WASTEWATER CONVEYANCE

DESIGN PRINCIPLES FOR PIPELINES OVER 300mm DIAMETER

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More information

If you have further queries, please contact the Asset Lifecycle team at standards@water.co.nz

DOCUMENT CONTROL

Document owner Principal Asset Lifecycle Engineer (Standards)

Reviewers Jonathan Piggot – Head of Wastewater
Joel Jeffries – Transmission Manager (Wastewater)
Graham Nairn – Asset Specialist (Wastewater)
Waldo Strydom – Principal Asset Lifecycle Engineer (Standards)
Zahra Tizmaghz (Senior Standards & Products Engineer)

Approval Brendon Harkness – Head of Sustainability and Innovation

Version history

Revision	Description	Released By	Date
1	Updates from working draft. Document finalized	J de Villiers	12/08/2019
1.1	Minor updates include biofilters, dewatering and trench bedding	J de Villiers	1/09/2020
2.0	Separated wastewater from water standard	W Strydom	11/09/2025

This document takes effect on the date of release and supersedes all prior versions.

Summary of Changes

Version	Section	Description of revision
2.0	Document	Updated document format and numbering
	Definitions	Updated, new definitions added
	Acronyms	Updated
	1.1	Updated introduction and included table.
	1.7	Updated list of applicable referenced standards and documents
	1.8	New section added
	1.9	Significant update to section.
	2.3.2	Minor updates to wording to consider steeply graded pipes
	2.4	Included example illustration of siphon
	3.2.1.5	Wording updated regarding continuous grade
	3.2.1.6	Wording updated
	3.2.1.9	Wording updated regarding satellite manholes
	3.2.2	Updated section
	3.3.1.4	Updated section to include half-diameter access platforms and drawing reference.
	3.3.2.2	Updated section
	4.2.2	Updated section on loading to reference applicable standards
	4.6.1	Adde references to pipe bridge colours, example figures, and access requirements.
	4.6.2	Updated image
	4.6.3	New section added
	4.6.4	New section added
	4.9	Updated section including reference sections.
	4.11.1.1	Added notes to clarify use of tape systems
	4.11.1.3	Added reference to new document
	4.12	Added reference documents
	4.13	Added reference documents

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Definitions

Assets	Water and wastewater infrastructure legally owned and operated by Watercare.
As-built drawing	Drawings showing the exact dimension, geometry and locations of assets, as constructed.
Chamber	A partially below ground or below ground enclosure where equipment and dry pipework is housed for inspection or maintenance purposes.
Control systems (DCS, SCADA, RTU's, and PLC's)	Devices to control equipment and return data on processes and devices of operational infrastructure.
Designer	Person(s) or company responsible for the design output.
Drop	Difference in level between the inlet and outlet pipework.
Easement	A contractual agreement that grants a right to use another person's property for a particular purpose such as access.
Flexible joint	A joint that can accommodate angular deflection during and after installation.
Function class	Classification system used to define criticality of a pipeline's function in the context of lifeline systems (such as water) and their performance during natural hazards like earthquakes.
Grade	Ratio between vertical drop / rise and horizontal runs of pipe.
Gravity pipe [system]	A piping system where flow occurs through gravitation fall of the liquid medium without exerting internal pressure on the pipe walls and for which no pumping is required.
Local networks	Reticulated piping that collects wastewater and is located upstream of a satellite manhole where pipe diameters are generally smaller than 300mm.
Manhole	A partially below ground or below ground enclosure Manholes are wet areas where pipework or channels have open flow. Typical examples are directional changes and for maintenance access of wastewater gravity systems.
Nominal diameter (DN)	Average internal pipe diameter expressed in millimetre (mm) irrespective of the pipe class or wall thickness. Dimension used for pipe where the manufacturing process controls the internal pipe diameter – at different pressure classes the external diameter changes. **Note:** for PE or PVC the nominal diameter does not reflect the average internal diameter (ref.

	Nominal bore) but the average external diameter. Nominal diameter is not to be used alone where an additional lining has been used to extend the asset life.
Nominal bore (NB)	Average internal pipe diameter expressed in millimetre (mm). Dimension used for pipe where the manufacturing process controls the external pipe diameter. Applies to PE, PVC or where a lining significantly alters the nominal diameter (i.e. CLS pipe) of the host pipe.
Pump(ing) station	Structure containing pumps, associated pipes, valves, mechanical and electrical equipment for pumping fluid.
Pressure main	Piping system where fluid exerts internal pressure on the pipe walls by liquid elevation or by means of pumping
Rising main	A pumped pressure main discharging into a receiving structure. See **Pressure main**.
Satelite manhole	A manhole that is strategically positioned to collect local network flows before transitioning to the transmission network. Satelite manholes aim to limit the number of connections to the transmission network.
Siphon	A pipe section where fluid is drawn from a higher section to a lower section by gravity and atmospheric pressure.
Soffit	The top of the inside of a pipe.
Surcharge	Pipelines surcharge when the wastewater collected is greater than the capacity of the pipe to carry the flow. This results in the surface of the wastewater in manholes rising above the top of the sewer pipe and the pipeline is then under pressure.
Surge	A rapid change of pressure resulting from flow fluctuations over a short period of time
Transmission wastewater	Pipe collecting Wastewater from a number of smaller sewers and conveying it over long distances for pumping or treatment.
Treatment (plant)	Wastewater treatment that receives wastewater and remove contaminants through mechanical, chemical and biological processes.
Tunnel	An underground passage for conveyance of wastewater, vehicles piping or conduit.
Valve	A mechanical device used for regulating flow and / or pressure. Examples include isolation, air release and control valves.

Wet well	Chamber in which wastewater is collected, prior to pump station.

Acronyms

CAD	Computer aided design
CLS	Cement (mortar) lined steel [pipe]
De	External diameter
DI	Ductile iron
DN	Nominal diameter
ESF	Engineering standards framework
FD	Functional description
GIS	Geospatial information system
GRP/FRP	Glass fibre reinforce pipe
ha	Hectare
kg	Kilogram
kN	Kilo Newton
kPa	Kilo Pascal
L	Litre
p/ha	persons per hectare
l/p/d	Litres per person per day
l/s	Litre per second
m	Metre
m^2	Metre square
m^3	Cubic Metre
MDD	Maximum daily demand
mm	Millimetre
NB	Nominal bore
O&M	Operations and Maintenance
Pdf	Portable document format (Adobe Acrobat)
PE	Polyethylene

ppb	Parts per billion
PVC	Polyvinyl chloride pipe
RCRRJ	Reinforced concrete rubber ring jointed (pipe)
sec	seconds
SCADA	Supervisory control and data acquisition – A control system used for alarm monitoring, control and data collection
SN	Nominal stiffness
SoP	Standard operating procedure
UO/DO	Meter upstream/downstream irregularity tolerance

1. Preamble and general design requirements

1.1 Introduction

1.1.1 Purpose

This standard sets out the design principles for Watercare's wastewater pipes larger than 300mm internal diameter including transmission pipelines. Linear transmission pipelines are bulk systems that collect wastewater from the local network. Transmission pipelines include wastewater mains that convey sewage from the collective residential or commercial zone to the treatment plants, and from treatment facilities to outfalls. The purpose of this design standard is to define the design requirements that is appropriate for the size, pressure and structural complexity of these linear assets. Transmission assets are typically constructed through Watercare's infrastructure projects.

Local wastewater network assets shall be designed and constructed in compliance with the Auckland Code of Practice for Land Development and Subdivision, Chapters 5, and are limited to a maximum internal diameter of 300mm. Developers are referred to this standard for sizes over 300mm and through early consultation with Watercare to establish the criticality and suitable standard associated with larger infrastructure.

Where smaller infrastructure is directly associated with a wastewater transmission system, it must be designed and constructed to the transmission standards due to the criticality of the infrastructure it is connected to. For example, a wastewater system that transitions between a satellite manhole and a transmission manhole must meet the same standards to ensure compatibility, reliability and performance within the larger transmission network.

Table 1.1*: Watercare standards reference for pipeline design*

Document to be referenced when designing	Type of pipeline
Code of Practice for Land Development Based on NZS 4404 and for local network applications	• Local gravity networks up to and including 300mm internal diameter • Local pressure networks up to and including 300mm internal diameter
Design Principles for Pipeline Systems Over 300mm Diameter (this document)	• Local networks larger than 300mm internal diameter • Transmission pipelines (gravity and pressure) including scour valve pipework • Pipework that transitions between satellite manholes and transmission manholes • Pipework at treatment plants

This standard covers the pipeline design standards that include considerations for:

- Criticality and resilience
- Hydraulic design
- Location, layout and clearances of pipelines and associated infrastructure
- Pipe structural design
- Facilities in linear systems e.g. dry and wet chambers

This standard excludes specific requirements for:

- Pump stations
- Treatment plants and processes
- Structural design of associated structures such as bridges or buildings that are covered by the New Zealand Building Act
- Electrical and control/automation design

1.1.2 'Must' versus 'Shall' versus 'Will'

Where the verbs must, shall and will (or its past tense forms) are used they describe a requirement for compliance with the statement or context in which it is used.

'Shall' and 'must' expresses a mandatory condition or action. 'Will' is used to prescribe a performance outcome or intent.

1.2 Standard documents overview

1.2.1 Relationship of Watercare standards

Watercare standards comprise of codes of practices, design standards, standard design drawings, construction standards, asset and material standards, and guidance notes.

Watercare standards define requirements additional to nominated national standards, international standards and industry best practice, and in some cases exceed legislative requirements, to accomplish long term operability and good asset management practices to benefit our customers.

1.2.2 Design Standards

The design standard sets a level of design for particular types of infrastructure based on operational area and associated risk. The design standards provide the minimum criteria for:

- Establishing standard design drawings
- Interface design between standard drawings and specific design
- Establishing the correct sizing of components to meet the baseline parameters of the standard drawings.
- The basis for developing specific designs.

1.2.3 Design drawings

Standard design drawings support the requirements of the design standards. Minimum and maximum criteria are set, and specific standard details are shown. Standard design drawings must not be amended.

1.2.4 Asset and material standards

Asset standards describe the requirements for asset as-builts creation, asset numbering, asset capture, production of operational manuals and documentation. Material standards describe the minimum compliance requirements of materials and products supplied for asset acceptance. Often selected materials will have limitations of applicability and requirements specific to the operating environment and infrastructure classification. Additional requirements may be specified based on a specific design.

1.2.5 Construction standards

Construction standards prescribe the methods and requirements for workmanship to be employed when constructing works in accordance with the design requirements, standard drawings and bespoke designs. To achieve the best outcome the construction requirements, focus on proven methods and best practice to ensure quality is maintained to achieve the design life of infrastructure, maintainability, health and safety and environmental requirements are met. Where construction standards are used or referred to in contracts they form part of the specification of the contract.

1.2.6 Project specific specifications (particular specifications)

These specifications identify mandatory or site/project specific requirements that are not covered by the above.

1.2.7 Design-build projects

Design-build projects (also known as design & construct) shall follow the minimum requirements set out in all the above standards.

1.3 Quality control and quality assurance

1.3.1 Dispensations

Any departure from the standards for the works shall not compromise quality, whole of life performance, safety, operation and maintenance, and regulatory requirements including health and safety and environmental requirements. Any proposed departure shall be evaluated by completing an Application for Dispensation from / relating to the applicable standard and by demonstrating that the departure complies with the requirements and applicable certification by providing proof of quality documentation.

1.4 Materials

1.4.1 Material standards

Materials shall include all equipment, machinery, components, or products used to complete the works.

All materials necessary for the work shall be supplied in accordance with Watercare's Material Supply Standard. Materials shall be new and suitable for their intended purpose and performance requirements.

Machinery and equipment shall be in a good, maintained condition and safe.

1.4.2 Recycled and reused materials

Recycled material and material reuse shall not be accepted unless beneficial circular resources are quantified and specifically approved by Watercare.

1.5 Asset information

Asset information shall be progressively captured and supplied in accordance with the requirements of Watercare's asset recording standards. These standards shall be followed for new, upgraded or decommissioned assets.

1.6 Design requirement exemptions

The following projects are typically excluded from design work:

a) Installation or replacement of like-for-like valves and equipment with components that are fully compliant with Watercare's Material Supply Standard and designed to handle flow and pressure conditions typical of wastewater systems, including gravity or pumped systems.

b) Repair of a system component or replacing it with a similar Watercare approved component of the same operational capacity as described in the original design, provided no significant changes in material specifications or operational requirements necessitate design updates, refer to Note 1.

c) Maintaining corrosion protection on facilities unless a new corrosion protection system is proposed, refer to Note 2.

Note 1: Where changes in material specifications over time could impact the compatibility or performance of the component, specific design considerations in line with current standards may be required.

Note 2: Maintenance of cathodic protection systems must also adhere to the relevant cathodic protection standards. This ensures compliance and alignment with best practices, even when the work involves routine maintenance rather than the installation of a new system.

To qualify for the design exemption the works must be reviewed by the appropriate Watercare controller.

Where materials or equipment deviates from Watercare's Materials Supply Standard, an Application for Dispensation shall be prepared and assessed by Watercare's technical governance group.

1.7 Referenced standards

This standard must be read in conjunction with the Watercare, national and international standards listed below. Where conflict or ambiguity exists, this standard shall take precedence. Where there is conflict between referenced standards, the standard with more rigorous performance requirements shall take precedence.

1.7.1 Watercare standards

- DP-09 Electrical design standard
- DP - 10 Safety in Design guide
- ESF-500-STD-401 – General plant layout and equipment selection
- CG - General civil construction standard
- ESF-600-STD-701 - General mechanical construction standard
- ESF-600-STD-206 – General requirements for the installation of lining systems
- ESF-600-STD-207 – CIPP-Performance specification guideline
- ESF-600-STD-208 – Spiral wound lining-Performance specification guideline
- ESF-600-STD-209 – Slip lining - Performance specification guideline
- ESF-600-STD-210 – Fold and form-Performance specification guideline
- ESF-600-STD-211 – Pipe segment lining-Performance specification guidelineESF-500-STD-601 - Material supply standard
- ESF-500-STD-502 - Watercare CAD manual
- AI - Data and Asset Information standard
- ESF-700-STD-801 - Code of Practice for commissioning
- ESF-500-STD-704 – Cathodic protection standard

1.7.2 Watercare drawings

- ESF-500-FOR-203 (DW05) - Access structure drawings for wastewater infrastructure
- DW07 - Access structures general drawings for public and non-public areas
- ESF-500-FOR-204 (DW08) - Pipelines for wastewater greater than 300mm diameter
- ESF-500-FOR-205 (DW09) - Wastewater manhole drawing set for pipelines 375mm and greater

1.7.3 National and international standards

- NZS 1170 Structural design actions
  - Part 5 Earthquake actions – New Zealand
  - Part 5 Supp 1 Earthquake actions – New Zealand – Commentary
- AS/NZS 4219 Seismic performance of engineering systems in buildings
- AS/NZS 2566 Buried flexible pipelines
  - Part 1 Structural design
  - Part 1 Supp 1 Structural design – Commentary
- AS/NZS 2566 Buried flexible pipelines, Part 2: Installation
- AS/NZS 2033 Installation of polyethylene pipe systems

- AS/NZS 3725 Design for installation of buried concrete pipes
- AS1657 Fixed platforms, walkways, stairways and ladders. Design, construction and installation
- AS/NZS 5131 Structural steelwork – Fabrication and erection
- AS/NZS 4853 Electrical hazard on metallic pipelines
- AS/NZS 2832.1 Cathodic protection of metals. Pipes and cables
- AS/NZS 2832.2 Cathodic protection of metals Part 2: Compact buried structures

1.7.4 Other publications

- American Lifelines Alliance, 2005. Seismic Guidelines for Water Pipelines
- American Water Works Association, M11 Steel pipe – A guide for design and installation, 5th Ed.
- CPAA, Concrete pipe association of Australia, 2012. Hydraulics of precast Concrete conduits
- CPAA, Concrete pipe association of Australia, 2013. Jacking design guidelines
- Gumbel, J.E and Wilson J, 1981. Interactive design of buried flexible pipes – a fresh approach from basic principles, V14 No.4
- Menon, E Shashi, 2015. Transmission pipeline calculations and simulations manualMoore, I.D, 1993. Structural design of profiled polyethylene pipe
- Mott, R L, 1994. Applied fluid Mechanics, 4th Ed.
- New Zealand National Society for Earthquake Engineering, 2009. Seismic Design of Storage Tanks
- NICEE, 2007. Guidelines for Seismic Design of Buried Pipelines
- NPCA, National Precast Concrete Association (USA), Manhole sizing recommendations
- Opus International Consultants, Water NZ, 2017. Underground Utilities – Seismic assessment and design guidelines
- PIPA POP001: Electrofusion jointing of PE pipes and fittings for pressure applications
- PIPA POP003: Butt fusion of PE pipes and fittings – recommended parameters and practices
- PIPA POP007: Flanged joints for polyethylene (PE) pipes
- PIPA POP010A: Part 1 – Polyethylene pressure pipes design for dynamic stresses
- Roberts, R, New Zealand Geotechnical Society, 2017, New Zealand Ground investigation specification, Volume 0, 1, 2 and 3
- SteelMains: Sintakote Steel Pipeline Systems - Design Manual
- SteelMains: Sintakote Steel Pipeline Systems – Handling and Installation

- Van Vuuren, S.J. & van Dijk, M, 2011. Waterborne Sanitation Design Guide. Water Research Commission. TT 481/11.
- WSA 201: Manual for selection and application of protective coatings
- WSA TN-06: Guidelines for the use of cement mortar linings in sewer applications

1.8 Material selection guidance

Material selection shall be completed by the designer on the following principles:

a) Feasible materials shall be shortlisted based on their limitations of use to ensure reliability, future maintenance and the cost of repair is kept to a minimum. The consideration of technical advantages shall only be taken on the shortlisted materials. Function and maintainability shall take precedence.

b) For pressure mains, all pipes and fittings must have a minimum pressure class of PN16. For gravity transmission pipes, a minimum stiffness rating of SN16 is required (unless specified lower) to ensure structural integrity against external loads and internal conditions. The selected material shall be fit for purpose and submitted to Watercare for approval before commencing with detailed design. Refer to Watercare's Material Supply Standard for accepted materials and the expected service life of assets.

c) As part of the design output, the designer shall complete the procurement schedules for the products and identify any design specific requirements over the minimum requirements stated by Watercare's Material Supply standard. In addition to this, material selection shall take into account the considerations listed in Table 1.2 below.

d) Pipeline materials selection should be carefully considered to ensure adequate strength and resilience, enabling the asset to behave in the manner for which it is designed for and for the duration of its expected service life. Materials selection process shall consider the pressure rating, structural behaviour, operational regimes, environmental setting, installation methods and asset criticality.

e) The asset criticality assessment of the proposed installation shall be assessed in conjunction with Watercare and shall consider as a minimum: operating pressures, risk profile, loss effect, network redundancy and operability

***Table1.2**: Material selection requirements for design compliance*

Pressure pipelines										
Pipe Material	**Minimum Pressure/stiffness rating/Class**	**Acceptable sizes**	**Acceptable internal lining**	**Acceptable external lining**	**Installation techniques**	**Acceptable jointing methods**	**Other considerations**			**Applicable asset categories**
							Cathodic Protection	**Ground movement**	**Contaminated ground**	
Mild Steel (CLS)	PN16 (Can also be considered for gravity applications where pipe bridges are required)	DN 300 to DN 2000 [a]	H^2S resistant mortar lining (CAC) – Also refer WSA TN-06 Epoxy lining (refer to WSL coatings) Polyethylene lining (high resistance to corrosive environment)	Fusion bonded polyethylene coating to AS 4321 Tape wraps[b]	Open trench Pipe bridges	Welded Flanged	Shall be considered where: Pipes cross water bodies Corrosive / acidic soils Locations susceptible to stray currents or in the vicinity of power lines	Welded joints or Sintalock joint with weld, further details to be specified in design criteria	Suitable for contaminated ground conditions (highly acidic soils should be confirmed with the manufacturer), specific external lining should be considered in design criteria, should be treated case by case	Critical Essential lifeline Pipe bridges
Polyethylene	PN16	DN OD) 355 to 1000	N/A	N/A	Open Trench or HDD	Butt welded (preferred) Stub flanged with backing ring Mechanical end-restraint joint [c] Electrofusion coupling [c]	N/A	Welded joints can accommodate ground movement	Ok for acidic ground conditions	Low Moderate Critical Essential Life-line
GRP	PN16	DN300 to above [c] (case by case)	N/A	N/A	Open trench and trenchless methods (e.g., slip lining)	Coupling with rubber rings, adhesive bonded joints, flanged joints	N/A	Proper bedding and backfilling required with flexible joints	Highly resistant to chemicals, making GRP suitable for installation in contaminated soils. For highly abrasive or aggressive installations, a factory-applied abrasion-resistant coating may be added.	Critical Essential Lifeline

Table1.2: Material selection requirements for design compliance (continued)

Gravity pipelines										
Pipe Material	**Minimum Pressure/stiffness rating/Class**	**Acceptable sizes**	**Acceptable internal lining**	**Acceptable external lining**	**Installation techniques**	**Acceptable jointing methods**	**Other considerations**			**Applicable asset categories**
							Cathodic Protection	**Ground movement**	**Contaminated ground**	
Concrete	Class 4	DN 525 to DN 3050	Polyethylene lining Calcium Aluminate Cement (CAC) for highly acidic environment	Not typically required, however the following can be considered for highly corrosive environments: bitumen coating, polyethylene coating / sleeve	Open trench or via trenchless methods (e.g., jacking or microtunneling)	Spigot / Socket joints, Rubber ring joints,	Not typically required unless reinforced with steel exposed to corrosive environments. Coatings and sacrificial anodes may be used for protection.	Proper bedding and backfilling required with flexible joints to accommodate minor ground shifts.	Needs protective coatings (e.g., PE or CAC linings) to resist chemical corrosion, especially in acidic conditions or exposure to sulphates.	Critical Essential lifeline
Polyethylene (including PKS profile pipes)	SN16	DN 355, 450	N/A	N/A	Open Trench	Butt welded Flanged with backing ring Electrofusion coupling [c] Mechanical end-restraint joint [c] Spigot / Socket joints, Rubber ring joints,	N/A	Welded joints can accommodate ground movement	Ok for acidic ground conditions, but should not be used where hydrocarbons / organic compounds are present	Low Moderate
GRP	SN10	DN300 to above [c]	N/A	N/A	Open trench and trenchless methods (e.g., pipe jacking or slip lining)	Coupling with rubber rings, adhesive bonded joints, flanged joints	N/A	Proper bedding and backfilling required with flexible joints	Highly resistant to chemicals, making GRP suitable for installation in contaminated soils. For highly abrasive or aggressive installations, a factory-applied abrasion-resistant coating may be added.	Critical Essential Lifeline

Notes:

(a) Refer to Watercare's Material Supply Standard for standardised pipe sizes. Also note smaller sizes may be applicable on bypass configurations.
(b) Acceptable tape coating methods may be used for bends or joint repairs where heat shrink sleeves are not considered practical.
(c) Requires approval from Watercare

In cases of significant differential settlement or ground movement, appropriate considerations and measures must be specified to address potential impacts.

1.9 Criticality and infrastructure flexibility principles

1.9.1 Design life

All pipeline systems and associated structures are to provide a 100-year service life within an acceptable level of service (quality and capacity of service) and maintenance considerations. Some components may require maintenance or intervention before the 100-year service life, refer to Watercare's Material Supply Standard for detailed design life expectancies for various asset types. These elements must be included in the assessed lifecycle cost and sustainability evaluation of the system. A specific design must be an amenable proposal compared to alternative design options.

Note: *Further information on life cycle cost and optimal point of replacement can be found in Watercare's Asset Lifecycle Framework.*

1.9.2 Function classes and criticality

1.9.2.1 Seismic displacement for pipeline design

The designer shall use commonly accepted analysis methods, as outlined in the following New Zealand guidelines, for project-specific assessments:

(a) **Fault Offset** – Fault rupture hazards can be assessed in accordance with ***Underground Utilities – Seismic Assessment and Design Guidelines*** (Opus, 2017)

(b) **Liquefaction** – Liquefaction hazards and liquefaction-induced PGD can be assessed in accordance with ***Earthquake Geotechnical Engineering Practice Module 3. Identification, Assessment and mitigation of liquefaction hazards*** (MBIE & NZGS, 2021).

(c) **Slope Movement / Landslide** – The Newmark sliding block method can be used for estimating PGD of slope instability in accordance with ***Bridge Manual (SP/M/022) Third Edition, Amendment 4*** (Waka Kotahi, 2022).

Table 1.3*: Applicable Design Reference for Seismic Permanent Ground Displacement*

<table>
<tr><th colspan="2" rowspan="2">Pipe function class</th><th rowspan="2">Description</th><th rowspan="2">Annual probability of exceedance (APE) for the ultimate limit state
(100-year design life)
NZS 1170.0:2002</th><th colspan="3">Applicable Design Reference for Seismic Permanent Ground Displacement</th></tr>
<tr><th>Fault Offset</th><th>Liquefaction</th><th>Slope movement /Landslide</th></tr>
<tr><td>1</td><td>Low</td><td>Pipework in the local network area that service areas of no or limited economic impact. Post event repairs can be extended for a significant time.</td><td>1/250</td><td rowspan="2">(a)</td><td rowspan="2">(b)</td><td rowspan="2">(c)</td></tr>
<tr><td>2</td><td>Moderate</td><td>Common pipework in the Transmission networks, or Local Network mains larger than 150mm</td><td>1/1000</td></tr>
</table>

Pipe function class		Description	Annual probability of exceedance (APE) for the ultimate limit state (100-year design life) NZS 1170.0:2002	Applicable Design Reference for Seismic Permanent Ground Displacement		
				Fault Offset	Liquefaction	Slope movement /Landslide
		diameter, that if lost would result in unsatisfactory service disruption for 12 to 24 hours causing moderate economic impact.				
3	Critical	Pipelines servicing larger numbers of customers (>10,000 people) that if lost causes significant economic impact or substantial hazard to human life, the natural environment and properties.	1/2500			
4	Essential lifeline	Pipelines that are essential to maintain service post natural disaster or man-made mishap and are intended to remain in service.	1/2500			

Accepted reference documents for analysis:
(a) Underground Utilities – Seismic Assessment and Design Guidelines (Opus, 2017)
(b) Earthquake Geotechnical Engineering Practice Module 3. Identification, Assessment and mitigation of liquefaction hazards (MBIE & NZGS, 2021)
(c) Bridge Manual (SP/M/022) Third Edition, Amendment 4 (Waka Kotahi, 2022)

Note: *Pipelines with multi-use functionality should be classed as type 4. Pipelines that branch off a higher importance level pipe shall be classed at the same importance level as the higher function pipe unless the branch can be demonstrated to be isolated from damage or disruption from the lower function class pipe.*

Pipelines servicing critical functional infrastructure of importance level 4 shall be class 4.e.g. hospitals.

1.9.2.2 Design factors of safety for slope stability analysis

Wherever practicable, conservative design approaches should prevail, including pipelines located outside the influence of a potentially unstable slope. Figure below illustrates how a pipeline can be positioned within a slope. Zone A indicates a slope zone that cannot achieve the minimum FoS shown in Table 1.4 for a given load case. Pipelines are expected to be located within Zone B, where the minimum FoS can be met for all of the design load cases. This implies that the pipeline will fall outside of the area prone to slipping when considering the angle of the slope, adhesion properties of the ground, and applying a FoS.

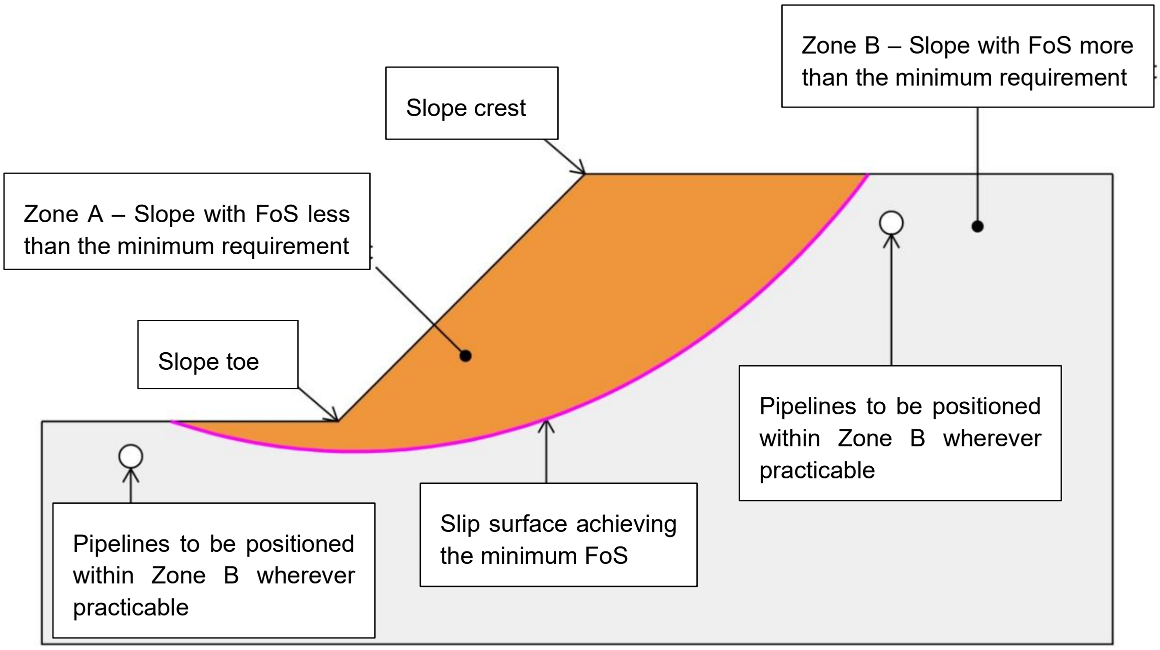


***Figure 1.1**: Pipeline Location within a Slope (a cross-section view)*

If it is not possible to avoid a potentially unstable slope, the designer should explore structural options to **eliminate or at least reduce the potential for pipeline damage** due to slope movement, thereby achieving the necessary resilient outcome.

The **minimum acceptable factors of safety for slope stability assessment** are presented in Table 1.4. These minimum requirements have been adopted by Auckland Council (2023) and should be followed by engineers and developers for all new pipeline projects.

***Table 1.4**: Minimum FOS for slope stability assessment*

Load Case	Minimum FoS
Long term static - normal groundwater [(a), (c)]	1.5
Short term static - worst credible groundwater [(b)]	1.3
Seismic - pseudo-static seismic loading using Ultimate Limit State (ULS) Peak Ground Acceleration (PGA)	1.0, or **FoS < 1.0** and **seismic permanent ground displacements** are considered to achieve required pipeline performance. Refer to *Guidance Note – Seismic Displacement for Pipeline Design*.

***Notes for Table 1.4**:*

a. This refers to the typical annual high groundwater level during winter, which may persist for an extended period (months), the design reflecting this.

b. This represents the highest peak groundwater level that typically occurs for short, transient periods (days or weeks). However, if a lower groundwater level presents a more critical condition, this scenario should be considered the worst-case and the design adjusted accordingly.

Also refer to *Guidance Note: Factors of safety for slope stability analysis (ESF-500-GDN-301)* for more detailed information.

1.9.2.3 Manholes and chambers

Manholes and chambers shall be classified in accordance with the pipe function class that it is connected to as per Section 1.9.2. Refer to Section 4.10 for connection practices between structures and pipelines.

1.9.3 Resilience and redundancy

Resilience of linear assets is the ability of the system of components to sustain a level of service and absorb or adapt to changing conditions when there is a failure of part of the system.

Resilience shall be considered in conjunction with the pipe function class. The vulnerability assessment shall include:

- Customer criticality or requirements,
- Consequences of outages – the social, economic, environmental and reputational impact
- Location of the system i.e. proximity to potential natural hazards such as fault lines or coastal inundation areas.
- System redundancy, e.g. duplicating rising main crossing under bodies of water. Operability, e.g. spacing and frequency of valves and chambers to access the network for inspection, maintenance and future replacement. This includes accessibility to manholes.
- Maintainability of the supply chain, i.e. identification of any special equipment resources, parts or components and alternative products that could be used under emergency. Items that are not readily available shall be avoided

System reliability options may include:

- System reconfiguration and interconnectivity
- Adequate system storage
- Sufficiently spaces valves (rising mains)
- Independent power supplies, or portable power, or battery backup
- Alarming systems, interlocks and suitable manual overrides

  System reconfiguration and interconnectivity

1.9.3.1 Resilience measurements

***Table 1.5**: Assessment methods to measure vulnerability and resilience (Table based on the IIMM, 2015 example table 3.2.8).*

Dimension	Principle	Indicators	Assessment method
Technical vulnerability	Robustness	Maintenance regime i.e. preventative or run-to-failure	Audit against best practice
		Asset renewal strategy is up to date	Audit against standards
		Design standards are followed and reviewed	Audit against best practice
		Reconfiguration capacity in the network system	Audit / system modelling
		Condition rating of exiting asset/system	Audit
	Redundancy	Supply of backup equipment/components are identified, and suppliers hold stock	Supplier audit
		System diversion and contingency plans are in place, kept up to date with new assets/system changes	System modelling and audit of plan
		Capacity from alternative source and system reconfiguration	System modelling
	Modularity / flexibility	Modular systems, interchangeability	Standard design / best practice
		Future allowance for upgrade, improvements and strengthening	Audit against best practice
Organisational vulnerability	Variation readiness	Qualifications and experience of staff are appropriate to roles and responsibilities	Audit
		Staff quantity and resources are adequate to deal with reactive changes	Audit
		Continual development of staff	Survey / audit
		Communication is clear with protocols in place	Survey
		Information on systems and assets such as GIS, drawings and operational manuals are readily availability	Survey / audit
		Readiness/response planning are in place and practiced	Audit
		Funding availability to effect operational variance	Audit
		Insurance are up to date and with appropriate risk cover	Audit
	Leadership / culture	Decisive decision making	Survey
		Situational awareness	Survey
		System knowledge	Survey
		Innovative thinking	Survey
		Ability to leverage on external knowledge	Survey

Dimension	Principle	Indicators	Assessment method
	External partners	Partnerships, design and service delivery arrangements	Audit
		Behavioural/communication barriers that could restrict productive solutions	Survey

1.9.3.2 Scoring

Scores are assigned based on the assessment outcome for the individual fields listed in Table 1.5 and collated up under the principle categories and rolled up as averages for technical and organisational averages.

***Table 1.6**: Score rating based on assessment.*

Score	Description
1	Poor, not adaptive, complete loss of level of service
2	Marginal, adaptive but with system constraints or reduced level of service
3	Good, adaptive
4	Excellent, very adaptive/diverse with multiple redundancy options

1.10 Asset lifecycle risk

Risk shall be assessed in accordance with the current Watercare Risk Management Framework.

1.10.1 Safety in Design guidelines

Refer to the Watercare Safety in Design standard for output requirements on linear asset systems.

Refer also to Watercare's General Plant Layout and Equipment Selection Principles (ESF-500-STD-401) for output requirements on infrastructure connected to linear systems such as wet and dry chambers.

1.10.2 Existing infrastructure interfaces

During the planning phases, high level consideration is given to the effect of integrating new infrastructure with the existing system. The baseline boundaries are set to provide the framework in which the design is to be developed, this will typically include operational needs, identifying existing infrastructure that are at risk as well as commissioning concerns. Within this framework more detail is developed during the design phase.

Replacing or connecting new infrastructure in the network will typically involve connecting or undertaking work on existing infrastructure. There are some challenges when the integrity and operational changes to the original design may impact on the new infrastructure. The designer shall include in their design the following factors and information:

a) Appraisal of original design with information, where available, provided for:

- As-built drawings
- Existing calculations
- Site testing records

- Field investigations
- Commissioning records
- Risk register
- Geotechnical reports
- Operation and Maintenance manuals
- Standard operating procedures including shutdown and continuity of operation

b) Assessment of current conditions that include:

- Operational parameters as adjusted from original design – current standard operating procedures and maintenance manuals may have been amended, or been neglected to have been updated to reflect actual operation
- Ground conditions e.g. updated ground investigation to identify changes to groundwater level that affect trench structural support and floatation design, or material selection due to soil contamination
- Adjacent infrastructure, structures and impact such as loading, support and movement
- Physical alterations to the infrastructure that deviates from the original design
- Infrastructure integrity and condition affecting the connectivity design, including site condition assessments.

c) Alterations and interface with existing infrastructure affecting:

- Floatation and settling
- Material condition
- Strengthening work to meet the new infrastructures resilience requirements
- Flexibility / interacting forces

1.11 Design alternatives and standard design detail

In some instances, the proposed infrastructure design may not be able to meet the standard design criteria. Alternative designs may need to be investigated due to site peculiarity or innovative technologies.

Alternative design proposals may be considered where:

- Watercare's standardised design is not suitable.
- Watercare's Health and Safety in design minimum standards needs to be achieved.
- The alternative design is able to demonstrate that the required performance outcomes are met.

Acceptance of an alternative design in concept does not conclude approval of any design criteria, construction technique or material selection. Specific approval must be sought during the design process.

2. Wastewater Pipeline Hydraulic Design

2.1 Scope

The hydraulic design parameters provided in this section applies to all wastewater pipeline systems larger than 300mm including transmission systems. Specific design requirements for pump stations with rising mains, treatment and process design are not covered. The hydraulic design parameters for local network wastewater pipe (typical pipe diameter ≤300mm) are given in the Wastewater Code of Practice for Land Development and Subdivision, Chapter 5.

2.2 Maximum population density

The maximum population density will be provided by Watercare.

2.3 Wastewater gravity hydraulics

2.3.1 Design flows

a) Two methods may be used for determining design dry weather and peak flows in transmission systems.

   i. The static model derives flows from projected population (or population equivalents for commercial areas) and a per capita flow rate.

   ii. The dynamic model uses these same basic figures and with a number of additional parameters.

2.3.1.1 Static Model

a) Design flows shall be based on the population and zoning for full or staged development of the catchment area to provide a first estimate of flow requirements.

Table 2.1*: Basic flow parameters*

Flow category	**Flow ratio**	**Flow rate** (l/p/d)
Yearly average flow (YAF)	-	300
Dry weather flow (DWF)	0.6 x YAF	180
Peak flow (WWF) < 40 p/ha Population > 40 p/ha	5 x DWF	900 540

Table 2.2*: Industrial zone parameters - applies where the gross area (including streets) is greater than 400 ha.*

Industry type	**Flows**	**Flow rate** (l/sec/100ha)
Light or dry industry	YAF	25
Workday average	1.4 x YAF	35
Peak flow	2 x YAF	50
Wet industry, hospitals etc.	-	Specifically assessed

2.3.1.2 *Dynamic flow model*

a) Hydraulic model

Dry weather and design peak flows for a particular pipeline or pumping station shall be confirmed by Watercare from the dynamic hydraulic model of the existing sewer network.

Greenfield areas

i. Where modelling is to be utilised for greenfield or redeveloped areas, the following parameters will be specified by Watercare:
   - Catchment runoff characteristics
   - Population density projections
   - Design storm duration
   - Infiltration provision
   - Any other relevant items

ii. Where the wastewater system has been modelled, the pipeline is to provide capacity to accommodate a five-year return storm period (or other defined period). Under this condition, pipe surcharging will be permitted provided that:
   - water levels in manholes do not rise to within one metre of the lowest manhole lid level
   - no overflows are caused in the reticulation manholes or from property services

2.3.1.3 *External flow contributions*

a) Groundwater infiltration into pipelines = 2,200 l/ha/day.

b) Manhole infiltration during peak wet weather flows: 12 l/minute/manhole.

2.3.2 Grades and Velocity

Minimum gradients are to be set by pipe diameter and minimum velocities. All three of these conditions shall be met:

***Table 2.3**: Minimum flow velocities:*

Flow condition	Minimum velocity
Average dry weather flow in early stage of operation (catchment being extended)	Exceed 0.6m/s at least once a day
Peak dry weather flow	Minimum 0.75m/s
Peak wet weather flow	Pipe full flow capacity not exceeded and maximum 3m/s

__Table 2.4__: Minimum pipe grades (Flow at 30% pipe capacity to achieve 0.6m/s)

Pipe diameter (mm)	Minimum grade (%)
375	0.24
450	0.2
525	0.15
600	0.13
≥750	0.1

2.3.2.1 Maximum pipe grade

The pipe grade for 3m/s velocity at peak wet weather flow shall not be exceeded. Pipe-full capacity shall not exceed 75% of the depth of the pipe diameter. Steeply graded pipes may require specific design to ensure the integrity of bedding and haunching materials and prevent the migration of fines along the trench alignment – refer to Section 3.2.1.2: Pipe trench dewatering.

2.3.3 Head losses

2.3.3.1 Pipelines

a) The minimum transmission pipe size shall be 375mm diameter.

b) Maximum pipe capacity of a gravity pipeline is to be taken as the pipe running full with no surcharge.

c) For partially filled gravity wastewater pipe the Colebrook-White method shall be followed.

d) The linear measure of roughness (Colebrook-White coefficient) for any gravity pipe material shall be 1.5 (x 10^{-3}) m.

e) Overflows must be designed for surcharge at 500mm head.

2.3.3.2 Manholes, bends and junctions:

a) Junctions shall be designed to reduce turbulence in the wastewater pipeline to a minimum.

   Flows must join at or below the level of average dry weather flow.

b) Changes in direction at junctions and connections must not exceed 90 degrees.

i. Head loss in bends through manholes and junctions

a) For manholes on bends or with junctions, a minimum loss of head shall be as shown in the following table. Velocity is that for the sewer flowing full, losses are shown in millimetres for angles and velocities given, for bend centreline radius ≥3. For R/d of 2, increase losses by 50%.

Table 2.5: *Head loss through manholes*

Velocity (m/s)	Bend angle				Additional for MH & junction
	0°	30°	60°	90°	
	Head loss (mm)				
0.6	0	10	20	20	10
0.9	10	10	20	20	10
1.2	10	20	20	30	10
1.4	20	20	30	30	20
1.6	20	30	40	50	20
Velocities >1.6	$0.13(v^2/2g)$	$0.19(v^2/2g)$	$0.26(v^2/2g)$	$0.32(v^2/2g)$	$2.0(v^2/2g)$

Note: this table considers energy losses for smooth benching/bends.

ii. Change in pipe grade

a) Where pipe grades are changed to a steeper grade and as a result the manhole outlet pipe size being reduced, provision shall be made for the drop of inverts:

$$\textbf{Head loss (mm)} = (1.2\ v^2_{outlet}/2g - v^2_{inlet}/2g)$$

b) For pipe grades of 7% or more, a change in slope through a manhole is not allowed unless a drop structure is used [a].

c) see section 2.3.4 below for special hydraulic conditions as a result of change in pipe grade.

[a] **Note** – drop structures are generally not preferred for transmission manholes and shall be by Watercare approval only.

2.3.4 Special hydraulic conditions

a) Where the sewer changes in size (and at junctions), pipe soffits are matched in level to maintain airflow through the pipelines, minimise corrosion and prevent air-locking.

b) Where the velocity in the sewer increases through changes in grade and particularly if the size of the sewer is decreased, the profile of the water surface at maximum flow shall be confirmed to ensure it falls below pipe soffit at top of the steeper grade. (Reference: Camp SWJ, 1946 Fair and Geyer page 407).

c) Draw-down will occur in certain circumstances e.g. above a drop manhole, or above a point where noticeable increase in velocity occurs. The velocity due to draw-down may require a drop invert.

d) A downstream manhole junction from a wastewater pipe with high velocity is susceptible to hydraulic jump (collision of fast-moving incoming flow with slow-moving fluid head). Also, steep slopes at the inlet to inverted siphons may lead to air entrapment causing periodic blow-back and damage.

Possible solutions or prevention of hydraulic jump includes:

- Reducing the pipe grade transition and allow sufficient airflow
- Change manhole to a drop structure, subject to specific design and Watercare approval
- Change pipe diameter

2.4 Wastewater inverted siphons (Depressed wastewater system)

a) Inverted siphons shall be avoided as far as practicable due to their maintenance constraints. A pipe bridge is Watercare's preferred option unless proven to be unfeasible.

b) Follow design methods described by Metcalf and Eddy (1981) and as supplemented by equations in Chow (1959) and, Viessman and Hammer (1998).

Reference:

- Chow, V. T. 1959. Open-Channel Hydraulics. McGraw-Hill, Inc.
- Metcalf and Eddy, Inc. 1981. G. Tchobanoglous, editor. Wastewater Engineering: Collection and Pumping of Wastewater. McGraw-Hill, Inc.
- Viessman, W. and M. J. Hammer. 1998. Water Supply and Pollution Control. Addison-Wesley, 6ed

c) The siphon entry structure shall be configured to assist in maintaining self-cleansing velocity within the siphon at normal flows.

d) Where flow rate is dominated by the periodic discharge from a pumping station, a single siphon barrel may be acceptable provided that there is sufficient storage at the pumping station to provide sufficient flushing flow and duration.

e) The hydraulic capacity of an inverted siphon shall never be less than the capacity of the sewer system upstream of the inverted siphon.

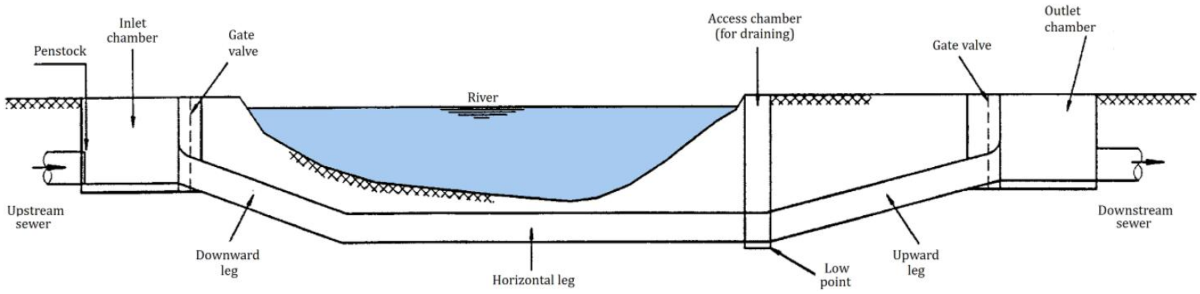


Figure 2.1: *Example configuration for an inverted siphon (Ref. Van Vuuren & Van Dijk, 2011)*

2.4.1 Flushing

a) Provide an effective means of flushing to manage build-up of sediment in the siphon. This may also provide a useful degree of flushing to the sewer downstream of the siphon.

b) Provide an internal bypass structure to guard against overflow in the event that the penstock valve fails to open for flushing. The bypass can also assist with accelerating the downstream sewer flow in the siphon before the flush is released.

2.4.2 Air pressures and ventilation

a) Provide inlet and outlet ventilation for the sewers downstream and upstream and with odour control due to the full-pipe state of the siphon.

b) Rapid changes in flow rate or water level, as during siphon flushing or rising main start-up, can cause excessive air pressures in a section of pipeline between a rising main and siphon, or between two siphons. The design shall include air pressure management and odour containment.

2.4.3 Crossing under water bodies

a) Crossing siphons under water bodies or marine areas must be provided with suitable access of minimum 300mm above the 1 in 100-year flood line and tidal areas.

3. Layout design

3.1 General

Transmission or bulk pipelines are typically installed in the road whilst local network pipelines are generally installed within the berm of the road corridor. Layout requirements for local networks are described in the Auckland Council Code of Practice for Land Development and Subdivision, Chapter 5.

3.2 Transmission pipe systems

3.2.1 Pipes

3.2.1.1 Spatial location

a) Pipes shall where practicable be buried in the road reserve and where there isn't sufficient berm space, within a traffic lane so as to minimise temporary traffic control for future maintenance and access. The alignment of the pipeline **shall avoid** so far as practically possible the positioning of manhole covers within the wheel path of vehicles.

b) Above ground pipe must be suitably coated and UV protected and be accessible for maintenance and regular visual inspection. Refer to Section 4.6.1 for pipe bridge design.

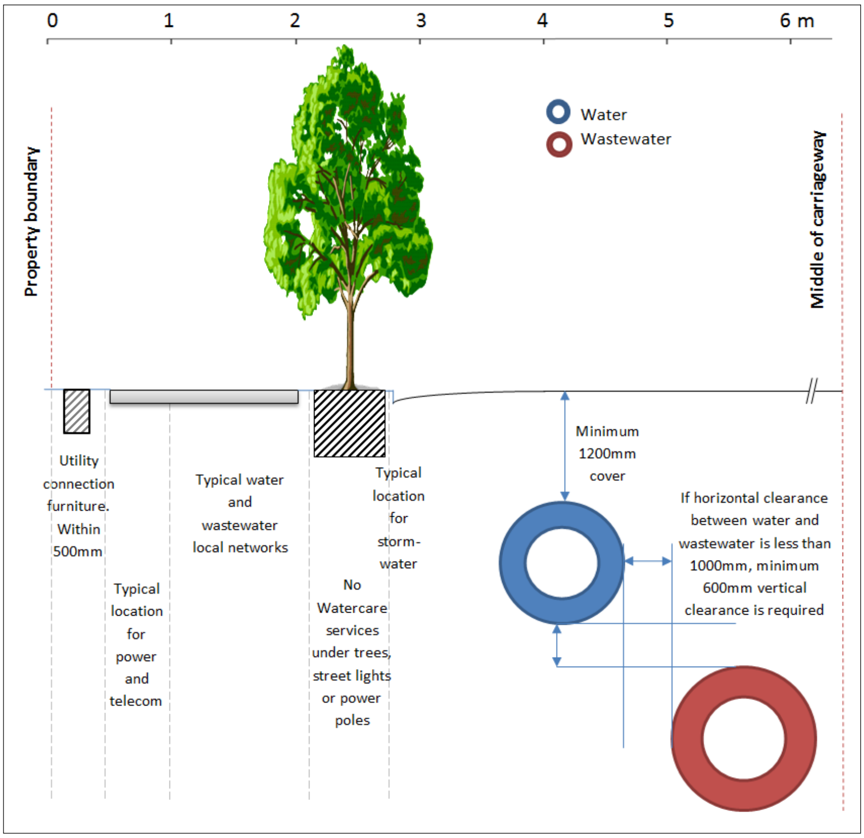


***Figure 3.1**: Spatial clearance and cover required for pipelines.*

c) Avoid private property and the need for easements.

d) Pipes shall be at a minimum finished depth of 1200mm under the carriageway. This depth may need to be increased for larger pipe diameters (typically over 800mm) to accommodate impediments such as air valves or utility services exist. The pipe depth shall also consider existing and future connections, and the designer shall prove that the design achieves the most optimum outcome, including minimum life cycle cost and carbon.

Note: *Geographical or existing infrastructure in brownfield areas may restrict the minimum depth. Suitable pipe protection methods may need to be specified, or the pipe must be located in the berm*

e) The minimum horizontal and vertical clearances from other services, shall be as listed in Table 3.1 below in respect of the largest service:

Table 3.1: *Minimum clearances from other services*

External pipe diameter (mm)	Minimum horizontal clear spacing (mm)	Minimum vertical clear spacing (mm)
≥63 to ≤375	300	150
>375 to ≤600	600	500
>600 to ≤800	1000	500
>800	1000 + De/4	500

f) The minimum clearance for transmission pipe from any type of structure shall be 1500mm (unless connecting to the structure, see “Pipe through structures”). Critical mains may require greater separation.

Note: *Contact Watercare for assistance on a specific main or structure’s criticality classification*

g) The pipe shall be isolated from any structural loading influence or installed outside the zone of influence.

h) Water and wastewater shall be vertically separated by minimum 600mm when in horizontal proximity of 1000mm or less. Wastewater **shall always be** at a lower level.

3.2.1.2 Pipe trench dewatering

a) Steep sloping pipe trenches (water draining in pipe trenches can erode the bedding material away) or where there is a high-water table could cause the surrounding areas to be drained leading to ground settlement. Under these conditions trench stops may need to be considered with suitable draining solutions.

b) Where practical, pipe trenches shall be drained to stormwater or low-lying areas. The environmental effects of long-term dewatering must be considered along with resource consent conditions.

c) Where dewatering is not practical, alternative solutions for issues such as corrosion protection, specific trench design with suitable geotextile lining, pipe anchorage for effects of hydraulic uplift during maintenance (or normal operation if gravity) must be addressed in the design.

3.2.1.3 Pipe movement and flexible joints

a) The design shall include design-actions for ground movements. Suitable locations for anchoring and flexibility shall be provided.

Note: *Also refer to pipe seismic evaluation when considering joint flexibility and their limitations, Section 4.9.*

b) Mechanical fittings shall be located with clear vertical access for maintenance, inspection or replacement. Their use should be avoided on deep mains due to access and operational challenges, unless specifically justified by design.

3.2.1.4 Pipe bends

a) Gravity wastewater system horizontal changes shall be through manholes.

b) Pipe vertical bends for pressure mains may pass over, or under with a designated high or low point for drainage or ventilation where the deviation is ≥ ½ of the pipe nominal bore.

3.2.1.5 Pressure pipe ventilation

a) The pipe gradient shall be arranged to minimise hollows and high points. The pipe shall, wherever possible, rise continuously from the pumping station and terminate at its upper end into the receiving structure.

b) The pipe shall not be without grade. The grade shall be a minimum of 1 in 500 to a ventilation point.

c) Dual action (air release and vacuum break) air release valves shall be installed on high points. Refer to Section 3.2.3 for air release valve details.

3.2.1.6 Gravity pipe ventilation

a) Vented manholes shall facilitate the flow of air through the pipeline resulting from rising and falling levels.

b) Air extraction shall be at downstream ends of the system at:

- Pumping stations
- Siphon inlet
- Discharge manholes
- Drop structures
- Strategic manholes depending on the age of the wastewater

c) Air flow may be active or passive and must be designed to maintain air flow in the pipe.

d) Pipe ventilation shall be minimum 0.2m/s at 75% cross sectional area.

e) Refer to Section 3.4 for ventilation odour control.

3.2.1.7 Pipe drainage points

a) Wastewater pressure pipe drainage shall be into a manhole for removal by sucker truck.

b) Access to drainage valves shall where practicable be off the carriageway, in the berm.

3.2.1.8 Pipe scour points

a) Scour points shall be designed for effective drainage of the pipeline at suitable low points. High-velocity flushing is not required for wastewater pressure mains.

b) Wastewater pressure pipe drainage shall be into a manhole for removal by sucker truck.

Access to scour valves shall be off the carriageway.

3.2.1.9 Connection to local networks

a) The transition from the local gravity wastewater network to the transmission system shall be via a satellite manhole which ties into a transmission manhole. The soffit of the incoming pipe shall be aligned with the soffit of the transmission pipe.

b) Connecting a local network pipe to a transmission wastewater gravity or pressure system is not allowed.

3.2.1.10 Electrical induction hazard with metallic pipes

a) Electrical hazard analysis to AS/NZS4853 (refer to Watercare Electrical design standard for approved evaluators) must be completed for all metallic pipelines that:

- Are longer than 300m, and
- Have high voltage cables, within 150m of the pipeline(s) for a total aggregate distance of 300m or longer, or
- Have high voltage system pylons, transformer earth beds or similar earth discharge structures within 50m of a pipeline chamber or exposed pipe section, or
- Have high voltage system pylons, transformer earth beds or similar earth discharge points within 10m of the pipeline.

b) The design solution should address pipe location to prevent electrical interference or the installation of a permanent zinc reference cell with interference test point.

c) Refer to Section 4.11.1.3 for cathodic protection.

3.2.2 Isolation valves for pressure systems

Mainline isolation (line valves) are typically installed at pump stations, and other locations dependent on project specific requirements. These valves facilitate operational control, maintenance, and emergency response by enabling the isolation of pipeline sections without disrupting the entire system..

a) Isolation valves shall as far as practicable be located off carriageways, clear of intersections and not obstruct property access.

b) Isolation valves are installed in dry chambers and above ground buildings. The installation location must be demonstrated to be the best practicable option with consideration to:

- The means of access for maintenance and replacement of the complete unit or maintainable parts such as gearboxes
- The type of valve being installed. Typically gate valves are best suited for buried applications
- The whole of life cost benefit for the proposed installation method

c) Handwheels shall be 300mm clear of obstacles.

d) All isolation valves shall be metal-seated gate valves per Watercare's Material Supply Standard.

3.2.3 Air release valves

a) Air valves shall be installed in dry chambers or by specific requirement be surface mounted.

b) Air valves shall be fitted with an isolation valve to allow the valve to be removed or replaced without isolating the main.

c) The air release valve vent shall be above the groundwater and 100-year flood levels. Connecting direct to a surface vent may be required or must be vented through a flood-safe valve.

d) Where air valves are installed underground within chambers the lid arrangement typically does not allow for adequate air flow rate. An air vent is required to be installed in the back berm and connected to the underground air valve chamber.

e) Where the flow velocity in the pipeline is more than 2.4 m/s the air valve design shall take into account an anti-slam device/feature.

f) Appropriate treatment of the outlet air is required to reduce hydrogen sulphide to less than 1ppb.

3.3 Dry chambers

Dry chambers typically house equipment and valves that require frequent maintenance and operational access for inspection. These spaces should be limited as far as practicable by considering surface or remote operation and locating equipment for surface/walk-in access. Introducing confined spaces must be avoided. Where underground dry chambers are unavoidable the following shall be considered:

3.3.1.1 Location

a) Chambers shall be clear of the carriageway and allow adequate space where future road widening is a possibility.

b) Dry chambers shall be located in public property to avoid easements.

c) Allow for chamber sump drainage outfall.

d) The number of chambers should be minimised. Where practicable a single chamber shall be used.

e) Air valves shall not be installed in dry chambers with other equipment unless it can be remotely isolated and has a direct sealed connection venting outside the chamber.

f) Chambers shall be designed for HN-HO-72 bridge loading as per NZTA-Bridge Manual SP/M/22 regardless of location.

3.3.1.2 Overall size

a) The overall size shall be sufficient for safe installation, removal and operation of all the equipment.

b) Chamber lids shall be designed to be removable. Panel lift size and arrangement shall be adequate for the size and location of key equipment to be removed from the chamber but limited by access and weight constraints of readily available cranes to remove the panels when needed.

c) Dry chambers larger than 2m square or 2,5m diameter shall be provided with minimum two full sized operator access lids strategically placed at opposite points of the chamber. Smaller chambers shall allow for minimum one full sized operator access and a secondary lid for forced ventilation. Where a secondary access for ventilation cannot be provided the complete chamber lid shall be removable.

3.3.1.3 Sealing requirements

a) Chambers shall be designed watertight to the full buried depth. Lids shall be sealed against surface water ingress.

b) Installing chambers in flood prone or low-lying areas subjected to surface water shall be avoided, however where approved to be installed in overland flow paths, chambers shall be designed to withstand a minimum 1 metre head above the 100-year flood level.

3.3.1.4 Access and platforms

a) The chamber access shall have a minimum clear opening of 600mm diameter - a 600mm cylinder should be able to pass through a square lid.

b) The access design shall include working at height requirements for controlling access to the opened access lid, such as integrated safety barriers or a safety grille.

c) Ladders and landings shall comply with AS1657 for design, construction and layout. Stairways are preferred over ladders.

d) Access platforms shall be provided to allow optimal operation position and clearances. For large diameter manholes / chamber “half-diameter” access platforms may be considered to facilitate lifting of equipment through chamber, however the necessary fall protection and design should be applied for safe working conditions.

e) Working areas around equipment and the access or thoroughfare to the equipment shall provide minimum 1000mm diameter horizontal clearance to a minimum height of 1900mm.

f) The minimum internal height of dry chambers shall be 2150mm.

g) Access shall be lockable with a specific key or lock down mechanism for the operational area (refer standard drawing ESF-500-FOR-203 / DW05).

3.3.1.5 Internal clearances around equipment

a) Pipe through a chamber may be positioned off-centre to reduce the overall size of the chamber.

b) The non-access sides for off-set chambers shall have a minimum of 500mm clearance to the chamber wall at any point. No equipment that requires operation shall be placed on this side.

c) A clearance of 500mm shall be allowed between the nearest fitting and pipe train and to the chamber wall.

d) Handwheels shall be located at an operating height of between 900mm and 1300mm. Platforms, multiple levels, valve extensions and orientation (valve specification permitting) may be used to achieve the correct height.

e) Instrumentation requiring visual inspection or readings shall be placed at 1200mm to 1500mm from the operator standing platform. The location shall not require the operator to lean over any other equipment or platform railing.

f) A minimum clearance between the base of the chamber and the bottom of the pipe shall be 600mm unless specified otherwise on Watercare's standard drawings.

g) Equipment requiring vertical lift for maintenance or replacement shall not have any other equipment placed above it. Equipment or components weighing more than 15kg shall not be positioned for horizontal or angular lift during maintenance or replacement.

3.3.1.6 Ancillary components

a) Access chambers should as far as practicable be situated outside overland flood areas. Dry chambers shall be ordinarily sealed for groundwater ingress and overland flooding. Additionally, a sump drain shall be provided. In low lying areas the sump may need to be equipped with drainage pump. Valves and equipment inside chambers shall be designed with the necessary structural support, preventing the transfer of stress to adjacent flanged assemblies and pipework.

3.3.2 Manholes

Manholes are typically used for gravity wastewater applications where:

- Directional changes or changes in gradient occur.
- There are changes in pipe diameter.
- At pipe junctions (pipes converging to the same manhole).
- Maintenance access is required.
- A pressure main is discharged to the gravity network.
- A pressure main is scoured within the manhole structure.

Manholes are not ordinarily accessed for operation. Any equipment installed in these environments should be avoided and be remotely accessible to minimise the need to access into the manhole.

Note: *The clearances around equipment for operation and access may require the typical size of a manhole to be increased.*

3.3.2.1 Location

a) Manholes shall be located clear of:

   i. gutters

   ii. open drains

   iii. low points

   iv. access to property

   v. mainstream of traffic

b) Manholes located on private property must be avoided. Adequate access shall be maintained for future maintenance, large scale rehabilitation and future connection works. The **minimum clearance** around any manhole shall be **horizontally 1m and vertically 5m**.

c) Manholes shall be clear of any structural zone of influence (typical 45^{o}). Design for consideration inside the zone of influence must be demonstrated by structural analysis not to place influence on the adjacent structure or manholes as well as consider future maintenance and upgrade works.

d) Manholes shall be designed for HN-HO-72 bridge loading as per NZTA-Bridge Manual SP/M/22 regardless of location.

Gravity wastewater specific requirements

   i. The distance between manholes should be maximised to reduce maintenance cost and confined spaces.

Table 3.2*: Maximum spacing between manholes.*

Pipe size	Maximum spacing
Up to 300mm diameter – local networks(typical)	*100 metres*
375 to 875mm diameter	180 metres
900mm and larger	240 metres

   ii. Spacing may be increased if additional manholes is not necessary for access

   iii. The table listed in (i). does not apply to large tunnels where access shafts are specifically designed to the structures' servicing requirements

b) Catchment boundaries to any part of a newly reticulated area will generally be defined by the natural topography. Provision shall be made for pumped flow, or flow otherwise discharged to the transmission main from adjacent areas. Full development of the catchment is to be assumed unless there is a reason for the area to remain permanently undeveloped.

c) Local network connections shall be connected via a satellite manhole – refer Section 3.2.1.9.

3.3.2.2 Overall size

a) Manholes shall be sized to meet hydraulic and capacity requirements with specific consideration to:

- Volume of discharge/containment and rate of discharge
- Energy attenuation
- Cavitation and erosion
- Hydraulic influence on pump inlets

Circular wastewater manhole sizing

a) Circular manholes shall be installed, unless specified otherwise by design.

b) Minimum manhole diameter used for transmission pipes is minimum 1500mm internal diameter.

c) Circular manholes are determined as either coincident (geometrically two points are the same point) or translated (geometric one-to-one correspondence between two set points) manholes.

d) Within the above groupings manholes are either Type A1 (pipe bends fit within the manhole diameter) or Type A2 (pipe bends extend beyond the manhole diameter). Refer below images:

- Type A1 where: $\sin\frac{\theta_p}{2} < 0.1333\ \frac{B}{D}$
-
- Type A2 where: $\sin\frac{\theta_p}{2} > 0.1333\ \frac{B}{D}$

Where:

θ_p = Channel (pipe) angle

B = Manhole internal (nominal) diameter

D = Pipe internal diameter

***Note**: Type A1 manholes are generally preferred as bespoke base designs are required for Type A2. Where Type A2 manholes are identifies, larger manhole sizes should be investigated to achieve a Type A1.*

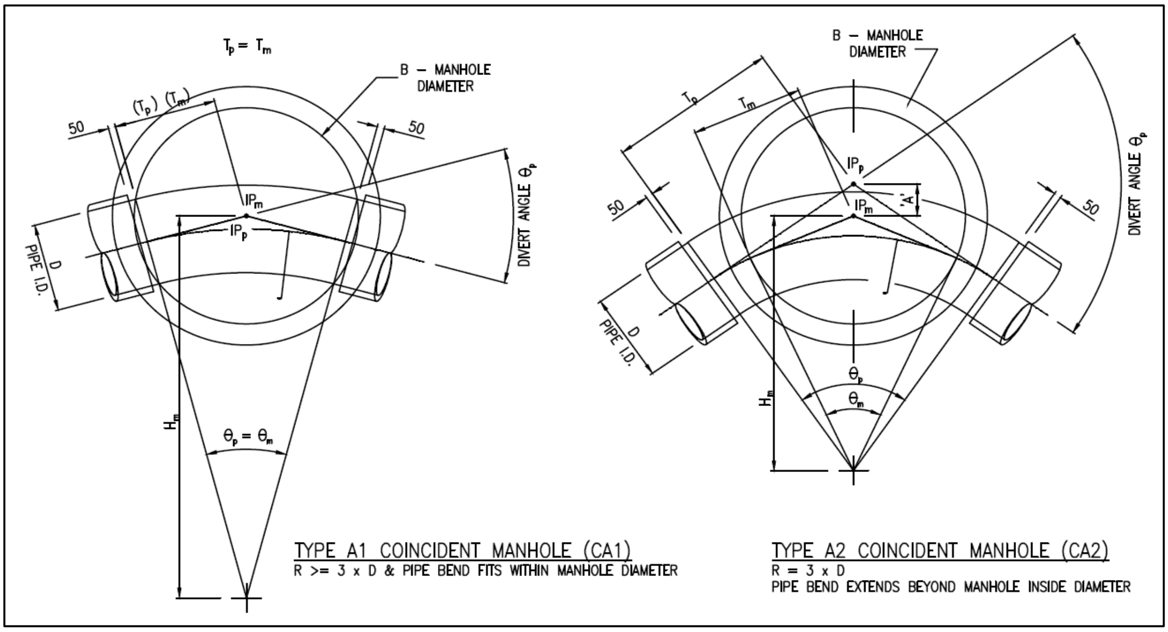


***Figure 3.2**: Coincident type manholes – geometrical layout.*

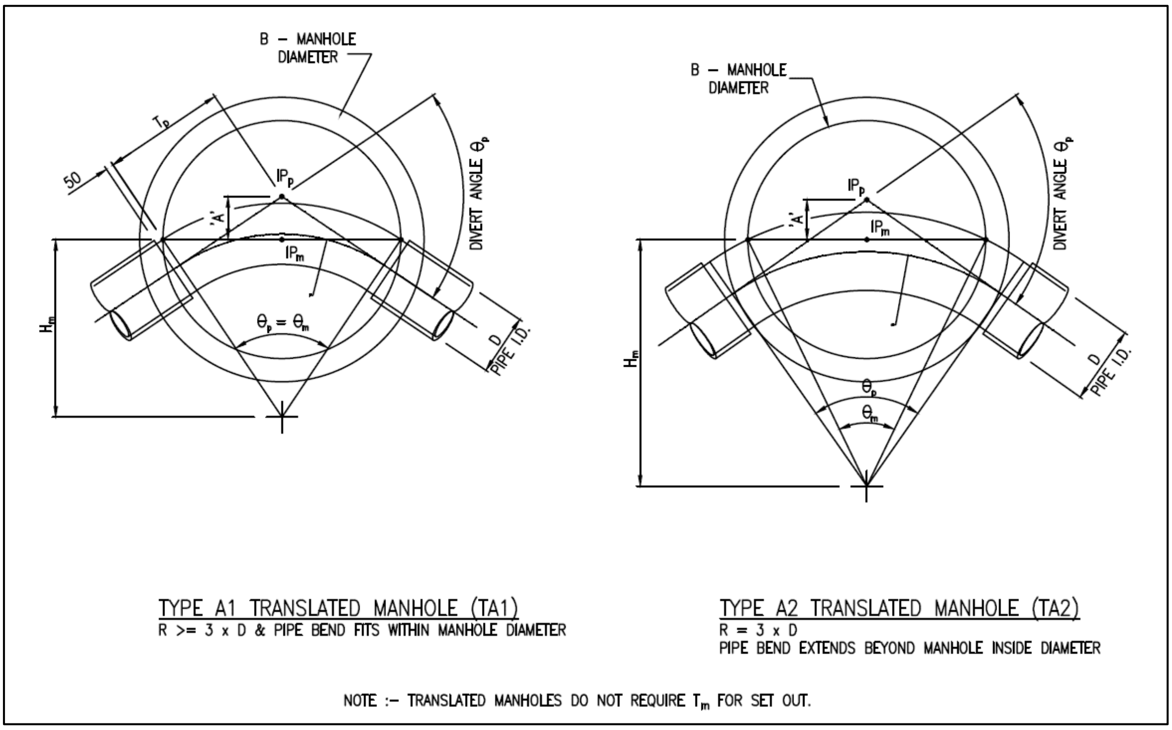


***Figure 3.3**: Translated type manholes – geometrical layout.*

__Table 3.3__: Manhole sizes for two (2) pipes.

Pipe nominal diameter[1] (mm)	Manhole minimum size, Nominal Diameter (mm)	Flow diversion angle (deg.)[2]	Channel angle (deg.)
375	1500	0-90	90-180
450	1500	0-90	90-180
525	1500	0-90	90-180
600	1500	0-90	90-180
675	1500	0-90	90-180
750	1500	0-69	111-180
750	1800	70-90	91-110
825	1500	0-73	107-180
825	1800	74-90	90-108
900	1500	0-60	120-180
900	1800	61-88	92-119
900	2050	90	90
975	1500	0-39	140-180
975	1800	79-90	101-139
975	2050	79-90	90-100
1050	1500	0-25	155-180
1050	1800	26-70	110-154
1050	2050	71-90	90-109
1200	1800	0-48	132-180
1200	2050	49-77	103-131
1200	2550	78-90	90-102
1350	2050	0-60	120-180
1350	2550	61-90	90-119
1600	2050	0-37	143-180
1600	2550	37-67	113-143
1600	3000	68-90	90-113
1800	2550	0-25	155-180
1800	3000	25-75	105-155

***Notes**:*

1. *Inlet and outlet pipe is assumed at the same pipe diameter. Where the outlet pipe is required to be larger, or smaller, the designer shall assume the manhole size to the larger pipe diameter.*
2. *This table is based on a maximum flow diversion of 90 degrees. Sharper diversions are not typically approved and requires specific design or a drop structure.*

***Table 3.4**: Manhole sizes for three (3) pipes (two inlet, one outlet).*

Pipe diameter[1] (mm)		Manhole minimum size, Nominal diameter (mm)
Pipe 1 & 2 inlet	Pipe 3 outlet	
375	450	1500
450	525	1500
525	600	1500
600	675	1500
675	750	1800
750	825	1800
825	900	1800
900	975	2050
975	1050	2050
1050	1200	2550
1200	1350	2550
1350	1600	3000
1600	1600	3000
1800	1800	-

***Notes**:*

1. *Two inlet pipes at the same diameter is assumed. Should the pipe sizes differ the inlet shall be based on the larger pipe diameter. The outlet pipe has been based on a larger pipe size. Where the outlet pipe is a larger diameter the manhole size should be based on the matching outlet pipe size.*
2. *Manhole sizing is based on the angle between pipe 1 and 3 at 180° and the second inlet at 90°. Where the angle between pipe 1 and pipe 3 is less than 180° ensure that adequate clearances are maintained.*

e) Channel offset may be selected by the engineer to provide adequate step-down space. The following limitations apply:

- The minimum chamber wall remaining between inlet and outlet must be 300mm, or 0.5x pipe diameter, whichever is greater.
- Step-down landing behind ladders shall be a minimum of 600mm.

The base design shall include prevention for hydraulic uplift (floatation). Refer to Section 4.8.

3.3.2.3 Sealing requirements

a) Manholes shall be designed watertight to full depth.

b) The interface between the concrete/manhole lid and cover and frame shall be sealed to prevent groundwater infiltration (refer drawing set ESF-500-FOR-205 / DW09).

c) Typical manholes for wastewater are required to “breath” for airflow through the gravity system. Chambers with lids Shall be located outside the extents of the 100-year overland flow path flood level, or where this cannot be avoided extend at least 300mm above this level. Where there is a reasonable risk of a manhole lid being submerged by stormwater, a sealed lid must be used. The use of bolt down manholes shall be assessed based on risk associated with the potential infiltration and exfiltration (surcharge) at the location, and possible upstream implications.

3.3.2.4 Access and platforms

a) Ladders and landings shall comply with AS1657 for design, construction and layout. Where ladders are provided it shall be extendable to a minimum of 1000mm through the manhole lid above ground level.

b) The chamber access shall have a minimum clear opening of 600mm diameter.

c) Manholes shall be fitted with a removable safety grille supported by the lid frame.

d) The access design shall include working at height requirements for controlling access to opened access lids, such as integrated safety barriers.

e) Access platforms shall be provided to allow optimal operation position and clearances at a minimum depth interval as required by AS1657. Over 15m depth, man-cages may be considered for access over ladders and platforms, depending on the site conditions and maintainability

f) Working areas around equipment and the access or thoroughfare to the equipment shall provide a minimum of 1000mm diameter horizontal clearance to a minimum height of 1900mm. In the case of drop structures, the manhole diameter may need to be increased to allow for the minimum horizontal clearance inside the manhole.

g) Access hatches excluding standard manholes shall be lockable with a specific key or lock down mechanism for the operational area.

Note: *The standard lock and key mechanism are manufactured specifically for Watercare. A 'dummy' hex lock must be provided during construction and replaced after commissioning has been completed, refer to standard drawing.*

3.3.2.5 Ancillary components

a) Ventilated systems must be design for the specific air flow and air filtration requirements. Relying on the permeability of lids and structures is not acceptable.

3.4 Odour control for wastewater systems

3.4.1 General control of septicity

a) During breakdown of wastewater in the network with a lack of oxygen, hydrogen sulphide forms. Septicity becomes problematic with long retention times and temperature increase.

b) High sulphide concentrations cause corrosion and odour issues at the pumping station, high points releasing air and rising main discharge structures. Delivery of highly septic wastewater hinders the treatment process.

Common mitigation measures include:

- Minimise retention time

- Aeration in the wet well and frequent cleaning
- Chemical dosing
- Where these remedies are uneconomical, and the main retention time cannot be reduced by sizing and pump station location, vented air treatment may be required, typically at the wet well, receiving structure and air relief valve along the rising main length, examples include: Biofilters, carbon filters, and biological scrubbers

c) The ventilation system shall be designed to provide an appropriate ventilation velocity through a treatment filter.

d) Ventilated air through a filter shall have a hydrogen sulphide concentration of less than 1ppb.

3.4.2 Carbon and mixed media filters

a) The capacity design for filter replacement frequency shall be considered site specifically for Watercare's acceptance. The frequency must be more than 12 months.

b) The designer needs to specify the inlet and outlet flow velocity as well the hydrogen sulphide concentration.

c) Suitable location for access to replace media should be allowed and consideration given to aesthetics with suitable screening design.

3.4.3 Biofilters

3.4.3.1 Timber posts and walls structures

a) Posts for the perimeter walls and any intermediate walls, and the sawn timber for the walls, battens, and fillets shall be radiata pine treated to Class H5. Posts for intermediate walls shall be to provide flat areas.

b) All cut surfaces shall be treated with a preservative to the requirements of NZS3640, to maintain the integrity of the preservative treatment.

c) Posts must be thick end down, vertical and true to line.

d) The designer must specify the post depth. Posts in bored holes are to be concrete encased. Posts that are driven shall be long enough to achieve the full embedment required below the base of the biofilter.

3.4.3.2 Concrete structures

a) Concrete containment walls shall be used where ground levels do not permit a complete in-ground biofiltration structure or as otherwise specified by the designer.

b) Pre-cast modular panel solutions are preferred to allow flexibility.

3.4.3.3 Biofilter liner

a) The internal surfaces of the biofilter shall be lined to prevent leakage of water and air out of the biofilter, to prevent short circuiting of untreated air around the edges of the biofilter compartment, and to protect the supporting structure from corrosion.

b) The liner design and material shall be presented to Watercare for approval.

c) Where a plastic sheet liner is used, it shall be a complete integral membrane fully sealed to meet the requirements of this specification.

d) The plastic sheet liner shall be flexible polypropylene film with a minimum film thickness of 0.5mm (500 microns). It shall be fusion welded together to provide a single impervious uniform liner free from wrinkles that could contribute to foul air tracking causing leakage.

e) Appropriately sized inward facing boots, fusion welded to the sheet liner, shall be used at pipe penetrations and shall be fully sealed against the pipe.

f) The perimeter strip around the biofilter just below the media layer may be taped or glued to the liner to provide a fully sealed joint.

g) For cast concrete structures, alternative liner options such as flexible membrane coatings may be offered for consideration by Watercare. If approved, the membrane coating shall be durable and be resistant to the acids and other chemicals in the biofilter. It shall form a complete integral membrane fully sealed to meet the requirement of this specification. It shall be fully sealed around pipes at pipe penetrations. The finished liner shall be at least 3mm thick on the floor and at least 2.5mm thick on the walls.

3.4.3.4 Ducts and fittings

a) The main air supply pipework shall be fabricated from corrosion resistant plastic. The design and installation of pipes shall be as described elsewhere in this specification for the pipe material used.

b) Where a piped secondary air distribution system is used pipes shall be slotted heavy duty PVC. The slots shall be a minimum 5mm wide with number of slots to suit the airflow. Sockets for the secondary air distribution pipes shall be plastic heat welded onto the header pipes and GRP reinforced. Where bedded in scoria the air distribution pipes fitted into the header pipe sockets shall be taped in place. End caps may be taped in place or be otherwise removable.

c) PVC and PE pressure pipes and fittings shall comply with the requirements of the Watercare material supply standards.

d) Piping used for internal underdrains and external groundwater drains shall be corrugated land drainage pipe.

e) Air pipe connections to the inlet and outlet of the fan shall be arranged and supported to not bear any stresses on the fan.

3.4.3.5 Trenching and Pipe Bedding

a) Trench design and pipe bedding shall comply with AS/NZS2566.

3.4.3.6 Air distribution and intermediate filter layers

a) The air distribution pipework and the under-drain pipes shall be surrounded and compacted as specified in the design.

b) Where wind stop fabric is installed under an intermediate filter layer or under the top surface layer a 200 mm overlap at joints should be maintained.

3.4.3.7 Media and cover layer

a) The biofilter media shall be supplied and installed as per the design.

b) A 150mm wide strip of media around the edge of each compartment of the biofilter shall be packed down firmly against the liner and wall to prevent short-circuiting of air adjacent to the walls during operation of the biofilter.

c) The top level of the media must be screeded and finished at the level 50mm below the finished level of the biofilter.

d) Wind stop cloth final layer must be covered with either a 50mm deep fresh bark layer or as specified by the design.

3.4.3.8 Irrigation system

a) The irrigation will be controlled by a timed solenoid valve.

b) Connection of the irrigation system to the public supply shall be in accordance with the requirements of the Code of Practice for Land development and Subdivision, Chapter 6.

3.4.3.9 Chambers for air distribution

a) Material selection shall consider that inside walls and floor of air distribution chambers will be subject to corrosive gas. Concrete chambers/surfaces in contact with the gas shall be painted with an appropriate and approved corrosion resisting coating system as per Watercare's Material Supply Standard (ESF-500-STD-601).

b) Chamber covers must be completely air-sealed and unless otherwise specified the standard Watercare hatches should be used with appropriate seals (refer Watercare standards drawings 2003160.001 - -2003160.009.

c) Any other equipment in the chambers, such as acoustic fittings, shall be fixed in a manner that will allows access for maintenance and replacement.

3.4.3.10 Fan and internal biofilter drainage pump

i. The fan, drainage pump (if required), control cabinet and componentry shall comply with Watercare's Electrical and control standards.

3.5 Colour and identification of linear assets

Refer to Watercare's General Civil Construction Standard for painting colours of assets.

4. Structural design

4.1 Ground investigations

a) Ground investigations shall be completed in accordance with the New Zealand Ground Investigation Specification, 2017 (http://www.nzgs.org/library/nz-ground-investigation-specification).

b) All data collected shall be uploaded to the New Zealand Geotechnical Database in AGS4 format at: *https://www.nzgd.org.nz*

4.2 Buried flexible pipelines

a) Buried pipelines shall be designed typically in accordance with AS/NZS 2566.1 and as specified in this section for the following material types:

- CLS – Cement (mortar) lined steel pipe
- ELS – Epoxy lined steel pipe
- DI – Ductile iron
- GRP – Glass reinforced pipe
- PVC – Polyvinylchloride pipe
- PE – Polyethylene pipe

b) Pipe dimensions shall be selected based on minimum hydraulic diameter requirements before determining pipe structural strength.

Note: *where the pipe is lined with an additional material (e.g. CLS pipe) the lining bending modulus must be added to the design.*

4.2.1 Embedment characteristics

a) Embedment material shall be selected to suit the specific ground conditions. Consideration must be given to the future state or possible interactions with the trench that could affect the bedding material's ability to continue functioning as designed, for example very fine self-compacting material may affect the cost of retaining the trench during replacement or other construction work near the trench.

b) Watercare standard drawings provide standardised embedment geometry. These drawings stipulate the minimum dimensions for trenched pipe installations. The designer's calculations must confirm appropriate dimensions over these minimum requirements.

c) The minimum cover shall meet the requirements set by Auckland Transport for pipe in the road corridor. The table below is for straight vertical walled trenches and are with conservative minimum cover and bedding widths for up to 1500mm OD pipe.

***Table 4.1**: Minimum cover and bedding widths for pipes up to 1500mm OD.*

Pipe OD (mm)	**Embedment material under pipe** (mm)	**Side clearance from trench** (mm)	**Embedment over pipe** (mm)	**Minimum cover over top of pipe** (mm)
Up to 300 (typical local network or ventilation pipes)	*100*	*150*	*150*	*900 in berm or under road*
310 to 450	100	250	150	1200
460 to 900	150	300	150	1200
910 to 1500	150	350	200	1200
Over 1500	Design specific	Design specific	Design specific	1200

d) In some cases, due to seismic mitigation measures or for example alterations to accommodate other services the embedment geometry may need to be changed. Where the total trench width is greater the 5 x $D_{e;}$ the Leonhardt correction factor, $\zeta = 1$ shall be used.

e) Where soft clays or organic and expansive soils are encountered, and the embedment detail is supported with low strength material or geotextile separation, the embedment material shall be excluded as a support from the calculations.

4.2.2 Imposed loadings

a) Consider internal pressure for pipe with greater than internal atmospheric pressure (non-gravity), both positive and negative.

b) For pipes under vehicle lanes of Motorways and Expressways; the superimposed live load on the pipe shall be calculated as the average intensity due to HN-HO-72 loading on top of the pipe distributed, as per NZTA-Bridge Manual SP/M/22.

c) For pipes under vehicle lanes of Arterial or Secondary Roads; the superimposed live load on the pipe shall be calculated as the average intensity due to HN-HO-72 loading on top of the pipe distributed, as per AS/NZS 2566:1:1998.

d) Construction machinery load shall be considered and limitations of the loads that may be imposed during construction shall be defined in the design report.

e) For pipes under other areas such as, railways, parks, residential and commercial buildings/ structures; the superimposed live load on the lines shall be determined by the designer.

***Note**: Rail crossing shall comply with AS 4799 and the railway authority's requirements. Cathodic protection system to control the stray-current corrosion caused by electrified railway systems shall be considered based on project specific basis.*

4.2.3 Pipe deflection and buckling

a) Designers shall place importance on flexible pipe reaction in relation to the bedding and backfill material. For typical trench bedding where the side cover ratio of (Trench base/Pipe diameter) > 2, the pipe deflection ration shall be determined with the modified Iowa formula:

$$\frac{\Delta_y}{D} = D_l K W_t \div \left(\frac{EI}{R^3} + 0.061E'\right)$$

Where:

$\frac{\Delta_y}{D}$ = defection ration (%)

D_l = deflection lag factor = 1.5

K = bedding constant = 0.1 for direct bury with surrounded support

W_t = Total vertical load per unit pipe length (soil and live loads)

EI = pipe wall stiffness (EI = $(EI)_{pipe}$ + $(EI)_{lining}$ + $(EI)_{coating}$)

R = pipe radius

I = $t^3/12$, where t is the pipe wall thickness, lining thickness, coating thickness

E = modulus of elasticity for the pipe, lining and coating

E' = modulus of the soil reaction

b) Where narrow trench design is required outside the minimum specified embedment zone and there is a greater reliance on the pipe structural strengths, or other obstructions such as adjacent services could impact on the deflection response, the Moore (1993) or Gumbel and Wilson (1981) design methods shall be followed. (Moore, I.D, 1993. Structural design of profiled polyethylene pipe. Gumbel, J.E and Wilson J, 1981. Interactive design of buried flexible pipes – a fresh approach from basic principles, V14 No.4).

c) The allowable long-term strain for steel pipe shall be calculated using the Ramberg-Osgood stress-strain relationship.

d) The effects of groundwater and vacuum on pipe buckling shall be included in calculations.

e) High risk assets where there is key structural impact on the pipe such as at pipe bridges, critical anchorages or connections to chamber, shall be assessed with finite element analysis.

4.3 Rigid pipe structural design

a) Rigid pipe structural design shall be required for concrete pipe pipe materials in accordance with AS/NZS 3725.

b) The relationship between factory test load and installed field conditions is given by the Marston and Spangle equation:

$$W_T = W_l \times \frac{FS}{B_F}$$

Where:

Wt = required proof load

W_l = external load (kN/m)

FS = factor of safety

B_F = bedding factor

Note variations on formula for different pipe reinforcing materials in AS/NZS 3725

c) Minimum concrete pipe class shall be Class4.

d) A vehicle wheel load of minimum 72kN shall be used. Construction machinery load shall be considered and limitations of the loads that may be imposed during construction shall be defined in the design report.

e) Watercare standard drawings (ESF-500-FOR-204 / DW08: 2000244.021) provide standardised embedment geometry. These drawings stipulate the minimum dimensions for trenched pipe installations. The designer's calculations must confirm appropriate dimensions over these minimum requirements.

4.4 Drilled or tunnelled pipelines

a) With jacked pipe installations, the vertical load on the pipe is less than for an excavated pipe due to the cohesion and friction remaining in the in-situ material above the pipe. Where fill heights exceed 10 times the outside diameter, full arching will take place.

b) Where the pipe carries all or part of the vertical load an appropriate bedding factor must be included based on the jacking annulus (width of contact between the outside of the pipe and the soil material). By applying Spangler's method: For slurry-based annulus fillers the contact is typically over 120º and a value of 1.9 can be used. For grouted pipe a value of 3 can be used. Refer Section 4.3 above.

c) Notwithstanding the above, the designer must consider the installation's vulnerability to future disturbance to the homogeneous nature of the soil over the life of the pipeline, or other adjacent pipelines that could affect the vertical load design.

d) The design for backfilling of the jacking pits must be in accordance with an excavated design taking into consideration the width of the jacking pit.

e) The designer must consider the jacking or tunnelling length and soil conditions when specifying the pipe properties for compression (pipe jacking) or tension (continuous pipe pull) forces as well as the limitations of joint stresses with pipe deflection during installation.

4.5 Hydraulic thrust and fluid impulse

4.5.1 Forces in fittings

a) Deflected flow causes a resulting force on the fittings such as bends, tapers and junctions. These forces must be placed in equilibrium by a supporting structure such as an anchor block or welded support.

4.5.2 Impulse momentum

a) The forces caused by the change in flow velocity transferred to fittings and restraints need to be considered.

b) With the impulse momentum quantified some solution options to dissipate surge energy may include:

- Surge tanks and surge shafts
- Relief valves
- Appropriately selected air/vacuum valves
- Non-slam non-return valves

- Increase pipe diameter
- Higher rated pipe or different pipe material to withstand surge and fatigue over time
- Soft starters and VSD's on pumps

c) To accurately model the effect of surge for complex systems and determine solution options, software models may be employed such as Bentley Hammer, Surge2000 or Hytran or as supplied by some valve manufacturers.

For elementary systems:

d) The force transferred can be expressed as:

$$F = m \times \left(\frac{\Delta v}{\Delta t}\right)$$

e) Typical causes of flow variation include:

- Stopping and starting of pumps
- Flow control valves
- Check valves or similar fast acting valves
- Sudden air release or air pocket movement
- Flow convergence or diversion
- Seismic movement

f) Acoustic velocity of confined liquid:

$$c = \frac{1}{\sqrt{\frac{w}{g} \times \left(\frac{1}{K} + \frac{d}{tE}\right)}}$$

Where:

c = acoustic velocity of fluid (m/s)
w = specific weight (N/m³)
g = gravitational acceleration (9.81m/s^2)
K = Bulk modulus of the fluid (2300MPa for cold water)
d = pipe outside diameter (m)
t = pipe wall thickness (m)
E = Young's modulus of elasticity of the pipe material (N/m²)

g) Water hammer head rise:

$$\Delta h_i = \frac{cv}{g}$$

Where:

Δh_i = head increase (m)
v = liquid velocity (m/s)
g = gravitational acceleration (9.81m/s^2)

h) As the impulse wave travels down the pipe and is reflected to interact with the original event. The surge period is calculated using:

$$T_{pp} = \frac{2l}{c}$$

Where:

T_{pp} = impulse period (sec)
l = pipe length (m)
c = acoustic velocity of fluid (m/s)

4.6 Suspended pipe and pipe support structures

4.6.1 Pipe bridges

4.6.1.1 General design considerations

a) As far as is practical, pipe bridges should be avoided. Pipe bridges should preferably be designed as a standalone structure. They may be incorporated into a pedestrian or road bridge where suitable legal instruments are in place that allows ready access for inspections and maintenance. Stakeholders must be engaged at an early stage during the design to negotiate these agreements as they could affect the design outcome.

b) The pipe must not be integrated with the bridge support structure. The design must provide for safe and unrestricted access for maintenance, upgrade or replacement. Pipe hung from a bridge shall be positioned clear of the 1% AEP flood levels.

c) The design shall consider the span between the supports of mechanically jointed pipe or for welded pipe joints as a build-in beam for fixed supports, or as a simply supported beam where the pipe support/saddles allow pipe deflection.

d) Flexible joints shall be restraint type. “Gibault” joints are not acceptable.

e) All design actions completed by hand shall be structurally assessed with a finite element analysis model.

f) The pipe shall be structurally designed to meet the following conditions:

i. Empty and full static loads

ii. Any dynamic loads and vibration

iii. Expansion and contraction

iv. Seismic action. Refer to Section 4.9

g) The corrosion protection system must be adequate to minimise access required for spot repairs to reduce operational costs. Refer to Section 4.6.1.2 for access considerations.

h) Pipe bridge colour is dependent on location. Generally, where blending into a natural environment the pipe colour shall be BS5252 (12 B29) “*Rangoon green*”, and when installed along roading infrastructure BS5252 (16 A07) “*Boulder*”, or as required by the roading authority.

Figure 4.1*: Example of a standalone pipe bridge located in natural environment.*

Figure 4.2*: Example of a pipe bridge incorporated in a road crossing (colour: BS5252: 16 A07)*

4.6.1.2 Access onto pipe bridges

a) Unauthorised bridge access (i.e. onto the pipe) shall be prevented with an adequate barrier structure and if necessary, on-bridge railing for fall protection.

b) A formal agreement with the bridge owner must provide Watercare with the ability to access, operate and maintain the pipe on the bridge. Conversely, where Watercare owns the bridge, other utility providers must establish a formal agreement with Watercare to access the bridge for inspection, maintenance, and necessary operations of their assets. Access to key componentry such as air valves must be provided with safe access for maintenance and replacement.

c) The pipe surface must be protected from bird roosting or nesting on the pipe.

d) The designer must consider the probable construction methodology as a permanent access solution for future pipe replacements i.e. temporary works or methods that can be adopted as the standard operating procedure.

e) Scaffolding lugs shall be included in the design where required for maintenance access.

4.6.1.3 Pipe bridge pipe material considerations

Acceptable material solutions are:

a) **Steel (Lined mild steel or stainless steel):** Welded or flange joints. Pipe hangers or supports should be fully welded solution to reduce corrosion and simplify maintenance. Ring girders are preferred.

b) **Polyethylene pipe:** this material must be butt welded and supported inside a full-length carrier pipe of suitable rigidity and durability. Cradles are not acceptable. The carrier pipe must be of suitable internal diameter to allow both future pipe size upgrades and thermal expansion and contraction. Proprietary spacers shall be used to centre the pipe inside the carrier pipe.

c) **Ductile iron:** with flanged joints with hangers or supports that prevent galvanic corrosion and provide water run-off. Ductile iron is usually only used where a single pipe fully spans the bridging width.

4.6.1.4 Bridge abutment transition

For the selection of suitable transitioning design between the buried pipe and bridge abutment the design shall determine the following:

a) Type of movement i.e. lateral, angular, bi-planar, etc.

b) The magnitude of expected forces

c) Temperature range for thermal movement

d) Displacement due to settlement or subsidence

e) Effects of cyclic fatigue and vibration

f) Design impact ratios:

   i. 5% of design movements - maintenance

   ii. 25% of design movements – events (seismic, subsidence)

   iii. 80% of design movements – daily variation (temperature, pressure changes, vibration)

Note: *Refer to Watercare's material supply standards for fitting procurement schedule.*

4.6.2 Pipe support configurations

a) Timber supports are unacceptable.

b) Provision shall be made for access and clearances to maintain the pipe, connecting structures, drainage, articulation joints, valves and associated fittings as necessary.

c) Metallic pipe must be electrically isolated from the bridge structure.

d) The supports shall be structurally designed to meet the following conditions:

   i. Empty and full static loads

   ii. Any dynamic loads and vibration

iii. Expansion and contraction

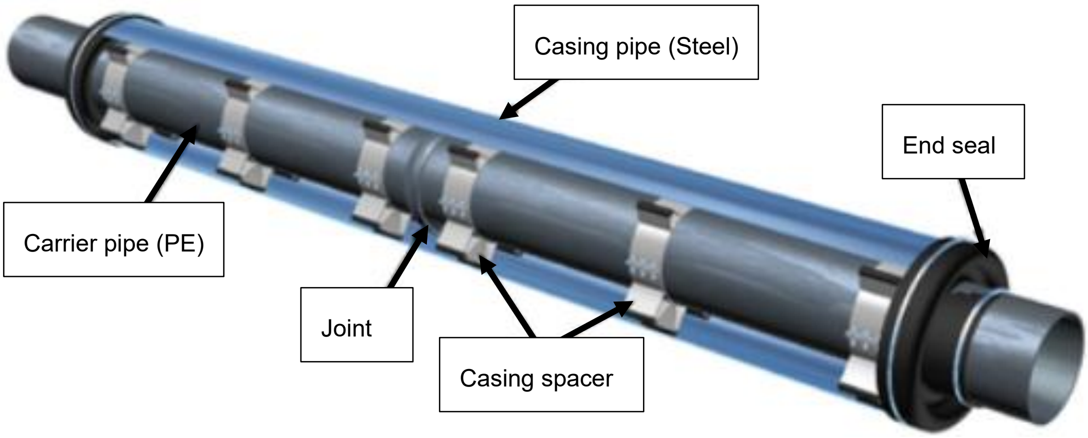
iv. Localised saddle stress and in some cases friction on the pipe

v. Seismic action - refer to Section 4.9

e) Refer to Section 4.6.1.3 for Watercare's preference on support methods specific to the material type for pipe bridges.

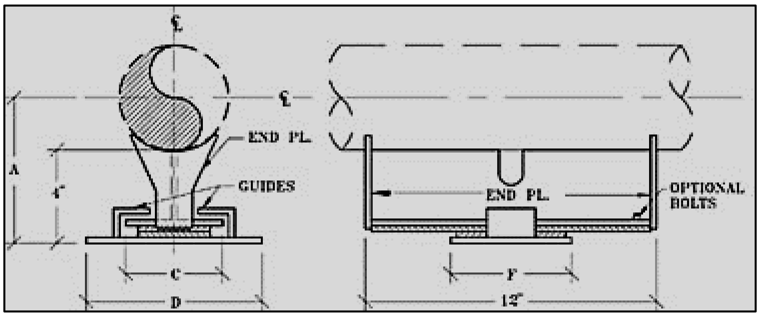
Potential support examples:

i. Host/carrier pipe

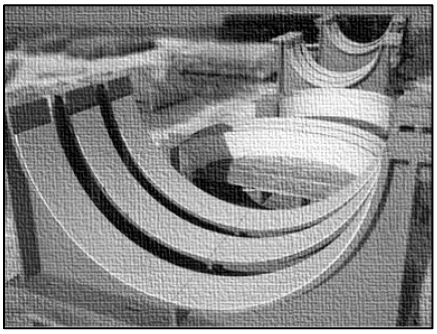


ii. Welded girders

iii. Girder with sliding base



iv. Insulated hangers or supports



<u>Not</u> acceptable:

<u>Example:</u> Pinch point / hanger with no insulation and poor water run-off

Example: Un-insulated support, no protection between the support and the pipe material:

4.6.3 Pipe saddle interface

Where the pipe-saddle interface must accommodate sliding, an arrangement of suitable materials must be included such as PTFE or Teflon. In addition, neoprene may be required to protect the pipe coating from localised stresses.

4.6.4 Pipe stress between pipe supports

Stresses shall be evaluated between pipe supports to prevent permanent deformation and damage to the pipe's internal lining.

Stresses to be considered include:

Longitudinal stresses (σ_L)

- Beam bending stress (based on design) (MPa)
- Temperature stress ($\sigma_T = E.\alpha.\Delta T$) (MPa)
- Poisson stress ($\sigma_v = v.\sigma_h$) (MPa)

Circumferential stress (σ_C)

- Hoop stress due to internal pressure ($\sigma_h = \frac{PD}{2t}$) (MPa)
- Localised stresses at the end of saddle supports ($\sigma_S = \frac{KP_S}{t^2}.log_e\frac{r_0}{t}$) (MPa)

Where:

- E = Young's modulus for steel (207,000 MPa)
- α = Coefficient of linear expansion for steel (12x10^{-6} mm/mm/°C)

- ΔT = Difference between pipeline operating and installation temperature (°C)
- υ = Poisson's ration (0.27)
- P = Maximum testing pressure (MPa)
- D = Outside diameter of pipe (mm)
- t = Pipe wall thickness (mm)
- K = Factor (ranges between 0.02 – 0.00012)
- P_S = Total load on saddle or saddle reaction (N)
- R_0 = Outside radius of pipe (mm)

The total equivalent stress (σ_e) can then be calculated using the following formula:

$$\sigma_e = (\sigma_L^2 + \sigma_C^2 - \sigma_L - \sigma_C)^{0.5}$$ (Hencky, H & von Mises, R, 1924)

Where ring girders are used to stiffen the pipe at the supports, additional stresses need to be considered. Refer AWWA M11.

4.7 Anchor structures

a) Anchorage of pipework is required in the following circumstances:

   i. Prevent transfer of stresses

   ii. Support of fittings and valves

   iii. Prevent floatation

   iv. Prevent displacements due to internal or external forces

   v. Prevent joint displacement

   vi. Bridging

b) Anchorage design shall include forces attributed to:

   i. Flow velocity and direction

   ii. Transient flows

   iii. Seismic actions

4.8 Buoyancy prevention

a) Buoyancy forces can pass stresses onto connected infrastructure causing premature failure of the service or complete surfacing of a pipeline.

b) Buried structures and pipelines susceptible to hydraulic uplift shall be designed with buoyancy prevention to a **safety factor of 1.5**.

c) The designer shall consider that filled pipe may be required to be emptied for maintenance. Hydraulic uplift shall consider all structures and pipelines in an empty state.

d) Equally the effects of liquefaction on filled, partially filled and empty structures and pipes shall be considered when determining suitable weighing or anchoring solutions.

Possible solutions include:

- Weighted collars around concrete manholes or a weighted base
- Piles and anchorage
- A water pressure relief system (drainage, pumping)

4.9 Seismic evaluation of pipelines

Southern parts of Auckland (Pukekohe to Mangere and south-east Manukau) are more susceptible to seismic actions. The seismic risk is lower in central and northern areas of Auckland; however the central and northern areas may be more susceptible to ground shaking from volcanic fields.

a) Pipelines shall be assessed for seismic vulnerability of:

- Landslides
- Liquefaction
- Compression and tension in pipe joints
- Fluid transients in channels and non-pressurised pipes

b) Acceptable methods for evaluation are provided in Section 1.9.2.

4.9.1 Supporting of tanks and equipment

Refer to Watercare's General Plant Layout and Equipment Selection Principles (ESF-500-STD-401).

4.9.2 Structural steel

a) Structural steel used for reinforcing purposes or supports shall be specified using the New Zealand Structural Steelwork Specification in Compliance with AS/NZS 5131.

b) The templates provided by *Steel Construction New Zealand* shall be edited to provide project specific selections.

4.10 Connectivity and interconnection of pipelines and structures

a) All pipes and structures shall be designed with adequate flexibility for ground settlement and special provisions to minimise risk of damage during earthquake.

b) Historical experience in New Zealand earthquake events suggests that suitable pipe options in seismically active areas may include PE pipes, ductile iron or steel pipe. Consideration must be given to the type of ground movement in relation to the pipe position before selecting bell-and-spigot (lap) joints or rubber ring jointed pipe. Butt-welded pipe is the preferred method in these areas.

c) Specially designed flexible joints shall be provided at all junctions between pipes and rigid structures (such as reservoirs, pump stations, bridges, and buildings) where pipe flexibility alone is not adequate to accommodate movement.

d) Where structures are closely spaced such as at pump stations, base isolation of the area may be considered where minor actions are expected. Connecting to the base isolation area requires a flexible connection.

e) Flexible connections or other mechanical joints must not be located under any structures and must be accessible for repair or replacement.

4.11 Maintaining structural integrity against corrosion

4.11.1 Corrosion protection systems

4.11.1.1 Tape systems

a) Buried steel pipe shall be tape wrapped with an accepted system to protect the pipe material in the buried environment.

b) Pipe transitioning into chambers shall be wrapped a minimum of 150mm past the chamber wall and overlapping onto the painted surface.

c) Pipe transitioning to an above surface pipe shall be wrapped at least 200mm past the soil to surface interface and onto the painted surface. The tape system shall be over-layered with a UV-stabilised tape system over the existing tape to 200mm into the buried section and a minimum of 50mm onto the painted steel.

Notes:

1) *This section applies where fusion bonded polyethylene coating (to AS 4321) of steel pipes is not achievable.*
2) *All buried bolted connections with bare metal exposed shall be protected with an accepted 4-stage petrolatum or butyl based wrapping system. Refer to Watercare's Material Supply Standard (ESF-500-STD-601).*

4.11.1.2 Paint systems

a) Steel pipe that is exposed, such as in chambers or on pipe bridges shall be painted with a suitable epoxy corrosion protection system as per Watercare Material Supply Standard (ESF-500-STD-601).

b) The appropriate system shall be determined with input from a coatings specialist / engineer and identify the site-specific macro and micro-environments. The designer must complete the project schedule in the Material Supply Standard and provide this to the coating supplier to support the coating selection.

Note: *Painting of bolts is not required for flanged connections of pipe bridges.*

4.11.1.3 Cathodic protection systems for metallic pipes

This Section shall be read in conjunction with Watercare's Cathodic Protection Standard (ESF-500-STD-704).

All mild steel (CLS) or ductile iron pipes shall be assessed in accordance with AS/NZS 2832 and AS/NZS 4853 where a technical report shall be submitted to Watercare with a recommendation on the requirement for cathodic protection.

The designer shall also refer to Watercare's Electrical Design Standard. The design must be determined with considerations to the site ground conditions and in consultation with a cathodic protection designer.

a) All joints of steel pipelines shall be electrically bonded.

b) Anode beds shall, as far as practicable, be near pump station

Cathodic protection test points are typically required where mild steel mains:

1. Cross rivers or railways.
2. Are fully or partially located in reactive or corrosive soils (based on soil testing).

Electrical isolation should be provided at flanges where necessary to prevent current from traveling along the pipeline or draining to the ground through direct-contact equipment (e.g., buried valves, flowmeters, or pit valves). Isolation is preferred at all offtakes.
All scour valves, air valves, and line valves, along with any equipment in direct ground contact, must be electrically isolated from the trunk main using approved insulated bolt sets, gaskets, or isolating flanges.

When steel mains are near power lines (e.g., high-voltage transmission lines or railway overhead power), cathodic protection design must account for Low-Frequency Induction (LFI) and Earth Potential Rise (EPR). Earth mats may be needed for fittings in these areas.
Third-party cathodic protection systems can impact Watercare pipework, so the Designer must assess and mitigate any risks to Watercare assets.
A whole-of-lifecycle cost approach should guide the selection of TWM pipe materials and arrangements.

4.11.1.4 Internal corrosion protection

a) Internal corrosion protection of pipe and fittings must consider the whole of life of the asset and choosing the appropriate method that considers re-application or repair of the lining system.

b) Metallic pipe is typically protected using a concrete lining solution resistant to H_2S.

c) Some systems such as epoxy systems may not be practical to reapply due to the operational constraints of taking a pipe out of service for an extended period and the preparation requirements for reapplication of the system. Such systems should be selected to the extent that the need for repair is not required for the life of the asset (typically 100 years).

4.12 Pipeline testing

Pipeline testing to be completed in accordance with Watercare's General Civil Construction Standard.

Note: *Testing of welds for steel pipes shall be in accordance with Watercare's General Mechanical Construction Standard (ESF-600-STD-701).*