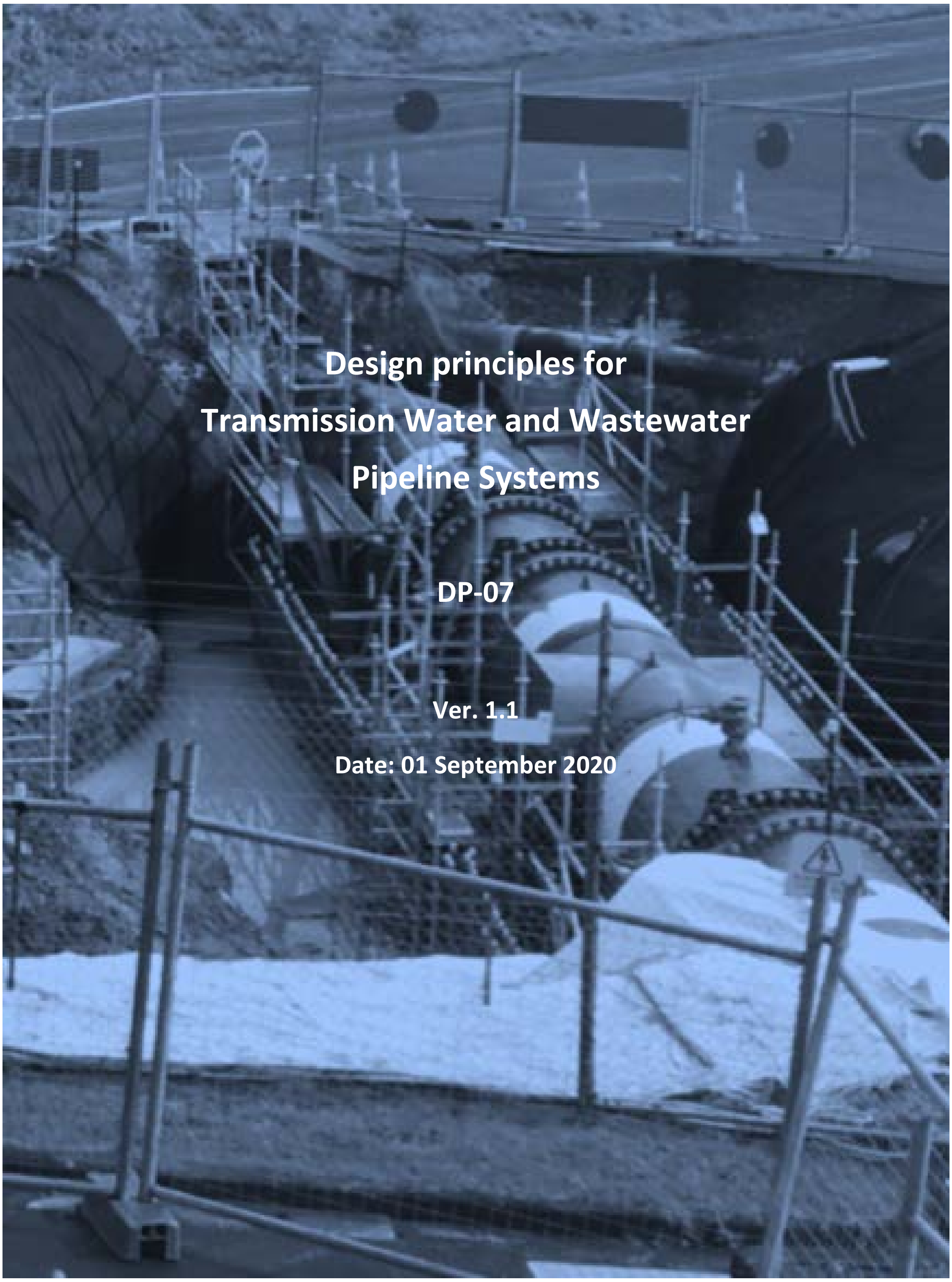

Design principles for Transmission Water and Wastewater Pipeline Systems

DP-07

Ver. 1.1

Date: 01 September 2020

Revision	Description	Released By	Date
0.1	First draft	J de Villiers	15/09/2017
0.2	Final draft	J de Villiers	20/02/2018
0.3	Working draft for comment	J de Villiers	22/06/2018
1	Updates from working draft. Document finalised	J de Villiers	12/08/2019
1.1	Minor updates include biofilters, dewatering and trench bedding	J de Villiers	1/09/2020

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Summary of changes

Version	Section	Description of revision
1	Part A, 3	Update referenced standards and documents
	Part B, 4.2	Correct pipe grades for gravity sewer in relation to pipe volume and self-cleansing flow
	Part C, 2.1.11	Included considerations to proximity of metallic pipe to electrical services
	Part D, 10	Additional seismic considerations and design guidance for equipment associated with transmission systems
	document	Minor grammar corrections
1.1	Part C, 2.1.2	Added clarifying text to pipe trench dewatering considerations
	Part C, 4	Update section on biofilters to allow more site-specific design
	Part D, 2.1	Update to selecting pipe bedding materials
	Part D, 12.1.4	Inserted section on internal pipe corrosion protection
	General	Updated references

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Definitions

Assets	Water and wastewater infrastructure owned and operated by Watercare, anything of financial value or provides service potential.
As-built drawing	Drawings showing the exact dimension, geometry and locations of assets
Bulk	The collective operational areas of **Transmission, Water supply** and **Treatment** (other than in networks) i.e. all infrastructure upstream of a bulk supply point for water or in reference to wastewater where the peak dry weather flow is more than 78l/s.
Bulk supply point (BSP)	Metered connection off a transmission pipeline to a network.
Chamber	A partially below ground or below ground enclosure where equipment and dry pipework is housed for inspection 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 equipment and return data on processes and devices of operational infrastructure
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.
Gravity pipe [system]	a piping system where flow occurs through gravitation fall of the liquid medium without exerting internal pressure on the pipe walls and for which no pumping is required
Interceptor [wastewater]	Sewer pipe that receives flow from a number of other, typically smaller, sewers or outlets to convey the flow for downstream pumping or treatment.
Local networks	Reticulated distribution piping that is downstream connected from a transmission water main or upstream for wastewater where the peak dry weather flow is typically less than 78l/s.
Manhole	A partially below ground or below ground enclosure where equipment is housed. Manholes are wet areas where pipework or channels have open flow. Typical examples are directional changes and for maintenance by man access for wastewater gravity systems, or man access to large diameter pressure pipe when not in service.
Master meter	Metered connection within a network system that operates as a main metering point for slave meters situated on a private network.

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 point at which an owned asset stops and a private network starts. At this point the responsibility for ownership and maintenance of assets and equipment transfers to the customer.
Potable water	Treated water that complies with the drinking water standards for New Zealand
Pump(ing) station	Structure containing pumps, associated pipes, valves, mechanical and electrical equipment for pumping fluid.
Pressure main	Piping system where fluid exerts internal pressure on the pipe walls by liquid elevation or by means of pumping
Raw Water	Untreated water from the water supply source
Reservoir	A water retaining structure where potable water is stored and controlled for distribution.
Rising main	A pumped pressure main discharging into a receiving structure. See **Pressure main**
Siphon	A pipe section where fluid is drawn from a higher section to a lower section by gravity and atmospheric pressure.
Transmission	High volume supply (water) or collection (wastewater) for the purpose of transmitting liquid in bulk over long distances. For Wastewater see **Interceptor.** Water is potable (after treatment stage in Water Supply – ref. “Water Supply”) and reticulated between reservoirs. Reservoirs are included.
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, or

	Wastewater treatment that receives wastewater from Wastewater transmission (ref. "Transmission") to remove contaminants through mechanical, chemical and biological processes.
Transmission watermain	A large main designed for the conveyance of bulk water to other transmission mains, reservoirs or bulk supply points. Transmission mains do not supply service connections to customers. Also see **Bulk supply point (BSP)**
Transmission wastewater main	See **Interceptor**
Tunnel	An underground passage for conveyance of water, vehicles piping or conduit
Watermain	Collective term used for pipe (any) carrying water in the transmission or network operational areas
Well [for water abstraction]	The subsurface source of water, typically accessed through drilling and supplied by an aquifer. See **Borehole.**
Wet well	Chamber in which water or wastewater is collected and to which a submersible pump is connected

__Acronyms__

ADD	Average daily demand
CAD	Computer aided design
CLS	Concrete lined steel [pipe]
De	External diameter
DI	Ductile iron
DN	See nominal diameter
DWSNZ	Drinking water standards of New Zealand
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
m²	Metre square
m³	Metre cubic
MDD	Maximum daily demand
mm	Millimetre
NB	See **Nominal bore**
O&M	Operations and Maintenance
Pdf	Portable document format (Adobe Acrobat)
PE	Polyethylene
ppb	Parts per billion
PVC	Polyvinyl chloride pipe
RCRRJ	Reinforced concrete rubber ring jointed (pipe)
sec	seconds
SCADA	Supervisory control and data acquisition – A control system used for alarm monitoring, control and data collection
SN	Nominal stiffness
SoP	Standard operating procedure
UO/DO	Meter upstream/downstream irregularity tolerance

Part A – Preamble and general design requirements

1. Introduction

1.1 Purpose

This design standard sets out the design principles for linear water and wastewater assets in the Watercare Transmission systems. Linear transmission installations are those that supply water to, or collect wastewater from, the local network systems. Transmission pipelines include raw water mains that convey untreated water from the dams to the treatment plants. However, the purpose of this design standard is to apply the level of design that is appropriate for the size, complexity and criticality of the linear assets. Transmission assets are typically constructed through Watercare's infrastructure projects.

Developers and local network projects are designed and constructed in compliance with the Auckland Code of Practice for Land Development and Subdivision, chapters 5 and 6, but limited in size of 250mm for water and 300mm diameter, or 78l/s, for wastewater. Developers are referred to this standard for sizes over those mentioned and through early consultation with Watercare to establish the criticality and suitable standard associated with larger infrastructure.

Where smaller infrastructure is directly associated with a transmission system it must be completed to the transmission standards due to the large infrastructure that it is connected to, e.g. the smaller sizes of a transmission system such as bypasses around line valves or the supply to a bulk supply point.

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

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

This standard excludes specific requirements for:

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

1.2 '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 in which it is used.

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

2. Standard documents overview

2.1 Relationship of Watercare standards

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

The Watercare standards sets are requirements additional to nominated national standards, international standards and industry best practice to meet, and in some cases exceed legislative requirements, to accomplish long term operability and good asset management practices to benefit our customers. The interface of these standards with each other and the project specifications are as follows:

2.2 Design standards

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 baseline standard design drawings, interface design between standardised components, establishing the correct sizing of components to complement the baseline parameters of standard drawings and the basis for developing bespoke designs.

2.2.1 Design drawings

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

2.2.2 Asset and material standards

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

2.2.3 Construction standards

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

2.2.4 Project specific specification

These specifications identify site/project specific requirements that are not covered by the normative construction standards or standard design drawings identified during specific design.

2.3 Design build projects

Design build projects shall follow the minimum requirements set out in the Watercare standard documents for design and construction.

3. Referenced standards

3.1 Standards list

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 higher level of standard shall take precedence.

3.1.1 Watercare standards

DP - 10 Safety in Design guide

DP - 11 Watercare, 2017. Health and Safety in Facility Design

DP-09 Electrical design standard

CG - General civil construction standard

ME - General mechanical construction standard

MS - Material supply standard

7363 - Watercare CAD manual

AI - Data and Asset Information standard

DW05 - Access structure drawings for wastewater infrastructure

DW06 - Access structure drawings for water infrastructure

DW07 - Access structures general drawings for public and non-public areas

DW08 - Pipelines for wastewater greater than 300mm diameter

DW09 - Wastewater manhole drawing set for pipelines 375mm and greater

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

DW23 - Cathodic protection mechanical and civil detail drawings

COP-03 Code of Practice for commissioning

COP-04 Code of Practice for disinfection of water systems

3.1.2 National and international standards

NZS 1170 Structural design actions
Part 5 Earthquake actions – New Zealand
Part 5 Supp 1 Earthquake actions – New Zealand – Commentary

AS/NZS 4219 Seismic performance of engineering systems in buildings

AS/NZS 2566 Buried flexible pipelines
Part 1 Structural design
Part 1 Supp 1 Structural design – Commentary

AS/NZS 3725 Design for installation of buried concrete pipes

AS1657 Fixed platforms, walkways, stairways and ladders. Design, construction and installation

AS/NZS 5131 Structural steelwork – Fabrication and erection

AS/NZS 4853 Electrical hazard on metallic pipelines

3.1.3 Other publications

Menon, E Shashi, 2015. Transmission pipeline calculations and simulations manual

American Water Works Association, M11 Steel pipe – A guide for design and installation, 4th Ed.

American Lifelines Alliance, 2005. Seismic Guidelines for Water Pipelines

NICEE, 2007. Guidelines for Seismic Design of Buried Pipelines

Opus International Consultants, Water NZ, 2017. Underground Utilities – Seismic assessment and design guidelines

New Zealand National Society for Earthquake Engineering, 2009. Seismic Design of Storage Tanks

Roberts, R, New Zealand Geotechnical Society, 2017, New Zealand Ground investigation specification, Volume 0, 1, 2 and 3

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

Mott, R L, 1994. Applied fluid dynamics, 4th Ed.

CPAA, Concrete pipe association of Australia, 2012. Hydraulics of precast Concrete conduits

CPAA, Concrete pipe association of Australia, 2013. Jacking design guidelines

NPCA, National Precast Concrete Association (USA), Manhole sizing recommendations

4. Design deliverables

Design work shall be completed by a Chartered Professional Engineer or a suitably qualified engineer who have their work reviewed by a Chartered Professional Engineer in accordance with the Watercare compliance statement policy. Any design produced may be subjected to review by a Chartered Professional Engineer.

The designer must consider the design under the full operational requirements and apply good engineering practice that reflects:

- Compliance with New Zealand legislation, the most recent national standards, regulations and local conditions
- Watercare standards as included and referenced in this standard
- Historical information that may impact on the design
- Community and customer expectations
- Other information or specific conditions as provided by Watercare

The design shall not re-draw or amend a current approved Watercare standardised design. Specific design drawings shall cross-reference to the standard Watercare design and constructions standards. Where template designs are provided they shall be amended for material components only.

The following comprehensive documents shall be provided to Watercare for evaluation of the design:

a) Geotechnical reporting on the suitability of the land for the life of the asset
b) Basis of design report describing options and selection of design
c) Risk analysis
d) Design report, see section 4.1
e) Material schedules, see section 4.2
f) Project execution plan, see section 4.3
g) Site specific specification for construction
h) Nominated minimum levels of construction supervision
i) Drawings showing location, detailed long sections, pipe grades and sectional details
j) Functional descriptions (FD) of the transmission system and any automation
k) Operations and maintenance (O&M) manual draft

l) Standard operating procedure (SoP) draft
m) New assets register in accordance with Watercare's data and asset information standards
n) Design compliance statement – See Watercare compliance statement policy

Note:

-Material template schedules are available in the Watercare Material Supply standard, see document number: MS
-Drawings must be produced to Watercare CAD manual, see document number: 7363
-Refer to the Watercare Data and Asset Information standard, document number AI, for requirements of i), j) and k)

4.1 Design report contents

The level of detail should reflect the complexity and scale of the project. The following sections shall be mandatory:

- Project description
- Planning considerations and level of service performance
- Analysis of alternatives
- Design criteria
- Resilience analysis
- Assumptions and non-compliance
- Engineering calculations
- Material selection
- Value engineering that includes, constructability analysis, simplification, innovation and life-cycle costing
- Legal considerations
- Operations and maintenance considerations

4.2 Material schedules - material selection at design

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

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.

The selected material shall be fit for purpose and submitted to Watercare for approval before commencing with detailed design.

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.

4.3 Project execution plan

The project execution plan identifies how the project must be executed based on:

- Assumptions made for execution of the construction that was used to complete design calculations. Changes in contractor methodology may require re-design or the calculations to be confirmed.
- Satisfying the requirements and conditions of any building consent, discharge consent or resource consents.

- Watercare's connection requirements and operational constraints that will impact the installation.

Significant deviation from the project execution plan requires the design be re-submitted for approval by Watercare and any consequent design rework. Significant changes include:

- Change in operational process/philosophy
- Change in elevations
- Change in material
- Change in control/automation method and behaviour
- Changes in size, diameter or capacity
- Significant re-alignment or change in location

4.4 Design requirement exemptions

The following projects are typically excluded from design work:

a) Installation or replacements of like-for-like valves, fittings and meter assemblies with componentry that are fully compliant with the Watercare Material Supply standard and operate within the pressure range of up to 1200kPa.
b) Repair of a system component or replacing it with a similar Watercare approved component of the same operational capacity as described in the original design.
c) Maintaining corrosion protection on facilities, unless a new corrosion protection system is proposed.

To qualify for the design exception the works must be reviewed by a Watercare engineer with suitable qualification and experience, completed to Watercare standard design and the asset data, including as-built drawings updated to the current standard.

5. Criticality and infrastructure flexibility principles

5.1 Design life

The design life for any pipeline system and associated structures is to provide a 100 year service life within an acceptable level of service (quality and capacity of service) offset against an acceptable cost of maintenance of the service at this level. Some components may require maintenance or intervention before the 100 year service life, such as valve replacements, and must be included in the overall lifecycle cost of the system. The lifecycle cost for the specific design must be an amenable proposal compared to alternative design options. Refer to section 9 for pipeline economics.

Note: *Further information on life cycle cost and optimal point of replacement can be found in the International Infrastructure Maintenance Manual (IIMM, 2015)*

5.2 Function classes and criticality

5.2.1 Pipelines

The design factors listed in the table below are not fixed and may be adjusted by the designer with confirmation of ground formations.

Note: *Refer to the New Zealand Ground investigation specification for the level of geotechnical information to be applied*

Pipe function class		Description	Design Safety Factors				Seismic return period factor (NZS1170) R_u
			Peak ground acceleration	Liquefaction /subsidence	Landslide/ lateral movement	Surface loading	
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	1	1	1.2	0.75
2	Moderate	Common pipework in the Transmission networks, or Local Network mains larger than 150mm diameter, that if lost would result in unsatisfactory service disruption for 12 to 24 hours causing moderate economic impact.	1.5	1.2	1.2	1.2	1.3
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.	1.8	1.35	1.6	1.5	1.8
4	Essential lifeline	Pipelines that are essential to maintain service post natural disaster or man-made mishap and are intended to remain in service.	2.3	1.5	2.6	2	1.8

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

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

5.2.2 Manholes and chambers

Manholes and chambers are classified in accordance with the pipe function class that it is connected to as per section 5.2.1. Refer to Part D, section 11 for connection practices between structures and pipelines.

5.3 Resilience and redundancy

Resilience of linear assets is the ability of the linear system to sustain a level of service and absorb or adapt to changing conditions when there is a failure in 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
- Reservoir storage or onsite storage of critical infrastructure such as 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

5.3.1 Resilience measurements {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

Dimension	Principle	Indicators	Assessment method
	Modularity / flexibility	Modular systems, interchangeability	Standard design / best practice
		Future allowance for upgrade, improvements and strengthening	Audit against best practice
Organisational vulnerability	Variation readiness	Qualifications and experience of staff are appropriate to roles and responsibilities	Audit
		Staff quantity and resources are adequate to deal with reactive changes	Audit
		Continual development of staff	Survey / audit
		Communication is clear with protocols in place	Survey
		Information on systems and assets such as GIS, drawings and operational manuals are readily availability	Survey / audit
		Readiness/response planning are in place and practiced	Audit
		Funding availability to effect operational variance	Audit
		Insurance are up to date and with appropriate risk cover	Audit
	Leadership / culture	Decisive decision making	Survey
		Situational awareness	Survey
		System knowledge	Survey
		Innovative thinking	Survey
	External partners	Ability to leverage on external knowledge	Survey
		Partnerships, design and service delivery arrangements	Audit
		Behavioural/communication barriers that could restrict productive solutions	Survey

5.3.2 Scoring

Scores are assigned based on the assessment outcome for the individual fields listed under section 5.3.1 and collated up under the principle categories and rolled up as averages for technical and organisational averages.

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

6. Risk

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

7. Safety and hazard mitigation

7.1 Safety in Design guidelines

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

7.2 Safety in Facilities Design guidelines

Refer to Watercare Health and Safety in Facilities, 2017 for output requirements on infrastructure connected to linear systems such as wet and dry chambers.

7.3 Existing infrastructure

During the planning phases, high level consideration is given to the effect of delivering new infrastructure into 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 transmission area will typically involve connecting or undertaking work on existing infrastructure. There are some challenges when the age and operational changes to its original design may impact on the new infrastructure connecting to it. The designer shall include in their design the following factors and information:

i. Appraisal of original design with information, where available, provided for:
    - As-built drawings
    - Existing calculations
    - Site testing records
    - Field investigations
    - Commissioning records
    - Geotechnical reports
    - Operation and Maintenance manuals
    - Standard operating procedures

ii. 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 structures and impact such as loading, support and movement
    - Physical alterations to the infrastructure that deviates from the original design
    - Infrastructure age and condition affecting the connectivity design

iii. Alterations and interface with existing infrastructure affecting:
    - Floatation and settling
    - Material condition
    - Strengthening work to meet the new infrastructures resilience requirements
    - Flexibility/interacting forces

8. Design alternatives and standard design detail

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

Alternative design proposals may be considered where:

- Watercare's standardised design is not suitable
- Watercare's Health and Safety in design minimum standards are 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.

9. Pipeline economics

1. *Capital cost*: The capital outlay to design, fabricate, install and commission the pipeline. Components include the pipe, balancing tanks, valve, fittings, meter stations, chambers, cathodic protection, control systems, consents, design, construction, commissioning and management of the project.

Typical capital cost spread for straight pipeline construction is:

- Consents and legal agreements = 4%
- Design = 6%
- Material = 45%
- Labour = 40 %
- Incidental = 5%

For straight length pipelines the capital cost can be expressed as:

Pipeline capital cost = Pipe diameter(mm) x (Average total construction cost per mm-diameter-km) x Length(km)

Detailed breakdown is required for some specific pipeline scenarios in instances such as control chambers, balancing tanks, bridge or stream crossings and rail crossings.

The capital cost spread for detailed components typically is:

- Consents and legal agreements = 5%
- Design = 20%
- Material = 25%
- Labour = 48 %
- Incidental = 2%

The detailed cost is added to the pipeline cost as a lump sum to obtain the total capital cost:

Capital cost = Pipeline capital cost + Detailed costs

2. *Operation and maintenance cost:* The operational cost for energy consumption, utility cost such as telecommunication, lease costs, routine inspections (staff, vehicles and other resources) and component replacements or renewals. This cost is typically estimated based on operational history of similar systems.

3. *Depreciation cost:* The loss of value of the pipeline assets over time. The typical useful life expectancy of various material types is listed in the Watercare Material Supply standard.

Annual Depreciation = (initial cost – salvage value) / useful life in years

4. *Net operating income (NOI):* The income generated by the pipeline by servicing a catchment area or providing security of supply.

NOI = Annual income – Annual Operation and maintenance cost – Loan repayment (if any)

5. *Cost return period:* The time taken for the project investment to be recovered

Cost return period = Capital cost / NOI

6. *Net present value (NPV):* The net present value of the pipeline project in contract to future value calculated by:

$$NPV = \left[\sum_{j=1}^{n} (NOI)_j \, (1+i)^{-j}\right] - Capital\ cost$$

Where i = Minimum acceptable rate of return (2%) and j = expected life (100 years)

Where the NPV < 0; the project is not financially feasible.

Part B – Water and Wastewater Pipeline Hydraulic Design

1. Scope

The hydraulic design parameters provided in this section applies to all transmission systems, including water supply headworks. Specific design requirements for pump stations with rising mains, treatment and process design are not covered. The hydraulic design parameters for local network water (typical pipe diameter ≤250mm) and local network wastewater pipe (typical pipe diameter ≤300mm) are given in the Water and Wastewater Code of Practice for Land development and Subdivision.

2. Maximum population density

The maximum population density will be provided by Watercare.

3. Water supply hydraulics

3.1 System zones

a) All water systems and zones must have source totalising meters. Pressure meters shall typically be installed at the source or zone meter.

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

- Climate, such as high temperatures during summer that leads to increased water use
- Soils and landscaping surfaces affecting irrigation practices
- 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 leakage rates
- System pressure. Higher system pressure increases system leakage and water use
- Socioeconomic impacts:
  - Property values/size relating to occupancy rate, density and owner investment
  - Degree of recreational use of water
  - Housing density relating to landscaping size and upkeep that requires the use of water
- Water efficiency practices

3.2 Demand design

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

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

b) The alternative to source maximum day demand is averaging monthly meter records to estimate the MDD. 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) The MDD to average daily demand (ADD) peaking factor shall be **1.45**.

d) PHD must be provided whilst maintaining the minimum design pressure, see section 3.5. PHD typically varies with seasonal changes and must be accounted for. Where specific data is not available, PHD = 2.5 X ADD.

e) Where metered ADD values are not available, such as for new local network systems, the ADD shall be determined using the Water and Wastewater 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 3.1 are similar between the systems. The use of comparative data must be approved by Watercare and with a project suitable safety factor being applied in consultation with Watercare.

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

3.3 Reservoir/storage system

a) A number of factors may influence utilising water storage to meet demand of a supply zone that include:
   - Long storage times leads to water quality problems
   - Underestimated storage could lead to higher demand from the connected transmission system affecting pressure and flow velocity
   - Large storage from fewer sources takes longer to replenish

b) To mitigate these factors 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.

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

d) The storage capacity for the graded supply zone as set by the DWSNZ shall be designed to meet the ADD for system resilience of a minimum of 24 hours. Distributed storage provides better redundancy and system flexibility.

e) Balancing tanks are distinguished from reservoirs by their purpose to provide steady supply from a supply source and are not primarily sized to provide storage or resilience for a supply zone.

f) 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.

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.

3.5 Design pressure

a) The typical operating pressure range for watermains are from 250kPa to 1200kPa.

b) Pressure zones shall be established according to ground level contours by dropping no more than 2m/1000m from the supply point.

c) Pipe material, componentry and flanges shall be rated to the minimum specified in the Watercare materials supply standard.

3.6 Head losses

a) Head loss through pipe with full-bore flow is preferred to be determined using the Hazen-Williams formula. The limitations for using the Hazen-Williams formula is listed below, outside these parameters the Colebrook-White formula shall be used:

- Shall not be used for pipe with internal diameter less than 50mm or larger than 1800mm
- Flow velocity shall not exceed 3m/s
- Fluid temperature at 15°C, ±2°C
- The head loss in the transmission system shall be less than 1m/1000m

b) Coefficients for using the **Hazen-Williams formula: C_h = 140 for all pipe materials**

d) Linear measure of roughness **for Colebrook-White formula:**

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/PVC/GRP	Recommended by supplier 0.003 – 0.015

e) 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)*

Ratio:

Fitting		$\left(\frac{L_e}{D}\right)$
Gate valve	Fully open	8
	¾ open	35
	½ open	160
	¼ open	900
Check valve	Swing type	100
	Ball type	150
Butterfly valve - fully open		45

Fitting			$\left(\frac{L_e}{D}\right)$
Y-strainer			250
Bends	90° standard bend		30
	90° long bend (r/d > 1)		20
	45° standard bend		20
	45° 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

Friction factor (f_T):

Size (mm)	PE/PVC/GRP	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

4. Wastewater gravity hydraulics

4.1 Design flows

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

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

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

4.1.1 Static Model

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

Basic Flow Parameters

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

Industrial zones - applies where the gross area (including streets) is greater than 400 ha.

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

4.1.2 Dynamic flow model

a) Hydraulic model

Dry weather and design peak flows for a particular pipeline or pumping station may be derived from the dynamic hydraulic model of the existing Watercare sewer network. This is particularly useful if the network incorporates on-line or off-line storage for peak flows.

b) Greenfield areas

i. Where modelling is to be utilised for greenfield or redeveloped areas, the following parameters will be specified by Watercare:

- catchment runoff characteristics
- population density projections
- design storm duration
- infiltration provision

- any other relevant items

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

4.1.3 External flow contributions

a) Groundwater infiltration into pipelines = 2,200 l/ha/day.
b) Manhole infiltration during peak wet weather flows: 12 l/minute/manhole.

4.2 Grades and Velocity

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

a) Minimum flow velocities:

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

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

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

c) Maximum pipe grade:

The maximum grade for 3m/s velocity at peak wet weather flow shall not be exceeded. Pipe-full capacity shall not exceed 75% of the depth of the pipe diameter.

4.3 Head losses

4.3.1 Pipelines

a) The minimum transmission pipe size shall be 375mm diameter.
b) Maximum pipe capacity of a gravity pipeline is to be taken as the pipe running full with no surcharge.
c) For partially filled gravity wastewater pipe the Colebrook-White method shall be followed.
d) The linear measure of roughness (Colebrook-White coefficient) for any gravity pipe material shall be 1.5 (x 10^{-3}) m.
e) Overflows must be designed for surcharge at 500mm head.

4.3.2 Manholes, bends and junctions:

a) Junctions shall be designed to reduce turbulence in the wastewater pipeline to a minimum.
b) Flows must join at or below the level of average dry weather flow.

4.3.2.1 Head loss in bends and junctions

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

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

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

b) Where bends are formed of chords instead of curves, an increased loss may also need to be provided for. R/d should preferably be kept at 3 or over where possible. Values under 2 are undesirable.

For lobster-back bends use: **Head loss (mm) = $1.3(v^2/2g)$**

c) To achieve good hydraulic conditions for lobster-back bends formed from CLS and PE pipe, and to minimise losses, the bends shall have a minimum nominal radius of 3 x pipe diameter. The deflection in any one joint shall not exceed 22.5 degrees.

4.3.2.2 Change in pipe grade

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

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

b) For grades 7% and over gradient change through a manhole is not acceptable without a drop structure.

Note: Also see section 4.4 below for special hydraulic conditions as a result of change in pipe grade.

4.4 Special hydraulic conditions

a) Where the sewer changes in size (and at junctions), pipe soffits are matched in level to maintain airflow through the pipelines, minimise corrosion and prevent air-locking.
b) Where the velocity in the sewer increases through changes in grade and particularly if the size of the sewer is decreased, the profile of the water surface at maximum flow shall be confirmed to ensure it falls below pipe soffit at top of the steeper grade. (Reference: Camp SWJ, 1946 & Fair and Geyer page 407).
c) Draw-down will occur in certain circumstances e.g. above a drop manhole, or above a point where noticeable increase in velocity occurs. The velocity due to draw-down may require a drop invert.
d) A downstream manhole junction from a wastewater pipe with high velocity is susceptible to hydraulic jump (collision of fast-moving incoming flow with slow-moving fluid head). Also steep slopes at the inlet to inverted siphons may lead to air entrapment causing periodic blow-back and damage.

Possible solutions or prevention of hydraulic jump includes:

- Reducing the pipe grade transition and allow sufficient airflow
- Change manhole to a drop structure
- Change pipe diameter

5. Wastewater inverted siphons (Depressed wastewater system)

a) Inverted siphons shall be avoided as far as practicable due to their maintenance constraints. Pipe bridges is Watercare's preferred option unless proven to be unfeasible.
b) Follow design methods described by Metcalf and Eddy (1981) and as supplemented by equations in Chow (1959) and, Viessman and Hammer (1998).

   Reference:

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

c) The siphon entry structure shall be configured to assist in maintaining self-cleansing velocity within the siphon at normal flows.
d) Where flow rate is dominated by the periodic discharge from a pumping station, a single siphon barrel may be acceptable provided that there is sufficient storage at the pumping station to provide sufficient flushing flow and duration.

5.1 Flushing

a) Provide an effective means of flushing to manage build-up of sediment in the siphon. This may also provide a useful degree of flushing to the sewer downstream of the siphon.
b) Provide an internal bypass structure to guard against overflow in the event that the penstock valve fails to open for flushing. The bypass can also assist with accelerating the downstream sewer flow in the siphon before the flush is released.

5.2 Air pressures and ventilation

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

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

5.3 Crossing under water bodies

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

Part C – Layout design

1. General

Transmission pipelines are typically installed in the road whilst local network pipelines are generally installed within the berm of the road corridor. Layout requirements for local networks are described in the Auckland Council Code of Practice for Land Development and Subdivision chapters 5 and 6. These chapters are maintained by Watercare, document numbers COP-01 and COP-02.

Note: *The Auckland Council code of practice can be accessed at www.aucklanddesignmanual.co.nz.*

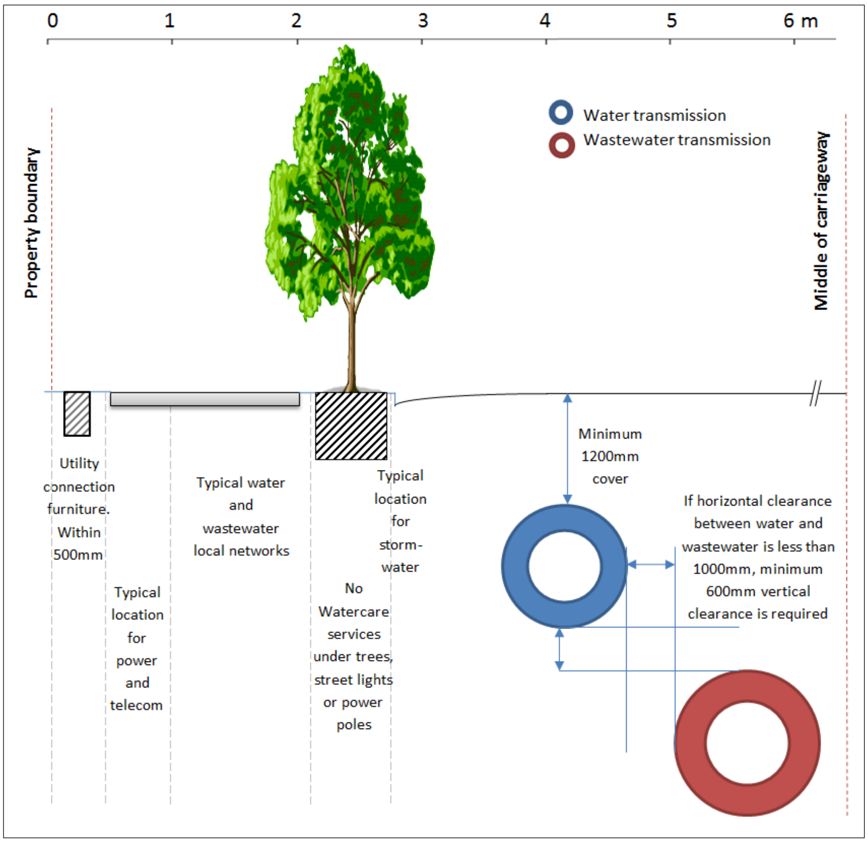
2. Transmission pipe systems

2.1 Pipes

2.1.1 Spatial location

a) Pipes shall where practicable be buried in the road reserve and where there isn't sufficient berm space, within a traffic lane so as to minimise temporary traffic control for future maintenance and access.

b) Above ground pipe must be suitably UV protected and accessible for maintenance and inspection. Refer to Part D, section 6.1 for pipe bridge design.



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) where impediments such as air valves or utility services exist. The pipe depth shall also consider existing and future connections to the transmission mains

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 the table below in respect of the largest service:

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

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

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

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

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

2.1.2 Pipe trench dewatering

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

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

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

2.1.3 Pipe movement and flexible joints

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

Note: *Also refer to pipe seismic evaluation when considering joint flexibility and their limitations,* *Part D, section 10**.*

b) Mechanical fittings shall be located with clear vertical access for maintenance, inspection or replacement.

2.1.4 Pipe bends

a) Pipe horizontal directional changes shall be by long radius, constructed to follow the curve of the road using up to 45° bends. Gravity wastewater system horizontal changes shall be through manholes.
b) Pipe vertical bends for gravity systems shall always pass under an obstruction and with a continued grade.
c) Pipe vertical bends for pressure pipe may pass over, or under with a designated high or low point for drainage or ventilation where the deviation is ≥ ½ of the pipe nominal bore.

2.1.5 Pressure pipe ventilation

a) The pipe gradient shall be arranged to minimise hollows and high points.
b) The pipe shall not be without grade. The grade shall be a minimum of 1 in 500 to a ventilation point.
c) Dual action (air release and vacuum break) air release valves shall be installed on high points within a suitable underground chamber. Refer to section 2.5 for air release valve details.

2.1.6 Gravity pipe ventilation

a) Air displaced by rising and falling of flow levels will be provided in vented manhole lids and terminal vents.
b) Air extraction shall be at downstream ends of the system at:
   - Pumping stations
   - Siphon inlet
   - Discharge manholes
   - Drop structures
   - Strategic manholes depending on the age of the wastewater
c) Air flow may be active or passive and must be designed to maintain air flow in the pipe.
d) Pipe ventilation shall be minimum 0.2m/s at 75% cross sectional area.
e) Refer to section 4 for ventilation odour control.

2.1.7 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 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.
g) Wastewater pressure pipe drainage shall be into a manhole for removal by sucker truck.

2.1.8 Pipe scour points

a) Scour point design to flush mains and remove sediment shall be based on suitable location for high velocity discharge at a minimum mainline velocity of 0.8m/s. Scour valves shall be selected suitable for the design target velocity.
b) The scour discharge shall allow for adequate attenuation of the discharge energy such as rip-wrap or a stilling chamber. The location shall be suitable for the maximum volume to be discharged.
c) Drainage points for treated water shall consider current Watercare de-chlorination practice and provide a suitable mixing point or structure.
d) Access to scour valves shall be off the carriageway.

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

2.1.9 Pipe through structures

a) Where the structure is designed to accommodate pipe thrust a fully welded puddle flange shall be used.
b) Where the structure is not designed to accommodate any pipe thrust or load, a suitable sized sleeve to accommodate expansion and contraction, provide a water stop and designed to allow access for maintenance shall be used.

2.1.10 Connection to local networks

Water specific:

a) The connection from a water transmission system to the local network shall be through a metered bulk supply point. Pressure reduction may be required.

Note: *Consult with Watercare service delivery for specific pressure zoning requirements*

b) The water bulk supply point shall be located at a mainline isolation point for bi-directional feed from the bypass pipework to provide security of supply. On small diameter pipe a Tee with three directional isolation valves may be considered.

Wastewater specific:

c) The connection from a gravity wastewater transmission system to the local network shall be though a transitional manhole connected the a transmission manhole above the soffit of the transmission pipe
d) Connecting a local network to a wastewater transmission rising main or pressure system is not allowed.

2.1.11 Electrical induction hazard with metallic pipes

a) Electrical hazard analysis to AS/NZS4853 (refer to Watercare Electrical design standard, DP-09 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 12.1.3 for cathodic protection.

2.2 Isolation valves for pressure systems

a) Mainline isolation (line valves) are typically spaced to provide drain down time within 6 hours. Refer to section 2.1.7 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, above ground buildings or may be direct buried. 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. Typically gate valves are best suited for buried applications
    - 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 allow for recharge and/or draining. Draining may require to be either side of the main isolation valve when installed at a low point, or from the upstream side when installed in a sloping mainline. A double bypass isolation setup is required to allow drainage from both sides of the main isolation at low points, or otherwise a single bypass valve only is required.
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 200mm shall be API Schedule 40 pipe.
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.

2.3 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 shall be provided with individual isolation at both ends.
g) It 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 2.7.5 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 200mm shall be API Schedule 40 pipe.
m) Design PRV bypass pipework for maximum ultimate flow rate in the pipeline at the projected minimum pressure differential.

2.4 Non-return valves

a) Non-return valves shall be installed as part of an isolation valve train to allow the valve to be taken out of service for maintenance.
b) Where reverse flow in the main is required an unobstructed bypass may be installed and isolated during normal flow direction.
c) The design shall consider the need for an anti-slam device.

2.5 Air release valves

a) Air valves shall be installed in dry chambers or by specific requirement be surface mounted.
b) Air release valves shall be installed with eccentric reducer at the pipe soffit. The eccentric reducer shall be sized for optimal air collection.
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.
g) In the case of wastewater pressure venting, appropriate treatment of the outlet air is required to reduce hydrogen sulphide to less than 1ppb.

2.6 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.
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 direct buried, installed in an above ground building or dry chamber.

2.7 Dry chambers

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

2.7.1 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 of large or deep valve chambers shall.
e) The number of chambers should be minimised. Where practicable a single chamber shall be used.
f) Air valves shall not be installed in dry chambers with other equipment unless it can be remotely isolated and has a direct sealed connection venting outside the chamber.
g) Chambers shall be designed for bridge loading (HN-HO-72) regardless of location.

2.7.2 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.

2.7.3 Sealing requirements

a) Chambers shall be designed watertight to the full buried depth. Lids shall be sealed against surface water ingress.
b) Where approved to be installed in overland flow paths, chambers shall be designed to withstand a minimum 1 metre head above the 100 year flood level.

2.7.4 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.
e) Access platforms shall be provided to allow optimal operation position and clearances.
f) 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.
g) The minimum internal height of dry chambers shall be 2150mm.
h) Access shall be lockable with a specific key or lock down mechanism for the operational area.

2.7.5 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 be 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.

2.7.6 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 is practicable be situated outside overland flood areas. Dry chambers shall be ordinarily sealed for groundwater ingress and overland flooding. Additionally a sump drain shall be provided. In low lying areas the sump may need to be a sealed sump with drainage pump.
c) Where chamber lids are not ordinarily removed for access, suitable lighting shall be provided.

2.8 Wet chambers

Wet chambers are typically used for gravity wastewater applications (manholes) for directional changes and maintenance access, where a pressure main is discharged, or pressure main (water or wastewater) is scoured within the chamber structure.

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

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

2.8.1 Location

a) Manholes shall be located clear of:
   i. gutters;
   ii. open drains;
   iii. low points;
   iv. access to property; and
   v. mainstream of traffic
b) Manholes located on private property must be avoided. Adequate access shall be maintained for future maintenance, large scale rehabilitation and future connection works. The minimum clearance around any manhole shall be horizontally 1m and vertically 5m.
c) Manholes shall be clear of any structural zone of influence (typical 45°). Design for consideration inside the zone of influence must be demonstrated by structural analysis not to place influence on the adjacent structure or manholes as well as consider future maintenance and upgrade works.
d) Chambers shall be designed for bridge loading (HN-HO-72) regardless of location.

2.8.1.1 Gravity wastewater specific requirements

a) For gravity wastewater, manholes shall be positioned at:
   i. Change in pipe diameter
   ii. Change in gradient
   iii. Change in direction
   iv. At pipe junctions
   v. The distance between manholes should be maximised to reduce maintenance cost and confined spaces. Ordinarily spacing shall be:

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

   vi. Spacing may be increased if additional manholes is not necessary for access
   vii. The table listed in v. does not apply to large tunnels where access shafts are specifically designed to the structures' servicing requirements

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

2.8.2 Overall size

a) Wet chambers are sized to meet hydraulic or capacity requirements with specific consideration to:
   - Volume of discharge/containment and rate of discharge
   - Energy attenuation
   - Mixing requirements (water scour chambers)
   - Cavitation and erosion
   - Hydraulic influence on pump inlets

2.8.2.1 Circular wastewater manhole sizing

a) Circular manholes are installed at transmission pipe depth greater than 1200mm. Refer to section 2.8.2.2 for square type wet chambers when pipe depth is less than 1200mm.
b) Normally the minimum manhole diameter used in transmission is 1540mm.
c) Circular manholes are determined as either coincident (geometrically two points are the same point) or translated (geometric one-to-one correspondence between two set points) manholes.
d) Within the above groupings manholes are either Type A1 (pipe bends fit within the manhole diameter) or Type A2 (pipe bends extend beyond the manhole diameter). Refer below images:
   - Type A1 where: $\sin\frac{\theta_p}{2} < 0.1333\ \frac{B}{D}$
   - Type A2 where: $\sin\frac{\theta_p}{2} > 0.1333\ \frac{B}{D}$

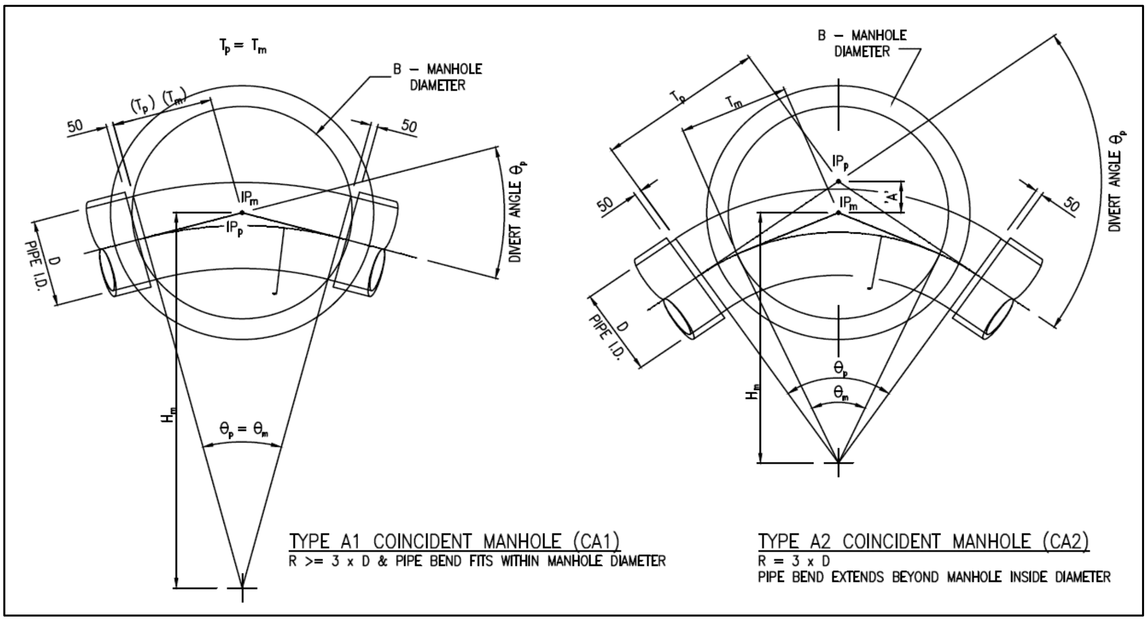
Where:

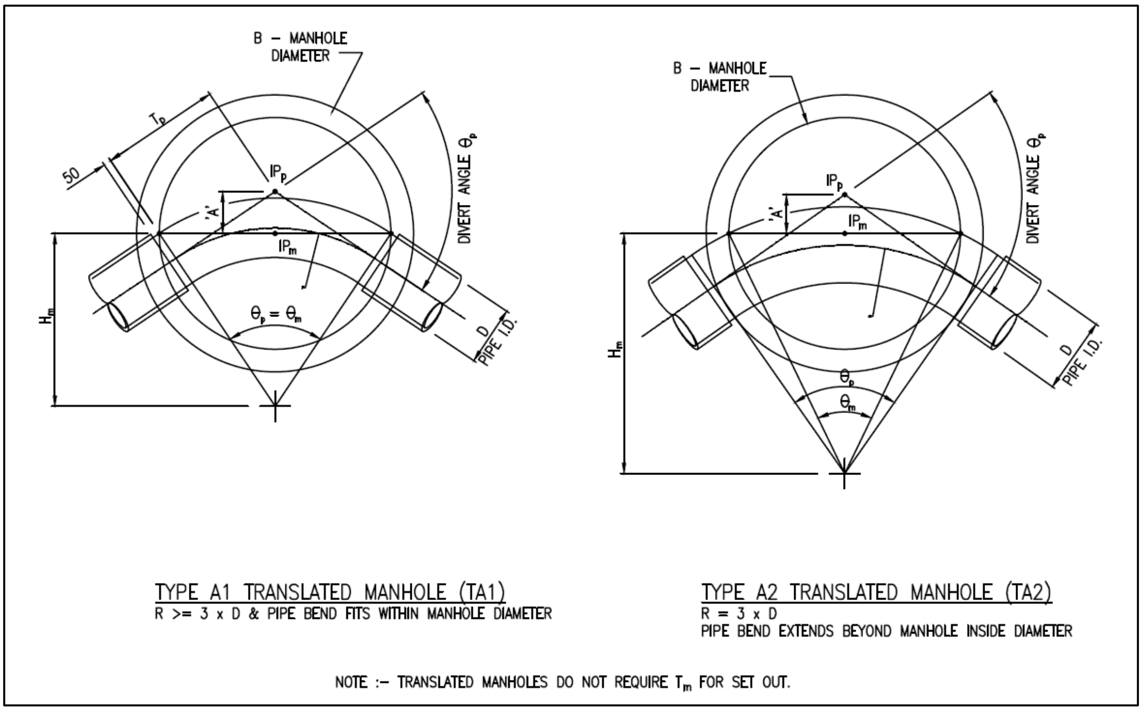
θ_p = Channel (pipe) angle

B = Manhole internal (nominal) diameter

D = Pipe internal diameter

Figure 1: Coincident and translated manholes





e) Manhole sizes for 2 pipes:

Pipe nominal diameter[1] (mm)	Manhole minimum size (mm)	Flow divert angle (deg.)[2]	Channel angle (deg.)
375	1500	0-90	90-180
450	1500	0-90	90-180
525	1500	0-90	90-180

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

Notes:

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

f) Manhole sizes for three pipes (two inlet, one outlet):

Pipe diameter[1] (mm)		Manhole minimum size (mm)[2]
Pipe 1 & 2 inlet	Pipe 3 outlet	
375	450	1500
450	525	1500

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

Notes:

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

g) Channel offset may be selected by the engineer to provide adequate step-down space. The following limitations apply:
- The minimum chamber wall remaining between inlet and outlet must be 300mm, or 0.5x pipe diameter, whichever is greater.
- Step-down landing behind ladders shall be a minimum of 600mm.

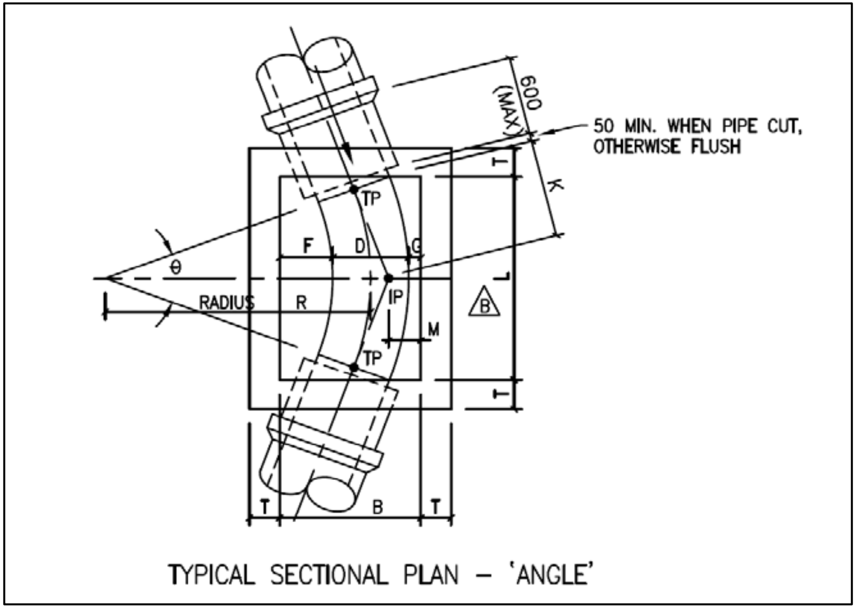
h) The base typically include the design for hydraulic uplift prevention. Refer to Part D, section 8.

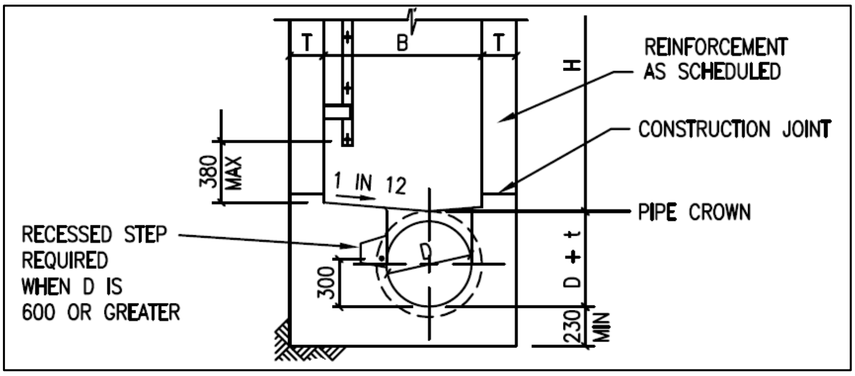
2.8.2.2 Square wastewater chambers and access shafts

a) Square chambers are installed at transmission pipe depth less than 1200mm. Refer to section 2.8.2.1 for circular chambers.

b) The minimum dimensions shall be:

i. Minimum internal length, L = 1400mm
ii. Minimum internal width, B = 800mm
iii. Minimum wall thickness, T= 200mm
iv. Minimum back of curve clearance, G = 100mm
v. Minimum front of curve clearance, F = 600mm
vi. Pipe curvature Radius R = 3 X Diameter (pipe)





c) The base typically include the design for hydraulic uplift prevention. Refer to Part D, section 8.

2.8.3 Sealing requirements

a) Chambers shall be designed watertight to full depth.
b) The interface between the concrete lid and chamber lid shall be sealed to prevent groundwater infiltration.
c) Lids shall be sealed against surface water ingress to a minimum of 1 metre head above the 100 year flood level in land overflow paths.
d) Typical chambers for wastewater are required to "breath" for airflow through the gravity system. Chambers with lids shall be located 300mm above the overland flow path and outside the 100 year flood level.

2.8.4 Access and platforms

a) 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.
b) The chamber access shall have a minimum clear opening of 600mm diameter.
c) Wet chambers shall be fitted with a removable safety grille supported by the lid frame.
d) The access design shall include working at height requirements for controlling access to opened access lids, such as integrated safety barriers.

e) 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.
f) Access platforms shall be provided to allow optimal operation position and clearances at a minimum depth interval as required by AS1657. Over 15m depth, man-cages are preferred for access over ladders and platforms.
g) Working areas around equipment and the access or thoroughfare to the equipment shall provide a minimum of 1000mm diameter horizontal clearance to a minimum height of 1900mm. In the case of drop structures the manhole diameter may need to be increased to allow for the minimum horizontal clearance inside the manhole.
h) Access shall be lockable with a specific key or lock down mechanism for the operational area.

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

2.8.5 Ancillary components

a) Access chambers should as far as is practicable be situated outside overland flood areas. Where there is a reasonable risk of a manhole lid being submerged by stormwater, a sealed lid must be used.
b) Ventilated systems must be design for the specific air flow and air filtration requirements. Relying on the permeability of lids and structures is not acceptable.

3. Reservoirs and balancing tanks

3.1 General considerations

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

Note: *Refer to Part D, section 11 for connectivity between structures*

3.2 Reservoir pipework

a) Inlet and outlet pipework shall be designed to allow water circulation and maintain water quality. The inlet shall be configured to encourage circulation of the whole volume of the reservoir. A typical option includes to separate the pipework locations or the inlet at a different height.
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 access and adequate clearances. Refer to section 2.2 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 Part D, section 11 for connectivity requirements.

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

3.3 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.
i) Access shall be lockable with a specific key mechanism for the operational area.
j) Above ground reservoirs and where public access to the reservoir roof is not permitted, shall be designed be have secured access.
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.

3.4 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.

3.5 Control and monitoring

a) Level control shall be by hydraulic altitude control valve with electronic/solenoid piloted control loops. (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.
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.

3.6 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.
c) An overflow/discharge and receiving environment shall be sized and designed to accommodate the maximum possible inflow.

4. Odour control for wastewater systems

4.1 General control of septicity

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

b) High sulphide concentrations cause corrosion and odour issues at the pumping station and rising main. Delivery of high septic wastewater hinders the treatment process.

Common remedies include:

- Minimise retention time
- Aeration in the wet well and frequent cleaning
- Oxygen injection into the rising main
- Dosing nitrate solutions
- Clean water flushing

c) Where remedies such as injection and flushing are uneconomical, and the main retention time cannot be reduced by sizing and pump station location, vented air treatment may be required, typically at the wet well, receiving structure and air relief valve along the rising main length.

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

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

4.2 Carbon and mixed media filters

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

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

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

4.3 Biofilters

4.3.1 Timber posts and walls structures

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

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

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

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

4.3.2 Concrete structures

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

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

4.3.3 Biofilter liner

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

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

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

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

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

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

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

4.3.4 Ducts and fittings

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

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

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

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

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

4.3.5 Trenching and Pipe Bedding

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

4.3.6 Air distribution and intermediate filter layers

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

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

4.3.7 Media and cover layer

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

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

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

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

4.3.8 Irrigation system

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

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

4.3.9 Chambers for air distribution

a) Material selection shall consider that inside walls and floor of air distribution chambers will be subject to corrosive gas. Concrete chambers/surfaces in contact with the gas shall be painted with an appropriate and approved corrosion resisting coating system.

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

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

4.3.10 Fan and internal biofilter drainage pump

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

5. Colour and identification of linear assets

Refer to the General Civil Construction standard for painting colours.

Part D – Structural design

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**

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 – Concrete lined steel pipe
   - ELS – Epoxy lined steel pipe
   - DI – Ductile iron
   - GRP – Glass reinforced pipe
   - PVC – Polyvinylchloride pipe
   - PE – Polyethylene pipe

b) Select pipe dimensions 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.*

2.1 Embedment characteristics

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

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

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

Pipe OD (mm)	**Embedment material under pipe** (mm)	**Side clearance from trench** (mm)	**Embedment over pipe** (mm)	**Minimum cover over top of pipe** (mm)
Up to 300 (typical local network pipes)	*100*	*150*	*150*	***Water:*** *600 in back berm 900 in front berm or under road* ***Wastewater:*** *900 in berm or under road*
310 to 450	100	250	150	1200
460 to 900	150	300	150	1200
910 to 1500	150	350	200	1200

Pipe OD (mm)	Embedment material under pipe (mm)	Side clearance from trench (mm)	Embedment over pipe (mm)	Minimum cover over top of pipe (mm)
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.

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 ratings are PN12 for networks and PN16 for transmission. Pipe for gravity applications and pipe sleeves or ducting shall have a minimum stiffness rating of SN16.

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

2.3 Pipe deflection and buckling

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

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

Where:

$\frac{\Delta_y}{D}$ = defection ration (%)
D_l = deflection lag factor = 1.5
K = bedding constant = 0.1 for direct bury with surrounded support
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 are key structural impact on the pipe such as at pipe bridges, critical anchorages or connections to chamber, shall be assessed with finite element analysis.

3. Rigid pipe structural design

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

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

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

Where:

Wt = required proof load

W_l = external load (kN/m)

FS = factor of safety

B_F = bedding factor

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

c) Watercare requires a minimum load class of SN16.

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

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

4. Drilled or tunnelled pipelines

a) With jacked pipe installation the vertical load on the pipe is less than for an excavated pipe due to the cohesion and friction exiting in the original material. Where fill heights exceeds 10 times the outside diameter, full arching will take place.

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

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

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

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

5. Hydraulic thrust and fluid impulse

5.1 Forces in fittings

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

5.2 Impulse momentum

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

b) With the impulse momentum quantified some solution options to dissipate surge energy may include:
  - Surge tanks and surge shafts
  - 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 Surge2000, Hytran, UPsurge 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 ($9.81 m/s^2$)
K = Bulk modulus of the fluid (2300MPa for cold water)
d = pipe outside diameter (m)

t = pipe wall thickness (m)
E = Young's modulus of elasticity of the pipe material (N/m²)

g) Water hammer head rise:

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

Where:

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

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

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

Where:

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

6. Suspended pipe and pipe support structures

6.1 Pipe bridges

6.1.1 General design considerations

a) As far as is practical, pipe bridges should be avoided. Pipe bridges may be designed as a standalone structure or can 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 bridge 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) The design actions completed by hand for pipe bridges over 300mm diameter 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 10
g) The corrosion protection system must be adequate to minimise access required for spot repairs to reduce operational costs. Refer to section 6.1.2 for access considerations.

6.1.2 Access onto pipe bridges

a) Unauthorised bridge access (i.e. onto the pipe) shall be prevented with an adequate barrier structure and if necessary on-bridge railing for fall protection.
b) A formal agreement with the bridge owner must provide Watercare with the ability to access, operate and maintain the pipe on the bridge.
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.

6.1.3 Pipe bridge pipe material considerations

Acceptable material solutions are:

a) **Steel (Lined mild steel or stainless steel):** Welded or flange joints. Pipe hangers or supports should be fully welded solution to reduce corrosion and simplify maintenance. Ring girders are preferred.
b) **Polyethylene pipe:** this material must be butt welded and supported inside a full length carrier pipe of suitable rigidity and durability. Cradles are not acceptable. The carrier pipe must be of suitable internal diameter to allow both future pipe size upgrades and thermal expansion and contraction. Proprietary spacers shall be used to centre the pipe inside the carrier pipe.
c) **Ductile iron:** with flanged joints with hangers or supports that prevent galvanic corrosion and provide water run-off. Ductile iron is usually only used where a single pipe fully spans the bridging width.

6.1.4 Bridge abutment transition

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

a) Type of movement i.e. lateral, angular, bi-planar, etc.
b) The magnitude of expected forces
c) Temperature range for thermal movement
d) Displacement due to settlement or subsidence
e) Effects of cyclic fatigue and vibration
f) Design impact ratios:
   i. 5% of design movements - maintenance
   ii. 25% of design movements – events (seismic, subsidence)
   iii. 80% of design movements – daily variation (temperature, pressure changes, vibration)

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

6.2 Pipe support configurations

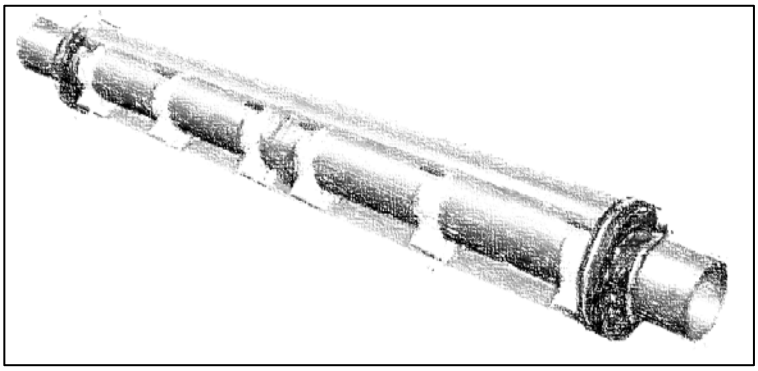
a) Timber supports are unacceptable.
b) Provision shall be made for access and clearances to maintain the pipe, connecting structures, drainage, articulation joints, valves and associated fittings as necessary.
c) Metallic pipe must be electrically isolated from the bridge structure.
d) The supports shall be structurally designed to meet the following conditions:
   i. Empty and full static loads
   ii. Any dynamic loads and vibration
   iii. Expansion and contraction

iv. Localised saddle stress and in some cases friction on the pipe
v. Seismic action. Refer to section 10

e) Refer to section 6.1.3 for Watercare's preference on support methods specific to the material type for pipe bridges.

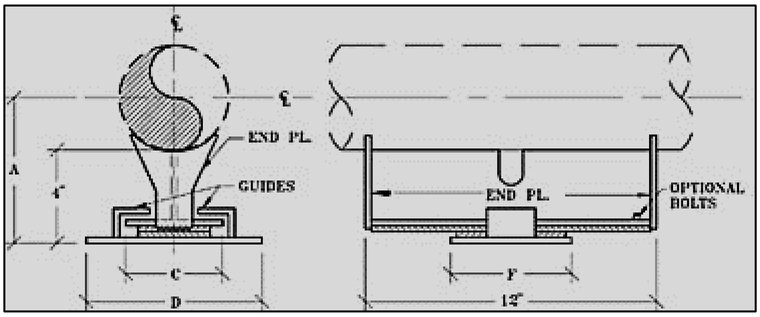
Acceptable support examples:

i. Host/carrier pipe

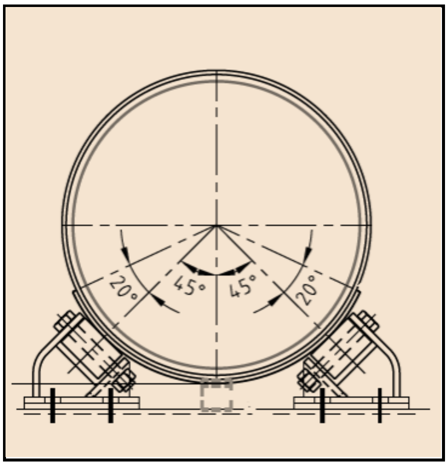


ii. Welded girders

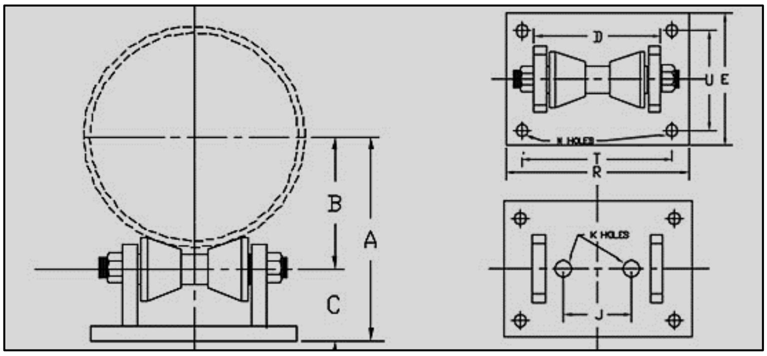
iii. Girder with sliding base



iv. Roller support



20°
45°
45°
20°



D
U
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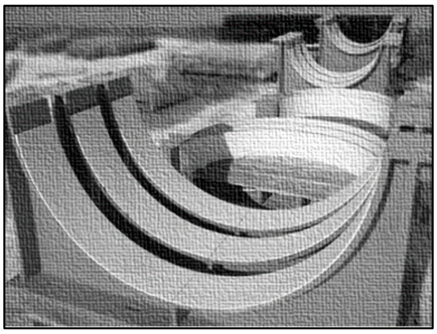
K HOLES
J

v. 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:

7. Anchor structures

a) Anchorage of pipework is required in the following circumstances:
   i. Prevent transfer of stresses
   ii. Support of fittings and valves
   iii. Prevent floatation
   iv. Prevent displacements due to internal or external forces
   v. Prevent joint displacement
   vi. Bridging

b) Anchorage design shall include forces attributed to:
   i. Flow velocity and direction
   ii. Transient flows
   iii. Seismic actions

8. Buoyancy prevention

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

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

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

d) Equally the effects of liquefaction on filled, partially filled and empty structures and pipes shall be considered when determining suitable weighing or anchoring solutions.
   Possible solutions include:
   - Weighted collars around concrete manholes or a weighted base
   - Piles and anchorage
   - A water pressure relief system (drainage, pumping)

9. 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: *M11, Steel pipe – a guide for design and installation*, AWWA.

10. Seismic evaluation of pipelines

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

a) Pipelines shall be assessed for seismic vulnerability of:
   - Landslides
   - Liquefaction
   - Compression and tension in pipe joints

- Fluid transients in channels and non-pressurised pipes

b) Acceptable methods for evaluation are provided by guidelines produced by the American Lifelines Association and the Water New Zealand Guidelines for Assessing Utilities in Seismic Areas. The design solutions shall be applied to the pipe importance levels as defined in Part A, section 5.2.

10.1 Supporting of tanks and equipment

a) Seismic loading s shall be determined using NZS1170.5 and consider the structural system comprising the equipment and its supporting systems.

b) Equipment mounts supported by building structures shall be fixed to have little or no ductility capability. If the equipment mounting is ductile, the seismic co-efficient shall be modified in accordance with NZS 1170.5.

c) Equipment installed in buildings or chambers shall be designed to AS/NZS4219.

d) Free-standing equipment shall be designed to remain elastic under seismic loading and coefficients depending on the natural period of vibration.

e) The seismic coefficient for pressure vessels shall be greater than 0.5.

f) For equipment structures higher than 10m a dynamic analysis shall be carried out to determine:

- The degree of ductility demand on the yielding elements
- The acceleration of equipment attached to the vessel
- The structural separations required for connecting bridges and accessories.

g) When selecting Serviceability limit states the risk fact shall be:

- Serviceability Limit State SLS1, R_s = 0.25
- Serviceability Limit State SLS2
  - i. Equipment/tanks essential to operational continuity after SLS2 earthquake (Schedule 1): R_s = 0.75
  - ii. Other equipment: SLS2 not required to be considered
- Ultimate Limit State
  - i. Equipment/tanks designated as post disaster (Schedule 1): R_u = 1.8
  - ii. Equipment/tanks containing hazardous materials capable of hazardous conditions beyond the boundary: R_u = 1.8
  - iii. Equipment/tanks part of the water treatment process (Schedule 1): R_u = 1.3
  - iv. Equipment/tanks containing hazardous materials not capable of hazardous conditions beyond the boundary: R_u = 1.3
- Other equipment/tanks: R_u = 1.0

10.2 Structural steel

h) 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.

i) The templates provided by Steel construction New Zealand shall be edited to provide project specific selections.

11. 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 rubber ring joint PVC pipes, 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.

12. Maintaining structural integrity against corrosion

12.1 Corrosion protection systems

12.1.1 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.

12.1.2 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.
b) The appropriate system shall be determined with input from a coatings 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.

12.1.3 Cathodic protection systems for metallic pipes

a) For the electrical design of cathodic protection systems refer to the Watercare electrical design standard. The design must be determined with considerations to the site ground conditions and in consultation with a cathodic protection designer.
b) All joints of steel pipelines shall be electrically bonded.
c) Isolation joints and test stations shall as far as practicable be located at main line valve installations.
d) Anode beds shall as far as practicable be near main line valve installation.

12.1.4 Internal corrosion protection

a) Internal corrosion protection of pipe and fittings must consider the whole of life of the asset and choosing the appropriate method that considers re-application or repair of the lining system.
b) Metallic pipe is typically protected using a concrete lining solution.

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 extent, without the need for repair, 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.

QA template

Design deliverables		**Y**	**N/A**
1	Geotechnical report		
2	Basis of design report		
3	Risk analysis		
4	Design report		
4.1	Project description		
4.2	Planning considerations and level of service performance		
4.3	Analysis of alternatives		
4.4	Design criteria		
4.5	Resilience analysis		
4.6	Assumptions and non-compliance		
4.7	Engineering calculations		
4.8	*Value engineering that includes:*		
	-constructability analysis		
	-simplification		
	-life-cycle costing		
4.9	Legal considerations		
4.10	Operations and maintenance considerations		
5	Material schedules completed		
6	Project execution plan		
7	Site specific specification for construction		
8	Nominate level of construction supervision		
9	Drawings		
10	Functional description		
11	O&M manual		
12	Standard operating procedures		
13	New assets register		
14	Design compliance statement		