CONDITION ASSESSMENT AND ASSET MANAGEMENT OF THE WEST DERWENT PIPELINE

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SUMMARY: Distribution water mains are a critical component of water supply networks and the integrity of these pipelines can affect the water supply to a large percentage of a city's population. The West Derwent Pipeline is one of the main distribution pipelines into Hobart and it supplies approximately 60% of the metropolitan water demand. Hobart Water, the owners and operators of this pipeline, have a responsibility to the community to ensure the continued supply of water to Hobart. Towards this goal, in 2004, Hobart Water began the process of developing a long term Asset Management Strategy Plan for the longevity of this pipeline system.

The Asset Management Strategy Plan was developed for the West Derwent pipeline system after reviewing all available historical performance data, assessing the current condition of the pipeline, and determining the probability of failure and the risk exposure for each subsection of the pipeline. The unique process of optimised decision making (ODM) analysis was the tool used for determining the most cost effective strategy for the management of this pipeline. All data gathered during the condition assessment of this pipeline, including the extensive field investigation, was captured in a GIS system to provide a central data base for future visual reference and performance data, and historical comparison.

Keywords: Corrosion, Pipeline, Asset Management, Condition Assessment, Risk, ODM.

1. INTRODUCTION

Distribution water mains are a critical component of water supply networks and the integrity of these pipelines can affect the water supply to a large percentage of a city's population. The West Derwent Pipeline (is one of the main distribution pipelines into Hobart and it supplies approximately 60% of the metropolitan water demand. Hobart Water, the owners and operators of this pipeline, have a responsibility to the community to ensure the continued supply of water to Hobart. Towards this goal, in 2004, Hobart Water began the process of developing a long term Asset Management Strategy Plan for the longevity of this pipeline system. In 2005 Maunsell Australia began the process of assessing the physical condition and the risks associated with the operation of the pipelines, and developing the Asset Management Strategy plan for Hobart Water. This paper discusses the processes used in the development of this Plan.

2. ASSET PROFILE - FACTS AND FIGURES ON THE PIPELINE

The West Derwent Pipeline System is a dual pipeline gravity fed system from the Box Hill Head Tanks to the Berriedale Valve pits, where it becomes a single pipeline continuing to the Domain Tanks and the Tasman Bridge. From the Domain, water travels east across the Tasman Bridge, or west, via Hobart City Council's water reticulation to Fitzroy pump station, where it is pumped to Lower Reservoir at the Waterworks complex in South Hobart. The majority of the pipeline was first installed in the 1960's, though the section from Fitzroy Gardens to Lower Reservoir was first installed in the 1920's. Several sections of the old pipeline have been replaced since it was first installed. Associated with this system is the Claremont Trunk pipeline which transports gravity fed water from the Berriedale Valve Pits to the Tolosa Dam. This pipeline was installed in the 1960's and it provides water to the City of Glenorchy and surrounding areas.

The final component of the West Derwent pipeline is the Hilton Road pipeline. This very short pipeline provides a point of connection between the West Derwent Pipeline and the Lake Fenton Pipeline.

Due to the gradual development of this pipeline system and the renewal processes the condition of the linepipe will vary across the system. The properties of the coated linepipe vary across the network as follows:

- Pipe– Locking Bar steel or welded steel
- Age–1-83 years
- Pipe joints–Spigot and socket joints, rubber ring joints or welded joints
- Diameter– 450 to 810mm
- Wall thickness– 4.7 to 8mm
- External coatings–Pitch/Hessian, Bitumen/felt overwrap, or Fusion bonded MDPE
- Internal coatings–Cement mortar lining or enamel

3. DEVELOPMENT OF A STRATEGY PLAN

Development of a strategy plan requires information regarding the historical performance of the pipeline (number and type of failures), knowledge of the current condition of the pipeline (estimated remaining life), asset criticality, assessment of the probability of failure of the pipeline, asset risk, and a cost analysis that would indicate which treatment option provides the best economic returns on the asset.

A failure of the pipeline was defined during the project as a circumstance that caused unintentional loss of water from the pipeline resulting in maintenance or renewal. For example a leak from a joint or a leak from a corrosion pit would both be considered a failure, as would a burst.

To assist with the condition and risk assessment the pipeline was segmented into 38 discrete elements determined by the following factors:

- Change in environment;
- Presence of road and rail crossings;
- Changes in terrain;
- Change in planning zone; and
- Pipeline situation eg above or below ground.

Treatment options are easier to select and provide better economic solutions for discrete elements than treatments selected for entire segments or pipeline systems. A number of treatment options were identified for pipe segments and an optimised decision making analysis undertaken to determine the optimal treatments, timing and associated cost. These outputs were consolidated into an overall asset management strategy for the pipeline.

3.1 Historical Data

The assessment of historical information regarding the corrosion related leaks provided performance related data for the assessment of the probability of failure of the pipeline. This data also indicated where corrosion hot spots occur in the pipeline system. The location of all previous failures (leaks and bursts) were recorded using GPS equipment and logged on the Graphical Information System (GIS).

Analysis of the data indicated that historically failures were recorded with the following descriptions:

- Pipe fracture;
- Perforation on a welding collar;
- External corrosion at the pipe joint;
- “Leaks”;
- Failure of the pipe invert through damaged coating;
- Failure of an off-take; and
- Failure of lead joints on locking bar steel pipe.

For the purpose of the analysis it was assumed that the failure mode would be either joint failure or barrel failure caused by perforation due to corrosion. Historically a higher proportion of failures was indicated to have occurred at joints due to poor quality field joint coatings.

3.2 Condition Assessment

The current condition of the pipeline was investigated using a range of non-destructive and destructive testing techniques. The condition assessment was conducted in three stages. Stage 1 involved assessing the buried environment at pipe depth along the pipe route, and the condition of the pipeline coating. Stage 2 involved exposing the pipeline at select locations and physically assessing the condition of the external coating on the pipeline and the extent of corrosion. At some of these sites internal examinations were also conducted. Stage 3 involved correlating the physical condition at the exposed sites to the corrosivity of the buried environment and applying this along the pipelines using the corrosivity at untested sites. It was assumed that soils with similar corrosivity have the potential to cause similar rates of corrosion of steel pipe.

The condition profile was used to determine corrosion rate, remaining life and an associated probability of failure for each element along the pipeline system.

3.2.1 Stage 1

The ANSI/AWWA standard C105 (1) was selected for the assessment of the corrosivity of the soil environment around the pipeline. This standard was written for ductile iron pipes but the soil corrosivity assessment is also appropriate for steel pipelines as the ductile iron and steel corrode at approximately the same rate in most soils (2). ANSI/AWWA standard C105 provides a point system for the following soil characteristics; resistivity, pH, redox potential, presence of sulphides (SRB) and moisture. In soil environment it is a combination of factors that determines whether the soil is considered to be corrosive to ferrous (steel, iron) materials. Using the point system in this standard, a cumulative total of 10 or more points is considered to indicate that the soil is corrosive to the steel pipeline.

As corrosion usually initiates externally on a pipeline at defects in the linepipe coating, it was important to assess the condition of the coating. Coating defect surveys usually require either physical exposure of the pipeline or a physical connection to the pipeline. Unfortunately as many water pipelines have rubber ring joints between each pipe length a physical connection would need to be made to each pipe length to enable a survey to be conducted. As this is not practical, coating defect surveys on water pipe are necessarily limited to fully welded sections or above ground sections.

3.2.2 Stage 2

At the sites selected for physical examination the external surface of the pipeline was assessed at the crown and invert for wall thickness, and depth and distribution of corrosion pits. Where coupons were removed from the pipeline, the internal condition of the pipeline was physically inspected. High resolution CCTV cameras were inserted after coupons were removed and the condition of the internal coating was inspected upstream and downstream. The CCTV inspection system utilised was able to clearly resolve longitudinal cracking, circumferential cracking, loss of lining material, erosion of mortar lining at offtakes, misaligned joints and sites of perforation/inflow. Examples of features located during the CCTV inspection are shown in Figures 1 and 2.

Figure 1: Infiltration leak

Figure 2: Corrosion at defects in the internal coating

3.3 Risk Analysis

The first step of the risk analysis was the determination of which elements or segments were critical to Hobart Waters business. The criticality of an element is defined as its importance to the supply of water to Hobart Waters customers.

The factors that influence criticality relate to the pipeline's surrounding environment and the function it performs. Using this as the basis of quantifying criticality the following factors apply:

- Depth of main;
- Exposure to Damage (from 3rd party);
- Pipeline redundancy;
- Depth below existing water table;
- Planning zone and existing facilities;
- Impact on adjacent services e.g. power, communications, gas;
- Accessibility; and
- Impact on Water Supply.

Each parameter is rated individually for each pipe segment and then aggregated to give a criticality score. Ranking of the scores for each pipe segment provides Hobart Water with a list of assets that potentially have the greatest impacts on the business should they fail. These criticality scores were purely subjective and the category of the ratings was designed to bring an even spread of scores in each category.

Critical assets are not necessarily high risk assets. They will be deemed high or low risk based on the potential consequential damage and the likelihood of failure. Critical assets tend to focus operational activity to these specific assets. Assets however, can be high or low risk but not critical. A high risk asset while potentially leading to a high cost of repair may not impact on business continuity and is therefore not critical.

Risk can be defined as the likelihood of specific consequence relating to a pipeline failure occurring within a nominated timeframe. The consequences of risk considered during this analysis assessment of the pipelines included physical damage to the pipeline, property damage, environmental damage and public relations damage. For the purpose of the analysis it was assumed the pipe failure would occur in the location that would potentially result in the greatest consequence along the pipe element. The risk exposure was calculated for each element and this represents the cost associated with the risk for each element. This cost or exposure is calculated by multiplying the consequential cost of failure by the probability of failure.

3.4 Treatment Options

A number of treatment options for corrosion control were then identified for the pipe segments and an optimised decision making analysis undertaken to determine the optimal treatments, timing and associated cost. The results of the condition assessment provided the basis for identification of treatment options for each pipe element. The treatment options available for assignment to pipe elements are:

- Monitor and repair as required;
- Blast and recoat at joints;
- Cathodic protection;
- Line the pipe;
- Duplicate main with 800mm diameter pipe;
- Repair internal lining, internally clean and coat corroding/uncoated joints; and
- Replace at failure.

The number of treatment options available for each pipe element was dependent on the condition of the pipeline and the findings of the physical inspection. The monitor and repair option was assigned to those pipe elements that were in reasonable or good condition. Multiple options were assigned to pipe elements that exhibited varying degrees of failure.

3.5 Cost benefit analysis

The cost-benefit analysis for the treatment options for the WDP took the form of an Optimised Decision Making (ODM) analysis. ODM analysis is a clearly defined analysis method for the evaluation of the risk and the reduction of risk through implementation of maintenance procedures. The outputs of the ODM analysis define the most economic treatment and appropriate timing of treatment, taking into account the following:

- Risk cost reductions;
- Maintenance cost reductions;
- Operating cost reductions;
- Life extension;
- Treatment and treatment cost; and
- Discount factor.

The ODM analysis for the WDP system used a net present value analysis and the outputs from the analysis were consolidated into an overall asset management strategy for the pipeline.

3.6 Graphic Information Systems

For ease of assessing all the data on the pipeline a graphic information system (GIS) was used to capture and display the information gathered during the development of the strategy plan. The graphical map of pipeline system was linked to site photos, condition assessment data, soil corrosivity data, CCTV survey extent data, CCTV defect summaries, and coating defect survey data.

3.7 Process Summary

A summary of the overall methodology used in the risk and condition assessment process is summarized in Figure 3. This process combines engineering and scientific knowledge to produce a strategy plan for the pipelines.

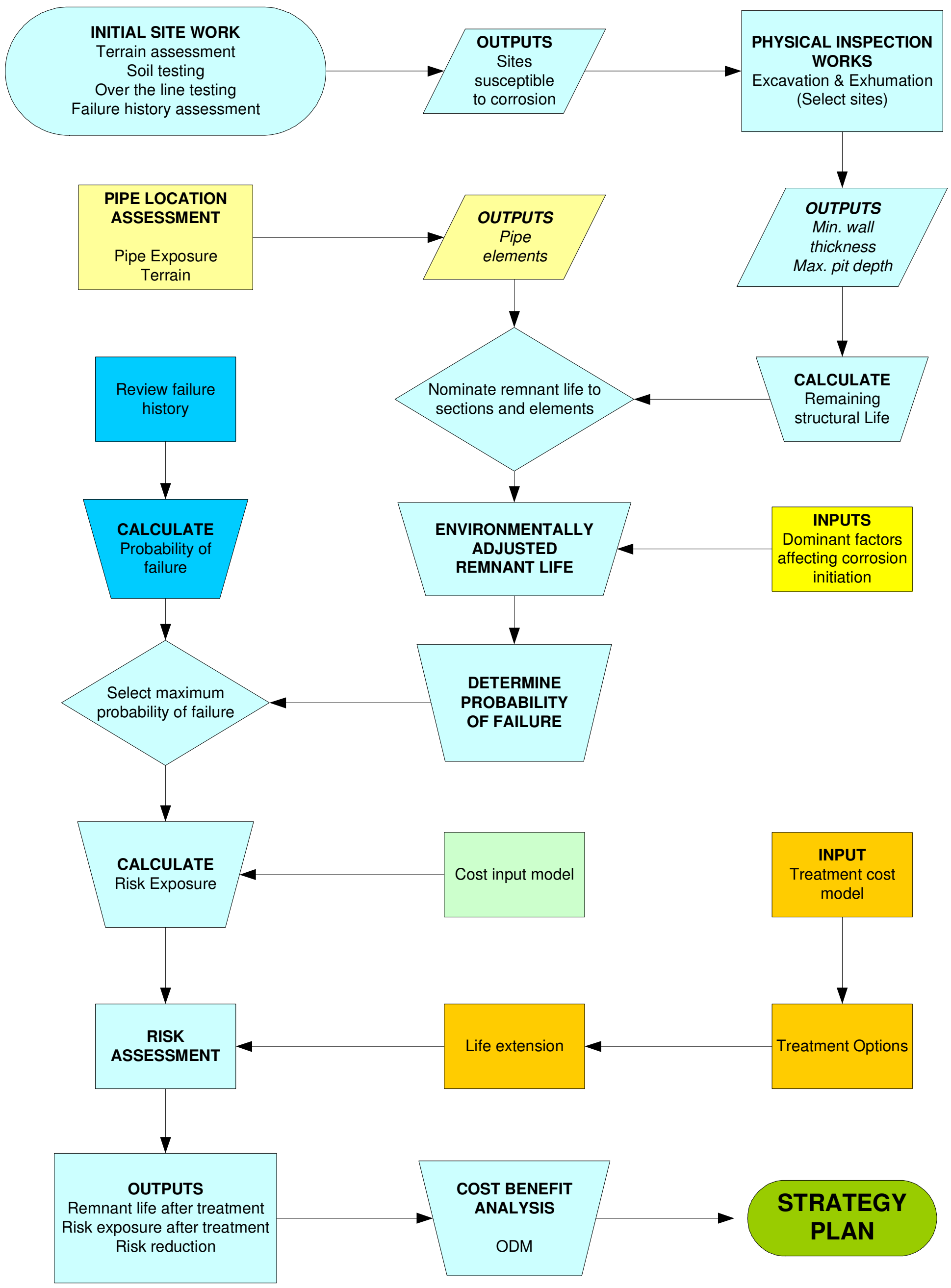

Figure 3: Condition and Risk Assessment Process Flow Diagram

4. DISCUSSION

4.1 Condition Assessment

The results of the inspection and testing program indicated that the condition of the pipeline was dependent on the following factors:

- Original quality pipe and joint coatings;
- Degradation of the pipe and joint coatings; and
- Corrosivity of the local environment.

These factors contribution to the variations noted in the overall condition of the pipeline. Most elements were found having a calculated remaining life between 3 to greater than 100 years. Perforations at two sites resulted in a local remnant life of zero years. This rating was given to the element containing the perforation where no other excavation data was available. This rating should be used to indicate that more data should be gathered, not that the section needs replacement, as the affect may be very localized. The analysis of failure modes indicated that economic failure (eg due to capacity or repair costs) was more likely than structural failure. The exception is the river flats section which has undergone extensive general wall thinning. Failure for economic not structural reasons became evident as a local failure of the pipeline due to corrosion is rarely expected to result in the total failure of the element. Most corrosion failures result in local perforation, not general thinning, and this can usually be repaired. Economic failure may occur when the capacity of the pipeline no longer meets demand or when the cost or number of local failures requiring repair becomes excessive.

4.2 Outcomes of ODM Analysis

The risk exposure was calculated for each of the thirty-eight elements. The elements that have a risk exposure greater than $20,000 are priority listed below in the Table 1 in order of greatest to least risk exposure.

Table 1: WDP Priority listing of element with risk exposure over $20,000

No.	Pipe Element	Priority
32	Davey St. Commercial	1 (Highest Risk Exposure)
12	Dodson St. Rail Crossing	2
33	Davey St. Commercial to Fitzroy Place	3
38	Southern Outlet Road Crossing to Lower Reservoir	4
37	Southern Outlet Road Crossing	5
20	Queens Domain to Domain Tanks	6
18	Highway Crossing New Town	7
17	New Town Rivulet to Highway Crossing (New Town)	8/9
13	Dodson St Rail Crossing to Elwick Pit Road Crossing	8/9
34	Fitzroy Place to Sandy Bay Rivulet	10
36	Sandy Bay Rivulet to Southern Outlet Road Crossing	11
25	Tasman Bridge	12
24	Tasman Bridge Road Crossing (West side of bridge)	13

These elements are considered the greatest risk for Hobart Water. Treatments that extend the life of the element reduce the risk exposure of the element. Suitable life extending treatments were identified for elements 12, 13, 32 and 33. For many of the other elements the best treatment involves monitoring and repairing on demand which neither extends the life of the element nor reduce the risk associated with a failure. The ODM analysis was conducted on elements where multiple treatment options were available. The outcomes from the ODM analysis is presented in Table 2.

Table 2: Outcomes from the ODM analysis

Element No.	Element Description	ODM Outcomes
11	Berriedale Pits to Dodson Street Rail Crossing	Based on the analysis, it is recommended that Hobart Water defer any capital works on this line and continue to monitor and repair the main for the foreseeable future.
12	Dodson St. Rail Crossing	It is recommended that a sacrificial anode cathodic protection system be installed at this crossing.
13	Dodson St. Rail Crossing to Elwick Pit Road crossing	It is recommend that cathodic protection be implemented in the short term with a program of CCTV inspection to be undertaken over a number of years to identify those areas of the pipeline requiring repair to the internal lining with subsequent cleaning and coating of corroding joints in the vicinity.
14	Elwick Pit Road Crossing	Cathodic protection provided the best return and is therefore the recommended treatment for this element.
28	Domain tanks to Brooker Avenue Road Crossing	At this time it is recommended that an ongoing monitoring program be implemented for this pipeline element.
29	Brooker Avenue Road Crossing	It is recommended that an ongoing monitoring program be implemented with the recoating of the joints undertaken as they are found.
30	Brooker Avenue Road Crossing to Brooker Avenue/Campbell St	It is recommended that an ongoing monitoring program be implemented with the recoating of joints undertaken as they are found.
33	Davey St. Commercial through to Fitzroy Place	It is recommended that the Davey St. commercial to Fitzroy place be investigated to undertake the relining of the pipeline however, based on available data, Davey St. commercial could be relined in the future as phase 2 of the project while Davey St. commercial through to Fitzroy St. would be phase 1.
38	Southern Outlet Road Crossing to Lower Reservoir (River Flats section only)	It is recommended based on the available data that the replacement of the main be undertaken in the next five years.
1	Hilton Road	Based on the available results, the recommendation is to externally coat the offtakes within the next five years.

4.3 AM Strategy

Based on the findings of the condition assessments and the outcomes of the risk and ODM analysis, an overall strategy was developed for the pipelines. This strategy identifies the treatments and timing of the treatments over the forthcoming years. The strategy developed for the West Derwent pipeline includes the treatments noted in Table 3 with the years the treatments should be conducted. For some sections it is recommended that monitoring includes conducting CCTV scans inside the pipeline element every five years.

Table 3: WDP strategy

Segment	Element No.	Element Description	Treatment Option	Year
A - B	2	Berriedale Pits to Oak Hill	Replace at end of life	2030
	3	Oak Hill	Blast and recoat at joints	Ongoing
	4	Oak Hill Residential	Blast and recoat at joints	Ongoing
	5	Oak Hill Residential to Islet Rivulet	Blast and recoat at joints	Ongoing
	6	Islet Rivulet	Blast and recoat at joints	Ongoing

Segment	Element No.	Element Description	Treatment Option	Year
	7	Islet Rivulet to Humphrey Rivulet	Monitor and repair if required	Ongoing
	8	Humphrey Rivulet	Monitor and repair if required	Ongoing
	9	Humphrey Rivulet to Recreation Reserve	Monitor and repair if required	Ongoing
	10	Recreation Reserve to Tolosa Dam	Monitor and repair if required	Ongoing
A - C	11	Berriedale Pits to Dodson St. Rail Crossing	Monitor and repair if required	Ongoing
	12	Dodson St. Rail Crossing	Sacrificial cathodic protection	2006
	13	Dodson St. Rail Crossing to Elwick Pit Road Crossing	Cathodic protection	2006
	14	Elwick Pit Road Crossing	Cathodic protection	2006
C - D	15	Elwick Pit Road Crossing to New Town Rivulet	Monitor and repair if required	Ongoing
D - E	16	New Town Rivulet	Monitor and repair if required	Ongoing
	17	New Town Rivulet to Highway Crossing (New Town)	Monitor and repair if required	Ongoing
	18	Highway Crossing (New Town)	Monitor and repair if required	Ongoing
	19	Highway Crossing (New Town) to Queens Domain	Monitor and repair if required	Ongoing
	20	Queens Domain to Domain Tanks	Monitor and repair if required	Ongoing
E - F	21	Domain Tanks to Botanical Gardens Road Crossing	Cathodic protection	2007
	22	Botanical Gardens Road Crossing	Monitor and repair if required	Ongoing
	23	Botanical Gardens Road Crossing to Tasman Bridge Road Crossing	Line or replace when necessary	2033
	24	Tasman Bridge Road Crossing	Line or replace when necessary	2024
	25	Tasman Bridge	1. Replace on failure. 2. External sleeve on failure	2043
	26	Tasman Bridge to Road Crossing (East)	Monitor and repair if required	Ongoing
	27	Road Crossing (East) to Riawena Road	Monitor and repair if required	Ongoing
E - G	28	Domain tanks to Brooker Avenue Road Crossing	Monitor and repair if required	Ongoing
	29	Brooker Avenue Road Crossing	1. Monitor and repair if required. 2. Replace coating with tape or paint	Ongoing
	30	Brooker Avenue Road Crossing to Brooker Avenue/Campbell St.	1. Monitor and repair if required. 2. Replace coating with tape or paint	Ongoing
	31	Brooker Avenue/Campbell St. to Davey St. Commercial	Monitor and repair if required	Ongoing
	32	Davey St. Commercial	Re-line in heritage zone	2007

Segment	Element No.	Element Description	Treatment Option	Year
	33	Davey St Commercial to Fitzroy Place	Re-line in heritage zone	2006
G - H	34	Fitzroy Place to Sandy Bay Rivulet	Monitor and repair if required	Ongoing
	35	Sandy Bay Rivulet	Monitor and repair if required	Ongoing
	36	Sandy Bay Rivulet to Southern Outlet Road Crossing	Monitor and replace as deterioration accelerates. - CCTV inspections every 5 years.	Ongoing
	37	Southern Outlet Road Crossing	Monitor and replace as deterioration accelerates. - CCTV inspections every 5 years.	Ongoing
	38	Southern Outlet Road Crossing to Lower Reservoir	Monitor and replace as deterioration accelerates. - CCTV inspections every 5 years. Replace River Flats section	Ongoing 2007
I - J	1	Hilton Road	Externally coat offtakes	2006-2011

5. OPTIMISATION OF THE STRATEGY PLAN

An asset management plan is a "live" document. It should be updated and modified as the level of knowledge increases regarding the performance of the pipeline. To optimise the asset management strategy plan that was developed for the WDP was recommended that the following actions were undertaken:

1. Implement the preferred treatments recommended in the years nominated in the pipeline strategy.
2. Implement the planned maintenance program.
3. Conduct additional inspections on the pipeline in areas where little data is available to provide more confidence in the risk assessment and recommended strategies. The areas of high risk exposure should initially be targeted for inspection.
4. Expand the program of data collection that is currently undertaken at failure sites and link the data into the GIS.
5. Instigate a program of regular CCTV inspections to expand the current knowledge of the internal condition of the pipelines.
6. Assess the current asset management practices and update to include current best practice to optimise the management of the pipeline system.
7. Link all captured data for the pipeline including financial, works management and GIS information.
8. Conduct further studies into the strategic improvements.

6. REFERENCES

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