Design Principles to Aid Condition Assessment of Pressure Pipes

Date July 2023 Version 1.0

Design Principles

Document Owner: Manager Design

Version 1.0 Version Date: 21 July 2023

This document was developed for Porirua, Hutt, Upper Hutt and Wellington city councils, South Wairarapa District Council, Greater Wellington Regional Council and Wellington Water Limited.

Document Control

Rev No	Revision description	Date
0.0	First Draft Connect Water	20/4/23
0.1	Second Draft for issue to 3WDC – prepared by Connect Water	30/6/23
0.2	Final version incorporating comments from 3WDC	7/7/23
1.0	Published in QPulse	24/7/23

Description	Name	Date	Signature
Prepared by	Jonathan Morris, Harrison Stroud	7/07/23 10/07/2023	
Document Owner	Francis Leniston, Head of Design	21/07/2023	
Reviewers	John Scott, Programme Lead – Very High Critical Asset Assessment Emily Greenberg, Project Manager Standards	 17/07/23	
Approver	Francis Leniston, Head of Design	21/07/2023	

Acknowledgements: These guidelines respond to observations collected during Wellington Water's condition assessments of Very High Criticality Assets. We would like to especially acknowledge Oliver Modricker of Promax and the Wellington Water project team of Aidan Crimp, Rob Blakemore, John Scott and Ed Rafferty.

TABLE OF CONTENTS

1 INTRODUCTION

This document describes design principles that enable or facilitate current or future condition assessments of pressure pipelines.

Condition assessment is the systematic determination of the present physical state of an asset. Depending on the system and the cause(s) of any changes, condition assessment may also provide information that can be used to estimate future changes to the condition and to determine remaining life, which supports planning for optimisation of renewals and future investments.

These design principles are especially relevant when designing new pressure pipelines classified as Very High Criticality Assets (VHCA), and can also be used for:

- Other less critical pipelines
- When working on existing pipelines during upgrades and enhancements (e.g., when making a new connection, installing, or replacing a valve or other fitting)
- When planning the condition assessment of an existing pipeline and access is required.

1.1 Exclusions

This is a design principles document and therefore does not provide detailed solutions. However, relevant documents and drawings are referenced in Table 2-1 and Section 6.

This document also does not identify which pressure pipelines need design components to enable future condition assessments[1]. This should be identified in Phase 3 (Concept Design) and Phase 4 (Detailed Design) of the Wellington Water Capital Project Phases and Gateways shown in Figure 1-1. This determination, however, should be guided by the design principles contained in this document.

Figure 1-1. Wellington Water Capital Project Phases and Gateways.

1.2 Other Design Guidance

The design principles in this document are to be used in conjunction with other Wellington Water design guidance and standards, including the following:

(a) Regional Standard for Water Services and Regional Specification for Water Services

(b) Intervention Guides for Water, Wastewater and Stormwater

(c) Condition Assessment Techniques for Pipes

(d) Safety in Design Process.

Any conflict with Regional Standards for Water Services to accommodate the implementation of these design principles would require a dispensation as per the standard process.

[1] *These principles should also be useful to facilitate performance assessment of pressure pipelines as well as condition assessment.*

2 BACKGROUND

The design principles outlined in this document respond to the need for condition assessments and the challenges of accessing pressure pipelines in the future to conduct these condition assessments.

2.1 The need for condition assessment

Once a pipeline has been constructed and put into service, the condition will change due to:

- Wear and tear (including ageing, or cumulative damage due to operations)
- Internal corrosion (from interaction with the contents)
- External corrosion (from interaction with the environment)
- Changes to the system (e.g., installation of new or replacement fittings, repairs, changes to service conditions)
- Other external events (e.g., accidental damage, ground movements, seismic events).

Wellington Water has recently published intervention guides for water mains, stormwater pipes and wastewater pipes, an asset criticality framework, and a pipe inspection techniques guide (Table 2-1). These documents outline the Wellington Water strategy for maintaining levels of service for pipes and rising mains. They describe the interventions required at various stages of the asset lifecycle, how to assess asset information and how to decide when to undertake intervention activities.

Table 2-1 – Wellington Water reference documents

Reference	Document Title	Location
AMPG_0002	Intervention Guide – Water Mains	QPulse – Asset Management
AMPG_0003	Intervention Guide – Stormwater Pipes	QPulse – Asset Management
AMPG_0004	Intervention Guide – Wastewater Pipes	QPulse – Asset Management
AMPG_0005	Condition Assessment Techniques for Pipes	QPulse – Asset Management
IMMG_02	Asset Criticality Framework	QPulse – Asset Management

2.2 The need for design principles

The condition assessment programme associated with the Very High Critical Asset (VHCA) study, undertaken by Wellington Water (ProjectMax, 2022) found several challenges when attempting to conduct assessments of pressure pipelines, such as:

- Access to the pipeline
- The ability to locate the assets
- The need for a safe working area
- Data recording

There are also potential benefits if access needs can be incorporated into facilities with other operational uses. These are addressed in Section 4.

A key message from this study was that condition assessment could be enabled or facilitated if access to the pipeline for assessment was considered at the time of design and construction. Figure 2-1 illustrates how condition assessment can be linked to the design process.

Design principles provide a means to promote this practice in the processes shown in Figure 1-1. Refer to the Asset Criticality Framework and Intervention Guides referenced in Table 2-1 to assist with Steps 1 and 2. For Step 3, refer to this document. Step 4 refers to Wellington Water data capture processes as part of the design process shown in Figure 1-1.

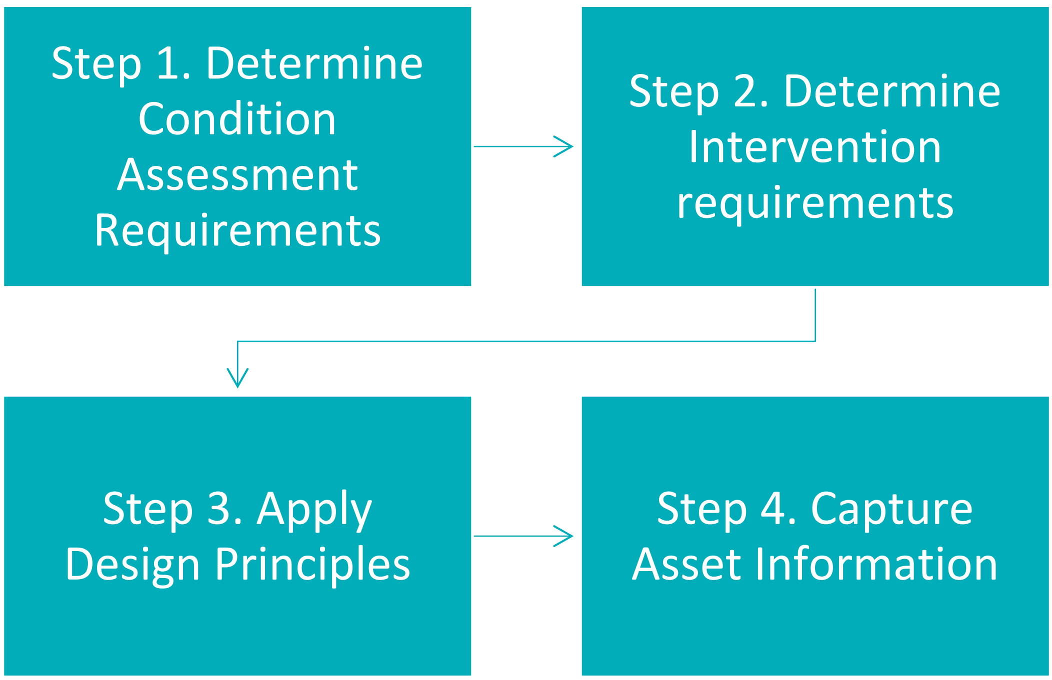


Figure 2-1. Design Process.

3 ASSESSMENT CONSIDERATIONS

As noted in Section 2.1 once a pipeline has been constructed and put into service, its condition can change. Condition assessment provides a means to check and track the physical state of an asset to confirm if it is fit and is likely to remain fit for purpose.

Before thinking about what can be done to enable or facilitate future condition assessments, it is useful to think about what level of assessment may be required at various stages of the pipe's service life. Refer to the Intervention Guides, Condition Assessment Techniques for Pipes and the Asset Criticality Framework listed in Table 2-1 for more information on condition assessment requirements and considerations.

3.1 General principles

There is no single approach to design detailing that can facilitate condition assessment for every pipe asset. However, general principles that apply to pressure pipe condition assessment that need consideration during the design development process are outlined below.

The main influences on what kind of access will be required include how much space is needed for the preferred or likely assessment techniques and whether local access to the pipe surface is sufficient, or if more extensive or intrusive works are needed.

Other important considerations include how to mitigate safety risks associated with access for condition assessment work and if planned and existing valves, hydrants, and associated chambers can be used or modified to permit access for condition assessment.

These factors are best considered at an early stage of the design when there is more opportunity to make minor changes in alignment that could facilitate planned condition assessments.

3.1.1 Criticality

The more critical a pipeline, the more likely it is that condition assessment will be needed to track current conditions, predict future changes, and plan for any required intervention to maintain performance. The Asset Criticality Framework covers assessing the criticality of an asset. It is useful to bear in mind that criticality could change during the design process or in service, so these design principles may need to be applied part-way through the design process.

3.1.2 The type of assessment

There are many different condition assessment methods, each of which has its own requirements for pipeline access. Where specific access requirements can be defined in advance, suitable fittings and other access points can be designed to suit. In other circumstances, it may be appropriate to install more general access features, such as a chamber which could later be used to provide access to install a fitting or to take a measurement.

> *Factors that drive change in condition can vary considerably according to the material of construction, service environment, installation practice and service conditions.*

Installation of real-time or remote monitoring equipment such as smart water meters, listening devices, pressure transducers can be facilitated by installing testing shafts. An example of a testing shaft designed by GHD and approved by RCA's is shown in Appendix 1. Installation of a testing shaft is illustrated in Appendix 2. Note this testing shaft is an example only and not a recommended design detail.

Other important considerations include the safety and asset management challenges of making connections to an existing pipeline (e.g., the risk of damaging a pipe or contaminating the water, how much space is needed to safely make a connection in a chamber, and what materials are suitable for connection points).

3.1.3 When to install

It is useful to consider the advantages and disadvantages of building in an access point during construction. Assessment may not be needed until 20 to 30 years into the pipeline's design life. Advantages include more convenient access when an inspection is needed and lower cost by combining construction programmes. Disadvantages include ongoing maintenance or the best locations for measurement may no longer be accessible. Refer to the intervention guides in Table 2-1 to determine the required time to carry out the first condition assessment.

> *For existing systems, if there are access points or fittings already in place, are they still fit for purpose?*

Similar considerations apply when installing a line that may need cathodic protection in the future. Building in the connection points and associated chambers and ensuring that joints are electrically bonded or isolated as appropriate is much more convenient and much cheaper at the time of construction and aids in future inspections. However, if cathodic protection is not implemented until the line has been in service for some time, there is a risk that the fittings will have deteriorated or that the detailed system requirements will have changed.

3.1.4 The degree of inspection

Ideally, pipelines need to be inspected over the whole length but at times inspection will be possible only at selected locations (for example higher-risk areas). There may also be obstructions that hinder assessment or prevent some measurement systems from being used. The degree of inspection could change over the pipeline's lifetime. These factors can influence what kind of access might be needed as well as at what intervals along the pipeline.

For example, equipment such as in pipe inspection tools require launching and retrieval points. Some systems may only require access points about every 2 kilometres, while others may need access points every 100 to 150 metres.

3.1.5 Technique limitations

Some inspection techniques may be sensitive to local interference. For example, acoustic techniques may be limited by background noise from traffic and other nearby utilities. Some techniques are slow or require substantial working space or have demanding health and safety considerations (for example radiography), while others require minimal space, take little time and present very few safety hazards. The presence of laterals and connections may influence some measurement techniques and it may be necessary to isolate these laterals and connections to permit measurement.

Pipeline material and pipe size can influence the ability to conduct assessments and changes in either can influence assessment accuracy. For assessment purposes, it is best to minimise changes in pipe size and material.

Where the planned condition assessment techniques require the line to be temporarily taken out of service, it may be necessary to install storage or a bypass line. The need for additional structures and systems should ideally be considered for the system as they may provide other benefits by improving operational flexibility for repairs and maintenance or by improving overall system resilience (see also Section 0).

3.2 Other condition assessment considerations

The following aspects of condition assessment techniques also need to be considered:

- Does the technique require direct access to the pipeline or to the water column or can information be gathered remotely or by another means? (e.g., leakage that can be viewed directly, determined from flow monitoring or by leak noise correlation).
- Is the technique destructive or non-destructive? Cutting a piece from a pipeline is destructive, while using a magnetic coating thickness gauge or ultrasound measuring probe is non-destructive. In some cases, damage from destructive testing can be fully restored, but minor damage may remain, while some non-destructive techniques require extensive work to gain access to take the measurements.
- How intrusive is the technique? An intrusive method requires access to the inside of the pipeline. This could include placing a free-flowing sensor, in-pipe hydrophone, or CCTV camera into the pipe barrel. In a pressure pipeline, this will usually require a special launching point or fitting, and potable water systems will need consideration of how to disinfect the probe and maintain water quality. Non-intrusive measurements usually require access to the outside of the pipe but don’t need to penetrate the pipe wall, so the water safety implications are avoided.
- How disruptive is the technique? For example, cutting a section of a pipe from a line requires depressurisation and draining of the line, whereas recovering a core sample using a modified under-pressure tapping rig does not. Some acoustic techniques and pressure measurements require a specific maximum or minimum test pressure and may require flow to be temporarily stopped. Works may also be considered disruptive if they require road closures, major excavations, or other major works.

Other supporting information that may be useful to document is listed below:

- Consider what as-built, geotechnical and groundwater information has been or needs to be captured and assigned to the pipe asset at the design stage.
- Information about the surrounding soil properties (for corrosion assessment), any hazards or contaminants risks (e.g., presence of salinity, presence of hydrogen sulphide etc), groundwater and neighbouring utility systems can be helpful for future assessments.
- As-built drawings (including records of access and inspection points), the design capacity when new, wall thickness, joint construction details, transient pressures, break history,

existing pipe testing data (for example from coupon samples or from repair data), groundwater presence and fluctuations.

- Associated equipment that helps enable the inspection (e.g., isolation valves, bypasses, and storage tanks). This can include assets installed specifically to aid condition assessment, as well as assets that have other purposes such as for operational needs or to improve system resilience. Minimising changes in pipeline size or material is also helpful.

3.3 Inspection Techniques

The bibliography (Section 6) includes documents that discuss the pros and cons of the various techniques used internationally and in New Zealand as of 2023. Some examples of testing techniques, with the pros and cons are also shown in Figure 3-1 below. The Wellington Water intervention guides listed in Table 2-1 also provide useful guidance.

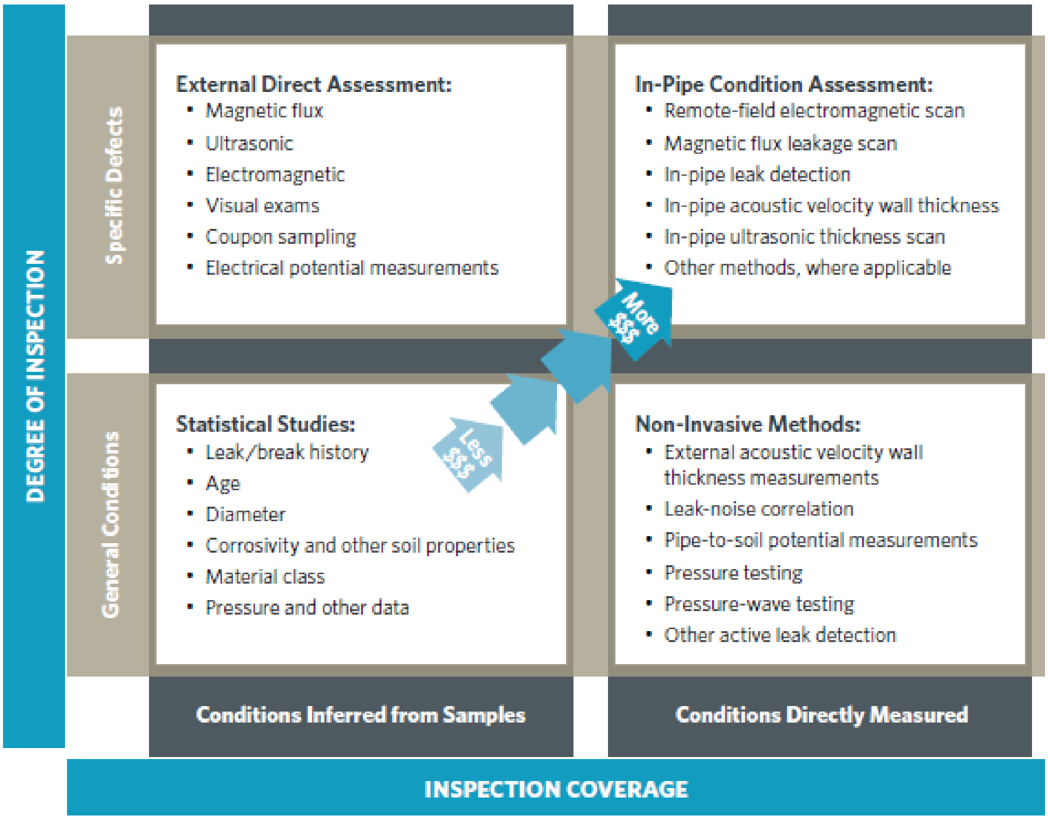


Figure 3-1 Summary of features of different assessment techniques (HDR, 2019)

4 DESIGN PRINCIPLES TO FACILITATE CONDITION ASSESSMENT OF PRESSURE PIPELINES

The following design principles can enable or make it easier to conduct a condition assessment.

4.1 Design Principle One: Provide access in a convenient, easily identified location

4.1.1 Consideration of position

Access points should be in a suitable location for the expected measurement approach. The ideal position for an access point to permit access for current or future condition assessment would minimise problems for safe work and access. For example:

- In a conveniently accessible site that minimises the need for off road driving, and that remains accessible in all weather.
- Provides appropriate working space to permit the use of essential equipment (including tripods, safety barriers etc) without causing needless inconvenience to the community. If entry into the chamber is needed, the chamber should be large enough to enter and work in, along with any required ventilation, power, and lighting also present.
- Where access to the chamber does not require lane closure or speed restrictions.
- Where practical, being sited within the boundaries of Wellington Water sites, but otherwise accessed through agreed easements.
- Where public inconvenience is reduced by locating the site away from major transport routes to minimise traffic management needs and minimising community impact.

4.1.2 Locating access and measurement points

The access points should be sited where they are reasonably accessible as noted above, but they should also be readily located in the field, on plans and drawings and in the GIS and asset management systems. Marker posts can help locate structures that are overgrown or that are otherwise difficult to find. Access points (testing shafts) that allow access to the pipe surface (see Appendix 1) are useful but could be easier to locate if a metallic component could be included to aid location when overgrown.

Each access point should be clearly identified through information on the marker post, but it is also helpful to include asset ID information on or inside the inspection point or chamber as well in case the marker post is damaged or missing.

Consider providing additional information such as key contact details, and permissions required before installing equipment, taking a measurement or operating valves. This information should ideally be accessible without entering the chamber – for example inside a cabinet or safely accessed from the surface if in the chamber itself.

4.1.3 Other Services

For ease of construction, chambers should ideally be located away from trafficked areas where possible and should avoid areas with service clashes.

In addition, sites intended to support specific measurement techniques should be selected to minimise risk of interference with the measurement system or with existing services. As an example, acoustic monitoring systems may be affected by pump operation in a nearby parallel rising main.

4.1.4 Easements

Access points should preferably be in places where Wellington Water has the right to access them. Where the preferred sites for access chambers are located on private land or are accessed through private land, easements should be identified at the design and planning stage and agreed as part of the asset development process.

4.2 Design Principle Two: Provide suitable access to the pipeline

While there are some non-contact methods of condition assessment, condition assessment generally requires access directly to the pipeline itself, or to the water column inside the pipeline, even if only at isolated locations. Any additions that facilitate access should have the same design life as the pipeline they allow access to.

4.2.1 Access to external features

Condition assessment may require access only to the outside of the pipeline, for example, to attach a gauge or meter, to connect a leak detection system or to check thickness or to operate and inspect isolation valves to check operation.

When access is required only to the outside of the pipeline, it may be sufficient to provide an access chamber or a simpler structure such as testing shafts allowing access to the surface of the pipe from ground level (Appendix 1).

In addition to providing physical access to the pipeline, it is also important to consider safe and convenient access, for example by locating access chambers where traffic management requirements are minimised and where safe vehicle parking and safe working is possible (see also Section 4.3).

4.2.2 Access to water column

Some condition assessment techniques require direct access to the water column including pressure logging and transient wave condition assessment techniques. Water sampling would also require direct access to the water column.

Creating access to the water column always requires access to the outside of the pipeline and for potable water systems will require consideration of water safety implications to minimise contamination risk. Because water quality risks need to be managed a larger chamber may be more appropriate than a testing shaft.

4.2.3 Larger pipeline access

For larger pipelines, the general access requirements are likely to be similar, but chambers are more likely to be large and deep. Identifying a suitable location where such a chamber can be located is more challenging, especially in a crowded urban environment with many existing services. To minimise the number of such large chambers, it is good practice to design valve chambers and the like to also allow the opportunity to access the pipeline itself or to attach fittings to allow access to the water column. This could include building in launch and receiving valves to facilitate in-pipe inspection techniques. This may require a larger chamber than would otherwise be expected.

4.3 Design Principle Three: Ensure access points are safe to use and to build

The ideal site for a chamber or inspection port would have all-weather access and no requirement for traffic management, along with sufficient space to allow safe working in or around the chamber. Avoiding the need for working in or near roads and managing the risks of confined spaces and other critical access hazards are key considerations.

For construction, it is also important to consider the working and storage space required to construct the structure. For smaller access structures such as listening posts this will likely be a relatively minor matter but becomes more important for larger structures such as valve chambers.

4.3.1 Traffic Management

Traffic management is expensive and inconvenient, and the location of asset inspection points should, as far as possible, be selected to avoid or minimise the need for traffic management when accessing the site, both during construction and during any future inspections. This should include minimising the need for off road travel.

4.3.2 Safe working

Work at the access point can be made safer by providing all-weather access and sufficient space to work by avoiding trafficked areas where possible, considering safety during construction and use by providing sufficient working space in and above the chamber.

Chambers big enough to enter should be considered as confined spaces. Safe working can be promoted by minimising the need for work inside the confined space (for example, key fixtures are accessible from the surface without entering the chamber). Where entry is unavoidable, design chambers with sufficient space to access the pipeline and operate any equipment. Allowing sufficient working space at the surface to set up a tripod winch and allow essential workers to safely work around the opening is also helpful.

The risk from falls can be minimised using grilles under chamber lids, or by including a smaller port within the lid or in the underlying grille that permits access from the surface without fully opening the chamber lid or grille. Where the chamber cover needs to be fully opened, the provision of stays and permanent anchor points for safety lanyards can be considered.

If regular access to a chamber is needed, consider including permanent ventilation and gas monitoring, alarms and fixed access ways.

4.3.3 Public safety

Works in public areas can create a potential safety risk, including through interruptions to pedestrian and vehicle traffic. Ideally, access points should be in Wellington Water owned and operated sites, well away from the public but this will only rarely be possible. In general, access points should preferably be located away from busy areas, where there is space to work safely without risk to the public. Chambers and inspection points in publicly accessible areas should be locked or otherwise secured from unauthorised access.

4.3.4 Safety documentation

Safe working during and after construction can be improved by avoiding sites near rail and road corridors, power lines, flood, slope, or seismic hazards. Safety in Design processes includes consideration of how to minimise risks during construction and in operation. Safety In Design therefore provides the ideal forum for identifying and discussing future condition assessment access needs.

While it is possible to develop a condition assessment approach and facilities separately, often the access considerations will relate to safe working (for example by locating access points to minimise exposure to traffic hazards, ensuring that there is reasonable space within chambers to permit the planned assessment activities). These aspects can be considered and documented under existing Safety In Design processes.

4.4 Design Principle Four: Consider combined functionality

In some cases, the facilities installed to enable or facilitate condition assessment can be combined with facilities needed for ongoing operational activities and emergency response activities. For example, valve chambers for routine operational access could be modified to work as inspection points for condition assessment. Conversely, if condition assessment facilities are included, they may also provide a convenient location for a valve or other fitting.

Impressed Current Cathodic Protection systems on steel pipelines need periodic testing and maintenance, while operational information such as current drawn can indicate whether or not there is corrosion along the protected section and approximately how much of the pipeline surface is exposed. In addition, the fittings and configuration required for cathodic protection also permit the use of electrically based systems (such as DCVG or ACVG[2]) for detecting defects in the coating whether the cathodic protection system is operational or not.

After a seismic event or other emergency then access points for condition assessment can provide a convenient opportunity to check for leakage, pressure, water quality etc. Any additional storage and bypass facilities installed with a view to aiding condition assessment are likely to also be useful when dealing with emergency events or damage. In addition, condition assessments can be used to help with post-event inspections – for example after seismic or storm events, the condition assessment points may assist in checking system condition, integrity, leakage etc, and may provide useful indications of displacements or other damage (since they are already documented from condition assessments).

If a critical pipeline is designed to be taken out of service to permit condition assessment, any storage and bypass lines can also increase resilience against emergency events, and assist with operational activities, such as cleaning, repair maintenance and inspection whether associated with condition assessment or not.

Access points can sometimes be combined with other required structures. For example, a valve chamber that was required for operational reasons could also be used to permit access to the pipe for assessments, or an access chamber intended for condition assessment could also be convenient for taking flow monitoring or pressure monitoring. For example, fire hydrants or air pressure release valves at regular intervals facilitate acoustic leak detection. However, bear in mind that, while multi-purpose access chambers are potentially useful, they are not always a good option.

---

[2] *Direct Current Voltage Gradient or Alternating Current Voltage Gradient can be used to locate breaks in the protective coating, with reasonable accuracy where ground conditions and surface access are suitable.*

4.5 Design Principle Five: Record key information

While not conventionally a design principle, this is included because dedicated sampling sites are such an important aid to condition assessment. As-built data and other design and construction data (pipe class, construction details etc) that are captured and stored securely can be used in the future for condition assessment. However, where facilities have been specifically designed and constructed to enable to facilitate future condition assessment these should be recorded as special features on as-built drawings and GIS records and within asset management systems. This may, however, require additional asset classes to be created for chambers and other access features that are intended specifically to assist condition assessments.

Examples could include:

- Recording the access points associated with the assets they allow access to.
- Noting which condition assessment techniques, the access points are intended to be used for.
- Recording sections of pipeline that can or can't be inspected.
- Documenting any special preparations or precautions needed to facilitate inspection, including changes of pipeline material or size.
- Noting any joint functionality (where a chamber, for example, provides valve access, and inspection access).
- Showing safe access routes, design working space and easements.

Existing safety in design practices provides an additional opportunity to record safety-related information in design drawings and as-built drawings.

GIS and asset management system records can be complemented by supporting information inside the chamber or on the asset itself – for example confirming the asset ID and noting requirements that will permit or facilitate condition assessment along with key contact numbers.

5 OPPORTUNITIES FOR IMPROVEMENT

Additional observations that were outside the main scope of the document have been noted below for reference:

- Consider developing an overarching design approach that collates current design guidance and that shows how each standard links with each other, e.g., Asset criticality documentation, pipe intervention guidelines, Wellington Water Regional Standard and Specification and this current document. This could be conveyed in a decision matrix/criterion for new pressure pipelines.
- Build up a collection of reference drawings to aid in assessment. Initially, this would mainly refer to standard drawings that could be adapted, but as and when specialized drawings are developed these should be recorded for reference.
- Include essential assessment features e.g., testing shaft and chambers as nodal points in asset registers. This may need new asset types to be created.
- Consider creating a condition assessment-related layer that documents planned inspection methods, physical facilities and prior assessment reports and scheduled works. This should also include records of inspection that did not succeed so that lessons can be learned.

6 BIBLIOGRAPHY

Note that references to specific techniques or systems are for information purposes only and are not an endorsement of that technique or system.

6.1 Other Wellington Water documents

Newton, C. (2022). Wellington Water – Very Highly Critical Asset- Pipe Health Assessment – e Pulse Testing of Potable Water Pipes. Wellington Water.

6.2 Inspection techniques references

These web links contain a selection of useful information on some of various technologies currently available and they include photographs, videos and diagrams of the application of these technologies. This information may serve as a good prompt when undertaking the design scoping exercise. No comment is made as to the appropriateness or not of this these technologies. Refer to the Condition Assessment Techniques for Pipes document (shown in Table 2-1) for further inspection technique examples.

No comment is made as to the appropriateness or not of this these technologies. Mention of suppliers or products does not signify endorsement.

Condition Assessment and Rehabilitation Guide HDR

HDR. (2019). *Condition Assessment and Rehabilitation Guide*. HDR. https://www.hdrinc.com/insights/condition-assessment-and-rehabilitation-guide

Inspection Techniques for Pressure Pipes in New Zealand

Prince, A. (2022). Pressure Pipe Condition – Right Pipe, Right Test (Technical paper of acoustic testing). https://www.waternz.org.nz/Attachment?Action=Download&Attachment_id=5309

Leak Detection

Office of Federal Energy Management. (2023). Water-Efficient Technology Opportunity: Distribution System Leak Detection, https://www.energy.gov/eere/femp/water-efficient-technology-opportunity-distribution-system-leak-detection.

Acoustic/Transient Pipe Monitoring Links

Kim, Y. (2017). P-CAT – Pipeline Condition Assessment Technique for Water and Sewer Mains. https://www.waternz.org.nz/Attachment?Action=Download&Attachment_id=2816

Remote Sensing Technology - Remote Sensing for Leaks via Satellite

Gagliardo, P. (2018). Assessing The Effectiveness Of Leak-Seeking Satellites. https://www.wateronline.com/doc/assessing-the-effectiveness-of-leak-seeking-satellites-0001

Rezatec. (2023). Geospatial AI for Water Leaders. https://www.rezatec.com/solutions/water-utilities/

Sixense. (2021). Satellite monitoring (Atlas InSAR). https://www.sixense-group.com/en/offer/monitoring/satellite-monitoring-atlas-insar

Free Flowing Sensor Links

These web links have information free flowing sensors from SmartBall® and Nautilus©.

Pure Americas Inc. (2011). SmartBall® Inspection Report of North Beach Force Main. https://your.kingcounty.gov/dnrp/library/wastewater/wtd/construction/NorthBeachFM/1108_NorthBeachForceMainInspectionReport.pdf

Pure Americas Inc. (2022). SmartBall® Brochure. https://www.xylem.com/en-us/brands/pure-technologies/technologies/smartball-inline-free-swimming-inspection-platform/

Detection Services. (2023). Nautilus©: Leak Detection Large Diameter Pipes. https://www.detectionservices.co.nz/technologies/nautilus/

WRC. (2023). SmartBall® Pipeline Inspection Technology. SmartBall ® Pipeline Inspection Technology | WRc (wrcgroup.com)

6.3 Failure mode references

These references provide information on pipeline failure modes that can be used to help select condition assessment approaches.

Ellison, D. (2019). "Condition assessment of water mains (AWWA Manual M77)". *Manual of Water Supply Practices,* M77.

NZWWA. (2008). Visual assessment of utility assets. NZWWA, Wellington. https://www.waternz.org.nz/Folder?Action=View%20File&Folder_id=101&File=081216_visual_assessment_manual_final.pdf

OPUS. *Technical note 09 - Photobook of Damaged underground Utilities. OPUS.* https://www.waternz.org.nz/Resources/Attachment?Action=Download&Attachment_id=2043

Project Max. (2022). *Very High Critical Pipeline Assets – Updated Interim Health Assessment.* Project Max. (Woogle linked here)

Panchoy, P, et al. (2020). *Review of Condition Assessment Techniques for Pressure Pipes for Water*. Building Innovation Partnership. https://bipnz.org.nz/wp-content/uploads/2022/05/Pressurepipe_co_Ass_Techs_Rep_final_2020_05_11-6-1.pdf

The Water Research Foundation. (2017). *Visual Guidance for Common Pipe Failures.* The Water Research Foundation. https://www.waterrf.org/research/projects/visual-guidance-common-pipe-failures

Water Services Association of Australia. (2013). *Common Failure Modes In Pressurised Pipeline Systems.* Water Services Association of Australia. https://sswm.info/sites/default/files/reference_attachments/WSAA%202003%20Common%20Failure%20Modes%20in%20Pressurised%20Pipeline%20Systems.pdf

APPENDIX 1 EXAMPLE OF A TESTING SHAFT

Note: This is an example of a testing shaft and is not a recommended design detail.

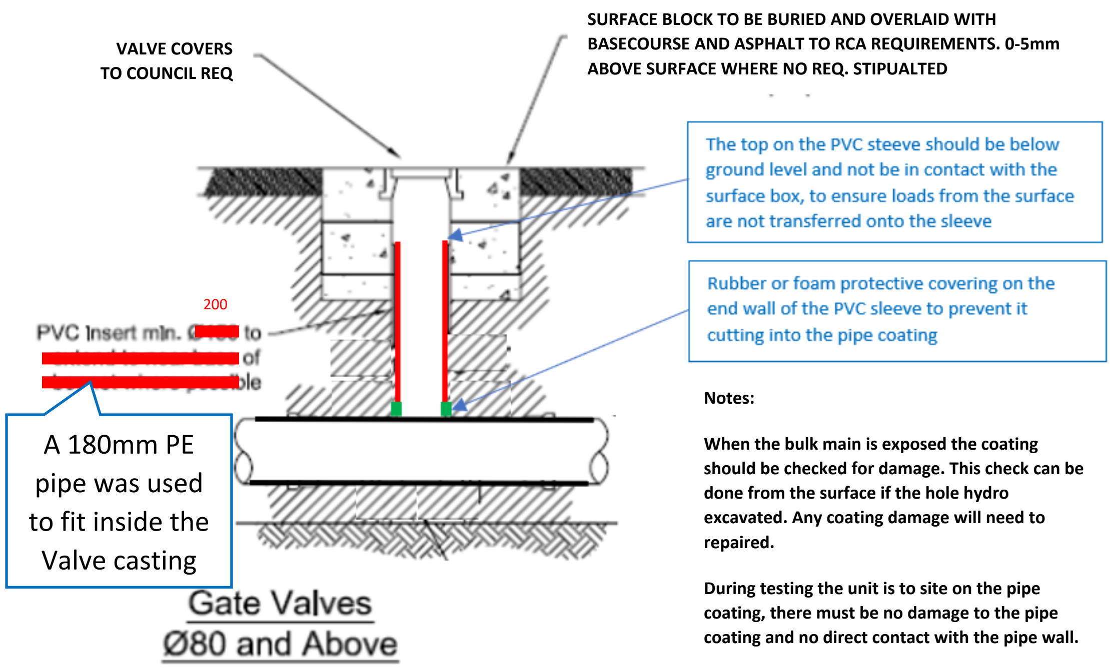


Figure 0-1. Testing Shaft Example – based on a valve box (Newton, 2022).

APPENDIX 2 INSTALLATION AND USE OF TESTING SHAFTS FOR ACOUSTIC TESTING OF PRESSURE PIPELINES

Photos were collected from the Very Highly Critical Asset – Pipe Health Assessment acoustic testing of potable Water Pipes document (Newton, 2022).

Note: This is an example of a testing shaft and is not a recommended design detail.

Testing Shaft Installation

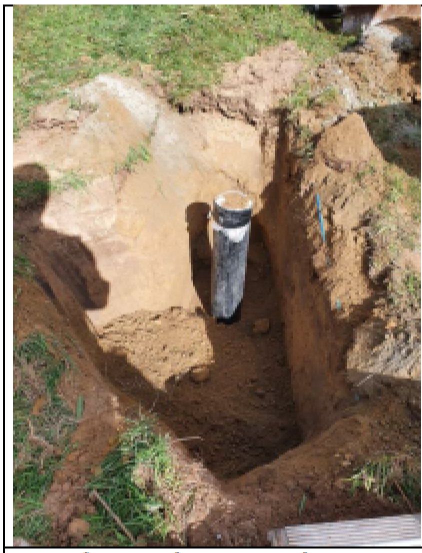
	
PE testing shaft installed vertically on top of the pipe	*Cast concrete collar and Valve cover being installed flush with the surrounding surface*
	
Cast concrete collar and valve cover being installed flush with the surrounding surface	*Asphalt reinstatement to match surrounding surface*

Figure 0-2 Testing Shaft Example

Testing

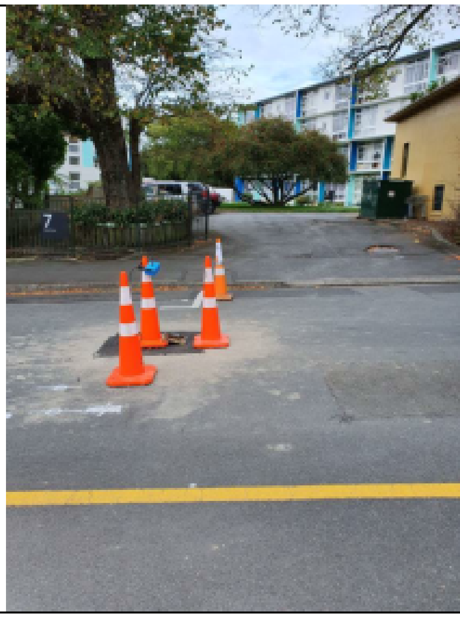
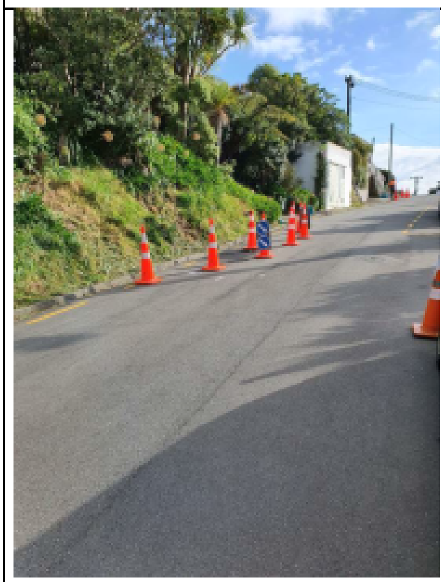
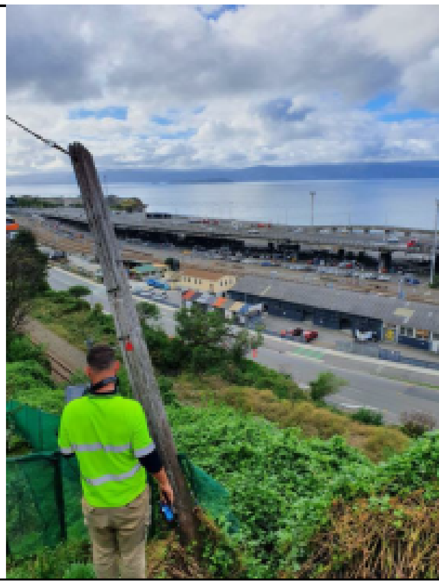
	
Delivering the acoustic sound to the pipe through the valve handle	***Sensor 1 in place down the newly installed Testing Shaft on top of the pipe***
	
Sensor 1 in place down the newly installed Testing Shaft on top of the pipe	***Monitoring the sound travelling through the pipe between the two sensors to ensure quality of data being collected***

Figure 0-2.1. Testing Shaft Example