OPTIMISED LONG TERM CONDITION-BASED RENEWALS OF HASTINGS DISTRICT COUNCIL TRUNK SEWERS

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ABSTRACT

It is every wastewater asset owner's desire that their wastewater systems should operate with minimum or no interruptions (Beardi et al, 2008). Hastings District Council (HDC), who own over 400 kms of wastewater pipeline assets and historically used the age-based approach for sewer rehabilitation, have adopted a new optimization strategy to improve its sewer renewal programme from a value for money perspective. Patterson and James (2007), and Ali and Schofield, (2017) presented the application of facets of this new approach to small diameter reticulation and large diameter pipes at Clive Wastewater Treatment Plant (WWTP).

A key feature of the strategy is the two stage approach; Level One involving the determination of condition-based residual life and programming for rehabilitation or further monitoring followed by Level Two targeted at optimizing the prioritization of short term (<5 years) repairs using risk matrix scoring. This paper focuses on the recent application of the new strategy to HDC trunk sewers and features the following:

- Outline of optimized framework for trunk sewer renewal.
- Criticality-based framework for identification pf asset groups targeted for rehabilitation
- Condition investigations including; CCTV inspection, laser/sonar clear and objective profiling, and pipe coring.
- Visual scoring system based on the extent of internal surface corrosion.
- Progress to date on trunk sewer condition assessment and rehabilitation
- Program of renewal, replacement and on-going inspection proposed over the next 10 years.

The adoption of this trunk sewer renewal strategy allowed HDC to unlock value from their assets by utilizing them to the end of their real of life whilst remaining vigilant to mitigate the risk of catastrophic failure in service. More importantly, the funding requirements have been evened out, in contrast to age- based replacement where the renewal of large portions of the trunk sewers would coincide within a small 10-20 year window period.

KEYWORDS

Renewal, condition-based, risk-based, rehabilitation, criticality, CCTV, pipe coring, laser/sonar profiling

1 INTRODUCTION

The spine of the Hastings District Council's (HDC) wastewater trunk was constructed between the late thirties and early sixties. The reality of wastewater asset ownership is that larger infrastructure like trunk sewers have low failure rates but when they fail, the consequences can be severe (Kleiner, 2001). Historically Hastings District Council (HDC) has programmed wastewater renewals using an age -based methodology. Early intervention is imperative but this would be problematic for HDC if the age-based renewal was adhered to as most of the trunk sewers would require replacement in the next two decades or so.

In addition to aging, the corrosive conditions within the domestic and industrial sewers has resulted in some of the sewers being in need of rehabilitation prior to the age-based trigger. In response, HDC assessments of the rehabilitation programme against the age asset's age and performance highlighted a mismatch between the forecast age-based renewal profile and actual asset condition and performance. This led HDC to adopt the optimized sewer renewal strategy

2 OVERVIEW

The areas serviced by HDC wastewater infrastructure is shown in Figure 1 and consists of all urban areas within the Hastings District area, including Flaxmere, Hastings City, Havelock North, Whakatu and Clive. The wastewater network comprises pumping stations, pressure pipelines and gravity pipelines. This paper is focuses on gravity pipelines.

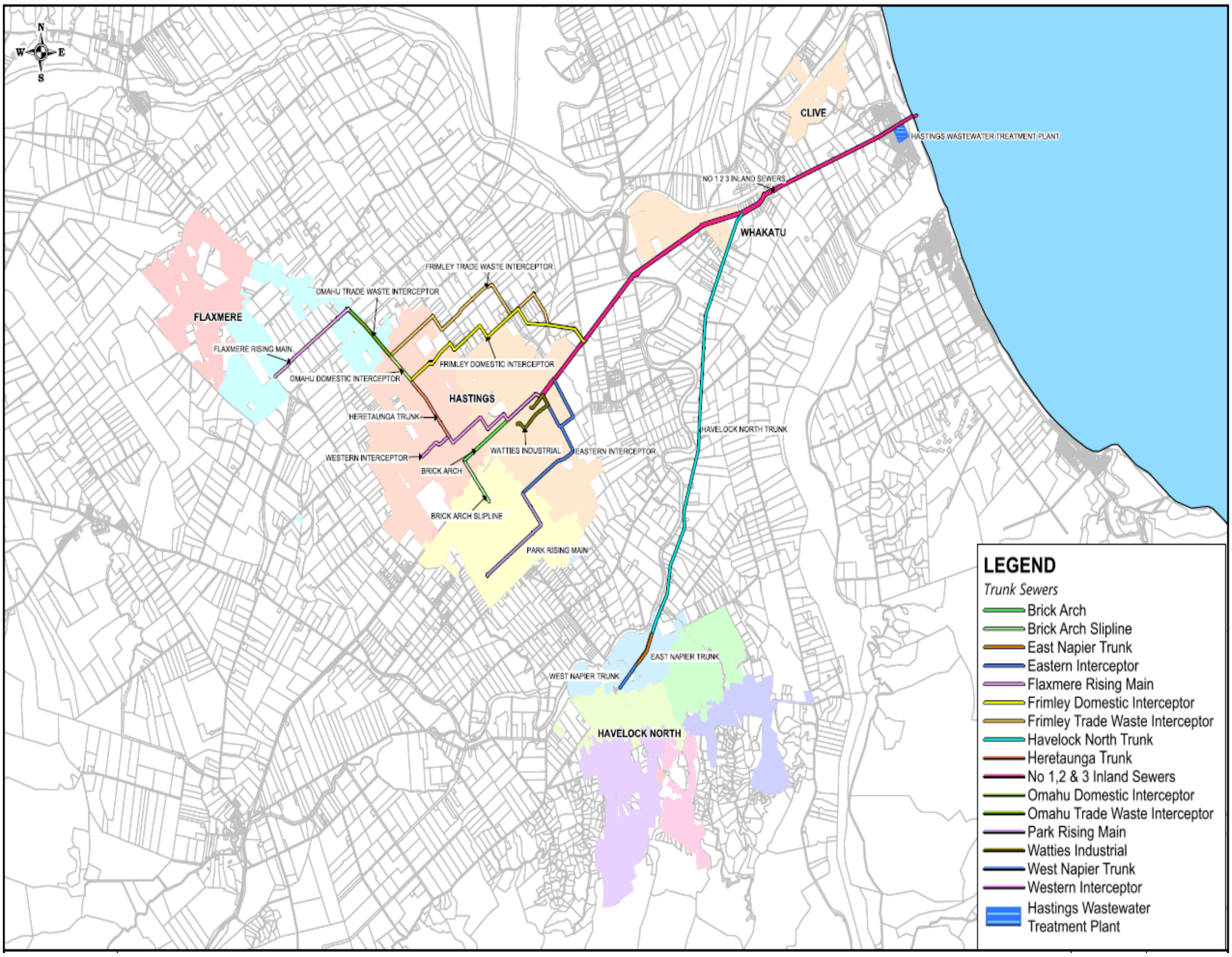

Figure 1 Hastings Wastewater Trunk Network

3 DISCUSSION

3.1 THE PROBLEM

The main challenges facing HDC emanate from the need to manage the asset renewal programme in an optimum manner that balances the risk of failure against the cost of monitoring the condition of the asset. An age-based approach would require significant investment in infrastructure investment given that the main trunk sewers were constructed within a 10-20 year period, so would be due for age-based replacement at the same time. This is exacerbated by most of the pipes being concrete, susceptible to corrosion from the septic environment within the sewers, and which is accelerating failure and the need to replace some of the newer trunk sewers.

3.2 OUTLINE OF CONDITION AND RISK-BASED RENEWAL

The strategy adopted by HDC to address the problem statement outlined above involved a combination of approaches that became integrated into the optimized risk-based asset renewal program as follows:

1. As is now common with New Zealand local authorities, HDC categorized their assets into three broad categories that recognize the criticality and priority of each pipe segment within its wastewater system. Category A, B, and C being high priority and critical, high priority and non critical, and low priority assets, respectively. This categorization is the first risk-based screening phase whereby budget allocations for investigations are allocated in favour of critical and high priority assets.

2. Condition assessment is based on CCTV inspection and scoring in accordance with New Zealand Pipe Inspection Manual Guidelines, verification is done by core sampling, laser/sonar survey, coring and laboratory testing. This includes repeat inspections for pipes whose condition warranted further monitoring prior to rehabilitation.
3. Level One broad remaining life categorization (>5 years) using custom developed structural scoring (MWH, 2013) uses the pipe condition information (core samples, CCTV and profile data) as well as broader understanding of the pipe materials and their historical performance. Pipe residual life estimation up to a maximum life of 50 years was made into 5 life categories based on condition assessment results.
4. Level Two comprises prioritization and optimization of the pipe replacement programme (1-5 years) in respect of the order and timing of rehabilitation of all pipes with an expected life of less than 5 years. Actual pipe lives will depend on whether and at what rate the pipes continue to deteriorate. It is expected that repeat CCTV / pipe profiling inspections will enable an assessment of the rate of deterioration to be made and allow for on-going refining of the remaining life assessments. This may include creating additional categories or assessing the prioritization within each pipe remaining life category.

All HDC trunk sewers (Figure 1) feature in the critical and high priority Criticality Category A due to their features as follows:

- Large diameter (generally 375mm diameter or larger)
- Critical to the function of the wastewater network
- Surrounding connectivity within the network
- Service large catchments and convey significant flows
- Would cause significant disruption above and below ground in the event of structural failure
- Have a low number or no lateral connections
- Are high value assets within the network

The maximum pipe life assigned is 50 years based on a reasonable expectation of deterioration. This life could be reasonably extended for recently installed sulphate resistant pipes and PVC lined pipes based on an expected reduced rate of deterioration in these pipes. However, that will depend on operating conditions in the future.

Pipes classified as requiring urgent renewal or replacement were given a 5 year life based on further optimization and refinement as part of the Level Two assessment. It is expected that the pipes with the highest risk and/or poorest condition will be replaced first.

3.3 SELECTION OF ASSETS FOR INSPECTION

The lead activity in optimized condition-based renewal of trunk sewers is the selection of pipes to be inspected. This was critical for HDC given that they have almost 400 km of wastewater network pipes which entail a large budget for condition assessment only. An inspection programme is critical in ground truthing the perceived risks and confirm that the pipes thought to be in distress are indeed worth spending money on investigations.

So far condition assessment work has been carried out as follows:

- Complete coverage of the Three Inland Main Sewers and Frimley Domestic Sewer
- 75 % coverage of the Eastern Interceptor
- Partial completion of the Heretaunga Trunk Sewer
- 25% completion in the Omahu Domestic Trunk sewer
- Work in progress in the Omahu Industrial Sewer

3.4 EXPECTED PIPE WALL THICKNESS

Data was provided by Humes on typical pipe construction for the reinforced concrete pipes made historically, as shown in Table 1, and Table 2 depicts the estimated wall thicknesses and reinforcement cover for recently installed concrete pipe.

The trunk sewers with diameters greater than 825mm are likely to have oval reinforcement cages. This means that the rebar will be closer to the internal wall at the pipe soffit. There will be some variation in the placement of the rebar within the pipe wall e.g. 5 mm tolerance is common. Pipe with oval cages is required to be orientated correctly in the trench for optimum life. Incorrect orientation is a potential reason for variation in rebar location and cover depth around the pipe wall.

The smaller diameter pipes, based on the core results, appear to have circular cages, which aligns with the information provided by Humes. Reinforcement within the pipe is a circular mesh cage. Distances to the reinforcement will vary depending upon if the reinforcement encountered runs longitudinally or circumferentially along the pipe.

There is often some discrepancy in respect of the extent of reinforcement for any given pipe. However, regardless of what reinforcement may be present the effects of reinforcement being just (or partially) exposed or seriously degraded can be identified.

Table 1 Historical Pipe Manufacturing Data

Pipe Diameter (mm)	Sewer Construction date	Wall thickness (mm)	External wall to centreline of reinforcement (mm)	Expected internal cover to centre of reinforcement (mm)
Historical				
450	1962	38 (S,X,Y) 41 (Z)	CIRC cage, 0.55 times wall	17.1 to18.5
525	1962-3	41 (S,X)	CIRC cage, 0.55 times wall	18.45
600	1958-1962	44 (S,X), 48 (Y), 54 (Z)	CIRC cage, 0.55 times wall	19.8 to 24.3
825	1958-1962	54 (S,X)	CIRC cage, 0.55 times wall OVAL cage 10 – 14 cover inside T & B, 19 – 23 outside haunches	24.3 or Soffit 40 to 44 Side 31 to 35
825	1938[1]	54 (S,X)	OVAL cage, 12 to in T & B, 20 to outer sides	Soffit 42 Side 34
1050	1938	64 (S,X)	OVAL cage, 12 to in T & B, 20 to outer sides	Soffit 52 Side 44
1050	1958	64 (S,X), 70 (Y), 86 (Z)	OVAL cage, 12 to in T & B, 20 to outer sides	Soffit 52 to 74 Side 44 to 66
1200	1958	76 (S,X,Y), 92 (Z)	OVAL cage, 13 to in T & B, 21 to outer sides	Soffit 63 to 79 Side 55 to 71
1350[3]	1970's	76 (S,X), 82(Y), 98 (Z)	OVAL cage, 13 to in T & B, 21 to outer sides	Soffit 63 to 85 Side 55 to 77
1575 1800	1970's Unknown	88 (assumed to be the old Class Y for 1600 dia pipe) Unknown	OVAL cage, 10-16 to in T & B, 22-27 to outer sides Unknown	Soffit 72 to 78 Side 61 to 66 Unknown

[3] Opus 2007 report records 1,350 mm pipe with 98 mm wall thickness (22 mm extra cover), 1,600 mm pipe with 88 mm wall thickness and 1,800mm pipe with 101 mm wall thickness.

[1] Humes were unable to identify any information on this pipe diameter and age. Reinforcement arrangement assumed to be the same as 900mm diameter concrete pipe from 1938.
Pipe Class and wall thickness assumed to be the same as 1960's pipe of the same diameter.

Table 2   Current Pipe Manufacturing Data[2]

Pipe Diameter (mm)	Sewer Construction date	Wall thickness (mm)
Current Pipe Classes		
450	Current	40 (Class 2 & 4)
525	Current	45 (Class 2 & 4)
600	Current	50 (Class 2 & 4)
825	Current	54 (Class 2) 57 (Class 3) 70 (Class 4)
1050	Current	76 (Class 2 & 3) 86 (Class 4)
1200	Current	76 (Class 2 & 3) 96 (Class 4)
1350	Current	76 (Class 2) 82 (Class 3) 96 (Class 4)
1575	Not Available	
1600	Current	82 (Class 2) 88 (Class 3) 108 (Class 4)

3.5 PIPE FAILURE MECHANISM

3.5.1 PIPE CORROSION

Typically for a pipe, it is expected that corrosion occurs at the soffit first and that if side wall corrosion is present it will be at a slower rate. If reinforcement is central, then corrosion of the soffit reinforcement is more critical than for the pipe wall. This means that when reinforcement is exposed (in the soffit or wall) then collapse of the roof is more likely to occur before any wall collapse. If reinforcement is oval (and the pipe has been placed correctly), then collapse will occur sooner. That means that pipe condition assessment can be based on the extent of reinforcement exposure, whether in the soffit or wall.

3.5.2 EMBEDDMENT

The structural performance of a concrete pipe is dependent on both the strength of the pipe and also the pipe embedment conditions. Pipe embedment conditions can be highly variable and/or are unknown. For example, the trench condition (support type, compaction, etc.) is unlikely to be known accurately and therefore the effectiveness of any lateral support to the pipe is difficult to determine. Any assessment considering external pipe support can only be at a coarse screening level, since variability in key parameters may be significant.

For this reason, external pipe support has not been used in assessing the priority for pipe rehabilitation or replacement.

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[2] Information on current pipe dimensions from Humes website and assumes Roller Compacted pipe for diameters 600 mm or less.

3.6 CONDITION INVESTIGATION

Condition assessment completed on the Three Inland and Frimley Domestic trunk sewers includes:

- CCTV inspection and visual scoring of the pipe to determine a condition score. The extent of CCTV inspection is shown in Table 3.
- Laser profiling of a portion of the CCTV inspected pipe length to estimate effective cover, to provide a comprehensive view of any corrosion by measuring the existing internal diameter and determining the change compared with the original internal diameter, for the full pipe circumference. This information was used to help determine locations for core sampling.
- Pipe coring of selected pipes to confirm structural pipe condition. Pipe cores were taken to assess the extent to which corrosion had penetrated the existing concrete wall. This was used to establish sound wall thickness to guide pipe remaining life estimates.
- Phenolpthalein testing during coring is an important field tests whereby an organic compound can be used to measure alkalinity of the concrete core. The core turns purple after applying phenolphthalein liquid to its surface, if alkaline (PH >8.6), or colourless if acidic. Colourless (acidic) results are indicative of the possible leaching of the concrete by carbonation or sulphate attack and the risk of corrosion of the rebar. This simple test could also be carried out on site during the recovery of the core samples.

Table 3 outlines the extent of each type of investigation

Table 3 Extent of Condition Investigations

Trunk Sewer	CCTV Inspection			Laser and Sonar Profiling[1,2]		Pipe Coring[3]
	Total Length of Sewer (m)	Length Net of Renewals (m)	Length of Pipes Surveyed (m)	Length of Pipes Surveyed (m)	Proportion Surveyed (by length) (%)	Number of Pipe Core Location
No 1 Trunk	6,996	1,728	6,908	1,043	5.4	2
No 2 Trunk Sewer	7,048	86	6,989	2,773	14.2	10
No 3 Trunk Sewer	6,988	2,036	5,591	3,406	17.5	4
Frimley	4,156	530	2,810	700	17	4
Total	**25,186**	**4,335**	**22,297**	**7,922**		**20**

Notes:

[1] Selected on the basis of CCTV scoring and represents approximately 30% of CCTV coverage sufficient to validate CCTV visual scoring.

[2] Measures the existing internal diameter for comparison against the original diameter.

[3] To assess how much corrosion had penetrated the pipe wall and estimate the sound wall thickness to guide remaining pipe life estimates.

Table 4 outlines the distribution of condition scores along each of the trunk sewers. No1 trunk sewer has the longest length within the worst condition score recorded (1,576m).

Table 4 Frimley Trunk Sewer Pipe Condition Scores

Condition Score Category	Frimley Trunk Sewer		No.1 Trunk Sewer		No 2 Trunk Sewer		No 3 Trunk Sewer	
	Pipe Length (m)	Proportion of Total Pipe (%)	Pipe Length (m)	Proportion of Total Pipe (%)	Pipe Length (m)	Proportion of Total Pipe (%)	Pipe Length (m)	Proportion of Total Pipe (%)
0 to <1.06 (1)	4159	13.8	1,671	23.9	375	5.3	1,770	25.3
1.06 to <2.06 (2)	4653	15.7	2,935	41.6	3,265	46.3	2,800	40
2.06 to <3.06 (3)	2,670	64.2	767	10.9	3,019	42.8	2,202	31.5
3.06 to <4.06 (4)	239	5.8	1,576	22.4	367	5.2	200	2.9
4.06 to < 5 (5)	0	0.0	0	0	0	0	0	0
Unknown	435	10.5	46	0.7	21.7	0.3	17	0.2
Grand Total	**4,156**	**100.0%**	**6,996**	**100.0%**	**7,048**	**100.0%**	**6,988**	**100.0%**

For the Frimley Trunk Sewer, the laser profiling was carried out on various sections of the trunk main. The results showed some isolated areas of corrosion of up to 34 mm   Most of the pipes have insignificant areas with mild corrosion. However, some of the pipes were observed to be in high risk with the poorest condition. These sections are summarized in Table 5 with a description of their conditions and the general locations.

Table 5 Frimley Trunk Sewer Profiling Results

Asset No.	Diameter (mm)	General Corrosion (mm)	Equivalent Visual CCTV Score	General Condition	Location
51155384	457	181	>23 mm	Very Poor	Hapuka St; in carriageway
51155369	525	29	0 mm - 22 mm	Poor; newly renewed in 2015.	Lindisfarne College driveway
51154047	600	240	10 mm - 20 mm	Poor	Under driveway and buildings on Tomoana Warehousing
50002013	600	100	0mm – 10 mm	Good	Under paddock on 1002 Pakowhai Road
51133265	600	277	0 mm – 10 mm	Reasonable	Agricultural land between 1411 and 1419 Pakowhai Road

Figure 2 provides a visual summary of the high risk Frimely Trunk Sewer pipes with the poorest conditions.

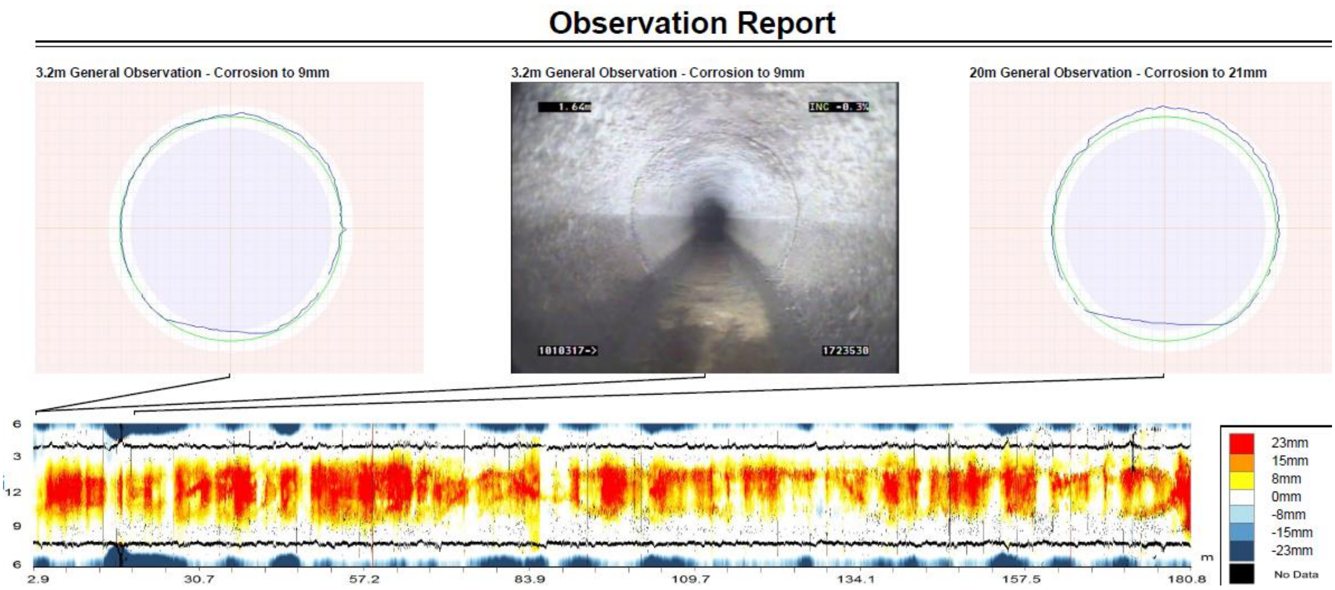

Figure 2 ***Profiling Visual Summary of the Pipe SUFI ID 51155384***

Core sample locations were selected to provide a spread of pipe condition, diameter and age of the trunk sewers. Generally three cores around the pipe wall were taken at each site. For larger pipe diameters cores were taken from inside of the pipe, while for smaller diameter pipes (less than 825 mm) external cores where taken. Pipe coring was limited by a number of factors including flow in the pipe, proximity to other services (including adjacent sewers) and difficulty of access for personnel and machinery.

The pipe cores were taken from three positions on the inside of the pipes – the top (12 o'clock), side (3 o'clock) and bottom (4 or 5 o'clock). Depending on the flow in the pipe, the bottom position was drilled just above the water level. For each core sample, the wall thickness was measured and then measurements from the centre of the reinforcement to both the inside and outside of the pipe were taken. Appendix A provides a summary of the information collected during the core sampling, CCTV and profiling work.

In addition to core thickness and reinforcement cover measurements outlined above, additional information on the extent of corrosion within the concrete wall could also be obtained by using the phenolphthalein test.

3.7 LEVEL ONE-CONDITION-BASED RESIDUAL LIFE

3.7.1 VISUAL SCORING

Visual scoring of the CCTV inspection was completed in line with the New Zealand Pipe Inspection Manual prescribed standard, while the structural score was determined using the approach developed by MWH (2013). This structural scoring approach defines 5 corrosion condition categories or scores summarised and defined in Table 6 below.

Table 6 Visual Scoring Guide

Score	Description
Score 1	No significant pipe wall deterioration visible.
Score 2	Pipe material corroded and aggregate exposed.
Score 3	Rebar staining visible but rebar not exposed and/or severe aggregate exposure.
Score 4	Rebar just visible, generally less than 25% diameter.
Score 5	Rebar significantly exposed, generally between 25-50% diameter.

3.7.2 LEVEL ONE –RESIDUAL LIFE ASSESSMENT

At Level One the remaining estimated lives were assessed based on the CCTV visual score and remaining reinforcement cover as identified by profiling and pipe cores. At Level One pipes are categorized into 5 expected life categories ranging from 5 to 50 years. Level Two comprises prioritization in respect of the order and timing of rehabilitation of all pipes with an expected life of less than 5 years.

Actual pipe lives will depend on whether and at what rate the pipes continue to deteriorate. It is expected that repeat CCTV / pipe profiling inspections will enable an assessment of the rate of deterioration to be made and allow for on-going refining of the remaining life assessments. This may include creating additional categories or assessing the prioritization within each pipe remaining life category.

The maximum pipe life assigned is 50 years based on a reasonable expectation deterioration. This life could be reasonably extended for recently installed sulphate resistant pipes and PVC lined pipes based on an expected reduced rate of deterioration in these pipes. However that will depend on operating conditions in the future.

Pipes classified as requiring urgent renewal or replacement have been given a 5 year life based on further optimization and refinement as part of the Level Two assessment. It is expected that the pipes with the highest risk and/or poorest condition will be replaced first.

As of July 2015 and based on 2014 scores, all inland trunk sewer pipes with a visual condition of 5 have been replaced or relined. Work is now focused on visual condition 4 pipes, with priority based on risk.

While the visual score is a crude measure, it appears to provide a good guide to the extent of degradation of the pipe cover over a range of pipe diameters, installation dates and wall thicknesses. The point at which significant rebar staining is observed (scores >3) indicates cover loss ranging from 18 to 40 mm.

While using rebar staining and corrosion incidence evidenced by scores 4 and 5, as the trigger for renewal and replacement appears a high risk approach, there is no evidence of significant catastrophic or structural failure of pipes with condition scores >4. The fact that pipes with visual scores >4 continue to function and have not collapsed suggest there is some conservatism built into the approach. That does not diminish the need for timely renewal / relining of pipes falling within the highest conditions scores.

Table 7 summarises the level one visual score and residual life categories as well as indicating the recommended priority for action. The 'cut-off score' between the different categories has been chosen conservatively such that when more than 5% of the pipe is considered to fall into the next worst CCTV visual score, the remaining life estimate and priority for renewal changes.

Table 7 Residual Life Prediction of Trunk Sewers

Typical Description	Reinforcement Cover at top (mm)	Residual Life (Years)	Equivalent Visual CCTV Score	Summary Score	Recommended Action
Pipe in sound condition. Liner (if any) generally remaining.	Original cover	>50	<1.05	1	No work.
Liner is corroded or missing and/ or up to 5mm of concrete has corroded at the top (reinforcement not visible).	>10	25-50	1.06 - 2.05	2	Monitor sample sites at least 10 yearly.
Up to 10mm corrosion of concrete at top or rust staining from steel apparent.	5-10	10-25	2.06 – 3.05	3	Monitor all sites at least 5 yearly. Address isolated areas and faults.
Reinforcement just showing (up to 25% bar diameter) or heavy rust staining, minor spalling.	<5	0-10	3.06 – 4.05	4	Replace / reline within 5 years. Consider high risk sites first.
Reinforcement exposed more than 25% bar diameter or absent.	Nil	0-5	>4.05 or greater than 5% of length in score 5	5	Replace/reline immediately. Consider high risk sites first.

Where pipes are not likely to be rehabilitated within the next 5 years (visual scores <3.06) as a minimum repeat CCTV inspections should be undertaken to try to identify the rate of any further degradation. Priority for repeat CCTV inspections should be given to the condition score 3 pipes. Sewers with minimal visual defects could be grouped and only a sample inspected every 10 years, while pipes with more frequent visual defects (overall score 2.06 and greater) should be inspected individually every 5 years.

Table 8 summarises the findings of the trunk sewer investigations with the residual life based on condition scores, core sampling and risk categorisation. Note how the core sampling residual life is more conservative in the mid-condition scores. Some Inland Trunk Sewer pipe segments which score 5 were repaired immediately after CCTV inspection and do not feature in this table.

Table 8 Pipe Sections Requiring Renewal in The Next 10 years

SUFI No	PIPE DIA (mm)	PIPE MATERIAL	LENGTH (m)	CCTV DATE (YEAR)	SCORE	BASE LIFE	CONDITION - BASEDREMAINING LIFE (YRS)	Core Sample Based Remaining Life
Frimley Trunk Sewer								
51133266	600	CONC	266	2014	2.53	50	10 - 25	N/A
51154047	600	CONC	239.79	2014	3.15	50	0 – 10	0-8
51155384	450	RC	181	2014	2.17	50	10 - 25	66
50002013	600	RC	100	2014	2.16	50	10 - 25	29
51133271	600	RC	255	2014	2.15	50	10 - 25	N/A
51133272	600	CONC	152.4	2014	2.13	50	10 - 25	N/A

51133265	600	CONC	277	2014	2.61	50	10 - 25	133
Inland Trunk Sewers								
51139002[1]	1050	RC	370	2009	3.07	50	10	N/A
51138998[1]	1050	RC	462	2009	3.09	50	10	N/A
50000000[1]	1050	RC	385	2009	3.23	50	10	N/A
51138987[1]	1050	RC	359	2009	3.35	50	10	N/A
51139163[3]	1575	RC	199	2014	3.19	50	10	N/A
511389990[2]	1200	RC	367	2014	3.14	50	10	N/A

Notes

1. No.1 trunk sewer
2. No. 2 trunk sewer
3. No. 3 trunk sewer

3.8 LEVEL TWO RISK-BASED REFINEMENT

Level Two is a risk-based refinement stage to smoothen the gaps that cannot be adequately covered by Level One such as the capturing and assessment of isolated pipes/segments on a stretch of pipe in good condition and prioritising pipe rehabilitation for the immediate (5 year) planning horizon.

3.8.1 ISOLATED STRUCTURAL DEFECTS

A pipe could score as a good structural condition pipe, but has a short (1m or more) segment with poor scoring defect would pose a high risk of spot failure. To mitigate this risk, the condition assessment has been extended to identify if poor structural condition (score 4/5) defects over 1 m in length have been recorded. Further specific investigations would then be carried out on these pipes to identify if spot repairs or replacements should be implemented.

3.8.2 RISK MATRIX SCORING FOR IMMADIATE RENEWAL PLANNNING

To enable prioritisation of renewal or replacement of the pipes which are assessed to have a remaining life of 5 years or less, a risk matrix scoring approach was adopted. Three main risk factors pertinent to the HDC wastewater system and adopted for Level Two refinement are:

- exposure to traffic loadings in and off the road
- ground conditions based on a combination of soil type and water table levels
- proximity to built assets such as buildings and amenity assets such as ponds, gardens, vegetation etc.

A proposed matrix with suggested categories and scores is outlined in Table 9 below. The rank order used in the CCTV visual scoring has been adopted where higher risks are assigned higher scores. A summation of the three scores would provide a combined ranking to be used to prioritise renewal or rehabilitation of the specific pipe section.

Table 9 Level Two Risk-based Residual Life Prediction

Risk ID	Risk Category	Score 1	Score 2	Score 3	Score 4	Score 5
1	Exposure to traffic loads:	Pipe within grazing land	Pipe is located in intensively cultivated land with potential heavy machinery	Pipeline passes under or close to property access way	Pipe passes under or within road reserve corridor of local road	Pipe passes under or road reserve corridor of arterial road
2	Ground conditions / Soils	Coarse granular / well drained soils e.g. sands	Coarse grained soils with high water tables	Medium textured soils with low water tables	Medium / fine textured soils with high water tables	Organic soils with high water tables
3	Proximity to Buildings / Amenity Asset	Pipe more than 20m from any asset or amenity feature	Pipe passes close (20m) to any other significant amenity feature – e.g. pond, tree stand	Pipe passes under yard, garden or other significant amenity area	Pipe passes within 10m of external wall of building or dwelling	Pipe passes under building commercial or dwelling

The assessment of the risk for each of the categories is based on the following:

EXPOSURE TO TRAFFIC LOADS:

Risk increases for the pipe depending on the likelihood and magnitude of any traffic load exposure. Highest risk is represented by proximity to the arterial roads with high frequency heavy truck use.

GROUND CONDITIONS / SOILS:

Risk is assessed to be greatest with soils that are weak in structure as well as conditions with elevated water tables as both reduce the support provided by the soil under external load. The assessment is based on regional soil maps coupled with knowledge of groundwater levels in the area. The approach is considered even though imported bedding and backfill may have been used. Even with an envelope of quality material, pipeline failure risk will be influenced by the in-situ soils. Coarse textured and well drained soils are considered to have the least risk, while organic soils under high water table conditions are considered to present the greatest risk.

PROXIMITY TO BUILDINGS / AMENITY ASSET:

This risk is considered to capture both the likelihood that activities undertaken in and around other built and natural assets may lead to inadvertent damage to pipe assets as well as the potentially higher cost of remediation should pipe failure occur in proximity to built structures and other amenity assets.

At this stage the risk scoring is a proposal only provided for consideration. It draws on early risk scoring developed by HDC to guide trunks sewer renewal prioritisation. The scoring is subsidiary to the visual condition scoring and designed only to assist with developing the program timing for priority renewal and rehabilitation works.

Table 10 shows the final result for Frimley trunk sewer showing condition-based results and risk categorisation.

Table 10 Frimley Pipe Sections Requiring Level Two Assessment[1]

Asset No.	CONDITION-BASED REMAINING	Core Sample Based	Level 2 Risk Score for 0-5 year residual life[2]	PIPE RENEWAL DATE

	LIFE (YRS)	Remaining Life	Risk 1	Risk 2	Risk 3	Aggregate	
51154047	0 – 10	0-8	4	2	4	3.32	2018

Notes

[1] Only pipes programmed for repairs/rehabilitation in the short term horizon

[2] Refer Table 9

Refer to Appendix B for the Frimley and Inland Trunk Sewer renewal dates.

4 CONCLUSION

This paper presents and discusses HDC's adoption of the risk-based approach to optimise trunk sewer renewals. The approach involves a further refinement (Level Two prioritisation) of the structural condition-based residual life assessment developed by Level One work to develop an optimised renewal program for pipes to be rehabilitated in the next 5 years. Level One results are broader, and are classed into five categories over a 50 year base life. The Level Two approach uses a simple three risk scoring assessment. As a result of this approach, HDC have appreciated its merit and value so have started to apply it to develop the estimates of remaining life for the trunk sewers that have been covered by their CCTV inspection programme since 2008.

So far the correlation of CCTV and laboratory based assessments (Table 10) showed that CCTV inspection scoring was conservative for pipes categorised into medium risk categories whereas laboratory results were more conservative for pipes categorised into the high risk category. Coring and laboratory verification will continue to be used as a verification tool.

This methodology has identified a number of pipe segments requiring rehabilitation within the next ten years and now forms the basis of HDC's LTCPP instead of the age-based assets used in the previous approach.

It has also been established that CCTV inspections are now getting into CCTV re-run mode and HDC are gearing to start monitoring deterioration by comparing previous and current CCTV inspection results.

Based on HDC's experience on the previous rehabilitation programme, it is now acknowledged that for some pipe rehabilitation methods, establishment costs are higher than the pipe rehabilitation costs proper. In preparing their rehabilitation specifications, it is now HDC's preference to also reassess the pipes adjacent to the target pipes for the cost benefit of bringing forward their repairs to take advantage of the significant establishment costs of the target pipe.

The assessment has confirmed the value of condition-based scoring to develop more appropriate estimates of residual life. To ensure that the renewal planning remains valid, further CCTV inspections of selected sections of the trunk sewers need to be completed to monitor the rate of deterioration. It is recommended that a CCTV inspection schedule be developed to enable inclusion of budget for the activity.

Currently, HDC are continuing with the investigation and rehabilitation programme targeting the remainder of the trunk sewers.

PRESENTER PROFILE

Elias is an experienced professional in the investigation, design and project management.of water and wastewater services. He has been working on the Hastings District Council trunk sewers for the past two years.

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Appendix A – Frimley CCTV, Pipe Coring and Laser/Sonar Profiling Correlation

Trunk Sewer Diameter[2] (mm)	Pipe SUFI ID (CCTV ID)	2014 Survey Overall Score	Profile Typical corrosion (mm)	Expected depth to reinforce-ment (top-side) (mm)	Original wall thickness (mm)	Side 2 or 3 O'clock Position				Bottom 3, 4 or 5 O'clock Position				Top 12 O'clock Position			
						Core wall thickness[1] (mm)	Reinforce-ment from inside (mm)	Reinforce-ment from Outside (mm)	Wall thickness lost (mm)	Core wall thickness[1] (mm)	Reinforce-ment from inside (mm)	Reinforce-ment from Outside (mm)	Wall thickness lost (mm)	Core wall thickness[1] (mm)	Reinforce-ment from inside (mm)	Reinforce-ment from Outside (mm)	Wall thickness lost (mm)
450	51155384	2.17	9 – 40 Average 22. Generally around the soffit.	20.9 – 22.5	38 or 41	35	10	25	6	Only two pipe cores sampled due to pipe diameter and ground water level				30	Not visible	Not visible	11
525	51155369 (Renewed in 2015)	3.91	11 – 22 Average13. Generally around the waterline.	22.5	45	30	12	25	15	40	20	22	5	30	10	25	15
600	50002013	2.16	10 – 25 Average 10. Generally around the soffit.	24.2 -29.7	44, 48, 54	37	5	33	11	40	20	20	8	40	25	15	8
600	51133265	2.61	5 – 28 Average 5. Generally around the soffit.	24.2 -29.7	44, 48, 54	42	20	24	6	45	27	20	3	40	17	27	8
600	51154047	3.15	9 – 32 Average 18. Generally around the soffit.	24.2 -29.7	44, 48, 54	45	19	26	3	45	10	35	3	40	10	30	8

Notes: [1] Pipe cores are 40mm diameter, through the wall of the concrete pipe. Some of the wall thickness may have been lost in the pipe coring process.

[2] Pipes are listed from upstream (intersection of Omahu Road and Hapuku Street) to downstream (intersection of Elwood Road and Otene Road)

Appendix B Trunk Sewer Renewal Programme 2014-2024

SEWER	SEWER	SUFI NUMBER	PIPE DIAMETER	PIPE MATERIAL	LENGTH	YEAR OF INSTALLATION	CCTV DATE (YEAR)	SCORE	BASELIFE	CONDITION-BASED REMAINING LIFE (YRS)	CONDITION-BASED PREDICTED DATE OF RENEWAL	RENEWAL DATE
INLAND	No1	51139002	1050	RC	370	1938	2009	3.07	50	10	2019	2019
INLAND	No1	51138998	1050	RC	462	1938	2009	3.09	50	10	2019	2019
INLAND	No1	50000000	1050	RC	385	1938	2009	3.23	50	10	2019	2019
INLAND	No1	51138987	1050	RC	359	1938	2009	3.35	50	10	2019	2019
INLAND	No2	51138990	1200	RC	367	1958	2014	3.14	50	10	2024	2024
INLAND	No3	51139163	1575	RC	199	1974	2014	3.19	50	10	2024	2024
FRIMLEY DOMESTIC	FRIMLEY DOMESTIC	51155384	450	RC	181.154	1/01/1962	2014	2.17	50	25	2039	2024
FRIMLEY DOMESTIC	FRIMLEY DOMESTIC	50000140	525	RC	52.574	1/01/1950	2014	3.16	50	10	2024	2024
FRIMLEY DOMESTIC	FRIMLEY DOMESTIC	51155369	525	RC	56.811	11/01/2009	2014	3.91	50	10	2024	2018
FRIMLEY DOMESTIC	FRIMLEY DOMESTIC	50002013	600	RC	100	11/14/1958	2014	2.16	50	25	2024	2024
FRIMLEY DOMESTIC	FRIMLEY DOMESTIC	51133271	600	RC	254.958	1/01/1950	2014	2.15	50	25	2020	2020
FRIMLEY DOMESTIC	FRIMLEY DOMESTIC	51133272	600	CONC	152.4	11/14/1958	2014	2.13	50	25	2039	2020
FRIMLEY DOMESTIC	FRIMLEY DOMESTIC	51156452	600	RC	4.058	03/30/2011	2014	1	50	50	2064	2064
FRIMLEY DOMESTIC	FRIMLEY DOMESTIC	51133264	600	CONC	10.338	11/14/1958	2014	2.9	50	25	2024	2024
FRIMLEY DOMESTIC	FRIMLEY DOMESTIC	51133265	600	CONC	277	11/14/1958	2014	2.61	50	25	2020	2020
FRIMLEY DOMESTIC	FRIMLEY DOMESTIC	51133266	600	CONC	266	11/04/1958	2014	2.53	50	25	2039	2018
FRIMLEY DOMESTIC	FRIMLEY DOMESTIC	51154047	600	CONC	239.79	11/14/1958	2014	3.15	50	10	2024	2018