2	Class B1 Trench Detail Medium Risk PCCP
T-1110.01-3	Class B Trench Detail Low Risk PCCP
T-1110.01-4	Open Cut Protection for Non-Encased Pipe (High Density Polyethylene) High and Medium Risk
T-1110.01-5	Trench Detail Low Risk High Density Polyethylene Pipe
T-1110.01-7	Trench Detail Low Risk Polyvinyl Chloride Pipe
T-1110.01-8	Trench Detail Low & Medium Risk Stainless Steel Pipe
T-1110.01-9	Trench Detail Low & Medium Risk Steel Pipe
T-1110.01-10	Trench Detail High Risk Concrete Encasement (Welded Steel Pipe)

City of Toronto Manuals

Chapter 6 – Material Specifications	Design Criteria for Sewers and Watermains

Ontario Provincial Standard Specifications

OPSS 441	Construction Specification for Watermain Installation in Open Cut
OPSS 1842	Material Specification for Pressure Polyethylene Pressure Pipe Products

Canadian Standards Association

B137.3	Rigid Polyvinyl Chloride (PVC) Pipe for Pressure Applications

American Society of Testing and Materials

A139	Standard Specification for Electric-Fusion (Arc) – Welded Steel Pipe (NPS 4 and Over)
A240	Stainless Steel Selection Guide
A312	Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes
A778	Standard Specification for Welded, Unannealed Austenitic Stainless Steel Tubular Products

F2620	Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings

American Water Works Association

C104	Cement-Mortar Lining for Ductile-Iron Pipe and Fittings
C105	Polyethylene Encasement for Ductile-Iron Pipe Systems
C110/A21.10	Ductile-Iron and Gray-Iron Fittings
C111/A21.11	Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings
C150/A21.51	Thickness Design of Ductile-Iron Pipe
C151	Ductile-Iron Pipe, Centrifugally Cast
C153	Ductile-Iron Compact Fittings
C200	Steel Water Pipe – 6 In. (150 mm) and Larger
C205	Cement-Mortar Protective Lining and Coating for Steel Water Pipe – 4 in (100 mm) and Larger
C206	Field Welding of Steel Water Pipe
C207	Steel Pipe Flanges for Waterworks Service – Sizes 4 In. Through 144 In. (100 mm Through 3600 mm)
C208	Dimensions for Fabricated Steel Water Pipe Fitting
C213	Fusion-Bonded Epoxy Coating for the Interior and Exterior of Steel Water Pipelines
C220	Stainless Steel Pipe, 1/2 in. (13 mm) and Larger
C222	Polyurethane Coatings for the Interior and Exterior of Steel Water Pipe and Fittings
C226	Stainless-Steel Fittings for Waterworks Service, Sizes ½ In. Through 72 In. (13 mm Through 1800 mm)
C301	Pre-stressed Concrete Pressure Pipe, Steel-Cylinder Type
C304	Design of Pre-stressed Concrete Cylinder Pipe
C602	Cement-Mortar Lining of Water Pipelines in Place – 4 In. (100 mm) and Larger
C905	Polyvinyl Chloride (PVC) Pressure Pipe and Fabricated Fittings, 14 In. Through 48 In. (350 mm Through 1200 mm)
C906	Polyethylene Pressure Pipe and Fittings, 4 In. (100 mm) Through 63 In. (1600 mm), for Water Distribution and Transmission
M9	Concrete Pressure Pipe
M11	Steel Pipe – A Guide for Design and Installation
M23	PVC Pipe Design and Installation
M41	Ductile Iron Pipe and Fittings
M55	PE Pipe Design and Installation Manual

American Society of Mechanical Engineers

B31.1	Power Piping

NSF International

NSF/ANSI Standard 61 Drinking Water System Components – Health Effects

TS 7.80.03 DEFINITIONS

For the purpose of this specification, the following definitions apply:

TS means Toronto Specification

Stainless Steel means stainless steel 304L or 316L.

Dimension Ratio (DR) means outside pipe diameter (inches) ÷ wall thickness (inches).

Working Pressure (WP) means maximum sustained operating pressure excluding transient surge pressures.

Surge Pressure (Ps) means transient surge pressure attributable to abrupt change in flow.

Pressure Class (PC) means numerical value assigned to standard manufactured pipe sizes reflecting their structural capacity for sustaining working and surge pressures with an appropriate factor of safety.

Professional Engineer means a Professional Engineer licensed to practice in the province of Ontario.

AWWA M-Series Design Guide means AWWA manuals M9, M11, M23, M41 or M55.

High Risk Areas means mixed use areas, open areas *(Public Utilities: Reservoirs & Pumping Stations to the first line valve)*, institutional areas, employment areas, utility corridors, major streets and highways, railway lines, hydro corridors and watercourse crossing.

Medium Risk Areas means apartment neighbourhoods, natural areas *(Environmentally sensitive, TRCA regulated area but not a water course crossing)*, and regeneration areas.

Low Risk Areas means neighbourhoods and other open space areas.

TS 7.80.04 DESIGN AND SUBMISSION REQUIREMENTS

TS 7.80.04.01 Design

Pipe design shall be governed by the latest edition of the appropriate AWWA M-Series Design Guide at the time of the advertise date of the Tender Call and the Design Criteria for Sewers and Watermains manual.

The Contractor is required to submit Shop Drawings for all pipe sections including design calculations and demonstrate the pipe design meets:

1) Appropriate AWWA M-Series design guide requirements and AWWA specifications;

2) TS 7.80 specification and other contract requirements; and

3) The following design criteria are utilized for all calculations unless specifically noted otherwise:

    i. Internal working pressure: 1100 kPa

    ii. Additional allowance for surge pressure: 550 kPa minimum (1650) kPa together with working pressure.

    iii. _____kPa. If higher surge pressure is expected, the designer shall include that information here in step iii and this pressure will supersede 550 kPa minimum surge pressure. If it is left blank, surge pressure shall be according to TS 7.80.04.01 (3)(ii) above.

    iv. Test pressure: 1500 kPa

    v. Trench supported full vacuum: −100 kPa

vi. Variable depth of cover to the top of the pipe: 1.7 to 3.5 m or higher according to the Contract Drawings.

vii. Live load: HS-20 and/or E-80; rail crossings – pipe strength shall meet rail loading requirements at crossings.

viii. Groundwater table: 1.0 m below finished grade–irrespective of the geotechnical report as ground condition can vary over time.

ix. Pipe loading calculations based upon backfill material and geotechnical report provided with the Tender Call.

x. Vertical deflection limit shall not exceed 2.5 per cent for low risk areas and 2 per cent for medium and high risk areas.

xi. Factor of design safety shall be 2 for relevant AWWA calculations.

xii. For steel pipe use 50 per cent yield stress under design working pressure and 75 per cent yield stress under design working pressure plus surge pressure.

In the event that the design calculations as per the design conditions listed above and as per relevant AWWA M-Series design guide requirements and specifications, result in a wall thickness dimension greater than specified elsewhere in the Contract Documents, the larger of the two values shall be used at no additional cost. It is the responsibility of Bidders to complete calculations during the tender stage.

The calculations shall be certified by a Professional Engineer and acknowledging that all fabricated pipe will be as specified on the Contract Drawings, applicable AWWA M-Series design guidelines and specifications, and MOECC guidelines.

Pipe pressure class, wall thickness or dimension ratio shown on the Contract Drawings or in the Contract Documents take precedence and may vary from those determined through the application of AWWA M-Series design guide methodologies and procedures.

The pipe material, any internal coating, gaskets, and any other parts which come in contact with potable water must be NSF/ANSI 61 compliant, and meet MOECC guidelines.

Referenced pipe sizes are nominal based on a conversion factor of 25 mm equals one inch.

Table 2: Pipe material suitability for large diameter watermains

Pipe Material	High Risk Areas		Medium Risk Areas		Low Risk Areas	
	Open-cut	Tunnel	Open-cut	Tunnel	Open-cut	Tunnel
Ductile Iron	NA	NA	NA	NA	✓	NA
High Density Polyethylene (HDPE)	✓	✓	✓	✓	✓	✓
Pre-stressed Concrete Cylinder Pipe (PCCP) – Bell and Spigot Joints	NA	NA	NA	NA	✓	NA
Pre-stressed Concrete Cylinder Pipe (PCCP) – Mechanically Restrained Joints	NA	NA	✓	✓	✓	✓
Pre-stressed Concrete Cylinder Pipe (PCCP) – Welded Joints	✓	✓	✓	✓	✓	✓
Polyvinyl Chloride (PVC)	NA	NA	NA	NA	✓	NA
Stainless Steel – welded lap joints or butt welded	✓	✓	✓	✓	✓	✓
Steel – gasketted bell and spigot joints	NA	NA	NA	NA	✓	NA
Steel – welded lap joints, concrete encased, cement mortar lined	✓	✓	✓	✓	✓	✓
Steel – butt welded, concrete encased, cement mortar lined ('Metro Main')	✓	✓	✓	✓	✓	✓

NA – Not applicable (Not suitable), ✓ – Applicable

Note: The above table provides guideline line for the permitted pipe materials and joint types based upon area classification. However, not all pipe materials and joint types identified in Table 2 may be suitable for this project and as a result, the designer may exclude pipe material(s) and stipulate joint types based upon their soil condition, their investigations and design. If the designer excludes pipe material(s) and stipulates joints for this project, then the designer will provide such limitations separately in the Contract Documents. Such limitations will supersede Table 2 above.

TS 7.80.04.02 Submissions

The Contractor shall submit Shop Drawings for review for the pipe material(s) the Contractor has selected for the project including pipe design calculations as identified in subsection TS 7.80.04.01 herein, pipe lining, pipe coatings, concrete mixtures, fittings, couplings, gasket material, additional protection material, and special fabrications based on field measurement as necessary. The pipe material, any internal coating, gaskets, and any other parts which come in contact with potable water shall be NSF/ANSI 61 compliant, and MOECC guidelines.

Submit joint details showing type of non-restrained or restrained joint being proposed, welding procedures and detail drawings. The drawing must be certified by a Professional Engineer including an acknowledgement that the joint is a non-restrained or a restrained joint. Provide factory welding and site welding procedures when welding is required. The procedures shall comply with Canadian Welding Bureau specifications and requirements. Where a restrained joint is required for a pipe due to additional protection requirements, the restrained joint requirement is for the entire pipe length including all pipe joints, pipe transition joints, connection joints, joints between valves and pipe and at the project end limits.

Transition coupling details between various pipe types and between pipe and appurtenances such as a valve may be provided on the Contract Drawings. However, if the Contract Drawings do not include transition coupling detail drawings for a specific transition or joint, then the Contractor is responsible to ask for this information during the tendering period. Otherwise, the contactor is to provide the transition detail drawings certified by a Professional Engineer for approval by the Contract Administrator.

For special pipe pieces such as bends, the Contractor is to provide detail drawings certified by a Professional Engineer for prior approval by the Contract Administrator and show the welding details and material used.

For welding of steel to stainless steel or comparable dissimilar metal, the Contractor shall provide welding detail certified by a Professional Engineer including welding procedure and welding rod material information.

TS 7.80.05 MATERIALS

TS 7.80.05.01 Ductile Iron Pipe

Ductile iron pipe is only permitted in open cut low risk areas in sizes 750 mm to 1050 mm diameter.

Wall thickness design according to AWWA C150/A21.50 and minimum Class 250.

Pipe manufactured to AWWA C151/A21.51 with push-on or mechanical joints.

Mechanical joint fittings to AWWA C110/A21.10 or AWWA C153/A21.53 and rubber gaskets to AWWA C111/A21.11.

Factory applied internal cement mortar lining for pipe and fittings to AWWA C104/A21.4 with NSF/ANSI 61 compliant seal coat.

External asphaltic coating according to ANSI/AWWA C151/A21.51 for pipe and fittings.

Ductile iron pipe shall be installed according to T-1110.01-4.

Approved manufacturers list for all restrained pipe joints:

- Clow Tyler Union – TUFGrip
- Ebba Iron – Megalug Series 1100 and 1700
- Uni-flange UFR1400-D and UFR1450-D

Copper bonding cables are required at all joints where electrical conductivity is not provided by restrained joint couplings.

Cathodic protection is required and shall be according to TS 7.22. Any nuts, bolts and washers used for the installation of the pipe shall be stainless steel.

TS 7.80.05.02 High Density Polyethylene Pipe

High density polyethylene pipe is permitted in low, medium, and high risk areas in sizes 750 mm to 1600 mm diameter.

Wall thickness design and manufacture for pipe and fittings shall be according to AWWA M55 and AWWA C906 to iron pipe size (IPS) or ductile iron pipe size (DIPS) dimensions as shown on the Contract Drawings. Internal diameter (ID) shall be used to match alternate materials, not the pipe outside diameter (OD).

Dimension ratio (DR) shall be according to AWWA C906 based on compound selection and a minimum of DR 11 for PE3608 and DR 13.5 for PE4710.

Continuous co-extruded blue stripe for potable water identification and markings shall be according to AWWA C906.

All joints shall be butt-end fusion-welded unless shown otherwise on the Contract Drawings or as specified elsewhere.

High density polyethylene pipe in low risk areas shall be installed according to T-1110.01-5.

TS 7.80.05.02.01 *Additional Protection*

Mechanical connections and transition couplings shall be coated with fusion bonded epoxy according to AWWA C213-07 and supplied with stainless steel nuts, bolts and washers. Mechanical connections and transition couplings are required as shown on the Contract Drawings. Any nuts, bolts and washers used to connect the pipe shall be stainless steel.

In high and medium risk areas high density polyethylene pipe must be protected with concrete according to T-1110.01-4.

TS 7.80.05.03 Pre-stressed Concrete Cylinder Pipe

Pre-stressed concrete cylinder pipe is permitted in low, medium, and high risk areas in sizes 750 mm to 2300 mm diameter.

Design and manufacture for pre-stressed concrete pressure pipe and fittings—steel cylinder type—according to AWWA M9 and AWWA C304 and AWWA C301.

Lined cylinder pipe according to AWWA C301(L) for diameters from 750 to 1500 mm and embedded cylinder pipe according to AWWA C301(E) for larger diameters.

Concrete materials shall meet a minimum 30 MPa for 28-day strength and silica fume admixture shall be 8 per cent by weight as a cement replacement to core concrete and mortar coating.

Type II (CSA A23.1 Type HS) sulphate resistant cement.

Rigid 100 per cent solids, blue pigmented polyurethane exterior coating shall be minimum 1000 µm (40mils).

Pre-stressed concrete cylinder pipe in low risk areas to be installed according to T-1110.01-3.

Cathodic protection is not required unless specified in the Contract Documents. However, even if cathodic protection is not specified, a provision for continuous and dual bonding cable is required and the Contractor shall connect the bonding cable according to AWWA requirements to ensure there is continuous electrical conductivity and testing locations according to AWWA standards shall be provided. This will assist in monitoring of corrosion and to provide protection if required in the future.

All exposed metallic parts and joints shall be covered with diapers approved by the pipe supplier and filled with grout (3:1 sand to cement ratio) or as specified by the pipe supplier. Any nuts, bolts and washers used for the installation of the pipe shall be stainless steel.

TS 7.80.05.03.01 *Additional Protection*

In high risk areas pre-stressed concrete cylinder pipe shall be installed on a concrete bedding according to T-1110.01-1. For additional protection in high risk areas provide:

1) Minimum steel cylinder thickness of 10 gauge.

2) The pre-stressed wire shall be one gauge greater in thickness than required by the AWWA standard, while maintaining the same wire spacing requirement.

3) Internally or externally welded lap joints according to AWWA C206, with internal and external grouted joint protection and nominal 50 mm external mortar cover is required. Snap ring restraints are not acceptable in high risk areas.

4) Provide nominal 50 mm external mortar cover with similar silica fume admixture,

In medium risk areas pre-stressed concrete cylinder pipe must be installed on granular bedding in according to T-1110.01-2. For additional protection in medium risk areas provide:

1) Minimum steel cylinder thickness of 12 gauge.

2) Internally or externally welded lap joints according to AWWA C206 or mechanically restrained joints or specific joints as shown on the Contract Drawings, with internal and external grouted joint protection.

3) Provide nominal 50 mm external mortar cover with similar silica fume admixture.

4) All nuts, bolts and washers used for the installation of the pipe shall be stainless steel.

TS 7.80.05.04 Polyvinyl Chloride Pipe

Polyvinyl chloride pipe is permitted in open cut low risk areas only in sizes 750 mm to 900 mm diameter

Wall thickness design and manufacture for pipe and fittings according to AWWA M23 and AWWA C905, certified to CSA B137.3, IPS or DIPS dimensions as shown on the Contract Drawings.

Dimension ratio (DR) according to AWWA C905 and a minimum of DR 18.

Blue pigmented resin for potable water identification and markings according to AWWA C905.

Polyvinyl chloride pipe to be installed according to T-1110.01-7.

Approved manufacturers list for all restrained pipe and fitting joints are

- Ebba Iron – Megalug Series 2500
- Uni-flange UFR1450-D.

All nuts, bolts and washers used for the installation of the pipe shall be stainless steel.

TS 7.80.05.05 Steel Pipe

Steel pipe is permitted in low, medium, and high risk areas in sizes 750 mm to 2300 mm diameter. Spiral or straight seam full penetration butt-welded carbon steel pipe fabrication shall be according to TS 1802 and AWWA C200.

Fabricated fittings to AWWA C208.

Mill certified steel sheet ASTM A139 Grade C 290 MPa (42,000 psi) or higher.

Minimum internal 13 mm cement mortar lining shall be factory applied to AWWA C205 (with steel mesh) or minimum internal 19 mm cement mortar lining if field applied according to AWWA C602 (with no mesh). Variation for field applied mortar thickness is observed as being higher and as a result lining thickness requirement is higher for field application.

Steel pipe in low risk areas to be installed according to T-1110.01-9.

Cathodic protection shall be provided according to AWWA or TS 7.22 for steel pipe in low risk areas.

The pipe shall be factory coated externally with polyurethane according to AWWA C222. All nuts, bolts and washers used for the installation of the pipe shall be stainless steel.

For low risk areas any of the below joint type is permitted:

1) Butt-joint end preparation for pipe continuously field welded shall be according to AWWA C206 where shown on the Contract Drawings.

2) Lap joints for pipe continuously field welded shall be according to AWWA C206 where shown on the Contract Drawings.

3) Bell and spigot joints shall be according to AWWA C200 where shown on the Contract Drawings.

TS 7.80.05.05.01 *Additional Protection*

In high risk areas steel pipe shall be concrete encased and installed according to T-1110.01-10. Only welded joints are permitted. For welding details for butt and lap joints, respectively shall be according to T-1110.04-1 or T-1110.04-2. Butt-joint end preparation for pipe continuously field welded shall be according to AWWA C206. Lap joints for pipe continuously field welded shall be according to AWWA C206. External weld up to 900 mm pipe diameter is permitted and internal weld is required beyond 900 mm pipe diameter. Contractor to provide detail of field welding and welding procedure for pre-approval by the Contract Administrator. Cathodic protection is not required for concrete encased pipe, unless specified in the Contract Documents.

In medium risk areas steel pipe shall be concrete encased and installed according to T-1110.01-9. The type of pipe joints permitted are butt weld, lap weld or mechanical restrained joints.

For welding details for butt and lap joints, respectively, shall be according to T-1110.04-1 or T-1110.04-2. Butt-joint end preparation for pipe continuously field welded shall be according to AWWA C206. Lap joints for pipe continuously field welded shall be according to AWWA C206. External weld up to 900 mm pipe diameter is permitted and internal weld is required beyond 900 mm pipe diameter. Contractor to provide detail of field welding and welding procedure for pre-approval by the Contract Administrator. Mechanical restrained gasketted joints are permitted where shown on the Contract Drawings.

For metallic restrained joint components epoxy coating according to AWWA C213-07 and any nuts, bolts and washers shall be stainless steel. Cathodic protection is not required for concrete encased pipe, unless specified in the Contract Documents.

TS 7.80.05.06 Stainless Steel Pipe

Stainless steel pipe is permitted in low, medium, and high risk areas in sizes 750 mm to 2300 mm diameter.

Spiral or straight seam full penetration butt-welded stainless steel pipe fabrication according to TS 1802 and AWWA C220.

Fabricated fittings shall be according to AWWA C208.

Mill certified steel sheet shall be Grade 304L or 316L 290 MPa (42,000 psi) or higher. ASTM A778 or A312. Dual certification is acceptable.

No internal lining or external coating is required unless specifically noted otherwise on the Contract Drawings.

Stainless steel pipe in low and medium risk areas shall be installed according to T-1110.01-8. Provide cathodic protection only if specified in the Contract Documents.

TS 7.80.05.06.01 *Additional Protection*

In high risk areas stainless steel pipe must be additionally protected with a coating recommended by the pipe supplier to protect against galvanic corrosion, stray currents and other forms of corrosion. At a minimum the pipe shall be coated with polyethylene copolymer film backing and non-corrosive resins. Installation of the pipe shall be according to T-1109.01-8 including welded joints according to AWWA C206.

TS 7.80.05.07 Installation in Tunnel

When HDPE, PCCP or steel pipe are installed in a tunnel, the annular space between the tunnel liner and the watermain pipe shall be filled with a grout. The heat of hydration from curing of grout shall be removed specifically in case of softer HDPE pipe material. The Contractor shall provide the submittal of grouting mix and a grouting plan certified by the Professional Engineer to the designer or Contract Administrator.

When a steel pipe or a PCCP pipe is installed in a tunnel external corrosion protection coating is not required as the annular space is grouted.

Material for tunnel liner is not included in this specification.

TS 7.80.06 EQUIPMENT – Not Used

TS 7.80.07 PRODUCTION – Not Used

TS 7.80.08 QUALITY ASSURANCE

TS 7.80.08.01 Certification

The Contractor is responsible to provide all test results and factory data as required according to applicable AWWA standard and the Contract Documents to the Contract Administrator. The Contractor shall request approval in advance of an inspection and prior to initiating delivery of the pipe to the site. All factory test results, mill tests and other test results shall be signed and dated by qualified quality assurance staff.

Submit certified mill test reports for all metal pipe materials.

Provide factory data and test result for all pipe types as required according to AWWA standards prior to inspection invitation or prior to delivery of the pipe on site.

Provide copies of welder qualifications from a recognized regulatory authority for hand-welded fabrications. Provide test results for factory welding as required according to AWWA standards.

For PCCP pipe, provide pre-stressed wire strength data including tensile and compressive strength, wire carbon content and category, wire thickness.

Provide data and certificate for factory cement mortar lining mix and coating thickness measurement prior to inspection invitation or prior to delivery of the pipe on site.

Provide data and certificate for factory coatings of polyurethane including material and thickness test results prior to inspection invitation or prior to delivery of the pipe on site.

TS 7.80.08.02 Inspection

The City has the right to inspect the fabrication and testing of pipe and fittings at the factory at any time having given prior notice and with the agreement of the supplier with respect to schedule and protocols.

The Contractor or supplier shall rectify materials and workmanship that fail to comply with these specifications and accepted industry practice as determined by the Contract Administrator. As required, the Contract Administrator will arrange testing for compaction, soil testing and concrete strength and the Contractor shall coordinate with the Contract Administrator and cooperate in completing the required testing. The Contractor shall also complete their own testing and coordinate with the Contract Administrator all testing.

TS 7.80.09 OWNER PURCHASE OF MATERIAL – Not Used

Appendix 7.80-A, November 2016
For Use While Designing and Administrating City Contracts

Note: This is a non-mandatory commentary intended to provide information to the designer and the Contract Administrator during the design and construction stages of a project on the use of this specification for a City project. This appendix does not form part of the standard specification. Actions and considerations discussed in this appendix are for information purposes only and do not supersede an owner's design decisions and methodology.

Notes to Designer:

Large diameter watermains differ significantly from distribution watermains in terms of their function in a water supply system. Distribution watermains provide service to consumers through service connections and fire protection through hydrants whereas larger watermains provide transmission between facilities such as pumping stations, reservoirs, etc. and trunk supply to distribution watermains. Large diameter watermains are typically considered to be 750 mm to 2300 mm diameter requiring special design considerations. The anticipated service life for large diameter watermains is 80-100 years. The design requirements and criteria for large diameter watermains is the focus of this appendix.

Risk Assessment

Transmission watermains provide a significant role and service in a water supply system. Failure of these watermains can impact entire areas of a water system, operation of the water system, and cause catastrophic environmental and structural damage. Conversely, the failure of a local distribution watermain will generally impact a limited number of customers and damage is generally localized to the failure location. The City of Toronto has traditionally designed their large diameter watermains to a higher standard than minimum accepted industry requirements to guard against the potential consequences of a pipe failure. The City has not had any failures of large diameter transmission watermains.

The City conducted a study[1] in 2013 to classify the watermains based primarily on land use and identify the pipe requirements, additional pipe protection requirements, and the permitted watermain materials. The study[1] identified three classes – high, medium, and low risk areas based on land use[2], proximity to public utilities, the ability to maintain or repair the watermain, and the alignment in relationship to major transportation facilities.

Definitions

The definitions of high, medium and low risk areas are as follows:

High Risk Areas: Mixed use areas, open areas *(Public Utilities: Reservoirs & Pumping Stations to the first line valve)*, institutional areas, employment areas, utility corridors, major streets and highways, railway lines, hydro corridors and watercourse crossings.

Characteristics include

- dense residential and employment populations
- close proximity to critical infrastructure
- high risk and high cost of collateral damage
- watermain repairs – complex and prolonged
- prolonged delays in restoration of services.

Medium Risk Areas: Apartment neighbourhoods, natural areas *(Environmentally sensitive, TRCA regulated area but not a water course crossing)* and regeneration areas.

Characteristics include
- mderately dense residential population
- good separation from critical infrastructure
- some risk of collateral damage; incl. environmental and potential high cost
- high rather than low density redevelopment more likely
- watermain repairs – moderately complex and prolonged
- limited interruption to services.

Low Risk Areas: Neighbourhoods, other open space area

Characteristics include
- low density residential populations
- good separation from critical infrastructure
- limited risk and cost of collateral damage
- watermain repairs – less complex
- minimal interruption to services.

Source: Additional Protection for Large Diameter Trunk Watermains, October 2013, Delcan Corporation

Material Selection

Process

The determination of the risk area along the route of a watermain shall be made during the Class Environmental Assessment for the project. The determination will consider land use plans from the latest version of the City of Toronto Official Plan. If a Class Environmental Assessment was not required for the project then the risk determination must be made during the preliminary design stage for the project. Using the risk evaluation and other guidelines mentioned in the Additional Protection for Large Diameter Trunk Watermains matrix, the designer can determine the pipe materials which are suitable for the risk identified and the project as a whole. It is expected that the designer would:

- Identify more than one pipe material for a project to ensure a competitive bid process.
- Limit the changes in pipe materials for a project. When there is a short length transition of the project area to a lower risk area from high risk or medium risk areas, there is no need to change the pipe material for the short section in the lower risk area. A short section is defined as being approximately 100 m or less in length. The same pipe material shall be used in the lower risk area. Conversely, if a short section is located in a higher risk area and the majority of the pipe is in a lower risk area, then the pipe material for the short section of the higher risk area shall govern the design and the higher risk pipe material shall be used.
- Consider that at the transition between risk areas, the pipe material of the standard of the higher risk area will extend into the lower risk area,
- Recognise that not all pipe materials are available in sizes being considered and hence some pipe material can be ruled out accordingly by the designer. The designer is required to document the rationale for eliminating the pipe material, and
- On special short bends standard off the shelf restrained joints may not be constructible. The consultant is responsible to either i) provide a specific detail for such joints or ii) require the

Contractor to provide a restrained joint for such special pipe section. For example: specify flanged joints, welded joints or other joints.

Pipe Material Suitability Matrix

The study[1] determined the suitability of the pipe materials based on risk area and construction type. The following is a summary of the matrix of watermain pipe material suitability per location. A more detailed matrix for the use of the designers is included at the end of the Appendix.

Table A-1: Pipe material suitability for large diameter watermains

	High Risk Areas		Medium Risk Areas		Low Risk Areas	
Pipe Material	**Open-cut**	**Tunnel**	**Open-cut**	**Tunnel**	**Open-cut**	**Tunnel**
Ductile Iron	NA	NA	NA	NA	✓	NA
High Density Polyethylene (HDPE)	✓	✓	✓	✓	✓	✓
Pre-stressed Concrete Cylinder Pipe (PCCP) – Bell and Spigot Joints	NA	NA	NA	NA	✓	NA
Pre-stressed Concrete Cylinder Pipe (PCCP) – Mechanically Restrained Joints	NA	NA	✓	✓	✓	✓
Pre-stressed Concrete Cylinder Pipe (PCCP) – Welded Joints	✓	✓	✓	✓	✓	✓
Polyvinyl Chloride (PVC)	NA	NA	NA	NA	✓	NA
Stainless Steel – welded lap joints or butt welded	✓	✓	✓	✓	✓	✓
Steel – gasketted bell and spigot joints	NA	NA	NA	NA	✓	NA
Steel – welded lap joints, concrete encased, cement mortar lined	✓	✓	✓	✓	✓	✓
Steel – butt welded, concrete encased, cement mortar lined ('Metro Main')	✓	✓	✓	✓	✓	✓

NA – Not applicable (Not suitable), ✓ – Applicable

Source: Additional Protection for Large Diameter Trunk Watermains, October 2013, Delcan Corporation – with revisions

Contract Drawings

When the designer prepares the Contract Drawings for a large diameter watermain project, the plan and profile drawings need to indicate the risk area and the criteria for the suitable pipe materials. The designer can identify on each drawing, which pipe materials are permitted for the specific plan and profile drawing. The risk area and pipe material information together with specification TS 7.80, will assist suppliers and Contractors in understanding the requirements of the products to be supplied and installed.

Design Requirements

Criteria

The design engineer is responsible to complete the pipe design and determine pipe specifications for all pipe material which is applicable and proposed to be used for the project.

Pipe design is governed by the applicable AWWA M-Series design guides and the following criteria unless specifically noted otherwise:

1) Internal working pressure: 1100 kPa

2) Additional allowance for surge pressure: 550 kPa minimum (1650) kPA together with working pressure. The designer shall determine actual surge pressure and mention in contract documents to supersede surge pressure information in specification subsection TS 7.80.04.01 (3)(iii), so that the Contractors can complete their calculation for higher surge pressure requirements.

3) Test pressure: 1500 kPa

4) Trench supported full vacuum: -100 kPa

5) Variable depth of cover to the top of the pipe: 1.7 to 3.5 m

6) Live load: HS-20 and/or E-80 (rail crossings – pipe strength shall meet rail loading requirements at crossings)

7) Groundwater table:1.0 m below finished grade

8) Factor of Design Safety shall be 2 for relevant AWWA calculations.

9) Determine soil reaction factor utilizing geotechnical and soils investigation and complete pipe design.

10) Vertical deflection limit shall not exceed 2.5% for low risk areas and 2% for medium and high risk areas.

Pipe pressure class, wall thickness or dimension ratio shall be shown on the Contract Drawings with examples as follows:

- 1800mm Dia. Pre-stressed Concrete Pressure Watermain, AWWA C301, Class 14, Standard Drawing T-1110.01-1
- 1200mm Dia. Steel Watermain, AWWA C200, Standard Drawing T-1110.01-10
- 750mm Dia. PVC Watermain, AWWA C905, DR18, Standard Drawing T-1110.01-7
- 900mm Dia. HDPE Watermain, AWWA C906, DR11, Standard Drawing T-1110.01-4

Pipe, Bedding and Connections

Standard drawings have been prepared by the City for the bedding for all acceptable pipe material for low, medium, and high risk areas, where applicable. Additionally, standard details have been prepared for the connection requirements between various pipe materials. With regard to the various pipe materials the designer should consider the following:

Ductile Iron Pipe

Ductile iron pipe is manufactured in sizes up 3600 mm diameter but is not readily available in southern Ontario. Designers should consider using this pipe for 750 mm to 1200 mm and confirm the availability of these sizes from at least two different local suppliers before permitting this material.

High Density Polyethylene Pipe

HDPE pipe is manufactured in sizes up 1600 mm diameter and is readily available in southern Ontario, however, in the higher pressure classes (DR11) the sizes are limited to about 900 mm diameter. Designers could consider using this pipe for 750 mm to 1200 mm but confirm the availability of these sizes from at least two different local suppliers before permitting this material.

HDPE pipe installation in tunnel is permitted. The annular space between the tunnel liner and the HDPE pipe shall be filled with a suitable strength grout which can resist corrosion. The heat of hydration from setting of the grout material can damage the soft HDPE pipe and as a result the heat of hydration is required to be removed through water cooling. Only a Contractor or sub-contractor having such experience shall be permitted to complete grouting. The design engineer shall specify performance specifications for the grout and the qualifications required from the Contractors for grouting.

Pre-stressed Concrete Pressure Pipe

Pre-stressed concrete pressure pipe is available in sizes up to 2400 mm diameter in Southern Ontario. All sizes meet the additional requirements defined in the specifications.

Bell and spigot joints are not permitted in tunnel. The annular spaces between the tunnel liner and the PCCP pipe shall be filled with a suitable strength grout with silica fume and have corrosion resistance characteristics. The design engineer shall specify performance specifications for the grout and the qualifications required from the general contractors for grouting.

Polyvinyl Chloride Pipe

PVC pipe is manufactured in sizes up 1200 mm diameter and approved by AWWA but is not readily available in southern Ontario. Designers could consider using this pipe for 750 mm to 1200 mm but need to confirm the availability of these sizes from at least two different local suppliers before permitting this material. Fusible PVC is also available in smaller diameter (up to 600 mm) but not available in large sizes at this time.

Steel Pipe

Steel pipe has traditionally used by the City for all the large diameter watermains has been known as the 'Metro Main' which is a steel pipe, cement mortar lined, and concrete encased. The designer shall comply with the requirements of AWWA M11 and other applicable specifications, and ensure the minimum wall thickness specified in Table A-1 is sufficient for the project or determine if a greater wall thickness is required. If required, the designer shall specify a greater wall thickness for i) the entire project length or ii) for specific sections based upon pipe design calculations which can depend on:

- external pipe loading (example: rail crossing E80)
- transient analysis (surge allowance beyond 550 kPa)
- geotechnical investigations and soil analysis
- permitted or anticipated pipe bedding material
- requirements due to pipe handling and transportation
- pipe wall thickness requirement to protect pre-mortar lined pipes during transportation, handling and installation.

Minimum steel pipe wall thicknesses are as follows:

Table A-2: Steel pipe wall thickness

Nominal diameter	Minimum wall thickness for concrete encased pipe (high and medium risk areas)		Minimum wall thickness for non-concrete encased pipe (low risk areas) *	
mm	mm	inches	mm	inches
750 – 850	6.35	1/4	7.92	5/16
900 – 1450	7.92	5/16	9.53	3/8
1450 – 1800	9.53	3/8	11.11	7/16
1850 – 2200	11.11	7/16	12.70	1/2
2250 – 2300	12.70	1/2	14.29	9/16

* *Additional thickness identified is to allow for corrosion when the steel pipe is not embedded in concrete for low and medium risk areas.*

Steel pipe with bell and spigot ends is an acceptable material that can be used only in Low risk areas as specified.

Steel pipe with bell and spigot ends is not permitted in a tunnel. The annular space between the tunnel liner and the bare steel pipe shall be filled with a suitable and corrosion resistant grout. The design engineer shall provide performance specifications for the grout and the pre-qualifications required from the general contractors for grouting.

Stainless Steel Pipe

The City requires Stainless steel 304L or 316 L pipe in all valve chambers, at locations where the pipe is exposed to high humidity, where corrosion is a concern and at other specified locations such as railway crossings, and on land under the jurisdiction of a third party railway under crossings. All sizes meet the requirements defined in the specifications. Designer shall clearly indicate on Contract Drawing and in Contract specifications mandatory stainless streel 304L or 316L requirements for chamber piping and other locations where applicable. If the soil is highly corrosive, specify cathodic protection or another form of corrosion protection in contract drawings and specifications.

Pipe Materials in Valve Chambers

Due to exposure, space limitations, strength issues, and the humid environment in all chambers only Schedule 40, Grade 304L or 316L 290 MPa (42,000 psi) or a higher grade stainless steel pipe is permitted in all chambers where the pipe will be exposed. Transition from any pipe material to stainless steel pipe shall be according to T-1110.07 to T-1110.12.

Tunnel Liner and Other Design

Tunnel liner design and material is not included in this specification. The designer will be completing tunnel liner design calculations and preparing a special specification for tunneling including tunnel liner material requirements. If the trenchless methodology is to be conducted by the Contractor, the designer is required to prepare performance specifications to be followed by the Contractor.

Inspection During Construction

The designer or Contract Administrator should determine and implement the field inspection regime according to any applicable AWWA standard and the *Field Services Manual*. The designer or Contract Administrator shall additionally specify the field inspection regime in the Contract Documents and prepare a separate specification as required.

The City has independent material testing contracts for soils, concrete, welding and asphalt. Depending on the requirements, the designer or Contract Administrator shall specify:

- Percentage of welding joints to be inspected through radiography, ultrasonic and visual methods. For example radiography (5%) by the Contractor, ultrasonic (10%) and visual (all) by City's independent material testing Contractor. The City will pay its material testing Contractor directly and the Contractor will be responsible to pay for testing of activities under the responsibility of the Contractor.

- Percentage of HDPE or PVC fusion joints shall be inspected through ultrasonic, microwave and visual methods. For example, ultrasonic (10%) and visual (all). City will pay for such testing cost directly to the material testing company.

- Portion of testing that shall be completed by the Contractor irrespective of City's independent testing.

Specify in Contract Documents sufficient testing requirement and arrange compaction, concrete and unshrinkable fill strength testing as required to comply with installation specifications through the City’s material inspection Contractor.

Specify in Contract Documents any other testing requirements and implement the inspection program.

[1] *Additional Protection for Large Diameter Trunk Watermains, October 2013, Delcan Corporation*
[2] *City of Toronto Official Plan, Land Use Plans (latest version)*

RISK RELATED TO LAND USE [1]	PIPE SYSTEM	ADDITIONAL PROTECTION REQUIREMENTS [2] OPEN-CUT	TUNNEL [3]	NOTES
HIGH RISK AREAS				
Mixed Use Areas **Open Space Areas (Public Utilities**: Reservoirs & Pumping Stations to the first line valve) **Institutional Areas Employment Areas** **Utility Corridors** **Major Streets & Highways Railway Lines** **Hydro Corridors** Characterized by: • Dense residential and employment populations • Close proximity to critical infrastructure • High risk and high cost of collateral damage • Watermain repairs – complex and prolonged • Prolonged delays in restoration of services	**Ductile Iron** (DI)	NOT SUITABLE	NOT SUITABLE	Non-welded mechanical joints only – even if restrained, failure considered more likely than for welded construction
	High Density Polyethylene (HDPE)	ACCEPTABLE – continuous length, butt fused joints, concrete protection system	ACCEPTABLE – continuous length, butt fused joints	Concrete protection system against damage required – encasement is not a good option due to high coefficient of expansion ; minimal maintenance; repairs and modifications require specialized equipment and technicians
	Prestressed Concrete Cylinder Pipe (PCCP)	ACCEPTABLE – welded and grouted lap joints, silica fume admixture, nominal 50 mm mortar cover, polyurethane coating	ACCEPTABLE – welded lap joints	Site modification of prefabricated pipe to suit conditions is not an option for open-cut construction which may leave excavations open for prolonged periods; more suitable for tunnel construction or where alignments and obstructions clearly defined; welded lap joints (internal only) allow for some joint deflection reducing the need for special fittings; silica fume admixture and external coating for protection against chlorides; repairs and modifications require specialized equipment and technicians
	Polyvinyl Chloride (PVC)	SUITABILITY subject to compliance with approved AWWA Standard for butt fused joints [4]	NOT SUITABLE [4]	Concrete protection system against damage required—encasement is not a good option due to high coefficient of expansion. Even if restrained, failure of bell & spigot joints considered more likely than for fusion welded construction. Not suitable for tunnel construction because of inaccessibility to affect joint or pipe repairs.
	Stainless Steel – welded lap joints or butt welded	ACCEPTABLE – concrete encased	ACCEPTABLE – concrete encased	Welded lap joints (internal only) allow for some joint deflection reducing end preparation requirements and special fittings; compact construction zone; concrete encasement for physical protection required; no internal lining required; minimal maintenance; repairs and modifications using readily available equipment by City Staff; typically for special applications due to material cost
	Steel – gasketted bell & spigot joints	NOT SUITABLE	NOT SUITABLE	Non-welded mechanical joints only – even if restrained, failure considered more likely than for welded construction
	Steel – welded lap joints	ACCEPTABLE – concrete encased, cement mortar lined (equivalent to 'Metro Main')	ACCEPTABLE – concrete encased, cement mortar lined	Welded lap joints (internal only) allow for some joint deflection reducing end preparation requirements and special fittings; compact construction zone; minimal maintenance; repairs and modifications using readily available equipment by City Staff
	Steel – butt-welded, concrete encased, cement mortar lined (**'Metro Main'**)	ACCEPTABLE	ACCEPTABLE	Benchmark Toronto Standard – butt-welded steel joints (internally on bottom chord, externally on top chord); compact construction zone; minimal maintenance; repairs and modifications using readily available equipment by City Staff.

RISK RELATED TO LAND USE [1]	PIPE SYSTEM	ADDITIONAL PROTECTION REQUIREMENTS [2] OPEN-CUT	TUNNEL [3]	NOTES
MEDIUM RISK AREAS				
Apartment Neighbourhoods **Natural Areas** (Environmentally sensitive TRCA regulated) **Regeneration Areas** Characterized by: • Moderately dense residential populations • Good separation from critical infrastructure • Some risk of collateral damage – incl. environmental – and potential high cost • High rather than low density redevelopment more likely • Watermain repairs – moderately complex and prolonged • Limited interruption to services	**Ductile Iron** (DI)	NOT SUITABLE	NOT SUITABLE	Non-welded mechanical joints only – even if restrained, failure considered more likely than for welded construction
	High Density Polyethylene (HDPE)	ACCEPTABLE – continuous length, butt fused joints, concrete protection system	ACCEPTABLE – continuous length, butt fused joints	Concrete protection system against damage required – encasement is not a good option due to high coefficient of expansion; minimal maintenance; repairs and modifications require specialized equipment and technicians
	Prestressed Concrete Cylinder Pipe (PCCP)	ACCEPTABLE – welded and grouted lap joints, polyurethane coating, silica fume admixture on case-by-case evaluation	ACCEPTABLE – welded lap joints	Site modification of prefabricated pipe to suit conditions is not an option but less of a concern in open areas where fewer utilities are likely to be encountered and excavations may be left open for longer periods; welded lap joints (internal only) allow for some joint deflection reducing the need for special fittings; repairs and modifications require specialized equipment and technicians
	Polyvinyl Chloride (PVC)	SUITABILITY subject to compliance with approved AWWA Standard for butt fused joints [4]	SUITABILITY subject to compliance with approved AWWA Standard for butt fused joints [4]	Concrete protection system against damage required—encasement is not a good option due to high coefficient of expansion. Even if restrained, failure of bell & spigot joints considered more likely than for fusion welded construction. Suitability for tunnel construction subject to approved pipe/grout bond breaker and accessibility to affect joint or pipe repairs.
	Stainless Steel – welded lap joints or butt welded	ACCEPTABLE – concrete encased	ACCEPTABLE – concrete encased	Welded lap joints (internal only) allow for some joint deflection reducing end preparation requirements and special fittings; compact construction zone; concrete encasement for physical protection required; no internal lining required; minimal maintenance; repairs and modifications using readily available equipment by City Staff; typically for special applications due to material cost
	Steel – gasketted bell & spigot joints	NOT SUITABLE	NOT SUITABLE	Non-welded mechanical joints only – even if restrained, failure considered more likely than for welded construction
	Steel – welded lap joints	ACCEPTABLE – concrete encased, cement mortar lined (equivalent to 'Metro Main')	ACCEPTABLE – concrete encased, cement mortar lined	Welded lap joints (internal only) allow for some joint deflection reducing end preparation requirements and special fittings; compact construction zone; minimal maintenance; repairs and modifications using readily available equipment by City Staff

RISK RELATED TO LAND USE [1]	PIPE SYSTEM	ADDITIONAL PROTECTION REQUIREMENTS [2] OPEN-CUT	TUNNEL [3]	NOTES
	Steel – butt-welded, concrete encased, cement mortar lined (‘**Metro Main**’)	ACCEPTABLE	ACCEPTABLE	Benchmark Toronto Standard – butt-welded steel joints (internally on bottom chord, externally on top chord); compact construction zone; minimal maintenance; repairs and modifications using readily available equipment by City Staff
LOW RISK AREAS				
Neighbourhoods ***Other Open Space Areas*** *Characterized by:* • *Low density urban residential populations* • *Good separation from critical infrastructure* • *Limited risk and cost of collateral damage* • *Watermain repairs – less complex* • *Minimal interruption to services*	***Ductile Iron** (DI)*	*ACCEPTABLE – cement mortar lined, external corrosion protection, restrained joints*	*NOT SUITABLE*	*No additional physical protection required; limited to non-aggressive soils; not suitable for tunnel construction because of inaccessibility to affect joint or pipe repairs*
	High Density Polyethylene (HDPE)	ACCEPTABLE – continuous length, butt fused joints	ACCEPTABLE – continuous length, butt fused joints	No additional physical protection required; minimal maintenance; repairs and modifications require specialized equipment and technicians
	Prestressed Concrete Cylinder Pipe (PCCP)	ACCEPTABLE – mechanical restrained joints or welded and grouted lap joints	ACCEPTABLE – welded lap joints	Site modification of prefabricated pipe to suit conditions is not an option but of limited concern in areas where fewer utilities are likely to be encountered and excavations may be left open for longer periods; mechanical restrained joints for open-cut and welded lap joints (internal only) for tunnels allow for some joint deflection reducing the need for special fittings; repairs and modifications require specialized equipment and technicians
	Polyvinyl Chloride (PVC)	ACCEPTABLE – mechanical restrained joints	SUITABILITY subject to compliance with approved AWWA Standard for butt fused joints [4]	No additional physical protection required; minimal maintenance; repairs and modifications using readily available equipment by City Staff. Suitability for tunnel construction subject to approved pipe/ grout bond breaker and accessibility to affect joint or pipe repairs.
	Stainless Steel – welded lap joints or butt welded	ACCEPTABLE	ACCEPTABLE	Welded lap joints (internal only) allow for some joint deflection reducing end preparation requirements and special fittings; compact construction zone; no additional physical protection required; no internal lining required; minimal maintenance; repairs and modifications using readily available equipment by City Staff, typically for special applications due to material cost
	Steel – gasketted bell & spigot joints	ACCEPTABLE – external corrosion protection, restrained joints, cement mortar lined	NOT SUITABLE	Allows for some joint deflection reducing end preparation requirements and special fittings; no additional physical protection required; external corrosion protection required; limited to non-aggressive soils; compact construction zone; minimal maintenance; repairs and modifications using readily available equipment by City Staff; not suitable for tunnel construction because of inaccessibility to affect joint or pipe repairs
	Steel – welded lap joints	ACCEPTABLE – external corrosion protection, cement mortar lined	ACCEPTABLE – concrete encased, cement mortar lined	Welded lap joints (internal only) allow for some joint deflection reducing end preparation requirements and special fittings; no additional physical protection required; external corrosion protection required; limited to non-aggressive soils; compact construction zone; minimal maintenance; repairs and modifications using readily available equipment by City Staff.

RISK RELATED TO LAND USE [1]	PIPE SYSTEM	ADDITIONAL PROTECTION REQUIREMENTS [2]		NOTES
		OPEN-CUT	TUNNEL [3]	
	Steel – butt-welded, concrete encased, cement mortar lined (‘**Metro Main’**)	ACCEPTABLE	ACCEPTABLE	Benchmark Toronto Standard – butt-welded steel joints (internally on bottom chord, externally on top chord); compact construction zone; minimal maintenance; repairs and modifications using readily available equipment by City Staff.

1 For current land use designations go to latest amendment of http://www.toronto.ca/planning/official_plan/pdf_chapter1-5/13-23_landuseplan_keymap_dec2010.pdf

2 Pipe materials deemed NOT SUITABLE may be acceptable under specific circumstances as determined by the City on a case-by-case basis

3 Tunnel construction may be by ‘jack and bore’ or ‘tunnel boring machine’ typically with a carrier pipe designed for full earth loads and transmission main positioned using spacers and grouted in place

4 Designation to be reviewed pending acceptance of fused jointing techniques under revisions to AWWA C605-05