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PAPERS

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DHV wins major drinking water contracts in Vietnam

Dutch engineering and consultancy firm DHV has won two contracts to improve the drinking water supply in southern Vietnam.

DHV has been commissioned to design two water treatment plants, a pumping station, and up to 150km of potable water pipelines.

The first contract involves an expansion of the drinking water supply system in Ban Tre province where DHV will also work on a new pumping station with a capacity of 5000 to 10,000m^3/day.

The second project is in the Ba Ria Vung Tau region near Ho Chi Minh City, and is aimed at providing a clean water supply to the rural population.

In addition to the designs and technical specifications, DHV will also undertake environmental impact assessments and socio-economic studies for both projects. ●

Mott Mac wins Africa MDG investment study contract

Mott MacDonald has been appointed by the European Investment Bank (EIB) to undertake multi-country preparation studies for investments in the African water sector. The studies will take place across Burundi, Ghana, Rwanda and Zambia and will contribute to their plans of action for achieving the relevant Millennium Development Goal.

Preparation studies will be identified and conducted to develop a series of projects that could be supported by EIB and other potential financiers. As part of phase one, Mott MacDonald's team will carry out a review of already-identified projects and identify gaps in the preparation studies for these projects.

Phase two will involve undertaking detailed studies to determine the technical, financial, social and environmental viability of the proposed projects. ●

Legislation to reduce lead in plumbing fixtures enacted

The US' President Obama has signed into law the Reduction of Lead in Drinking Water Act, which amends the Safe Drinking Water Act and significantly reduce the amount of lead in drinking water supplies.

The AWWA hailed the move, saying: 'The American Water Works Association (AWWA) will support implementation of the bill signed by President Obama and pledges to work with its membership to help reduce the amount of lead in water supplies.

'Minimising potential sources of lead helps assure that high quality drinking water delivered from treatment plants remains safe after it reaches our homes, schools and businesses.

'Controlling lead exposure in tap water requires a sustained commitment from manufacturers who create fixtures, water providers who optimize corrosion control, and consumers, who can take simple steps to reduce exposure at home. AWWA will continue to provide guidance in each of these areas as part of our longstanding commitment to protect public health.'

The law allows a 36-month implementation period after which manufacturers and importers will have to comply with the new standard, which reduces the level of permissible lead content in the composition of plumbing fixtures from 8% to 0.25% nationwide.

This level is consistent with the 2006 law passed in California, and subsequent legislation in Vermont and Maryland. ●

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Mott Mac wins climate resilience planning contract

Engineering consultancy Mott MacDonald has been appointed by the Asian Development Bank (ADB) to undertake climate resilience planning and capacity building in Tajikistan. The studies form part of the joint ADB, European Bank for Reconstruction and Development (EBRD) and World Bank Pilot Programme for Climate Resilience in nine countries around the world.

Mountainous, landlocked Tajikistan is among the countries most vulnerable to climate change, and is suffering worsening weather conditions, more frequent floods and droughts, increasing glacier melt, combined with already frequent earthquakes, landslides and avalanches, says Mott MacDonald.

Mott MacDonald's role, as technical consultant, involves assessing the vulnerability of Tajikistan's water sector assets to climate impact. This will include identifying and prioritising vulnerable communities, ecosystems and infrastructure.

The consultancy will be required to develop adaptation and mitigation measures for climate change, based on downscaled hydroclimate impact models.

The company will demonstrate ways to integrate climate risk and resilience into core development planning as well as prepare sector-based hazard management investment plans. ●

EBRD and TASK join to increase private sector participation

The European Bank for Reconstruction and Development (EBRD) and TASK Group, a privately owned group that specialises in water and waste-water management, have joined forces to increase private sector participation in Turkey's mainly-municipally owned water and wastewater sector.

The bank is extending two loans to TASK Group companies worth a total of €16 million ($21 million) to finance TASK's planned investments.

The first two loans have been signed with TASK Güllük and TASK Dilovasi, two regional branches of TASK Group.

EBRD's director for municipal and environmental infrastructure, Jean-Patrick Marquet, said these were the first EBRD loans in Turkey's municipal sector, providing long-term funding for securing investments in water and wastewater.

He added: 'Our financing is helping a domestic private water operator develop its business and expand private sector participation in the water and wastewater sector in Turkey. With the EBRD's support, TASK will be able to provide a major improvement in water and wastewater services for the people in these regions.' ●

Veolia wins management services contract

Veolia Water has won a contract to provide co-management services to the Sultanate of Oman's water sector on behalf of the Public Authority for Electricity and Water (PAEW). This is a five-year contract, with a two-year extension option.

In addition, the state-owned Majis Industrial Services Company has entrusted Veolia Water, through Azaliya Water Services, with a 'strategic alliance partnership'– a six-year contract for the operation, maintenance and management of water in the Omani port of Sohar.

Veolia Water will provide PAEW with experienced operational staff to oversee operations and also experts for specific projects to develop IT systems, documentation and operational performance. ●

EIB agrees loan for water and wastewater project

The European Investment Bank (EIB) has signed an agreement with Syria for a €55 million ($74 million) loan to help the country develop modern water supply, wastewater collection and treatment infrastructure in its north western region.

The work is part of the European Union Horizon 2020 initiative, one of the priorities for the Union for the Mediterranean (UfM), which aims to tackle major sources of Mediterranean Sea pollution by 2020.

The project will improve water and wastewater services for over 370,000 inhabitants of 200 villages and will improve environmental sustainability by reducing wastewater discharges into the Mediterranean Sea.

The project area includes the city of Banias and surrounding villages, and villages in the four river catchments of Hreisun, Jobar, Al Ghamkah and Al Dabousiah, which drain into the Mediterranean Sea.

The funds will contribute to various improvements, including rehabilitation and upgrading of existing infrastructure for groundwater abstraction, focusing on the Banias catchment area, where the aim is to reduce leakage from the current 70% to 40%.

The funding will also help develop and upgrade separate systems for domestic wastewater and stormwater and construct a wastewater treatment plant for the town of Banias and the two river basins of Hreisun and Jobar, as well as a further six wastewater treatment plants in Al Dabousiah and Al Ghamkah. ●

Is asset management just for developed nations?

Although there is a large focus on asset management in developed countries, the management of assets in developing countries is not discussed as often. In this article, Jo Parker explains the challenges of asset management in low and middle income countries, and the need for area-specific approaches to achieve the greatest success.

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Most asset management articles discuss how high value assets in highly developed countries, which are essential for the maintenance of daily life, can be managed for the least cost. They describe sophisticated management techniques and the latest IT systems that optimise maintenance and expenditure, and are accompanied by images of gleaming transport systems, power installations and water plants. So you might be forgiven for wondering whether asset management is practiced or even relevant in developing countries.

The fact is, they have large numbers of assets. They may not always look like the ones in developed countries – a village water system in India is likely to be rather different from one in the UK, and construction and maintenance techniques may vary – but many of the infrastructure assets will be based on technology familiar to those from Europe, USA and Australia, and indeed may well have been installed using standards developed elsewhere.

In most developed countries, proactive asset management is encouraged or even required by regulators, and risk management, criticality assessment, capital expenditure optimisation and regularly updated asset management plans are very much 'business as usual'. It is seen as the best way to get best value from asset-intensive industries and meet stakeholder needs. Asset management policies and procedures may be scrutinised by public bodies and failure to have detailed records can lead to serious consequences. For instance, in the case of a water quality incident in the UK, maintenance and operation procedures may be cited in order to demonstrate that due diligence was observed.

In his presentation to the Infrastructure Asset Management Exchange in 2004, David Openshaw of EDF pointed out that performance of the infrastructure affects a country's economy, environment, gross domestic product (GDP), productivity, manufacturing costs, business confidence, inward investment, disposable income, public safety, quality of life and the 'feel good factor'. There is no doubt that water and sanitation services can be considered as essential for all these aspects of a country's performance.

Poor asset management can have a huge impact on the lives of people in developing countries... It is difficult to develop asset management plans for the future, or even the next year, when failures are occurring today.

However, is this true in developing countries? They too are trying to build their GDP, attract inward investment and encourage business confidence, and there is an even greater need to increase disposable income and the quality of life. While public safety and the environment sometimes appear to have to take a back seat, there can be just as much concern for these in developing countries – even if there is not the means to improve performance.

Challenges facing AM in low and middle income countries

In low and middle income countries, there are huge demands on the existing water infrastructure, which can barely meet even quite basic standards. In Delhi (India), Dhaka (Bangladesh) and Kathmandu (Nepal)[1], only one percent of connected people enjoy a continuous water supply. Many low-income areas have little or no service whatsoever, and in some rural areas water collection is a time-consuming and arduous process, which diverts members of the community, particularly women and children, from more constructive activities such as income generation and studying.

These problems are exacerbated by poor asset management. In the case of water supply, a lack of maintenance and poor investment decisions can lead to higher losses from the system and higher running costs. These in turn lead to less water being available for sales and, therefore, less income and loss of other essential services such as electricity. It is a vicious circle with services gradually deteriorating unless a means can be found to interrupt the cycle.

Poor asset management can have a huge impact on the lives of people in developing countries, and, sadly, many things can get in the way of improving it. Often, there are pressing immediate needs, and a 'fire fighting' approach can get in the way of longer-term planning. It is difficult to develop asset management plans for the future, or even the next year, when failures are occurring today.

Politicians and engineers also love building large structures and installations, and opening a new plant will always make more headlines than changing even thousands of inaccurate customer meters.

Funders can be equally unhelpful, promoting expenditure on new assets in preference to renovating existing assets, or providing much-needed spares. And, often, the future maintenance of new installations is not always taken into consideration. On one project I have been managing in Madagascar, obtaining spares for the repair of pumps has proved difficult even for me with my easy access to the internet and fluent understanding of both English and French. The engineers in the water utility, with far more limited means, just did not know where to start. Importing goods was complicated, and even once the materials had arrived in Madagascar, clearing customs was a lengthy process and required extreme patience if you decided not to expedite it with unofficial payments.

Sadly, many utility and service organisations in developing countries do not have access to the same level of technical, business and management training as those in developed countries, and even quite simple concepts such as business planning and risk assessment may be new to managers. In Indonesia, staff working for water utilities in major cities who have supposedly obtained degree-level engineering qualifications, struggle with the most basic concepts of mathematics and fluid mechanics. In other countries, superbly trained engineers are thirsty for knowledge but they do not have access to the continuing professional development that is the norm for their peers in developed countries.

IWA's role

IWA is starting to recognise these issues and a small group of members working in developing countries, or 'low and middle income countries' (LAMIC) have established an advisory group to help promote participation and learning amongst these countries, in a similar way to that of the Young Professionals Network, which seeks to promote participation by young people in the industry.

At a recent meeting of the LAMIC advisory group, established by the IWA, a manager from an African water utility described how he had established a planning department, which would focus on developing project proposals for future schemes that could be submitted to funding agencies. When he first set up the team, his colleagues questioned why it was needed. Now they are following his example. Examples like this can help develop the expertise in other low and middle income countries, and it is to be hoped that papers detailing such successes will feature on IWA conference agendas alongside the papers giving details of the sophisticated techniques which push the boundaries elsewhere.

The need for case-specific training

In some cases, scientists and engineers may pursue their training overseas and gain excellent degrees, only to find that many of the approaches they have been taught are inappropriate back in their country. Some materials may not be available, climatic conditions may well mean that standard practices from the developed world cannot or need not be used, and construction techniques may be completely different. How many European civil engineering courses give any reference to bamboo scaffolding? Any country where freezing temperatures are never encountered will have a different view on how water mains should be installed to a country where temperatures below zero are routinely met. The whole life cost of some local construction techniques and methods may be far lower, even if at first sight they do not appear to be as robust.

Considering the optimum regime of maintenance, monitoring performance and making provision for the eventual renewal of an asset is just as necessary for a hand pump serving rural Africa as it is for a state-of-the-art filtration plant in Europe.

Where training is provided, some consultants do not consider their audience or tailor their course to meet specific needs. It is no use discussing criticality analysis if even basic breakdown maintenance is not being carried out. It is no good considering how to prioritise mains for renewal when the water utility does not even have the money to buy basic repair materials.

The concept of risk can be very difficult to convey in some cultures where consideration of future possible events is not usually part of their mentality. Similarly, long-term planning is a completely alien concept in some cultures and needs more explanation than in others. Maintenance simply may not be part of the culture, and team work and co-operation might be less ingrained.

In spite of these differences, the basic concepts of asset management apply worldwide. Considering the optimum regime of maintenance, monitoring performance and making provision for the eventual renewal of an asset is just as necessary for a hand pump serving rural Africa as it is for a state-of-the-art filtration plant in Europe.

Thankfully, many non-governmental organisations do take these requirements into account, and some are starting to train utilities in such subjects as business planning and asset management. The World Bank Institute supported the development of a specialist training package in asset management for water utilities, which has been delivered in a number of developing countries, each time being customised to focus on some of the critical issues for that country.

Quite small changes in procedures can have a huge impact on operations. For example, establishing a regime of leakage monitoring and repair, with a well-managed store of repair materials, can start to reduce losses and provide more water for additional communities. Compiling a sensible business plan, which identifies and prioritises capital expenditure and operational costs, can be used to educate the authorities who make decisions regarding charging regimes.

More importantly, any water utility which can demonstrate that it is managing its assets responsibly to optimise service and minimise cost and risk is much more likely to be able to attract funding from the development banks and other such agencies. Asset management plans can demonstrate to a funding agency that it has considered the future and has a strategy which will ensure that once the investment outcome is delivered, whether it is a new treatment plant, water resource development or a non-revenue management plan, the benefits will continue to be delivered.

Asset management is without doubt just as powerful a concept for developing countries as in the developed world, provided care is taken in how it is applied. The water utility in Senegal was one of the first in Africa to obtain ISO 9000 accreditation. I wonder who will be the first to gain PAS55. ●

Note

[1] Janssen, J. (2008) 'Strategic Asset Management (SAM) at the utility level'. IWA World Water Congress and Exhibition, Vienna, Austria.

Optimizing asset management decisions: a risk-based approach to capital investment

Australia's State Water Corporation, in order to meet its service and business requirements, undertook an assessment of if its assets in order to identify the expected remaining life of the assets, estimate a forward programme of asset renewals, and identify assets requiring more detailed investigation in the short-term. Amit Chanan, Stephen Farrelly, Jaya Kandasamy and Sarvanamuthu Vigneswaran discuss the asset management process used.

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Jaya Kandasamy and Sarvanamuthu Vigneswaran, Faculty of Engineering & Information Technology, University of Technology, Sydney, Broadway, NSW, Australia.

State Water Corporation is a bulk water delivery business in regional New South Wales (NSW), in Australia. State Water Corporation (State Water) was established as a State Owned Corporation on 1 July 2004, under the provisions of the State Water Corporation Act 2004. State Water owns and operates major infrastructure assets that enable delivery of an average of 5500 GL of water per annum. River operations, headwork storage operation and delivery of water are underpinned by asset and commercial management practices that support State Water's business.

State Water's diverse assets portfolio is worth AUS$3.6 billion (Modern Engineering Equivalent Replacement Asset value, as at July 2008). These include 20 major dams, 280 weirs and regulators, over 200 buildings and numerous minor assets such as plants and equipment to provide water to customers.

State Water's organisational context, including regulatory environment, is depicted in Figure 1. State Water operates in a highly regulated environment. The main statutory and regulatory instruments are:

- State Water Corporation Act 2004
- State Owned Corporation Act 1989
- Dams Safety Act 1978
- NSW Water Act 1912
- Water Act 2007 (Commonwealth of Australia)
- NSW Water Management Act 2000
- Environmental Planning & Assessment Act 1979
- Fisheries Management Act 1994

The NSW government grants an operating licence, which authorises State Water 'to capture, store and release water; and to construct, maintain and operate water management works'. The term of the operating licence is three years. On behalf of the NSW government, the Independent Pricing and Regulatory Tribunal (IPART) regulates State Water's water pricing as well as audit the performance against the operating licence. Under part 4 of the State Water Corporation Act 2004, IPART undertakes audit of this licence at times directed by the portfolio minister. In late 2008, IPART completed such an audit and State Water's operating licence was renewed until 2013.

The Department of Environment Climate Change and Water (DECC&W) is the natural resource manager in NSW, and it provides State Water with a licence to access and use water by means of a works approval. This legislative arrangement of keeping a natural resource manager and a separate water operator minimises conflict between water resource management and operational activities. The Department of Industry and Investment (DII) is responsible for the administration and implementation of the Fisheries Management Act 1994. The DII regulates the impact of State Water river structures on fish migration, and works with State Water in developing likely improvement actions in relation to these assets.

Under the state owned corporation model, the NSW Treasury is a shareholder, and State Water is required to provide the Treasury with return on and of assets. State Water is required to run its business with the goal of 'maximising the net worth of the State's investment in the Corporation'.

Strategic asset management planning

The NSW Treasury (2006) published the total asset management plan (TAMP) policy and guidelines to assist State agencies develop their TAMPs. These guidelines were introduced to achieve better planning and management of the State's physical assets, both existing and planned. The TAM policy advises government agencies to develop an asset strategy that supports the provision of services.

In line with the TAM policy, State

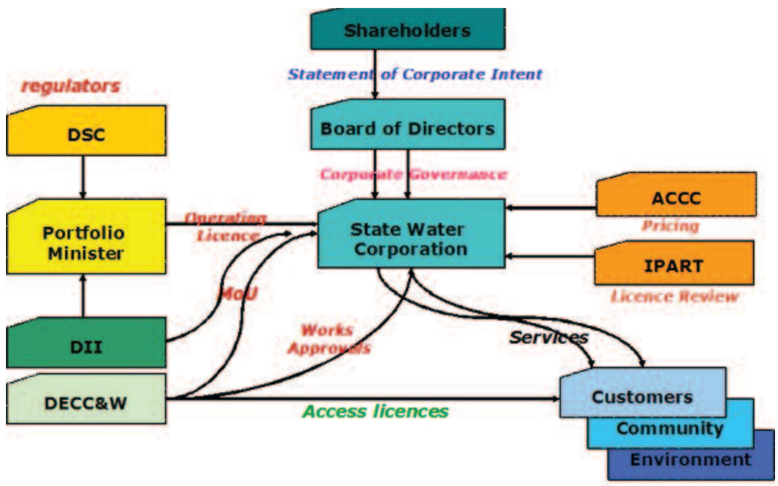

Figure 1 State Water Corporation's statutory landscape

Water is required to analyse the assets in its portfolio for their regulatory and stakeholder requirements, and their ability to address those requirements. This analysis forms the primary basis of the strategic asset planning process. In order to analyse its assets portfolio, State Water developed an in-house asset service potential assessment (ASPA) project.

Asset service potential assessments

The ASPA process is a comprehensive assessment of the continuing usefulness of State Water's infrastructure assets, assessed at the asset component level. The service potential of assets was evaluated on a seven point ASPA Scale. An asset with a score of 7 is considered to be in new condition with an acceptable level of risk, whereas a rating of 1 signifies unsatisfactory / failed condition and intolerable risks.

In determining where an asset ranks on the ASPA scale, each of following four factors are considered:

- Expected usage (service output)
- Expected wear and tear (physical condition)
- Technical and commercial obsolescence (including risk)
- Legal and similar limits on usage

These four factors were chosen as they align with the requirements of the Australian Accounting Standard AASB 116 for the assessment of asset life for depreciation purposes. Figure 2 outlines the step-by-step process followed for determining asset service potential for State Water assets in TAMP 2009. Field staff and / or regional engineers trained in the assessment system made assessments for each asset component, based on the ASPA scale and their intimate knowledge of the asset. This assessment highlighted any technical obsolescence issues and provided a detailed appraisal of the physical condition of the assets. This information is critical in estimating the asset lives and determining their respective probability of failure.

Asset risk can be defined as the degree to which the business is exposed to asset failure event causing potential unwanted loss (Buckland, 2005). The magnitude of risk is the mathematical product of the projected frequency of occurrence of a loss event and the consequences of that event. In context of State Water's ASPA project, risk is defined as:

Risk = (Probability of failure) x (Consequences of failure)

Given that the probability of failure is measured on a per annum basis and consequences of failure are measured in dollars, asset risk can therefore be represented as a per annum cost. The inclusion of asset risk as a cost along with the other costs of asset ownership such as maintenance, operations, depreciation, disposal etc. provides a more accurate cost of ownership and better decision making (Buckland, 2005).

Probability of failure

In order to estimate the probability of failure for each asset, a probability of failure versus time function has been developed (see Figure 3). The process adopted a common relationship assigned to all asset classes. The cumulative probability of failure (cpf) function is based on a Weibull distribution as:

- The Weibull function mimics the shape of a normal distribution
- Probabilities of less than zero are not generated by this function
- The Weibull is well established as a suitable distribution for modelling the failure of physical assets

Preliminary parameters for the Weibull distribution have been assigned based on:

- Order-of-magnitude estimates (by experienced State Water employees) on the probability of failure of old valve components
- Surveys of dam operators as to the observed failure rate of valves in a new to satisfactory condition

The resultant probability estimates were cross checked against an extreme opposite asset class (dam wall structures) for order of magnitude comparability with the dam failure probabilities derived from the detailed portfolio risk analysis process conducted for State Water's dams, in accordance with the risk assessment guidelines of the Australian National Committee on Large Dams (ANCOLD) (2003).

Consequence of failure

State Water's corporate risk management framework includes a risk matrix that identifies nine categories, capturing the full range of tangible and intangible consequences linked back to State Water's corporate values. Each asset component is assessed against each risk category of the matrix, and assigned a criticality rating from 1 (being catastrophic) to 7 (being minor). The criticality rating evidently corresponds to the order of magnitude of the consequence. For example, a financial loss of AUS$3000 (US$3005) to AUS$30,000 (US$30,045) is assigned a criticality rating of 6, AUS$30,000 to AUS$300,000 (US$300,480) a criticality rating of 5, and so on.

The intent of the consequence scale

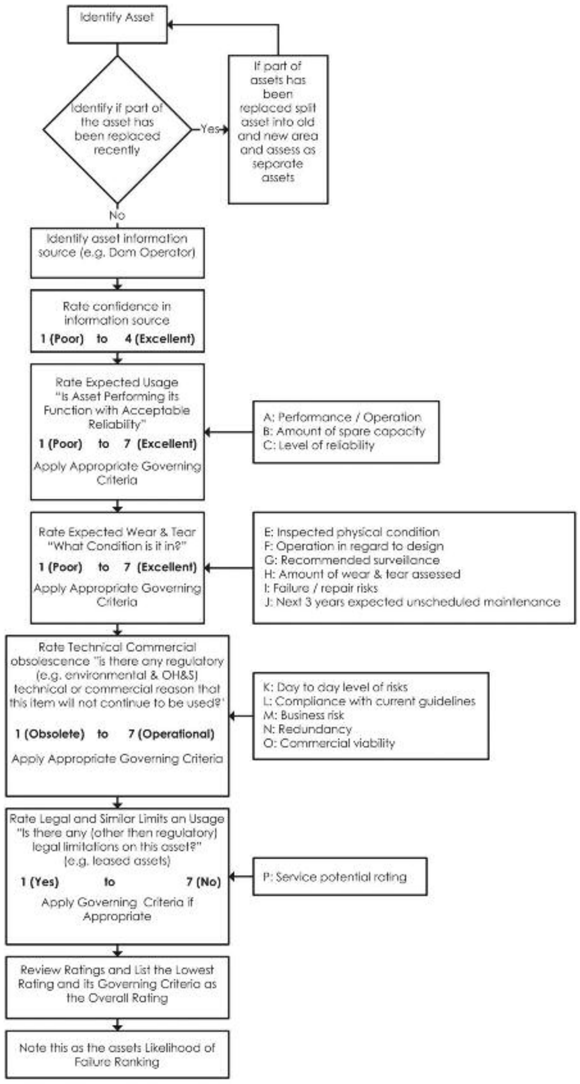

Figure 2
State Water's asset service potential assessment process

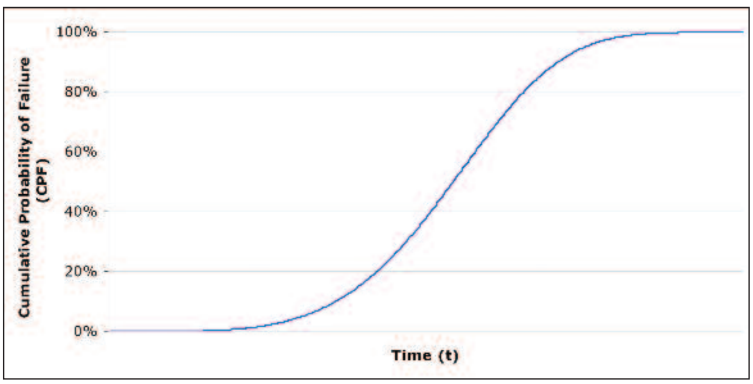

Figure 3
Probability of failure for each asset

is to capture the various adverse outcomes in different categories for which the corporation's aversion is equivalent and the prevention efforts would therefore be equal. With this equivalence across categories, each criticality rating is associated with a consequence cost, allowing an economic evaluation of intangible risks to be approximated. For example, a high profile legal challenge and prosecution with heavy fine corresponds to a criticality rating of 4 under legal, regulatory and compliance, which is equivalent to a financial loss using a zero-order approximation of AUS$1 million (US$1.2 million). Summing of all the consequence costs assigned to an asset component generates the consequences of failure for that component.

The outcomes of the ASPA methodology were used by the asset planning team to develop asset-specific, detailed five-year investment plans and macro-level 30-year strategic plans. Each assets 'assessment table' covers information such asset input data as name, river, area, type, location, ownership, use, ratings, risk assessment, capital works, maintenance and disposal costs. A sample of some of this information is provided in Table 1.

Capital investment planning

Capital investment decisions relating to maintenance, renewal or replacement are now based on asset risk cost considerations. For example, an asset with high criticality, with no failure history, and limited maintenance cost, may be justified for replacement by benefit / cost analysis using mitigation of risk costs as the only benefit. Under State Water's capital investment strategy (included in TAMP 2009), when the lowest ASPA rating, including revised commercial risk, of an asset reaches 1, the asset is identified for intervention. In other words, the methodology defines a level of tolerance below which asset risk is held within the business. Where assets are above this level of tolerance they are promoted for intervention. Intervention may include major asset renewal or full replacement. Reasons for identification of a specific asset are:

- Decay, i.e. the lowest future service potential rating reaches 1.
- High risk cost, i.e. >AUS$10,000 (US$10, 016) and a deteriorating physical condition resulting in a revised commercial risk reaching 1.
- Risk cost > annualised weighted cost of replacement, i.e. weighted average costs of capital x replacement cost and a deteriorating physical condition resulting in a revised commercial risk reaching 1.
- Dependent, i.e. the asset must be replaced because it is tied to an asset which is scheduled for replacement.

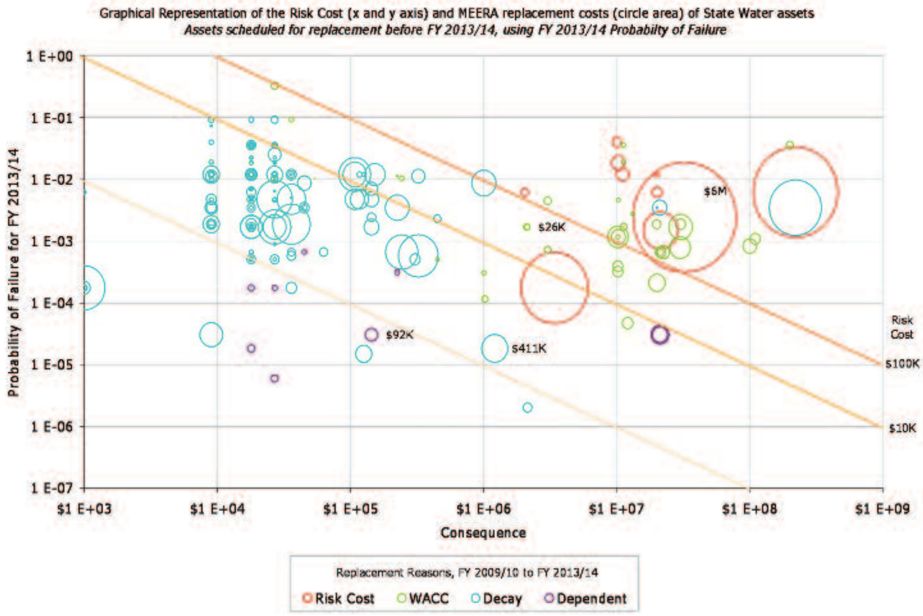

Figure 4
Risk based asset replacement by Financial Year 2013/14

The capital investment strategy outlines a single common process for the review of all capital expenditure proposals. It provides an integrated and rigorous approach to the screening and prioritisation of proposed capital investment in asset management.

The outcomes of this risk based asset assessment process are presented in Figure 4. Each asset component is represented as a circle, the size of which indicates the Modern Engineering Equivalent Replacement Asset (MEERA) value of the asset. The figure presents the asset risk for all water infrastructure assets in State Water's portfolio that have been identified for 'intervention' over the next five years period.

Conclusion

State Water's ASPA methodology provides an extensive and complicated, yet practical risk based approach to asset management investment. It ensures that capital investment will deliver business outcomes that reduce asset risk, and thereby minimising organisational exposure. State Water's TAMP 2009 is based on sound and defensible fundamental principles, addressing the life cycle of the assets and corporate risk management framework.

The TAMP 2009 and the capital investment proposals contained within, recently underwent a detailed scrutiny by the IPART appointed reviewers Atkins / Cardno. The reviewers concluded in their final report that 'State Water has developed decision making, prioritisation and review processes which are now in place to manage the capital program. These processes are consistent with good practice and should provide a process to manage within budget constraints. The approach provides a programme of work for the future Determination period founded on its best assessment of needs to maintain the asset base'. For a regulated business like State Water, where justification of investment decisions to the customers and regulators is an essential aspect, the Atkins / Cardno finding confirms the value of ASPA methodology. ●

Acknowledgement

The authors would like to acknowledge the contributions of Darren Anderson (former Infrastructure Economist, State Water), David Hope, David Watson and Andrew Fraser (Consultants) at various stages of the development of State Water's Asset Management Framework.

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Table 1
An example of Asset significant assessment outcomes from ASPA process

Structure	ASPA Rating	Criticality	Issue and capital project	Cost
Mollee Weir	4h	4	Mechanical hoist risk cost due to water delivery failure will exceed $10,000 per annum by 2019	$1.65 million (Likely in 2020)

A data framework approach to unlock the value of your data

In order to achieve effective asset management within an organisation, a framework is required to efficiently manage asset data acquired across different departments. In this article, Dilip Kumar, Simon Heart and Nigel Kent discuss the implementation of an asset data framework and its benefits.

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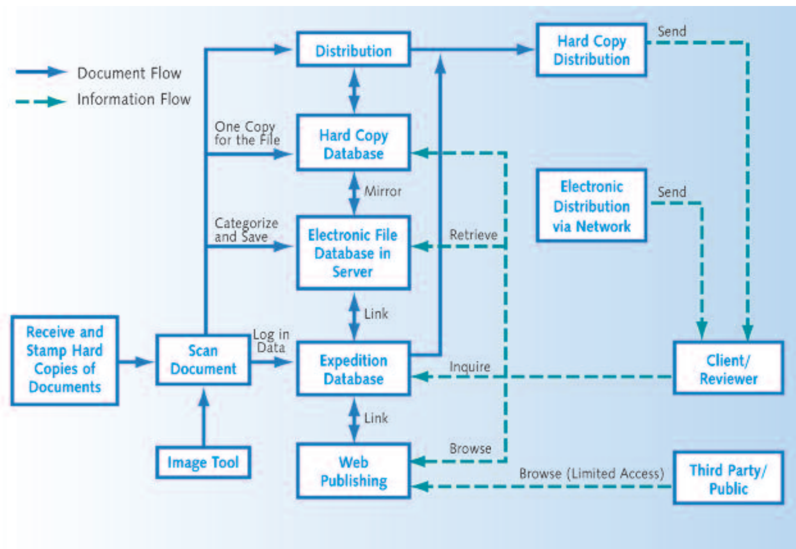


Figure 1 Typical dataflow within the organization

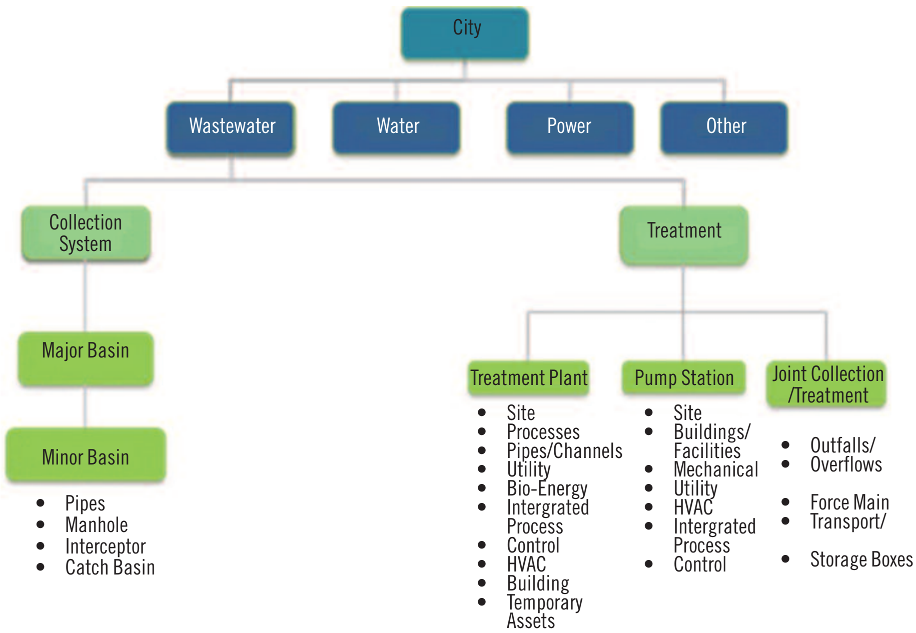


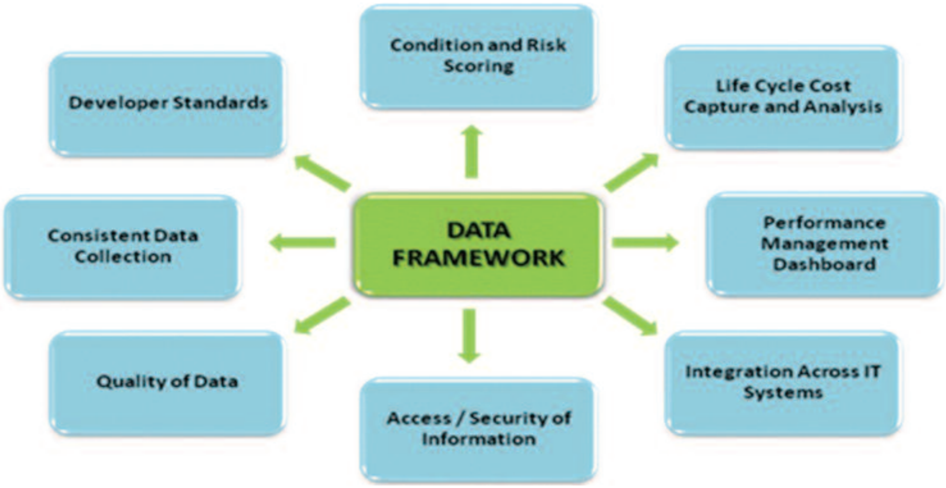
Figure 2 Unique asset hierarchy across the organization's assets

Asset information management and establishing a clear data framework to guide the way data are captured, stored, retrieved, shared, analyzed, and reported across your organization is essential for effective enterprise performance and risk management. Left unchecked, processes and systems for data capture and management tend to evolve in departmental silos within organizations – leading to inefficiencies, frustration and impaired decision making. By analyzing true data needs in light of high level organizational performance objectives, structures and processes can be established to efficiently manage the data and improve information flow throughout the organization.

What is a data framework?

A data framework is a defined structure and set of approaches for data capture and management within your organization. It addresses several fundamental questions:

- What business decisions do we need to make?
- What information do we need to make these decisions?
- What asset data must be captured to yield this information?
- Where should the data and information be stored?
- Who gathers, accesses or uses the data and for what purposes?
- How do we determine and verify the data is of the right quality and accuracy?
- How should the information roll up for analysis and reporting purposes?
- Does our business have the right balance between people, process, and systems?
- How do we protect data integrity?



- Is there any information we are collecting that we do not need?
- How do we maximize information sharing and access across the organization?
- Are there cultural and business transformation issues that need to be addressed?

Based on answers to these questions, an appropriate asset hierarchy and corporate asset register are established as the baseline to codify and enable the effective implementation of sustainable data capture and achievement of your organizational objectives. Alongside the data focused elements, early consideration is made of the impacts of these changes on teams and individuals within the business, and a plan developed to manage these impacts and communication of the intended changes through the appropriate levels of the business as the implementation of the data framework approach takes place.

Why develop a data framework?

Many utilities and other infrastructure-rich organizations experience great frustration and, as an outcome, performance and cost inefficiencies, related to the capture, management and retrieval of asset and business data. Important data gaps, disconnected systems, redundant or conflicting information, cumbersome analysis, poor reporting and decision making and lack of business engagement are just some of the challenges that staff face on a daily basis. Even more important are the potentially significant capital and operational investment decisions that need to be made with often incomplete or inadequate information.

Analyzing the Ofwat (the regulatory agency for water and sewerage services in England and Wales) Final Determination for Capital Maintenance based on the Asset Management Assessment (AMA), it can be seen that data has the highest weighting of the high-level areas in the assessment and comparatively has the lowest scores. The focus of the regulator is likely to increase on the outcomes of investment and service effectiveness and therefore the utilities need to make significant improvements in the major contributing pillars. For example, over the past five year investment period, Ofwat has imposed nearly £70 million ($112 million) worth of fines on water companies due to events relating to data quality / data integrity issues and its impact on service to customers.

Figure 3
Data framework benefits

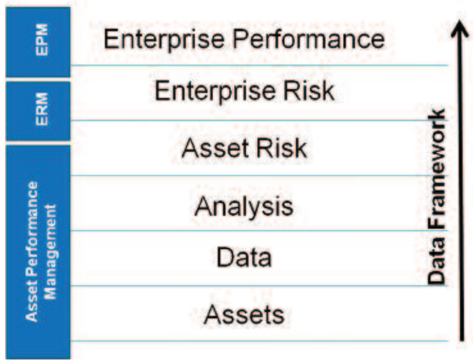


Figure 4
The asset register provides a common link between systems that allow data to be cross-referenced and retrieved as required

What are the benefits of a data framework?

A clear data framework can provide the following key cost-saving benefits: accurate asset data in the right format to support effective asset management practices; improved asset data content and quality to enable informed, confident decision making; rapid access to data across the organization; efficient data capture, storage and retrieval processes; elimination of redundant and inaccurate data sources; ease of integration between critical asset data systems (e.g., GIS, maintenance management, strategic investment planning, performance management and financial systems); connected business processes and data systems leading to more efficient data handling; easy and consistent performance monitoring and reporting

Developing a data framework for your organization

Step 1 - Review of business needs, systems and data structures

Examine existing asset structures, classifications, hierarchies, and systems to understand the 'as is' situation in light of business drivers, overall organizational performance targets and information needs.

Step 2 - Asset hierarchy and corporate asset register development

Hold collaborative workshops to review (or design) the asset hierarchy, determines desired asset data attributes, and appropriate data storage locations. This step will determine the types of data to collect for each asset type, where the data will be stored, and how it will roll up for analysis and reporting purposes. Example data attributes to be specified at this stage will include age, size, material, condition, consequence of failure, risk, replacement cost, and others.

Step 3 - Existing data review and gap analysis

Examine the data that are currently available within the organization in comparison to the desired data needs established in Step 2. This might show, for example, that a significant percentage of asset data is missing or unreliable. Each data gap is prioritized according to the business needs and benefits / costs of obtaining the missing data and considered in terms of the level of change required within the business to bring about the desired future state, informing the development on the supporting change management strategy.

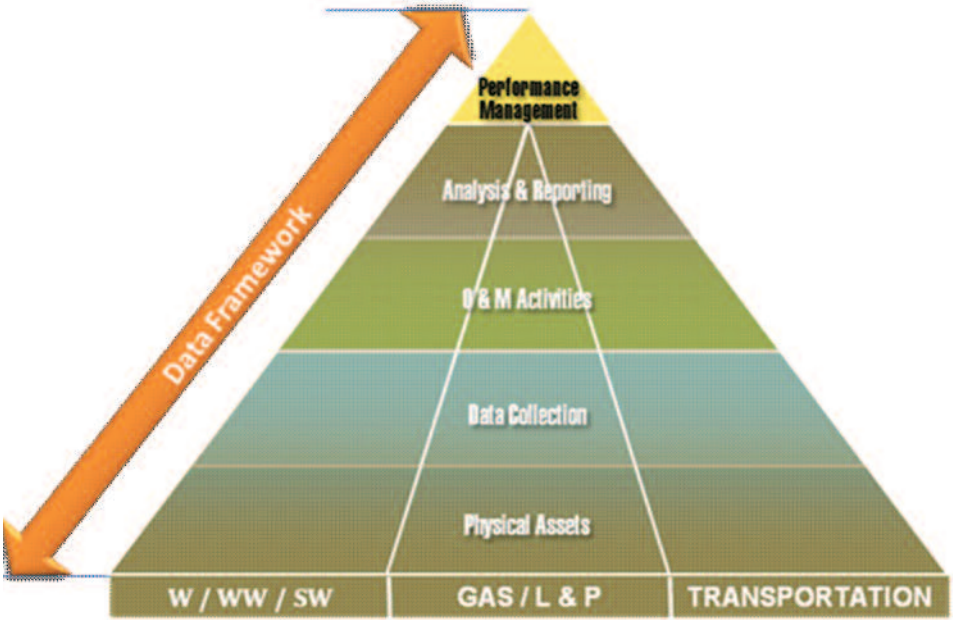


Figure 5
Performance management: similar analysis and reporting capabilities across the organization

Step 4 - Data management strategy
Based on the findings of Steps 1-3, establish a strategic plan for enhancing data management across the organization, including:

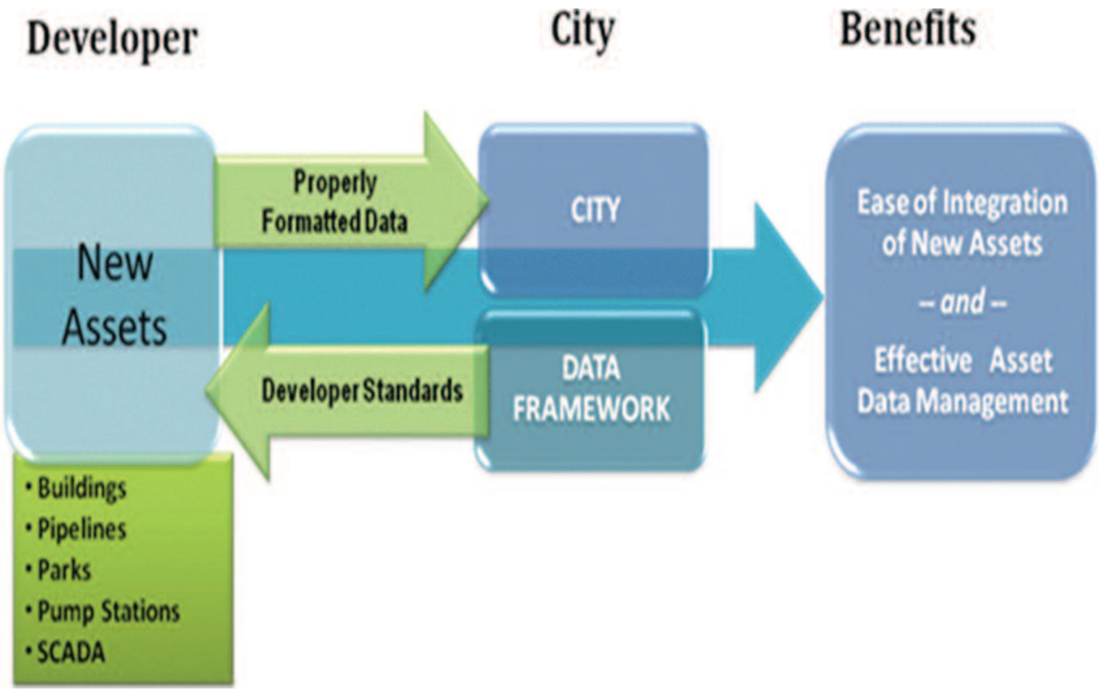
- Data migration and collection plan describe data management enhancement needs and key steps for migrating or collecting data to fill critical data gaps.
- Data model development – develop a data model to enable automated data-infilling and integration as new assets are brought online.
- Implementation plan development detail the specific implementation steps to achieve the desired data framework, including sequencing and resourcing of tasks, pilot implementation projects, and data monitoring and review requirements. The plan should also address clearly designed data collection and storage procedures, and protocols.
- Change management plan development – integral to success, it is essential that each element of the required change is planned and communicated effectively. As a result the implementation plan described above must include specific engagement with teams, training and communication activities.

Step 5 - data framework implementation
Implementation of the plan designed in Step 4 based on results of Steps 1-3. The plan should have a clear connection between the data being collected and the high level performance objectives of the organization. To be successful, it is essential that the plan includes appropriate change management activities.

Other industry standards
The resource www.assetdata.org (Project #4187, 'Key Asset Data for Water Sector Utilities', Water Research Foundation, 2009) fosters the discussion on terms and a classification system for key drinking water and wastewater system assets. The data is presented by asset hierarchy (a generic three-level asset hierarchy), performance indicator (for measuring performance and tracking improvements) and attributes (general categories of data that could be collected about an asset). The research team is expected to complete this project in 2011 (www.waterrf.org/Projects Reports/Documents/PSB.pdf).

Delivering value
Effective data / information management is not easy. There are often many systems to integrate, a huge range of business needs to meet, and complex organizational and cultural issues to address. Using our data framework approach and related information management strategies, with due attention given to business transformation and change management issues, we have helped many utility organizations get the balance right between people, process, technology and data, thereby unlocking the value of data and aligning it to business needs and delivering effective enterprise performance and risk management. ●

Figure 6
Developer standards for all assets coming into the organization



The influence of business culture on asset management decision making: a sustainability perspective

Engagement with sustainability can be conceptualised as a journey whereby initiatives involving management, employees, the community and stakeholders gradually facilitate a change in direction and attitude in line with sustainability principles. This view of sustainability implies that a utility's decision making culture and processes are key points of leverage in any attempt to move to a business model that is more closely aligned with sustainability principles. In this paper, David R Marlow, David J Beale and Magnus Moglia present an overview of research undertaken in an Australian utility to how sustainability is considered within decision making.

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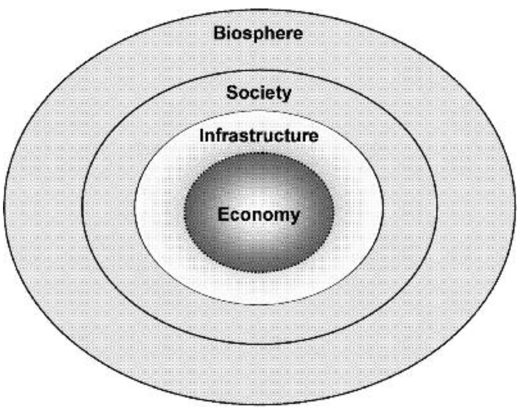
The urban water sectors of many countries face a complex range of challenges, including declining availability of water from the terrestrial environment, an unstable global economy, increasing energy prices, and increasingly complex regulatory and social circumstances. Meeting these challenges is vital if water utilities are to maintain the confidence of the communities they serve. Adapting business thinking to cope with emerging realities requires a new operating paradigm to be embraced – that of sustainability (Marlow & Humphries, 2009). Part of this challenge is to ensure that there is sufficient investment in the physical assets used to provide service to customers, communities and the environment. Formalized asset management is increasingly being put forward as a solution to this (e.g. Allbee, 2005).

To help the sector address these issues, research has been undertaken into the role sustainability principles play in asset management. In the initial stage of this research, a series of interviews were undertaken with water sector professionals and other stakeholder organisations within Australia, primarily to identify perceived challenges and research gaps for linking sustainability and asset management (Marlow, 2008; Marlow et al. 2010a).

A follow-on project was then undertaken in conjunction with two water utilities in Australia, which aimed to develop an approach for investigating business processes as a means of advancing sustainability culture; this work is the focus of this paper.

Some background discussions on the research context are presented, followed by the insights gained from the sector with respect the requirement for a more robust engagement with sustainability. Concepts drawn from the literature on organizational learning are also reviewed. An overview of the research approach is then given, and results from a case study presented. Conclusions relating to the case study and overall research are then provided.

Figure 1 Infrastructure as a critical dimension of sustainability



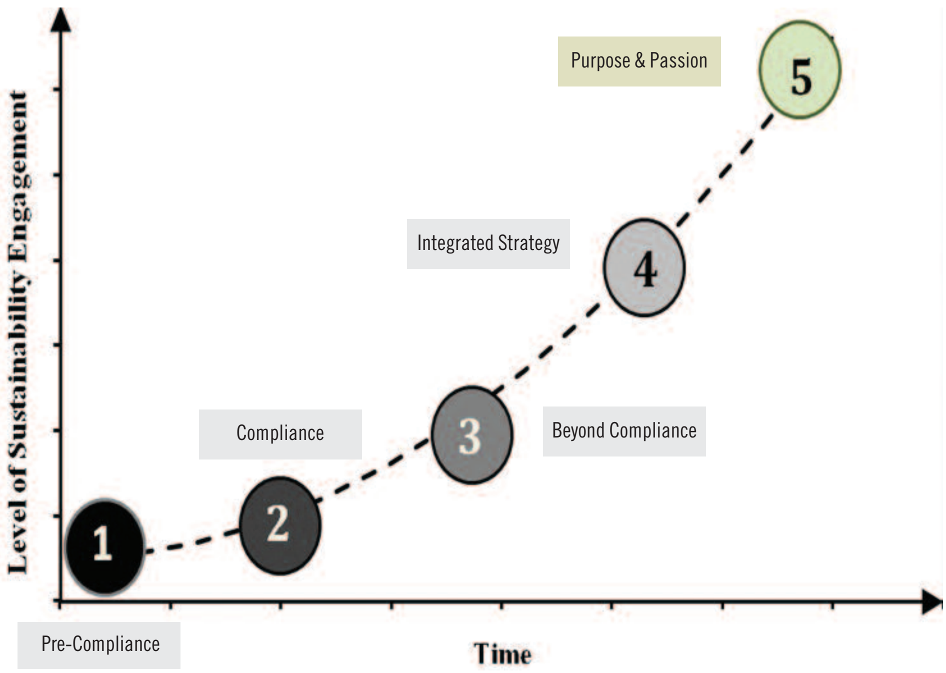
Sustainability concepts

The word 'sustainability' is currently used in a variety of ways. For example, the Water Environment Research Foundation (WERF, 2007) noted that sustainability can be considered in terms of the ability of a business to remain effective and functional despite large-scale changes in its operating environment. Klostermann & Cramer (2006) suggested that for most respondents 'sustainable' is now a label for all issues and activities previously labelled 'environmental'. In a broader context, 'sustainability' often relates to the concept of 'sustainable development', a widely quoted definition of which was given in the Brundtland Commission report (WCED, 1987), namely: 'Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.'

The Brundtland definition is explicitly global in scope, but any attempt to adopt it as a guiding principle requires action to be taken at a local level. As such, a multi-scale view is needed; hence the well known phrase 'think globally, act locally', coined for 'Local Agenda 21' of the International Council for Local Environmental Initiatives (e.g. ICLEI, 2008). Even with such refinements, 'sustainability' remains a vague concept, and can perhaps be best conceptualised simply as an aspiration, defining the direction towards some preferred state, even if that state is not well defined.

Sustainability in the water sector

The water sector is arguably in a unique position to take the lead on sustainability issues (Marlow, 2006;



Note: Step 1 – Pre-compliance: driven by financial profits. Step 2 – Compliance: manages liabilities; environmental and social actions to some extent treated as public relation (PR) exercises. Step 3 – Beyond compliance: active engagement with community and environmental issues, sustainability included in policy. Step 4 – Integrated strategy: sustainability integrated into business strategy, sustainability viewed as an investment and opportunity not a cost or risk. Step 5 – Purpose and passion: full committed to sustainability, driven by passion and a corporate commitment to improve the overall well being of the company, community and environment.

Figure 2 Conceptual pathway to sustainability (after Marlow et al. 2010b)

Marlow & Humphries, 2009), not least because water utilities supply services that underpin all other social and economic activity in a specific (spatially constrained) area. These aspects mean that there is an implicit requirement for water utilities to maintain a social license to operate from the communities they serve. Water utilities are also engaged with simultaneously delivering financial, social and environmental outputs, the so called triple bottom line (TBL) of business (e.g. Elkington, 1998; Kenway et al., 2006), which must be maintained into the future.

In practice, however, discussions of sustainability within the water sector still often focus on ecological sustainability alone (Berndtsson & Jinno, 2008). A more holistic definition was proposed by ASCE / UNESCO (1998), who defined a sustainable water system as: 'one that is designed and managed to contribute fully to objectives of society, now and in the future, while maintaining ecological, environmental and hydrological integrity'.

The ASCE / UNESCO definition provides a reasonable basis from which to assess the sustainability of a water utility, especially from the perspective of its management of water resources. However, it is still somewhat vague from an operational perspective. With this in mind, Marlow & Humphries (2009) discussed requirements for a useful operational definition, and proposed the following: 'For a water utility, sustainability is practically achieved when all its activities, both internal to the business and across its supply chain, achieve net added value when assessed across each of the triple bottom line outcomes (financial, social and environmental) over the medium to long timescales, considering all costs and benefits, including externalities.'

Although this definition does not explicitly address the asset base, these assets have a direct influence on TBL outcomes, and thus whether or not a water utility is sustainable in the context of this definition.

Links with asset management

As with sustainability, the term 'asset management' is ill-defined and numerous definitions are in use (Causey, 2005). For the purposes of our research, the following definition has been adopted: 'A combination of management, financial, economic, engineering and other practices applied to (physical) assets with the objective of maximizing the value derived from an asset stock over the whole life cycle, within the context of delivering appropriate levels of service to customers, communities and the environment, and at an acceptable level of risk.' This definition builds on that given in the International Infrastructure Management Manual (2006), with modifications to reflect the TBL focus of the water sector and to align with broader sustainability principles. With this in mind, it is interesting to address why we consider asset management in the water sector can be connected to sustainability concepts in this way.

Sustainability has been previously illustrated as a simple conceptual model highlighting the critical dependence of both human society and economic activity on the biosphere; i.e. the natural environment provides a wide variety of essential ecosystem services, without which human society and the economy would collapse (e.g. Porritt, 2005). In a similar vein, infrastructure can be conceptualised both as a key part of the economy and a way of linking society with broader economic activity. Unfortunately, news reports of natural disasters such as earthquakes often illustrate the function infrastructure plays in underpinning human activity. The simple conceptual model of sustainability can thus be expanded to show the key role of infrastructure, and by inference its management, as shown in Figure 1.

Services delivered by water and wastewater infrastructure are a particularly important part of the economy and society because they underpin all other economic and social activities and are:

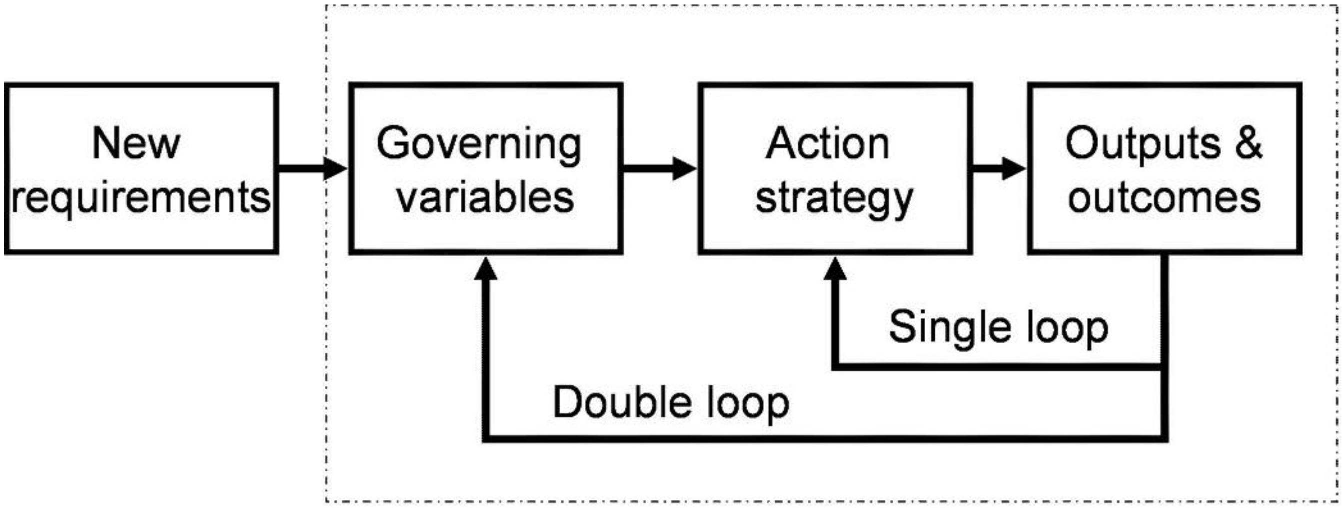
- Necessary for human health
- Intimately linked to local and regional environmental health
- Considered by many as a human right
- Subject to complex property and access rights

Links with business culture

When addressed by a business, sustainability is often treated as something to be attained through a change in operations facilitated by technological improvements and behavioural adjustments (Clark, 1994). In contrast, Willard (2005) highlighted the necessary organizational transition in terms of a journey, whereby initiatives involving management, employees, the community and stakeholders gradually facilitate a change in direction and attitude in line with sustainability principles. Hence, rather than considered as an end point, sustainability is perhaps better defined by the level of engagement with underlying principles, as illustrated in Figure 2.

Until sustainability is embedded into 'business as usual' practices, the ability to make decisions that align with broader sustainability principles is likely to depend on a wide range of influences, enablers and constraints, including an individual's interpretation of their role and duties. Of particular interest from the perspective of sustainability is that individuals can be driven to make decisions that they personally consider are suboptimal in the face of conflicting demands. This view implies that business culture, sustainability policy and decision making processes are all key points of leverage in any attempt to move a water utility to a business model that is more closely aligned with sustainability principles. As described later, engagement with sustainability is also about developing a learning culture open to organisational adaptation. Such insights reflect the assertion that sustainability is as much to do with 'hearts and minds' as it is to do with technical solutions and tools for decision making.

Figure 3
Single and double loop leaning



Views from the Australian water sector

In the initial stage of this research effort, a range of interviews were undertaken with individuals from five water utilities (in Victoria, New South Wales and Western Australia), comprising four senior managers (e.g. CEOs and general managers), 12 middle managers (asset managers and sustainability managers), five management support staff (asset management and sustainability), and four other stakeholders. In total, 25 formal interviews were undertaken. Details of the interviews and results are given in Marlow (2008). The interviews were a formal research effort, characterised as qualitative research using interviews as a data collection tool (e.g. Myers & Newman, 2007). The interviews were treated as a rich source of information and insights, rather than an independent and representative view from the sector.

As summarised in Marlow et al. (2010b), interviewees perceived that there was a significant high-level commitment to sustainability as a core business concept, expressed in terms of corporate goals and objectives, as well as planning frameworks. However, this high-level commitment was not considered to be embedded into day-to-day practices. It was also noted that while the water sector has a history of delivering good social and environmental outcomes aligned with the needs of society, the emerging challenge is that the world is changing rapidly and the solutions for yesterday's problems may not be suitable to meet emerging challenges such as climate change, changing demographics, and a hydrocarbon constrained future. Overall, there was a perception that the way in which the sector is operating needs to change.

Table 1
Modes of Operation

MODE 1: governing values:
Achieve the purpose as the actor defines it
Win, do not lose
Suppress negative feelings
Emphasize rationality

Primary Strategies are:
Control environment and task unilaterally
Protect self and others unilaterally

Consequences include:
Defensive relationships
Low freedom of choice
Reduced production of valid information
Little public testing of ideas

MODE 2: governing values:
Valid information
Free and informed choice
Internal commitment

Strategies include:
Sharing control
Participation in design and implementation of action

Consequences should include:
Minimally defensive relationships
High freedom of choice
Increased likelihood of double-loop learning

Considered to be much preferred for organisational learning, i.e. allowing for transitioning of the utility

Research approach

Given the results of these interviews, it was concluded that more research was needed into the technical, social and cultural aspects of how sustainability is considered within decision making, as well as the changes required to embed sustainability into business practices (Marlow et al., 2010b). The remainder of this paper addresses this later issue.

Organisational learning

The logic of the approach taken draws from the literature on action-research, which seeks to understand and modify the way in which organisations learn, considering the mental models and cognitive processes of personnel involved in decision making (e.g. see Anderson, 1994; Smith, 2001, both of which give an overview of the relevant body of work developed by Argyris).

A key concept addressed in this literature relates to the feedback loops that dictate how organisations learn. It is assumed that learning at any level requires the detection and correction of error. A useful conceptual model that illustrates the feedback processes involved is given in Figure 3, which shows the relationship between governing variables, actions and outcomes.

Governing variables are metrics or requirements that must be kept within some acceptable range; action strategies are used to keep governing variables within that range. Any action can impact a range of governing variables,

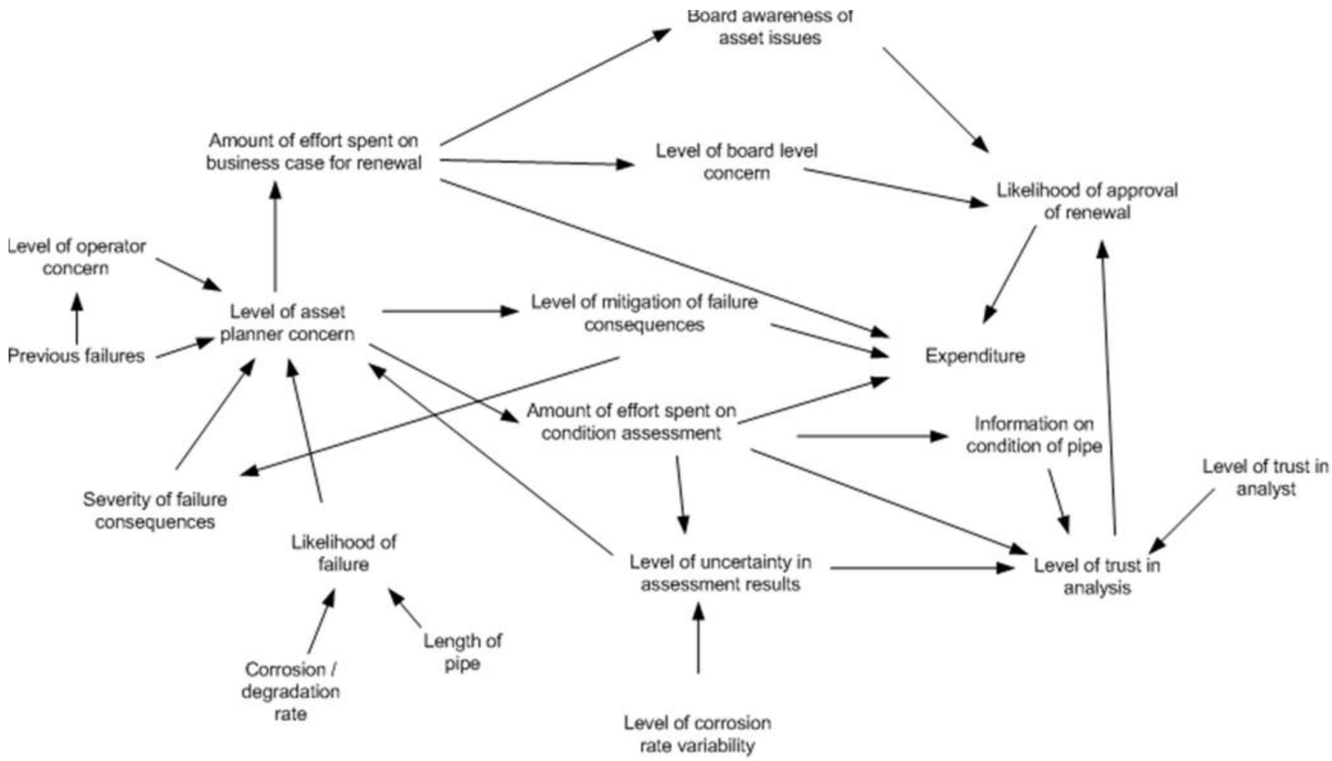


Figure 4
Elicited influence diagram

and thus may require a trade-off to be made. Furthermore, action strategies can have both intended and unintended consequences in terms of outputs and outcomes, which in turn dictates whether governing variables are actually kept within an acceptable range.

For the purposes of this research, we assume that this conceptual model is applicable at multiple scales, including at the level of the individual decision maker and the decision making culture within a water utility. With this latter perspective in mind, there are many governing variables involved in the delivery of water services, including resource availability and use, cost effectiveness, environmental health, service requirements, regulations etc. An additional complexity in the sustainability space is that governing variables are changing dynamically due to external factors like climate change, population growth and changes in water availability. Such changes create new requirements, which influence governing variables, as illustrated in Figure 3.

Within traditional organisations, individuals do not challenge what the governing variables of the business are; i.e. the specified business goals, values, plans and rules are accepted as 'givens' and thus operationalised. As such, when outputs and outcomes are not as desired, individuals seek an alternative action strategy, but within the context of the specified governing variables. This is termed 'single loop learning', as shown in Figure 3. Double loop learning is when action strategies and governing variables can be changed.

If single loop learning is applied, individuals and teams can attempt to meet targets associated with 'traditional' governing variables, even when the variables themselves should ideally be changed. In the context of this paper, this means actions could be taken in good faith that are not aligned with sustainability principles. For example, it can be anticipated that requirements to spend budgets at the end of the financial year will sometimes lead to sub-optimal use of funds when considered from a broader sustainability and even business perspective, yet this still remains a key governing variable in many organisations. In contrast, if double loop learning were applied, individuals would feel they had the ability to question both the action strategy and the governing variables. Hence, in this example, the governing variable that the budget must be spent would be challenged, rather than simply seeking ways to spend the budget.

The literature reviewed by Anderson (1994) and Smith (2001) also addresses the patterns that underpin single and double loop learning, which are essentially predominant 'modes of operation'. Two general modes of operation have been proposed (Mode 1 & 2), as detailed in Table 1. Mode 2 values and strategies are aligned with double loop learning.

The research detailed in the remainder of this paper is premised on the fact that the transitions embedded in Figure 2 align closely with the adoption of double loop learning. As such, commitment to sustainability requires adoption of Mode 2 values and strategies (see Table 1).

Research approach

The overarching aims of this research effort was to provide water utilities with an approach for identifying what is driving individual and group action, where the points of leverage are and thus how to encourage engagement with the utility's 'sustainability journey'.

To align the research with previous efforts, the initial focus was the identification and investigation of asset management decisions that had important business implications and could be analysed from a sustainability perspective. To achieve this, qualitative techniques were again used to elicit different view points of the decision using semi-structured interviews (e.g. Broom, 2005). The interviews were recorded for reference and a thematic analysis undertaken to identify common and differing opinions.

The specific aim of the analysis was to determine how constraints on asset management decision making (e.g. business rules, targets, competing demands, stakeholder priorities, organisational politics, tools, budgets, staff skills, etc.) influence sustainability objectives and vice versa. In summary, the pilot involved the following steps:

- Hold initial workshops with participating utilities to identify decisions with important business implications
- Gather and review background information on the selected decision, company sustainability and other relevant policies
- Identify a range of individuals involved in the decision making process
- Develop a questionnaire for use in interviews to provide structure
- Undertake interviews, which were recorded with permission of the interviewee
- Analyse interviews using a thematic approach
- Provide the utility with feedback on any insights

Role (number)	Involvement:
Asset managers (3)	Drove decision
Design Engineer (1)	Sizing of pipe
Operations (1)	Operational knowledge
Capital delivery (2)	Delivery of solution
Community (2)	Engagement
Finance (1)	Financial modelling
Corporate risk (1)	Corporate processes
Sustainability (1)	Corporate processes

Table 2 Summary of Interviews

This approach required the research team to obtain 'buy-in' from a range of individuals involved in a particular decision / initiative. To this end it was emphasised that the interviews were confidential and would be underpinned by an open, positive and 'no blame' approach. This was necessary because the researchers sought to understand the different viewpoints, motivations, constraints and enablers that influence decision making and action.

Pilot case study

The pilot case study involved a utility that has made a strong commitment to sustainability over the last few years. The asset management decision under study related to the replacement of a 250mm / 300mm diameter (NB: this diameter range is at the lower limit of what are considered 'large' pipes) cast iron water main that runs along a busy street and passes through an iconic shopping area. The pipe is approximately 2.5km long and was installed in the 19th Century, and remained unlined until the early 1980s, when it was cement lined in-situ.

The decision to replace the pipe was reached after assessing the asset's risk of failure. The failure risk was deemed unacceptable due to the poor condition of the pipe (considered to indicate high likelihood of failure) and the potential for significant reactive costs and other consequences in the event of any serious pipe failures. Failure consequence assessments showed there was potential for significant traffic, rail, social and commercial disruption, as well as negative impacts on company reputation. It is noteworthy that the utility's corporate risk assessment procedure explicitly includes an assessment of reputational impacts as part of the failure consequence assessment. The decision to replace the pipe also had high business importance because of the potential for public relations issues associated with disruption during the capital works.

Initial information on the decision was obtained from the utility and used to gain an understanding of the decision making process applied. To facilitate discussions and as a means of gaining a common understanding of the decision, an influence diagram was drawn, which is shown in Figure 4.

Interviews were then arranged with 12 individuals who had some involvement in the decision, some two years after the business case to replace the pipe was approved. The roles and level of involvement of those interviewed are given in Table 2.

After preambles to outline the scope of the research and introduce those involved, each interview was based around a standard questionnaire and conducted in three phases:

Phase 1: Baseline questions were asked to understand the interviewee's role and their view of the decision.

Phase 2: A brief overview was then given of research assumptions, including the link between sustainability and business culture. Questions were then asked to understand the interviewee's view of sustainability, including what role they felt a water company has to play in broader sustainability issues, and whether or not they feel sustainability is achievable.

Phase 3: In light of the discussions in Phase 2, the decision under investigation was revisited with a specific focus on its relation with sustainability policy of the company. Issues relating to the business culture were also discussed; for example, interviewees were asked about their influence over the decision and whether there was something they would change in the decision making process.

Insights gained

It was clear that a key factor in the decision was the assessment of reputational risks associated with serious pipe failures. It was also clear that this had been communicated to those not directly involved in the development of the business case and that this perception had, to some degree at least, been taken on faith. In particular, some such individuals used emotive language; e.g. referring to the 'disastrous economic impacts of a burst'. However, three individuals expressed reservations over whether a robust assessment of risk had actually been possible. Another individual noted explicitly that there were other high risk assets that should have been replaced first. These opinions reflect some risk aversion with respect decision making, as well as some differences in opinions that were left unmanaged.

Ten interviewees expressed a view that in some way reflected that sustainability was about balancing TBL outcomes over the long-term, which aligns with the definition adopted in the research. However, two individuals stated differing opinions; one noting that sustainability was just another hurdle to overcome when justifying a desired solution, while the other indicated that sustainability was essentially a business outcome that could be measured through key performance indicators. Another interviewee stated the opinion there was currently too much emphasis on heritage and the environment, and what was needed was a better balance across outcomes.

In terms of Figure 2, five individuals expressed attitudes that were considered to align with Stage 3 of the sustainability journey, and six individuals expressed attitudes that aligned with Stage 4. As such, the sustainability culture of the company, as reflected in the interviews, appears to be somewhere between Stages 3 and 4; i.e. moving beyond compliance to a more integrated strategy.

Most individuals considered that sustainability policy of the company had influenced the decision to replace the case study pipe. However, one individual noted that this was not the case because the issue was a purely technical one, associated with avoidance of failures. Another interviewee noted that the fact that the renewal was being done before any significant failures occurred meant that the pipe was being replaced too early, the implication being that the full life of the asset was not being achieved, which was considered contrary to sustainability principles. Interestingly, an asset manager noted that while there was a TBL aspect to the decision, it was still short-term in focus in that it did not consider the long-term service requirements of the area. As such, the decision was based on stationary assumptions; i.e. that water supply via a large pipeline would remain the model of service delivery into the future. Hence, this individual considered that the decision did not align with broader sustainability principles.

Overall, individuals stated that the decision culture was open in that they felt able to express their opinions, though one interviewee stated that the prevailing culture did not respond well to negative comments, which implies some elements of Mode 1 operation, as would be expected. Another interviewee noted that while people were free to express their concerns, whether or not those concerns would be taken into account was another matter. It was also noted that there were some communication and trust issues between the company and its contractors, essentially due to different priorities and focus.

In terms of improvements and changes to the decision making process, a number of individuals noted that sustainability models (conceptual and analytical) needed to be more robust. One individual noted explicitly that sustainability is a hurdle to overcome, indicating that back-analysis of sustainability issues would be undertaken so as to justify a preferred solution. Others indicated that earlier and broader communications across operations, asset management and other business functions was needed to get the best solution.

Conclusion

This paper has outlined a methodology for analysing decision making and business initiatives from the perspective of sustainability policy. The process utilises qualitative research techniques to understand the motivations, constraints and enablers that influence decision making. The approach was piloted in a case study, which is summarised in the paper.

Many of the insights gained reflected differences in individual and collective interpretation of sustainability and sustainability policy. Observations aligned with the concepts drawn from the literature with respect modes of operation, communication styles and institutional learning. For example, while generally positive in intent, it was observed that flows of information could be improved, and this was necessary to attain an appropriate level of engagement and prevent silo attitudes from developing.

An interesting technical insight was that more robust models of sustainability and risk are needed if decisions are to be correctly placed in the context of sustainability policy, rather than be used to justify preferred options. Furthermore, companies need to develop a broad sustainability strategy within which the context of individual rehabilitation projects can be assessed. In light of rapidly changing economic and social circumstances and environmental constraints, this will require strategies that avoid 'sinking' investment where possible. As such, tools are needed to allow asset managers to analyse future options and implement adaptive investment strategies. This is the next phase of research.

It is worth noting again that the utility involved in the case study was relatively advanced in terms of their engagement with sustainability issues, and comments made indicated a culture that was moving beyond compliance to a more integrated sustainability strategy (i.e. between Stage 3 and 4 of Figure 1). There was also evidence that individuals felt able to voice concerns and differences of opinion, though these were not always fully acknowledged. These observations imply that the company is undergoing a transition that shows Mode 2 attributes are being developed.

Overall, the process applied in the case study provided interesting insights, and could therefore be used by companies who wish to investigate their own sustainability culture. Use of independent interviewers would, however, seem desirable, given the need for honest and open discussion of issues. An extension to the research to provide experiential training in a facilitated workshop environment was under discussion at the time of writing. ●

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Modelling a large and complex potable water distribution system

In order for utilities to effectively manage a water network, different sources of data are required, but this data then needs to be processed in a way to advance the efficiency of the utilities' operations. In this paper, Giuseppe Gresta, Marco Ricciardulli, Riccardo Turco and Vincenzo Costantino Fisichella illustrate the implementation of a mathematical model for the very large water distribution network of the city of Quito in Ecuador, and its application for operation and management purposes, and how a mathematical model can be a valid and powerful tool for better comprehension of the hydraulic performance of the complexity of a water network.

Giuseppe Gresta, Marco Ricciardulli, Riccardo Turco and Vincenzo Costantino Fisichella,
C. Lotti & Associati Spa

The modernization and improvement of a water company is mainly based on implementing modern and advanced tools for the technical management of the water distribution networks. For this reason the implementation of a GIS system and a hydraulic mathematical model are necessary steps for the achievement of advanced operations and maintenance procedures.

Water utility departments collect information on water consumption, existing and future infrastructures, water flow and pressure measurements, and this information is used separately and for various purposes.

If there is no single tool to manage all the gathered information, comprehension of the system's hydraulic performance will be based only on fragmentary information and, therefore, on separate aspects of the problem's complexity. This aspect is of greater importance in large networks.

A mathematical model incorporating information on infrastructure from a Geographic Information System (GIS), water demand, measurement and equipment operation rules is a management and decision-support tool facilitating a thorough and accurate overview of the complexity of the system.

The project

The city of Quito in Ecuador's municipal potable water and sewerage company (EMAAP-Q) contracted C. Lotti & Associati (after a restricted international bid) for consulting services aimed at implementing the hydraulic model of the city's potable distribution system. The project lasted from the beginning of 2007 until February 2009 and was carried out under the supervision, and with the collaboration, of EMAAP-Q personnel, who assisted engineers and technicians throughout the study. Thanks to this collaboration it was possible to gather the large quantity of information used to implement the model.

Quito is located in one of the biggest and highest Andean sub-basins known as 'Hoya de (trench of) Guayllabamba' in the Sierra Region. The metropolitan area of more than 180,000 hectares extends mainly over the bottom of the trench with an altitude of 2800m above sea level, and partly on the surrounding steep slopes that reach 3200m above sea level.

The metropolitan area has a population of almost 1.5 million, while the studied peripheral areas have a population of almost 400,000.

Table 1 Temporal trend in produced and billed volumes

Year	Month	Produced water (l/s)	Billed water (l/s)	NRW (%)
2006	July	4,935.20	3,398.62	31%
	August	4,814.80	3,333.89	31%
	September	4,893.63	3,390.34	31%
	October	4,637.23	3,688.44	20%
	November	4,548.39	3,717.84	18%
	December	4,675.33	3,009.34	36%
2007	January	4,820.64	3,460.86	28%
	February	5,039.68	3,385.81	33%
	March	4,830.77	3,433.20	29%
	April	4,554.08	3,533.78	22%
	May	4,869.80	3,301.95	32%
	June	4,830.01	3,338.11	31%
Average		**4,787.46**	**3,416.02**	**29%**

City of Quito's potable water distribution network

The city of Quito is served by a network that extends for more than 3500km and has 180 tanks, 40 pump stations and 19 wells. The network is divided into 14 different systems but 93% of the water is supplied through five major systems.

The modelled network consists of almost 56,000 pipes with diameters ranging from 1 to 80 inches (250 to 2000mm); moreover the modelled network comprises almost 54,000 nodes, 11,000 valves and almost 232,000 connections.

At the time of the study, the total distributed flow was 4.8m^3/s with a specific flow of 276 l/hab/day, whereas total metered consumption was 3.4m^3/s with a non-revenue water (NRW) specific value of 521 litres/service connection/day, 29% of the input volume.

Each water supply system has its own water supply, mainly comprising an intake from rivers or artificial lakes and a conveyance system, a treatment plant and one or more reservoirs. Each reservoir supplies smaller distribution tanks that are mostly at the head of a single isolated district.

Operation and maintenance (O&M) personnel thought that the 14 water supply systems were divided into 145 districts, but the division was only hypothetical or 'on-paper'.

Once we had calculated the amount

Table 2 Calculation of NRW for the main water supply systems

Distribution systems	Population	Billed volumes		Produced volumes		NRW
		Sum (cu.m/day)	Specific (l/hab day)	Sum (cu.m/day)	Specific (l/hab day)	(%)
El Troje	175,262	23,233	133	41,334	236	44%
Puengasi	586,102	122,368	209	174,701	298	30%
El Placer	126,109	22,532	179	42,397	336	47%
Bellavista	460,772	108,486	235	112,523	244	4%
Noroccidente	51,605	5,945	115	14,969	290	60%
Minor systems	111,070	12,523	113	27,713	250	55%
Sum	**1,510,920**	**295,087**	**195**	**413,637**	**274**	**29%**

Distribution systems	Trunk mains	Tanks		Pump stations	Wells	Named Districts	Operational sub-districts	Distribution networks
	(km)	n.	Volume (cu.m.)	n.	num.	num.	num.	(km)
El Troje	26.82	21	31,455	2	2	21	61	773
Puengasi	60.76	47	105,286	19	4	43	201	1121
El Placer	1.23	6	8,520	6		8	39	160
Bellavista	63.17	59	133,754	9	10	47	140	1061
Noroccidente	15.68	16	12,365	4	3	13	21	112
Minor systems	14.56	31	8,450			13	17	195
Sum	**182.22**	**180**	**299,830**	**40**	**19**	**145**	**479**	**3421**

Table 3
Infrastructure data of Quito drinking water supply system

of water production and billed water, it was possible to calculate the percentage of NRW as indicated in Table 1, which shows the temporal trend, and Table 2 gives the values for each system.

From the data illustrated in Tables 1 and 2 it was possible to deduce that some systems were not closed or isolated. The most significant case is that of Bellavista with a 4% NRW value versus the city's average of 29%. For this reason, much of the study was concerned with investigating the real boundaries of water districts.

The topographic features of the city, with its very steep slopes, has led to the design of very narrow sectors, each served mostly by only one tank. Over time, however, owing to the chaotic development of the city and lack of water or reservoir capacity in some sectors, many links were made between districts, so that at present only 80 of the 145 districts can be considered isolated.

Even if this situation was well perceived, it was not however fully understood by the O&M department, for which reason it has been thoroughly investigated using the model and through interviews with the field technicians.
It has to be said that the efficiency and effectiveness of this operation has been possible only through the hydraulic model, which provides immediate answers to the many questions that arose during analysis of the water supply network.

Quito's water distribution system is fairly complex, as can be deduced from the large amount of existing infrastructure as shown in Table 3.

At the time of the study, the commercial department's database contained 232,000 consumers, with an average of 6.5 inhabitants/consumer. This data showed that 98.6% of customer meters are functioning and 96.4% of water consumption can be deduced by reading the meters.

Description of project activities

Project activities were divided into the following phases:

- Available data and information regarding the water supply network has been collected from the existing GIS and commercial department's database – information on 'modus operandi' was acquired from O&M personnel.
- The existing GIS was redesigned in order to rationalize the data coding system, to review and complete infrastructure information and improve the effective interface with the hydraulic model.
- A pressure and flow measurement campaign was planned and implemented in accordance with the EMAAP-Q's O&M department.
- The model was validated by means of Infoworks IWWS analysis tools and a campaign of site visits with O&M personnel in order to verify connections between supposedly isolated sectors.
- A second phase of pressure and flow measurements was implemented and developed.
- The model was calibrated with field measurements.
- Through the model, major problems were identified and the most appropriate solutions suggested
- Finally, a conceptual design for a Supervisory Control and Data Acquisition (SCADA) system was implemented.

The water network model

The mathematical model was implemented with Infoworks IWWS software. During data import, it was possible to detect and correct many of the errors of the GIS in terms of connectivity of graphic objects and of the network's hydraulic efficiency.

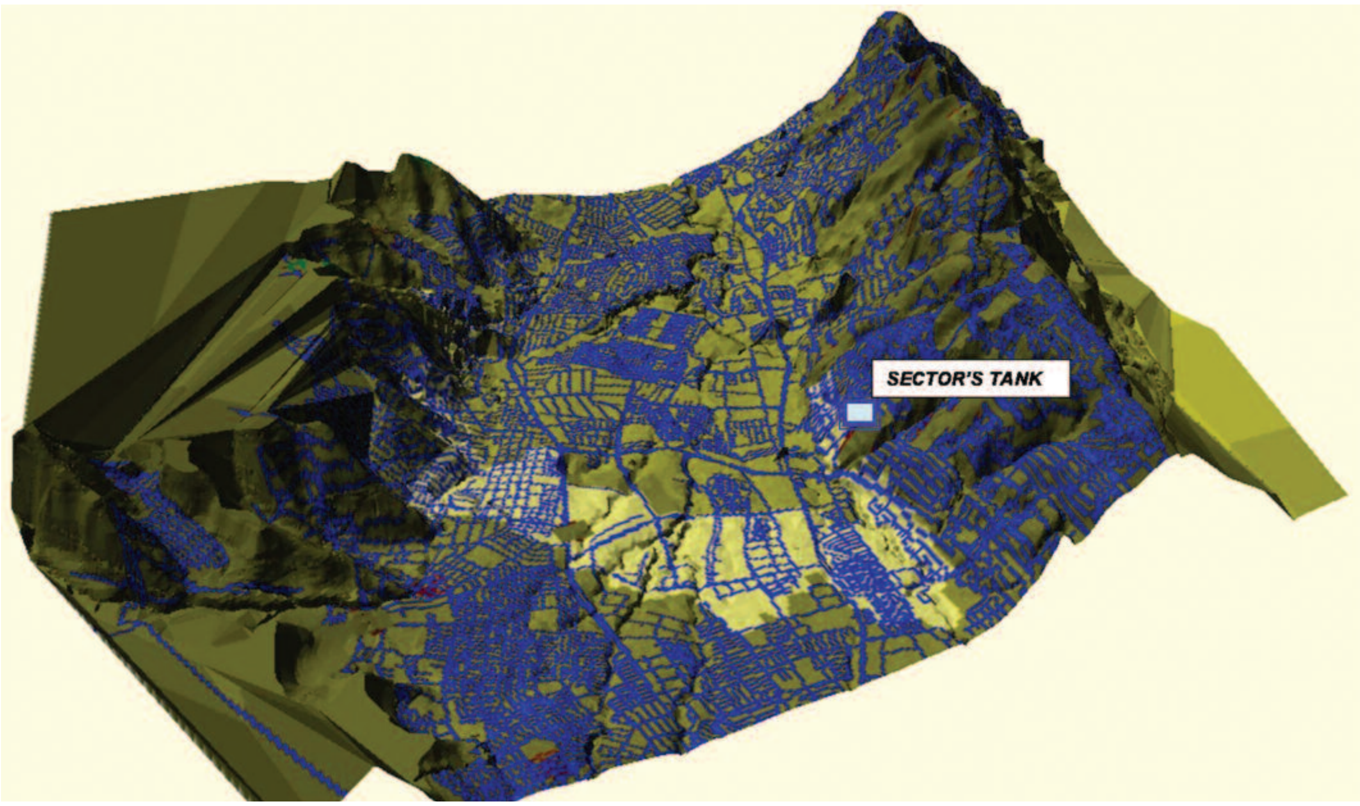

Figure 1
Chillogallo Medio sector orography (IWWS 3D visualization)

Table 4
Calibration results for Chillogallo Medio sector –flows

Sub-district	Day	∑ Volumes (m^3) Measured	Modeled	Difference (%)
Lucha de los Pobres	1	301.92	296.05	1.98%
	2	621.01	592.11	4.88%
	3	913.5	888.15	2.85%
Valle del Sur	1	452.26	459.41	1.56%
	2	930.26	918.78	1.25%
	3	1,397.42	1,378.18	1.40%
S.ta Cruz y Espejo	1	915.09	917.23	0.23%
	2	1,866.33	1,834.34	1.74%
	3	2,762.18	2,751.51	0.39%
General	1	8,289.12	8,313.78	0.30%
	2	16,640.66	16,628.64	0.07%
	3	24,728.11	24,942.99	0.86%

Table 5
Calibration results for Chillogallo Medio sector – pressure

SUB-DISTRICT	DIFFERENCES (%) Pressure measurement in wells	Pressure measurement at household meters
SS01 - Lucha de Los Pobres	6.86	3.89
SS02 - Valle del Sur	2.95	6.55
SS03 – Aymesa	1.01	6.78
SS04 - Estela Maris	2.45	13.34
SS05 – Quitumbe	0.78	2
SS06 - Las Cuadras	0.75	
SS07 – Chillogallo	2.06	
SS08 - Santa Rosa	3.98	14.3
SS09 - Santa Cruz	3.86	3.64

Information on customer location, typology and average water consumption were drawn from the commercial department database and automatically inputted in the model.

To achieve sound knowledge of the hydraulic operation of the network, a campaign of pressure and flow measurement was implemented in accordance with EMAAP-Q's O&M department. Moreover, chlorine measurements were obtained from the available data of the O&M department.

The following parameters were monitored or available data gathered:

- Inlet and outlet flow for the main tanks
- Inlet flow in sub-districts
- Pressure of the distribution network
- Residual chlorine at various points of the network.

Flow measurements were mostly extended to a 21-day period and pressure measurements to a seven-day period. Model calibration led to good results for most of the networks.

The results regarding the Chillogallo Medio district are shown as an example. The sector is on a plain and is supplied from a tank located on the slopes of the city as shown in Figure 1. The sector is divided into four sub-districts. Tables 4 and 5 illustrate results for a large sector of Chillogallo Medio.

In Figures 2 an example of two graphs is shown, indicating the flow entering a sector before and after calibration.

Eventually, modelling made it possible to plot a pressure map for every sector as, for example, Bellavista Medio sector (Figure 3).

The major critical aspect highlighted by the model was an inefficient district configuration, since many hypothetical or supposedly isolated districts are really interconnected and water flows from one zone to others, normally served by another tank. It was therefore recommended to isolate the districts as they were designed and try to solve pressure problems with more rational interventions.

Secondly, we saw that large areas were operating at very high pressures, and therefore with a high probability of water leakage and bursts. The adoption of pressure reducing valves was consequently recommended.

Generally speaking, the infrastructure is substantially well-sized, as in the case of the trunk mains and the capacity of some tanks. Some districts have to be redesigned in order to make them more operable.

Finally, the implemented model, albeit properly calibrated and tested, is a first step and will need constant and continuous updating and testing. The model is therefore a tool that will be used by EMAAP-Q in three different phases for the optimization of distribution network efficiency:

- A first short-term phase, during which the model will help identify (through a 'trial and correct' methodology) new water districts and pipes and valves that have to be closed;
- A second medium-term phase during which the model will be used to verify (by analysing measured pressure and flows) that the districts are really isolated;
- A third long-term phase during which the model will be completed with continuous measured pressure and flow data from the SCADA system, and will be used to verify various operating conditions and also the sectors' volume balances to identify water losses.

Analysis and study of metered districts in the peripheral zones of Quito

The project area totals 135,000 hectares and covers 15 peripheral

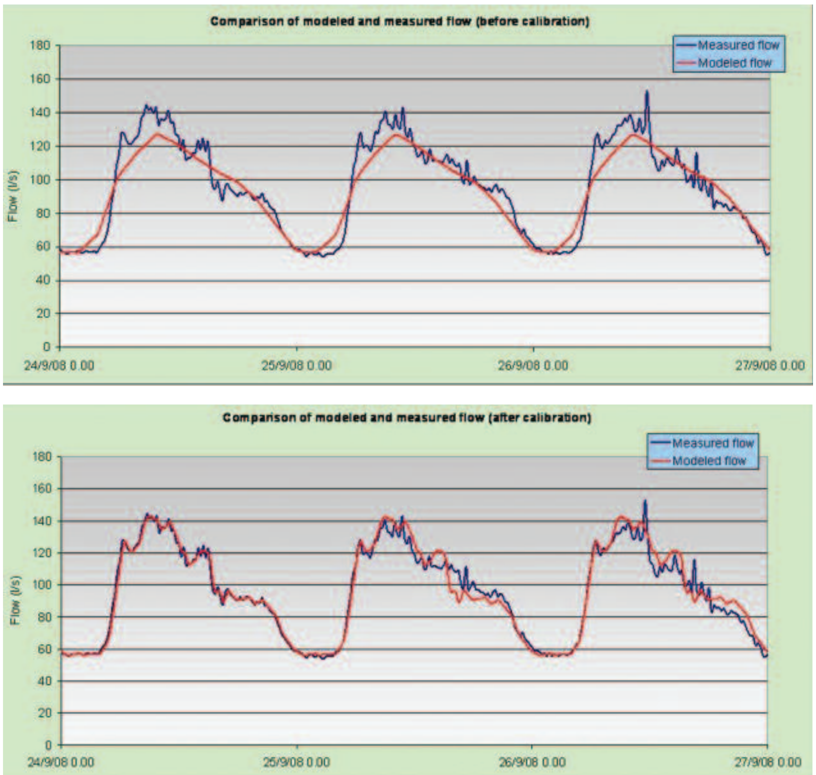

Figure 2
Example of pre- and post-calibration graph for flow in Chillogallo Medio sector

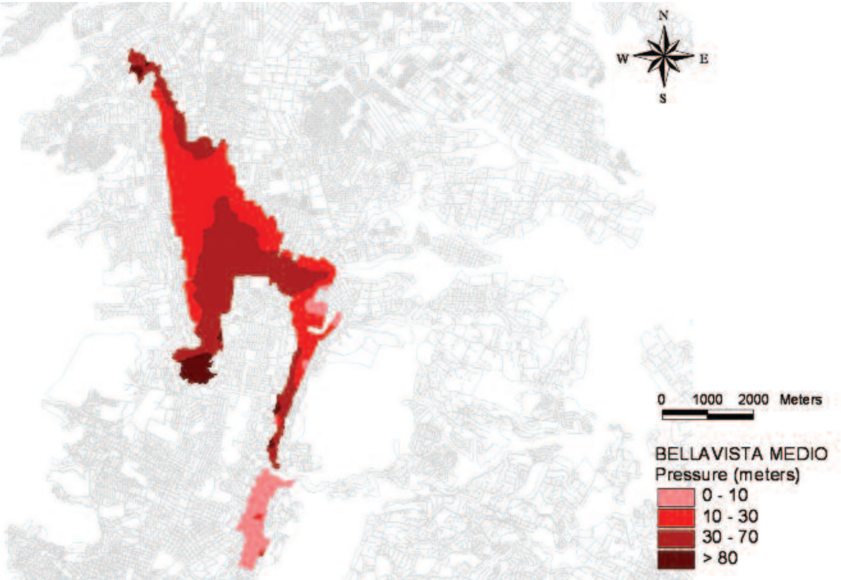

Figure 3
Pressure map of the Bellavista Medio sector (12 a.m.)

zones, called 'parroquias' in the south west of Quito. In that area live almost 400,000 people whose metered consumption is 1.4m^3/s. They are served by a network of about 1500km that has 104 tanks, 13 pump stations and 18 wells.

The principal aim of the study was rationalization of the water network through the design of metered districts. The first step consisted of verifying the information contained in the EMAAP-Q's GIS, which revealed many gaps. For this reason, an intensive field survey and pressure and flow measurement campaign were performed to obtain more accurate information.

Using the commercial software Infoworks WS made it possible to manage the huge quantity of collected information and to obtain a very good representation of the water network's function through a calibration process with field measurements. It was possible to identify weak points in the networks (e.g. interconnected areas served at the same time by two or more tanks located at different elevations and too high and too low pressure zones).

The design of the metered districts was rather difficult owing to the topography and also because we intend to reduce construction of new tanks and optimize existing ones. Thanks to the mathematical model, it has been possible to refine the design and we can assess whether the present network will be suitable for future water flows up to the year 2040. Indeed, by model simulation analysis it has been possible to identify pipes of insufficient diameter for future flows and to recommend to EMAAP-Q an accurate network redesign and substitution plan.

Conclusions and future developments

The Quito drinking water supply system is fairly complex and only by modernizing the O&M department will better understanding and efficient operation be possible. For this reason, the mathematical model was implemented and will be used during day-by-day O&M activities.

The project foresees:

- Optimization of water treatment plant production;
- The safety and efficiency of distribution system operation;
- Improving water distribution among the various tanks downstream from the water treatment plants;
- Measuring and controlling water distributed to districts and network pressures;
- Improving water quality control.

The successful outcome of the project has convinced EMAAP-Q to adopt Infoworks IWWS as the standard software for modelling activities in the company and to reproduce the same type of project in the peripheral areas of the city.

Finally, EMAAP-Q is trying to reorganize its technical and O&M departments by creating a new department to deal with the GIS, the mathematical model and software and finally the data from the SCADA system, thus uniting functions currently divided among various departments. ●

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