DRINKING WATER SUPPLY

DESIGN PRINCIPLES FOR PIPELINES OVER 250mm DIAMETER

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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 water from wastewater, updated document format and sections.	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.
	2.3.5	Updated operating pressure range
	3.2.1.7	Added scour pipe dimension table
	3.2.1.9	Added design considerations for bulk supply points
	3.2.4	Updated section including references to drawings
	3.2.6.6	Updated section with additional requirement
	4.2.2	Updated section on loading to reference applicable standards
	4.5.1	Adde references to pipe bridge colours, example figures, and access requirements.
	4.5.2	Updated image
	4.5.3	New section added
	4.5.4	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.
Borehole	Deep, narrow hole which is auger drilled into the ground to access underground water, typically from aquifers.
Bulk	The assets and systems designed for treatment, storage, conveyance, including transmission assets which are not intended for retail supply (i.e. customer connections). This generally includes infrastructure upstream of a bulk supply point (BSP) for water
Bulk supply point (BSP)	Supply connection between a transmission pipeline and a retail (local) network.
Cathodic protection	System to protect ferrous metal from corrosion by introducing an anode and using either galvanic or impressed current. This generally applies to buried steel pipelines.
Chamber	A partially below ground or below ground enclosure where equipment such as meters, valves and pipework is housed for inspection, testing or maintenance purposes.
Containment structures	An impounded body of material for distribution or process application such as a tank or reservoir for storage, regulation and control. Excluding **dams**.
Control systems (DCS, SCADA, RTU's, and PLC's)	Devices to control remote equipment and provide data on processes and operational performance.
Control valves	Valve designed to control flow, pressure or volume. The control valve may include mechanical and electrical control means necessary to operate the valve. The main valve may be a diaphragm valve, needle valve or float valve. It excludes ordinary automated operation for isolation valves.
Designer	Person(s) or company responsible for the design output.
Easement	A contractual agreement that grants a right to use another person's property for a particular purpose such as access.
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.
Local networks	Retail distribution networks with customer connections typically downstream of a bulk supply point and generally

operating at a lower pressure than the transmission or bulk network.

Master meter	Metered connection within a network system that operates as a main metering point for slave meters situated on a private network.
Mean day month maximum	The average of the daily peak water demands over the maximum-demand month of the year.
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.
Point of supply	The precise point Watercare asset ownership ends and private ownership starts. At this point (a fitting or geographic boundary) the responsibility for ownership and maintenance of assets and equipment transfers to the customer.
Potable (drinking) water	Treated water that complies with the drinking water standards for New Zealand. Water is potable (after treatment stage in Water Supply – ref. "Water Supply") and reticulated between reservoirs. Reservoirs are included.
Pump(ing) station	Structure or site 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 gravity head, or by means of pumping
Raw Water	Untreated water from the water supply source
Reservoir	A water retaining containment structure where potable water is stored and controlled for distribution.
Surge	A rapid (transient) change of pressure resulting from flow fluctuations or asset function over a short period of time
Treatment (plant)	Water treatment plants for the treatment of raw water by mechanical or chemical processes to meet the Drinking water Standards for New Zealand.

Transmission watermain	A large diameter main designed for the conveyance of water to other transmission mains, reservoirs or where water is delivered through bulk supply points. Transmission mains do not supply service connections to customers. Also see **Bulk supply point (BSP).**
Tunnel	An underground passage / structure which provides access by foot or vehicle, and houses assets (pipes, conduits, electrical systems).
Valve	A mechanical device used for controlling flow and / or pressure. Examples include isolation, air release, control and pressure reducing valves.
Watermain	Collective term used for pipe (any) carrying water within the transmission or local network system.
Well	The subsurface source of water, typically accessed through a borehole or submerged pumping system.

Acronyms

ADD	Average daily demand
CAD	Computer aided design
CLS	Cement (mortar) lined steel [pipe]
De	External diameter
DI	Ductile iron
DN	Nominal diameter
DWSNZ	Drinking water standards of New Zealand
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
MDMM	Mean day month maximum
mm	Millimetre
NB	Nominal bore
O&M	Operations and Maintenance

Pdf	Portable document format (Adobe Acrobat)
PE	Polyethylene
PVC	Polyvinyl chloride
sec	seconds
SCADA	Supervisory control and data acquisition – A control system used for remote 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 water pipeline assets larger than 250mm internal diameter (NB), including transmission pipes. These include raw water mains that convey untreated water from the dams to treatment plants, from treatment plants to reservoirs, and from reservoirs to local networks, mostly through bulk supply points. The purpose of this design standard is to apply the level of design that is appropriate for the size, pressure and structural complexity of these linear assets.

Local water network assets shall be designed and constructed in compliance with the Auckland Code of Practice for Land Development and Subdivision, chapters 6, and are limited to a maximum internal diameter of 250mm. Developers are referred to this standard for sizes over 250mm and through early consultation with Watercare to establish the criticality and suitable standard associated with larger infrastructure.

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 / retail networks up to and including 250mm internal diameter. • Includes: Water network downstream of bulk supply point (BSP). • Principal water mains, rider means, service connections to the point of supply.
Design Principles for Pipeline Systems Over 250mm Diameter (this document)	• Local / retail networks larger than 250mm internal diameter, including metro and non-metro networks. • Transmission pipelines including bypass and scour pipework of valves. • Pipework at reservoirs, treatment plants, headworks. • All pipework upstream of the bulk supply point (BSP).

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

- Interfaces with other systems (e.g.: chambers, reservoirs)

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 designs
- 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 design drawings and specific designs. To achieve optimal performance outcomes the construction requirements focus on proven methods and best practice to ensure quality, whole of life performance, safety, operation and maintenance, and regulatory requirements including health and safety and environmental requirements are met. Where construction standards are used or referred to in contracts they form part of the specifications of the contract.

1.2.6 Project specific specification

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 and meet all applicable water standards. 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

Installation or replacements of like-for-like valves, fittings and meter assemblies with componentry that are fully compliant with the Watercare Material Supply Standard are considered exempt from design requirements.

Design must be reviewed by Watercare here materials or equipment deviates from Watercare's Materials Supply Standard. An Application for Dispensation shall be prepared in these instances 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-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-600-STD-103 (COP-04) - Code of Practice for disinfection of water systems
- ESF-500-STD-704 – Cathodic protection standard

1.7.2 Watercare drawings

- DW06 - Access structure drawings for water infrastructure
- DW07 - Access structures general drawings for public and non-public areas
- ESF-500-FOR-103 (DW10) - Pipelines for water greater than 250mm diameter drawing set
- DW11 - Valve chamber detail drawings for transmission water
- DW12 - Water stand-alone sampling and rainfall metering
- DW19 – Electrical drawing set for automated line valves

- DW20 – Bulk supply meter electrical and control drawing set
- DW23 - Cathodic protection mechanical and civil detail drawings
- DW24: Magnetic flowmeter Endress and Hauser
- ESF-500-FOR-107 – Insertion flow meter: Standard details
- ESF-500-FOR-709 – Antenna pole details
- ESF-500-FOR-710 – Cathodic protection installation details

1.7.3 National and international standards

- AWWA M11: Steel Water Pipe – A Guide for Design and Installation
- AWWA M51: Air release valve pipe design
- AWWA M55: PE Pipe – Design and Installation
- 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 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 2832.1 Cathodic protection of metals. Pipes and cables
- AS/NZS 2832.2 Cathodic protection of metals Part 2: Compact buried structures
- AS/NZS 4853 Electrical hazard on metallic pipelines
- AS/NZS 4020 Testing of Products for use in contact with drinking water

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, 4th Ed.
- 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 manual
- Moore, 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
- PIPA POP010B: Part 2 – Fusion fittings for use with Polyethylene pressure pipes design for dynamic stresses
- PIPA POP207: Installation of potable watermains in contaminated ground
- 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
- WSA 201: Manual for selection and application of protective coatings

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) The pipe and fittings pressure class shall always be greater than the maximum design pressure. The minimum pressure class for all system components shall be at least PN16.

c) 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.

d) 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.

e) 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.

The asset criticality assessment of the proposed installation shall consider as a minimum: operating pressures, risk profile, loss effect, network redundancy and operability.

***Note**: Upon request, Watercare's can provide further information on asset criticality classification based on the developed risk.*

***Table 1.2**: Material selection requirements for design compliance*

Pipe Material	Minimum Pressure rating	Acceptable sizes	Acceptable internal lining	Acceptable external lining	Installation techniques	Acceptable jointing methods	Other considerations				Applicable asset categories[f]
							Cathodic Protection	**Compliant with AS/NZS 4020**	**Ground movement**	**Contaminated ground**	
Mild Steel (CLS)	PN16 [a]	DN 300 to DN 2000 [b]	Cement mortar lining Epoxy lining [c]	Fusion bonded polyethylene coating to AS 4321 Tape wraps [d]	Open trench Pipe bridges	Welded joints or Sintalock joint with weld	Generally required. Shall be considered where Pipes cross water bodies Corrosive / acidic soils Locations susceptible to stray currents or in the vicinity of power lines, rail, or other ferrous / isolated structures	Yes	Welded joints or Sintalock joint with weld, 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	Critical Essential lifeline Pipe bridges
Ductile Iron	PN35	DN 375, 450, 600, and 750 to be assessed on a case-by-case basis, refer to notes [e]	General purpose Portland cement with seal coat Epoxy lining	Zinc-Aluminium $400g/m^2$ with epoxy coating	Open Trench	Flanged	Not required on DI pipes	Yes	Rubber ring joint with lock	Generally, not suited for ground contaminated with organic compounds such as hydrocarbons.	Low Moderate
Polyethylene	PN16	DN (OD) 355, 450 500 and 600, to be assessed on a case-by-case basis, refer to notes [e]	N/A	N/A	Open Trench or HDD	Butt welded Flanged with backing ring Electrofusion coupling [e] Mechanical end-restraint joint [e]	N/A	Yes	Welded joints can accommodate ground movement	Ok for acidic ground conditions but should not be used where hydrocarbons / organic compounds are present.	Low Moderate Critical Essential Lifeline

Notes:

(a) Note, although the minimum pipe pressure class is PN16, spiral welded steel pipes manufactured to AS 1579 with a maximum rated pressure up to 6.8MPa (PN68)
(b) Refer to Watercare's Material Supply Standard for standardised pipe sizes. Also note smaller sizes may be applicable on bypass configurations.
(c) Specific to applications e.g. bypass pipework for line valves, generally not used for main pipelines, unless approved by Watercare.
(d) Acceptable tape coating methods may be used for bends or joint repairs where heat shrink sleeves are not considered practical.
(e) Requires approval from Watercare
(f) Refer to Table 1.3 for descriptions.

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).

Also refer to *Guidance Note: Seismic displacement for pipeline design (ESF-500-GDN-302)* for background information.

Table 1.3: Applicable Design Reference for Seismic Permanent Ground Displacement

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
1	Low	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.	1/250	(a)	(b)	(c)
2	Moderate	Common pipework in the Transmission networks, or Local	1/1000			

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
		Network mains larger than 150mm 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 structurally 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 1.1 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.

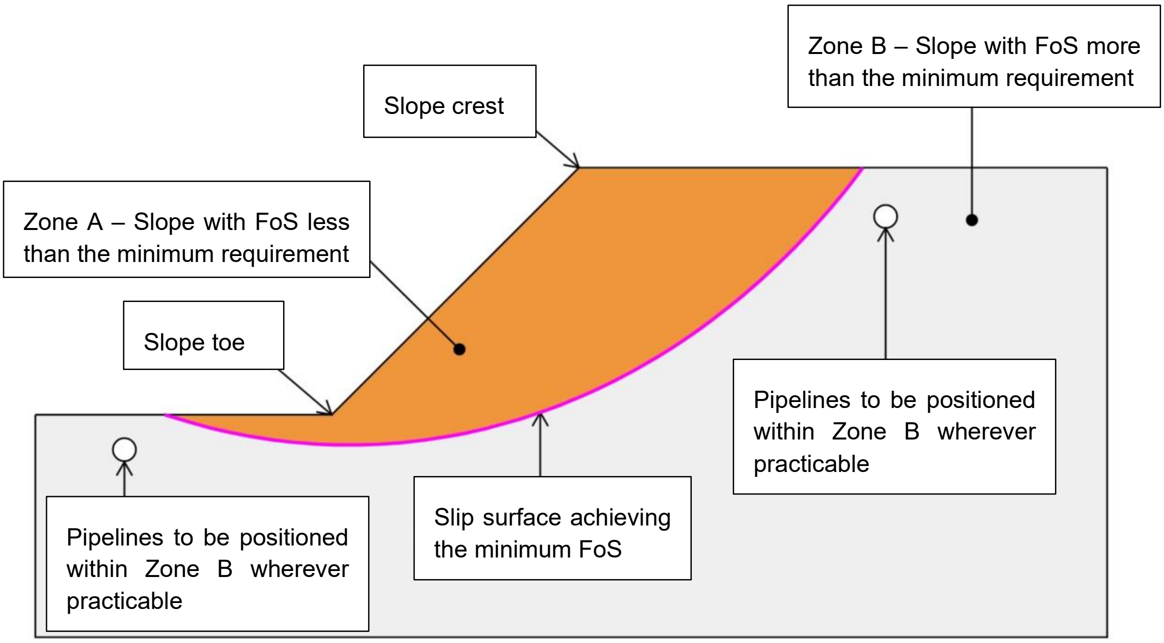


Figure 1.1: *Pipeline Location within a Slope (a cross-section view).*

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 Chambers

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, e.g. hospitals and customers that have onsite storage have different needs
- 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. two water supply mains into a local network area that are at opposite sides of the area thereby providing redundancy when one supply fails. Operability, e.g. spacing and frequency of valves and chambers to access the network for inspection, maintenance and future replacement.
- Critical infrastructure such as reservoirs or onsite storage servicing hospitals and the airport.
- 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:

- Two or more supply sources
- System reconfiguration and interconnectivity
- Adequate system storage and replenish times Combined system interconnectivity and system reverse flow
- Looped systems with key valve interchanges
- Sufficiently spaced main line valves

Valve duplication independent power supplies, or portable power, or battery backup alarming systems, interlocks and suitable manual overrides

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 is up to date and with appropriate risk cover	Audit
	Leadership / culture	Decisive decision making	Survey
		Situational awareness	Survey
		System knowledge	Survey
		Innovative thinking	Survey
	External partners	Ability to leverage on external knowledge	Survey
		Partnerships, design and service delivery arrangements	Audit

Dimension	Principle	Indicators	Assessment method
		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 (SiD)

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

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

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. Consultants or design managers must effectively demonstrate to Watercare why the standard design is unsuitable for the specific project before an alternative design will be considered.

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 design features do not involve extraordinary operational, maintenance or renewal obligations
- 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. Water Pipeline Hydraulic Design

2.1 Scope

The hydraulic design parameters provided in this section applies to all transmission systems, including water supply headworks and water pipes larger than 250mm (internal diameter). Specific design requirements for treatment and process design are not covered. The hydraulic design parameters for local network water (typical pipe diameter ≤250mm) are given in the Water Code of Practice for Land Development and Subdivision (Chapter 6).

2.2 Maximum population density

The maximum population density will be provided by Watercare.

2.3 Water supply hydraulics

2.3.1 System zones

a) All discrete water systems and zones must have input meters to enable flow/ mass balance. Pressure sensors shall typically be installed upstream of the flow meter and downstream of the zone meter / PRV.

b) Where possible water supply demand shall be based on measured data and an analysis of future water demand forecasts. Demand patterns are influenced by:

- Climate, such as high temperatures and soil moisture deficit during summer that leads to increased water use
- Land use types and the size of the development/operations within a zone
- Condition, material type and age of the water infrastructure that could lead to increased background leakage rates
- System pressure. Higher system pressure increases system leakage and water use
- Socioeconomic impacts:
    - Property values/size relating to occupancy rate, and owner/ occupier dynamics.
    - Degree of recreational use of water
    - Housing density relating to landscaping size and upkeep.
- Water efficiency practices

2.3.2 Demand design

Note: *Network system demand shall be determined as per the Water and Code of Practice for Land Development and Subdivision (Chapter 6).*

a) Transmission or bulk system and storage design must be designed to meet the source metered mean demand maximum month (MDMM) and include peak hourly demand (PHD) where bulk supply points are serviced from the main.

b) The alternative to source MDMM is averaging the monthly bulk records. This method is a practical approach for transmission lines that is not primarily used to supply a specific zone or zones but also used to transfer capacity between storage areas.

Service connection meter readings are not considered practical due to metering frequency and quantifying system leakage for peak demand.

c) Where metered ADD values are not available, such as for new local network systems, the ADD shall be determined using the Water Code of Practice for Land development and Subdivision. Alternatively for new systems only, comparative demand data may be used from an existing metered system provided that it is demonstrated that the water use patterns listed in Section 2.3.1 are similar between the systems. The use of comparative data must be undertaken by Watercare, ensuring an appropriate safety factor is determined and applied based on the specific project requirement.

d) The MDMM = average daily demand (ADD) x **1.45** (peaking factor).

e) PHD must be provided whilst maintaining the minimum design pressure, see Section 2.3.5. PHD typically varies with seasonal changes and must be accounted for. Where specific data is not available, PHD = 2.5 X ADD.

f) The water demand design shall address the specific operational philosophy and future anticipated demand patterns.

2.3.3 Reservoir/storage system

a) Watercare operates its systems with a combination of storage at source and within the transmission system using reservoirs, reverse flow options and where feasible filling of storage during off-peak hours.

b) Depending on the specific water supply system, the MDMM may not be met from the source supply in which case storage capacity in the system must be able to meet MDD.

c) The storage capacity as set by the DWSNZ (Drinking-Water Standards for New Zealand) shall be designed to meet the ADD for system resilience of a minimum of 24 hours. Distributed storage provides better redundancy, system flexibility, and increase turnover.

d) Balancing tanks are distinguished from reservoirs by their purpose to provide optimal hydraulic performance and are not primarily sized to provide storage or resilience for a supply zone.

e) The location of reservoirs shall be considered for optimal hydraulic advantage in relation to its servicing area and service connections, base elevation and overflow level.

2.3.4 Grades and Velocity

a) Pipelines shall have sufficient grade to facilitate air movement to air release valves.

b) The minimum grade shall be 1 in 500 (0.2%).

c) The minimum flow velocity in gravity supplied mains shall be 0.5m/s.

d) The maximum design flow velocity shall not exceed 3m/s.

2.3.5 Design pressure

a) The typical operating pressure range for watermains are from 250kPa to 1600kPa (1).

b) Pressure zones shall be established according to ground level contours by dropping no more than 3m/1000m from the supply point.

c) Pipe material, componentry and flanges for linear system shall be rated to the minimum specified in Watercare's Materials Supply Standard (ESF-500-STD-601).

d) For facilities such as reservoir outlets where pressure is exceptionally low, pressure rating selection is in accordance with the design needs, but consideration should be given to potential for bypass or reconfiguration, and common stockkeeping of spare parts.

(1) ***Note****: The maximum operating system pressure shall be confirmed with Watercare to inform the design and testing requirements.*

2.3.6 Head losses

a) Head loss through a pipe with full-bore flow shall be determined using the Colebrook-White formula. This formula provides the required accuracy for transmission systems and pipes larger than 250mm where precise hydraulic calculations are critical.

b) Linear measure of roughness for Colebrook-White formula:

Table 2.1*: recommended roughness value range based on pipe material.*

Material	Colebrook-White coefficient; linear measure of roughness (x 10^{-3} m)
	Design value (Water) (mm)
Steel pipe / DI with concrete lining	Recommended by supplier 0.01 – 0.06
Steel pipe / DI epoxy lined	Recommended by supplier 0.003 – 0.015
PE	Recommended by supplier 0.003 – 0.015

c) Head losses through proprietary fittings shall be determined using the component manufacturer's value with a 10% inaccuracy factor - manufacturer friction factors are often determined through experimentation. All losses shall be calculated and factored into the design model. For manufactured fittings with unknown friction factors, minor losses shall be equated as equivalent length (L_e) / diameter (D) ratio.

$$K = \left(\frac{L_e}{D}\right) f_T$$

Where:

K = Resistance coefficient
L_e = Length equivalent
D = Internal diameter
f_T = Friction factor of connected pipe

Note: *Solve for K, then determine the pipe equivalent length (L_e)*

Table 2.2*: Ratio based on fitting type.*

Fitting		$\left(\frac{L_e}{D}\right)$
Gate valve	Fully open	8
	¾ open	35
	½ open	160
	¼ open	900
	Swing type	100

Fitting			$\left(\frac{L_e}{D}\right)$
Check valve	Ball type		150
Butterfly valve - fully open			45
Y-strainer			250
Bends	90º standard bend		30
	90º long bend (r/d > 1)		20
	45º standard bend		20
	45º bend (r/d > 1)		16
	Tee – flow through run		10
	Tee – flow through branch		60
	Tee – radius branch		16
Tapers	Sudden contraction	D2/D1 = 0.9	9
		D2/D1 = 0.8	27
		D2/D1 = 0.7	65
		D2/D1 = 0.6	150
		D2/D1 = 0.5	370
		D2/D1 = 0.4	1000
	Sudden expansion	D2/D1 = 1.1	1.5
		D2/D1 = 1.3	8.5
		D2/D1 = 1.5	16
		D2/D1 = 1.7	22
		D2/D1 = 2	28
		D2/D1 = 2.5	35
		D2/D1 = 3	40
		D2/D1 = 4	44
	Long taper	D2/D1 = 0.9	3
		D2/D1 = 0.8	8
		D2/D1 = 0.7	18
		D2/D1 = 0.6	38
		D2/D1 = 0.5	85
		D2/D1 = 0.4	220

***Table 2.3**: Friction factor (f_T)based on pipe size.*

Size (mm)	PE	Steel epoxy coated / DI	Concrete (smooth) /Concrete lined pipe
300 - 400	0.005	0.013	0.018
450 – 600	0.0025	0.012	0.014
650 – 800	0.0023	0.01	0.012
>800	0.0015	0.08	0.01

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. Layout requirements for local networks are described in the Auckland Council Code of Practice for Land Development and Subdivision, Chapter 6.

3.2 Pipes and in-line equipment

3.2.1 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 chamber covers within the wheel path of vehicles.

b) Above ground pipe must be suitably UV protected and accessible for maintenance and regular visual inspection. Refer to Section 4.5.1 for pipe bridge design.

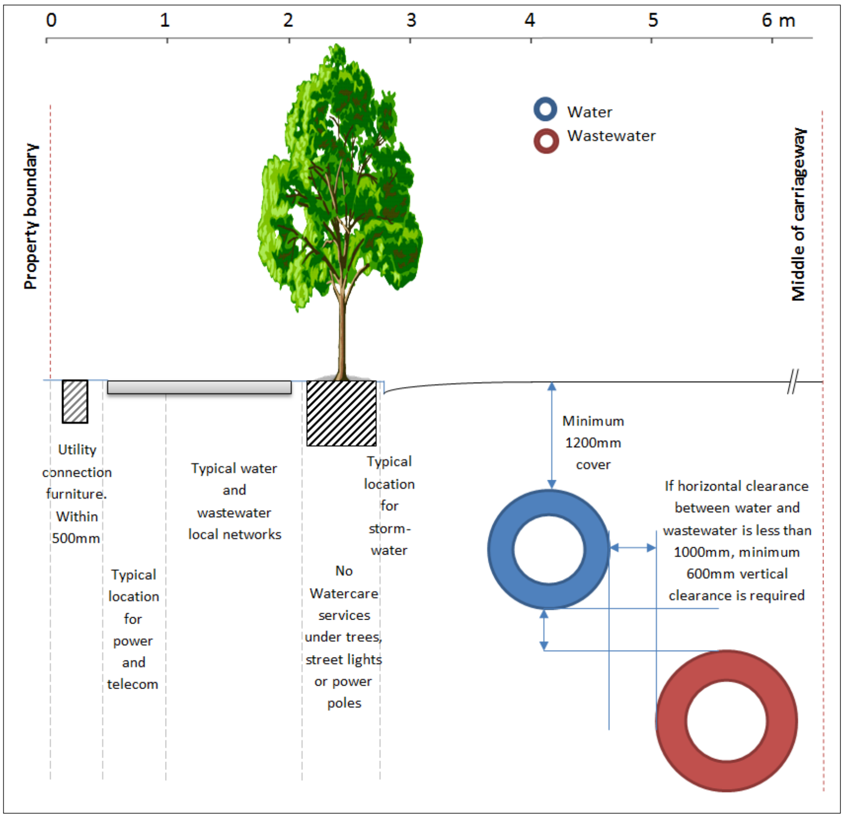


***Figure 3.1**: Spatial clearance and cover required for pipelines.*

c) Avoid private property and the need for easements.

d) Pipe 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 valve chambers 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)
250 to ≤375	300	150
>375 to ≤600	600	500
>600 to ≤800	1000	500
>800	1000 + De/4	500

f) The minimum clearance for pipes from any type of structure shall be 1500mm (unless connecting to the structure, see "Pipe through structures").

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.

3.2.1.1 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.

3.2.1.2 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.

3.2.1.3 Pipe bends

a) Horizontal directional changes shall be by long radius, constructed to follow the curve of the road using 45º bends or less.

b) Vertical bends for pressure pipe may pass over, or under services resulting in designated high or low points for ventilation or drainage where the deviation is ≥ ½ of the pipe nominal bore.

3.2.1.4 Pressure pipe ventilation

a) The pipe gradient shall be arranged to minimise hollows and high points; however the pipe shall not be without grade. The grade shall be a minimum of 1 in 500 to a ventilation point.

b) Dual action (air release and vacuum break) air release valves shall be installed on high points within a suitable underground chamber. Refer to Section 3.5 for air release valve details.

3.2.1.5 Pipe drainage points

a) Pipe drainage points shall be provided at low points and around mainline isolation valves.

b) The number of drainage points shall be capable of draining the pipe between isolation valves, to invert level within 6 hours.

c) Back syphoning must not be able to occur.

d) The drainage outlet shall consider the erosive effects of water discharge on the environmental. An appropriate energy dissipation or energy break shall be designed.

e) Drainage points for treated water shall consider current Watercare de-chlorination practice and provide a suitable mixing point or structure.

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

3.2.1.6 Pipe scour points

a) On watermains, scour valves are more effective for draining pipes and provide greater flushing velocities.

b) For scour points on pipelines larger than DN 750, a single gate valve is required.

c) Scour point design shall be based on suitable location for high velocity discharge at a minimum mainline velocity of 0.8m/s to flush and remove sediment. Scour valves shall be selected suitable for the design target velocity.

d) The scour discharge shall allow for adequate attenuation of the discharge energy such as riprap or a stilling chamber. The location shall be suitable for the maximum volume to be discharged.

e) Drainage points for treated water shall consider current Watercare de-chlorination practice and provide a suitable mixing point or structure.

f) Access to scour valves shall be off the carriageway.

g) Watercare may require that needle valves be installed at flushing points where accurate control is required during flushing.

The required scour pipe sizes shown in Table 3.2 below are based on minimum scour velocities.

***Table 3.2**: Minimum scour pipe size.*

Main size DN	Scour size DN
> DN250 - ≤ DN 350	100
> DN350 - ≤ DN600	150
> DN600 - ≤ DN1000	200
> DN1000 - ≤ DN1400	250
> DN1400 - ≤ DN1600	300
> DN1600 - ≤ DN2000	350
> DN2000 - ≤ DN2200	400

***Note:** These values are indicative. Designers must ensure the selected scour size can drain the pipeline within the required time at a velocity of 0.8 m/s, considering factors such as environmental conditions, e.g. A 400 mm scour may not be practical due to environmental constraints.*

3.2.1.7 Pipe through structures

a) Where the structure is designed to accommodate pipe thrust, a fully welded puddle flange shall be used (this is the preferred option).

b) Although not preferred, where the structure is not designed to accommodate any pipe thrust or load, a suitably sized sleeve shall be provided to accommodate expansion and contraction. A water stop shall also be included, and the necessary allowance made for maintenance access.

3.2.1.8 Connection to local networks

The connection from a water transmission system to the local network shall be through a metered bulk supply point (BSP).

BSPs must take into account the following design considerations to support operational reliability and ease of future upgrades:

a) Pressure reduction valves (PRVs) - Watercare will define specific pressure zoning requirements, whether for current or future needs.

b) The BSP shall be located at a mainline isolation point to provide bi-directional feed from the bypass pipework and enhance resilience.

c) BSP's should utilize 0-DN flow meters (FMs), which can be co-located with PRVs in the same chamber for efficiency.

d) Buried gate valves (up to~300mm) are acceptable; however, butterfly valves must be installed within a chamber.

e) Avoid dismantling joints where possible, as they are susceptible to corrosion in damp environments. Instead, account for welding and corrosion coating repairs (e.g., epoxy coating system).

f) Square chambers are preferred over circular ones, offering more space for equipment replacement and upgrades. Channel-lined pits or box culverts are recommended for installations within berms.

g) Water quality and sampling set out to comply with the standard drawings to ensure sufficient access (DW20).

h) BSP's shall be designed to accommodate equipment upgrades to allow for internal modifications or configuration changes to increase future capacity or performance.

i) Appropriate bolts shall be selected to comply with Watercare Standards. Threaded rods shall be avoided – refer to Guidance Note ESF-500-GDN-704.

j) Cabinets housing SCADA and flow meter (FM) equipment should comply with the standard drawings (DW20).

k) Humidity in enclosures shall be minimised to extend equipment life and reliability.

l) Batteries should primarily support FMs and SCADA systems during mains failure. Water quality monitoring systems do not require backup power in these cases. For compliance, refer to the standard drawings (DW20).

3.2.1.9 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.

3.3 Mainline isolation valves

a) Mainline isolation (line valves) is typically spaced to provide drain down time within 6 hours. Refer to Section 3.2.1.5 in consideration of drain-down times.

b) Mainline isolations are typically installed at bulk supply points to maintain continuity of water supplies and good locations for discharge of pipe drainage to stormwater, wastewater transmission (by approval) or permeable ground conditions.

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

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

- The need for ancillary equipment such as actuators

- The means of access for maintenance and replacement of the complete unit or maintainable parts such as gearboxes
- The type of valve being installed.
- The whole of life cost benefit for the proposed installation method

e) Remote operation by actuator and SCADA monitoring is used where response time for manual isolation is critical, or remote reconfiguration of the system provides value such as in emergency situations, or for planned works that can be arranged more efficiently. Refer to Watercare's electrical design standards for actuator design.

f) The main isolation valve shall include an isolation bypass to facilitate system recharge and/or draining. At low points in the pipeline, a double bypass isolation setup is required to enable complete drainage from both sides of the main isolation valve, which is essential for maintenance and ensuring the proper functioning of Pressure Reducing Valves (PRVs) and Pressure Sustaining Valves (PSVs). In other areas, a single bypass valve may suffice, allowing for controlled operations without unnecessary complexity.

g) Gate valves are used up to 300mm and geared butterfly valves for larger sizes.

h) For water pipes larger than 600mm the main pipe diameter may be reduced for economic benefit of a smaller isolation valve but only if it is hydraulically feasible.

i) Valve trains installed in sequence shall be of the same size.

j) Bypass valves are typically smaller than the main isolation valve to facilitate mainline charging and drainage. Bypass pipework up to and including 200mm shall be API Schedule 40 pipe and epoxy coated – refer to standard drawing 2001979.134.

k) The horizontal clearance between the main line and bypass shall be minimum 300mm at the closest point.

l) Handwheels shall be 300mm clear of obstacles.

m) Where pipe reducers are used it shall be an eccentric reducer, tapering down from the bottom of the pipe.

Note*: All valves shall be double flanged. The only exception would be where lugged valves are used for isolation of air valves (refer drawing 2001979.138).*

3.4 Pressure, flow and level control valves

a) Butterfly or gate valves shall not be ordinarily used for flow or pressure modulation. Fit for purpose control valves shall be used.

b) Control valves shall typically be SCADA monitored and may require to be fitted with an actuator for remote operation. Refer to Watercare's electrical design standards.

c) Control valves shall be installed in an above ground building or dry chamber. The installation location must be demonstrated to be the best practicable option.

d) Valve trains installed in sequence shall be of the same diameter, however where it may be considered that a future upgrade will require the valve train to be up-sized the isolation valves may be selected to be greater in diameter.

e) Isolation valves shall be provided at both ends of the installation; these may be direct buried outside the chamber if of suitable valve type.

f) Duplicated control valve trains may be required per design considerations, with individual isolation at both ends for enhanced operational flexibility and maintenance access.

g) If the installation is for a dual system (high flow with low flow) the bypass shall be provided to the principal set only.

h) The horizontal free clearance between the mainline and bypass shall be minimum 300mm at any point. Also see Section 3.7.1.5 for general clearances.

i) Pipework shall be arranged to provide vertical lifts on equipment that require ongoing maintenance.

j) Control valve train isolation valves shall be fitted with handwheels.

k) Where pipe reducers are used it shall be an eccentric reducer, tapering down from the bottom of the pipe.

l) Bypass pipework up to and including 200mm shall be API Schedule 40 pipe and epoxy coated.

m) Design PRV bypass pipework for maximum ultimate flow rate in the pipeline at the projected minimum pressure differential.

3.5 Air release valves

a) Air valves shall be installed in dry chambers or by specific requirement be surface mounted (e.g. on pipe bridges).

b) Air release valves shall be installed with concentric reducer at the pipe soffit. The reducer shall be sized for optimal air collection. Installations shall comply with standard drawings (2001979.137 – 2001979.145).

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

d) 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.

e) 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.

f) Where the flow velocity in the pipeline is more than 2.4 m/s the air valve shall be fitted with an anti-slam device/feature.

Air valves shall generally be located at:

- Intervals not exceeding 600m (This should be verified by the design to demonstrate that air is not entrapped for long distances as this can range from 400m – 800m based on air valve sizing)
- High points (summits)
- Significant increase in downward slop
- Significant reduction in upward slope
- On the downstream side of pressure reducing valves

- At stop ends

3.6 Meters

a) The meter must be selected at a suitable flow velocity for optimal accuracy (to be confirmed with Watercare). This often requires that the pipeline be reduced in diameter. Reducers shall be concentric.

b) Meters for transmission applications shall be electromagnetic type as per material supply standard.

c) The meter manufacturer's clear upstream and downstream diameter to length ratio shall be observed, taking into account the effect of eccentric reducers which may require greater clearance than valves and other fittings. Where upstream and downstream spacing for accuracy is not sufficient, then a UO/DO = 0/0 meter may be used.

d) Valve trains installed in sequence, including meters and strainers shall be of the same diameter, however where it may be considered that a future upgrade will require the valve train to be up-sized the isolation valves may be selected to be greater in diameter.

e) Meters are in order of preference to be installed in an above ground building or dry chamber.

3.7 Structures

3.7.1 Dry chambers

Dry chambers typically house equipment and valves that require frequent maintenance and operational access for inspection. While surface or remote operation should be considered where practical, dry chambers remain a preferred solution for reliable equipment protection and accessibility. Where underground dry chambers are necessary, the following shall be considered:

3.7.1.1 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) Ventilation louvers must be positioned away from carriageways and pedestrian walkways.

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

3.7.1.2 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.

3.7.1.3 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.

3.7.1.4 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. Where ladders are provided it shall be extendable to a minimum of 1000mm through the chamber lid above ground level.

d) Lighting shall be provided over critical equipment and operating areas, but only if electricity is already required for the chamber for other purposes. Access platforms shall be provided to allow optimal operation position and clearances.

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.

3.7.1.5 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.

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.

3.7.1.6 Ancillary components

a) Chambers shall be permanently ventilated by either passive air flow or by forced ventilation. Ventilation ducts are covered by standard louvre vents at surface level.

b) 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 if only gravity drainage is not feasible. In low lying areas the sump may need to be a equipped with a drainage pump.

c) Where chamber lids are not ordinarily removed for access, suitable lighting shall be provided, but only if electricity is already required for the chamber for other purposes.

d) Valves and equipment inside chambers shall be designed with the necessary structural support, preventing the transfer of stress to adjacent flanged assemblies and pipework.

3.7.2 Reservoirs and balancing tanks

3.7.2.1 General consideration

a) Architectural and landscaping standards for the reservoir and other structures shall be appropriate to the surrounding environment. Refer to Watercare's *Architectural design guidelines*.

b) The reservoir shall be vented to allow air transfer during normal level changes. Vents shall be protected from entry by vermin, other unauthorised access and water ingress.

c) A standard double sample box shall be provided at an easily accessible point, with samples sourced from specified locations within the reservoir as per standard drawings.

d) The roof of the reservoir and the connecting valve chamber structures are generally unpainted.

Note: *Refer to* Section *4.10 for connectivity between structures*

3.7.2.2 Reservoir pipework

a) The inlet and outlet pipework shall be designed to allow water circulation and maintain water quality. The configuration should consider the reservoir's shape and whether it is buried or above ground. A common approach is to place the inlet and outlet in different locations to help water move through the entire reservoir since using different inlet heights is not always practical.

b) Pipework and valves must allow for practical operation and full draining of the reservoir for periodic cleaning.

c) Bypass pipework connecting the inlet and outlet shall be provided that allows the reservoir to be taken out of service without disrupting the connected network.

d) All valves shall be positioned to allow easy operation and maintenance, with adequate clearance. Refer to Section 3.7.1.5 for general requirements.

e) Reservoirs shall be fitted with flow meters on both the inlet and outlet. This requirement may be reviewed when the connecting system can be easily balanced.

f) Flexible couplings may be required to accommodate differential settlement. Refer to Section 4.10 for connectivity requirements.

g) Pipework shall be selected fit for purpose. Typical material selections include concrete lined steel, ductile iron.

3.7.2.3 Reservoir access and platforms

a) The reservoir operator access shall have a minimum clear opening of 600mm diameter. Where equipment access is designed, sectioned openings may be required to be sized appropriately.

b) Access lids shall be to the standard Watercare details and fitted with an alarm that will signal unauthorised access through the security system.

Note: *Refer to Watercare standard drawings for standardised access hatch design.*

c) The access points shall be fitted with 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) Stairways are preferred over ladders. Where ladders are provided it shall be extendable to a minimum of 1000mm through the lid opening above the access hatch frame.

f) Access platforms shall be provided to allow optimal operational functions and access clearances.

g) Reservoir access not fitted with stairways shall have a fall restraint post or similar attachment point installed near the access hatch.

h) A minimum secondary access point should be located next to the overflow if this is practical. The feasibility of this access should take into account site constraints, reservoir design, and operational requirements.

i) Access shall be lockable with a specific key mechanism for the operational area.

j) Above ground reservoirs, where public access to the reservoir roof is not permitted, shall have secured access in accordance with standard drawings.

k) Handrails on above ground reservoirs and for external and internal platforms shall be provided to AS1657 and in accordance with Watercare standard layout requirements for the specific environment. Refer to Watercare's standard drawings for public and non-public areas.

3.7.2.4 Reservoir site access

a) The access road shall be a sealed road with adequate turning area for a hi-ab equipped truck.

b) Truck access shall continue through the reservoir site to associated valve chambers with suitable hard-stand areas provided around access hatches.

c) Buried reservoirs with site restrictions may require the designer to consider vehicle access onto the roof.

d) Refer to Watercare Architectural guidelines for more detailed aspects of site access and view lines.

3.7.2.5 Control and monitoring

a) Level control shall be by hydraulic altitude control valve with electronic/solenoid piloted control loops, where appropriate. (Spring-loaded altitude valves are not accepted).

b) Guard valves (typically butterfly valves) are required on the outlet pipe to be closed remotely in the event of a supply zone pipe burst. One valve shall be hard-wired to SCADA.

c) Level transducers installed on the scour pipework shall monitor levels to remote indication through SCADA.

d) Overflow probes shall be hardwired.

e) Underfloor drains shall be installed with discharge locations arranged to detect leakage from specific parts of the reservoir, where appropriate.

f) Power meters shall be located accessible for maintenance or replacement without the need to access the reservoir. Or surrounding complex. The preference is to have the meter installed at the property boundary.

g) Access hatches and cabinets shall be alarmed to signal entry through the SCADA system.

3.7.2.6 Drainage and run-off water

a) The discharge from the reservoir shall be into an accessible manhole.

b) The roof rainwater system and site stormwater drainage shall discharge to the area stormwater system. If there is no piped system, then arrangements must be made for disposal without causing erosion or potential property damage, following Auckland Council stormwater discharge guidelines.

c) An overflow/discharge and receiving environment shall be sized and designed to accommodate the maximum possible inflow in compliance with discharge consent.

3.8 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. Table 4.1 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)
250 to 300	100	150	150	600 in back berm, 900 in front 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 ζ = 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) Watercare minimum pipe material pressure rating is PN16 for transmission.

c) 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.

d) 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.

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 ratio shall be determined with the modified Iowa formula, Spangler & Watkins (1958):

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

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 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) 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.

c) 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.

d) 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.

4.4 Hydraulic thrust and fluid impulse

4.4.1 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.

4.4.2 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
- Surge anticipation valves
- Relief valves
- Flow control valves
- Appropriately selected air/vacuum valves
- Non-slam non-return valves
- Automated valve operation with designed open and closing times
- 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/m^3)

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/m^2)

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)

The principles outlined above are well-documented in Wylie & Streeter (1993), Fluid Transients in Systems.

4.5 Suspended pipe and pipe support structures

4.5.1 Pipe bridges

4.5.1.1 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 for pipe bridges 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 4.5.1.2 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)*

4.5.1.2 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.

c) Access to key componentry such as air valves must be provided with safe access for maintenance and replacement.

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

e) 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.

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

4.5.1.3 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.

4.5.1.4 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.*

4.5.2 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

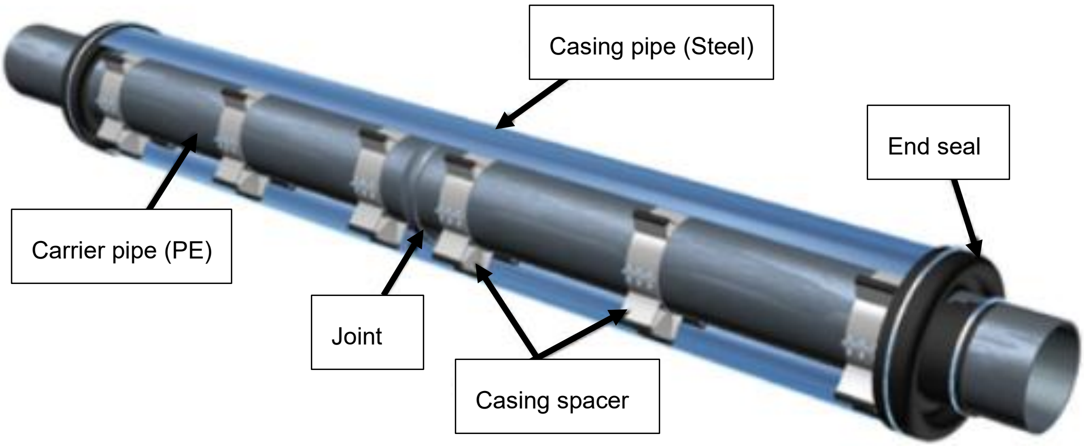
iv. Localised saddle stress and in some cases friction on the pipe

v. Seismic action. Refer to Section 4.9.

e) Refer to Section 4.5.1.3 for Watercare's preference on support methods specific to the material type for pipe bridges.

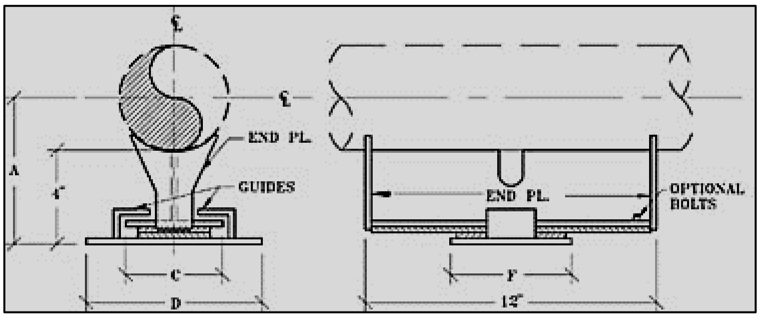
Potential support examples:

i. Host/carrier pipe

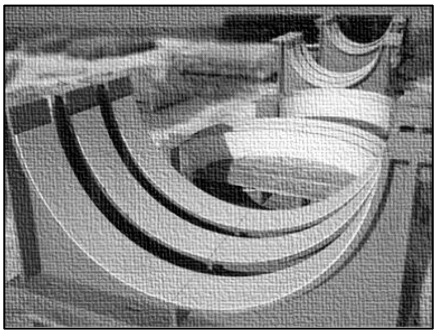


ii. Welded girders

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

<u>Example:</u> Un-insulated support, no protection between the support and the pipe material:

4.5.3 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.

4.5.4 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.

4.6 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

4.7 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)

4.8 Reinforcement of pipe fittings

a) Pipe fittings such as tees, wyes and headers are more at risk to longitudinal forces and pipe pressure due to the reduced side wall and distortion of forces by directional changes.

b) Where proprietary fittings are used the designer must confirm with the manufacturer that suitable safety factors have been used in the design of the fittings.

c) For fittings made from steel specific design must completed to confirm the type of branch reinforcing (collar plate, wrapper plate or crotch plate) and its dimensions. Refer: *AWWA M11, Steel pipe – a guide for design and installation*.

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:

- Fault offset
- Liquefaction
- Slope movement / Landslides
- Slope stability
- Compression and tension in pipe joints

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 and framing of water infrastructures 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.

f) Acceptable fuse locations must be designed where service breaks can be easily repaired to minimise disruption instead of compromising key infrastructure such as pump stations, plants and valve stations.

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 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) Isolation joints and test stations shall, as far as practicable, be located at main line valve installations.

c) Anode beds shall, as far as practicable, be near main line valve installation.

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 cement mortar lining solution.

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).

d) Where pipe and fittings are used for potable or raw water systems the lining system where in contact with water must comply with AS/NZS4020.

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).*

The minimum system test pressure which shall be applied at the lowest point in the test section, shall be the greater of:

(a) 1.25 times the system design pressure

(b) 160 m head

4.13 Water Quality

Planning and design shall consider the configuration of the network to manage water quality. Factors to consider include:

- Sizing of the network to achieve minimum velocities and prevent deposition of sediment
- Limiting maximum velocities to 2.5m/s to prevent discolouration
- Staging reservoir capacities to achieve the required turnover of stored water
- The inclusion of cross connections

4.14 Termination of Pipelines

Pipelines shall be terminated with an endplate, blank-end, or an end capped section valve as per standard drawing 2001979.029 (Drawing set: ESF-500-FOR-103 / DW10). Where future extension is a possibility, consideration should be given to using a suitable length of welded joint steel pipe or an alternative anchorage that will allow a straightforward connection to the extension.