CONFRONTING THE TSUNAMI – A NEW APPROACH TO RENEWAL PLANNING

Eric Skowron (ProjectMax Limited)

ABSTRACT (500 WORDS MAXIMUM)

If your renewal plan shows a backlog of $30M and $150M of renewals over the next three years, will you be spending $180M over that time? Certainly! We have a graph and some numbers to prove it! In reality, perhaps yes, but quite likely, probably not.

If we knew the condition and thus remaining life of all of our underground assets, renewal planning would be easy. The next best thing is to predict a likely condition of those assets so we can prioritise those to inspect and those most likely to fail.

'Install date' coupled with a formula for 'Expected life' based on material is typically used to establish a 'Renewal Date'. This approach can provide some useful insights, but unless backed with relevant fault records, observed condition evaluation and testing and/or other reality-based information, it may be best to leave the diggers in the yard for now and be bit more strategic with renewal planning first.

Every renewal decision must have a clear justification, which shouldn't be 'the pipe has reached the end of its predicted life'. For example, the average life expectancy for a male in New Zealand is approximately 80 years, (similar to that of AC pipe). Does that mean every male born in 1943 will die this year? Certainly not, and pipes are no different.

While renewal planning based on material and installation date can provide a good estimate of potential longevity, it can also be misleading as pipes can perform differently in different environments and under different operating conditions. Short-term and long-term renewal plans generated from these inputs are often not representative of the condition of pipe assets or the likely timing of renewal.

An improved approach integrates asset data with data confidence assessment and asset condition assessment to better understand what is known, what is not, why and how it impacts short-term and long-term planning outcomes.

By approaching renewal planning in this way, we can make better and more effective decisions on how our communities' infrastructure is managed and how financial resources are used.

This paper will describe how implementation of renewal strategies create better and more financially sustainable short-term and long-term asset renewal programs. It will highlight how integrating these approaches can yield improved results with more confidence and a greater understanding of risk. It will

summarise how limited budgets can therefore be more effectively used to address critical vulnerabilities while reducing the likelihood of replacing assets that aren't quite ready for the bone yard yet.

A case study will highlight a renewal planning strategy developed and applied, methodology adopted, time taken to produce renewal predictions (weeks rather than years) across 7,500km of network assets. Both short-term and long-term results will be summarised with discussion of how they are being applied.

The paper will conclude with discussion of how this approach could be applied to the proposed water service entities and benefits that could be expected.

KEYWORDS

Asset Condition, Renewal Planning, Criticality, Prediction, Optimisation, Pipeline Renewal Planning, Wastewater, Water, Stormwater

PRESENTER PROFILE

Eric is a Three Waters Network Strategy Executive for ProjectMax, a New Zealand based strategic consulting firm specialising in helping clients create strategies to maintain their communities' potable water, wastewater and storm water infrastructure. Based in Wellington, he has 23 years of engineering experience in New Zealand, Australia and the United States for both government and consulting entities.

He helps water utilities make better informed infrastructure investment decisions through development of strategic monitoring and renewal programs, network planning, criticality assessments and implementation of innovative solutions. Eric supports innovation initiatives in the water sector in the Asia-Pacific Region, participates in the WaterNZ SWIG and is co-chair of the SWAN APAC Alliance Partnerships Committee.

1. INTRODUCTION

The world is well within the Information Age, where data driven decision making is commonplace. These decisions include how we best invest in the renewal or replacement of our aging water, stormwater and wastewater pipes.

Most organisations collect large amounts of data on their operation, assets, outcomes, financial performance, maintenance, customer satisfaction and other measures. Water utilities use data to support a number of functions within the water utility including renewal planning of water, wastewater and stormwater infrastructure. There are a number of tools and solutions to assess inputs, automate processes, identify actionable insights and present outcomes. Collecting, storing and maintaining data is easier and more cost effective as technology continues to evolve.

Traditionally, renewal plans are based on applying estimates of expected useful life to material type and age data. Any errors, assumptions or omissions contained within that data are often carried through into the renewal plans.

In addition to questions of data completeness, accuracy and reliability, as three-waters networks age, further uncertainty is introduced into renewal programs if little is known about asset condition.

This can result in renewal plans that are not representative of actual network condition, with short-term renewal 'bow waves' containing tens of millions in projected short-term renewal costs, with often many millions more in backlog. Many assets prioritised for renewal planning using this approach may not yet be in need of replacement or renewal. This is because renewal plans are often not based on a clear understanding of asset condition.

Without an understanding of asset condition, a water utility runs the risk of replacing pipes that do not yet need to be replaced, not replacing pipes that need to be replaced and as a result placing increasing pressure on council budgets and rate payers.

Renewing assets earlier than required results in opportunity cost as funds could have been used on more urgent works for assets in urgent need of renewal or replacement because they are failing (or already have failed). This can result in significant risk to council and disruption to customers and community as a result of the consequence of failure and cost of emergency repair.

Asset failure can result in significant risks to the Council and community including health and safety, financial, reputational, environmental, loss of service, disruption and other consequences. Renewal strategies aim to reduce the likelihood of avoidable failures by informing renewal programs with better understood asset condition by applying confidence grading to prioritise renewal of assets that are most likely in need of renewal, leaving in service those that are less likely to result in a failure of greater consequence.

A renewal program developed using estimated useful life tables by pipe material often results in a backlog and bow wave within the short-term renewal window (within 3 years) that is many times greater than the budgets (and the resources) available to deliver asset renewal consistent with these plans.

Is it possible that the backlog and bow wave of renewals identified using this approach will be realised? Perhaps but more than likely not.

Consider planning for medical intervention or scheduling a funeral for somebody because they have just celebrated a birthday which puts their age above that stated in current actuarial tables. While it may sound preposterous, the analogy has direct parallels to an asset renewal approach that is based solely on material type, age and an estimate of useful life.

How can the reliability and accuracy of renewal planning be improved for making better asset renewal investment decisions? This paper outlines the benefits of a renewal planning strategy that integrates both components to the risk equation: asset criticality (consequence) and improved understanding of asset condition (likelihood).

2. BACKGROUND TO RENEWAL PLANNING

Renewal plans should be based on many sources of input information, which are assessed to determine and rank the understood condition of network assets.

2.1 GUIDELINES AND STANDARDS

Determining the condition of an asset is informed by many inputs, some of which often have varied accuracy and reliability.

Input data are ideally referenced from systems that are based on industry standards and guidelines for effective management of three-waters infrastructure. These can include (but are not limited to):

- GIS and meta data standards for capturing inventory of network assets and relevant attribute information
- Criticality frameworks for understanding criticality of network assets based on the consequence component of risk
- Asset management standards and guidelines
- Intervention guidelines

Renewal planning is based on current industry standards and guidelines for management and renewal planning of water infrastructure.

High level guidance standards such as the International Asset Management standard ISO55000:2014 provides general guidance on management of all types of assets and focuses on asset management principles, nomenclature and general guidance.

The International Infrastructure Management Manual (IIMM, which is largely based on ISO55000) provides guidelines for asset management more specific to infrastructure assets.

These standards have provided context for development of the New Zealand Gravity Pipe Inspection Manual (4th Edition released in 2019), which applies asset management concepts and 'evidence based' decision making principles for management planning of gravity pipe infrastructure in the New Zealand water services industry.

Guidelines for pressure pipe condition assessment are nearing early stages of development as technologies for condition assessment of pressure pipes continue to evolve and become available in New Zealand (including e-pulse, p-CAT, SmartCAT, and others, coupled with other sources of information including transient pressure monitoring and water quality testing).

2.2 GENERAL APPROACH FOR RENEWAL PLANNING

The timing and type of an asset renewal is dependent upon the individual asset and its characteristics, including material, operating environment, age, lifecycle stage, likelihood of failure, known (or unknown) condition and criticality.

Traditional renewal planning generally applies assumptions of useful asset life by age and material type to asset registers to generate a 'renewal date' for each asset. While this approach will generate an list of renewal dates across an asset register, it often results in a large 'bow wave' of renewal backlog and short-term renewals that is disproportionate of failing assets and available renewal budgets.

In addition to application of the guidelines and standards outlined in Section 2.1, this report emphasizes the importance of data confidence and enhanced condition knowledge for optimizing renewal planning outcomes.

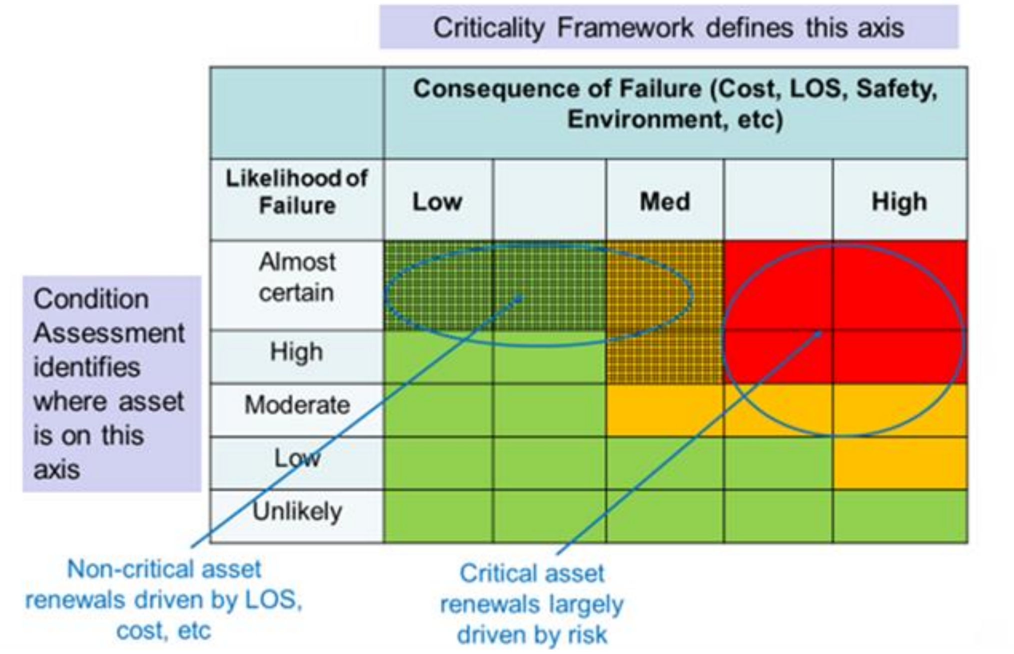
Asset criticality and condition are the two most consequential variables for optimizing asset renewal planning. Each is described in greater detail in the following sections.

2.3 CRITICALITY

Asset criticality is a measure of the consequence of failure if an asset is no longer able to function in accordance with defined performance metrics (or service goals).

Renewal planning is largely driven by mitigating exposure to risk by identifying assets for renewal based with high criticality, level or service, cost and other objectives as illustrated in Figure 1.

Figure 1: Criticality drivers for asset renewal



Criticality is used to determine the type and frequency of maintenance, condition assessment and renewal activities. It also is used to define which assets are to be included in an intervention program (including renewal planning) and which assets are intended to function without intervention until failure (service failure or structural failure) occurs.

Typically, criticality scores are applied across all water, stormwater and wastewater assets based on an adopted criticality framework.

Asset criticality frameworks are typically adopted to define factors, weighting and procedure for determining criticality. By applying a criticality framework, network assets are assigned criticality scores based on an assessment of factors that contribute to the consequence of failure including (but not limited to): impact to community, environment, delivery of defined levels of service, access, cost, duration for restoration of service and redundancy or contingency.

Criticality scores are defined by the severity of consequence and typically include the following criticality bands: very high criticality, high criticality, medium criticality, low criticality and very low (or no) criticality. Criticality scores typically range between 1 (very low criticality) and 5 (very high criticality).

Criticality should be assessed and recorded for all assets and should be updated in asset records whenever there is a significant intervention or change in operating conditions.

Figure 2 illustrates how criticality influences short-term renewal planning and long-term renewal planning.

Figure 2: Criticality and Renewal Planning

	Non-Critical Pipes	Critical Pipes
Short Term Planning (LTP)	Routine renewal of customer service pipes and collection systems	'Just in time' renewal of critical pipes
Long Term Planning (Infrastructure Strategy)	Predicting future renewals of collection systems	Predicting future renewal of critical pipes

Figure 2, also referred to as the '4 quadrant' approach illustrates assert renewal actions for short-term and long-term planning horizons based on criticality. These intermediate portions (orange lines) are a blend of the main drivers from each of the 4 main quadrants.

Short-term planning is where the renewals backlog and 'bow wave' are most pronounced and can best benefit from a strategy to increase data confidence and knowledge of asset condition. Long-term planning utilizes many of the same data sources and will also benefit from improved data confidence and asset condition understanding.

2.3 CONDITION GRADES

A condition grading consistent with the International Infrastructure Management Manual (IIMM) and the New Zealand Gravity Pipe Inspection Manual 4th Edition has been applied in this assessment. The condition grades are summarized in Table 1.

Table 1: Condition Grades

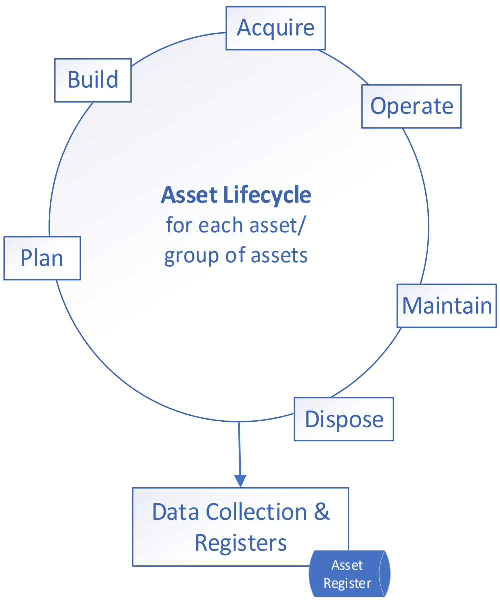
Condition Grade	Description	Definition	Remaining Useful Asset Life	Planning Cycle
1	Very Good	As new condition. No or insignificant loss of hydraulic performance has occurred and there is little likelihood of surcharge or overflow	>50 years	Outside 30-yr planning cycle
2	Good	Some defects present causing minor loss of hydraulic performance and there is only a minor likelihood of surcharge or overflow	30-50 years	Outside 30-yr planning cycle
3	Moderate	Defects present causing moderate loss of hydraulic performance and there is moderate likelihood of surcharge and possible overflow	10-30 years	Inside 30-yr planning cycle but outside Long-Term Plan (LTP) 3-year planning cycle

Condition Grade	Description	Definition	Remaining Useful Asset Life	Planning Cycle
4	Poor	Significant defects are present causing serious loss of hydraulic performance and there is a significant likelihood of surcharge and overflow.	3-10 years	Inside 10-yr planning cycle but outside Long-Term Plan (LTP) 3-year planning cycle
5	Very Poor	Defects are such that service failure has occurred and the pipe is blocked/surcharging and/or overflow is imminent or has occurred	<3 years	Inside 10-yr planning cycle but outside Long-Term Plan (LTP) 3-year planning cycle

2.3 ASSET LIFECYCLE

The timing for asset condition assessment to best understand asset condition and when asset renewal (or other interventions) are required will vary depending on the age of an asset and where the asset is located within the asset lifecycle (as presented in Figure 3). Generally, an asset that is in the early stages of its life cycle will need fewer interventions than an aged asset. As it moves closer to the expected lifespan for the asset type, both the number and frequency of interventions will increase. This is particularly the case for critical assets where it is important to regularly undertake maintenance and monitor condition and likelihood of failure.

Figure 2: Asset lifecycle



2.4 CONFIDENCE

Data confidence is a measure of the accuracy and reliability of the data used in renewal planning. This includes data accuracy, completeness, whether it is populated with assumptions or populated at all. For example, when asset information was initially captured in digital systems, important asset attributes are often populated with assumptions. For example, if the installation year for a large number of assets or in a large area are populated with identical values (ie: all water mains on west side of Main Street were installed in 1950), it is likely that many if not all of these fields were populated on an assumed value.

As databases become more frequently used with complex data assessments, algorithms or artificial intelligence (AI) solutions, it is important to have complete, reliable and accurate data to inform these processes.

2.4.1 DATA ERRORS

While all databases will inheritably contain data errors, omissions or assumptions of some measure, the degree of these inaccuracies is rarely quantified and often is not well understood.

Data accuracy, completeness and reliability tends to be lower for older assets where original sources of information were limited in detail, no longer retained in council files or archives or were not recorded at the time of installation. For more recently renewed or replaced water, wastewater or stormwater assets added to the network, many councils now have data standards in place for capturing asset spatial and attribute data within specified accuracy parameters. Councils that do not have asset data standards in place for new, renewed or replaced assets should consider implementing one so that information captured on these assets meets accuracy and reliability standards for use in council assessments including renewal planning. Such standards should apply to any replaced or renewed network asset, whether completed by the council or other third parties (for example new developments).

Solutions such as data wrangling have been developed to sift through databases and find high quality and extract information considered to be of high accuracy based on a set of pre-defined parameters. These solutions are not often applied to council asset databases and may not be practical as all assets need to be considered in renewal planning regardless of the accuracy and reliability of populated data of each asset.

Data errors, omissions and other issues are often picked up during technical reviews or manual checks of asset data when reviewing asset identified in renewal or maintenance programs. Some queries and other data tools can also be applied to asset databases to identify data errors. As resolution of identified data errors is often lengthy process requiring adherence to Council data standards and processes, it is important to document when asset data errors are identified so this can be known during renewal planning and assessment.

2.4.1 ASSET CONDITION KNOWLEDGE

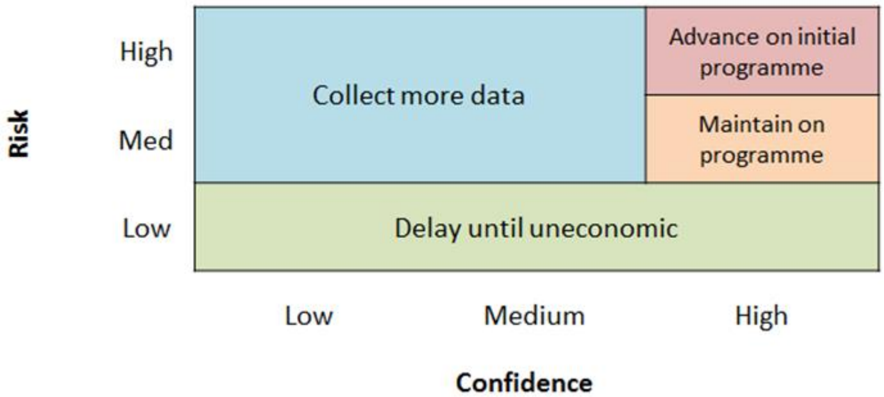
In addition to documenting where data errors, omissions or other issues are identified in asset data, it is important to quantify the confidence in what is known about the condition of an asset. For renewal planning, this is what the term data confidence is typically in reference to.

Asset knowledge confidence refers to the type and quality of information known that is used to inform the assessed condition of an asset. This is a key component of an asset renewal strategy and is the primary focus of this paper. For example, if pipe material, age and size are known for an asset (and are used to inform a 'desktop' assessment of remaining useful life based on these parameters) but there have been no physical inspections to confirm the condition of the pipe, there is low confidence in the knowledge of the pipe actual physical condition.

The confidence of asset knowledge refers to measure of understanding of the asset and its condition. For example, is only the age, material type and diameter known and used for a 'desktop' assessment to estimate likely remaining life of the asset (low confidence)? Or is information from condition assessment and/or physical testing of the pipe used to inform condition grade and remaining useful life (high confidence)? In some cases, inspection and physical condition data is extrapolated from inspected pipes to other pipes of same material, age or similar operating environment to better inform outcomes from a 'desktop' assessment (medium confidence).

Asset renewal is driven by the risk of failure which is defined by consequence (criticality) and likelihood (asset condition). As criticality is typically a static measure, the primary variable to risk is asset condition. To increase the confidence in the decision when to renew an asset thereby requires an increase in the confidence of understanding of an assets actual condition (both structural and service). Prior to advancing renewal, an optimized renewal program will require a high degree of confidence for high-risk assets as is illustrated in Figure 3.

Figure 3: Confidence and Risk



Data confidence grading is referenced in New Zealand water industry standards including the NZWWA Infrastructure Asset Grading Guidelines in 1999. These data confidence grading standards apply alphabet letter codes A, B, C and D for highly reliable, reliable, uncertain and very uncertain data, respectively and remain widely used today.

Table 2 has been modified from the NZWWA guidelines to add Confidence Grade E. Confidence Grade E has been added to enable tracking of reduced confidence as a result of known data errors.

Table 2: Confidence Grades

Confidence Grade	Description	Examples of asset condition information for asset planning
A	Highly Reliable Data based on sound records, procedures, investigations and analysis which is properly documented and quality assured. Recognised as the best method of assessment including verification on site.	**Gravity:** comprehensive inspections including full medium to high resolution CCTV, laser profiling and NDT/DT[2] (ie: coupon sampling) to confirm pipe wall thickness **Pressure:** P-CAT or SmartCAT inspection for confirmation of pipe wall thickness and Transient Pressure Monitoring (TPM) **Data:** known pipe attributes including duty range, pipe class and wall thickness.
B	Reliable Data based on sound records, procedures, investigations and analysis which is properly documented and quality assured. Has minor shortcomings; for example, the data is old, some documentation is missing, and reliance is placed on unconfirmed reports or some extrapolation.	**Gravity:** medium to high resolution CCTV, no laser profiling or NDT/DT[2] (ie: coupon sampling) to confirm pipe wall thickness; may contain previous inspections that are not considered 'current' **Pressure:** e-Pulse inspection assessment of pipe wall thickness and Transient Pressure Monitoring (TPM) **Data:** known pipe attributes including duty range, pipe class and wall thickness.
C	Uncertain Data based on sound records, procedures, investigations and analysis which is incomplete or unsupported, or extrapolation from a limited sample for which grade A or B data is available.	**Gravity:** NDT/DT[2] or low resolution, incomplete or otherwise uncertain CCTV inspection; may contain previous inspections that are not considered 'current' or condition extrapolated from inspections of other 'similar' assets **Pressure:** extrapolated e-Pulse, p-CAT or SmartCAT data from inspections of 'similar' assets; or e-Pulse, p-CAT or SmartCAT inspections performed but TPM assessment missing or not complete **Data:** some unknown pipe attributes including duty range, pipe class and wall thickness.
D	Very Uncertain Data based on incomplete information or of uncertain quality. May include unconfirmed verbal reports and/or cursory inspection and analysis and not verified by site checks.	**Gravity:** No NDT/DT[2] or CCTV inspection, condition grade based on visual or 'desktop' assessment of interim condition grade; historical test results but confidence not known; low resolution inspections or probability of failure assessments. **Pressure:** no inspection or inconclusive results from e-Pulse, p-CAT or SmartCAT assessment, condition grade based on visual or 'desktop' assessment of interim condition grade **Data:** key pipe attributes such as installation date, pipe material or size unknown

Confidence Grade	Description	Examples of asset condition information for asset planning
E[1]	Errors identified	**Gravity and Pressure asset data:** incorrect assumptions or errors identified including incorrect installation date, material, size, length, missing or duplicate asset ID, incorrect spatial orientation, connectivity or water type; if data used, would result in erroneous outcome in renewal plan

[1]Additional condition grade added that is not included in NZWWA Infrastructure Asset Grading Guidelines 1999

[2]NDT (non-destructive testing), DT (destructive testing)

3 RECOMMENDED STRATEGY

Development of both short-term and long-term renewal plans is a complex process. Optimising outcomes of renewal planning require high confidence in input data and knowledge of asset condition.

The renewal strategy should include integration of asset data capturing inventory of network assets and relevant attribute information, criticality frameworks (for understanding criticality of network assets based on the consequence component of risk), network operational data, asset condition assessment data and adopted guidelines and standards for intervention and renewal.

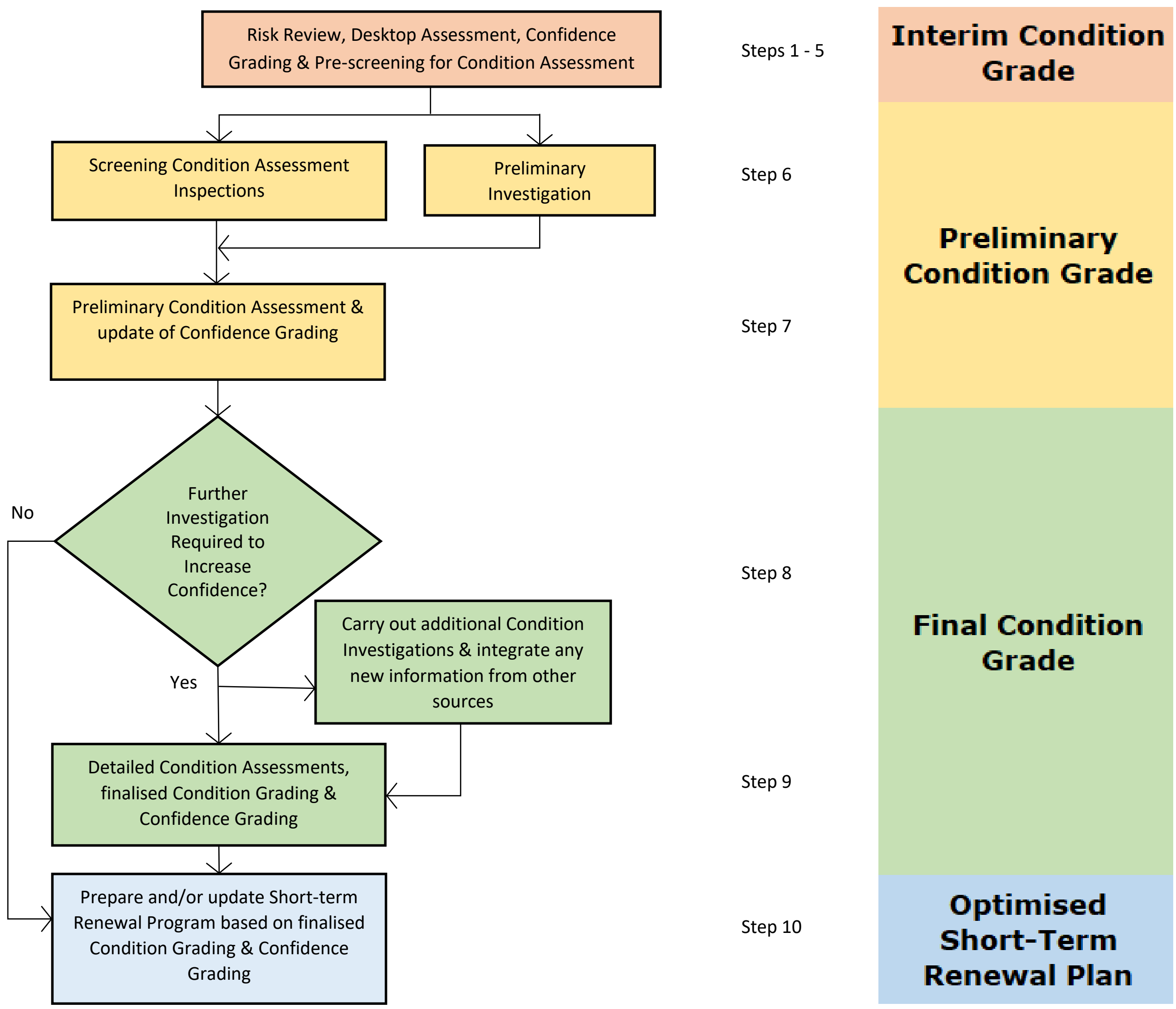
The recommended strategy for short-term renewal planning for all asset classes is presented below:

- Step 1: Define and confirm renewal strategy and approach
- Step 2: Identify and collect available data including asset data (capturing inventory of network assets and relevant attribute information), criticality frameworks (for understanding criticality of network assets based on the consequence component of risk), network operational data, asset condition assessment data and adopted guidelines and standards for intervention and renewal
- Step 3: Perform gap and data confidence analysis
- Step 4: Apply criticality framework across all assets
- Step 5: Perform initial ‘desktop’ review to calculate ‘Predicted Interim Condition Grade’ and confidence score
- Step 6: Review high criticality assets with poor condition grade (condition grade 5) and low confidence score (confidence score D) and other to prioritise assets for preliminary condition inspection
- Step 7: Apply condition inspection data to calculate ‘Preliminary Condition Grade’ and confidence scoring for prioritized assets for short-term renewal (condition grade 5), determine if additional inspection or remedial intervention required
- Step 8: Apply secondary investigation techniques to gain more data or confidence where required to increase confidence grade of prioritized assets to level required for renewal
- Step 9: Calculate ‘Final Condition Grade’ and prepare information for renewal team

- Step 10: Prepare optimized short-term renewal plan based on optimized understanding of asset condition grade

Figure 3 illustrates the recommended strategy steps, key actions and resulting condition grade.

Figure 3: Condition Grade Flowchart



The pathway illustrated in Figure 3 represents an idealised outcome where an optimised renewal program is achieved through desktop assessment, condition inspection and final assessment to generate grades for informing an updated renewal program. It is impractical to apply the full extent of Figure 3 across all assets due to the extent of water, wastewater and stormwater networks, limited condition assessment budgets and other constraints. This emphasises the importance of integrating a criticality framework across all assets to prioritise asset condition assessment and collection of other information to increase confidence for assets where failure is of greatest consequence and greatest likelihood based on the interim condition grade.

This approach is intended to inform a continuous program of condition assessment and renewals works, which aligns prioritised inspections and renewals with available budgets, with outcomes used to inform future year budgets for both assessment and renewal. It can also be used to maintain an up to date prioritised list for condition assessment and renewals so that alternative inspections or renewals can easily be selected from the prioritised lists should an identified inspection or renewal need to be delayed or postponed for any reason.

4. CASE STUDY

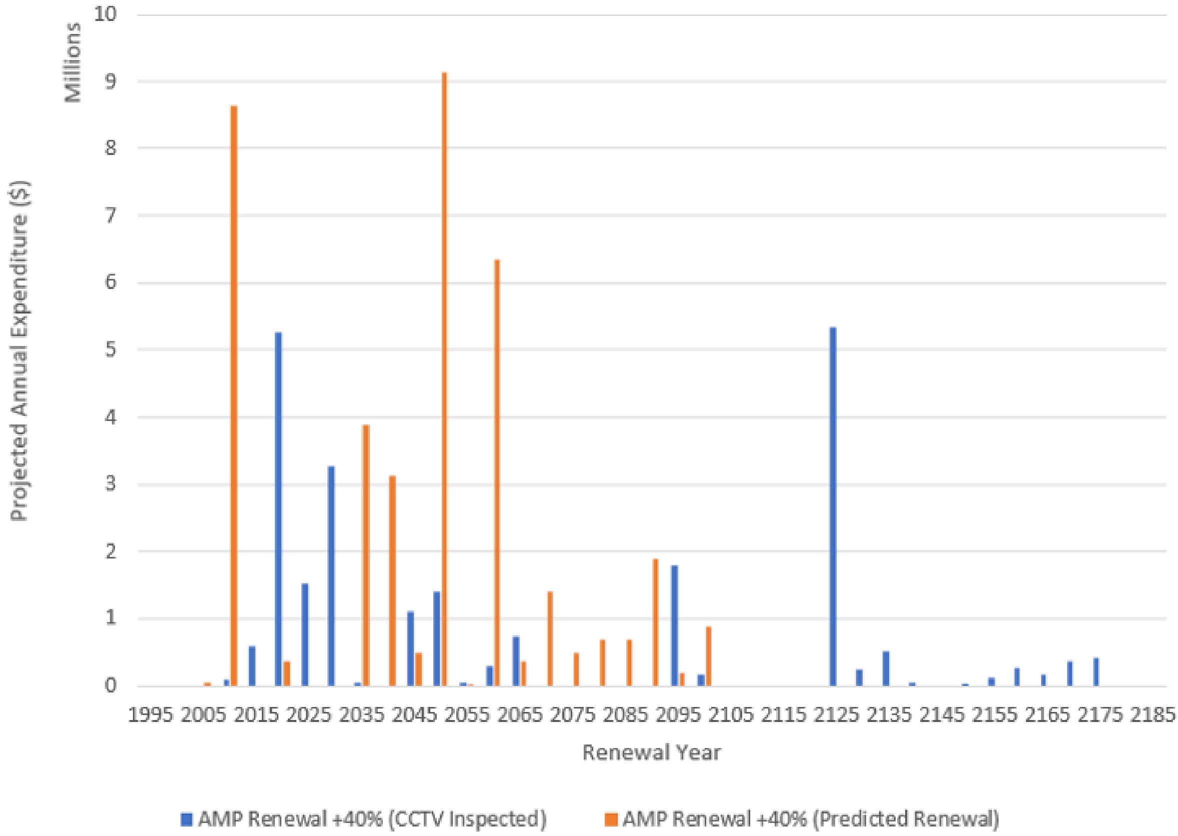
One New Zealand utility has implemented a renewal strategy focused on data confidence coupled with intervention strategies, a criticality framework and their level of service goals to generate an interim predicted score across all water, wastewater and stormwater assets of all criticality levels.

For many of their assets, there were historical inspections that had previously been conducted. Data from these inspections was also assessed in the predicted condition grade. Critical assets with poor interim (and predicted condition grades) were reviewed and a prioritized list was developed for condition inspection across water, wastewater and stormwater assets. This currently being incorporated into a 'rolling' asset inspection program and is intended to be used to inform the short-term renewal program. In addition, outcomes from the condition assessment program are intended to inform an updated maintenance program, asset risk analysis and will determine whether urgent repair or replacement should be accelerated.

At the time of this paper, the prioritised condition assessment program is being finalized to increase confidence of predicted condition grades for water, wastewater and stormwater assets with poor condition grades and high criticality. It is expected that outcomes from this assessment will be included in the presentation on this paper.

Figure 4 presents an example from another New Zealand Council whom was able to offset the 'bow wave' in their forecast of gravity wastewater renewals by integrating asset criticality and final condition grades based on CCTV data inspection.

Figure 4: Deferred renewal based on increased data confidence from CCTV inspection



The blue bars in Figure 5 represent offset renewals based in increased data confidence from the CCTV inspection when compared to the orange bars which are based on the interim preliminary grade based on a desktop assessment. It is noted that backlog is included in the data in Figure 5.

5. CONCLUSION

Often renewal planning (in particular short-term renewal planning) is informed by asset and condition information with low accuracy, completeness or reliability. Using this information can result in replacing assets with can benefit from a renewal strategy that incorporates grading asset data confidence to optimize condition assessment and renewal expenditure.

Most renewal programs present renewal program that cannot be achieved with available resources and budgets. A short-term renewal approach based on criticality and data confidence can enable prioritised inspection and renewal lists with greater confidence while reducing likelihood of renewing assets that are not yet at the end of their useful life. It can also increase the likelihood of identifying highly critical assets for renewal before failure occurs.

The strategy outlined herein highlights that tracking data and asset condition confidence enables prioritizing asset condition assessment and renewal efforts where the risk of failure is highly consequential.

ACKNOWLEDGEMENTS

REFERENCES