# PIPELINE SELECTION GUIDELINES

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# GLOSSARY

| | |
|---|---|
| Brown-field site | Developed area |
| Dewatering | The act of removing groundwater or surface water from a construction site |
| Drill string | The total length of drill rods/pipe, bit, swivel joint etc. |
| Drive Shaft | An excavation from which trenchless technology equipment is launched for the installation or removal of a pipeline, conduit, or cable. |
| Frac-out | The inadvertent loss of drilling fluid from the borehole annulus to the surrounding soil as a result of excess downhole fluid pressure. |
| Green-field site | Undeveloped area |
| Pull-back | That part of a guided boring or directional drilling operation in which the drill string is pulled back through the bore to the entry pit or surface rig. |
| Pull-back Force | Tensile load applied to a drill string during pull-back. |
| Reception/Exit Shaft/Pit | Excavated shaft at the end of a jacked section from which the jacking shield is recovered. |
| Slurry system | A type of system where soil is turned to slurry and is pumped to the surface. |
| Subsidence/ Settlement | Sinking of the ground surface. |
| Thrust | Force applied to a pipeline or drill string to propel it through the ground. |
| Trenching | Underground construction method involving excavation. |

# ABBREVIATIONS

| | |
|---|---|
| CCTV | Closed-circuit television |
| CIPP | Cured-in-place pipe |
| DN | Nominal diameter |
| GRP | Glass-reinforced plastic |
| HDD | Horizontal directional drilling |
| HDPE | High-density polyethylene |
| OD | Outer diameter |
| PE | Polyethylene |
| PVC | Polyvinyl chloride |
| SDR | Standard dimensional ratio |
| TT | Trenchless technology |

# 1 INTRODUCTION

## 1.1 PURPOSE

These guidelines outline processes to help Watercare staff, designers, and contractors to select the most appropriate techniques for installing pipelines in various circumstances and conditions. They cover both trenchless and traditional opencut installation methods. The guidelines highlight the degrees to which various techniques can contribute to the achievement of the Watercare 40:20:20 objectives. Risks and mitigation measures are outlined. The guidelines also contribute to other initiatives being undertaken by Programme 1st to improve cost estimation and to optimise geotechnical site investigations.

This document is intended to provide general guidance (rules-of-thumb) which should be tailored for specific situations and constraints. The guidance is not intended to be exhaustive but covers considerations that are generally applicable.

The document should be reviewed annually to incorporate lessons learnt from completed projects and changes in technology. Potential refinements that could be included in subsequent versions of the document are outlined in Section 5.

## 1.2 BACKGROUND

Watercare is striving towards reducing built carbon by 40%, capex costs by 20% and reducing health and safety incidents by 20% year on year.

A large portion of the annual budget is spent on installation of new pipelines and renewal of existing pipelines. Optimising these works can provide significant opportunities to achieve the 40:20:20 objectives.

There are many pipeline installation methods available, ranging from traditional opencut excavation, trenchless installation techniques (horizontal directional drilling, micro tunnelling, Direct Pipe), online replacement (pipe bursting) and pipeline rehabilitation. All of these techniques have their place, but some are more suitable for certain conditions that others.

Issues that should be considered when selecting the most appropriate installation method which are covered in more detail in the guidelines include:

1. Economic considerations - As a rough guide, it is generally cheaper to install shallow pipes in greenfield sites by opencut excavation. However, as depth and reinstatement requirements increase trenchless techniques are often cheaper than opencut excavation.
2. Disruption – trenchless techniques are generally less disruptive than opencut installations.
3. Environmental effects – trenchless methods typically require less built carbon than opencut excavation and cause less disturbance to the environment but can introduce other potential impacts such as frac-outs.
4. Design considerations - Achieving optimal hydraulic conditions and balancing these with other factors such as ground conditions, streams and ponded water crossings can influence choices (e.g. pipes installed by opencut are typically designed as shallow as possible, whereas

pipes installed by horizontal directional drilling are typically designed to be deeper to reduce frac-out risk.).

5. The pipe materials that the techniques can install.
6. Risk profiles and factors that might impact on constructability.

Therefore, a one size fits all approach is not appropriate. These guidelines help:

1. Identify the most appropriate technique for the circumstances.
2. Outline the cost, carbon and safety benefits of the various techniques and the recommended technique.
3. Describe items that should be considered when designing pipelines for the various techniques.
4. Set out appropriate site investigations for various techniques.
5. Describe risks and mitigation measures.

# 2 PIPELINE INSTALLATION TECHNIQUES

## 2.1 PIPELINE INSTALLATION CATEGORIES

Pipeline installation falls into three broad categories: New Installations; Online Replacement and Rehabilitation. These terms are defined as:

| | |
|---|---|
| New Installation | Methods that do not require replacement of an existing pipeline. If there is an existing pipeline, the new pipeline can be installed in a different position to the existing pipeline |
| Online Replacement | Methods that install the new pipeline on the same alignment as an existing pipeline. The existing pipeline is broken out during installation. The new pipeline can be bigger than the existing pipeline. |
| Rehabilitation | Upgrading of existing pipes. A new pipeline is installed inside the existing pipeline or the existing units are upgraded (relined) in situ |

## 2.2 SUB-CATEGORIES

Within each installation category in 2.1 there are several subcategories of installation techniques. The techniques covered in this document are outlined in Figure 2-1. The guidelines cover techniques that are most applicable to Watercare projects. Appendix A provides a more comprehensive list of available techniques including techniques that are not generally suited to Watercare projects. Section 4 provides a description of the techniques and their uses.

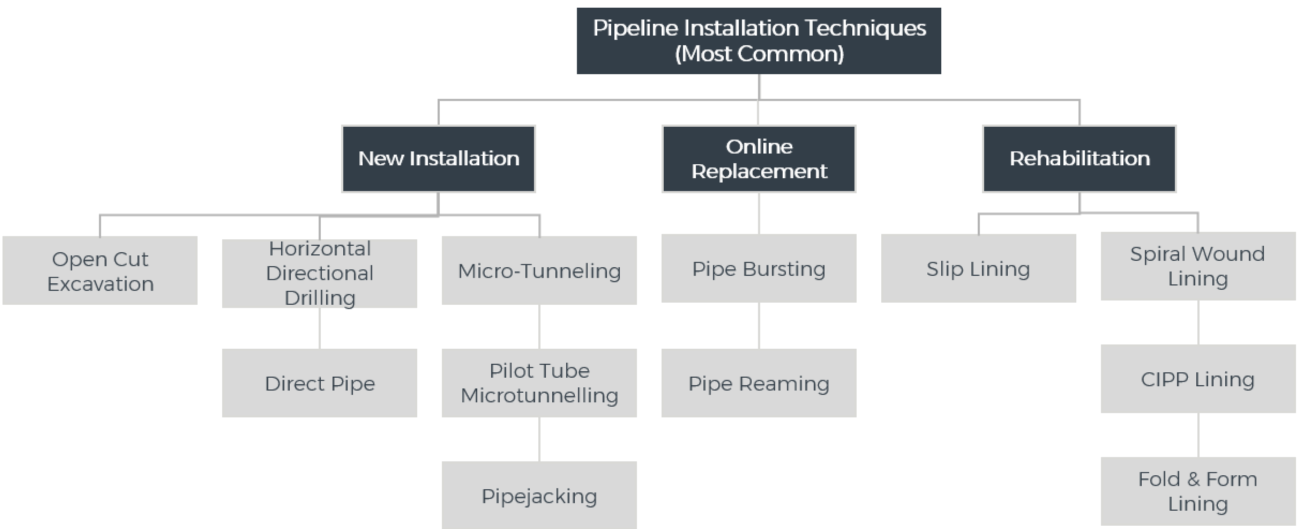



Figure 2-1 Pipeline Installation Techniques

# 3 THE PLANNING FRAMEWORK

A 4-step process is used to select the most appropriate installation technique.

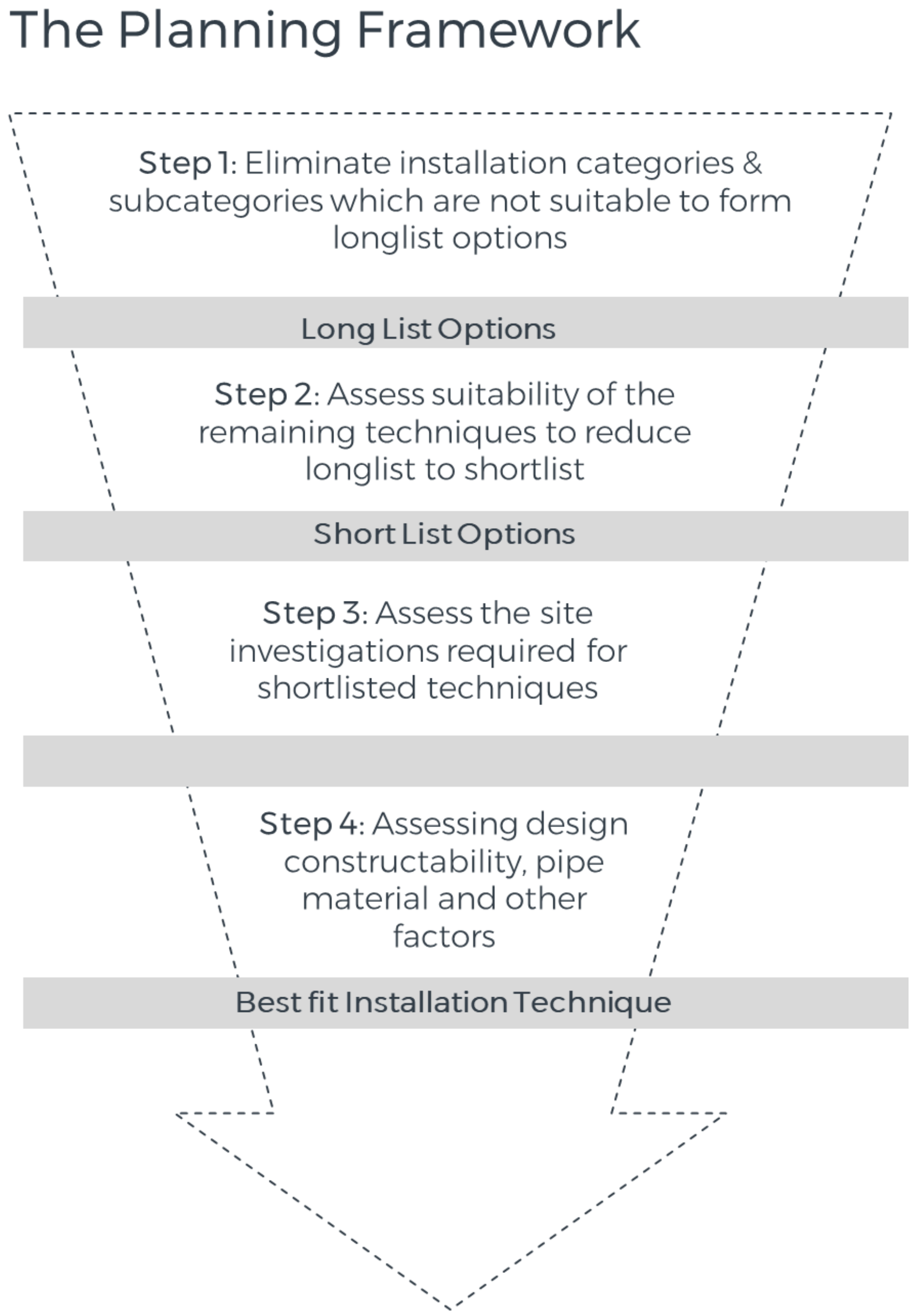



Figure 3-1 Planning Framework

# STEP 1 DEVELOP LONG LIST OF OPTIONS

## *1A ELIMINATE UNSUITABLE INSTALLATION CATEGORIES*

Use Table 3-1 to determine which installation techniques are not suitable.

Table 3-1 Installation Category Elimination Matrix

| | New Installation | Online Replacement | Rehabilitation |
|---|---|---|---|
| There is no existing pipeline that can be utilised | | Eliminate | Eliminate |
| The alignment of the existing pipeline is not acceptable (consider horizontal, vertical position, dips) | | Eliminate | Eliminate |
| The existing pipeline is under capacity | | | Eliminate |
| The existing pipeline is greater than 450 mm diameter | | Eliminate | |

## *1B ELIMINATE UNSUITABLE INSTALLATION SUBCATEGORIES FROM THOSE CATEGORIES TAKEN FROM STEP 1A*

Use Table 3-2 to determine which subcategories of New Installation are not suitable.

### *NEW INSTALLATION*

Table 3-2 New Installation Subcategory Elimination Matrix

| Cost, Carbon, Safety Hazard, Duration of Work, Disruption | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Open Cut | HDD | Direct Pipe | Micro-tunnelling | Pilot Tube microtunnelling | Pipe jacking |
| Pipe Size | 150 - 600 mm | | | Eliminate | | | Eliminate |
| | 600 - 1000 mm | | | | | | Eliminate |
| | 1000mm-1500 | | Eliminate | | | Eliminate | Eliminate if dia less than 1200mm |
| | 1500 - 2500 mm | | Eliminate | Eliminate | | Eliminate | |
| Pipe Shape | New pipe is non-circular | | Eliminate | Eliminate | Eliminate | Eliminate | Eliminate |
| Profile | Curved | | | | Eliminate[1] | Eliminate | Eliminate[1] |
| Access | No access from surface (e.g., under building) | Eliminate | | | | | |
| Depth | Less than 1.5m | | Eliminate[2] | | | | |
| Grade | Less than 0.5% | | Eliminate | | | | |

1 Microtunnelling and pipe jacking in a curve is possible but generally requires special equipment and the additional loading on the pipes being installed needs to be considered. Installation of a curved drive is normally significantly more expensive than a straight bore and other techniques are normally more appropriate.

2 Installation of shallow pipes by HDD is not recommended due to the risk of frac-out and ground heave. However, could be considered for the installation of small diameter pipes (150mm dia or less) where there is limited consequence should frac-out or ground heave occur. However other techniques will normally be more appropriate.

### *ONLINE REPLACEMENT*

Use Table 3-3 to determine which subcategories of Online Replacement are not suitable. If the category of Online Replacement was eliminated in Step 1A, this table is not required.

Table 3-3 Online Replacement Subcategory Elimination Matrix

| Cost, Carbon, Safety Hazard, Duration of Work, Disruption | | |
|---|---|---|
| | Pipe Bursting | Pipe Reaming |
| Existing pipe is flexible e.g., PVC, HDPE | Eliminate | |

### *REHABILITATION*

Use Table 3-4 to determine which subcategories of Rehabilitation should be eliminated. If the category of rehabilitation was eliminated in Step 1A, this table is not required.

Table 3-4 Rehabilitation Subcategory Elimination Matrix

| Cost, Carbon, Safety Hazard, Duration of Work, Disruption | | | | |
|---|---|---|---|---|
| | Slip Lining | Spiral Wound Lining | CIPP Lining | Fold & Form |
| Pipe is under internal pressure | | Eliminate | Eliminate | Eliminate |
| Existing pipeline does not have spare capacity i.e., diameter cannot be reduced | Eliminate | | | |
| Existing pipe is non-circular | | Eliminate[1] | | Eliminate |

1 Spiral wound liners have been used in some circumstances to rehabilitate non-circular pipes, but this is not normally appropriate as the finished liner is circular and as such there is a significant reduction in the capacity of the pipeline.

# STEP 2 ASSESS LONGLIST OPTIONS. DEVELOP SHORT LIST OF PREFERRED OPTIONS.

## *2A ASSESS LONGLIST INSTALLATION CATEGORIES, IDENTIFY CATEGORIES WITH LEAST SCORES*

Table 3-5 is used to assess the longlist of options at a high-level to determine which of the installation categories (that were not eliminated in Step 1A) are most appropriate for the site, with emphasis on the Watercare 40:20:20 objectives.

Each cell in the matrix provides a rating for the impact of using an installation category, with a particular site condition. The lower the score, the lower the cost, carbon, safety hazards, duration of work and disruption.

Table 3-5 Installation Category Assessment Matrix

| COST, CARBON, SAFETY HAZARD, DURATION OF WORK, DISRUPTION | | | | |
|---|---|---|---|---|
| | | New Installation | Online Replacement | Rehabilitation |
| Pipe depth | Shallow (<2.5m) | Lowest | Lowest | Lowest |
| | Moderate (2.5 – 5m) | Moderate | Moderate | Lowest |
| | Deep (>5m) | Highest | Moderate | Lowest |
| Site Type | Greenfield | Lowest | Lowest | Lowest |
| | Brownfield | Moderate | Moderate | Lowest |
| | High Density | Highest | Moderate | Lowest |

## *2B ASSESS LONGLIST INSTALLATION SUBCATEGORIES FOR THOSE CATEGORIES WITH LEAST SCORES. IDENTIFY INSTALLATION SUBCATEGORIES WITH LEAST SCORES*

Table 3-6 to Table 3-8 are to be used in the same way as Table 3-5, but at a subcategory level. The appropriate table to use will depend on which category was identified as most appropriate in Table 3-5.

Table 3-6 New Installation Subcategory Assessment Matrix

| COST, CARBON, SAFETY HAZARD, DURATION OF WORK, DISRUPTION | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Open Cut | HDD | Direct Pipe | Micro-tunnelling | Pilot Micro-tunnelling | Pipe Jacking |
| Pipe depth | Shallow (<2.5m) | Lowest | Highest | Lowest | Lowest | Lowest | Lowest |
| | Moderate (2.5 – 5m) | Moderate | Lowest | Lowest | Lowest | Lowest | Lowest |
| | Deep (>5m) | Highest | Lowest | Lowest | Moderate | Moderate | Moderate |
| Site Type | Greenfield | Lowest | Lowest | Lowest | Lowest | Lowest | Lowest |
| | Brownfield | Moderate | Lowest | Lowest | Lowest | Lowest | Lowest |
| | High Density | Highest | Moderate | Moderate | Moderate | Moderate | Moderate |
| Pipe Size | 150 - 600 mm | Lowest | Lowest | N/A | Lowest | Lowest | N/A |
| | 600 - 1000 mm | Lowest | Highest | Lowest | Lowest | N/A | N/A |
| | 1000 - 1500 mm | Moderate | N/A | Lowest | Moderate | N/A | Moderate |
| | 1500 – 2500mm | Highest | N/A | N/A | Highest | N/A | Highest |
| Ground | Impact of variable ground conditions, possibly of obstruction | Lowest | Highest | Moderate | Highest | Highest | Moderate |

*ONLINE REPLACEMENT*

Table 3-7 Online Replacement Subcategory Elimination Matrix

| Cost, Carbon, Safety Hazard, Duration of Work, Disruption | | |
|---|---|---|
| | Pipe Bursting | Pipe Reaming |
| General | Lowest | Moderate |

*REHABILITATION*

Table 3-8 Rehabilitation Subcategory Elimination Matrix

| Cost, Carbon, Safety Hazard, Duration of Work, Disruption | | | | |
|---|---|---|---|---|
| | Slip Lining | Spiral Wound Lining | CIPP Lining | Fold & Form |
| General | Moderate | Lowest | Lowest | Lowest |
| Bypass Pumping | Moderate | Lowest | Moderate | Lowest |

# STEP 3 UNDERTAKE SITE INVESTIGATIONS FOR SELECTED SUBCATEGORIES

Tables summarise the general site investigation to be undertaken. Undertake additional investigations where site conditions dictate.

Table 3-9 General Investigations – New Installations

| INVESTIGATION | OPENCUT | HDD | DIRECT PIPE | MICRO TUNNELLING |
|---|---|---|---|---|
| Survey to locate surface and features | ✓ | ✓ | ✓ | ✓ |
| Site investigation boreholes (typical spacing 200m centres, additional where potential for changing conditions or obstacles exists) | ✓ | ✓<br>Offset from new pipeline (10m) | ✓ | ✓ |
| Additional investigations boreholes | | | At location pipe thruster and shafts | At shafts |
| Contaminated land assessment | ✓ | ✓ | ✓ | ✓ |
| Identification of buried structures and utilities (3m either side of new pipeline, 8m for pipelines greater than 600mm diameter) | ✓ | ✓ | ✓ | ✓ |

Typical testing undertaken at investigation boreholes includes:

- Production of borelog showing soil profile and groundwater levels
- Determination of Atterberg limits
- Grain size analysis
- Determination of soil strength parameters
- In situ moisture contents of soil units
- Contamination testing including asbestos testing

For river crossings and outfalls river/seabed, depth, stability (lateral as well as scour), should be determine, e.g. through seismic survey.

Table 3-10 General Investigations – Online Replacement

| INVESTIGATION | ONLINE REPLACEMENT |
|---|---|
| Determine the depth and alignment of the existing pipe and topography of ground surface above pipe. Determine the position of manholes. | ✓ |
| Establish flow requirements for design of bypass pumping. | ✓ |
| CCTV inspection to determine the host pipe material, diameter, location of laterals, ferrules, tees, bends and accurate condition assessment. | ✓ |
| Determine the fittings that may be installed on the existing pipe (particularly ductile fittings i.e. gibaults, repair clamps that may affect pipe bursting) | ✓ |

| | |
|---|---|
| Determine soil condition and types and expected groundwater level. Desktop assessment will normally suffice. | ✓ |
| Determine position, type, material and expected condition of adjacent services (all services within 3m of existing pipeline). In particular those that cross the pipeline. | ✓ |
| Trial excavations may be required where concrete encasement is expected. | ✓ |
| Identify locations where ground heave may cause damage to surface features. | ✓ |
| Undertake analysis to assess the potential for contaminated land. | ✓ |

Table 3-11 General Investigations – Slip lining

| INVESTIGATION | SLIP LINING |
|---|---|
| Determine the depth and alignment of the existing pipe and topography of ground surface above pipe. Determine the position of manholes. | ✓ |
| Establish flow requirements for design of bypass pumping. | ✓ |
| CCTV inspection to determine the host pipe material, diameter, location of laterals, ferrules, bends, tees and accurate condition assessment. | ✓ |
| Measure dimensions of existing pipeline. For gravity lines undertake laser profiling if dimensions may vary along the pipeline. | ✓ |
| Determine soil condition and types and expected groundwater level. Desktop assessment will normally suffice. | ✓ |
| Determine position, type, material and expected condition of adjacent services (all services within 3m of existing pipeline). | ✓ |
| Undertake analysis to assess the potential for contaminated land. | ✓ |

Table 3-12 General Investigations – CIPP, Fold & Form, Spiral Wound Lining

| INVESTIGATION | CIPP, FOLD & FORM, SPIRAL WOUND LINING |
|---|---|
| Determine the depth and alignment of the existing pipe and topography of ground surface above pipe. Determine the position of manholes. | ✓ |
| Establish flow requirements for design of bypass pumping. | ✓ |
| CCTV inspection to determine the host pipe material, diameter and accurate condition assessment. | ✓ |
| Measure dimensions of existing pipeline. Undertake laser profiling if dimensions may vary along the pipeline. | ✓ |

# STEP 4 ASSESS DESIGN, CONSTRUCTABILITY, PIPE MATERIAL AND OTHER FACTORS

In Step 4 detailed design and assessment is undertaken on the shortlisted technique(s) considering the information determined from the site investigation. Items to consider include design, constructability, materials and risk. Information regarding these factors is covered in Section 4.

Also refer to Appendix C for Watercare's Pipe Material Guidelines.

# 4 DESCRIPTION OF PIPELINE INSTALLATION TECHNIQUES

## 4.1 NEW INSTALLATION

New Installation covers installation methods that do not require replacement of an existing pipeline.  If there is an existing pipeline, the new pipeline can be installed in a different position to the existing pipeline.  There are four types of new installation, being:

- Open cut excavation
- Horizontal directional drilling
- Direct Pipe
- Microtunnelling

### *4.1.1 OPEN CUT EXCAVATION*

#### 4.1.1.1 OVERVIEW

Open cut excavation is a traditional method for pipeline installation which remains widely used. It involves opening the surface of the ground (trenching) to the required depth to install the pipeline using mechanical or hand excavation techniques. Trenches should be supported by shoring. After completion of the works, the trench is backfilled, compacted and the surface is restored to the original condition.

Figure 4-1 Open Cut Pipe Trench

#### 4.1.1.2 USES

- Open cut excavation can be used for all pipe sizes and materials and a wide variety ground conditions. However, it is most suited for installation of shallow pipes and pipes in greenfield sites.

#### 4.1.1.3 ADVANTAGES AND DISADVANTAGES

Advantages

- Sophisticated equipment not required
- Easy to implement in unpaved ground

Disadvantages

- Significant surface disturbance and reinstatement costs in brownfield sites
- Area being excavated needs to be quarantined off or closed to through traffic.
- High costs and time for deeper installations
- High level of embedded carbon
- Greatest health & safety hazards, e.g. risk of trench collapse

#### 4.1.1.4 CONSTRUCTION & DESIGN CONSIDERATIONS

Depth

- Increasing the depth of a pipeline installed by open cut excavation has a more significant effect on cost than for trenchless methods. This is because any increased in depth of the pipeline will result in the need to excavate more material per metre of pipeline. For trenchless methods, the amount of material to be excavated is relatively independent of depth.
- Similarly, the deeper the pipe, the greater the built carbon (due to the increase backfill material and construction effort) and the greater the health and safety risk.

Horizontal and Vertical Alignment

- The nature of open cut excavation allows flexibility to install the pipeline on alignments that are curved in the vertical or horizontal plane.
- However, care is required to ensure that unintended dips are not created during installation.

Impact on adjacent structures and surface reinstatement

- Excavations close to structures and other utilities may result in settlement and damage to the adjacent structures/utilities.
- Dewatering may also cause settlement.
- The need to reinstate the surface adds to costs and increases construction times, particularly in built up areas.

Geotechnical Conditions.

- Opencut excavation can be undertaken through most ground conditions and is more able to accommodate changing ground conditions (which can be problematic for trenchless techniques).
- Rock and high groundwater levels increase cost and lower production rates.
- Weak ground requires robust trench support which increases cost.

- Groundwater inflows where both high levels and high permeability is present generate issues with environmental controls, increasing cost and slowing production.
- Pipe settlement may be a concern in soft ground conditions, e.g. peat.

Pipe Materials

- Open cut excavation is suitable for most materials

Other Issues

- The possibility of contaminated soil and how it would be disposed of should be considered.

#### 4.1.1.5 WHAT CAN GO WRONG

Significant issues that can occur include:

- Collapse of trench (inadequate shoring).
- Pipe settlement (soft material below pipeline).
- Settlement impacts on adjacent infrastructure.
- Trench settlement (inadequate compaction of backfill).

#### 4.1.1.6 INVESTIGATIONS

Key information that should be gathered to successfully design and implement opencut installations includes:

- Typographic survey
- General understanding of geotechnical conditions and parameters – required for pipe, backfill and bedding design, equipment selection, shoring design and estimation of expected production rates.
- Identifying where geotechnical conditions change or where obstructions may be present is important for the reasons outlined in the above bullet point but not to the same degree as for trenchless techniques.
- Determining the potential for contaminated land.

Site investigations are typically taken at 200m intervals, with additional investigations being undertaken where there is the potential for changing conditions or obstacles.

Typical testing undertaken at investigation boreholes includes:

- Production of borelog showing soil profile and groundwater levels
- Determination of atterberg limits
- Grain size analysis
- Determination of soil strength parameters
- Contaminated land analysis

All buried structures and utilities within 3m of the new pipeline should be identified and located. When installing larger pipes (greater than 600mm dia) all buried structures and utilities within 8m of the new pipeline should be identified and located.

#### 4.1.1.7 PRODUCTIVITY AND PRICING

Factors that can affect the cost of an open-cut excavation project include:

- Depth (deeper pipelines are more expensive)
- Geotechnical conditions (rock or very soft soils reduce production rates)
- Obstructions, services and proximity to structures
- Groundwater
- Location (reinstatement requirements and traffic management increases costs in brownfield sites)

### *4.1.2 HORIZONTAL DIRECTIONAL DRILLING*

#### 4.1.2.1 OVERVIEW

Horizontal directional drilling involves three phases.

- Firstly, a pilot hole is formed by the drill rig pushing the drill head through the ground. The drill head is steerable which enables a curved profile to be achieved. The drill head is tracked during installation by either a 'walkover' or a hand-wired system.
- The pilot hole is then reamed out to a larger diameter. Several passes may be required. The reamed hole is typically 50% greater than the outside diameter of the product pipe for pipes up to 600mm. For larger pipes, the reamed hole should be at least 300mm greater than the diameter of the product pipe.
- Finally, the product pipe is pulled into place.

The drill machine is located on the surface, offset back from the start of the drill shot. Throughout the operation the borehole hole is filled with drilling mud to provide positive pressure to hold the hole open. The drilling mud also conveys excavated material back to the surface and lubricates cutting equipment and the product pipe during installation. In competent rock drilling mud may not be required to support the hole and air and foam may be used to transport excavated material.

Continuous flexible pipe materials are used (e.g., HDPE) to withstand pulling forces.

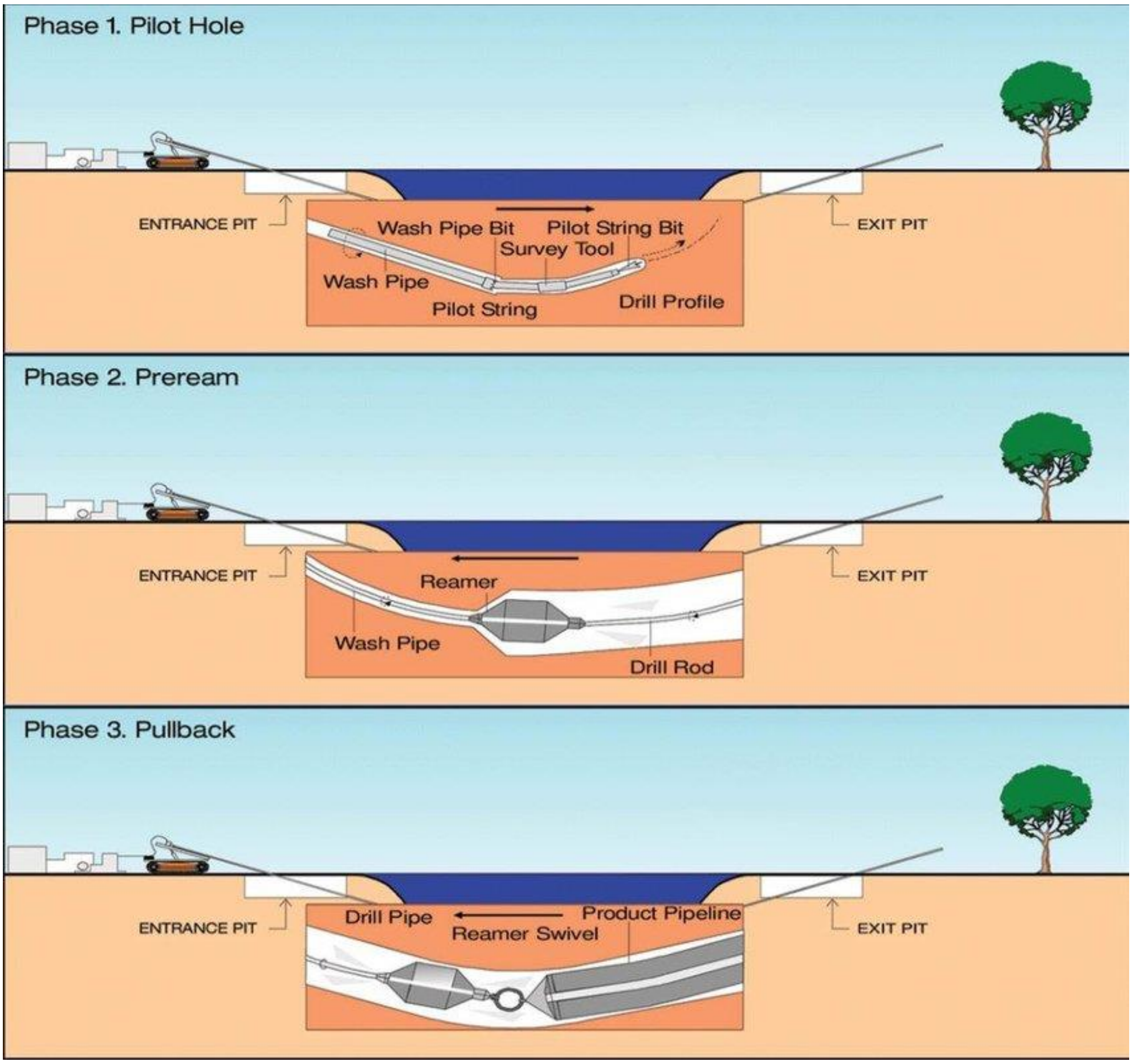



Figure 4-2 Overview of HDD Process

#### 4.1.2.2 USES

Horizontal directional drilling is a very versatile technique which can be used for a wide range of pipe sizes (100mm to 1,500mm dia) and through a variety of ground conditions. However, drill rigs and other equipment need to be selected for condition expected, refer Table 3-1 for general guidance.

Table 4-1 Classification & Characteristics of HDD Rigs

| | SMALL RIGS | MEDIUM RIGS | LARGE RIGS |
|---|---|---|---|
| |  |  |  |
| Description | Small, self- contained, self-propelled | Normally self-contained and self-propelled | May take 1-2 weeks to mobilise/demobilise |
| Uses | Utility cables, small diameter pipes | Pipes up to 400mm | 400-1,350mm pipes or long bores |
| Thrust/Pullback | <18,000 kg | 18,000 – 45,000 kg | >45,000 kg |
| Maximum Torque | 5,400 Nm | 5,400 – 27,000Nm | 27,000Nm |
| Rotational Speed | >130 rpm | | <210 rpm |
| Carriage Speed | 30 m/min | 27-30 m/min | <27 m/min |
| Carriage Drive | Chain, Cylinder or Rack & Pinion | Chain or Rack & Pinon | Rack & Pinion with or without Cable Assist |
| Drill Pipe Length | 1.5-3m | 3m – 10m | 10m – 12m |
| Drilling Distance | <200m | <600m | <1,500m |
| Power Source | <112 kW | 112 – 186 kW | >186 kW |
| Mud Pump | <280 lpm | 190 – 750 lpm | >750 lpm |
| Weight of Drill Rig | <6.8 tonne | <27 tonne | >27 tonne |
| Rig Footprint Area (width x length) | 0.9m x 3m to 2.1m x 6m | 2.1m x 6m to 2.4m x 13.5m | 2.4m x 13.5m |
| Recommended Work Area Requirements (width X length) | 6m x 18m | 30m x 45m | 45m x 75m |

### 4.1.2.3 ADVANTAGES AND DISADVANTAGES

#### Advantages

- There is no need for deep access and exit pits to install pipelines.
- There can often be considerable saving in time and on-site inconvenience by using HDD over open trench technology.
- Reduced reinstatement costs
- Uniform support to plastic and metal pipes is automatically provided in the HDD method.

- Built carbon is considerably less than for opencut excavation as backfill material is not required to be imported.

Disadvantages

- Risk of frac-out and ground heave
- Access is required at both ends of the drill shot.
- Location accuracy is less than for other techniques. Therefore, HDD may not be suitable for installation of pipelines on flat gradients or where dips cannot be tolerated.

#### 4.1.2.4 CONSTRUCTION & DESIGN CONSIDERATIONS

Depth – Shallow installations can be problematic due to the increased risk of frac-out, borehole collapse and heave. HDD installations are typically avoided where the depth is less than 6 to 8 times the bore diameter. It is often desirable to drill deeper through more competent ground where there is less risk of frac-out or encountering obstructions.

Site Area – Equipment access is required at both ends of the drill shot. The position of the drill rig is set by the angle of the borehole at the drill entry pit which is generally between 8 to 16 degrees, i.e. the drill rig is located back from what might be the start of the permanent pipeline. Table 4-1 provides indications of required work areas. The angle at the exit pit is generally 5 to 10 degrees. Space is required to string out and weld the pipeline, ideally this should be provided near the exit pit.

Geotechnical Conditions - Horizontal directional drilling can be completed through most ground conditions, it is important to know what conditions will be encountered during the works to optimise equipment tooling and design of the drill mud.

Cobbles and boulders can be problematic as they are difficult to drill through and it can be difficult to contain the drill mud in the borehole.

Whilst variable ground conditions can generally be accommodated, they may slow production

Utilities & obstructions - The bore path needs to be designed to avoid existing utilities and other obstacles. Consideration should be given to:

- How accurately the position of existing services can be located. It is often desirable to expose services prior to drilling.
- The accuracy of the drilling. This can be affected by the driller's experience/expertise, soil conditions and locator accuracy.
- The size of the reamed hole. Clearances need to be designed based on the diameter of the reamed borehole rather than the diameter of the product pipe.
- Utility bedding conditions. Pipelines are normally installed in coarse grained bedding material. The bedding material will often be more permeable than the surrounding soil. This can promote frac-out. The bedding material can also affect steering of the drill.
- Consideration needs to be given to the location of lateral pipes (e.g. house sewer connections) as well as the main utility services. The position and depth of laterals is often unclear.
- Consideration should be given to the potential for buried trees and other obstacles, e.g. at historic streams, buried valleys and abandoned landfills. Buried obstructions can cause the

drill to become stuck and drilling fluid migration leading to a frac-out. It is possible to pullback and drill on a different alignment, but this may not be acceptable from a permanent design perspective.

Frac-outs i.e. drilling mud is discharged at the surface. Frac-outs raise two concerns. Firstly if a frac-out occurs the borehole may not be full of drilling mud and maybe prone to collapse, which can increase the risk of further frac-outs occurring, increase resistance on drill rods and the new pipeline, causing installation issues or increase the risk of ground heave, particularly on shallow pipelines. Secondly frac-outs can cause environmental issues. Although drilling mud is typically non-toxic it is very turbid.

Frac-outs may occur due to drilling mud travelling through fissures in the soil or through permeable areas, e.g. backfill around services. Frac-outs also occur due to plastic yielding of the soil around the borehole when the borehole pressure exceeds the confining stress of the surrounding soils.

Settlement - Settlement is generally not a factor when installing small diameter product by horizontal directional drilling. However, it can be an issue with large installation.

On Grade Accuracy - Installation of pipes at 0.5% have been successfully completed. However, the risk of sags and dips being present in the pipe increases significantly. In installations where this critical the use of other techniques such as micro-tunnelling may be more appropriate.

#### 4.1.2.5 WHAT CAN GO WRONG

Significant issues that can occur include:

- Buckling/snapping of drill string (unexpected hard layers)
- Diversion from planned drill path (unexpected conditions, locator accuracy)
- Collapse of borehole (unexpected conditions, inappropriate drilling mud or management of mud, frac-out)
- Frac-out causing environmental issues (ground conditions, speed of reaming)
- Surface heave (shallow installations, hole collapse, speed of reaming)

Longer and larger installations are more complicated and there is an increased risk of things going wrong.

#### 4.1.2.6 INVESTIGATIONS

Key information that should be gathered to successfully design and implement horizontal direction drilling installations includes:

- Topographic survey
- General understanding of geotechnical conditions and parameters – required to design the profile of the drill shot, select tooling and other equipment, to determine the risk of frac-out, for selection of drilling mud and estimation of expected production rates.
- Identifying where geotechnical conditions change, especially identifying where there are mixed conditions, is particularly important for the reasons outlined in the above bullet point.
- Identifying obstructions that may stop the drilling processes, e.g. identifying historic

streams and valleys where there may be buried trees or areas of uncontrolled fill.

Site investigations are typically taken at 200m intervals, with additional investigations being undertaken where there is the potential for changing conditions or obstacles. For short shots (300m or less), as few as three site investigations may suffice.

The borings for site investigations should be near the drill-path to give accurate soil data, but sufficiently far from the borehole to avoid frac-outs by enabling the pressurized mud in the borehole from following natural ground fissures and rupturing to the ground surface through the soil-test bore hole. A rule-of -thumb is to take borings at least 10m to either side of bore path.

Typical testing undertaken at investigation boreholes includes:

- Production of borelog showing soil profile and groundwater levels
- Determination of atterberg limits
- Grain size analysis
- Determination of soil strength parameters

All buried structures and utilities within 3m of the drill-path should be identified and located. When installing larger pipes (greater than 600mm dia) all buried structures and utilities within 8m of the drill-path should be identified and located.

For river crossings and outfalls river/seabed, depth, stability (lateral as well as scour), should be determined.

#### 4.1.2.7 PRODUCTIVITY & PRICING

Factors that can affect the cost of a horizontal directional drilling project include:

- Mobilisation costs
- Geotechnical conditions (rock and changing conditions reduce production rates)
- Obstructions and services
- Complexity (longer/larger shots are more expensive)

Location and depth may impact productivity and price but not to the same degree as opencut excavations.

### *4.1.3 DIRECT PIPE*

#### 4.1.3.1 OVERVIEW

The Direct Pipe technique was developed by Herrenknecht. The technique merges the advantages of mircrotunelling and HDD. A pipe thruster and tunnelling machine are combined to simultaneously excavate the borehole and install the pipe in one step.

The new pipe is connected to the back of the tunnelling machine. As the tunnelling machine moves forward the pipe thruster clamps the pipeline from the side and pushes the pipe. The tunnelling machine is controlled by an operator on the surface near the rig. It is constantly monitored to keep it at the designed line and grade using a gyro compass and hydrostatic water levelling system. Location accuracy is in the order of +/- 75mm.

A slurry circuit is used to pump excavated material out of the pipeline. At the end of the operation a small pit is excavated to remove the tunnelling machine.

The borehole is fully supported by the new pipe during installation, greatly reducing the likelihood of hole collapse or frac-out.

Figure 4-3 Overview of Direct Pipe Installation

#### 4.1.3.2 USES

Direct pipe can be used to install pipes between 650mm & 1,500mm diameter.

The installed pipeline may be at grade or curved.

The installed pipe is required to withstand thrust. Typically, Direct Pipe is used to install steel pipes, with 5m long pipe sections being welded together.

Typical drive lengths range from 300m up to almost 2km. (Installation of the outfall for Watercare's Army Bay Wastewater set the record when it was installed at 1,930m).

Direct Pipe is suitable for use through most soil conditions. The cutter on the tunnelling machine is able to be configured to suit the prevalent soil conditions.

Direct Pipe is suitable for use in unstable soil, shallow installations or other situations where the HDD may not be suitable as the borehole is supported throughout installation.

Direct Pipe is suitable for installation of outfalls as only a small excavation is required at the downstream end to remove the tunnelling machine.

### *4.1.4 ADVANTAGES AND DISADVANTAGES*

Advantages

- Single phase installation – No Reaming
- Pipe directly installed during excavation removes the risk of hole collapse
- Suitable for installation through most ground conditions
- Reduced risk of frac-out
- Shorter and shallower profile than HDD
- Required workspace for pipe stringing is less than HDD.
- Shorter construction time than similar installations by HDD or microtunnelling.

Disadvantages

- High capital cost of equipment
- Heavy foundation required for pipe thruster unit
- Machine only installs one size of pipeline. Different tunnelling machines are required to install pipelines of varying size. However, a smaller diameter pipeline can be slipped inside the pipeline installed by Direct Pipe.

#### 4.1.4.1 CONSTRUCTION & DESIGN CONSIDERATIONS

Covered under Section 4.1.3.1.

#### 4.1.4.2 WHAT CAN GO WRONG

Significant issues that can occur include:

- Stuck tunnelling machine (Buried trees, obstructions)
- Damaged tunnelling machine (Unexpected ground conditions)
- Line and Grade Errors (soft material below tunnelling machine)

These issues are less likely to occur with Direct Pipe installations than with microtunnelling projects as the tunnelling machine is able to accommodate a wider range of ground conditions. It is also possible to pull back the installed pipe and change the alignment if issues are encountered.

#### 4.1.4.3 INVESTIGATIONS

Key information that should be gathered to successfully design and implement Direct Pipe installations includes:

- Topographic survey
- General understanding of geotechnical conditions and parameters – required to design the profile of the drive, select tooling and other equipment, to estimate jacking forces (for equipment and pipe selection) and estimation of expected production rates.
- Identifying where geotechnical conditions change, especially identifying where there are mixed conditions, is particularly important for the reasons outlined in the above bullet point.
- Identifying obstructions that may impact the processes, e.g. identifying historic streams and valleys where there may be buried trees or areas of uncontrolled fill.
- Determining the potential for contaminated land.

Site investigations are typically taken at 200m intervals, with additional investigations being undertaken where there is the potential for changing conditions or obstacles. Additional investigations should be undertaken where the pipe thruster is to be located to design the foundation and support for the thruster.

Typical testing undertaken at investigation boreholes includes:

- Production of borelog showing soil profile and groundwater levels
- Determination of atterberg limits
- Grain size analysis

- Determination of soil strength parameters
- Contaminated land analysis

All buried structures and utilities within 8m of the drive-path should be identified and located.

For river crossings and outfalls river/seabed, depth, stability (lateral as well as scour), should be determined.

### 4.1.5 PRODUCTIVITY AND PRICING

Factors that can affect the cost of a micro-tunnelling project include:

- Mobilisation costs
- Geotechnical conditions (rock and changing conditions reduce production rates)
- Obstructions and services

### 4.1.6 PIPE JACKING / MICROTUNNELLING

#### 4.1.6.1 OVERVIEW

Pipe Jacking

Pipe jacking is where a pipe is installed by pushing it forward from a launch pit using hydraulic rams. The pipes are jacked into an excavated face at the head of the progressing pipeline. The term pipe jacking usually applies to pipelines where person entry is available for excavation of the face, with a common minimum pipe diameter of 1200 mm. The excavated material is transferred from the face back through the installed pipe to the launch pit using muck carts on rails. The jacking force is resisted by a thrust block in the launch pit and applied to the pipeline end through a steel thrust ring. A steel cutting shield fitted to the lead pipe gives protection to the workers and allows steering and alignment adjustments. When the jacks reach the end of their stroke they are retracted, and another pipe length installed and then jacked forward. The pipeline alignment is continually monitored and adjusted by laser light from the launch pit to a target fixed to the inside crown of the lead pipe or shield.

Microtunnelling

Microtunnelling is a remotely controlled form of non-person entry pipe jacking using a tunnel boring machine at the front of the pipe string to excavate the face. The tunnel boring machine is remotely controlled from the surface or the launch pit and provides continuous support to the excavation face by applying mechanical or fluid pressure to balance groundwater and earth pressures. The excavated material is transported back to the launch pit using an auger or slurry system. The tunnel boring machine has a rotating cutting head to excavate the face and may have a crushing cone to crush larger particles into smaller sizes for transport through slurry lines or by the auger. The tunnel boring machine is extracted from a reception pit following pipe installation.

Drive lengths are controlled by the capacity of the jacks and the ability of the pipe material and joints to withstand the forces applied. Maximum drive lengths are typically in the order of 100m. However on man-entry pipes longer drives can be achieved if intermediate jacking stations are used.

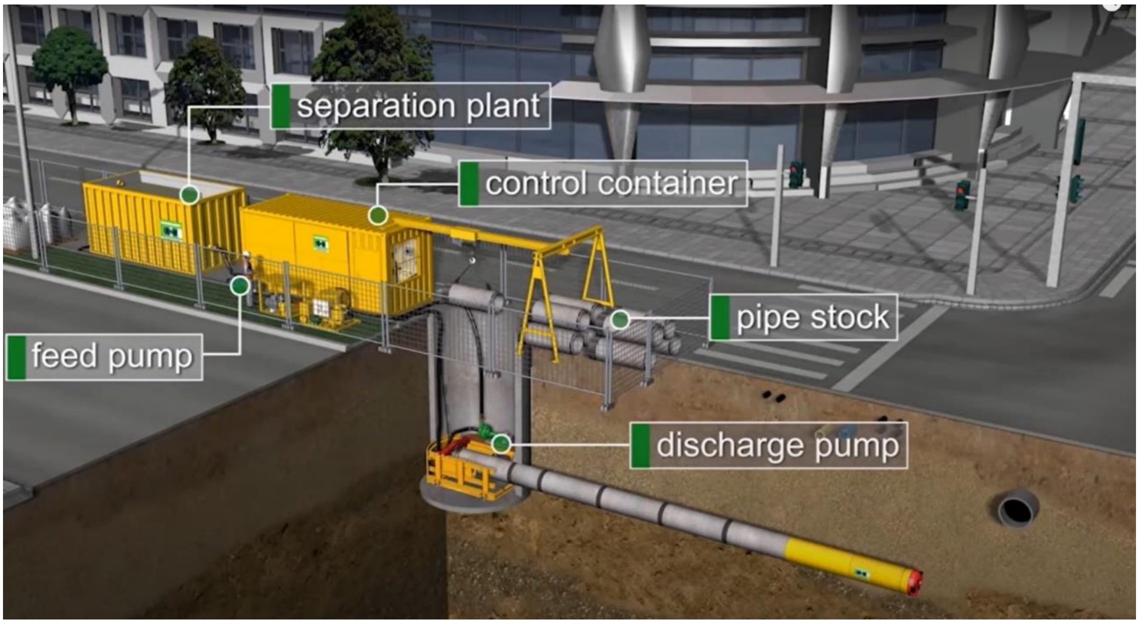



Figure 4-4 Microtunnelling Process (HerrenknechtAG)

Pilot Hole Microtunnelling

Pilot hole microtunnelling is a hybrid between HDD and standard micro-tunnelling. It can be used to install pipes from 150mm to 600mm. The maximum drive length is about 80m.

- Initially the jacking frame is established in the shaft with the drill string aligned closely to the required line and level of the finished pipeline. A pilot hole is then drilled in much the same way as for horizontal directional drilling. However, in pilot hole micro-tunnelling a laser theodolite-based steering system is used to maintain line and level of the cutter head.
- Once the pilot hole has been completed the hole is reamed out, normally using an auger spoil removal system with a casing being jacked into place behind the reaming head.
- The product pipe is then jacked into place and the casing removed.
- This technique has issues with soft ground andmay require ground stabilisation

For additional information and guidance refer to 'Small Diameter Tunnels and Pipejacks – A Reference Guide for New Zealand' published by New Zealand Tunnelling Society.

### 4.1.7 USES

Microtunnelling drives are normally straight, although curved drives are possible with special equipment.

Microtunnel bore lengths are normally in the range of 100m to 170m. The upper limit is a function of the jacking forces required to push the pipe into place. However, bores over 1000m long have been achieved with the use of lubricants and intermediate jacking stations.

Microtunnelling is used mostly on projects where surface heave or settlement may be a concern (as the hole is fully supported throughout the operation), or where accurate grade or alignment tolerances are required e.g., for pipes installed on flat gradients.

Rigid, segregated pipe materials are used to withstand jacking forces. Pipes may be sleeved with a small diameter pipe, e.g. to install a pressure pipe.

### 4.1.8 ADVANTAGES AND DISADVANTAGES

Advantages

- Minimum surface subsidence.
- By working underground there is no disruption of the area above and the area does not have to be quarantined off or closed to through traffic, except at jacking and receiving pits.
- In many situations, microtunnelling is substantially quicker than trenching and shoring operations.

Disadvantages

- Microtunneling machines are manufactured to install specific size pipes. The pipe installed may need to be larger than required to suit machine availability or a carrier pipe installed.
- Entry and exit pits are required to be excavated.
- Installation of curved pipelines difficult.
- Not possible to pull back if problems encountered during installation.

### 4.1.9 CONSTRUCTION & DESIGN CONSIDERATIONS

Depth

- Increasing the depth of a pipeline installed by microtunnelling is not affected by depth to the same extent as open-cut excavation. The major cost of deeper microtunnelling is the increased cost of the jacking and receiving pits. It is sometimes desirable to increase the depth of a pipeline to be installed by micro-tunnelling to take advantage of better ground conditions.
- Minimum ground covers can be as small as 1m as the pipe is fully supported throughout the operation

Shafts and Working Spaces

- Jacking pits must be of adequate size to accommodate the equipment and crews for installation of the pipes, e.g. 4.5m dia maybe required to install a 1m dia pipeline.. Space for storage of pipes is required near the jacking pit.
- Receiving shafts can be smaller and are needed only when the micro-tunnelling machine is being retrieved, e.g. in the order of 3m for installation of a 1m dia pipeline.
- Where feasible the works should be designed so that permanent structures, such as manholes, are located at jacking pit or reception pit locations.
- The shaft installation method should be selected based on the specific ground conditions and size of the required shaft. Shaft construction methods may include; soldier sheet piles and lagging, auger drilling, concrete caissons, sheet piles, secant piles and slurry walls.

Horizontal and Vertical Alignment

- Micro-tunnel drives are normally straight

- Pipe jacking in a curve is possible but requires special equipment and the additional loading on the pipes being installed needs to be considered. As a result, installation of a curved drive by micro-tunnelling is significantly more expensive than a straight bore.

### Impact on adjacent structures

- Micro-tunnelling will normally have minimal impact on adjacent structures.

### Geotechnical Conditions

- Whilst micro-tunnelling can be completed through most ground conditions, it is important to know what conditions will be encountered during the works. Where the machine is too small for man entry (less than 1200mm) the cutters on the micro-tunnelling machines cannot be changed during the drive. Thus, they must be selected for the types of materials likely to be accommodated and be able to last the duration of the drive.
- Mixed-face conditions can result in uneven forces on the boring machine, reducing steering control, which can affect alignment control and stability of the face. If possible, such conditions should be avoided
- Cobbles and boulders can stop a micro-tunnelling drive. Ground treatment may be required prior to micro-tunnelling where the soils have a high coarse granular content and low fines content.
- The presence of groundwater can affect the construction and design of the jacking and reception pits and jacking forces required to install the pipe.
- Buried obstructions can cause the boring machine to become stuck, requiring it to be removed by excavation. Fallen trees, e.g. in areas of past swamp can be a hazard.

### Design Considerations

- Optimise the alignment so the smallest number of shafts are used.
- Construct micro-tunnelling drives in both directions from a jacking shaft where possible. Micro-tunnelling may be advanced both upstream and downstream from the same jacking shaft.
- Minimize the number of pipe diameters. Changing pipe diameters may require a different boring machine to be used.
- Mud design for the pipe jack, for lubrication and if using a slurry machine for cuttings transportation.

### Pipe Materials

- Pipes used for micro-tunnelling are segmented, rather than continuous. Pipe segment length varies according to the micro-tunnelling system used, the pipe diameter and constraints of space.
- Pipe materials generally used for micro-tunnelling include:
  - Concrete
  - Polymer Concrete
  - GRP, e.g. Hobas pipe

- Typical pipe segment lengths usually range from 1.0 to 2.0 metres. Much of the cost of micro-tunnelling pipe is in the joints, so the use of longer pipe lengths tends to save cost on pipes; on the other hand, this may require larger shafts.
- Pipes need to be:
  - Circular with flush outside surface
  - Strength sufficient to withstand installation loads and long-term service loads
  - Durability for service exposure to internal and external corrosion resistance
  - Joints that are water tight and capable of transferring jacking loads between pipes
  - Allow angular deflection required for steering
- Due to installation loads the design of the joints are critical for pipes for micro-tunnelling. Frequently the highest loads are at misaligned pipe joints. In general, the deflection at the pipe joint face should not exceed 0.5°.

Other Issues

- The potential for contaminated soil and its disposal should be considered.

### 4.1.10 WHAT CAN GO WRONG

Significant issues that can occur include:

- Stuck micro-tunnelling machine (Buried trees, obstructions)
- Damaged micro-tunnelling machine (Unexpected ground conditions)
- Line and Grade Errors (soft material below tunnelling machine)
- Broken Pipe (excessive jacking forces)
- Shaft Failures (groundwater, unexpected ground conditions)
- Excessive cuttehead wear

Longer and larger installations are more complicated and there is an increased risk of things going wrong.

### 4.1.11 INVESTIGATIONS

Key information that should be gathered to successfully design and implement mircrotunnelling installations includes:

- Topographic survey
- General understanding of geotechnical conditions and parameters – required to design the profile of the drive, select tooling and other equipment, to estimate jacking forces (for equipment and pipe selection) and estimation of expected production rates.
- Identifying where geotechnical conditions change, especially identifying where there are mixed conditions, is particularly important for the reasons outlined in the above bullet point.
- Identifying obstructions that may impact the processes, e.g. identifying historic streams and valleys where there may be buried trees or areas of uncontrolled fill.
- Determining the potential for contaminated land.

Site investigations are typically taken at 200m intervals, with additional investigations being undertaken where there is the potential for changing conditions or obstacles. For short shots (300m or less), as few as three site investigations may suffice. Additional investigations should be undertaken at shaft locations for design of the shaft structure.

Typical testing undertaken at investigation boreholes includes:

- Production of borelog showing soil profile and groundwater levels
- Determination of Atterberg limits
- Grain size analysis
- Determination of soil strength parameters
- Contaminated land analysisOther tests may be needed if in rock, e.g.abrasively tests, tests to determine how much the rock will swell

All buried structures and utilities within 3m of the drill-path should be identified and located. When installing larger pipes (greater than 600mm dia) all buried structures and utilities within 8m of the drill-path should be identified and located.

For river crossings and outfalls river/seabed, depth, stability (lateral as well as scour), should be determined.

### *4.1.12 PRODUCTIVITY AND PRICING*

Factors that can affect the cost of a micro-tunnelling project include:

- Mobilisation costs
- Depth and diameter of shafts
- Geotechnical conditions (rock and changing conditions reduce production rates)
- Obstructions and services
- Complexity (longer/larger drives are more expensive)
- Groundwater

## 4.2 ONLINE REPLACEMENT

### *4.2.1 OVERVIEW*

#### Pipe Bursting

Pipe bursting installs a new pipe in the same position as the existing pipe.  The new pipe may either be the same size or a bigger diameter than the original pipe.

Pipe bursting involves breaking open the existing pipe by pulling or pushing a bursting head through it.  A new pipe is dragged in behind the bursting head.  A spreader device on the bursting tool pushes the fragments of pipe into the surrounding ground.

Pipe bursting requires excavation for entry and exit pits and for reconnection of laterals.

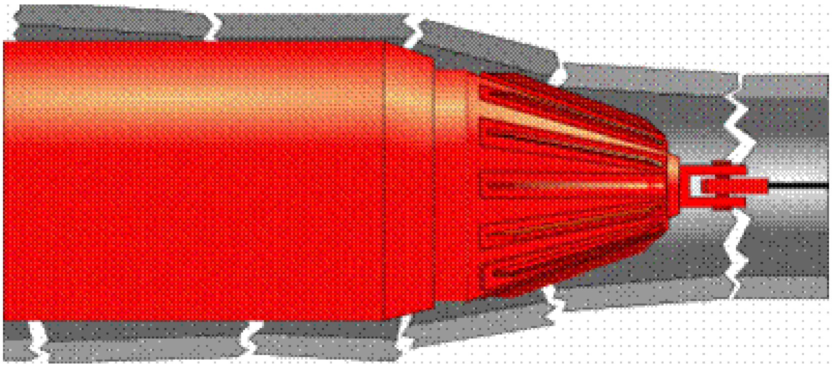


Figure 4-5 Pipe Bursting

### Pipe Reaming

Pipe reaming is similar to pipe bursting in its ability to allow a new pipe to be installed in the same position as the existing pipe (i.e., online replacement).

Pipe reaming uses a modified horizontal directional drilling machine with a specialised reamer tool. The reamer grinds up the old pipe while a new pipe (typically PE) is pulled in behind. Fragments of the old pipe are mixed with the drilling fluid and transferred to an exit point for removal.

Figure 4-6 Pipe Reaming Tool

### *4.2.2 USES*

Pipe bursting and pipe reaming are suitable for replacement on most types of brittle pipes such as vitrified clay, cast iron, plain concrete, asbestos, or some plastics. Reinforced concrete pipe can also be successfully replaced, if it is not heavily reinforced, or if it is substantially deteriorated. Pipe reaming is also suitable for replacement of flexible pipes such as PVC and HDPE.

The diameter of pipes that can be installed generally range from 100mm to 900mm.

Typically polyethylene pipe is pulled in behind the pipe bursting head. The pipeline is butt-welded above ground to form a continuous, joint free string.

The existing pipeline may either be replaced size-for-size, or upsized. The replacement pipe can be up to 2 nominal sizes greater than the existing pipeline. It depends on the ground heave.

### 4.2.3 ADVANTAGES AND DISADVANTAGES

Advantages

- Suitable for pressure pipelines
- A less disruptive way to install a new pipeline
- Pipeline upsizing possible

Disadvantages

- Excavation required at lateral connections and for launch and reception pits
- Can cause damage to adjacent services and ground surface.

### 4.2.4 CONSTRUCTION & DESIGN CONSIDERATIONS

Online replacement has limitations. Difficulty can arise in:

- Proximity of other utilities or buildings (services may be damaged, or the replacement pipeline diverted from the intended alignment)
- Shallow pipes (ground heave may occur)
- Pipes with point repairs that reinforce the existing pipe with ductile material (Gibaults may cause the burster to become stuck)
- Pipes encased in concrete (may need to be excavated before bursting)

Special care needs to be taken when pipe bursting under structures or other locations where the pipe burster cannot be exposed should a problem occur.

Pits are required to be excavated at the start and the start and end of the online replacement operations.

The length of these pits is governed by:

- Entry pit, the bending radius of the replacement pipe, refer sketch and table below.
- Exit pit, the room required to remove the pipe burster/reamer.

Soil Conditions

The most favourable ground conditions for pipe bursting/reaming are soils that can be moderately compacted (reducing the lateral extent of outward ground movements), in which the expanded hole behind the bursting head does not cave in before the replacement pipe is installed (lowering the drag and the tensile stresses in the pipe during installation).

Ground Heave and the Effect of Pipe Bursting on Adjacent Services

Ground displacements depend primarily on

- Degree of upsizing,
- Type and compaction level of the existing soil around the pipe,
- Depth of bursting.

Pipe Alignment – Pipe Bursting will install the replacement pipe on the same alignment as the existing pipe. It may slightly reduce dips in the existing pipe if the soil conditions around the existing pipe are uniform. However, if there is a soft zone beneath the existing pipe, the new pipe may be driven towards the soft zone and the dip may deepened.

Bypass Arrangement – the amount of flow to be by-passed during the pipe bursting and the position of bypass pipes and pumps need to be considered.

Other Considerations

Pipe Lay Down Area - The amount of area required for laying out the replacement pipe prior to pipe bursting needs to be considered.

Spacing of service connections and fittings. Where close together open cut may be cheaper.

### 4.2.5 WHAT CAN GO WRONG

Significant issues that can occur include:

- Stuck burster/reaming machine (fittings, concrete encasement, changes in material of existing pipeline)
- Ground heave (shallow pipelines)
- Damage to adjacent utilities
- Damage to new pipeline (excessive pulling forces, existing pipeline not adequately broken)

### 4.2.6 INVESTIGATIONS

The following investigations should be carried out:

- Determine the depth and alignment of the existing pipe and topography of ground surface above pipe. Determine the position of manholes.
- Establish flow requirements for design of bypass pumping/temporary connections.
- CCTV inspection to determine the host pipe material, diameter, location of laterals, service connections and accurate condition assessment.
- Determine the fittings that may be installed on the existing pipe (particularly ductile fittings that may affect pipe bursting)
- Determine soil condition and types and expected groundwater level. Desktop assessment will normally suffice.
- Determine position, type, material and expected condition of adjacent services (all services within 3m of existing pipeline).
- Trial excavations may be required where concrete encasement is expected.
- Identify locations where ground heave may cause damage to surface features.
- Undertake analysis to assess the potential for contaminated land.

### 4.2.7 PRODUCTIVITY AND PRICING

- The cost of pipe bursting is comparable to that of replacement by open cut excavation at shallow depths or where no surface reinstatement is required.
- It becomes cheaper an open cut replacement at deeper depths and where surface reinstatement is required.
- Pipe bursting is normally much less disruptive than open cut replacement.

Factors that can affect the cost of an online replacement project include:

- Depth of pipeline
- Number of laterals / service connections to be reconnected
- Reinstatement and traffic management for excavations at laterals and entry/exit pits

## 4.3 REHABILITATION

Rehabilitation involves installing or forming a new pipeline within the existing pipeline. The new pipeline can be designed to either withstand all of the loads expected to be applied, independent of the existing pipeline, or the new and existing pipe can be designed to work together as a system. There are two main types of rehabilitation, i.e.:

- Slip Lining, where the outside diameter of the pipeline installed is smaller than the diameter of the existing pipeline.
- Closefit lining where the outside of the liner is in contact with the existing pipeline.

### *4.3.1 REHABILITATION - SLIP LINING*

#### 4.3.1.1 OVERVIEW

Slip lining is the simplest technique for renovating man-entry and non-man-entry pipelines. It entails pushing or pulling a new pipeline into the old one.

Sliplining requires excavation for entry and exit pits and for reconnection of laterals.

Although, in theory, any material can be used for the new pipe, today polyethylene is the most common choice in smaller sizes as the material is sufficiently flexible to negotiate minor bends during installation. It can be butt-fused into a long length prior to being winched into the host pipe. For larger pipes where polyethylene is not suitable (i.e. above 800mm) and non-circular pipes, GRP, pushed into place can be used.

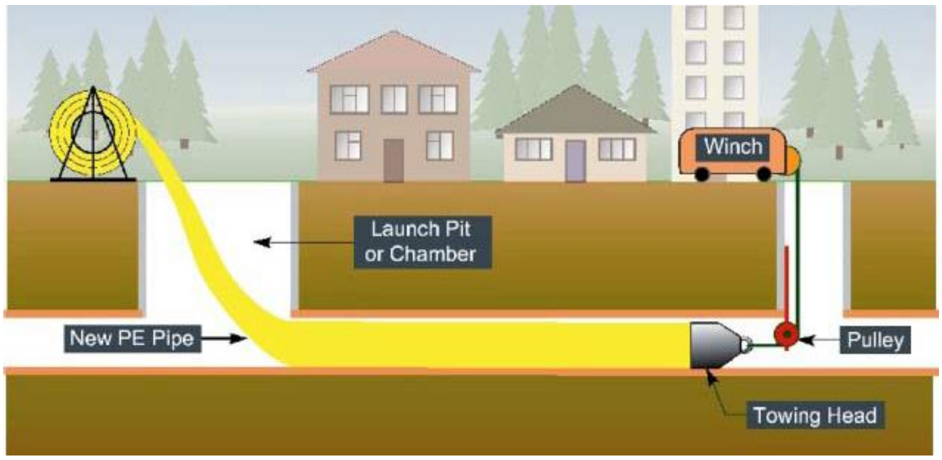



Figure 4-7 Slip Lining Installation Process

In most cases it will be necessary to grout the annulus between the host pipe and the inserted pipe to firmly hold the new pipeline in position. The loss of cross-sectional area may be significant. The size of the installed pipeline is governed by the diameter of commercially available extruded pipes, and the diameter required to negotiate deformations, intrusions or displaced joints in the host pipe.

Swaglining is a variant of sliplining for installation of PE pipes which does not reduce the cross-sectional area as much as traditional sliplining. However, it is not widely used in New Zealand. With swaglining the diameter of the PE pipe is temporarily reduced by pulling it through a reduction die under tension. The pipe is held under constant tension as it is installed in the host pipe. When the tension is released the pipe returns to its original size.

#### 4.3.1.2 USES

Sliplining is used where the existing pipeline has spare capacity.

It is generally used for rehabilitation of watermains or rising mains as the HDPE pipeline installed can withstand internal pressure.

For gravity pipelines other close-fit rehabilitation techniques are normally cheaper and easier to install.

#### 4.3.1.3 ADVANTAGES AND DISADVANTAGES

Advantages:

- Suitable for a wide range of pipe types and diameters
- Relatively cheap simple process

Disadvantages:

- Considerable loss of internal diameter
- Launch and reception pits must be dug
- Lateral/ service connections connections must be excavated and reconnected

#### 4.3.1.4 CONSTRUCTION & DESIGN CONSIDERATIONS

Key issues are:

- Ensuring that there is a gap between the outside of the new pipeline and the inside of the existing pipeline to enable the pipe to be installed.
- Ensuring that the entry pits are of adequate length. The required length is a factor the depth of the pipeline and the bending radius of the material being installed.
- Cleaning of existing pipelines in particular pressure pipelines to remove tuberculation.

#### 4.3.1.5 WHAT CAN GO WRONG

Significant issues that can occur include:

- New pipe stuck in existing pipeline before fully installed (existing pipeline smaller than expected, intrusions in existing pipeline)
- Damage to new pipeline (excessive pulling forces, intrusions in existing pipeline)

#### 4.3.1.6 INVESTIGATIONS

The following investigations should be carried out:

- Determine the depth and alignment of the existing pipe topography of ground surface above pipe. Determine the position of manholes.
- Establish flow requirements for design of bypass pumping and temporary connections.

- CCTV inspection to determine the host pipe material, diameter, location of laterals and service connections and accurate condition assessment.
- Measure dimensions of existing pipeline.  Undertake laser profiling if asset can be taken out of service dimensions may vary along the pipeline.
- Determine soil condition and types and expected groundwater level. Desktop assessment will normally suffice.
- Determine position, type, material and expected condition of services adjacent to excavations for entry and exit pits and for reconnection of laterals/service connections. (all services within 3m).
- Undertake analysis to assess the potential for contaminated land.

### 4.3.2 PRODUCTIVITY AND PRICING

Factors that can affect the cost of a sliplining project include:

- Depth of pipeline
- Amount of cleaning required
- Number of laterals to be reconnected
- Reinstatement and traffic management for excavations at laterals and entry/exit pits

### 4.3.3 REHABILIITATION - CIPP LINING

#### 4.3.3.1 OVERVIEW

Cured-in-place lining (CIPP)is a “close fit” lining technique that has been used around the world for about 50 years.

Whilst several variants are available, the common feature is the use of a fabric tube impregnated with a resin. The tube is inserted into the existing pipeline and inflated against the pipe wall, then cured.  Curing may be by re-circulating hot water or steam. Some variations cure using ultra-violet light.

Lateral connections are cut open robotically to re-establish flow.

For use on potable water systems the system must be certified, a wastewater liner must not be used as it can contaminate the drinking water supply. Service connections are reconnected using propriety fittings.

Bypass pumping or temporary connections are normally required as the existing pipeline is blocked during installation.

#### 4.3.3.2 USES

Cured-in-place liners can be manufactured to conform to almost any shape of pipe, making them suitable for lining of non-circular e.g. ovoid cross-sections.

Although used mainly in non-man-entry pipelines, some systems are also suitable for the renovation of large diameter sewers and culverts. The liner wall-thickness, weight and cost are the main limitations.

CIPP systems were originally developed for gravity pipelines, but certain proprietary techniques are available for pressure pipes.

CIPP can be used to line pipes from 100mm to 1800mm.

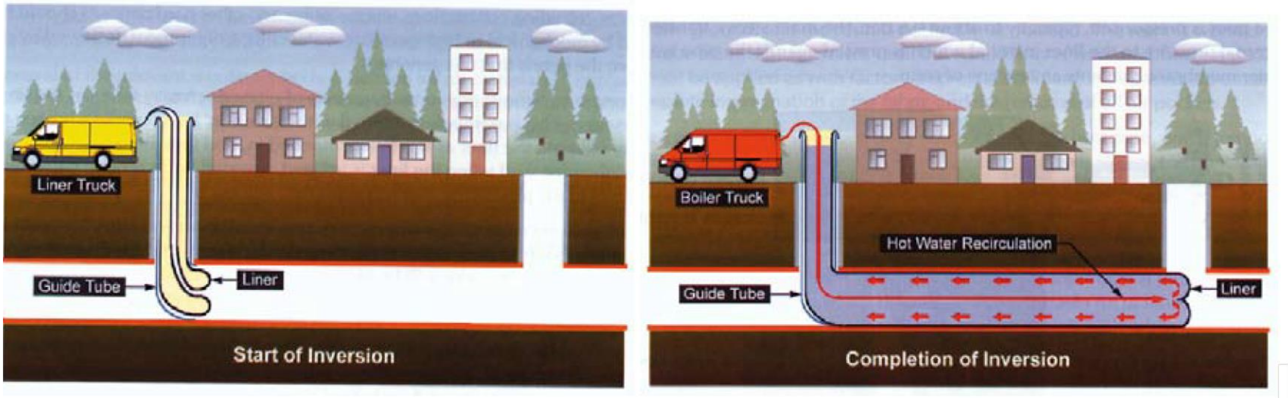



Figure 4-8 Overview of CIPP Process (Hot Water Cured)

### *4.3.4 ADVANTAGES AND DISADVANTAGES:*

Advantages:

- Close fit liner minimises loss of pipe bore
- Typically installed without evacavation
- Suitable for non-circular shapes
- Longest track record for close fit liners
- Can accommodate curves in pipelines
- Relatively cheap simple process

Disadvantages:

- Material properties depend on successful curing
- Susceptible to wrinkling due to variations in the diameter of the existing pipeline or due to pressure variations during installation
- Bypass pumping required
- Limited ability to accommodate variations in pipe diameter

### *4.3.5 CONSTRUCTION & DESIGN CONSIDERATIONS*

CIPP lining systems typically require the host pipe to be out of service during installation and curing necessitating the installation of bypass pumping or temporary connections.

Thorough preparation is important to the success of a CIPP installation. The following are among the factors to be considered:

- Intruding connections, encrustation and other hard deposits should be removed
- Thorough cleaning of the pipeline, including removal of fat, grease and debris
- Pre-lining repairs to missing inverts etc may be needed if the liner is to have a circular cross section

#### 4.3.5.1 WHAT CAN GO WRONG

Significant issues that can occur include:

- Wrinkling of liner (variations in diameter of existing pipeline, pressure not maintained during inversion)
- Incomplete curing

#### 4.3.5.2 INVESTIGATIONS

- Determine the depth and alignment of the existing pipe. Determine the position of manholes.
- Establish flow requirements for design of bypass pumping and temporary connections.
- CCTV inspection to determine the host pipe material, diameter and accurate condition assessment.
- Measure dimensions of existing pipeline. Undertake laser profiling if dimensions may vary along the pipeline.

#### 4.3.5.3 PRODUCTIVITY AND PRICING

Factors that can affect the cost of an online replacement project include:

- Bypass pumping requirements
- Complexity (rehabilitation of large diameter pipelines are significantly more complex than smaller reticulation pipelines)
- Condition of existing pipeline (extent of repairs to the existing pipeline required prior to lining, e.g. to remove deformed sections)
- Number of laterals to be reconnected

Depth and location impact price but not to the same level as for new installations.

### *4.3.6 REHABILITATION - FOLD & FORM*

#### 4.3.6.1 OVERVIEW

The principle of folded liners is to reduce the effective size of the liner during insertion, and then to revert it to its original shape to produce a close fit within the host pipe. The liner is folded in the factory and delivered to site in coils. It is then winched into the host pipe.

Once in place, the liner is heated with steam and inflated to expand the liner against the wall of the existing pipe. Pressure is maintained while the liner cools to a rigid state, after which the ends are trimmed, and laterals reopened.

#### 4.3.6.2 USES

The process is typically limited to liners between 150mm and 450mm in diameter.

The process is only suitable for gravity, circular pipelines.

#### 4.3.6.3 ADVANTAGES AND DISADVANTAGES:

Advantages:

- Close fit liner minimises loss of pipe bore
- Typically installed without digging
- Quick installation (1-2 hours)
- Can handle gentle pipeline curves
- Bypass pumping is not normally required

Disadvantages:

- Running infiltration can affect success of liner reversion and should be sealed prior to lining
- Only suitable for pipe diameters between 150mm and 450mm.
- Only suitable for circular pipelines

#### 4.3.6.4 CONSTRUCTION & DESIGN CONSIDERATIONS

As per CIPP except that bypass pumping is generally not required due to the short time that the existing pipeline is blocked during installation.

Running infiltration may adversely affect the ability of the liner to reform to the shape of the host pipe and should be sealed before installation.

#### 4.3.6.5 WHAT CAN GO WRONG

Significant issues that can occur include:

- Incomplete reversions (running infiltration)

#### 4.3.6.6 INVESTIGATIONS

As per CIPP, refer Section 4.3.5.2.

#### 4.3.6.7 PRODUCTIVITY AND PRICING

As per CIPP, however bypass pumping is not typically required.

### *4.3.7 REHABILITATION - SPIRAL WOUND LINING*

#### 4.3.7.1 OVERVIEW

A single strip of PVC is spirally wound into the existing pipeline using a patented winding machine. The edges of the strip interlock to form a continuous liner inside the host pipe.

Two techniques are used. In pipelines less than 1m diameter the winding machine is positioned at a manhole. The liner is wound into place and then expanded to fit tightly against the wall of the existing pipeline. In larger pipes the winding machine travels down the pipeline.

Flow can pass through the liner during installation, avoiding the need for bypass pumping.

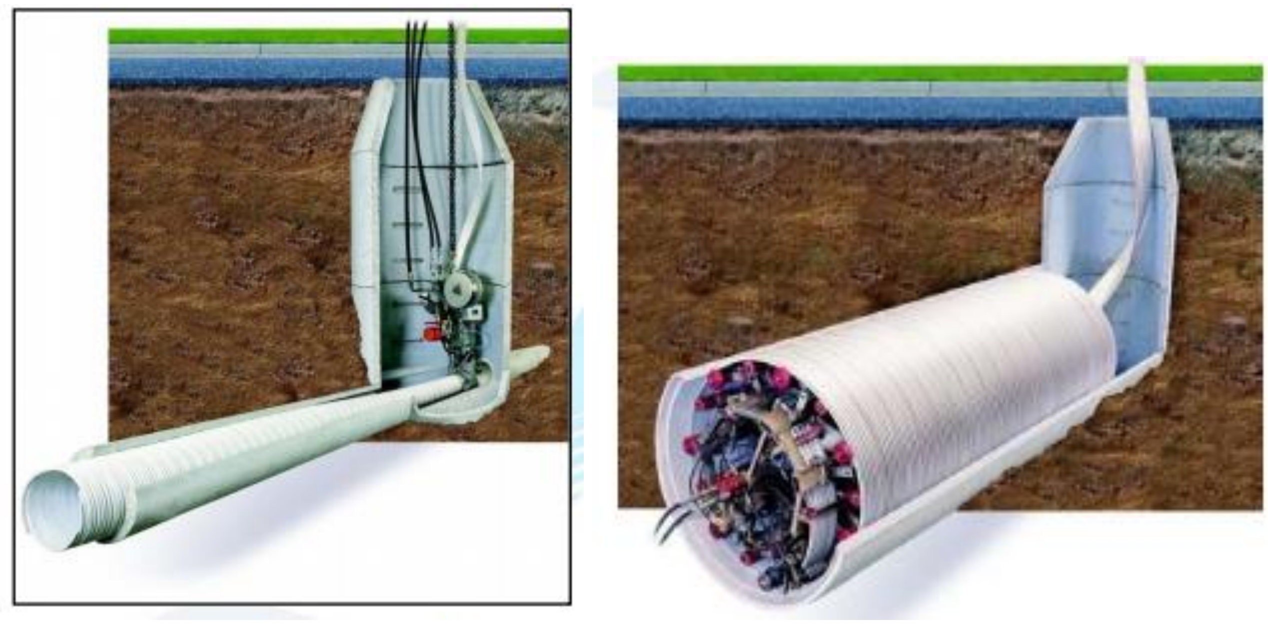


Figure 4-9 Overview of Spiral Wound Process (Left-hand image show process for lining pipes less than 1m dia, right-hand shows process for lining larger pipelines)

### *4.3.8 USES*

Spiral wound liners are suitable for pipes with internal diameters from 150mm to 1,800mm. A range of plastic profiles with varying stiffnesses is available to provide a liner that meets structural design specifications.

The process is only suitable for gravity, circular pipelines.

### *4.3.9 ADVANTAGES AND DISADVANTAGES*

Advantages:

- Assured material properties – not dependent on successful curing or heat treatment
- Diameter can vary according to the actual diameter of the host pipe
- Circular cross section with uniform wall thickness. No softening during installation, so does not take shape of deteriorated host pipe
- Fast installation as no heating or curing
- Bypass pumping rarely needed

Disadvantages:

- Only suitable for circular pipelines
- Limited ability to line around bends

#### 4.3.9.1 CONSTRUCTION & DESIGN CONSIDERATIONS

As per CIPP except that bypass pumping is generally not required as flow can pass through the liner during installation.

#### 4.3.9.2 WHAT CAN GO WRONG

Significant issues that can occur include:

- Localised disconnection of joint (if this occurs the liner can be removed and replaced or patched)

#### 4.3.9.3 INVESTIGATIONS

As per CIPP, refer Section 4.3.5.2.

#### 4.3.9.4 PRODUCTIVITY AND PRICING

As per CIPP, however bypass pumping is not typically required.

# 5 POTENTIAL REFINEMENTS

It is recommended that this document be reviewed annually to incorporate lessons learnt from completed projects and changes in technology.  Potential refinements that could be included in subsequent versions include:

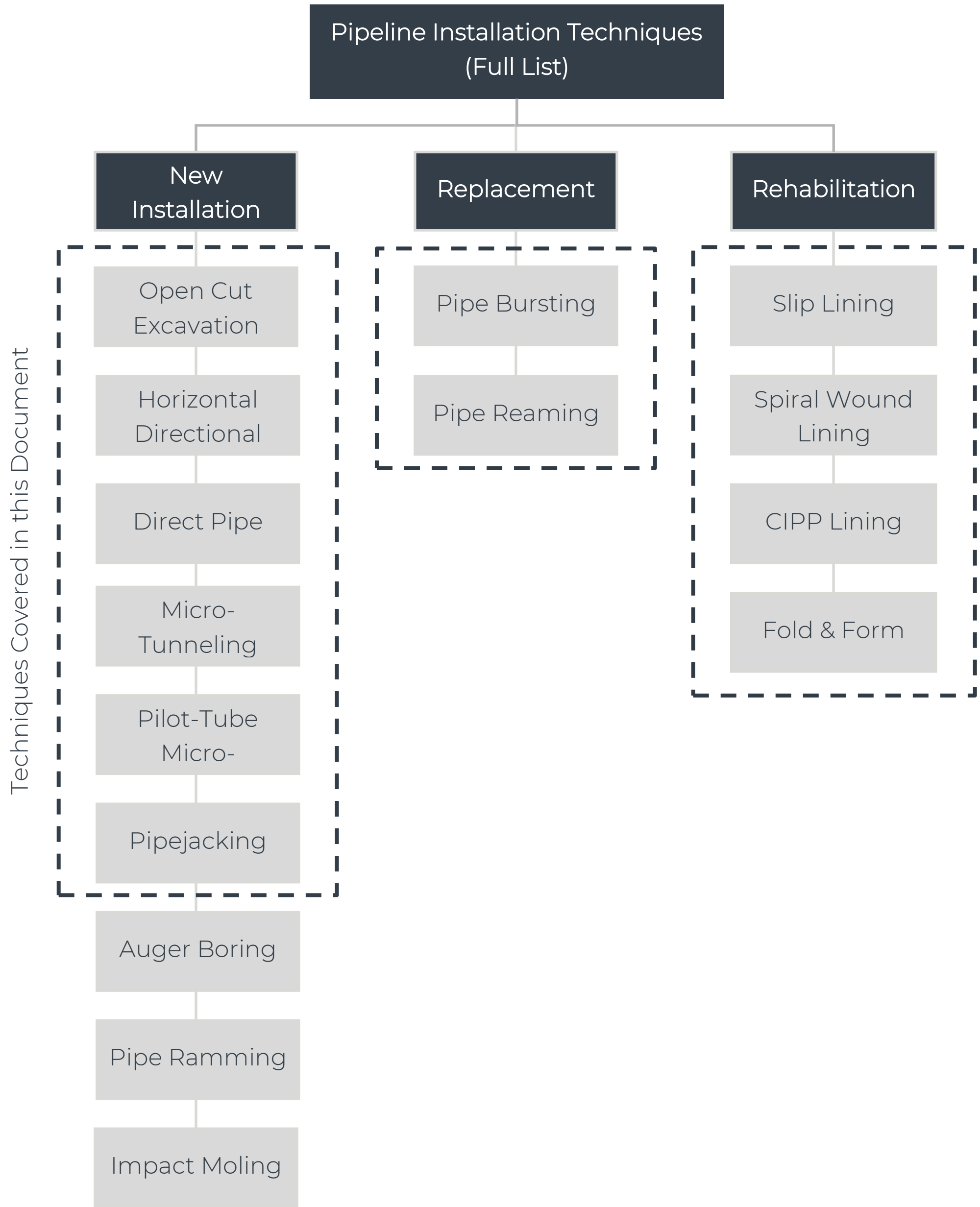
- Development of cost curves for estimation (building on the qualitative information in this version)
- Carbon calculator to quantify embedded carbon for the various techniques (building on the qualitative information in this version)
- Information to assist operations and maintenance, e.g. repair methodologies and recommendations on spare parts to hold in stock.

# 6 LIMITATIONS

This report ('Report') has been prepared by WSP New Zealand Limited ('WSP') exclusively for Watercare Services Ltd ('Client') in relation to the purpose outlined in Section 1.1 ('Purpose') and in accordance with the PO 410018392 ('Agreement'). The findings in this Report are based on and are subject to the assumptions specified in the Report. WSP accepts no liability whatsoever for any use or reliance on this Report, in whole or in part, for any purpose other than the Purpose or for any use or reliance on this Report by any third party.

# APPENDIX A

## FULL LIST OF AVAILABLE TECHNIQUES



# APPENDIX B

## OTHER TECHNIQUES (EXCLUDED FROM THIS GUIDANCE DOCUMENT)

Within the trenchless technology industry there are several other relatively simple, older style methods, that can be used for installing utilities over short distances. These techniques generally have no or limited steering capability and are not well suited to Watercare projects. These are summarised in the table below.

Other Trenchless Technologies

| | Overview | Uses |
|---|---|---|
| Auger Boring | Auger boring is a process that is fundamentally the same as the normal method used by people to drill holes in timber. However, in the trenchless technology case, the process is specifically adapted to earth and soft rock as the drilled material.<br><br>In the earth drilling case, a cutting head excavates soil and the cuttings are withdrawn from the hole by an auger screw. The cutting head is adapted to cutting hard and abrasive material as is the spoil-handling screw. | Most commonly the auger bore process is used inside pipejacked casings to cope with the collapsing nature of many types of soft ground.<br><br>This technique has not been covered in detail because it is only suited for small diameter holes such as those under private properties for service connections. |
| Pipe Ramming | Pipe ramming is a trenchless method for installation of steel pipes and casings over distances usually up to 50m long and up to 1375mm diameter.<br><br>A pneumatic tool is used to hammer the pipe or the casing into the ground. Excess soil from inside the pipe/casing is removed to the surface. The method is non-steerable. | Pipe Ramming is the most useful for shallow installations under railways and roads, where other trenchless methods could cause surface settlement or heave. When casings are installed, pipes of other types for distribution of sewerage, water or gas, or electrical or telecommunication cables can be inserted inside the casing. |
| Impact Moling | Impact moling is used to install small diameter pipes, ducts and cables. The hammering action of the mole is used to create the bore by compacting and displacing the soil rather than removing it.<br><br>Impact moling is typically non-steerable, although steerable systems are available.<br><br>Impact moling is the simplest, least expensive and most widely used trenchless technique. | Impact moling is suitable for the installation of service connections under sidewalks, driveways and other short crossings under 30m. It can be used for the installation of gas, water, sewer mains, cabling, cable ducts, garden irrigation and landscape lighting.<br><br>Installed pipes are usually made of PVC, HDPE or steel. Impact moling is most suitable for compressible soils.<br><br>This technique has not been covered in detail because it is only suited for small diameter holes such as those under private properties for service connections. |

# APPENDIX C

## WATERCARE'S PIPE MATERIAL GUIDELINES

The following extracts from the Pipe Materials Guidelines are provided for information only. Refer to the latest version of the Pipe Materials Guidelines to select pipe materials.

| Pipe materials | Normative standard | Pressure Wastewater | Gravity Wastewater | Water supply | Plants and processes | Selection notes |
|---|---|---|---|---|---|---|
| PVC-U | AS/NZS 1260 | ✗ | ✓ (Networks only) | ✗ | ✓ | Gravity applications only. Suitable for aggressive groundwater, anaerobic and tidal zones. Can be used for trenchless installations with suitable load resistant joints |
| PVC-U | AS/NZS 1477 | ✓ (Networks only) | ✗ | ✓ (Networks only) | ✓ | Alternative installation techniques possible e.g. slip lining.<br>Suitable for aggressive groundwater, anaerobic conditions and tidal zones.<br>Can be used for trenchless installation with suitable end load resisting joints.<br>Specific design for dynamic stresses (fatigue) required for pressure applications. |
| PVC-M | AS/NZS 4765 | ✓ (Networks only) | ✗ | ✓ (Networks only) | ✓ | Improved fracture toughness and increased hydraulic capacity compared to PVC-U.<br>Inferior fatigue resistance compared to PVC-U and PVC-O. Suitable for aggressive groundwater, anaerobic and tidal zones. Specific design for dynamic stresses (fatigue) required for pressure applications. |
| PVC-O | AS/NZS 4441 | ✓ | ✗ | ✓ | ✓ | Improved fracture toughness compared to PVC-U.<br>Improved fatigue resistance compared to PVC-U and PVC-M.<br>***NOTE** – Use only DI fittings in pumped mains to achieve full fatigue resistance.*<br>Has increased hydraulic capacity compared with PVC-U and PVC-M.<br>Suitable for aggressive groundwater, anaerobic conditions and tidal zones.<br>Specific design for dynamic stresses (fatigue) required for pressure applications. |
| PE | AS/NZS 4130<br>AS/NZS 4131<br>AS/NZS 4129 | ✓ | ✗ | ✓ | ✓ | Generally for pressure applications but limitation placed on size and application in Transmission areas. Retrospective installation of fittings / repair is complicated.<br>Can be curved to eliminate the need for bends.<br>Alternative installation techniques, e.g. pipe cracking, directional drilling and slip lining.<br>Can be welded to form an end load resistant system.<br>Compression couplings and end load resistant fittings are available in smaller diameters.<br>Pipe longitudinal flexibility accommodates large differential ground settlement.<br>Fusion jointing requires qualified skilled installers and special equipment. |

| Pipe materials | Normative standard | Pressure Wastewater | Gravity Wastewater | Water supply | Plants and processes | Selection notes |
|---|---|---|---|---|---|---|
| | | | | | | Specific design for dynamic stresses (fatigue) required for pressure pumping applications.<br>≤ DN 125 are available in long coiled lengths for fewer joints.<br>Suitable for aggressive groundwater, anaerobic and tidal zones but not where some hydrocarbons are present. Suitable for ground with high subsidence potential.<br>PE pressure fittings, including mechanical, compression, or electrofusion as approved by Watercare. Welding requires skilled and suitably qualified installers<br>• Butt fusion is preferred over electrofusion. Electrofusion should only be used where end connections or tie-ins are made.<br>• Electrofusion fittings are preferred over mechanical couplings. Limitations are placed on the size of mechanical fittings that can be used. |
| PE | AS/NZS 5065 | × | ✓ | × | | Only for gravity applications. Alternative installation techniques possible e.g. pipe cracking and slip lining. Can be welded to form an end load resistant system.<br>Fusion jointing requires skilled installers and special equipment.<br>Retrospective installation of fittings / repair complicated.<br>Smaller diameters available in long coiled lengths for fewer joints.<br>Suitable for aggressive groundwater, anaerobic and tidal zones.<br>Not suitable for ground with high subsidence or weak support. |
| GRP | AS 3571.1 | ✓ | ✓ | × | | Alternative installation techniques possible, e.g. slip lining.<br>UV resistant (special product).<br>Custom made fittings can be manufactured.<br>Suitable for use without additional corrosion protection in areas where stray electrical currents occur.<br>Low impact resistance and ease of damage to thermosetting resin makes GRP susceptible to damage. |

| Pipe materials | Normative standard | Pressure Wastewater | Gravity Wastewater | Water supply | Plants and processes | Selection notes |
|---|---|---|---|---|---|---|
| | | | | | | Suitable for aggressive groundwater, anaerobic and tidal zones. |
| GRP | AS 3571.2 | × | × | ✓ | | Alternative installation techniques possible, e.g. slip lining.<br>UV resistant (special product). Custom made fittings can be manufactured. Suitable for use without additional corrosion protection in areas where stray electrical currents occur.<br>Low impact resistance and ease of damage to thermosetting resin makes GRP susceptible to damage.<br>Suitable for aggressive groundwater, anaerobic and tidal zones. |
| VC | BS EN 295-1 | × | ✓ (Networks only) | × | | Gravity applications only for particularly aggressive industrial wastes. Not for general use.<br>Not recommended for active seismic (earthquake) zones or unstable ground. Limited diameter application. |
| RRJRC (Rubber ring jointed reinforced concrete) | AS/NZS 4058 | × | ✓ | × | | Requires protection from hydrogen sulphide attack in sewer applications by sacrificial layer, plastic lining or appropriate cement additives. |
| CLS | NZS 4442<br>AS 1579 | ✓ | ✓ | ✓ | ✓ | Cement mortar lined, external coated according to installation environment.<br>High mechanical strength and toughness. Easily customised, specially configured steel fittings can be made to order.<br>Can be welded to form a system that will resist end load and joint permeation.<br>Cathodic protection (CP) is required to electrically continuous pipelines to provide enhanced corrosion protection.<br>Standard Portland cement is not resistant to $H_2S$ attack at any high points or discharge points in the main. High alumina cement has improved resistance. |

| Pipe materials | Normative standard | Pressure Wastewater | Gravity Wastewater | Water supply | Plants and processes | Selection notes |
|---|---|---|---|---|---|---|
| | | | | | | Welded joints require skilled installers and special equipment. Welded joints require reinstatement of protection system on site.<br>Special design required for welded installations parallel and adjacent to high voltage transmission lines.<br>Cathodic protection requires regular monitoring and maintenance.<br>Suitable for high load applications, such as railway crossings and major roads. Suitable for aerial or suspended pipeline applications.<br>Gravity application considered for structural crossings. |
| ELS | NZS 4442<br>AS 1579 | ✓ | ✓ | ✓ | ✓ | Epoxy lined steel pipe, external coated according to installation environment. Limited use where pipeline can be removed such as process or plant environments.<br>High mechanical strength and toughness. Easily customised, specially configured steel fittings can be made to order.<br>Can be welded to form a system that will resist end load and joint permeation.<br>Cathodic protection (CP) is required to electrically continuous pipelines to provide enhanced corrosion protection.<br>Epoxy lining must be selected to suit specific environment – Note limited lifetime of linings and limitations of re-coating.<br>Welded joints require skilled installers and special equipment. Welded joints require reinstatement of protection system on site.<br>Special design required for welded installations parallel and adjacent to high voltage transmission lines.<br>Cathodic protection requires regular monitoring and maintenance.<br>Suitable for high load applications, such as railway crossings and major roads. Suitable for aerial or suspended pipeline applications. |

| Pipe materials | Normative standard | Pressure Wastewater | Gravity Wastewater | Water supply | Plants and processes | Selection notes |
|---|---|---|---|---|---|---|
| DI | AS/NZS 1831<br>AS 3681 | ✓ | ✓ | ✓ | ✓ | Fatigue analysis not normally required. High mechanical strength and toughness. Ease of jointing.<br>UV resistant / vandal proof / impact resistant. Well established methods of repair.<br>Suitable for high pressure and above ground pipelines. Restrained joint systems available.<br>Sufficient ring stiffness not to rely on side support for structural adequacy for the usual water supply installation depths. Elevated pH may occur when conveying soft water or in low flow extremities of reticulation mains.<br>PE sleeving is required and must be repaired when damaged. Not suitable for aggressive ground water, anaerobic conditions or tidal zones.<br>Gravity application – normally considered for structural crossings only. |
| Stainless steel | AS5200.053 | ✓ | ✓ | ✓ | ✓ | Performs well in high corrosion prone areas. Impact resistant and does not require additional lining or coatings in most situations.<br>Welded joints require skilled installers and special equipment.<br>Special design required for welded installations parallel and adjacent to high voltage transmission lines.<br>Gravity application – normally considered for structural crossings only. |