INNOVATION IN PIPELINE ASSET MANAGEMENT

Sarah Seel, Sandy Muir and Russell Fox

Maunsell Australia Pty Ltd and Hobart Water

Abstract
In 2005, Hobart Water identified the need to assess the condition of one of its major assets, the West Derwent pipeline, and develop an asset management strategy for the pipeline. We believe the West Derwent Pipeline Condition Assessment and Asset Management Plan Project, was the first project of its type in Australia to adopt a "fully integrated approach" to the development of a 20 year asset management strategy. The project combined asset management, insitu testing with condition assessments, risk, criticality ratings and optimised decision making (ODM) analysis, to provide economically sustainable and manageable network solutions. The project combined a number of skill sets such as, asset management, advanced materials and GIS personnel, and Hobart Water operational staff and local contractors.

As well as a 20 year strategy for the pipeline, Maunsell developed the processes, methodology and provided the analysis to enable Hobart Water to undertake the same activities for its other assets. This transfer of knowledge and skill is seen by Maunsell as paramount in the ongoing development of improved asset management.

Key Words: fully integrated approach; condition assessment; corrosion; criticality; risk exposure; pipeline; ODM; GIS

Introduction
Distribution water mains are a critical component of the water supply networks. 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 supplies approximately 60% of the metropolitan water demand. Hobart Water, the owner and operator of the pipeline, has a responsibility to the community to ensure the continued supply of water to Hobart.

Typically, the assessment of bulk supply pipelines was limited to desktop technology and analysis of known failure records, largely due to monetary and access constraints. With this in mind, Hobart Water decided to extend the assessment of the West Derwent Pipeline (WDP), from this typical model, to include on-site field investigation work to validate the findings of a desktop review. Furthermore, this study would become a pilot to establish a methodology to be used to assess the whole of the distribution system.

Objectives of the Project
Hobart Water's project objectives were twofold.

The first objective was to undertake a condition assessment of one of its major pipelines and produce a strategic asset management plan for the pipeline that takes into account condition, criticality and risk.

The second objective involved creating a project template which would be used to conduct similar condition studies of all its major underground assets in the future.

Background and Asset Profile
The total length of this steel pipeline is 47.8km. It is a combination of single and dual pipelines along its total length. The majority of the pipeline was first installed in the 1960's, though a small section was installed in the 1920's.

Due to the gradual development of this pipeline system and the renewal processes, the properties and therefore the condition vary across the system. The properties of the pipeline are shown in Table 1.

Pipe type	Locked bar or welded steel
Age	1 – 83 years old
Diameter	450 – 810mm
Wall Thickness	4.7 – 8mm
Pipe Joints	Spigot and socket, rubber ring or welded joints.

Table 1: West Derwent Pipeline Properties

For the purposes of this project the pipeline was split into six segments which were based on major landmarks e.g. Berriedale Valve Pits and Tolosa Dam. Each of the segments were then further split into 38 “elements”. The elements represent a change in the pipeline’s characteristics such as a change in material or environmental conditions such as location, traffic etc.

Recommended West Derwent Pipeline AM Strategy

Based on the findings of the condition assessments and the outcomes of the risk and ODM analysis discussed in the following sections, an overall strategy was developed for the pipeline. This strategy identified the treatment options and timing of the treatments, and takes into consideration risk and cost over the next 20 years.

The strategy developed for the West Derwent pipeline included the treatment options and timing shown in Table 2.

Segment	Pipe Element	Treatment Option	Year
A - B	Berridale Pits to Oak Hill	Replace at end of life	2030
A - C	Dodson St. Rail Crossing	Sacrificial cathodic protection	2006
	Dodson St. Rail Crossing to Elwick Pit Road Crossing	Cathodic protection	2006
	Elwick Pit Road Crossing	Cathodic protection	2006
E - F	Domain Tanks to Botanical Gardens Road Crossing	Cathodic protection	2007
	Botanical Gardens Road Crossing to Tasman Bridge Road Crossing	Line or replace when necessary	2033
	Tasman Bridge Road Crossing	Line or replace when necessary	2024
	Tasman Bridge	Replace on failure. External sleeve on failure	2043
E - G	Davey St. Commercial	Re-line in heritage zone	2007
	Davey St. Commercial to Fitzroy Place	Re-line in heritage zone	2006
G - H	Southern Outlet Road Crossing to Lower Reservoir	Replace section	2007
I - J	Hilton Road	Externally coat offtakes	2006

Table 2: West Derwent Pipeline Strategy

Hobart Water intends re-running the ODM with updated data at 5 yearly intervals, or as needed. Triggers to re-run the ODM may include:

- Changes to risk exposure;
- Timing of treatment; and
- Options for new treatments requiring an assessment.

Many of the processes developed in this project have been subsequently adopted by Hobart Water and used to manage other Hobart Water assets.

The Approach

The approach taken is summarised in Figure 1 and is described in detailed in the following sections.

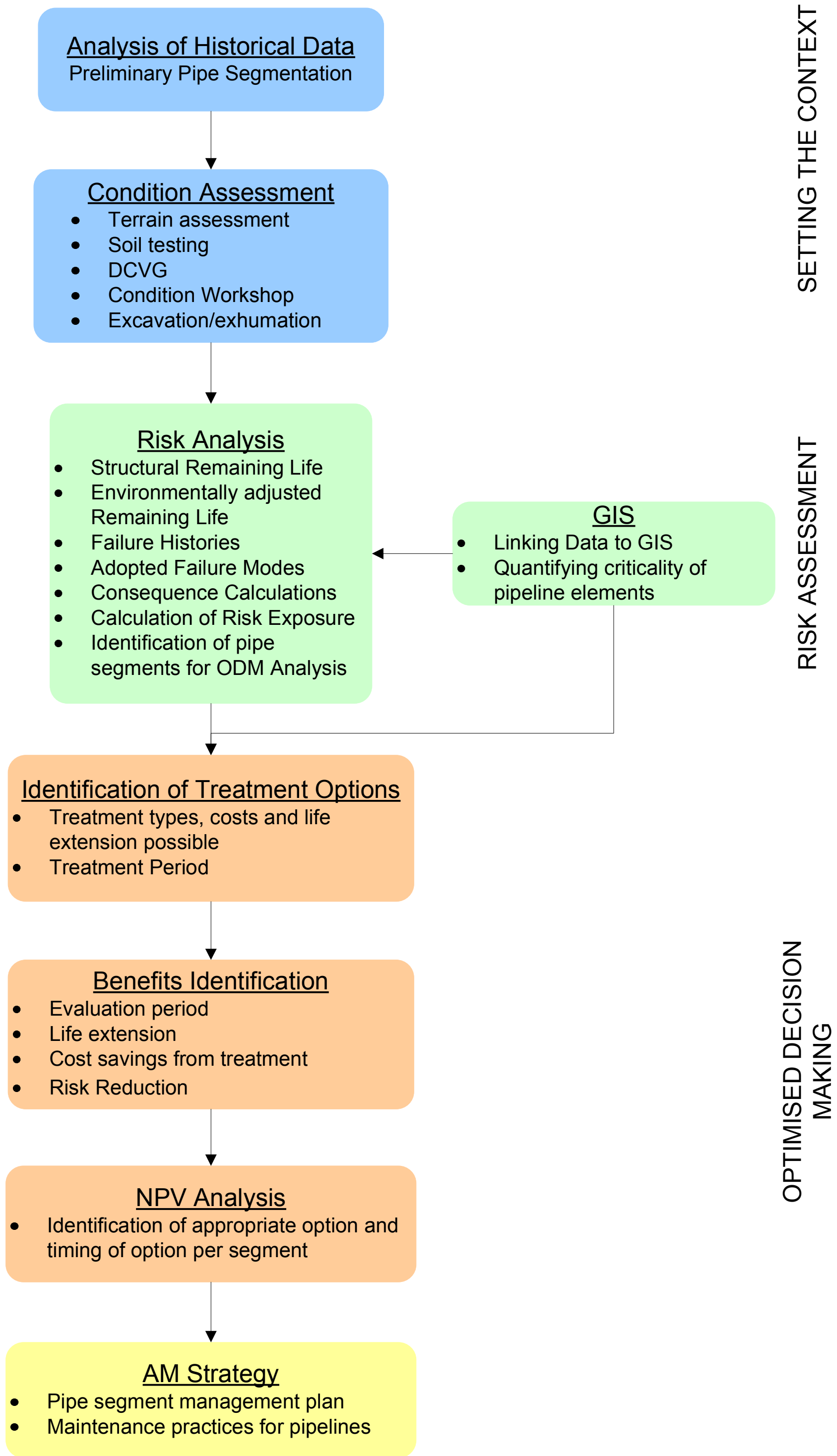

Figure 1: West Derwent Pipeline Strategy

Analysis of Historical Data

The assessment of historical information regarding 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 occurred in the pipeline system. The locations of all previous failures (leaks and bursts) were recorded using GPS equipment and logged on the Geographical Information System (GIS).

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

Condition Assessment

The current condition of the pipeline was investigated using a range of non-destructive and destructive testing techniques, and involved three stages.

Stage 1 involved assessing the buried environment at pipe depth along the pipe route, and assessing the condition of the pipeline coating. The ANSI/AWWA standard C105 (1) for DICL pipe was selected for the assessment of the corrosivity of the soil environment around the pipeline. This standard provides a point system for soil characteristics including resistivity, pH, redox potential, presence of sulphides and moisture. Using the point system, a cumulative total of 10 or more points is considered to indicate that the soil is corrosive to the steel pipeline. The coating defects survey was also carried out for fully welded sections or above ground sections of the pipeline.

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 selected sites the external surface of the pipeline was assessed at the crown and invert for wall thickness, and depth and distribution of corrosion pits, following removal of the pipeline coating. Examples showing the variation in the condition of similar aged pipelines are shown in Figures 2 and 3.

Figure 2: Pipeline with several small perforations located in a highly aggressive environment with defects in the pipe coating.

Figure 3: Pipeline in very good condition showing no evidence of corrosion. The pipeline was located in a slightly aggressive environment with no defects in the coating.

At multiple locations coupons were removed from the pipeline to enable physical assessment of the internal condition of the pipeline. High resolution CCTV cameras were inserted after coupons were removed and the condition of the internal coating was inspected upstream and downstream of the point of entry. The CCTV inspection system utilised was able to clearly indicate the location of:

- Longitudinal cracking;
- Circumferential cracking;

- Loss of lining material;
- Erosion of mortar lining at offtakes;
- Misaligned joints; and
- Sites of perforation/inflow.

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 in steel pipe.

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

While the condition of the pipeline material was used to determine the initial remaining life there are environmental factors that also influence the life of the pipeline. The factors used to adjust the remaining life were:

- Aggressive soil;
- Condition of Coating; and
- Ground Conditions (Wet or dry).

Use of the Geographical Information System (GIS)

For ease of access and assessment of all the data on the pipeline GPS was used to capture pipeline location and GIS was used to display information gathered during this project. Information linked to the pipeline on the GIS included:

- Site photos;
- Condition assessment data;
- Soil corrosivity data;
- CCTV survey extent data;
- CCTV defect summaries;
- Criticality and risk assessment; and
- Coating defect survey data.

An example of the excavation locations and criticality and risk assessment data displayed on the GIS is shown in Figure 4 and 5.

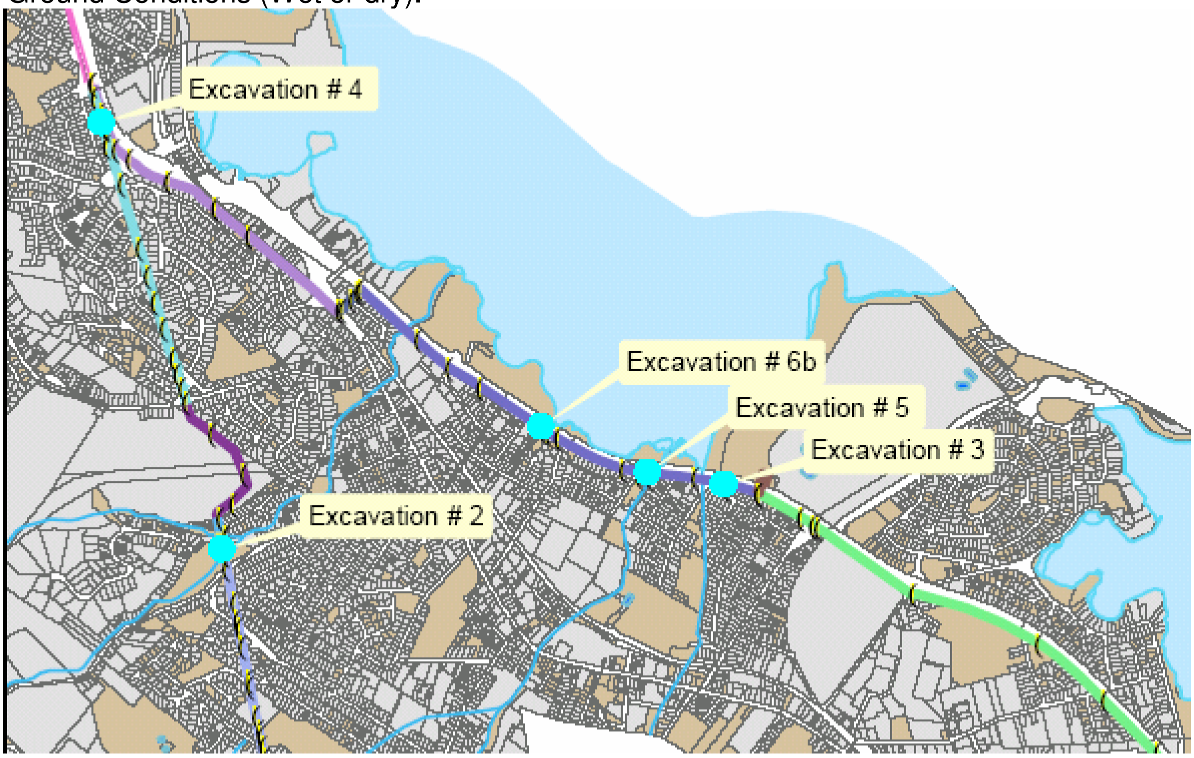

Figure 4: GIS map showing some of the physical inspection locations.

Criticality Assessment

The first step of the risk analysis was to determine which segments were critical to Hobart Water's business. The definition of a critical asset is:

Assets that would prevent the business from achieving their business objectives and severely disrupt the operations of the business should they fail.

This would then allow Hobart Water to focus on the critical pipe elements.

The factors that influence criticality relate to the asset's surrounding environment and the function it performs with respect to optimising services. Using this as the basis of quantifying criticality at Hobart Water the following parameters 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 was rated individually for each pipe element 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 impact on the business should they fail.

The criticality analysis identified critical elements along the pipelines length and there were a small number of elements where it was decided to undertake a risk assessment. This was used to assist in the identification of pipe elements for further analysis.

The criticality of each element was plotted on the GIS and the results of this assessment are shown in Figure 5.

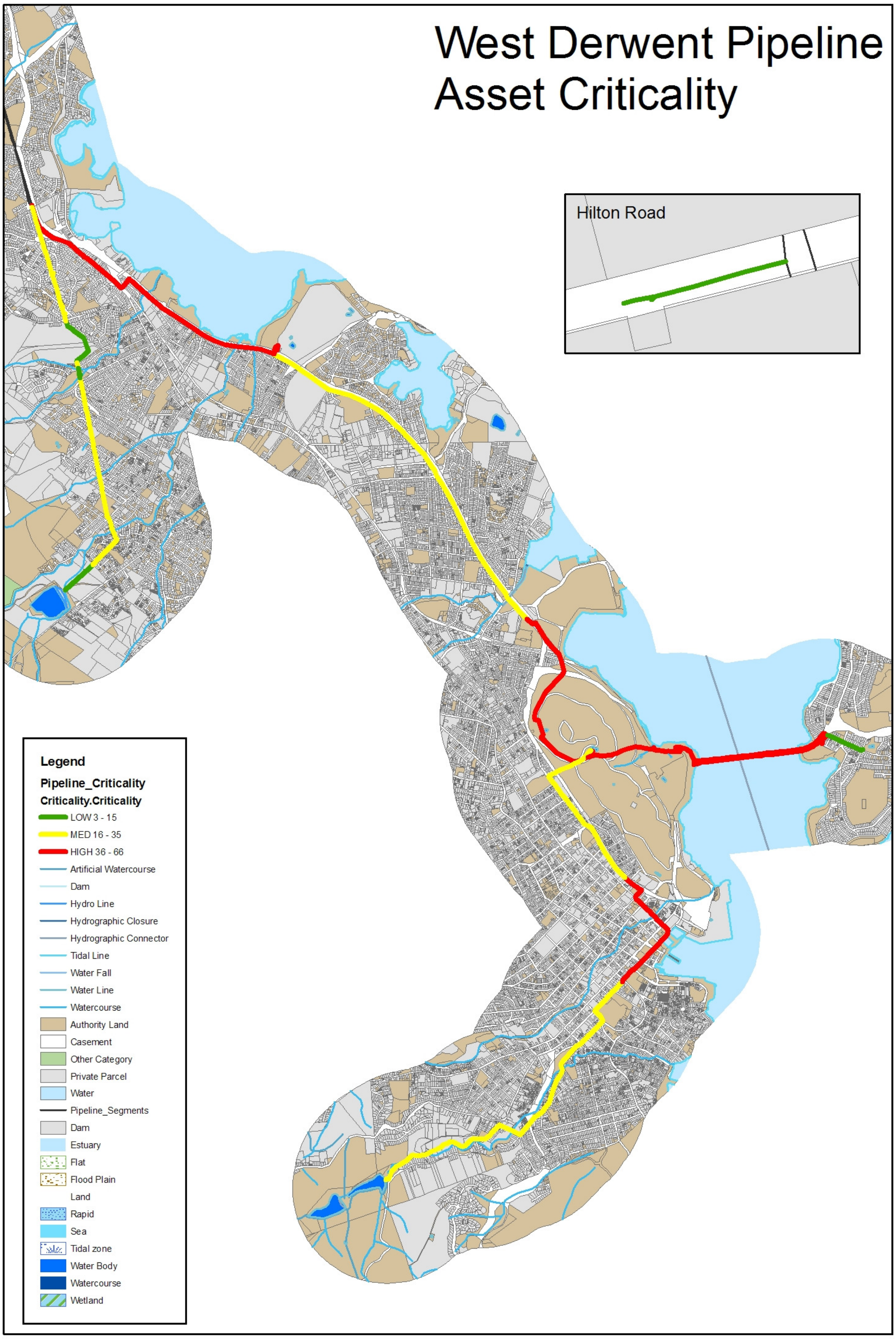

Figure 5: West Derwent Pipeline Asset Criticality

Risk Analysis

The risk exposure was calculated using the following formula for each element and this represents the cost associated with the risk of failure for each element.

Risk Exposure = Consequential cost of failure x Likelihood of failure.

The consequences of risk considered during this analysis assessment of the pipelines included:

- Physical damage to the pipeline;
- Property damage;
- Environmental damage;
- Loss of revenue; and
- Public relations damage.

For the purposes of the analysis, it was assumed the pipe failure would occur in the location that could result in the greatest consequence along the pipe element.

The risk exposure was calculated for each of the 38 elements. The elements of the WDP that had a risk exposure greater than $20,000 were priority listed below in Table 3 in order of greater to least risk exposure. These elements were considered the greatest risk for Hobart Water.

Pipe Element	Priority
12	1 (Highest Risk Exposure)
20	2
18	3
17	4
13	5
25	6
24	7

Table 3: Priority listing of pipe elements with risk exposure over $20,000

ODM Analysis

An optimised decision making (ODM) analysis was undertaken to determine the optimal treatments, timing and associated cost.

The ODM analysis was conducted on elements where multiple treatment options were available and risk exposure was high. For each pipe element the different treatment options were analysed using the ODM model and the outputs of the analysis were consolidated into the overall AM strategy for the pipeline.

Treatment Options

The treatment options available for assignment to pipe elements were:

- Monitor and repair as required;
- Blast and recoat at joint;
- 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 segment was dependent on the condition and type of pipe element. 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.

Treatment options that extend the life of the element reduce the risk exposure of the element. Suitable life extending treatments were identified for four pipe elements. For many of the other elements the best treatment involved monitoring and repairing on demand, which neither extends the life of the element nor reduce the risk associated with a failure.

ODM Model

An ODM model was developed by Maunsell using a simple excel spreadsheet to define the most economic treatment and appropriate timing of the treatment. The results took into account the following inputs into the model:

- Risk exposure reductions of applying the treatment;
- Maintenance cost reductions of applying the treatment;
- Operating cost reductions of applying the treatment;
- Life extension;
- Treatment cost;
- Discount factor; and
- Useful life.

Sample outcomes from the ODM analysis are presented in Table 4.

Pipe Element Description	ODM Outcomes
Berriedale Pits to Dodson Street Rail Crossing	Based on the analysis, it was recommended that Hobart Water defer any capital works on this line and continue to monitor and repair the main for the foreseeable future.
Dodson St. Rail Crossing	It was recommended that a sacrificial anode cathodic protection system be installed at this crossing.
Dodson St. Rail Crossing to Elwick Pit Road Crossing	It was 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.
Elwick Pit Road Crossing	Cathodic protection provided the best return and was therefore the recommended treatment for this element.
Hilton Road	Based on the available results, the recommendation was to externally coat the offtakes within the next five years.

Table 4: Outcomes from the ODM Analysis

Operations and Maintenance Improvements

In addition to the capital works projects, recommendations were also made on the operational and maintenance improvements needed to maintain the condition of the pipeline. These are shown in Table 5.

Activity	Frequency
Monitoring and inspections - Check for leaks along the main - Open pits and inspect for leaks - Clean corrosion and paint/wrap (recoat) on repair - Check flanges for corrosion - Walk pipeline and maintain test points	Ongoing
Bridge – inspect expansion joints	Yearly
Pipeline swabbing and check for lining in flushed water	6 months
Clean pits and keep dry	Ongoing and check 6 monthly
Repair corrosion damage found in pits	Ongoing

Table 5: Outcomes from the ODM Analysis

On Reflection

In undertaking a project of this nature, the following need to be considered:

- Representative test pits are needed to increase the level of confidence in the results. This would permit a high degree of confidence in the assumptions made regarding the pipeline condition. In assessing test pit sites, factors that should be accommodated include:
  - Surrounding environment e.g. proximity to water courses (salt and freshwater);
  - Type of soil; and
  - Soil moisture content.
- On-site work needs to be managed to reduce the risk of budget and time over-runs. Activities that need to be taken into account when setting the timeline for on-site work are:
  - Obtaining permits;
  - Road closures;
  - Bad weather;
  - Shut-off time and notification of customers; and
  - Locating 3rd party services.
- To improve confidence in the process there is a need to collect and retain failure histories.
- As this activity can be an expensive proposition, integrated planning is required to ensure a co-ordinated approach is delivered.
- Use of different skills and tools i.e. GIS, asset management, operations, contractors require extensive co-ordination to manage the total process. There is a need to stay focused on the required outcomes.
- Need to recognise both qualitative and quantitative data in the initial activity to gather sufficient data.
- When a break occurs along a main there is an opportunity to view an underground section of pipe. The following types of testing may be applied:
  - Pit gauge measurements;
  - Steel thickness measurements;
  - Soil resistivity; and
  - Soil to pipe potential.
- It is not the end, it is the beginning. Established processes and data

requirements during the project need to be retained for ongoing analysis.

Conclusion

The Asset Management Strategy Plan for the WDP was developed in conjunction with a criticality rating system, a methodology for assessing the condition of the water pipeline, a risk assessment methodology and an ODM analysis system.

The technology for these tools was transferred to Hobart Water to enable them to update and modify the strategy plan and optimise the performance of the water pipeline.

The implementation and future use of the plan and associated technology tools will ensure the long term supply of water to Hobart via the West Derwent Pipeline.

Epilogue

The report recommended the immediate installation of a cathodic protection system on pipeline section A-C. The design is now complete, with an impressed current cathodic protection system proposed, with an offshore silver anode bed. Liaison with infrastructure owners regarding the installation of the new system has commenced. Finance was included in the 2006/07 budget to complete the identified work. For example, work to upgrade the pits as recommended in the report is now underway, with the priority work already complete.

Hobart Water will continue to address the recommendations in this report over the remaining life of the asset.

References

(1) ANSI/AWWA C105/A21.5-99: Polyethylene encasement for ductile-iron pipe systems.

(2) L.L.Shreir (Ed), R.A. Jarman (Ed), G.T. Burstein (Ed): Corrosion, Butterworth-Heinmann Ltd, 1994.

(3) Maunsell Australia Pty Ltd, Condition Assessment of the West Derwent and Associated Lines Asset Management Plan, December 2005.

(4) Hobart Water, Consultant Brief for the Engagement of a Consultant to Undertake a Condition Assessment of the West Derwent Pipeline and Associated Lines, 2004.

About the Authors

Sandy Muir

Sandy is a civil engineer with 25 years experience covering a diverse range of infrastructure assets. Sandy was a principal author of the International Infrastructure Management Manual and principal author of the Optimised Decision Making Manual produced by INGENIUM in New Zealand. He has been active in asset management having been involved in its growth in the Australian and New Zealand market since 1989.

In recent years, Sandy has assisted many clients in developing their capabilities specifically in the field of Asset Management Systems, Implementation, Strategy development and guiding clients through the improvement process.

Sandy was the technical advisor on this project and guided the Maunsell team through the analysis process.

Sarah Seel

Sarah Seel is a senior consultant with Maunsell Australia. Sarah has ten years experience in the field of asset management in Australia and New Zealand. Since joining Maunsell Sarah has been involved in projects that include asset valuations and reviews, AM plan preparation, AM status reviews and improvement plans.

Sarah’s strategic approach and problem-solving skills have been used extensively on a variety of projects and has taken a primary support role on several leading edge projects for advisory services. In this project Sarah developed the Optimised Decision Making tool and was responsible for the ODM analysis.